

Microwave Temperature Profiler (MTP) Status Report

MJ Mahoney

CAMEX-4 Workshop

New Orleans, LA

March 13 -15, 2002

ER-2 Microwave Temperature Profiler (MTP)

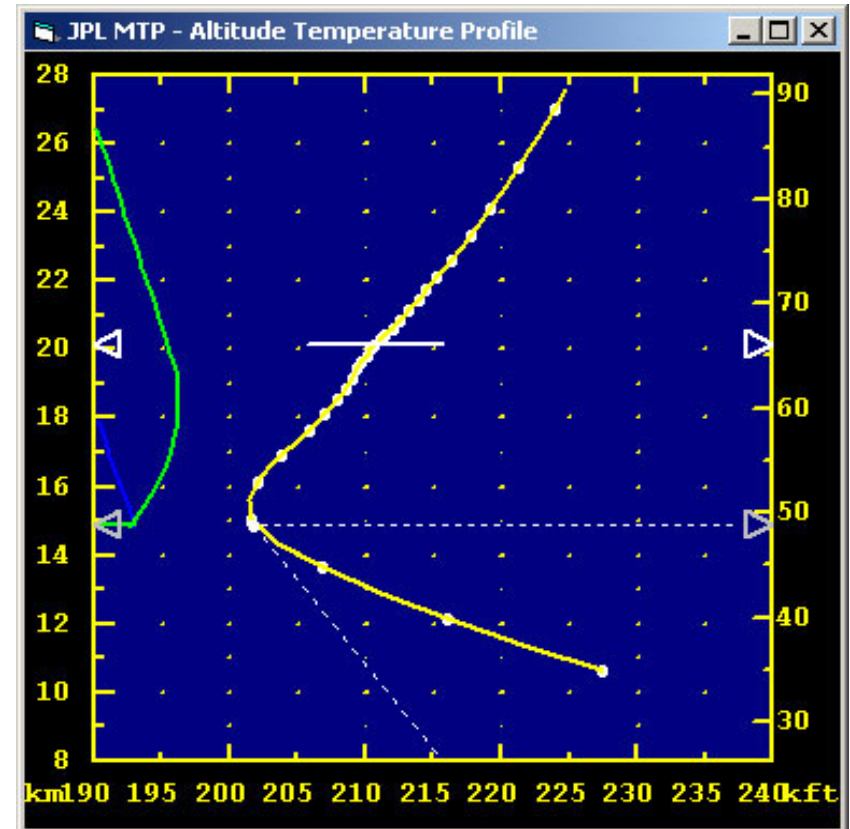


ER-2 on the ramp at JAX NAS during CAMEX-4. Photo Credit: mjm

- PI: MJ Mahoney, Jet Propulsion Laboratory, California Institute of Technology
- MTP measures the temperature profile above, below & at flight level by observing the natural thermal emission from oxygen molecules between 55 and 59 GHz
- MTP Heritage: >500 Flights (>3000 Flight Hours)
- MTP Sensor Unit and Data Unit are located on right engine cheek (see figure)

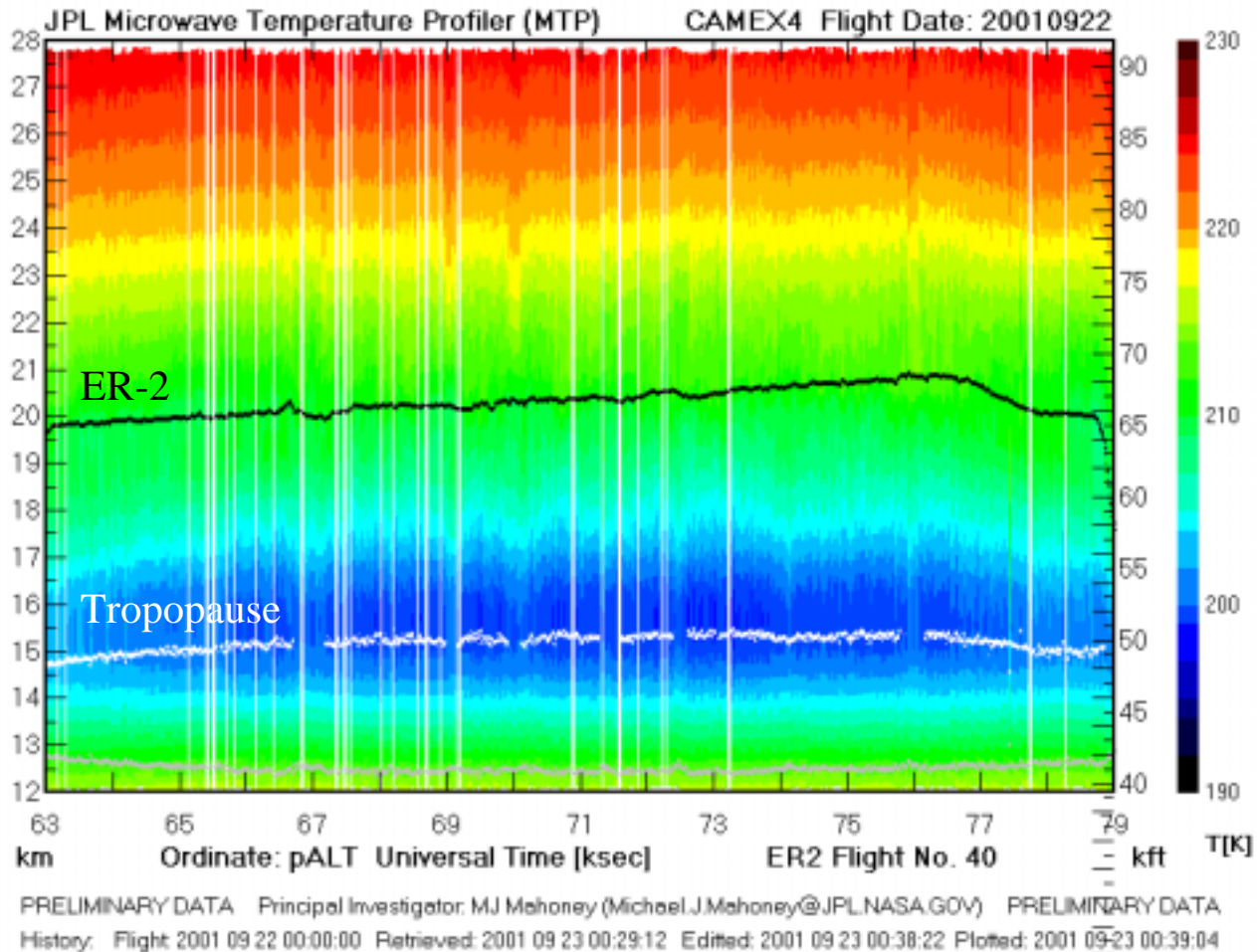
Microwave Temperature Profiler (MTP)

- Derived geophysical products:
 - Temperature profiles along the flight track
 - Tropopause altitude
 - Lapse Rate
 - Isentrope (θ) surfaces
- Science objectives
 - Provide mesoscale meteorological context for *in situ* measurements
 - Assimilate into meteorological models
 - Use derived isentrope surfaces to study dynamical phenomena
- Data availability and analysis plan
 - Within <1 hour after data taken from a/c
 - Final data within 6 months of end of deployment



An example of an altitude temperature profile (yellow trace) from 8-28 km (left) or 28-91 kft (right), with the temperature in Kelvin along the bottom. The ER-2 altitude is the horizontal white line at 20 km and the tropopause altitude is dashed white line at 15 km. The 2 K/km WMO criteria is also shown descending below the tropopause.

ER-2 Microwave Temperature Profiler (MTP)



An example of a MTP-derived temperature field along ER-2 flight track over TS Humberto during CAMEX-4. Black trace is ER-2 pressure altitude, and white trace is the tropopause altitude. The temperature scale is color-encoded in the bar to the right from 190-230 K. Vertical white stripes are data edited out because of radio frequency interference.

