Progress and Configuration of All-sky Microwave Radiances in the NCEP's Global Forecast 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

The 13th JCSDA Workshop on Satellite Data Assimilation, May 13-15, 2015, College Park, MD

OUTLINE

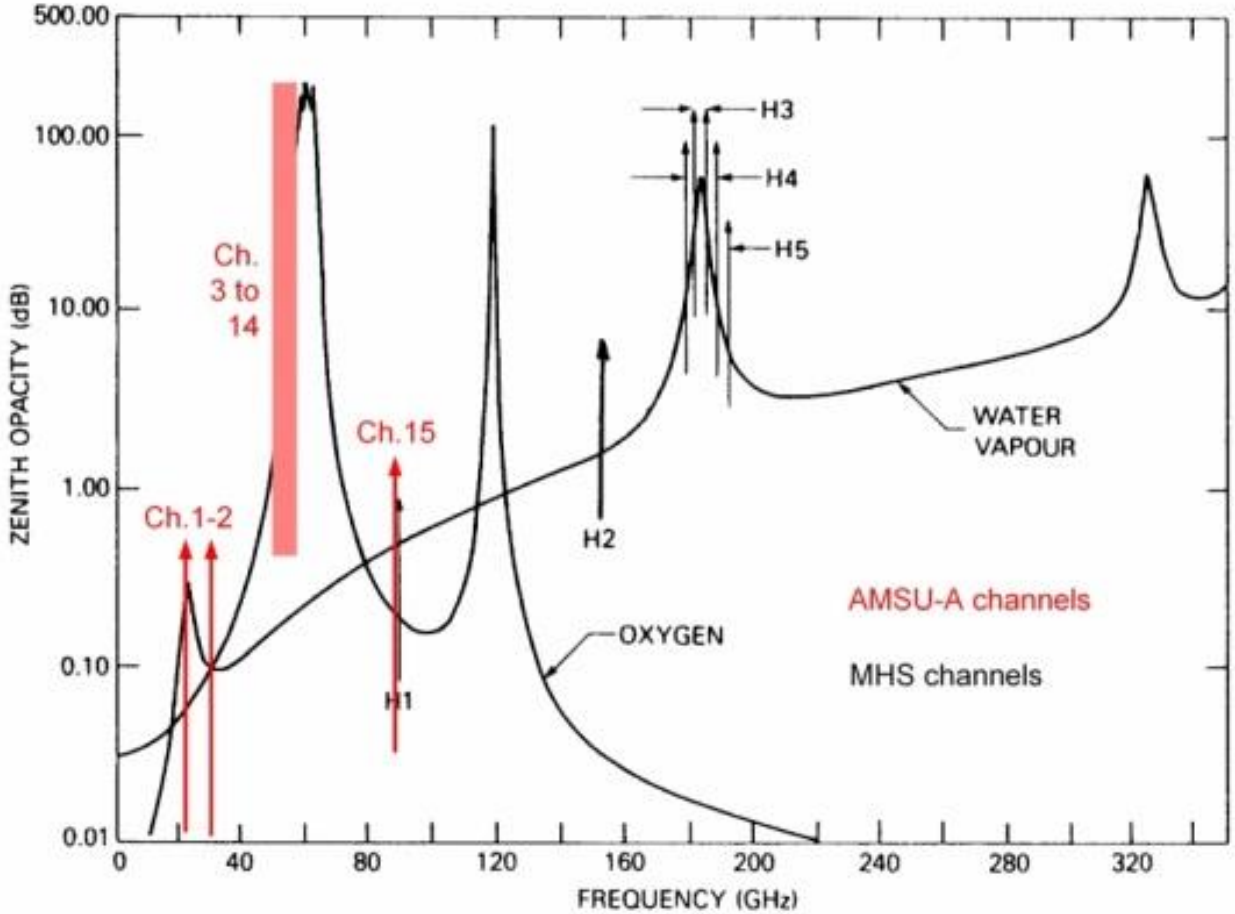
- Progression and configuration of all-sky microwave radiance assimilation at NCEP
- Benefits of all-sky approach as opposed to clear-sky approach
- Cloud increments the model retains
- Ongoing work and future plan

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;
  - 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 water control variable; New static background error variance and correlation lengths for cloud water; Non-zero Jacobian for locations of clear-sky or small amount clouds;
  - Validation and improvement of the CRTM under all-sky;
  - Other changes and bug fixes.
- **Parallel test in the 4D EnVar system for FY-16 implementation**
  - Included in the pre-implementation package

