Progress and Plan for Satellite Radiance Assimilation in the NCEP Global Data Assimilation System

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29th November 2022 Global Model Upgrade (GFSv16.3)

- Assimilate antenna corrected AMSU-A, ATMS and MHS Brightness Temperatures
- Upgrade to CRTM 2.4.0 and use GFDL cloud table
- Assimilate precipitation-affected AMSU-A and ATMS radiances. Turn on Cold Air Outbreak (CAO) QC. (Emily Liu: Poster 9p.04)
- Revise thinning box for VIIRS and AVHRR radiances (Near Sea Surface Temperature) and tighten QC.
- Reduce weight given to ASCAT observations.
- Prepare for NOAA-21, GOES-18 and Himawari-9 radiances.

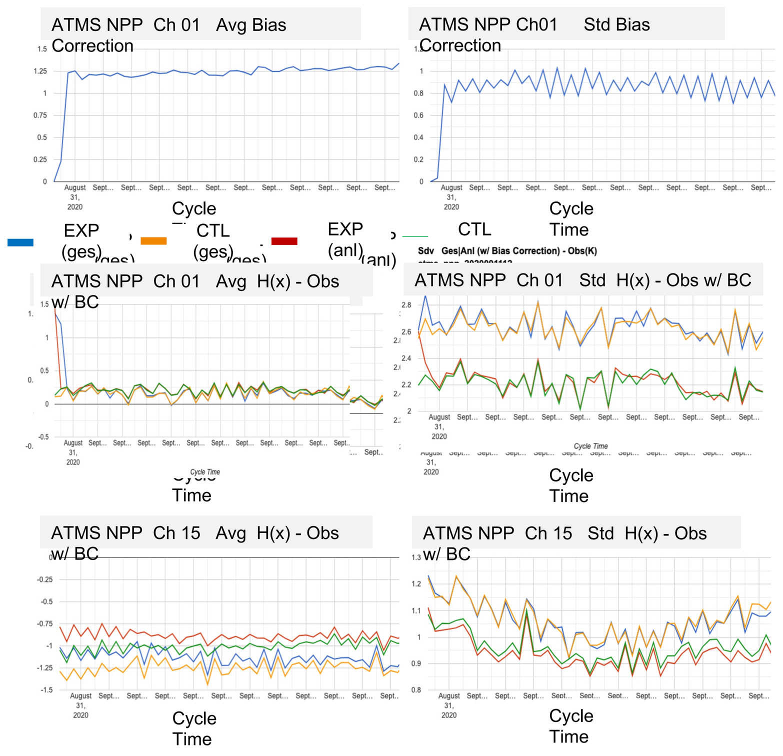
Assimilation of Antenna-Corrected Brightness Temperatures (SDR) from AMSU-A, MHS, and ATMS

Background

Observations from GTS and NESDIS
- Normal feed - antenna temperatures (Ta, TDR)
- DBNet - antenna-corrected (AC) brightness temperatures (Tb, SDR)

GSI Analysis (Operational: CTL) --- assimilate TDR
- Tb from DBNet is converted to Ta for assimilation (AC removed)
- The variational bias correction (BC) takes care the inconsistency between Ta observations and simulated Tb from background.

GSI Analysis (Experimental: EXP) – assimilate SDR
- Ta from normal feed is converted to Tb for assimilation (AC applied).
- Spin up bias correction coefficients from zero.
- GSI has a built-in self-initialization using the quasi-mode of all data.
- Adaptive background error variances for bias predictor coefficients are based on the Hessian (analysis error) from the previous cycle.



Bias correction spun up to steady estimations within 4 cycles.

The residual statistics with bias correction indicates that the control and experiment agree with each other.

Highest peaking channel has no bias correction applied to prevent aliasing model bias into observation.

In operational system, Ta is assimilated without antenna correction ---> less optimal.

