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

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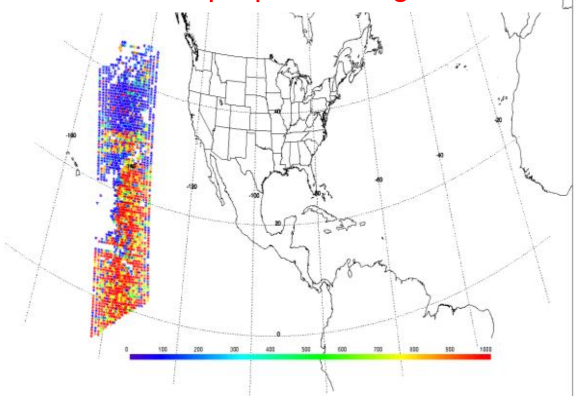
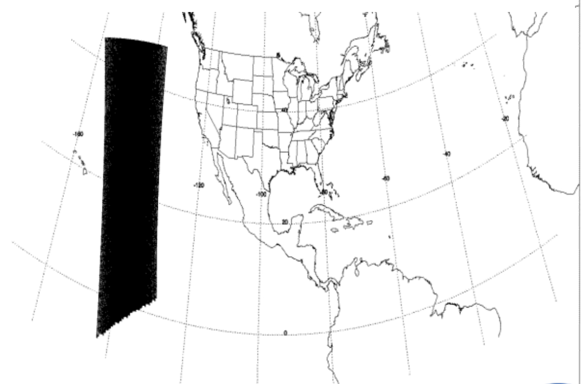
Project Concept

- **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 useable L2 profiles determined in preprocessing



Lowest extent of useable L1B radiances determined within GSI

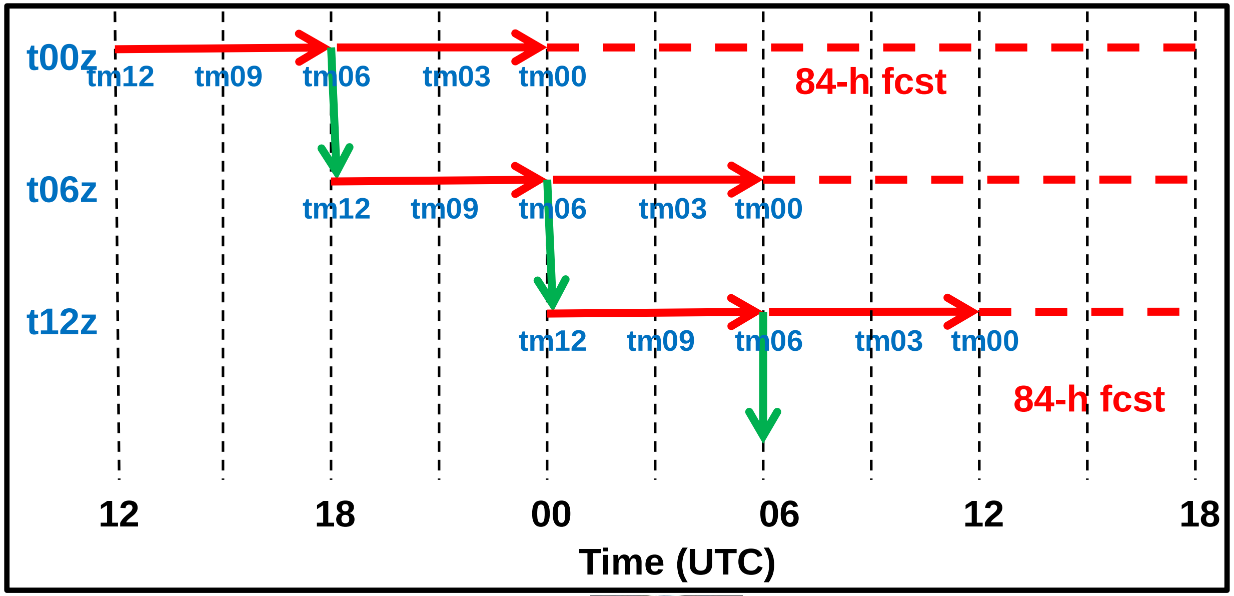


- **Lowest extent of quality AIRS L2 profiles determined by quality indicators in preprocessing**
- **Use MODIS as an additional resource to determine cloud location and vertical extent**

