Evaluation of the Impact of AIRS Radiance and Profile Data Assimilation in Partly Cloudy Regions

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Special Symposium on the Joint Center for Satellite Data Assimilation/
93rd AMS Annual Meeting

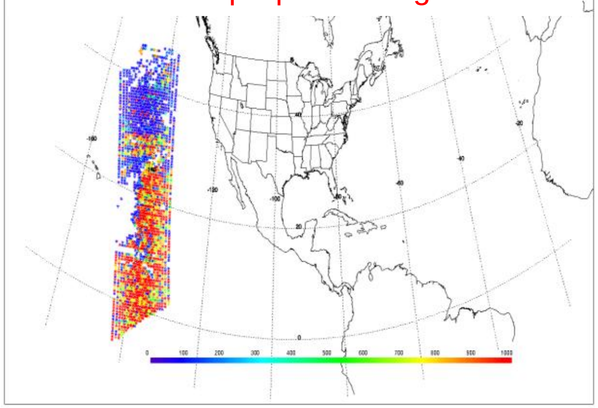
Austin, TX

8 January 2012

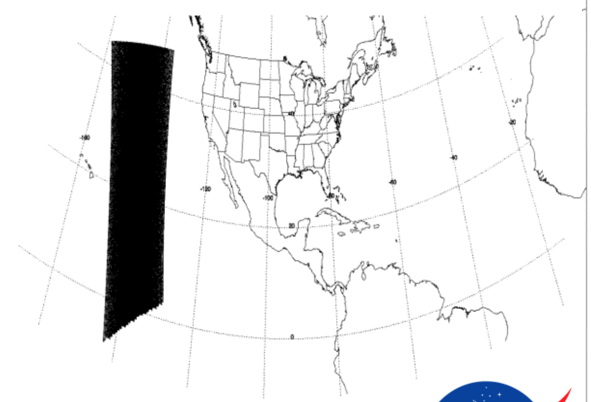
Project Concept

- **AIRS radiances currently assimilated operationally in GFS and NAM**
  - Cloud-free radiances from 281-channel subset
  - Cloud checks performed within GSI to determine which channels peak above cloud top
  - Inaccuracies may lead to less radiances assimilated or introduction of biases in cloud-contaminated radiances
- **Use AIRS L2 retrieved profiles to better understand the <u>optimal three-dimensional distribution of AIRS radiances assimilated within GSI</u> to engage the operational DA community regarding strategies for assimilating hyperspectral radiances**
  - Cloud contamination, channel reduction, spatial data reduction
- **Lowest extent of quality AIRS L2 profiles determined by quality indicators in preprocessing**
- **Use MODIS as an additional resource to determine cloud location and vertical extent**

