Configuration of All-sky Microwave Radiance Assimilation in the NCEP's GFS Data Assimilation System

Yanqiu Zhu[1], Emily Liu[1], Rahul Mahajan[1], Catherine Thomas[1], David Groff[1], Paul Van Delst[1], Andrew Collard[1], Daryl Kleist[2], Russ Treadon[3], John Derber[3]

[1] IMSG and NOAA/NCEP/EMC
[2] University of Maryland,
[3] NOAA/NCEP/EMC
College Park, Maryland, USA

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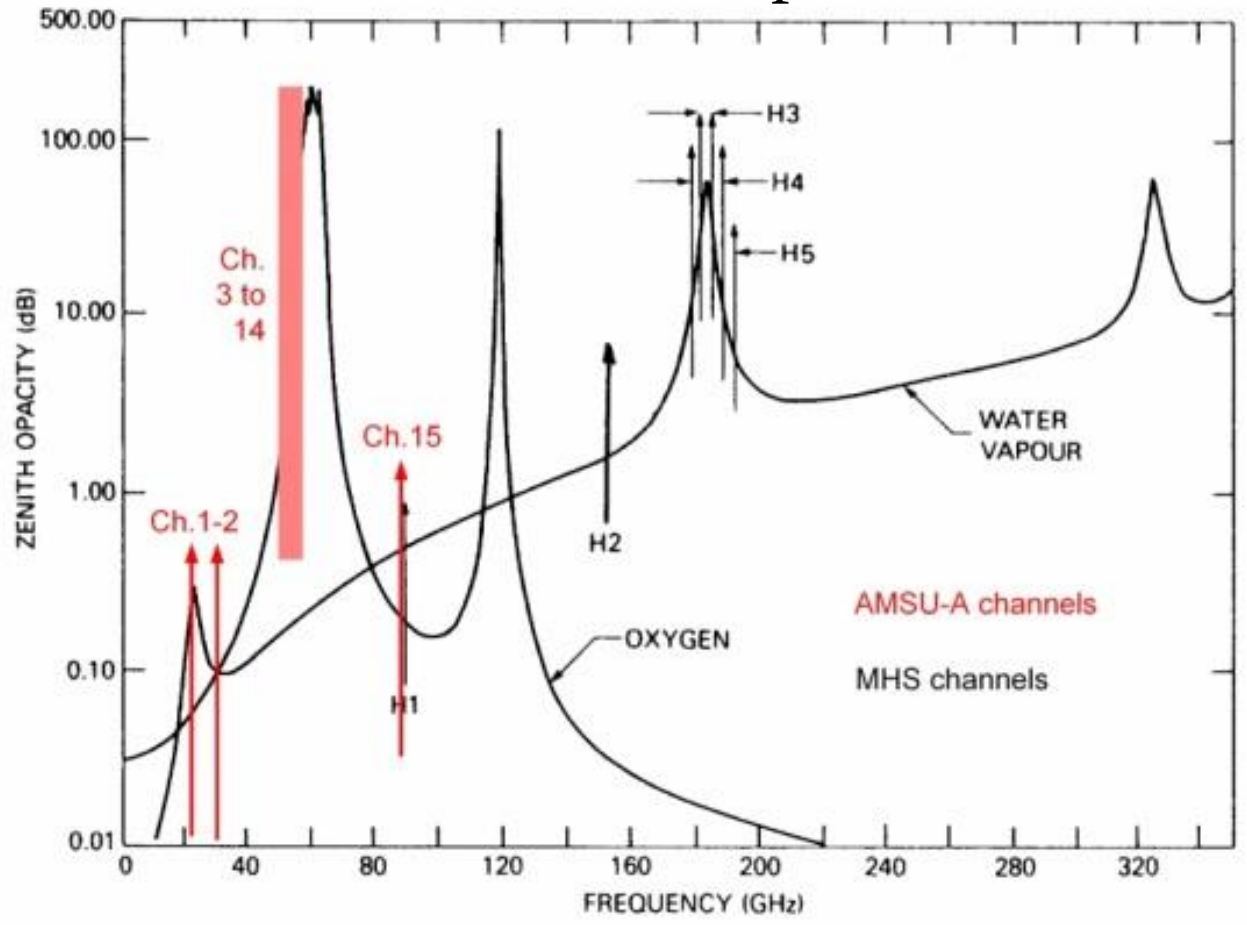
Progression of All-sky Microwave Radiance in NCEP's GFS System

- **Previous work**
  - Preference given to clear-sky in the data thinning was removed;
  - Cloud signal removal for radiances with thin cloud was turned off in bias correction;
  - Thick cloud filtering was turned off;
  - AMSU-A observation error: symmetric observation error (Geer et al. 2011).
- **Major upgrade in 2012: provided basic framework for all-sky radiance assimilation study for GFS, NAM and HWRF**
  - Introduced individual hydrometeors ql,qi,qr,qs,qg,qh into GSI as state variables;
  - Passed Jacobians w.r.t. hydrometeors into the GSI inner loop;
  - Control variable(s): cloud water (cw) or individual hydrometeors.
  - Observation operator revision and bug fixes
- **To present: in the hybrid 3D EnKF-VAR data assimilation system**
  - Situation-dependent observation error inflation; AMSUA-A observation error re-tuned;
  - All-sky radiance bias correction strategy (Zhu et al. 2014)
  - Additional quality control: cloud effect (Geer et al. 2013) and emissivity sensitivity screening;
  - Normalized cloud control variable; New static background error variance and correlation lengths for cloud control variable; Non-zero Jacobian for locations of clear-sky or small amount clouds;
  - Validation and improvement of CRTM under all-sky
  - Other changes and bug fixes.
- **Parallel test in the 4D EnVar system for FY16 implementation**
  - Included in the pre-implementation package (see poster from Derber 6.01)

- Include AMSU-A cloudy radiance affected by non-precipitating cloud over ocean from channels 1-5 and 15.
- Liquid water absorption is important in channels 1-5, and 15. Scattering becomes more important for channel 15.

