MTP Observations during the ATTREX Integration and Test Flights

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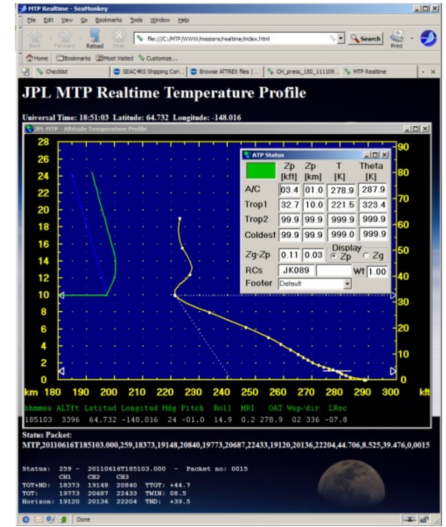
MTP Integration on the Global Hawk



The MTP Real Time Display

Comm Computer

-Sends status and data packets to ground for real time data processing and display

-Reads IWG1 UDP packets and reformats in ER-2 Nav Data Recorder RS-232 format to send to Data Unit

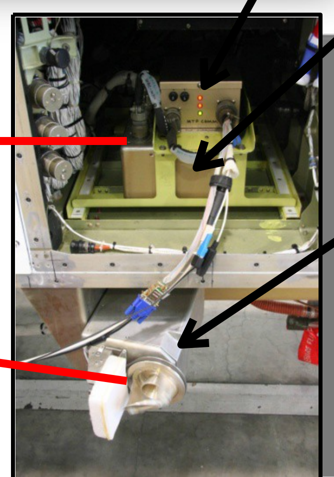
Data Unit

-PC-104 computer that runs code that controls the Sensor Unit

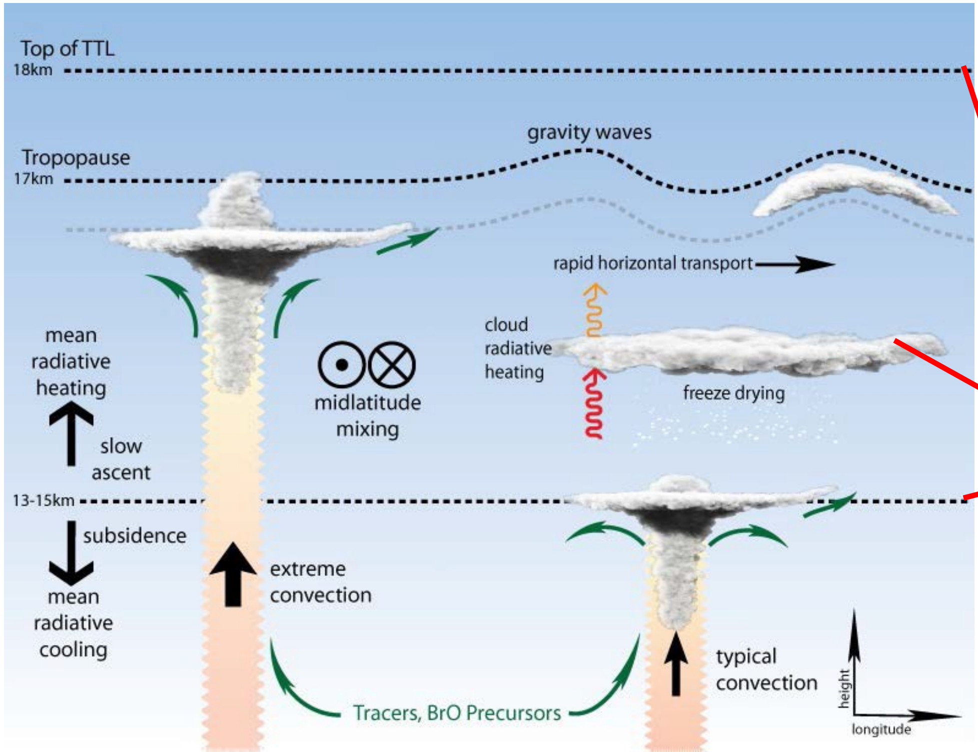
-Stores data that it receives from the Sensor Unit and also sends it to the Comm Computer

Sensor Unit

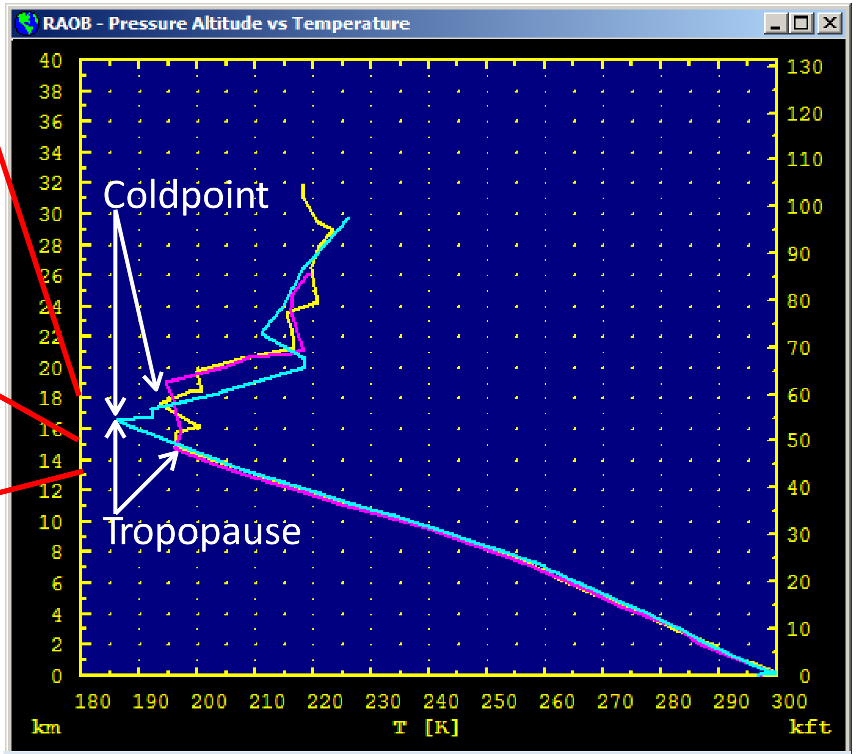
-Under control of the Data Unit, it scans from near zenith to near nadir making brightness temperature measurements at three frequencies. It also observes a reference target (white box) for calibration purposes. Measurements are sent to the Data Unit.



