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What is a good mix of observations?

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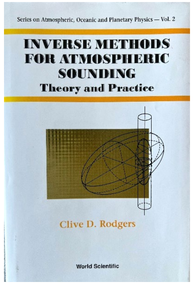
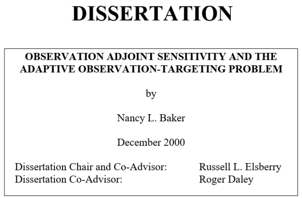
What is a good mix of observations?



Rodgers (2000)



DISSERTATION

OBSERVATION ADJOINT SENSITIVITY AND THE ADAPTIVE OBSERVATION-TARGETING PROBLEM

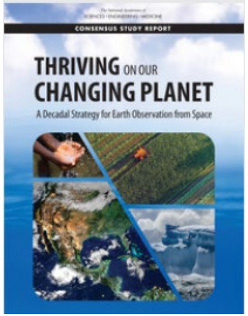
by

Nancy L. Baker

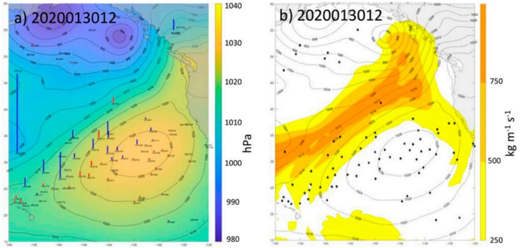
December 2000

Dissertation Chair and Co-Advisor: Russell L. Elsberry
Dissertation Co-Advisor: Roger Daley

Baker (2000)
Langland and Baker (2004)



2018 ESAS Decadal Survey



Reynolds et al, 2023

Fundamental Observations
- MW/IR sounders, radiosondes
- Information content, degrees of freedom/signal

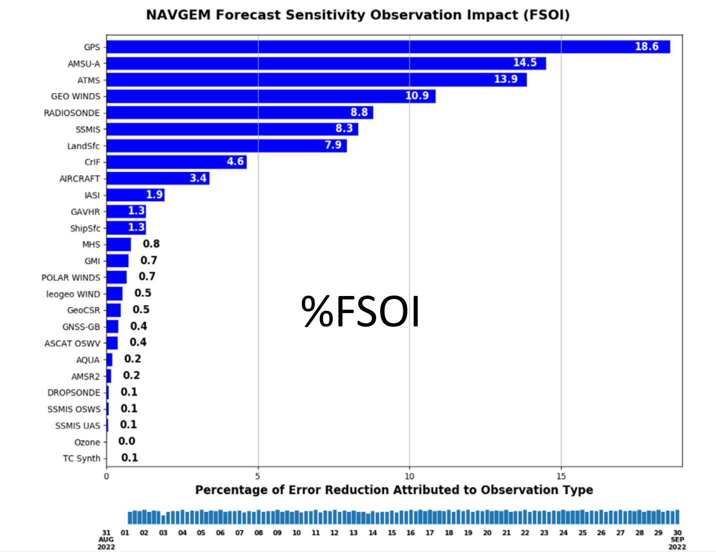
Complementary observations
- MW frequencies sensitive to clouds, surface
- Ozone
- Ocean, sea-ice (cryosphere), land

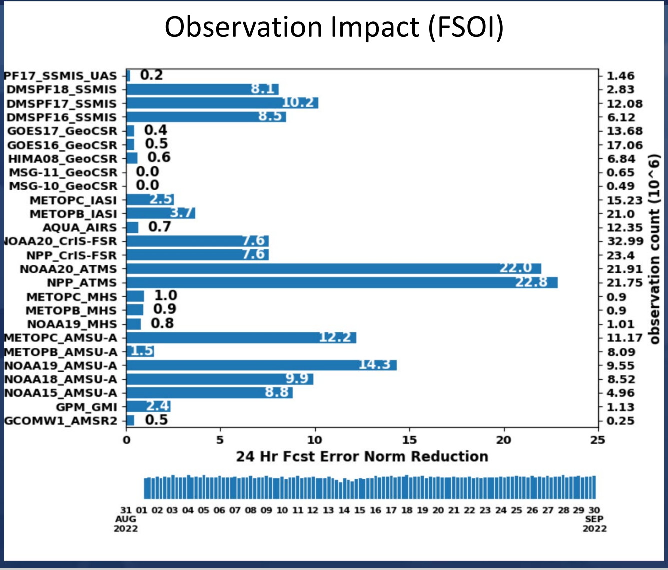
Anchoring observations
- GNSS-RO, surface pressure

Motivation: In a well-tuned DA system, the observations should have a "light touch". Large beneficial FSOI is gained through the assimilation of numerous observations with relatively small impact (small innovations, low sensitivity (FSO)).

