Use of MODIS Cloud Top Pressure to Improve Assimilation Yields of AIRS Radiances in GSI

Bradley Zavodsky[1] & Jayanthi Srikishen[2]

[1]NASA Marshall Space Flight Center, Huntsville, AL

[2]Universities Space Research Association, Huntsville, AL

1. MOTIVATION

- Radiances from hyperspectral sounders such as the Atmospheric Infrared Sounder (AIRS) are routinely assimilated both globally and regionally in operational numerical weather prediction (NWP) systems using the Gridpoint Statistical Interpolation (GSI) data assimilation system
- However, only thinned, cloud-free radiances from a 281-channel subset are used, so the overall percentage of these observations that are assimilated is somewhere on the order of 5%
- Cloud checks are performed within GSI to determine which channels peak above cloud top; inaccuracies may lead to less assimilated radiances or introduction of biases from cloud-contaminated radiances
- Relatively large footprint from AIRS may not optimally represent small-scale cloud features that might be better resolved by higher-resolution imagers like the Moderate Resolution Imaging Spectroradiometer (MODIS)
- <u>Objective of this project is to “swap” the MODIS-derived cloud top pressure (CTP) for that designated by the AIRS-only quality control within GSI to test the hypothesis that better representation of cloud features will result in higher assimilated radiance yields and improved forecasts</u>

2. EXPERIMENT DESIGN

- Experiments performed using Joint Center in a Big Box supercomputer
- Developmental Testbed Center (DTC) GSIv3.2 and WRF-NMMv3.3
- AIRSv5 L1B radiances in EMC “airsev” files; MODIS MYD06_L2 CTP files

2.1. Collocating MODIS and AIRS Footprints

- AIRS radiances have 13.5-km round fields of view (FOV) at nadir that stretch to 41-km at the limbs
- MODIS retrieved CTP is 5-km resolution
- Assumed linear change in AIRS diameter based on scan position
- Selected highest (in altitude) MODIS CTP value within any AIRS FOV (represented by red value in Fig. 1)
- Generated a text file for each analysis containing the AIRS FOV latitude and longitude and the MODIS CTP at that location

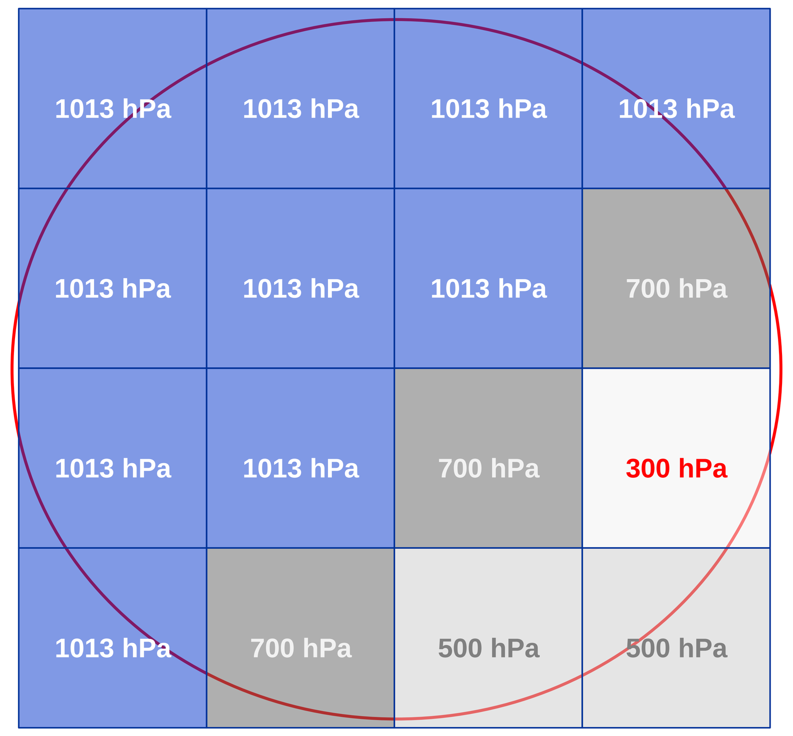

Figure 1. Depiction of collocating technique to match AIRS radiances (red circle) with MODIS CTP (boxes; colors attempt to match cloud enhancements applied to MODIS IR imagery).

