Planning for the Hyperspectral Environmental Sensor (HES)

Current Sounders

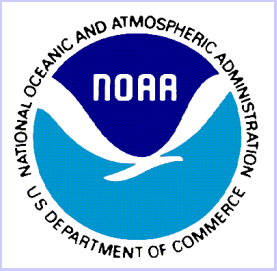
2002 Preparations for the Future

AIRS

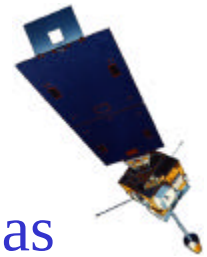
NOAA GIFTS Demonstration Planned

Anticipated HES Capabilities

Ralph Petersen and Paul Menzel - NOAA



Future GOES



GOES-R will address all four key remote sensing areas

- *Spatial resolution* – What picture element size is required to identify feature of interest and to capture its spatial variability?

- *Spectral coverage and resolution* – What part of EM spectrum at each spatial element should be measured? What spectral resolution is needed to analyze an atmospheric or surface parameter?

- *Temporal resolution* – How often does feature of interest need to be observed?

* *Radiometric resolution* – What signal to noise is required and how accurate does an observation need to be?

NOAA GIFTS Demonstration Plan states goals are to

* Conduct real time study of
    - Forecasting impact of radiances / winds
    - Nowcasting impact of derived product images
* Gather case study data sets to enable
    - Testing of NWP assimilation approaches
    - Validating GIFTS products
* Archive golden year of level 1-b radiances
    - Pacific winter storms
    - Severe storms in tornado alley
    - Hurricanes in the Atlantic
* Establish utilization approaches for HES day one

The road to HES

(~1600) ***HES*** (geo oper)

(~1600) ***GIFTS*** (geo exp)

CrIS (leo operational)

(~3600) **IASI** (leo operational)

(~2400) **AIRS** (leo operationally available)

NAST-I (airborne experimental)

IMG (leo experimental)

(18) ***GOES Sounder*** (geo operational)

HIS (airborne experimental)

(12) ***VAS*** (geo experimental)

VTPR, HIRS (leo operational)

IRIS (leo experimental)

(# of spectral bands)

time

Background for NOAA's GIFTS Activities

GIFTS NMP contract formulation phase ended in April 2001 following successful completion of Preliminary Design Review.

PDR was followed by extended formulation phase during Mission Confirmation Review (MCR).

Formal agreement between NASA, NOAA and the Navy signed in summer 2002 created a GIFTS partnership in which:

NASA would conduct the instrument development program,

Navy and Air Force would provide the launch, and

NOAA would provide the data collection and data processing capabilities leading to the measurement validation activities

NOAA wrote GIFTS Product Assessment Plan to assure that GIFTS Demonstration goals are met. Tasks include:

- Establish ground reception site (Wallops with UW backup)
- Establish seasonal suites of routine schedules for GIFTS
- Distribute level 1b radiances in real time to NWP and research centers via ground com lines
- Distribute derived product images to NWS FOs in virtual lab
- Archive all level 1b data and some of the derived products
- Develop NWP assimilation for radiances and winds
- Study impact of GIFTS images and derived products on forecasting / nowcasting at NWS FOs
- Establish HES utilization approaches for day one

Reducing "Launch to Use Lag" is NOAA (and NWS) Priority

Specifically:

Algorithm development will address GOES products

soundings
winds
cloud properties
land surface products
ocean products
earth radiation budget
ozone / trace gases / volcanic ash

Derived product images will include

3 layers of moisture and total column
atmospheric stability
cloud temperature and phase
land surface temperature diurnal excursions

NOAA GIFTS PAP is a seven year plan that details

* GIFTS Level 0 Data Acquisition

Primary ground system at Wallops
Backup at UW
Access to full data stream at UW

* Data and Metadata Archive

Some raw data (for NMP team)
Initially all Level 0 data (for NOAA reprocessing to level 1 with improved algorithms)
Evolves to Level 1 archive of "golden year" at NCDC

* Real Time Data Processing

Level 0 to Level 1 using software with real time efficiency provided by NOAA
Level 1 to 2+ using algorithms and software developed by largely at UW/CIMSS

* Demonstration of Utility of GIFTS Data and Products and Distribution to End-Users

Participation in cal/val intercomparisons of radiances and products
Real time distribution of GIFTS radiances (compressed or subset) and winds to EMC for NWP impact studies
Real time web access by selected NWS FOs to multispectral and derived product images of atmospheric water vapor, stability, cloud properties, land surface temperatures,…
Research on SST, volcanic ash, ERB, trace gases

Spans: winter storms in eastern Pacific (Feb, Mar),
severe storms in Midwest (Apr, May, Jun, Jul), and
hurricanes in Atlantic (Aug, Sep, Nov)
runs 24 hours per day seven days a week amap during demonstration year

* NWP impact & research continues with GIFTS until GOES-R

NOAA GIFTS Demonstration will engage

NESDIS/ORA to plan/conduct GIFTS science studies

NESDIS/OSD to infuse GIFTS technology in HES

NESDIS OSDPD to help plan data distribution

NESDIS Coop Insts to develop algorithms
and derived products

NWS NCEP to test GIFTS impact
EMC for data assimilation
SPC, AWC, TPC, HPC for derived products
FOs for operational real time utilization

NCDC for archive management

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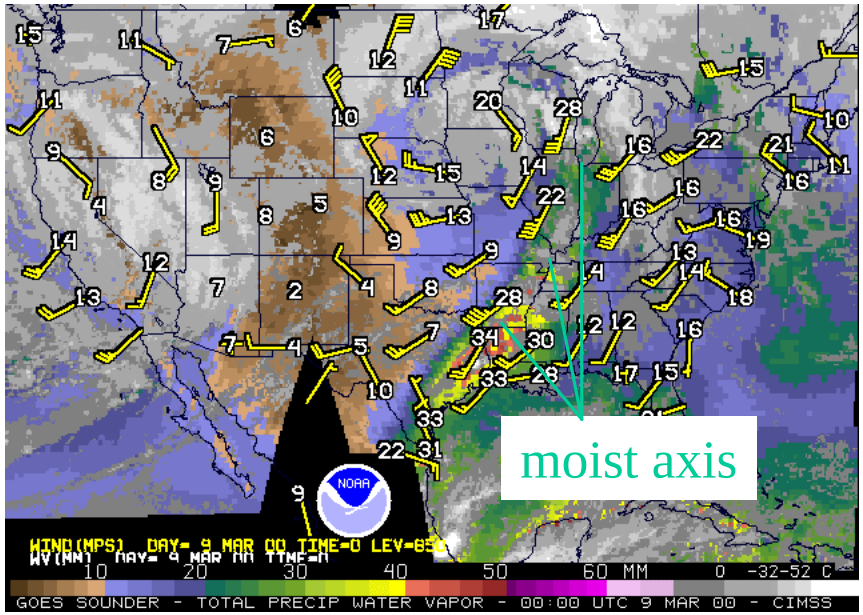
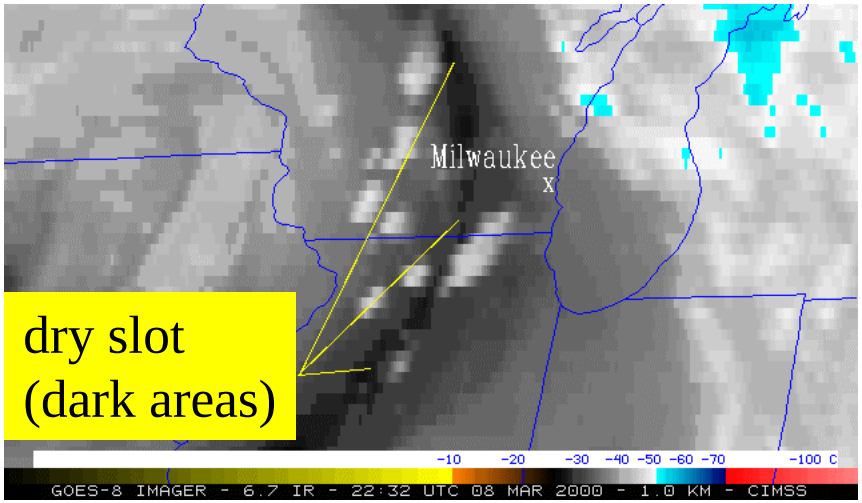
Anticipated HES Capabilities

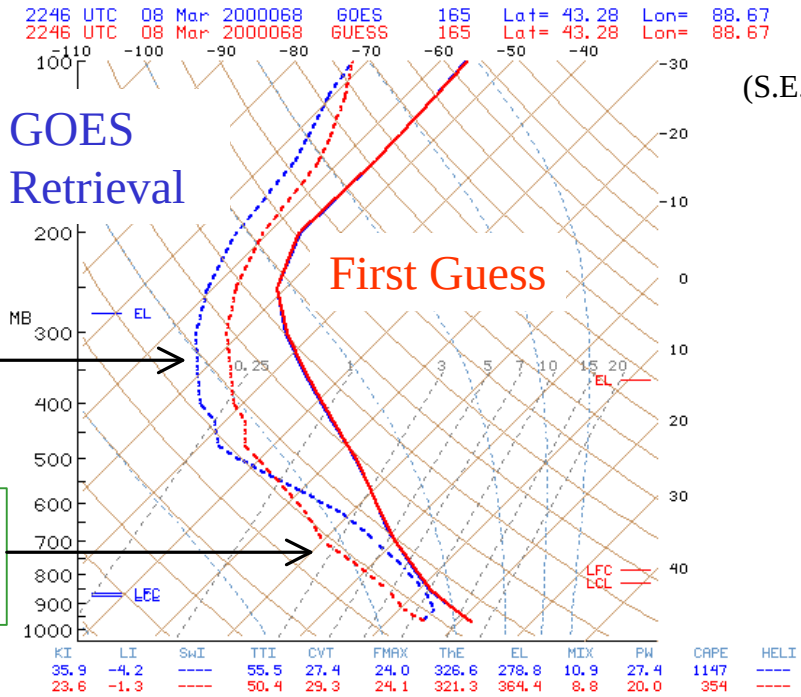
Record Earliest Tornado at Milwaukee, WI on 8 Mar 2000

- The GOES-8 Sounder monitors important precursors to the event.