What observations do we prioritize for assimilation?
- Overall atmospheric structure
- Gradients in space and time
- Observations that can be effectively assimilated

Motivation: revisiting NAVGEM Hybrid 4DVAR FSOI: Motivation– so many questions …





Why have these rankings changed in the past several years?

Why is the impact of Hyperspectral IR sounders so low?

If the impact of GeoCSR is so low, should we continue assimilating them? Do they increase computational cost?

Why is the impact of N20 CrIS FSR the same as NPP CrIS FSR if we use more channels from N20?

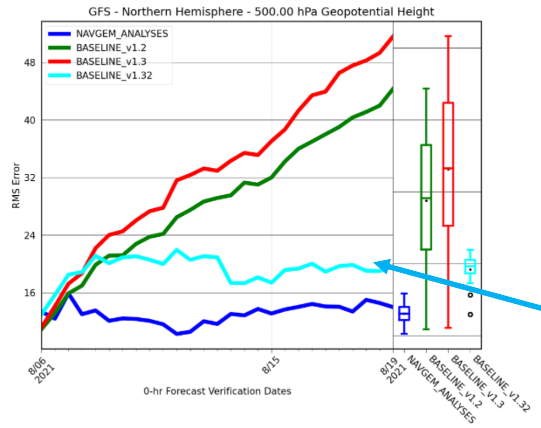
Why is the impact from MHS so low?

Why is the impact from METOP-B AMSU-A so low (compared to other AMSU-A)?

Are we underutilizing GPM GMI and AMSR?

Anchoring and Fundamental Observations
Example: NEPTUNE 3DVar enabled by JCSDA-JEDI

500 hPa Geopotential Height RMS Error



NAVGEM Analysis

V1.3 Old Baseline

V1.32 Baseline

- Includes hydrostatic column update for pressure

V1.32L101 Baseline

- Raobs, aircraft, AMVs (GEO and polar)
- Includes hydrostatic column update for pressure integrating from the surface
- No surface obs assimilated, but reflects changes due to temperature
- Slight changes to static background error covariance

Native v2_r4

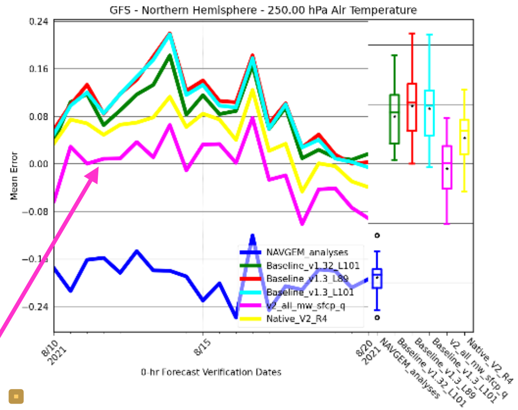
- **Increased observation density**
- **Surface pressure increment: Obs over water: coastal marine, ship, drifting and fixed buoy**

Baseline Q1FY23 V2_all_mw_sfcp_q

- Increased observation density
- Surface pressure increment: Obs over water: coastal marine, ship, drifting and fixed buoy
- **Revised Microwave (MW) channel selection**
- **Additional satellite winds, and MW radiometers: SSMIS F16, F17, F18, AMSR2, GMI**

NAVGEM Analysis

Mean T error at 200 hPa



Cycling assimilation tests using the JCSDA JEDI 3DVar and NEPTUNE

Assimilation of surface pressure observations over ocean regions dramatically lowers the analysis errors.