2.2. Model Setup

- Dynamic scripts (see EIPT 501 for more details) used to mimic the operational North American Mesoscale (NAM) model (Fig. 1)
- Assimilated real-time BUFR files archived during the period from 4 Nov to 20 Dec 2011; 48 hour* forecasts every 6 hours
  - Satellite: AIRS, AMSU, HIRS, MHS, GOES Sounder, GPSRO, and radar winds
  - Conventional: All observations used in EMC’s Table 4

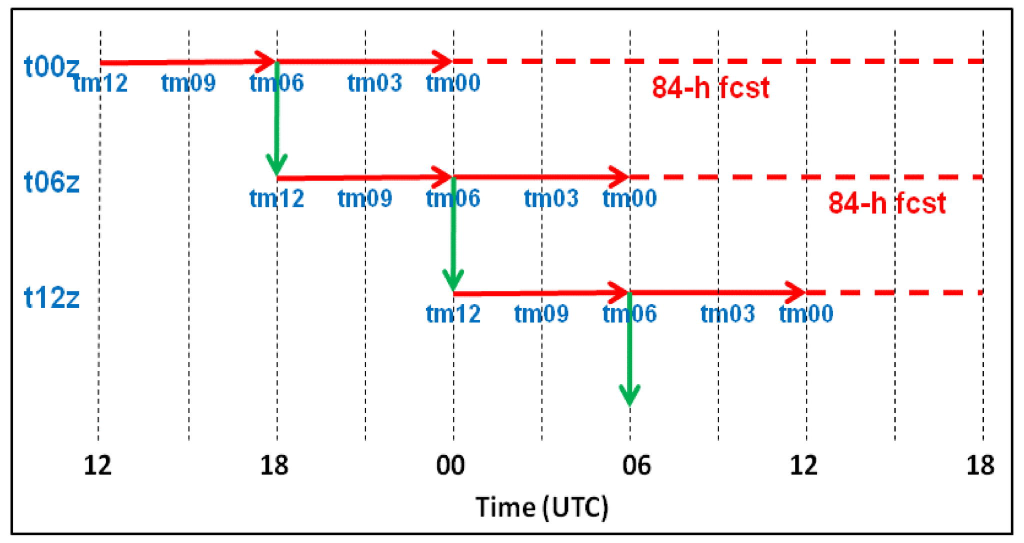

Figure 2. Schematic of NAM cycling system (DiMego, personal communication).

- Two “parallel” 2-week experiments with 2-week spin-up (all results are for 21 Nov to 10 Dec 2011); do not include spin-up
  - CNTL: Operational GSI IR radiance CTP designation
  - EXP: Swap MODIS CTP for GSI-derived CTP designation
- Forecasts from 23 and 30 Nov. had missing data

*48 hour forecasts were run instead of 84-hour forecasts due to disk space limitations

3. CODE CHANGES TO GSI TO INCORPORATE MODIS CTP

- setuprad.f90 reads in the various satellite radiance data sets and calls a subroutine called qc_irsnd to apply quality control to IR sounder data
- Modifications to the GSI source code were made to qc_irsnd, which is in a subroutine in the program qcmod.f90
- The text file created from the MODIS/AIRS match-ups (Section 2.1) is read into the subroutine and then matched up to the latitude and longitude of each FOV in the airsev BUFR file
- The MODIS CTP and a corresponding sigma level associated with the CTP (calculated using standard surface pressure) are then used to determine the cloud-free radiances

4. RESULTS

- GSI CTP is generally good at designating areas cloud cover; however, there are some areas where the GSI-derived CTP differs considerably from higher-resolution MODIS imagery