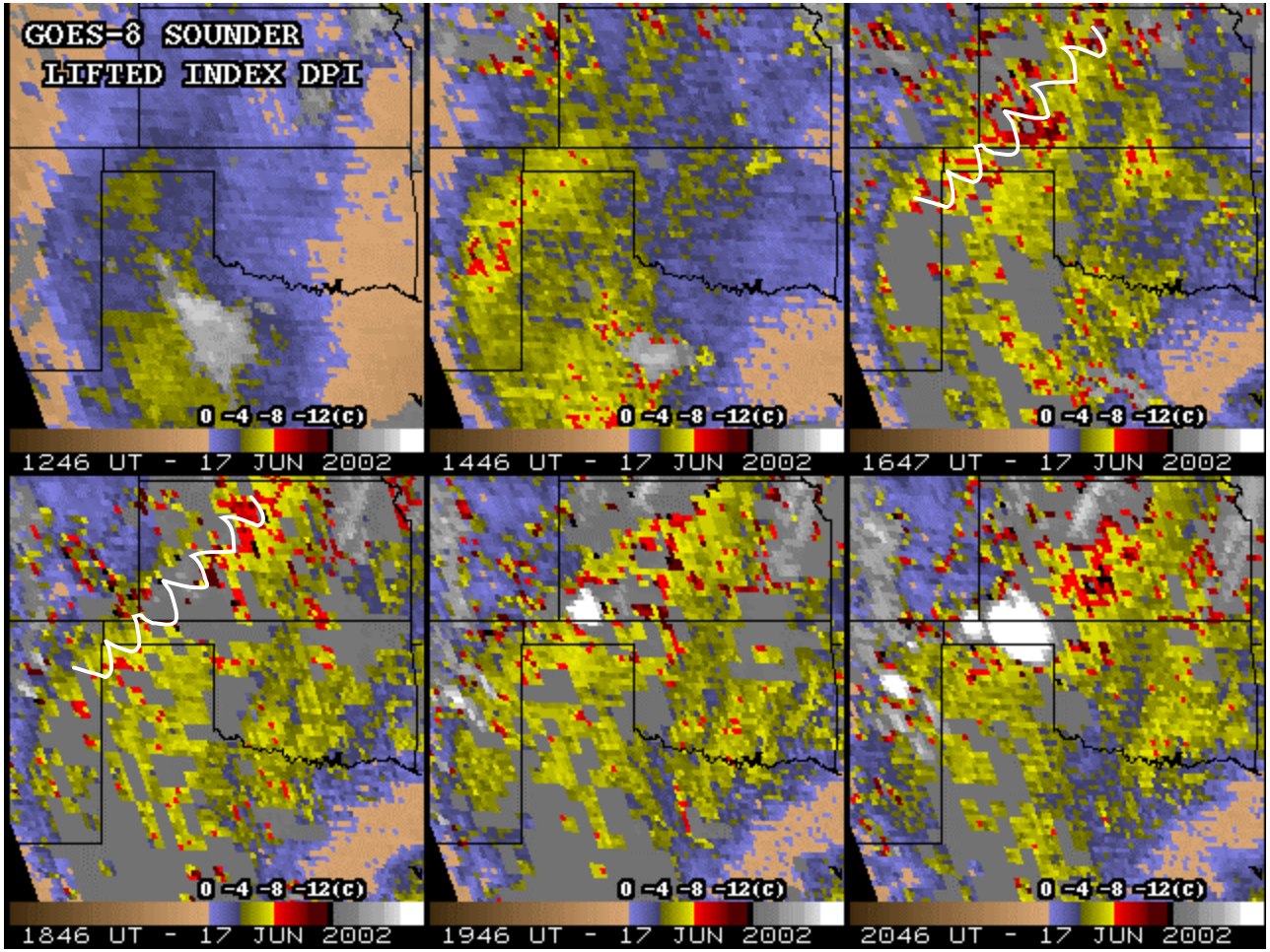
(S.E. WI)



Retrieval correctly subtracting moisture aloft (within the mid-level dry intrusion)

Retrieval correctly adding moisture in the lower levels (within the moist axis)

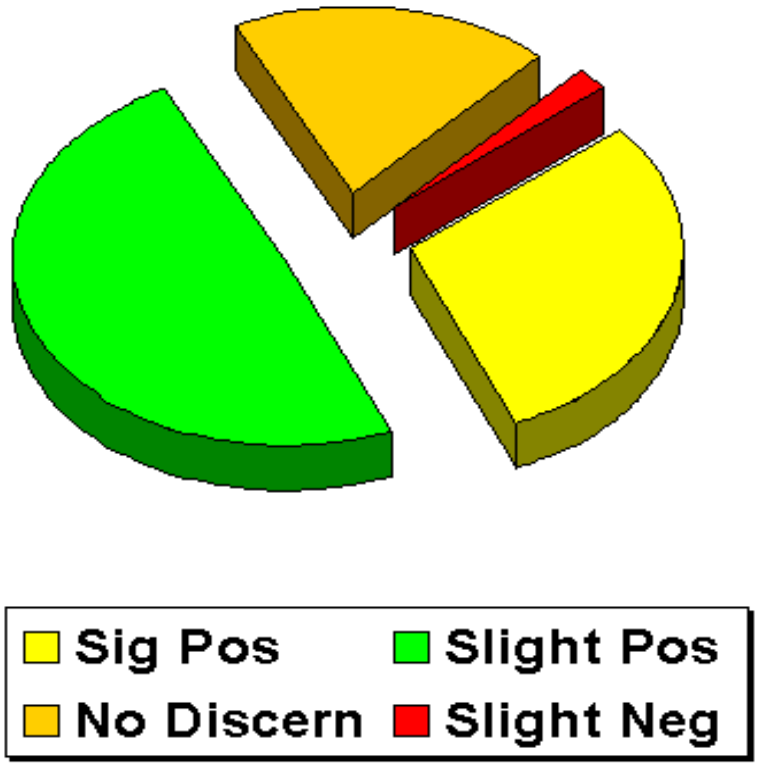
Evolution of GOES Sounder SFOV Lifted Index (stability) DPI on 17 June 2002



Panels show nominal times from 13 to 23 UTC.

Axis of instability (<-8) and its persistence in sequence of two-hourly interval GOES LI DPI focus attention for favorable convective conditions to central west Kansas and Oklahoma - Texas Panhandles. Later severe weather reports included numerous hail reports (to 1.25”) from far northern Texas Panhandle into far southwest Kansas. Other hail also fell around western central Kansas/Nebraska border region.

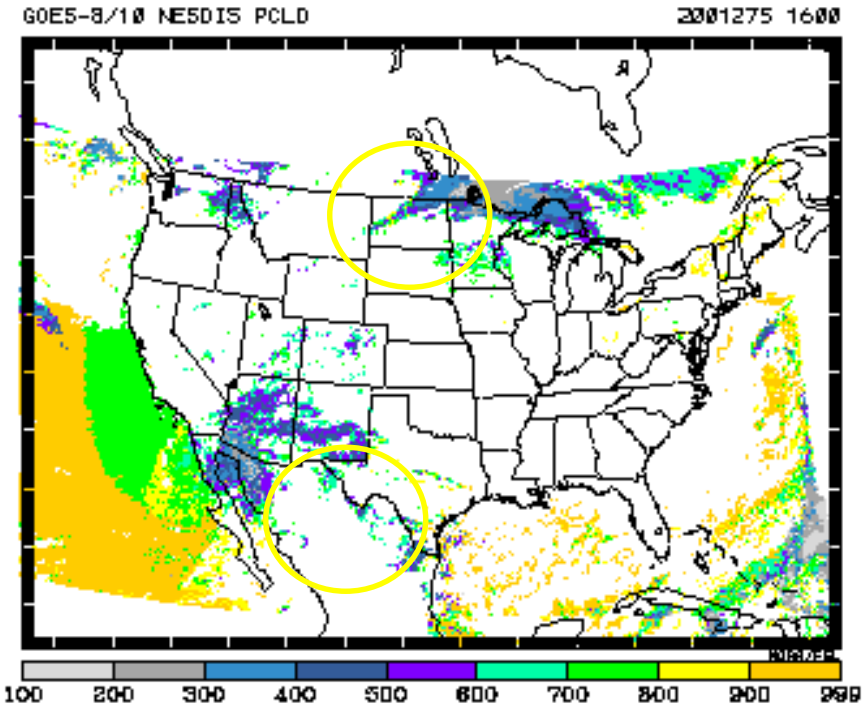
NWS Forecast Office Assessment of GOES Sounder Atmospheric Instability



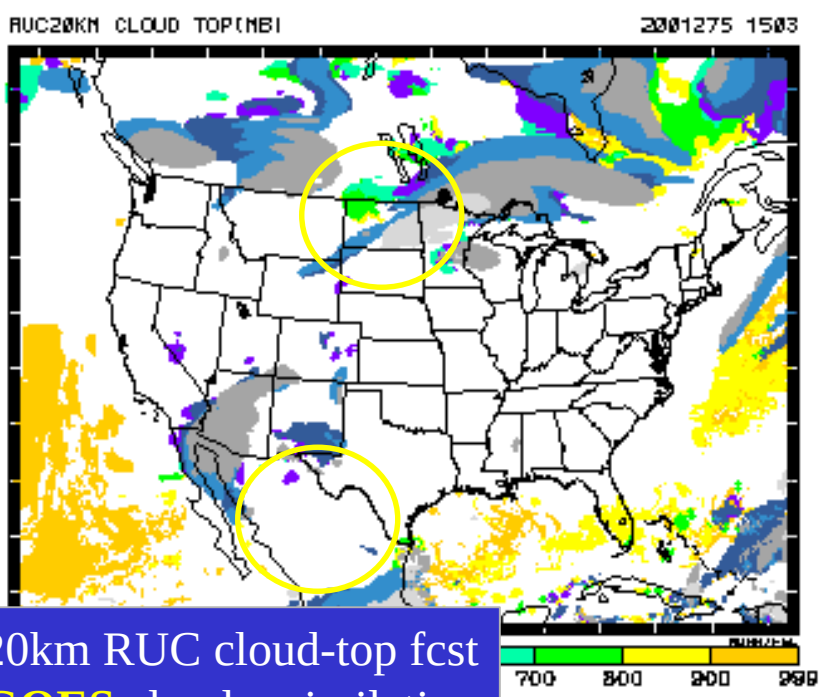
Summer 1999 assessment of usefulness of hourly LI, CAPE, & CINH product for predicting location/timing of thunderstorms

There were 248 valid weather cases.
- Significant Positive Impact (30%)
- Slight Positive Impact (49%)
- No Discernible Impact (19%)
- Slight Negative Impact (2%)
- Significant Negative Impact (0)