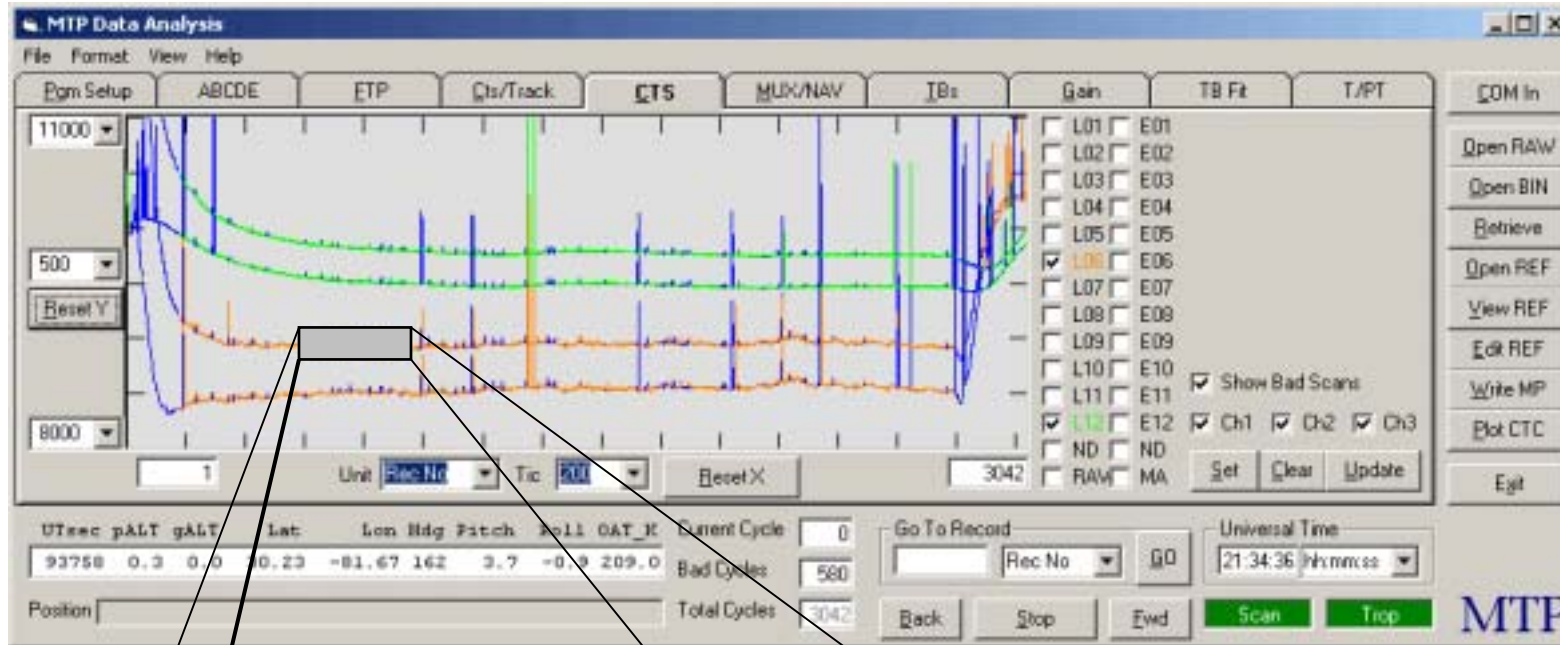
Microwave Temperature Profiler (MTP) Status

Report on ER-2 MTP Data and Data Analysis

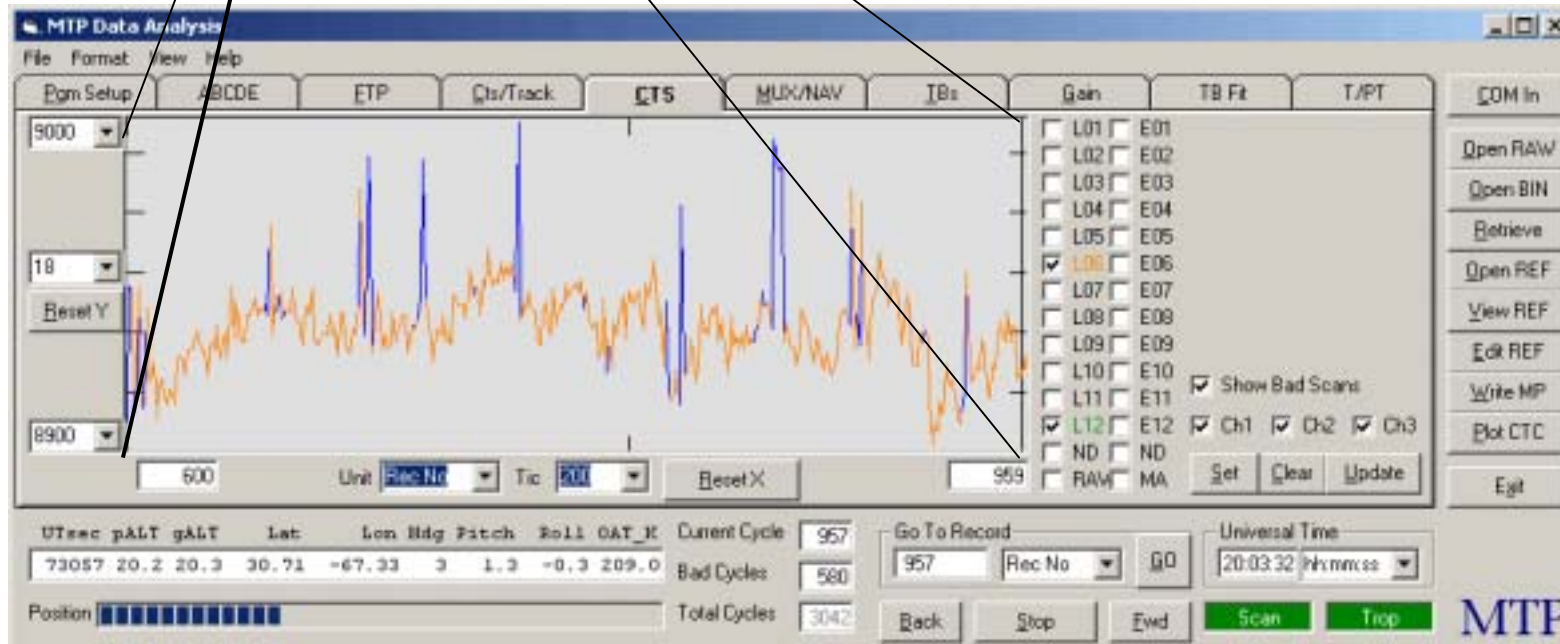
- Heavy & weak interference - typically 20-25% of each flight