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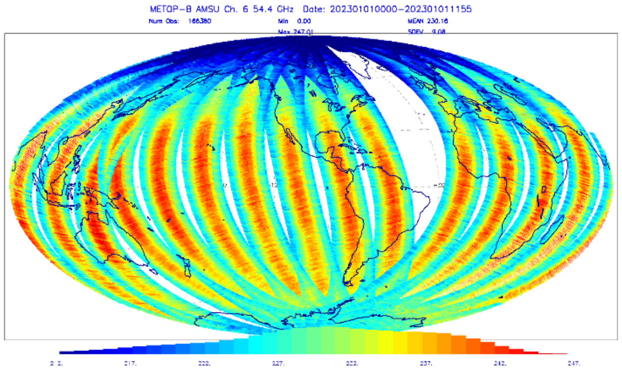
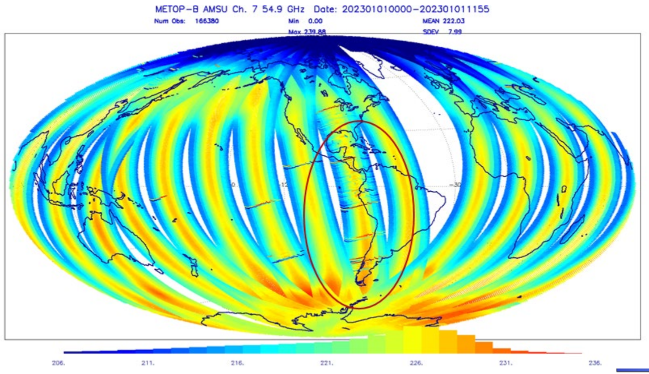
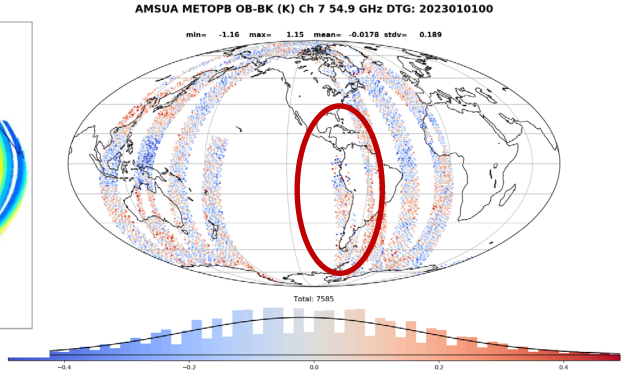
Microwave Sounders: Fundamental Observations
Noisy/bad scans with AMSU-A METOP-B channels 6 & 7







Channel 6 for AMSU-A METOP-B:

1. Channel 6 is noisy and has been removed from active assimilation.

Channel 7 for AMSU-A on METOP-B:

1. 21 Dec2022: Niels Borman (ECWMF) via ITWG email: Noted large erratic departures for several scan lines. Confirmed by Yong Chen (NOAA/NESDIS)
2. NRL/NAVGEM: QC looks like it is removing bad scans in channel 7
3. Bias corrected mean and S.D. are similar to METOP-C channel 7
4. Ch. 7 has the largest FSOI for METOP-B and is similarly beneficial for METOP-C. → assimilate

Complementary Observations
MW channels sensitive to clouds and water vapor

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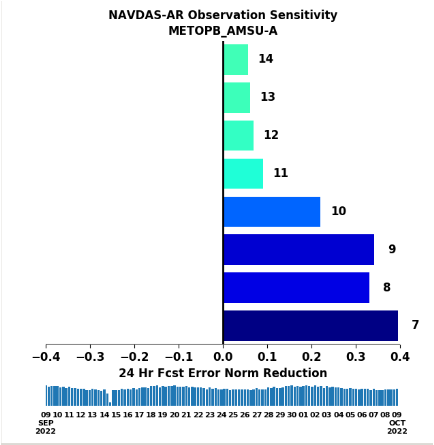
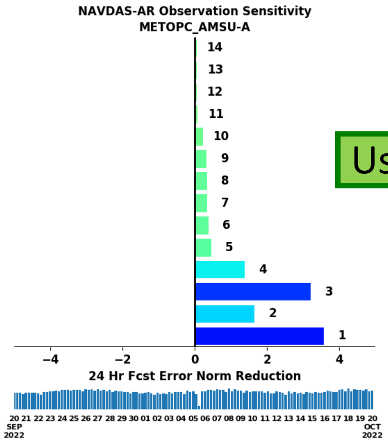
METOP-B AMSU-A
OPS and develop

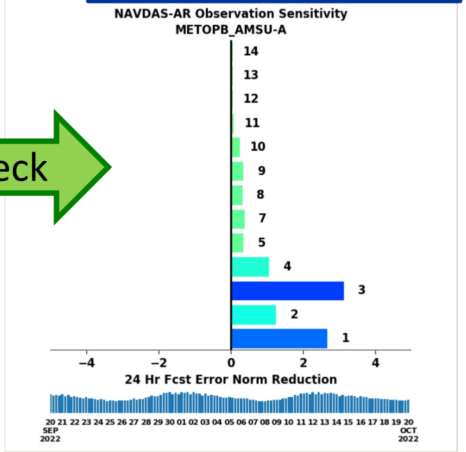


METOP-C AMSU-A
OPS and develop



Use ch 1&2 CLW check

METOP-B AMSU-A
test



Clear-sky MW assimilation: emission rather than scattering regime.

