Assimilation Impacts of SSMIS Upper Atmosphere Soundings with Improved Orbital Bias Predictors in NAVGEM

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ITSC-XX

Lake Geneva, Wisconsin

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NAVGEM v1.3

NAVGEM 1.3 Operational June 2015 at FNMOC

Data Assimilation Additions

- SSMIS Upper Atmosphere Sounding (UAS) assimilation capabilities
- GPS-RO addition of GRACE-B and TanDEM-X
- SNPP VIIRS Atmospheric Motion Vectors

Forecast Model Upgrade

- T425L60 resolution (31km, top at 0.04 hPa or ~70km) Reduced Gaussian grids
- New stratospheric physics for water vapor photochemistry, sub-grid-scale non-orographic gravity wave drag, and stratospheric humidity quality control
- New dynamics formulation utilizing perturbation virtual potential temperature to improve numerical stability and reduce semi-implicit decentering
- Convective cloud fraction predicted based on Xu-Randall
- Improved initialization of ground wetness and ground temperature
- LIS soil moisture initialization
- New snow albedo
- WAVEWATCH® III v4.18

NAVGEM/NAVDAS-AR Operational Data

LEO Radiances Imagers/Sounders

DMSP F16 SSMIS Imager
DMSP F17 SSMIS LAS, UAS, Imager
DMSP F18 SSMIS Imager
DMSP F19 SSMIS LAS, UAS, Imager
METOP-A AMSU-A, IASI, MHS
METOP-B AMSU-A, IASI, MHS
NASA EOS Aqua AIRS, AMSU-A
NOAA 15 AMSU-A
NOAA 16 AMSU-A
NOAA 18 AMSU-A, MHS
NOAA 19 AMSU-A, MHS
NOAA NPP ATMS, CrIS, VIIRS
GCOM-W1 AMSR-2
Megha-Tropiques, SAPHIR
MSG Severi
MSG-II HIR
Jason-2 (SSH, SWH)
Cryosat2 (SSH, SWH)
Himawari-8
Aquarius (Salinity)

FY-3A,B,C,D,E,F MWTS,MWHS,MAIRS
MERSI
FY-RM 1,2
Meteor 3M MTVZA

Satellite Winds LEO and GEO Derived

Coriolis WindSat Ocean Wind Vector
DMSP F16 SSMIS Ocean Wind speed
DMSP F17 SSMIS Ocean Wind speed
DMSP F18 SSMIS Ocean Wind speed
DMSP F19 SSMIS Ocean Wind speed
METOP-A AVHRR, ASCAT
METOP-B AVHRR, ASCAT
NASA EOS Aqua MODIS
NASA EOS Terra MODIS, MISR
NOAA NPP VIIRS

Meteosat 9
Meteosat 10
MTSAT
NOAA GOES E
NOAA GOES W
NOAA GOES-R
KMA COMS

FY-2E,F,G,H (Geo Winds)
FY-4A,B,C (Geo Winds)
FY-4A,B,C IR Spectrometer, MW??