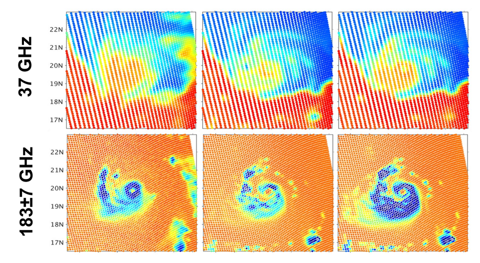
The antenna correction bring the observations closer to the simulated Tb.

Assimilation of Precipitation-Affected AMSU-A & ATMS Radiances

New Features
- Use antenna-corrected brightness temperature for AMSU-A and ATMS radiance assimilation
- Improve CRTM accuracy under scattering conditions
- Enhance CRTM to handle fractional cloud coverage
- Use CRTM cloud optical table consistent with model particle size distribution (under testing)
- Augment GSI control variable to include precipitating hydrometers
- Calculate GFDL cloud fraction at each observation footprint
- Enhance data quality control
- Assess the impact of precipitation-affected radiances

New Cloud Optical Property Table

Using scattering table for spherical particle leads to systematic errors:
- too much scattering at low frequencies
- too little scattering at high frequencies

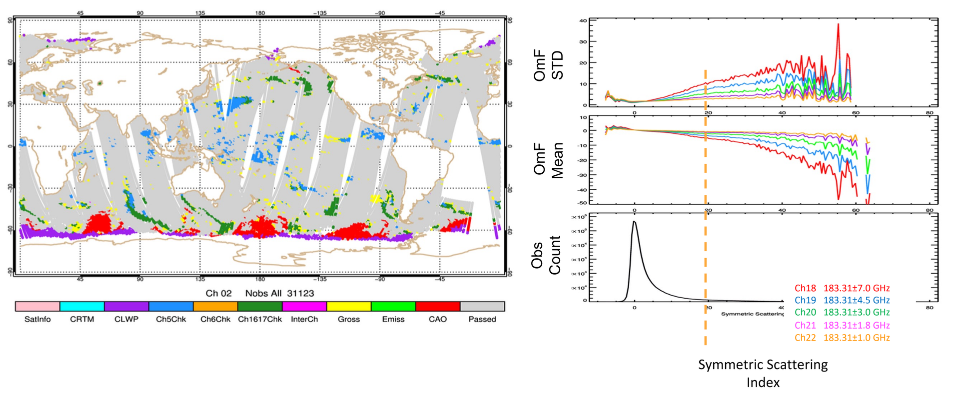


Credit: Figures and information from Yinghui Lu, Penn State

- New LUTs generated by integrating scattering properties over expontial GFDL PSD.
- Use scattering properties of sector snowflakes in Liu (2008) scattering database.
- Replace sphere snow particles in model with sector snowflakes.

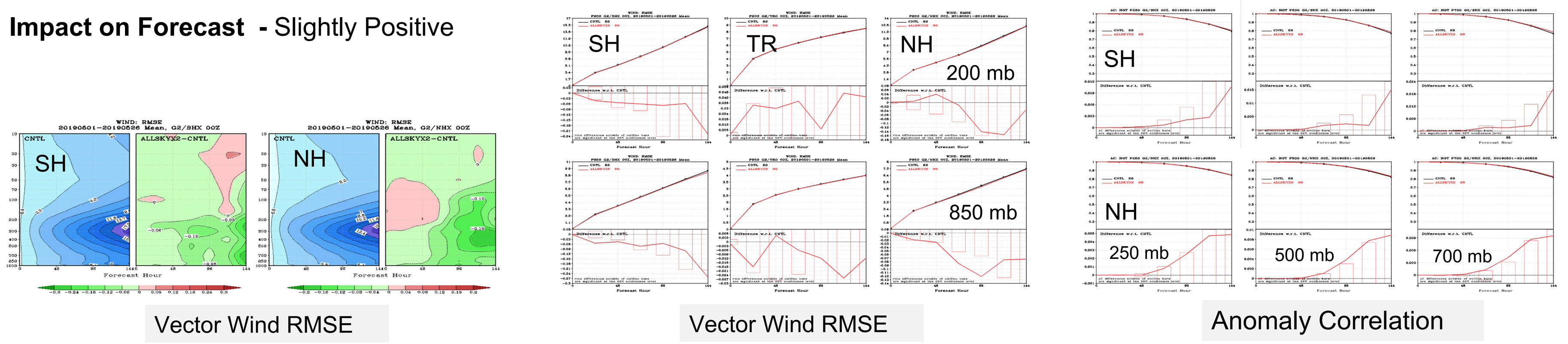
  One sphere snow is replaced by multiple sector snowflakes of the same size to preserve total mass of particles within each size bin.

