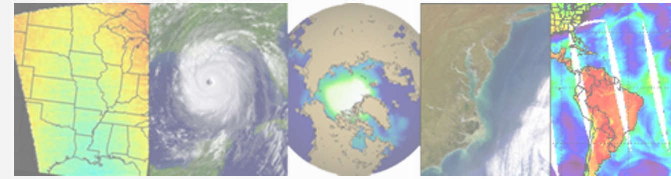
Research and Education at CIMSS

2020-2024

Mission and Vision



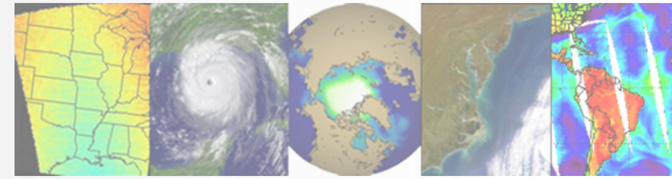
CIMSS Mission

To advance the use of meteorological satellite data to enable the National Oceanic and Atmospheric Administration to meet the nation’s weather and climate needs.

CIMSS Vision

A more informed society, prepared for and resilient to weather and climate changes through the effective use of meteorological satellite observations.

CIMSS Theme Areas



- Satellite Meteorology Research and Applications

  To support weather analysis and forecasting through participation in NESDIS product assurance and risk reduction programs and the associated transitioning of research progress into NOAA operations.

- Satellite Sensors and Measurement Techniques

  To conduct instrument trade studies and sensor performance analysis supporting NOAA's future satellite needs as well as assisting in the long term calibration and validation of remote sensing data and derived products.

- Environmental Models and Data Assimilation

  To work with the Joint Center for Satellite Data Assimilation (JCSDA) on improving satellite data assimilation techniques in operational weather forecast models.

- Outreach and Education

  To engage the workforce of the future in understanding and using environmental satellite observations for the benefit of an informed society.

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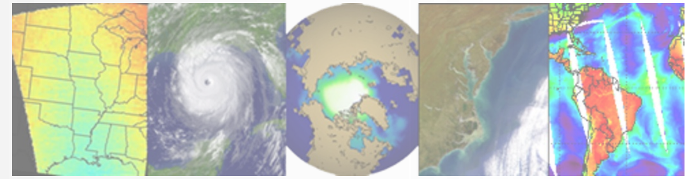
Satellite Research and Applications

Contents



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ProbSevere Version 3

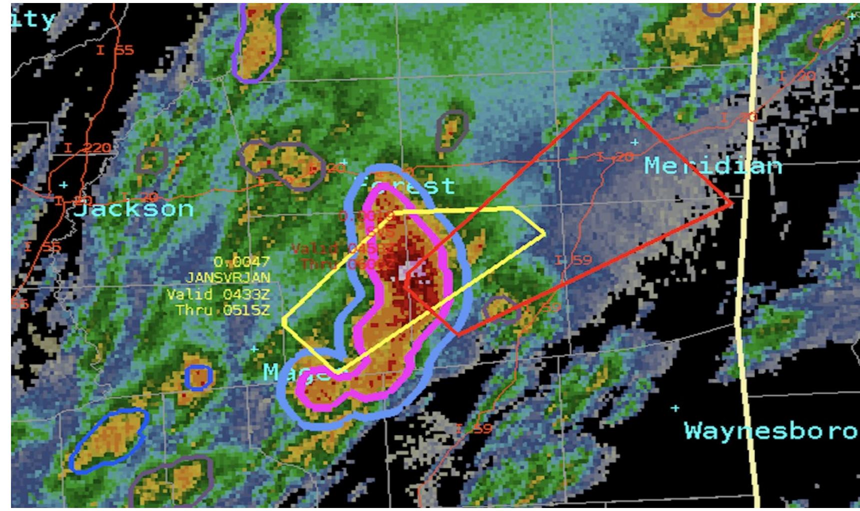
Mike Pavolonis, John Cintineo, Justin Sieglaff, Lee Cronce

Using remotely sensed data and machine learning to predict severe convective hazards.

- Main goal is to protect life and property from severe hail, severe wind gusts, and tornadoes.
- Gives forecasters early indication of severe potential of storms in an objective and automated fashion.
- Key stakeholder is National Weather Service (NWS).

Approach:

- ProbSevere version 3 (**PSv3**) is comprised of four models: ProbHail, ProbWind, ProbTor, and ProbSevere
- PSv3 models are gradient-boosted decision trees
- PSv3 uses radar, satellite, lightning, short-term NWP data and multi-sensor storm-tracking to predict the probability of severe hazards in the next hour.
- PSv3 utilizes ProbSevere **IntenseStormNet** output
  - Detects "intense" parts of storms from a satellite perspective
  - Uses deep-learning AI methodology



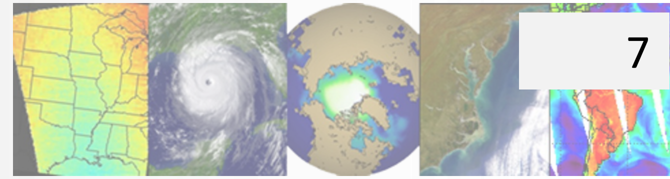
ProbSevere storm-object contours for a tornado-warned storm in Mississippi. The pink contour signifies ≥ 85% probability of any severe, and the light blue contour represents 40% probability of tornado.

Outcomes:

- ProbSevere v3 is demonstrably better than the operational ProbSevere version 2 (PSv2)
- PSv3 experimental output is routinely used in NWS offices as guidance.
- 2023 HWT report: ***"highly recommended that ProbSevere v3 be implemented in NWS operations to replace ProbSevere v2"***

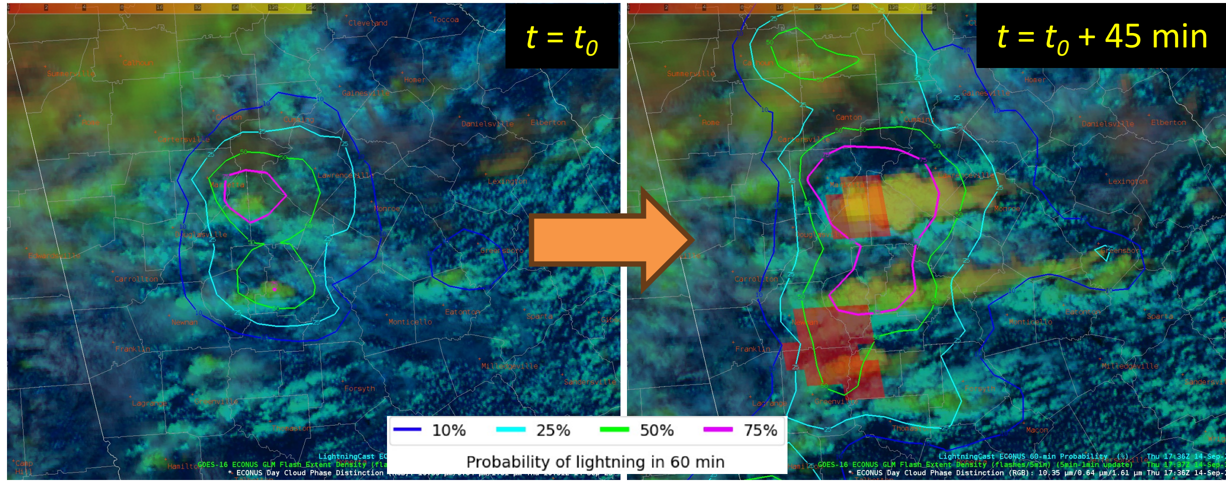
ProbSevere LightningCast

Mike Pavolonis, John Cintineo, Justin Sieglaff, Lee Cronce, Stephanie Ortland



Using GOES-R data and machine learning to predict next-hour lightning probability.

- Key stakeholder: National Weather Service (NWS)
- Emergency management, aviation, and recreation interests are also stakeholders.



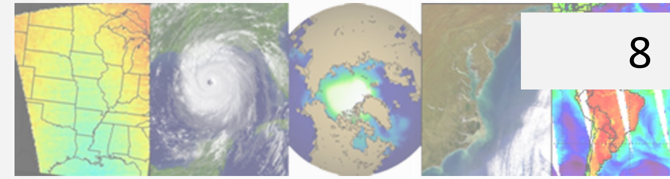
LightningCast probabilities (contours) in Georgia. Background is GOES-16 day cloud phase distinction RGB. Orange-to-yellow foreground pixels are Geostationary Lightning Mapper flashes.

Approach:

- Use visible (0.5-km), near-infrared (1-km) and longwave infrared (2-km) geostationary satellite data and deep-learning methods to predict the probability of lightning in the next hour.
- Output provides actionable lead time to lightning initiation often well ***before radar signatures.***
- LightningCast has learned multi-spectral and spatial patterns in data.

Outcomes:

- LightningCast is routinely used by many NWS offices.
  - Used at 2022 World Games in Birmingham, AL
  - Used at NFL football games,
  - Used at state fairs, music concerts
- 2023 HWT report: ***"highly recommended that LightningCast be implemented in NWS operations"***
  - Transition-to-operations for LightningCast is now funded.
- *"LightningCast is magic"*
  - CWSU meteorologist-in-charge

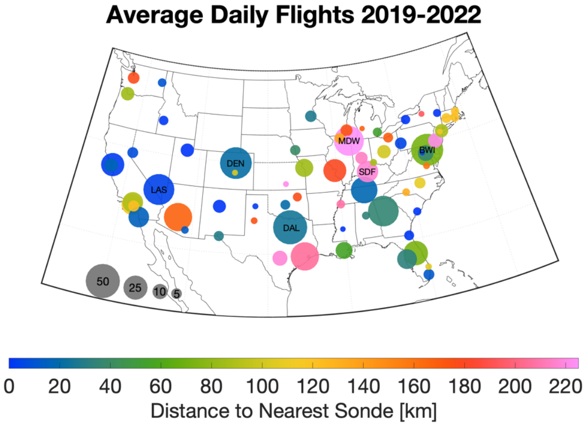


Aircraft Soundings

Timothy Wagner and Ralph Petersen

Objective

- Commercial aircraft equipped with WVSS-II water vapor sensor provide hundreds of radiosonde-like profiles daily at locations across CONUS
- Many of these flights are in close spatial and temporal proximity to operational radiosonde launches
- With ongoing supply chain / helium shortages, can resources be be
- Stakeholders include NWS Office of Observations, operational meteorologists at NWS WFOs nationwide



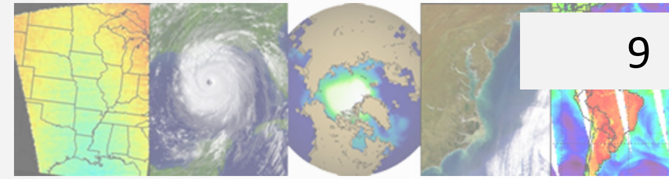
Locations of aircraft-based profiles of temperature and water vapor. Size of dot corresponds to average number of daily profiles while color represents the distance to nearest radiosonde launch site.

Approach

- Use archived aircraft data from the MADIS archive
- Identify the diurnal, hebdomadal, and annual cycles in data availability for each airport
- Look at trends before, during, and post pandemic-induced flight reductions.
- Match airports to radiosonde sites to see how many aircraft profiles are available in close proximity to regular and asynoptic radiosonde launch times.

Outcomes

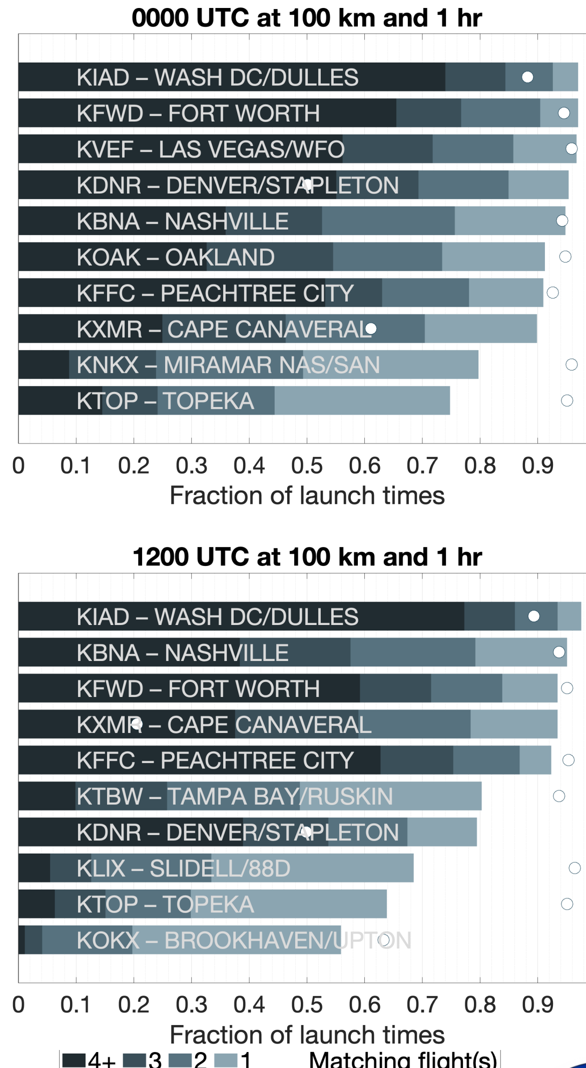
- Several radiosonde sites are well-covered by aircraft observations at typical launch times (Fort Worth, Dulles, Nashville, and others).
- A spreadsheet containing the number of sonde launches matched with AMDAR flights for every radiosonde site has been delivered to NWS Office of Observations.
- PI delivered an in-person briefing at the NWS Office of Observations highlighting the results of this work.
- NWS HQ is currently using this information as part of their planning for resource allocation



Aircraft Soundings

Timothy Wagner and Ralph Petersen

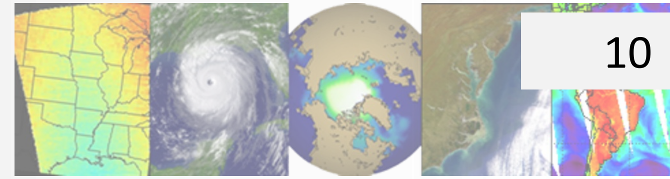
- At several radiosonde sites, almost every balloon launch has multiple aircraft profiles within 100 km and 1 hr.
- At Denver, sonde launches have been severely curtailed due to resource constraints.
  - Aircraft provide a reliable alternative
  - Aircraft observations typically more accurate than sondes as sensors are no disposable
- NWS HQ is very eager to take these results into account for operational planning



Right: Top ten radiosonde sites in terms of fraction covered by at least one matching ABO profile within 1 h and 100 km for each of the launch times at 0000 and 1200 UTC. Colors represent the number of matching flights following the legend at the bottom of the figure. White dots note the fraction of successful radiosonde launches at that site for the given launch time.

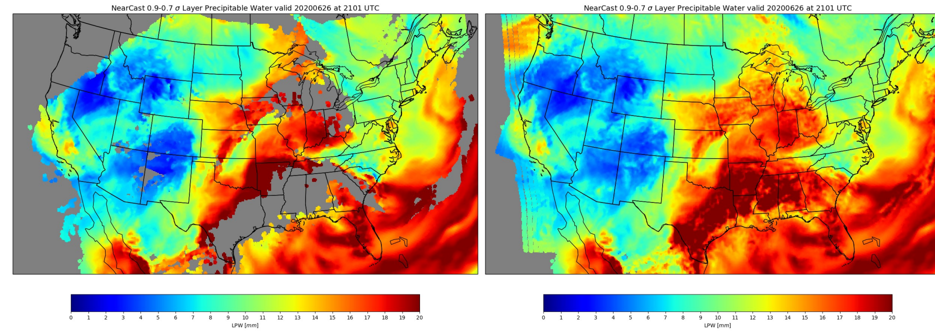
Improving Geostationary Moisture and Temperature Retrievals

Lee Cronce and Ralph Petersen



Objective:

- To improve analyses and short-range projections of infrared-based geostationary (GEO) satellite retrievals of moisture and temperature by incorporating microwave-based low-earth-orbit (LEO) satellite retrievals to:
  - *Add information in data void cloudy areas and*
  - *Corroborate GEO data in clear areas*
- Benefits NWS forecasts and NESDIS product developers and users



0.9-0.7 sigma layer precipitable water valid 2101 UTC 26 June 2020 using GOES-only (left) and GOES+MiRS (right) profiles for heavy rain event south central WI. MiRS improving product utility and consistency by filling most GOES data gaps

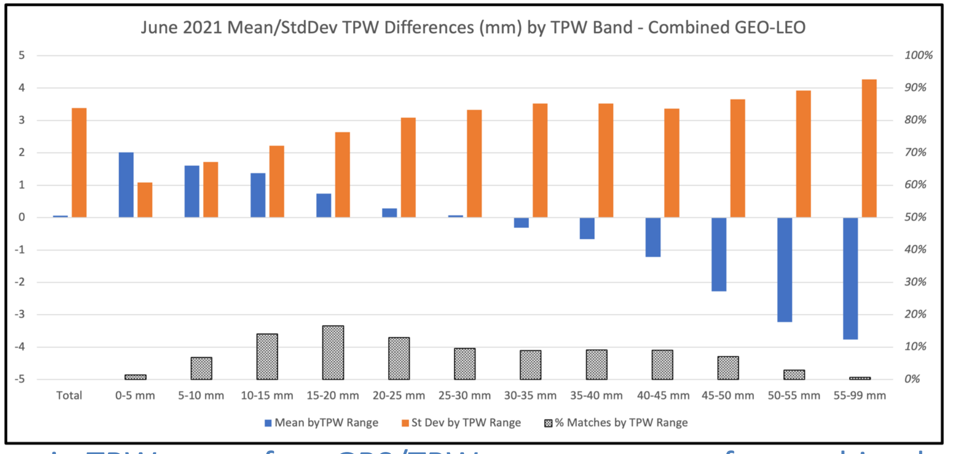
Approach:

- Real-time JPSS (LEO) profiles were synchronized and merged with standard GEO profiles using the CIMSS NearCast system to provide analyses and 9 hour projections of precipitable water and derived stability products.
- The new, non-linear bias correction approach was developed to remove moisture biases across the full range of both satellite data sets.

Outcomes:

- Produced first-ever, real-time, all-weather analyses and short-range forecasts of spatially continuous satellite moisture and stability products that combined the strengths of both GEO and LEO observations
- Enhanced the operational use of JPSS observations in operational forecasting, exposed forecasters to the benefits of otherwise infrequently used microwave observations
- Relieved previous forecaster frustration over data voids in GEO moisture/stability products

- Non-linear Precipitable Water Bias Correction key to combining Leo and GEO data has broad application to future Retrievals
  - Approach provides correction as function of moisture content
    - Constant updating improves products and reduces extreme
    - Automatically adapts to different error structures of Geo and LEO retrievals

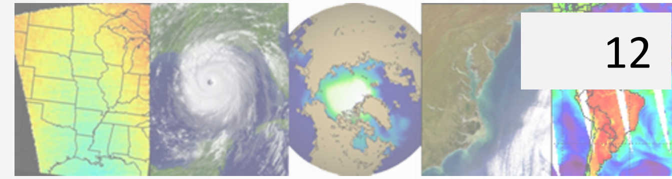


Errors in TPW vs. surface GPS/TPW measurements for combined GEO/LEO analysis before bias correction

  - Applying Non-uniform Corrections using overlapping quadratic fits separately to GEO and LEO observations nearly eliminated both absolute (mm, shown in figure) and relative (%) biases in multi-layer moisture products
  - Removed harsh GEO/LEO transitions that forecasters disliked

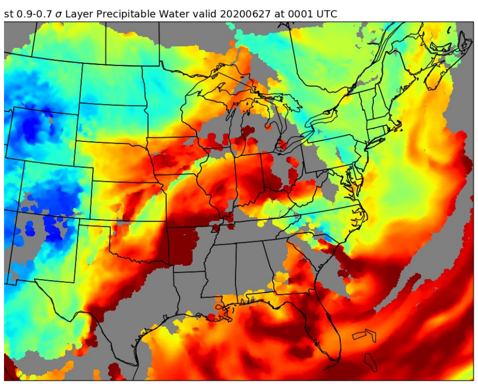
Improving Geostationary Moisture and Temperature Retrievals

Lee Cronce and Ralph Petersen

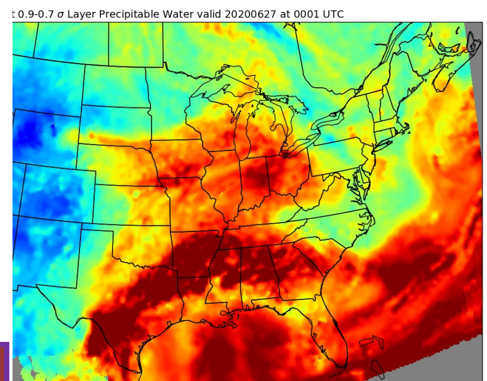


Hourly-updated, real-time GEO/LEO NearCasts of multi-layer moisture and stability products improve the spatially consistency and accuracy of short-range predictions of convective potential across the continental United States.

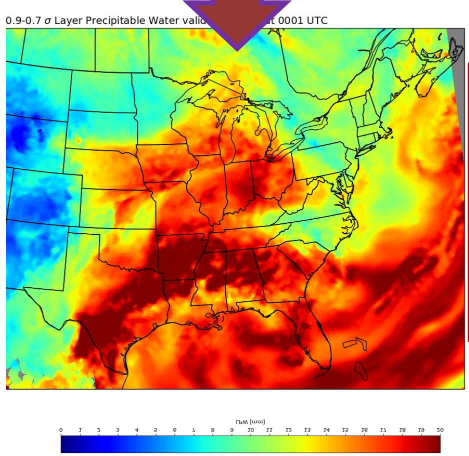
3 hour GOES-only NearCast of Lower-Tropospheric Precipitable Water Valid 00Z 27 June 2020



3 hour MiRS-only NearCast of Lower Tropospheric Precipitable Water Valid 00Z 27 June 2020



3 hour Combined GOES-MiRS NearCast of Lower Tropospheric Precipitable Water Valid 00Z 27 June 2020



Case: Convective development over eastern WI and north of Gulf Coast

- An Innovative method for Combining Bias-Corrected GOES IR and LEO MiRS retrievals (including microwave) profiles in CIMSS Real-Time LaGrangian NearCast System substantially improved continuity and quality over GOES-only analyses and short-range forecasts
- Identifies areas of potential thunderstorm development and continued growth
- Rectifies shortcoming of data gaps noted by forecasters in previous GOES-only NearCast
- GOES provides updates in clear regions between LEO overpasses

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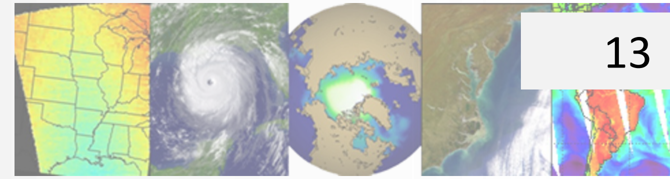
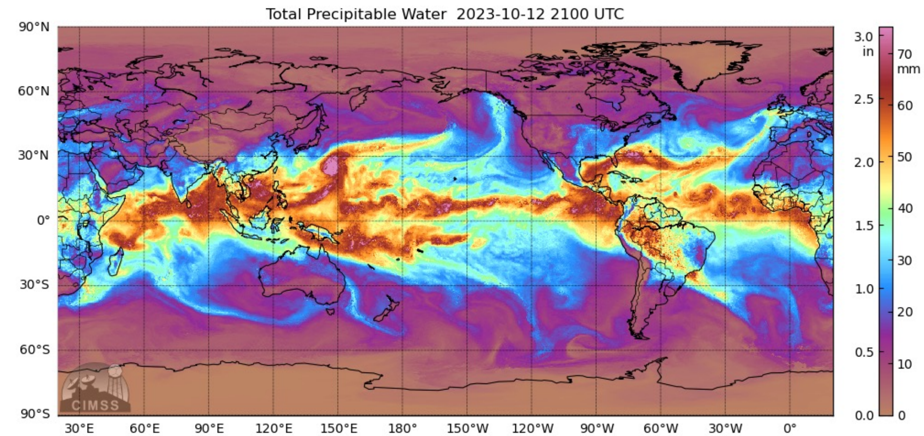
Blended Hydrometeorological Product Upgrades

Anthony Wimmers (PI), Liqun Ma, and Walter Wolf (OSPO)



Objective

- CIMSS is a partner in the joint effort with CIRA to deliver the capability to create blended precipitable water products through the NDE (Linux/Cloud) to NOAA/NESDIS.
- Stakeholders include NWS, DoD, public and private users of precipitable water forecasts and international partners.
- Value is especially high for the Pacific Region, Alaska, Puerto Rico, and other maritime environments.



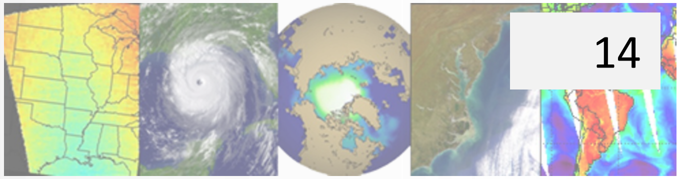
This project will bring the morphed, global TPW hourly product into operational use.

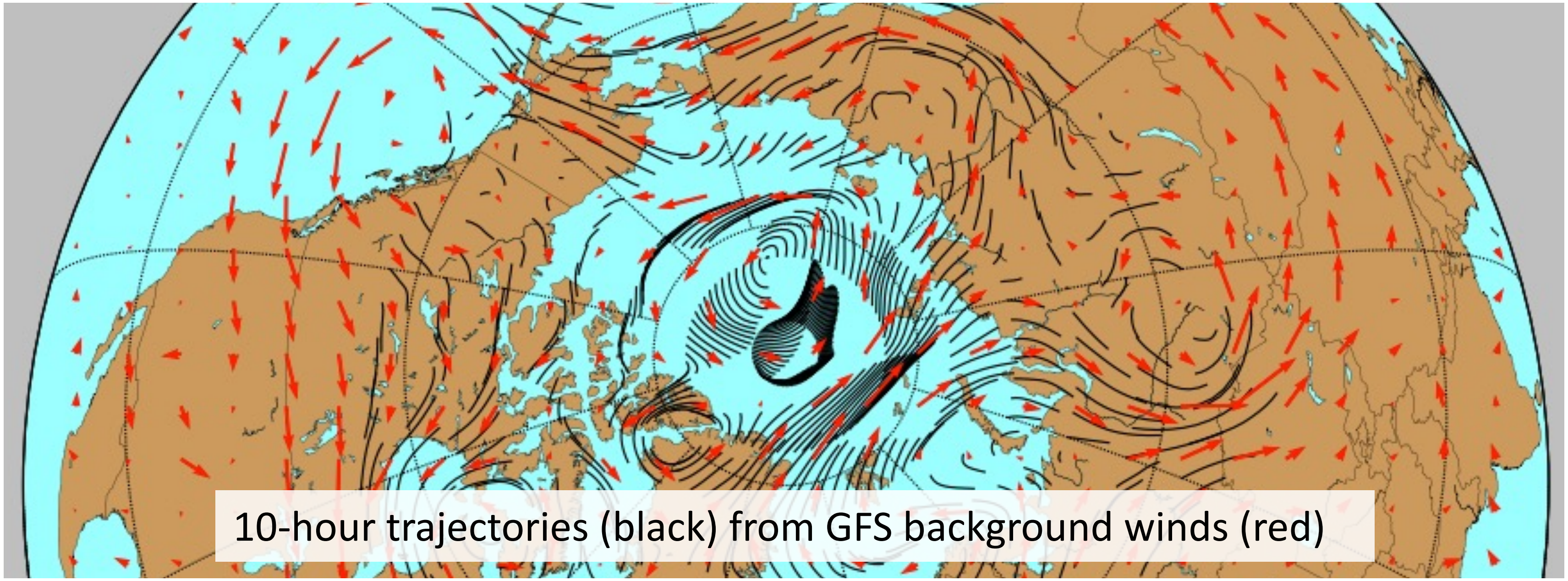
Approach

- CIMSS is to deliver the capability to produce low-earth orbiting satellite data advection through reverse domain filling (RDF).
- This means using the scheme from MIMIC-TPW to process GFS wind fields, weighted to vertical layers, and producing regular RDF gridded fields that specify the direct transform of image coordinates from original to advected space.

Outcomes

- We have completed the delivery of the MIMIC scheme to OSPO and have addressed all known issues with integration.
- This will lead to an operationally supported product that is more resilient to power interruptions, network interruptions and satellite constellation evolution.
- “Being able to look at the last few days of TPW history is a quick and accurate way of understanding both antecedent conditions and TPW which is still over the Gulf of Alaska and headed our way…” - Celine van Breukelen, Senior Service Hydrologist, WFO Anchorage



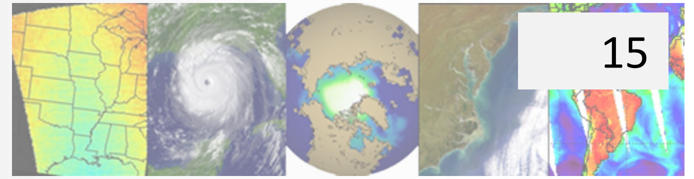


10-hour trajectories (black) from GFS background winds (red)

- The CIMSS TPW advection scheme delivered to OSPO is rapid, accurate, and applies globally.
- The method applies seamlessly to high latitudes, making it especially important for stakeholders in the Alaskan WFOs.

NextGen Satellite Sounding Proxy

W. Smith Sr., A. DiNorscia, Q. Zhang, E. Weisz, B. Pierce

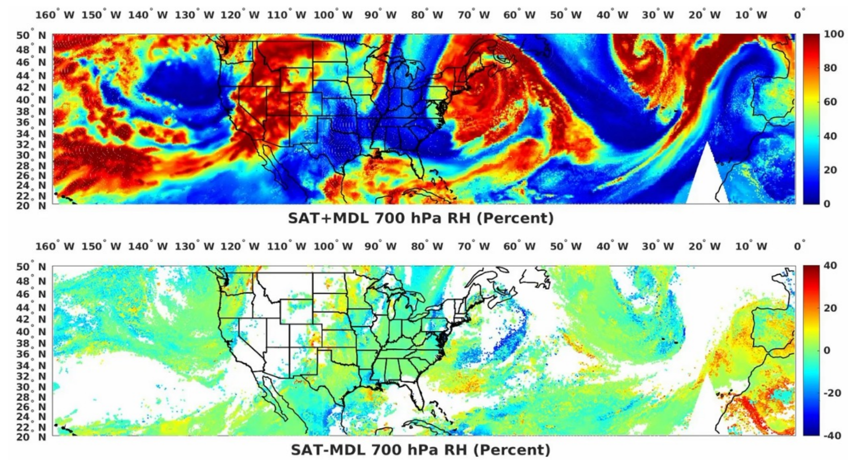


Objective

- Simulate the expected meteorological observation capabilities of the next generation polar/geostationary satellite system through the fusion of real-time GOES/MSG and JPSS/Metop data.

Stakeholders/users

- NOAA/NASA Geo-XO project
- NWP model developers and users
- International scientific community



Satellite sounding/model 700-hPa relative humidity (top) and satellite/model difference (bottom).

Approach

- Geo-hyperspectral resolution soundings, with 2-km and 30-minute resolution, are created by the fusion of polar sounder and geostationary imager radiances
  - Full spectral and spatial resolution of data used
  - Hyperspectral clear air and MW below cloud used
  - 4-km Res. NWP Model with continuous 3-hourly humidity data assimilation used to diagnose winds
  - 0-to-9-hour forecast cycle conducted every 2 hours

Outcomes

- Smith, W. L., Q. Zhang, M. Shao, and E. Weisz, 2020: Improved Severe Weather Forecasts Using LEO and GEO Satellite Soundings. J. Atmos. Oceanic Technol., 37, 1203–1218.
- Forecaster evaluations during 2 HWT experiments confirm improvement in nowcasting severe storms.
- Provided scientific justification for the measurement requirements of the GeoXO sounding instrument.
- Proxy data to be used for development of algorithms for future geostationary hyperspectral sounding data.

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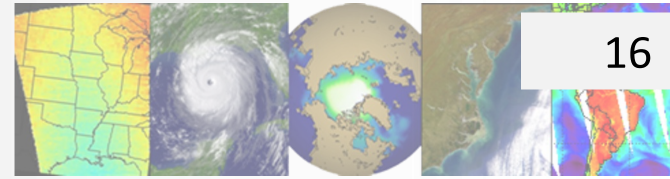
NexGen Satellite Sounding Proxy

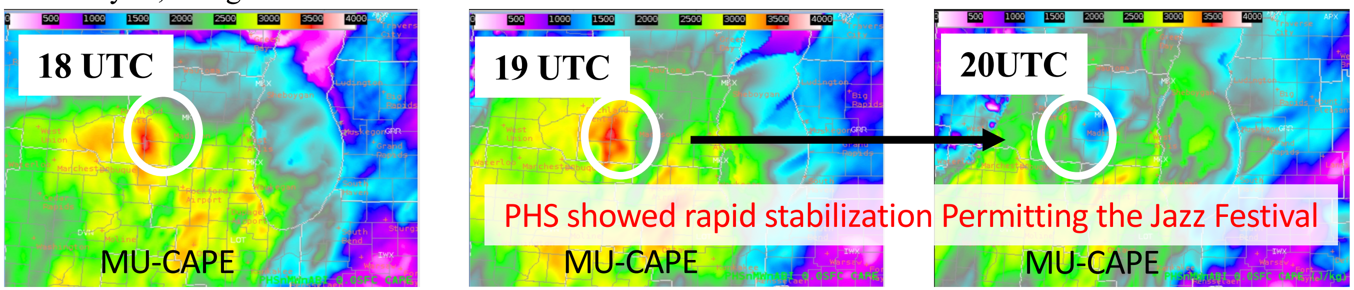
W. Smith Sr.



CAN PHS (NEXGEN PROXY) IMPROVE MESOANALYSIS AND NEAR-TERM CONVECTIVE FORECASTS?

Posted in DSS, LightningCast, PHSnMWnABI, ProbSevere, SPG2022 on June 24, 2022, by Kevin Thiel.

- A large portion of the MKX CWA was included in a MDT severe risk, so by the start of the operational period, we had to assess the evolving severe threat spreading in from the west. Meanwhile, our DSS event was the Madison Jazz Festival, which entailed a focus specifically on **south central Wisconsin**. The PHS CAPE forecast appeared to be a noteworthy improvement from the CAPE fields on the SPC Mesoanalysis, along with the short-term forecast



- Based on the PHS forecast combined with satellite analysis, we were able to focus the convective threat for the Madison area toward 6PM and onward, tied to the stronger forcing and better moisture arriving from the west where the ongoing convection resided closer to the cold front. It appears that the PHS sampling of moisture in the column applied to the near-term forecast strongly outperformed the SPC/RAP Mesoanalysis model background and OA algorithm.
- **Feedback from the daily and weekly surveys echoed the utility of the PHSnMWnABI model as described previously and provided some additional quantitative insights. Forecasters overwhelmingly felt that the PHSnMWnABI model gave a more accurate view of where strong convection was more likely, with up to 92% (49/53) of responses supporting this statement.**

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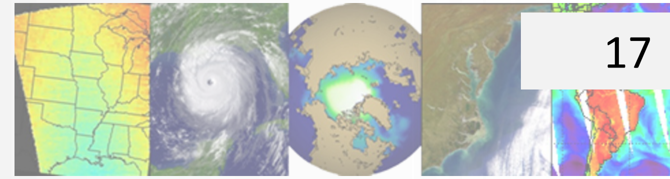
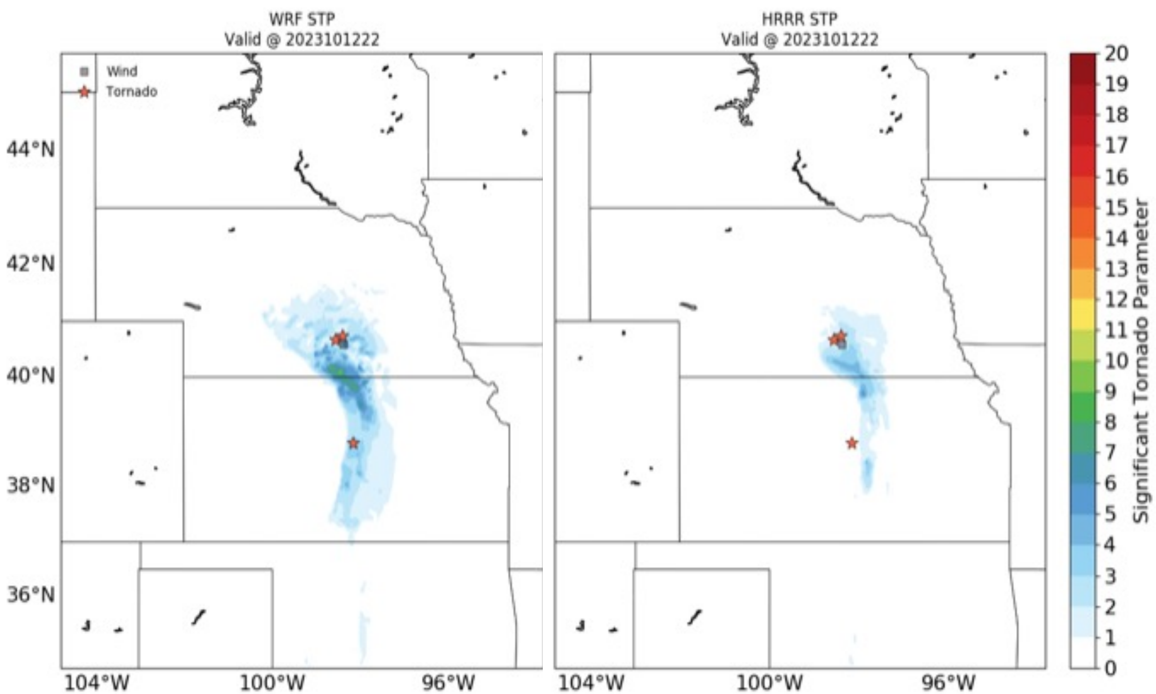
Example: NexGen Proxy Tornado Forecast

W. Smith Sr. A. Q. Zhang, and A. DiNorscia

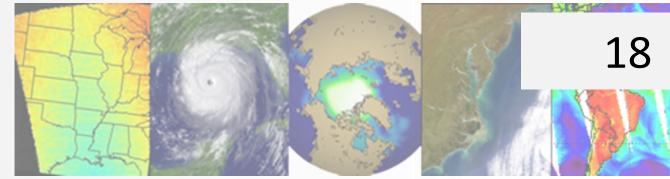


NexGen Proxy combines clear sky polar satellite hyperspectral /below-cloud microwave soundings with full-resolution geostationary imagery to provide high resolution (2-km/hourly) soundings to initialize mesoscale NWP weather forecasts.



STP forecast 12 October 2023 (22 UTC).

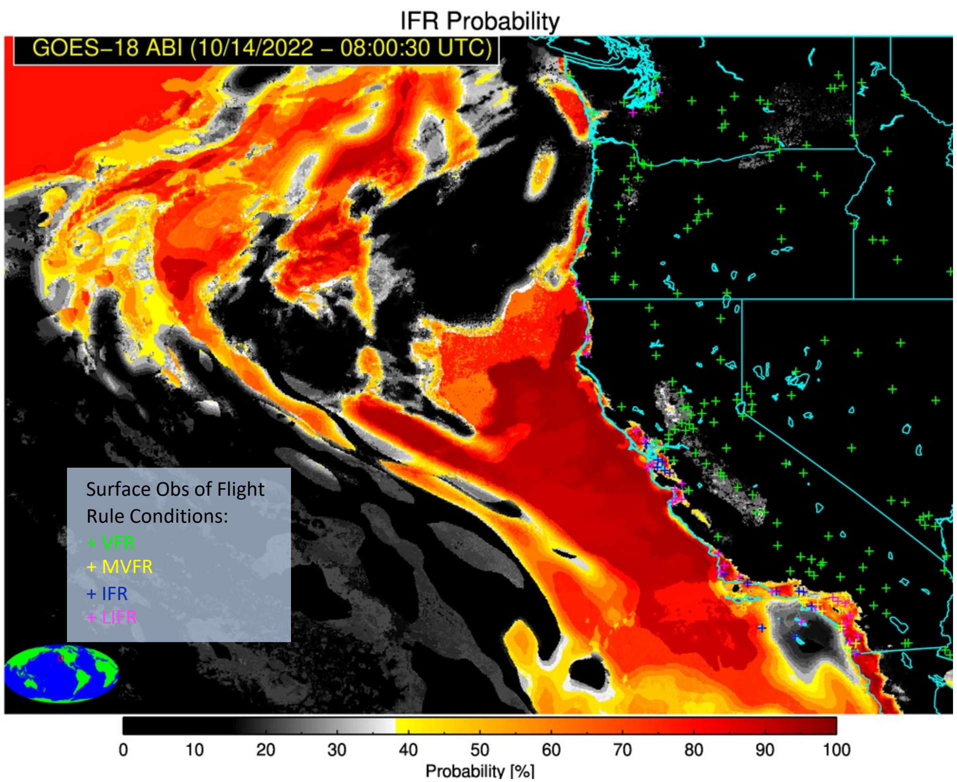
- High density NexGen Proxy data enabled Significant Tornado Parameter (STP) forecast for area of severest/Tornado weather.
- Highest STP values identify areas of highest probability of severe weather conditions.
- Satellite data assimilated forecasts provide higher STP values than operational forecasts in regions of severe weather development.
- Studies indicates that SAT-STP forecasts provide prediction lead time of approximately 6-hours.



GOES-R Fog/Low Stratus (FLS)

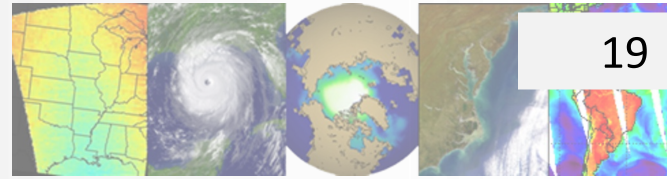
Corey Calvert and Michael Pavolonis

The GOES-R FLS detection algorithm combines satellite, numerical weather prediction model, and other ancillary data sets to produce probabilistic products for various hazardous low cloud conditions.



GOES-18 IFR probability product from 14 October, 2022.

- Uses a naïve Bayesian model and classifier to fuse multiple data sources to produce probabilistic maps where MVFR, IFR, and LIFR aviation flight rule categories are present.
- Helps forecasters identify areas of hazardous low cloud and fog during both day and night for the aviation community.
- Also produces an estimation of the cloud thickness which can be used to infer fog dissipation time under certain conditions
- **These products, elevated by special request from the NWS, were successfully transitioned into NOAA/NESDIS operations and are freely available to the public.**

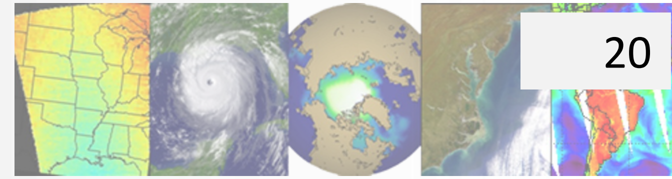


VOLcanic Cloud Analysis Toolkit (VOLCAT)

- Developed by NOAA/UW-CIMSS
- Leverage NOAA satellite data (and other data), physical retrievals and AI/ML data processing techniques to monitor, detect, alert, and characterize volcanic activity
- Airborne volcanic hazards are a threat to life, health, and property—especially the aviation sector
- VOLCAT team is partnered with NOAA ARL group to improve dispersion modeling of volcanic clouds
- VOLCAT system is currently being transferred to NESDIS operations in a 3 stage project.
- VOLCAT experimental real-time data processing, alerting and website at UW/CIMSS has served end-users for a number of years and will continue until VOLCAT is fully transitioned to NOAA operations.

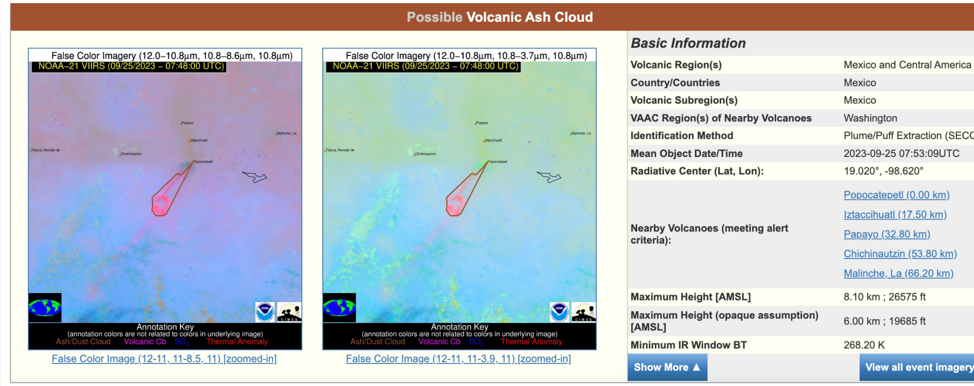
VOLCAT: New Sensor Support

Mike Pavolonis, Justin Sieglaff, Brianne Andersen, Corey Calvert



Extend VOLCAT volcanic cloud products to GOES-18 ABI and NOAA-21 VIIRS.

- Main goal is to protect life and property from volcanic aviation hazards.
- **Provide volcanic ash advisory center (VAAC) meteorologists needed detection, characterization, and alerting of volcanic hazards from new NOAA sensors from the VOLCAT system.**
- Key stakeholders are aviation industry—VAAC meteorologists (NOAA, NWS, and international partners) and airlines.



NOAA-21 VOLCAT ash alert provided via near real-time processing at UW/CIMSS. VAACs (and other users) subscribe to VOLCAT alerts and receive them automatically via email and other methods.

Approach:

- Modify VOLCAT code to process GOES-18 ABI and NOAA-21 VIIRS data.
- Evaluate VOLCAT output from these new sensors to ensure products are performing within specifications. VOLCAT team quantitatively compared VOLCAT ash detection, ash cloud height and ash cloud mass loading retrievals to truth data.
- VOLCAT validation showed GOES-18 and NOAA-21 performance was meeting product specifications and was consistent with other similar satellite imagers that have been fully validated.

Outcomes:

- Process GOES-18 ABI and NOAA-21 VIIRS data in near real-time at UW/CIMSS to support aviation sector end-users (among others).
- GOES-18 and NOAA-21 VOLCAT alerts are being distributed to end-users and imagery is populating the VOLCAT website.
- Demand for VOLCAT products by end-users has resulted in a research to operations project. VOLCAT will be run in the NESDIS Common Cloud Framework operationally upon that project competition.

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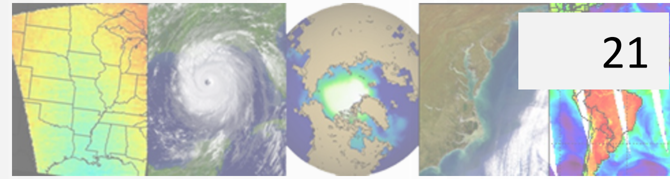
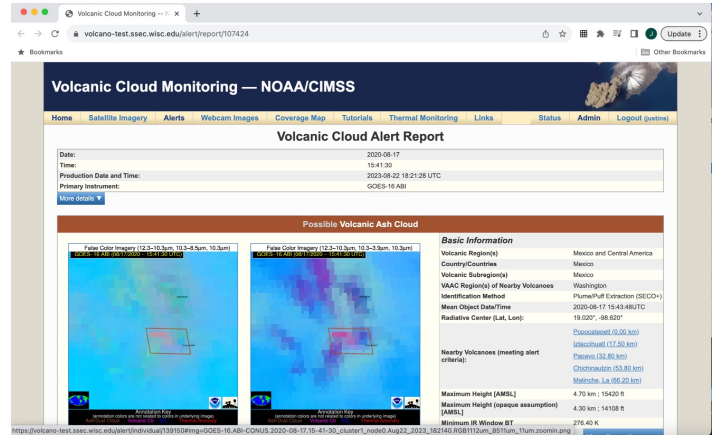
VOLCAT: Transition to NOAA Operations

M Pavolonis, J Sieglaff, R Garcia, W Roberts, L Pfantz, C Calvert



Transition VOLCAT to operations in the NESDIS Common Cloud Framework (NCCF)

- Main goal is to protect life and property from volcanic aviation hazards.
- VOLCAT products are routinely used by NOAA/NWS Volcanic Cloud Advisory Centers and airlines. VOLCAT processing is experimental at UW/CIMSS.
- Transition of VOLCAT processing, alerting service and website to NOAA operations will ensure 24/7/365 support for VOLCAT products.



VOLCAT test system alert generated from VOLCAT containers deployed on SSEC Cloud Infrastructure.

Approach:

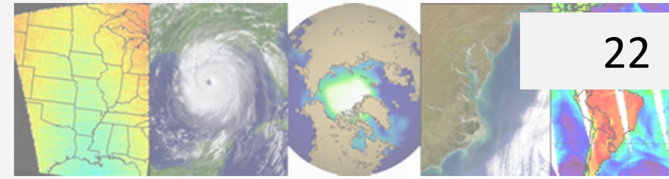
- VOLCAT system consists of satellite data processing, advanced image-based post-processing, alerting service, website and database services and did not fit into existing NESDIS operations.
- VOLCAT was selected for transition to operations via NESDIS Common Cloud Framework.
- VOLCAT has been containerized for cloud applications. The approach allows for automated testing, building and deployment of VOLCAT system. Following an 'agile' approach future enhancements and added sensor support can quickly and easily be transitioned to operations over time.

Outcomes:

- VOLCAT system has been containerized and cloud-ready deployment orchestration has been developed at UW/CIMSS.
- UW/CIMSS team is working with NOAA group in transitioning VOLCAT to NCCF operations in 3 stages.
- Currently VOLCAT Stage 1 transition is progressing with operational date planned sometime in 2024.
- UW/CIMSS team is preparing VOLCAT system for Stage 2 of operational transition (alerting, website, and database capabilities as well as added new sensors).

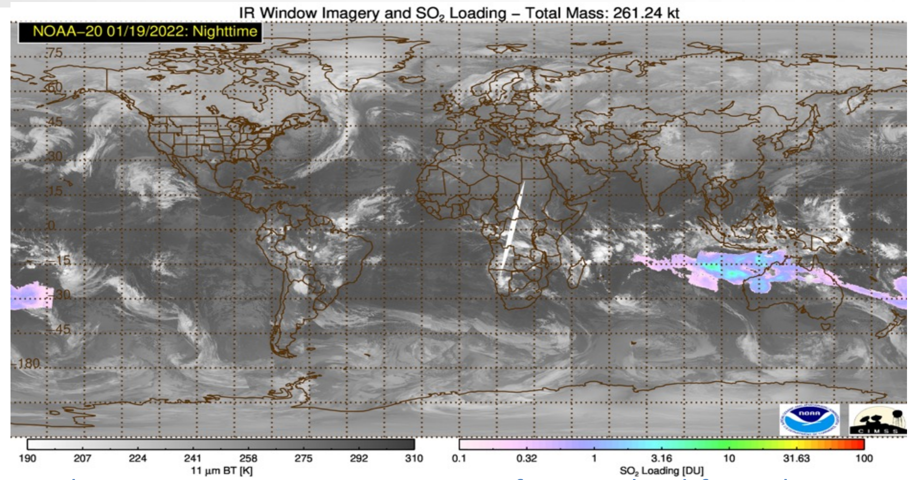
VOLCAT: SO_2 Detection and Characterization

Mike Pavolonis, Justin Sieglaff, Kati Togliatti, Dave Hyman



Using JPSS VIIRS+CrIS instruments to detect and characterize volcanic sulfur dioxide (SO_2)

- Main goal is to protect life and property from volcanic-borne SO_2.
- Provide NWS/VAAC forecasters with SO_2 detection, height, and loading information.
- Provide NOAA dispersion model group (ARL) with SO_2 data for improving dispersion model forecasts of SO_2.
- Key stakeholders are National Weather Service (NWS) and modeling groups.



Example NOAA-20 VIIRS SO_2 composite for SO_2 cloud from the eruption of Honga Tonga-Hunga Ha'apai in Tonga in January 2022.

Approach:

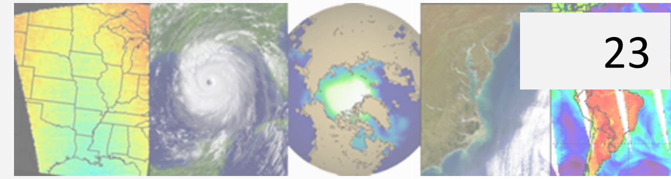
- Developed a VIIRS+CrIS (Infrared-based) SO_2 detection and characterization algorithm within VOLCAT system.
- VIIRS + CrIS VOLCAT SO_2 algorithm output was quantitatively compared to Ultra-Violet (UV) based SO_2 detection. Comparisons indicate VIIRS+CrIS approach agree well with UV-based retrievals. Novel IR-based approach helps fill UV gaps during nighttime and during polar winter.
- Created compositing capability for daily ascending and descending JPSS nodes for global depiction of SO_2 …critical for incorporation in dispersion models.

Outcomes:

- Created novel IR-based VIIRS+CrIS SO_2 detection and characterization in VOLCAT from NOAA JPSS satellites.
- Enabled near real-time VIIRS+CrIS SO_2 processing at UW/CIMSS for S-NPP, NOAA-20, and soon NOAA-21 satellites.
- Publishing near real-time VIIRS+CrIS SO_2 alerts to VOLCAT website.

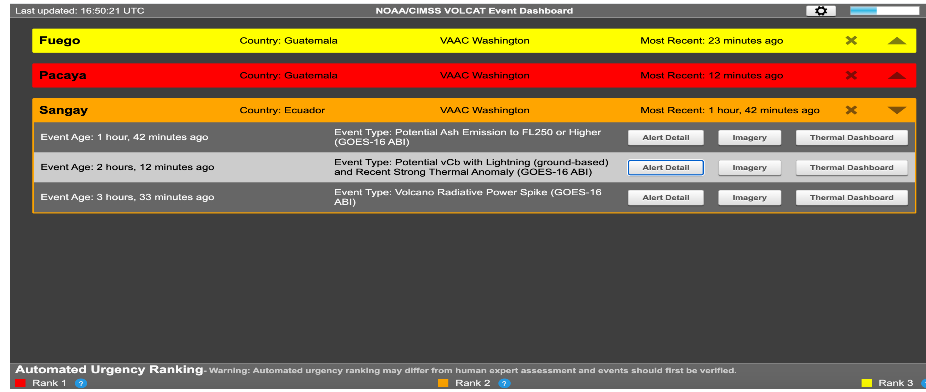
VOLCAT: Improvements for Volcano Monitoring

Mike Pavolonis, Justin Sieglaff, Brianne Andersen, Corey Calvert, Kati Togliatti



Improve VOLCAT volcanic cloud monitoring using enhanced techniques and new data sources.

- Main goal is to protect life and property from volcanic aviation hazards.
- Provide end-users with more accurate detection and characterization of volcanic clouds thereby improving their forecasts.
- Key stakeholders are aviation sector, Volcanic Ash Advisory Centers (VAACs) and National Weather Service (NWS).



Screenshot of the VOLCAT Event Dashboard demonstrating the incorporation of lightning data in VOLCAT. In this example, VOLCAT issued a vCb alert (due to rapid cloud growth) with lightning present from a ground-based network (ENI).

Approach:

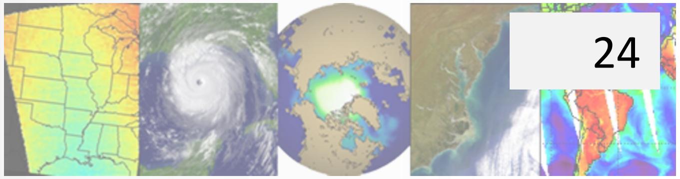
- Developed ingest and application of a variety of lightning data (space-based and land-based detection) into VOLCAT.
- Designed VOLCAT algorithm modifications to operate with fewer ABI spectral bands during GOES-17 ABI Loop Heat Pipe band saturation periods.
- Added VOLCAT capability to ingest and leverage full spatial resolution data (visible and near IR channels from GEO satellites and I-band data from VIIRS).

Outcomes:

- Addition of lightning data helps end-users have increased confidence in VOLCAT detection of explosive volcanic events.
- GOES-17 Loop Heat Pipe VOLCAT improvements resulted in longer periods of high quality VOLCAT output for end-users during saturation periods.
- Incorporation of full spatial resolution data in VOLCAT has resulted in improved skill of thermal anomaly detection.
- VOLCAT website has 300-400 unique daily users, with higher spikes (2K+ unique users) during notable volcanic eruptions. The heaviest users are NOAA/NWS VAACs, airlines, volcano observatories and international VAACs.