Figure from the National Weather Service, Office of Services



Verification
Cloud-top pressure
based on NESDIS product



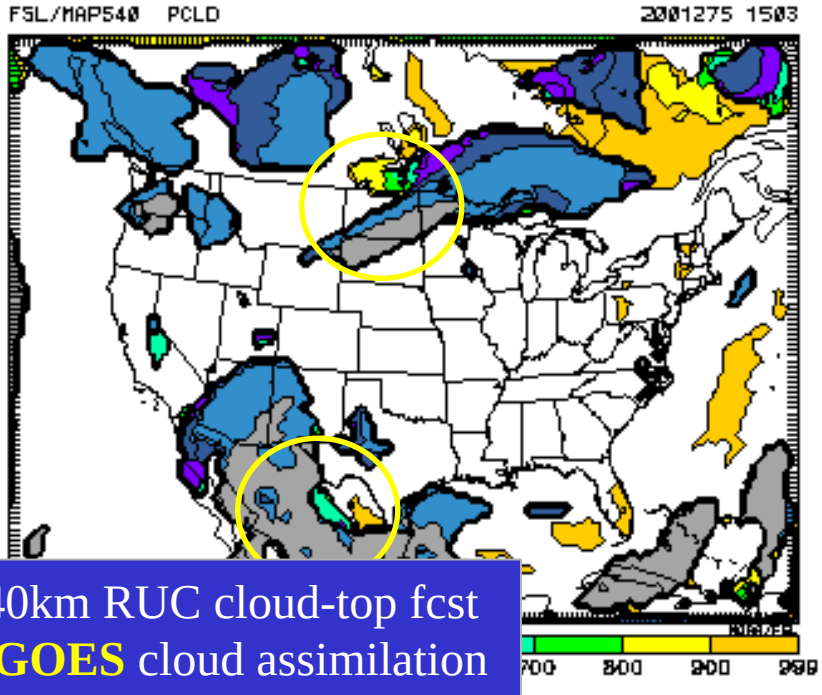
3h 20km RUC cloud-top fcst
w/ GOES cloud assimilation

Effect of GOES (sounder cloud) data on 3-h RUC cloud **forecasts**

"much improved cloud forecasts"

Stan Benjamin – NOAA/FSL

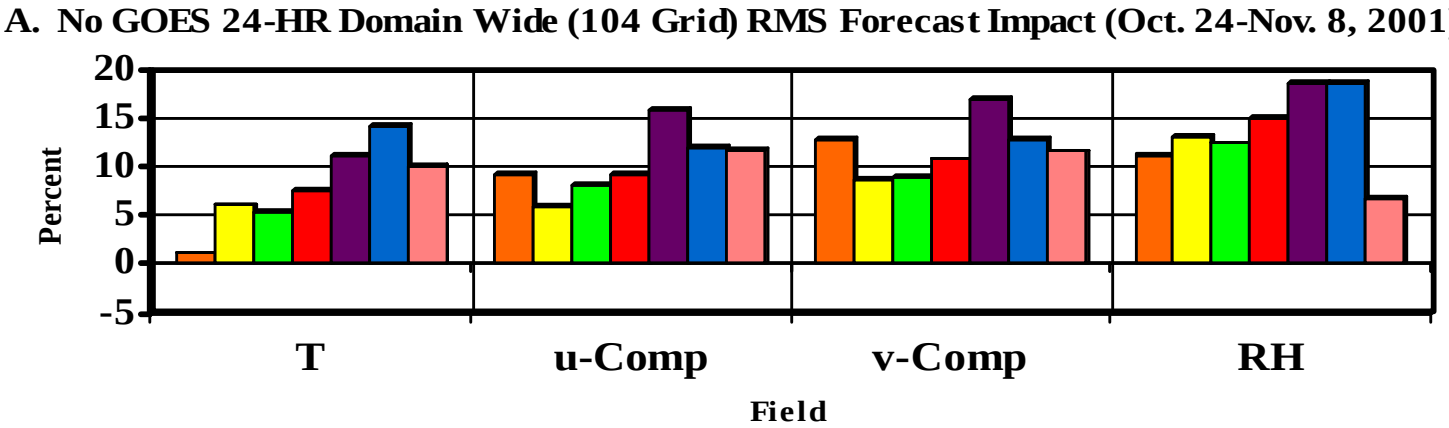
1800 UTC
2 Oct 2001



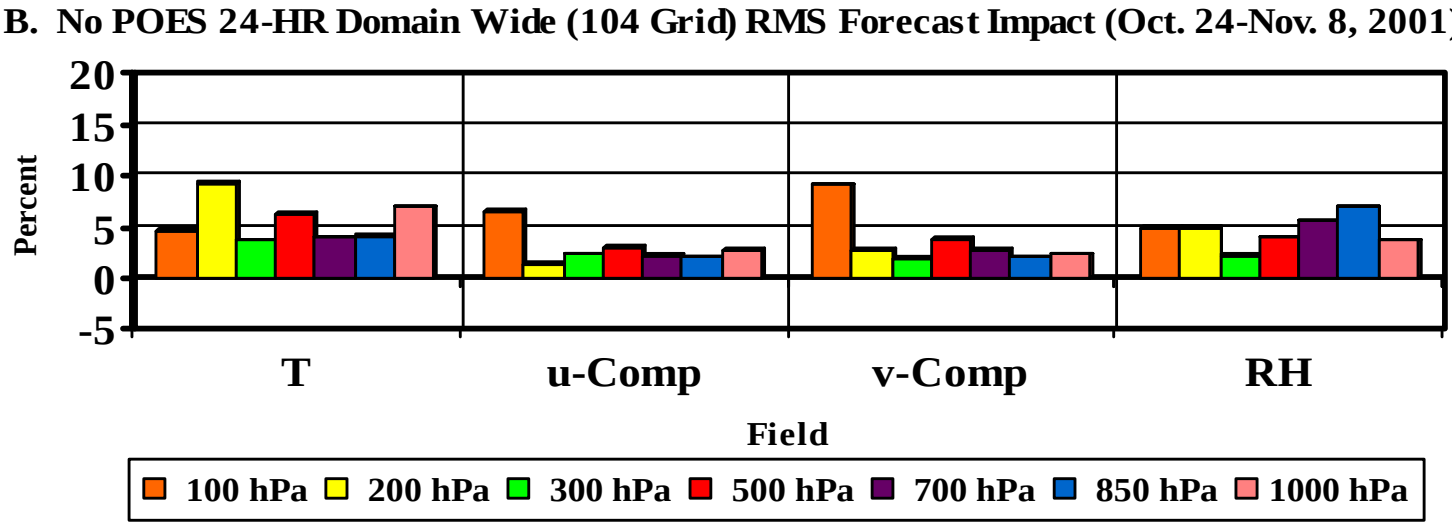
3h 40km RUC cloud-top fcst
No GOES cloud assimilation

GOES impact on Eta forecast significant and positive last autumn

No-GOES



No-POES



Time summed forecast impact (%) of no GOES and no POES on 91 km grid covering nearly entire EDAS domain for T, RH, u, and v meteorological fields after 24-hrs of 32-km Eta model integration. Test period is 0000 UTC 24 October 2001 to 1200 UTC 08 November 2001.

GOES in NWP, routine and experimental:

Model	GOES Data
NCEP Global	Sounder Radiance, Imager Winds, Imager Radiances
Eta Model	Sounder Radiance, Sounder PW, Imager Winds, Data for LandDataAssimilationScheme, Sounder Clouds
FSL's RUC	Sounder TPW, Sounder Clouds, Rapid-scan winds (exp)
CIMSS CRAS	Sounder PW, Sounder Clouds
Australia (LAPS)	Imager Winds
ECMWF	Imager Winds, Imager Radiances
GFDL (experimental)	Imager Winds
NOGAPS	Imager Winds, Sounder Winds
NAAPS	Imager Biomass Fire Product
CSU RAMS	Imager Biomass Fire Product
UW ALEXI	Change of Sounder Skin Temperature, Imager insolation

Data Assimilation -- GOES radiances and products have a major role

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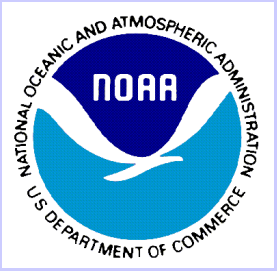


*** Current GOES sounder resolves three tropospheric layers of temperature and moisture every 30-50 km in clear skies over CONUS plus in cloudy skies it determines cloud top properties.**

*** It is filling gaps in conventional and polar orbiting observing systems.**

*** GOES sounder DPI depiction of changes in time and space are being embraced by the NWS forecast offices**

*** NWP impact from three layers of GOES moisture is positive in Eta model. Direct radiance assimilation in GDAS progressing well.**

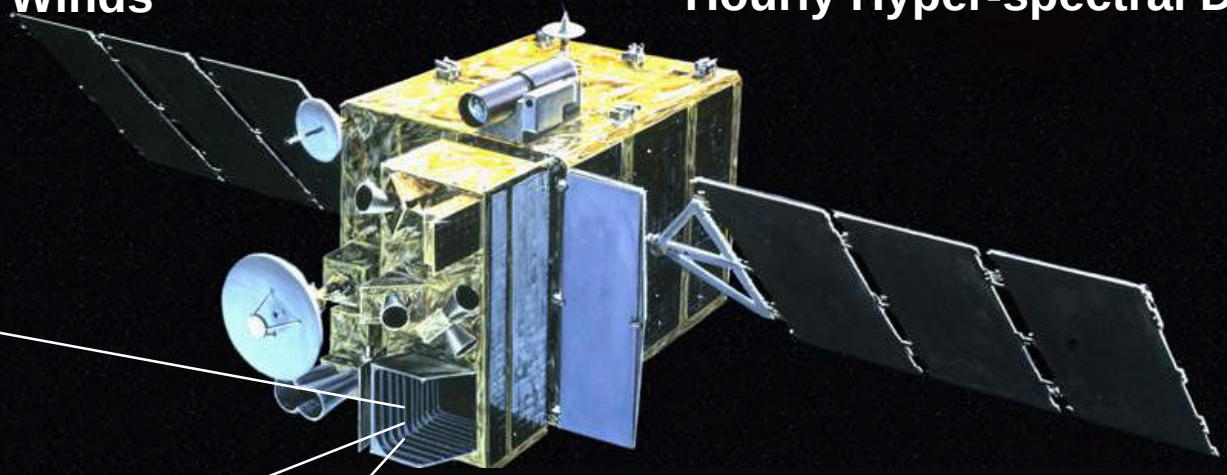
*** But, full worth of geostationary data not yet realized; 4-DVAR strategies offer hope.**

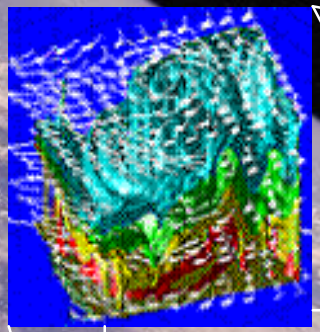
*** Beyond NWP, there are other areas where GOES data can be useful but metrics are elusive**

GIFTS in 2008 will be pathfinder for HES

NASA Test of New Technology for Atmospheric Temperature, Moisture, & Winds

NOAA Demo of Real Time Processing and Use of Hourly Hyper-spectral Data





4-d Digital Camera:

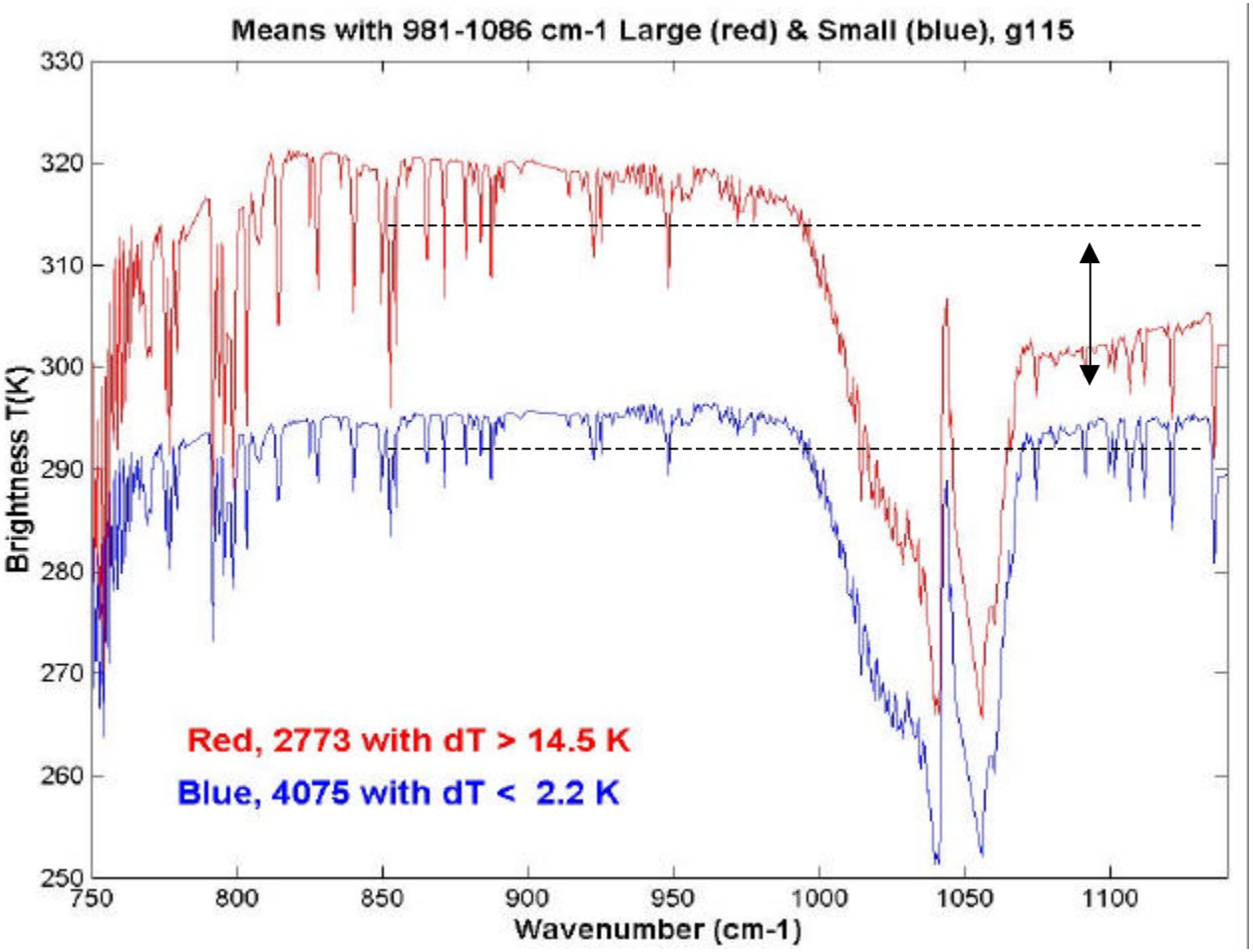
Horizontal: Large area format Focal Plane detector Arrays

Vertical: Fourier Transform Spectrometer

Time: Geostationary Satellite

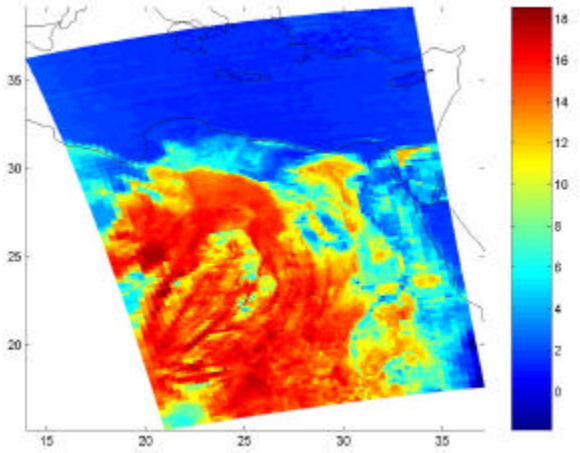
Inferring surface properties with high spectral resolution data
Barren region detection if T1086 < T981

Barren vs Water/Vegetated

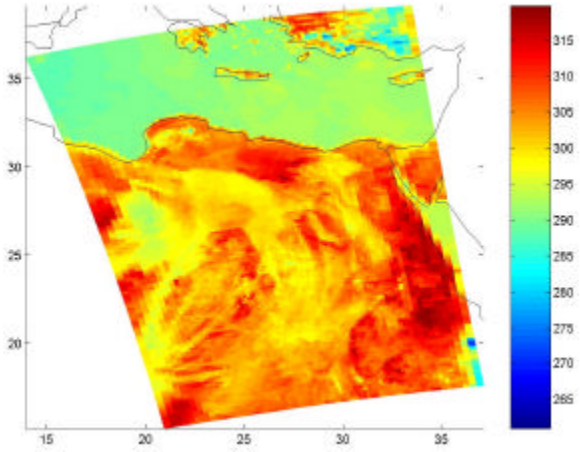


AIRS data from 14 June 2002

T(981 cm^{-1})-T(1086 cm^{-1})

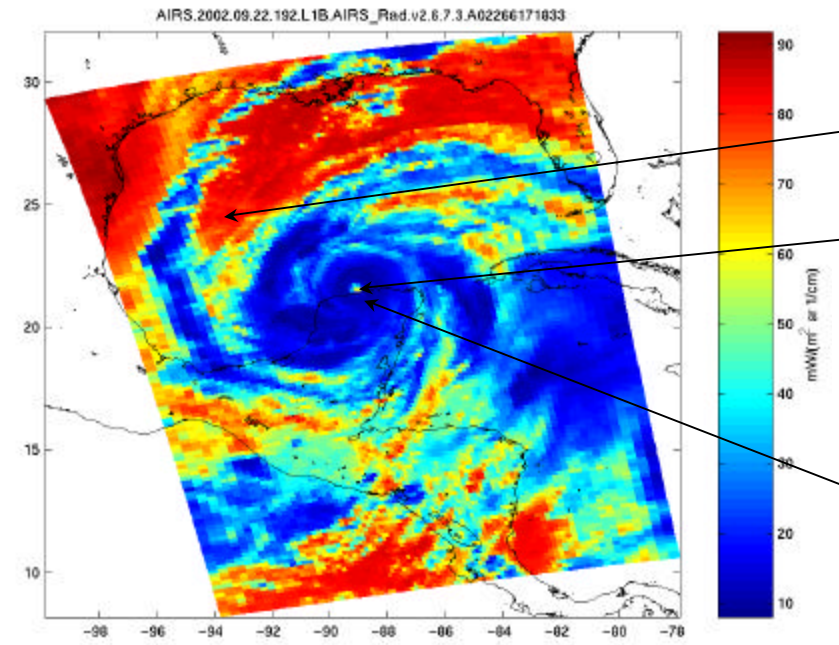


T(1086 cm^{-1})

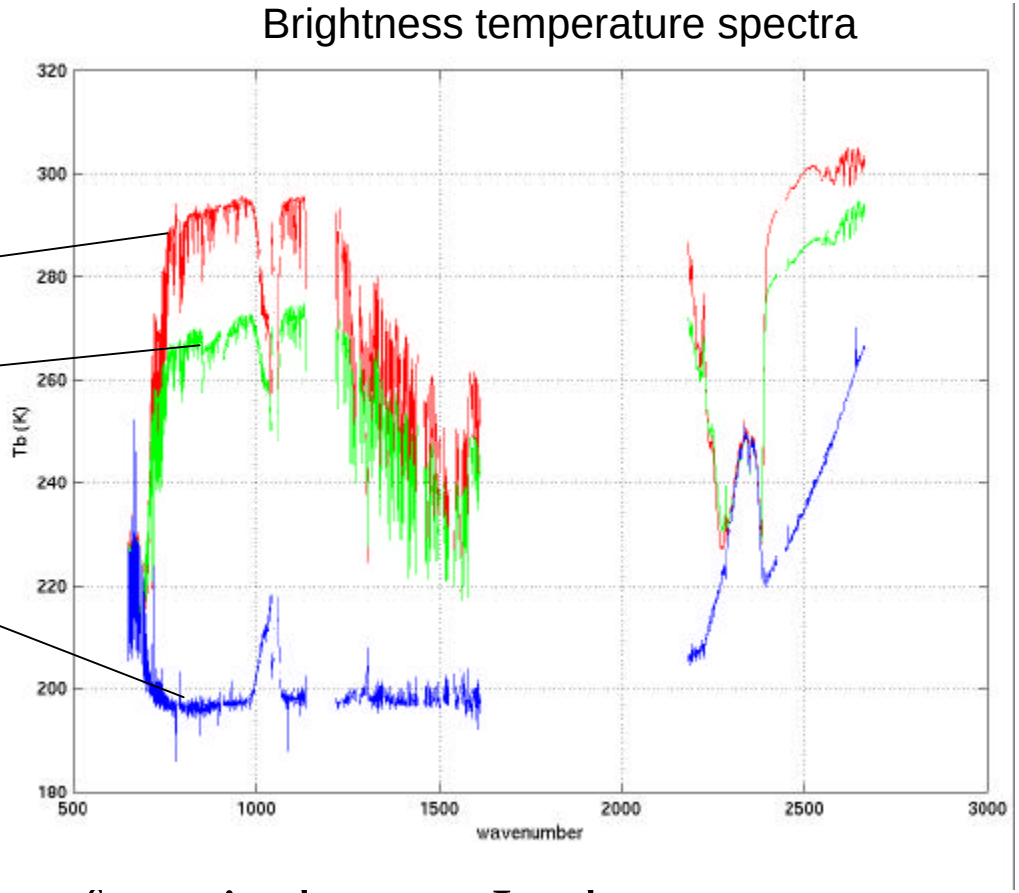


Brightness Temperature Spectra reveal changes in atmosphere from eye to boundary of Tropical Cyclone