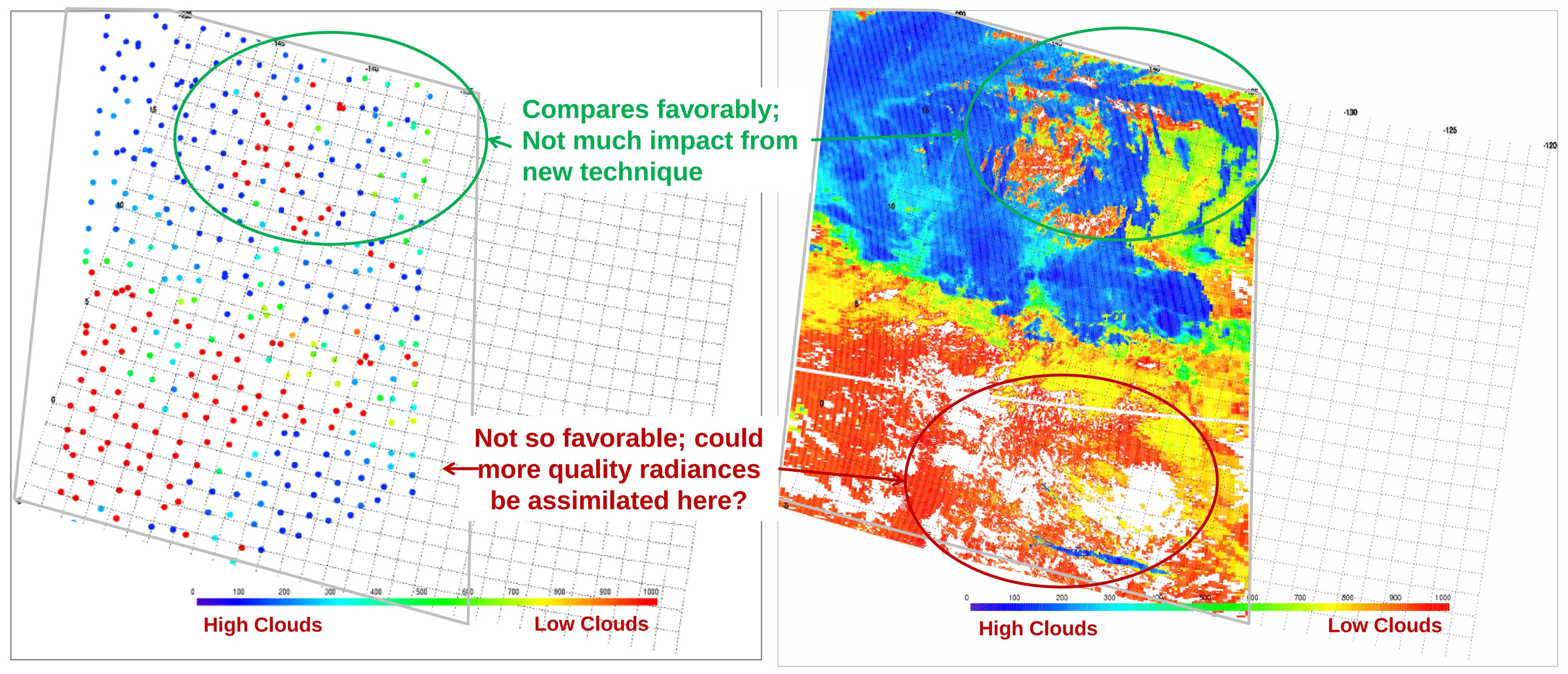

Figure 3. Comparison between operational GSI CTP detection for AIRS radiances assimilated at 0000 UTC on 22 November 2011 (left) and MODIS CTP valid at 2240 UTC on 21 November 2011 (right).

4.1. Designated CTP and Number of Assimilated Radiances

- GSI gives CTP ≥ 1000 hPa more frequently than MODIS; MODIS has more total CTP >700 hPa (with large differences at 900 and 950)
  - Is MODIS detecting non-opaque near-surface clouds that do not impact AIRS, thus incorrectly reducing the number of surface assimilated channels?
  - Or is AIRS not detecting smaller low-level cloud features that are detectable by MODIS, thus introducing potential near-surface cloud contamination biases?
- Total number of assimilated radiances actually is reduced when using MODIS considering large number of 1000 hPa GSI cases

