Assimilating Satellite Observations of Clouds and Precipitation into NCEP NWP Models

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1. Introduction

- The majority of satellite channel data affected by clouds are discarded in the NCEP operational data assimilation systems. These systems have been geared towards utilization of observations in clear sky conditions, since this is the most straightforward use of the data.
- However, as clouds and precipitation often occur in regions with high forecast sensitivity, improvements in the temperature, moisture, wind and cloud analysis of these regions are likely to contribute to significant gains in NWP accuracy.
- Efforts to assimilate cloud affected radiance data in the NCEP NWP models has been progressing continuously under NOAA/NCEP, NASA, HFIP and JCSDA support. The work initially is directed towards the inclusion of microwave satellite data with a cloud signal, since the microwave data has the ability to penetrate most clouds.

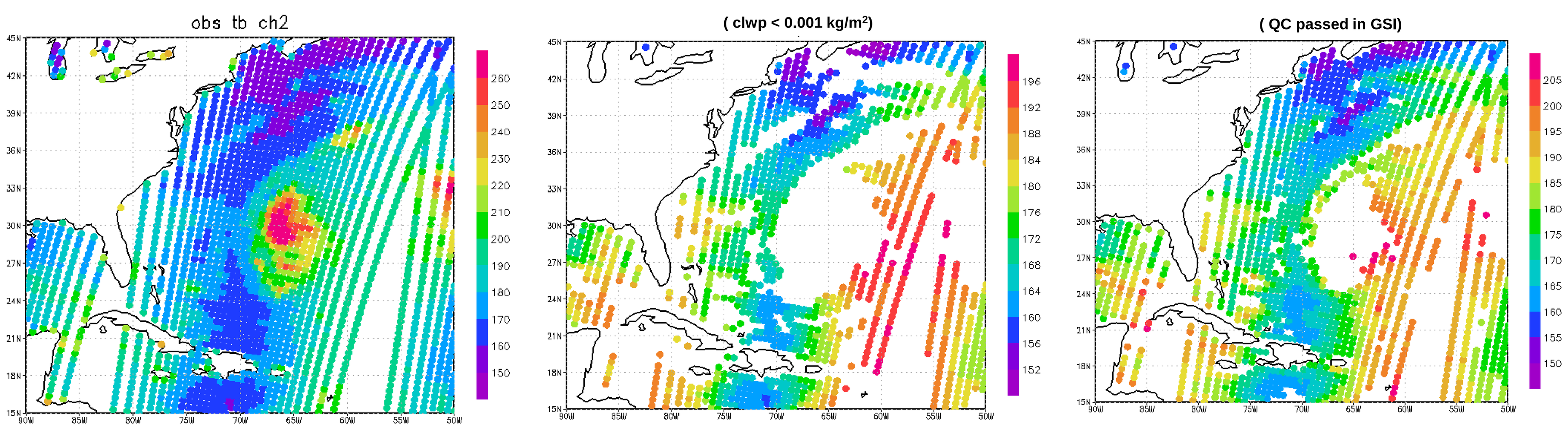

Figure 1. NOAA-19 AMSU-A observations for Hurricane Igor (09/19/2010).

2. NCEP Global Data Assimilation System (GDAS)

- NCEP GDAS is composed of (1) Gridpoint Statistical Interpolation (GSI) system, (2) Global Forecast System (GFS) system, and (3) Community Radiative Transfer Model (CRTM).
- GSI is an unified variational data assimilation system for both global and regional applications. It was initially developed by the NOAA NCEP. The GSI analysis system became operational as the core of the North American Data Assimilation System (NDAS) in June 2006 and the Global Data Assimilation System (GDAS) in May 2007 at NOAA.
- Since then, the GSI system has been adopted in various operational systems, including the NASA global atmospheric analysis system, the NCEP Real-Time Mesoscale Analysis (RTMA) system, the Hurricane WRF (HWRF), the Rapid Refresh (RR) system, and the Air Force Weather Agency (AFWA) operational system.
- Getting analyses by assimilating observations can be described as minimizing a cost function J, which is defined as

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

where x= Analysis, x_b= background , B= Background error covariance ,
H= Observation operator, y_0= Observations, R = Observation error covariance

