Further development in the all-sky microwave radiance assimilation and expansion to ATMS in the GSI at NCEP

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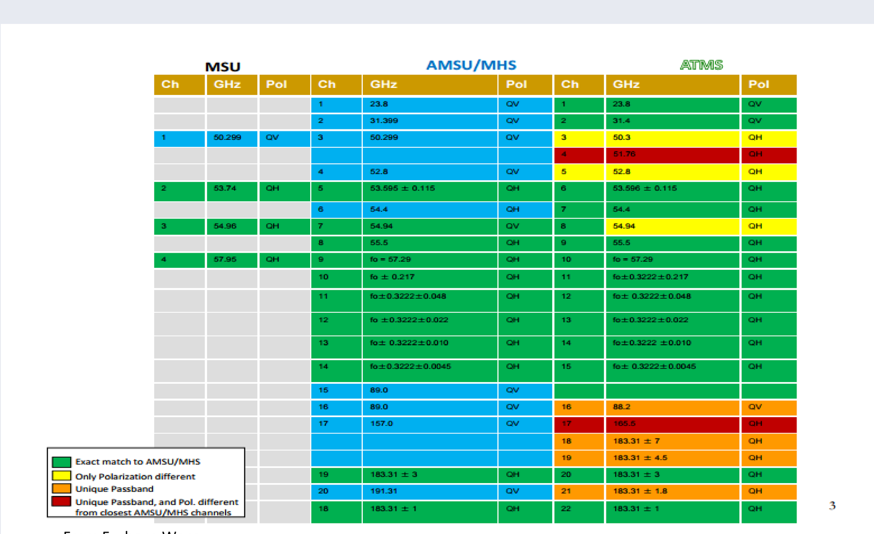
1. INTRODUCTION

Since the implementation of all-sky radiance assimilation of AMSU-A in the operational hybrid 4D Ensemble-Variational (EnVar) Global Forecast System (GFS) at NCEP, significant progress has been made in the all-sky efforts in the Gridpoint Statistical Interpolation (GSI) analysis system. To facilitate the expansion of the all-sky approach to additional microwave and infrared sensors, the GSI codes for the all-sky capability have been generalized with a centralized module and data structure as well as flexible selections of all-sky sensors and cloud control variables. Moreover, the all-sky approach is being expanded to radiances of Advanced Technology Microwave Sounder (ATMS). Two other efforts on subgrid-scale clouds and handling of non-Gaussian distribution of radiances are also under development for the general enhancement for all-sky radiance assimilation. Meanwhile, fractional cloud coverage (Geer and Bauer 2009) is incorporated in the CRTM 2.3.0.

In this poster, the following issues will be discussed in more detail:

1. All-sky ATMS radiance assimilation (currently, precipitation and snow information as well as subgrid-scale clouds from GFS are not available for use in the GSI, only radiances affected by non-precipitating clouds and clear-sky radiances are used);
2. Why and how to include subgrid-scale clouds in the all-sky radiance assimilation;
3. Application of variational quality control (VQC, Purser 2011 & 2017) to radiances;
4. Impact of fractional cloud coverage on microwave radiances.

2. ALL-SKY ATMS RADIANCE ASSIMILATION



ATMS is composed of AMSU-A- and MHS-like channels. Like all-sky AMSU-A, observation error is assigned as a function of the symmetric cloud amount (Geer et al. 2011) with situation-dependent observation error inflation.

For all-sky ATMS radiances, the quality control and bias correction procedures basically follow those of all-sky AMSU-A radiances.

2.1 SPECIAL CONSIDERATIONS FOR ALL-SKY ATMS RADIANCES:

- ❑ **Obtain a common beamwidth** for all ATMS channels in calculating Field of View (FOV) and cloud amount/detection: ATMS has varied beam widths (5.2 degrees for channels 1-2, 2.2 degrees for channels 3-16, 1.1 degrees for channels 17-22). In all-sky ATMS assimilation, AAPP spatial averaging is applied to all ATMS channels, while in clear-sky ATMS assimilation it is only applied to channels 1-16 to convert the beamwidths to 3.3 degrees.
- ❑ **Remove large OmFs along coastlines and cryosphere boundaries**:
  - In clear-sky ATMS assimilation, surface properties at observation locations are calculated as interpolations using the four nearest model surface grid points.
  - In all-sky ATMS assimilation, the capability of modeling surface properties based on the FOV size and shape is activated, and cloudy radiances over mixed surfaces are excluded.

