Assimilation of Cloudy Affected Radiance Data in NCEP GDAS

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1. Introduction

Data assimilation plays a crucial role in operational forecast system to provide the forecast model with the best initial state to which forecast results are critically sensitive (Courtier et al. 1994; Rabier et al .1996). Many forecast centers have been successfully implementing 3-dimensional (3D) or 4-dimensional (4D) variational analysis approach which minimizes the global distance of the new atmospheric state to both the observations and the model background state. One of challenges currently facing operational centers that perform variational data assimilation is incorporating satellite information over cloudy regions. The presence of clouds and precipitation indicates that some dynamically important weather is occurring. The correspondence of cloud and precipitation occurrence with regions of high forecast sensitivity suggests that improving initial conditions in cloudy and precipitating regions is particularly important for advancing the skill of numerical weather prediction systems (Errico et al. 2007). Whether a given numerical model is able to properly forecast the state of the atmosphere up to 10 days or to produce realistic climate simulations on monthly time scales strongly depends on its ability to represent the observed spatial distribution of clouds and their various effects on the environment, through latent heat release, radiative effects, and precipitation.

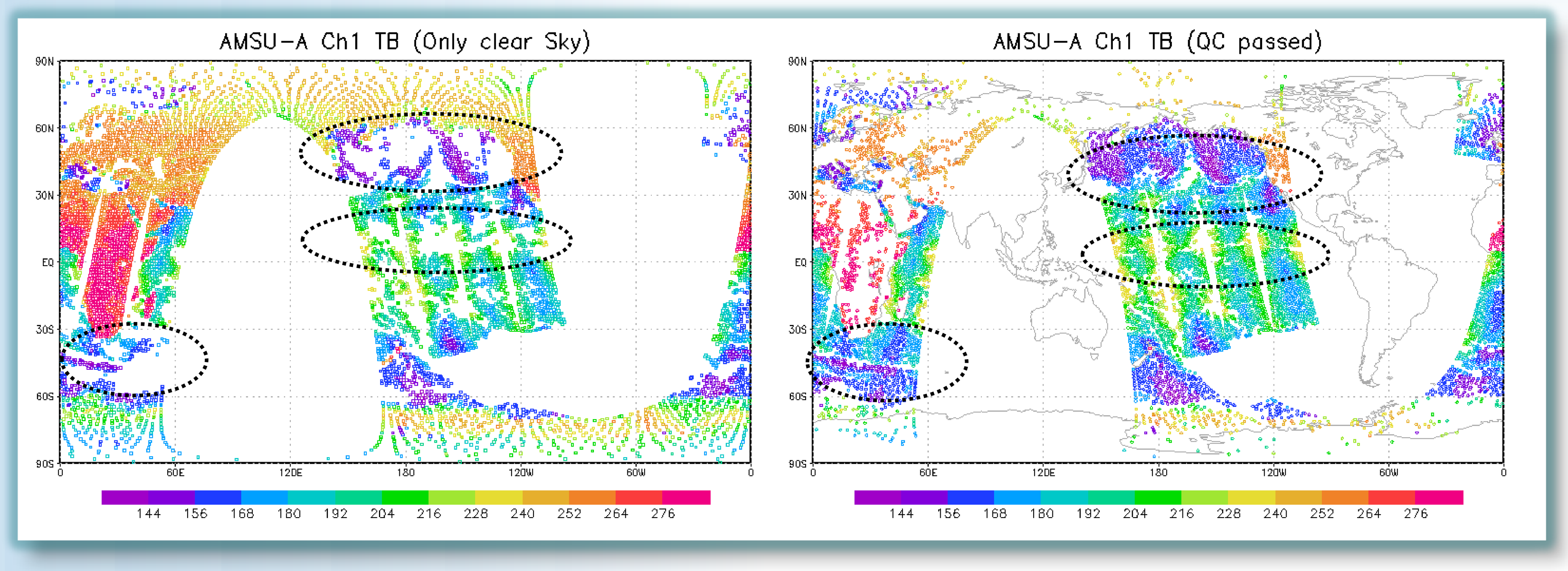

Figure 1. AMSU-A Tb data screened out with retrieved cloud liquid water (left) and the same data employed in NCEP operational GDAS after quality control process.

