All-Sky Microwave Radiance Assimilation in the NCEP's GSI Analysis System

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INTRODUCTION

In the current operational hybrid 3D Ensemble-Variational (EnVar) Global Forecast System (GFS), the clear-sky approach of radiance data assimilation is employed. With the development effort made for all-sky conditions on modifying and assessing quality control, observation error assignment, bias correction, and background error covariance in the EnVar framework, the capability of all-sky microwave radiance assimilation in the Gridpoint Statistical Interpolation (GSI) analysis system has been developed at the NCEP. Because the current GFS output does not provide snow and precipitation profiles, the AMSU-A cloudy radiances affected by non-precipitating cloud over ocean are assimilated in this study.

This work of all-sky microwave radiance assimilation is included in the FY16 GFS pre-implementation package, and has been tested along with other upgrade components in the 4D EnVar GFS parallel experiment at NCEP. In this poster, we will present the configuration of the all-sky microwave radiance assimilation for the FY16 GFS implementation, and discuss in more detail about observation error, bias correction, cloud water background error variance and ensemble spread. Outstanding issues and ongoing/future work are also presented.

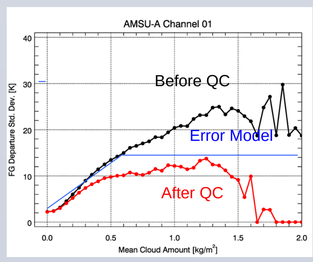
ALL-SKY MICROWAVE ASSMILATION CONFIGURATION

	Clear-sky approach	All-sky approach
Data used	Clear-sky data + radiances affected by thin clouds	Clear-sky data + radiances affected by thin and thick clouds
Input to CRTM	Cloud info is not an input to CRTM	Cloud info is taken into account in CRTM
Cloud related quality control	Thick cloud filtering; Precipitation screening	Precipitation screening; Cloud effect screening (Geer et al. 2011a); Emissivity sensitivity screening.
Observation error	Clear-sky observation error	Symmetric observation error (Geer et al 2011b); Situation- dependent observation error inflation
Bias correction	Enhanced radiance bias correction with a CLW difference (obs-fg) bias term to remove cloud signal.	Enhanced radiance bias correction with the CLW difference bias term turned off; A new all-sky bias correction strategy.
Cloud control variable	Cloud water (cw); T,q,u,v,sst as the state variables; Radiance data info is mapped onto the fields of state variables	Normalized cw or individual hydrometeors; Individual hydrometeors are added as the additional state variables; Radiance data info is also mapped onto cloud fields via Jacobians w.r.t individual hydrometeors.
Background error covariance	Background error covariance (ensemble contribution + static term); Static cloud background error variance generated using the NMC method.	Background error covariance (ensemble contribution + static term); Normalized cloud control variable, reduced correlation lengths.

OBSERVATION ERROR (symmetric + situation-dependent)

Symmetric obs error

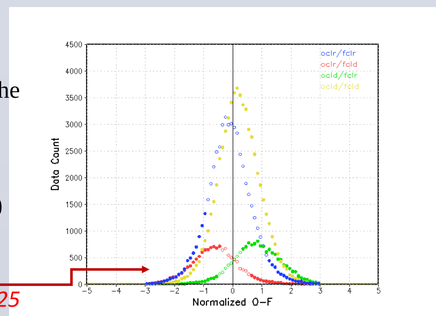
- Observation error is assigned as a function of the symmetric cloud amount (Geer et al. 2011b)

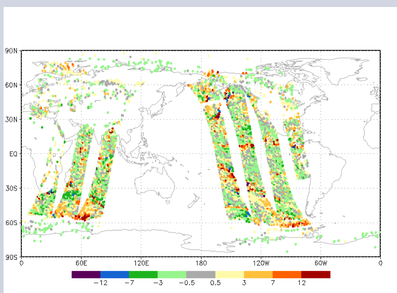


Situation-dependent obs error inflation is based on:

- Different placements of clouds 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





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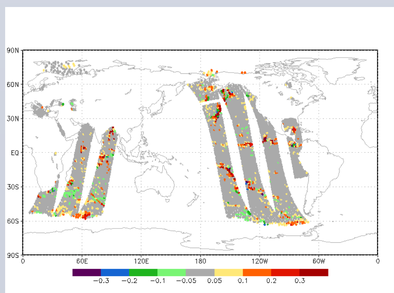
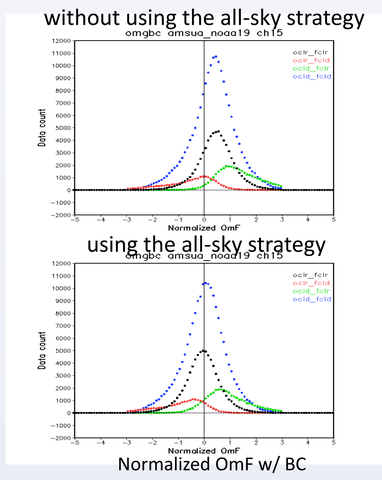


Cloud water difference between FG and observation

ALL-SKY RADIANCE BIAS CORRECTION STRATEGY (Zhu et al. 2014)