3. Quick View of Progress to Date

	Operational GSI (Clear Sky radiance DA)	New GSI (All-sky radiance DA)
(1) Forward operator & First guess fields	Do not include cloud	Include clouds for Tb and jacobians
(2) AMSU-A radiance Observations	Clear sky over land and ocean	Clear sky over land and ocean + Cloudy sky over the ocean
(3) Observation error	Statistics based in clear sky conditions	Statistics based in clear and cloudy sky conditions
(4) Control variable	T, q, ozone profiles, sfc P, u, v Not including cloud water	Several different approaches including RHtot are currently being tested..
(5) Background error covariance	T, q, ozone profiles, sfc P, u, v Using NMC method	T, q, ozone profiles, sfc P, u, v + cloud water Using NMC method
(6) Quality control	• Screen out cloudy data • Gross check: $\frac{\lvert Tb_{obs} - Tb_{FG} \rvert}{\sigma_{clear\ sky}} > 3$	• Keep cloudy data unless cloud liquid water path > 0.5 kg/m^2 • Gross check: $\frac{\lvert Tb_{obs} - Tb_{FG} \rvert}{\sigma_{all\ sky}} > 3$

4. AMSU-A Observation vs. NCEP Global NWP Model

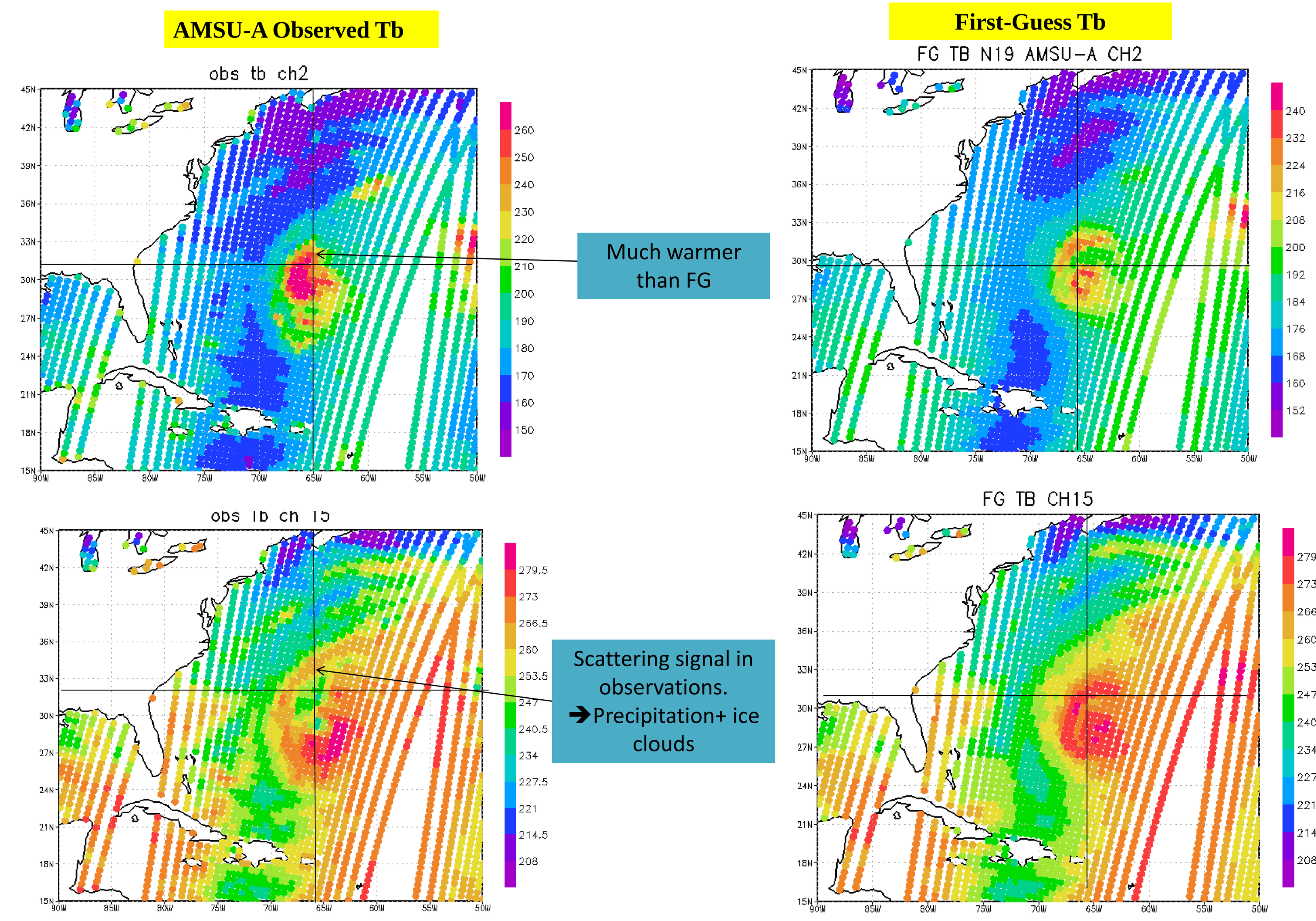

Figure 2. Comparisons of observed brightness temperatures and calculated brightness temperatures using NOAA NCEP global model forecasts. NOAA-19 AMSU-A observations.