An Example of Interference Seen on an ER-2 CAMEX-4 Flight

Entire Flight
Vertical Tic
~25 K



25-X Zoom
Vertical Tic
~1 K

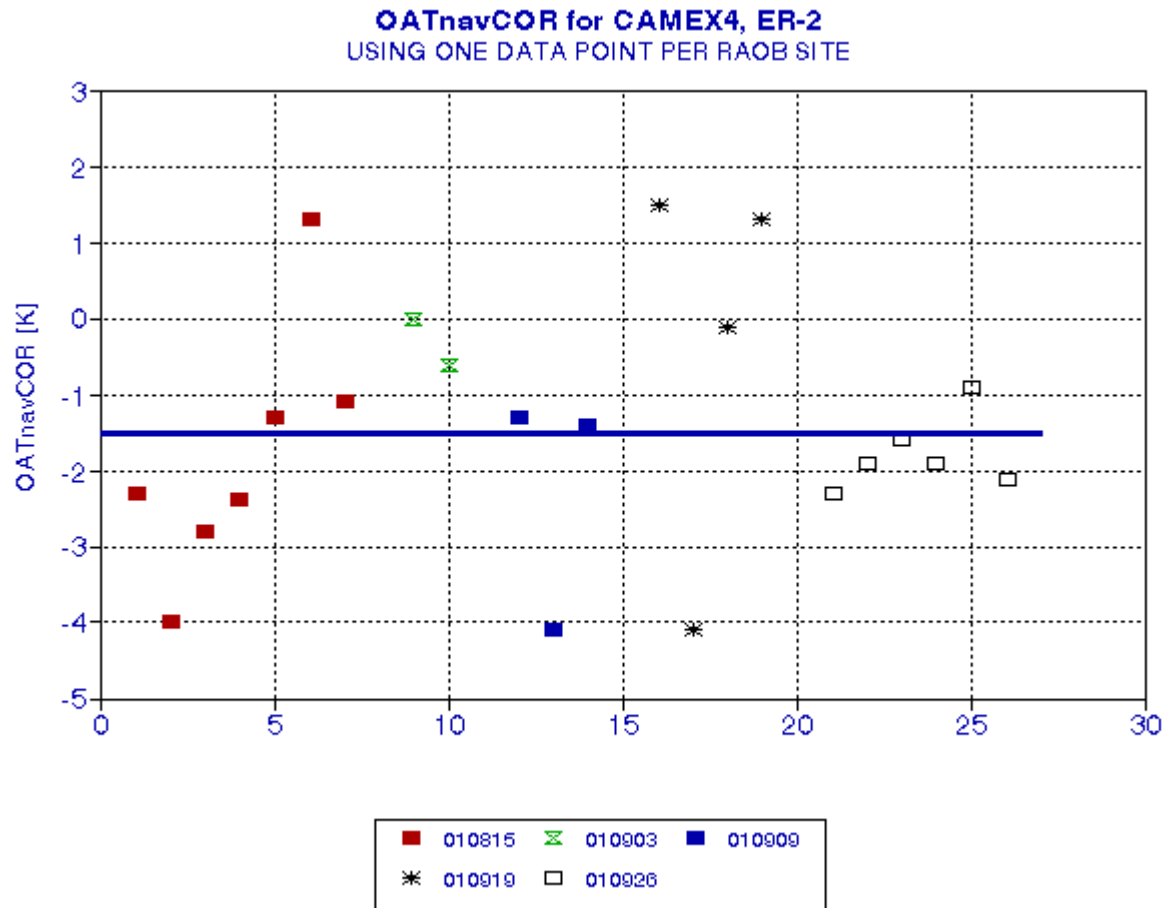


Microwave Temperature Profiler (MTP) Status

Report on ER-2 MTP Data and Data Analysis

- Heavy & weak interference - typically 20-25% of each flight
- Nav Data Recorder Outside Air Temperature is *too warm*
 - Based on RAOB comparisons, the required correction is: -1.51 ± 0.36 K

ER-2 Nav Data Recorder Temperature Calibration



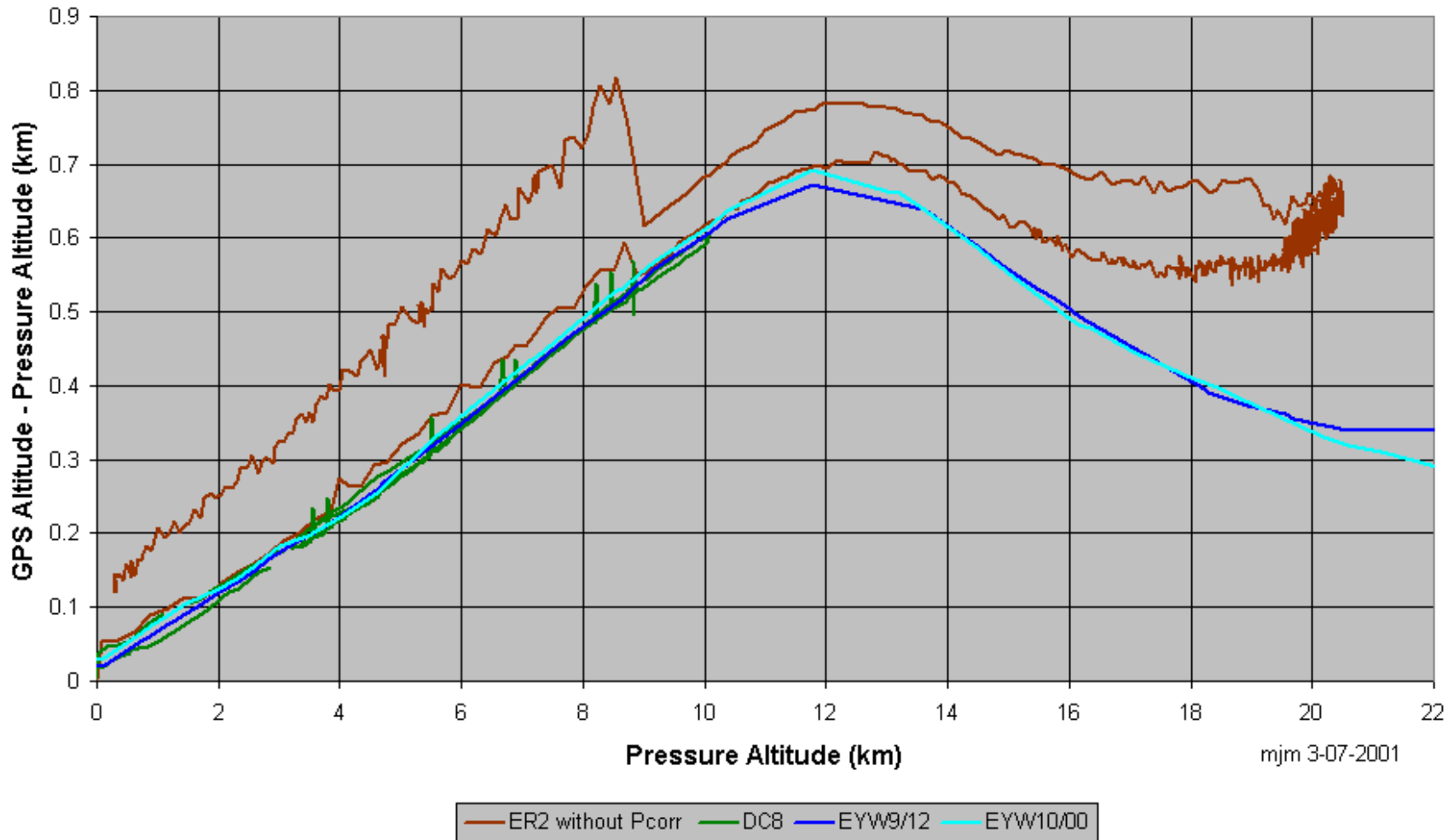
- Thirty-one (31) RAOB comparisons in total from five CAMEX-4 ER-2 flights
- Passes over the same site were averaged unless the altitude differed by >1.5 km
- Result is that OAT_{nav} is too warm, correction = -1.51 ± 0.36 (N=22)

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- Nav Data Recorder (NDR) Pressure Altitude (Z_p) is *too low*
 - The error is 400-600 meters (~ 3 -5 hPa) at 21 km
 - Procedure developed to reduce this error to <100 meters
 - Impact is to increase MTP retrieval error significantly if error is >100 meters