Microwave Spectrum

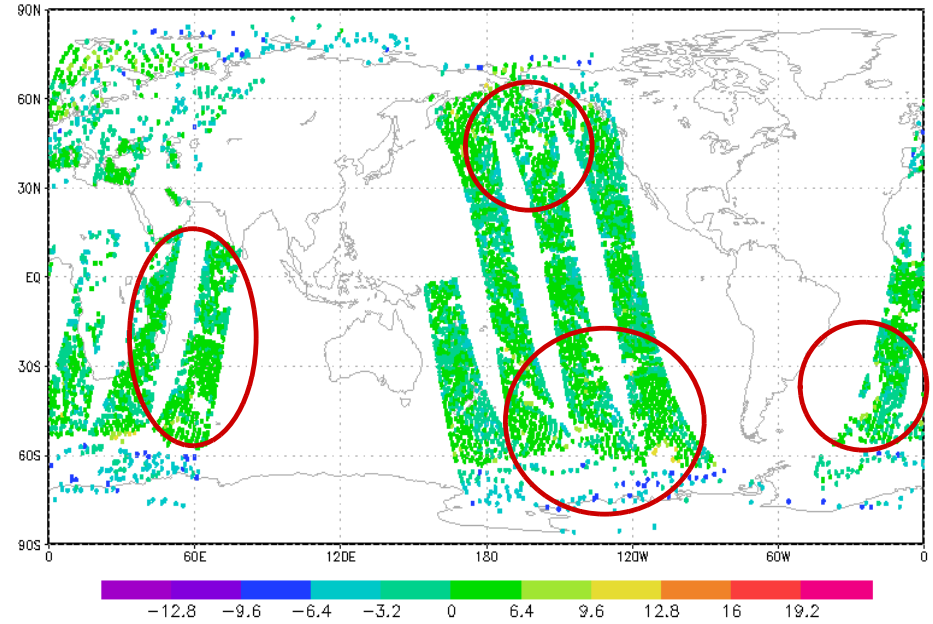


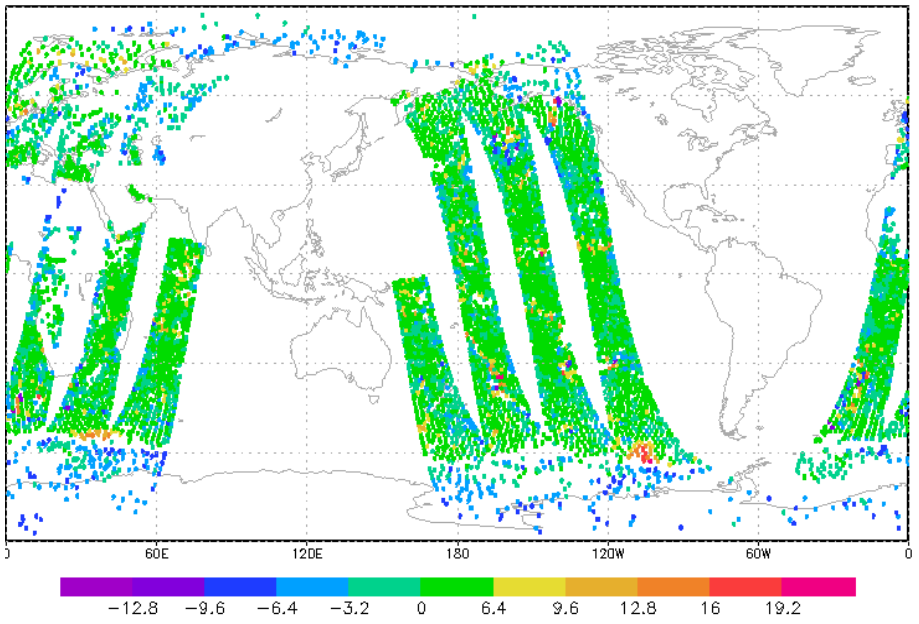
(Figure from Grody et al)