How the MTP Can Contribute to ATTREX



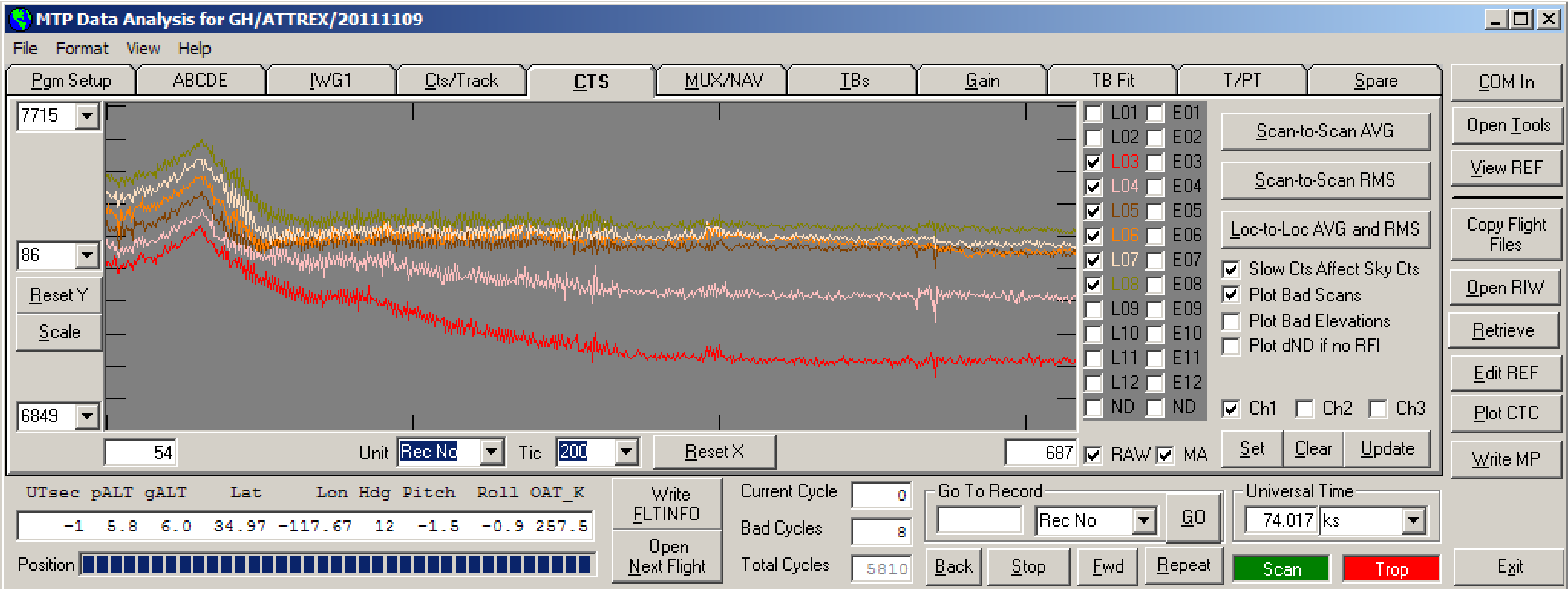
Schematic of the Tropical Tropopause Layer (TTL) from ~13-18 km. T structure of the TTL controls H_20 flow.



Soundings from Padang, Indonesia, on 2010-08-07,-08, and -15 showing typical (cyan), cold point (yellow) and isothermal (magenta) TTL

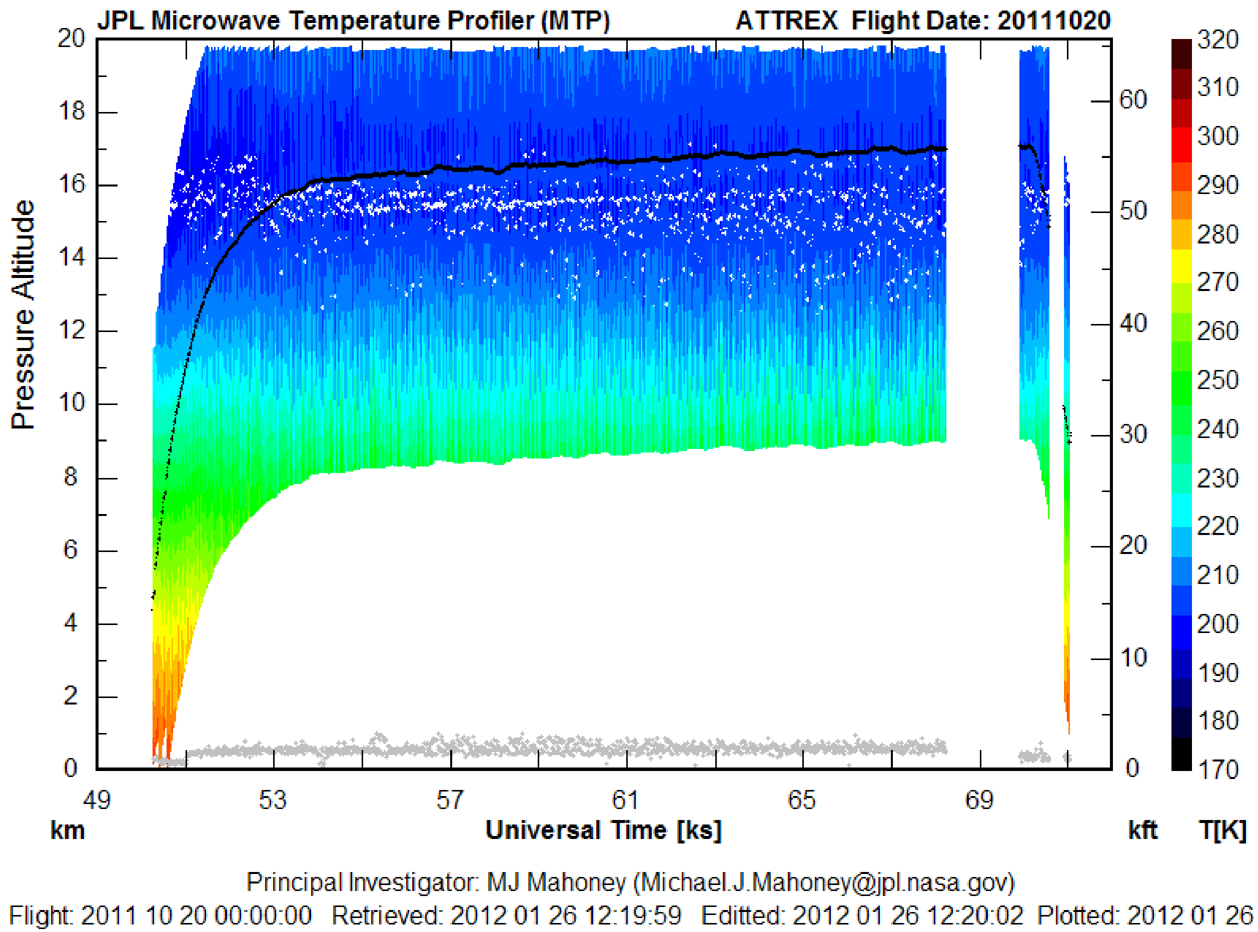
- The MTP measures the cold-point of the TTL, which is the throttle that controls whether or not trace gases freeze out and precipitate, or enter the stratosphere
- The MTP is able to 'see' gravity waves which are one of the most important dynamic phenomena in the tropical atmosphere: they interact strongly with convective processes, and they can affect the thermal structure of the TTL if they dissipate and transfer momentum