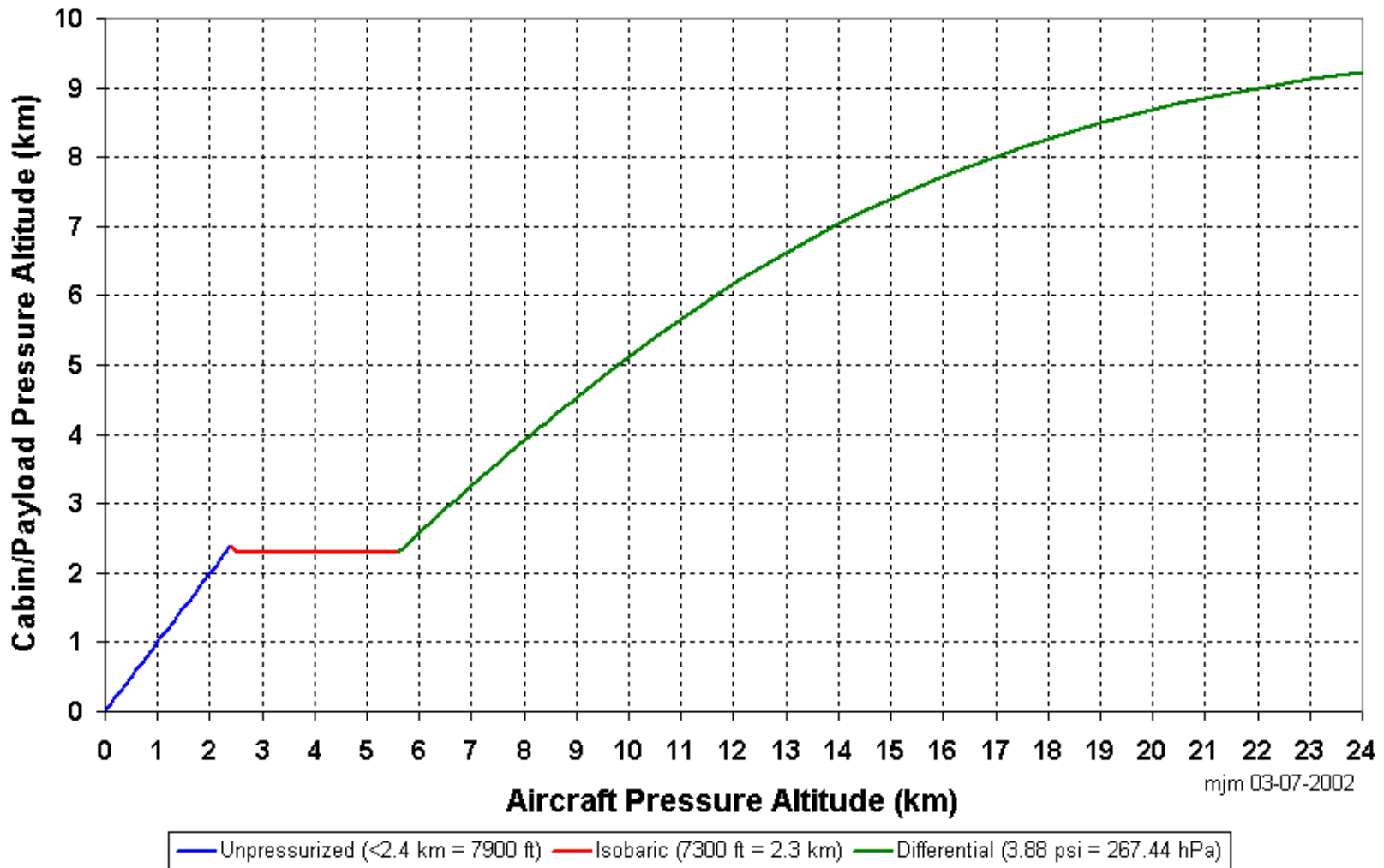
http://mtp.jpl.nasa.gov/missions/camex4/Science/NDR_Corrections.html



An Example of the Erroneous ER-2 Nav Data Recorder Pressure Altitude

- Note that error is larger on descent than on ascent
- A large discontinuity occurs at ~8.5 km when switching from fine to course sensor

ER-2 Microwave Temperature Profiler (MTP)



The ER-2 Environmental Control System (ECS) Pressure Profile

- ECS is under differential control mode for useful Z_p (green)

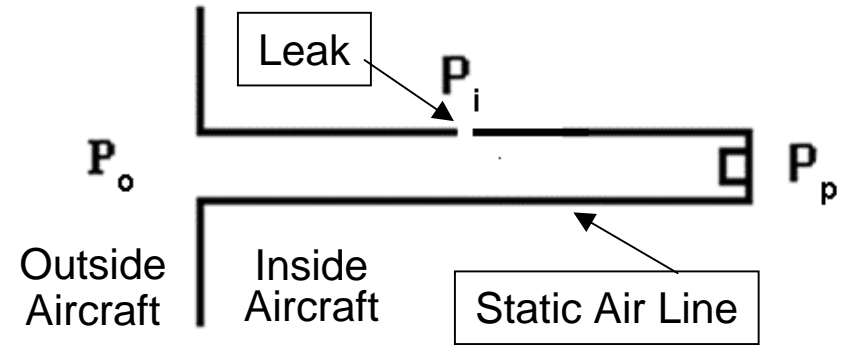
ER-2 Microwave Temperature Profiler (MTP)

A Model for a Static Pressure Leak

Under perfect ECS differential control mode:

$$P_i - P_o = 3.88 \text{ psi} = 267.44 \text{ hPa}$$

Therefore, a leak will produce a constant increase, P_{corr} , in the measured pressure P_p .



In addition, due to the finite response time of the ECS, there is a temporal correction, UT_{corr} :

- On ascent, $P_i - P_o > 3.88 \text{ psi} + P_{corr}$
 - Therefore, the pressure altitude (Z_p) is even further under-estimated
- On descent, $P_i - P_o < 3.88 \text{ psi} + P_{corr}$
 - Therefore, the pressure altitude (Z_p) is even further over-estimated

Equation to correct NDR pressure altitude, Z'_p :

$$Z'_p(\text{km}) = f_{PtoZ}(f_{ZtoP}(Z_p) + P_{corr}) + UT_{corr}(UT - UT_{takeoff})/3600 + Z_{offset}$$

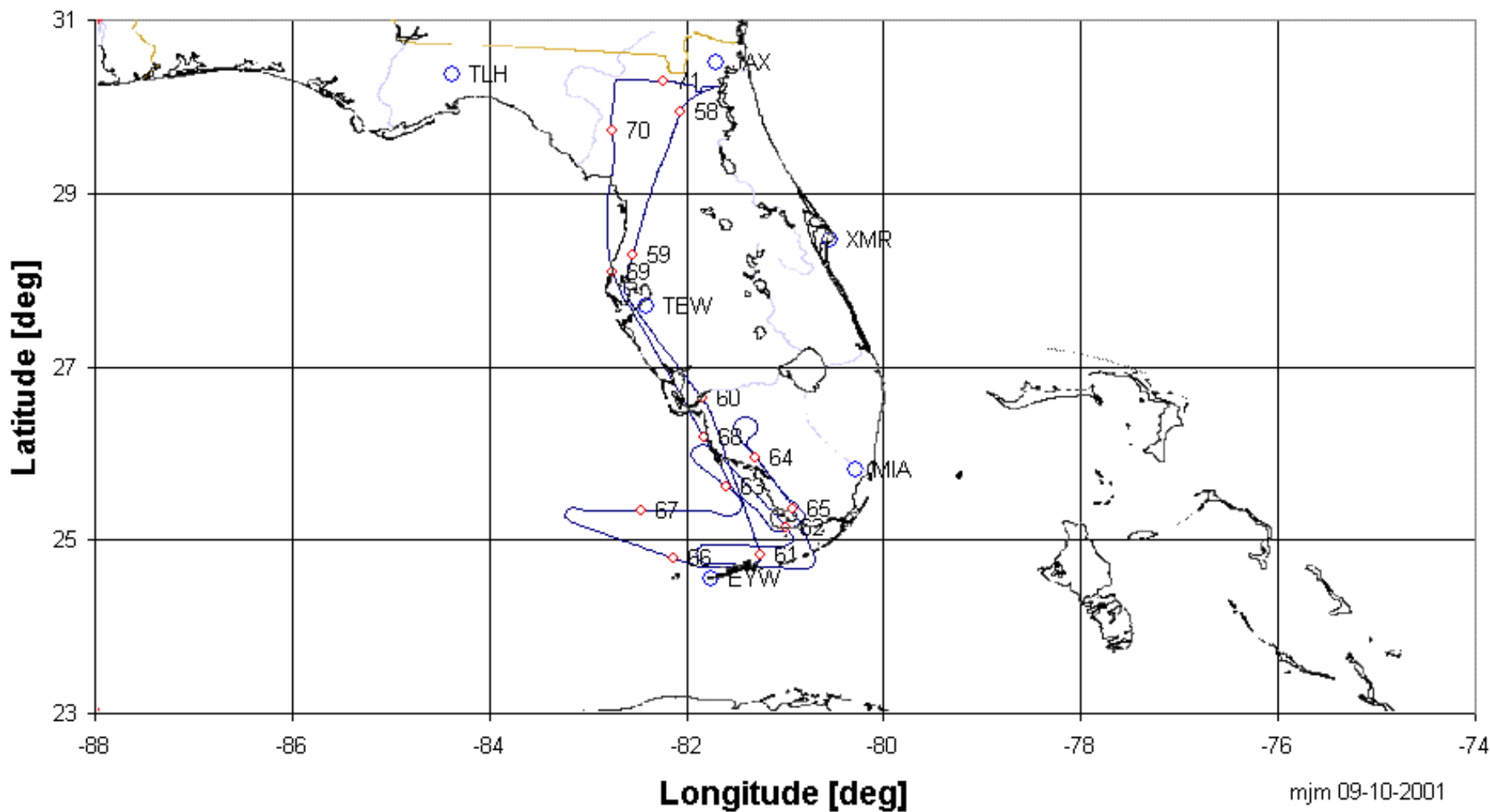
where Z_p is in km; UT is in seconds; P_{corr} , UT_{corr} , and Z_{offset} vary from flight to flight; and the functions $f_{PtoZ}(p)$ and $f_{ZtoP}(Z)$ convert between pressure and pressure altitude.