2. Overview of NCEP Global Data Assimilation System (GDAS)

The **Gridpoint Statistical Interpolation (GSI)** system was initially developed as the next generation global analysis system.
It is based on the Spectral-Statistical Interpolation (SSI) analysis system and replaced spectral definition for background errors with grid point version based on recursive filters.
After initial development, GSI analysis system was modified for applications of single global/regional analysis system. **Became operational in June 2006(regional analysis) and in May 2007 (global analysis**).

First guess fields: 06hr GFS fcst (global), 03hr NMM fcst (regional)
Background errors: NMC method (global), ensemble method (regional)
Currently assimilated observations: conventional data, GPS, SSMI-rain, TMI-rain, sbuv, goes-snd, AMSU-A and B, HIRS2,3, and 4, MHS, MSU, and AIRS data. New instruments like SSMIS, OMI, and IASI are being tested.

Community Radiative Transfer Model (CRTM) was developed and maintained by JCSDA. The CRTM calculates radiances and jacobians in GDAS.
The current analysis variables are unbalanced temperature, specific humidity, ozone, cloud liquid water, velocity potential, surface pressure, and stream functions.
Cloud liquid water is only being modified slightly.

$$J = (x-x_b)^T B^{-1}(x-x_b) + (H(x)-y_0)^T(E+F)^{-1}(H(x)-y_0) + J_C$$

x= Analysis, xb= Background, B= Background error covariance , H= Forward model, y0= Observations E+F= R = Instrument error + Representativeness error, JC = Constraint term

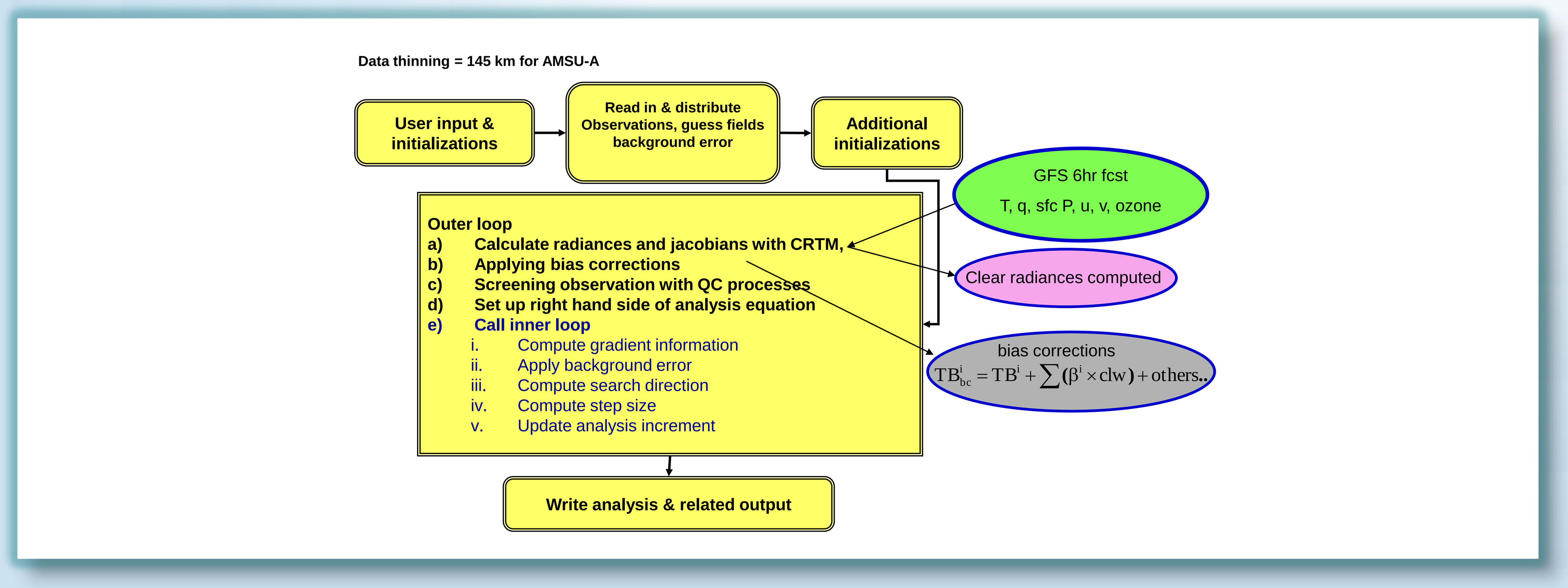

Figure 2. Schematic diagram showing the current radiance data assimilation process in the NCEP GDAS

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3. Progress in cloud affected microwave radiance assimilation

We made a great progress while working to add cloudy radiance data assimilation component to current NCEP Global Data Assimilation system. For now we are focused on including AMUS-A radiances affected by clouds in addition to the all other observations employed in the current Global Data Assimilation System (GDAS). During the last year, we especially made significant changes on the observation side of GSI (e.g. observation operator and observation errors). Observation operators were set up in the GSI to calculate background cloudy radiances.