- 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

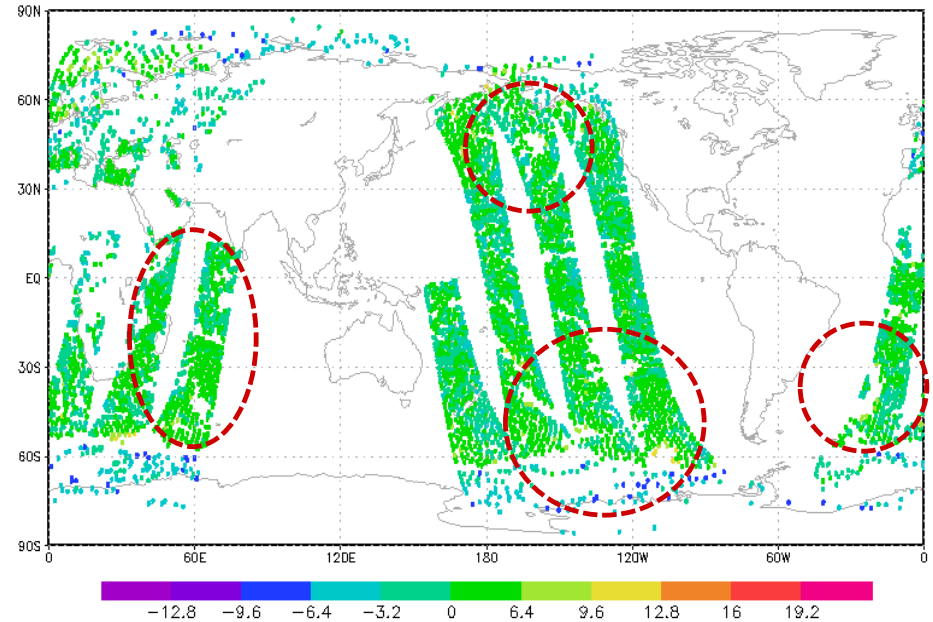


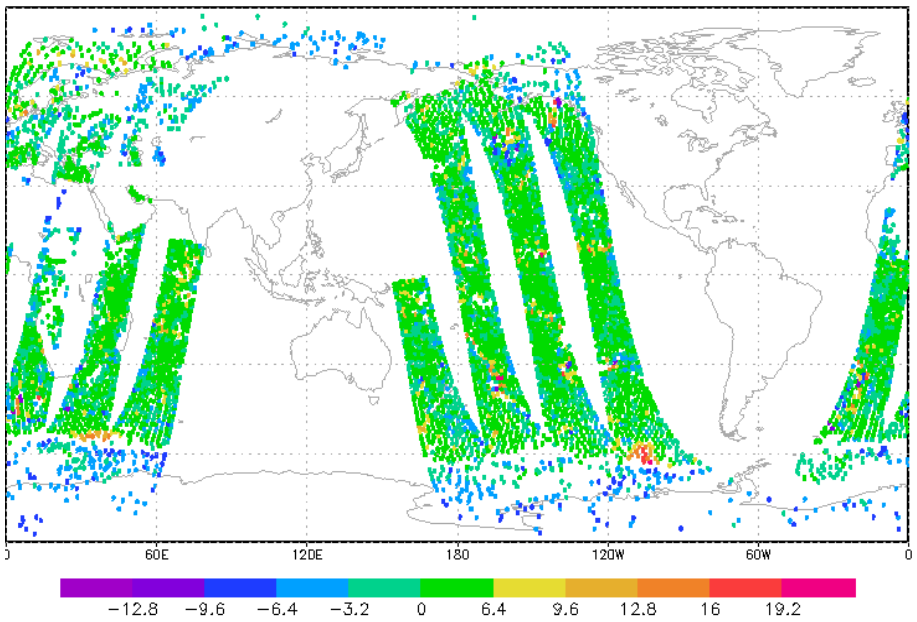
(Figure from Grody et al)

OUTLINE

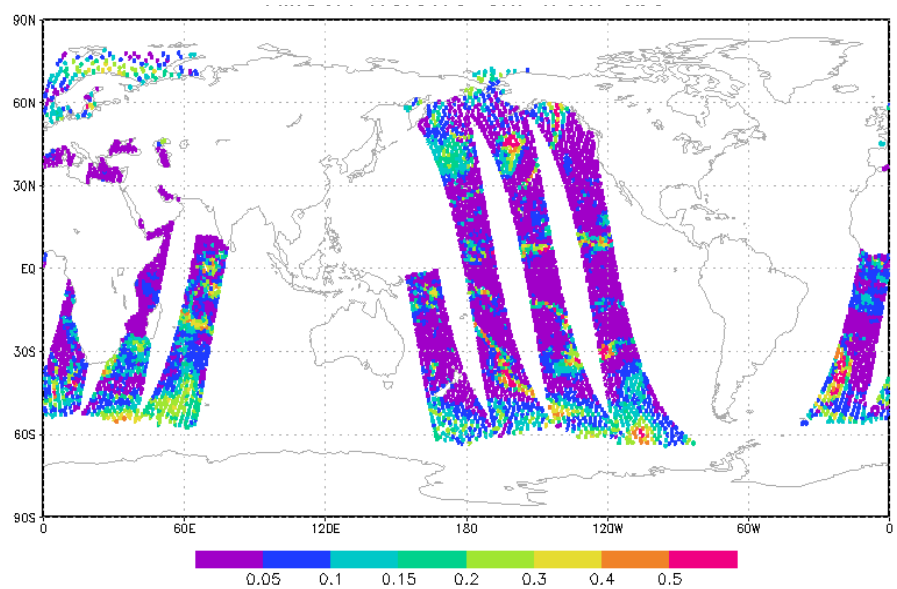
- Progression and configuration of all-sky microwave radiance assimilation at NCEP
- Benefits of all-sky approach as opposed to clear-sky approach
- Cloud increments the model retains
- Ongoing work and future plan

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

AMSUA NOAA19 CH1 00Z 20131029

Clear-sky approach

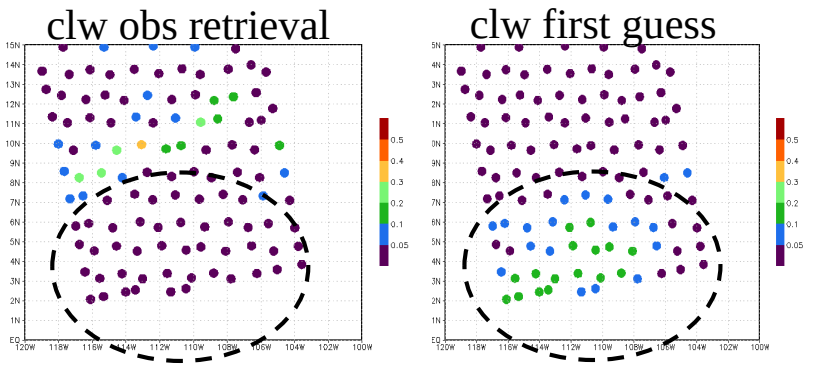
- No cloud info is provided as input to the CRTM; Cloud signal is removed by applying a cloud liquid water bias term in radiance bias correction scheme.
- Radiance data information is mapped onto temperature and moisture fields
- Cloud analysis increments are produced through the background error cross-covariance

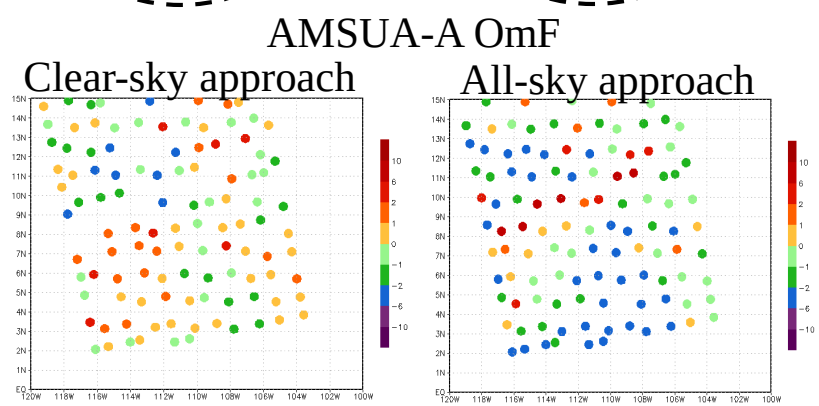
All-sky approach allows us to improve the satellite radiance innovation (OmF) statistics for cloud affected FOVs, enabling the production of better analyses of temperature and moisture