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Flight Track - Latitude vs Longitude

MTP

CAMEX4 - ER2 20010909



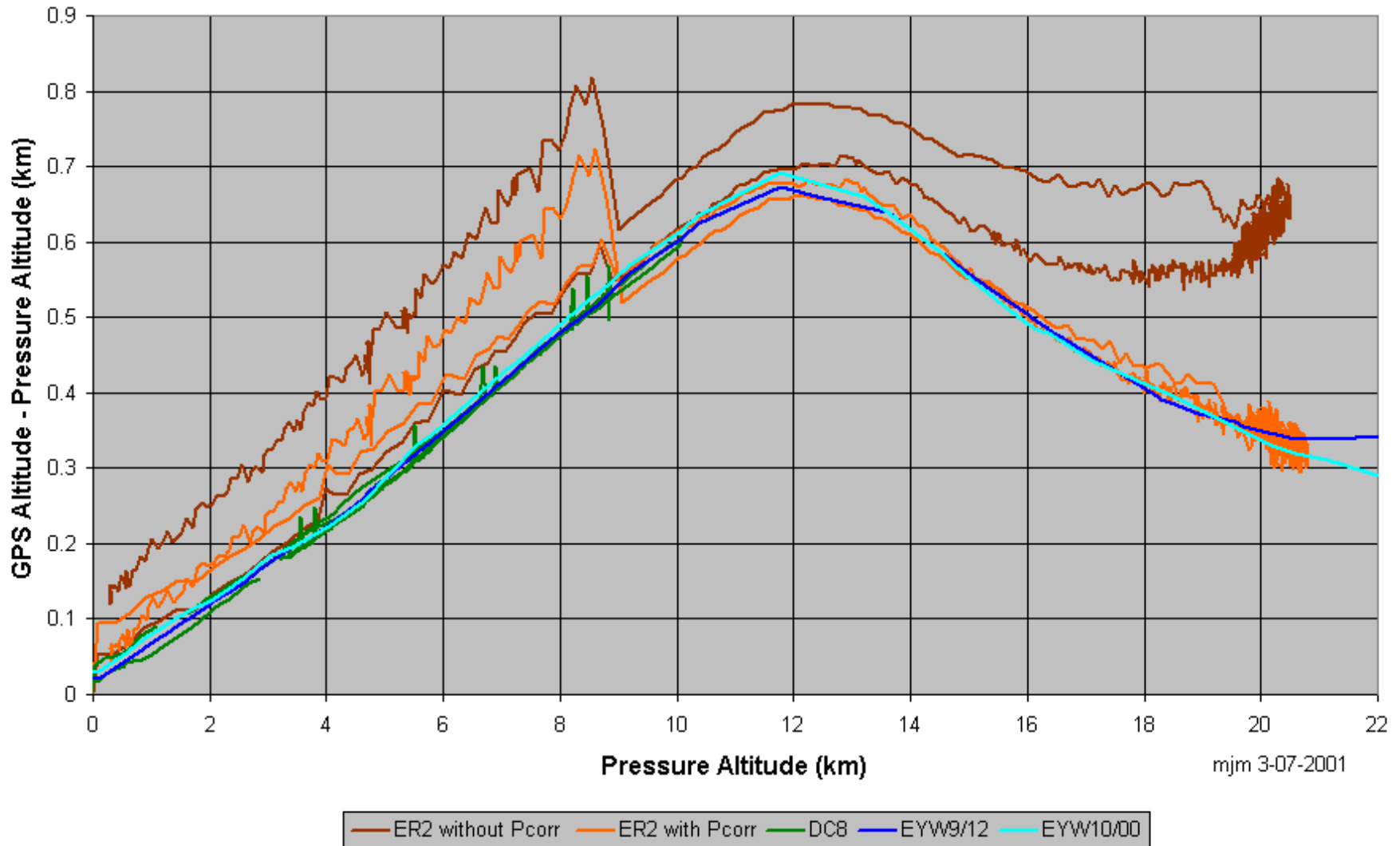
mjm 09-10-2001

— Flight Track • UT [ks] • RAOB Sites

JPL

Comparison of ER-2 GPS and Pressure Altitudes with EYW RAOBs for 2001.09.09

MTP



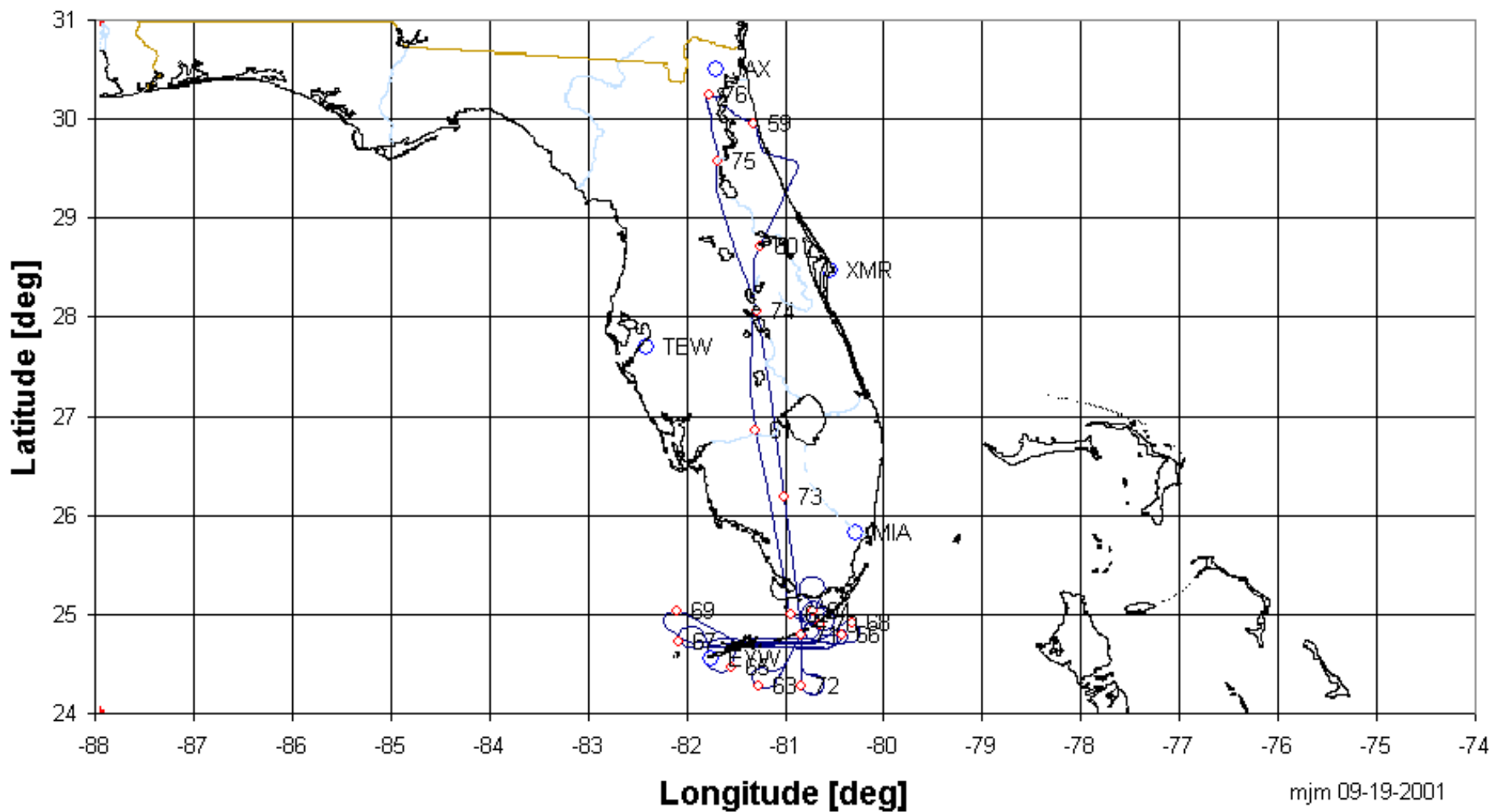
Model for pressure leak does an excellent job of correcting error (orange)