GNSS Radio Occultation

C/NOFS CORISS
COSMIC FM1-6
GRACE-A
GRACE-B
MetOp-A GRAS
MetOp-B GRAS
SAC-C
TerraSAR-X
TanDEM-X
COMS

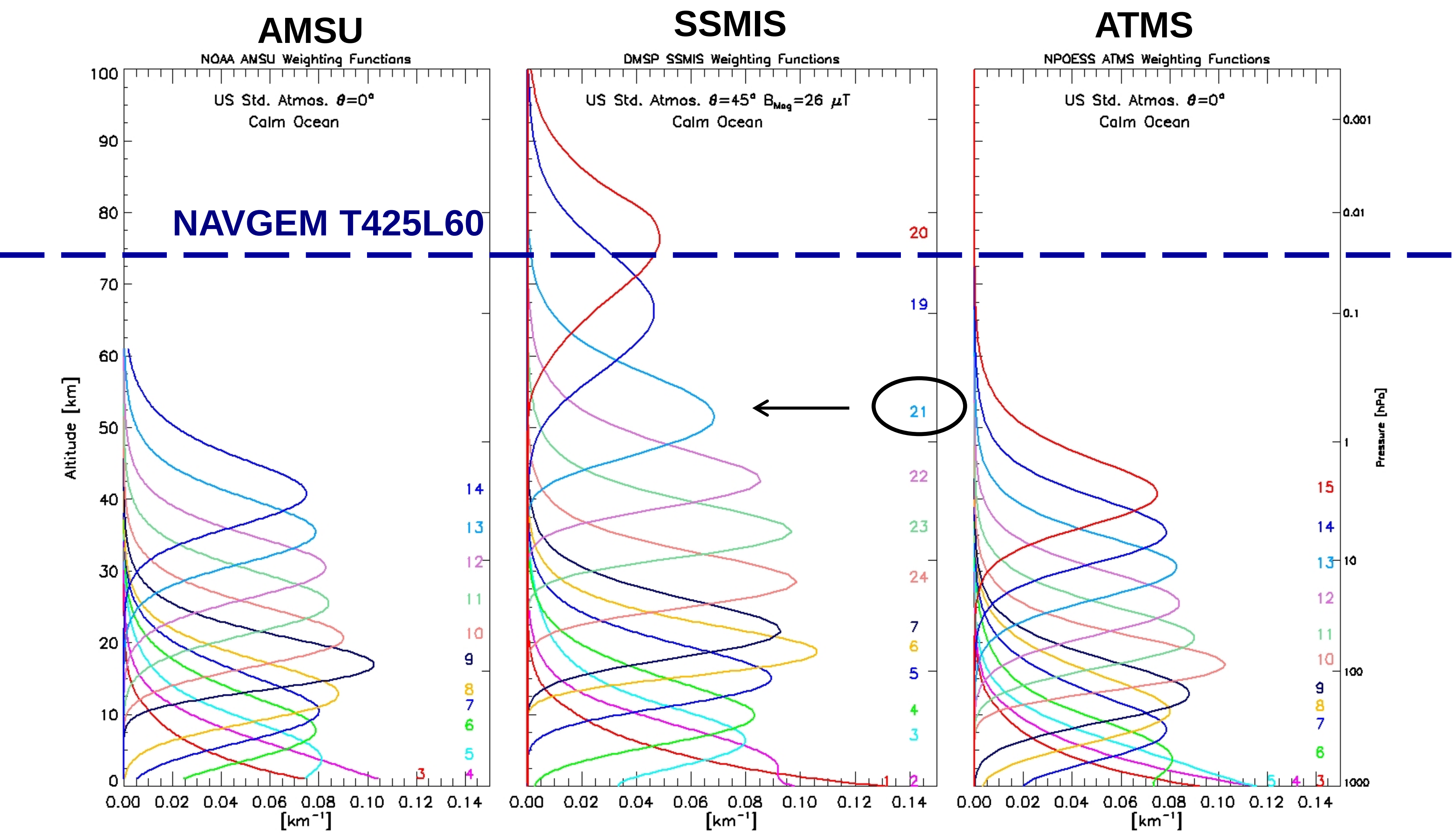
Other Satellite Products

NASA EOS Aura MLS, HRDLS, OMI
NASA TIMED SABER
NOAA SBUV
JPSS NPP OMPS
SMOS
SMAP
INSAT-3D
FY-3A,B,C,D,E,F TOU

Coriolis WindSat TPW
DMSP F16 SSMIS TPW
DMSP F17 SSMIS TPW
DMSP F18 SSMIS TPW
DMSP F19 SSMIS TPW

Operational Research Planned Restricted Use

Current Operational MW Sensors



SSMIS Channels assimilated: 2-7, 9-11, 22-24

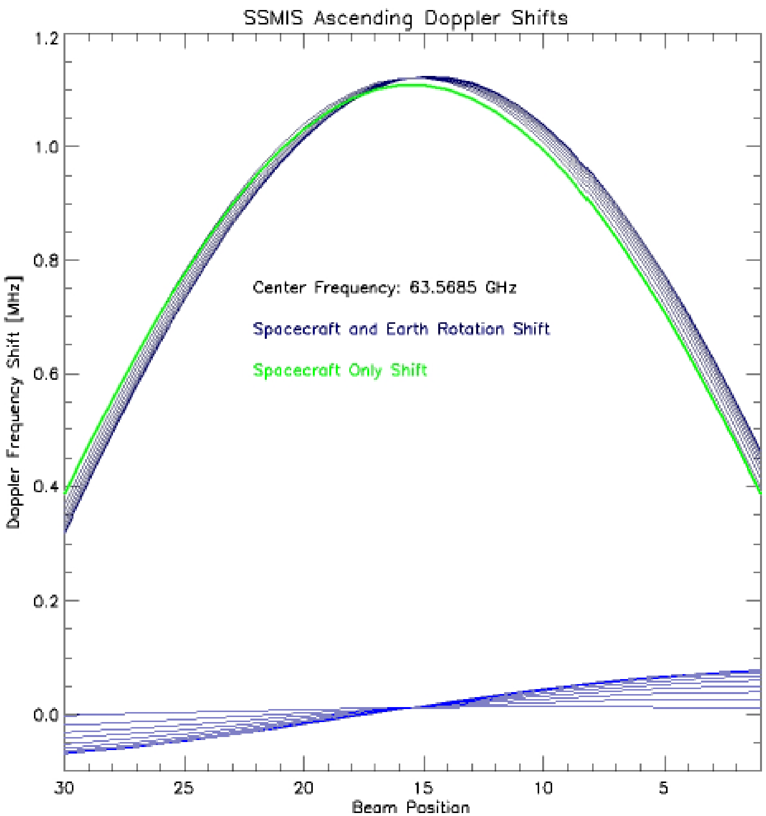
UAS Assimilation Challenges

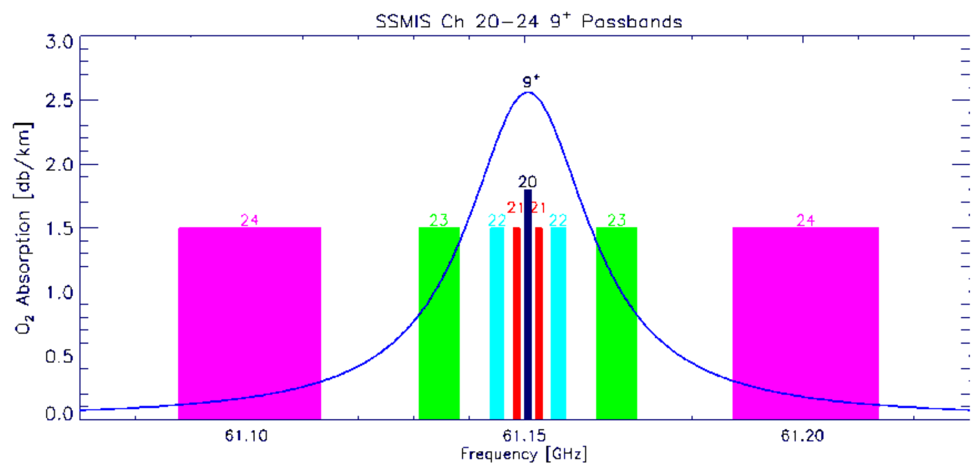
Narrow Channel Passbands

- UAS channels highly sensitive to frequency shifts and oscillator drifts
- Higher NEDT (LAS NEDT ~ 0.3 – 0.4 K)
- Doppler Shifts must be accounted for in the software

SSMIS UAS Channel Characteristics

SSMIS UAS Channel	Center Frequency (GHz)	3-db Width (MHz)	Frequency Stability (MHz)	NEΔT (K)	Sampling Interval (km)
19	63.283248 ±0.285271	1.35(2)	0.08	2.7	75
20	60.792668 ±0.357892	1.35(2)	0.08	2.7	75
21	60.792668 ±0.357892 ±0.002	1.3(4)	0.08	1.9	75
22	60.792668 ±0.357892 ±0.0055	2.6(4)	0.12	1.3	75
23	60.792668 ±0.357892 ±0.016	7.35(4)	0.34	0.8	75
24	60.792668 ±0.357892 ±0.050	26.5(4)	0.84	0.9	37.5