RFI was an Issue near Edwards AFB



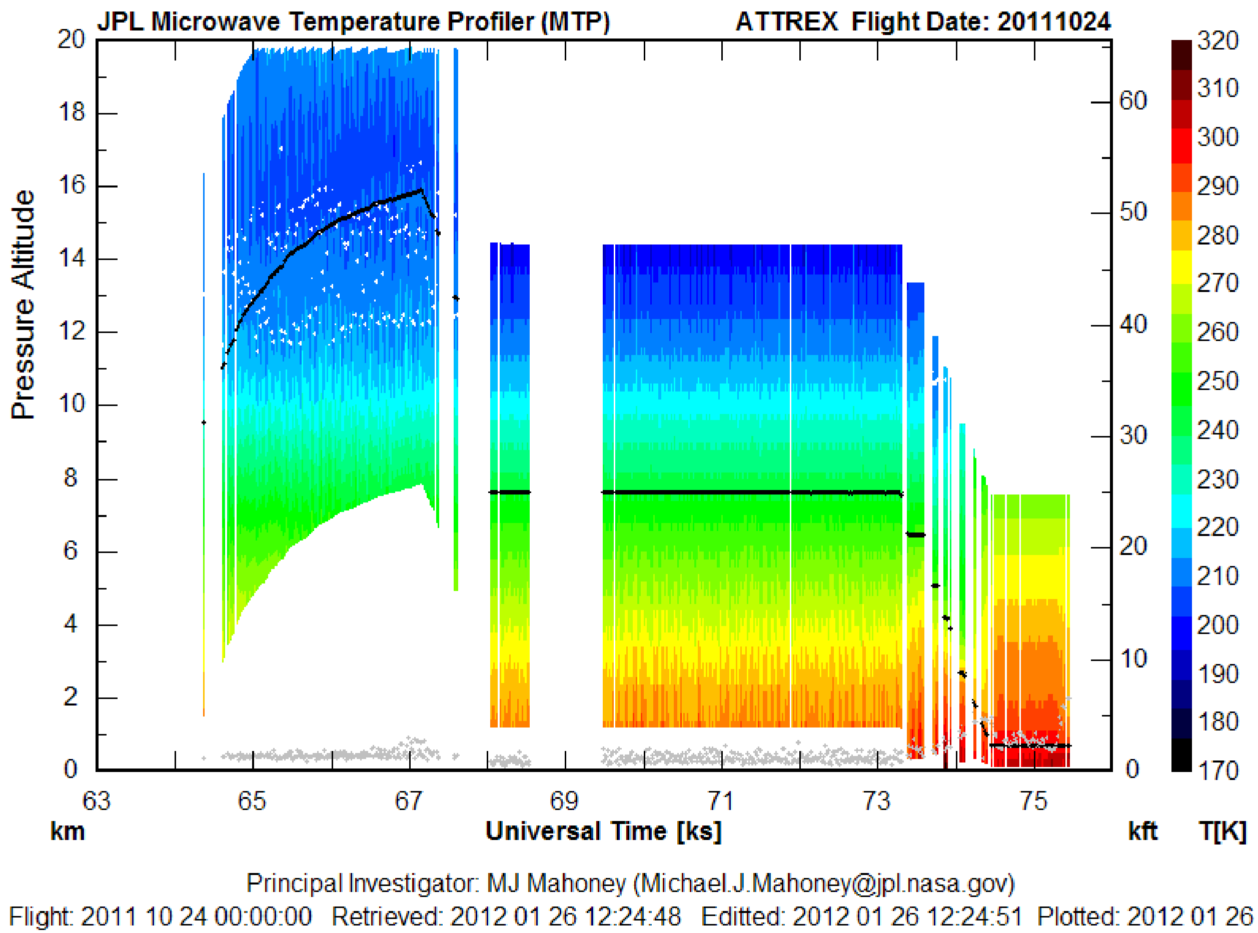
- The 'counts' plot above at 6 different elevation angles at one frequency of the MTP clearly shows the enhanced 'noise' early on during the 2011-11-09 GH science flight
- Increased radar coverage associated with the stealth Northrop-Grumman X-45 UCAV tests are the most likely cause of the interference
- Radar interference has never been an issue in the past at Edwards AFB
- Instrument performance was nominal by the time the GH reached Lost Link on the west coast of California off Vandenberg AFB

The Effect of RFI on MTP Retrievals (1)



•This color-coded temperature curtain (CTC) of the Edwards range flight on 2011-10-20 clearly shows the scatter in the retrieved tropopause height (white dots) caused by the RFI. The black trace shows the GH flight altitude, and the bottom gray trace is a retrieval quality metric. If it is <1 on the pressure altitude scale, the retrieval is good.

The Effect of RFI on MTP Retrievals (2)



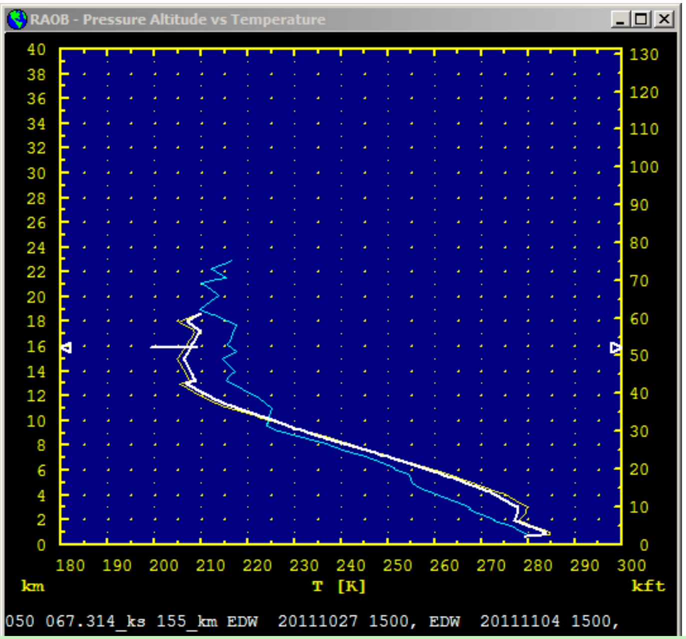
- This CTC shows the aborted science flight on 2011-10-24
- Note again the impact of the RFI up to 68 ks when the GH descended to FL250 to dump fuel
- At this lower altitude the RFI was not visible and the MTP performed nominally

MTP Temperature Calibration (1)

- Temperature calibration is independent of the MTP measurements
- We compare an *in situ* T measurement to radiosondes launched near the GH flight track
- GH avionics temperature probe was of poor quality; we used preliminary MMS data instead
- Quality control is everything in RAOB comparisons:
  - Look at before/after closest approach soundings to avoid temporal variability (see example =>)
  - Avoid excessive altitude excursions during the comparisons so the lapse rate is not a factor
  - Avoid excessive pitch and/or roll changes which could affect the T accuracy
  - Avoid redundant RAOB comparisons which would adversely weight the results
- A good calibration could not have been achieved without the Edwards soundings (Thanks Lenny. Please include them on all future flights!)
- We found that the preliminary MMS data had an average warm bias of +0.25 K with a slight Mach Number-squared correction:

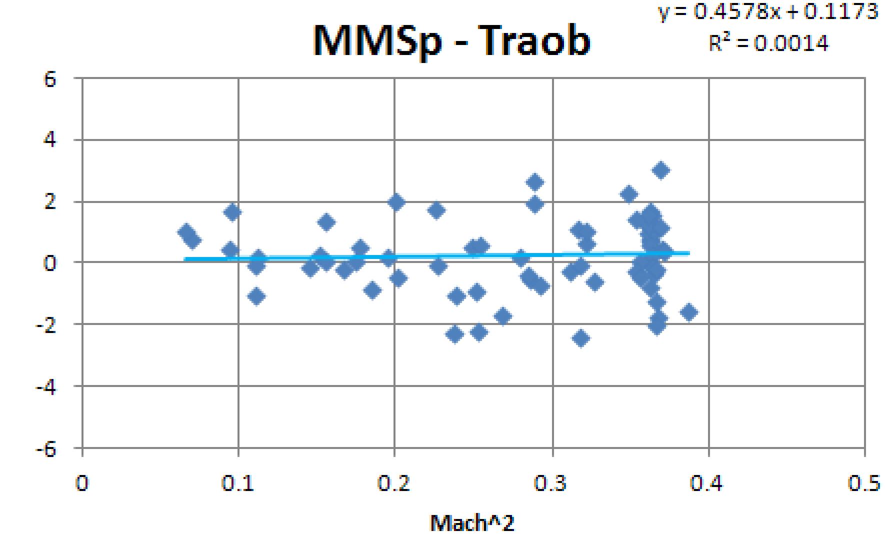
$$MMSp = Traob + 0.1173 + 0.458\ M^2$$

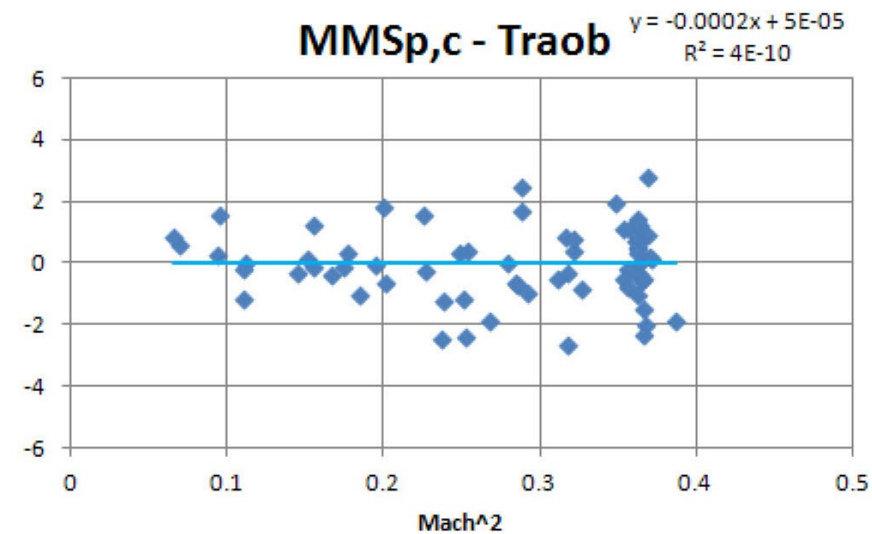
- This is discussed further on the next slide