Configuration of all-sky microwave radiance assimilation for FY16 implementation

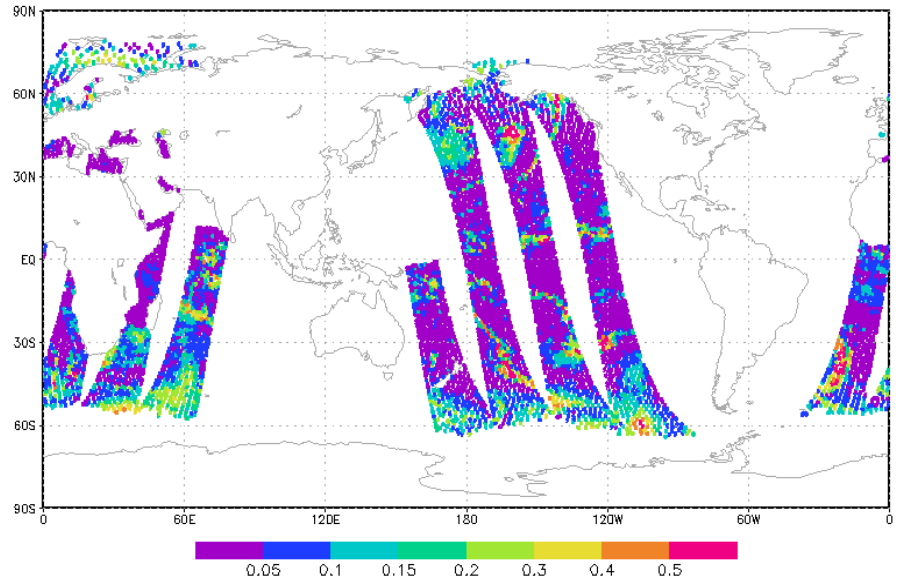
	Clear-sky approach	All-sky approach
Data thinning	**P**reference given to cloud-free FOVs	**N**o preference given to cloud-free FOVs
Input to CRTM	**C**loud info is not an input to CRTM	**C**loud info is taken into account in CRTM
Cloud related quality control	**T**hick cloud filtering; **P**recipitation screening	**P**recipitation screening; **C**loud effect screening (Geer et al. 2013); **E**missivity sensitivity screening.
Observation error	**C**lear-sky observation error	**S**ymmetric observation error (Geer et al 2011); **S**ituation- dependent observation error inflation
Bias correction	**E**nhanced radiance bias correction with a difference (obs-fg) CLW bias term to remove cloud signal.	**E**nhanced radiance bias correction with the difference CLW bias term turned off; **A** new all-sky bias correction strategy.
Cloud control variable	**C**loud water (cw); **R**adiance data info is mapped onto temperature and moisture fields	**N**ormalized cw/individual hydrometeors; **I**ndividual hydrometeors as the state variables; **R**adiance data info is mapped onto not only temperature and moisture fields, but also cloud fields via Jacobians w.r.t individual hydrometeors.
Background error covariance	**B**ackground error covariance (ensemble contribution + static term); **S**tatic cloud background error variance generated using the NMC method.	**B**ackground error covariance (ensemble contribution + static term); **N**ormalized cloud control variable, reduced correlation lengths.

Clear-sky OmF vs. All-sky OmF





CLW



- More data coverage: Thick clouds that are excluded from clear-sky assimilation are now assimilated under all-sky condition
- Rainy spots are excluded from both conditions

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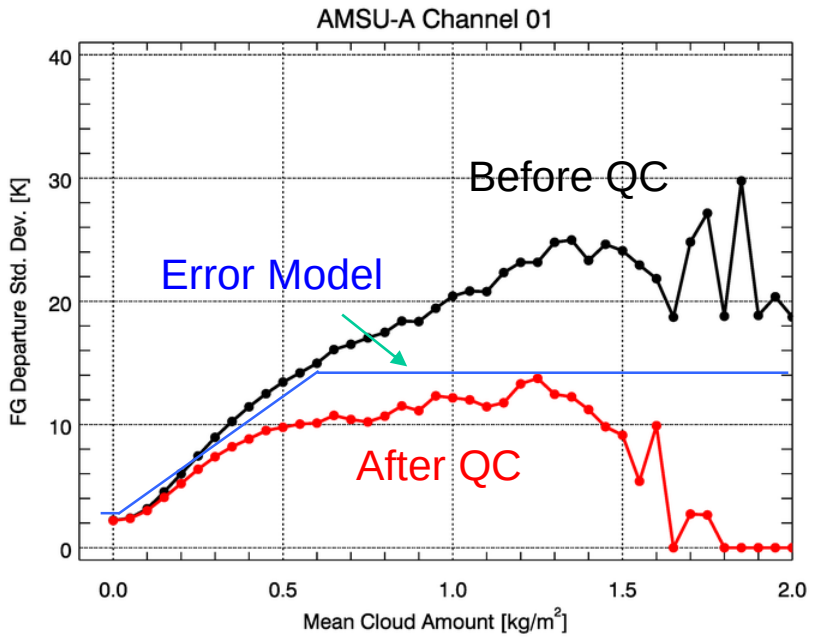
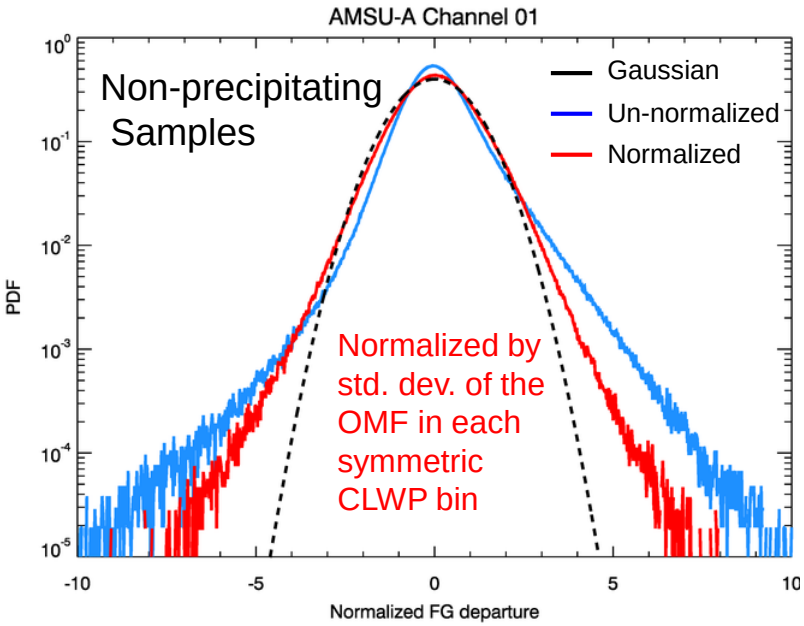
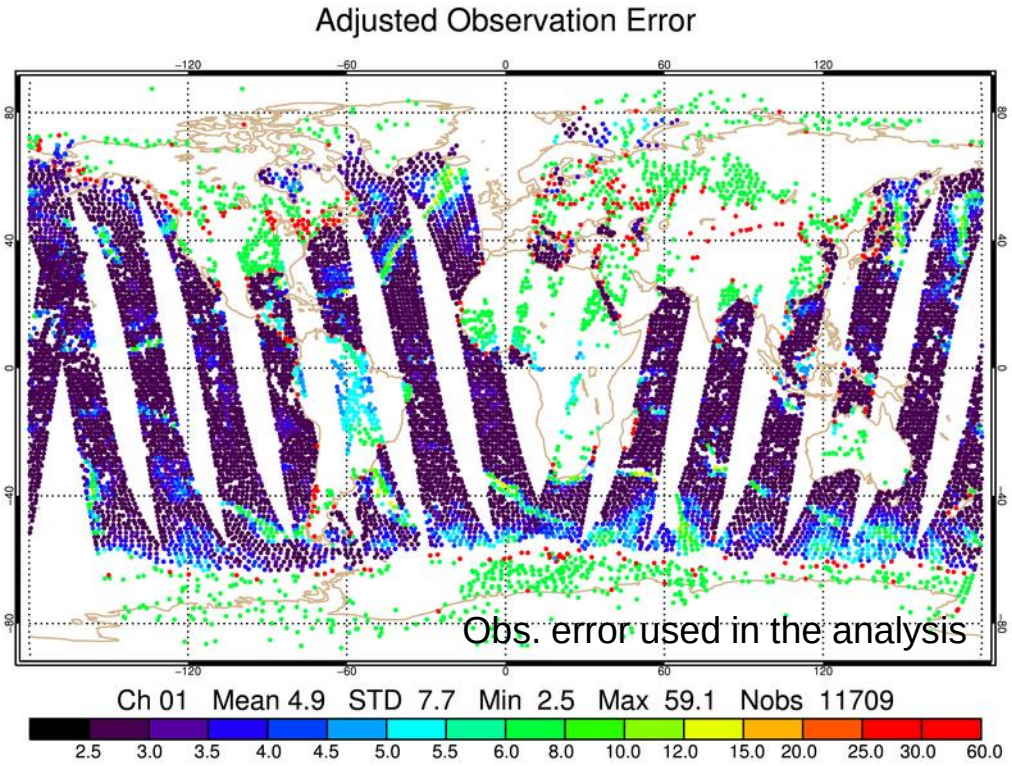
Symmetric Observation Error Assignment for AMSU-A under All-sky Condition