~999 1/cm radiances

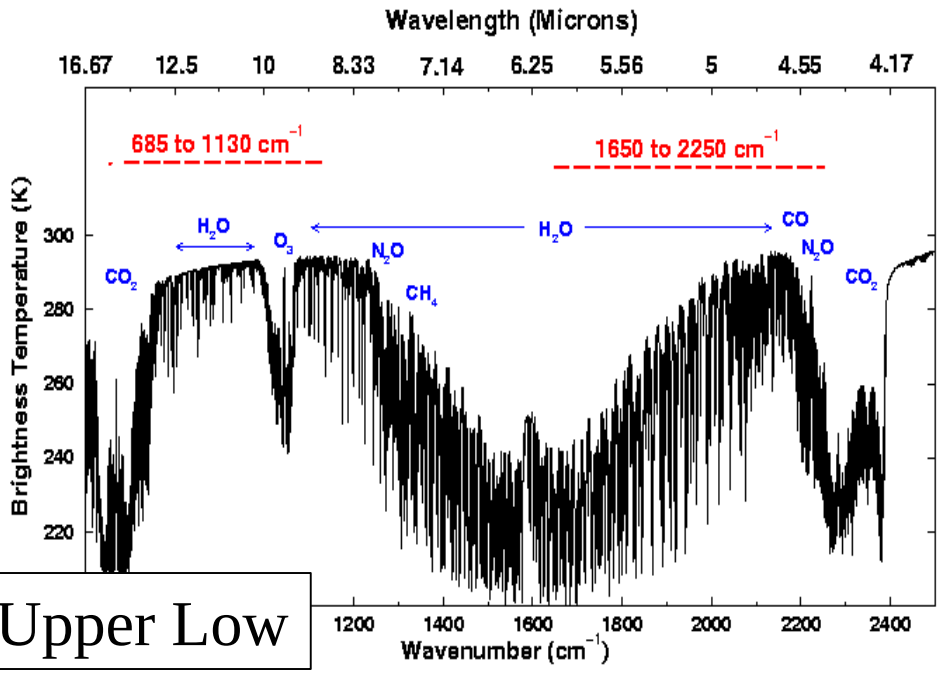


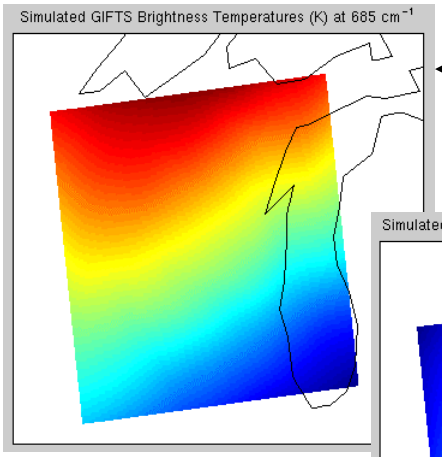
Brightness temperature spectra



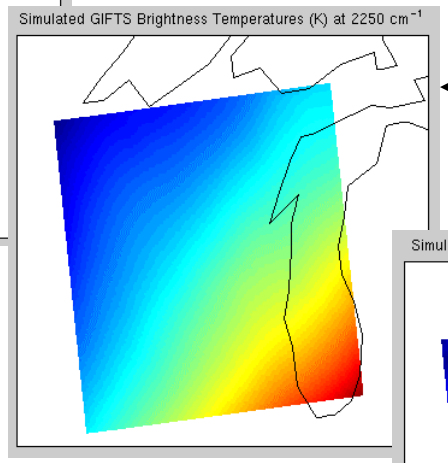
AIRS observations of tropical storm Isadore
on 22 Sept 2002 @ ~19:12-19:18 UTC

GIFTS Spectral Imaging Simulation



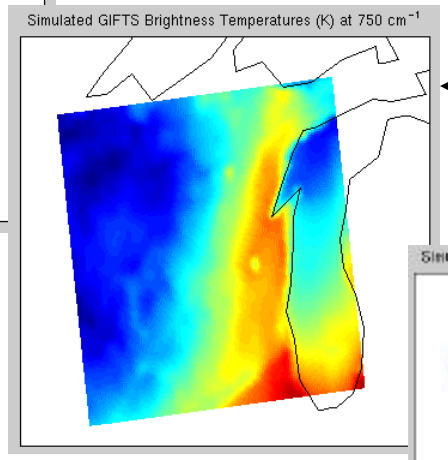


Upper High

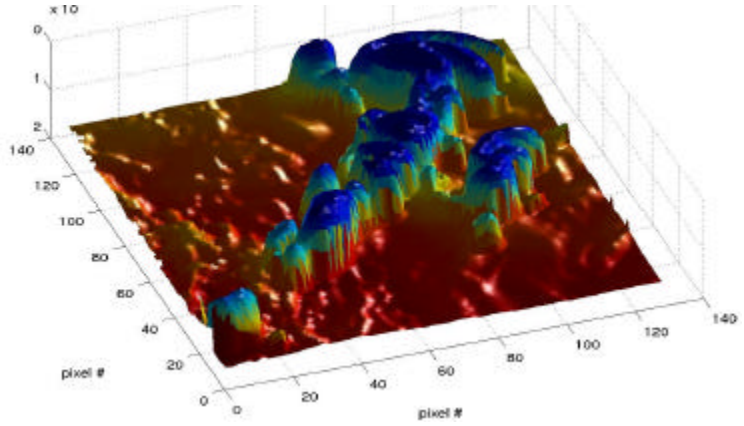


Upper Low

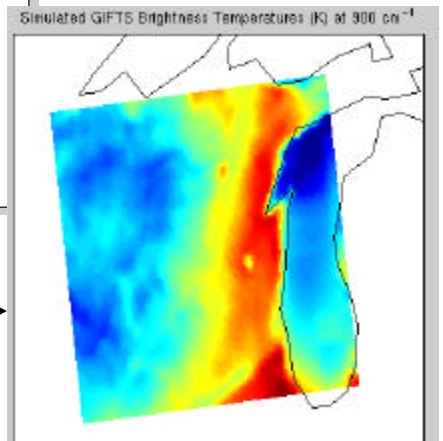
GIFTS 2 Bands Spectral Measurements



Middle

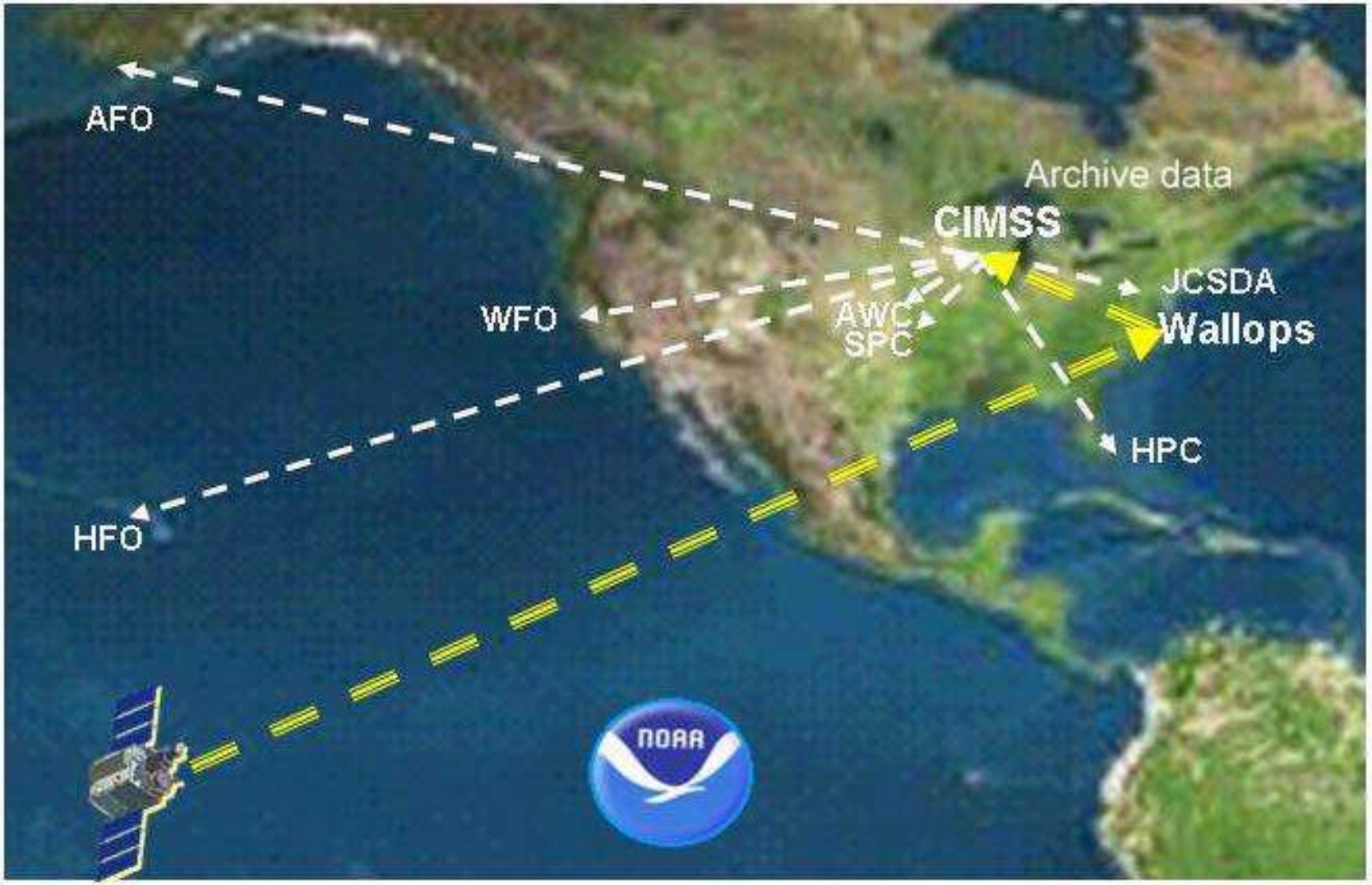


Surface



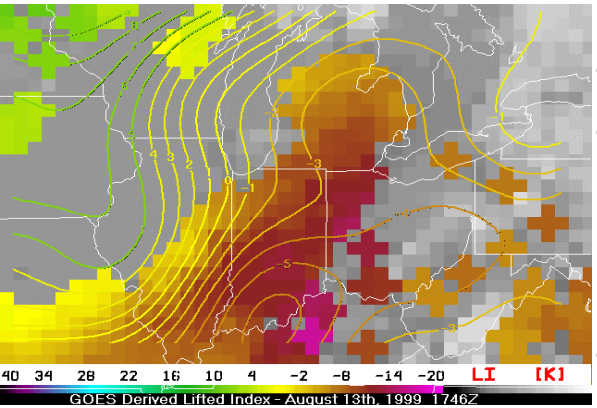
NOAA Demonstration Plan

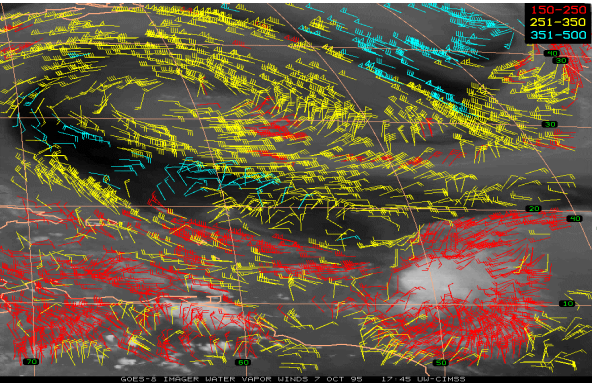
NMP Earth Observing 3



GOES in Numerical Weather Prediction
0-2 Days

- Build on activities of Joint Center for Satellite Data Assimilation
  - GOES impact on weather forecasts likely to be greatest in first 2 days