Lowest extent of useable L2 profiles determined in preprocessing



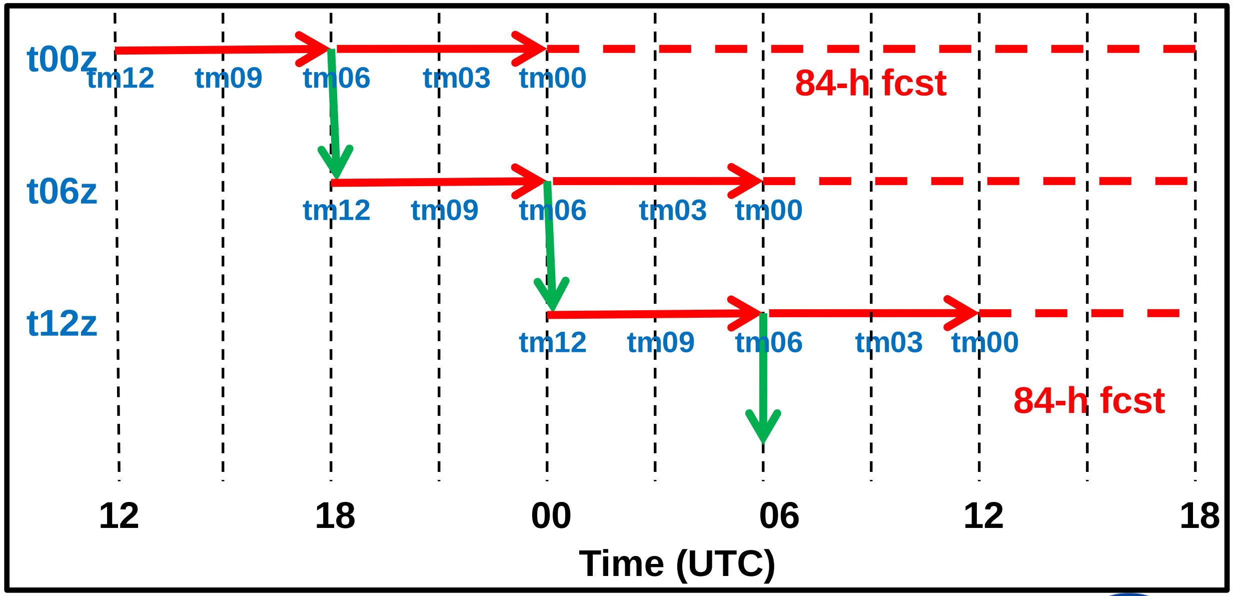
Lowest extent of useable L1B radiances determined within GSI



Experimental Setup

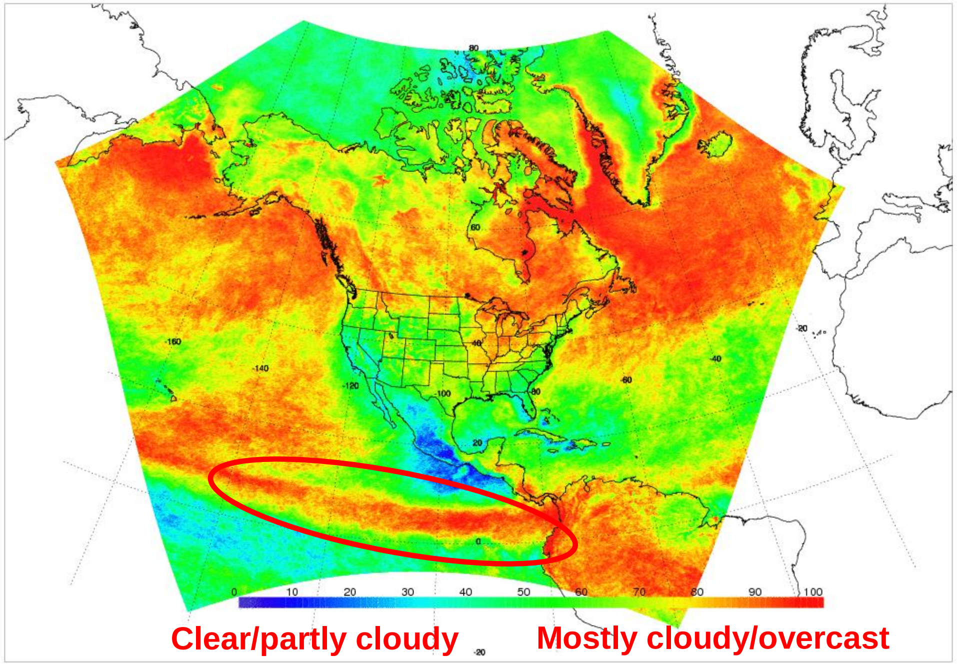
- **Developmental Testbed Center (DTC) GSIv3.0 and WRF-NMMv3.3 code configured in forecast cycling methodology that mimics the operational NAM**
- **Real-time BUFR files archived during assimilation period (4 Nov.–20 Dec. 2011)**
  - Satellite: AIRS, AMSU, HIRS, MHS, GOES Sounder, GPSRO, radar winds
  - Conventional: All observations used in EMC's Table 4
- **Two "parallel" 4-week experiments with 2-week spin-up:**
  - RAD
    - assimilate AIRS radiance data using operational procedures
  - PROF:
    - append PREPBUFR to include AIRS profiles as sondes ensuring consistency with real-time RAD swath locations
    - quality flag P_{best} to select data in the vertical to be assimilated
    - no observation thinning