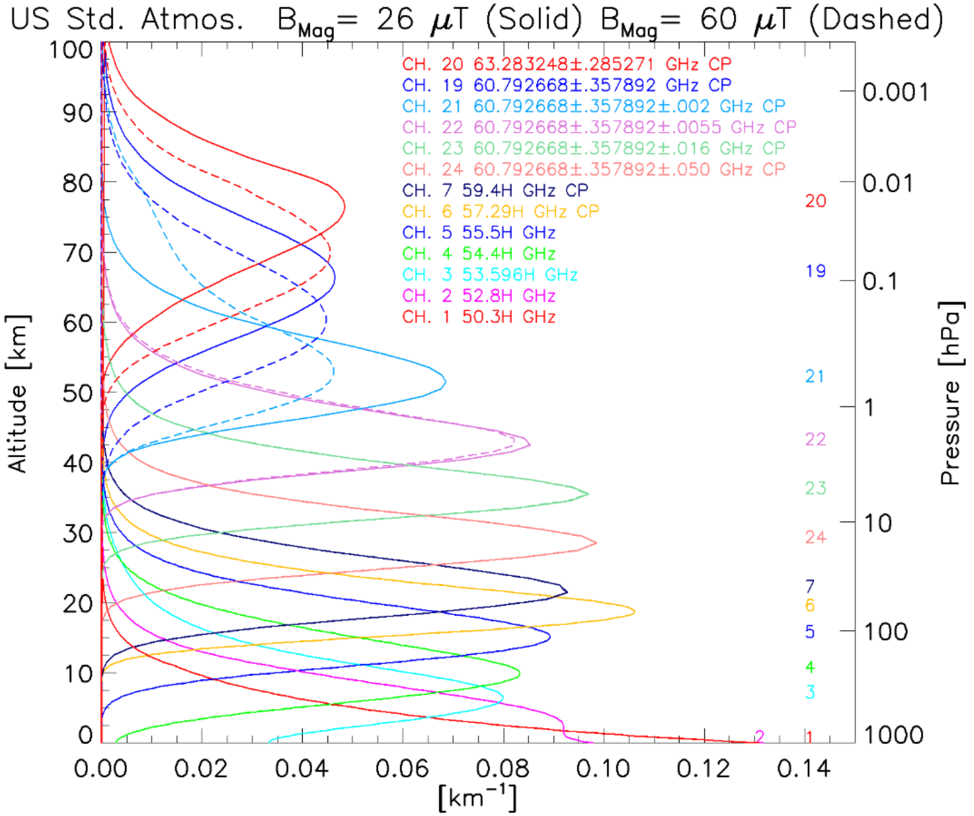
UAS Assimilation Challenges

Zeeman Effect

- Mesospheric sounding is affected by the Zeeman splitting of the O_2 absorption lines due to interaction with Earth's magnetic field at high altitudes
- Accounted for in the CRTM: requires magnetic field strength, |B|, and the angle between the antenna boresight and the geomagnetic field vector, Θ_B

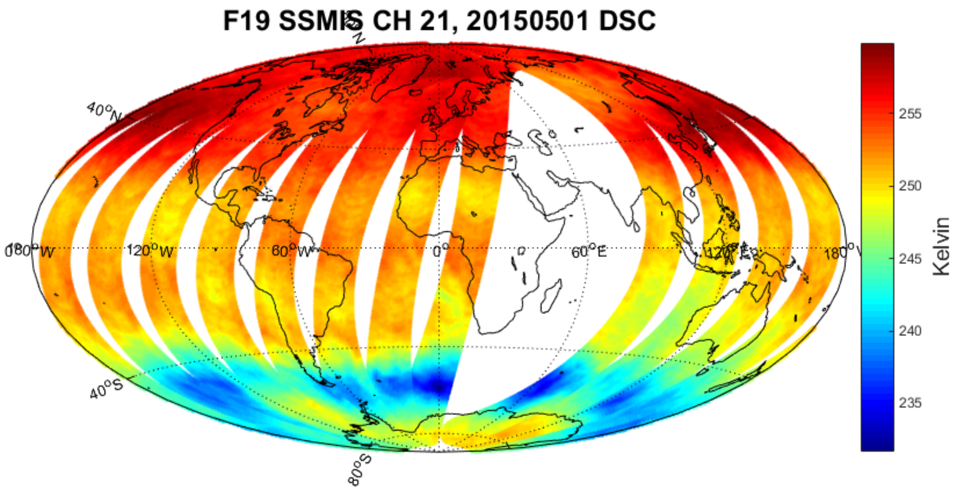
Solid: Weak B_{mag}

Dashed: Strong B_{mag}



SSMIS Unified Pre-Processor (UPP)

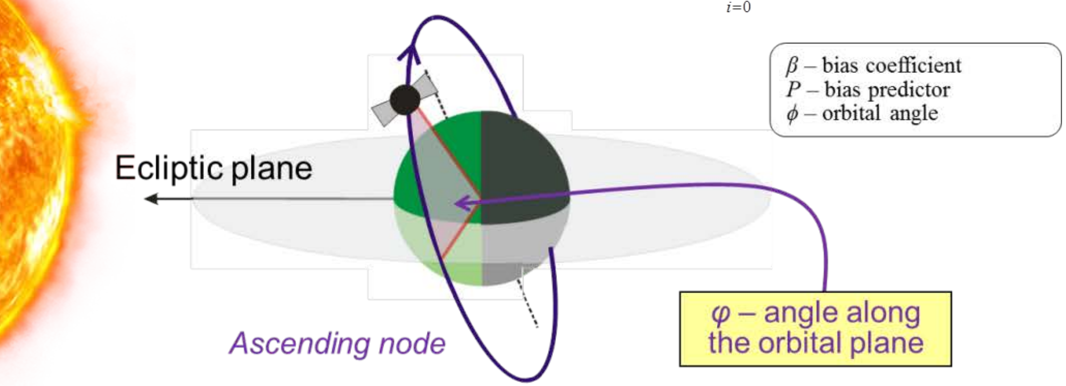
- Joint development by NRL and UK Met Office
- Produces calibrated SSMIS TDR files suitable for radiance assimilation
- Recent additions include F19 data processing and Orbit Angle, *φ,* calculation for Bias Correction Predictor (A. Booton)
- LAS and UAS versions available
- UAS-specific UPP processing includes:
  – Calculation of the SSMIS Propagation Vector, **k**, as the vector difference between the spacecraft and the UAS scene position vectors
  – Extraction of the Geomagnetic field vector (**B**) components at 60 km from the International Geomagnetic Reference Field (IGRF) model (5% uncertainty)
  – Estimates of mean $\mathbf{B}_{mag}$, **B**-dot-**k**, θ_B , and std_dev (**B**-dot-**k)** within averaging domain
  – Gaussian spatial averaging with σ=75km