All-sky approach

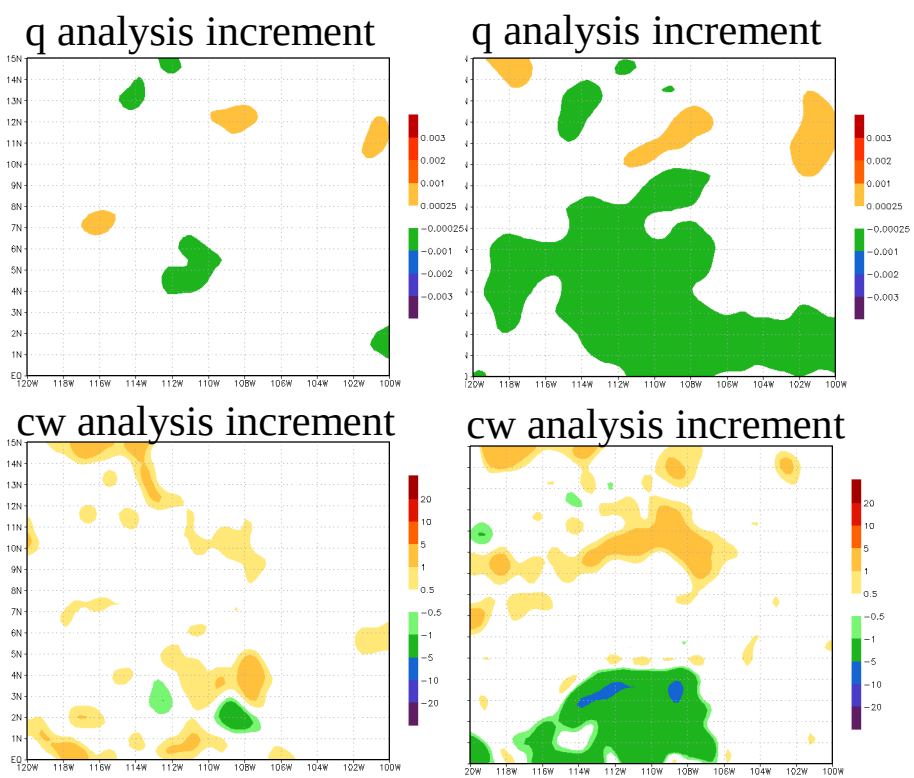
- Cloud info is accounted for in the CRTM, simulations of radiances are more realistic over a much larger footprint of meteorologically active weather conditions.
- Due to the use of cloud control variable, radiance data info is mapped onto not only temperature and moisture fields, but also cloud fields via Jacobians w.r.t hydrometeors
- Additional analysis increments are generated from the projection of the radiance data info onto the cloud fields through the cloud background error variance for clouds and through the background error cross-covariance for temperature and moisture

Over ocean, at locations where observations have no or very few clouds but first guess has clouds, for the clear-sky approach, OmF of AMSU-A channels 1 or 2 is likely to be over-estimated



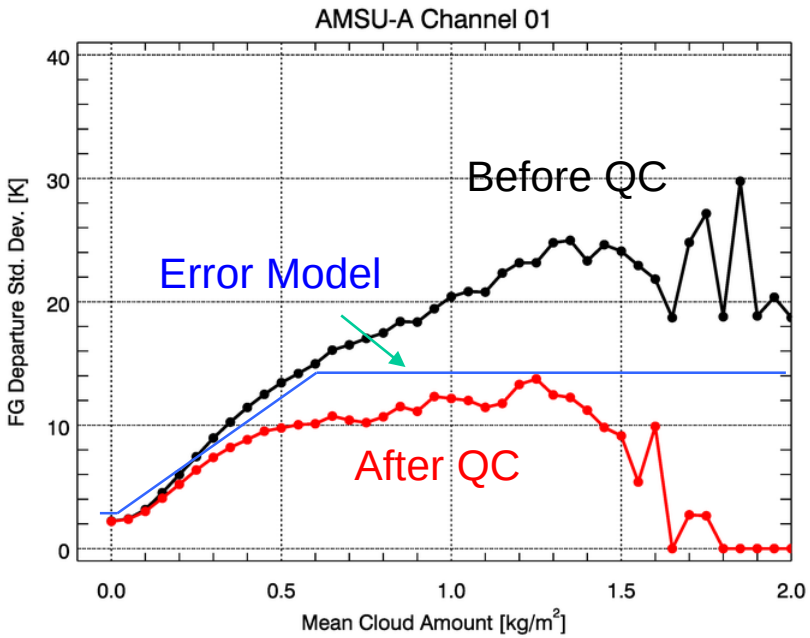


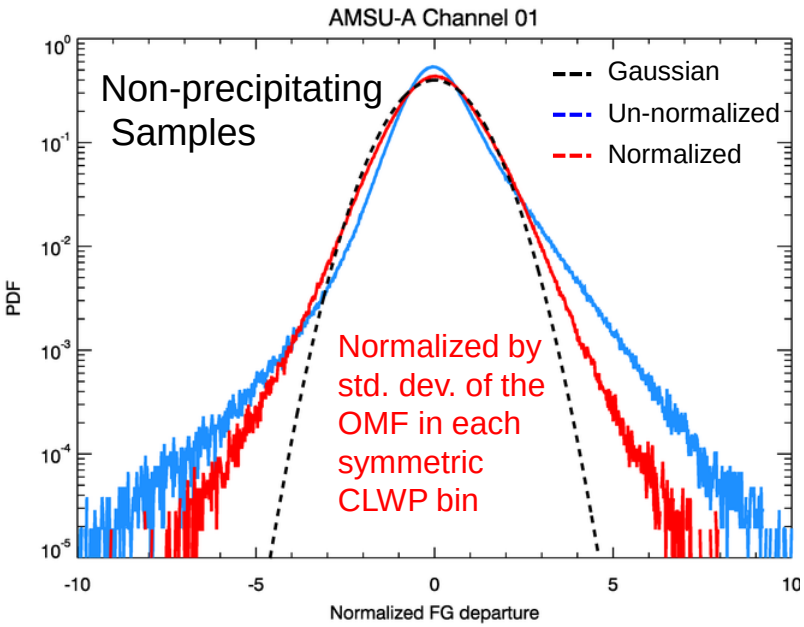
Clear-sky approach **All-sky approach**

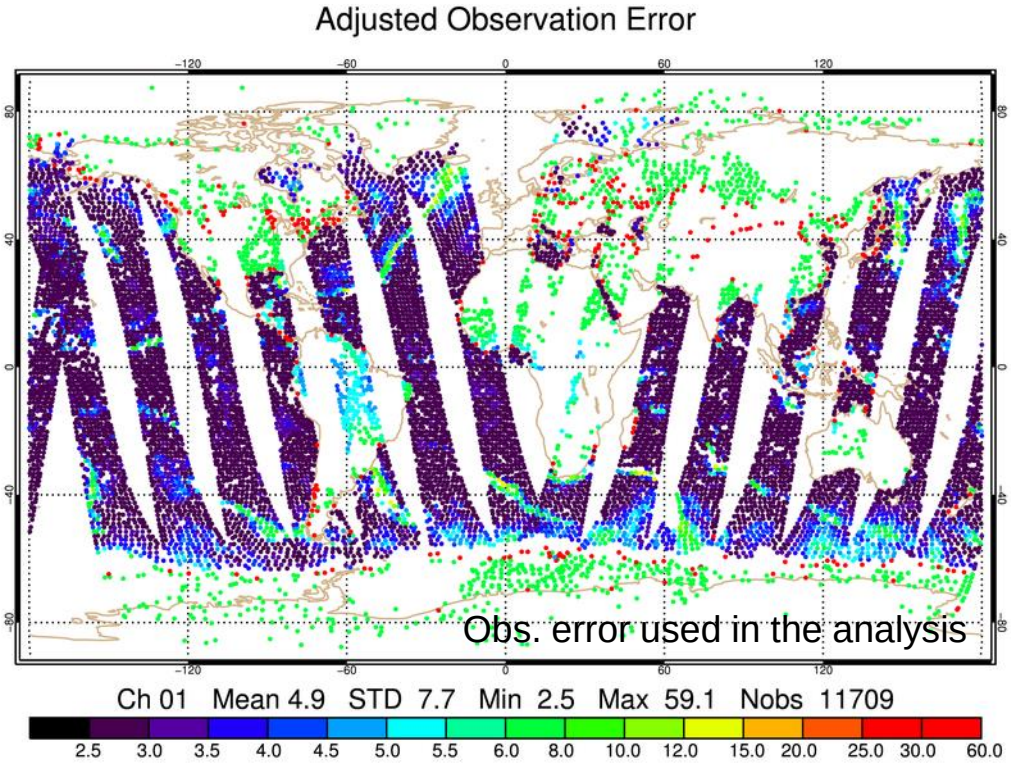


The all-sky approach allows the moisture and clouds to be reduced/removed at those locations.