Schematic for GSI scripts (DiMego, personal communication, 2011)

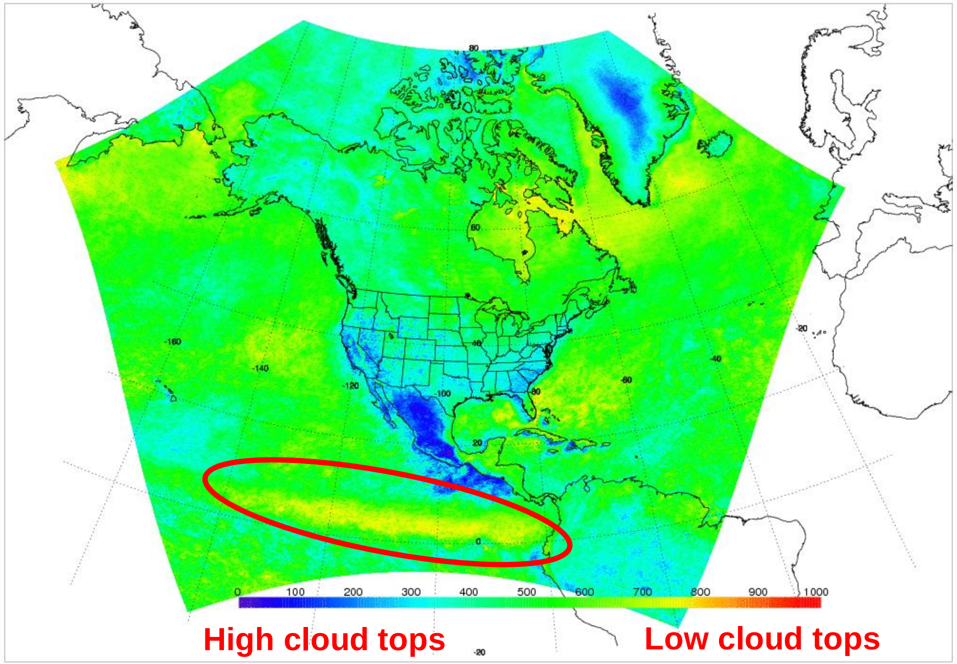


Bulk Cloud Information

Mean MODIS cloud fraction: 20 Nov - 20 Dec 2011



Mean MODIS CTP: 20 Nov - 20 Dec 2011

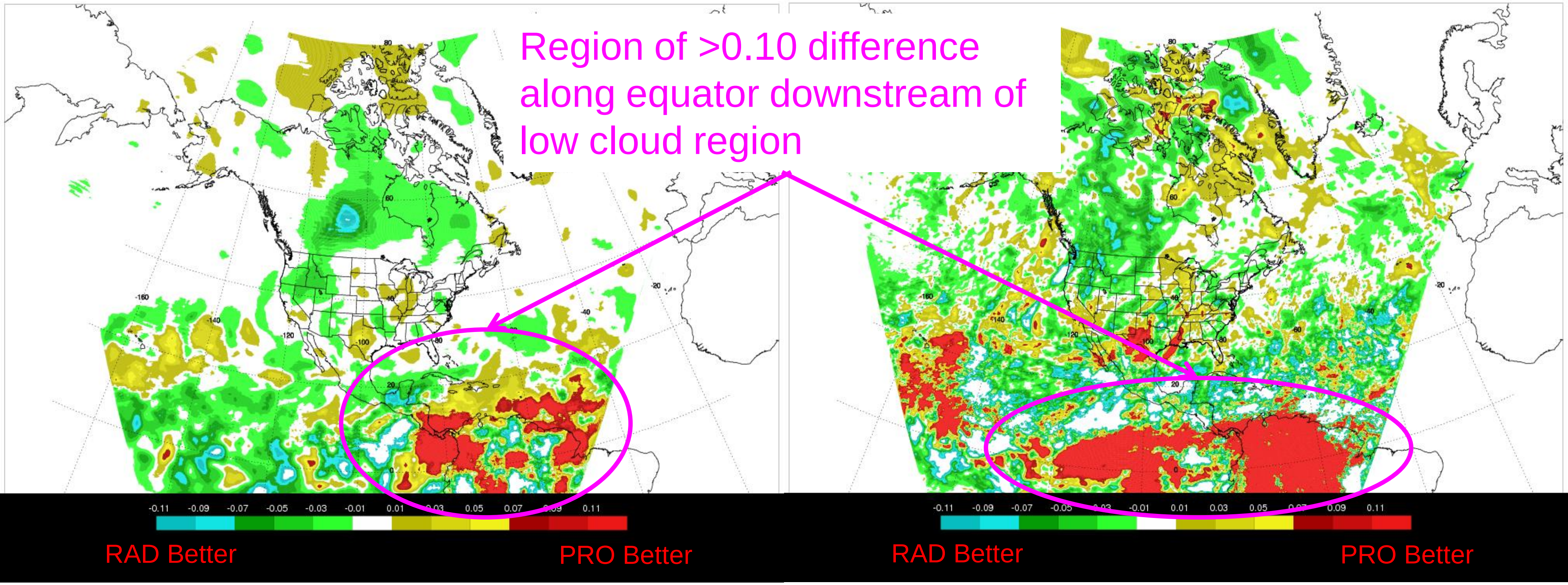


- **Mean cloud information from Aqua MODIS interpolated to WRF-NMM grid**
- **Main focus is on strip of persistent low, opaque clouds just north of Equator**
- **Regions with low, opaque clouds (assimilate additional channels above cloud) and regions with cloud gradients (assimilate in partly cloudy or scene incorrectly deemed cloudy) should be areas where profiles will be most impactful**