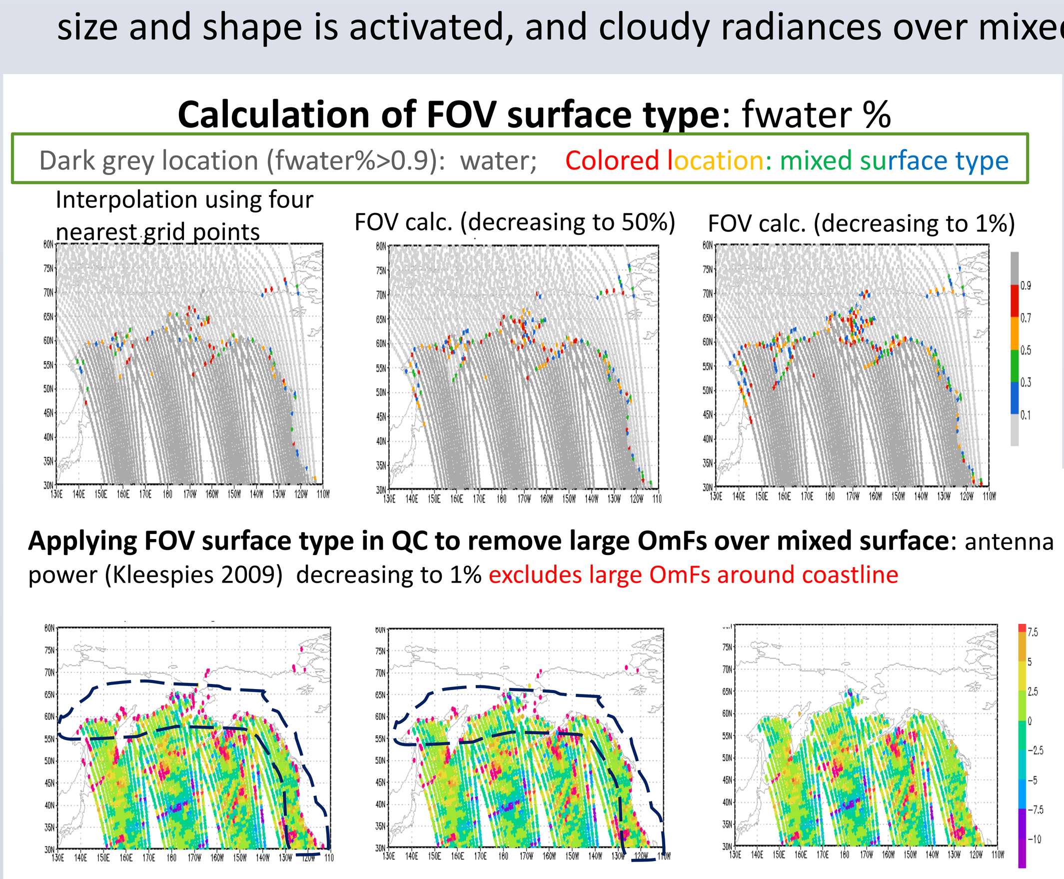
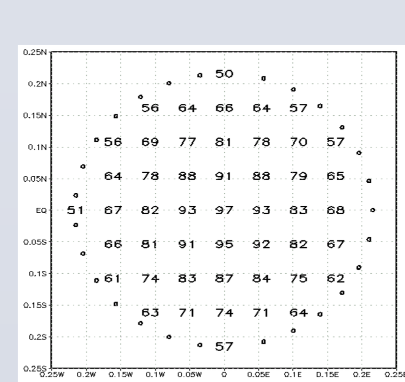
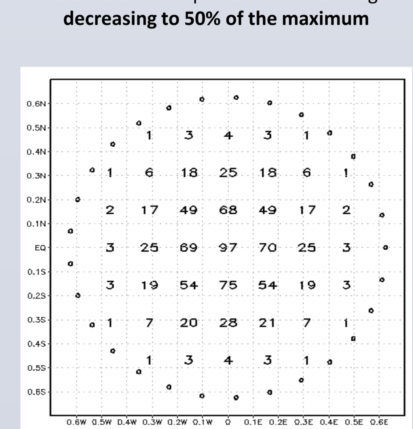


Fig. 1 Surface type at observation location (upper row): Dark gray for water, light grey for land, colored for mixed surface type; OmF of channel 2 over water surface (lower row).