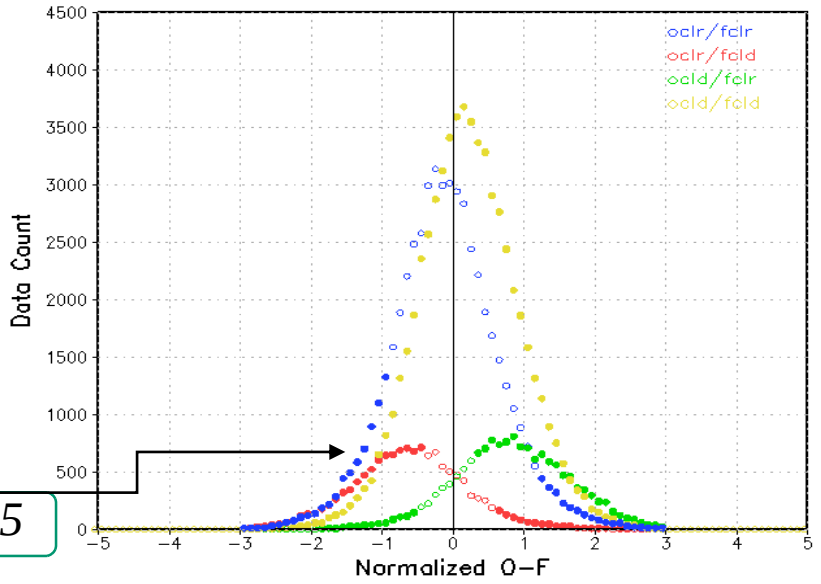
- Observation error is assigned as a function of the symmetric cloud amount (Geer et al. 2011)
- Gross check ±3 of the normalized FG departure (accept Gaussian part of the samples)