Forecast Impact

Mean (21 Nov-19 Dec 2011) 500 hPa Z AC difference at F48 for 00Z initialization

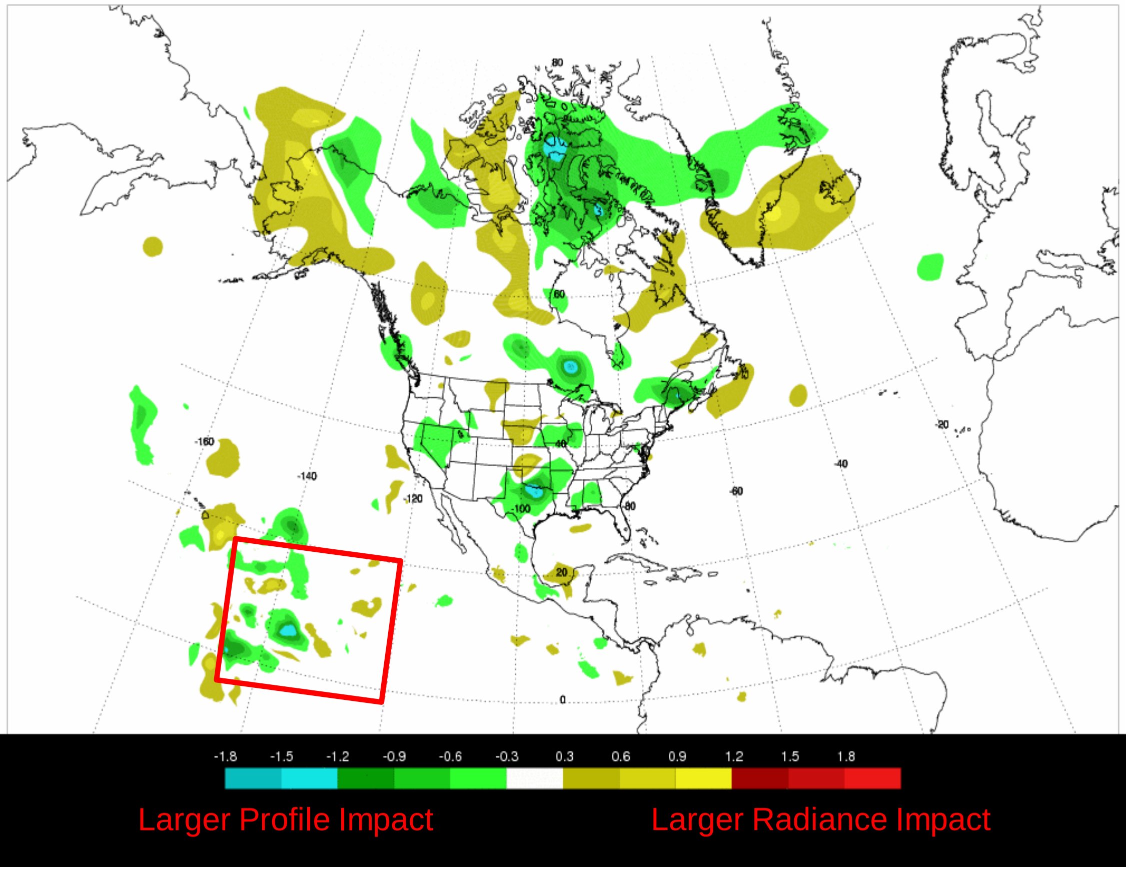
Mean (21 Nov-19 Dec 2011) 500 hPa T AC difference at F48 for 00Z initialization



- Using same-cycle analysis valid at forecast time as verification field
- NCEP GFS climatology interpolated to NMM grid used for AC calculation
- 500 hPa anomaly correlation differences between profile and radiance –
- Downstream of low cloud region, which is coincident observations valid for the 00 and 12 UTC analyses

Impact Difference for Select Case

Temperature (K) ID at σ=39 (≈500 hPa) for 00Z analysis on 22 November 2011



- **Impact Difference (ID) was calculated for each 00Z analysis and interesting cases for further investigation were selected**

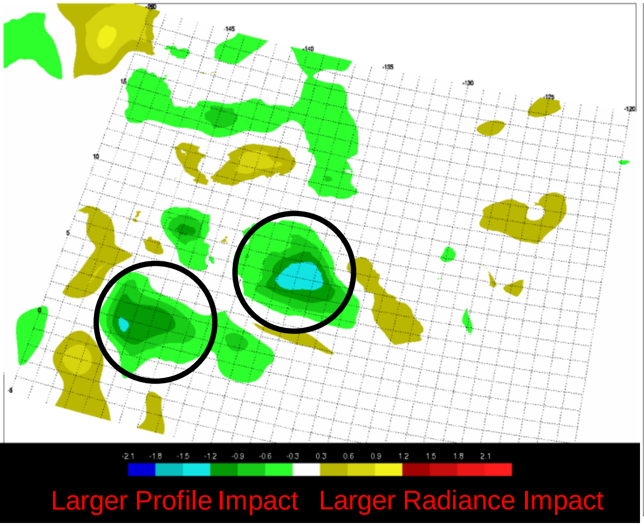
$$ID_{i,j} = |RADALYS_{i,j} - RADBKGDi_{,j}| - |PROFALYSi_{,j} - PROFBKGDi_{,j}|$$

- **What follows is an example of the analysis being performed for a single case (22 Nov 2011)**
- **Following slides examine possible explanations in GSI diagnostics and MODIS cloud products for area over SE Pacific near the equator to help explain improved profile forecasts**