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Flight Track - Latitude vs Longitude

MTP

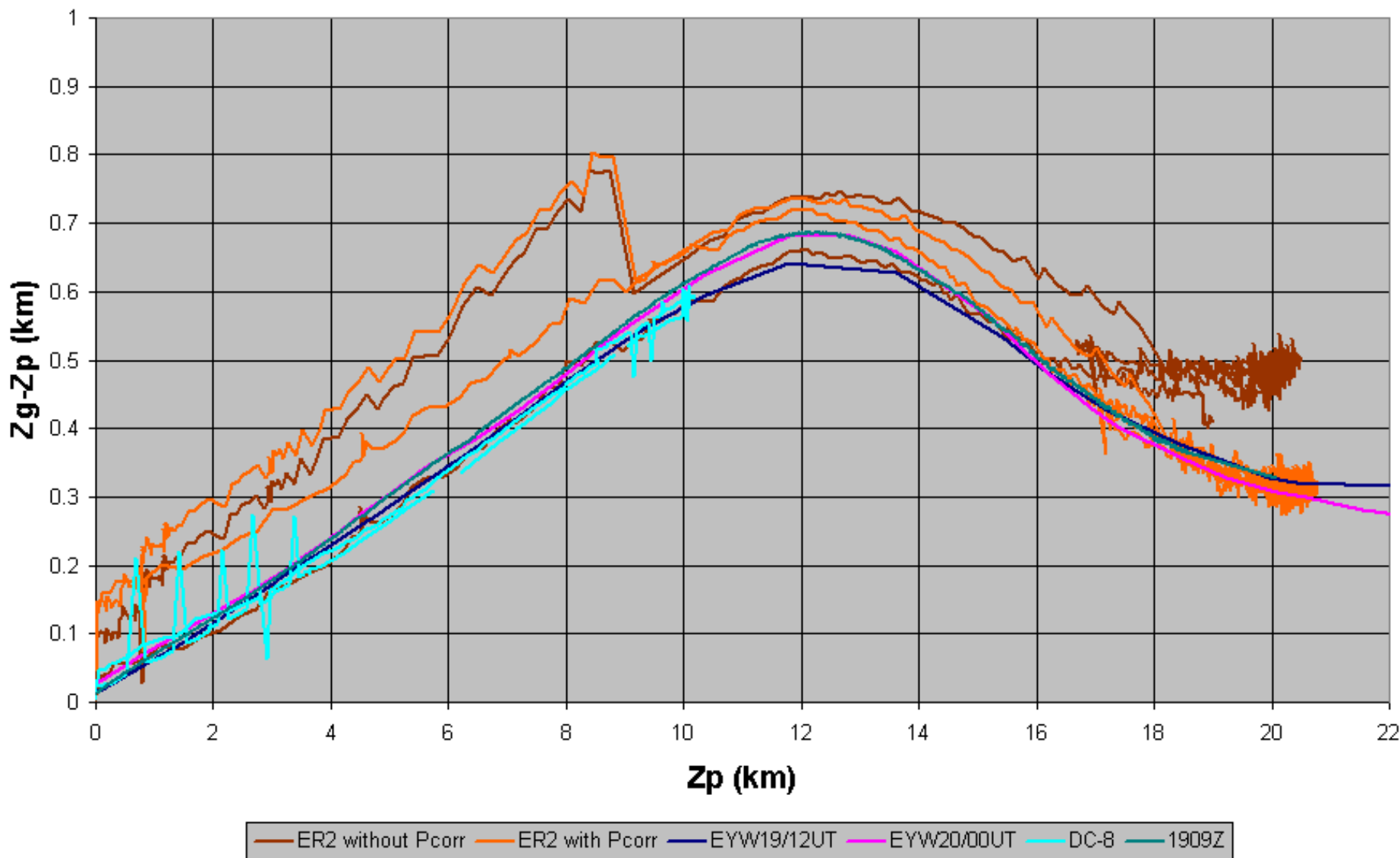
CAMEX4 - ER2 20010919



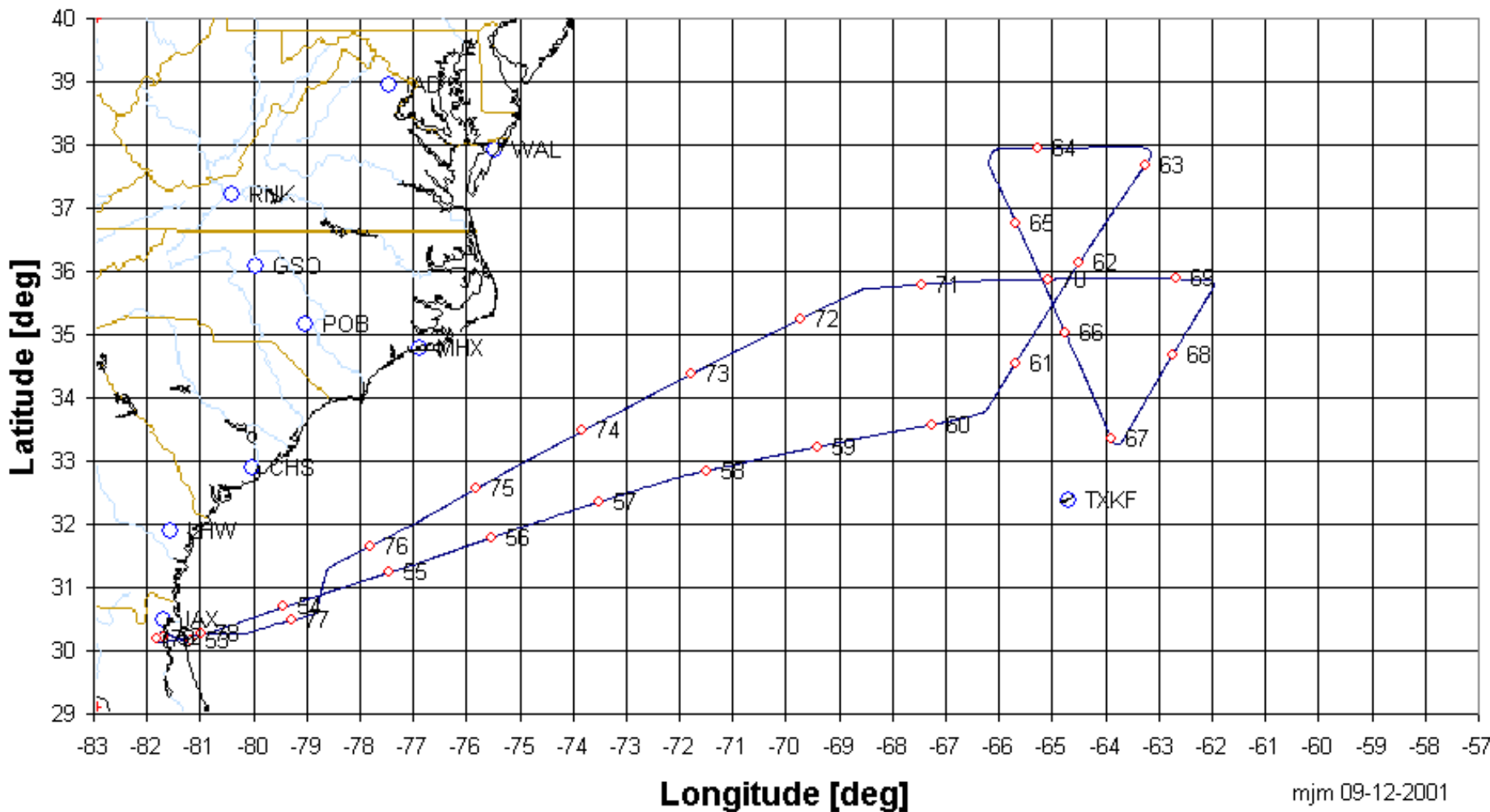
— Flight Track • UT [ks] • RAOB Sites

JPL

CAMEX-4 ER-2 Flight of 2001.09.19 over Key West, FL