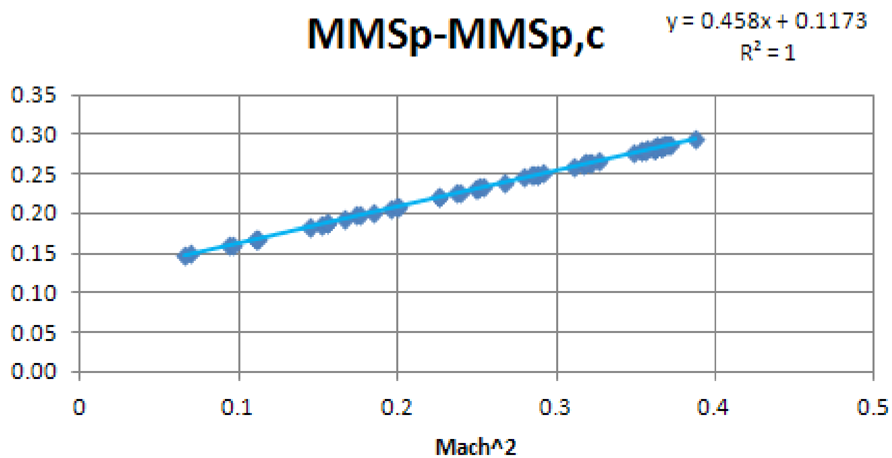


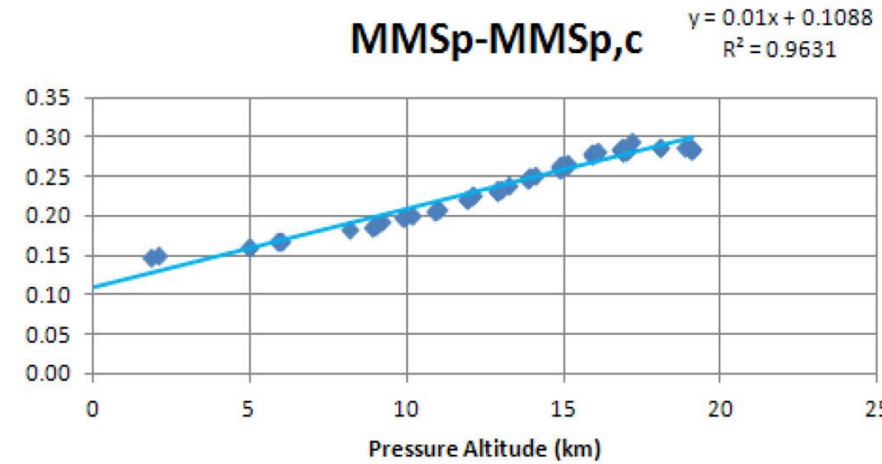
- An example of a RAOB comparison that could not be used (one of three on this date)
- The 'before' sounding (yellow profile) was launched at 2011-11-27 16UT, the 'after' sounding (cyan profile) at 2011-11-04 15UT – a week later! The GH comparison was at 2011-11- 28 18.7UT (white profile)
- Lack of an adequate 'after' sounding is a problem

MTP Temperature Calibration (2)





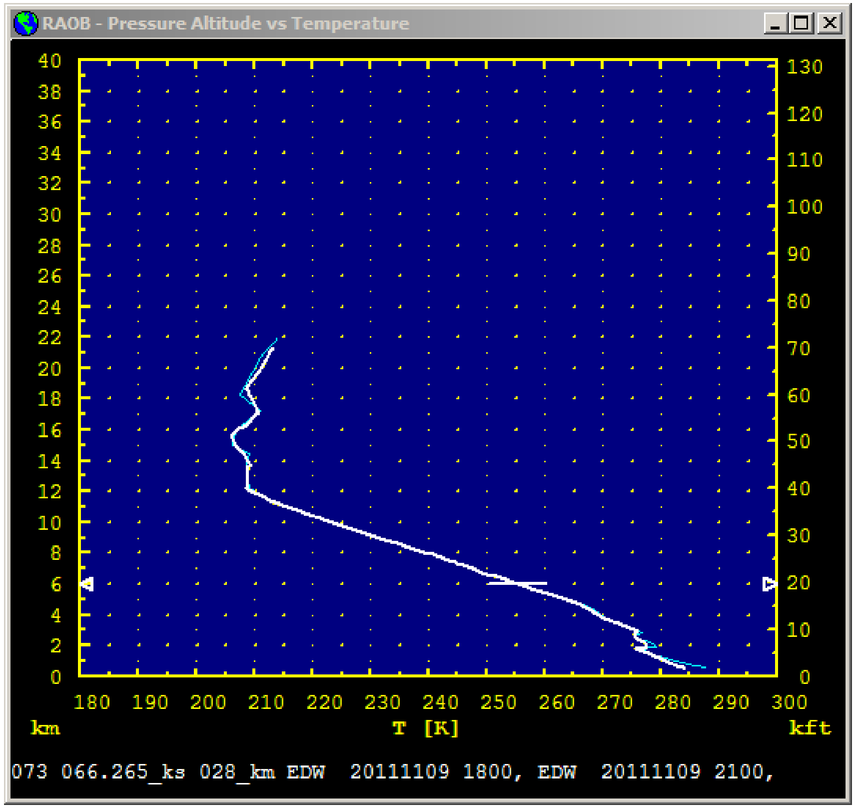




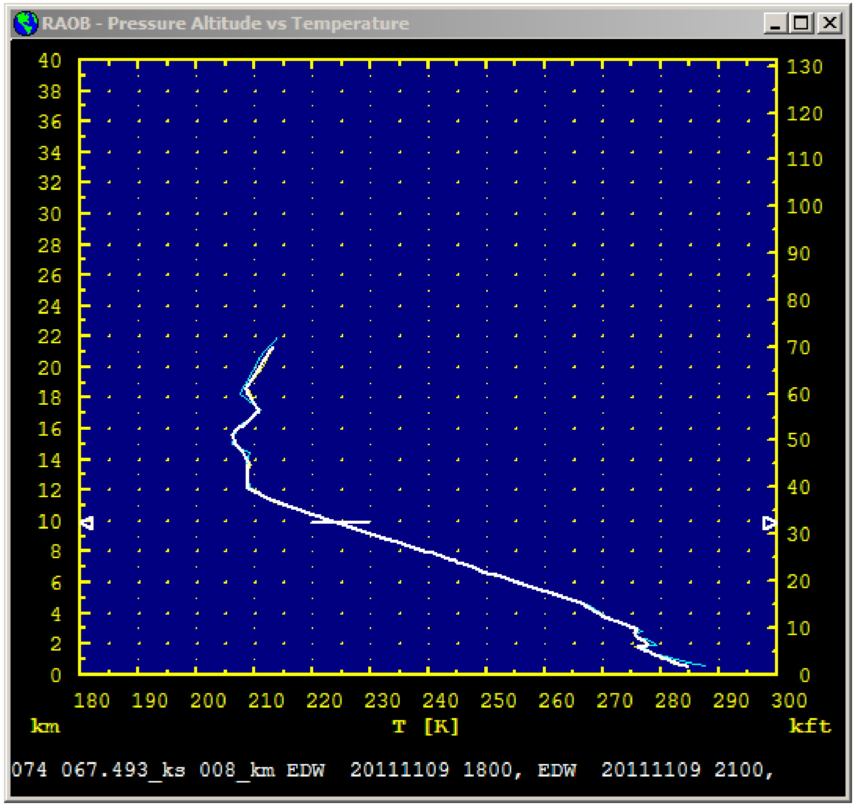
- The relationship between the recovered (*Tr*) and static (*Ts*) temperatures of an *in situ* probe is dependent of the recovery factor (*R*) and the Mach Number (*M*) squared
- This suggests an M^2 dependent T correction. This worked better than a *M* or *Zp* correction.
- Of 74 possible comparisons, 71 were used (excellent statistics). Three edited for variability.