Over open ocean, we reject observations in the presence of large values of cloud liquid water, surface ice and by ice cloud scattering:

- Ch 1 (23.8 GHz) & 2 (31.4 GHz) to calculate cloud liquid water, Ch 1 & 3 (50.3GHz) to detect surface ice, Ch 15 (89.0 GHz) with Ch 1 & 2 to compute scattering index (SIW).

→ But Ch 15 is always 0.0, so channels 1-6 & 15 were always rejected.

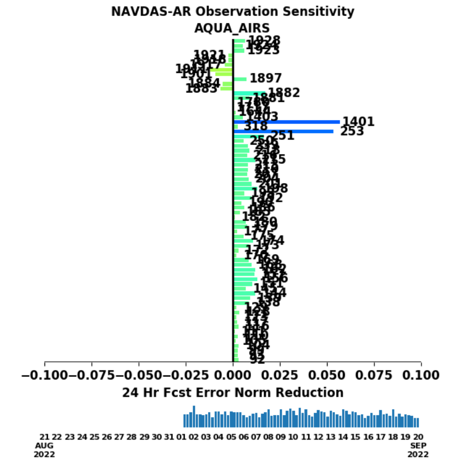
Comment: The FCC sale of C-Band spectrum near 4 GHz for 5G wireless applications netted ~ $80B. Weather related disasters in 2021 were ~ $450B (NOAA NCEI)

Fundamental Observations: Hyperspectral IR Sounders

Interactions between evolving variational bias correction and FSOI

We re-established a consistent AIRS/Aqua data feed from NASA

AIRS onboard Aqua (launched 2002) has providing scientific applications for Navy's global model for a long record. Recently, given its near end of life and limited resources, NOAA stopped the real-time data feed for AIRS/Aqua. Because of such change in data dissemination, FNMOC ops run stopped the assimilation since late 2021 (Figure 1). NASA took over the data feed and distributed the near-real-time data to the scientific community.



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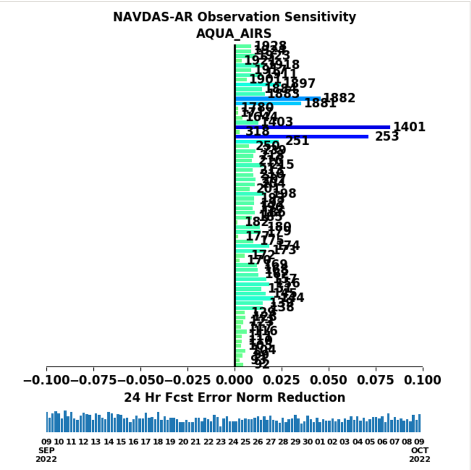

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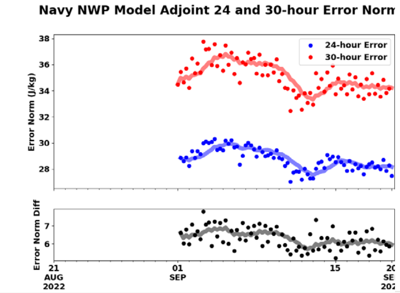
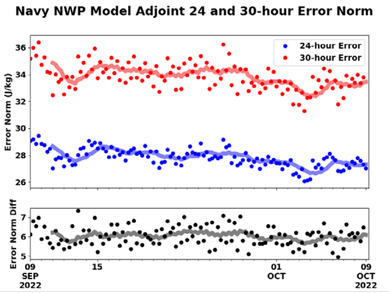
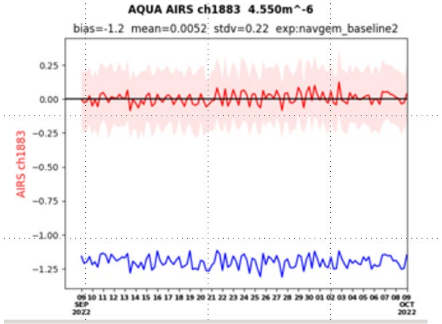
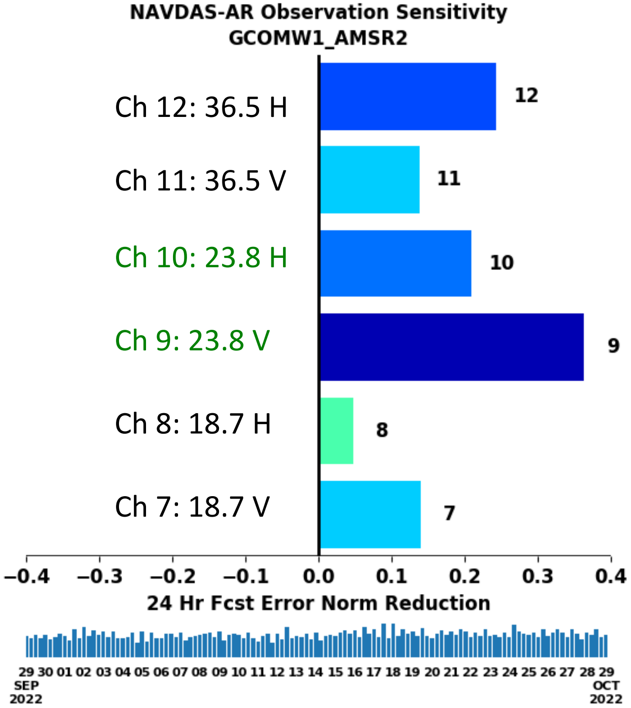