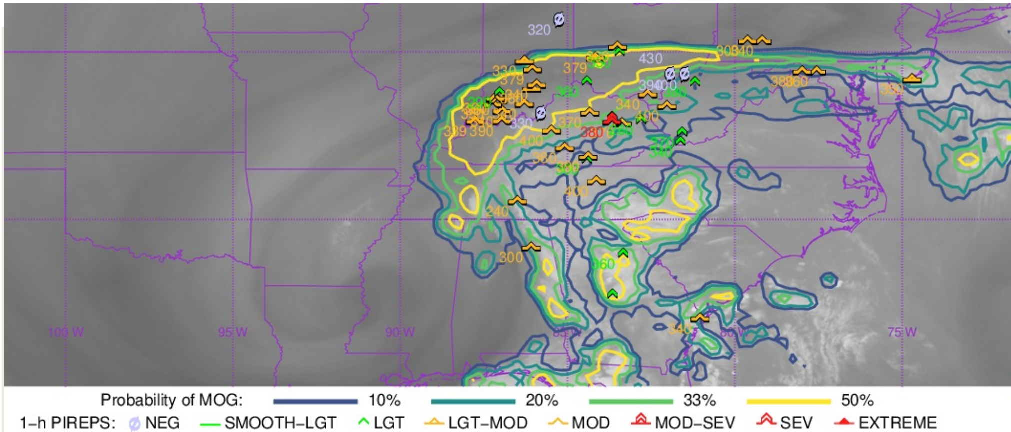
Nowcasting Aviation Turbulence

Anthony Wimmers, Sarah Griffin, Will Robus, Jason Otkin



Objective

- Objective: The development and deployment of a multi-geostationary-satellite turbulence nowcasting product trained from ABI imagery and automated aircraft turbulence reports.
- Stakeholders include the Honolulu Forecast Office, the Alaska Aviation Weather Unit, the Aviation Weather Center, the Central Weather Service Units that support regional airspace management, Boeing, and the major U.S. passenger air carriers represented by the Aviation for America (A4A) organization.



GOES-16 Moderate turbulence probability (contours) with pilot report overlay (symbols).

Approach

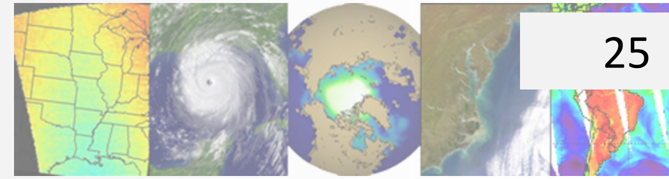
- Our approach uses deep learning applied to the GOES ABI imagery and the GFS model, and trained on objective aircraft-based measurements of turbulence.
- The deep learning model uses a unique, fully-convolutional architecture that successfully integrates GOES and GFS to process full disk estimates of cruising altitude turbulence in under 30 seconds.

Outcomes

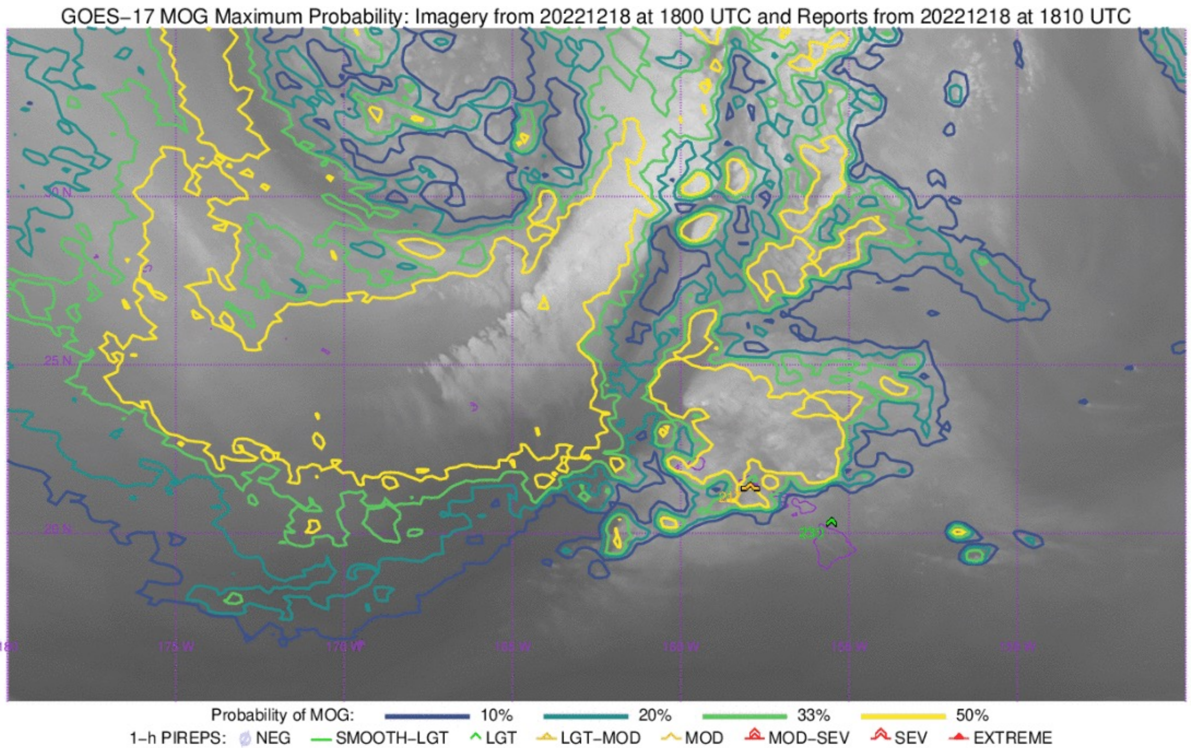
- We run an experimental, global product in real time with interactive viewing. The product is generated from GOES-16/18, Meteosat and Himawari.
- This has allowed us to evaluate the product and advance the state of readiness.
- We receive regular feedback from forecasters and airlines.

Nowcasting Aviation Turbulence

Anthony Wimmers, Sarah Griffin, Will Robus, Jason Otkin



The CIMSS CruiseNet Turbulence Product uses deep learning to interpret the potential for turbulence at airline cruising altitude determined by GOES imagery.

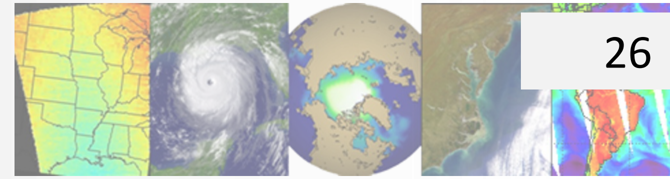


High-Impact event: HAL 35, from Phoenix to Honolulu, 18 December 2022

- Easily integrates GOES and matching GFS fields to maximize relevant information.
- Processes real-time estimations of turbulence in less than 30 seconds for a full disk.
- Has been extended in application to Meteosat and Himawari for global situational awareness.
- Product is delivered directly to NWS forecast offices.

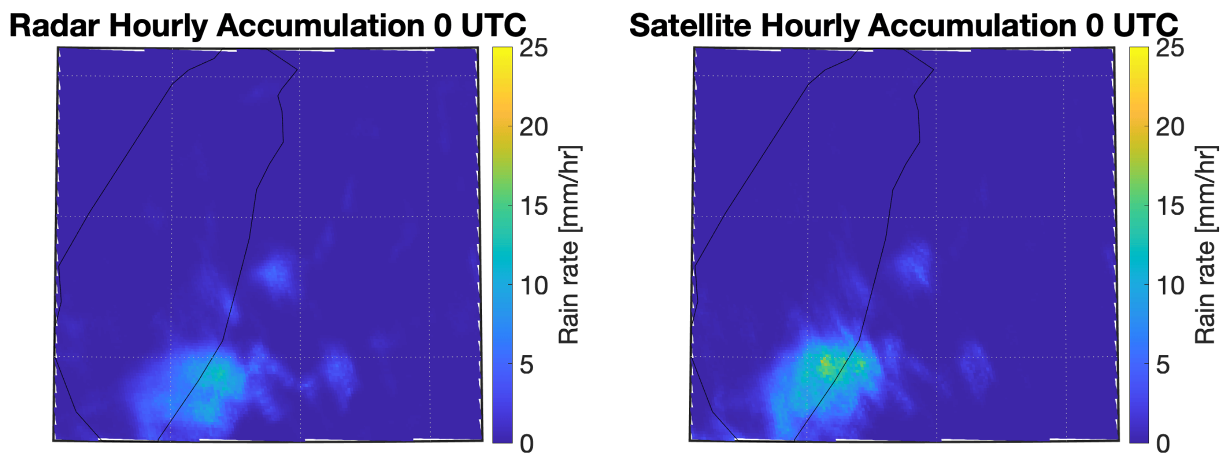
Precipitation Retrieval from Himawari-8/9

Tim Wagner and Mike Foster



Objective

- It is challenging to view approaching tropical systems from Taiwan using radars due to limited range
- A satellite-based approach enables forecasters to understand the strength of Pacific typhoons while they are still away from shore
- We are coordinating with Central Weather Administration of Taiwan (CWA) for implementation of this product



Animation comparing radar-observed (left) and satellite-derived hourly accumulation (right) from 0-6 UTC on 24 Aug 2022.

Approach

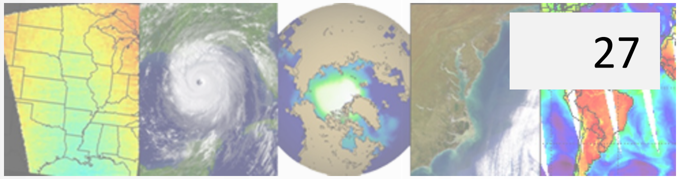
- Use a convolutional neural network (CNN) applied to CLAVR-x cloud products
- CLAVR-x provides microphysical information crucial to precipitation development (liquid water path, effective radius)
- CNN enables the spatial shape of the relevant inputs to matter in the retrieved product
- Use a custom loss function to enhance weight of relatively rare high rain pixels so that final product is more accurate.

Outcomes

- Product shows strong qualitative and quantitative agreement with radar-derived truth, especially when comparing 1 h accumulation totals.
- Meetings with CWA have focused the product on tropical systems as that is the greatest concern for radar limitations
- Product will contribute to more accurate and relevant tropical weather alerts for Taiwanese people

Improving Cloud and Solar Insolation Products Using Combined VIIRS and ABI High-Resolution Channels

Mike Foster, Coda Phillips, Tom Rink, Andrew Heidinger

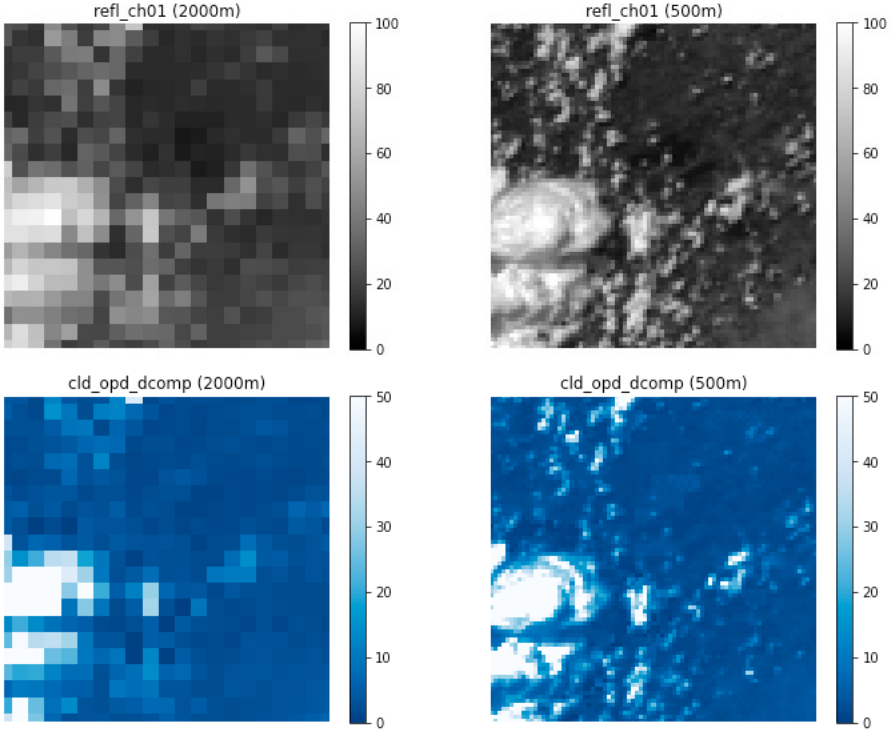


Objective

- Clouds processes can occur on very fine spatial scales and be missed or misrepresented by satellite sensors with finite resolution. This project takes advantage of high spatial resolution channels on the JPSS and GOES imagers to create 'Super-resolution' cloud products
- Applications for these products include:
  - Solar products for the National Solar Radiation Database (NSRDB) and other users in the solar community.
  - Products reliant on cloud top height (e.g. atmospheric motion vectors and aviation safety).
  - Products requiring clear conservative cloud mask (e.g. aerosol retrieval).

Approach

- Using the high-resolution visible channels on the JPSS/VIIRS and GOES/ABI imagers a convolution neural network (CNN) AI model was used to upscale coarser resolution radiometric channels.
- The CLAVR-x cloud processing system was modified to process this data to produce 'super-resolution' cloud products.



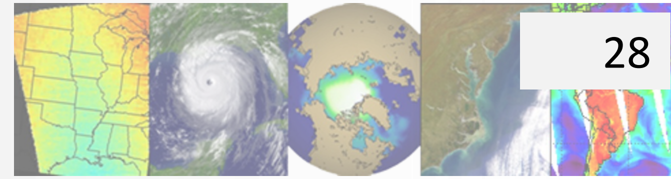
Example of super resolution cloud products identifying small scale features that effect solar radiation. Visible reflectance measured from the GOES-16 satellite (top panels) show a cloud 'self-shadowing' effect in the 500 m retrievals (right panels) not seen in the 2000 m retrievals (left panels). This effect can be seen in the retrieved cloud optical depth (bottom panels), which will impact solar radiation fields estimated at the surface. This scene is over Madison, Wisconsin.

SSEC

CIMSS

Development of MetOp-SG Cloud Properties

Mike Foster, Sharon Nebuda, Yue Li, Andi Walther, Mark Kulie



Objective

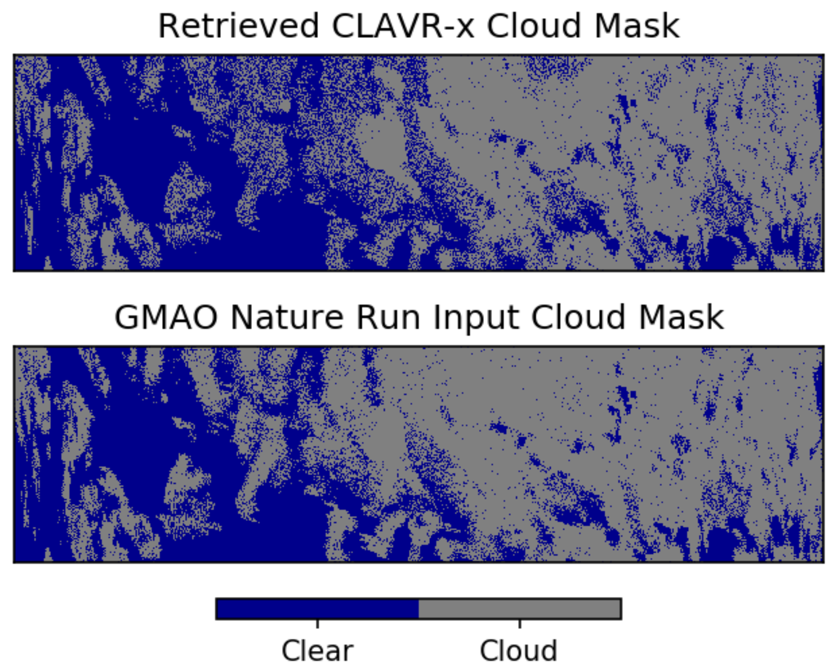
- Develop a tool to simulate EPS-SG METImage radiances for testing CLAVR-x algorithm
- Stakeholders include products and users that rely on operational cloud products once the EUMETSAT EPS-SG satellite is launched

Approach

- Using NASA GMAO Nature Run global model data and the RTTOV forward model, create 20 channels of simulated radiance data in which the cloud fields are specified and known for comparison to CLAVR-x products.

Outcomes

- Simulated data was created based on L1b proxy orbit data provided by EUMETSAT
- CLAVR-x L2 data was generated for evaluation
- Metrics for CLAVR-x product performance have been created
- Developed a subgrid cloud model to increase horizontal variability of the 7 km Nature Run input at the 500 m METImage pixel size



Cloud mask from CLAVR-x (top) using simulated radiances from the Nature Run (bottom) for a granule of proxy EPS-SG METImage.

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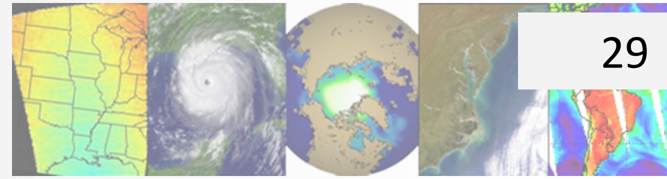
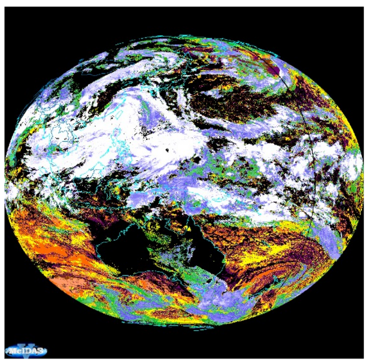
GOES-R/JPSS and Himawari Clouds

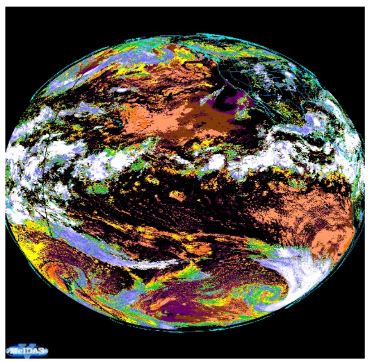
Mike Foster, Steve Wanzong, William Straka, Yue Li, Coda Phillips, David Loveless, Andi Walther, Andrew Heidinger, Mark Kulie



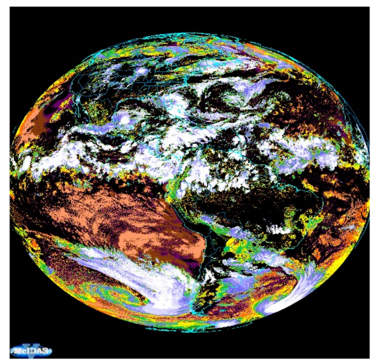
Cloud products are critical inputs to downstream algorithms such as Derived Motion Winds (NWP data assimilation), the enterprise cryosphere, aerosol and radiation budget algorithms, Clear Sky radiances (NWP data assimilation) and many others.



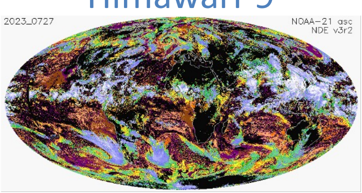
Himawari-9



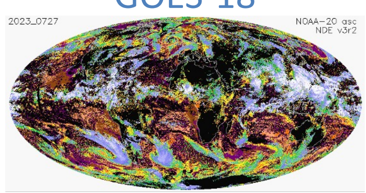
GOES-18



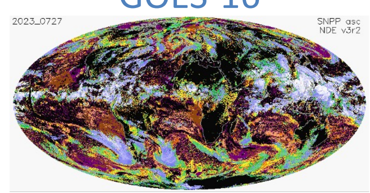
GOES-16



NOAA-21



NOAA-20



SNPP

Figure 1: Example cloud top pressure from some recently launched operational geostationary and polar weather satellites.

Outcomes

- Successfully transitioned the cloud algorithms from Baseline versions to Enterprise versions in NOAA Operations.
- Worked closely with teams that rely on cloud products (e.g. atmospheric motion vectors) to ensure the cloud products meets necessary standards.
- Worked with NOAA GOES-R PRO team to diagnose cloud product issues.
- Completed product reviews for NOAA-20, GOES-16, GOES-17, GOES-18 and Himawari-9

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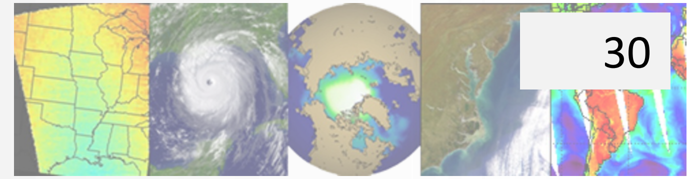
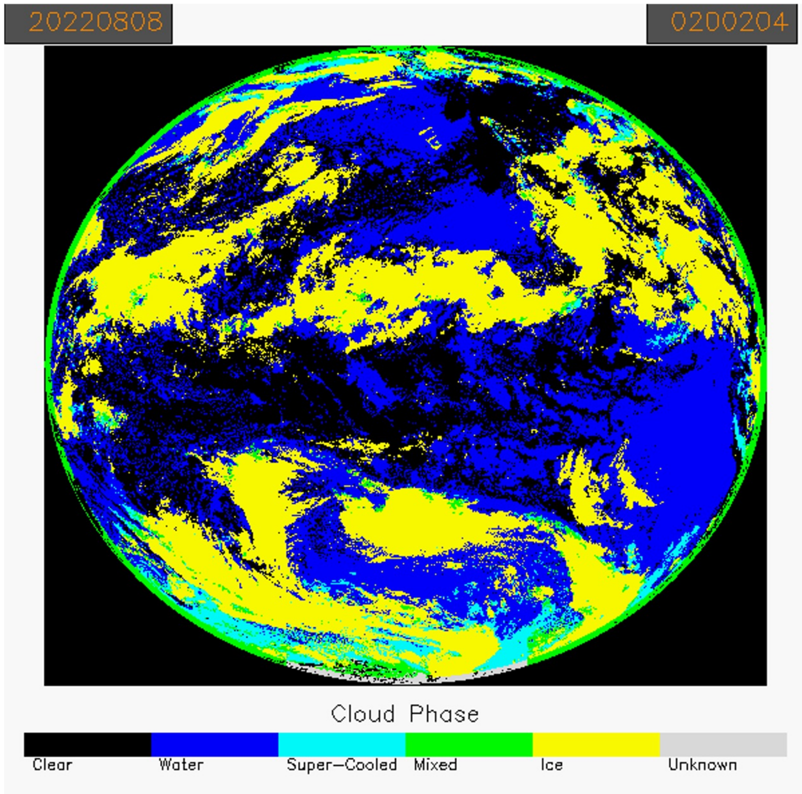
GOES-R/JPSS and Himawari Clouds

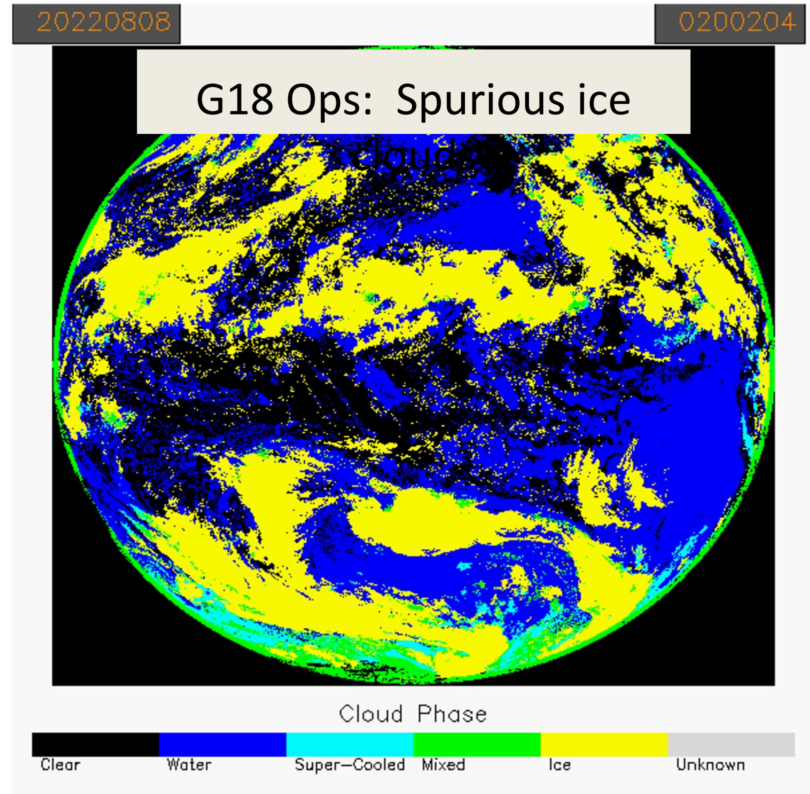
GOES-18 Example



Local NOAA Framework



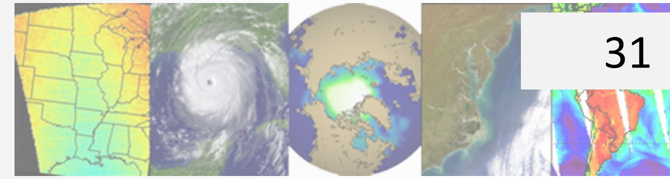
GOES-18 OPS



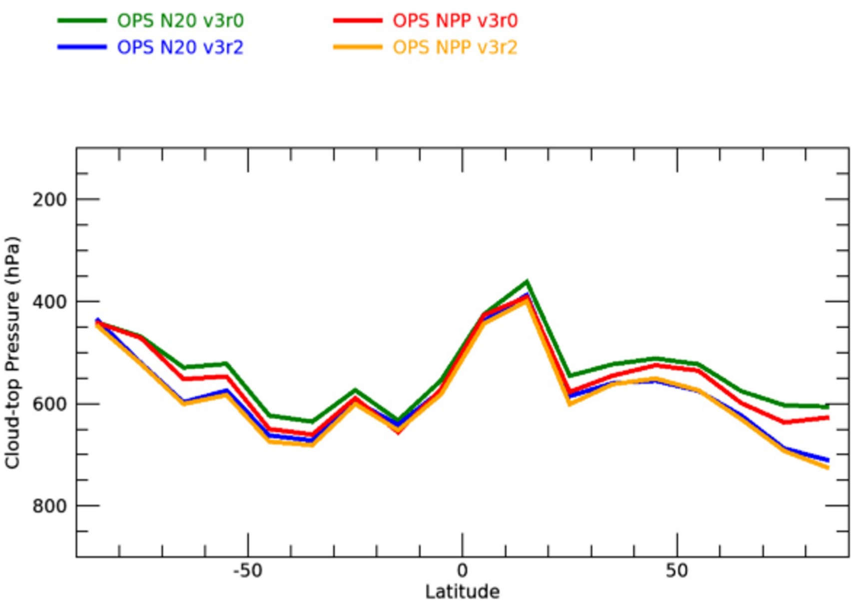
Example from the GOES-18 Cloud Phase review showing an overicing issue which was investigated and corrected within the GOES-R Ground System

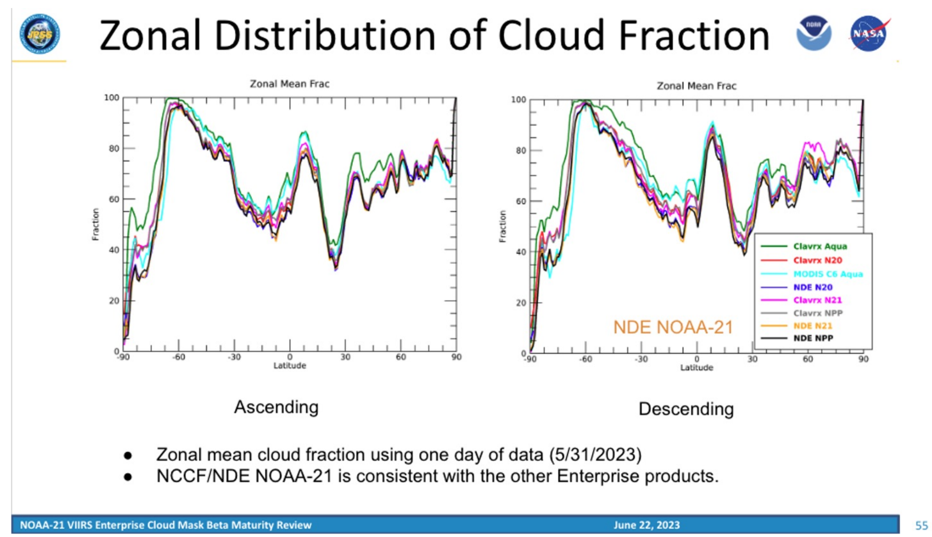
GOES-R/JPSS and Himawari Clouds

JPSS Example



- The JPSS cloud algorithms have been expanded to include the Cloud Cover layers product
- In addition, the Cloud Mask and DCOMP algorithms now use information from the lunar reflectance as derived from the Day Night Band





Comparison of the upgrade from v3r0 to v3r2 (the current ops code) showing that the algorithm performs as expected. The lines display the old and upgraded versions of code for NOAA-20 and Suomi NPP satellites

Comparison of the zonal cloud fraction for NOAA-21 as compared with other processing systems done for the NOAA-21 ECM Beta review, showing that the ops code performs as expected

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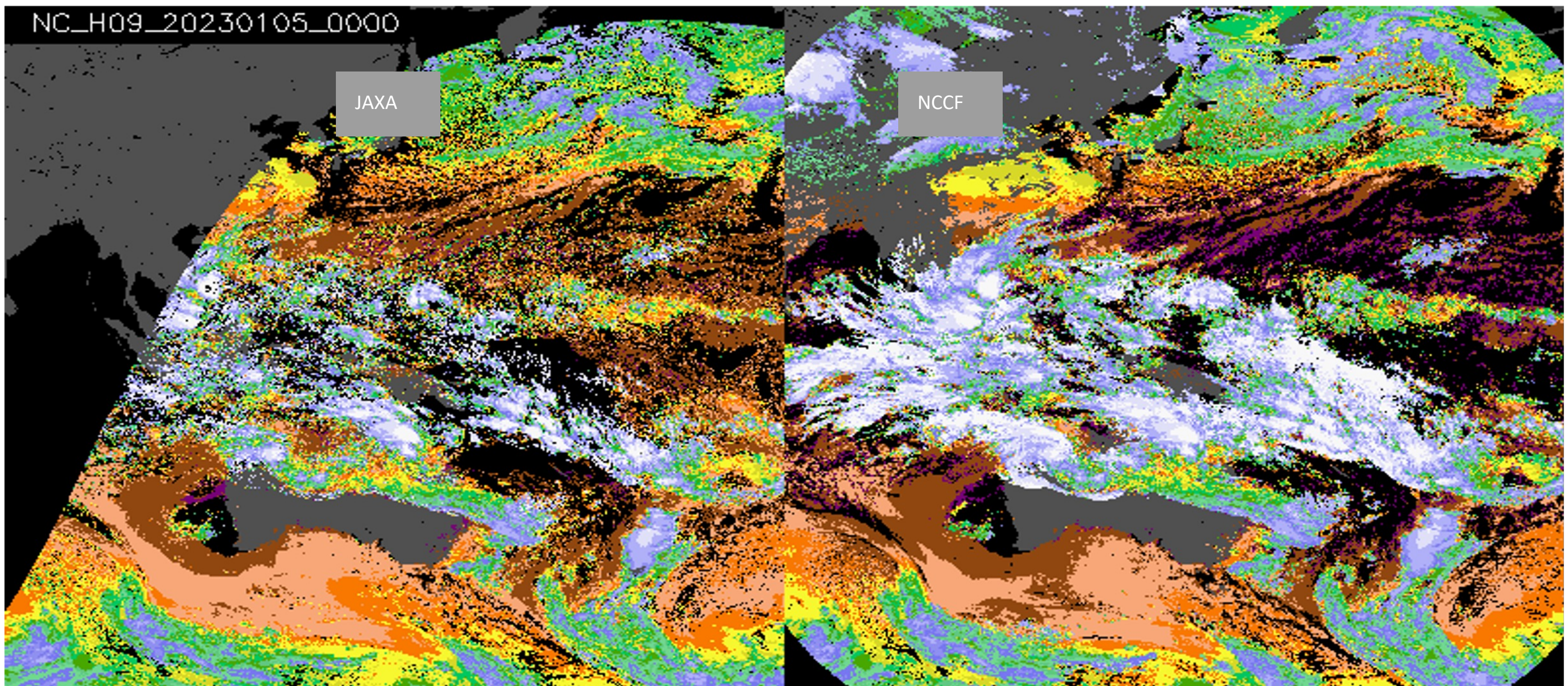
GOES-R/JPSS and Himawari Clouds

Himawari-8/9 Example

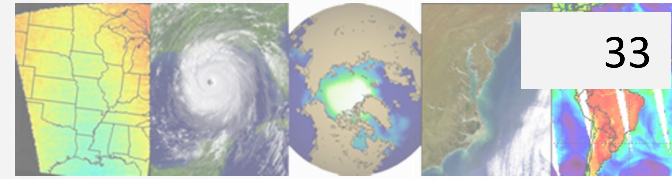
A successful review was conducted in 2023 to verify and validate the implementation of the Enterprise algorithms using Himawari-9 after it took over operations for Himawari-8



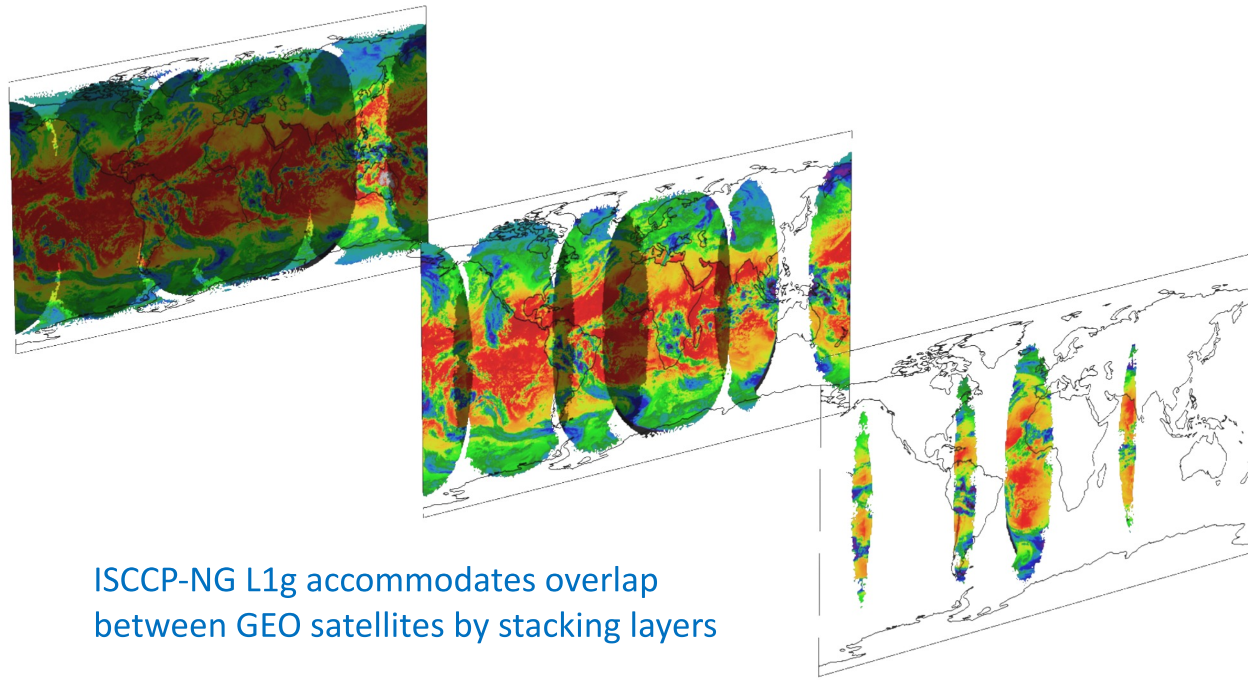
A comparison of JAXA cloud top temperature product as compared to the Enterprise Cloud Height product (ACHA) from Himawari-9.

GeoXO: International Satellite Cloud Climatology – Next Generation (ISCCP-NG)

Coda Phillips, Andrew Heidinger, and Mike Foster



- The ISCCP-NG project composites geostationary satellite data onto a uniform grid to form a global geo-ring of data.
- It offers 30-minute temporal resolution on a 0.05-degree spatial grid, utilizing anti-aliasing sampling techniques.
- Each timestep contains 17 spectral bands stacked into layers to accommodate satellite overlap.
- Subpixel statistics are provided specifically for 0.65µm and 11µm wavelengths, covering metrics like minimum, maximum, standard deviation, and count.



ISCCP-NG L1g accommodates overlap between GEO satellites by stacking layers

- Solar and satellite geometry information is also included for convenience.
- The L1g global composite of five satellites include GOES-16, GOES-17, Meteosat-8, Meteosat-11, Himawari-8, but can be adjusted for different periods of time.
- Data for the year 2021 is now publicly available as a demonstration. (http://tyr.ssec.wisc.edu/isccp/demos/demo_202307/)

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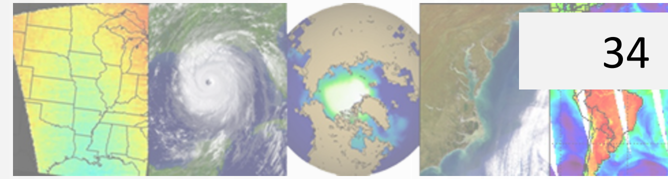
JPSS-VIIRS Cryosphere Products

R Dworak, X Wang and H Zhang; NOAA Collaborators: Jeff Key and Yinghui Liu



Objective

- Meet the need of the scientific community by development, implement, validate, improve, and document JPSS-NPP/NOAA20/21 Visible Infrared Imaging Radiometer Suite (VIIRS) algorithms for the generation of ice concentration, ice surface temperature, ice thickness and age and ice motion products.

Stakeholders/users

- NOAA/NASA
- NWP model developers and users
- Scientific community and the public

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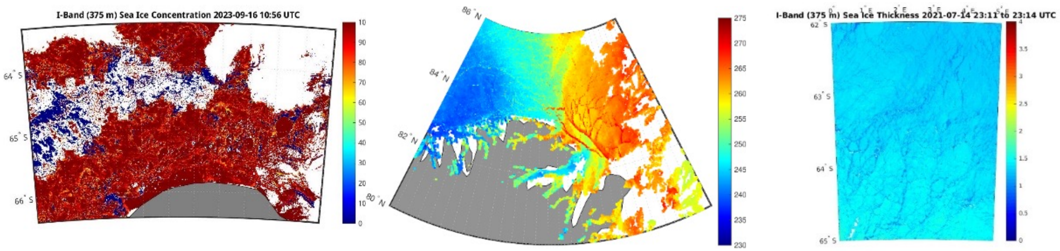


Examples of the highest resolution (via I-band, 375-m) of ice concentration (left), ice temperature (middle) and ice thickness (right) for various cases from NOAA-20 with time stamps given above the image. Note that data only available under clear sky condition determined by VIIRS CM.

Approach

- Ice surface temperature is retrieved with split-window technique. Ice concentration retrieval is based on a tie point algorithm with channel reflectances (daytime only) and brightness temperatures. Ice thickness is estimated by the One-dimensional Thermodynamic Ice Model (OTIM), which is based on ice surface energy budget theory. Ice motion utilizes a cross correlation technique for sets of pixels in image pairs to determine ice motion speed and direction.

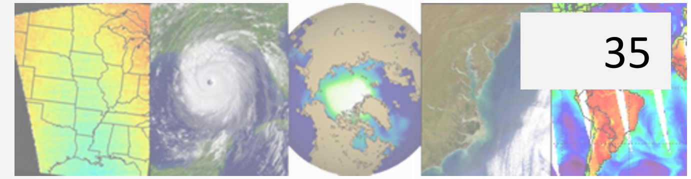
Outcomes

- Generation of ice products including ice concentration, ice surface temperature, ice thickness/age, and ice motion with VIIRS NPP/20/21 data. Latest products generated at UW-CIMSS.

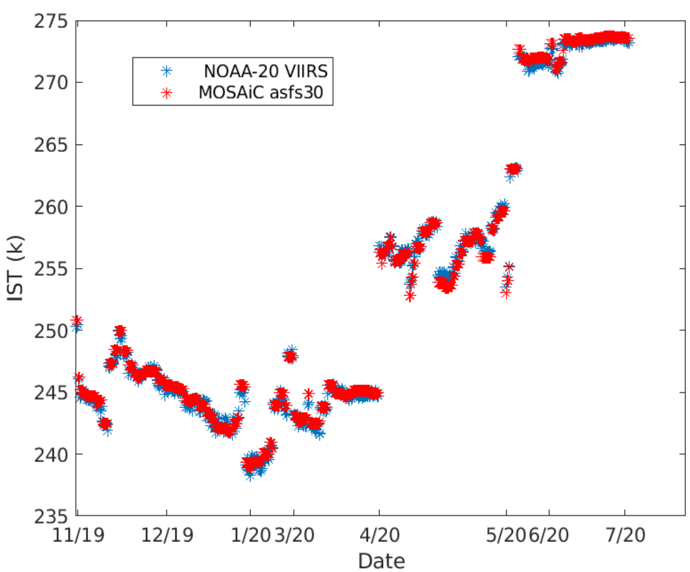
- Dworak R, Liu Y, Key J, Meier WN. A Blended Sea Ice Concentration Product from AMSR2 and VIIRS. *Remote Sensing*. 2021; 13(15):2982. https://doi.org/10.3390/rs13152982
- Dworak R, Liu Y, Key J, Zhang H, Wang X. Observing Sea and Lake Ice Through JPSS VIIRS. Presented at AMS 25th Conference on Satellite Meteorology, Oceanography and Climatology/ Joint 2022 NOAA Satellite Conference Madison, WI.

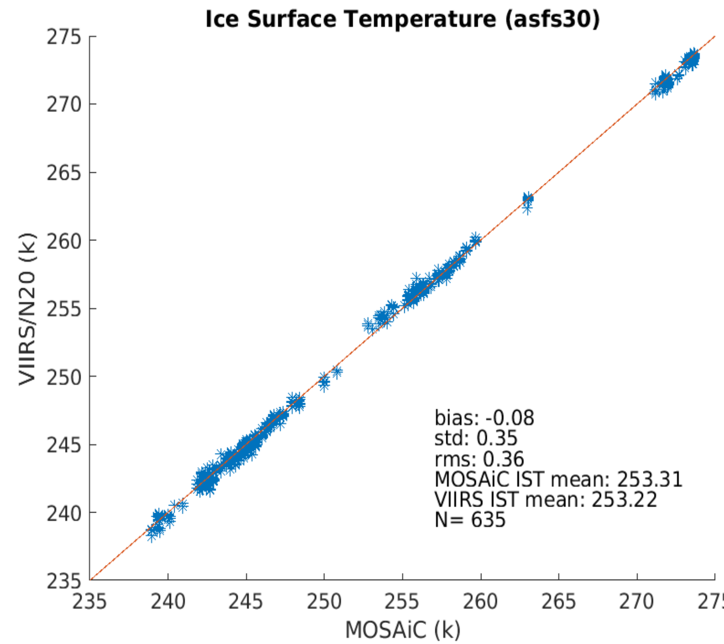
JPSS-VIIRS Cryosphere Products

Richard Dworak and Hong Zhang



- The Enterprise ice products are now operational for the JPSS NPP/NOAA-20 and 21 (VIIRS). Validation studies of these ice products have been performed against in-situ, field campaign, and other satellite measurements from buoys, IceBridge aircraft campaigns, MOSAiC ICESat, and CryoSat-2. Results show that the performance of ice product retrieval algorithms meets the measurement accuracy requirements. These ice products are suitable for a variety of applications by the science community and the public.

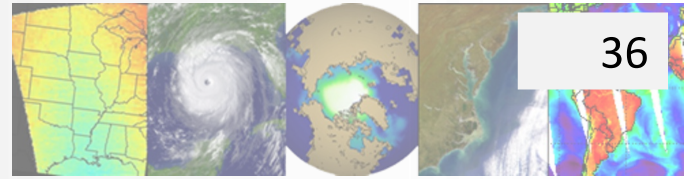


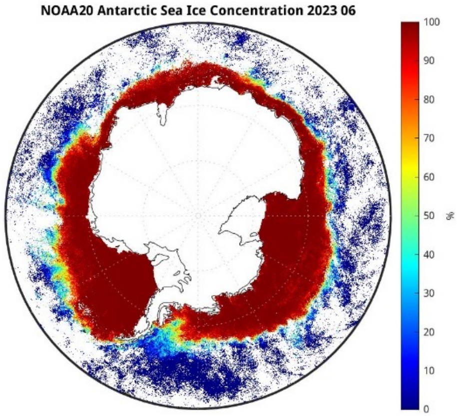


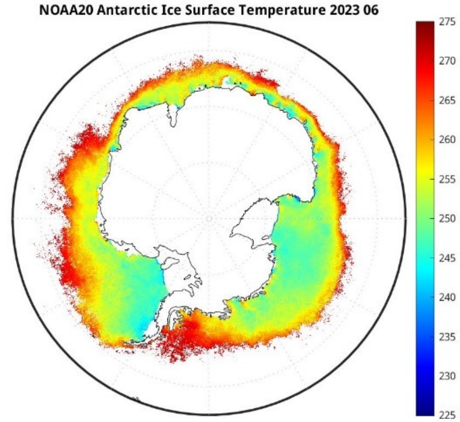
Ice Surface Temperatures (IST) under clear sky condition from NOAA-20 VIIRS compared to MOSAiC data, during November 2019 through July 2020 period over central Arctic north of Svaalbard.

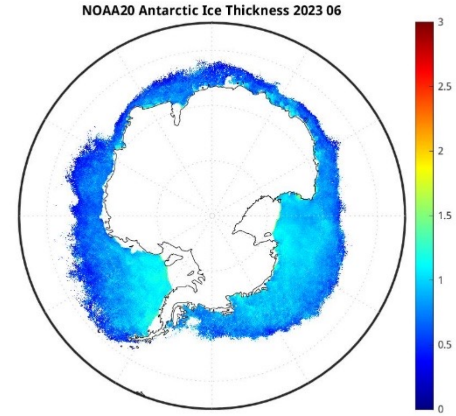
JPSS VIIRS Cryosphere Products

Richard Dworak

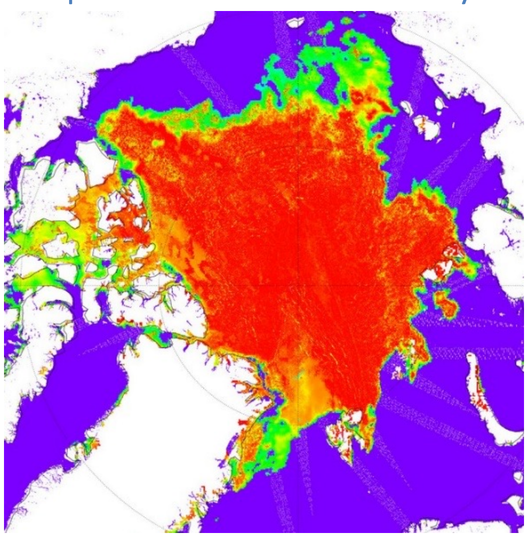




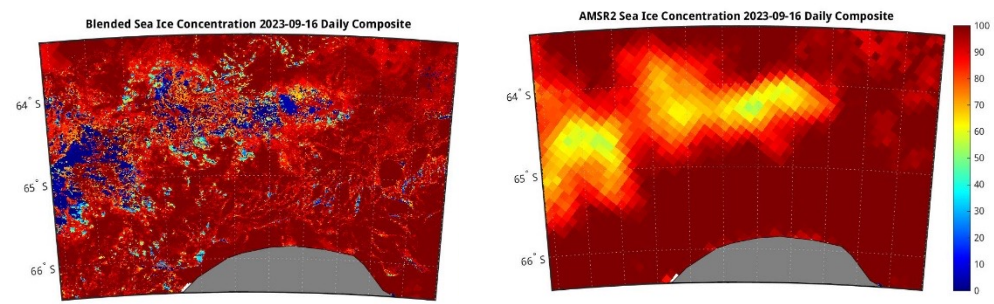


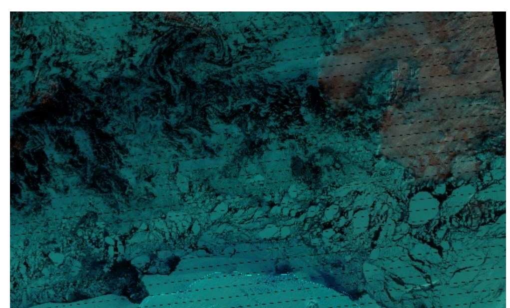


Ice Concentration (left), Ice surface temperature (middle), and ice thickness (right) from NOAA-20 VIIRS monthly composite data under clear sky conditions



Blended AMSR2-VIIRS Ice Concentration product for 29 July 2019 over central Arctic.

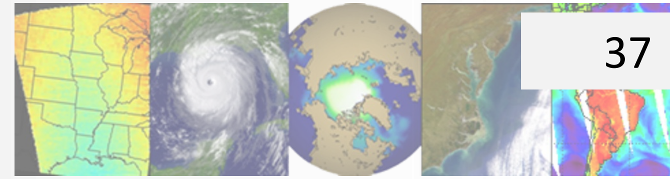




Blended (upper-left) and AMSR2 (upper-right) Ice Concentration products for 16 September 2023 aprox.10:56 UTC. NOAA-20 VIIRS 375m RGB image (bottom)

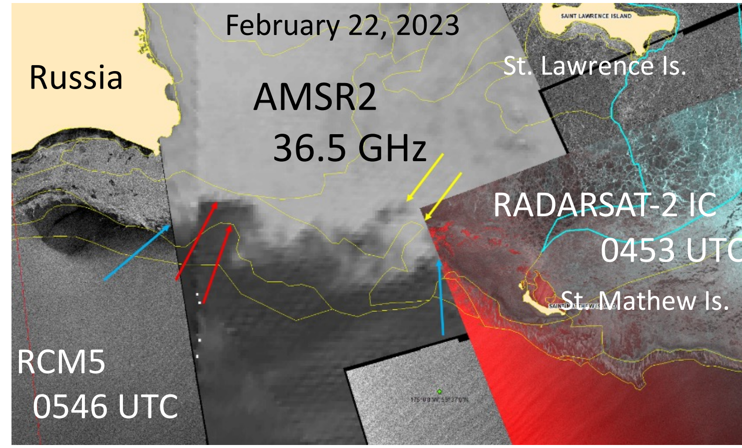
Improved Operational Sea Ice Products using Spatially Enhanced AMSR2 Data

Tom Greenwald, Yinghui Liu, Mary Brodzik, Walt Meier, Scott Lindstrom, Sean Helfrich, Jeff Key



Objective

- Motivation: AMSR2 data has, typically, not been one of the primary sources of sea ice information used by ice analysts in operations because of its coarse spatial resolution.
- Goals: To meet the needs of users, we will provide enhanced spatial resolution AMSR2 imagery and derived sea ice concentration products, as well as transfer the new products to operations.
- Stakeholders: Ice analysts and forecasters at the NWS Alaska Sea Ice Program (ASIP) and ice analysts at the US National Ice Center (USNIC).



Enhanced (3.125 km) AMSR2 imagery is most valuable to forecasters during gaps in hires SAR imagery coverage when conditions are cloudy.

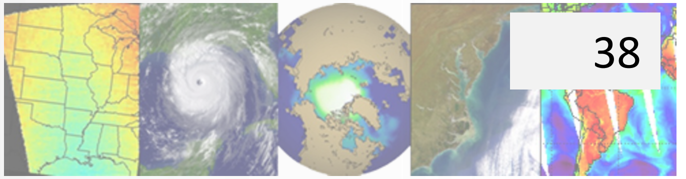
Approach

- A signal processing method is applied to multiple overlapping AMSR2 measurements to synthesize the signal onto 3.125, 6.25, and 12.5 km spatial grids, depending on the channel.
- Key innovation: Overlapping field-of-views provide angular information about a given scene that is exploited to enhance the spatial resolution.
- These image composites are produced separately for local day and night for a given day.

Outcomes

- Significant results: Near-real-time enhanced AMSR2 imagery and sea ice concentration products are being produced for users at ASIP and USNIC.
- Benefits: Higher resolution AMSR2 sea ice products provide reliable data in cloudy conditions or when other satellite data are unavailable.
- Feedback: Users say the new products are “**a more reliable and consistent tool for ice detection**;” “**allows … finer scale changes to the analysis that simply wasn't possible with the original product**.”
- Training: Developed training materials for end-users through two Quick Guides.

EPS-SG Cryosphere Products



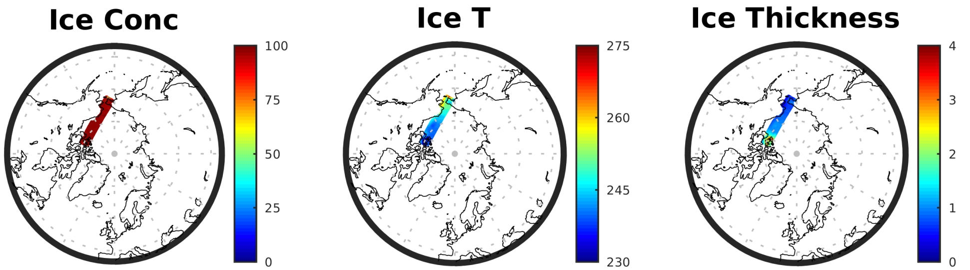
Xuanji Wang and Feng He; NOAA Collaborators: Jeff Key and Yinghui Liu

Objective

- Support NOAA's NESDIS/STAR activities on generating Cryosphere products for the EUMETSAT EPS-SG.

Stakeholders/users

- NOAA/NASA/EUMETSAT Satellite projects
- NWP model developers and users
- Scientific community and the public



Sea ice concentration (left), ice surface temperature (middle), and ice thickness (right) for the Arctic Ocean from simulated METimage L1b data (version 2.0) on January 3, 2020 at 05:36 UTC.

Approach

- Adapt existing ice algorithms for the Visible and Infrared Imaging Radiometer Suite (VIIRS) to the EPS-SG METimage instruments. METimage is used to produce binary ice cover mask and ice concentration (IC), ice surface temperature (IST), and ice thickness/age. METimage ice products will also be applied to large inland lakes and rivers.

Outcomes

- Generation of ice products including ice concentration, ice surface temperature, ice thickness/age, and ice motion with METimage proxy data.
- Xuanji Wang, Yinghui Liu, Jeff Key, Aaron Letterly, Rich Dworak, Feng He, Sea and Lake Ice Products from NOAA Satellites, ***2022 AMS Collective Madison Meeting***, 08-12 August 2022, Madison, Wisconsin.
- Feng He, Xuanji Wang, Yinghui Liu, An intercomparison of Arctic sea ice thickness from contemporary satellite observations and climate model simulations, ***2022 AMS Collective Madison Meeting***, 08-12 August 2022, Madison, Wisconsin.

EPS-SG Cryosphere Products

Xuanji Wang

Adapting sea and lake ice algorithms for the Visible and Infrared Imaging Radiometer Suite (VIIRS) to STAR Simulated EUMETSAT Polar System-Second Generation (EPS-SG) METimage Data for the future Metop-SG-A and -B satellites.

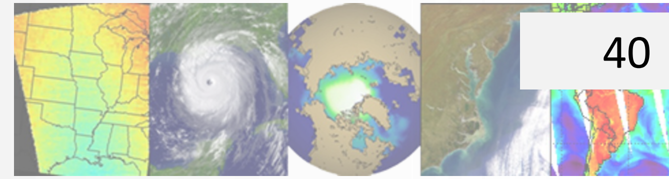
- Our Enterprise algorithms for VIIRS are adapted to work with EPS-SG METimage, which has 20 multi-spectral (visible and IR) bands and different swath characteristics. The task includes algorithm modification, implementation, and product evaluation.

- METimage ice products include a binary ice cover mask, ice concentration, ice surface temperature (IST), and ice thickness/age. The METimage ice products are also derived for large inland lakes and rivers. Quantitative comparisons between METimage and VIIRS products are performed. The METimage algorithm software, documentation (ATBDs), and test results are also provided as part of this work.

- The validation of EPS-SG METimage Ice Surface Temperature (IST) was conducted by the comparison with the ERA5 reanalysis surface temperature that was used as the input of surface skin temperature for the METimage radiance simulation. EPS-SG IST products derived from 14 overpasses of STAR-simulated proxy data on Jan 3, 2020 were compared with the corresponding ERA5 reanalysis input surface temperature data.