$$\frac{Tr}{Ts} = 1 + R(M)\frac{\gamma - 1}{2}M^2$$

MTP Temperature Calibration (3)



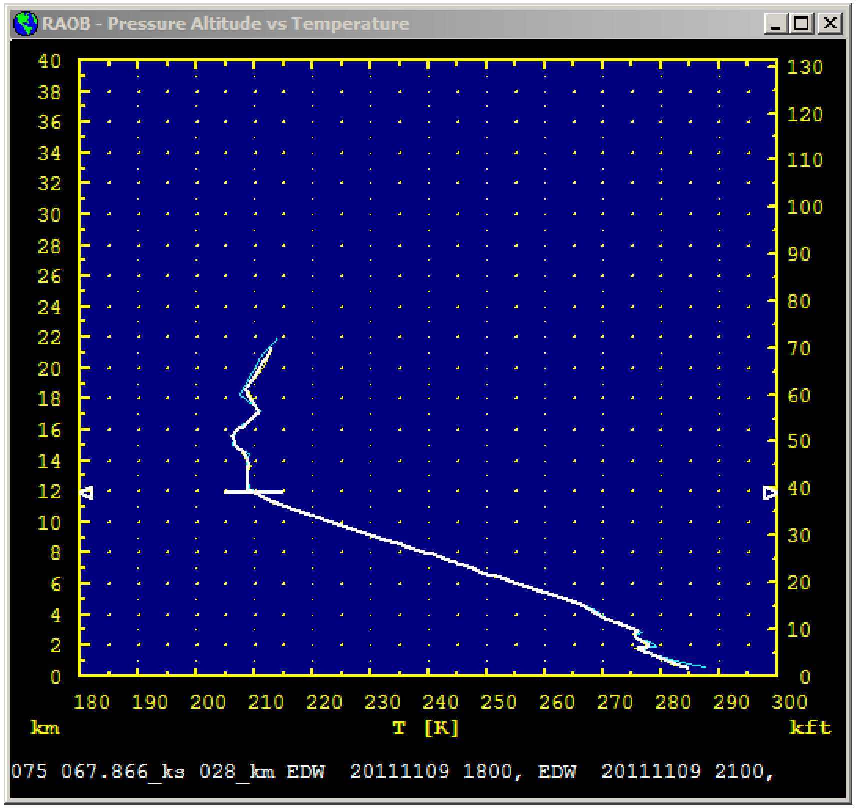
RAOB comparison at Zp=6 km



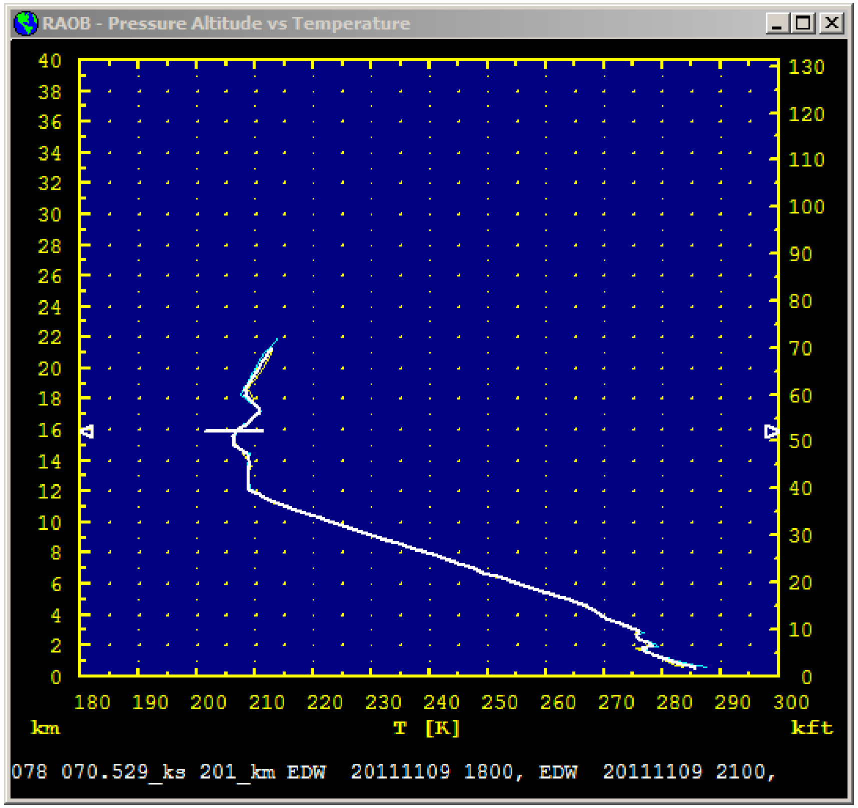
RAOB comparison at Zp=10 km

- An example of four RAOB comparisons using two Edwards AFB soundings (EDW) launched three hours apart at 18UT and 21UT on 2011-11-09.
- There is no tropospheric difference between the soundings (i.e., no temporal variability).
- The 18UT sounding is plotted as a yellow line, but is not visible because it coincides with the white temporally interpolated profile. The 21UT sounding is shown as the cyan line.

MTP Temperature Calibration (4)