Experimental Setup

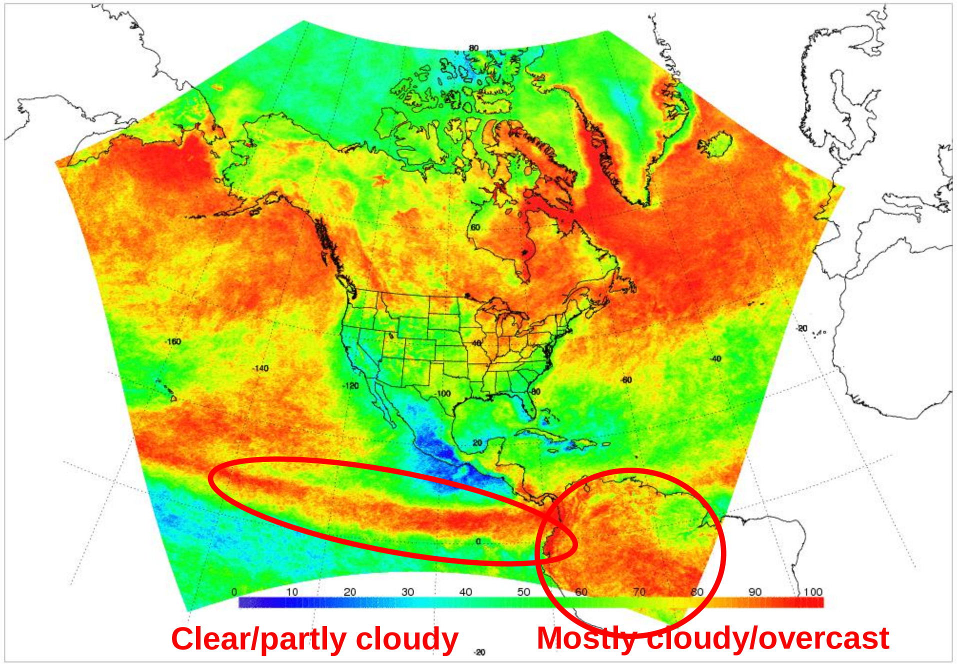
- **Developmental Testbed Center (DTC) GSIv3.0 and WRF-NMMv3.3 code configured in forecast cycling methodology that mimics the operational NAM**
- **Real-time BUFR files archived during assimilation period (4 Nov.–20 Dec. 2011)**
  - Satellite: AIRS, AMSU, HIRS, MHS, GOES Sounder, GPSRO, radar winds
  - 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
  - PRO:
    - 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 for results in this presentation