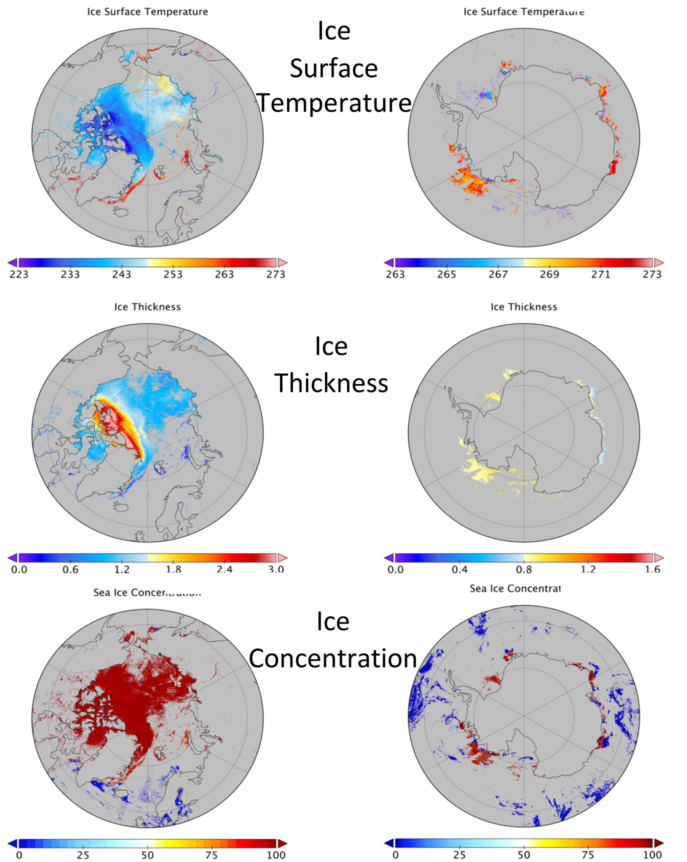
- The overall IST difference between EPS-SG and ERA5 for all 14 overpasses is -0.60 K with the standard deviation of 0.25 K, which satisfies the METimage threshold quality requirements of 1 K for measurement accuracy and 1.5 K for measurement uncertainty.

EPS-SG Cryosphere Products

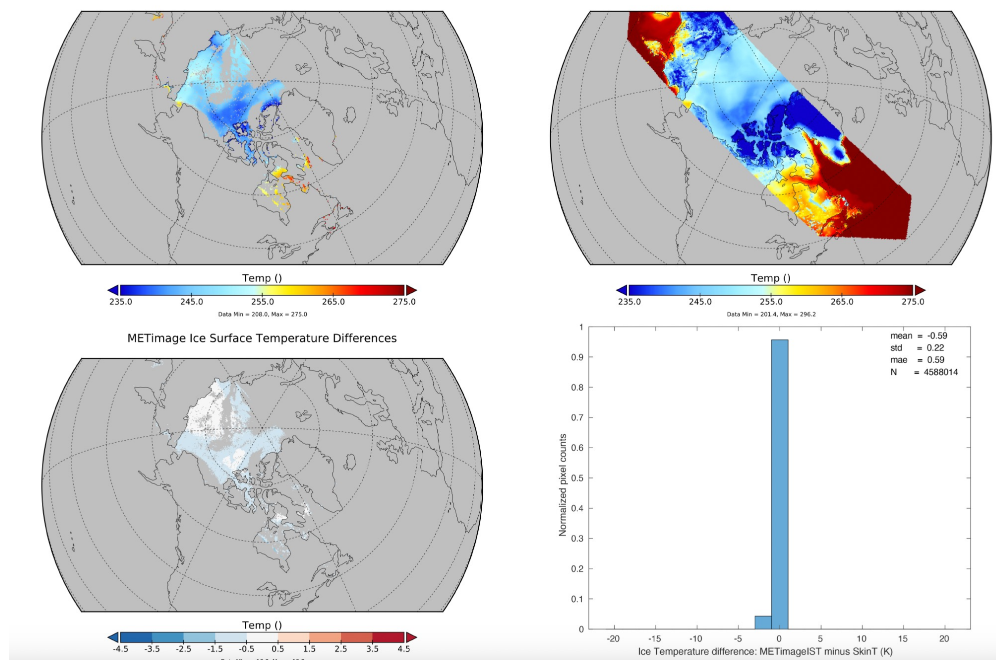


Xuanji Wang and Feng He; NOAA Collaborators: Jeff Key and Yinghui Liu

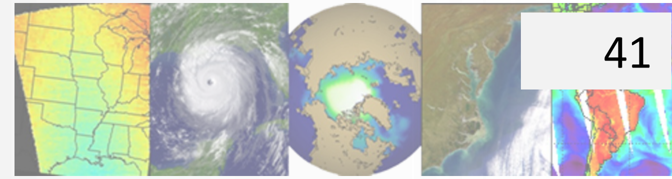
Adapting sea and lake ice algorithms for the Visible and Infrared Imaging Radiometer Suite (VIIRS) to STAR Simulated EUMETSAT Polar System-Second Generation (EPS-SG) METimage Data for the future Metop-SG-A and -B satellites.



Daily clear sky composite ice products from EPS-SG METimage proxy data. The ice surface temperature (K), ice thickness (m) and ice concentration (%) from the top to the bottom sequentially on January 3, 2020 for the Arctic Ocean (left column) and the Antarctic Ocean (right column).



Difference of ice surface temperature between STAR Simulated EPS-SG proxy data and ERA5 reanalysis data for the first overpass on Jan 3, 2020. Top left: METimage IST; top right: ERA5 IST; lower left: the IST difference between EPS-SG and ERA5; lower right: the histogram of the IST differences.



Cryosphere Climate Data Records

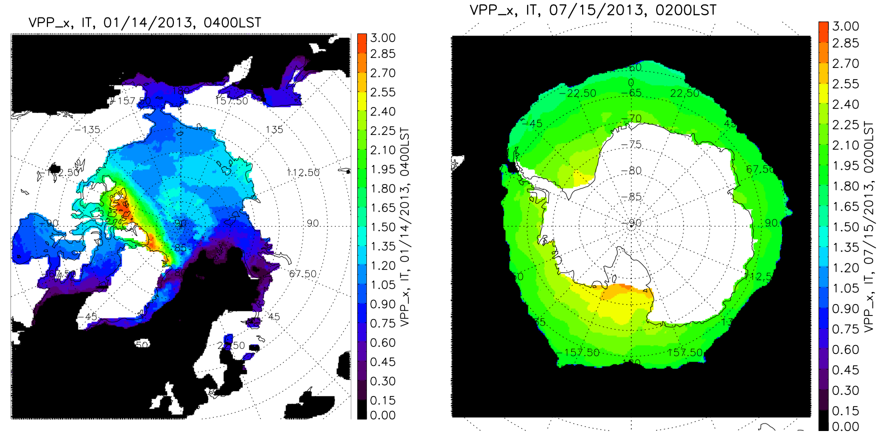
X Wang, R Dworak, S Moeller; NOAA Collaborators: J Key and Y Liu

Objective

- Support NOAA's National Centers for Environmental Information (NCEI) by developing, producing, and extending two climate data records (CDRs), FCDR and TCDR, from AVHRR and VIIRS to monitor changes in atmospheres, oceans and land.

Stakeholders/users

- NOAA/NASA LEO projects
- NWP model developers and users
- Scientific community and the public



The Arctic (left) and Antarctic (right) sea ice thickness retrieved with VIIRS data on January 15, 2013 (Arctic winter) and July 15, 2013 (Antarctic winter), respectively.

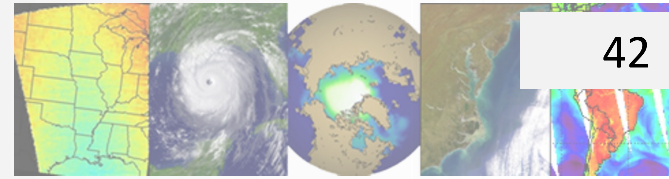
Approach

- The generation of CDRs daily composites includes the following steps: 1) collecting AVHRR/VIIRS GAC/VGAC Level 1b data from NOAA POES, 2) calibrating the data to obtain the visible channel reflectances and thermal channel Brightness Temperatures, 3) navigating the data to obtain accurate longitudes/latitudes and viewing angles, 4) applying a set of retrieval algorithms to retrieve surface, cloud, radiation, and Cryosphere products, 5) delivering CDRs daily to NCEI for archiving and distributing purposes.

Outcomes

- Near-real time generation of daily composite of the FCDR and TCDR with AVHRR and VIIRS data to extend these CDRs from 1982 to the present. These CDRs are delivered to NECI for archiving and distribution to the public.
- Xuanji Wang, Yinghui Liu, Jeffrey R. Key, and Richard Dworak, 2022, A New Perspective on Four Decades of Changes in Arctic Sea Ice from Satellite Observations, ***Remote Sensing***, 2022,14(8), 1846, https://doi.org/10.3390/rs14081846.
- Rudong Zhang, Hailong Wang, Qiang Fu, Philip J. Rasch, Xuanji Wang, 2019, Unraveling driving forces explaining significant reduction in satellite-inferred Arctic surface albedo since the 1980s, ***Proceedings of the National Academy of Sciences***, Nov 2019, 201915258; DOI: 10.1073/pnas.1915258116.

Cryosphere Climate Data Records

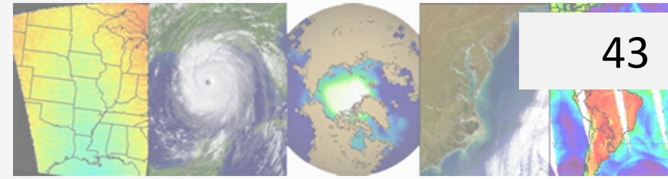


Xuanji Wang

The Polar Pathfinder Fundamental Climate Data Record (FCDR) is a Climate Data Record (CDR) for the Polar Regions derived from Advanced Very High Resolution Radiometer (AVHRR) and Visible Infrared Imaging Radiometer Suite (VIIRS) data.

- **Polar Pathfinder Fundamental Climate Data Record (FCDR) :**
  - The north polar region (Arctic) and the south polar region (Antarctic).
  - From 1982 to the present.
  - Two visible channel reflectances and three infrared channel brightness temperatures.
  - Twice-daily composites at local solar times (LST) of 14:00 (Arctic and Antarctic) , 02:00 (Antarctic only), and 04:00 (Arctic only) on a 5 km Equal-Area Scalable Earth (EASE)-Grid over the Arctic and the Antarctic.
  - Used for retrieving geophysical parameters, e.g., input to generate The Polar Pathfinder Thematic Climate Data Record (TCDR).

- **Polar Pathfinder Thematic Climate Data Record (TCDR) :**
  - The north polar region (Arctic) and the south polar region (Antarctic). Twice-daily composites at local solar times (LST) of 14:00 (Arctic and Antarctic) , 02:00 (Antarctic only), and 04:00 (Arctic only) on a 25 km Equal-Area Scalable Earth (EASE)-Grid over both poles.
  - From 1982 to the present.
  - Parameters include Surface albedo, surface temperature, cloud properties (phase, particle size, optical depth, temperature, pressure, type), cloud radiative forcing, ice concentration, ice thickness and age, radiation fluxes (TOA and Surface).
  - Used by the science community for climate monitoring, global and polar climate changes, trend analysis, and studies of climate interactions and feedbacks.

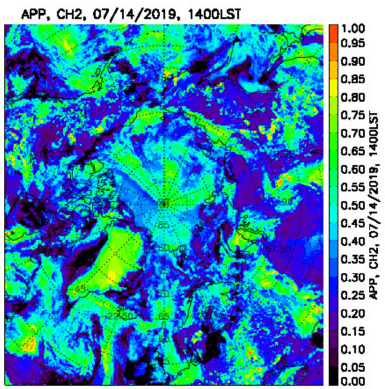


Cryosphere Climate Data Records

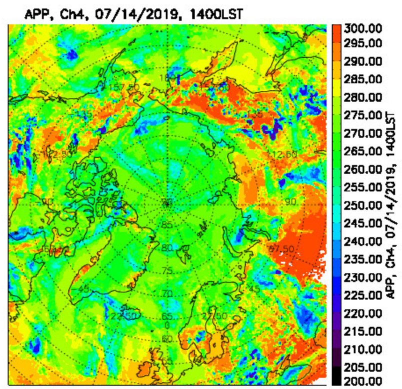
X Wang, R Dworak, S Moeller; NOAA Collaborators: J Key and Y Liu

The Polar Pathfinder Fundamental Climate Data Record (FCDR) is a Climate Data Record (CDR) for the Polar Regions derived from Advanced Very High Resolution Radiometer (AVHRR) and Visible Infrared Imaging Radiometer Suite (VIIRS) data.

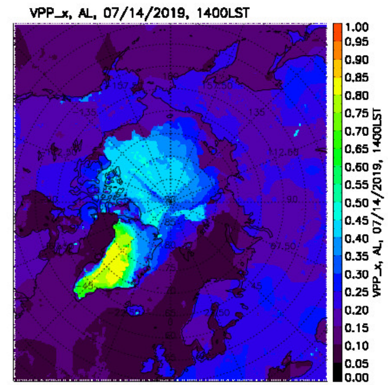
2019-07-14 at 14:00 LST, CH2



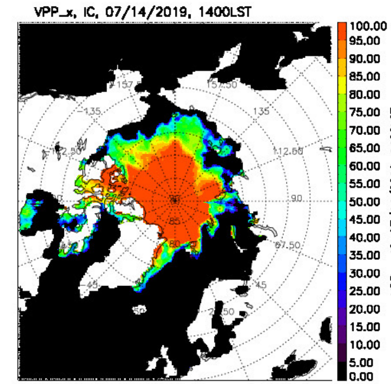
2019-07-14 at 14:00 LST, CH4



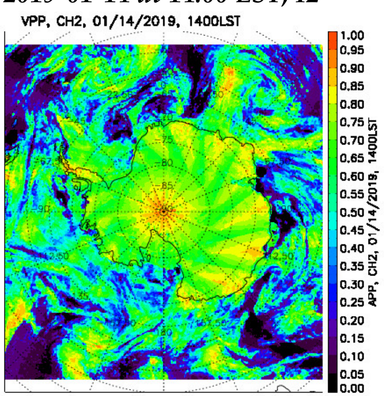
2019-07-14 at 14:00 LST, Albedo



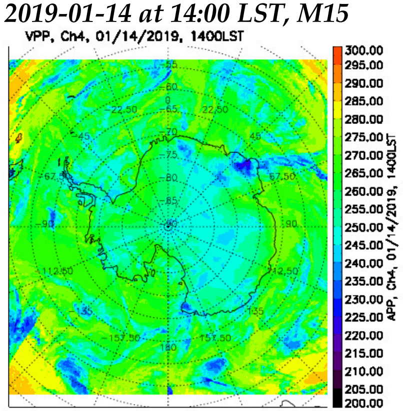
2019-07-14 at 14:00 LST, Ice Concentration



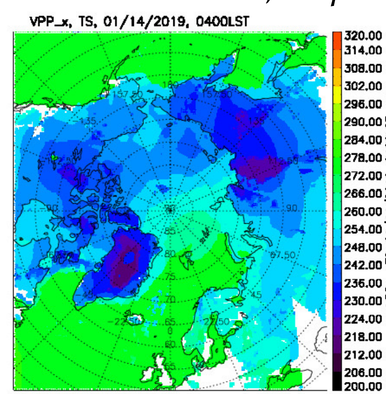
2019-01-14 at 14:00 LST, I2



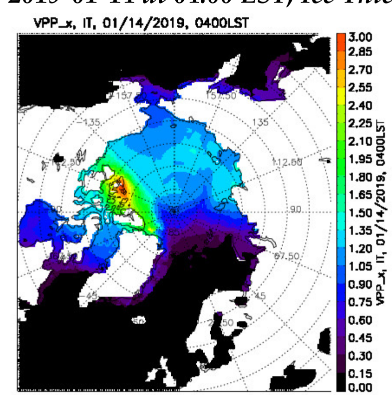
2019-01-14 at 14:00 LST, M15



2019-07-14 at 04:00 LST, Temperature



2019-01-14 at 04:00 LST, Ice Thickness

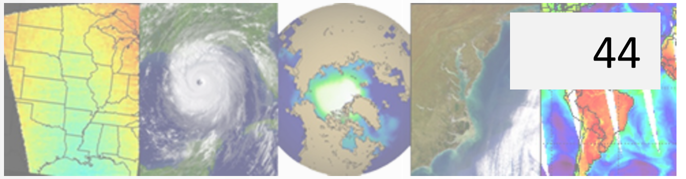


AVHRR/VIIRS channel 2/I2 reflectance and channel 4/M15 brightness temperature for the Arctic (top) on July 14,2019 and for the Antarctic (bottom) on January 14,2019.

Arctic surface broadband albedo and ice concentration (top) on July 14,2019 and Arctic surface skin temperature and ice thickness (bottom) on January 14,2019.

GOES-R Cryosphere Products

X Wang, F He, J Hoffman, H Zhang; NOAA Collaborators: J Key and Y Liu



Objective

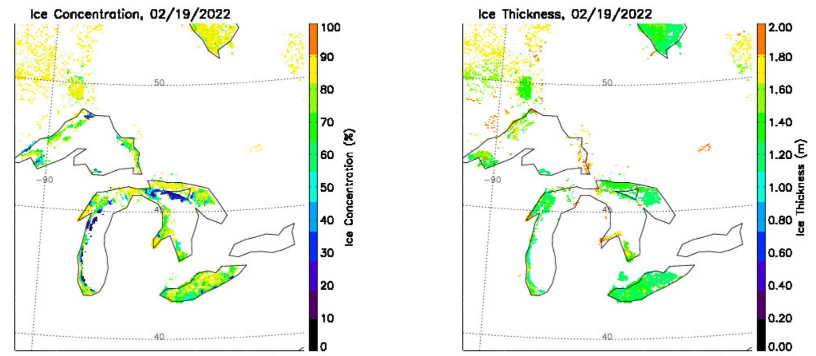
- Develop, implement, validate, improve, and document GOES-16/17/18 Advanced Baseline Imager (ABI) algorithms for the generation of ice concentration, ice surface temperature, ice thickness and age, and ice motion products.

Stakeholders/users

- NOAA/NASA
- NWP model developers and users
- Scientific community and the public

Approach

- Ice surface temperature is retrieved with split-window technique. Ice concentration retrieval is based on a tie point algorithm with channel reflectances (daytime only) and brightness temperatures. Ice thickness is estimated by the One-dimensional Thermodynamic Ice Model (OTIM), which is based on ice surface energy budget theory. Ice motion utilizes a cross correlation technique for sets of pixels in image pairs to determine ice motion speed and direction.



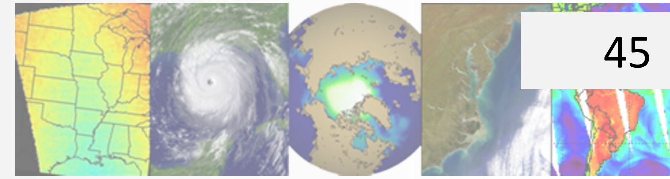
Daily composite ice concentration (left) and ice thickness (right) for the Great Lakes from GOES-16 ABI data on 19 February 2022 under clear sky condition.

Outcomes

- Generation of ice products including ice concentration, ice surface temperature, ice thickness/age, and ice motion with GOES-16/18 ABI data.
- J. Key, Y. Liu, X. Wang, A. Letterly, and T. Painter, 2019, Snow and Ice Products from ABI on the GOES-R Series. In The GOES-R Series: ***<<A New Generation of Geostationary Environmental Satellites>>***, S. Goodman, T. Schmit, J. Daniels, and R. Redmond (eds.), Elsevier, September 18, 2019, 304 pp., ISBN: 0128143274.
- Xuanji Wang, Yinghui Liu, Jeff Key, Aaron Letterly, Rich Dworak, Feng He, Sea and Lake Ice Products from NOAA Satellites, ***2022 AMS Collective Madison Meeting***, 08-12 August 2022, Madison, Wisconsin.

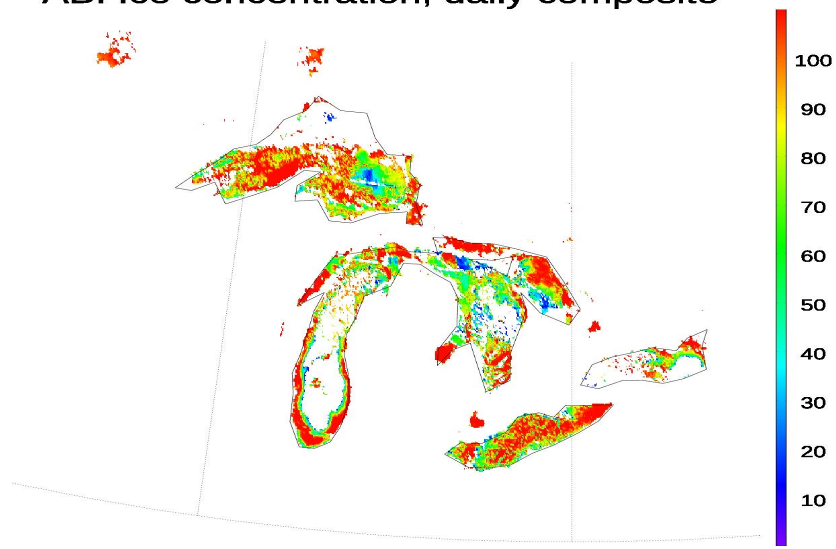
GOES-R Cryosphere Products

Xuanji Wang



- The Enterprise ice products are now operational for the GOES-16/17/18 Advanced Baseline Imager (ABI). Validation studies of these ice products have been performed against in-situ, field campaign, and other satellite measurements from buoys, IceBridge aircraft campaigns, ICESat, and CryoSat-2. Results show that the performance of ice product retrieval algorithms meets the measurement accuracy requirements. These ice products are suitable for a variety of applications by the science community and the public.

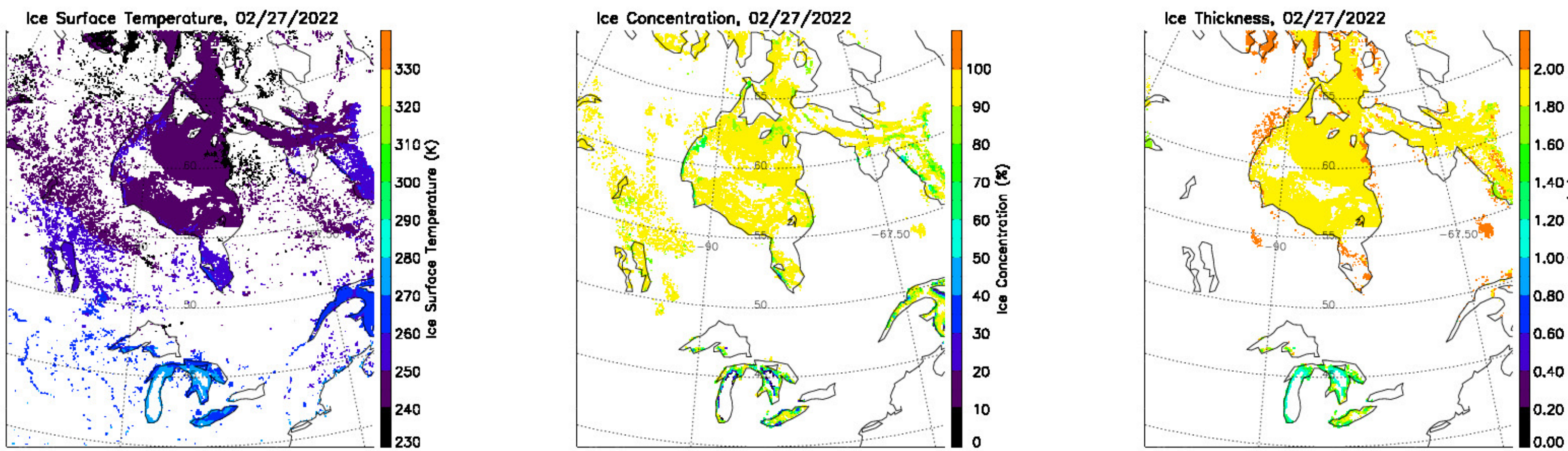
GOES-16 ABI natural-color composite on 14 February, 2018.



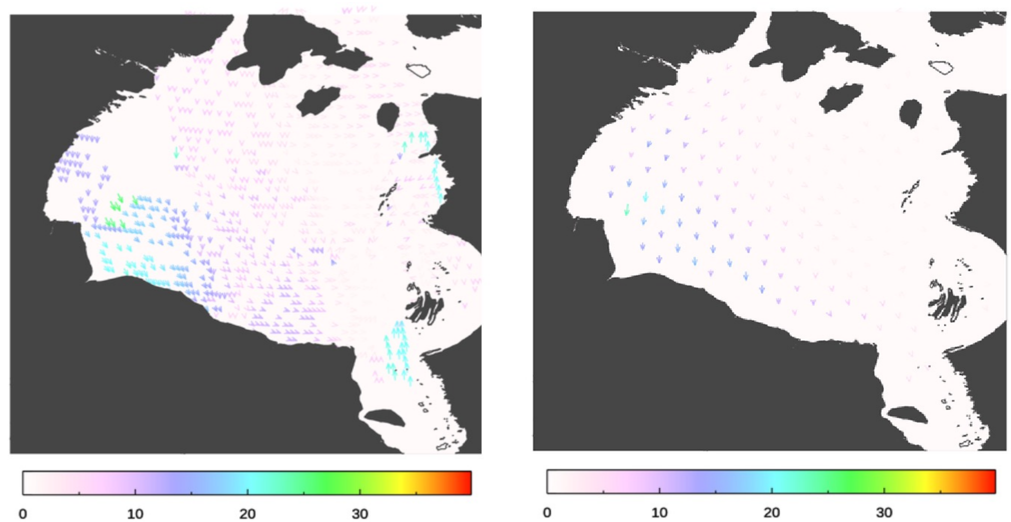
Ice concentration (IC) under clear sky condition from GOES-16 ABI data in the Great Lakes (right), and GOES-16 ABI true color composite image (left) on February 14, 2018.

GOES-R Cryosphere Products

X Wang, F He, J Hoffman, H Zhang; NOAA Collaborators: J Key and Y Liu



Ice surface temperature (left), Ice concentration (middle), and ice thickness (right) from GOES-16 ABI daily composite data under clear sky conditions on February 27, 2022.



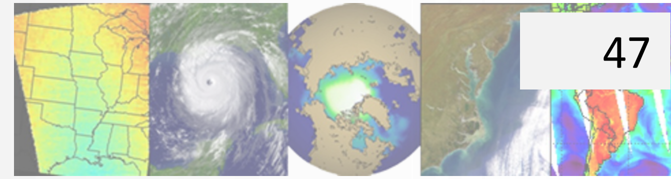
“Clustered” ice motion (km/day) from GOES-16 ABI (Feb 19, 2020) vs. EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI-SAF) ice motion (Feb 17-19, 2020).

SSEC

CIMSS

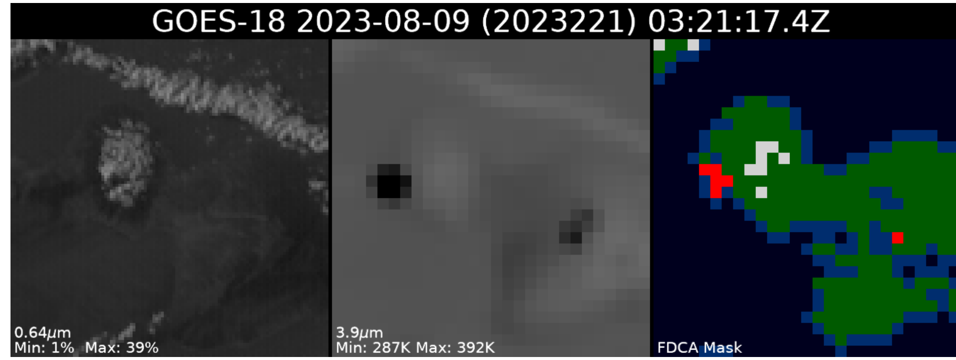
GOES-R Fire Detection and Characterization

Chris Schmidt



Objective

- To support, maintain, and update the GOES-R ABI Operational Fire Detection and Characterization Algorithm (FDCA)
- Provide training and information for users
- Users and stakeholders include but are not limited to NWS forecasters and Incident Meteorologists, emergency managers, smoke and aerosol modelers, and power utilities



Left to right, GOES-18 visible and 3.9 μm (fires are dark) raw data and the FDCA mask (red is detected fires) for Maui on 9 August 2023.

Approach

- Utilize the difference between the spectral peak of fire emissions (around 3.9 μm) and longwave infrared (such as 11.2 μm) to identify probable fires, and use contextual information to refine the detection
- Operates at 2 km resolution on all data collected by ABI
- Fire radiative power, size, and temperature characteristics and a metadata mask labeling the algorithm's decision about every pixel are provided

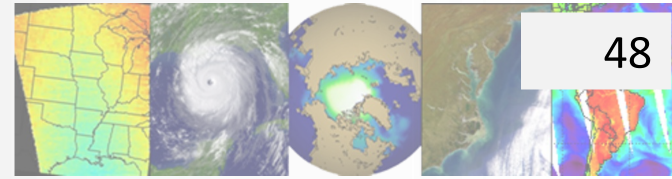
Outcomes

- The FDCA augments the ability of NWS and others to detect and monitor wildfires
- Multiple trainings performed at short courses, conferences, and student-focused events
- Use of ABI for wildfire work has greatly increased
- Project produced terrain correction for GOES data, which is critical for the pixel-level granularity of fire data where ground position truly matters
- Build relationships with new user bases, most recently the prescribed fire community

SSEC

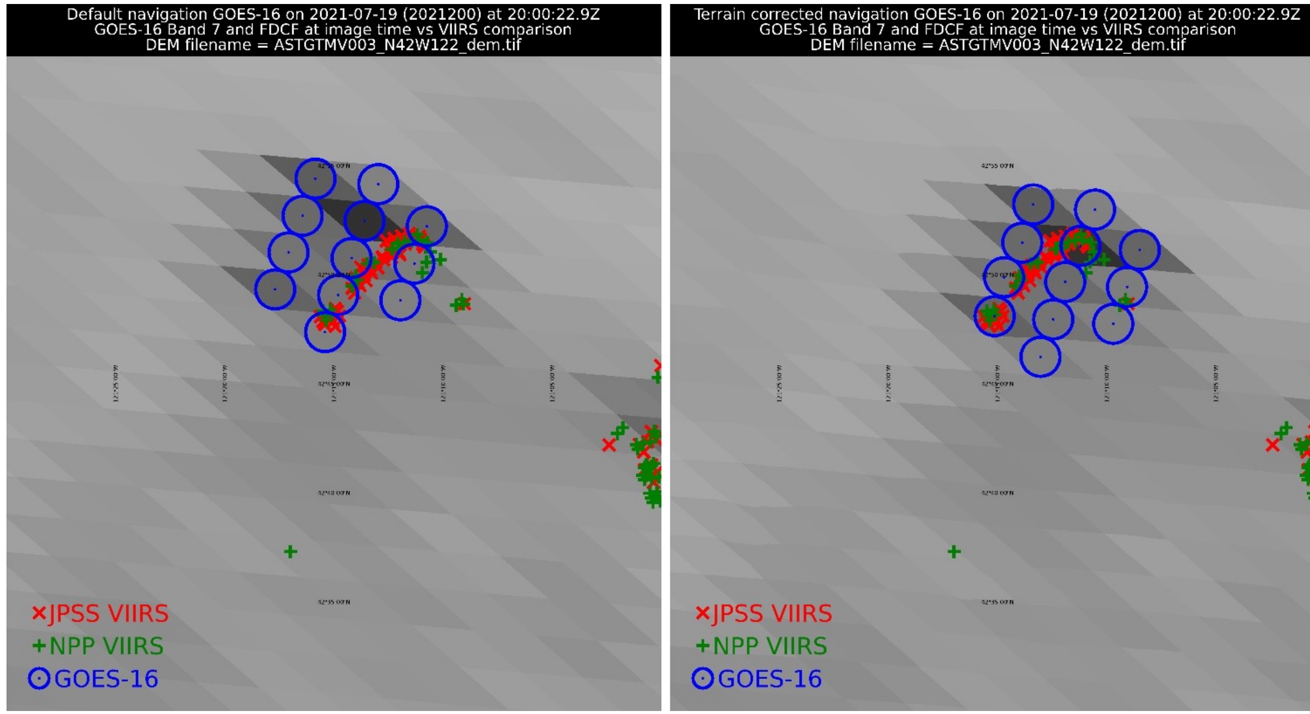
CIMSS

Chris Schmidt



Terrain Correction

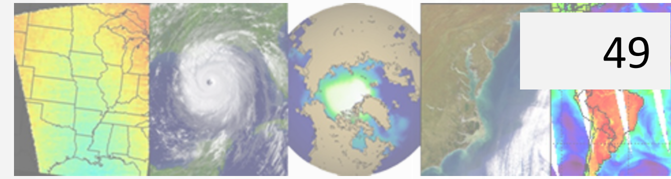
- The standard GOES-R navigation puts features like fires in the wrong place when viewed on a map and compared to polar orbiting platforms
- Users of the FDCA would fault the algorithm, so correcting the locations became a priority
- The method utilizes a high-resolution digital elevation model to accurately represent the nominal footprint of the pixel on the ground
- This will lead to better pixel surface area calculations and mapping of locations that are not visible to GOES



GOES-16 3.9 µm imagery of a fire in Oregon on 19 July 2021 (left: standard navigation, right: terrain corrected). Users at the Satellite Analysis Branch had noted the offset between VIIRS fire detections (red and green markers) and the FDC product (blue circles). Terrain correction of the FDC detections and the underlying GOES data showed excellent agreement between the two instruments. The temporal difference between the scans was less than 5 minutes.

ABI Flood Monitoring

Jay Hoffman, William Straka, Dave Santek

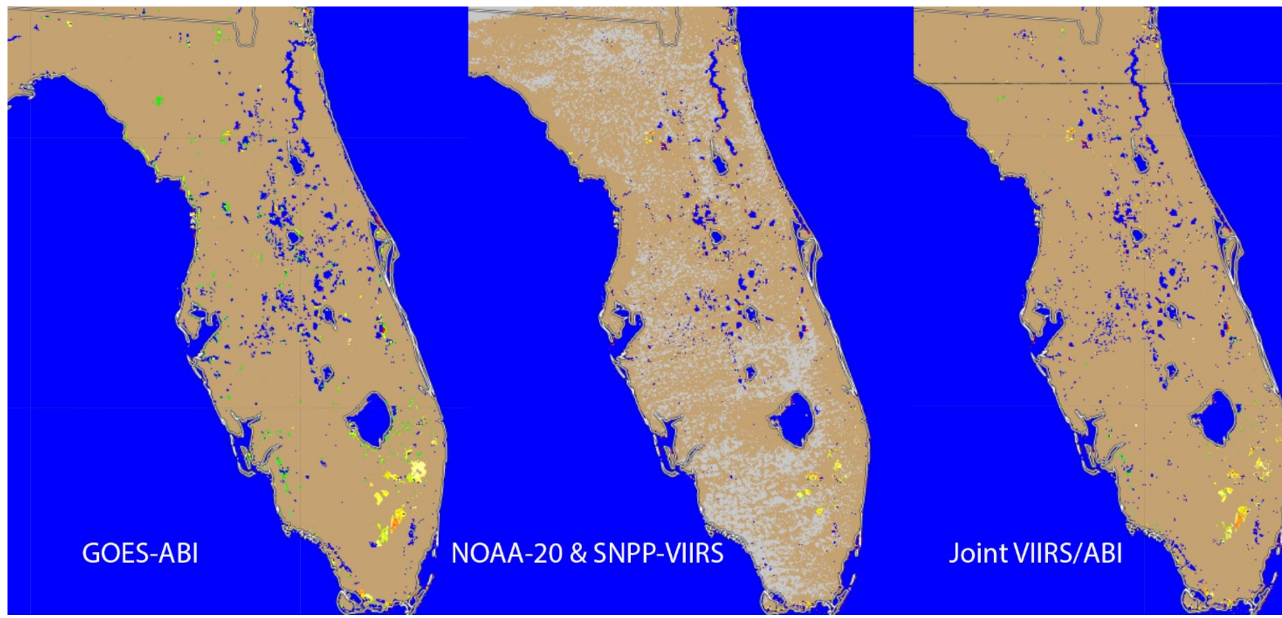


Objective

- By taking advantage of the frequent imaging, the ABI flood product reduces the extent of cloud coverage by building a mosaic of daylight clear-sky observations.
- Building on the partnership established for the JPSS flood product, CIMSS provides support for the GOES-ABI flood product.

Approach

- Flood product developed for JPSS at George Mason University (GMU), the software was transitioned to GOES ABI. CIMSS provides support for this project by routinely running the ABI flood software.
- Using the SSEC datacenter imagery, ABI flood products are run routinely for GOES-East and GOES-West with low latency.
- ABI/VIIRS composites are generated.
- Products are distributed to users via a dedicated RealEarth server (https://floods.ssec.wisc.edu), http/ftp, AWIPS/LDM, (https://floodlight.ssec.wisc.edu), and GEONETCast Americas



Example ABI (left), VIIRS (center), and Joint flood product (right) over Florida from March 15, 2020. This case does not contain significant flooding but does illustrate how the cloud cover (grey) can be reduced by using a time series of geostationary imagery.

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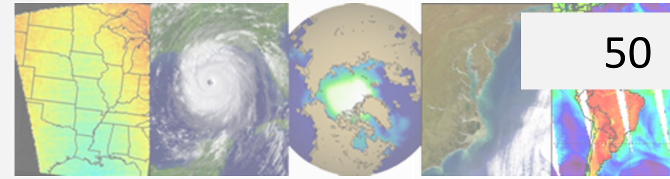
VIIRS Flood Monitoring

Jay Hoffman, William Straka, Dave Santek

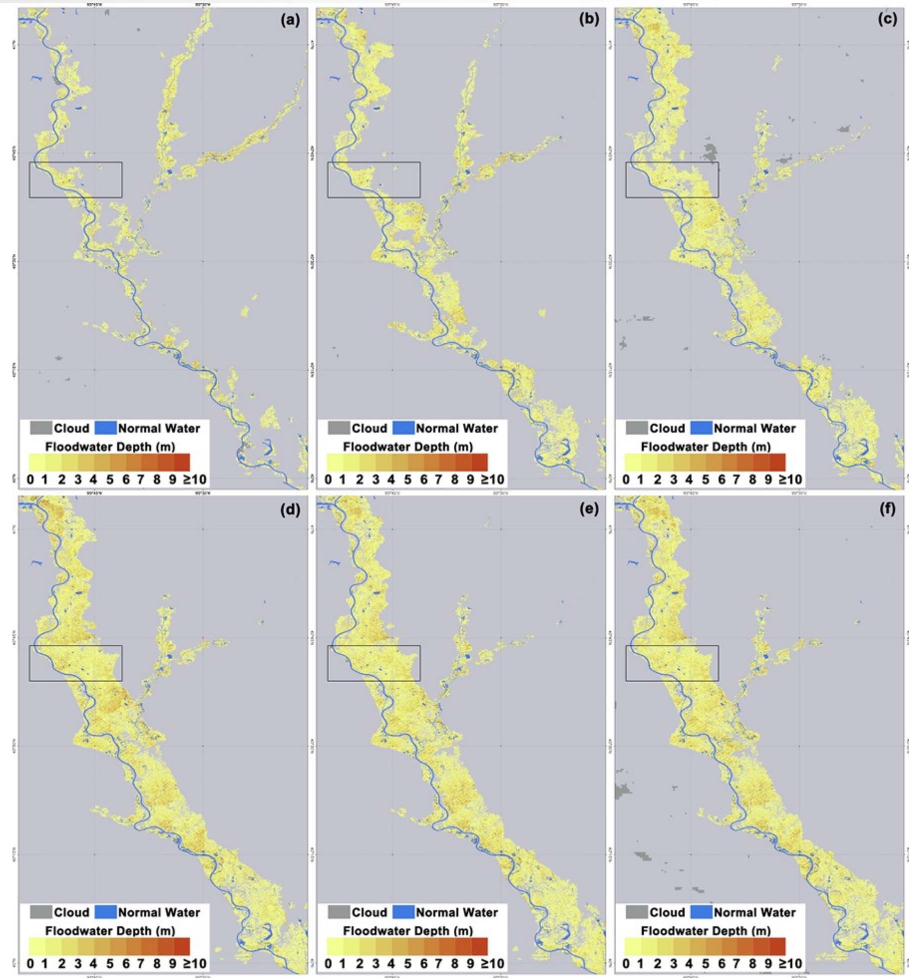


Objective

- As the Flood Products transition into NOAA operational products, routine product generation continues at CIMSS to confirm the successful installation of the science code.
- Support GMU in the development of a 3-D flood detection product.

Approach

- Flood product originally developed for VIIRS at George Mason University (GMU). CIMSS provides support for this project to run routinely providing global VIIRS coverage
- Using direct broadcast and archival global VIIRS flood product coverage from NOAA-20, NOAA-21, and SNPP are routinely available with low latency.
- Joint and merged products are produced daily, including a one-day and a five-day composite of VIIRS; daily AHI/VIIRS composites are also generated.
- A 3-D, 30m resolution floodwater depth product is being tested. By using high resolution topography, the science code is able to estimate flood extent and flood depth with much finer resolution than the satellite imagery.
- Paper: A downscaling model for derivation of 3-D flood products from VIIRS imagery and SRTM/DEM https://doi.org/10.1016/j.isprsjprs.2022.08.025



VIIRS downscaled 30-m floodwater depth along the Missouri River 2019: (a) 3/15, (b) 3/16, (c) 3/18, (d) 3/20, (e) 3/21 and (f) 3/22.

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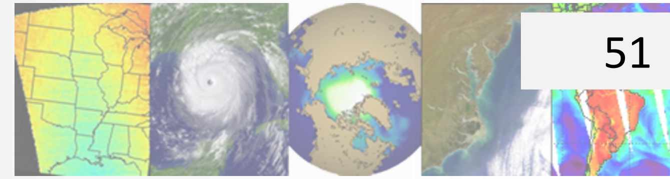
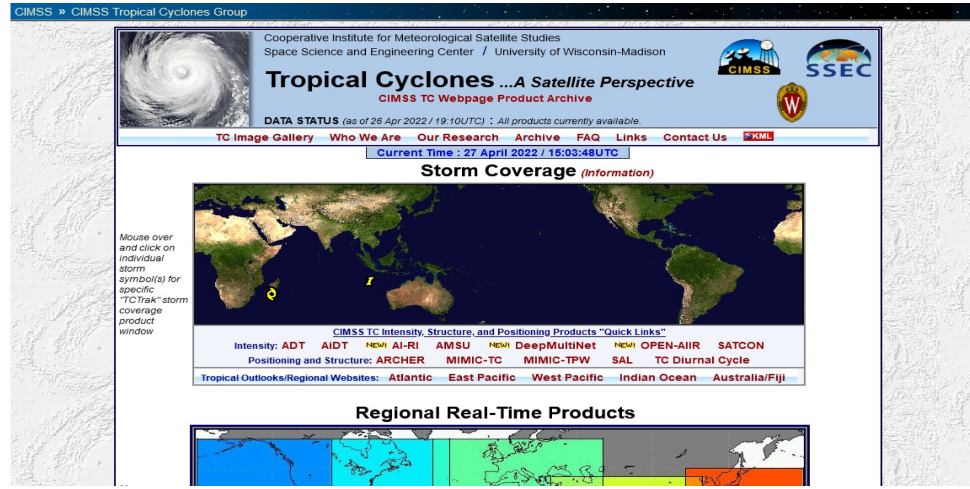
CIMSS Contributions to the NOAA Hurricane Proving Ground

Tropical Cyclone Research Group



Objectives

- The CIMSS Tropical Cyclones group has recently developed a number of new TC applications using satellite data
- These new products and algorithms can be demonstrated to the TC research and operational communities most effectively via web resources as part of the NOAA Hurricane Proving Ground
- The public CIMSS TC web page (panel to the right) is a popular site for displaying these new products (some may be password protected for initial demo and viewing by designated user groups)



Real-time TC group webpage: https://tropic.ssec.wisc.edu/tropic

Approach

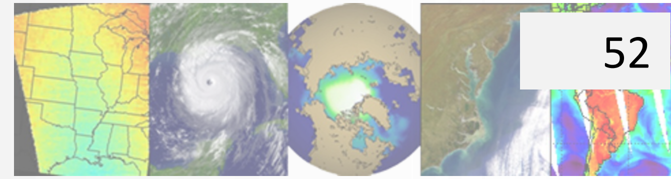
- Product/algorithm R&D leverages multiple agency support including NOAA and ONR
- Focus is on innovative automated satellite-derived products that provide objective TC support tools
- Recent efforts aimed at the development of Deep Learning models to estimate/forecast TC intensity (such as AiDT, AIRI, DMINT, DPRINT) are included in the Product Summary Dashboard shown on the next slide

Outcomes

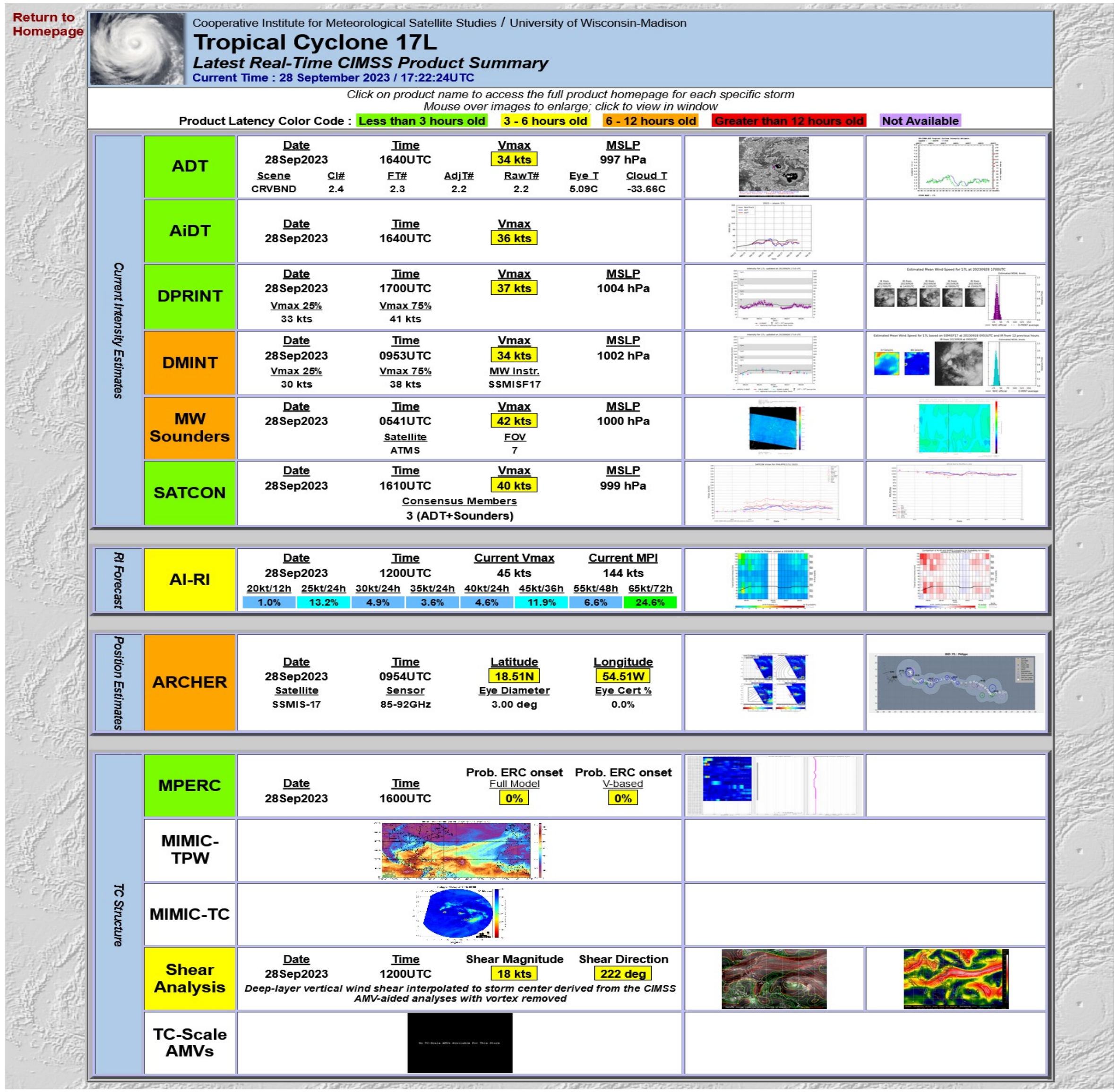
- The newest TC applications are being produced and displayed in near-real-time on our public CIMSS TC web site along with pre-existing products
- Operational users (e.g. NHC, CPHC, JTWC) are very familiar with this site and have been viewing these new products during the recent TC seasons, often citing them in their forecast discussions

CIMSS Contributions to the NOAA Hurricane Proving Ground

Tropical Cyclone Research Group

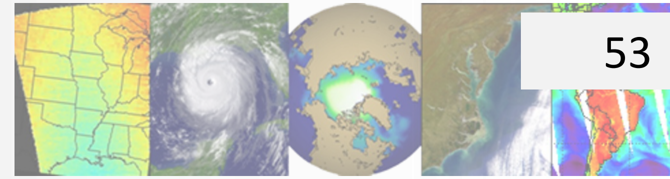


Real-Time CIMSS TC Product Summary Dashboard:
Various TC algorithms or products (second column from left) designed and implemented by the CIMSS TC Research Group for near-real-time on-line demonstrations (color code indicates product latency)



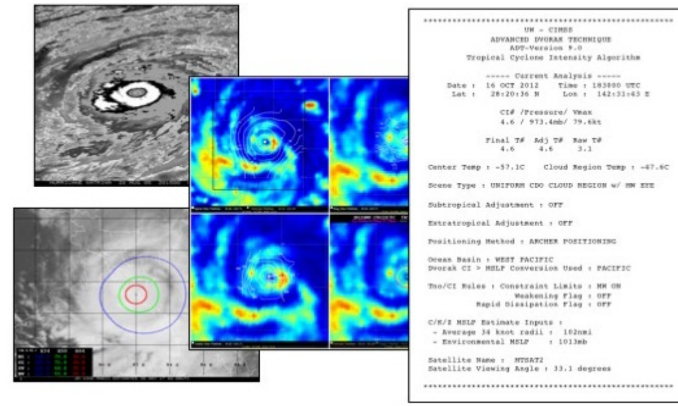
Advanced Dvorak Technique (ADT)

Tim Olander and Chris Velden



Objective

- The ADT is an automated algorithm that operates on satellite imagery to provide tropical cyclone (TC) intensity estimates to operational tropical forecast centers worldwide.
- Science upgrades continue to improve the algorithm functionality and these are delivered from CIMSS to NOAA/STAR for operational implementation.
- NOAA Users/Stakeholders
  - NOAA/Satellite Analysis Branch, Washington DC
  - NOAA/National Hurricane Center, Miami FL
  - NOAA/Central Pacific Hurricane Center, Honolulu, HI



Example of ADT output products derived from image analysis including TC center location, 2D wind radii, MW structure, and intensity estimates

Approach

- The ADT was originally developed to provide objective TC intensity estimates by mimicking the manually-intensive but reliable Dvorak Technique.
- The ADT is fully automated and provides estimates of TC max wind speed at 30 minute intervals (as well as TC position) for all global TCs using geostationary satellite Infrared-window imagery (augmented with polar orbiting microwave imagery in certain situations).
- The algorithm was successfully demonstrated by CIMSS, and since then has been used operationally at NOAA TC centers for over 20 years. It is especially important for estimating TC intensity when reconnaissance aircraft in-situ measurements are not available.

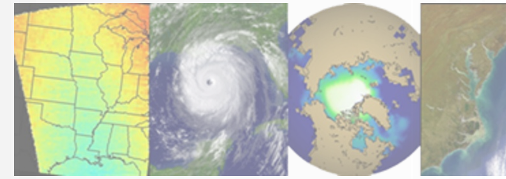
Outcomes

- The ADT is regularly referenced by forecasters in real-time applications and is used to help derive Best Track historical records for North Atlantic and East/Central Pacific TCs.
- ADT is also used in influential climatological studies of TC intensity trends during the satellite era.
- Publications

  - **Olander, T. and C. Velden, 2019:** The Advanced Dvorak Technique (ADT) for Estimating Tropical Cyclone Intensity: Update and New Capabilities, ***Wea. Forecasting*, 34**, 905-922.
  - **Kossin, J.P., K. Knapp, T. Olander, and C. Velden, 2020:** Global increase in major tropical cyclone exceedance probability over the past four decades, ***Proc. Nat. Acad. Sci.*, 117**, 11975-11980

Advanced Dvorak Technique (ADT)

Tim Olander and Chris Velden



The ADT continues to be utilized at operational tropical cyclone forecast centers, such as NOAA/NHC, to aid in the determination of storm intensity estimates.

Hurricane Lee Discussion Number 10
NWS National Hurricane Center Miami FL AL132023
500 PM AST Thu Sep 07 2023

Lee continues to strengthen at an exceptional rate. The hurricane has quickly developed a clear symmetric eye surrounded by very cold cloud tops. **The intensity estimate of 115 kt is based primarily on recent UW-CIMSS ADT intensity estimates near that value.** The 102 kt subjective Dvorak intensity estimates from TAFB and SAB at 18Z were constrained by Dvorak rules…

- An ADT operational upgrade at NOAA in 2022 attracted national interest, including a prominent story on the CNN website (right).

Meteorologists get key upgrade just in time for 2022 hurricane season

By Allison Chinchar, CNN Meteorologist
Published 5:00 AM EDT, Sat April 23, 2022

CNN Weather

Hurricane Larry is shown on satellite imagery in September 2021.

(CNN) — The official start of Atlantic Hurricane Season is less than six weeks away, and forecasters will be getting an essential upgrade just in time for the season to begin.

New technology from the University of Wisconsin will help with preparation of more detailed forecasts and provide more reliable information to meteorologists and emergency planners, which should ultimately result in better, safer outcomes for public safety.

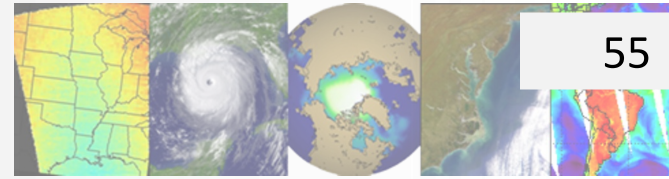
The Advanced Dvorak Technique (ADT) is a satellite-based method for determining tropical cyclone intensity. Planned upgrades include the use of full-resolution images from weather satellites, better identification of the location of each storm's eye and the ability to better analyze hurricanes occurring outside tropical regions.

Sign up for weekly weather dispatches from our own meteorologists

Developed by researchers at the University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS), the ADT provides an indication of how a storm might strengthen, especially one approaching populated coastal areas.

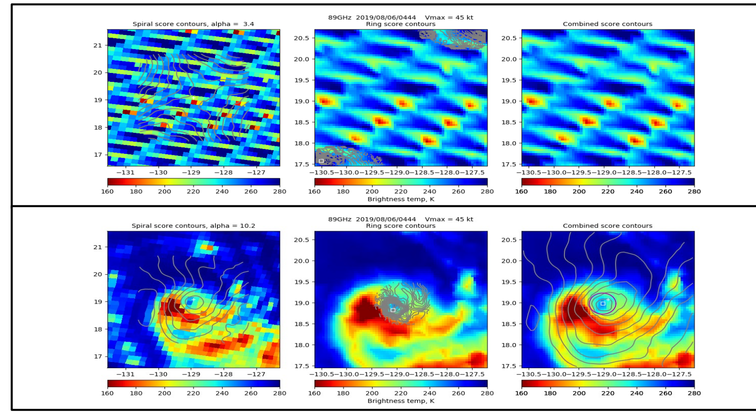
Advanced Dvorak Technique (ADT) at CWA

Tim Olander and Mike Foster



Objective

- Provide Taiwan Central Weather Bureau (CWB) with ADT-Version 9.0 for local installation and use to investigate local tropical cyclones within their area of analysis
- Provide support to CWB for use of ADTV9.0, including answering questions on proper utilization of code with locally-provided data sources
- Users/Stakeholders
  - Central Weather Administration, Taiwan



Example of incorrect microwave data reading and plotting issue at CWB (top) and corrected display after CIMSS code fix delivery

Approach

- ADT provides estimates of TC wind speed at 30 minute intervals (as well as TC position) for all global TCs using geostationary, Infrared-window imagery (augmented with polar orbiting microwave imagery in certain situations)
- ADT has been used operationally at tropical cyclone forecast centers around the world for over 20 years.
- ADT was developed to provide operational TC forecasters an objective intensity estimate by mimicking operational subjective Dvorak Technique

Outcomes

- ADT-V9.0 has been successfully installed at CWA
- Documentation and test data cases have been provided to provide written support and ensure ADT is working properly with known data sources.
- Modification of existing code and additional code have been provided to help alleviate issues created by local Taiwanese data sources. The modifications have resulted in upgrades to ADT-V9.1 (not yet installed at CWA).
- Further questions from CWA scientists about additional ADT issues have centered on local tuning of the ADT algorithm resulting from local testing and real-time use of the ADT at CWA.