For precipitation forecasting

- Improve specification of precipitation location and intensity
- Could be key to location and timing of "Storm Initiation"
  - Differential moisture flux

Assimilation over land "easier" for smaller, IR FOVs

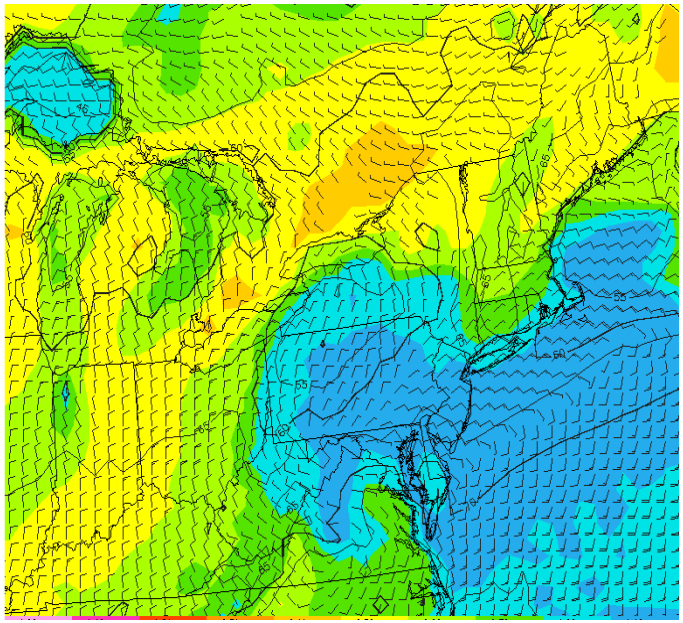
- Direct use of radiances for vertical moisture and temperature gradients
  - Need to define "reasonable" subset of representative channels
    - Build on AIRS
    - Build on GIFTS
- Direct use of Cloud Imagery
  - Cloud composition, placement, removal, motion and trends

- Apply a measure of "confidence" in the observation – especially important for ensemble and targeting strategies.

GOES in "Objective Nowcasting 0-6 hours - - - - The "Watch Period"

By 2010, forecasters will ***not*** be able to look at all observations individually

- Emerging new users need frequent updates
  - Energy sector (Max/min temps for days and hours)
- Need to provide forecaster tools that depict all data as closely as possible
  - Allow users to see high-resolution, 4-D depictions of "Gridded Obs"
  - Less "dynamically constrained" than longer-range NWP
  - Needs fast turn-around



- "Instant integration"
- Combine best of all systems
  - Combine Raob, Aircraft, Profile winds and GOES RH to produce Moisture Flux
  - Need to capture both current and past observations
  - Add/subtract/move clouds
  - Need new ideas
- Note Different roles of Products and Radiances vs. NWP
- Need to identify areas of "Confidence" in analysis and nowcasts

Direct use of GOES Products by forecasters
0-2 hours - - - - The "Warning Period"

- Will continue to rely on "Products" instead of radiance

  * Derived Product Image (DPIs) information will become increasingly important

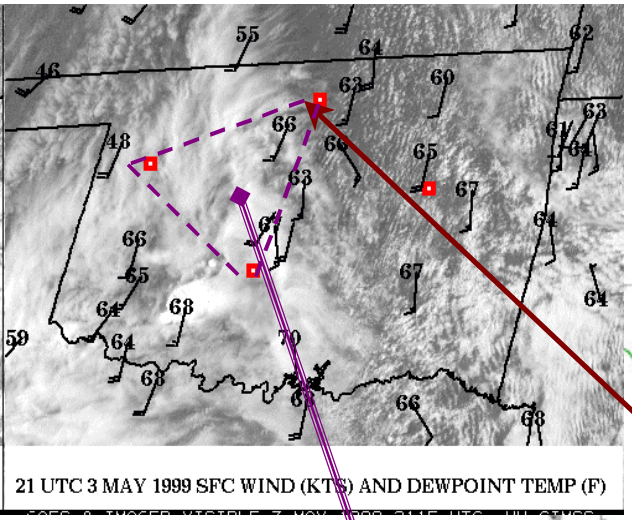
    - Easy to *interpret*
    - Easily integrated with "Nowcasting" products
      - Need techniques for "Auto Alerting"

  * Applications likely to expand

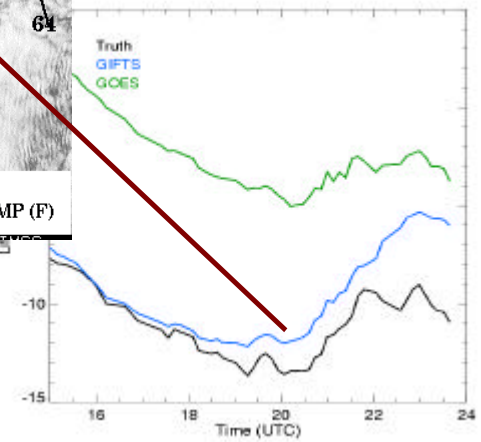
    - Pre-convective storm location/intensity
    - Icing
    - Fog - Development/Dissipation
    - Wild fires
    - What the user needs - especially for products from new sounder

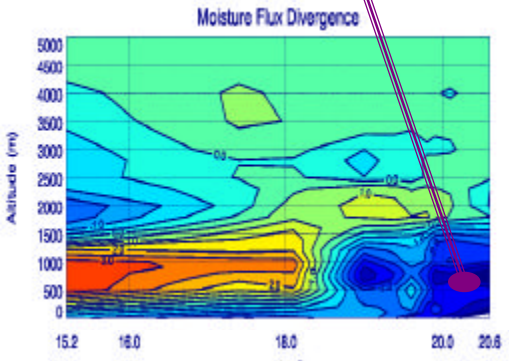
  * Real-time model verification

    - Model products will be displayed as "Synthetic GOES Images"



Lifted Index

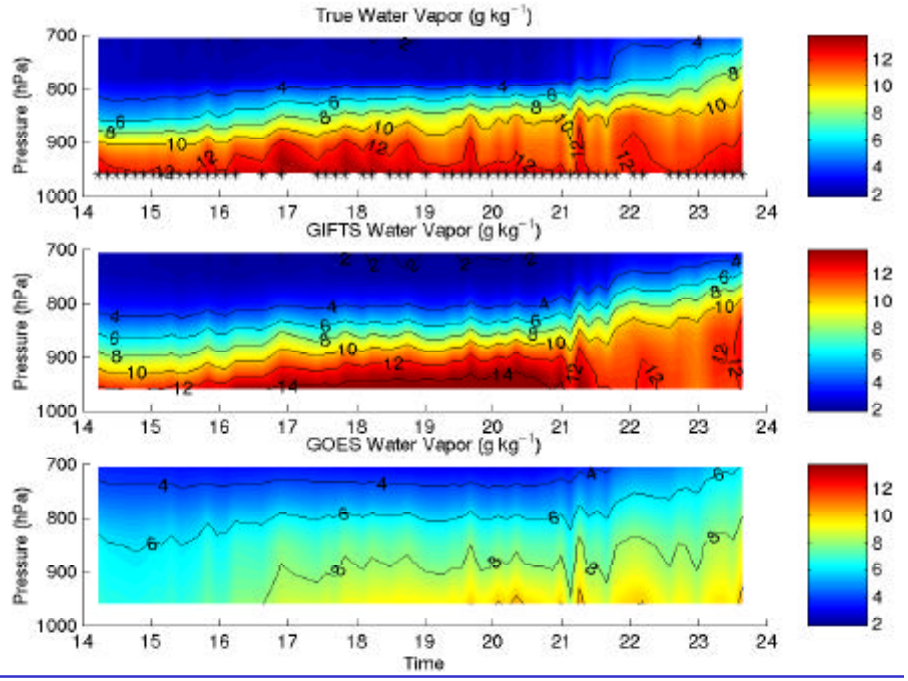




How do we get there?

- *Build Upon Existing Research/Development Programs*

Time series of low-level vertical moisture structure during 9 hours prior to Oklahoma/Kansas tornadoes on 3 May 1999



Truth>

GIFTS>

Note GIFTS retains strong vertical gradients needed to detect changes in convective instability

Current GOES>

GIFTS traces moisture peaks and gradients with greatly reduced errors

- Include Total Infrastructure
  - Ground Receivers
  - Data Ingest Systems
- Applications Development
  - Data Assimilation
  - Product Generation
  - User ***Information*** Displays
- Data System Emulations
  - Know what you will see

Remember the End User

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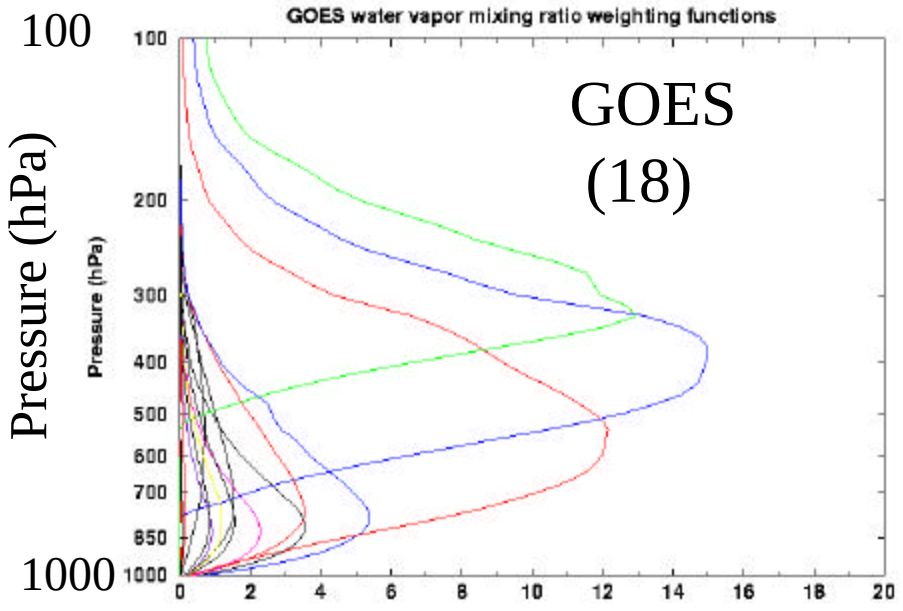
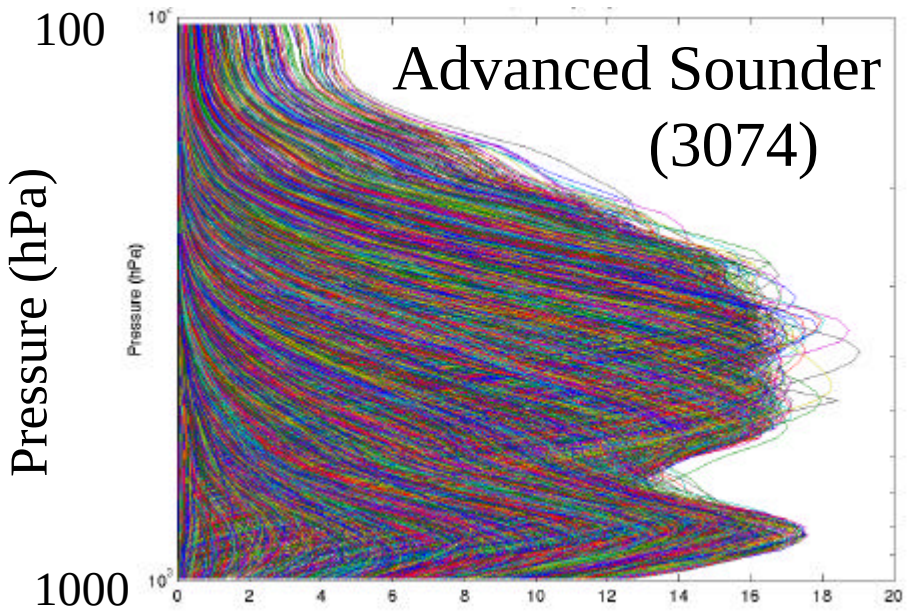