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







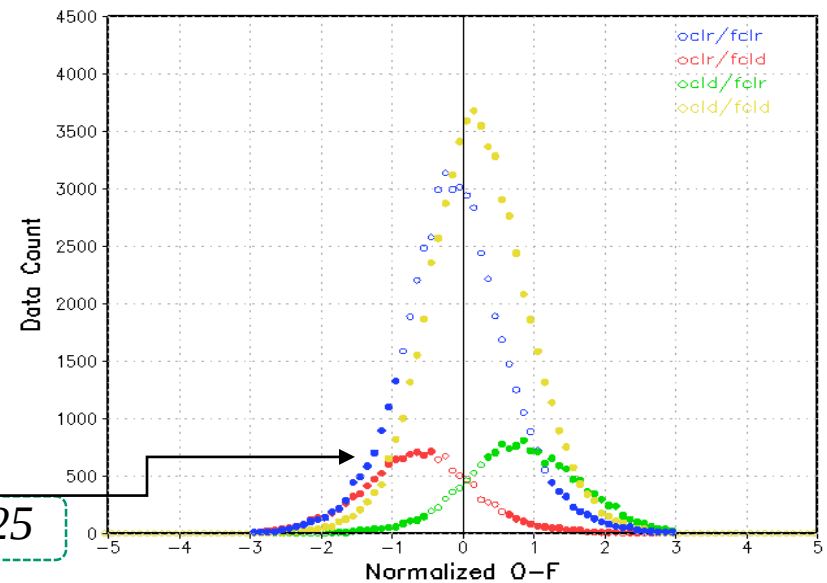
- Observation error is assigned as a function of the symmetric cloud amount (Geer et al. 2011)
- Gross check ±3 of the normalized FG departure (accept Gaussian part of the samples)

Situation-dependent Observation Error Inflation under All-sky Condition

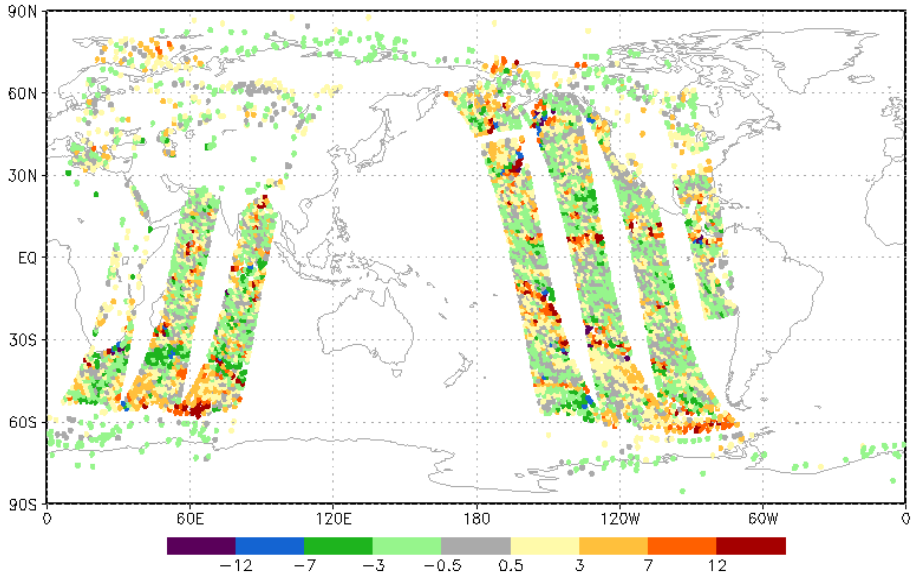
Observation error is inflated based on:

- **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.**

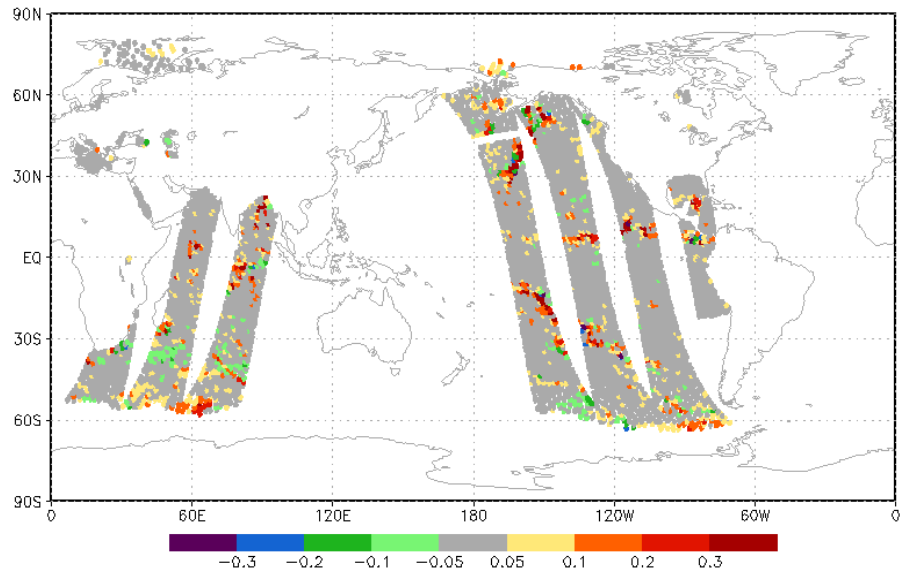
filled circle: averaged obserr_inverse < 0.25



OmF AMSUA METOPA Ch 2



Cloud water difference between FG and observation

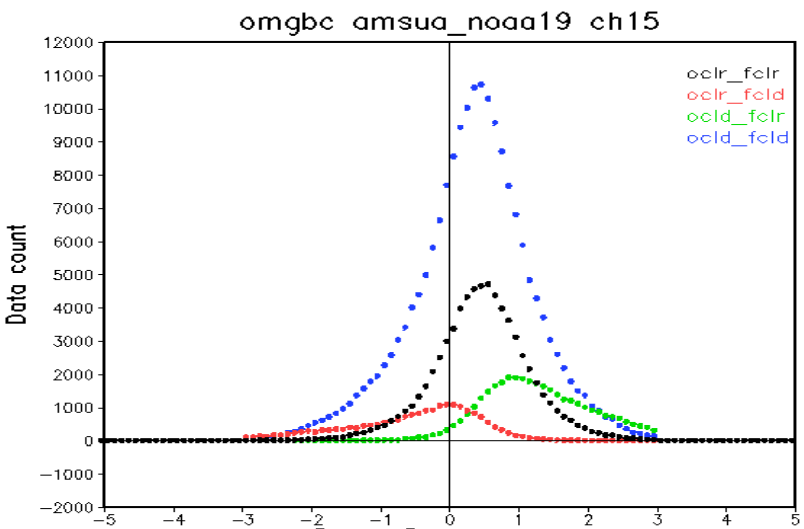


All-sky Radiance Bias Correction (Zhu et al. 2014)