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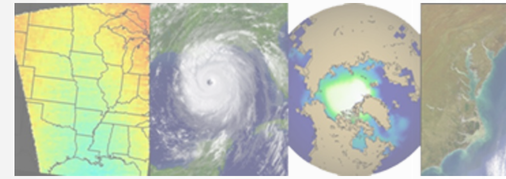


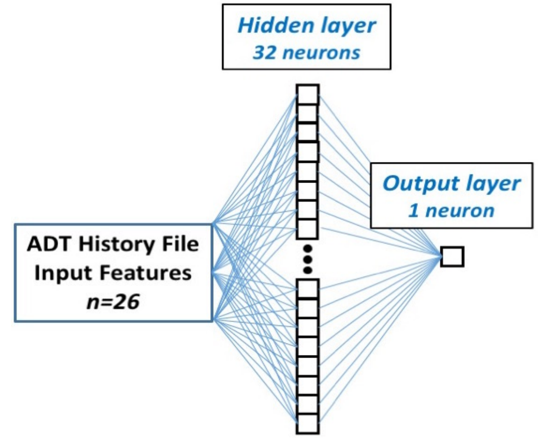
AI-enhanced ADT (AiDT)

Tim Olander, Tony Wimmers, and Chris Velden

Objective

- Enhance and improve the ADT tropical cyclone (TC) intensity estimates using a Neural Network.

- Users/Stakeholders
  - NOAA/Satellite Analysis Branch, Washington DC
  - NOAA/National Hurricane Center, Miami FL
  - NOAA/Central Pacific Hurricane Center, Honolulu, HI
  - DoD/Joint Typhoon Warning Center, Pearl Harbor, HI



Schematic diagram of the AiDT Neural Network model, consisting of 26 input parameters (from ADT analysis) and an output wind speed estimate

Approach

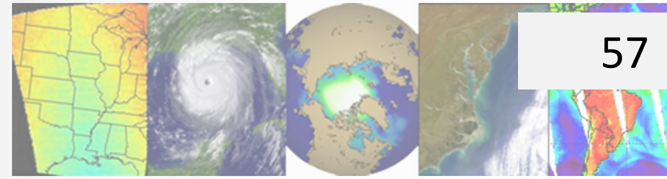
- First employ the ADT, which provides estimates of TC max wind speed for all global TCs using geostationary satellite Infrared-window imagery (augmented with polar orbiting microwave imagery in certain situations) along with ancillary diagnostic outputs.
- The AiDT then executes after the ADT analysis and utilizes the ADT output parameters within a regression-based Neural Network to generate adjusted TC intensity estimates.
- The AiDT retains the familiarity of the ADT to the operational TC forecasters but can significantly improve the accuracy of the ADT max wind speed estimates in certain situations where the ADT can struggle.

Outcomes

- **The AiDT can improve the ADT intensity estimates.**
- The AiDT outputs are currently available on the CIMSS Tropical Cyclone website in real-time, and have been referenced by operational TC forecast centers in their Discussion products as a important factor in determining TC intensity estimates.
- Publication
  - **Olander, T., A. Wimmers, C. Velden, and J.P. Kossin, 2021:** Investigation of Machine Learning using Satellite-Based Advanced Dvorak Technique Analysis Parameters to Estimate Tropical Cyclone Intensity**,** ***Wea. Forecasting*****, 36**, 1261-2186**.**

AI-enhanced ADT (AiDT)

Tim Olander, Tony Wimmers, and Chris Velden



The AiDT has shown to be an important addition to the operational TC forecaster's "toolbox" by augmenting the ADT intensity analysis using Neural Network insights

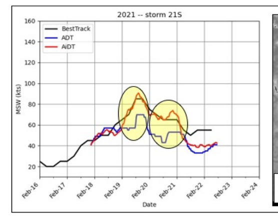
Hurricane Danielle Discussion Number 20
NWS National Hurricane Center Miami FL AL052022
300 AM GMT Tue Sep 06 2022
Danielle's cloud pattern has deteriorated during the past several hours. The outer curved band cloud tops have warmed while becoming ragged, and the eye temperature has cooled while becoming partially obscured. A recent microwave image, however, indicated very little vertical tilt while maintaining a symmetric structure. A blend of the subjective satellite intensity estimates from TAFB and SAB **along with the AI-enhanced Advanced Dvorak Technique (AiDT) from UW-CIMSS** yields an initial intensity of 70kt for this advisory.

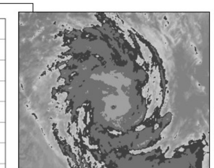
- AiDT helps improve ADT TC intensity estimates in several phases of the TC lifecycle, as highlighted in the examples to right.
- NOAA/STAR plans to implement the AiDT in 2024 as an operational product.

Storm Examples

- Below are select TC time series MSW comparisons to illustrate AiDT impact
- **Note impact of AiDT during highlighted periods of storm history**

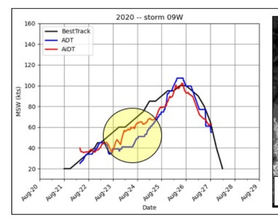
Legend: ***ADT*** ***AiDT*** ***NHC/JTWC Best Track***

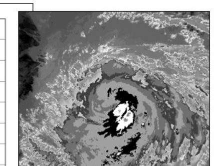




Feb 19/11:30Z

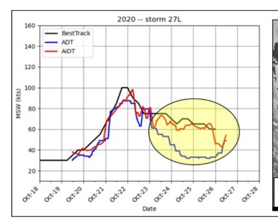
- **Eye Scenes**
  - ADT classified a brief Eye for three hours with CDO scene types afterwards. AiDT was able to better diagnose the eye/warm spot and increase the intensity.

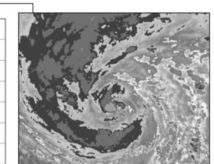




Aug 24/01:10Z

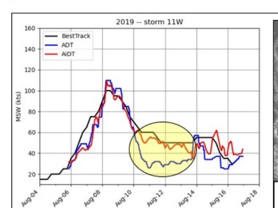
- **Convective Dense Overcast Scenes**
  - AiDT improved intensity estimates during ADT classified CDO scene type period during TC formation period prior to appearance of an eye

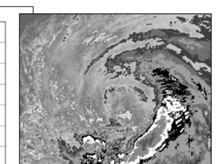




Oct 24/09:20Z

- **Curved Band Scenes**
  - During extended ADT Curved Band scene type period, AiDT drastically modified ADT intensity estimates during TC dissipation phase





Aug 10/18:10Z

- **Shear Scenes**
  - AiDT increased ADT intensity estimates during period of ADT mis-classified Shear scene types *(large displacement of convection from TC center interpreted as Shear by ADT)*

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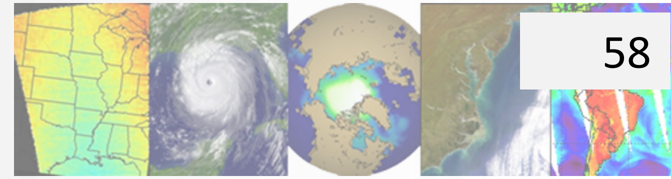
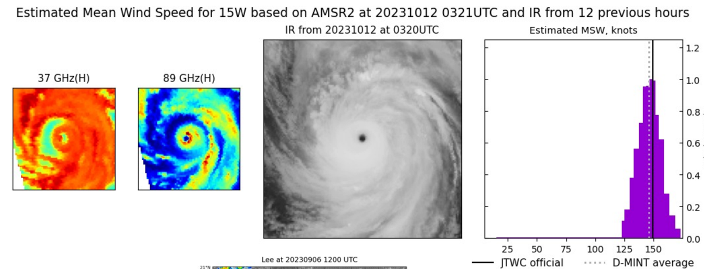
Tropical Cyclone Prediction with Machine Learning

Sarah Griffin, Anthony Wimmers, Chris Velden



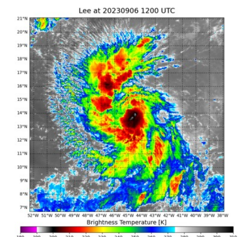
Objective

- Employ ML with satellite imagery to predict tropical cyclone current intensity, future intensity, and probability of rapidly intensifying.
- Stakeholders include TC analysis and forecasting centers, including NHC, CPHC, JTWC and agencies/entities that rely on their warnings.



Current TC intensity estimation of Bolaven

Probability of RI for Lee



Lee at 09/06/23 12 UTC. Intensity = 60 kts, MPI = 155 kts

AI-RI Matrix of RI probabilities

RI (kt / h)	20/12	25/24	30/24	35/24	40/24	45/36	55/48	65/72
AI-RI	36.1%	57.3%	50.3%	35.5%	25.1%	38.8%	36.7%	19.4%

Approach

- A deep learning model is trained with satellite data to predict either a histogram of current/future TC intensity (top of image), or probabilities or rapid intensification (bottom of image).
- These products are some of the first to produce real-time estimates and prediction of TC intensity using machine learning.

Outcomes

The real-time 'D-MINT' and 'D-PRINT' products are regularly used in operational TC forecasts:

- NHC discussion on TC Margot on 11 Sept 2023: "With the improvement in the satellite presentation, the initial wind speed is set to 60 kt, closest to the D-MINT intensity estimate from UW-CIMSS, but below recent Dvorak DT estimates of 65 kt."
- JTWC discussion on TC Mocha on 14 May 2023: "FINALLY, D-PRINT AND D-MINT ESTIMATES AT 1400Z WERE IN THE 145-148 KNOT RANGE. TAKING THESE ESTIMATES INTO ACCOUNT, THE 1400Z INTENSITY HAS BEEN REVISED TO 150 KNOTS AND MARKS THE PEAK INTENSITY OF TC 01B."

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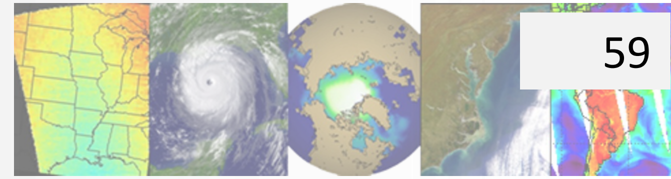
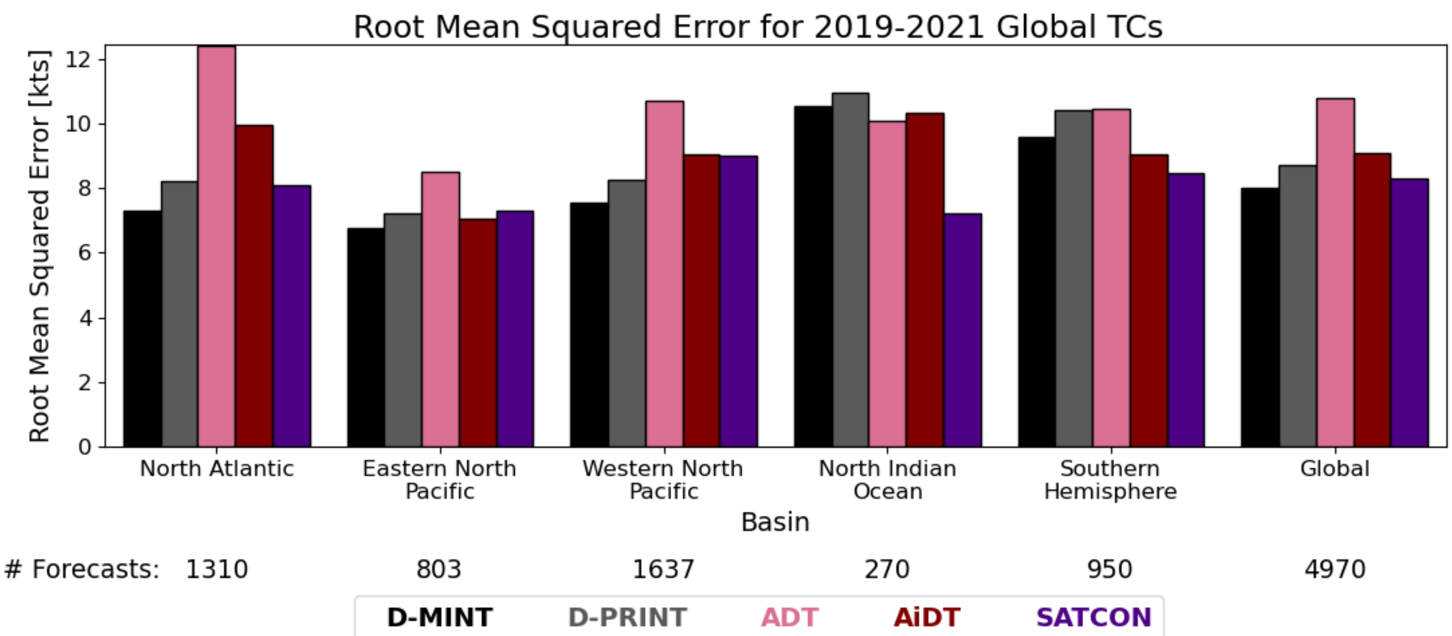
Sarah Griffin, Anthony Wimmers, Chris Velden



D-MINT and D-PRINT use infrared imagery, while D-MINT also employs microwave imagery, to estimate current and future TC intensity.



Root Mean Squared Error for current TC intensity estimation.

- D-MINT and D-PRINT are more skillful than most previous methods from CIMSS.
- D-MINT and D-PRINT have been routinely used by forecasters in operational TC discussions.

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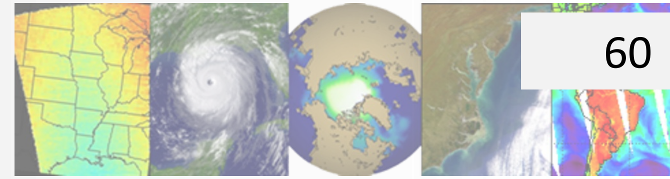
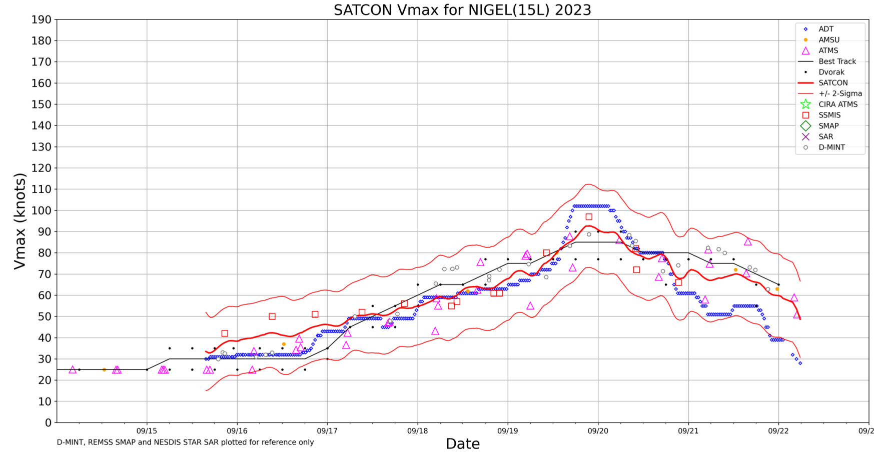
Tropical Cyclone Analysis Using SATCON

Derrick Herndon and Chris Velden



Objective

- Improve Tropical Cyclone (TC) intensity analysis by combining multiple intensity estimates into a single estimate
- Make the forecast process at TC warning agencies more efficient by reducing the number of algorithms the agency needs to consult
- Reduce TC forecast errors by improving analysis intensity
- Provide a display platform to highlight new technologies in an easy, comparative way



SATCON display of maximum sustained winds for Hurricane Nigel (2023).

Approach

- There are numerous TC algorithms that are used to estimate storm intensity. Individual intensity estimates can be combined using a weighting approach that gives more weight to the member with the greatest skill for a given storm type or intensity.
- The CIMSS SATellite CONsensus (SATCON) is routinely used by warning agencies worldwide.
- SATCON has the highest skill among operational TC intensity methods.

Outcomes

Example uses of SATCON by TC warning agencies:

- NHC discussion for TS Calvin: "[T]he latest objective estimates from SATCON and ADT are higher than 55 kt. Given the improved structure on satellite, the initial intensity is raised to 55 kt for this advisory based on a blend of the various intensity estimates."
- NHC discussion for HU Teddy: "[T]he improved satellite presentation since that time suggests that the hurricane should have winds of at least 105 kt, which is the initial intensity for this advisory, which could even be a little conservative based on the latest UW-CIMMS ADT and SATCON values of 120 and 111 kt, respectively."
- 30 mentions of SATCON by NHC in 2023

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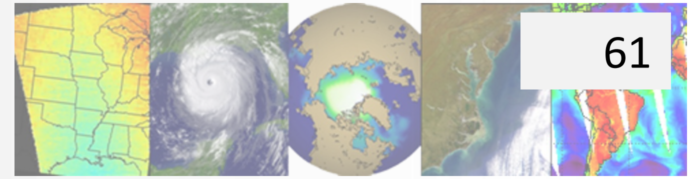
Tropical Cyclone Analysis Using SATCON

Derrick Herndon and Chris Velden



CIMSS TROPICAL CYCLONE INTENSITY CONSENSUS FOR FRANKLIN (08L) 2023

CURRENT ESTIMATE
Date (mmddhhmm): 09040016
SATCON: MSLP = 980 hPa   MSW = 58 knots
SATCON Member Consensus: 56.0 knots
Pressure -> Wind Using SATCON MSLP: 64 knots
Distance to Outer Closed Isobar Used is 200 nm
Eye Size Correction Used is 0 knots   Source: NA

← Current SATCON Intensity

Member Estimates

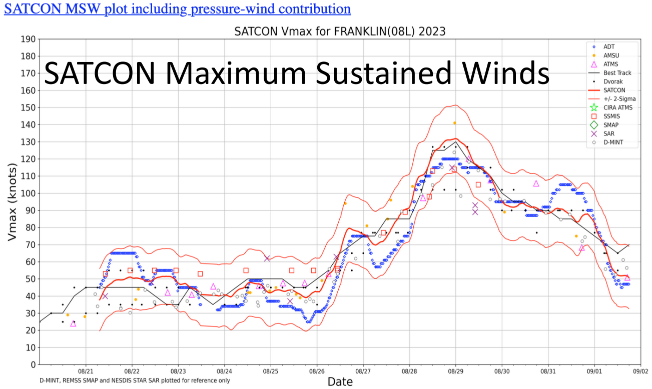
ADT: 982 hPa   47 knots   Scene: CDO   Date: SEP011850
CIMSS AMSU: 998 hPa   35 knots   Bias Corr: 0 (MW)   Date: 09040016
ATMS: 982.1 hPa   50.9 knots   Date: 09011703
SSMIS: 982.1 hPa   50.9 knots   Date: 09011703
CIRA ATMS: hPa   knots   Date:

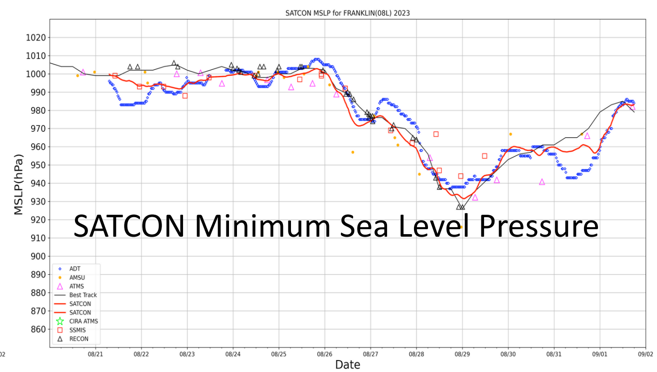
← Individual intensity member information

SATCON HISTORY FILE for 2023 08L FRANKLIN

SATCON MSW plot including pressure-wind contribution

SATCON display also provides comparative TC intensity estimates from NOAA/NESDIS/STAR Synthetic Aperture Radar (SAR), CIRA ATMS and REMSS SMAP algorithms





- SATCON paper published in 2023
- 2023 work to incorporate new CIMSS machine learning algorithms (AiDT and D-MINT)
- Implementation of SATCON at NOAA NESDIS scheduled for 2024

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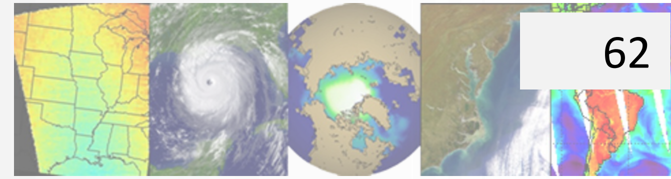
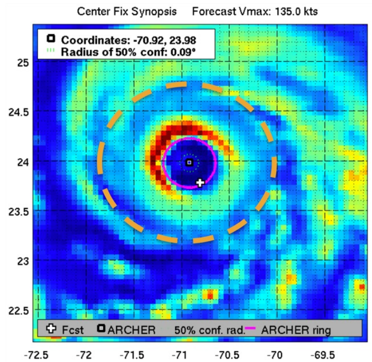
Tropical Cyclone Analysis Using M-PERC

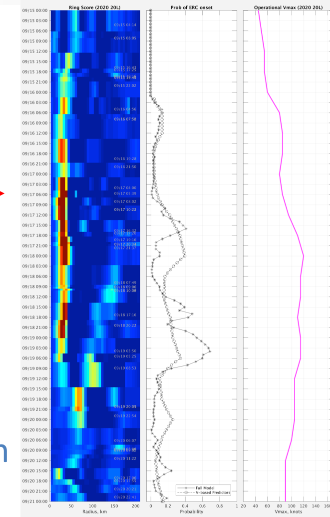
Derrick Herndon, Tony Wimmers and Chris Velden



Objective

- Tropical Cyclone intensity changes during eyewall replacement cycles (ERC) are difficult to time and pose a significant forecasting challenge
- Storm intensity may change by a full Saffir-Simpson category
- Forecasters need better tools to predict ERC onset
- First of its kind algorithm that gives forecasters a 12-36 hour warning that an ERC is imminent





Passive microwave imagery displayed as a Hovmöller diagram in M-PERC product display

Approach

- Use passive microwave imagery (89 GHz) processed by the CIMSS ARCHER algorithm to extract features relevant to ERC onset
- Classify microwave images to determine labels for each image that identify ERC onset, mature phase and completion time
- Train a logistic regression model on subset of these features, the time-evolving changes in the features and storm intensity
- Microwave Probability of Eyewall Replacement Cycle (M-PERC) produces probability of ERC onset

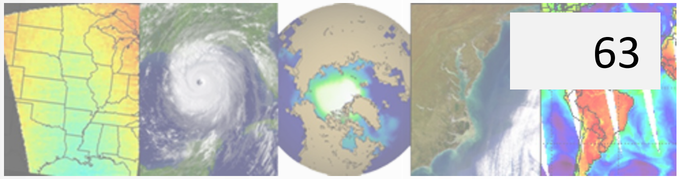
Outcomes

Comments from warning agencies noting use of M-PERC and need for ERC guidance tools:

- JTWC quote for Super Typhoon Mawar 2023: “Super Typhoon (STY) 02W continues to undergo an eyewall replacement cycle (ERC) as predicted by the UW-CIMSS M-PERC product over the past 12 hours.”
- NHC highlighting need for guidance: “The latest intensity forecast still peaks Franklin as a Category 4 (115-kt) major hurricane. However, inner-core changes, such as eyewall replacement cycles, could occur at any time, making it somewhat tricky to pinpoint exactly when.”

Tropical Cyclone Analysis Using M-PERC

Derrick Herndon, Tony Wimmers and Chris Velden

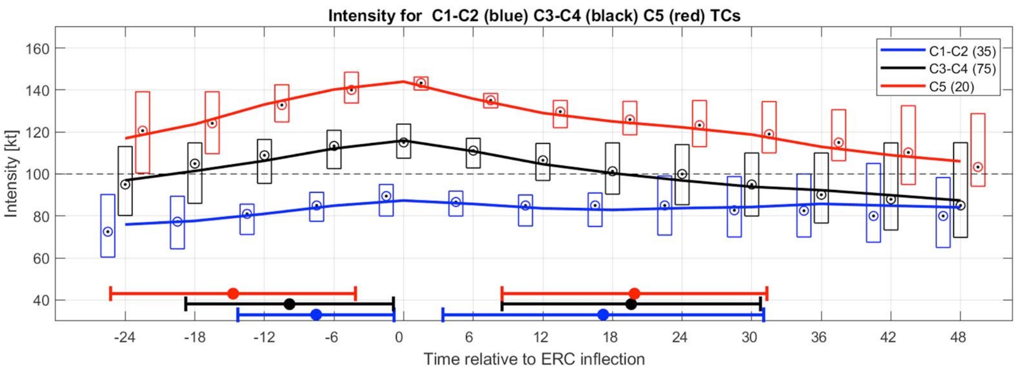


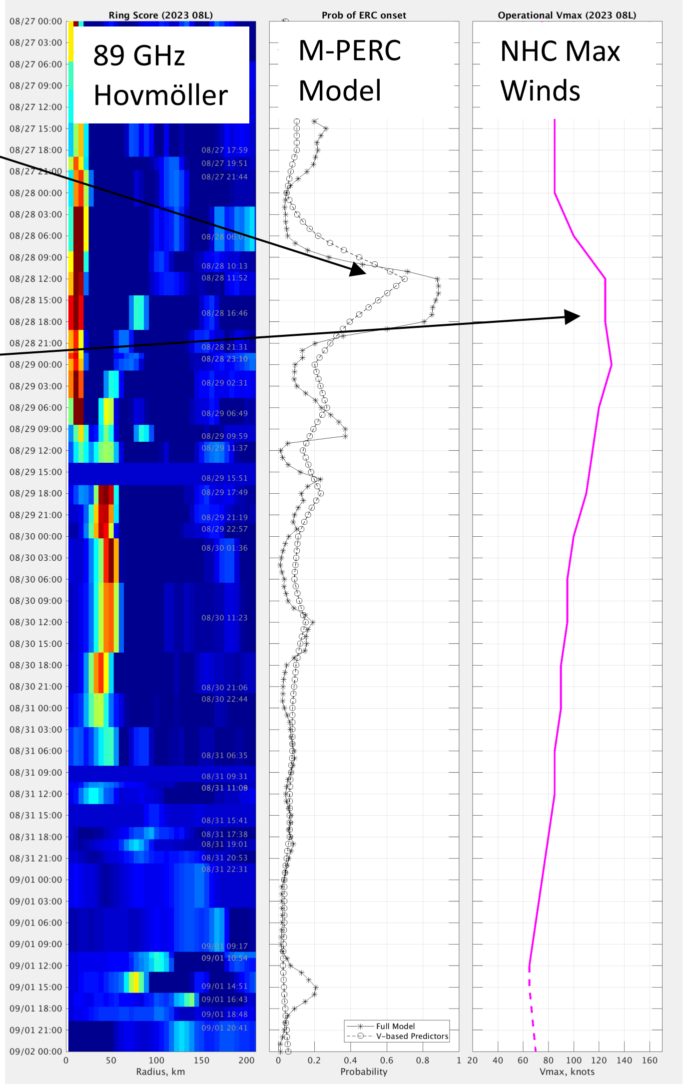
Example of M-PERC model output for 2023 Hurricane Franklin

Franklin is intensifying; however, the forecast is complicated by the fact that NHC expects an ERC to arrest this intensification process but does not know when. High M-PERC probabilities provide guidance that peak intensity should occur soon with subsequent weakening.

M-PERC probabilities rapidly increase heralding the onset of an ERC

Storm intensification rate slows and weakening ensues





Our study of the ERC process during the development of the algorithm has resulted in new insights into the storm intensity response from ERC events (figure from Kossin et al 2023). This work helps to inform warning agencies on the intensity rate changes that may result from an ERC for given storm intensities.

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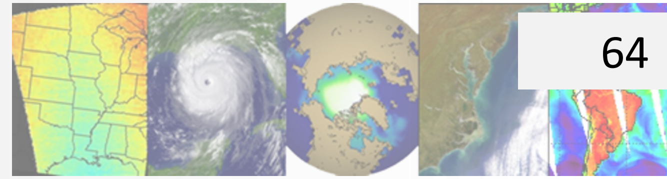
Hurricane-Scale Atmospheric Motion Vectors

Chris Velden, David Stettner, Robert Rabin, Jaime Daniels



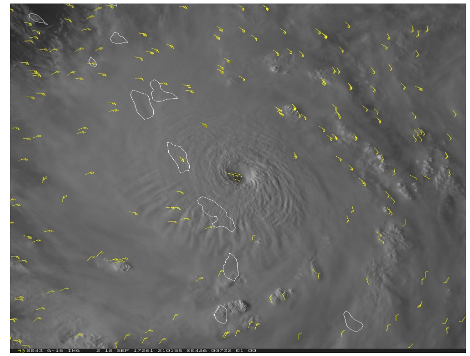
Objectives

- Improve the monitoring of rapidly-evolving wind fields over the core of hurricanes from high spatiotemporal resolution geostationary satellite (GEO) observations
- Build upon recent advances in extracting enhanced tropospheric wind information from meso-scan sectors provided by new-generation GEO satellites in hurricane environments and complete the research needed to demonstrate and bring this advanced capability to NOAA's operational hurricane applications

Approach

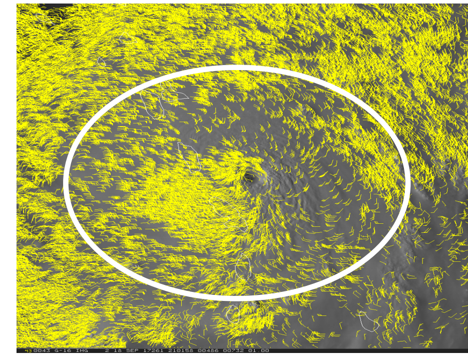
- The hurricane-scale AMV product consists of enhanced, storm-focused AMV data derived from multispectral imagery with high spatiotemporal coverage during tropical cyclone (TC) events targeted by the NOAA/NESDIS GOES-16/18 1-min. meso-sector imaging mode
- Provides AMV observations with much higher temporal and spatial resolution over the TC core area than is available in current operational AMV products
- These datasets can be assimilated in an demonstrational mode into the NOAA's next generation operational hurricane analysis and forecast system (HAFS)

Hurricane Maria (2017) AMV Comparison



Operational AMVs

(From 15-min. GOES-16 FD images) (upper-level AMVs, plotted in yellow)



Enhanced AMVs

(From 1-min. GOES-16 Meso-sector images and tailored TC-scale processing. White circle indicates storm core region)

Outcomes

- Successfully completed a real-time end-to-end processing demonstration of the GOES-16/18 hurricane-scale AMV product during the last two hurricane seasons. The datasets were made available to NWP colleagues with 15 minute frequency and latency for experimental hurricane model ingest and assimilation. The maturity and quality of the data/product, as well as the real-time operability of the processing strategies were all successfully demonstrated.
- Now working with the STAR GOES-R Algorithm Working Group AMV team to transfer this product and processing strategy over to STAR for further operational assessment. The end goal is to get this product operational at NOAA/NESDIS/OSPO.

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Publication:

Stettner, D.; Velden, C.; Rabin, R.; Wanzong, S.; Daniels, J.; Bresky, W. Development of Enhanced Vortex-Scale Atmospheric Motion Vectors for Hurricane Applications. *Remote Sens.* **2019**, *11*, 1981.

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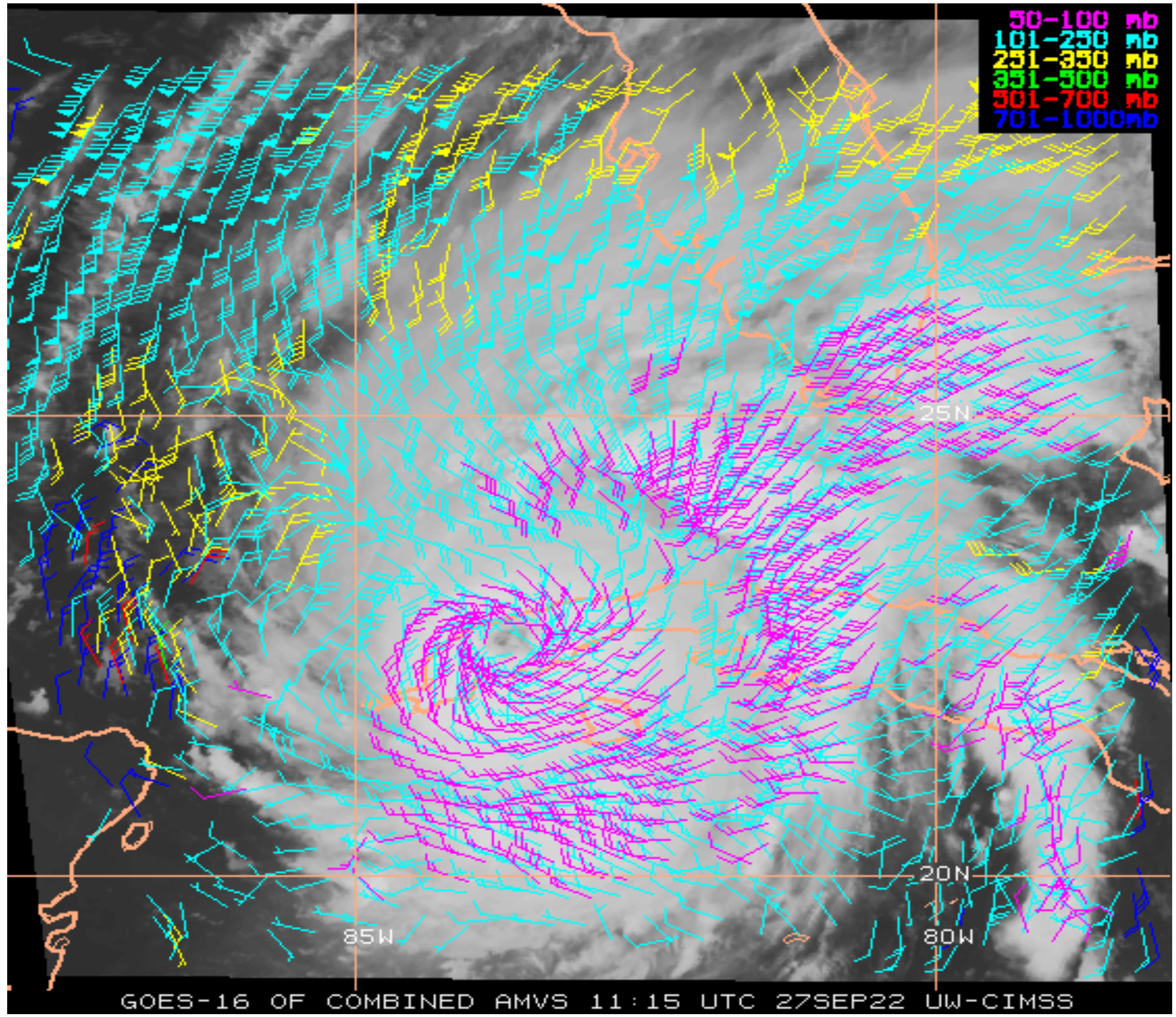
Chris Velden, David Stettner, Robert Rabin, Jaime Daniels

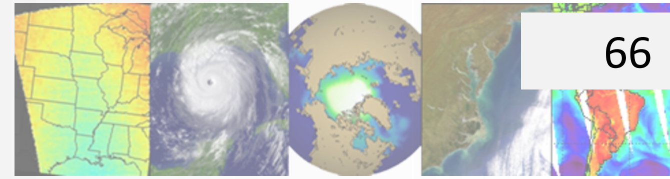
Example: Hurricane Ian (2022)



This 12-hr loop at 15-min. dataset intervals was produced in near-real time at CIMSS as part of a product Proving Ground demonstration

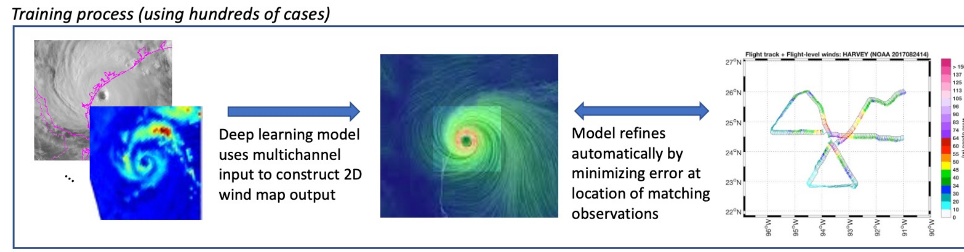
JPSS Tropical Cyclone Surface Wind Structure Retrievals Using Deep Learning

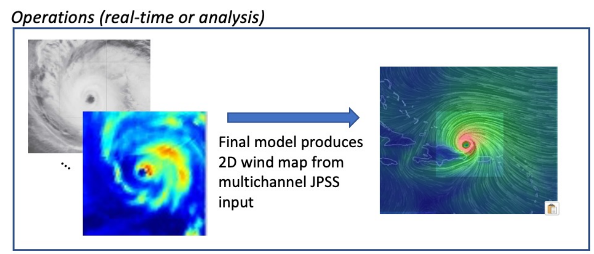
Anthony Wimmers, Derrick Herndon, Chris Velden



Objective

- Rather than using satellite data to estimate tropical cyclone intensity like many other algorithms do, this work estimates the 2D surface windspeed using the rich 2D structural features in ATMS imagery.
- Stakeholders include TC analysis and forecasting centers including NHC, CPHC, JTWC and agencies/entities that rely on their warnings.





Schematic of the 2D wind model

Approach

- As depicted in the schematic, a deep learning model is trained with JPSS imagery to estimate 2D winds as measured by flight reconnaissance transects.
- In real-time deployment, the model produces 2D winds directly from JPSS imagery.

Outcomes

- The model successfully depicts horizontal TC wind profiles and identifies key properties of the major structures (eyewall, radius of hurricane-strength winds, asymmetry with storm motion).
- We have developed an optimized flight-to-surface level conversion calibrated and validated with collocated Synthetic Aperture Radar observations.
- In this work we are collaborating with the Joint Tropical Warning Center to help this meet the main interests of forecasting offices.

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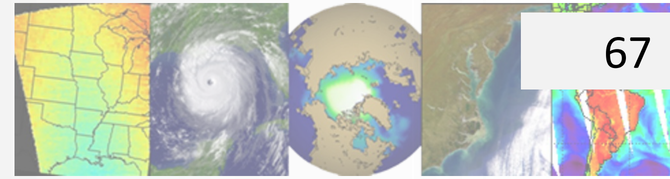
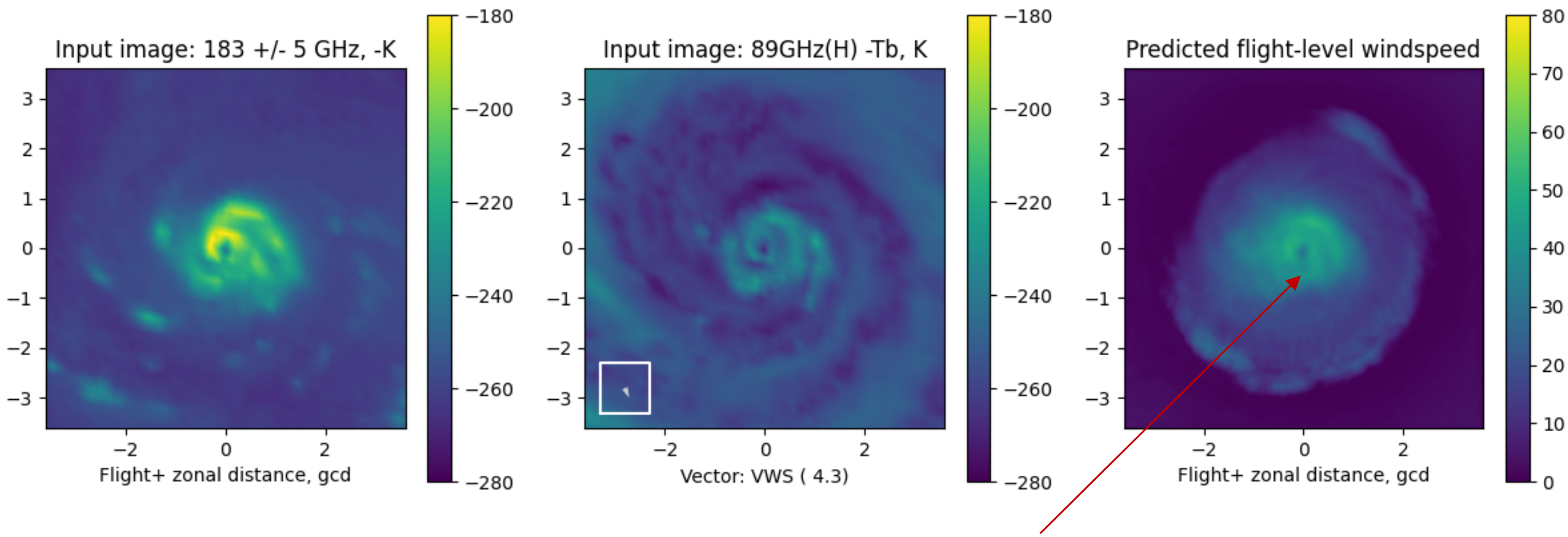
Anthony Wimmers, Derrick Herndon, Chris Velden



Irma, 2017



The model resolves small eyes and a double eyewall, as revealed in the ATMS imagery

- This is the first major application of *image-to-image* deep learning for tropical cyclones with JPSS
- Mid-project results show that this produces a unique estimation of TC properties that can be used by forecasters

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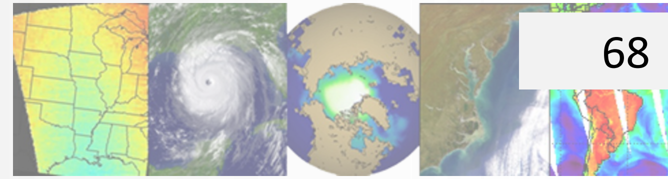
TROPICS

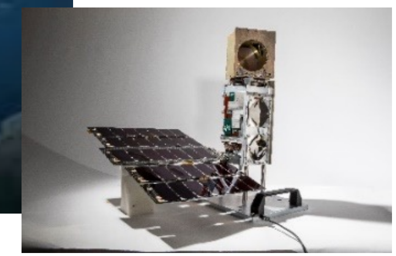
Christopher Velden and Derrick Herndon



Objective

- The TROPICS (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats) mission is a NASA constellation consisting of small satellites (3U CubeSats) in inclined orbital planes designed to demonstrate microwave measurements of temperature and moisture profiles and precipitation in tropical systems with unprecedented temporal frequency
- NOAA will benefit from this technology demonstration by informing planners of it's next-generation polar-orbiting system architecture and instrumentation

Rendering of TROPICS satellite constellation



TROPICS CubeSat

Science Goals

Utilize rapid-refresh (~1 hr) TROPICS microwave sounder overpasses to observe tropical cyclones:

- Relate storm precipitation structure to the evolution of the upper-level warm core and associated intensity changes
- Observe and study the occurrence of intense precipitation cores (convective bursts) to storm intensity evolution
- Relate retrieved environmental moisture measurements to coincident measures of storm structure and intensity
- Assimilate microwave radiances and/or retrievals in mesoscale and global numerical weather prediction models to assess impacts on storm track and intensity

Outcomes

- All science core processing algorithms have been delivered by the TROPICS Science Team to the TROPICS Data Processing Center hosted at UW-SSEC and are operational
- The TROPICS Engineering Qualification Unit (a CubeSat) was launched and flown in 2021 in advance of the constellation mission to verify critical flight and ground elements to reduce risk and expedite science returns
- The TROPICS Mission Operations Center are receiving NRT data from 4 constellation satellites successfully launched in 2023 with multispectral atmospheric microwave sounders

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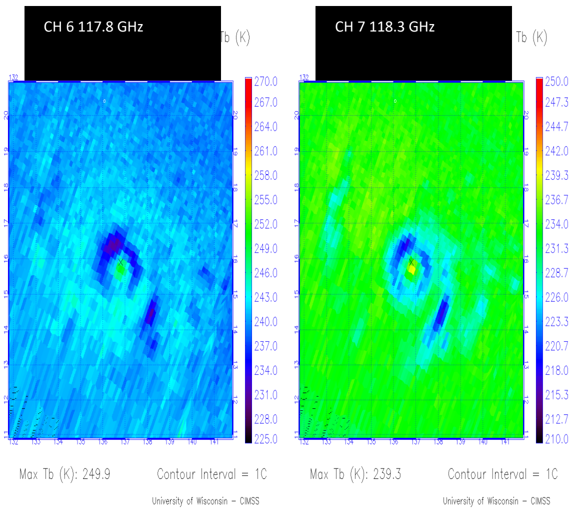
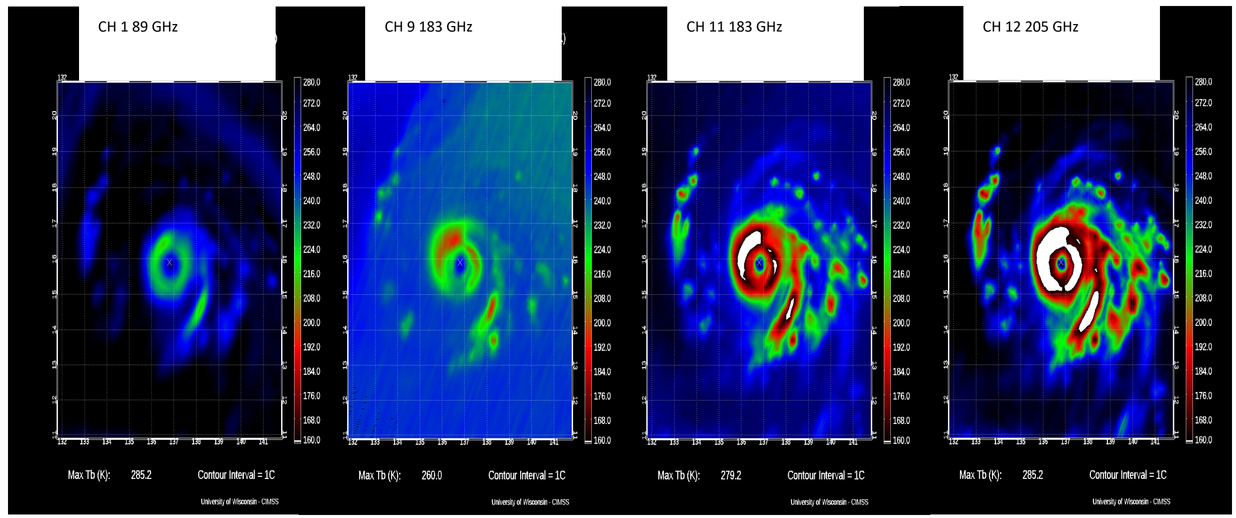
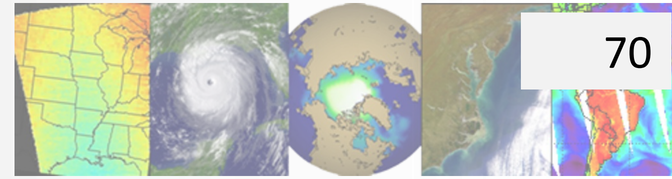
Example: TROPICS overpass of Typhoon Mawar on May 26, 2023



Temperature Channels



Moisture/Hydrometeor Channels

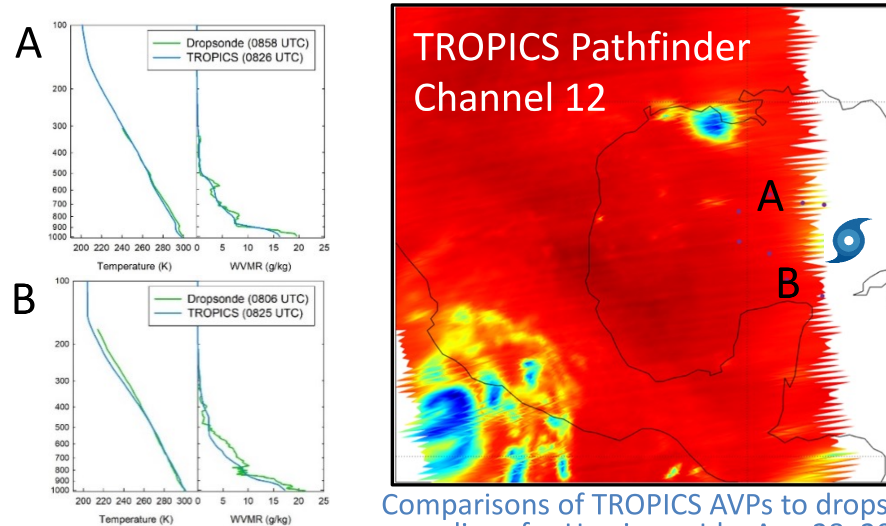


TROPICS

Tom Greenwald

Objective

- Central to the science goals of the TROPICS mission is the production of Level 2 Atmospheric Vertical Profiles (AVPs) of temperature and moisture for characterizing the 3D environment in and around tropical cyclones.
- Users of these products include forecasters and numerical weather prediction centers that will ingest them into data assimilation systems.



Comparisons of TROPICS AVPs to dropsonde soundings for Hurricane Ida, Aug 28, 2021.

Approach

- The TROPICS AVP products are produced only over the oceans using NOAA's Microwave Integrated Retrieval System (MIRS).
- An important task to ensure accurate retrievals is to derive along-scan bias corrections to account for instrument biases.
- The main innovation is the use of GEOS-5 forecasts, rather than climatology, as background information for the MIRS 1DVAR algorithm.

Outcomes

- Initial validation efforts have shown the products compare well to island-based and ship-based radiosonde soundings, in addition to dropsonde measurements.
- TROPICS AVP products will improve weather forecasts by providing better initial conditions for numerical weather prediction models.

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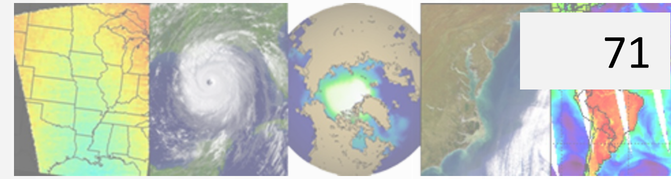
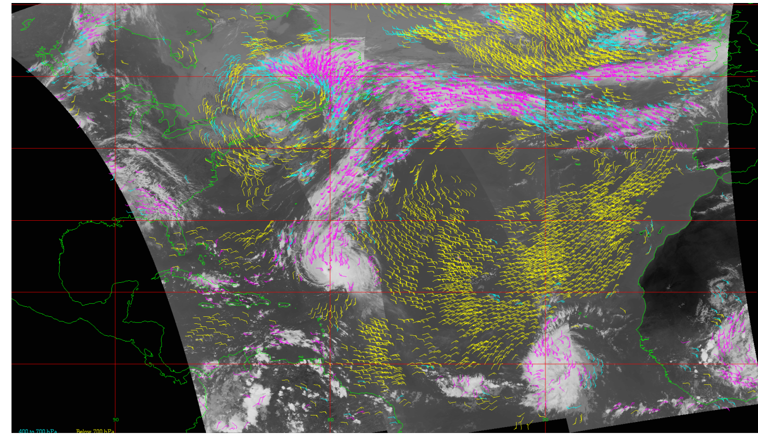
Global VIIRS Winds

D. Santek, Tim Olander, D. Stettner



Objective

- Demonstrate and evaluate the derivation winds from alternating passes of VIIRS on S-NPP and NOAA-20, which are flying in tandem (similar orbit, separated by 50 minutes).
- With the reduced time interval, the resulting winds will have lower latency, potentially higher quality, and global rather than only high-latitude coverage.
- However, to achieve global coverage the wind derivation would operate on only a pair (doublet) of images instead of a the typical triplet.



An example of low-latitude coverage over the northern hemisphere Atlantic Ocean of VIIRS IR winds from alternating passes from S-NPP/NOAA-20, color-coded by height: Yellow (> 700 hPa), cyan (400 - 700 hPa), magenta (< 400 hPa).

Approach

- Modify the CIMSS heritage winds algorithm to operate on a pair of images, instead of a triplet.
- Using a triplet of images results in a vector pair for each tracked feature, which is used in the quality control (QC). When using a pair of images, a proxy wind is used as the 2nd vector in the QC. Proxy winds are from other satellite-derived wind products.
- In addition, a correction was made for parallax effects which is significant in low- to mid-latitudes for overlapping swaths from two satellites.

Outcomes

- 6-week case study 18 Sept to 03 Nov 2021.
- Winds were derived from image pairs of S-NPP and NOAA-20. Result: 16 million quality controlled winds.
- Comparison to rawinsondes speed showed a -1 ms^{-1} bias and RMS difference of 4 ms^{-1}; slightly degraded compared to the operational VIIRS wind product.
- GDAS/GFS experiment resulted in a generally neutral impact, although for Day1 there was a negative impact on wind and temperature RMSE, and a positive impact on the geopotential height bias.

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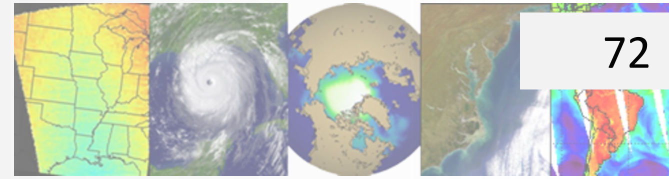
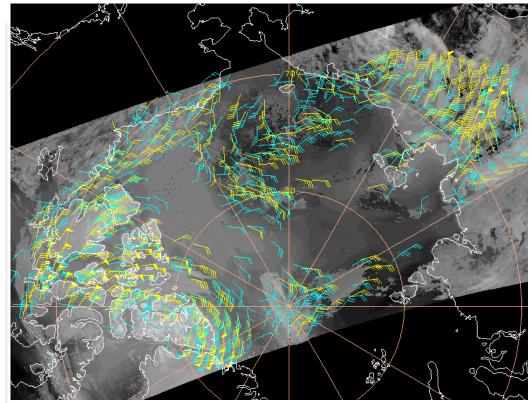
EPS-SG METimage Polar Winds

D. Santek, T. Olander, S. Nebuda

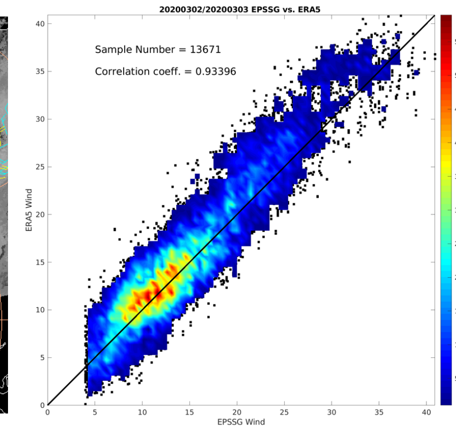


Objective

- Adapt the current polar winds algorithm for use with the EPS-SG METimage data using proxy data in preparation for an operational EPS-SG satellite in 2024.
- The VIIRS polar winds are being operationally assimilated or monitored in many numerical weather prediction global models, including at NCEP, the Naval Research Lab (NRL), and the NASA Global Modeling and Assimilation Office (GMAO). It is expected the METimage winds will also be used at many NWP centers.



Simulated 10.69 µm IR METimage data; 3 Jan 2000 at 0217 UTC. Raw winds (cyan); quality controlled (yellow).



ERA5 vs EPS-SG wind speed density plot from 03:30 UTC on 3 Jan 2020.

Approach

- Adapt and evaluate the existing polar winds algorithm for VIIRS to the EPS-SG METimage instrument.
- The current VIIRS polar winds product uses the 10.76 µm (M-15 band) which has a nearly equivalent wavelength to the METimage 10.69 µm (VII-37 band).
- In addition, the METimage 6.72 µm (VII-33 band) has the same central wavelength as the MODIS band 27 water vapor band, which will enable the production of clear-sky winds which was not possible from VIIRS.

Outcomes

- The Enterprise winds algorithm is not yet METimage-capable, therefore winds were derived using the CIMSS heritage winds algorithm (left figure).
- Procedures were developed to compare METimage winds to the ERA5 reanalysis.
- Right figure is a density plot of ERA5 vs EPS-SG wind speed; correlation coefficient 0.93.
- Bias is -0.78 ms^{-1}; RMS difference is 3.89 ms^{-1}, which is similar to VIIRS winds as compared to the ERA5.