CAMEX4 - ER2 20010910



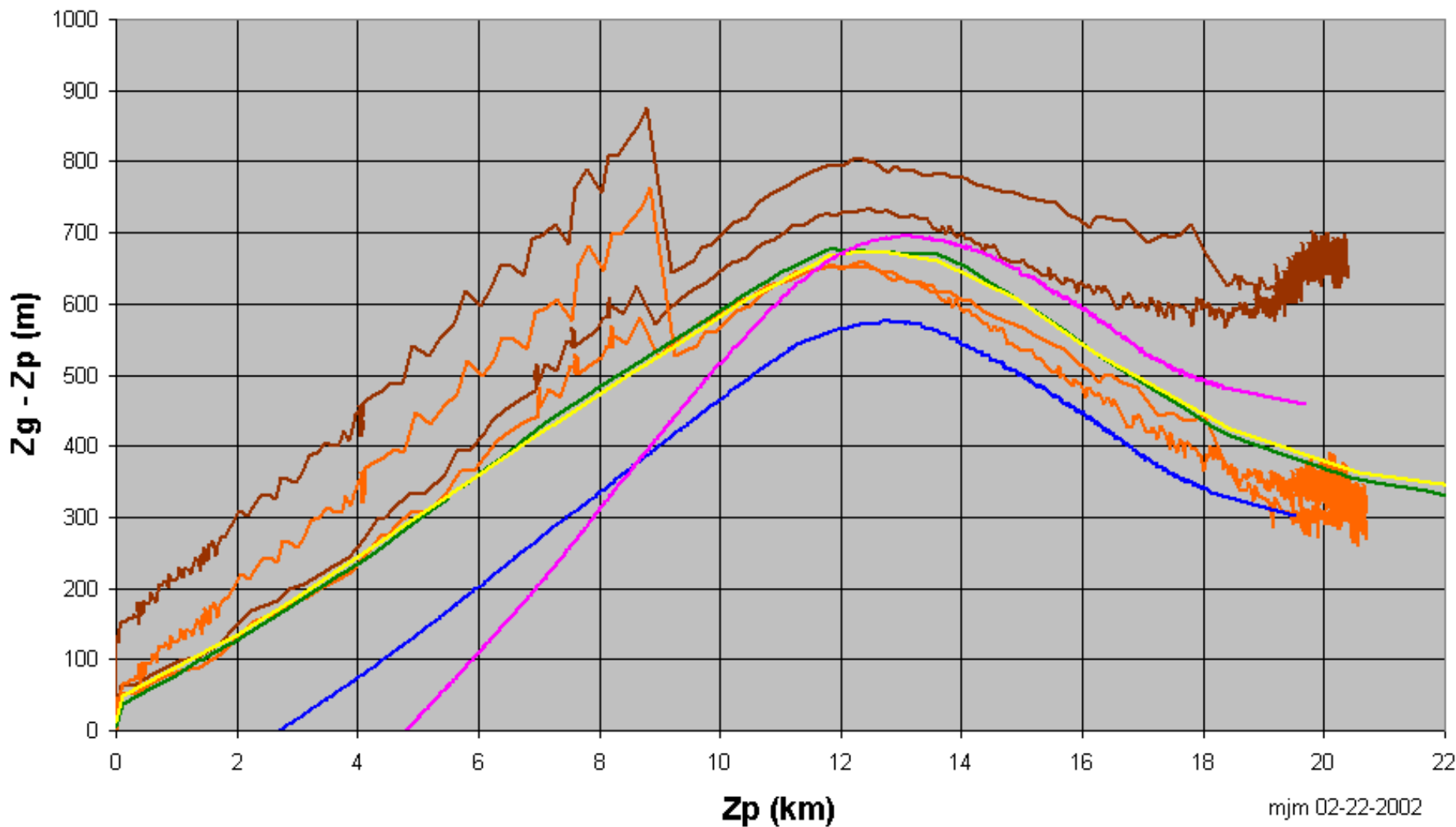
mjm 09-12-2001

— Flight Track • UT [ks] • RAOB Sites

JPL

CAMEX-4 ER-2 2001.09.10 (Hurricane Erin)

MTP



mjm 02-22-2002

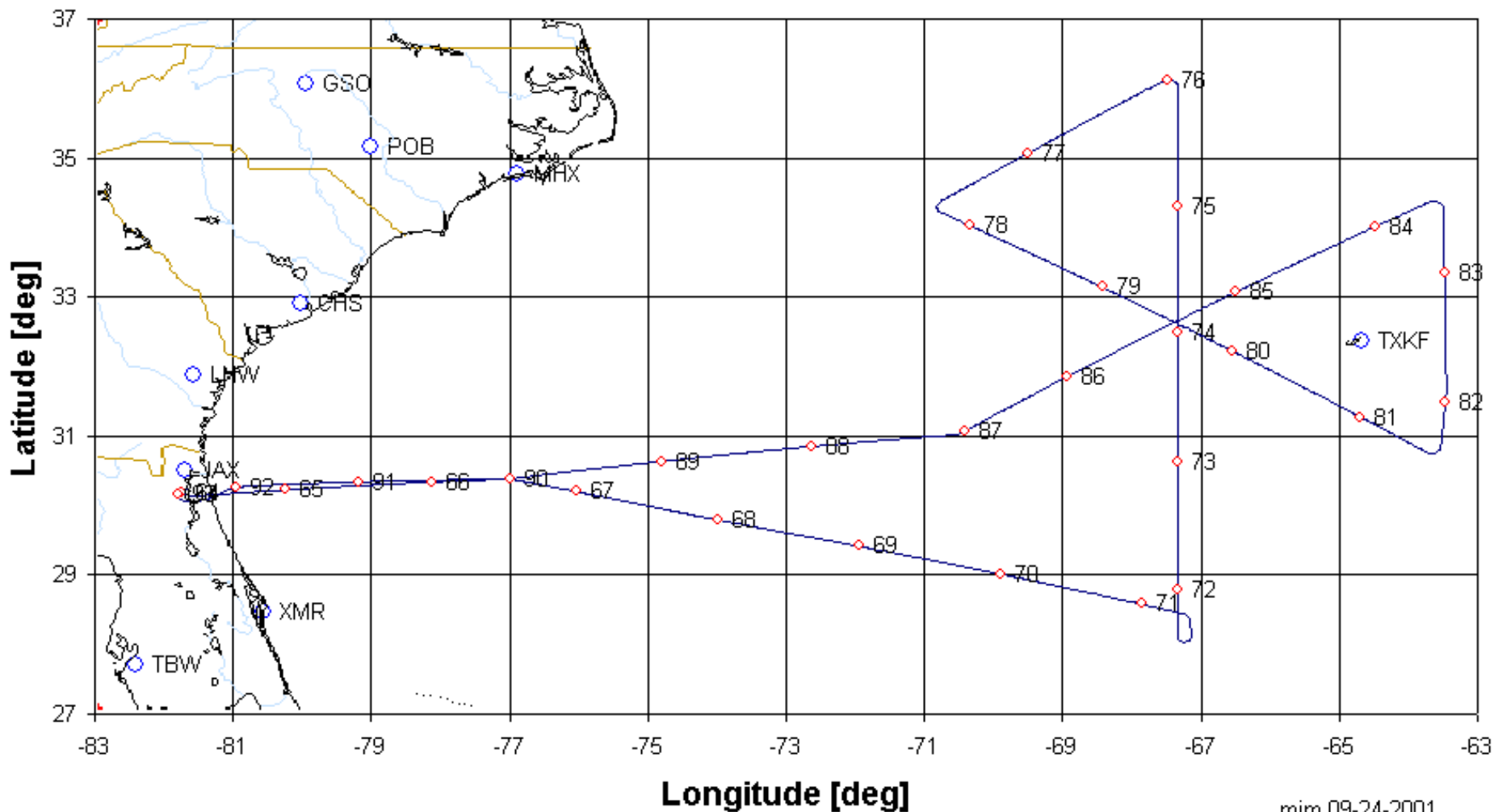
ER2 without Pcorr ER2 with Pcorr TXKF-10/12UT TXKF-11/00UT 1647Z (Outside) 1704Z (Eye)