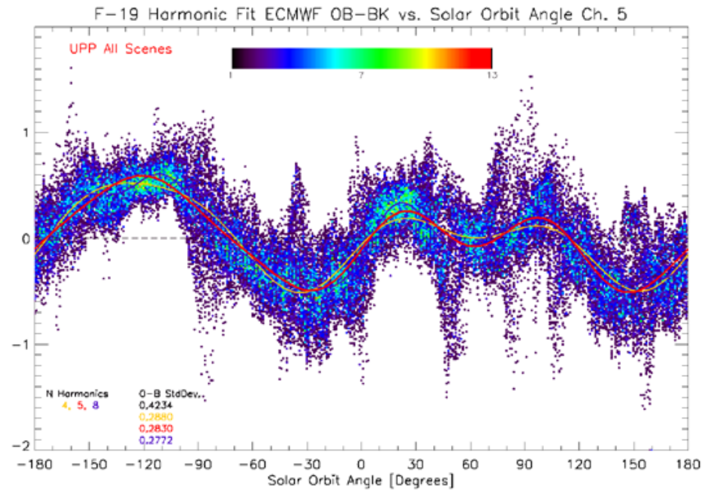
SSMIS Orbital Bias Correction

- All SSMIS instruments exhibit orbital biases (reflector emissions, solar intrusions)
- Previous orbital bias prediction scheme a function of latitude (asc/dsc); did not capture complexity of the biases
- New orbital bias correction scheme uses a Fourier Series in orbit angle, ϕ, as bias predictor
- Using reference relative to the position of the sun results in a more stable predictor
- Developed by Dr. Anna Booton (Met Office) during visit (Nov-Dec '14)
- Assimilation trials in NAVGEM use N=5 coefficients (10 predictor components)

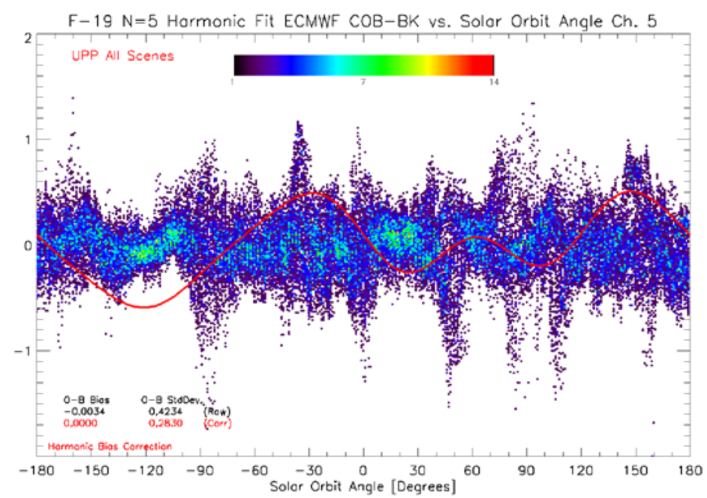
$$\Delta T_B = \sum \beta P \quad = \sum_{i=0}^{N} a_i \cos(i\phi) + b_i \sin(i\phi)$$



Uncorrected



Corrected



UAS Assimilation Trials in NAVGEM

What impact does assimilation of SSMIS UAS Ch 21 have in NAVGEM 1.3?
What bias prediction scheme for UAS Ch 21 is most effective?

3 experiments + OPs:
March-June, 2015

1. **UAS CNTL**: NAVGEM 1.3, including SSMIS-UAS CH 21 and using current operational bias prediction scheme (including asc/desc orbital bias predictor).

2. **UAS ORB**: NAVGEM 1.3, including SSMIS-UAS CH 21 with improved orbital bias prediction scheme for all sounding channels (replaces asc/desc with Fourier-based method).

3. **UAS RED**: NAVGEM 1.3, including SSMIS-UAS CH21 with reduced set of bias predictors (uses improved orbital bias prediction scheme for all sounding channels and no atmospheric thickness predictors for Ch 21).

4. **OPS (No UAS)**: NAVGEM 1.3 Operational (as of June 15), with no SSMIS-UAS, uses offset, thickness, scan angle, and asc/desc orbital bias predictors for LAS channels.