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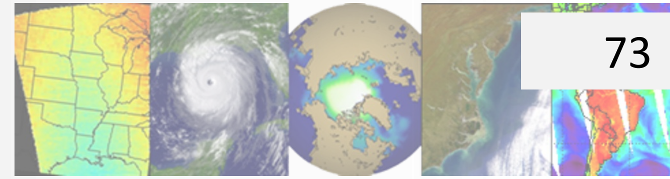
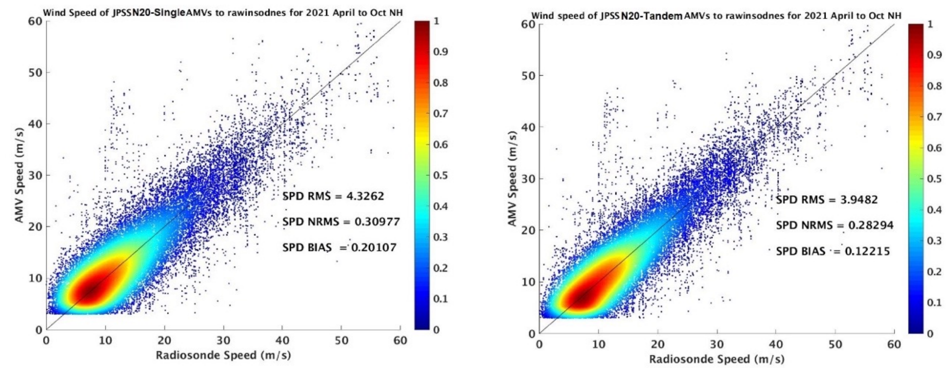
Tandem VIIRS Winds

D. Santek, R. Dworak



Objective

- The VIIRS polar winds product uses three successive orbits (100-minute time step) from a single satellite to derive cloud motion. Since NOAA-20 is in a similar orbit as S-NPP but delayed by ½ orbit in time, there is an opportunity to track clouds from the NOAA-20/ S-NPP tandem.
- The time interval between images will be reduced to 50 minutes, resulting in: Reduced latency in product availability, higher quality winds due to the shorter time interval for tracking, and extending the spatial coverage more equatorward.



April through October Arctic VIIRS AMVs compared to rawinsondes, for NOAA-20 single-satellite (left) and S-NPP/NOAA-20 tandem (right). Density scatter plot of VIIRS AMVs vs rawinsonde wind speed.

Approach

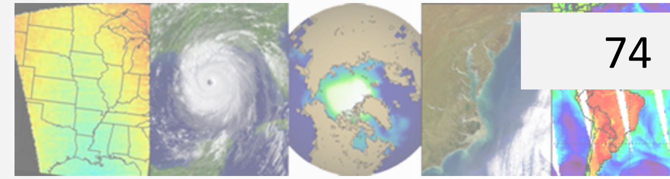
- Use the NOAA Enterprise winds algorithm to track cloud features from a triplet of images, assembled from alternating passes of S-NPP and NOAA-20, which are flying in tandem.
- Generate the product from the two combinations of triplets:
  S-NPP, NOAA-20, S-NPP and NOAA-20, S-NPP, NOAA-20

Outcomes

- The speed RMS difference is reduced from 4.3 ms^{-1} for single-satellite NOAA-20 to 3.9 ms^{-1} for the tandem-satellite. Bias is also reduced from 0.20 ms^{-1} to .12 ms^{-1} for the single satellite vs tandem configuration..
- The U.S. Naval Research Laboratory (NRL) demonstrated the positive impact of the tandem VIIRS winds in the global NAVGEM. NRL's test results for April 2021 show that the SWIR product is beneficial to numerical weather forecasts, and they are used operationally.

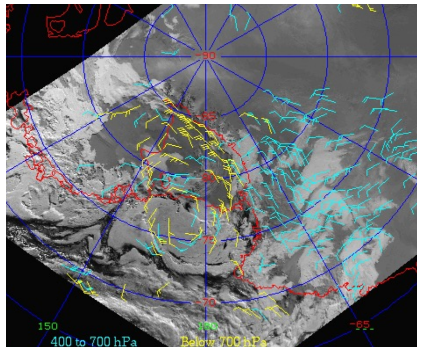
VIIRS Shortwave IR (SWIR) Winds

D. Santek, R. Dworak, D. Stettner

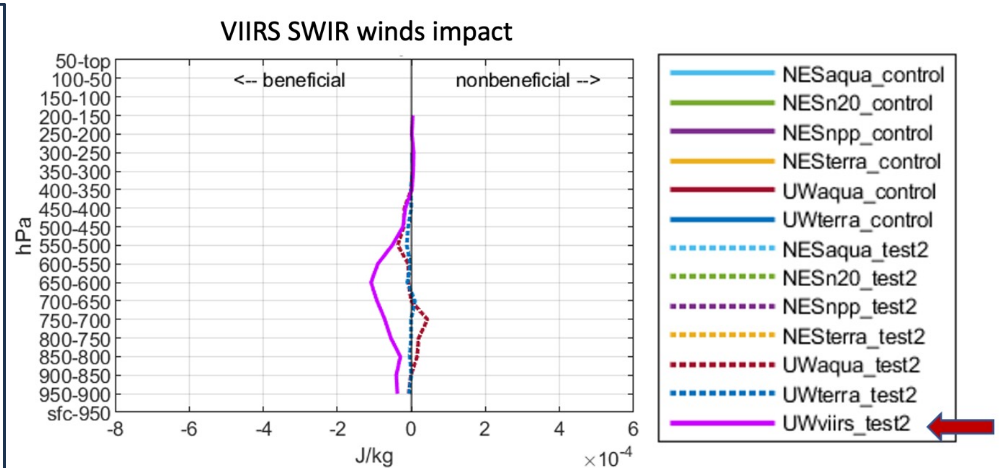


Objective

- Derive atmospheric motion vectors (AMVs) using SWIR band as it provides greater contrast between liquid clouds and the underlying snow/ice surface compared to the visible and IR window bands.
- Users of the product are primarily NWP centers (e.g., NCEP and the U.S. Naval Research Lab).



VIIRS SWIR 2.25 µm polar winds in the Antarctic from S-NPP on 08 January 2021 at 0953 UTC. Color-coded height: Yellow (below 700 hPa), cyan (400 to 700 hPa)



Impact of VIIRS SWIR in an April 2021 at NRL. The magenta line "UWviirs_test2" shows the beneficial impact (Rebecca Stone SAIC/NRL)

Approach

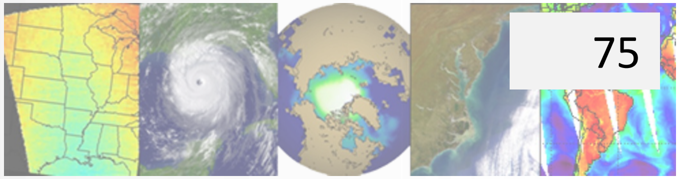
- For many years, SWIR winds have been routinely generated using MODIS band 7 (2.1 µm) from both Terra and Aqua satellites. Beginning in early 2021, VIIRS SWIR winds have been routinely generated at CIMSS using the M11 (2.2 µm) band.
- The initial product generation uses the CIMSS heritage winds algorithm. With assistance from the NOAA ASSISTT team, the product is now being produced with the Enterprise winds algorithm.

Outcomes

The SWIR winds were evaluated using two methods:

- S-NPP VIIRS SWIR winds were compared to rawinsonde wind speed for a 3-month period over Antarctica. SWIR AMV wind speed had an RMS difference of 3.58 ms^{-1} and bias of -0.95 ms^{-1}; similar to MODIS SWIR AMVs.
- The U.S. Naval Research Laboratory (NRL) demonstrated the positive impact of the SWIR winds in the global NAVGEM. NRL's test results for April 2021 show that the SWIR product is beneficial to numerical weather forecasts (magenta line in figure above).
- The SWIR winds product is expected to be transitioned to NESDIS operations in 2024.

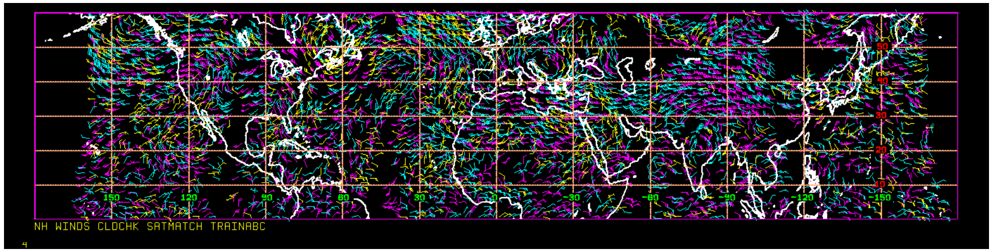
Generating Simulated 3D Winds



D. Santek, T. Olander, D. Stettner

Objective

- Generate datasets of Atmospheric Motion Vectors (AMVs) derived from global Nature Runs (NR) to simulate the spatial and vertical coverage expected from prescribed future satellite missions.
- Configurable missions are described in terms of the number of satellites, orbit configuration, and instrument characteristics (e.g., IR sounder, microwave). Result: Tropospheric 3D winds.
- These AMVs are designed for use in Observing System Simulation Experiments (OSSEs).



Scenario: Nine polar-orbiting satellites flying as 3-satellite trains each equipped with a hyperspectral IR sounder. Equator crossing times of 0530, 0930, 1330 local time. The figure depicts the AMVs derived from the ECO1280 in a three-hour time window covering latitudes from equator to 60° N. Color coded by height: Yellow below 700 hPa; cyan 400-700 hPa; magenta above 400 hPa.

Approach

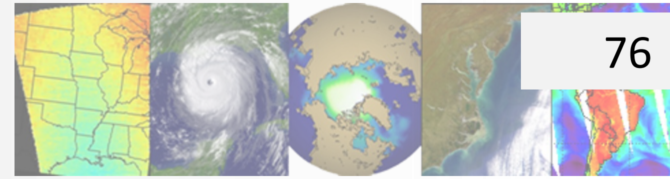
- Track humidity features in the ECMWF Cubic Octahedral (O1280) grid Nature Run (ECO1280).
- Winds produced on eight pressure levels: 200, 250, 300, 400, 500, 600, 700, 850 hPa.
- To simulate the coverage obtained by an IR hyperspectral sounder, the ECO1280 cloud top grid used to retain AMVs only in clear sky and above cloud.
- Polar satellite orbits are used to discard AMVs not viewed by the satellite.

Outcomes

- AMVs generated from the ECO1280 NR for June and July 2016.
- The result is a dataset of AMVs that compare favorably to the NR wind field: The bias ranges from near 0.0 ms^{-1} at low levels to -0.7 ms^{-1} in the upper troposphere, with an RMS difference of approximately 2 ms^{-1}.
- These AMVs were used in an OSSE for a companion CIMSS project.

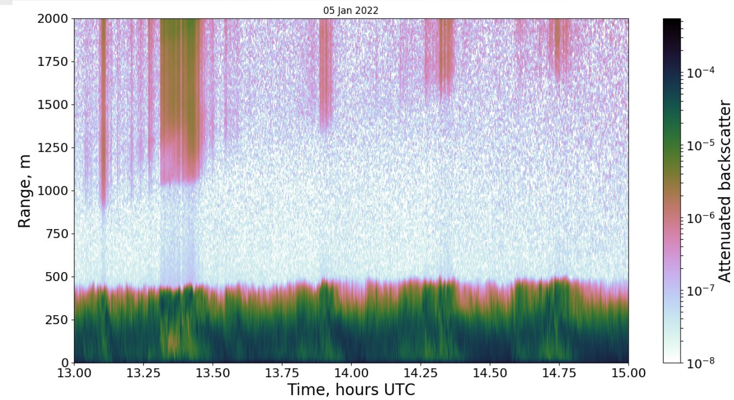
Snowfall Properties in Blizzards

N. Wood, A. Kennedy, M. Kulie, C. Pettersen, and D. Wright



Objective

- Develop tools to reduce adverse outcomes related to transportation, commerce, and public health associated with blizzard events
- For National Weather Service forecast office personnel primarily with potential application to transportation sector (e. g., state Departments of Transportation)



Ceilometer-observed lidar backscatter profiles for blowing snow near the surface with cloud aloft from our field site near Emerado, North Dakota

Approach

- Exploit advanced particle imaging and lidar backscatter profiling obtained from cost-effective, commercially-available sensors to diagnose blizzard threats
- Employ nanocomputer-based, low-power, open-source design imaging systems
- Exploit existing lidar backscatter profiling data such as that produced by standard ASOS/AWOS ceilometers
- Evaluate a trade-space matrix of operational performance versus enhanced instrument capabilities

Outcomes

- Demonstrating distinguishing microphysical and structural features of blowing versus falling snow (Wood et al., 2023, “Assessing blowing snow hazards with particle imager and ceilometer observations”, 103 AMS Annual Meeting, 9 Jan 2023).
- Will improve short-term forecasts of blizzard/blowing snow duration and intensity
- Has provided support and training for one PhD student and one undergraduate student, supervised by Kennedy at UND.
- Collaborative activities at UND have included outreach as well as instrument deployments and demonstrations at Sitting Bull College, a tribal institution on the Standing Rock Reservation

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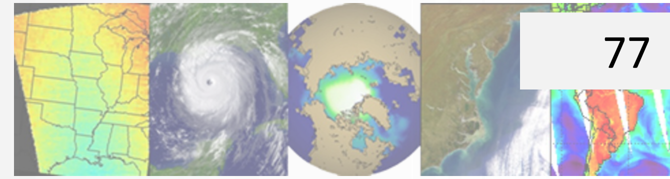
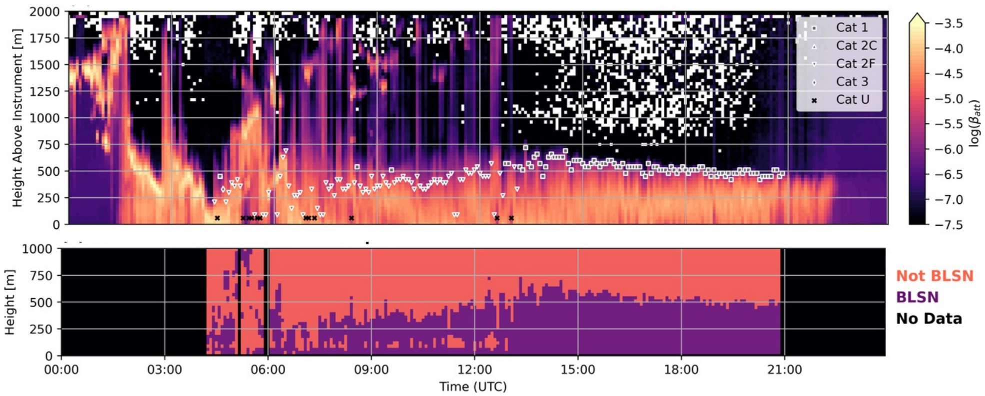
Snowfall Properties in Blizzards

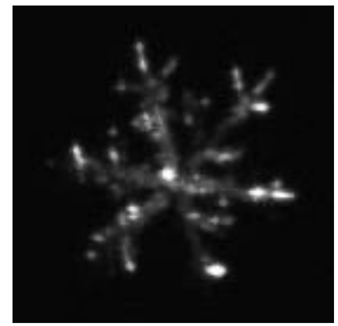
N. Wood, A. Kennedy, M. Kulie, C. Pettersen, and D. Wright

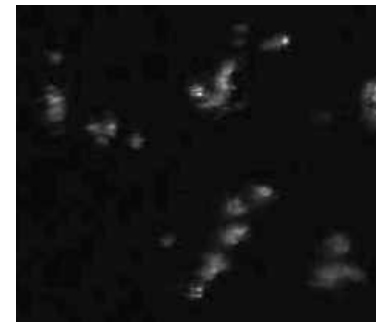


Snow microphysical, structural features distinguish blowing and falling snow hazards to inform forecasting and nowcasting



Machine-learning algorithm determines (top) snowfall categories and (bottom) extent of blowing snow from ceilometer backscatter profiles.



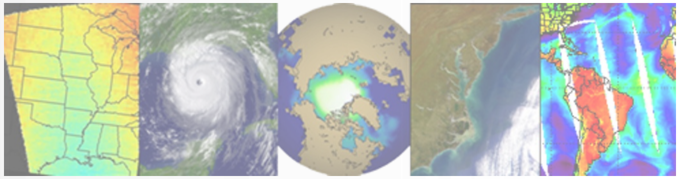


Distinct particle characteristics during (left) falling snow with pristine particles versus (right) blowing snow with fractured and rounded particles from imager observations.

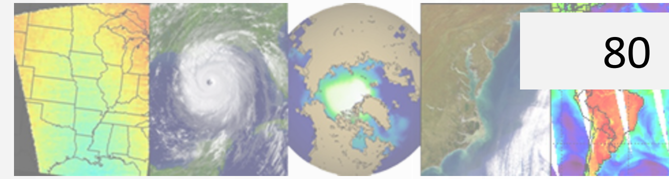
- Combined structural (ceilometer) and microphysical (imager) information allows determining both the current blizzard process (blowing versus falling snow) as well as the susceptibility of the recently fallen snow to lofting by wind.
- This informs assessments of current and near-term risks for nowcasting and near-term forecasting.
- Using readily-available commercial sensors lends itself to deploying networks of sensors in blizzard- and blowing-snow-prone areas

Data Visualization

Contents



VIIRS Imagery Support in McIDAS

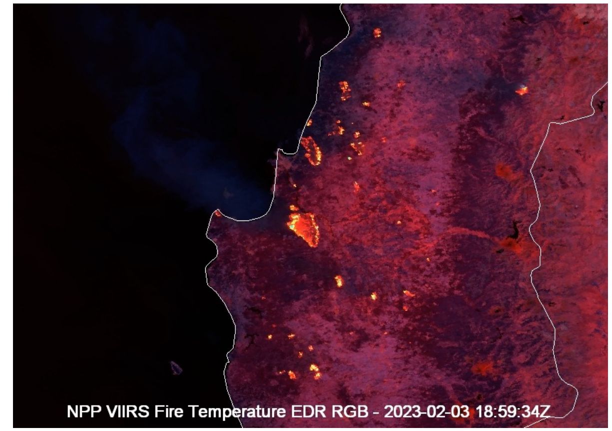


David Santek, Tommy Jasmin, Robert Carp

Objective

- Atmospheric scientists, Earth scientists, and other researchers who work with VIIRS data benefit from the availability of flexible visualization and analysis tools. This project expands and improves VIIRS support in the McIDAS-X and McIDAS-V software packages.

- The project directly supports the VIIRS Imagery Team, based at the Cooperative Institute for Research in the Atmosphere (CIRA), but benefits educational settings and broader science communities.



Chilean wildfires in McIDAS-V, February 2023

Approach

- Scientists at CIRA convey to CIMSS their research needs in regards to VIIRS imagery data products. These features and improvements then become available to all McIDAS users.
- Development of ADDE servers, now including Imagery EDRs, provides remote data access with spatial subsetting, for any ADDE-enabled clients.
- Background scripting hooks make McIDAS-based VIIRS RGB generation possible in automated data flows.

Outcomes

- This work was featured at the 2023 McIDAS Users' Group Meeting.
- McIDAS-V is open source and freely available.
- This work is frequently featured in the popular CIMSS Satellite Blog.
- This work is used in educational settings such as the most recent CIMSS Student Workshop, which brings together a very diverse set of high school students in Madison, WI every year.

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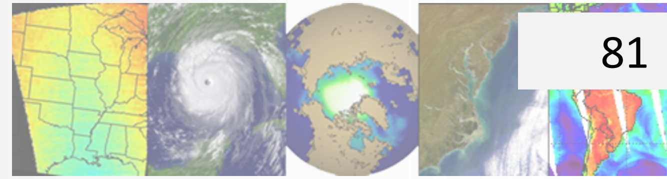
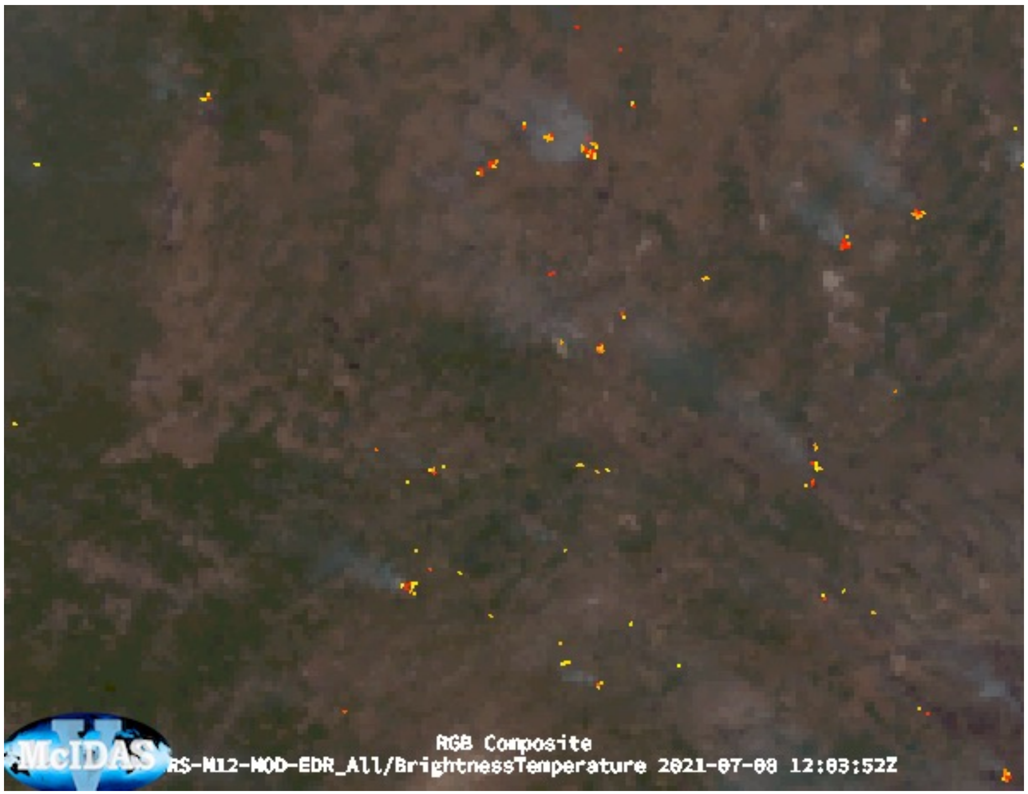
Tommy Jasmin and David Santek



McIDAS provides the ability to interactively merge 1-N VIIRS bands into a single product, leveraging formulas, RGBs, and transparencies over key data ranges.



African wildfire smoke and hotspots, VIIRS M3-M4-M5-M12

1. Easily aggregate consecutive VIIRS granules into a single true-color RGB (using M-Bands 3, 4, and 5). This **highlights wildfire smoke** in Figure 2.
2. Overlay 3.7 micron band M12, with full transparency, **except** the high end of the data range. This **highlights wildfire hotspots** in the same product.

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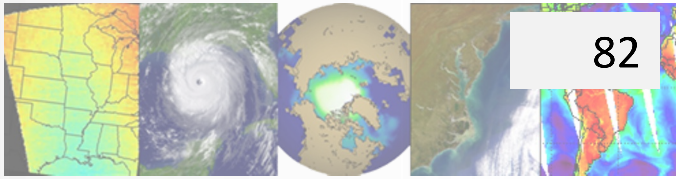
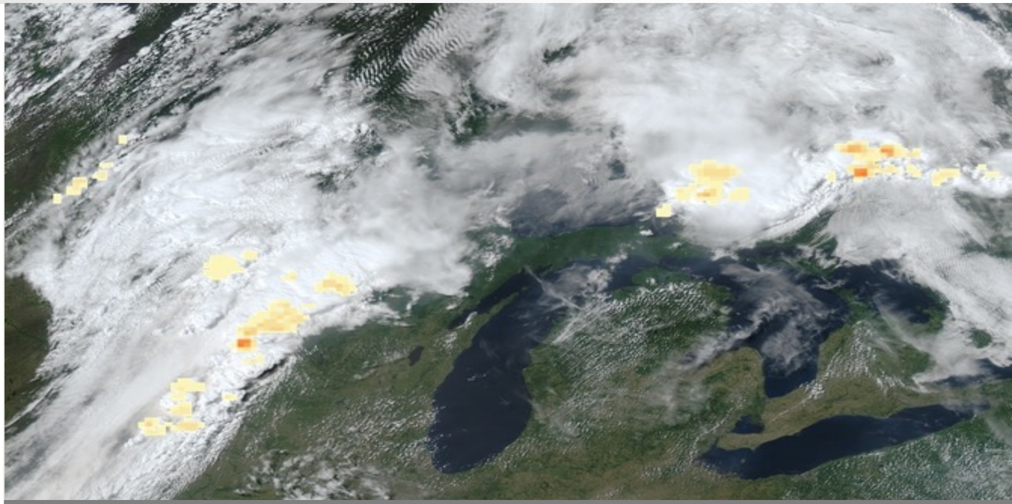
The Community Satellite Processing Package for Geostationary (CSPP Geo)

Liam Gumley, Graeme Martin, Nick Bearson, Jessica Braun, Geoff Cureton, Alan De Smet, Ray Garcia, Dave Hoese, Tommy Jasmin, Scott Lindstrom, Levi Pfantz, Eva Schiffer, Kathy Strabala



Objective

- The CSPP Geo project develops and distributes software allowing users to process geostationary satellite data.
- The software is used at a majority of sites receiving data from GOES satellites via GRB (direct broadcast), including sites operated by NWS
- CSPP Geo is a conduit for release of NOAA-developed algorithms to the public
- CSPP Geo products and imagery support a wide variety of time-critical user applications and operational decision-making



Imagery created with the Geo2Grid package: GLM Flash Extent Density overlaid on ABI true-color

Approach

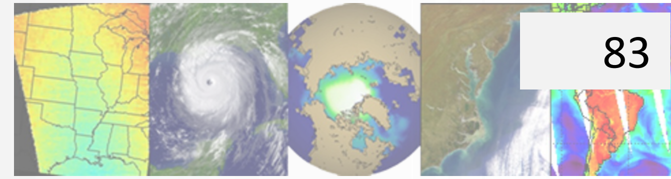
- Software is distributed as self-contained binary packages that are easy to install and run, using a methodology that has been developed at CIMSS over years of supporting the direct broadcast community
- Packages generally contain a mix of original and third-party software, tied together with glue logic
- Documentation and test datasets are provided
- Dynamic ancillary data is automatically downloaded from servers maintained by CIMSS
- User support is provided by email and a user forum

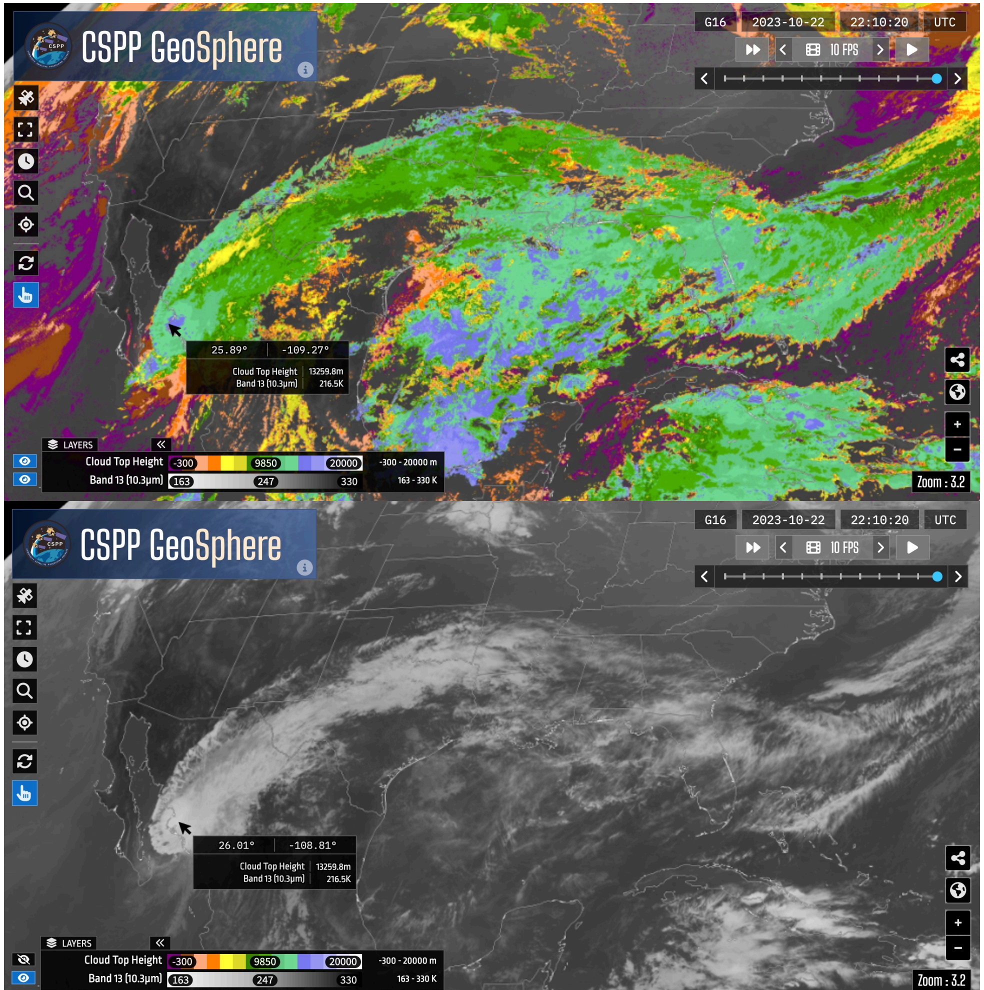
Outcomes

- CSPP Geo by the numbers:
  - 6 software packages are available, offering a combined 34 products and a wide selection of imagery
  - 9 instruments are supported on 8 satellites.
  - 29 software releases, including 14 since 2020
  - 1115 individuals from 63 countries have registered to download software (as of 2022)
- Users include NOAA / NWS, NASA, government contractors, international meteorological agencies, receiving station vendors, providers of satellite data services, and the research community
- CIMSS has participated in testing of the GOES-R ground system, providing valuable feedback to the program
- Availability of CSPP Geo software has prepared users to process data from new satellites and encouraged usage of GOES-R series data

The Community Satellite Processing Package for Geostationary (CSPP Geo)

Liam Gumley, Graeme Martin, Nick Bearson, Jessica Braun, Geoff Cureton, Alan De Smet, Ray Garcia, Dave Hoese, Tommy Jasmin, Scott Lindstrom, Levi Pfantz, Eva Schiffer, Kathy Strabala





Products and imagery generated with CSPP Geo software and displayed in CSPP GeoSphere: Cloud Top Height (top) and Band 13 (bottom).

CSPP Geo software puts product and imagery creation in the hands of users

- The CSPP GeoSphere website was developed to make GOES imagery more accessible to users, and as a demonstration of CSPP Geo software capabilities
- GOES data is received on an antenna at CIMSS and streamed into a chain of containerized CSPP Geo software running in an on-premise cloud
- Images and animations can be viewed in near real-time via an interactive Google-maps style interface
- GeoSphere has also been demonstrated in the Amazon and Google clouds
- NOAA Level 2 products are currently being added to provide access to quantitative retrieved products which many users may be unaware of.

https://geosphere.ssec.wisc.edu/

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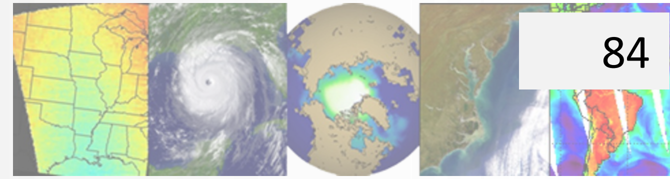
CIMSS

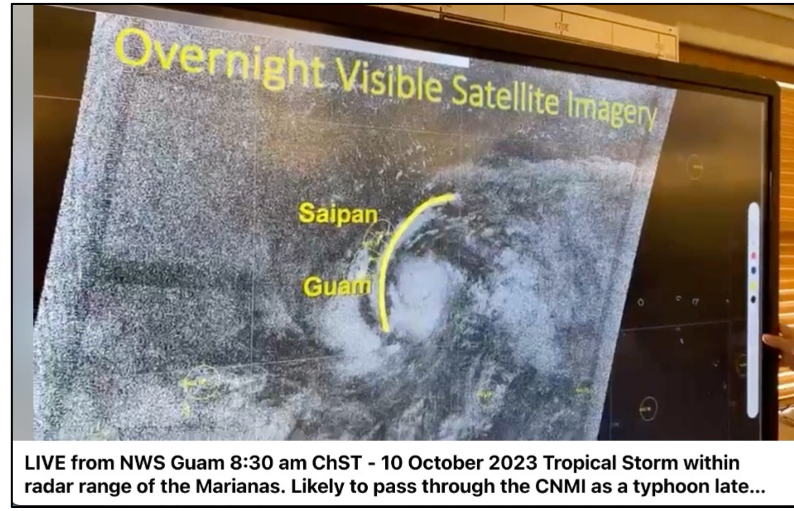
CSPP Polar2Grid

Kathleen Strabala and David Hoese



Promote the use of Polar Orbiter Satellites

- Facilitates the creation of high quality satellite data and product images.
- As part of the Community Satellite Processing Package (CSPP) the software supports the global direct broadcast community including the US National Weather Service (NWS).
- Easy to use and efficient, the software allows the products to be used operationally.



VIIRS Day/Night Band used by Guam NWS Forecasters in evaluating strength and course of Typhoon Bolaven. Screen Capture from Facebook Live stream.

Approach

- Simple bash shell execution scripts wrap underlying python.
- Uses Dask library for efficient parallel processing.
- Supported on most Linux Operating Systems.
- Supports a number of LEO satellites/instruments including:
  - JPSS SNPP, NOAA-20 and NOAA-21 SDRs and EDRs including ACSPO, MiRS, CLAVRx, Active Fires.
  - AMSR2 GAASP Brightness Temperatures.
  - NOAA-18, NOAA-19, Metop-A, Metop-B AHRR.
  - EOS Aqua and Terra MODIS.

Outcomes

- Code refactoring with major release of Polar2Grid 3.0 - significantly improves performance, especially of large data files such as multi-VIIRS granules.
- Software used around the world.
  - US National Weather Service creates AWIPS compatible files from co-located direct broadcast antenna data.
  - Students, global meteorological and research institutions. To date 800 different users from 61 countries.

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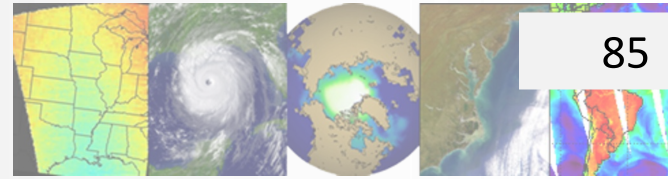
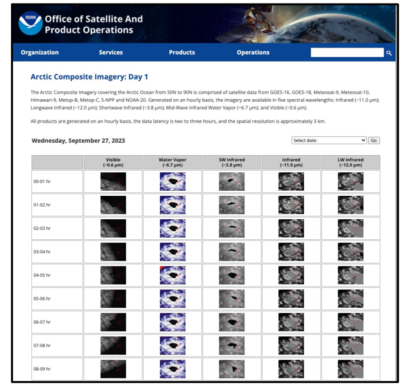
Arctic Composite Imagery

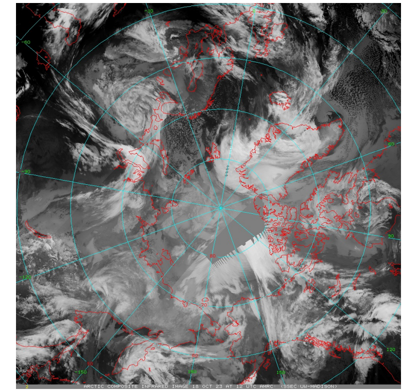
David Mikolajczyk, Matthew Lazzara, Rick Kohrs



Objective

- Realtime and operational production of Arctic Composite Imagery (ACI)
- 5 Channel imagery
- Combination of polar orbiting and geostationary satellite imagery
- CIMSS serves as backup for primary production at NOAA/NESDIS/OSPO
- Integrate MTG-I1 imagery into ACI when data are available at end of 2023





Screenshot of NOAA OSPO realtime ACI imagery (left)

Sample ACI infrared image from 12 UTC on 18 Oct 2023 (right)

Approach

- Work within the existing ACI framework and other satellite compositing methods as outlined in Kohrs et al, 2014.
- Include the most recent satellites: e.g. NOAA-20
- Correspond with NOAA/NESDIS/OSPO on ACI updates and issues
- Provide code documentation, send code packages for testing

Outcomes

- PyADDE Server for MTG-I FCI will be fully available in McIDAS-X December 2023 release.
- OSPO providing realtime ACI: (https://www.ospo.noaa.gov/Products/imagery/arctic/)
- CIMSS backup available via LDM, McIDAS ADDE and online at: https://arctic.ssec.wisc.edu/data/view-data.php?action=list&product=noaa

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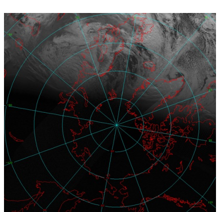
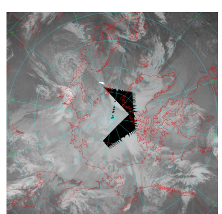
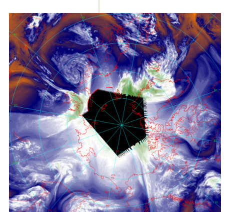


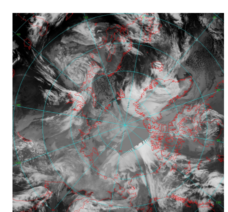
0.65 microns



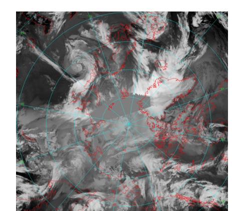
~3.8 microns.



6.7 microns



11.0 microns.

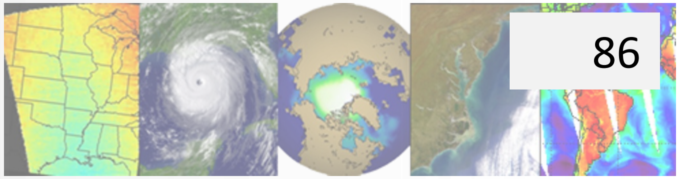


12.0 microns

CIMSS

Algorithm Integration Team

R. Garcia, W. Straka, E. Schiffer, A. De Smet, E. Olson



Objective

- Support LEO and GEO CIMSS algorithm development and delivery to NOAA with tools, programming expertise, data, and infrastructure
- Verification and report generation program "Glance" maintained as tool across a wide swath of projects
- Understand, devise, and assist with best practices as Agile and Cloud-compatible development practices are worked into NOAA integration flow

report-25-CG_ABI-L2-CPSNM1-M6_G16_s20191471800485_e20191471800554_c20201761959040
15 / 15 variables passed comparison

Passed comparison: DQF , PSD , geospatial_lat_lon_extent , goes_imager_projection , nominal_satellite_height , nominal_satellite_subpoint_lat , nominal_satellite_subpoint_lon , t , time_bounds , x , x_image , x_image_bounds , y , y_image , y_image_bounds

report-26-CG_ABI-L2-CTPM1-M6_G16_s20191471800485_e20191471800554_c20201761959040
13 / 15 variables passed comparison

Variable	Mismatch Count	Mismatch %	Mean Diff	Median Diff	Max Diff	A Range	B Range
DQF	1041	0.5409871846839824	0.027283216	0.0	6.0	0.0 to 0.0	0.0 to 6.0
PRES	191331	99.97178462261932	31.703241	18.463684	830.37964	160.71811 to 1009.56146	103.01065 to 1010.35034

Passed comparison: geospatial_lat_lon_extent , goes_imager_projection , nominal_satellite_height , nominal_satellite_subpoint_lat , nominal_satellite_subpoint_lon , t , time_bounds , x , x_image , x_image_bounds , y , y_image , y_image_bounds

report-27-CG_ABI-L2-LSTM1-M6_G16_s20191471800485_e20191471800554_c20201761959040
13 / 15 variables passed comparison

Variable	Mismatch Count	Mismatch %	Mean Diff	Median Diff	Max Diff	A Range	B Range
DQF	51172	77.26991317478293	1.8078672	2.0	4.0	0.0 to 2.0	0.0 to 4.0
LST	27506	100.0	1.8326937	1.7567749	4.341919	272.5355 to 321.24472	279.7268 to 318.09897

Passed comparison: geospatial_lat_lon_extent , goes_imager_projection , nominal_satellite_height , nominal_satellite_subpoint_lat , nominal_satellite_subpoint_lon , t , time_bounds , x , x_image , x_image_bounds , y , y_image , y_image_bounds

Partial illustration of Glance verification report

Approach

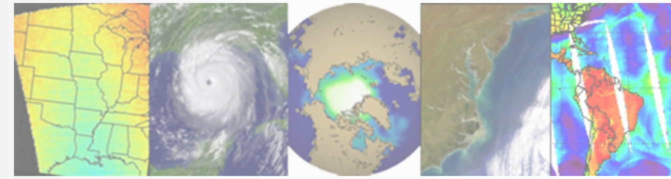
- Act as a cross-cutting computer science support/advice/coding group specialized to data, computing, analysis and software lifecycle needs for CIMSS algorithm developers.
- Participate in deliveries, software development and integration, and test data management.
- Gain expertise in cluster and cloud computing and provides examples and assistance in getting algorithms integrated and delivered.

Outcomes

- Consistent and collaborative technical interchange with NOAA ASSISTT and operations teams
- Computing, storage resources, datasets for algorithm testing and development
- Tools and utilities used at CIMSS/SSEC, NOAA, NWS
- Preparatory work toward cloud-ready algorithm development, continuous integration, automated testing, and rapid software delivery as NOAA migrates processing and software facilities to Gitlab and AWS

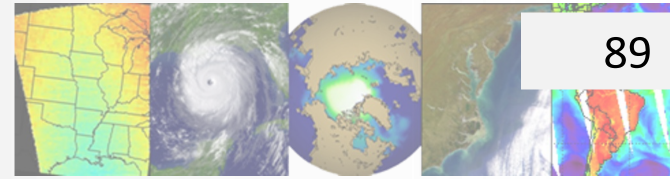
Satellite Sensors and Measurement Techniques

Contents



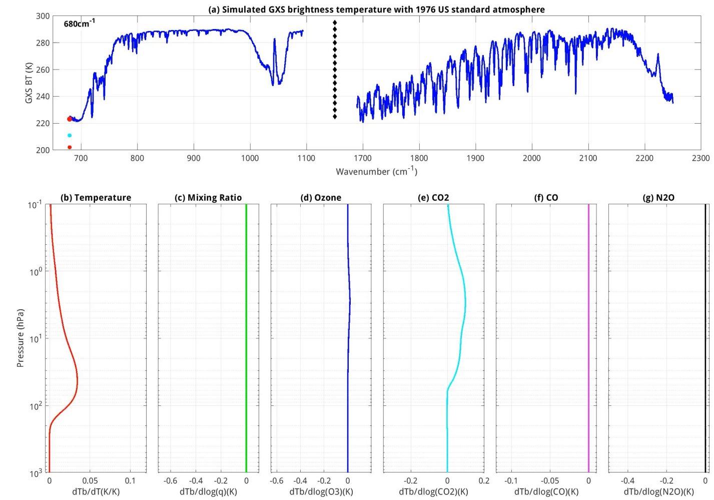
GeoXO Sounder (GXS) Studies

Z Li, J Li, C Moeller; NOAA Collaborators: T Schmit, A Heidinger



Objective

- Understand the sounding information content of GXS
- Understand the impact of diffraction effects on ensquared energy (EE) and the impact of EE on sounding retrievals
- NESDIS, GeoXO program



GXS Jacobians with respect to temperature, moisture and gases

Approach

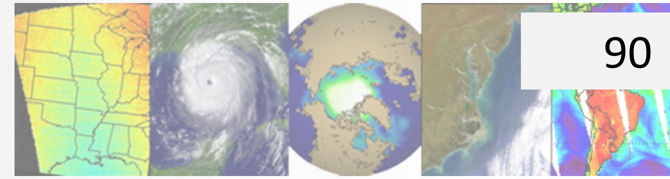
- Developed the capability to simulate GXS radiances
- Carried out information content analysis of GXS
- Simulated the diffraction effects with point spread function, and simulated GXS radiances from 50m Moderate Resolution Imaging Spectroradiometer airborne simulator data
- Analyzed the impact of EE on pseudo noise
- Analyzed the impact of EE on sounding retrievals

Outcomes

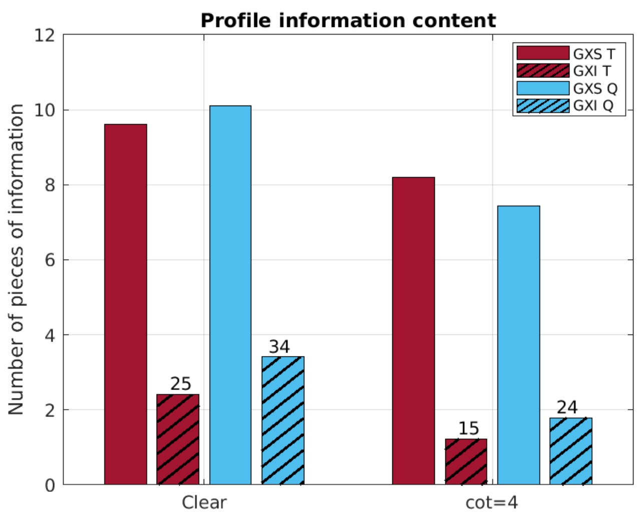
- GXS has abundant sounding information content for temperature, moisture, and selected gases
- GXS provides 4-6 times more temperature information content than GXI, and 3-4 times more moisture information content than GXI
- An EE of 70% meets the requirement that all GXS channels having pseudo noise smaller than instrument noise
- Pseudo noise due to imperfect EE always degrades the sounding quality
- Manuscript accessible at https://doi.org/10.1109/TGRS.2023.3271931

GeoXO Sounder (GXS) Studies

Z Li, J Li, C Moeller; NOAA Collaborators: T Schmit, A Heidinger



Perform information content analysis of GXS to understand the usefulness of GXS in nowcasting

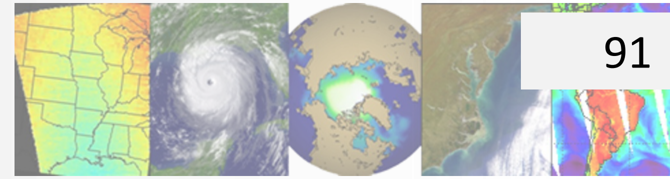


The information content of GXS and GXI for temperature and moisture in both clear and cloudy conditions. The numbers on top of the bars indicates the percentage of information content from GXI compared to GXS. The cloud has a cloud optical thickness of 4 and cloud top pressure at 300 hPa. The tropical atmosphere profile is used.

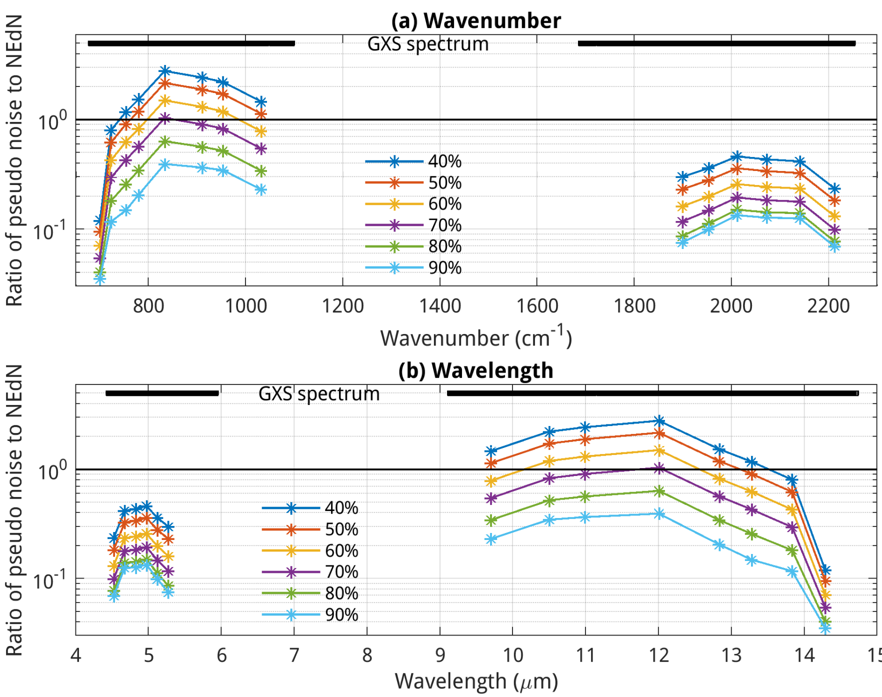
- Typical profiles were used to simulate GXS and GXI radiances as well as the Jacobians in both clear and cloudy conditions, which are used to calculate the information content.
- Left figure shows that GXS has 4-6 times more temperature information content than GXI, and 3-4 times more moisture information content than GXI
- GXS and GXI coefficients were generated for the in-house all sky Pressure-layer Fast Algorithm for Atmospheric Transmittance (PFAAST) model
- GXS provides abundant sounding information content of temperature, moisture, and gases

GeoXO Sounder (GXS) Studies

Z Li, J Li, C Moeller; NOAA Collaborators: T Schmit, A Heidinger



Understand diffraction effects on the GXS ensquared energy (EE) and how this affects sounding quality

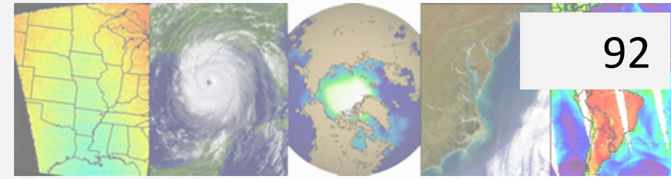


The ratio of pseudo noise to the instrument noise equivalent radiance differential (NEdN) for different EE values. The EE numbers are determined based on 680 cm^{-1}

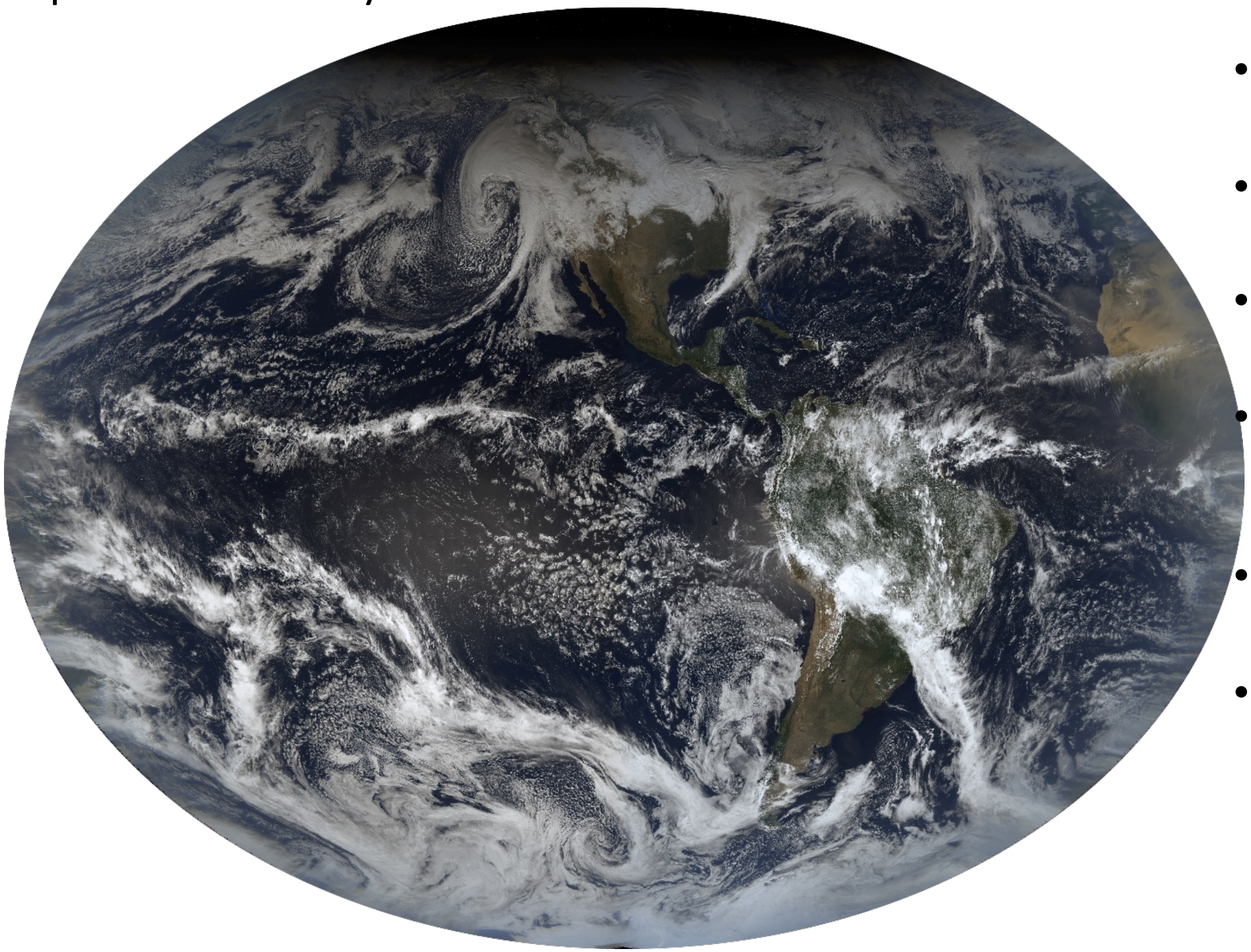
- A point spread function (PSF) is used to simulate the diffraction effects on GXS and calculate the EE
- The PSF is applied to the 50m Moderate Resolution Imaging Spectroradiometer airborne simulator data to simulate GXS radiances
- Left figure shows that an EE of 70% is recommended to ensure all GXS channels having pseudo noise less than instrument noise
- An EE of 70% results in RMSE increase by 3-4% for temperature and by 1-4% for relative humidity due to pseudo noise
- Reduced EE leads to further RMSE increase in temperature and moisture soundings
- Manuscript accessible at https://doi.org/10.1109/TGRS.2023.3271931

GOES-R Imagery & Cal/Val

Mathew Gunshor, J. Nelson, and R. Kohrs; NOAA Collaborator: T. Schmit



The GOES-R Imagery Team at CIMSS ensures Advanced Baseline Imager (ABI) imagery product accuracy on the GOES-R Series of satellites.



January 4, 2023 GOES-West/GOES-East composite: “CIMSS Natural Color Local Noon” image on the day GOES-18 became Operational as GOES-West.

- First Light image generation for ABI (GOES-18 First Light was May 2022).
- Cloud and Moisture Imagery Product (CMIP) real-time monitoring.
- GEO-GEO Difference Statistics for Level-1b radiance file monitoring.
- Provided Focal Plane Module (FPM) temperature thresholds for GOES-17 data quality flags.
- Test backup satellites GOES-14, -17 with NOAA/NESDIS Operations.
- ABI data quality monitoring tools website at CIMSS: http://cimss.ssec.wisc.edu/goes-r/abi-/16band_mainmenu.html

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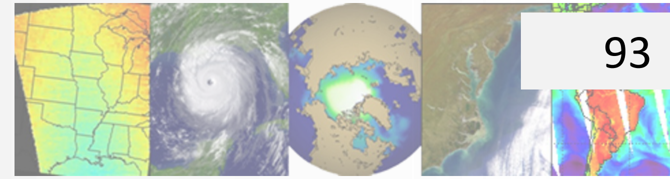
GOES Weighting Functions

M. Gunshor, S. Moeller, J. Nelson, S. Bachmeier, S. Lindstrom; NOAA
Collaborator: T. Schmit

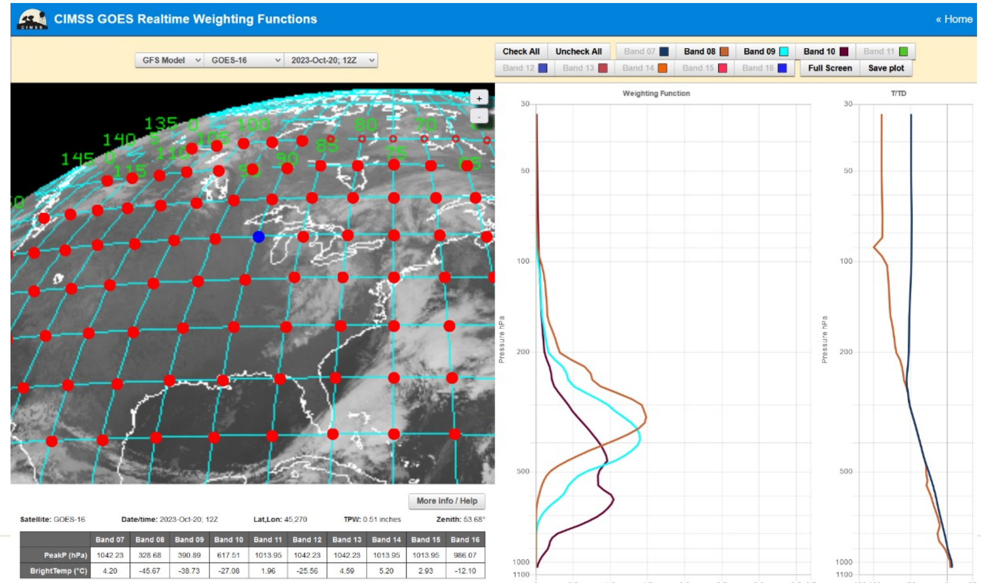


Objective

- Provide realtime access to GOES, and other geostationary satellite, weighting functions for training and operational use.