- 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 — eliminate cloud
  3) O:cloudy vs. F:clear — generate cloud
  4) O:cloudy vs. F:cloudy

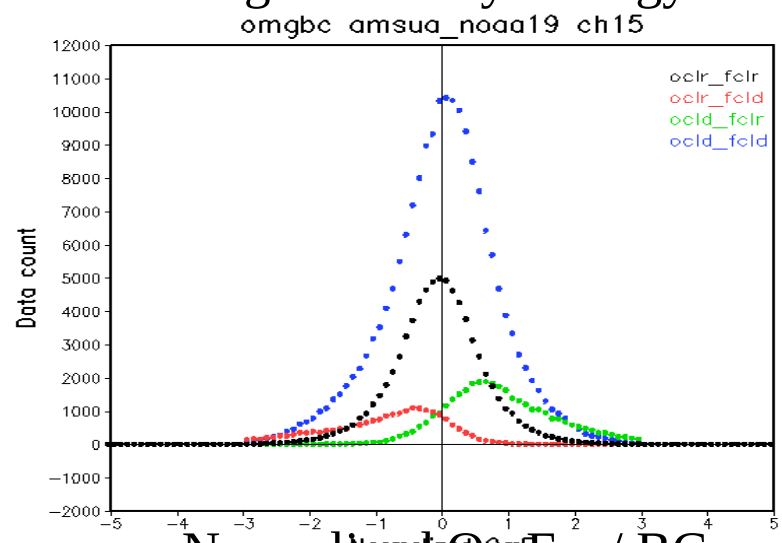
  ❯ Mismatched cloud info
- Bias correction coefficients are obtained using only a selected data sample with consistent cloud info between the first guess and the observation
- Use latest bias coef. available to bias correct the data with mismatched cloud info

without using the all-sky strategy



Normalized OmF w/ BC

using the all-sky strategy



Normalized OmF w/ BC

OUTLINE

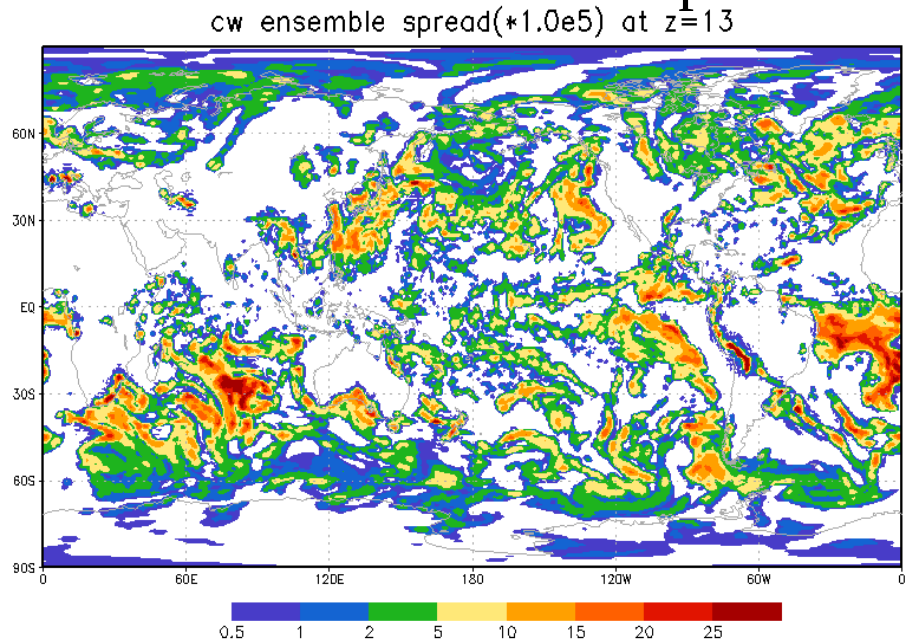
- Progression and configuration of all-sky microwave radiance assimilation at NCEP
- Benefits of all-sky approach as opposed to clear-sky approach
- Cloud increments the model retains
- Ongoing work and future plan

Background Error Covariance: ensemble part + static term

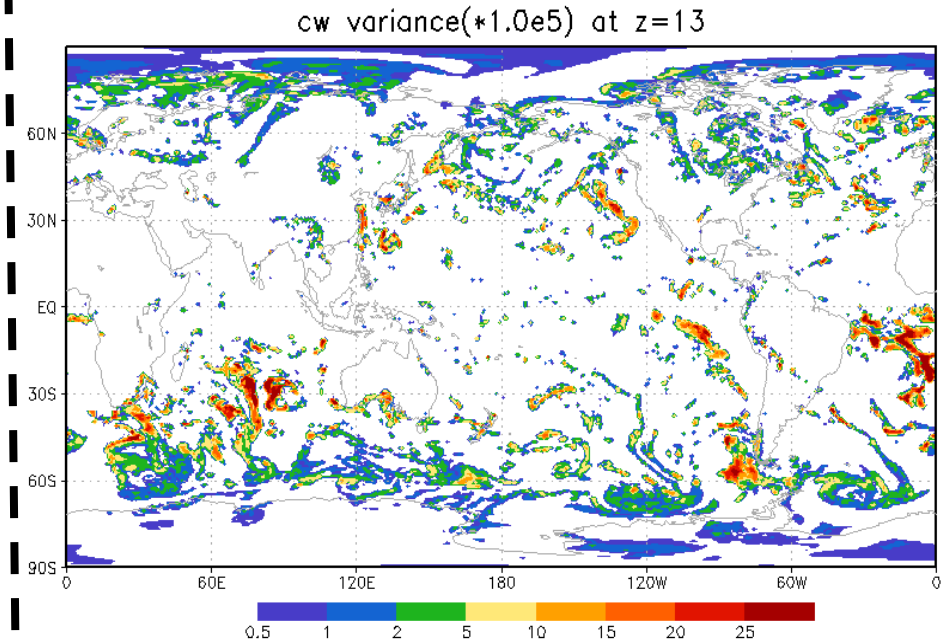
- **Ensemble part**: Stochastic physics helps to improve ensemble sample's representativeness of probability distributions; localization and nonlinearity may be detrimental to multi-variable balance.
- **Static part for cloud**: Considering the discontinuity of localized clouds and physical constraint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

pre-implementation configuration	Comparison test
▪ 87.5% ensemble, 12.5% static ▪ Multi-variable cloud water analysis	Same as pre-implementation configuration except: ▪ Univariate cloud water analysis ▪ Actual static cloud water background error variance is increased to be 10% of its first guess