Relative antenna power at the FOV edge **decreasing to 50% of the maximum**



Relative antenna power at the FOV edge **decreasing to 1% of the maximum**

- ❑ **Screen out radiances affected by clouds with large scattering for MHS-like channels**:

Scattering = cldeff(Ch16) – cldeff(Ch17)
Where
cldeff = Tb(cloudy) – Tb(clear-sky)

Fig. 2 indicates that OmF becomes larger as scattering increases. If (|scattering|>10.0), channels 1-7 and 16-22 are excluded

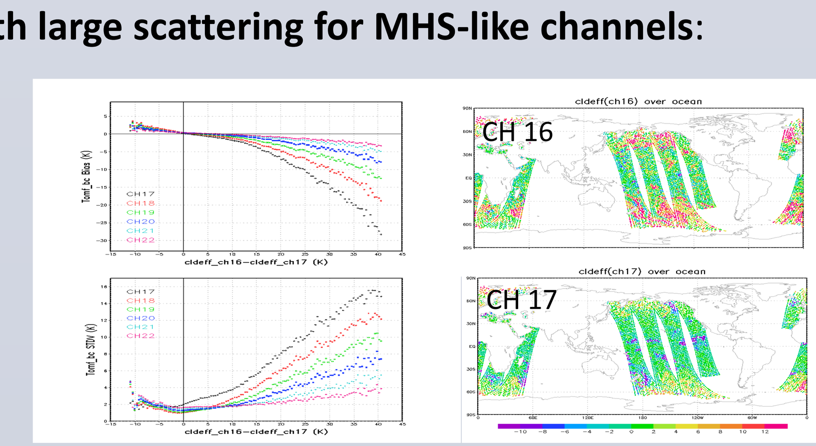


Fig. 2 OmF bias (upper left) and STD (lower left) w.r.t. scattering index, and cloud effect over ocean for channels 16 (upper right) and 17 (lower right).

Overall the assimilation of cloudy ATMS radiances has neutral or slightly positive impact on forecast skills.

2.2 OMF COMPARISON AND DATA CONSISTENCY

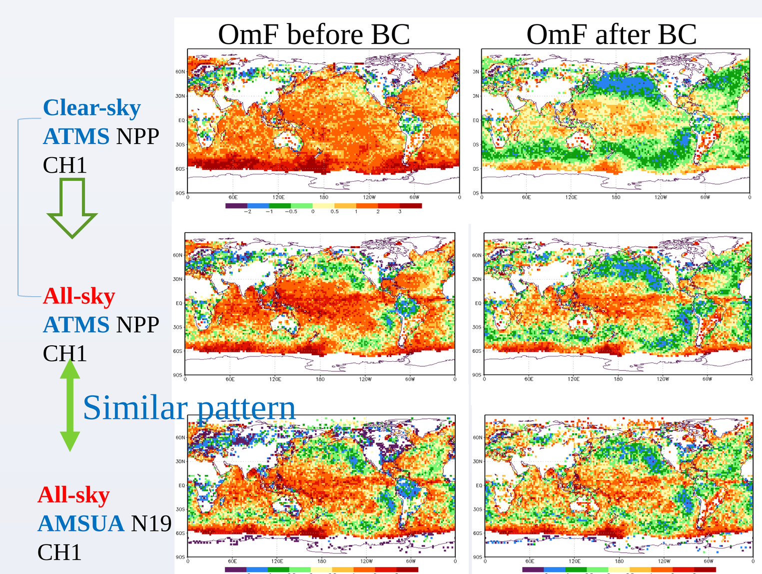


Fig. 3 One-month averaged OmF before (left column) and after (right column) bias correction for ATMS channel 1 in clear-sky approach (top), ATMS (middle) and AMSU-A NOAA19 (bottom) channel 1 in all-sky approach.