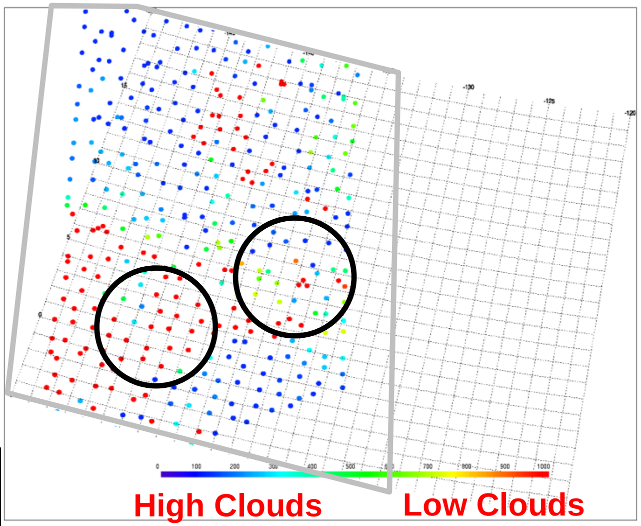
Comparison to MODIS CTP

- Two regions with ≈1.5K larger analysis impact in profile analysis
- Overall, GSI does a good job of determining cloud top pressure (CTP); devil is in the details
- For regions of largest profile impact differences, GSI detects CTP of <500 hPa
- However, Aqua MODIS CTP valid at concurrent time as AIRS observation indicates CTP is ≥800 hPa (right circle) and 950 hPa (left circle)

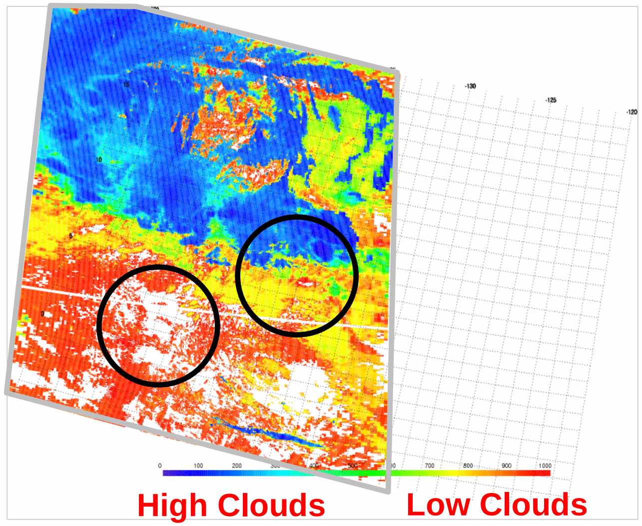
T (K) ID at σ=39 (≈500 hPa) for 0000 UTC analysis 22 November 2011



GSI CTP for 0000 UTC analysis on 22 November 2011



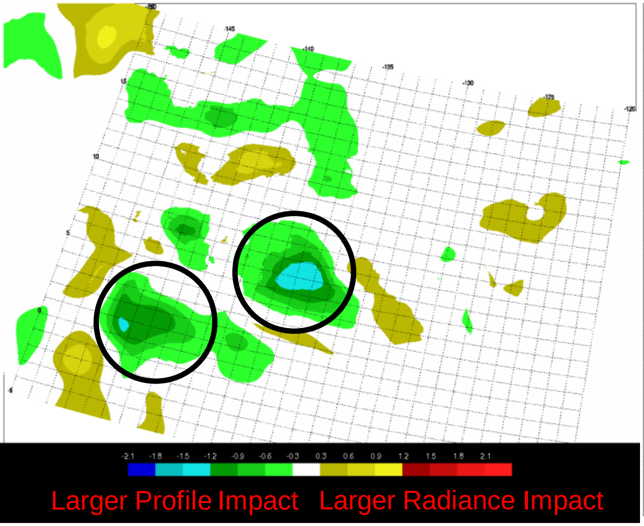
MODIS CTP valid 2240 UTC on 22 November 2011