Secondary

- Modernize previous Weighting Function Page
- Expand input data beyond RAOBs to use model analysis to increase geographical coverage



https://cimss.ssec.wisc.edu/goes-wf/

Approach

- Modernize Current Weighting Function Page
- Stop generating static imagery and make use of dynamic web plotting tools.
  - We now generate large datasets of weighting function calculations that can be plotted upon user demand.
  - These data are available upon request
- Model data on a 5-degree grid
- Data stored in JSON files valid for 00 and 12 UTC
- WF data calculated at each grid point, updated software allows for more highly interactive plots than old WF Webpage.

Outcomes

- Added global GDAS data as input
- Added GOES-16, -17, and -18 to the site
- Added Japanese AHI data to the site
- Expanded available RAOB stations to cover more of the globe
- Have received positive feedback from NWS WFOs
- Have seen figures from our website used in multiple NWS Satellite Book Club (SBC) presentations
- Website regularly used by CIMSS scientists in training materials, including on the CIMSS Satellite Blog. Example:
  - https://cimss.ssec.wisc.edu/satellite-blog/archives/51689

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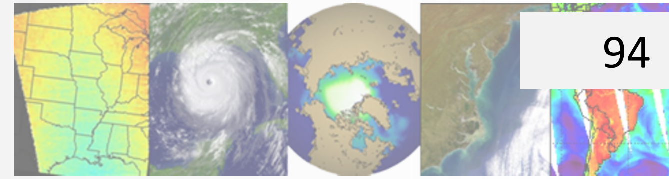
JPSS Radiosonde Program

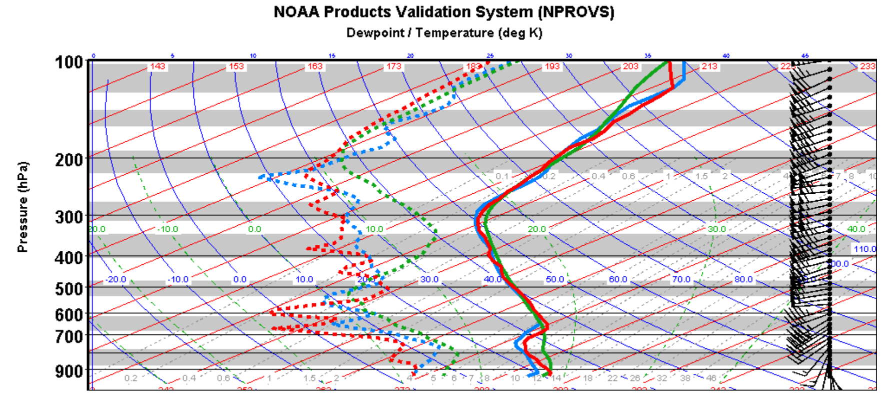


Lori Borg, Tony Reale, Nick Nalli, Bomin Sun

Objective

- The JPSS Radiosonde Program is a long-term collaboration between UW-Madison, NOAA, and the ARM program to validate atmospheric temperature and water vapor retrieved profiles from S-NPP, NOAA-20, & NOAA-21 at the ENA, NSA, SGP, and TWP (formerly) ARM ground sites.

- Validation of NUCAPS sounding products is crucial before use by weather forecasters and researchers and requires accurate and on-going validation data, which the ARM field sites provide.



Example of 'golden' collocation. ARM radiosonde collocated with NUCAPS & GNSS-RO COSMIC-2 sounding.

Approach

- Radiosondes are launched coordinated with satellite overpasses and occur across seasons and for both day and night time overpasses to sample a range of atmospheres at each ARM site.

- Radiosonde data is combined with ancillary data to create a best estimate of the atmospheric state which is used to validate the NUCAPS retrievals.

Outcomes

- Collecting a set of collocated satellite and ARM radiosonde observations provides a valuable training dataset from which statistics on the performance, tendencies, and uncertainty of NUCAPS soundings are studied.

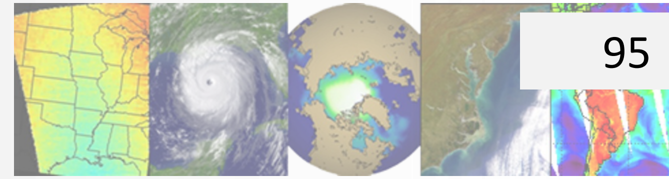
- Such statistics directly help forecasters to optimally utilize NUCAPS to navigate when and where severe weather will occur.

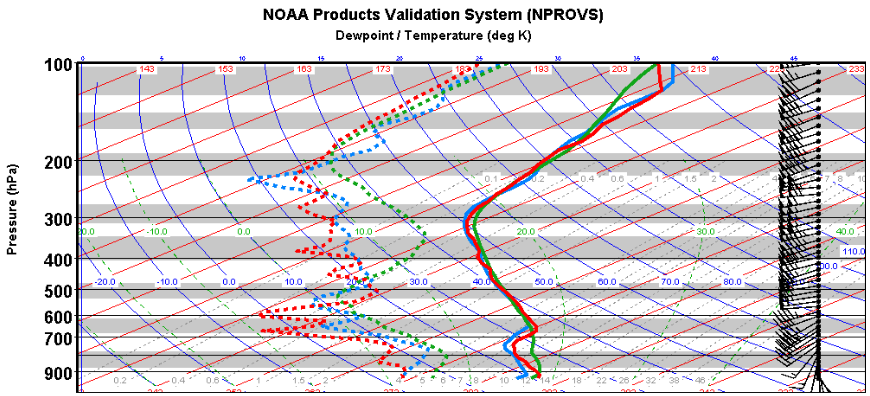
Borg, Lori A., Ruud J. Dirksen, and Robert O. Knuteson. "Chapter 12 - Land-Based Cal/Val Campaigns." In FieldMeasurements for Passive Environmental Remote Sensing, edited by Nicholas R. Nalli, 219–33. Elsevier, 2023. https://doi.org/10.1016/B978-0-12-823953-7.00001-0.

Sun, B., A. Reale, M. Pettey, R. Smith and C. Brown. "Chapter 16 - NOAA Products Validation System (NPROVS)", In Field Measurements for Passive Environmental Remote Sensing, edited by Nicholas R. Nalli, 281–296. Elsevier, 2023. https://doi.org/10.1016/B978-0-12-823953-7.00009-5

JPSS Radiosonde Program

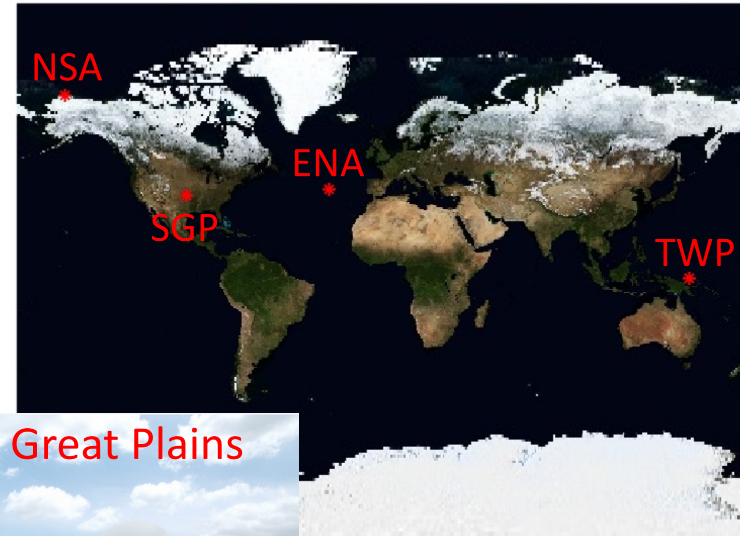
Lori Borg, Tony Reale, Nick Nalli, Bomin Sun





Radiosonde 74646 (141) Radiosonde 2/28/2023 8:13:00Z 36.6 N / 97.5 W
NUCAPS NOAA-20 2/28/2023 7:43:33Z (-0.5 hours) 36.5 N / 97 W (46.7 km)
COSMIC2 2/28/2023 9:03:17Z (0.8 hours) 37 N / 98.3 W (84.4 km)

Example of ‘golden’ collocation. ARM radiosonde collocated with NUCAPS & GNSS-RO COSMIC-2 sounding.

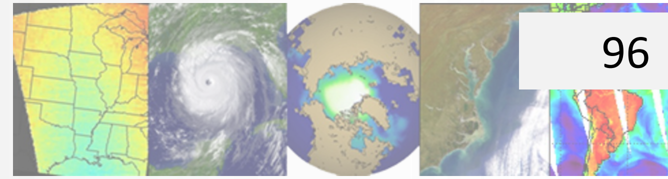


The JPSS Radiosonde Program provides validation of NUCAPS temperature and water vapor retrievals using radiosonde launches coordinated with S-NPP, NOAA-20, and NOAA-21 overpasses from the ENA, NSA, SGP, & TWP (formerly) ARM sites.

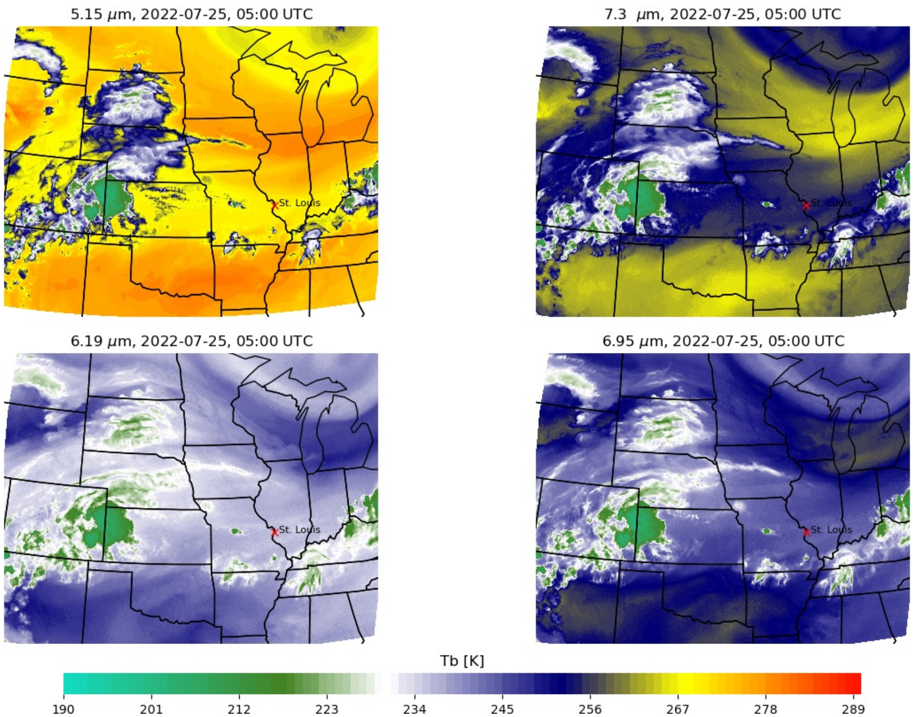
Validation of NUCAPS sounding products is crucial before use by weather forecasters and researchers and requires accurate and on-going validation data, which the ARM field sites provide.

GeoXO Imager (GXI) Band Selection

N. Miller, M. Gunshor, T. L'Ecuyer, T. Schmit, N. Gordillo, Z. Li



A new imager being planned for the GeoXO Program is an opportunity to think about what critical capabilities will be needed for the next generation of geostationary imagers and to simulate the potential uses.



All-sky simulations of GXI demonstrate potential of the ~5.1um low-level water vapor band.

- Improved ability to detect wildfires (improved resolution shortwave window band) with the GeoXO Imager (GXI).
- Improved ability to detect low-level moisture (~5.1um water vapor band). Gives us a chance to catch low level moisture that will turn into convection; for Nearcasting. https://cimss.ssec.wisc.edu/satellite-blog/archives/54494
- Improved ability to detect clear air turbulence using improved resolution water vapor band(s).

"Imaging Considerations From a Geostationary Orbit Using the Short Wavelength Side of the Mid-Infrared Water Vapor Absorption Band" – Miller et. al. 2022

https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021EA002080

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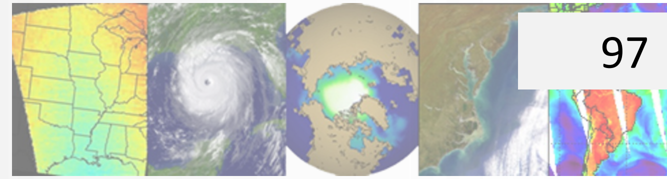
S-HIS: Scanning High-resolution Interferometer Sounder

Joe Taylor



Instrument characteristics

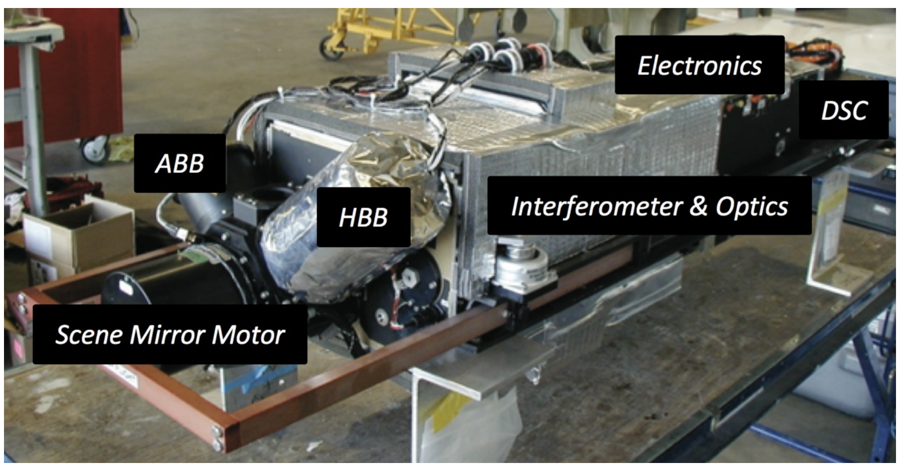
Spectral range	580 – 2850 cm^{-1} 3.5 – 17.3 µm
Spectral resolution	0.5 cm^{-1}
Vertical resolution (Sounding)	2 km
Footprint Size at nadir	2 km from 20 km 100m from 1km
Swath	ER-2: 40 km (20 km altitude)

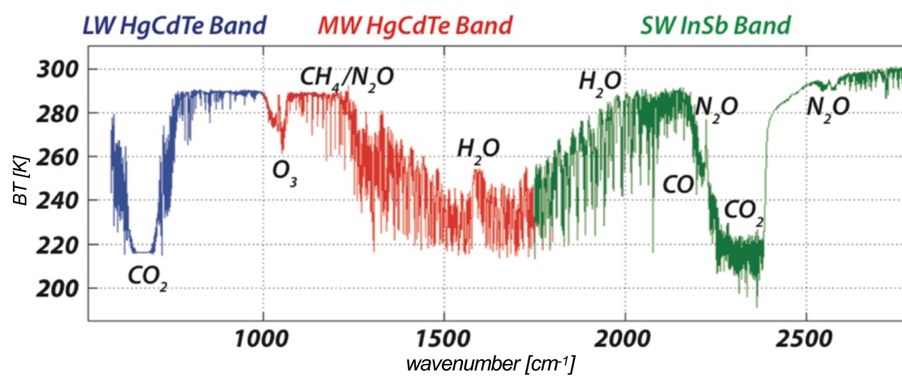
Dynamically aligned FTS
Programmable cross-track scan coverage
UW-SSEC designed Michelson mirror assembly
4-band detector option for extended LW IR coverage
Zenith view on Proteus and WB-57

36 missions on 5 aircraft (ER-2, Global Hawk, WB-57, Proteus, DC-8) since 1998
Excellent calibration accuracy and proven traceability
Extremely dependable, with preliminary products typically available within a few hours after data download
Near real-time products available within 1-minute of observation when a high bandwidth downlink is available

Geophysical Retrievals (Dual Regression)
Temperature Profiles
Water Vapor Profiles (RH, Mix Ratio)
CO, N_2O, CH_4, O_3 Profiles
Total Column CO_2 concentration
Surface temperature and emissivity

Past Measurement Applications
Radiative transfer model assessment
Trace gas retrievals
Cloud radiative properties
Cloud top retrievals
Fire characterization
Thermodynamic environment around hurricane and tropical storms
Saharan air layer studies
Calibration validation (L1b and L2)





Recent Deployments: ecoDemonstrator (DC-8), AEROMMA (DC-8), FIREX-AQ (ER-2), GOES PLT ABI Cal Val (ER-2), CrIS Cal Val (ER-2)

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Taylor, Joseph K., et al. "High-altitude aircraft radiometric calibration-validation campaigns." Field Measurements for Passive Environmental Remote Sensing. Elsevier, 2023. 159-184.

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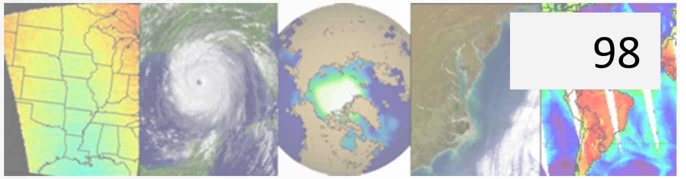
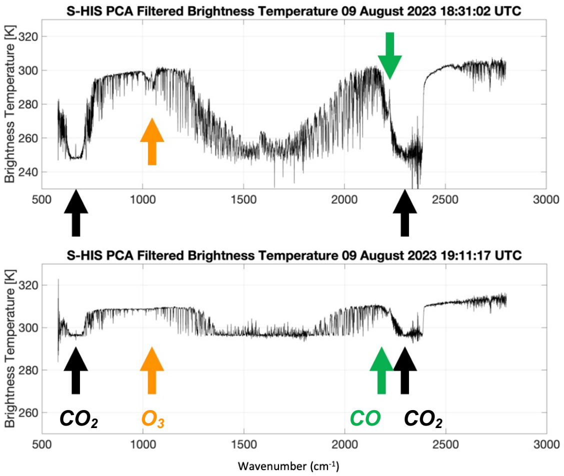
AEROMMA Field Campaign S-HIS Deployment

Joe Taylor, Hank Revercomb, Dave Tobin, Fred Best and the S-HIS Team



Objective

- The goal of this project is to support
  1. Deployment of the UW-Madison SSEC/CIMSS Scanning High- resolution Infrared Sounder (S-HIS) on the NASA DC-8 aircraft for participation in the AEROMMA (Atmospheric Emissions and Reactions Observed from Megacities to Marine Areas) field campaign, and
  2. Post-mission data processing and analysis of the S-HIS data.



Examples of S-HIS upwelling atmospheric spectra for two single footprint observations during the August 9, 2023, flight. The top panel corresponds to a high-altitude approach over Pennsylvania and the bottom panel corresponds to a low-level flight leg over New Jersey.

Approach

- Conduct science flights from NASA Armstrong Flight Research Center (AFRC) in Palmdale CA and Wright-Patterson Air Force Base (AFB) in Dayton OH.
  - Marine Flights over the Pacific Ocean
  - East Coast Urban Flights over Toronto, Chicago, and New York City
  - West Coast Urban Flights over Los Angeles
- Complete preliminary processing and analysis in the field in a timely fashion.
- Perform post-mission detailed data processing and analysis.

Outcomes

- The Scanning High-resolution Interferometer Sounder (S-HIS) was successfully operated and collected high quality data during the AEROMMA science campaign.
- AEROMMA flights concluded at the end of August 2023.
- AEROMMA addresses emerging research needs in urban air quality, marine emissions, climate feedbacks, and atmospheric interactions at the marine-urban interface and future satellite capabilities of monitoring atmospheric composition over North America. AEROMMA will bring together airborne, ground, and satellite observing systems, and state-of- the-art air quality and climate models, to investigate these research topics.
- Preliminary data processing of S-HIS was completed during the deployment and the results are being analyzed by the S-HIS team.
- Post mission data processing and analysis is underway.

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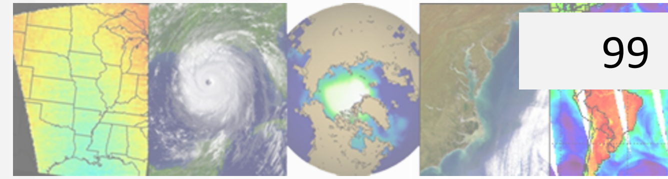
Monitoring VIIRS Long-term Stability

Zhenglong Li, Pei Wang, Jinlong Li, Chris Moeller



Objective

- Monitoring the VIIRS/SNPP long-term stability at Salton Sea

The precision of the 4 clear/cloud categories from the GBDT models and the VIIRS cloud mask algorithm

Model Accuracy	VIIRS cloud mask	GBDT model
Confident clear	75.65%	86.90%
Probably clear	64.86%	79.79%
Probably cloud	63.76%	80.01%
Confident cloud	94.17%	95.73%

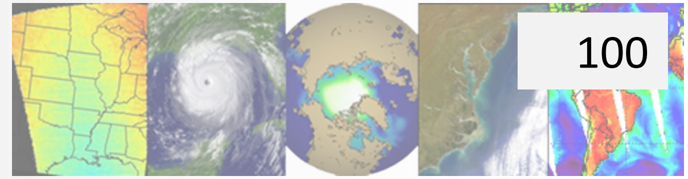
Approach

- Developed a machine learning (Gradient Boosted Decision Trees) technique to better detect clear and cloud pixels, especially the confident clear pixels
- Time series analysis of VIIRS/SNPP SDR and reprocessed SDR to quantify the long-term trend over Salton Sea

Outcomes

- A machine learning based clear/cloud detection is developed and applied to VIIRS/SNPP
- The new detection correctly finds more clear and cloudy pixels than VIIRS cloud mask, and the precision of all 4 clear/cloud categories is significantly improved
- VIIRS/SNPP is a very stable instrument. SDR shows insignificant trends and reprocessed SDR shows even smaller insignificant trends.

Monitoring VIIRS Long-term Stability



Zhenglong Li

Improving VIIRS clear detection

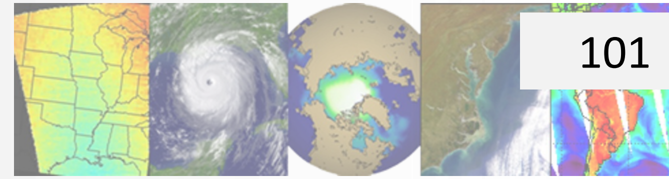
The hit rates for clear and cloudy for all data as well as land and water only. TCRR stands for true clear hit rate, and TCDR stands for true cloudy hit rate.

Model	TCRR (Clear rate)		TCDR (Cloud rate)	
	VIIRS	GBDT	VIIRS	GBDT
All Data	0.8457	0.8655	0.8566	0.9288
Over Land	0.8888	0.9032	0.7643	0.9059
Over Water	0.8081	0.8405	0.8966	0.9431

- Time series analysis is a great tool to monitor sensors' long-term stability
- To minimize the cloud contamination, a machine learning algorithm based on Gradient Boosted Decision Trees (GBDT) is developed
- A 3-year global dataset (White et al. 2021) containing VIIRS SDR, cloud mask, and CALIOP cloud measurements was used for training
- The GBDT algorithm significantly improves the detection precision of all 4 clear/cloud categories
- Left table shows that the GBDT algorithm correctly finds more clear and cloudy pixels than the VIIRS cloud mask over both land and water
- These results indicate that the confident clear from GBDT should be able to provide more clean clear pixels for long-term stability monitoring

Monitoring VIIRS Long-term Stability

Zhenglong Li



Monitoring VIIRS/SNPP long-term stability at Salton Sea

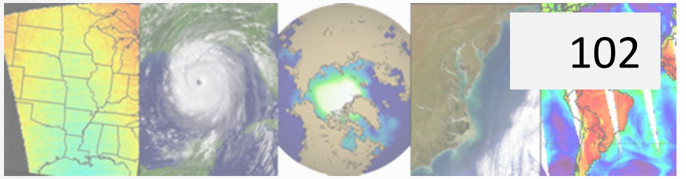
Monthly trend of SDR and reprocessed SDR

	Monthly Reflectance Trend (Operational) (%/year)		Monthly Reflectance Trend (Reprocessed) (%/year)	
	Trend (%/year)	95% confidence intervals	Trend (%/year)	95% confidence intervals
I1	-0.0449	0.0369	-0.0361	0.0393
I2	0.0059	0.0256	-0.0029	0.0262
I3	0.0113	0.0174	-0.0031	0.0183
M1	-0.1534	0.3681	-0.0502	0.3708
M2	-0.1241	0.2833	-0.0400	-0.2867
M3	-0.0964	0.2098	-0.0358	-0.2121
M4	-0.0803	0.1509	-0.0345	-0.1528
M5	-0.0405	0.0859	-0.0211	0.0856
M6	-0.0152	0.0594	-0.0014	0.0601
M7	-0.0125	0.0389	-0.0043	0.0387
M8	-0.0077	0.0181	-0.004	0.0181
M9	-0.0018	0.0026	-0.0004	0.0030
M10	-0.0063	0.0133	-0.0036	0.0133
M11	-0.0054	0.0090	-0.0035	0.0092
I4	-0.0752	0.1273	-0.0585	0.1407
I5	-0.0683	0.1328	-0.0518	0.1411
M12	-0.0762	0.1271	-0.0582	0.1408
M13	-0.0832	0.1365	-0.0628	0.1480
M14	-0.077	0.1325	-0.0566	0.1414
M15	-0.0685	0.1293	-0.0559	0.1382

- Time series analysis was carried out to monitor the long-term stability of VIIRS/SNPP at Salton Sea for both SDR and reprocessed SDR
- Only confident clear and water pixels were retained
- 2013-2019, zenith angle <6°
- Seasonal variations removed
- Left table shows that
  - ➢ All VIIRS channels have no significant trends (trends are smaller than the 95% confidence intervals)
  - ➢ All VIIRS channels from reprocessed SDR have smaller trends than those from SDR
- VIIRS/SNPP is a radiometrically stable instrument

Suomi-NPP and JPSS CrIS Sensor Data Records (SDRs)

David Tobin, Hank Revercomb, Joe Taylor, Michelle Loveless, Bob Knuteson, Lori Borg, Dan DeSlover



Objective

- In collaboration with the NOAA/STAR team, create Cross-track Infrared Sounder (CrIS) geo-located and spectrally and radiometrically calibrated radiance products with characteristics suitable for weather and climate applications

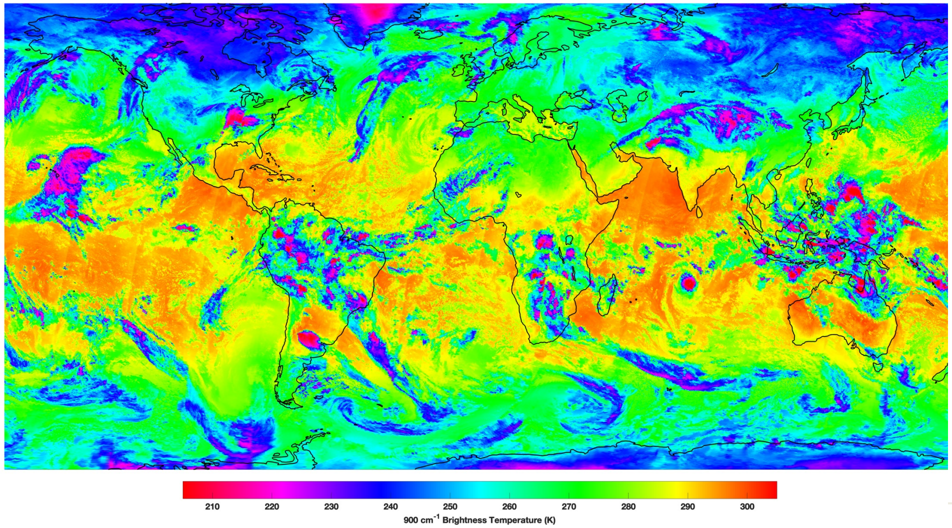
Stakeholders/Users

- Users include medium range NWP, atmospheric sounding products and applications (e.g. NUCAPS and AWIPS), and climate process and trending studies

Approach

- Drawing upon many decades worth of experience with the calibration of ground, aircraft, and satellite based FTS sensors, the approaches include a broad range of studies/efforts from sensor design studies, requirements definition, pre-launch thermal vacuum sensor performance characterization, post-launch sensor tailoring, calibration algorithm assessments, and cal/val activities.

Descending composite of NOAA-21 and NOAA-20 CrIS data on 16 Feb 2023



Outcomes

- On a per-sensor basis, the advanced IR sounders, including CrIS, are most influential for ECMWF and UKMet NWP forecasts (Dec 2021 NOAA Workshop on IR sounders)
- Robert H Goddard Award for Science as part of the JPSS SDR/Imagery Science team support for NOAA-21
- Loveless, M. et al., Comparison of the AIRS, IASI, and CrIS infrared sounders using simultaneous nadir overpasses: Novel methods applied to data from 1 October 2019 to 1 October 2020. Earth and Space Science, 10, 2023, e2023EA002878. https://doi.org/10.1029/2023EA002878
- Taylor, J.K. et al., Assessment and Correction of View Angle Dependent Radiometric Modulation due to Polarization for the Cross-Track Infrared Sounder (CrIS). Remote Sens. 2023, 15, 718. https://doi.org/10.3390/rs15030718
- Borg, L. et al., Simulation of CrIS Radiances Accounting for Realistic Properties of the Instrument Responsivity That Result in Spectral Ringing Features. Remote Sens. 2023, 15, 334. https://doi.org/10.3390/rs15020334

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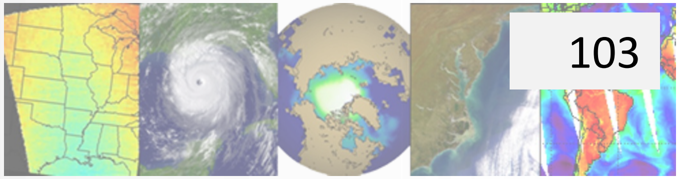
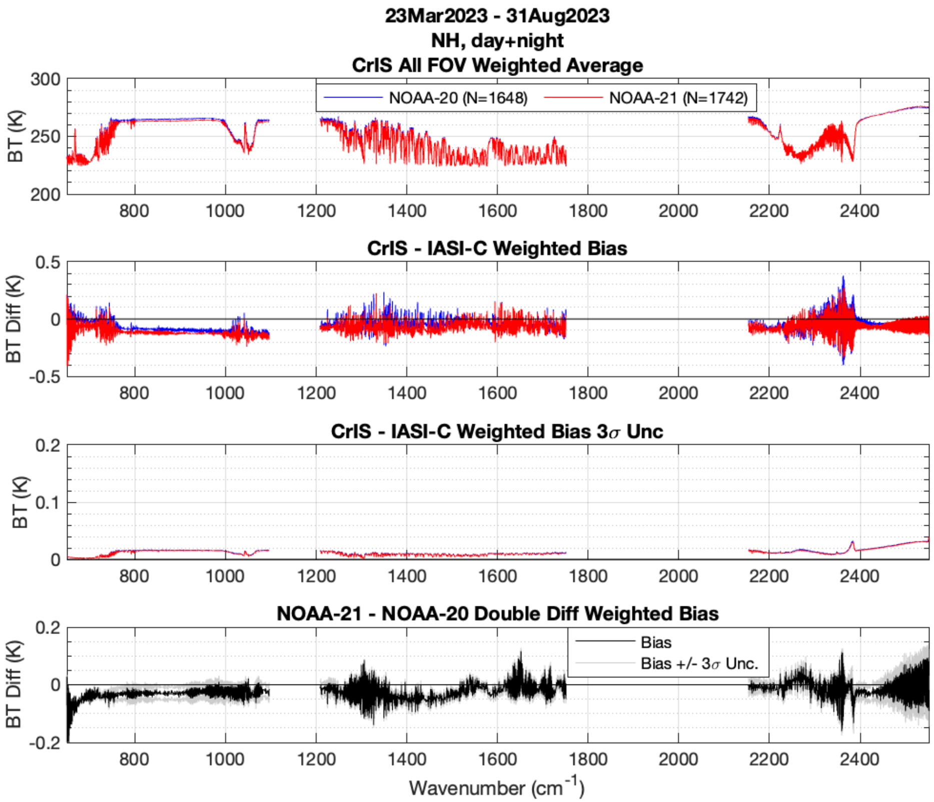
David Tobin, Hank Revercomb, Joe Taylor, Michelle Loveless, Bob Knuteson, Lori Borg, Dan DeSlover



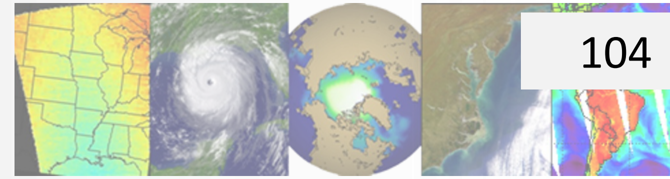
NOAA-20 CrIS /METOP-C IASI /NOAA-21 CrIS Example comparisons from Loveless et al. 2023



- Comparisons using Simultaneous Nadir Overpasses are one example showing the excellent agreement between two CrISes and IASI on METOP-C.
- Reflects the excellent spectral and radiometric performance and calibration of the CrIS radiances products provided for under this project, which is required for high impact in operational NWP atmospheric sounding, and climate studies.

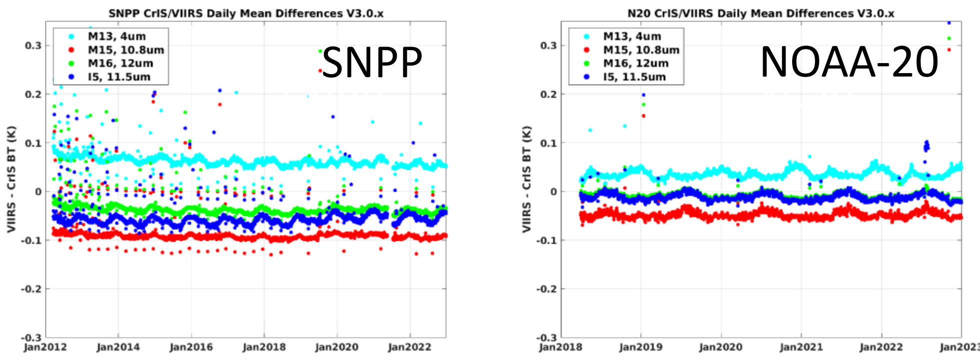
S-NPP and JPSS VIIRS SDR Performance

Chris Moeller, Zhenglong Li and Greg Quinn

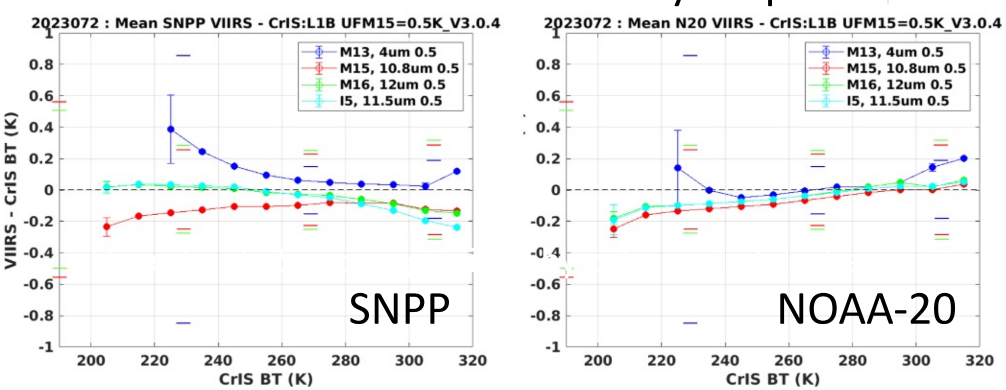


Establish, monitor, and maintain SDR performance for all VIIRS sensors, utilizing pre-launch test characterization with on-orbit SNOs evaluation to optimize accuracy and precision of the radiance product.

VIIRS Trending based on SNOs w/CrIS



VIIRS BT Biases and Uncertainty Requirement

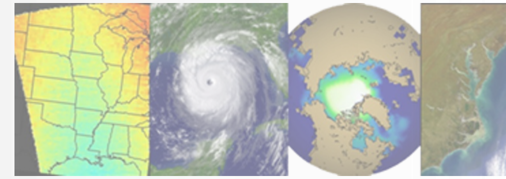


Uncertainty Requirement given by color coded dashes

- Monitor/document VIIRS long term calibration drift in thermal bands and assess VIIRS compliance with key performance specifications.
- Based on SNOs with CrIS and with IASI, SNPP and NOAA-20 VIIRS thermal band trending is less than 5 mK/year.
- VIIRS thermal band biases with CrIS fall within the VIIRS uncertainty requirement for each sensor.
- NOAA-21 VIIRS early on-orbit evaluation shows thermal band performance that is in-family with that of SNPP and NOAA-20 VIIRS.

LEO-GEO Fusion

Elisabeth Weisz and Paul Menzel

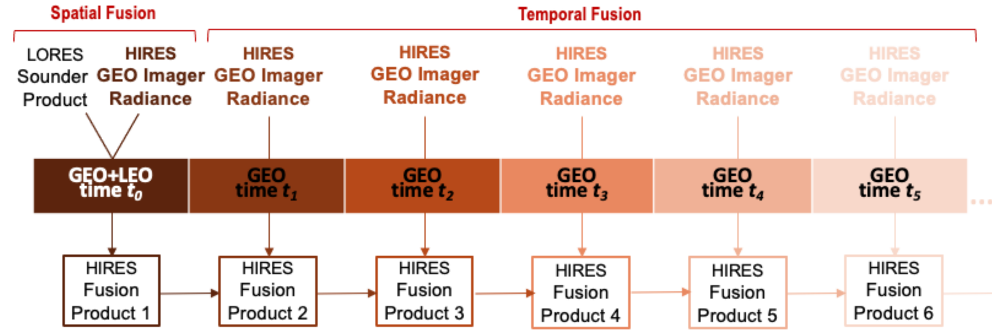


Objective

- Enhance utilization of GEO sensors, especially through multi-sensor/platform data fusion
- Develop GEO/LEO fusion (e.g., ABI + CrIS) to demonstrate value of GEO hyperspectral (HS) measurements and retrievals
- Suggest improvements to weather monitoring, warning and nowcasting operations through the fusion of GEO and LEO assets

Approach

- GEO and LEO spatial and temporal fusion method (Fig. 1) consists of one spatial fusion step and multiple temporal fusion steps (Fig. 1). Whereas spatial fusion results in HS sounder radiances - or retrieval products - at increased spatial resolution, temporal fusion transfers the HS data to subsequent (or preceding) times by utilizing ABI radiance information at every ABI measurement time (e.g., every 10 minutes)
- Both spatial and temporal fusion employ a multidimensional (or k-d tree) search between high spatial resolution (HIRES) and low spatial resolution (LORES) imager radiances or between HIRES imager radiances from subsequent time steps, respectively
- ABI imager radiances used in the search are often split window but also any other set of ABI bands depending on the desired fusion product



Spatial and Temporal GEO plus LEO Fusion schematics. LORES/HIRES stands for low and high spatial resolution, respectively.

Outcomes

- Imager/sounder radiance and product fusion has been demonstrated for ABI, AHI, CrIS, IASI, VIIRS and TROPOMI
- Several case studies validated fusion radiances, moisture and trace gas retrievals via comparison to NWP model fields, radar data, ground and other satellite measurements
- GEO+LEO fusion captures rapid changes in convective moisture fields (Fig. 3) as well as in industrial, wildfire and volcanic trace gas emission events (Fig. 2). However, favorable timing of LEO sounder overpass is requisite
- Work offers an early look at the remote sensing capabilities that will be possible with new instruments and platforms (e.g., GEO HS sounder)
- Publications:

Weisz, E., and W. P. Menzel, 2023: Monitoring the 2021 Cumbre Vieja volcanic eruption using satellite multisensor data fusion. Jour. of Geophys. Res. Atmos., 128(2), e2022JD037926; https://doi.org/10.1029/2022JD037926

Weisz, E. and W. P. Menzel, 2022: Tracking Atmospheric Moisture Changes in Convective Storm Environments Using GEO ABI and LEO CrIS Data Fusion. Rem. Sens. Env. 14(21), 5327; https://doi.org/10.3390/rs14215327

Weisz, E., and W. P. Menzel, 2020: An Approach to Enhance Trace Gas Determinations through Multi-Satellite Data Fusion, J. Appl. Remote Sens. 14(4), 044519; https://doi.org/10.1117/1.JRS.14.044519

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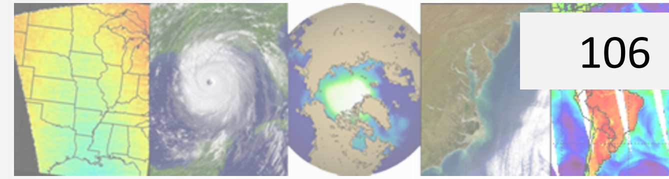
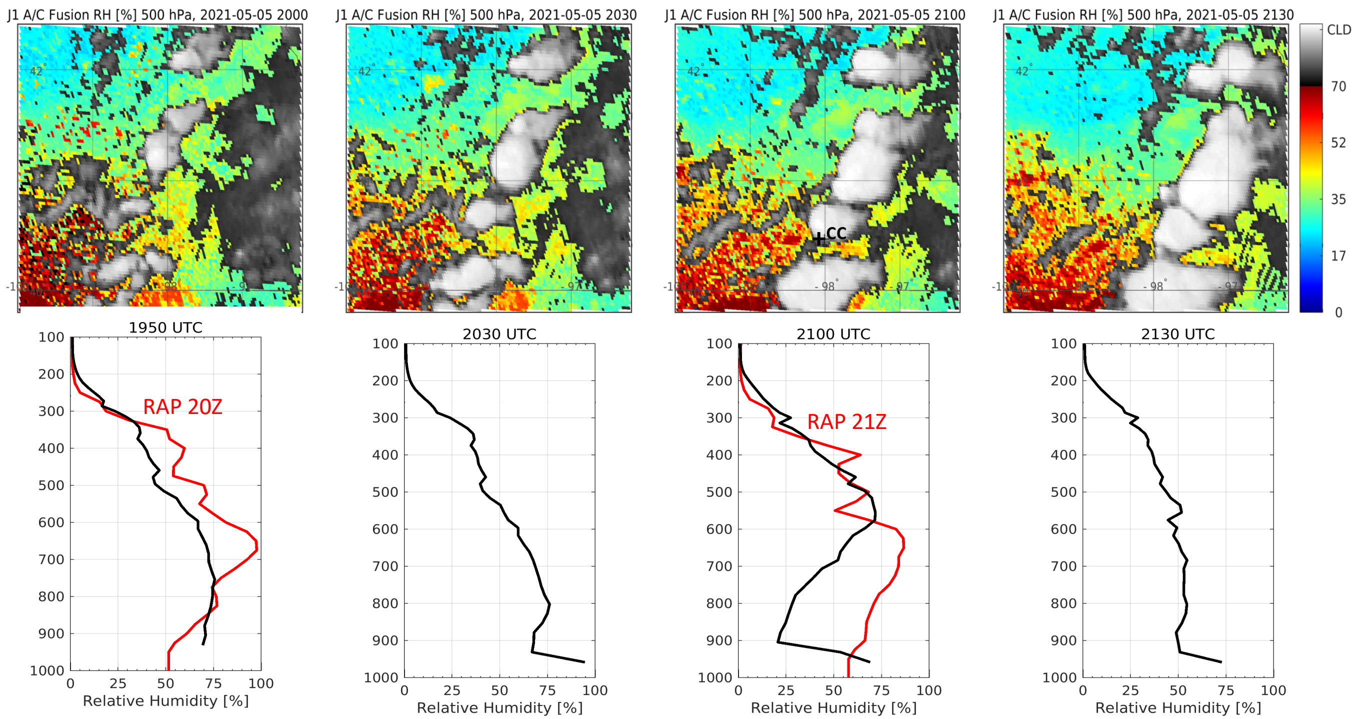
LEO-GEO Fusion

Elisabeth Weisz and Paul Menzel



Realizing LEO Sounder Products at GEO Imager Spatial and Temporal Resolution

Atmospheric Moisture Changes in Pre-Convective Environment of a Tornado

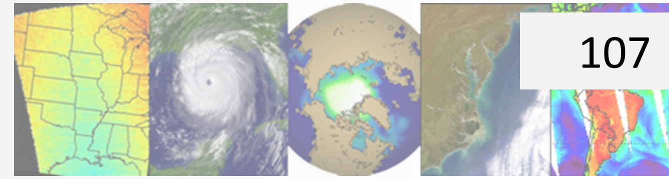


Top: Relative Humidity [%] at 500 hPa from ABI/CrIS (JPSS-1) spatial/temporal fusion at 2000, 2030, 2100 and 2130 UTC. Bottom: ABI/CrIS RH fusion profiles (black) at location 40.48°N/98.54°W, approx. 45 km west of Clay Center (CC) tornado that happened at 2130 UTC on 5 May 2021.

- ABI and CrIS spatial-temporal fusion captures the rapidly evolving atmospheric changes during the May 5th, 2021 severe storm event and provides a detailed picture of thunderstorm dynamics and tornado development
- Vertical detail from CrIS humidity profiles (from one JPSS-1 overpass) is realistically transferred by fusion with GOES-16 ABI radiances to higher spatial resolution at preceding and subsequent times

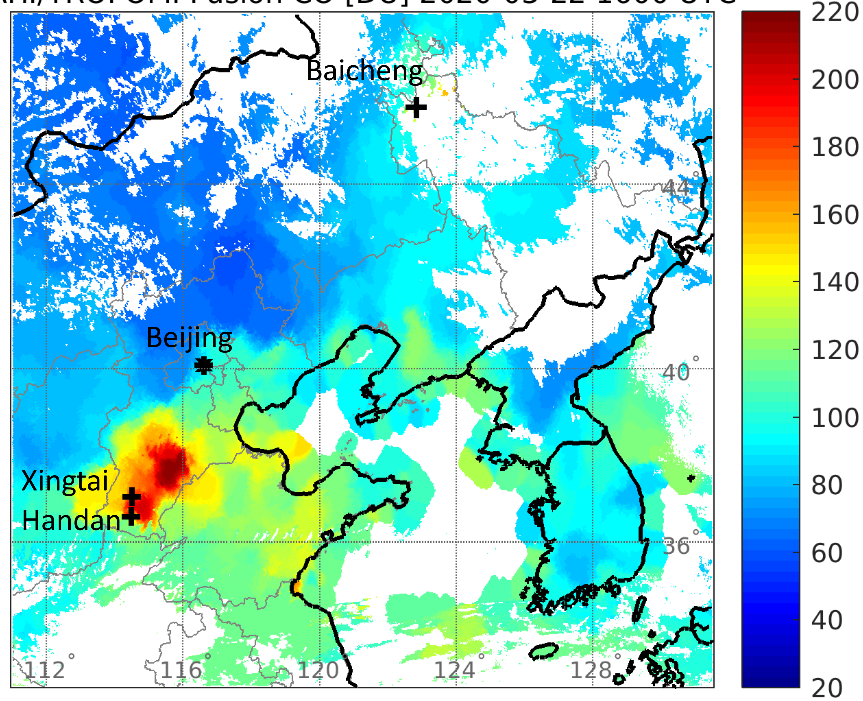
LEO-GEO Fusion

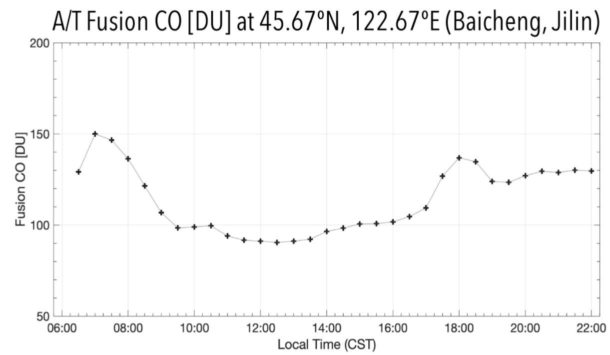
Elisabeth Weisz and Paul Menzel

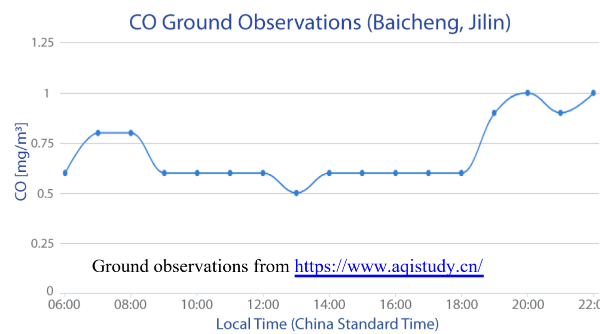


Enhancing Urban/Industrial/Agricultural Trace Gas Determinations through GEO/LEO Fusion

AHI/TROPOMI Fusion CO [DU] 2020-03-22 1600 UTC





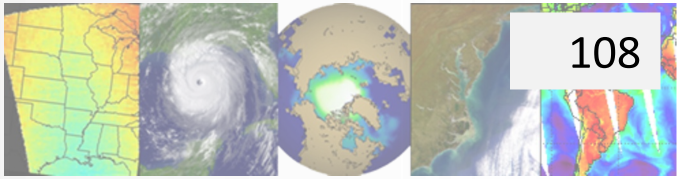


Left: 24-hour animation of CO concentrations over northern China starting at 16 UTC (or 12 AM Chinese Standard Time) on 22 March 2020, derived from AHI/TROPOMI product fusion (TROPOMI overpass occurred at ~0440 UTC on 23 March 2020). Right: AHI/TROPOMI CO fusion timeline at a selected location near Baicheng, where emissions were caused by rural agricultural burning, is compared to CO ground observations.

- AHI and TROPOMI product fusion offers an accurate depiction of intensity and distribution of the trace gases such as CO from industrial (e.g., near Xingtai and Handan, and also near Beijing airport) and agricultural (e.g., Baicheng) sources over China for several hours before and after the TROPOMI overpass time
- Spatial and temporal fusion of TROPOMI trace gas products with GEO imager radiance data enables better depiction of trace gas emissions and their dissipation (e.g., volcanic eruption or industrial pollution)

Simulating ABI 5.15 µm and 0.91 µm via GEO-LEO Fusion

Elisabeth Weisz and Paul Menzel

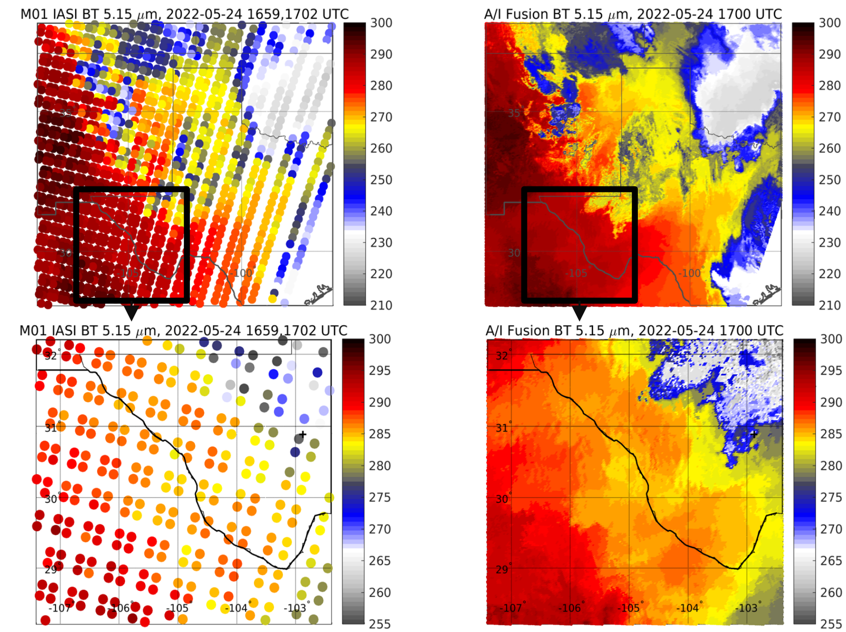


Objective

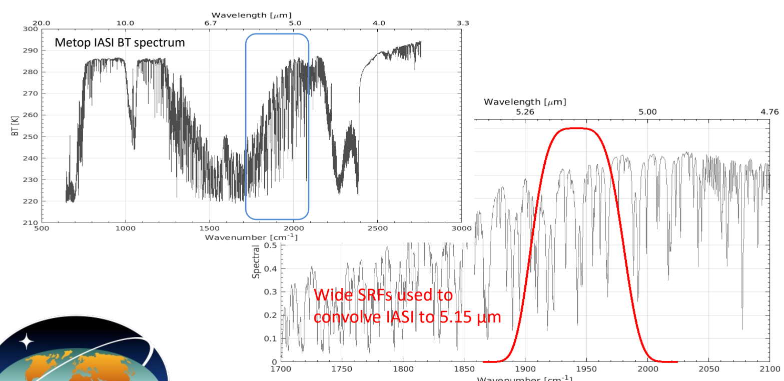
- Study the addition of one short-wave water vapor and one reflective band to GeoXI
- Apply ABI/IASI and ABI/MODIS fusion methodology to create ABI-like 5.15 µm and 0.91 µm band, respectively
- Investigate the spectral information from the new bands and compare to original ABI bands, especially to benefit the monitoring of low-level moisture changes in pre-convective environments

Approach

- GEO/LEO spatial/temporal fusion transfers LEO data (radiances or retrievals) to the GEO imager's high spatial and high temporal resolution
- For example, Metop IASI data, convolved via SRFs to ABI-like 5.15 µm band (Fig. 1), are fused with 10-minute ABI radiance data to create a new 5.15 µm band at ABI's high spatial (Fig. 2) and temporal resolution (Fig. 3)



IASI (left) and ABI/IASI Fusion (right) 5.15 µm Brightness Temperatures [K] over the New Mexico/Texas border on 24 May 2022.



IASI BT spectrum and 4.8–5.9 µm spectral range with 5.15 µm SRFs overlaid in red.