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

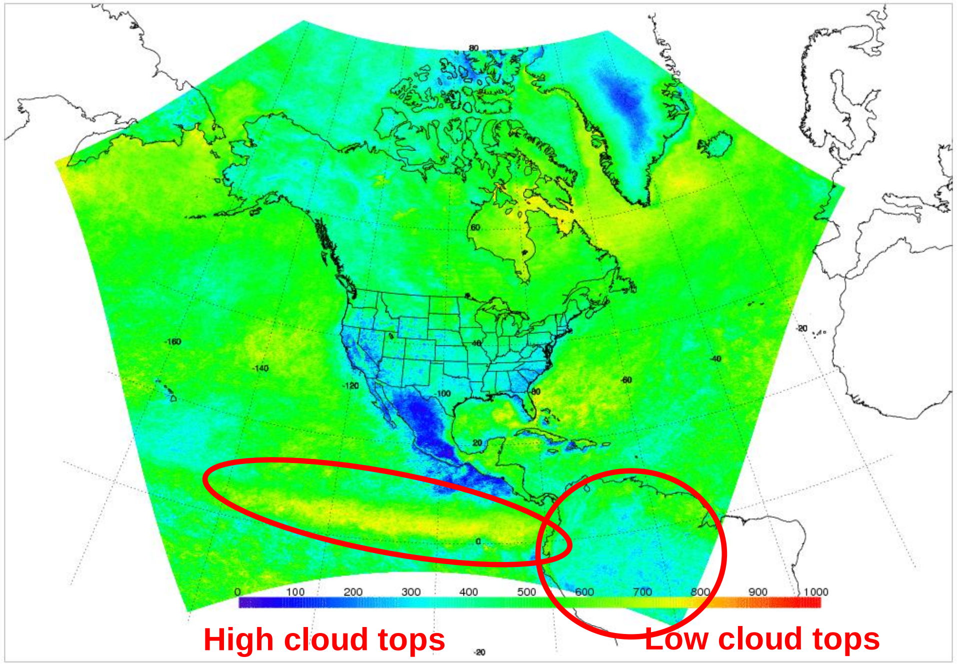


Bulk Cloud Information

Mean MODIS cloud fraction: 20 Nov - 20 Dec 2011



Mean MODIS CTP: 20 Nov - 20 Dec 2011

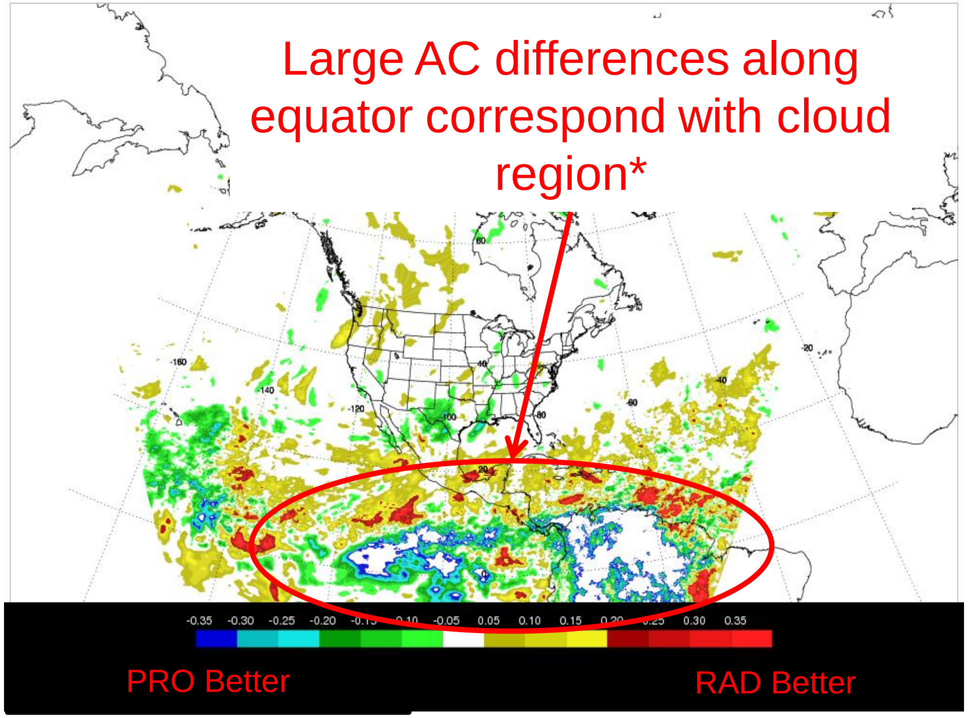


- Mean cloud information from Aqua MODIS interpolated to WRF-NMM grid
- Regions of low- and mid-level, opaque clouds (assimilate above cloud) and regions with cloud gradients (assimilate in partly cloudy or scene incorrectly deemed cloudy) should be areas where profiles have most impact
- Main focus of results will be on persistent low- and mid-level, opaque clouds just in the ITCZ

Forecast Impact

- **Using same-cycle analysis valid at forecast time as verification field to calculate anomaly correlations (AC); NCEP GFS climatology interpolated to NMM grid**
- **500 hPa AC differences between profile and radiance show that differences occur in the presence of the low- and mid-level clouds**
- **Evaluation of T anomaly correlations between -10°S and 10°N latitude where largest differences occur yields:**
  - RAD: 0.552
  - PROF: 0.667