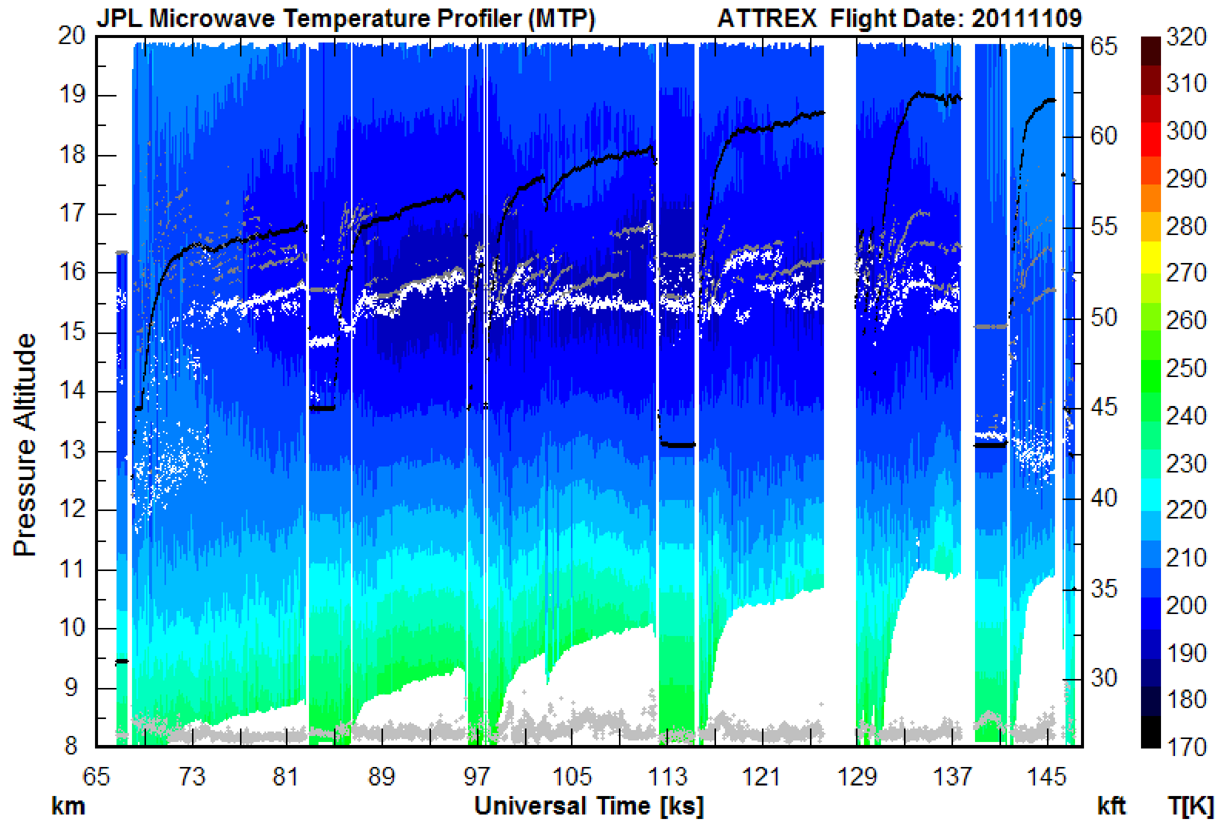
RAOB comparison at Zp=12 km



RAOB comparison at Zp=16 km

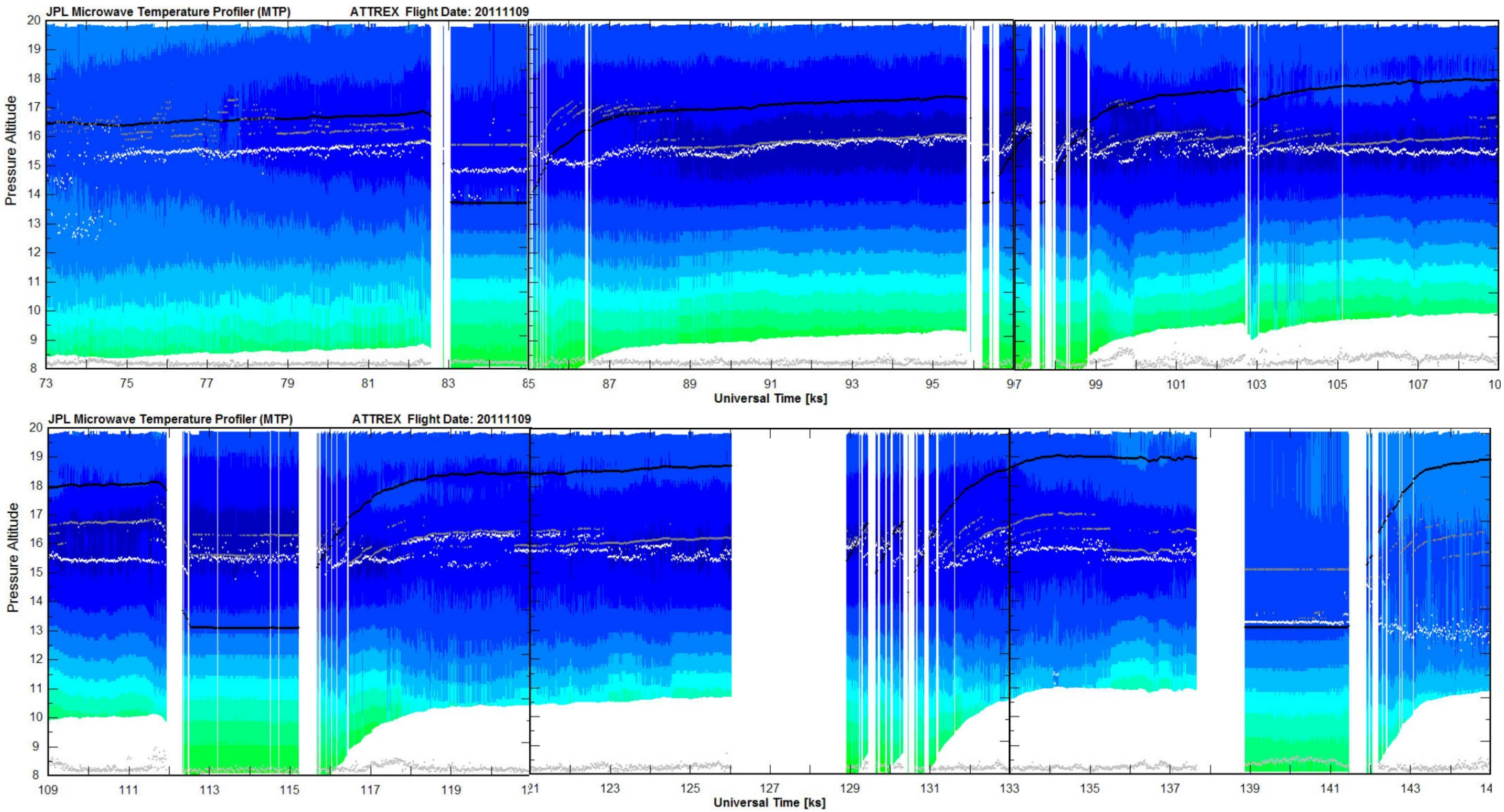
- The center of the 10 K-long white horizontal bar at the Global Hawk flight level represents the corrected MMS temperature based on the EDW RAOB comparison on this date. It is clear that the RAOB comparisons are excellent.
- The final MMS data showed an average 0.05 K warm bias compared to the preliminary MMS data, which had a warm bias of 0.25 K compared to RAOBs. This is consistent with the stated MMS accuracy of 0.3 K. Good work Paul!

MTP Measurements of the Cold-Point (1)



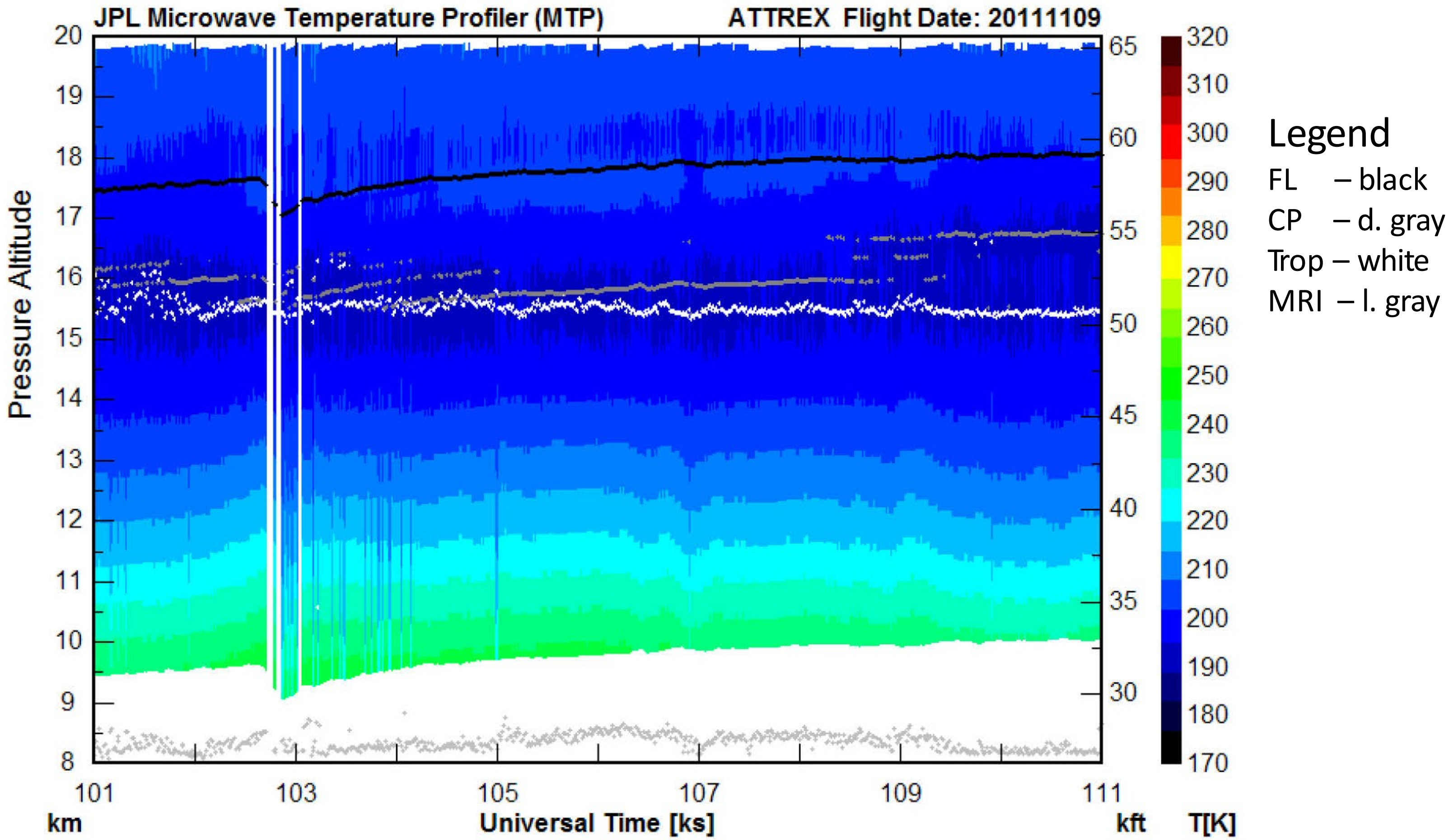
- As mentioned earlier, the cold-point in the TTL is the throttle that controls the transport of trace gases into the stratosphere
- The CTC above shows the cold-point as gray dots at or above the tropopause, which is shown as white dots, for the entire flight of 2011-11-09
- It looks terrible! BUT, looks can be deceiving.