Outcomes

- ABI/IASI fusion approach offers a valuable preview of the future ABI bands and their information content
- 5.15 µm weighting function peaks lower in the atmosphere and therefore complements the existing WV bands for low-level moisture detection
- CIMSS/SSEC blog entry titled "Using data fusion to create 5.15 micrometer imagery" is available at https://cimss.ssec.wisc.edu/satellite-blog/archives/51489
- Results (e.g., Fig. 3) received widespread interest in GeoXO science community

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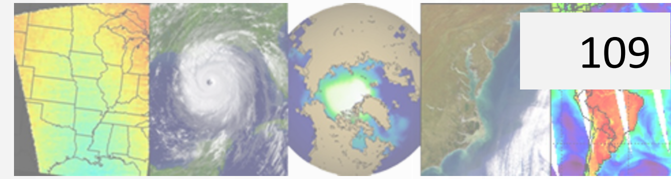
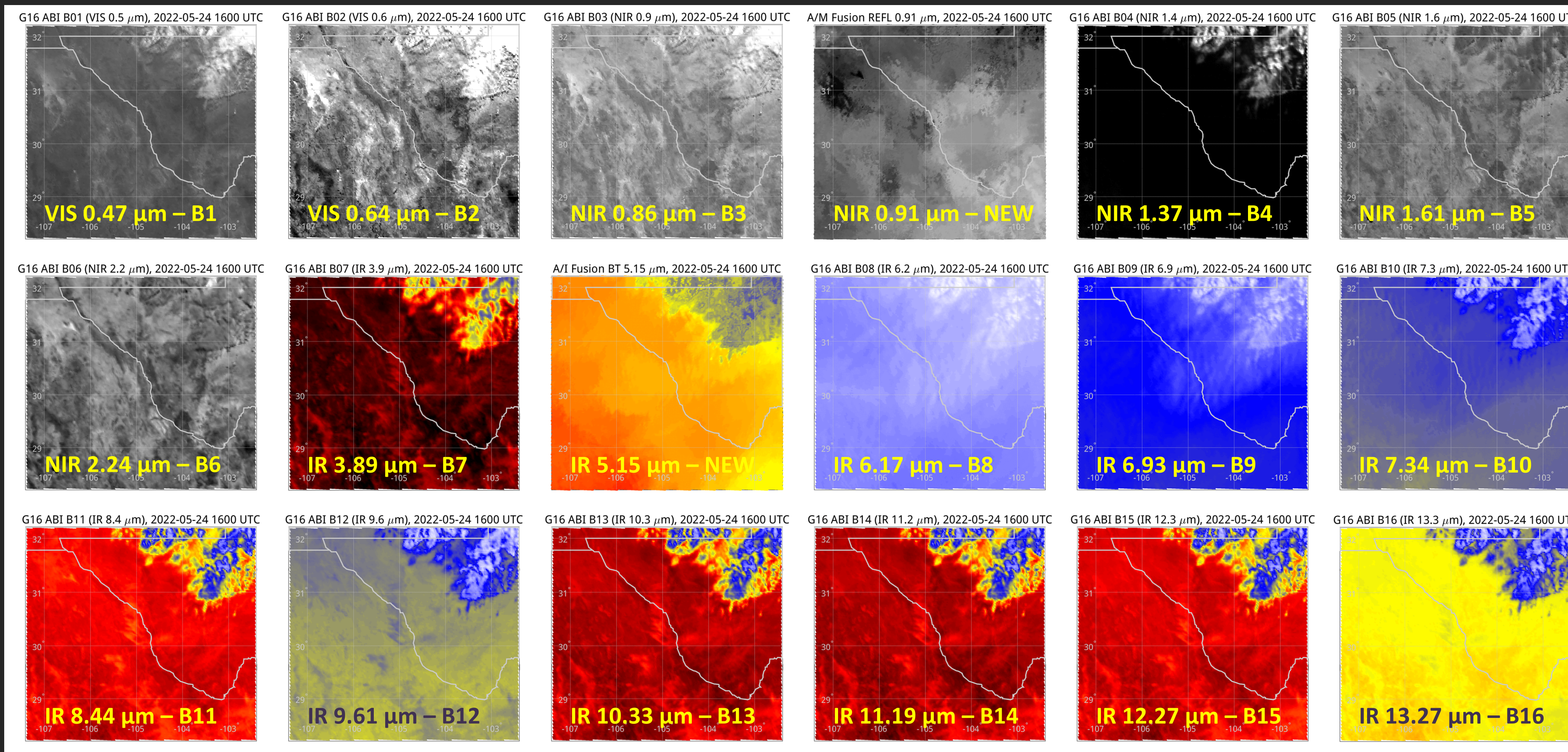
Simulating ABI 5.15 µm and 0.91 µm via GEO-LEO Fusion

Elisabeth Weisz and Paul Menzel



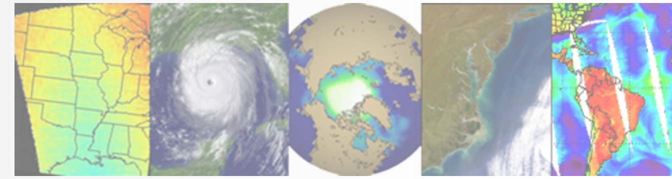


6-hr Animations of 16 ABI bands plus 2 proposed bands (0.91 µm and 5.15 µm)

- ABI/IASI fusion demonstrates future GeoXI IR 5.15 µm band, whereas ABI/MODIS fusion demonstrates future GeoXI NIR 0.91 µm band
- GEO/LEO temporal fusion enables evaluation of the information these new ABI bands add to the depiction of low-level moisture transport (e.g., for the 24 May 2022 NM/TX MCS event)

Environmental Models and Data Assimilation

Contents



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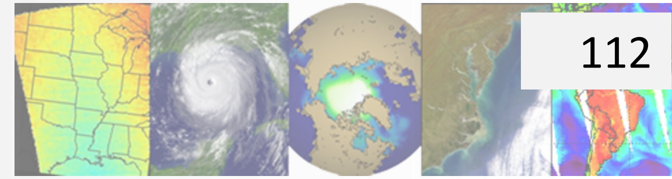
Geostationary IR Sounder Hybrid-OSSE

Jun Li, Pei Wang, Zhenglong Li, W. Paul Menzel and Timothy J. Schmit

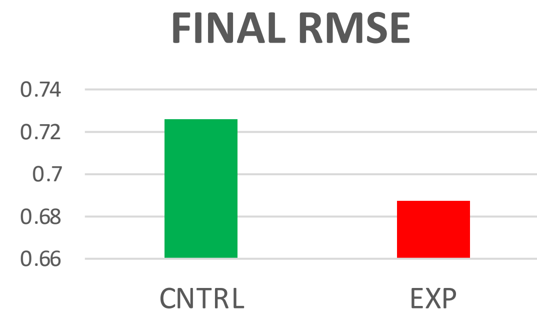


Objective

- Evaluate and understand the potential impacts of hyperspectral IR sounders onboard GEO satellites over CONUS
- NESDIS, GeoXO, and GOES-R

Assimilation of GEO IR sounder radiances leads to substantial overall improvement of forecast

RMSE	CNTRL	EXP
Total	0.7258	**0.6872**



Approach

- Hybrid OSSE
- Developed capabilities to simulate GEO IR sounder radiances
- Advantage of hybrid OSSE is that only observations from future sensors are simulated from ERA5 while all other observations are real
- Hybrid OSSE is more affordable than traditional OSSE
- More realistically assess the impact of future sensors

Outcomes

- Manuscript accessible at https://doi.org/10.1007/s00376-021-0443-1
- Demonstrated the value of GEO sounder in local severe storm forecast

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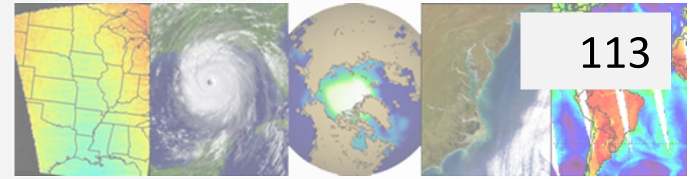
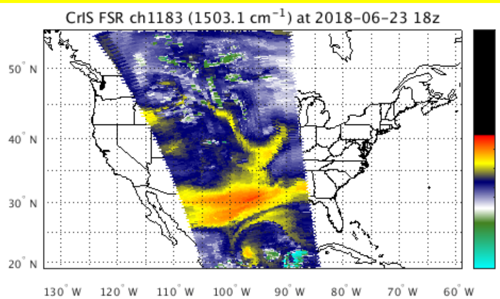
Geostationary IR Sounder Hybrid OSSE

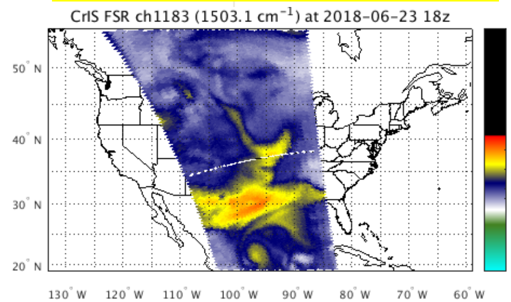
Jun Li



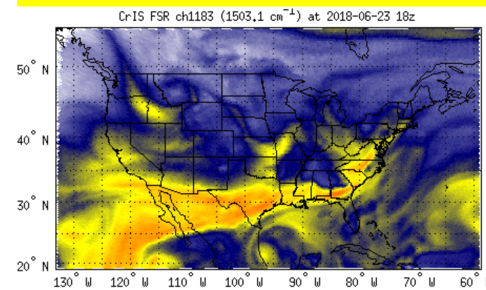
CrIS FSR observations – NOAA20



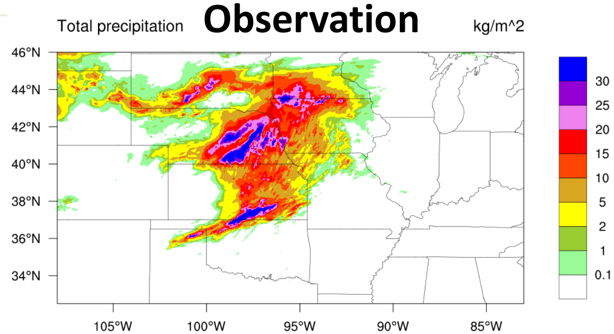
CrIS FSR simulated – ERA5



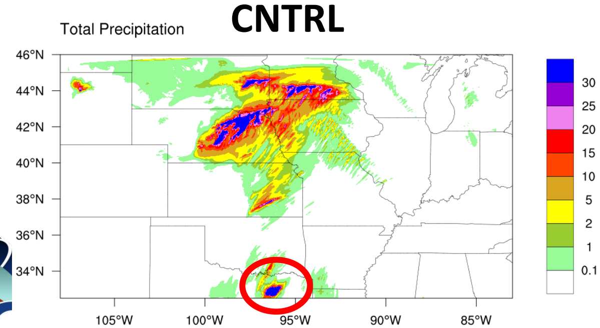
Simulated GEO CrIS FSR – ERA5

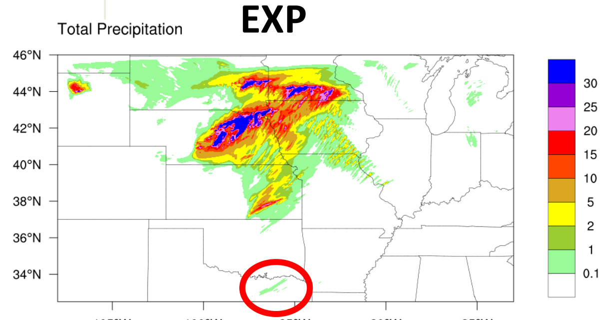


A hybrid Observing System Simulation Experiment (OSSE) method is used to evaluate and understand the potential impacts of hyperspectral sounders onboard GEO satellites over CONUS.

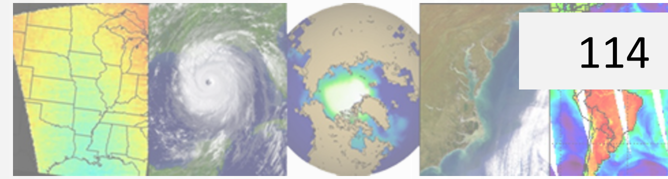


The 6-hour accumulated precipitation observation (upper), forecast from control with assimilation of data from the current observing system (lower left), and forecast from the assimilation of current observing system plus simulated GEO hyperspectral IR sounder (lower right). The hyperspectral IR was able to remove a spurious storm from forming over Eastern Texas!

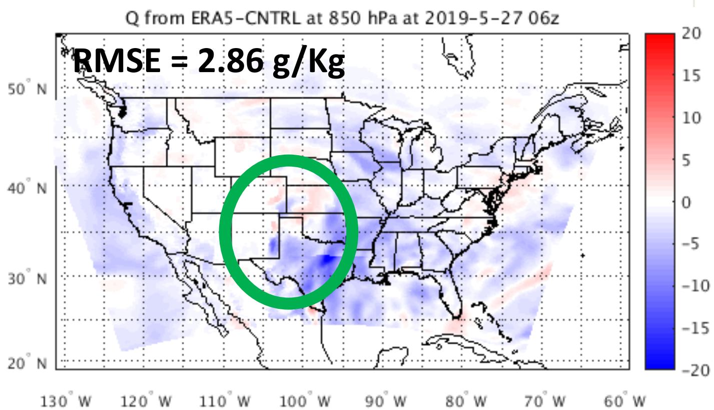


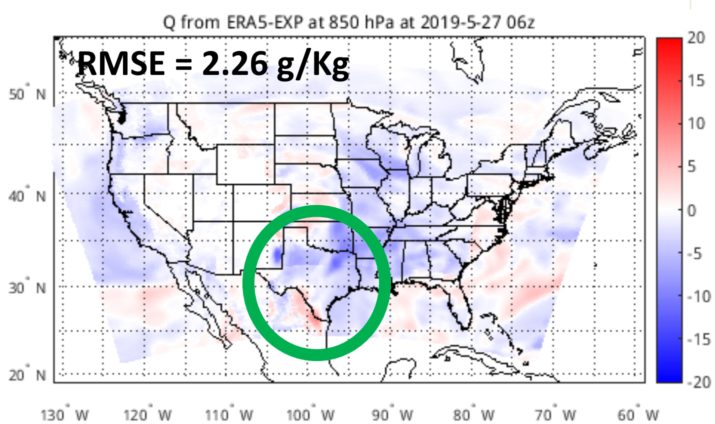


Geostationary IR Sounder Hybrid OSSE



Jun Li



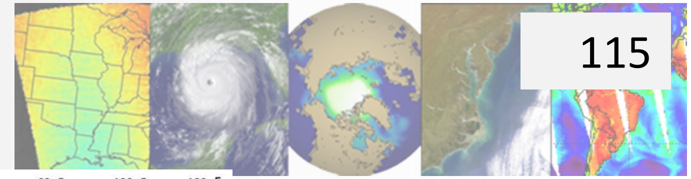


Significant improvement found in moisture over the lower Mississippi Valley

- A hybrid OSSE allows for real observation for all types except the future one, i.e. simulated high-spectral IR sounder.
- With the assimilation of the GEO hyperspectral IR information, it improved the moisture, temperature, winds fields and then improved the precipitation formats.
- Manuscript accessible at https://doi.org/10.1007/s00376-021-0443-1

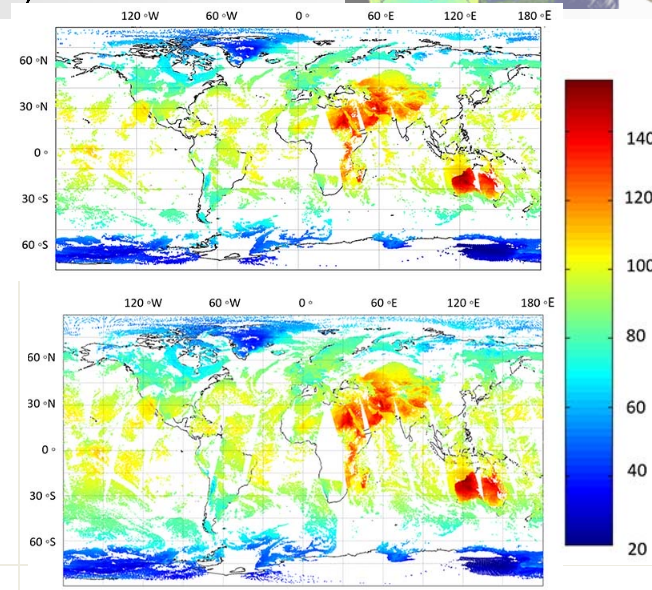
Assimilating CrIS Radiances in Operational NWP Models

J Li, J Li, K Baggett, P Wang, M DeMaria, V Tallapragada, and A Collard



Objective

- Improve the assimilation of JPSS series CrIS cloudy radiances with NOAA's operational NWP models
- EMC/NCEP, NWS



The global data coverage for CrIS radiances from (top) original clear only and (bottom) clear plus cloud cleared on 30 October 2015

Data in radiance units (mw /(m^2 sr cm^{-1}))

Approach

- Use VIIRS to help cloud clear the CrIS radiances
- The cloud cleared CrIS radiances can be assimilated as clear radiances
- New quality controls developed to remove CrIS radiances that are poorly cloud cleared
- Observation errors inflated to assimilate CrIS cloud cleared radiances as the observation noise is enlarged during the process

Outcomes

- Cloud cleared radiances substantially increase the number of CrIS radiance measurements for assimilation
- Manuscript on all-sky IR radiance assimilation is accessible at https://doi.org/10.1007/s00376-021-1088-9
- Manuscripts on ABI AMV assimilation is accessible at https://doi.org/10.1029/2019JD031647
- Positive impact on hurricane forecast from cloud cleared CrIS radiance and ABI water vapor and AMV assimilation

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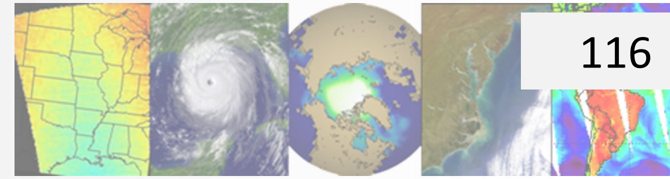
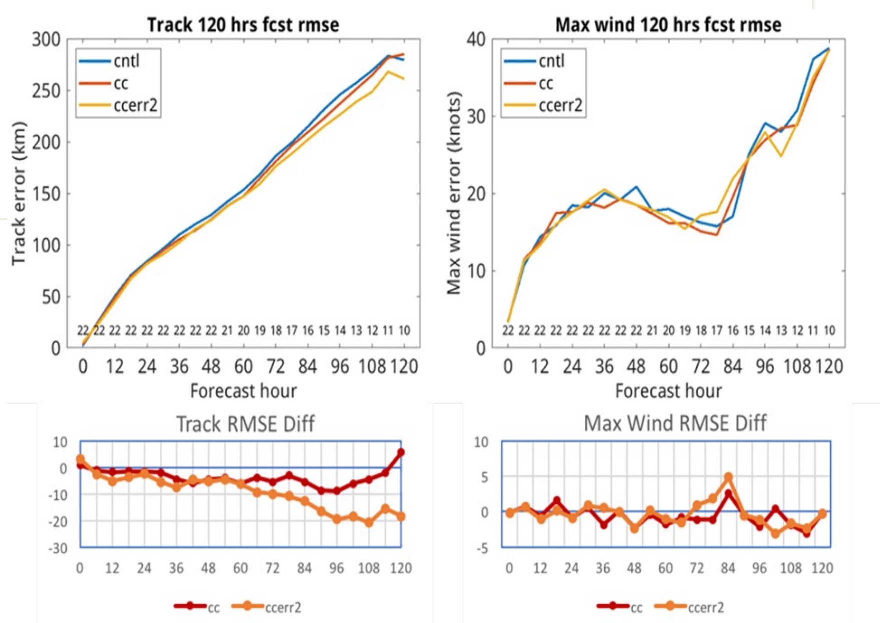
Assimilating CrIS Radiances in Operational NWP Models

J Li, J Li, K Baggett, P Wang, M DeMaria, V Tallapragada, and A Collard



The imager based cloud-clearing (CC) technique developed by CIMSS scientists, provides an alternative and effective way to remove the cloud effects from a partially cloudy field-of-view (FOV) of hyperspectral infrared (IR) sounder and derive the equivalent clear sky radiances, or the cloud-cleared radiances (CCRs). This project aims to improve the assimilation of JPSS series CrIS radiances with focus on cloudy region in NOAA's operational NWP models.



The RMSE of track (upper left) and maximum wind speed (upper right) forecasts for hurricane Irma in 2017 from three different experiments. The lower panels show the RMSE difference from the control for the track (lower left) and the maximum wind speed (lower right).

- Developed methodologies for improving CrIS radiances assimilation in cloudy region by removing cloud effects using collocated VIIRS data. Manuscript on all-sky IR radiance assimilation is accessible at https://doi.org/10.1007/s00376-021-1088-9
- This approach has been successful demonstrated using NOAA operational NWP models such as GFS and HWRF.
- Improving the assimilation of ABI water vapor information and rapid scan AMVs has also been developed and tested using HWRF. Manuscripts on ABI AMV assimilation is accessible at https://doi.org/10.1029/2019JD031647
- Those findings and progress have the potential for operational transition.

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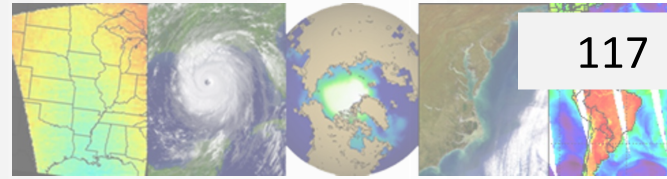
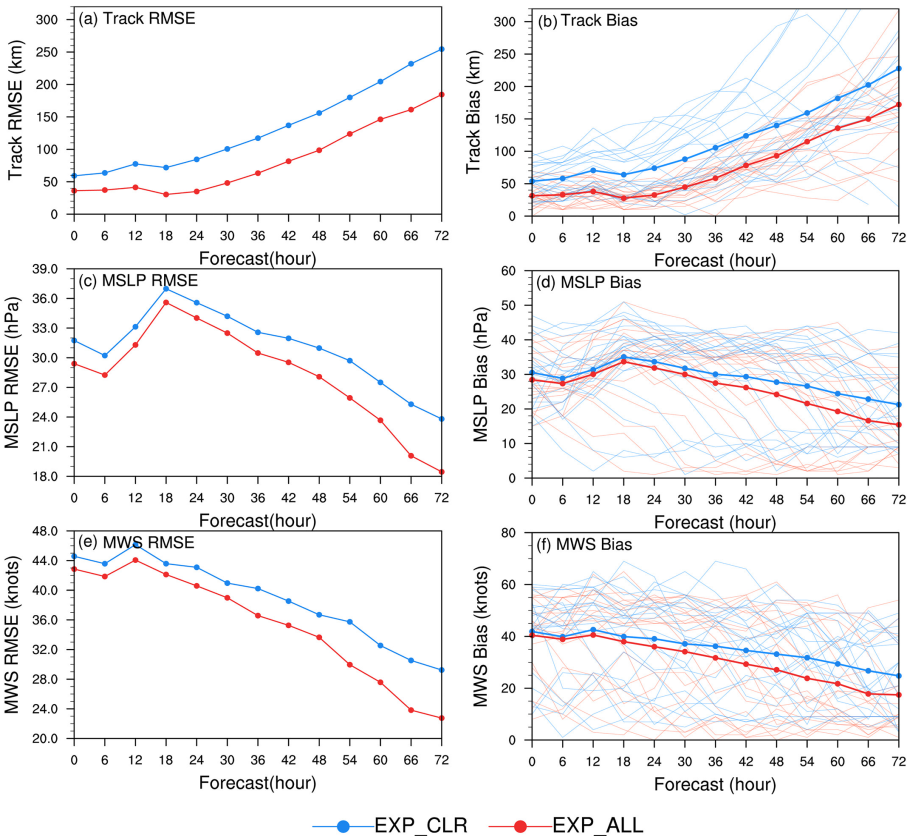
Value of ABI Cloud Water Paths for Hurricane Forecasts

Jun Li



The cloud liquid/ice water path (LWP/IWP) provide valuable information about the cloud and precipitation that assimilated can improve the hurricane forecast.

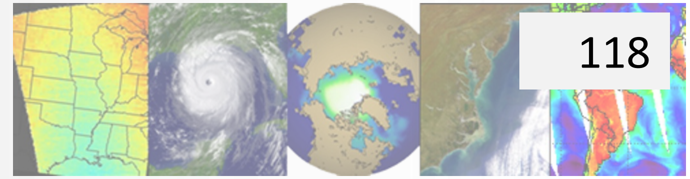


The forecast (left) RMSE and (right) bias of track, minimum sea level pressure (MSLP), and maximum wind speed (MWS) of Hurricane Irma as a function of forecast time. The light blue and light red lines in (b, d, and f) are the forecast biases for each initiating forecast time.

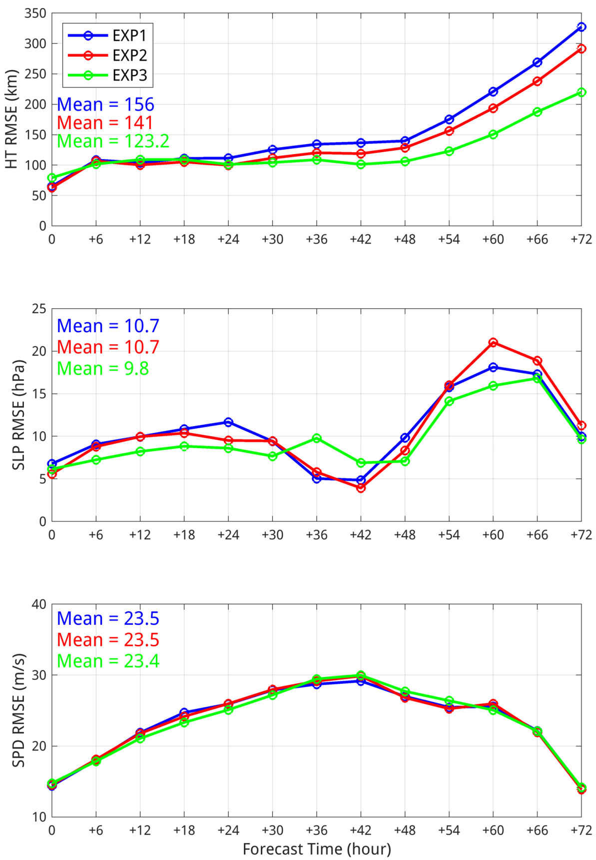
- New observation operators and associated Jacobians were developed to build the direct relationship between LWP/IWP and water vapor, which allows assimilating LWP/IWP observations
- Assimilating ABI LWP/IWP observations improves the water vapor field and thus influences the temperature and geopotential heights fields
- Track forecasts of Hurricane Irma (2017) and Maria (2017) were improved with the assimilation of ABI LWP/IWP observations. Manuscript accessible at https://doi.org/10.1029/2022JD036910
- Figure on the left show assimilating ABI LWP/IWP in addition to clear sky water vapor radiances improves track and intensity forecast for Hurricane Irma (2017). Manuscript accessible at https://doi.org/10.1029/2020JD034164

Objective Quality Control for ABI Water Vapor Radiance Assimilation

Zhenglong Li



A machine learning based quality control (QC) scheme is developed to find surface contaminated water vapor radiances that may lead to reduced or compromised observation impacts in NWP models.

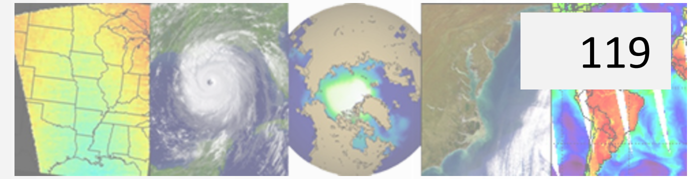


The 72-hour forecast impacts on the RMSE of (top) hurricane track (HT), (middle) minimum seal level pressure (SLP), and (bottom) maximum wind speed (SPD). EXP1 is control run experiment with GSI default QC; EXP2 uses Lee QC scheme; EXP3 uses the new QC scheme.

- A new QC scheme based on the combination of multi-layer perceptron network and random forest is developed to find surface contaminated ABI water vapor radiances
- The new QC scheme uses only observations as input thus is independent of the background
- Simulation studies show the new QC scheme is effective in retaining radiances unaffected by the surface or with very small surface contamination
- Left figure shows that the new QC scheme has a positive impact on Hurricane Harvey (2019) track forecasts compared with existing QC schemes.
- Manuscript accessible at https://doi.org/10.1029/2021JD036061

Earth Imaging from Tundra Orbit

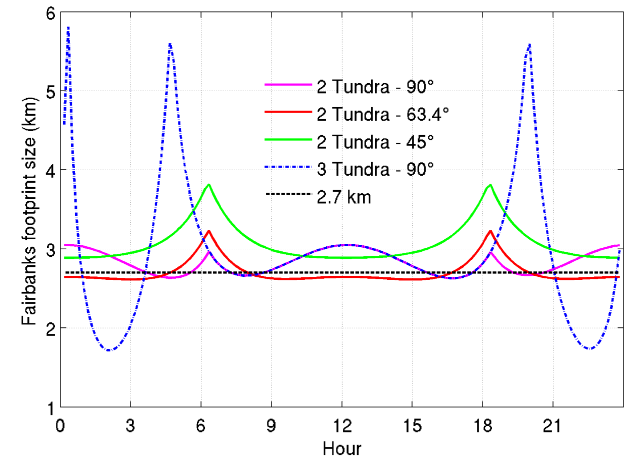
Z Li, J Li, M M. Gunshor, and F W. Nagle; NOAA Collaborator: T Schmit



Objective

- Investigate Tundra satellites' imaging capability in both regional and global scale
- NESDIS, NWS

The minimum footprint size of Fairbanks AK observed by different constellations.



Approach

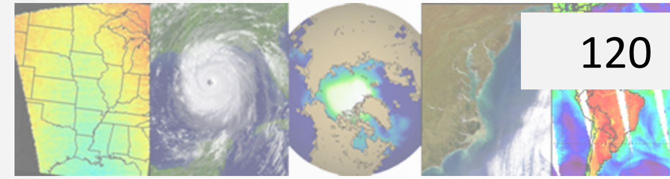
- Developed an orbit simulator to simulate Tundra orbits
- Use ABI as the payload to simulate the imaging sensor on Tundra satellites
- Use different constellations to understand the imaging capabilities of Tundra satellites in regional and global scales

Outcomes

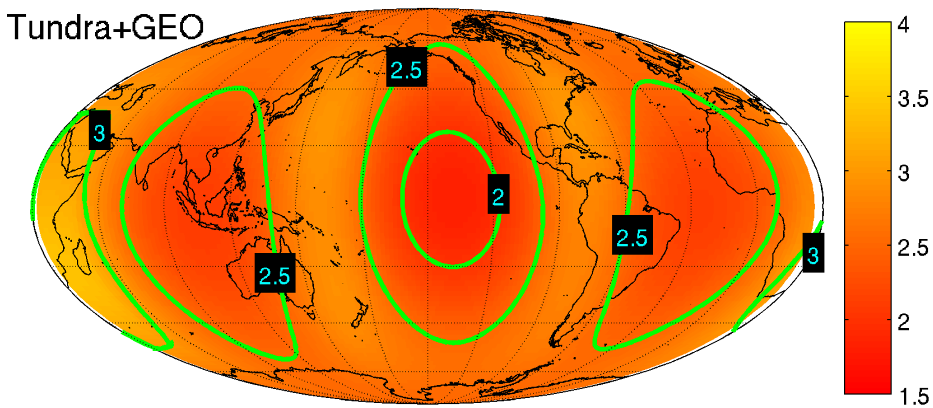
- Manuscript accessible at https://doi:10.1109/TGRS.2021.3051527
- Figure shows that 2 Tundra satellites with the critical inclination angle of 63.4° has the smallest overall footprint size over Fairbanks AK.
- 3 Tundra satellites can provide global imaging capability, especially when in combination with 3 GEOs

Earth Imaging from Tundra Orbits

Zhenglong Li



Investigate Tundra satellites' imaging capability in both regional and global scale



The effective footprint size imagery of the constellation of 3 ABI/Tundra and 3 ABI/GEO. Green lines show the contours of effective footprint size.

- Geostationary satellites (GEO) have much reduced imaging capabilities over high latitudes due to increased footprint size
- Tundra orbits with non-zero eccentricity and non-zero inclination angle have longer dwell times near the apogee than the perigee, allowing better monitoring high latitudes and polar regions.
- Assuming an ABI-like instrument on Tundra orbits, imaging capability in both regional and global scales with different constellations were analyzed.
- Figure shows that the constellation of 3 Tundra and 3 GEO satellites have great imaging capabilities globally.
- Manuscript accessible at https://doi:10.1109/TGRS.2021.3051527

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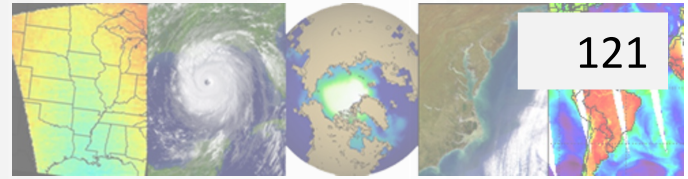
CIMSS

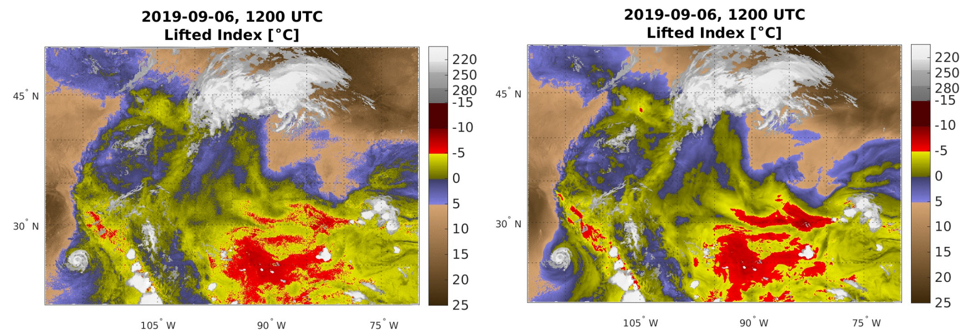
Nowcast OSSE Demonstrations

Z Li, Z Ma, J Li, T J. Schmit, L Cucurull, R Atlas, and B Sun



Objective

- Use nowcasting OSSE to understand the impact of planned observing systems on Local Severe Storms situation awareness and nowcasting
- Stakeholders:QOSAP, NWS



The lifted index imagery from (left) the GXS and (right) the truth

Approach

- Created machine learning based nowcasting tools
- Developed the nowcasting OSSE framework
- Studied the value of GEO sounder in local severe storm nowcasting

Outcomes

- A deep neural network based sounding retrieval algorithm was developed to enhance the NUCAPS sounding retrievals in the lower atmosphere. Manuscript accessible at https://doi.org/10.1029/2020EA001402
- A random forest based nowcasting tool was developed to predict if a storm is going to be severe or not. Manuscript accessible at https://doi.org/10.3390/rs15102672
- Demonstrated the value of GEO sounder in nowcasting local severe storms

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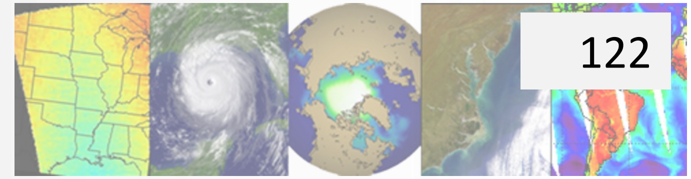
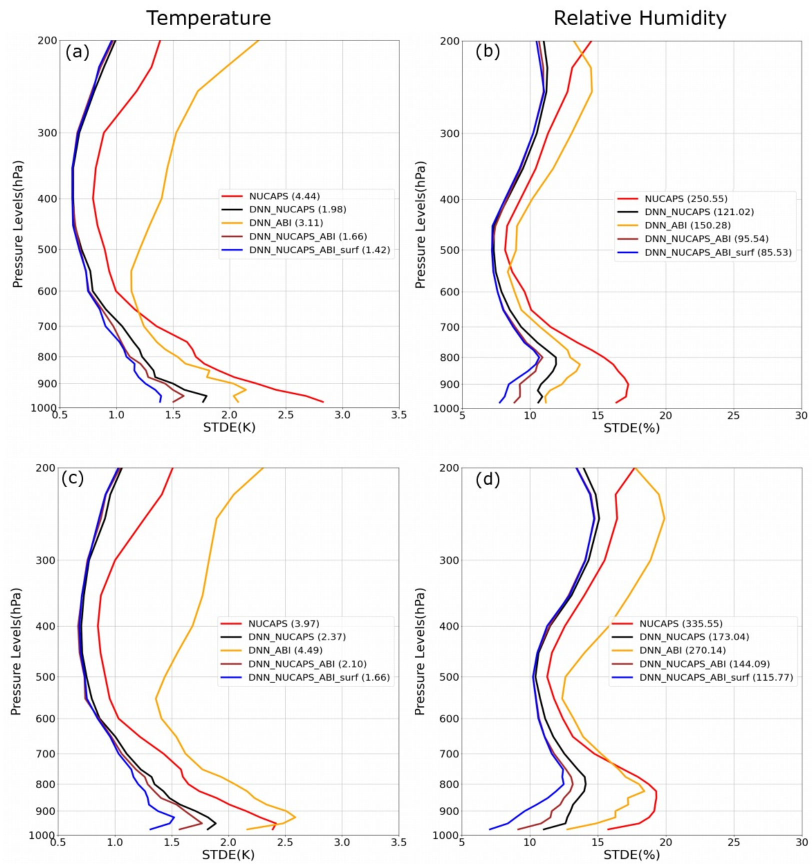
Nowcast OSSE Demonstrations

Zhenglong Li



Use nowcasting OSSE to understand the impact of current and planned observing systems on Local Severe Storms situation awareness and nowcasting



The standard deviation (STDE) error of vertical profiles for (left) temperature and (right) relative humidity. Red from NUCAPS, black uses only NUCAPS profiles as predictors, orange uses only ABI related predictors, brown uses both NUCAPS and ABI predictors, and blue uses all data sources. Top for clear sky and bottom for partially cloudy conditions.

- UW/CIMSS hybrid nowcasting OSSE framework was developed, including two nowcasting tools:
  - ➢ improve sounding products using deep neural network (DNN)
  - ➢ improve local severe storm prediction using random forest: Storm Warning and Nowcasting Model in Pre-Convection Environments (SWIPE)
- The DNN tool was applied to improve the low level soundings from NUCAPS with the help from ABI radiance observations and surface analysis from Real-Time Mesoscale Analysis
- The temperature and moisture RMSEs are reduced by more than 30% in the lower atmosphere in both clear and partially cloudy conditions.
- Left figure shows that both ABI and RTMA are effective in reducing the temperature and moisture errors in the lower atmosphere.
- Manuscript accessible at https://doi.org/10.1029/2020EA001402

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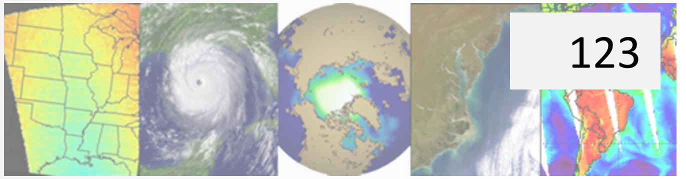
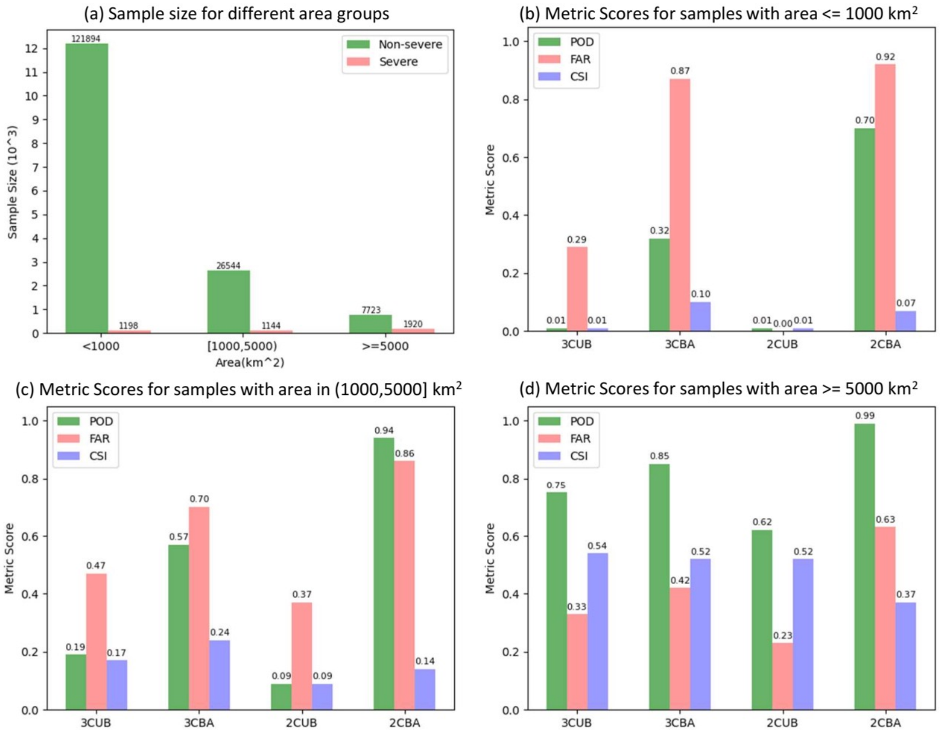
Nowcast OSSE Demonstrations

Zhenglong Li



Use nowcasting OSSE to understand the impact of current and planned observing systems on Local Severe Storms situation awareness and nowcasting



(a) Sample sizes of non-severe and severe cases for small area group, medium area group and large area group in the validation dataset. POD, FAR, and CSI scores for the severe cases with (b) small area group, (c) medium area group and (d) large area group, respectively.

- An enhanced version of Storm Warning and Nowcasting Model in Pre-Convection Environments (SWIPE) was developed to predict if a convective storm once initialized is going to be severe or not over the contiguous U.S. (CONUS)
- The enhancement comes from the improved storm time and location identification with optical flow and continuous tracking technique
- The optimized models are found to have higher accuracy for severe storms with areas >5000 km^2, and less accuracy for storms with areas <1000 km^2
- Manually balancing the ratio between severe and non-severe sample in the training is needed to increase the possibilities of detection
- A case study shows that the model successfully provides warnings with a lead time of 1-2 hours before heavy rainfall
- Manuscript accessible at https://doi.org/10.3390/rs15102672

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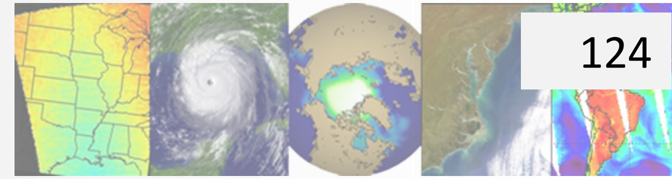
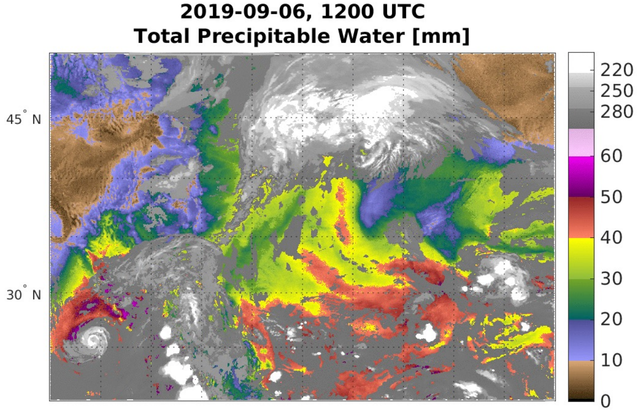
Nowcast OSSE Demonstrations



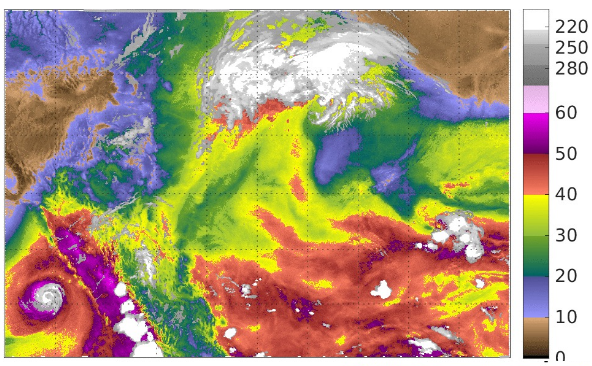
Zhenglong Li

Use nowcast OSSE to understand the impact of current and planned observing systems on Local Severe Storms (LSS) situation awareness and nowcasting

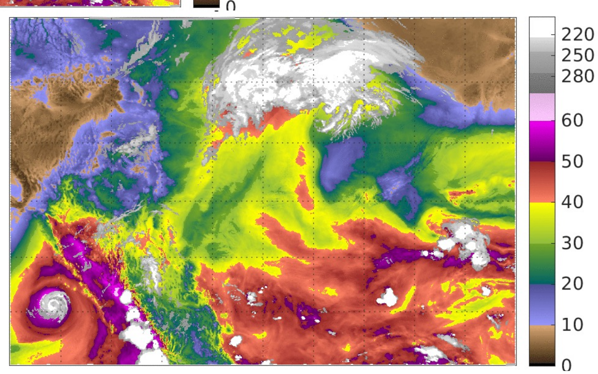
Clear sky Retrieval



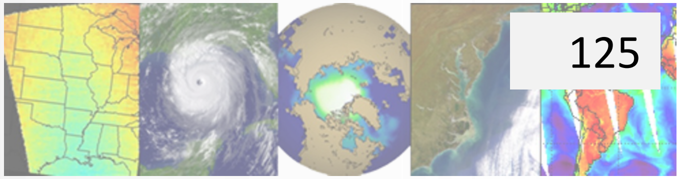
All sky Retrieval



True



- 4km GXS radiances were simulated from the 1km ECMWF nature run (XNR1K) over the Contiguous U.S. (CONUS)
- A DNN-based algorithm was developed to retrieve the temperature and moisture profiles from GeoXO Sounder (GXS) radiances
- Nowcasting products such as total precipitable water (TPW), lifted index (LI), and Convective Available Potential Energy (CAPE) are generated from the profile retrievals
- Left figures show that
  - The GXS TPW can accurately depict the moisture field
  - The all sky retrievals significantly increase the useful coverage from 34% to 80%
- These nowcasting products will provide timely useful information for forecasters to help them with storm forecasting

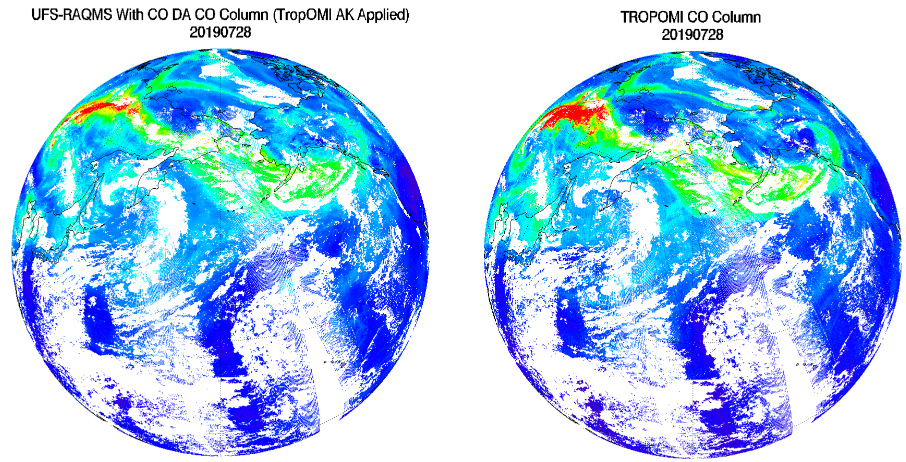


Assimilating JPSS Atmospheric Composition and Aerosol Products within NGGPS

Brad Pierce, Allen Lenzen, Aditya Kumar, and Maggie Bruckner

Objective

- Create and verify capabilities to assimilate JPSS composition products within a Unified Forecast System (UFS) stratospheric/tropospheric chemistry (UFS-RAQMS) version of Next Generation Global Prediction System (NGGPS) Unified Forecasting System (UFS) and transition these capabilities to NOAA ESRL for pre-operational testing.
- The data assimilation capabilities developed under this project will align with Joint Effort for Data Assimilation Integration (JEDI) development.
- Results of this project will be evaluated by NWS colleagues from the National Center for Environmental Prediction (NCEP) for operational implementation.
- Stakeholders: NOAA Global Systems Laboratory (GSL, George Grell, Ravan Ahmadov), Chemical Sciences Laboratory (CSL, Brian McDonald, Rebecca Schwantes), National Weather Service (NWS, Jeff McQueen)



Results from the UFS-RAQMS TROPOMI data assimilation experiment. UFS-RAQMS (left) and TROPOMI (right) column carbon monoxide ($1e^{18} mol/cm^2$) on July 28, 2019

Approach

- The project is being conducted in three phases:
  - Phase 1: Develop and verify capabilities to assimilate JPSS aerosol and composition products within the UFS-RAQMS version of NGGPS.
  - Phase 2: Conduct full year analysis/forecast experiments to assess overall meteorological/ chemical forecast skill and port capabilities to ESRL/GSL.
  - Phase 3: Real-time demonstration and verification
- Phase 1 focuses on the NOAA/NASA FIREX-AQ field campaign timeperiod (July-September, 2019) and includes assimilation of VIIRS AOD, OMPS Limb Profiler and Nadir Mapper O3, TROPOMI CO, and NUCAPS+TROPOMI CO
- Phase 2 focuses on updating UFS-RAQMS anthropogenic emissions to CEDS, conducting full year control/assimilation experiments, and porting UFS-RAQMS to GSL/CSL
- Phase 3 focuses on real-time forecast demonstration and retrospective data assimilation during the 2023 wildfire season.

Outcomes

- Assimilation of VIIRS AOD, OMPS Limb Profiler and Nadir Mapper, and NUCAPS/TROPOMI CO improves comparison with Aeronet, ozonesonde, and airborne insitu measurements during July-September, 2019
- Assimilation of JPSS aerosol and trace gas retrievals within UFS-RAQMS improves weather forecasts by taking into account aerosol effects on radiation, clouds and precipitation, improves the handling of satellite observations by properly accounting for aerosol and trace gas effects during data assimilation, provides lateral and upper boundary conditions for regional air quality predictions, and provides information for air quality management, health applications, environmental Policy making, climate science, and renewable energy planning.
- This JPSS proposal has provided support for a graduate student (Maggie Bruckner) who is pursuing her PhD within the UW Madison Atmospheric and Oceanic Sciences Department.
- Training of the next generation of women atmospheric scientists contributes to diversity, equity, inclusion, and justice (DEIJ) efforts at NOAA and SSEC by increasing the representation of women in STEM.

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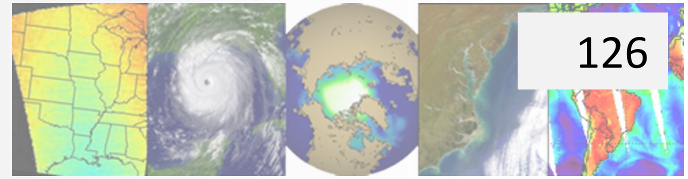
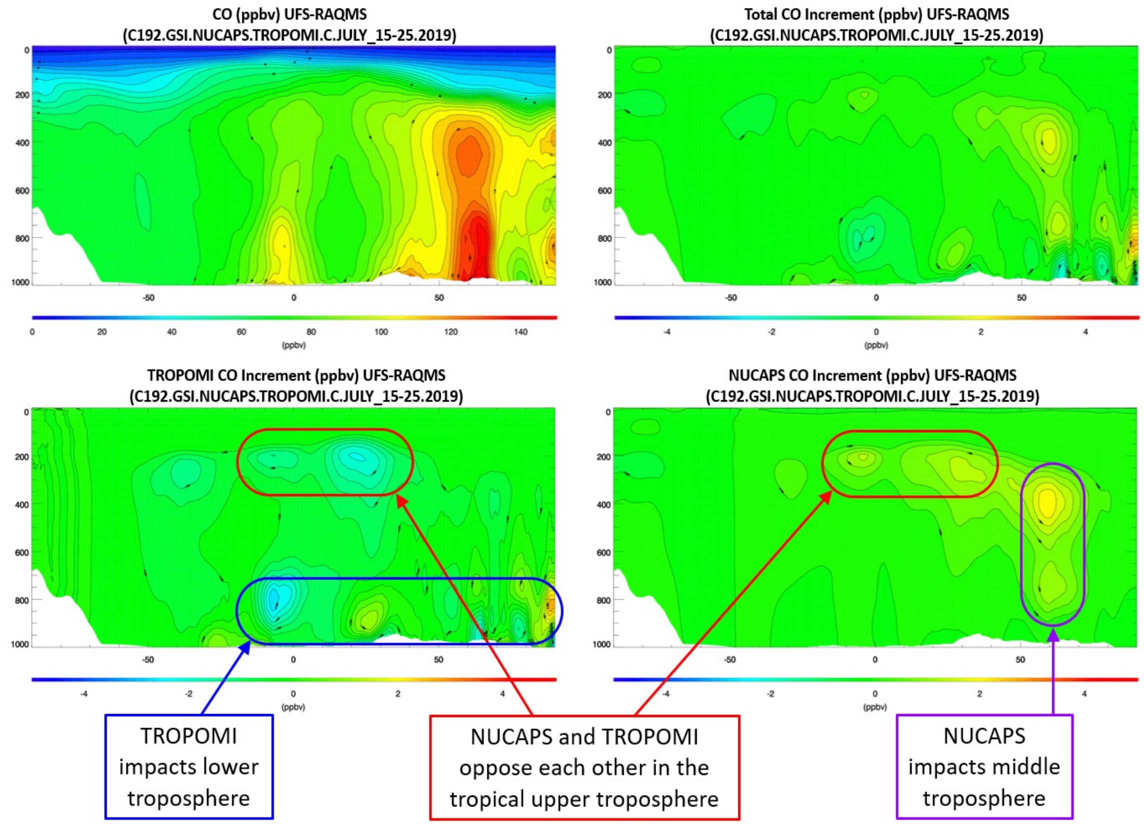
Brad Pierce, Allen Lenzen, Aditya Kumar, and Maggie Bruckner



UFS-RAQMS NUCAPS and TROPOMI CO Assimilation

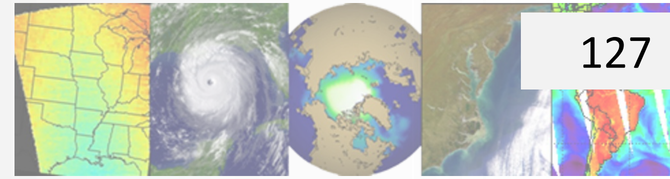
- GSI 3DVAR (3hour cycle)
- Full NUCAPS Science Retrieval
  (Thermal IR (day/night) is sensitive to mid tropospheric CO)
- TROPOMI Column
  (Shortwave IR (daytime only) is sensitive to total column CO)
- Combined assimilation provides constraints on both middle and lower tropospheric CO



Results from the UFS-RAQMS July 15-25, 2019, NUCAPS/TROPOMI data assimilation experiment. Top left: zonal mean analyzed carbon monoxide. Top right: total carbon monoxide analysis increment. Bottom left: TROPOMI carbon monoxide analysis increment. Bottom right: NUCAPS carbon monoxide analysis increment.

GOES-18 CSR/ASR Radiance Evaluation

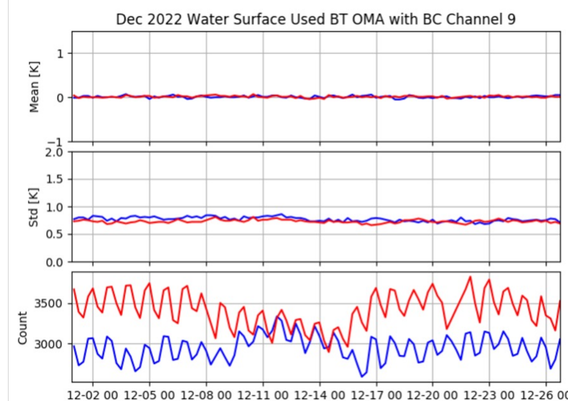
Sharon Nebuda and Agnes Lim; NOAA Collaborator: Mark Kulie



Objective

- Evaluate the GOES-18 ABI Clear Sky Radiance (CSR) & All Sky Radiance (ASR) product during ABI transition to operational status

- Ensure acceptable quality for use in NOAA/NCEP GFS data assimilation



CSR minus GFS Analysis brightness temperature mean, standard deviation, and data count for ABI Channel 9 with the VarBC bias correction in GSI for used water surface observations.

Approach

- Monitored CSR & ASR beginning Nov 2022 for both GOES-16 & -18 to compare product statistics and examined results for outliers or other concerns

- Collected and analyzed departure statistics for both GOES-16 and -18 CSR from a GFS DAS experiment on UW-Madison S4

Outcomes

- Confidence in product to allow timely use in operations, metrics indicate similar performance to GOES-16 CSR & ASR
- Confirmed successful update of NESDIS BUFR Tool Kit on NDE I&T
- Updated ATBD with prior modifications to mitigate suboptimal GOES-17 ABI focal plane temperature and addition of surface information

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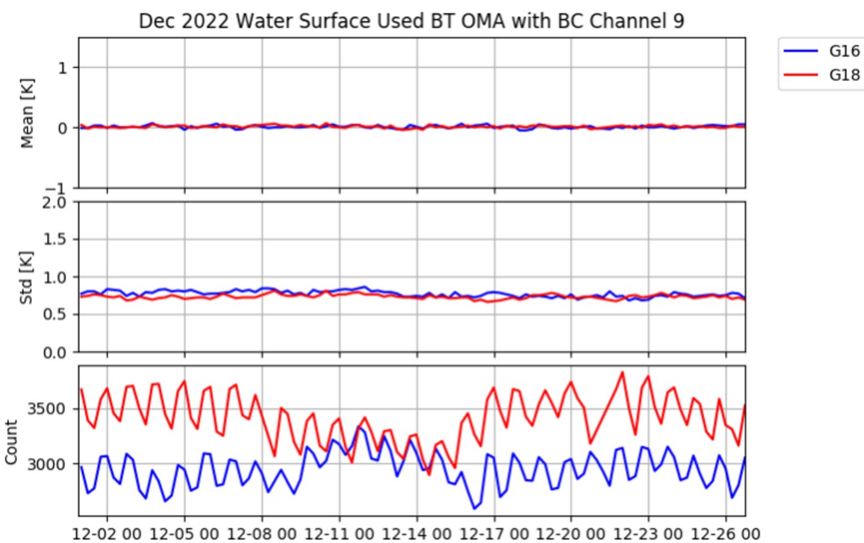
GOES-18 CSR/ASR Radiance Evaluation

Sharon Nebuda and Agnes Lim; NOAA Collaborator: Mark Kulie

Evaluate the GOES-18 ABI Clear Sky Radiance (CSR) & All Sky Radiance (ASR) product during ABI transition to operational status for NOAA/NCEP GFS use

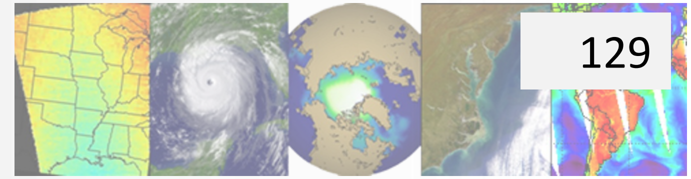


CSR minus GFS Analysis brightness temperature mean, standard deviation, and data count for ABI Channel 9 with the VarBC bias correction in GSI for used water surface observations.

