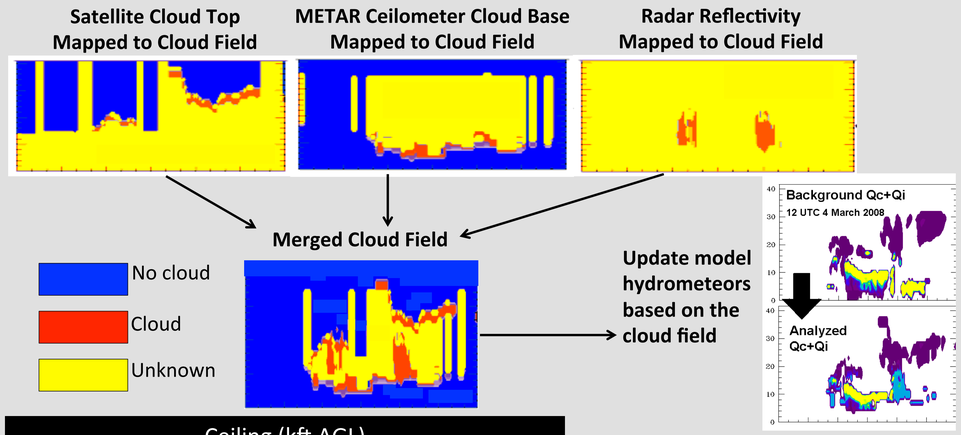
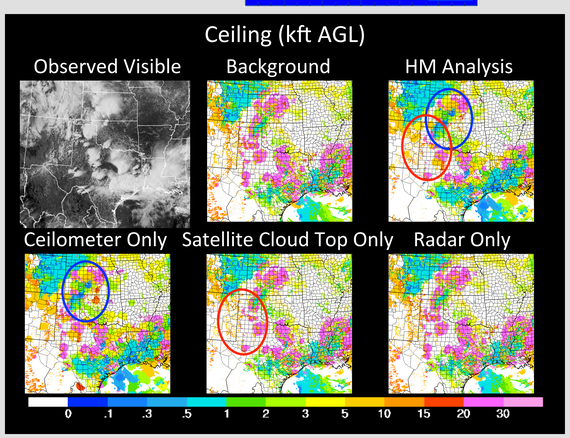
Current and Future GSD Cloud and Precipitation Analysis Using GSI in the RAP and HRRR Models

Therese T. Ladwig, M. Hu, C. Alexander, S. S. Weygandt, S. Benjamin, D. Dowell, J. Olson, J. Kenyon

Current Cloud and Precipitation Hydrometeor Analysis

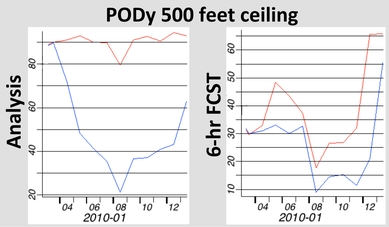
The GSD Cloud and Precipitation Hydrometeor analysis (HM analysis) uses cloud and precipitation observations to update a model first guess, in an effort to improve the initial conditions of a new model forecast. Satellite observations are used to determine where clouds are located and the height of the cloud tops. Ground based cloud measurements from ceilometers are used to determine cloud base heights. Finally, radar reflectivity observations are used to determine precipitation regions.





The HM-Analysis plays an important role in improving the RAP and HRRR analyses and forecasts of cloud fields. For example, the ceiling forecast is of particular interest to the aviation community.

This example shows the ceiling diagnostic from the background, full HM-Analysis, and the analysis output using each observation type. The primary impact of the ceilometer obs was to lower ceiling in heavily cloudy regions. The satellite obs primary impact was to clear spurious clouds. The radar obs did not show an impact to ceiling, however they impact precipitating hydrometeors and other diagnostics (e.g. reflectivity).

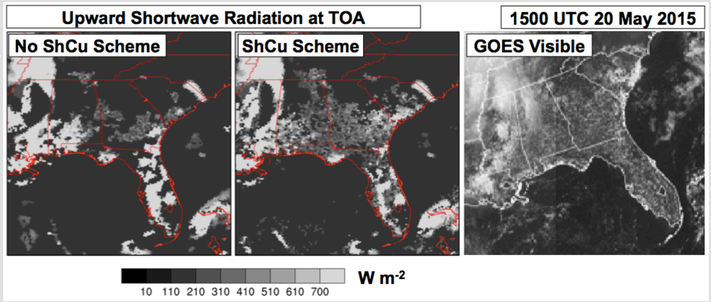


The HM-Analysis has a positive impact on the probability of detection for low ceiling forecasts in the RAP and HRRR.

Model Physics Improvements

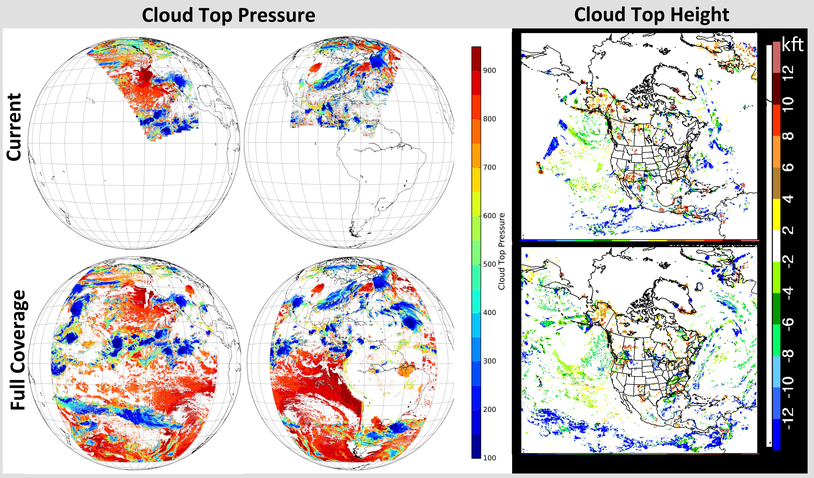
In addition to cloud analysis improvements, GSD is enhancing model physical parameterizations to improve the retention and development of clouds in forecasts. For example, sub-grid scale clouds are now parameterized with the addition of cloud probability distribution functions that are coupled to the radiation scheme. Also, improvements to the Grell-Frietas-Olson shallow-cumulus scheme allows for more accurate representation of the areal coverage of clouds (right).