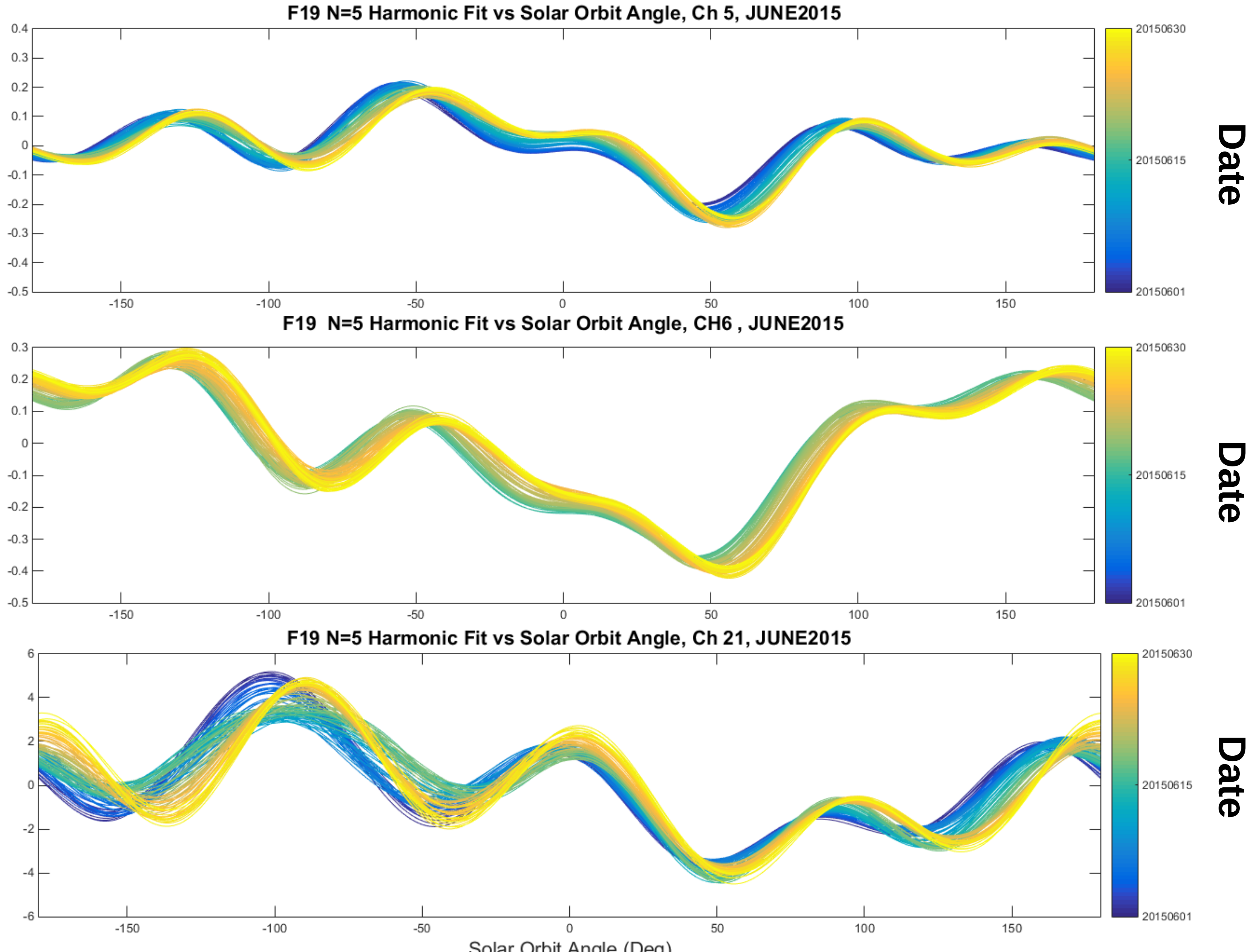
UAS Ch 21 Assimilation Trials in NAVGEM

Reconstructed harmonic fit vs Solar Orbit Angle

F19 CH 5

F19 CH 6

F19 CH 21



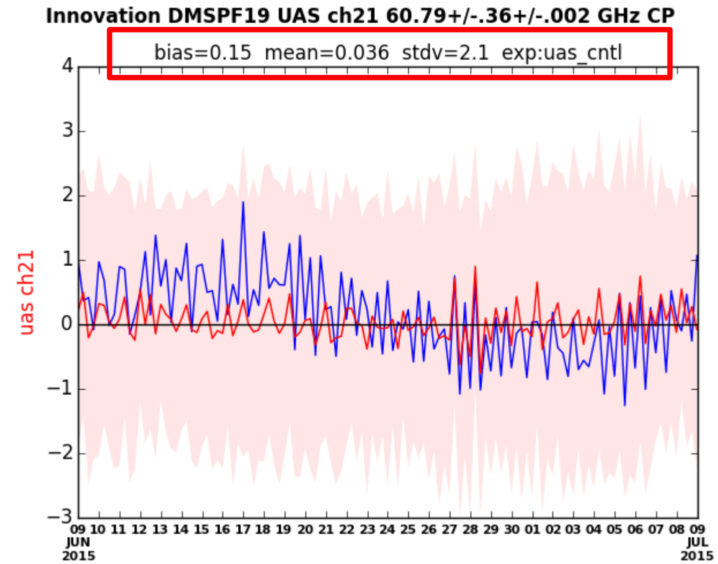
UAS Assimilation Results

RADGRAMS – SSMIS UAS Ch 21

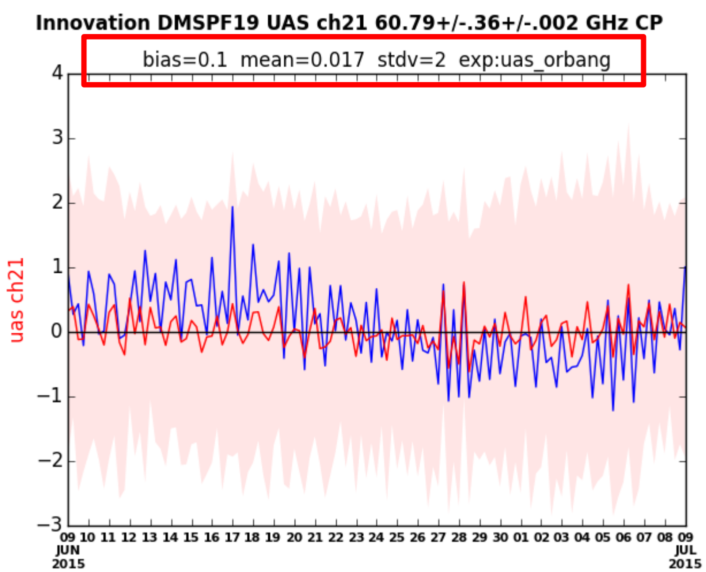
OPS

- No UAS -

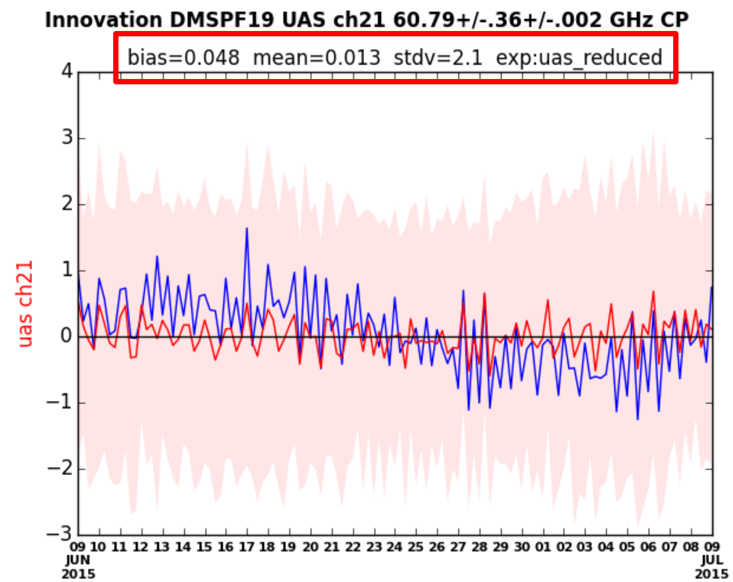
CNTL



ORB



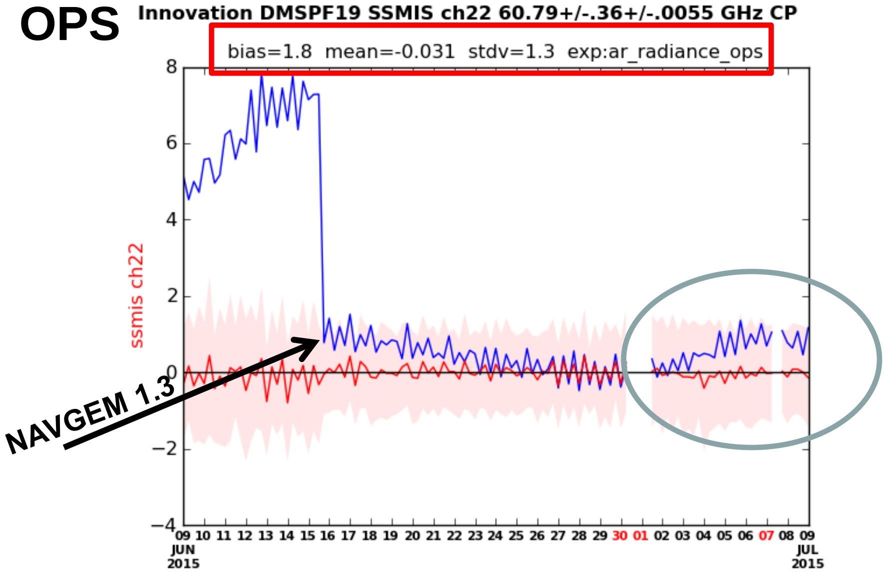
RED



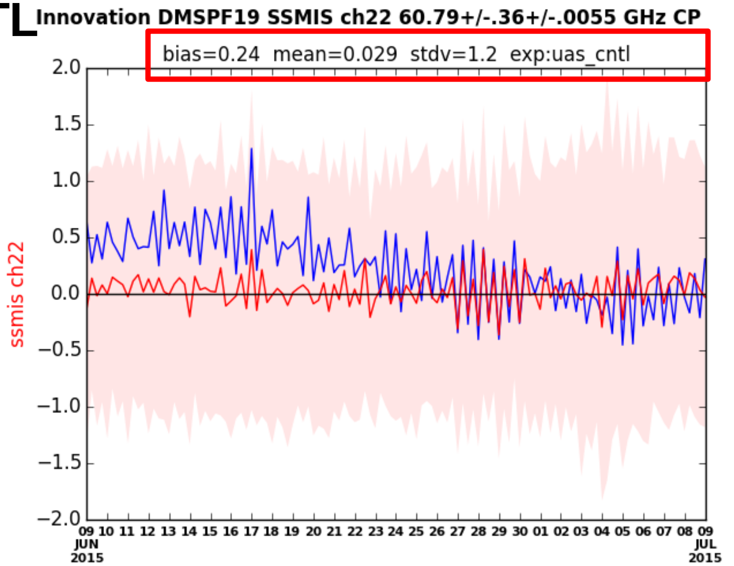
UAS Assimilation Results

RADGRAMS – SSMIS stratospheric Ch 22

