Microwave Radiance Assimilation at NRL: Advanced Techniques, Developments and Future Sensors

U.S. NAVAL RESEARCH LABORATORY

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Introduction

Assimilation of passive microwave radiometers has proven useful in Numerical Weather Prediction (NWP), providing temperature sounding information, water vapor information, along with precipitable water information. The focus of this work is how best to incorporate this information into the Naval Research Laboratory Atmospheric Variational Data Assimilation System-Accelerated Representer (NAVDAS-AR), along with recent improvements which enable better use of this information. Some key developments have been: experiments replacing Total Precipitable Water (TPW) retrieved products with direct assimilation of channels sensitive to TPW (18, 23, and 37 GHz), addition of correlated observation error for microwave and Infrared sensors, and addition of GMI, SAPHIR, and AMSR2 to NAVDAS-AR. Key among these developments is the ability to assimilate with correlated observation error in NAVDAS-AR, however, the only microwave sensor which is assimilated using correlated observation error is ATMS, currently. We are currently considering using correlated observation error for sensors with water vapor sensitive channels such as SAPHIR, MHS, and AMSU-A. Finally, as part of the calibration and validation of the Compact Ocean Wind Vector Radiometer (COWVR), we will discuss plans for assimilation of products, and direct assimilation of microwave channels (18.7GHz, 23.8GHz, and 34.5 GHz). We use SDR radiance products from Windsat (a similar radiometer to COWVR with full polarimetric capability) to investigate the ability of fast radiative transfer models to simulate the third and fourth Stokes parameters.

Questions

- What are the benefits of adding SAPHIR, AMSR2, and GMI?
- What is the impact of removing TPW retrieval assimilation from NAVDAS-AR?
- How should we approach sensors with slightly different characteristics that appear on multiple platforms such as AMSU-A?
- What improvements are necessary to simulate the third and fourth Stokes parameters?

Methods

- Add new sensors to NAVDAS-AR and run cases with NAVGEM global model utilizing available system metrics (Forecast Sensitivity Observation Impact, Radiance Fits to Observations, etc.)
- Desroziers Method (Desroziers, 2005) to calculate correlated observation error for new sensors
- Replacing TPW retrievals with direct assimilation of microwave channels
- Preparing for COWVR: ECMWF Analysis Fields in combination with RTTOV and CRTM to simulate Windsat, and compare with Windsat observations of 3rd and 4th Stokes parameters

New Microwave Sensors in NAVDAS-AR

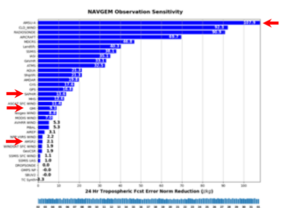


Figure 1: NAVGEM FSOI by Sensor type ranked by decreasing FSOI

- AMSU-A now ranks highest out of all sensors owing to replacing TPW retrievals with direct assimilation of window channels
- Of the new sensors added SAPHIR ranks the highest as measured by FSOI
- GMI and AMSR2 show positive impact as measured by FSOI
- Metrics shown are for July 1, 2017 to August 01, 2017 with a run initialized May 15, 2017

SAPHIR

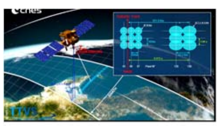
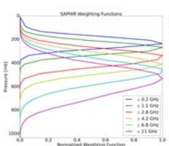


Figure 2: Illustrating SAPHIR swath and scanning geometry taken from https://megha-tropiques.cnes.fr/en/MEGHAT/lien2_sat.htm



Channel	Frequency (183 GHz +/-)
1	0.2
2	1.1
3 (~GMI 12)	2.8
4	4.2
5 (~GMI 13)	6.8
6	11

Figure 3: Weighting Functions for six channels on SAPHIR

- With it's orbit focusing on the tropics, and a unique 183 +/- 11 GHz channel, SAPHIR provides valuable and unique information
- Figure 4 shows the FSOI breakdown by channel with Channels 4,5, and 6 showing significantly positive impact, and neutral to slightly negative impact for channels 1,2, and 3.
- The innovation statistics in Figure 5 show a good fit between simulations an observations
- With water vapor channels that are highly correlated, along with errors that are correlated, SAPHIR is a prime candidate for correlated observation error treatment