Enhanced Quality Control Procedures



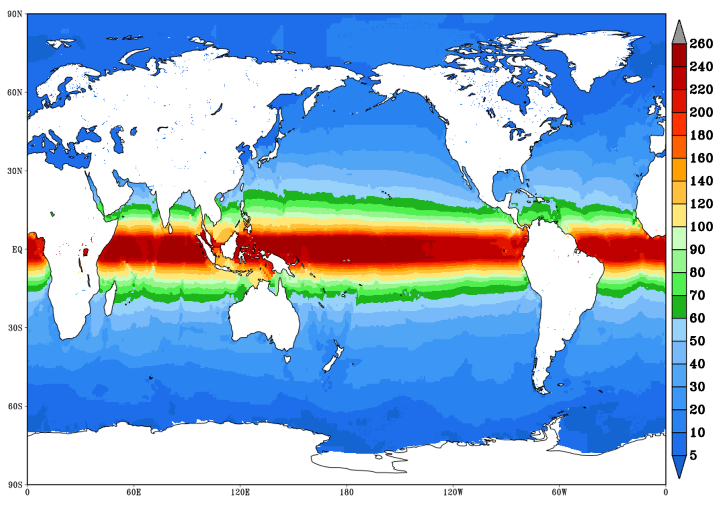
- Relax precipitation screening by removing the 54.5GHz precipitation check.
- Screen observations affected by strong convective situations by
- Enhancing the cloud affect brightness temperature difference check using the 53.6 GHz band
- Using a symmetric scattering index derived from 90 and 150 GHz
- Cold air outbreaks are screened out (these are regions of super-cooled liquid water where the forecast model predicts ice clouds)

Impact on Forecast - Slightly Positive



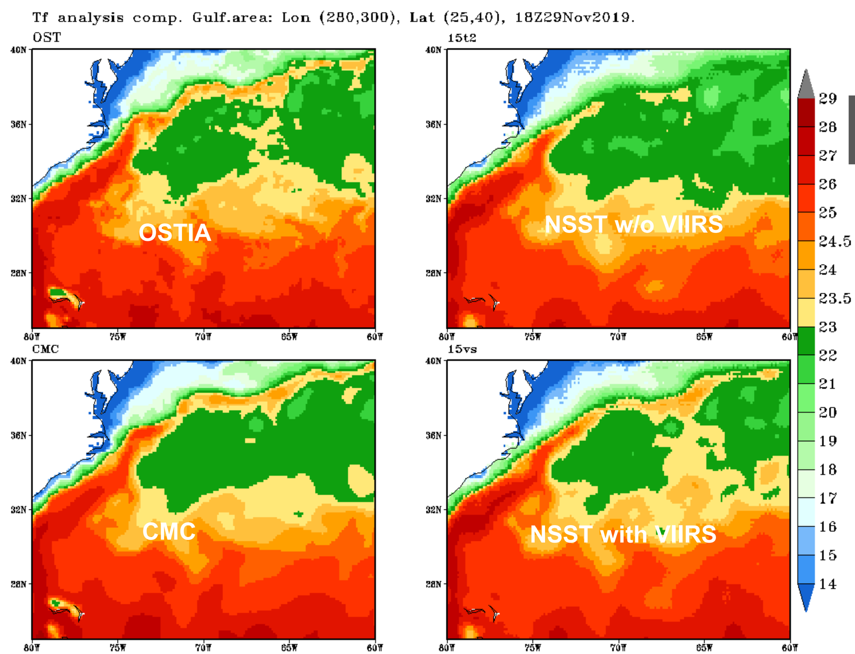
Improvements to Near Sea-Surface Temperature (NSST) Analysis