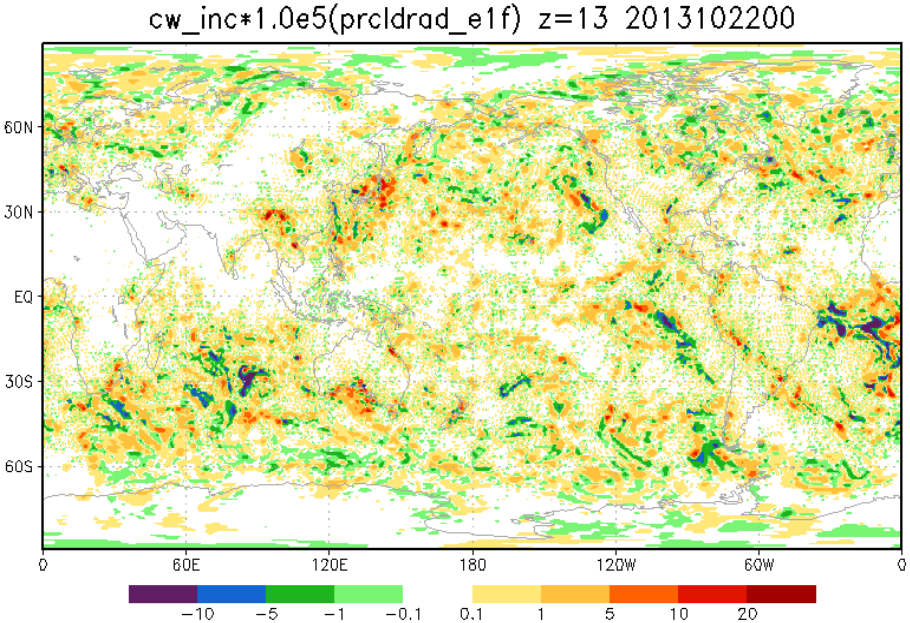
cloud water ensemble spread



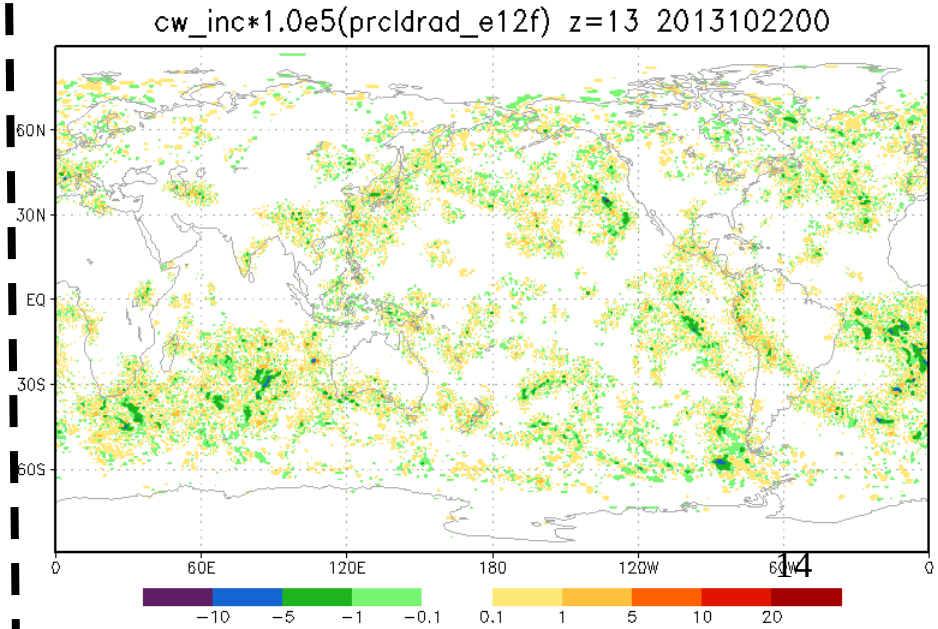
Cf: static cloud water variance



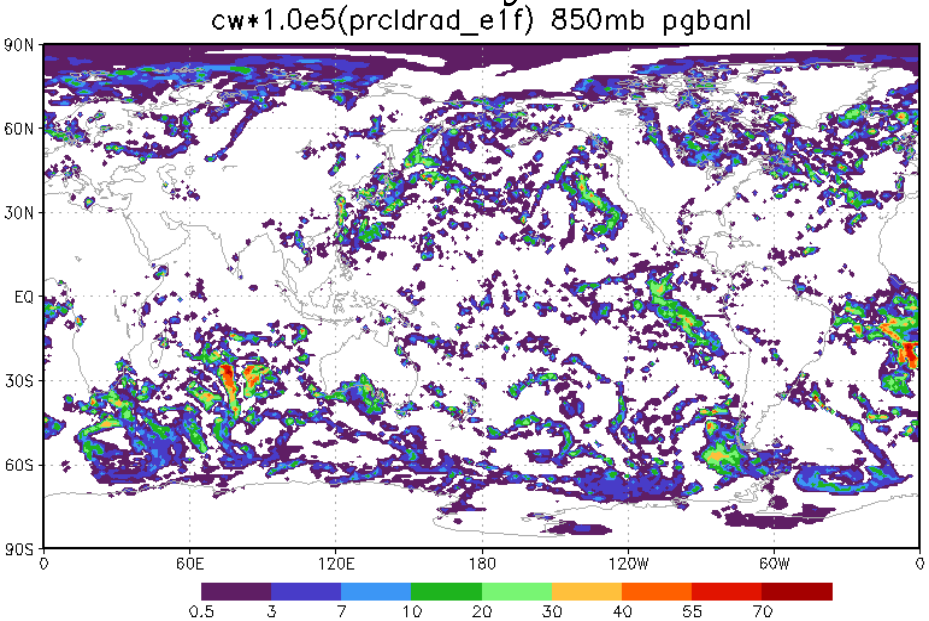
cloud water increment



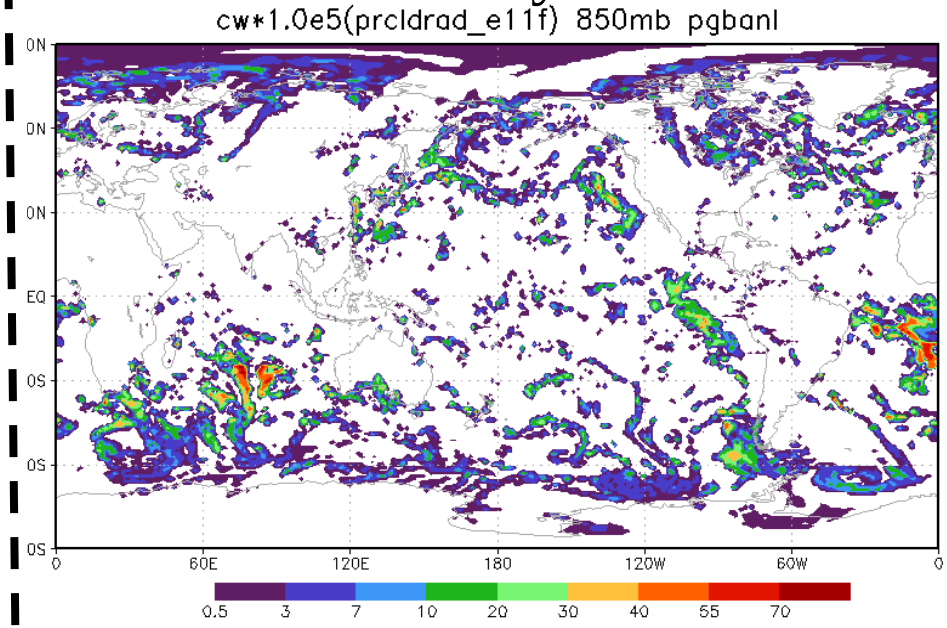
cloud water increment



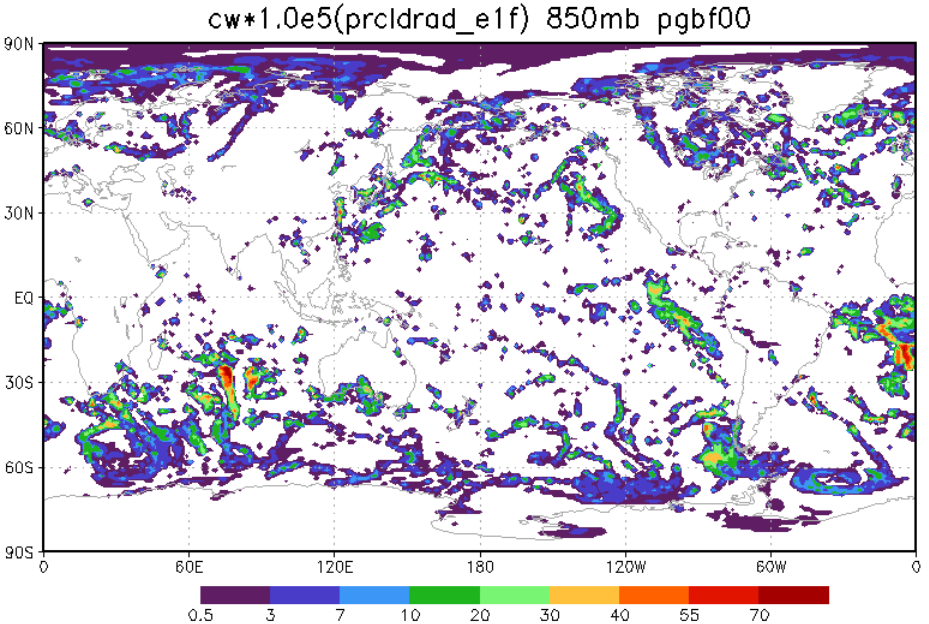
cloud water analysis at 850mb



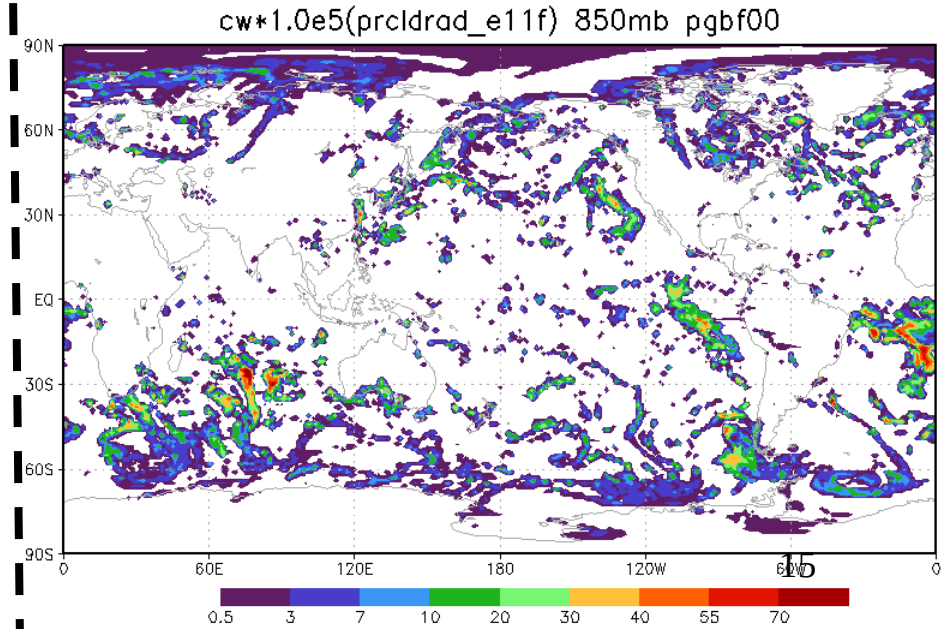
Cf: cloud water analysis at 850mb



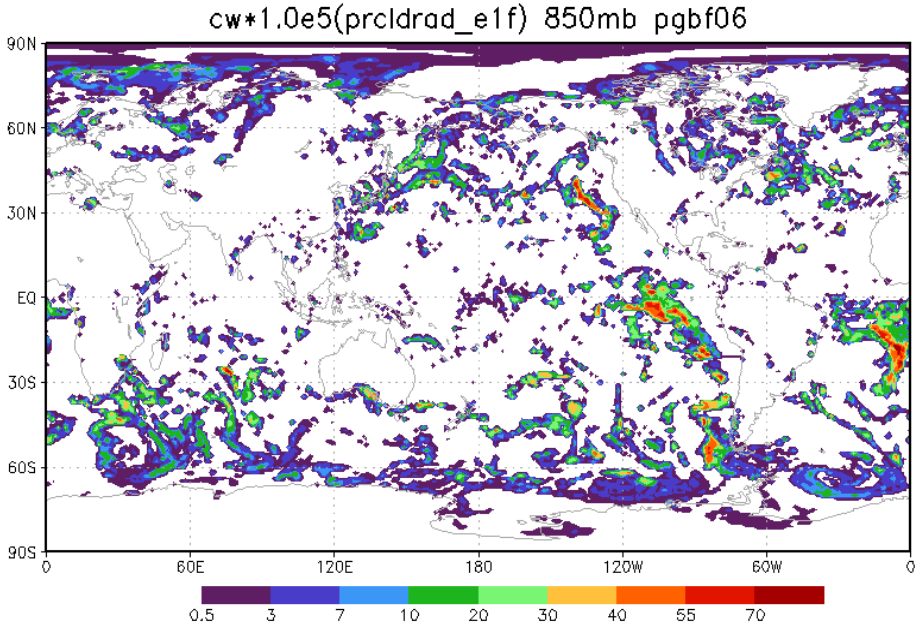
cloud water f00 at 850mb



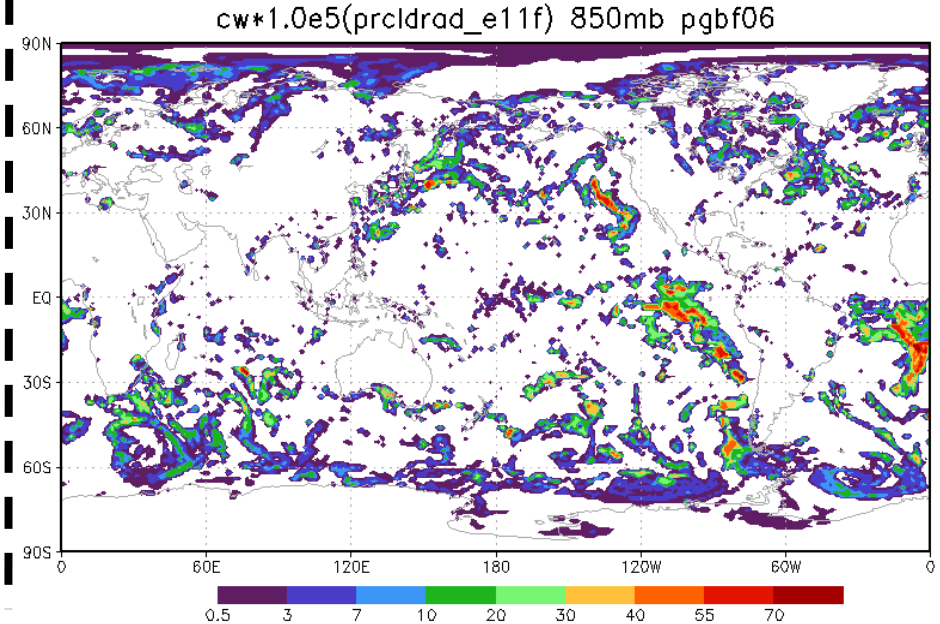
cloud water f00 at 850mb



cloud water f06 at 850mb



Cf: cloud water f06 at 850mb



- Static error variance for cloud water is designed to be localized; Ensemble spread is much broader structure-wise
- When cloud exists in some ensemble members, clouds generated sometimes may not be compatible with model physics