Situation-dependent Observation Error Inflation under All-sky Condition

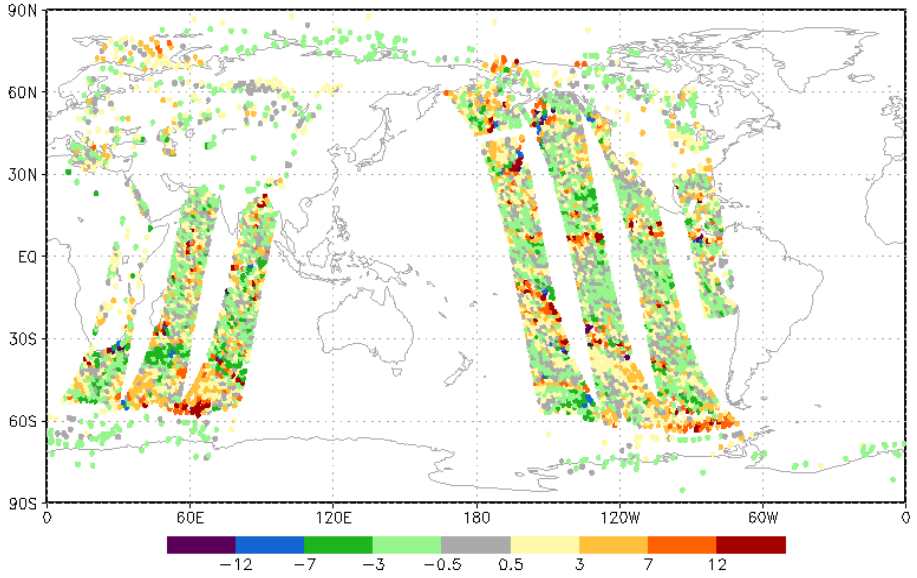
Observation error is inflated based on:

- Cloud mismatch information between the observation and the first guess;
- Cloud water difference between the observation and the first guess;
- Large scattering index (Weng et al. 2003) value;
- Surface wind speed.

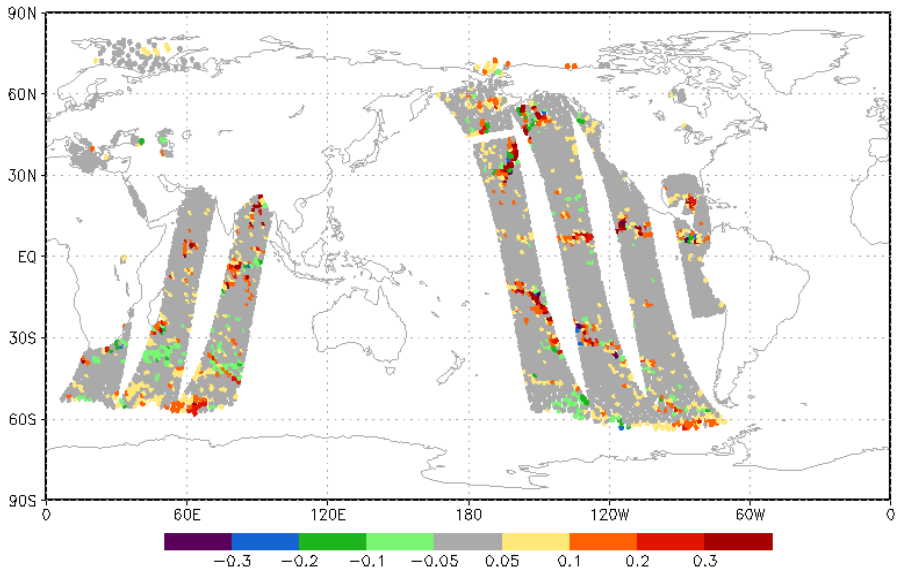
filled circle: averaged obserr_inverse < 0.25



OmF AMSUA METOPA Ch 2



Cloud water difference between FG and observation



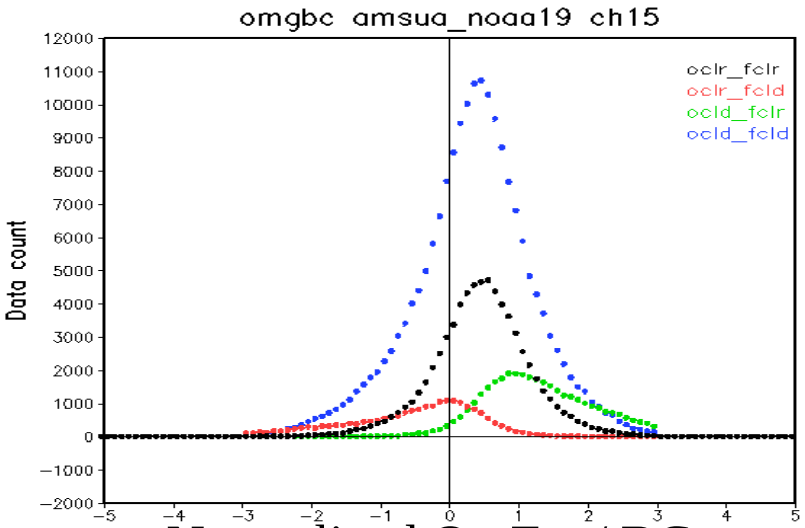
All-sky Radiance Bias Correction (Zhu et al. 2014)

- Based on cloud liquid water (clw, Grody et al. 2001) calculated from radiance observation (O) and first guess (F), different cloud information:
  1) O:clear vs. F:clear
  2) O:clear vs. F:cloudy
  3) O:cloudy vs. F:clear
  4) O:cloudy vs. F:cloudy