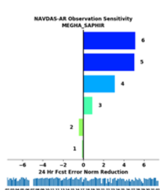


Figure 4: FSOI impact by channel for SAPHIR

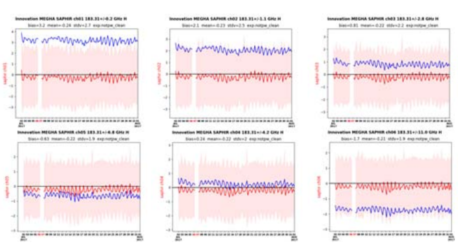


Figure 5: Innovation Statistics for SAPHIR 1 July 2017 to 1 Aug 2017

GMI

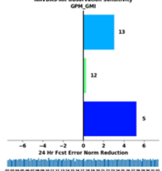


Figure 6: FSOI by Channel for GMI

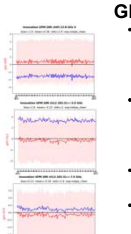


Figure 7: Innovation Statistics for GMI 1 July 2017 to 1 Aug 2017

- With two 183 GHz Channels (+/- 3GHz, and +/7GHZ), along with a 23 GHz channel GMI has the potential to provide information regarding water vapor
- Channels 12 and 13 perform similarly to SAPHIR Channels 3 and 5, where Channel 12 is neutral to slightly positive, whereas Channel 13 shows good positive impact
- Channel 5, the 23 GHz channel seems to outperform all others
- Innovation statistics in Figure 7 show a good fit between simulations and observations
- Additional channels near 18, and 37 GHz may add more information as with other sensors AMSU-A, MHS, and SSMIS

AMSR2

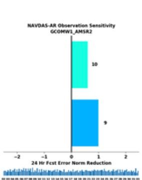


Figure 8: FSOI by Channel for AMSR2

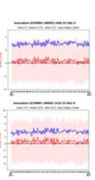


Figure 9: Innovation Statistics for AMSR2

- With two 23 GHz channels (V/H) AMSR has the potential to provide information regarding water vapor
- Both channels show positive impact as measured by FSOI
- Both channels show a good fit between simulations and observations
- Additional channels near 18 and 37 GHz may add more information as was recently done with AMSU-A, MHS and SSMIS

Correlated Observation Error: Future Sensors

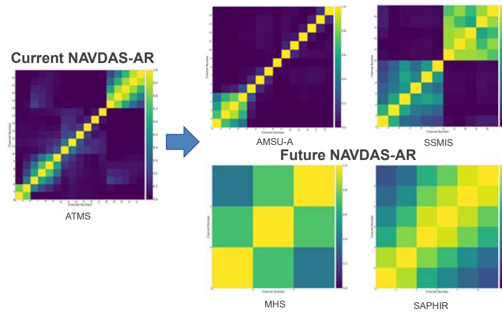


Figure 10: Correlated Observation Error Matrices for Current an future versions of NAVDAS-AR

- Correlated observation error matrices computed using the Desroziers method
- Currently ATMS is the only microwave sensor with correlated observation error
- In the future we will add AMSU-A, SSMIS, MHS and SAPHIR
- Sensors on multiple platforms such as AMSU-A with slightly different characteristics may possess a challenge. What is the best strategy?
  - Treat each platform individually
  - Create a superset/matrix for all platforms

Replacement of TPW retrievals: Effects upon Forecast

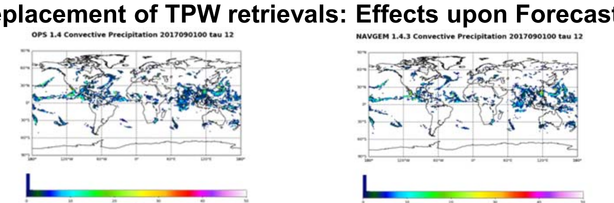
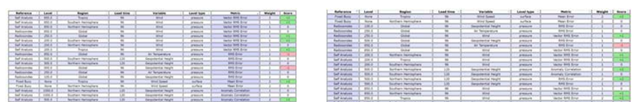