The RAP and HRRR models take advantage of aerosol-aware microphysics and radiation schemes, which makes cloud cover forecasts more accurate, and coupled with the better shallow cumulus scheme, make more accurate short-wave radiation estimates in clear-sky conditions.



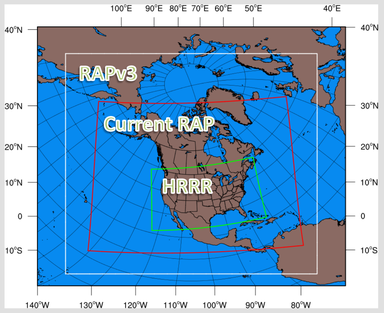
Use of Global Satellite Observations

The RAP model domain will be enlarged in the next upgrade at NCEP (RAP version 3). Experimentally, global satellite observations (GOES East & West, MT-10, MT-2) will be leveraged for improved obs coverage in the enlarged RAP model domain.



In the top row, the current GOES West & East data for the RAP are shown, and the obs coverage edges can be seen cloud top height increments.

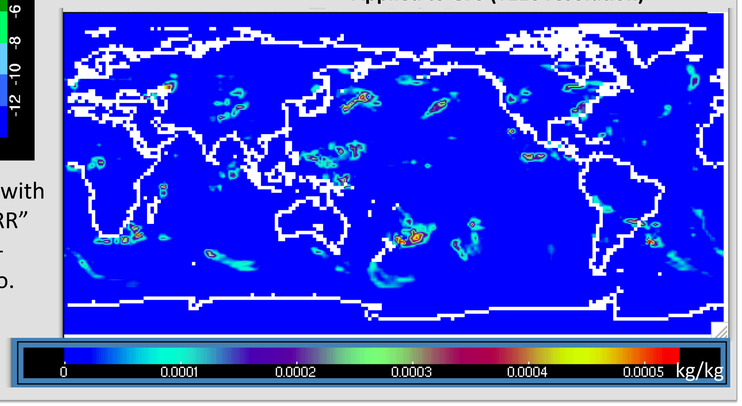
In the bottom row, the full disk GOES obs processed by NASA Langley are shown. When those data are used the RAP the cloud top height increments cover the RAP domain.



GSD is working to apply the HM-Analysis to global models starting with the GFS, and in the future the FIM and the global rapid refresh "GRR" with hourly data assimilation. In initial tests with the GFS, the HM-Analysis is successful in removing spurious cloud water mixing ratio.

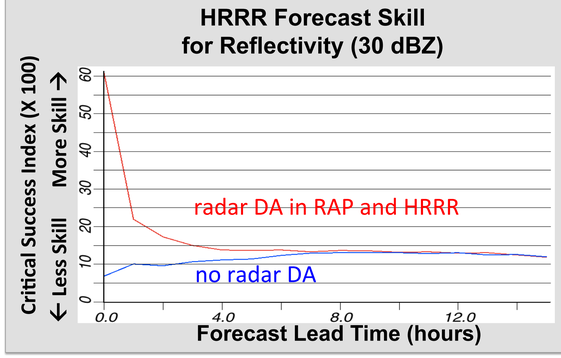
In this example, positive values indicate where cloud water was removed (clearing) from the background by the cloud analysis.

Example Increments for HM-Analysis Applied to GFS (T126 resolution)



Radar Data Assimilation

The RAP and HRRR models primarily rely on quality-controlled, composite radar reflectivity observations from the Multi-Radar Multi-Sensor (MRMS) system for data assimilation of precipitation.



Reflectivity Assimilation Method:
Temperature tendency from precipitation microphysics scheme replaced by reflectivity-based heating during WRF model integration.

$$LH(i,j,k) = \left(\frac{1000}{p}\right)^{R_d/c_p} \frac{(L_v + L_f)(f[Z_e])}{t * c_p}$$

LH = latent heating rate
f[Ze] = reflectivity converted to rain/snow
t = time period of condensate formation (20 min)

Future Variational/Hybrid Cloud and Precipitation Hydrometeor Analysis

GSD is working to incorporate the HM-Analysis into the variational/hybrid framework within GSI. We are focusing on cloud water and cloud ice assimilation. As a first step, the cloud water and ice from the current GSD cloud analysis is being used as pseudo observations and simplified static background covariance are being used to build the var-cloud analysis framework, including the development of cloud control variable(s). Further development will focus on:

- Developing observation operators to use satellite cloud top pressure/temperature and ceilometer estimated ceiling height and cloud fraction directly,
- Determining appropriate observation errors,
- Establishing static background covariances for cloud hydrometeors, and
- Adding code to do variational-ensemble hybrid cloud analysis with global or regional ensemble perturbations.

Future work will also include the assimilation of cloud fraction to interface with the sub-grid clouds physics.

In addition, development of a HRRR ensemble is underway. Real-time testing is planned in 2016 and radar data assimilation will be included. Going forward this ensemble could provide ensemble-based covariances between cloud water and ice mixing ratios with other variables.

For questions and comments contact: Terra.Ladwig@noaa.gov