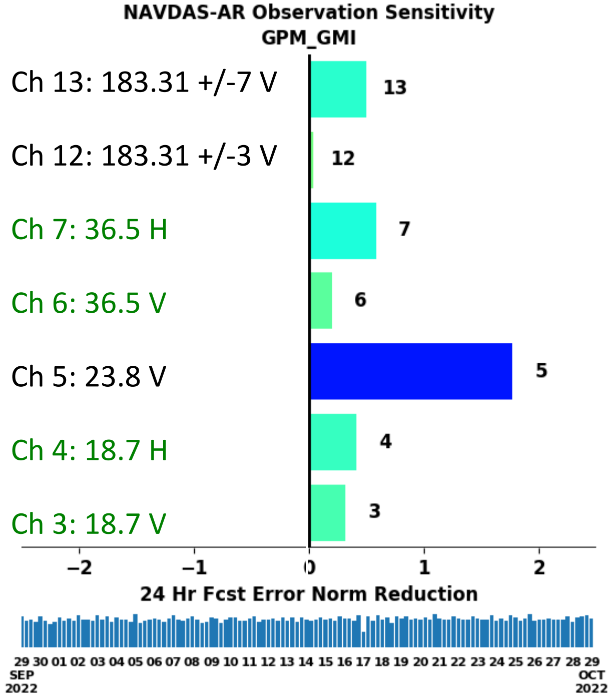




Complementary Observations
MW channels sensitive to clouds and water vapor



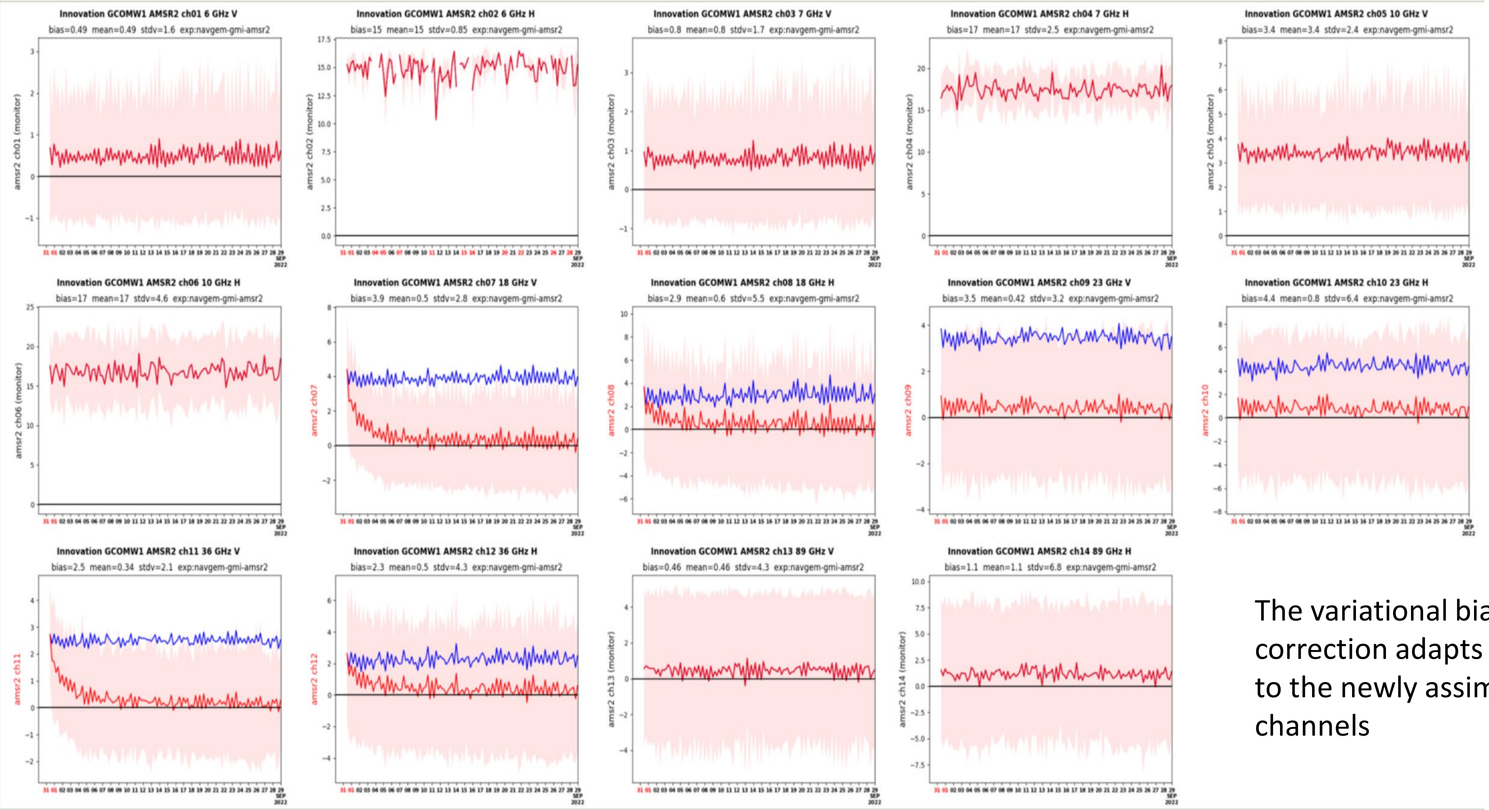
Newly added channels in green



AMSR-2: Window channels only. Conical 55 deg, swath 1450 km, 10 km/scan. Global coverage 