  eliminate cloud / generate cloud ❯ Mismatched cloud info

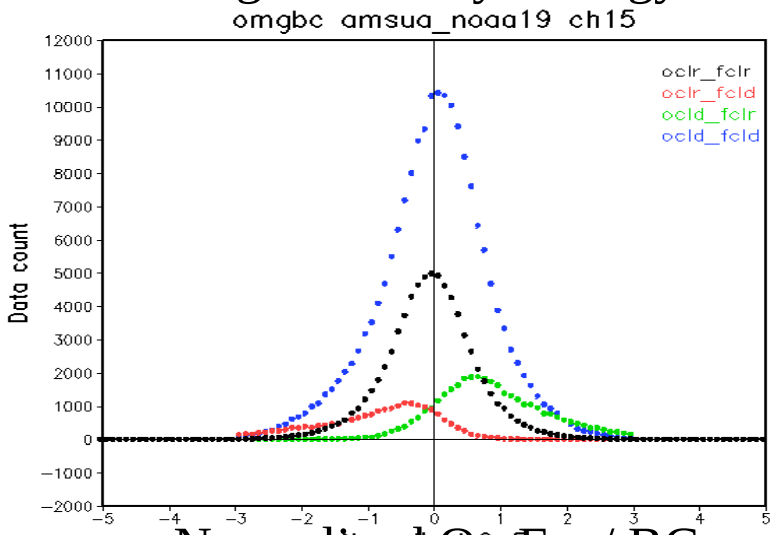
- Bias correction coefficients are obtained using only a selected data sample with consistent cloud info between the first guess and the observation
- Use latest bias coef. available to bias correct the data with mismatched cloud info

without using the all-sky strategy



Normalized OmF w/ BC

using the all-sky strategy

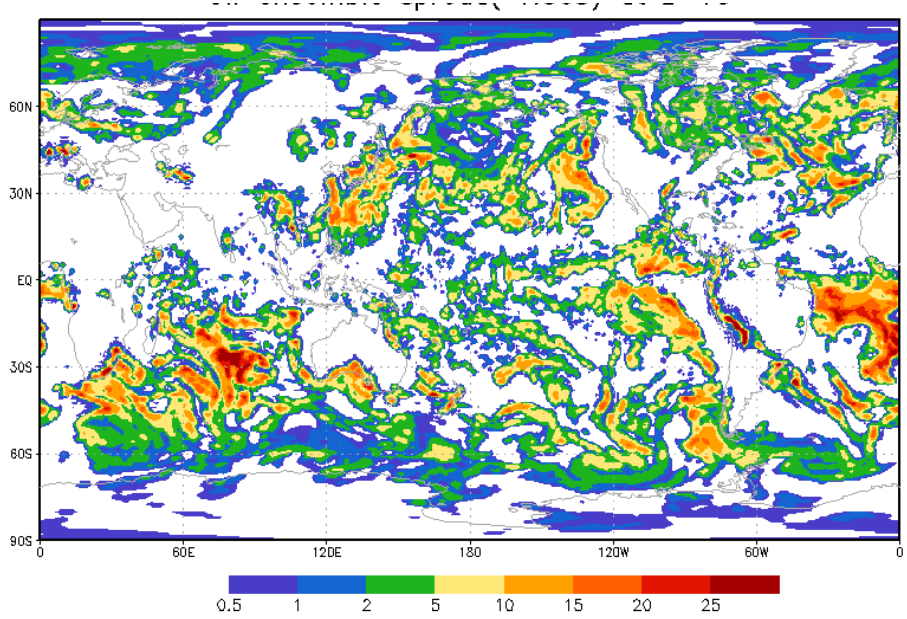


Normalized OmF w/ BC

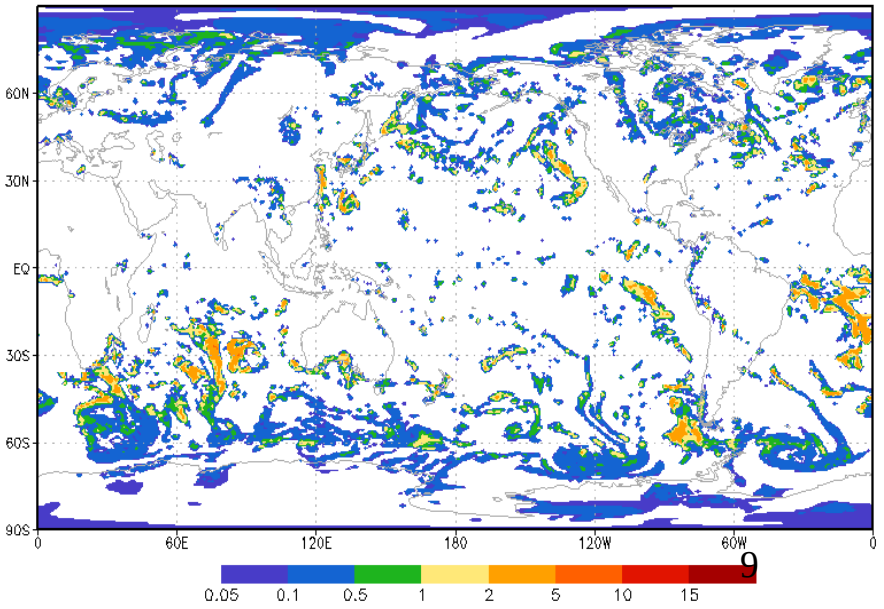
Background Error Covariance: ensemble part + static term

- **Ensemble part**: Stochastic physics helps to improve ensemble sample's representativeness of probability distributions; localization and nonlinearity may be detrimental to multi-variable balance.
- **Static part for cloud**: Considering the discontinuity of localized clouds and physical constraint by temperature and moisture, cloud water error variance is designed to be only large where clouds already exist, thus reducing spurious cloud increments.