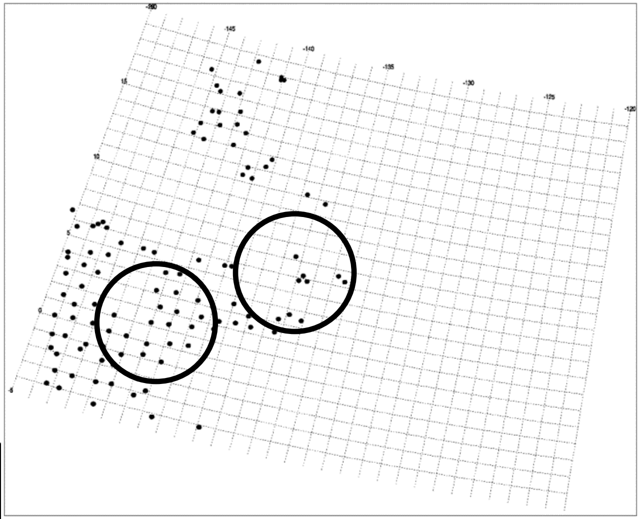
Location of Assimilated Data

- **Limited radiance assimilation around 500 hPa in area of largest profile impact**
- **A number of observations retained in the thinning process are not used in the analysis due to CTP in GSI being at a higher elevation**
- **Locations of retrieved L2 profiles are larger in number (no data thinning) but also provide more data in regions where CTP is lower than 500 hPa**

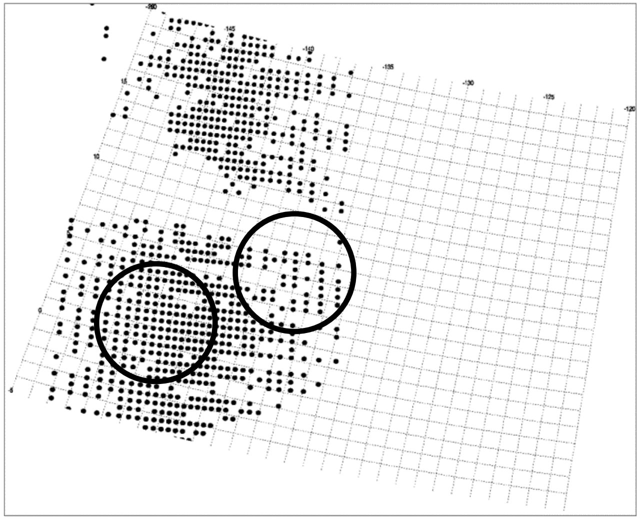
T (K) ID at σ=39 (≈500 hPa) for 0000 UTC analysis 22 November 2011



Assimilated AIRS Radiance Locations at 722cm^{-1} (≈501 hPa)



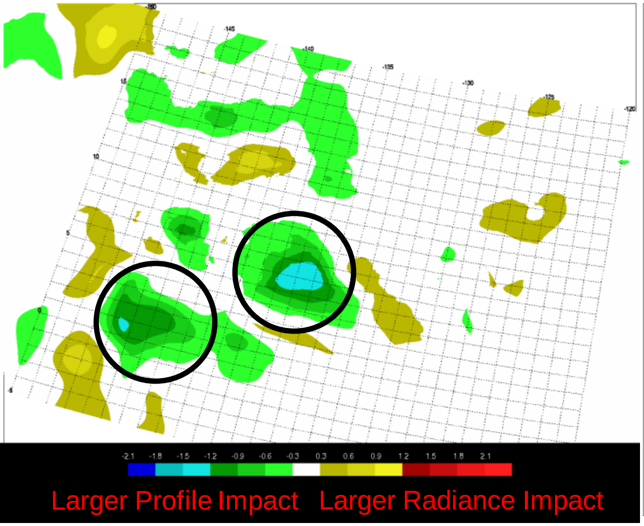
Assimilated L2 Profile Locations at 500 hPa