- Use new background error correlation length based on the first baroclinic Rossby radius of deformation
- Turn on VIIRS radiances
- Assimilate AVHRR radiances for NSST analysis with the smaller data thinning box and partly clear data removed
- Assimilate new in-situ observations: Saildrone, Argo and Glider
- Allow the assimilation of NSST-related in-situ observations over the mixed surface type
- Relax gross check threshold for NSST-related in-situ observations



- Rossby radius of deformation (modified) is used as the background error horizontal correlation which is used in some oceanic data assimilation
- It decreases towards the higher latitudes. 250+ km at equator, 10- km at the pole areas. Over Gulf Stream area, it is about 10 to 20 km
- 100 km length is used currently in the NSST

Impact of adding VIIRS



VIIRS clear-sky radiances from NPP and J1 channels: M12 (3.7 micron), M15 (10.8 micron), and M16 (12 micron) are assimilated

Data source: ACSPO SST data set

Positive impact of VIIRS on GFS GFS NSST performance, particularly in areas such as Gulf Stream, Bering Sea, Hudson Bay, and North Pacific.

Radiance Usage in Global and Regional Models

Global and Regional Models:
- Geostationary Clear Sky Radiances: (Haixia Liu: Poster 15p.11)
  - GOES-16 and GOES-18* ABI Channels 8-10
  - Himawari-9* AHI Channels 8-10
- AMSU-A
  - NOAA-15 Channels 1-5, 7-10, 12-13, 15
  - NOAA-18 Channels 1-4, 6-7, 10-15
  - NOAA-19 Channels 1-6, 9-15
  - Metop-B Channels 8-14
  - Metop-C Channels 1-15
- MHS
  - NOAA-19 Channels 1,2,4,5
  - Metop-B Channels 1-5
  - Metop-C Channels 1-5
- ATMS
  - SNPP, NOAA-20, NOAA-21* Channels 1-22
- SSMIS
  - DMSP-17 Channels 1, 5-7, 24
- IASI
  - Metop-B 119 Channels
  - Metop-C 119 Channels
- CrIS
  - SNPP, NOAA-20, NOAA-21* 100 Channels
- AVHRR
  - Metop-B, Metop-C, NOAA-18, NOAA-19 Channels 3-5
- VIIRS
  - NOAA-20 Channels 12, 15, 16