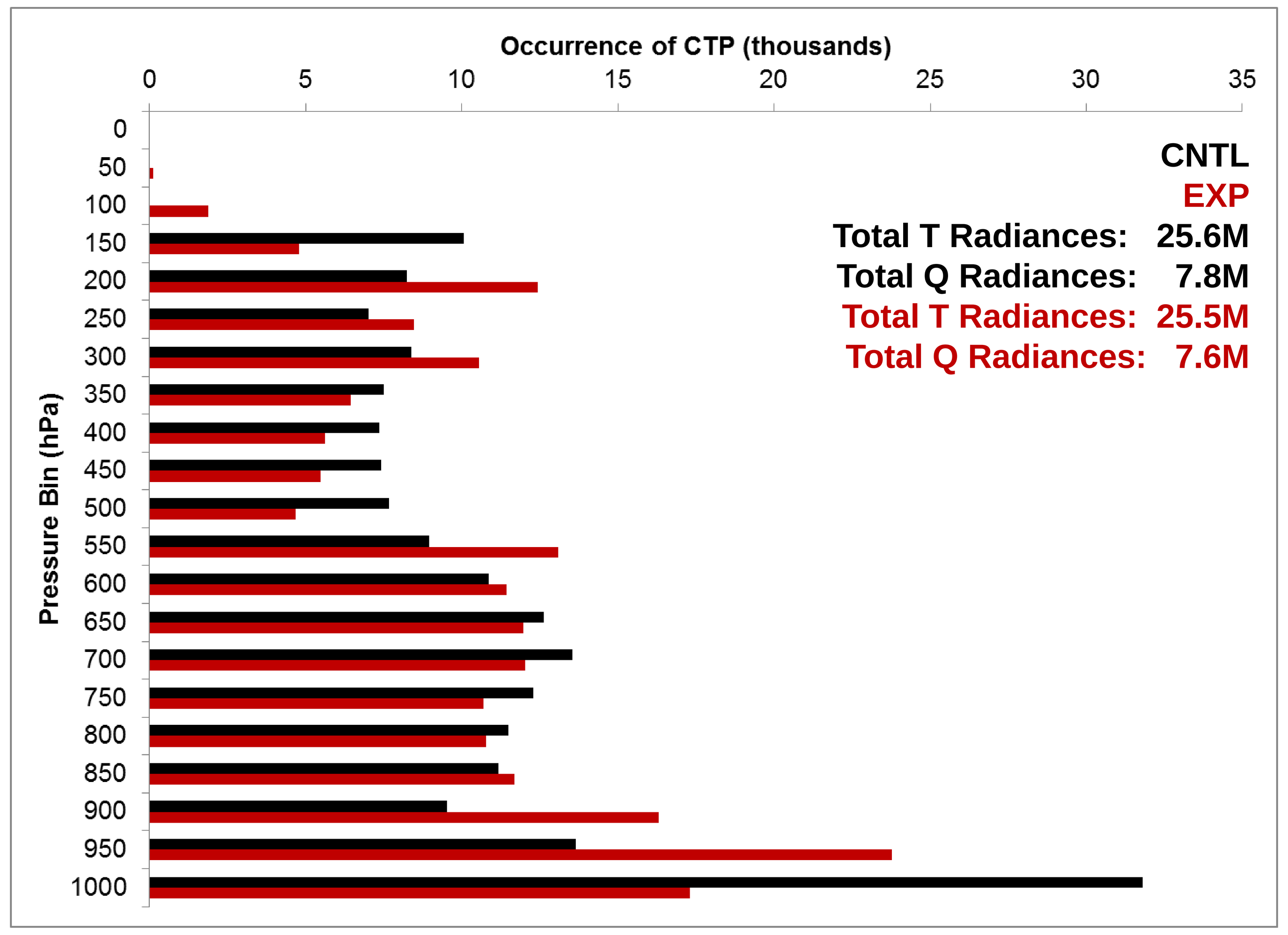

Figure 4. Binned occurrence of CTP for each assimilated AIRS radiance for the CNTL (black bars) and experiment where MODIS CTP has been swapped in (red bars). Inset is the total number of temperature- (T) and moisture-affecting (Q) radiances