- It seems that the cloud increments generated at the locations where clouds already exist are most likely to be retained by the model so far
- Necessitate further study on how to handle the balance among temperature, moisture and clouds

OUTLINE

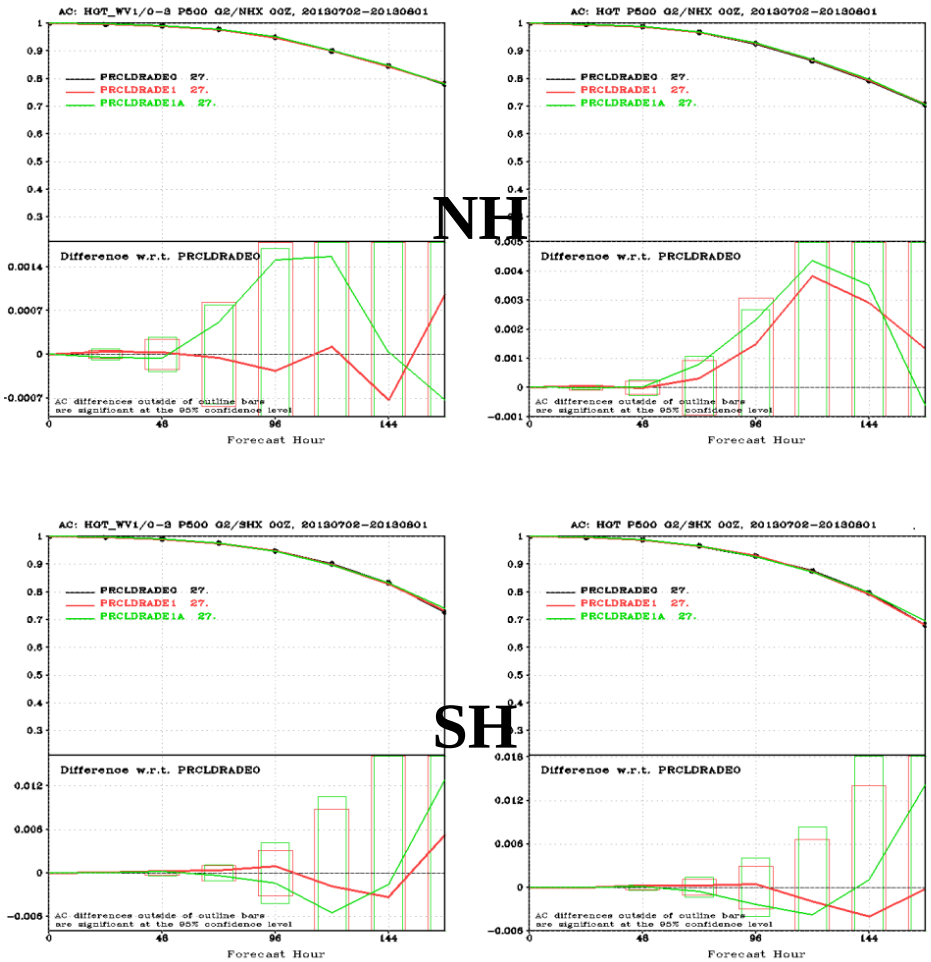
- Progression and configuration of all-sky microwave radiance assimilation at NCEP
- Benefits of all-sky approach as opposed to clear-sky approach
- Cloud increments the model retains
- Ongoing work and future plan

T670/T254 All-sky Radiance Runs in 4D EnVar

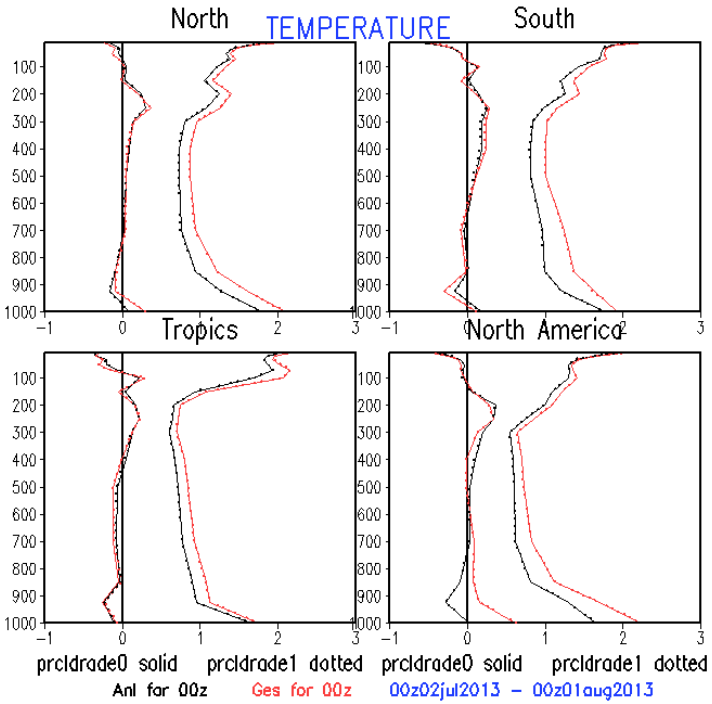
4D EnVar

4D EnVar + Cloudy

Anomaly Correlation at 500 hPa



Analysis & 6h forecast fits to the radiosonde data



Conclusions and future work

- The cloudy AMSU-A radiance with non-precipitating clouds from channels 1-5 and 15 have been tested in NCEP's GFS system.
- The configuration of all-sky microwave radiance for FY-16 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.
- All-sky microwave radiance has been tested with 4DEnVar in the GFS' parallel for FY-16 implementation.
- Tests with an additional predictor, e.g., averaged cloud liquid water, are underway to further improve all-sky bias correction.
- Observation error angle-dependency will be examined.
- Further investigate the balance among temperature, moisture and cloud analysis fields.
- Plan to expand the all-sky approach to other instruments.
- Plan to validate the CRTM under all-sky with the scattering condition.

Acknowledgement: This work is funded by EMC Sandy Supplemental and EMC Base funding