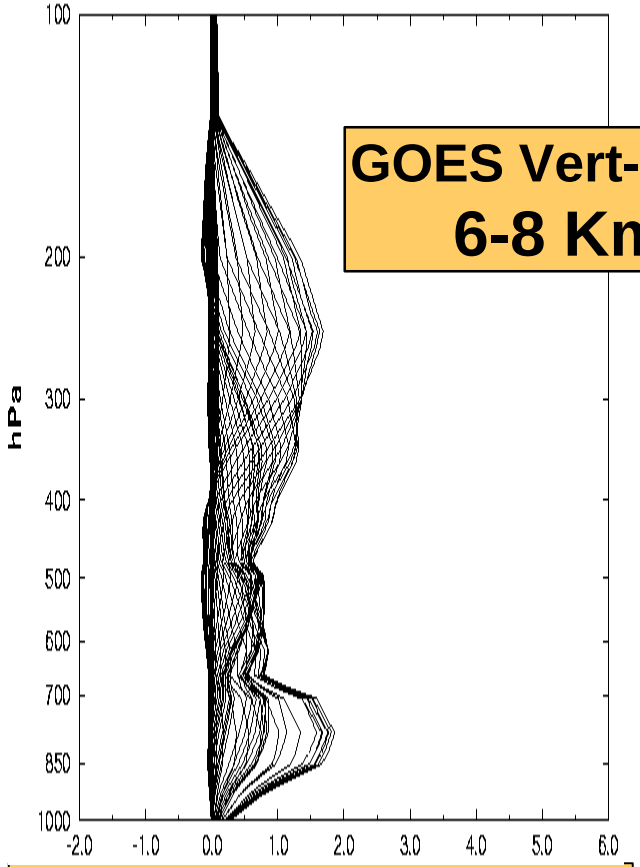
Moisture Weighting Functions

High spectral resolution advanced sounder will have more and sharper weighting functions compared to current GOES sounder.

Radiance data and retrievals will have better vertical resolution.

GIFTS Vertical Resolution Analysis for WV

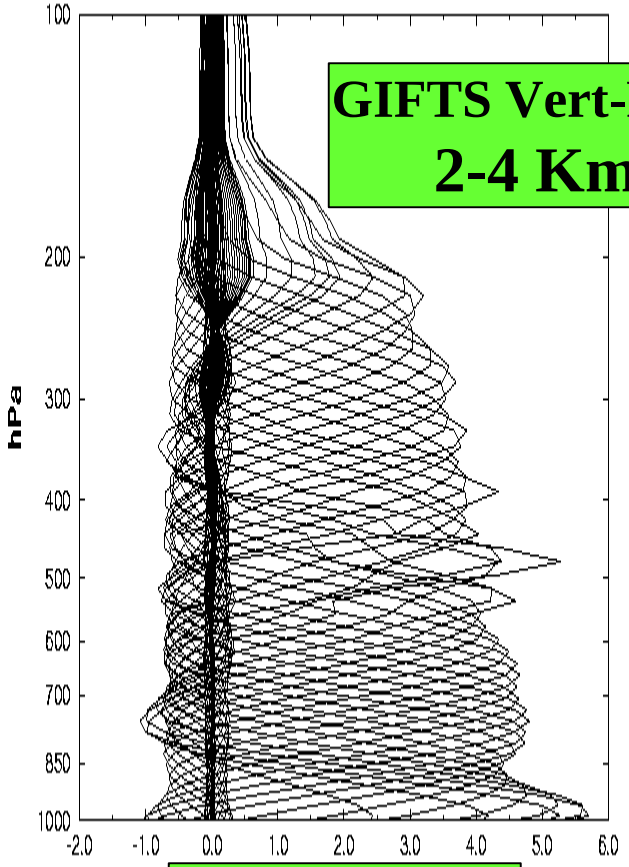
Objective: Improved Water Vapor Information