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

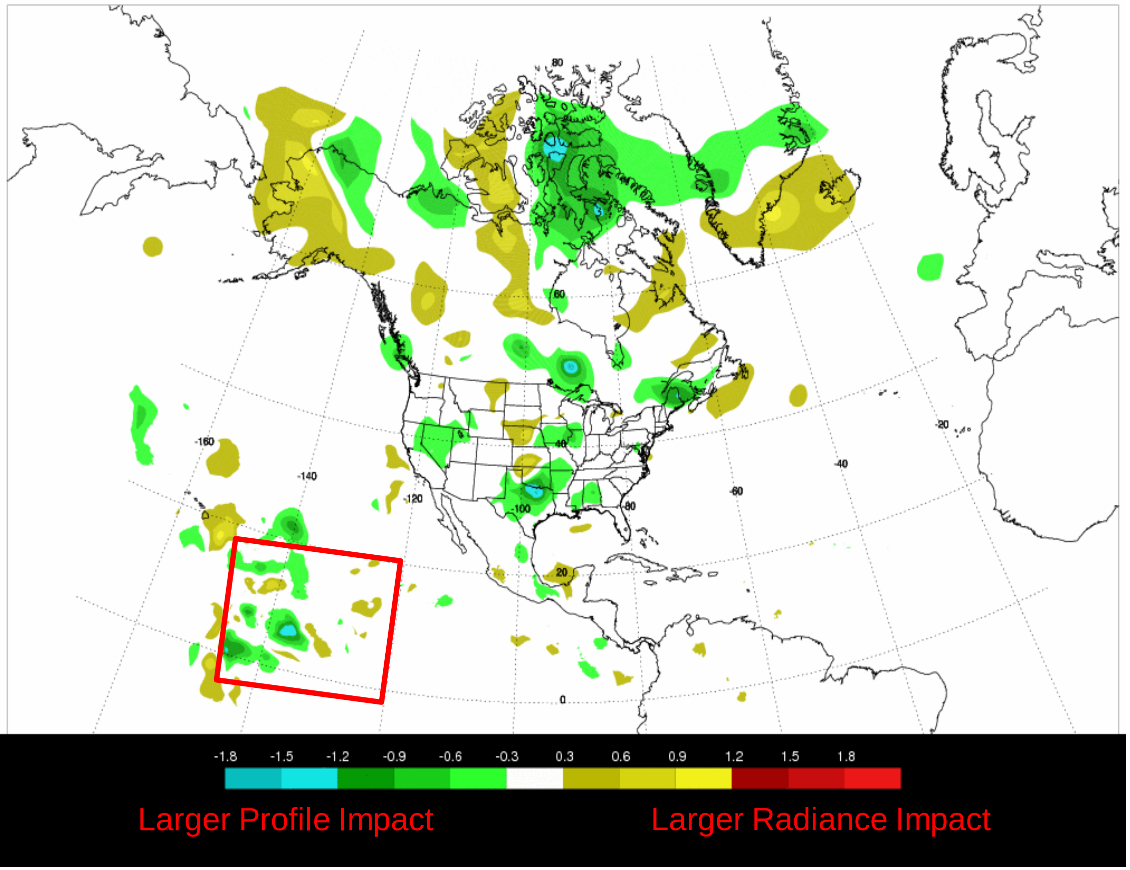


- **500 hPa height AC shows similar trend but with much less magnitude in difference**

**large white areas in center of green and blue areas are artifacts of the plotting routine*

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**

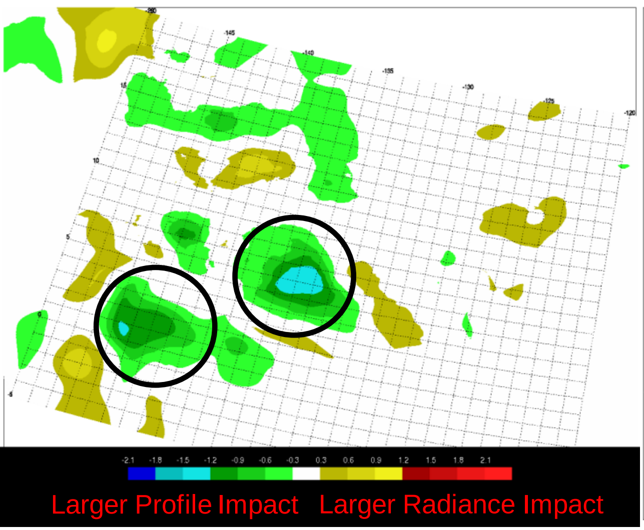
$$ID_{i,j} = |RADALYS_{i,j} - RADBKGDi_{,j}| - |PROFALYSi_{,j} - PROFBKGDi_{,j}|$$

- **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 in the ITCZ to help understand improved profile forecasts**