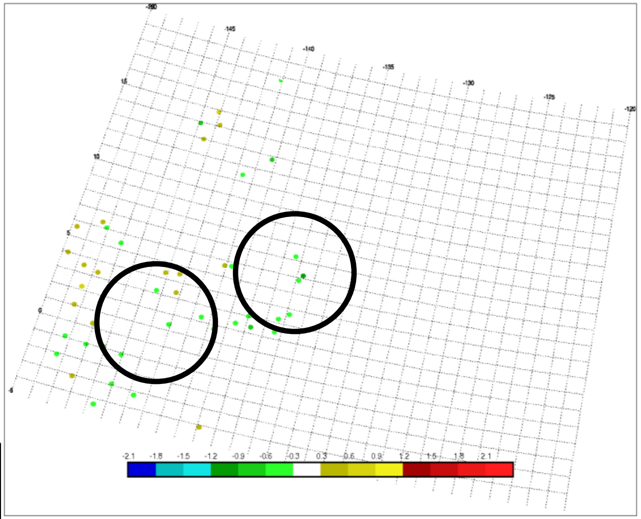
Temperature Innovations

- Unrealistic innovations not the cause of large analysis impact from the profiles in this region
- Combination of radiances removed due to cloud check and spatial thinning are the likely causes for analysis differences
- Further investigation into positive or negative analysis and forecast impact

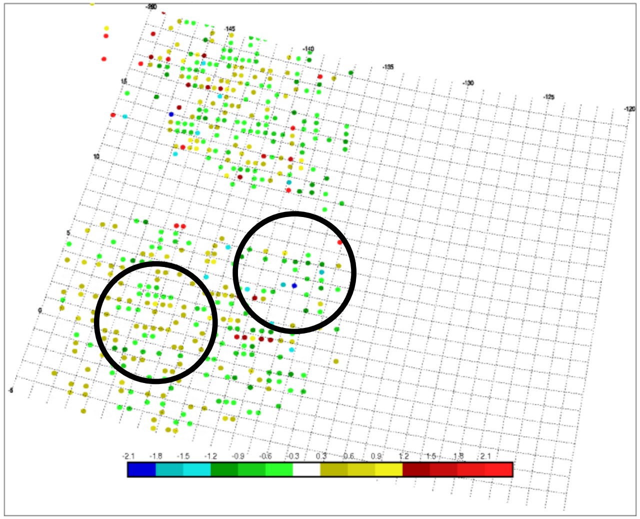
T (K) ID at σ=39 (≈500 hPa) for 0000 UTC analysis on 22 November 2011



AIRS Radiance T (K) Innovations (OB-BG) at 722cm^{-1} (≈501 hPa)



AIRS L2 Profile T (K) Innovations (OB-BG) at 500 hPa



Summary/Future Work

- **Summary**
  - Parallel experiments using AIRS L1B and L2 retrieved profiles were run for 29 case study days for early Winter 2011
  - Forecasts over and downstream regions of low, opaque cloudy regions yield improved T and Z anomaly correlations when non-thinned set of profiles is assimilated instead of radiances
  - Initial results indicate that GSI does a good job on the whole of determining cloud-free radiances there are some areas coincident with areas of larger profile impact that are misrepresented (compared to MODIS) that may result in reduced analysis impact
- **Future Work**
  - Investigate regions where AIRS radiances have larger impact for possible cloud contamination affects
  - Produce quantitative statistics comparing GSI CTPs with MODIS CTPs
  - "Turn knobs" within GSI to determine analysis/forecast impact from different cloud detection, quality, and spatial thinning options

Acknowledgments

- Work is supported by Tsengdar Lee of the NASA Science Mission Directorate through the JCSDA and SPoRT
- EMC staff (Geoff DiMego, Justin Cooke, Michael Lueken, et al.) for helping understand the cycling and configuration of the operational NAM and for making NAM PREPBUFR observations available to the research community
- Jim Jung and JIBB IT staff for allowing us to run our simulations and store our large analysis and forecast files
- Fanglin Yang for providing the climatology files used by EMC for calculating anomaly correlations