MTP Measurements of the Cold-Point (2)



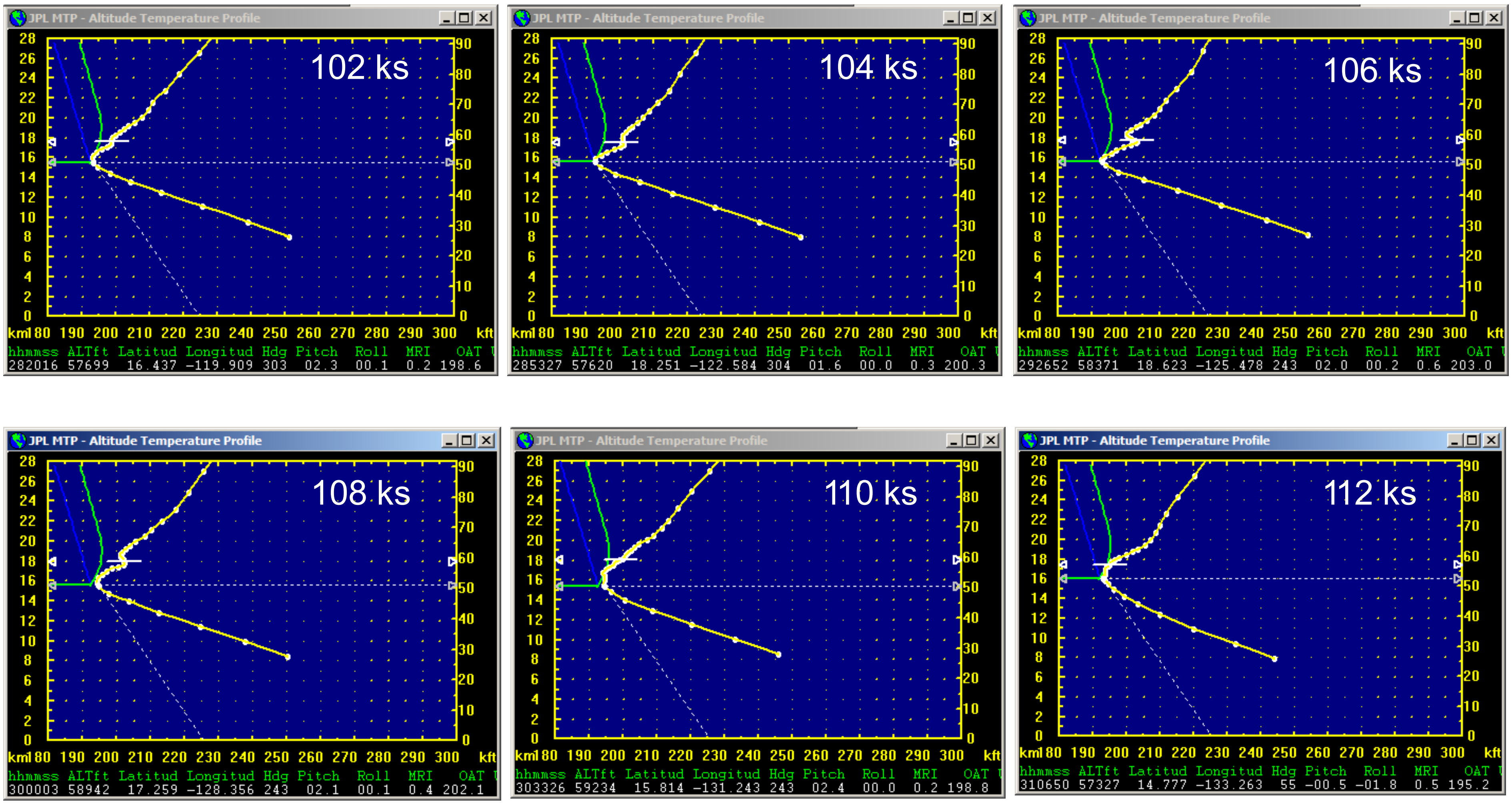
- The problem arises by the combination of long ATTREX flights and the plotting algorithm
- When shorter time periods are plotted, everything looks much better

MTP Measurements of the Cold-Point (3)