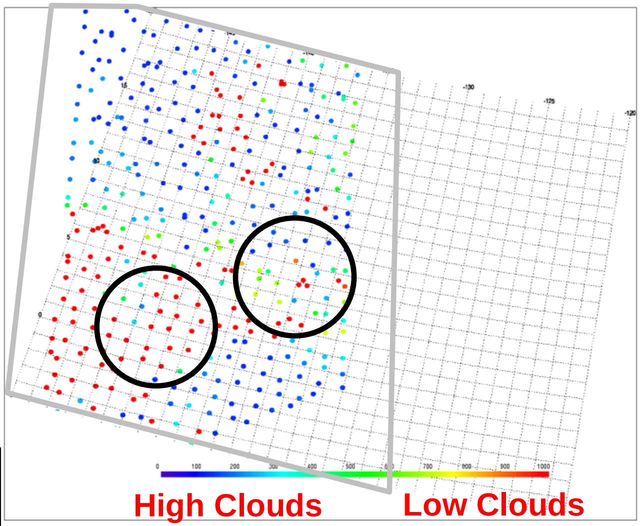
Comparison to MODIS CTP

- **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)**

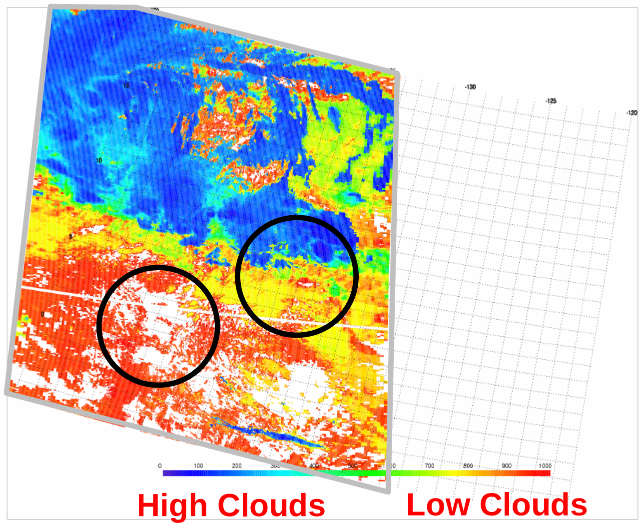
T (K) ID at σ=39 (≈500 hPa) for 0000 UTC analysis 22 November 2011



GSI CTP for 0000 UTC analysis on 22 November 2011



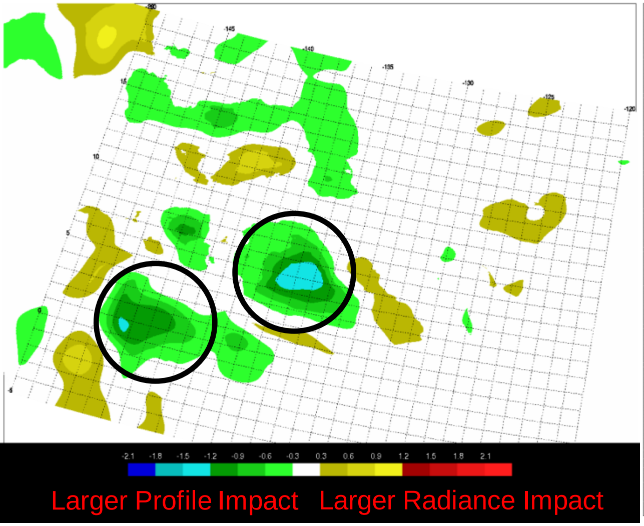
MODIS CTP valid 2240 UTC on 22 November 2011