1x/day. Integrated water vapor ~ 23 GHz dual polarization. 13:30 asc (Before: Ch 9, 10 only)

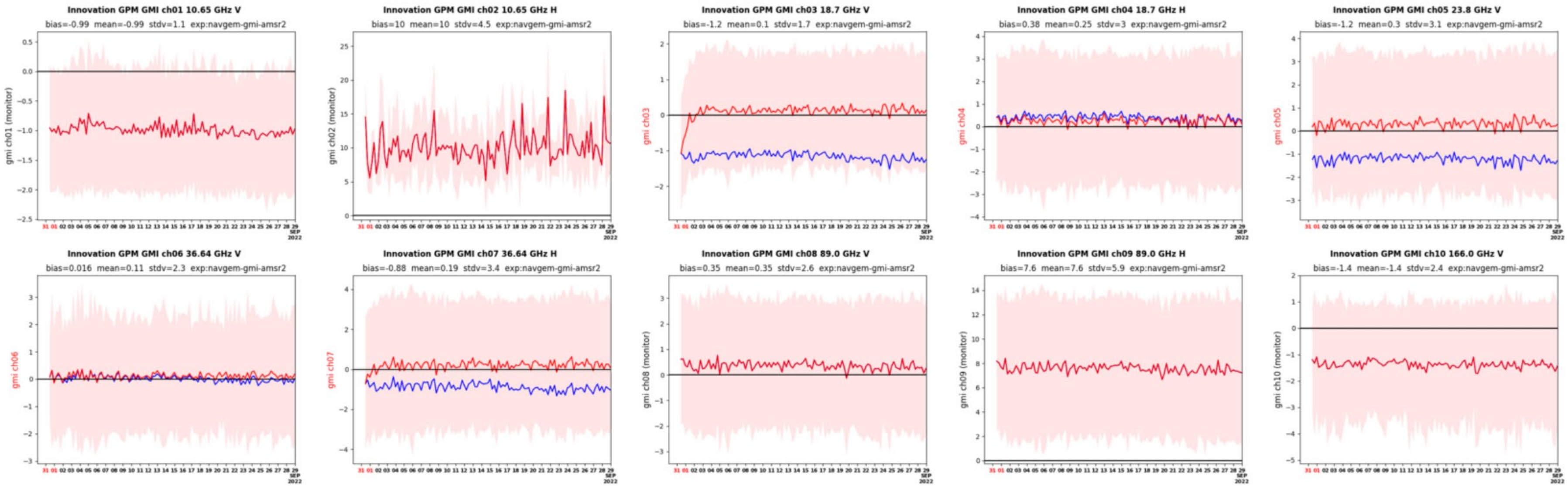
GMI: Conical: 53deg, useful swath 850 km ~13.4 km/scan. Near global coverage in 2 days. High latitudes >70deg not covered. (Before: Ch 5, 12, 13 only)