cloud water ensemble spread

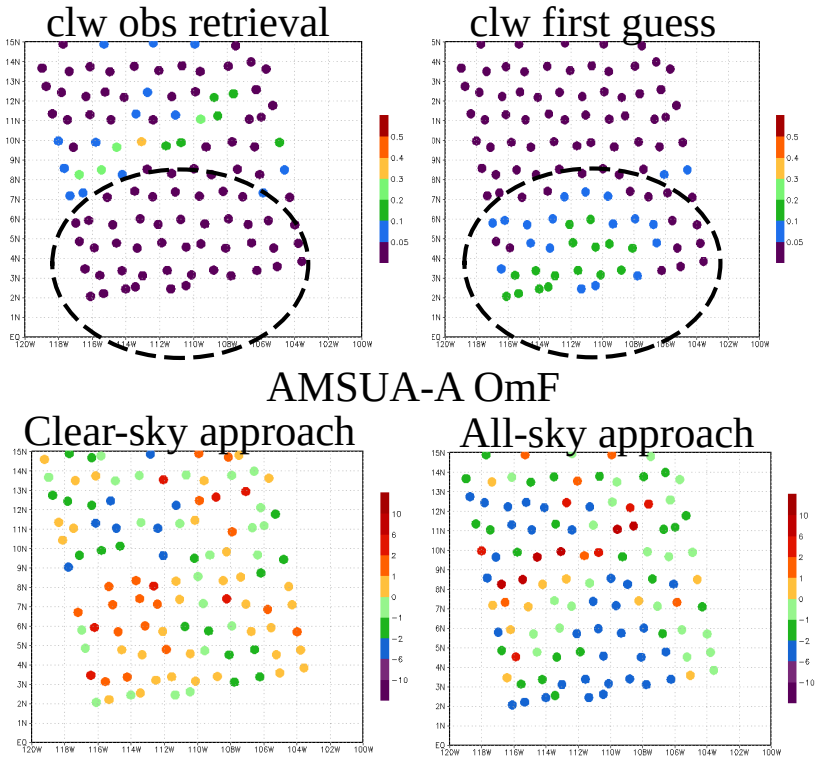


static cloud water variance



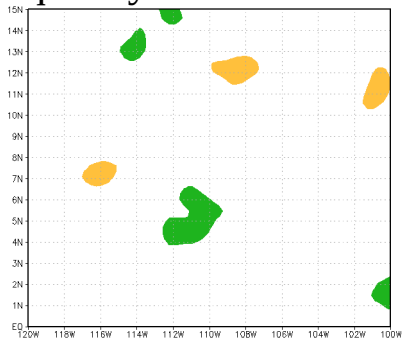
Impact on analysis increments

Example: Over ocean, at locations where observations have no or very few clouds but first guess has clouds ⟹