Based on statistics of the first guess departures from 28 GSI analyses between 00Z April 1st to 18Z April 7th, 2010, we tried to redefine the observation errors for all-sky(i.e. clear and cloudy) radiance data assimilation. It is typical to prescribe observation error as a function of first guess or observed cloud amount. However, defining observation error in one way or the other will end up with causing biases. We defined the observation errors as a function of mean of observed cloud amount and first guess cloud amount. This may not be the best method but it is a good way to start. Figure 3 shows the mean and standard deviation of first guess departures depending cloud liquid water path. While examining results from GSI runs before and after including cloudy radiance data, observation errors will be redefined and/or tuned.

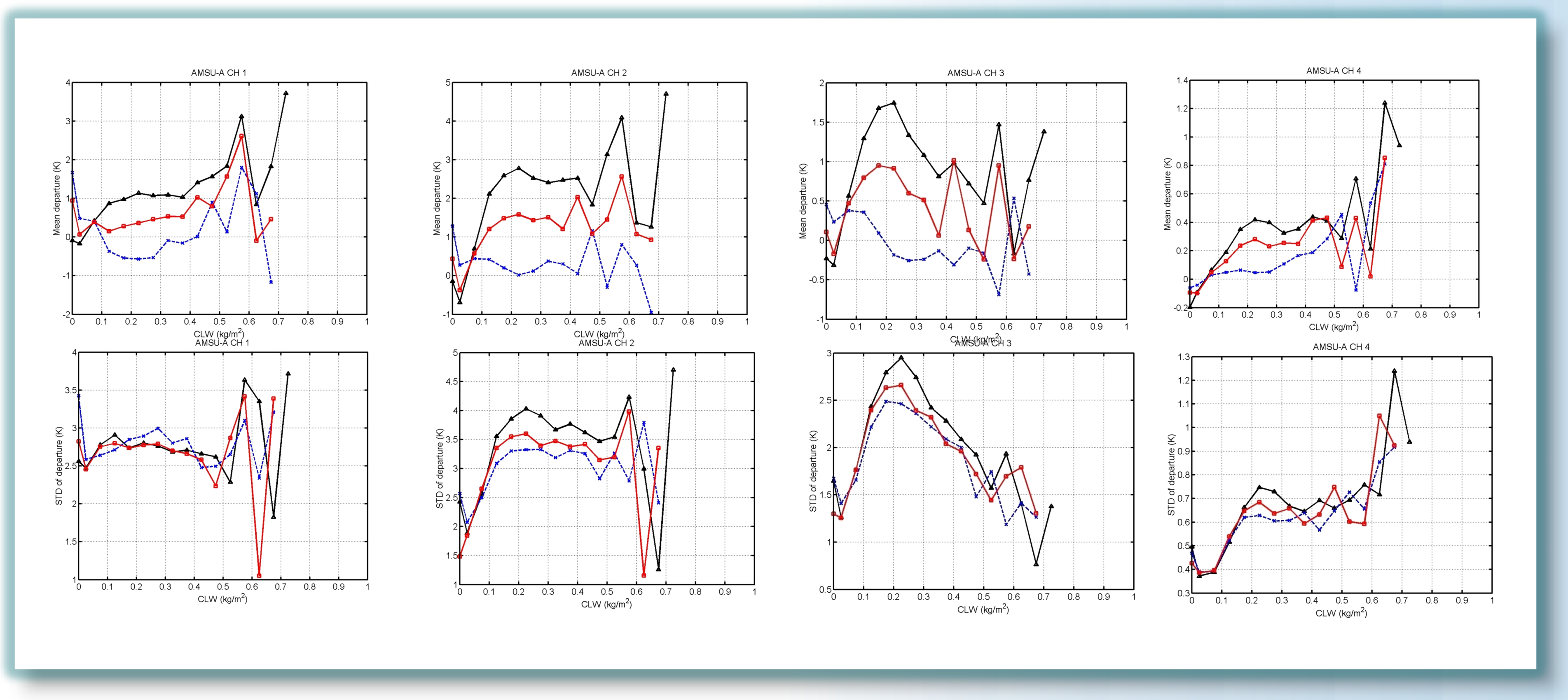

Figure 3 Mean and STD of first guess departures for AMSU-A channels over the range of cloud liquid water paths calculated with observed Tbs (black line) and first guess Tbs (blue line), and mean of observed cloud and first guess cloud water path.