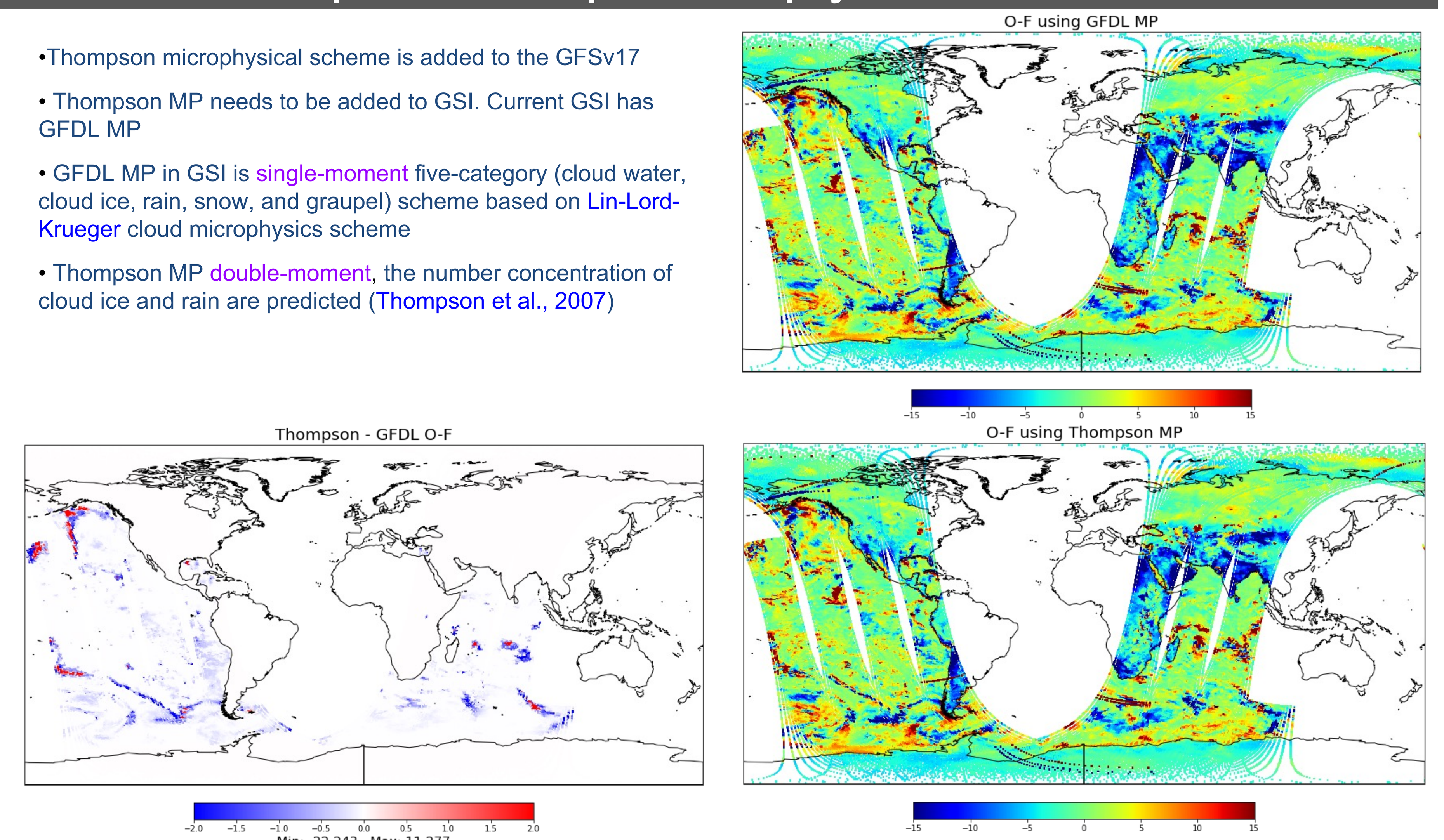
* Expected implementation May 2023

Planned Upgrades: GFSv17 and beyond

- Upgrade to CRTM 3.0
- Extend microwave all-sky assimilation to land (Azadeh Gholoubi: Poster 9p.02)
- Improvements to bias correction of satellite radiances and use of high peaking channels in the Rapid Refresh Forecast System (RRFS) (Xiaoyan Zhang: 12.05)
- Assimilation of GMI
- Prepare for MetOp-SG, MTG
- Assimilate Meteosat All Sky Radiance products
- Improved QC of water vapor Jacobians
- JEDI (Andrew Collard: Poster 4p.06)

Update to Thompson Microphysics for GFSv17

- Thompson microphysical scheme is added to the GFSv17
- Thompson MP needs to be added to GSI. Current GSI has GFDL MP
- GFDL MP in GSI is single-moment five-category (cloud water, cloud ice, rain, snow, and graupel) scheme based on Lin-Lord-Krueger cloud microphysics scheme
- Thompson MP double-moment, the number concentration of cloud ice and rain are predicted (Thompson et al., 2007)



GFS v17 will be coupled

- Atmosphere
  - GSI-based hybrid 4DEnVar deterministic analysis
  - GSI-based 4D-LETKF ensemble analysis
  - Additional early cycle ensemble analysis for GEFS initialization (if resources allow)
- Marine
  - Sea-ice Ocean and Coupled Analysis (SOCA): ocean and sea ice are strongly coupled
  - JEDI-based hybrid 3DEnVar for deterministic analysis
  - JEDI-based 3D-LETKF for ensemble analysis
- Land
  - JEDI-based 2D OI for snow
  - Possible LETKF (GSI or JEDI) for soil
- Aerosol
  - JEDI-based 3DVar
  - Initializes central analysis only (no ensemble perturbations)
  - Inclusion of aerosols is undecided for deterministic GFS forecast