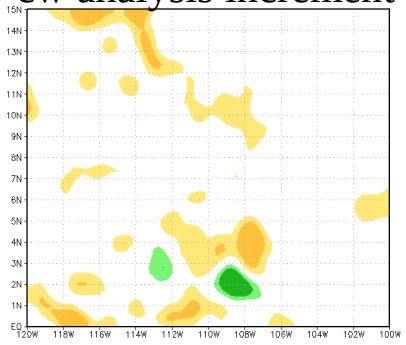


Clear-sky approach

q analysis increment

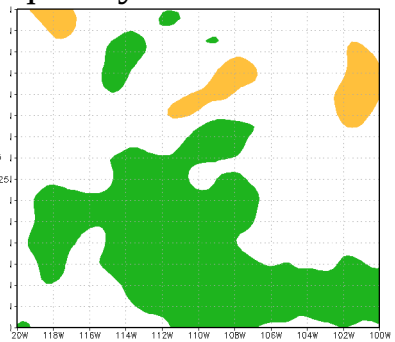


cw analysis increment

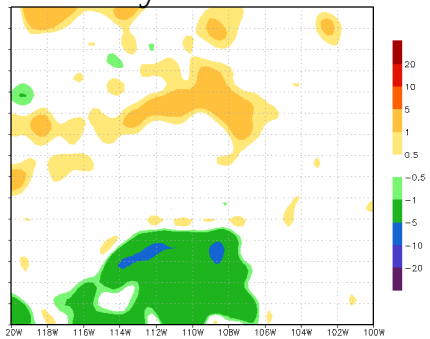


All-sky approach

q analysis increment



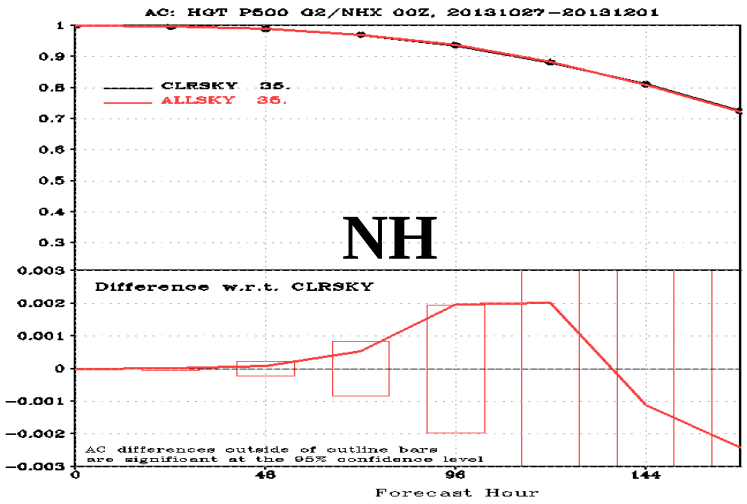
cw analysis increment

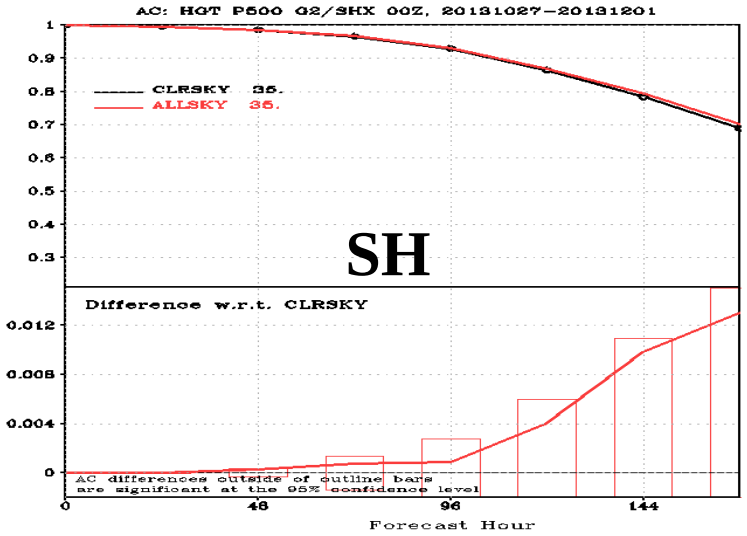


The all-sky approach allows the moisture and clouds to be reduced/removed at those locations.

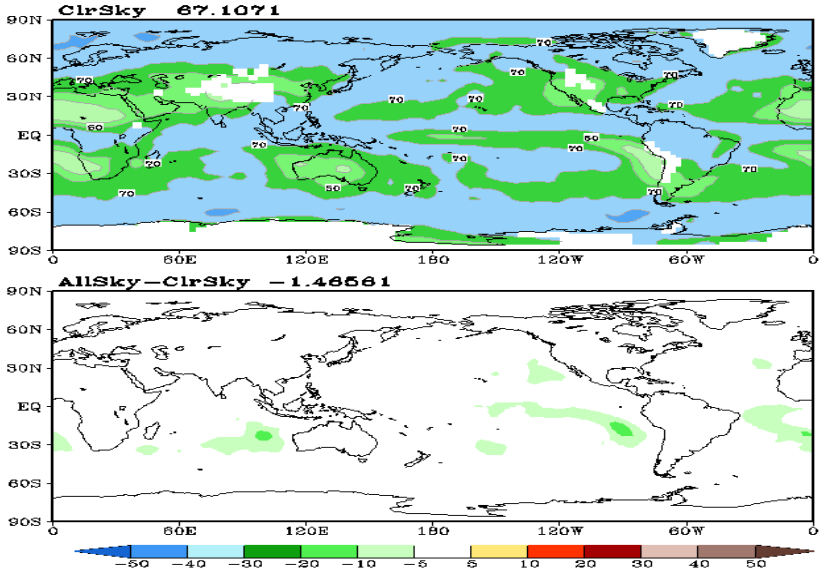
T670/T254 All-sky Microwave Radiance Assimilation in 3D EnVar

Anomaly Correlation at 500 hPa

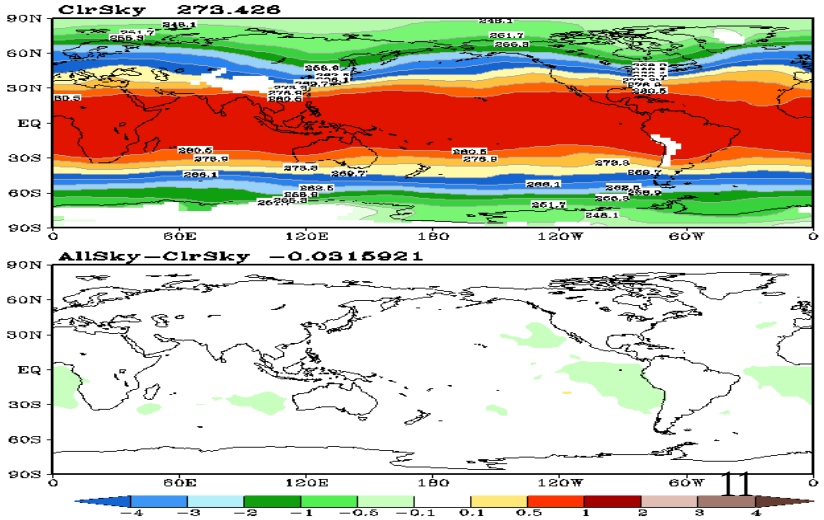




Impact on RH at 850hPa



Impact on T at 700hPa



Conclusions and ongoing work

- The all-sky microwave radiance assimilation has been included in the FY16 GFS pre-implementation package. It has been tested with the 4DEnVar in the GFS's parallel at NCEP.
- The configuration of all-sky microwave radiance for FY16 implementation includes additional quality control procedures, symmetric observation error, situation-dependent observation error, new all-sky bias correction strategy, normalized cloud water control variable, etc.
- An additional 10% cloudy AMSU-A radiance with non-precipitating clouds from channels 1-5 and 15 have been assimilated in NCEP's GFS system.
- Ongoing efforts of including cloudy ATMS radiance in the GFS
- Tests with an additional predictor, e.g., averaged cloud liquid water, are also underway to further improve all-sky bias correction.
- Ongoing efforts performed to restructure the GSI code for all-sky radiance assimilation -- centralize all-sky radiance related information, and enhance flexibility to enable all-sky assimilation capabilities for both microwave and infrared satellite-based instruments.
- Ongoing effort to validate the CRTM under all-sky with scattering condition (see posters from Emily Liu 8p.01 & Paul van Delst 2p.03)