5.AMSU-A Observation Error for All-Sky (Clear+Cloudy Sky) Condition

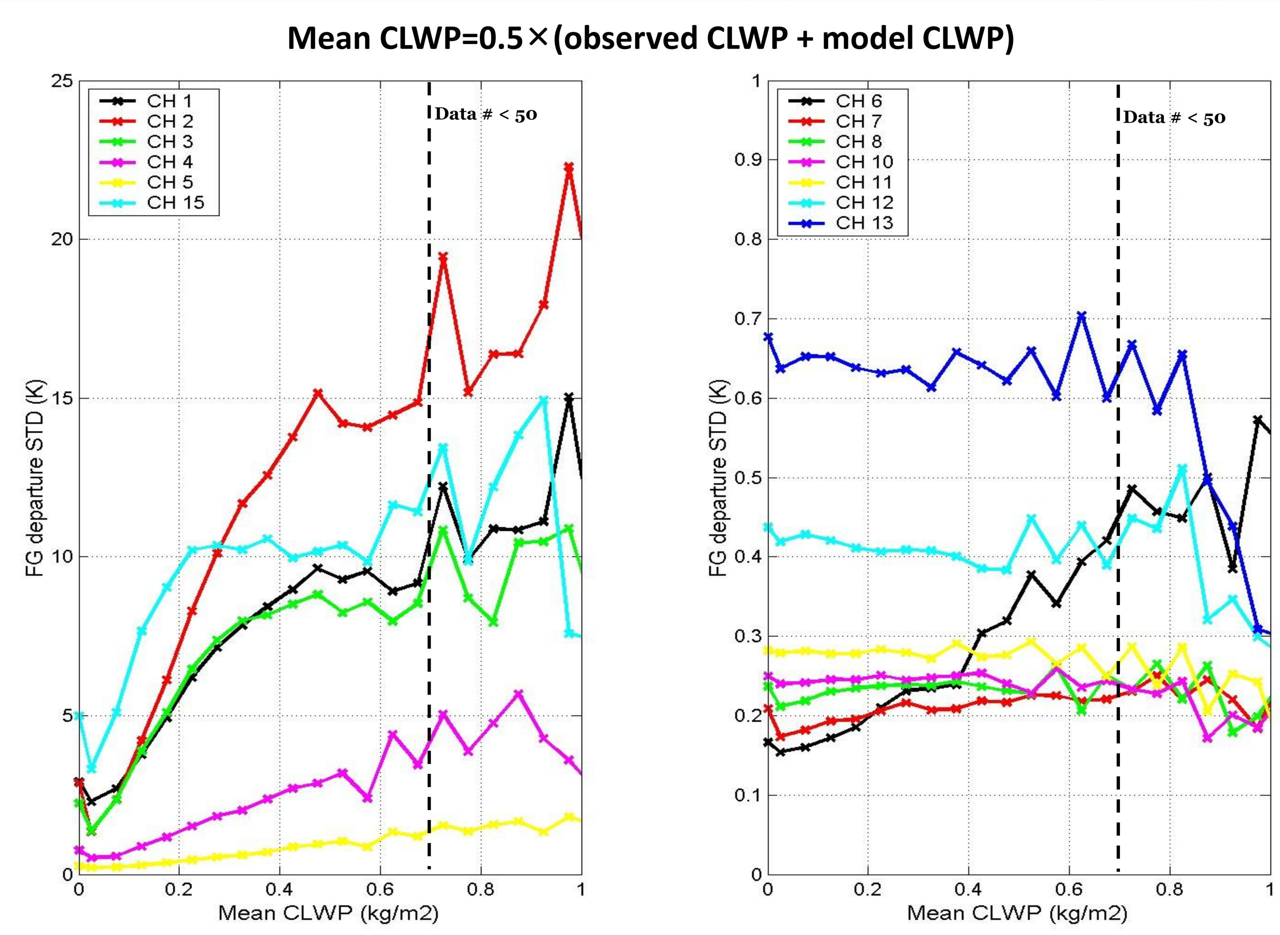

Figure 3. AMSU-A observation errors applicable for all-sky condition.

6. Preliminary Results

- Assimilating AMSU-A Cloud affected radiance data in NCEP Global Data Assimilation System (GDAS) resulted in cloud analysis fields much closer to the satellite observed clouds.
- Including NCEP Global Forecast System (GFS) model's cloud and precipitation microphysics schemes in optimizations improved cloud analysis fields.