GOES Vert-Res.:
6-8 Km

Current - GOES

~2 Pieces



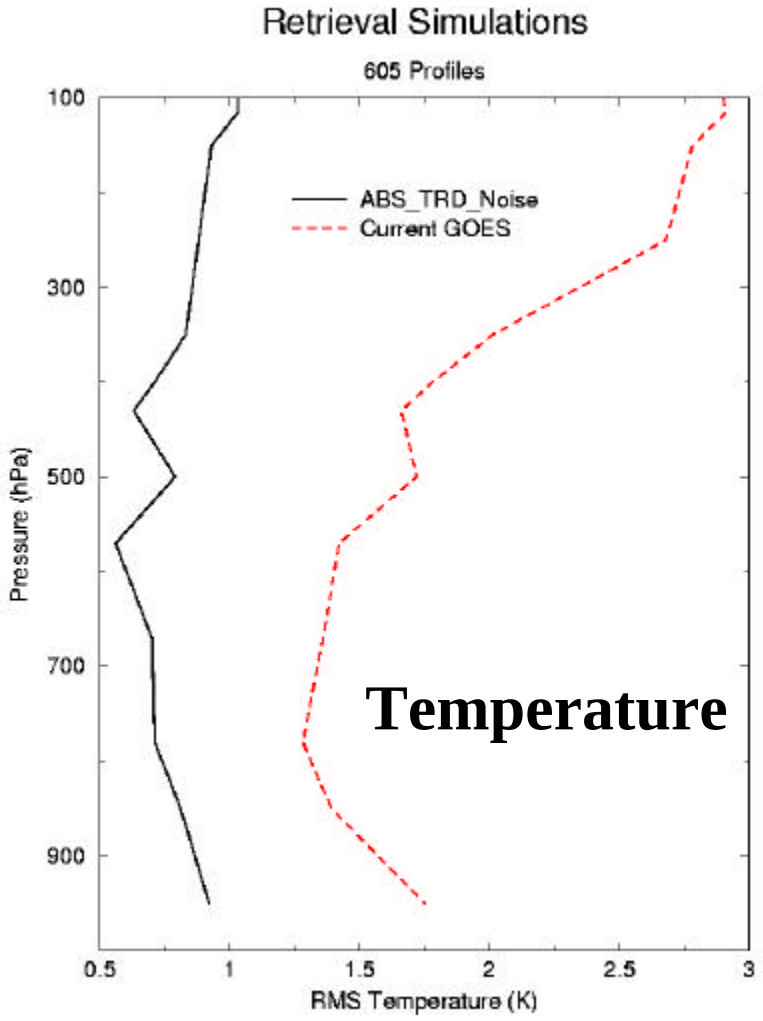
GIFTS Vert-Res.:
2-4 Km

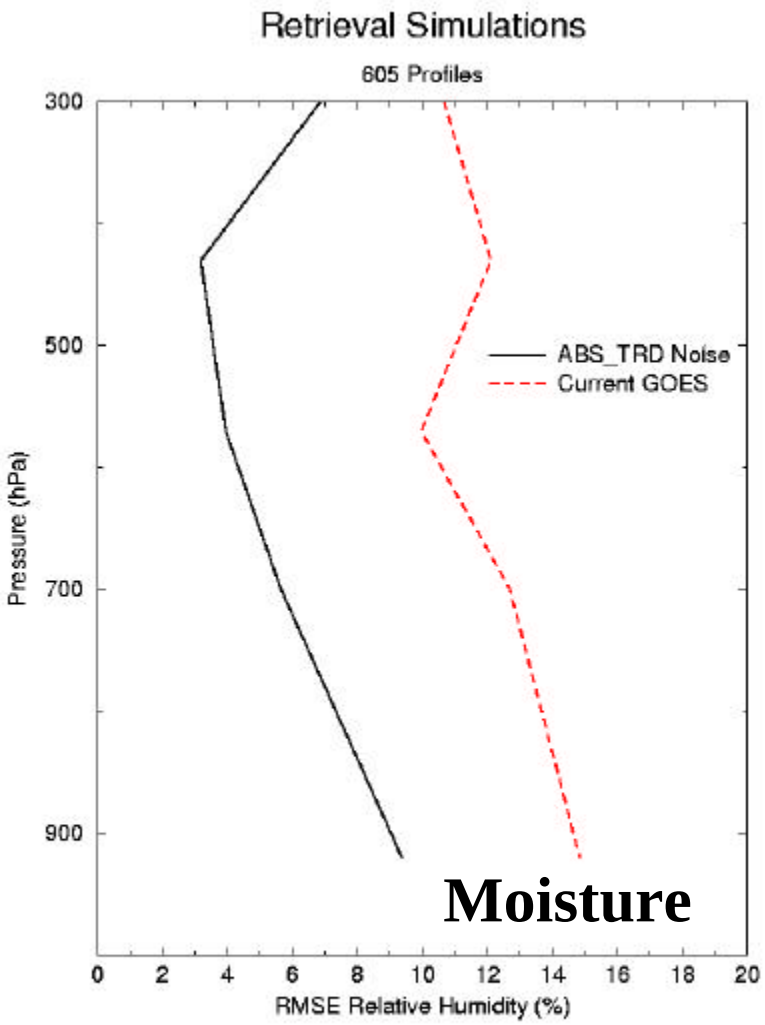
GIFTS

8-9 Pieces

Simulations of Low vs High Spectral Resolution Retrievals

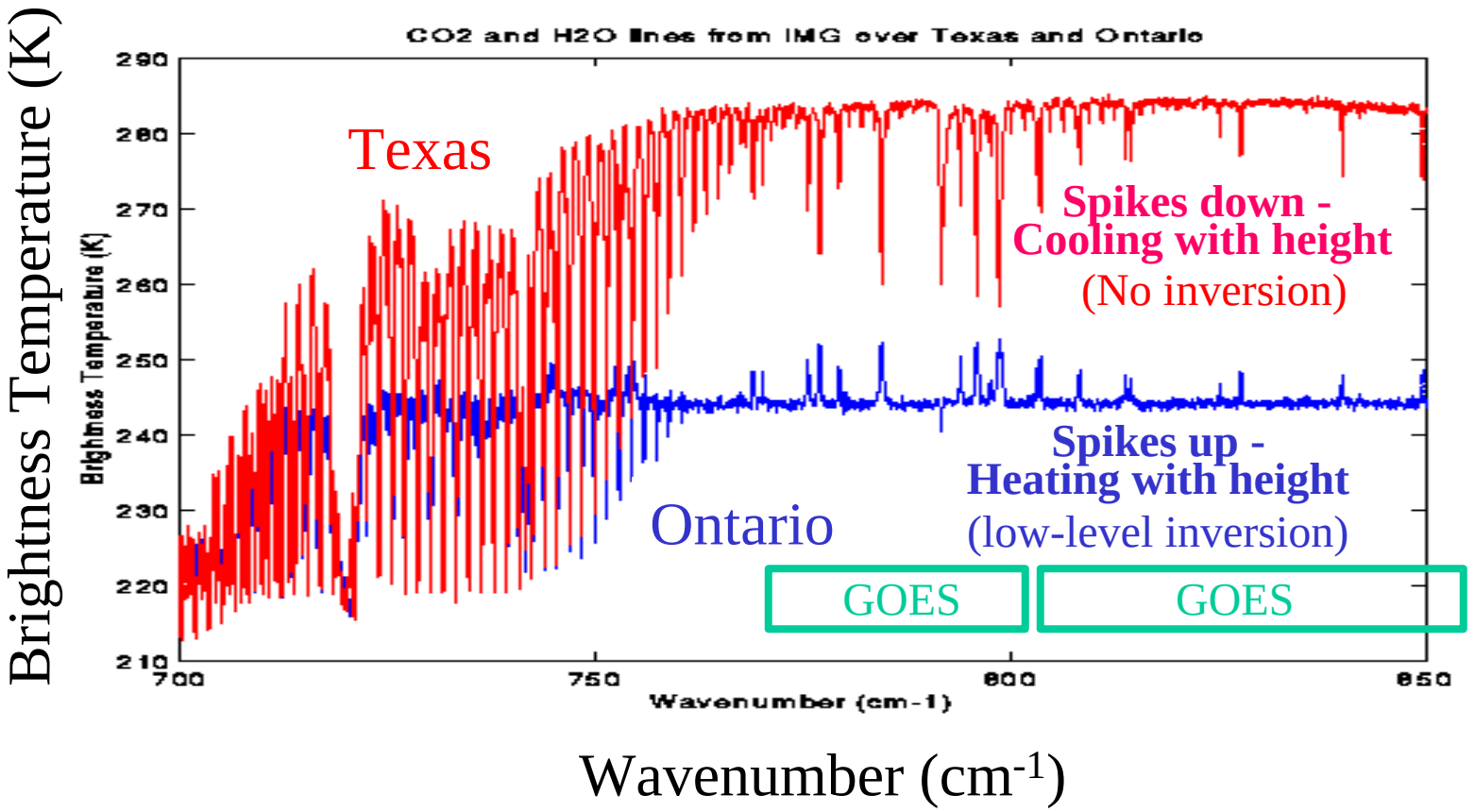
Geo-I gets <1 K rms for 1 km T(p) and <10% rms for 2 km RH(p)





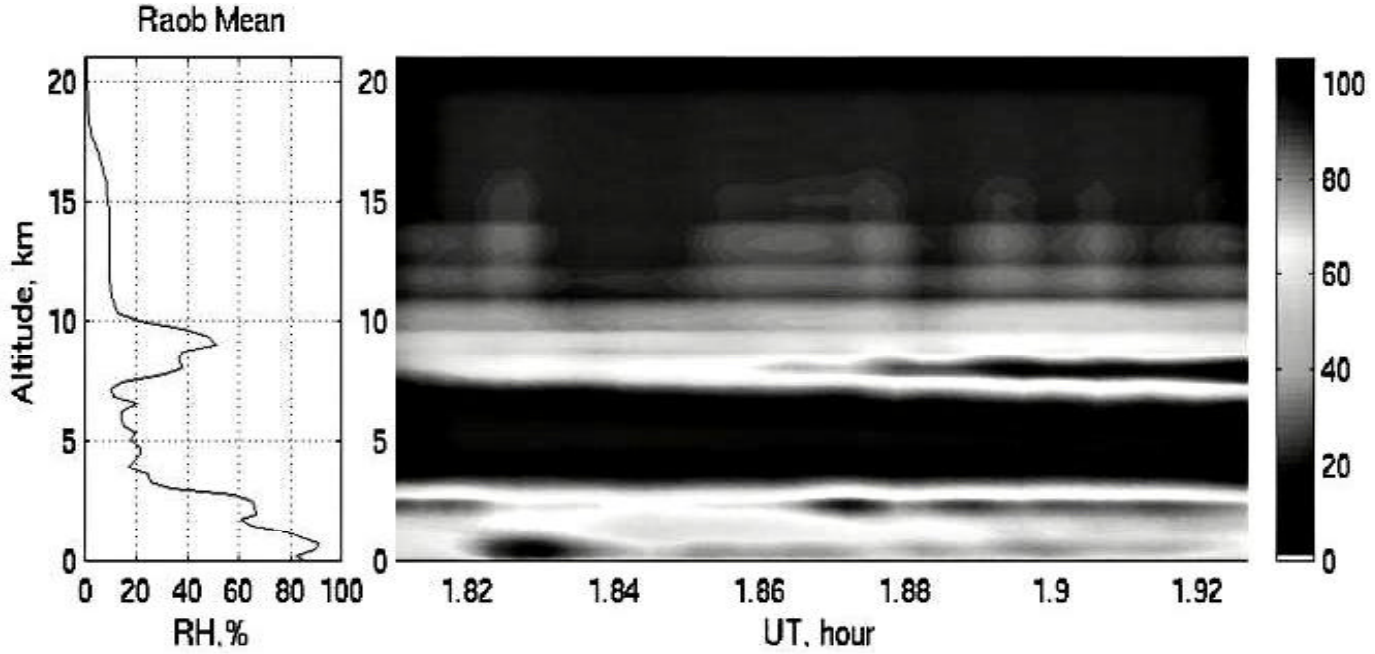
Strategy is (1) use all channels in a regression first guess and then (2) use sub-set of channels for physical retrieval

Detection of Temperature Inversions Possible with Interferometer

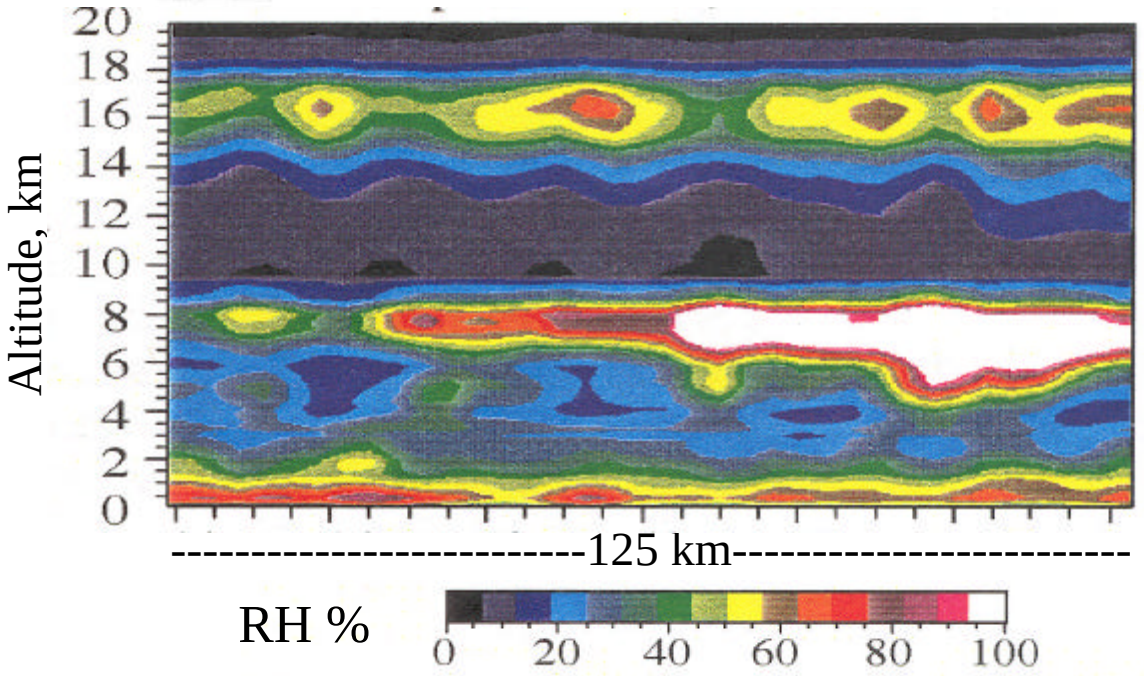


Detection of inversions is critical for severe weather forecasting. Combined with improved low-level moisture depiction, key ingredients for night-time severe storm development can be monitored.

WV vertical structure revealed with Geo-Interferometer



Two flight tracks from NAST-I during CAMEX-3 September 14, 1998



HES balance of temporal (15 min), spectral (.5 cm-1), spatial (1-10 km), and radiometric (.1 K) capabilities will

* Depict water vapor as never before by identifying small scale features of moisture vertically and horizontally in the atmosphere

* Track atmospheric motions much better by discriminating more levels of motion and assigning heights more accurately

* Characterize life cycle of clouds (cradle to grave) and distinguish between ice and water cloud (which is very useful for aircraft routing) and identify cloud particle sizes (useful for radiative effects of clouds)

* Measure surface temperatures (land and sea) by accounting for emissivity effects (the improved SSTs would be useful for sea level altimetry applications)

* Distinguish atmospheric constituents with improved certainty; these include volcanic ash (useful for aircraft routing), ozone, and possibly methane plus others trace gases.

Summary

*** GOES Sounder utilization is still evolving and improving; another decade of opportunity**

*** Excellent data sets are being gathered to facilitate sounder science and algorithm development (e.g. IHOP, AIRS, 4 geo sounders)**

*** GIFTS is serving a pathfinder role for HES; NOAA will use GIFTS to set early utilization of HES**

*** The right balance of spatial, temporal, spectral, and radiometric capabilities is nearer**

FY03 GIFTS-PAP Activities

On critical path are

1. **Ground system design for reception and L0 to L1 processing**
2. **ATBDs for primary GIFTS products**
3. **Validation Plans**
4. **Data Assimilation Strategies**
5. **Visualization systems design**

FY04 is first year with competed participation

Initial R&D activities emphasize experiments with current GOES Sounder and EOS (Earth Observing System) AIRS (Atmospheric InfraRed Sounder) data and with aircraft high spectral resolution data sets from Scanning HIS and NAST-I (NPOESS Airborne Sensor Testbed-Infrared).

GIFTS PAP will be administered by ORA with TAC guidance

GOES Program Manager

ORA GOES Scientist « EMC GOES Scientist

ICAPOP SPOP WPOP PPOP --- POPs

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Plans