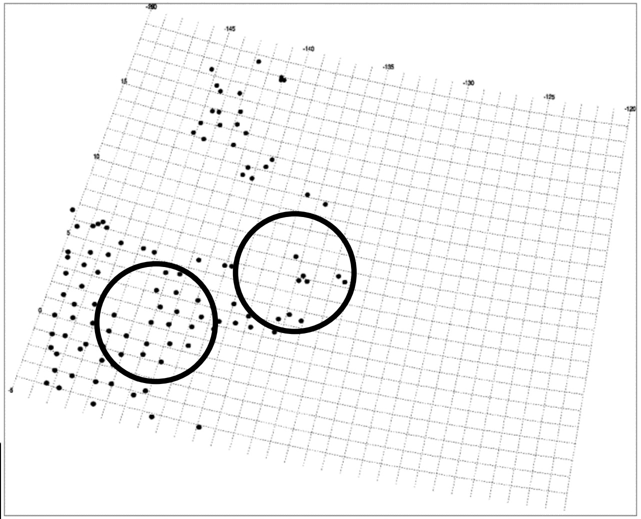
Location of Assimilated Data

- **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**

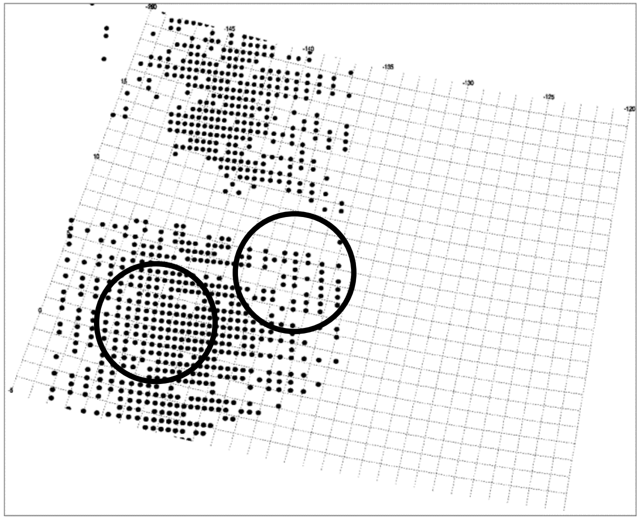
T (K) ID at σ=39 (≈500 hPa) for 0000 UTC analysis 22 November 2011



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



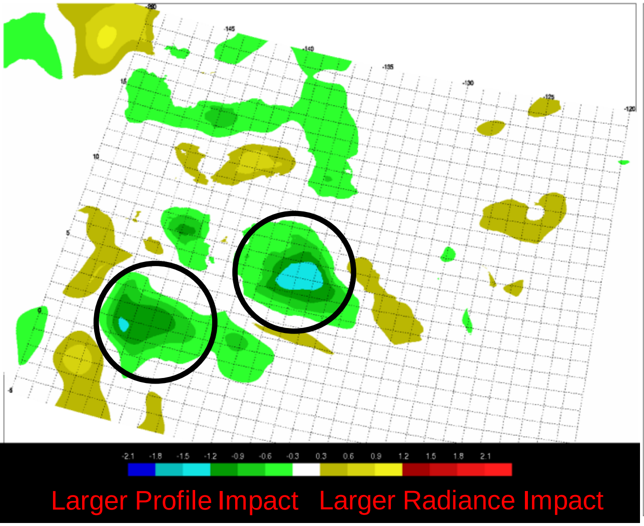
Assimilated L2 Profile Locations at 500 hPa



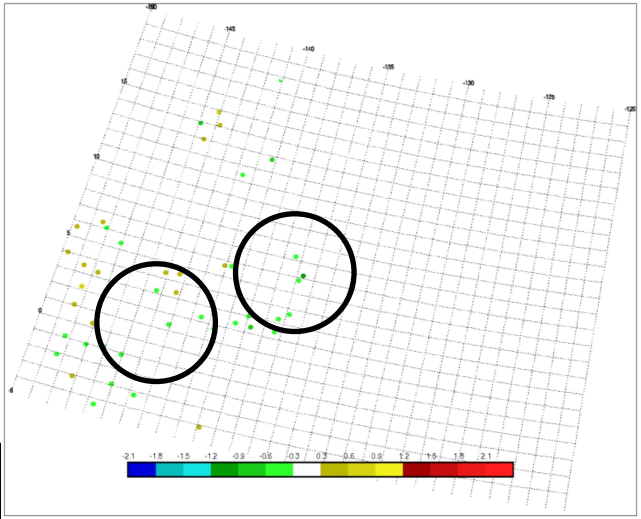
Temperature Innovations

- **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 spatial thinning by mapping profile locations to assimilated radiance locations**

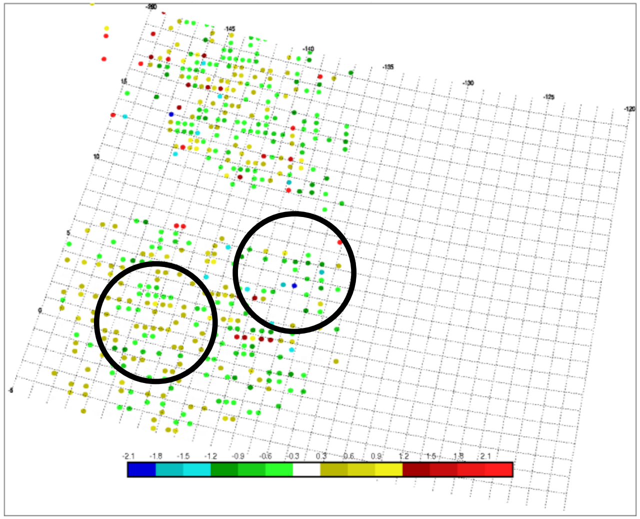
T (K) ID at σ=39 (≈500 hPa) for 0000 UTC analysis on 22 November 2011



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 ITCZ where of low- and mid-level, opaque cloudy areas occur yield regions of improved temperature anomaly correlations when a 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 causes of analysis/forecast impact from different cloud detection, quality, and spatial thinning options

Acknowledgments

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