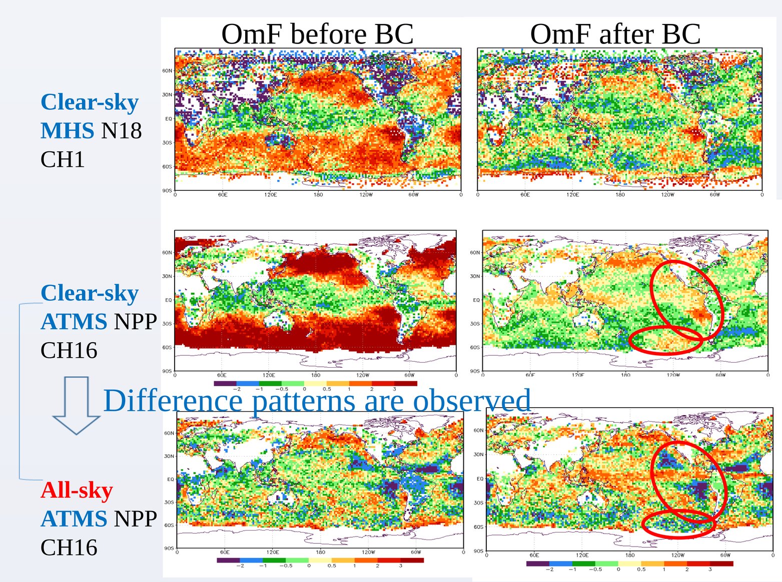


Fig. 4 Same as Fig. 3 but for MHS NOAA18 channel 1 (top) and ATMS channel 16 (middle) in clear-sky approach, and ATMS channel 16 in all-sky approach (bottom).

- ❑ **From ATMS clear-sky to all-sky,** although data sample may be different, ATMS radiances exhibit similar bias-corrected OmF patterns in channels 1 and 2 (Fig. 3), but large differences are observed in some areas for some other cloud sensitive channels (Fig. 4). Such differences may indicate issues with quality control and bias correction in the clear-sky approach (e.g., possible leaking of cloudy MHS radiances into the GSI, cloud predictor (calculated from ch. 1 & 2) may not be adquate for other ATMS channels; etc.)
- ❑ **All-sky ATMS vs. All-sky AMSU-A**: similar patterns of OmF are observed (Fig. 3).

3. USING SUBGRID-SCALE CLOUDS IN ALL-SKY RADIANCE ASSIMILATION

In the current GFS forecast model, the subgrid-scale cloud condensate in the convective plume is not included in the total condensate of the forecast model output, thus only gridscale clouds are used in the radiance simulation calculation for Figures 3 and 4, and the lack of model clouds in the lower and middle levels in the tropics ITCZ and SPCZ regions is evident. This affects not only cloud ensemble spread but also moisture and temperature analyses. The cloud analyses produced also involve subgrid-scale cloud information obtained from the data.

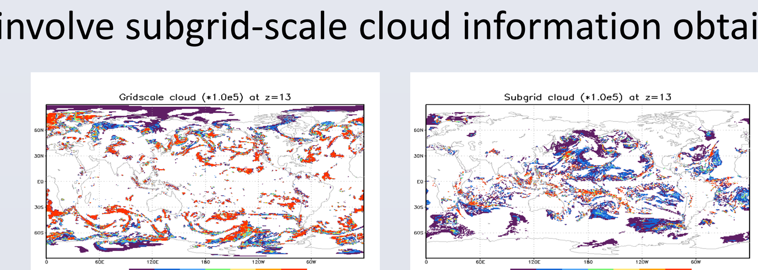


Fig. 5 Gridscale (left) and subgrid-scale (right) cloud water at model level 13 (about 850hPa).

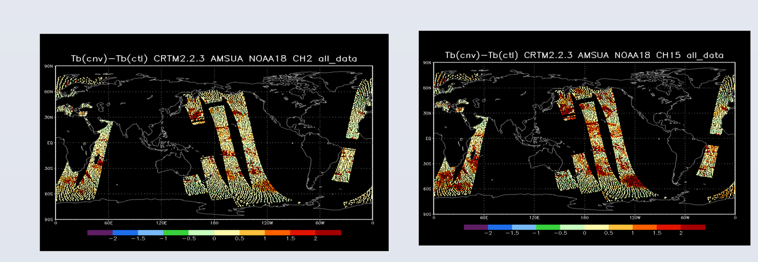


Fig. 6 The difference of simulated brightness temperature with and w/o subgrid-scale clouds for AMSU-A NOAA18 channel 2 (left) and 15(right).

Overall, OmF biases of channels affected by clouds are reduced after including subgrid-scale clouds (Fig. 7). Approaches to include these clouds while preserving forecast model water budget:

- ❑ Combine subgrid and grid scale clouds as one variable in the GSI, but remove subgrid-scale clouds (by employing convective schemes in the GSI) from cloud analyses before passing them back to the model;
- ❑ The same as above but do not pass cloud analyses back to the model;
- ❑ Treat convective clouds separately as additional control variable(s). Testing is under way.