- One primary ABI observation used in NWP data assimilation is the CSR infrared data available for the full disk at 10 minute frequency
- Degradation of CSR quality due to excessive GOES-17 ABI focal plane temperature prevented or reduced use of this observation
- Scientific monitoring of GOES-18 ABI CSR departure in GFS provides confidence for quality of the newly operational data for NOAA/NCEP use
- ATBD updates were also provided to NESDIS for documentation of prior algorithm modifications

Assimilating Water Vapor Radiance Tendencies Using FV3GFS

James Jung, Agnes Lim, Zhenglong Li

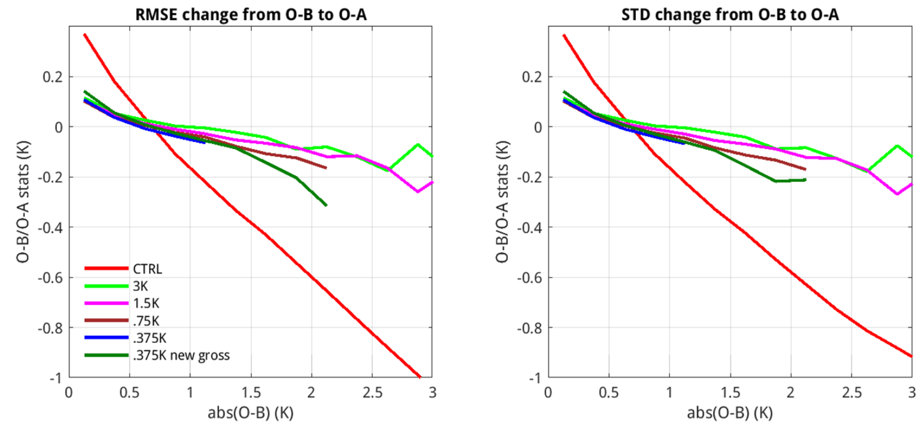


Objective

- Investigate a new approach for Assimilating Radiance Tendency of temperature and water vapor (WV) observations available from geostationary satellites.
- Improved assimilation of geostationary radianes within coupled model environments.
- No radiance bias correction is needed because radiance tendency is bias free within a short period of time.
- NCEP/EMC and other NWP centers may adopt this technique.

Approach

- A methodology was developed to calculate radiance tendency from ABI/GOES-16/18 and AHI/Himawari-8CSR BUFR data .
- Methodologies developed and implemented in the National Centers for Environmental Prediction’s FV3GFS to assimilate tendency measurements.
- Experiments carried out to determine the observation errors.
- Expand to non-water vapor bands over ocean
- Include GOES-18 and Himawari-8.
- Choose time period where enterprise cloud mask is available.
- Expand to non-water vapor bands over land.
- Computing resources for these experiments were provided by SSEC on S4.



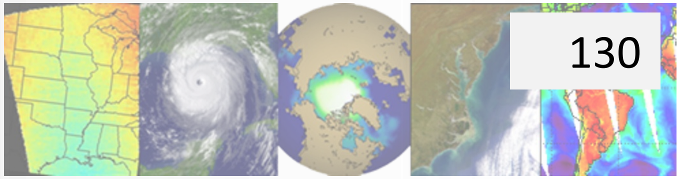
Change in observation minus background (O-B) and observation minus analysis (O-A) (left) root mean square error (RMSE) and (right) standard deviation (STD) for ABI band 8. Control (CTRL) is the operational setup. Remaining experiments assimilate tendency observations with observational errors of 3, 1.5, 0.75 and 0.375K. 0.375K new gross uses prescribed values estimated from the histograms of radiance tendency measurements for gross check.

Outcomes

- Assimilation of WV radiance tendency is successful as fits to ABI/GOES-16 observations are improved, but with neutral impact
- Assimilation of non-WV bands tendency leads to more reasonable results
- No degradation to the fits to ATMS surface channels as well as ATMS and IASI temperature channels.
- Forecast verification from assimilation of non-WV bands over both ocean and land shows improvements in 500 and 1000 hPa geopotential heights anomaly correlation in southern hemisphere and reduction in temperature bias at 500 and 850 hPa for all regions.

Quantitative Observing System Assessment Program (QOSAP) Research Activities

Allen Huang, Agnes Lim, Sharon Nebuda and James Jung



Objective

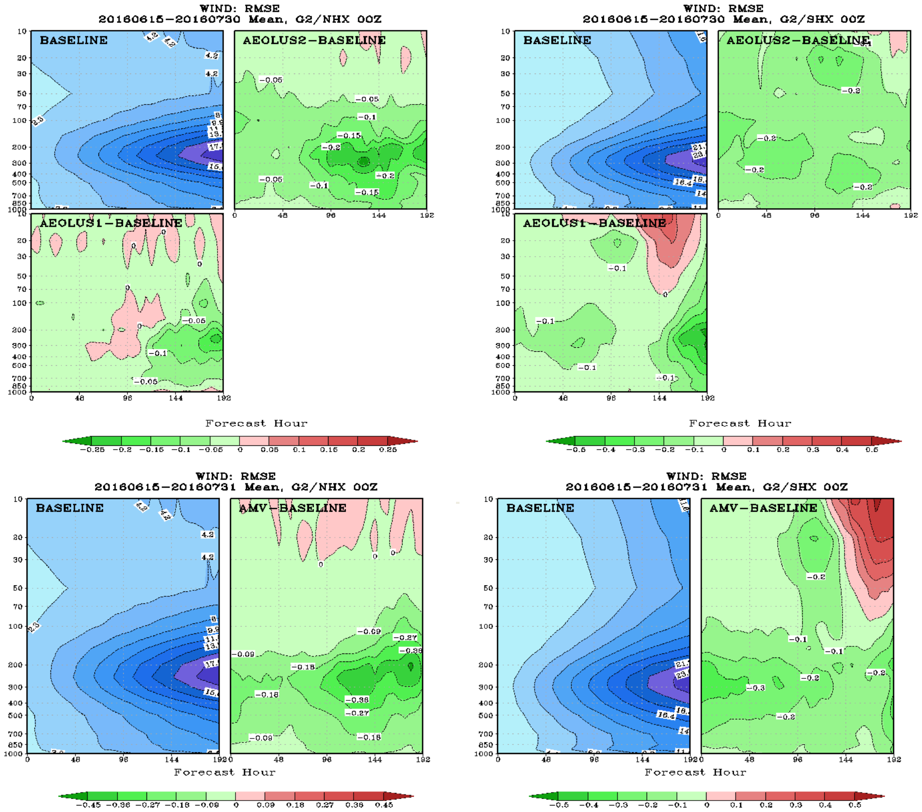
- Demonstrate the impact of 3D winds derived from active and passive satellite observations on global NWP forecasts
- NSOSA architecture program under NOAA NESDIS.

Approach

- Data assimilation experiments conducted by assimilating simulated 3D active and passive winds using a recent version of the operational GFS for a period of 2 months.
- Forecasts from these experiments are compared with a control that does not assimilate the active or passive winds and verified using the nature run, "known" true atmospheric state produced by ECMWF model.

Outcomes

- Stronger laser energy produce better quality active winds is more beneficial to global NWP forecasts.
- Active and passive 3D winds are beneficial to global NWP forecasts.
- Results provide NOAA guidance in planning for future missions.



Forecast wind field root-mean-square (RMS) cross section for Northern (left) and Southern Hemisphere.(right). (Top) Aeolus1 assimilates wind observations from the current Aeolus configuration. Aeolus2 assimilates wind observations from Aeolus follow-on which has a higher laser power. (Bottom) AMV assimilates passive winds retrieved at 8 pressure levels from 3 polar orbiters.

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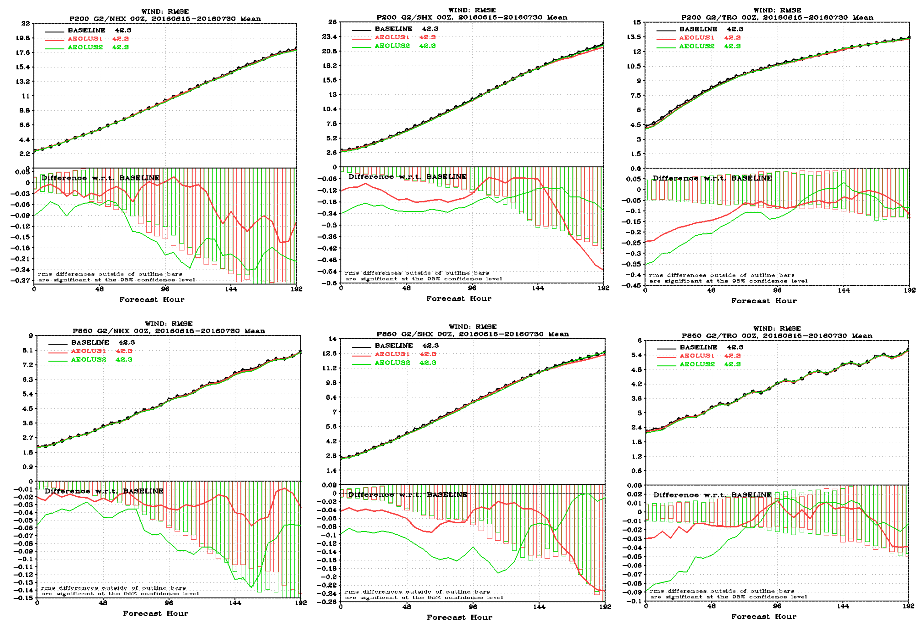
Active 3D winds show potential benefits in global NWP forecasts

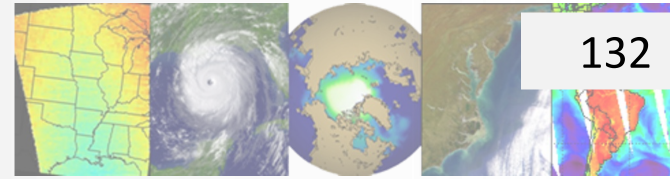
- Simulated observations retrieved from a laser energy of 0.02J and another that has 4 times more laser power (0.08J).
- OSSEs conducted over a 6-week period in the presence of the 2020 observing system.
- OSSE results indicated that the forecasts benefited from having Aeolus winds included in the observing system.
- The impact from wind observations if the laser power was to be increased, showed even larger improvements indicating having a stronger laser produces better wind observations and hence better forecast.



Root Mean Square (RMS) dieoff curves for wind field at 200hPa (top) and 850hPa (bottom) for Northern Hemisphere (left), Southern Hemisphere (center) and Tropics (right). Baseline (black) acts as the control which assimilates all observations from the 2020 observing system. Aeolus1 (red) assimilates the horizontal line of sight winds simulated using the real-world Aeolus configuration. Aeolus2 (green) assimilates horizontal line of sight winds with the same configuration as Aeolus1 that has a stronger laser power.

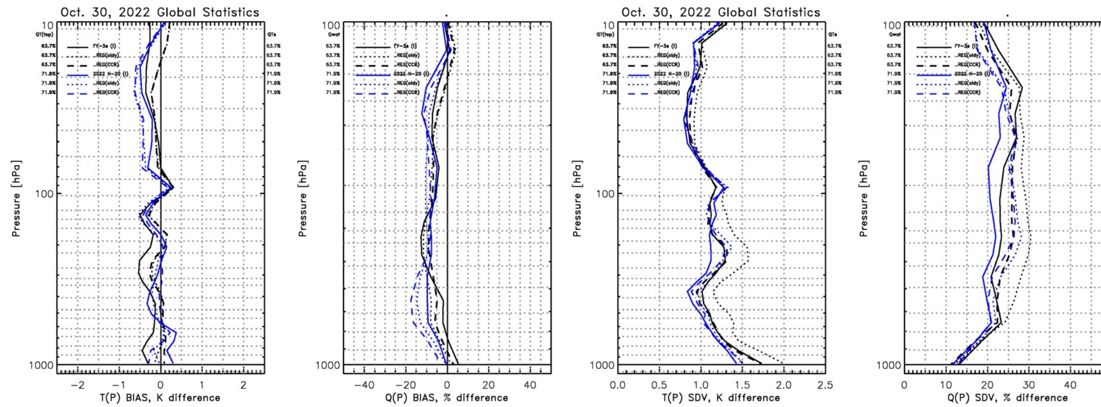
Developing NUCAPS for Processing FY3D/3E Hyperspectral Sounding Suites

Allen Huang, Agnes Lim and Zhenglong Li



Objective

- To expand NUCAPS (NOAA Unique Combined Atmospheric Processing System) hyperspectral sounding profile capability to process CrIS/ATMS type of observations from FY-3E, supplementing infrequent radiosondes with wide swaths of model-independent soundings over the whole globe and evaluate the benefits of an early morning orbit.
- NESDIS and NWS forecasters



Temperature and moisture bias (left) and standard deviation (right). Coupled physical retrieval is plotted in solid line. Regression trained on cloudy radiances [REG(cldy)] is plotted as dotted line. Regression trained on cloud clear radiances [REG(CCR)] Is plotted as dashed line. NOAA-20 statistics in blue on 30 Oct 2022 was included for comparison.

Approach

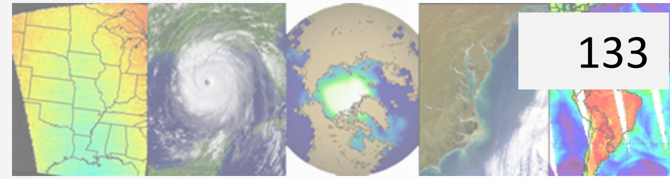
- Build a forward model for FY-3E microwave instruments (MWTS and MWHS).
- Build a forward model for FY-3E hyperspectral instrument (HIRAS). Identical to CrIS with dummy slots for added for extra channels of HIRAS.
- Training cloud cleared eigenvector regression coefficients using FY-3E and ECMWF data.
- System optimization.

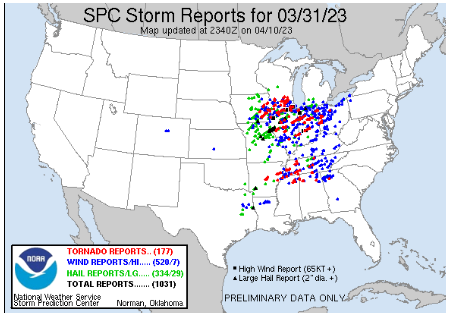
Outcomes

- Using only CrIS/ATMS identical channels from FY-3E instruments, statistics of retrieved soundings against ECMWF analyses show similar performance as those obtained from CrIS/ATMS.
- Early morning (5:30am) soundings available in addition to those from METOP (9:30am) and NOAA-20 (1:30pm)

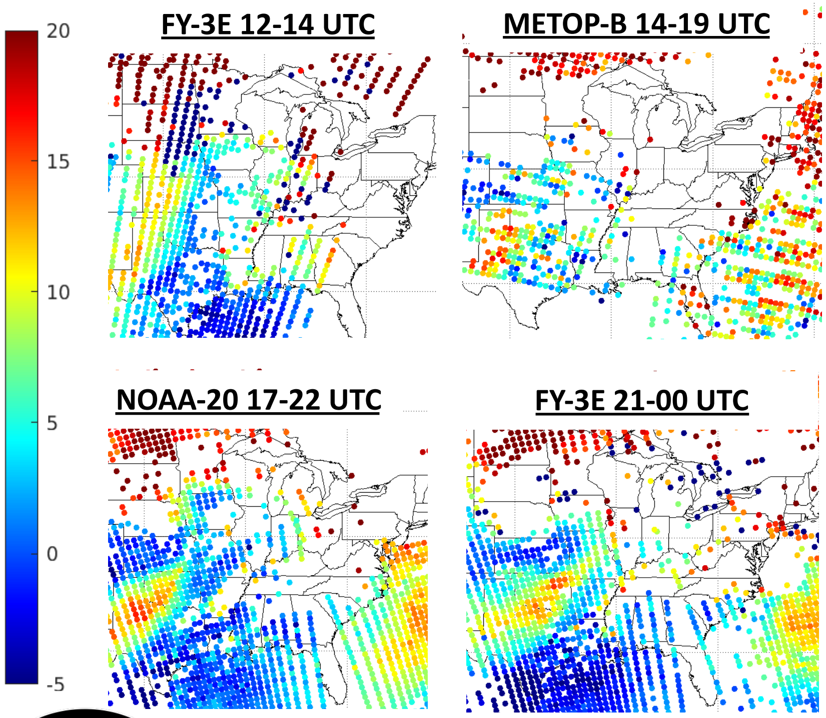
Developing NUCAPS for Processing FY3D/3E Hyperspectral Sounding Suites

Allen Huang





NUCAPS soundings from CrIS/ATMS type of observations onboard FY-3E to supplement infrequent radiosondes and evaluate the benefits of an early morning orbit.

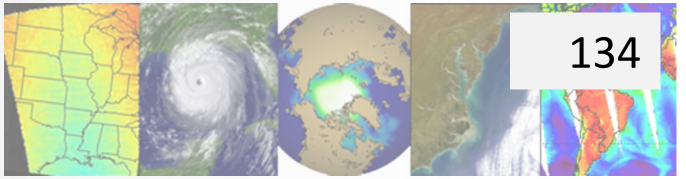


Time series of lifted Indices time series 12 hours leading up to the severe weather at 01 UTC 1 April 2023.

- Soundings from early morning orbits filled in sounding gaps for convective weather forecast.
- Statistics verifying against ECMWF analyses reveal FY-3E retrieved soundings are comparable to those from NOAA-20.
- Evaluating convective weather forecast performance through case studies.

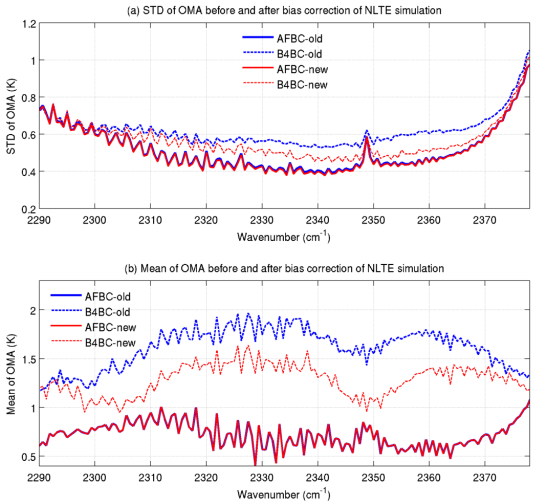
Assimilating Shortwave Infrared Radiances Using FV3GFS

Agnes Lim Zhenglong Li, Sharon Nebuda, Szuchia Moeller and Kevin Baggatt



Objective

- Develop CrIS-FSR shortwave infrared (SWIR) radiance assimilation technique in GFS to enhance CrIS-FSR impact on weather forecasting.
- EMC/NCEP and other NWP centers.



Daytime observation – analysis (O-) (before and after bas correction of NLTE simulated from CRTM. Dashed lines indicate before bias correction (BABC) and solid lines are for after bias correction (AFBC). Two sets of CRTM coefficients are used here. (a) Standard deviation and (b) mean.

Approach

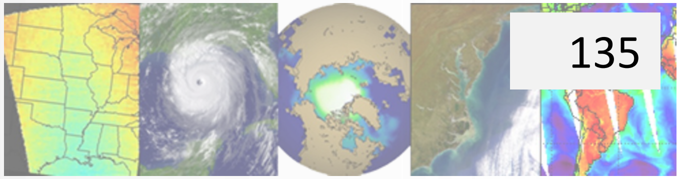
- A bias correction scheme to correct CRTM estimated non-local thermodynamic equilibrium (NLTE) was developed to correct CrIS SWIR radiances for assimilation .
- NLTE bias correction implemented into GSI to correct SWIR radiances on the fly.
- QC procedures implemented to rejected SWIR observations that cannot be corrected by NLTE bias correction.
- Assess effectiveness of scheme through analyzing assimilation statistics and forecast impact.

Outcomes

- Develop NLTE bias correction scheme using statistical approach and implemented within GSI.
- Assimilation of SWIR radiances both day and night.

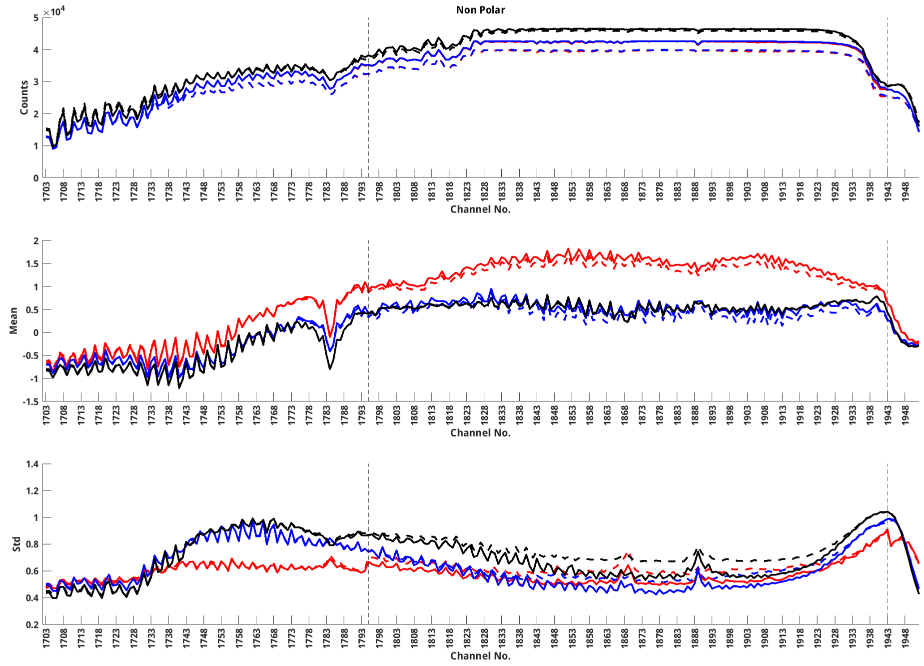
Assimilating Shortwave Infrared Radiances Using FV3GFS

Agnes Lim



A bias correction scheme to correct CRTM estimated non-local thermodynamic equilibrium (NLTE) using statistical approach for SWIR radiance assimilation.

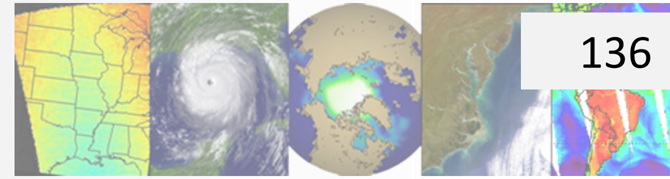
- Statistical approach to quantify NLTE radiances, called Spectral Correlations to Estimate Non-local Thermal Equilibrium (SCENTE).
- Bias correction scheme developed to correct NLTE biases.
- Day/night biases similar.
- Assimilation of SWIR radiances both day and night.



Counts (top panel), bias (middle panel) and standard deviation (bottom panel) of observation – first guess (dashed line) and observation – analysis (solid line) for observations excluding polar regions. Red indicates daytime without NLTE bias correction. Blue indicates daytime with NLTE bias correction. Black indicates nighttime. Solar zenith angle has been used to separate observations into day and night. Channels bounded by two vertical dashed lines are the 149 stratospheric sensitive SWIR channels.

Improved Use of ATMS Using VIIRS Cloud Products

James Jung, Aditya Kumar, Sharon Nebuda, Allen Lenzen



Objective

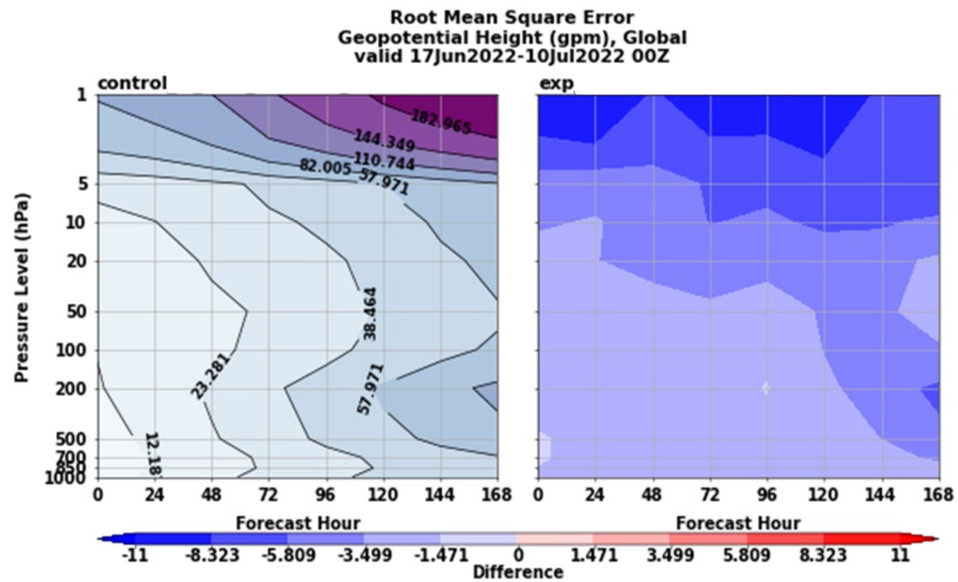
- Incorporate the VIIRS cloud product information into the ATMS profile thinning routine within NCEP's Global Forecast System to Improve the assimilation of ATMS.

Approach

- Choose the profile with the least amount of cloud by adjusting the profile selection criteria to use VIIRS cloud information instead of ATMS channel differences.
- Avoid profiles containing precipitation and supercooled water when possible.

Outcomes

- Improved extraction of temperature and moisture information from ATMS profiles
- Improved bias ccorrections of both clear and cloudy radiances.
- Decrease in temperature RMSE at all levels through 168 hours.
- Improved 1000 and 500 hPa geopotential heights anomaly correlations through 168 hours.
- Computing resources for this project are being provided by SSEC on S4.



The left panel indicates the geopotential height forecast error growth within the model out to 168 hours of the control. The right panel is the ***change*** in geopotential height error growth when using the new profile selection criteria. The varying shades of blue indicate improvements (less error) in the geopotential height forecast when using the new profile selection scheme.

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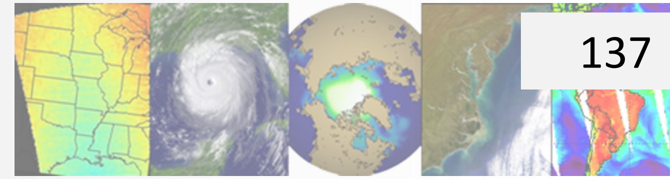
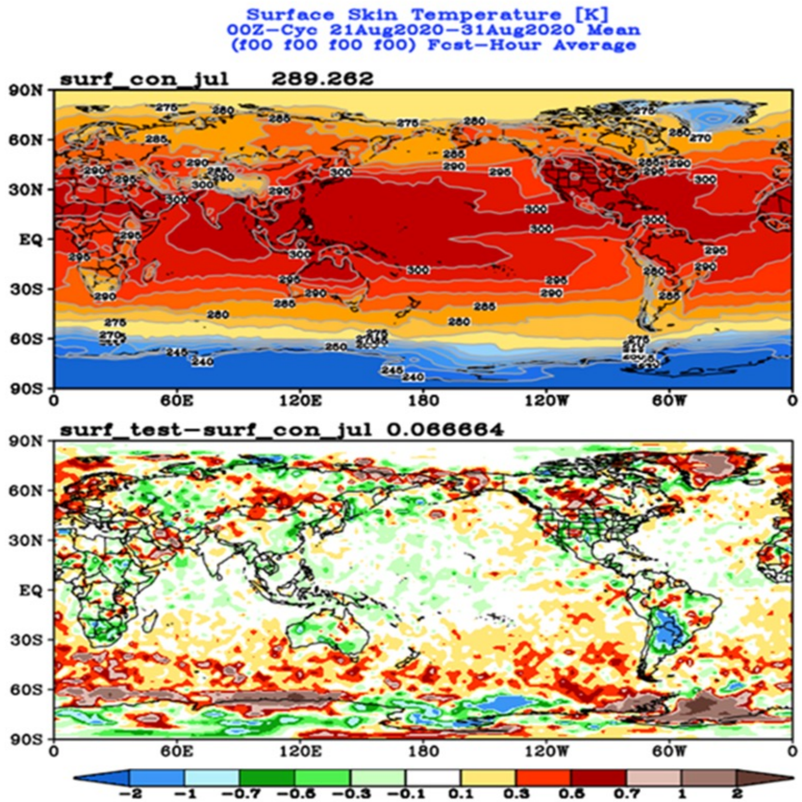
Improvements NWP Infrared Ocean Emissivity Models

James Jung, Nick Nalli (NESDIS) and Andrew Collard (NCEP)





Surface skin temperature from the experiment consistent with operations (suf_con, top) and the difference generated from using the new infrared sea surface emissivity model (surf_test – surf_con, bottom). The greatest differences are in the cold-water regions where temperatures are increased by up to 0.6K. This is consistent with the expected theoretical temperature differences.

Objective

- Improve the assimilation of information from surface and near surface hyperspectral infrared instruments in the NOAA/NCEP Global Forecast System.

Approach

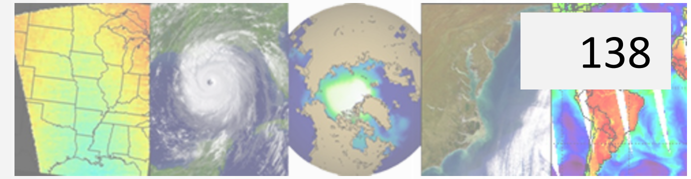
- Nick Nalli developed a infrared ocean surface emissivity model which incorporates the temperature dependency on emissivity. This model was verified using the Marine Atmospheric Emitted Radiance Interferometer (MAERI) data collected on various science expeditions.
- This new infrared ocean emissivity model was incorporated into a research version of NOAA's Community Radiative Transfer Model (CRTM) and a low resolution version of NCEP's Global Forecast System.
- Seasonal tests were conduced between the new and current ocean emissivity within NCEP's Global Forecast System.

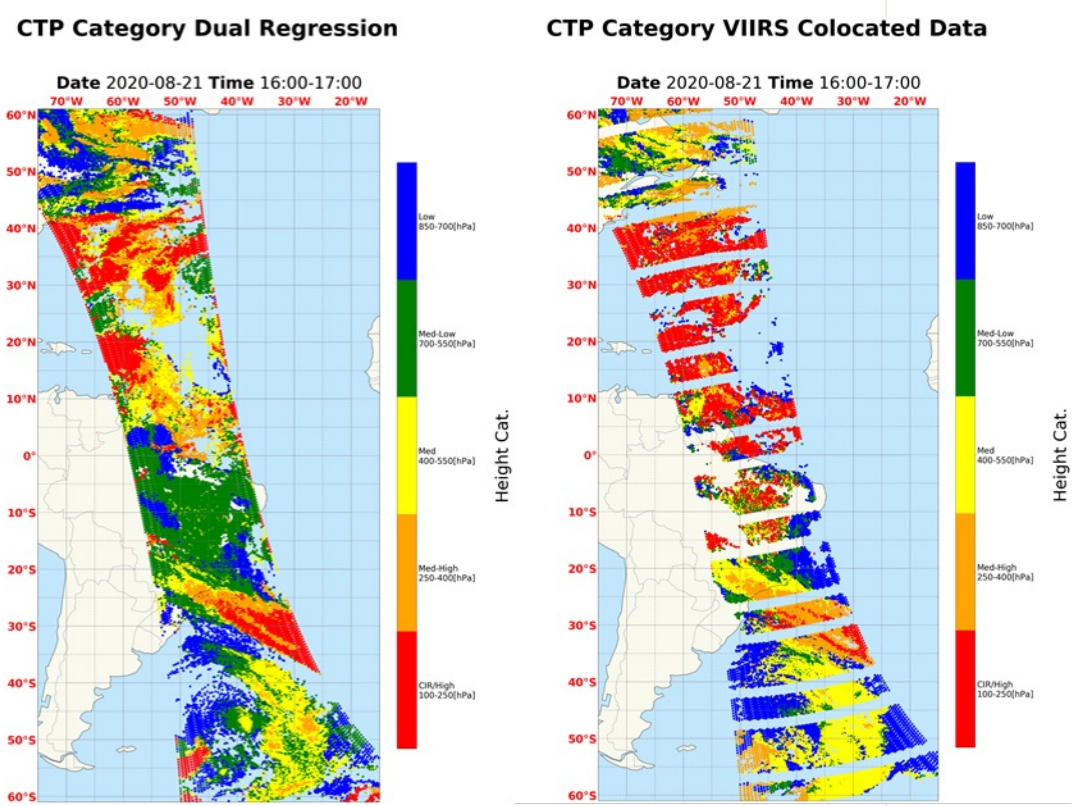
Outcomes

- This new infrared ocean emissivity model significantly reduces the cold temperature biases observed at high latitudes (cold SSTs) and improves the atmosphere and ocean SST forecasts.
- NCEP is awaiting a CRTM version release which includes this emissivity model for implementation in NOAA/NCEP's Global Forecast System.
- Computing resources for this project were provided by SSEC on S4.

Comparing Infrared Cloud Detection Algorithms used by NWP

James Jung, B. Andersen, W. P. Menzel and S. Nebuda





Comparison of cloud heights between the dual regression cloud detection algorithm (left) and the Visible Infrared Imaging Sounder cloud product collocated to the Cross-track Infrared Sounder footprint (right). In general, the dual regression technique is consistent with the Visible Infrared Imaging Sounder cloud product in detecting low, middle and high clouds.

Objective

- Improve the use of atmospheric hyperspectral infrared radiances in the NOAA/NCEP Global Forecasting System.

Approach

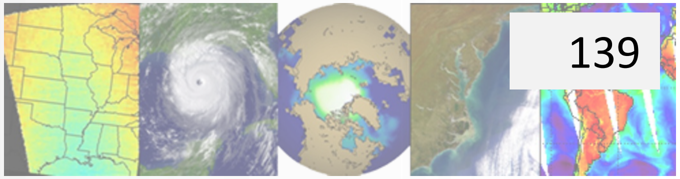
- Review various IR cloud detection schemes for efficacy.
- Compare techniques to "truth" to determine strengths and weaknesses of each.
- Develop a potential path to operations for the best technique with NCEP.

Outcomes

- Andersen, B., 2022: Comparing Infrared Cloud Detection Algorithms to Improve the Current National Weather Prediction Infrared Cloud Detection Algorithm, M.S. Thesis, May 2022.
- A variant of this dual regression technique is currently in software and science review by NCEP for implementation in the NOAA/NCEP Global Forecast System (under a follow on project).

NPP and JPSS Data Assimilation Improvements.

James Jung, Sharon Nebuda, Andrew Collard (NCEP)

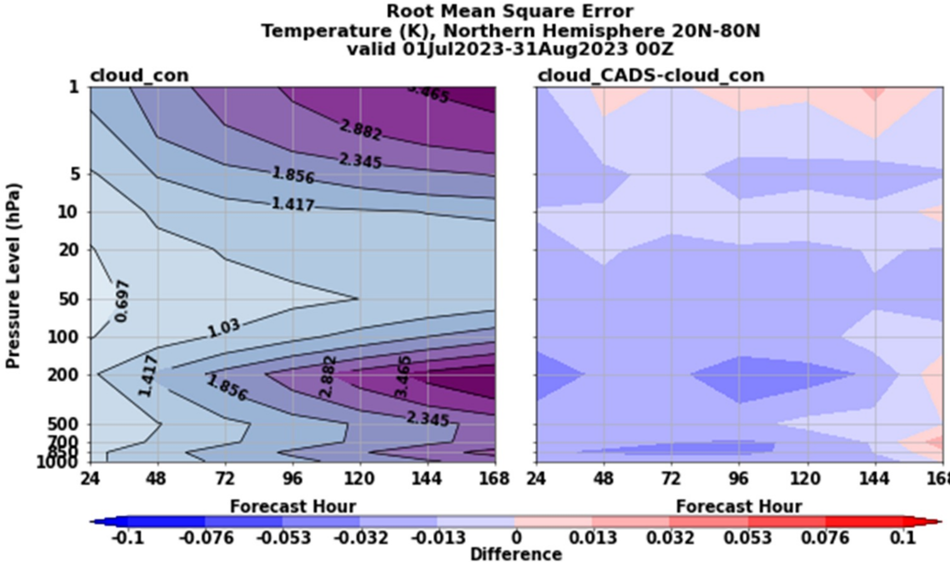


Objective

- Improve the use of atmospheric hyperspectral infrared radiances in the NOAA/NCEP Global Forecasting System.
- Identify clouds and other atmospheric contaminants (dust) to improve the use of clear infrared radiances.
- Help to facilitate the use of the CrIS-VIIRS collocated information into NESDIS Operations.
- Help to facilitate the use of the dual regression cloud detection routine into NCEP Operations.

Approach

- Expand on the work started by Brianne Andersen (previous slide).
- Incorporate the dual regression cloud test (developed by McNally and Watts, 2003) into NCEP's Global Forecast System (NCEP software review).
- Coordinate with NESDIS/JPSS, NESDIS/ASSISTT, and NCEP/EMC to incorporate VIIRS information into the CrIS BUFR to improve cloud detection.
- Conduct seasonal observing system experiments using the new cloud detection scheme (NCEP science review).



The left panel indicates the temperature forecast error growth within the model from 24 to 168 hours of the control (cloud_con). The right panel is the ***change*** in temperature error growth when using the new cloud detection scheme (cloud_CADS – cloud_con). The varying shades of blue indicate improvements (less error) in the temperature forecast when using the new cloud detection scheme.

Outcomes

- This project is work in progress.
- Initial tests indicate significant improvements are possible.
- Some required data (CrIS-VIIRS colocation) is not available yet.
- The success of this project is dependent on SSEC providing computing resources on S4.

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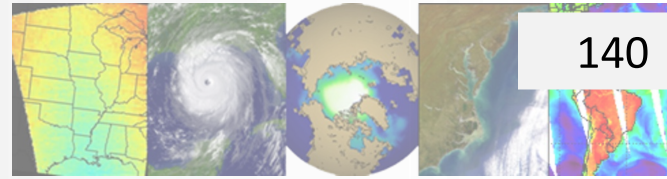


Assimilating Radiance Tendencis from Geostationary Satellites

James Jung, Agnes Lim, Zhenglong Li

Objective

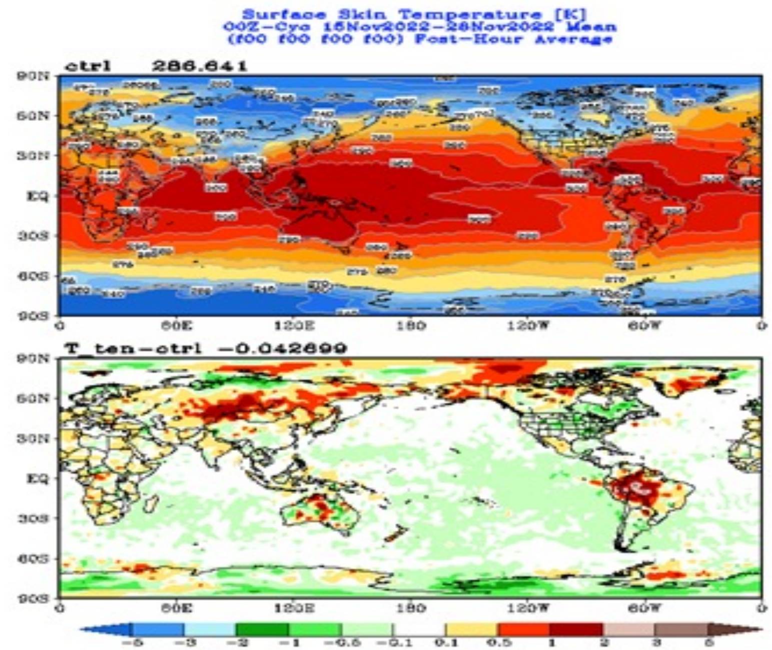
- Investigate a new approach for assimilating radiances in Numerical Weather Prediction, assimilating radiance tendency.
- If this technique works as expected, it will improve geostationary hyperspectral radiance assimilation at and near the surface.
- Improved assimilation of radiances within coupled model environments.

Approach

- This technique uses clear infrared radiance (temperature and moisture) information at a specific location separated by time.
- Features of this technique include:
    - ➢ Surface emissivity estimates are not needed.
    - ➢ Bias corrections are not needed.

Outcomes

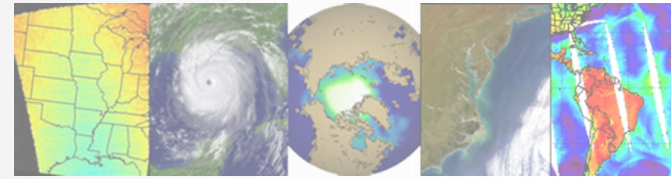
- This is a proof of concept.
- Assimilating temperature tendency from geostationary satellites is generating expected results.
- Assimilating radiance tendencies in regions with geostationary satellites with minimal surface observations show large differences (Amazon region, SA (GOES-E), Desert regions, Australia(Himawari)).
- Computing resources for this project are being provided by SSEC on S4.



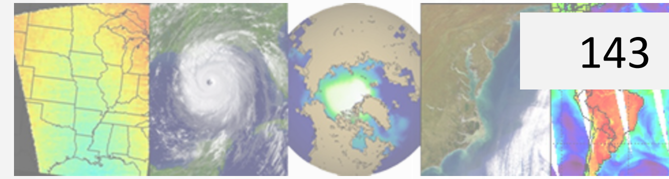
Top panel is average analysis skin temperature from 15 Nov – 29 Nov 2022 for the control (ctrl). The bottom panel is the analysis difference between assimilating the temperature radiance tendency (T_ten –ctrl).

Education and Outreach

Contents



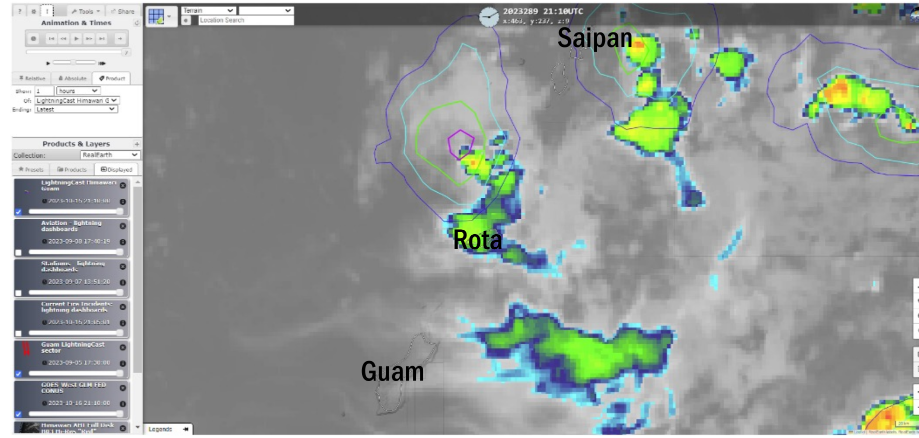
CIMSS Satellite Training Support to OCONUS



Scott Lindstrom

Objective

- Foster an environment that helps forecasters think of satellite imagery first as a means of determining present conditions and in aiding Decision Support,
- Stakeholders: National Weather Service Offices in Guam, American Samoa, Honolulu, Fairbanks, Anchorage, Juneau



Real Earth presentation of LightningCast probabilities over Marianas

Approach

- In-person training at Guam, American Samoa (2022) and Honolulu (2023) highlighting the different types of satellite imagery for particular weather events
- Multiple CIMSS Satellite Blog Posts on events that have occurred within the AORs of the forecast offices.
- Weekly telecons to Pago Pago to discuss the past weather and how satellite imagery could help
- Attendance at twice-weekly HFO online weather discussions
- Telecons as needed to WFO GUM to discuss weather events and how satellite data are vital

Outcomes

- Volcanic Ash training (StoryMap format) created with and for Alaska Region
- Ongoing discussions with GINA/CIRA on JPSS Training
- LightningCast domains created for Guam and American Samoa, courtesy John Cintineo/CIMSS.
- Talks at AOMSUC-13 on Lightning Work over Western Pacific using LIS data, and at AOMSUC-12 on LightningCast at Guam
- Presentation creation by staff at WSO Pago Pago for presentation at AMS/NWA meetings

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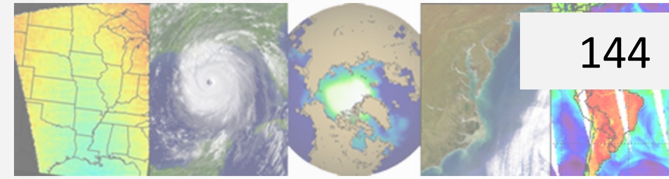
FDTD Satellite Applications Webinars 2017-present



Objective

- Help National Weather Service forecasters present information about local events for which satellite imagery was useful for forecasting/nowcasting or for providing Decision Support to stakeholders.
- Done in collaboration with NWS offices and with the Cooperative Institute for Reseach in the Atmosphere (CIRA)

First Slide from Patrick Ayd (WFO DLH) talk on the use of SAR data

Approach

- Typically, Scott Lindstrom or Dan Bikos will contact a forecaster when we are aware of an interesting event in their forecast office for which the satellite data tells a compelling part of the story
- Similar to the more recent Satellite Book Club that TOWR-S runs.

Outcomes

- Peer-to-peer training allows NWS forecasters to share information and ideas
- Forecasters become comfortable advocates of Satellite Data
- Session are recorded and available for later viewing; Presentations are also available for download: https://rammb2.cira.colostate.edu/training/visit/satellite_chat/

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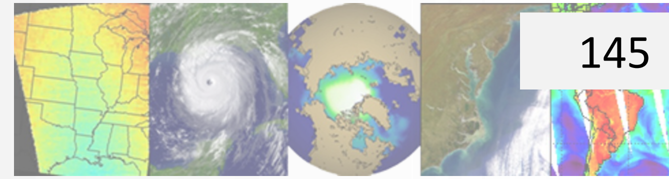
International Training Activities

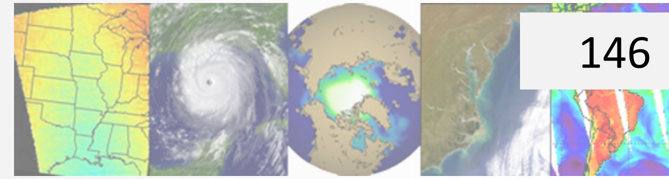
Scott Lindstrom, PI



- Support for AMS SATMOC and GOES-R/JPSS Short Course activities (image and content creation, participation in presentations), 2020-2023
  - Topics: Cryosphere ; Floods/Inundation ; Data Access
  - Created Data for Short Courses in Chile, Costa Rica, Barbados
- Training on Sounder Data (Polar Orbiters, and Geostationary) at AOMSUC-13 in Korea
- Week-long in-person Training given to Oman Civil Aviation Authority on Tropical Cyclones
- Training to Myanmar Dept of Meteorology/Hydrology (Synoptic and Tropical Meteorology)
- Talks given to ECCC on Satellite views of important weather events in 2022 and in 2023

Training Material for the NWS

Scott Lindstrom, PI

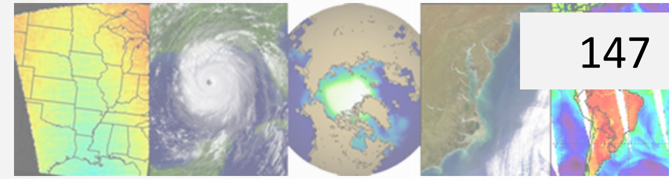


A selection of Cryosphere-related Quick Guides created in 2022/2023

- In addition to VISIT training (already discussed) and FDTD Satellite Applications Webinars (already discussed) Quick Guides are created as needed as new products become available in AWIPS.
- The most recent set of Quick Guides (2022/2023) have focused on Ice Products.

Workshops and Bootcamps

Margaret Mooney, Derrick Herndon, Scott Lindstrom and Scott Bachmeier



CIMSS develops tools, hosts workshops and shares resources to train today's researchers and the next generation of scientists to help maintain the pipeline to NOAA's future workforce, while also routinely promoting the benefits of satellite remote sensing with society.

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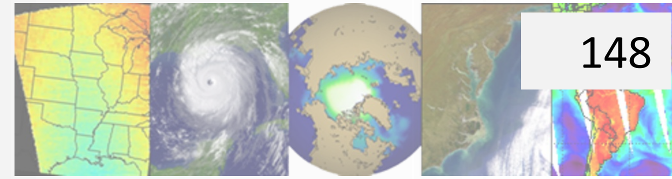
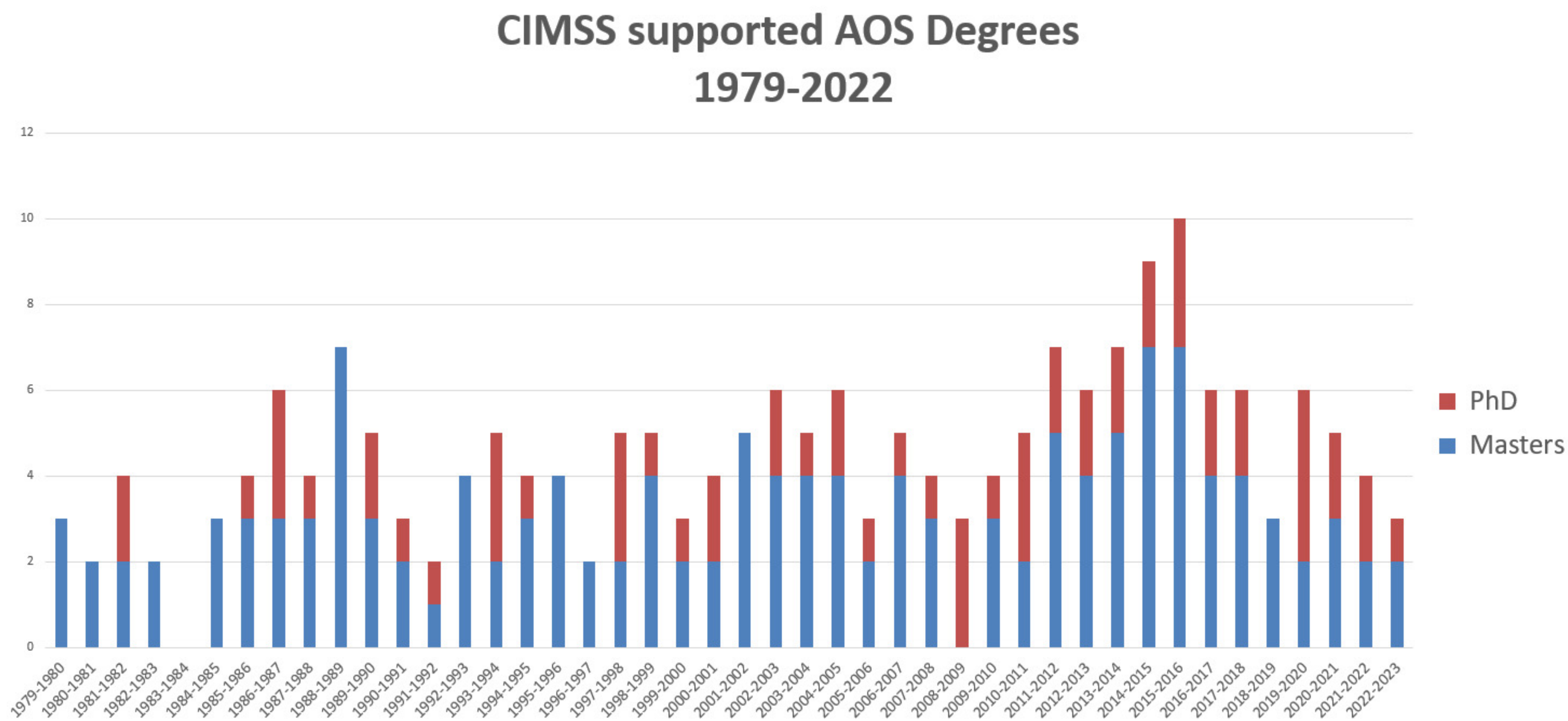
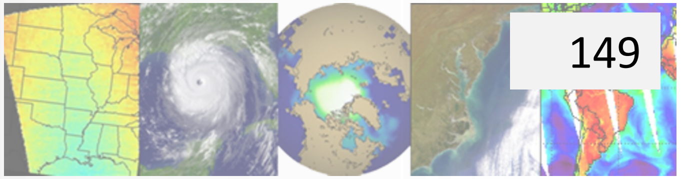
Graduate Education





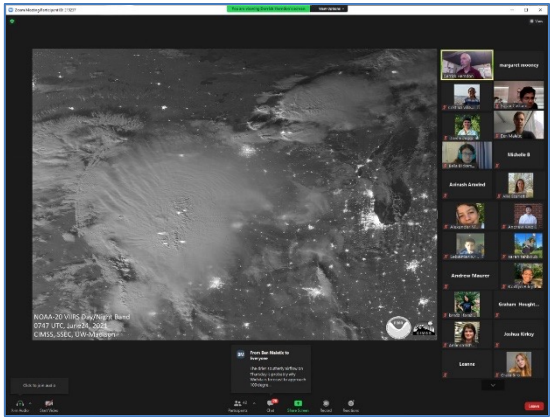
Multiple AOS students earn their Masters and PhD degrees each year working on CIMSS research projects. CIMSS also co-developed an undergraduate course on Climate and Climate Change with AOS (AOS 102) educating hundreds on this important topic.

Engaging Pre-College Students and Teachers



CIMSS hosts a GOES and JPSS Virtual Science Fair for middle and high school students each year.

CIMSS has held a 1-week Earth Science Camp for high school students each summer since 1995. (but not during covid)



CIMSS debuted an on-line Weather Camp in 2021 for high school Students.

CIMSS held a teacher workshop at the historic GOES-R launch with another planned for the GOES-U launch.

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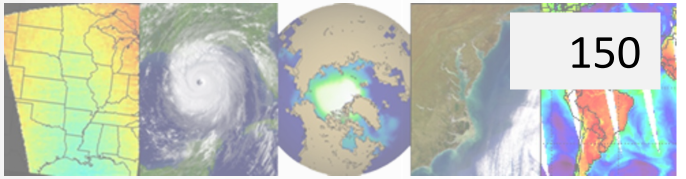
Training Professionals



VISIT Trainings

The VISIT program is a collaboration between CIMSS, CIRA, the NWS and NESDIS to train NWS forecasters. The Virtual Institute for Satellite Integration Training (VISIT) distance learning program was created in 1998 with funding from NOAA featuring a distance learning software package developed at CIMSS called **VISITview**.

AMS Short Courses and Professional Meetings

CIMSS staff present and participate in annual meetings of the American Meteorological Society (AMS) and EUMETSAT, keeping the meteorological and broadcast community up to date on products and capabilities in the JPSS and GOES-R era and the upcoming Geo-XO mission.

AMS 2017 Broadcasters meeting

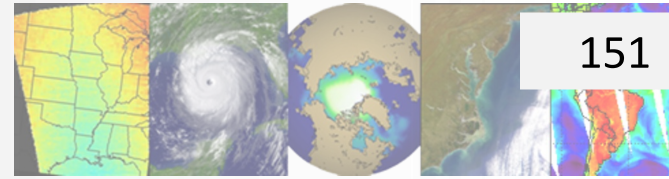
AMS 2021 Short Couse

EUMETSAT 2023 meeting

CIMSS Satellite Blog

CIMSS maintains a searchable library (by Category, Date or Keyword) of meteorological cases from 2006 to present, showcasing a variety of satellite images, products and applications. Content and discussions provides satellite remote sensing insights for professional meteorologists and researchers, while imagery attracts all levels of interests.

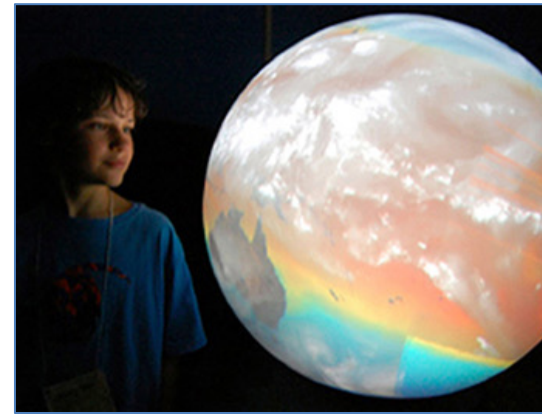
Engaging the Public



CIMSS participates in several in-person outreach events each year

AOSS Open House

Grandparents University



School Tours

CIMSS maintains a vibrant online presence sharing science with society

Along with the Satellite Blog, CIMSS maintains additional social media accounts with 23k followers on X (formally twitter) and 27k on Facebook. For the month of February 2022 surrounding the GOES-T launch, total reach topped 4 million people.