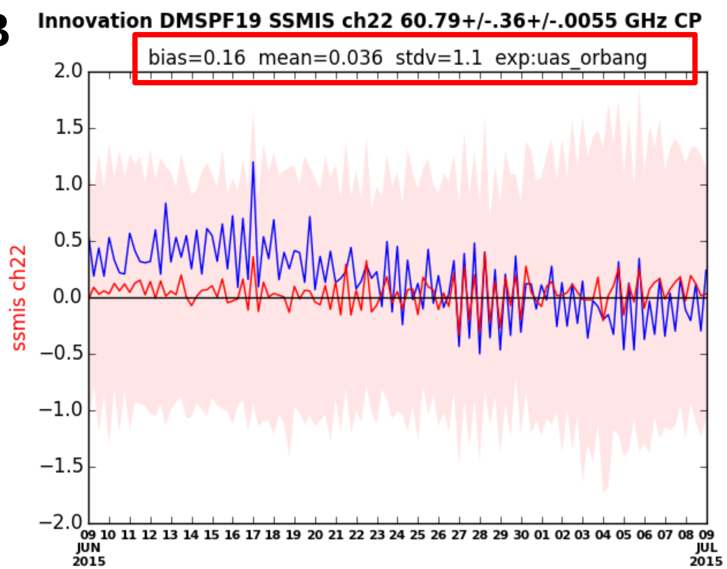
OPS



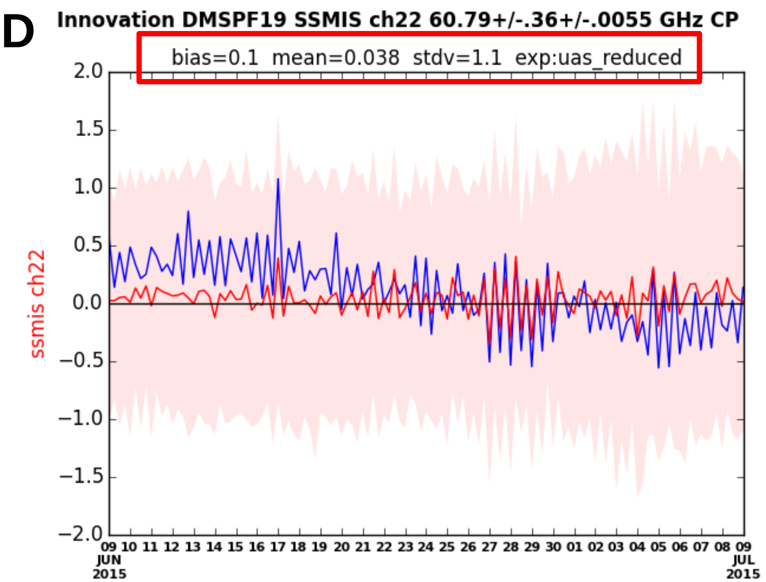
CNTL



ORB



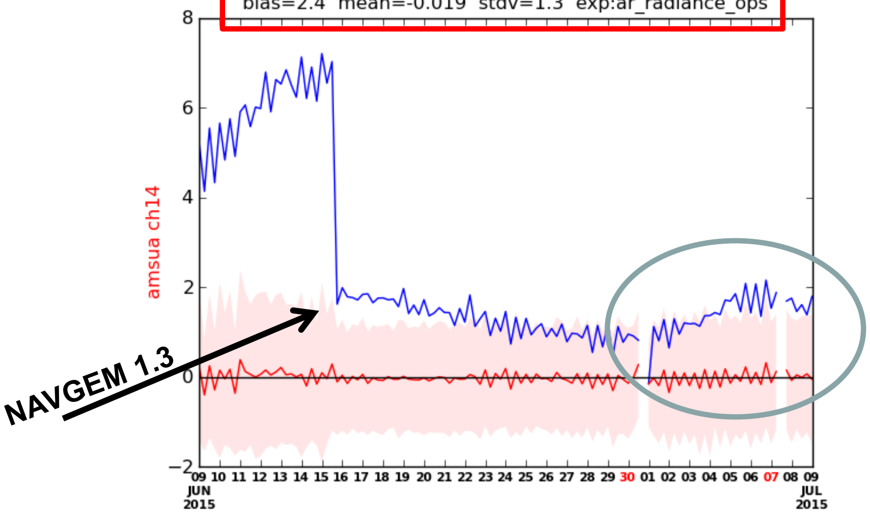
RED



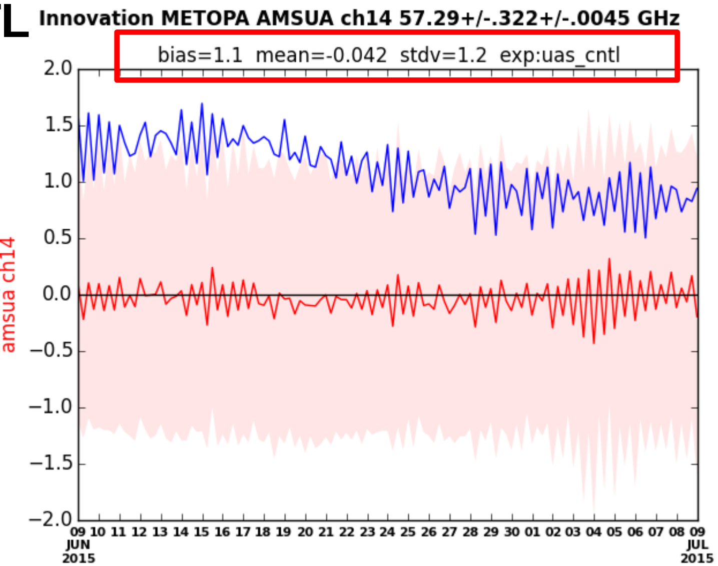
UAS Assimilation Results

RADGRAMS – AMSUA stratospheric Ch 14

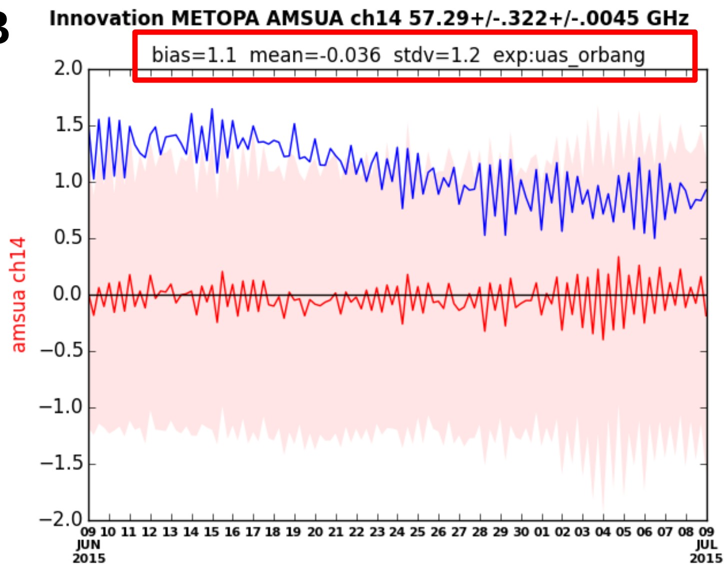
OPS



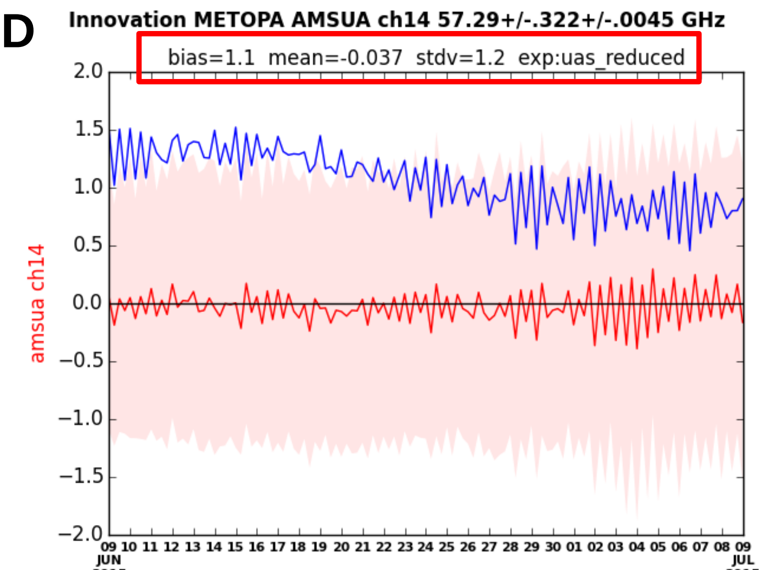
CNTL



ORB



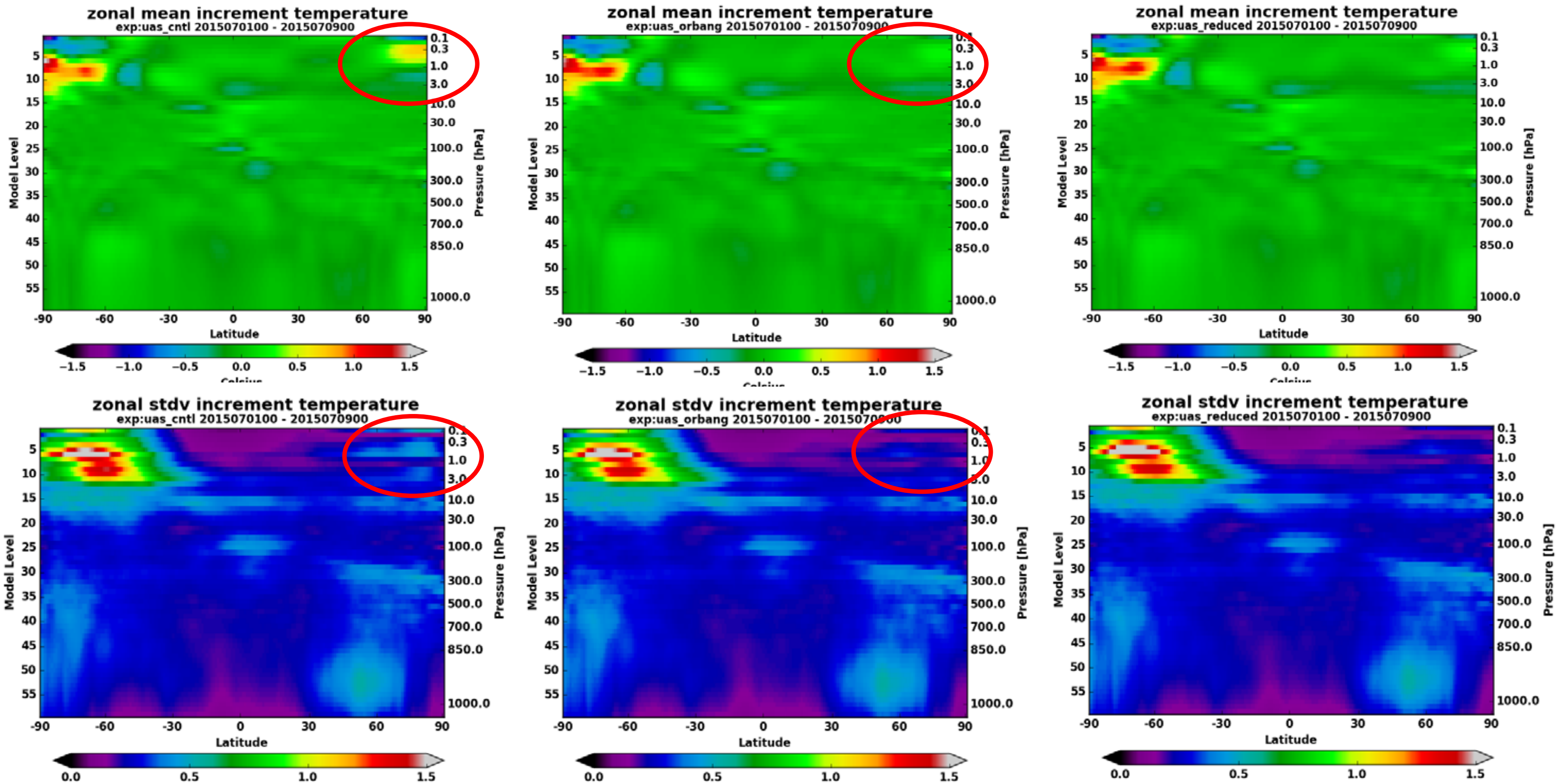
RED



UAS Assimilation Results

Zonal Temperature Increments

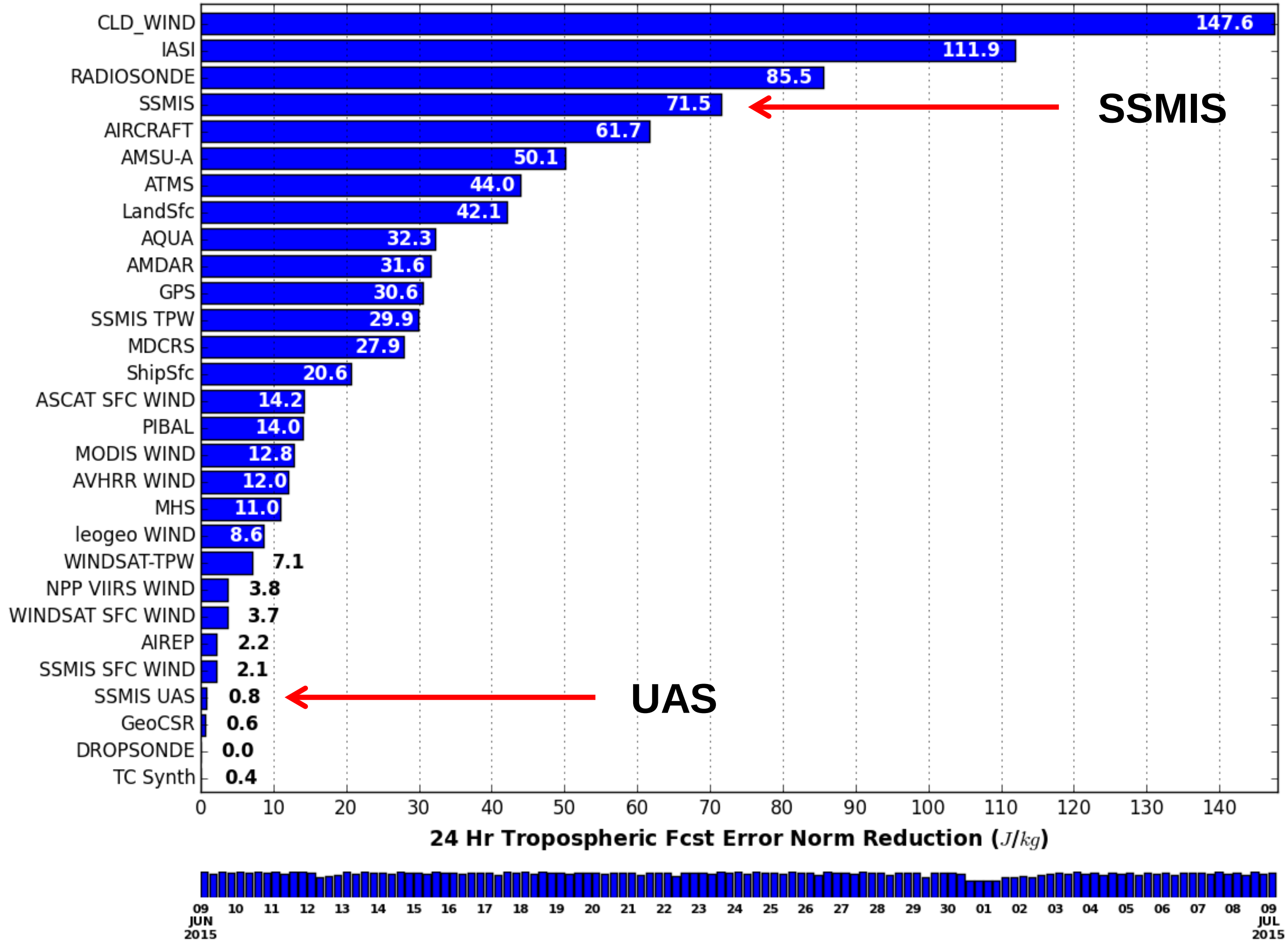
UAS CNTL | **UAS ORB** | **UAS RED**



Inclusion of new SSMIS orbital bias predictors shows reduction in northern polar temperature increment.

UAS Assimilation Trials in NAVGEM

Forecast Sensitivity Observation Impact



Summary

- SSMIS currently the only microwave radiometer providing mesospheric soundings – UAS assimilation capabilities part of NAVGEM 1.3
- Assimilation of SSMIS UAS is unique, requires information on Earth geomagnetic field and scene boresight angle to account for Zeeman effect
- Orbital Angle, ϕ, for Bias Correction Predictor now implemented in SSMIS LAS and UAS UPPs
- Assimilation of UAS Ch 21 in NAVGEM shows a small but consistent reduction in bias statistics for stratospheric MW radiances
- Inclusion of UAS Ch 21 with new Orbital Angle Bias Correction Predictor shows reduction in the temperature increment in northern polar region of the upper atmosphere
- Impact from removal of UAS atm thickness bias predictors is minimal
- UAS UPP data now operational; full-res UAS UPP files being distributed through NOAA via FNMOC

END