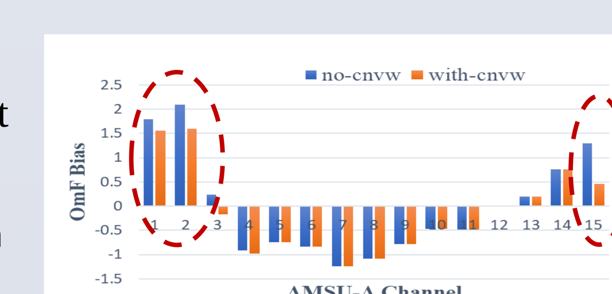


Fig. 7 OmF bias for AMSU-A NOAA18 with (orange) and w/o (blue) subgrid-scale clouds.

This effort will depend on and adjust with the status and progress of the microphysics and convective schemes in the FV3 model.

4. APPLICATION OF VQC TO RADIANCE DATA

Some radiance channels are found to be of non-Gaussian distribution, e.g., AMSU-A channels 1-5 and 15 resemble logistic distribution (Fig. 8). A new probability model for representing realistic measurement errors, which generalizes the "logistic" distribution and is free of multiple minima in cost function, was developed by Purser (2011 & 2017). The effort of applying this probability model to radiance data is underway.

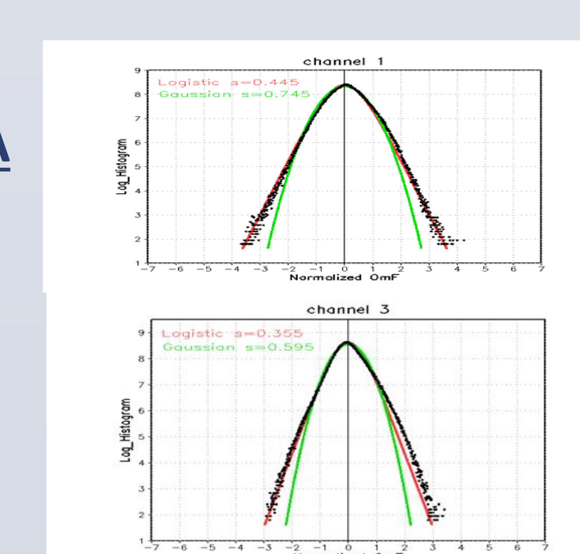


Fig. 8 Logarithm of OmF histogram (black dots) of AMSU-A channels 1 (upper) and 3 (lower), Gaussian (green) and Logistic (red) distributions.

5. FRACTIONAL CLOUD COVERAGE

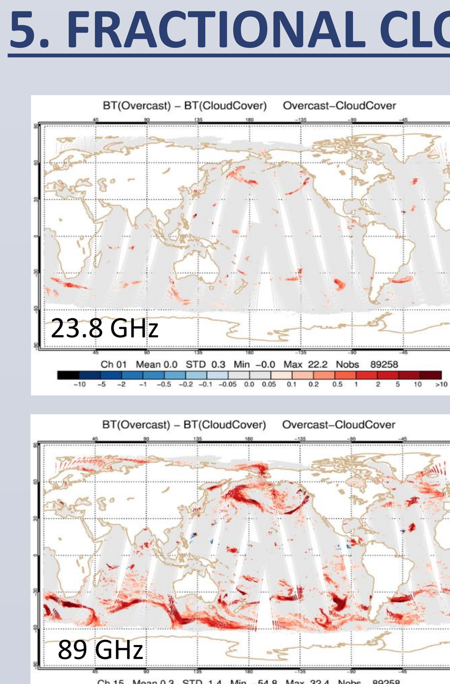


Fig. 9 Tb difference due to the use of fractional cloud coverage.

New feature of fractional cloud coverage is included in CRTM 2.3.0:

- ❑ Four cloud overlap schemes (maximum, random, maximum random, and hydrometeor weighted average)
- ❑ Two-column radiance calculation

Impact of fractional cloud cover on AMSU-A brightness temperatures (Tb): hydrometeor weighted average total cloud cover is used for AMSU-A, and the impact on Tb is larger in high frequency channel in rainy and snowy regions (Fig. 9). Also, the impact of using fractional cloud coverage on Tb OmF is found to be affected by forecast model cloud bias.