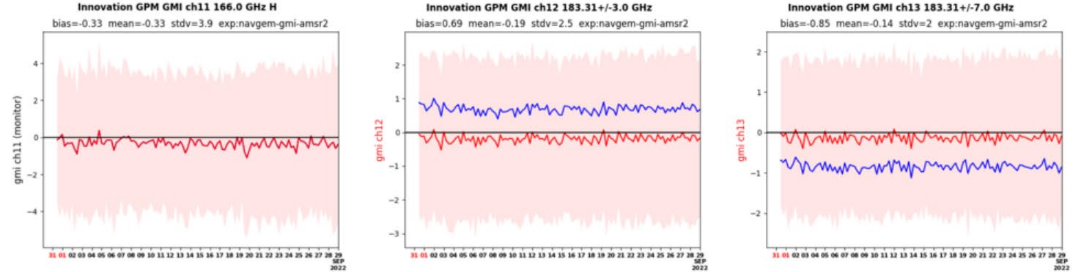
Complementary Observations
GCOM W1 AMSR2 MW channels sensitive to clouds and water vapor



The variational bias correction adapts quickly to the newly assimilated channels

Complementary Observations
GPM GMI MW channels sensitive to clouds and water vapor

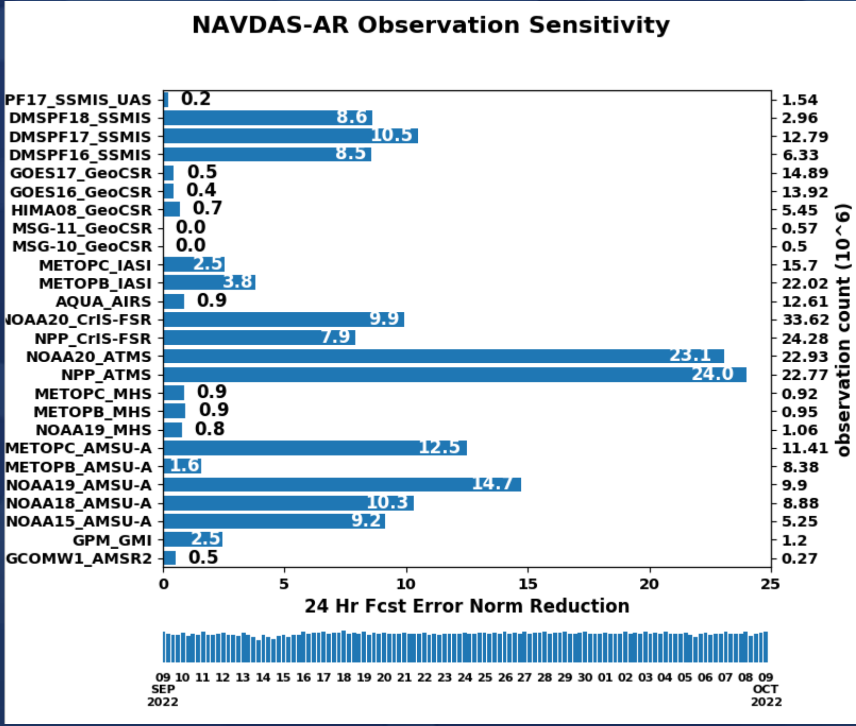


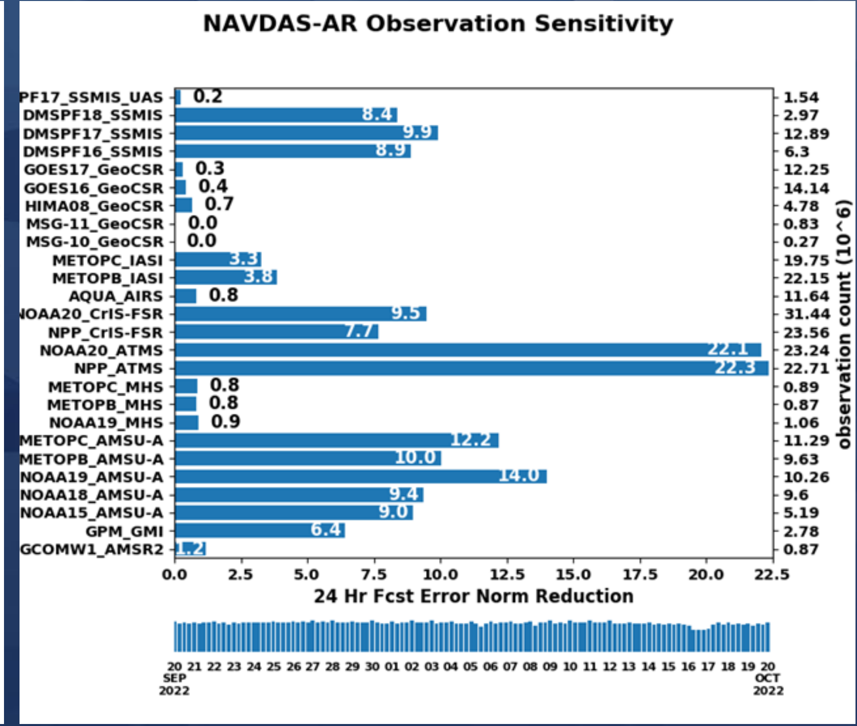


The variational bias correction adapts quickly to the newly assimilated channels

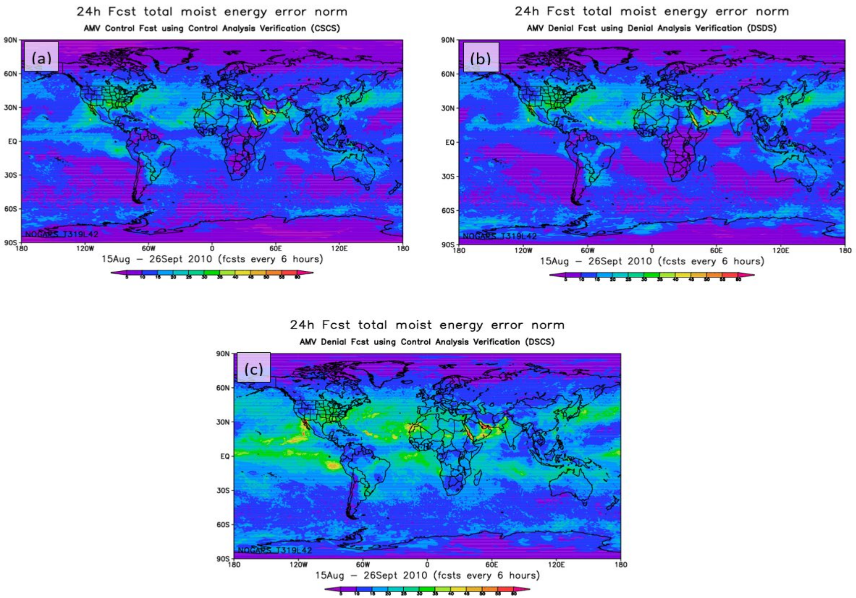
Motivation

So many questions … and now a few answers





Interpretation of Forecast Sensitivity Observation Impact (FSOI) in Data Denial Experiments



Baker, N.L., R.E. Stone, R.H. Langland and P.M. Pauley, 2021: Interpretation of Forecast Sensitivity Observation Impact in Data-Denial Experiments, Data Assimilation for Atmospheric, Oceanic and Hydrologic Applications, Vol. IV, Springer International Publishing.

Comparison between 24-hr total moist energy error norms, computed using self-analysis.

a) Control run that assimilated all observation
b) Data denial run with Atmospheric Motion Vectors (AMVs) removed
c) Data denial run, but with error norm computed using control.

Comment 1: Figures (a) and (b) are remarkably similar, and could lead to the erroneous conclusion that AMV assimilation has little impact on either the forecasts or analyses.

Comment 2: The 24-hr total moist energy error norms for the denial run computed using the control analyses is strikingly different in both magnitude and spatial structure (Figure (c)).

Conclusion: The interpretation of FSOI for data denial scenarios can be highly misleading. This is especially true when the change to the observing system is substantial (such as denying all satellite AMVs).

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Summary and Next Steps

Summary of Key findings:

- Assimilation of cloud and water vapor sensitive radiances in NAVGEM/NAVDAS-AR has significant issues with the under-utilization of water vapor sensitive observations.
- Identified sensor issues with AMSU-A on METOP-B that led to insufficient identification of cloud-affected radiances. We also removed the noisy Ch. 6 from active assimilation.
- Demonstrated that the slow spin-up of variational bias correction coefficients can lead to non-beneficial FSOI. This suggests that longer assimilation runs are necessary to identify beneficial/non-beneficial channels.
- Demonstrated the importance of anchoring observations (surface pressure).

Next Steps

- Increase utilization of humidity sensitive satellite observations
- Reduce inappropriate thinning of observations relative to spatial scales of phenomena and the model/DA resolution (analyze gradients in space and time).
- Revisit pseudo relative humidity control variable and corresponding static B covariances