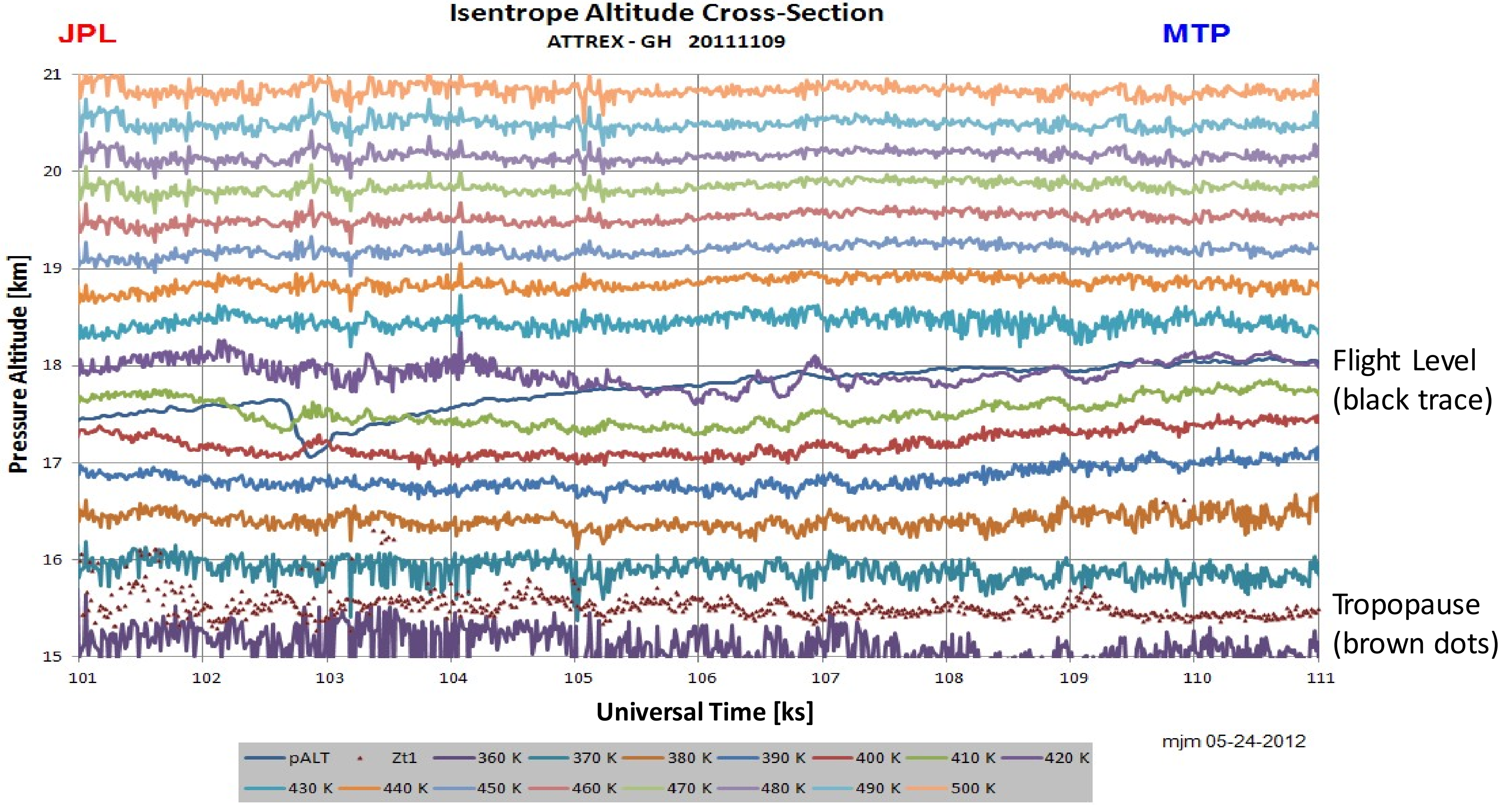
- If we enlarge one of the panels on the previous slide, you can see episodic changes in the cold-point on timescales of ~2000 sec or longer, or ~400 km and longer.
- I am unaware of any previous work showing the TTL cold-point variation with such good spatial resolution.
- Notice the cold region above flight level from 106-109 ks at ~18.5 km.

Using MTP Isentropes to Study Dynamics (1)



- Starting at 102 ks, an inversion begins to develop just above the GH flight level
- It peaks between 106 and108 ks
- This unstable layer allows Kelvin-Helmholtz waves to develop

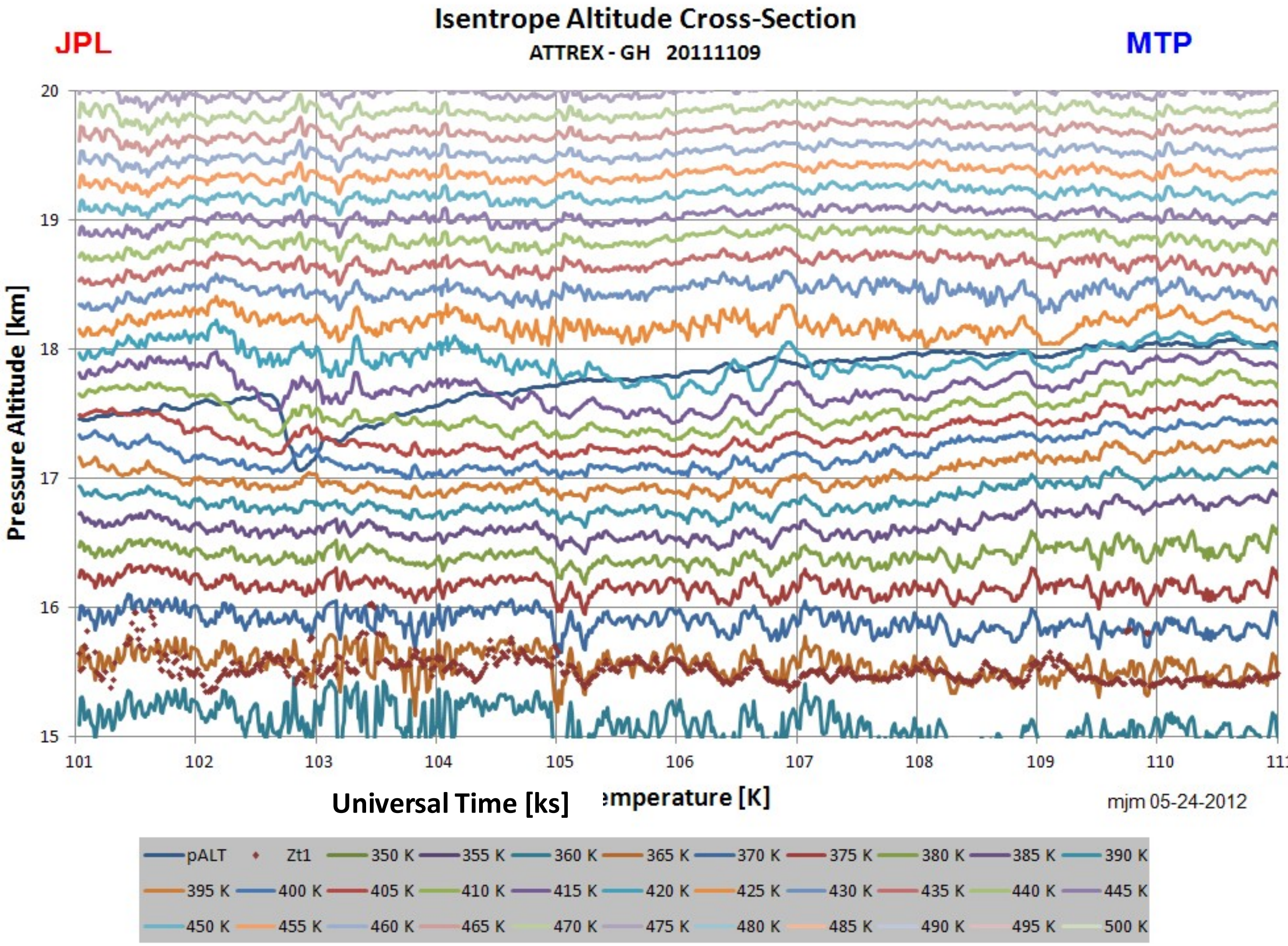
Using MTP Isentropes to Study Dynamics (2)



•We show above the data in the CTC shown earlier as an isentrope altitude cross-section (IAC)

•What is immediately apparent is the isentrope divergence from 104-109 ks, and the 5K gravity wave (GW) on the 420 K PT surface (purple) near the GH flight level.

Using MTP Isentropes to Study Dynamics (3)



- This IAC is the same as the previous slide, but with 5 K isentrope steps instead of 10 K
- Examination of Ri shows that there is a thin layer near flight level where Ri<0.25
- However, the MTP vertical accelerometer showed no indication of turbulence
- Perhaps Ri was not <0.25 for long enough for turbulence to develop

Conclusions

•The MTP temperature calibration is excellent and agrees with the MMS calibration (or MMS agrees with MTP, since its calibration was completed long before that of MMS!)
•Having radiosondes launched from the Global Hawk base is extremely important for accurate temperature calibration in radiosonde-sparse oceanic regions
•The MTP measurement of the cold-point will make an important contribution to the future ATTREX field campaigns because the demonstrated spatial variation of cold-point requires continuous measurements which only the MTP can provide. Profiling with the aircraft is not adequate.
•The MTP-measured isentropes will be important in studying atmospheric dynamics in the TTL, and how this dynamics affects both the composition and (possibly) the thermal structure of the TTL.