4. Preliminary results: Analysis differences

Currently, the control vectors for radiance data assimilation in GSI are temperature, humidity, surface pressure, and surface winds and does not include cloud water. Cloud water is currently being used as a control vector for TMI surface rain rate data assimilation and so the background error covariance matrix actually includes cloud water components which were calculated by NMC method. So we included the cloud water as an additional control vector for radiance data assimilation component. This background error covariance matrix, in which cloud error variances of cloud water and covariance between cloud water and other analysis variables were constructed by the NMC method, may not result in the best result but it is a good to have something to start with. While collaborating with Emily Liu who recently joined the JCSDA, moisture control variable working best for the NCEP GDAS will be redefined eventually. Figure 4 shows the preliminary results from implementing AMSU-A cloudy radiance assimilation in GSI. The preliminary results show that more impacts on southern hemisphere than northern hemisphere overall. Results are currently being examined for further details to understand the issues and benefits of using cloudy radiances in the analysis results.

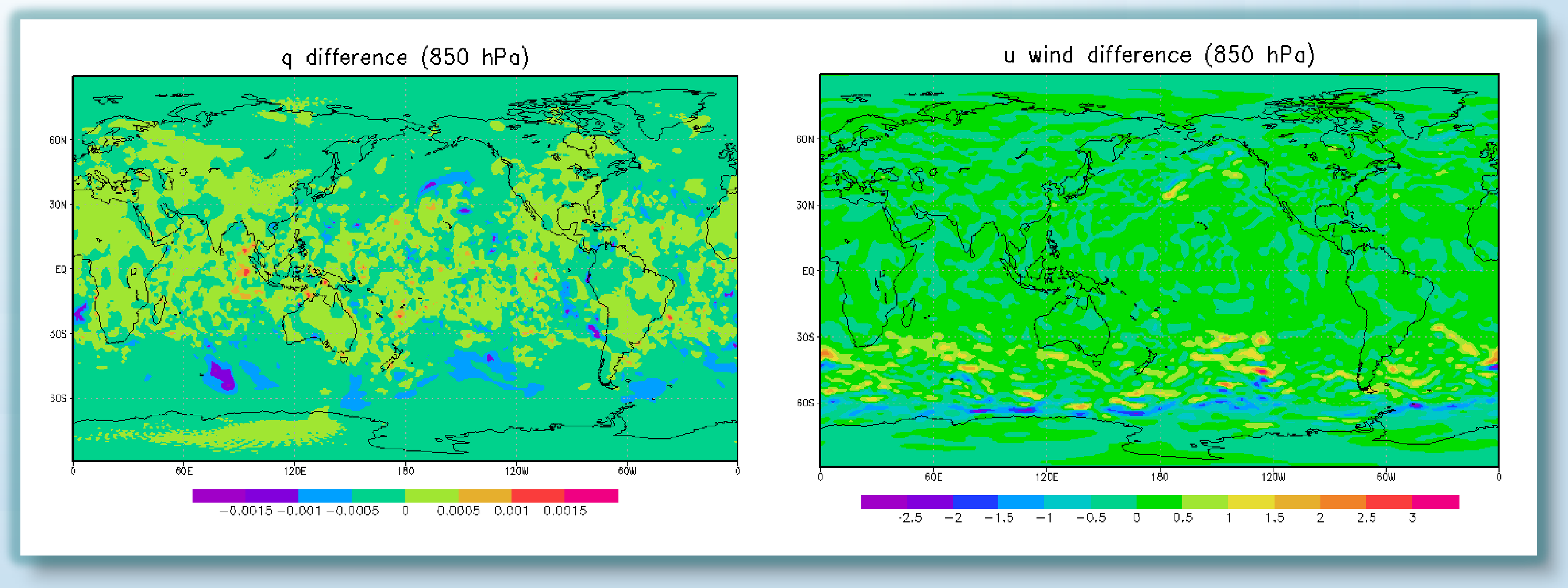

Figure 4. Analysis difference between GSI run with conventional data and AMSU-A all sky radiance data and GSI run with conventional data and AMSU-A clear sky radiance data