Figure 11: 12 hour convective precipitation for current OPS (left) vs replaced TPW retrievals (right)



Total Score: +8

Total Score: +11

Figure 12: Scorecard with correlated error and new sensor upgrades but without TPW modification (left) and with TPW modification (right)

- The replacement of TPW retrievals with direct assimilation resulted in slightly less convective precipitation for light rain events (Figure 11)
- Replacement of TPW retrievals created a small reduction in humidity totals in the lower troposphere which subsequently reduced rainout at early taus at the start of the forecast
- Experiments with TPW retrieval vs no TPW retrieval resulted in a modestly improved score of +8 vs +11 against OPS (Figure 12).

Preparing for COWVR: Polarimetric Observations and Simulations

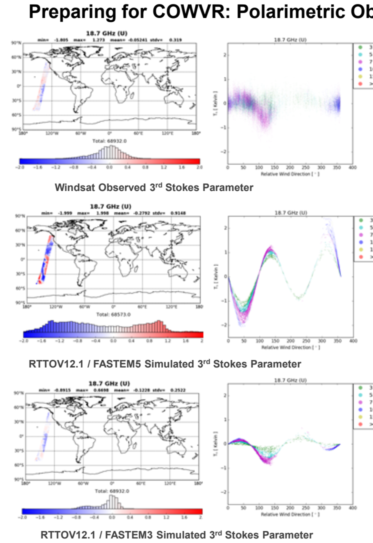


Figure 13: Windsat Observation of 18.7 GHz 3rd Stokes parameter (top), RTTOV12.1 FASTEM5 simulation (middle), RTTOV12.1 FASTEM 3 simulation

- Here we use Windsat's 18.7 GHz 3rd Stokes parameter measurement as means of validating RTTOV and CRTM in preparation for Windsat
- We use 0.5 degree ECMWF fields and the Python RTTOV 12.1 interface (rttov_direct)
- Comparing the upper panel and middle panel in Figure 13 there is clearly a phase difference between the observed (top) and simulated (middle) using FASTEM5
- Chen and Wang, 2016 pointed out this phase shift for FASTEM5, previously
- When reverting to FASTEM3, this phase difference disappears, see bottom panel in Figure 13
- We have developed a Python interface along with a modified version of the CRTM 2.2.1, and we observe the same phase difference between observed and simulated using FASTEM5. FASTEM3 is not available in the CRTM
- RTTOV 12.1 has components which can be used to simulate the 3rd Stokes parameter, while the CRTM requires some modification, and perhaps modifications to update FASTEM or revert to FASTEM3.

Summary

- Three new microwave sensors (SAPHIR, GMI, and AMSR2) have been added to NAVDAS-AR/NAVGEM and show good impact as measured by FSOI, and forecast scores
- Correlated observation error was recently added to NAVDAS-AR, along with one microwave sensor (ATMS), more microwave sensors will be added in the near future
- Comparing Windsat observations of the 18.7 GHz 3rd stokes parameter with simulated from RTTOV12.1 and FASTEM3 are comparable. FASTEM5 appears to have a 90 degree phase shift. Work is needed to update FASTEM 5-6, and CRTM needs modifications to enable 3rd and 4th Stokes

Future Work

- Add Windsat V/H channels to NAVDAS-AR similar to what has been done for GMI, and AMSR2
- Add Correlated observation error capability for SAPHIR, MHS, and AMUS-A, keeping in mind AMSU-A has slightly different channel selection per platform
- After Launch COWVR Calibration and Validation along with adding direct assimilation of V and H channels initially, and perhaps 3rd and 4th Stokes parameters

Acknowledgements

BMK, BCR, and SDS would like greatfully acknowledge support from the U.S. Naval Research Laboratory under element X.

References

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