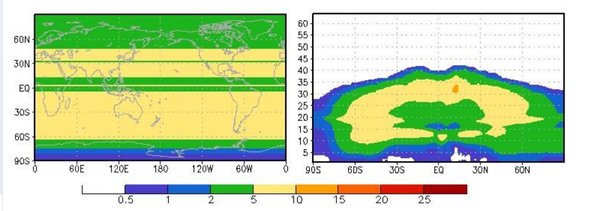
On top of the variational radiance bias correction,

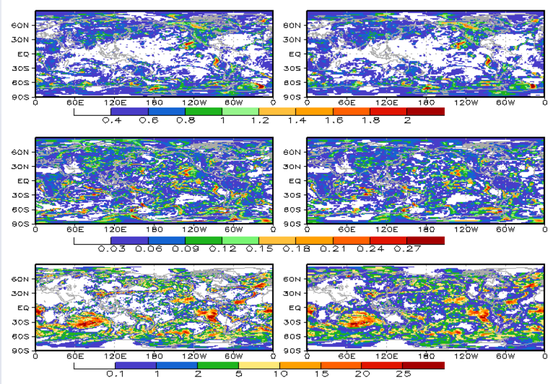
- Based on cloud liquid water (clw, Weng et al. 2003) calculated from radiance observation (O) and first guess (F): data sample with consistent cloud info (O:clear vs. F:clear & O:cloudy vs. F:cloudy), and data sample with mismatched cloud info (O:clear vs. F:cloudy & O:cloudy vs. F:clear).
- Bias correction 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.



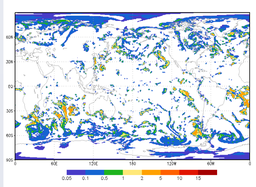
CLOUD STATIC BACKGROUND ERROR VARIANCE & ENSEMBLE SPREAD

Cloud static background error variance: 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.





An example of ensemble spreads for T (top), RH(middle), and cloud water(bottom) in single-resolution (left panels) and dual-resolution (right panels) configurations.



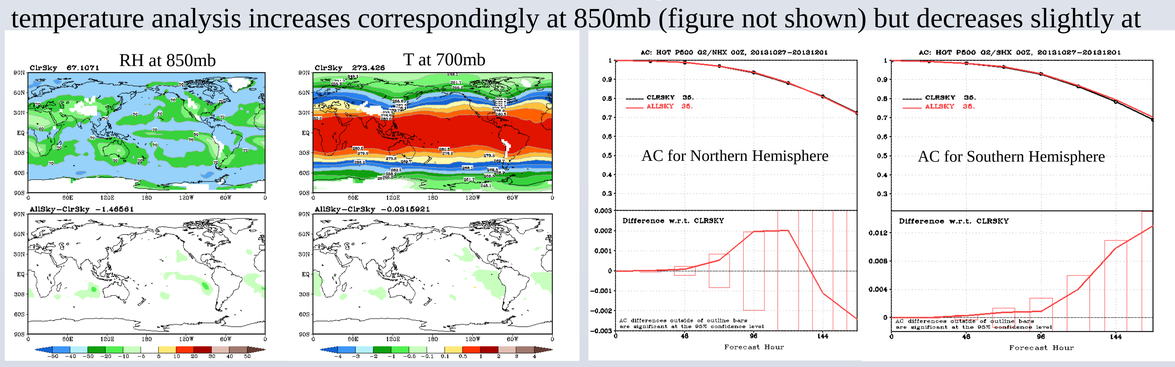
Static cloud water background error variance used in the clear-sky (upper panels) and all-sky at level 13 (left panel) approaches.

Cloud ensemble spread: Stochastic physics helps to address the model uncertainties.

Outstanding issues include: the accuracy of the model cloud forecast (which is related to the physical parameterization schemes), the tuning of the stochastic physics for cloud variability as well as the consistency of model uncertainties among temperature, moisture, and cloud variables in the stochastic physics (Zhu et al. 2015).

IMPACT ON ANALYSIS AND FORECAST SKILL

Around 10% more radiance data from AMSU-A channels 1-5 and 15 are used in the all-sky approach. Compared to clear-sky, the all-sky approach reduces relative humidity analysis over several areas (e.g. over the Pacific Ocean to the west of South America, left panels of left column) at 850mb, and temperature analysis increases correspondingly at 850mb (figure not shown) but decreases slightly at



700mb (right panels of left column). The stratus at continental western boundaries has been a problem (too much stratus cloud a little too far from these coasts) in GFS. The all-sky approach pushes the analyses to the right direction. In terms of anomaly correlation (AC) of geopotential height at 500mb, neutral to slightly positive impact is observed in both Hemispheres.

CONCLUSIONS AND ONGOING WORK

Assimilation of all-sky microwave radiance in the GSI analysis system has been developed at NCEP including the flexibility of selecting either cloud water or individual hydrometeors as the cloud control variable(s). It has been tested along with other upgrade components in the 4D EnVar GFS parallel experiment for the FY16 implementation at NCEP.

Ongoing and future work:

- Expand the all-sky approach to other microwave instruments such as ATMS;
- Tests with an additional cloud-related bias predictor to further improve the bias correction;
- Optimal combination of cloud water static background error variance and ensemble spread;
- Effort to validate the CRTM under all-sky with scattering condition (See P. van Delst 's talk & E. Liu's poster)
- Improve the cloud variability and consistency of perturbations among T, q, and cloud in the stochastic physics.

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