4.2. Preliminary Forecast Results

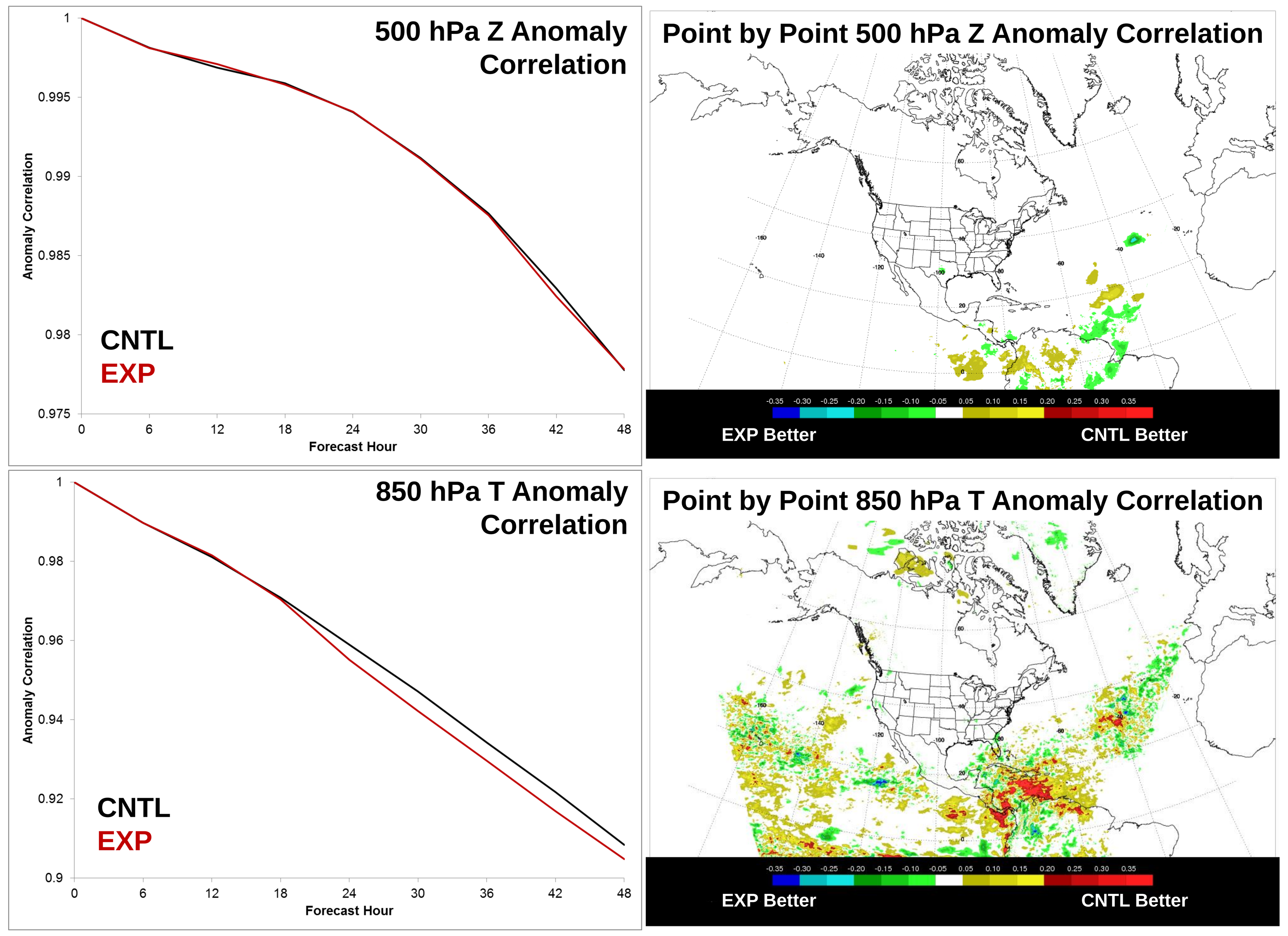

Figure 5. Forecast anomaly correlation for every 6-hour forecast for 500 hPa height (top left) and 850 hPa temperature (bottom left). Plan view of grid point by grid point anomaly correlation differences (EXP – CNTL) pinpointing areas where largest forecast differences occurred for 500 hPa height (top right) and 850 hPa temperature (bottom right).

- Using same-cycle analysis valid at forecast time as verification field to calculate anomaly correlations (AC); NCEP GFS climatology interpolated to NMM grid

$$ACC = \frac{\overline{(f-c)(a-c)}}{\sqrt{\overline{(f-c)^2}\,\overline{(a-c)^2}}}$$

f: forecast value
c: climatology correction
a: analysis value at forecast time

- 500 hPa height anomaly correlation (Fig. 5; top left) shows very minute improvements with the new technique; not statistically significant
- Areas of improvement and degradation cancel out (Fig. 5; top right)
- To test the impact of the change in distribution of CTP (as shown in Fig. 4), 850 hPa temperature anomaly correlation is plotted (Fig. 5; bottom left)
- 850 hPa temperature anomaly correlation in EXP run is degraded (by about 1.5 hours at 48 hour forecast) compared to the CNTL indicating that method of determining CTP currently used in GSI is more appropriate
- Large area off north coast of South America where EXP degrades the forecast (Fig. 5; bottom right); need to further investigate this region

5. SUMMARY AND FUTURE WORK

- A technique whereby CTP from MODIS is swapped in for the AIRS CTP used for quality control within GSI was tested
- Swapping in MODIS CTP for AIRS-only derived CTP in GSI yields more instances of radiances being assigned a CTP >700 hPa, but more radiances were assigned as cloud-free when derived by AIRS
- 500 hPa height anomaly correlations reveal very little impact from the new technique; 850 hPa temperature anomaly correlations reveal that current technique produces better forecasts meaning that the added AIRS radiances likely did not suffer from cloud contamination
- Future work will focus on looking at single cases where the GSI derived CTP was >1000 hPa to better determine the specific cloud features present in the regions of largest impact as shown in Fig. 5