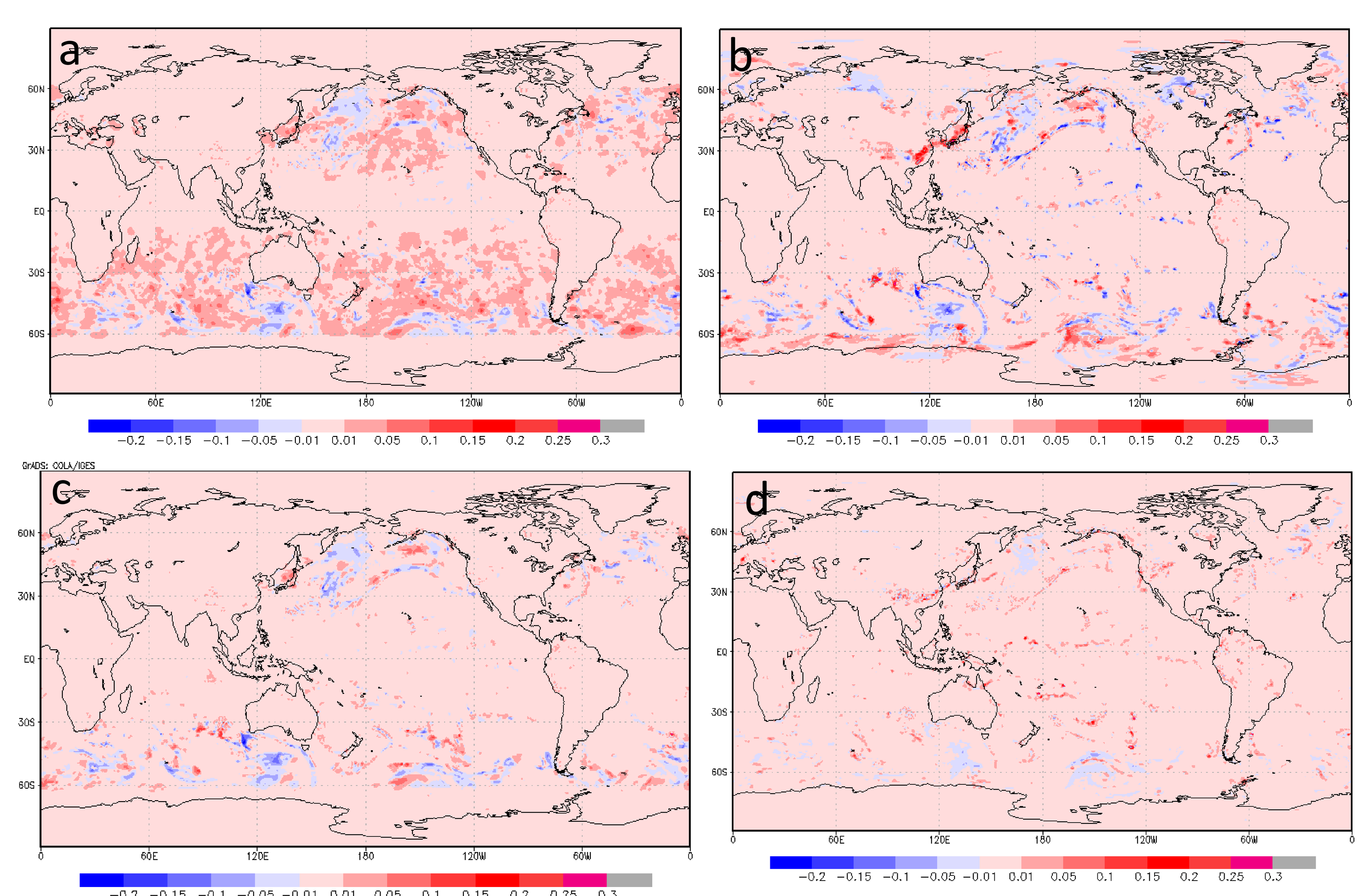

Figure 4. Comparisons of cloud analysis fields from different approaches such as (a) cloud water (cw) as control variable, (b) qtot (cw+q) is control variable, (c) cw as control variable and GFS moisture physics applied, and (d) no cloud related control variable while cloud fields are updated through moisture physics using temperature and humidity increments.

7. Future Work

- Comparisons of static background error covariance with ensemble background error covariance for hybrid GSI system are under way.
- Testing impacts on GFS model forecasts and HWRF model forecasts skill scores.