JPL

Flight Track - Latitude vs Longitude

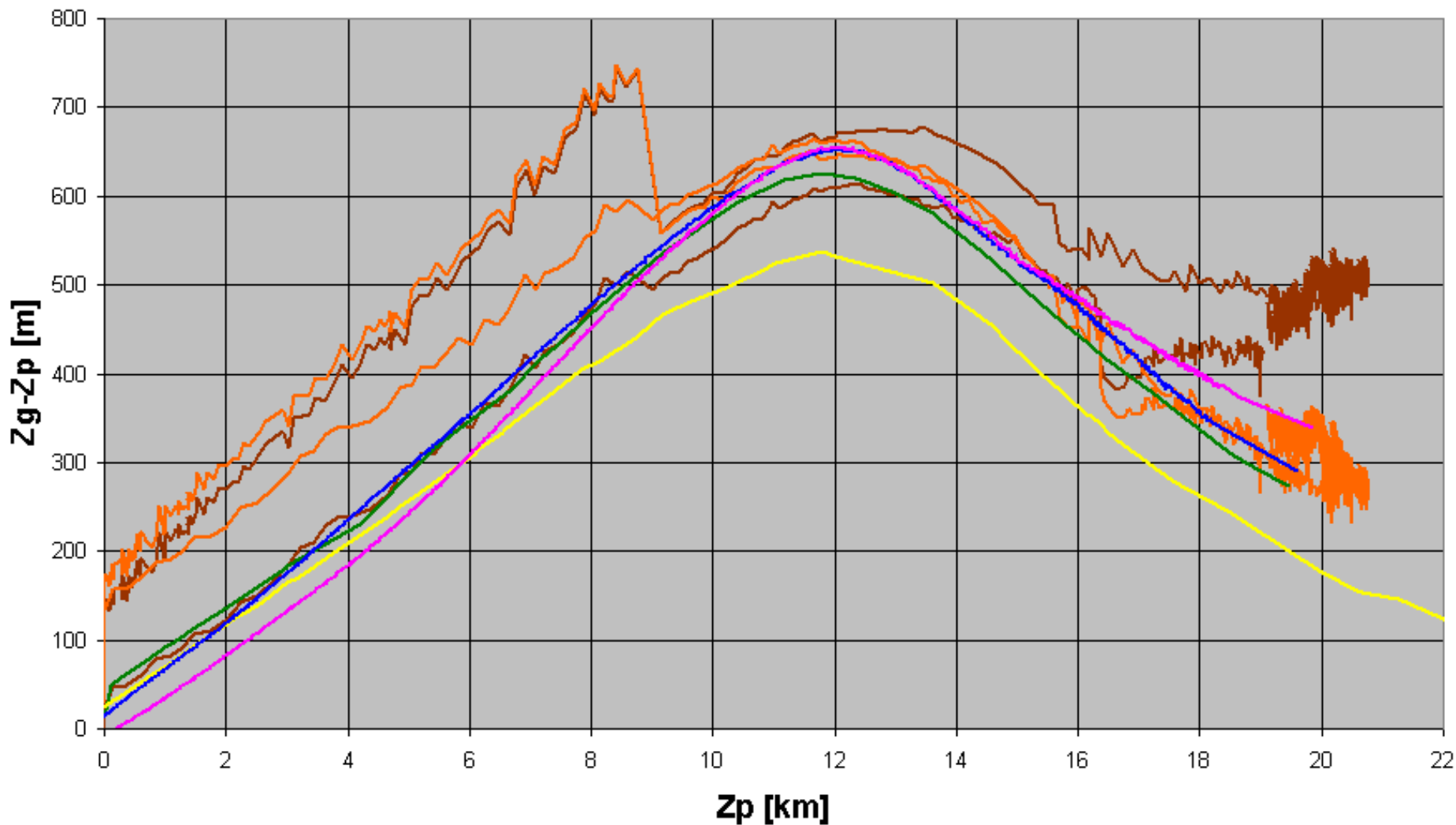
MTP

CAMEX4 - ER2 20010923



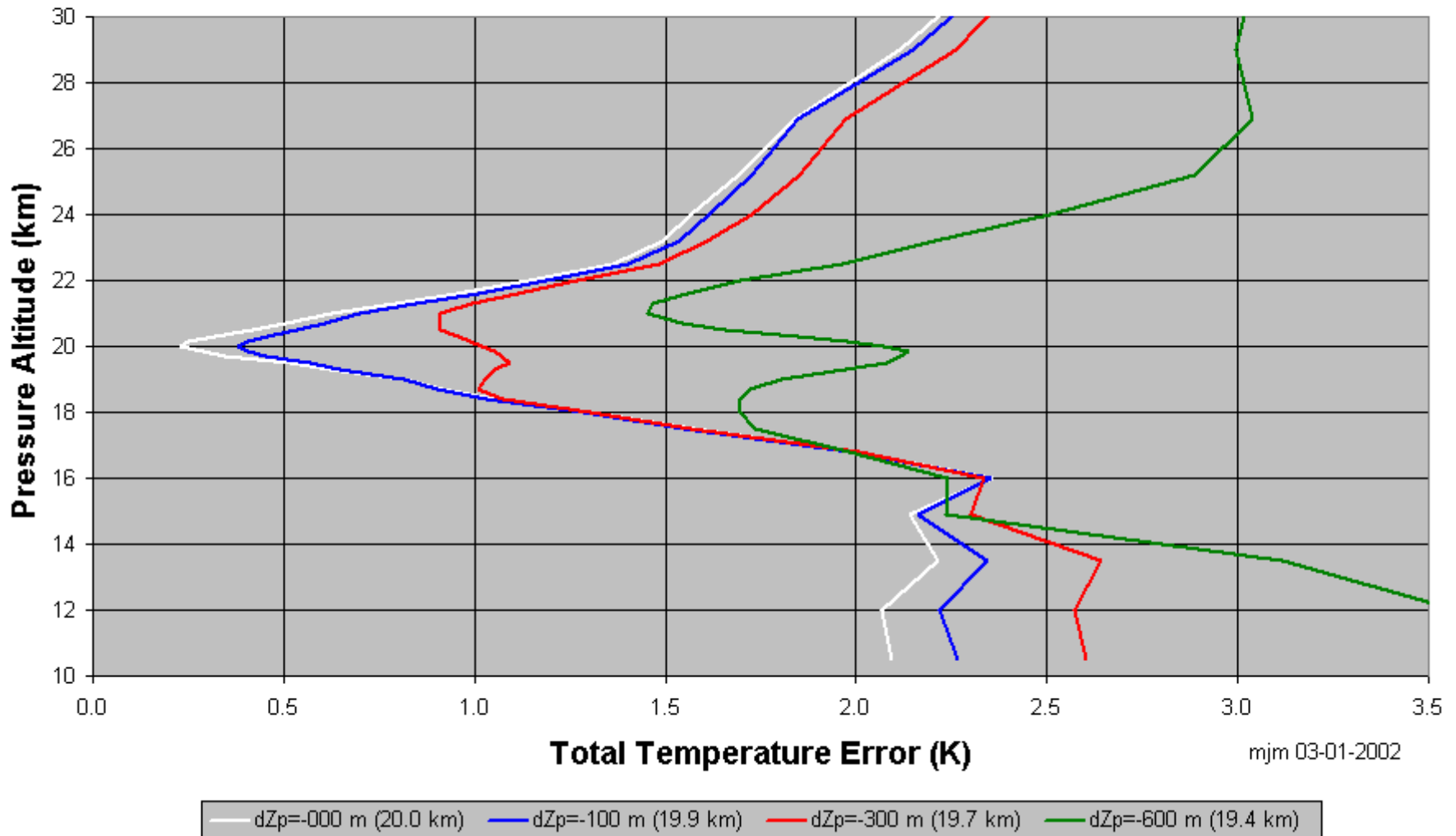
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CAMEX-4 ER-2 2001.09.23 (Hurricane Humberto)



ER2 without Pcorr ER2 with Pcorr TKXF JAX 2000Z 2041Z

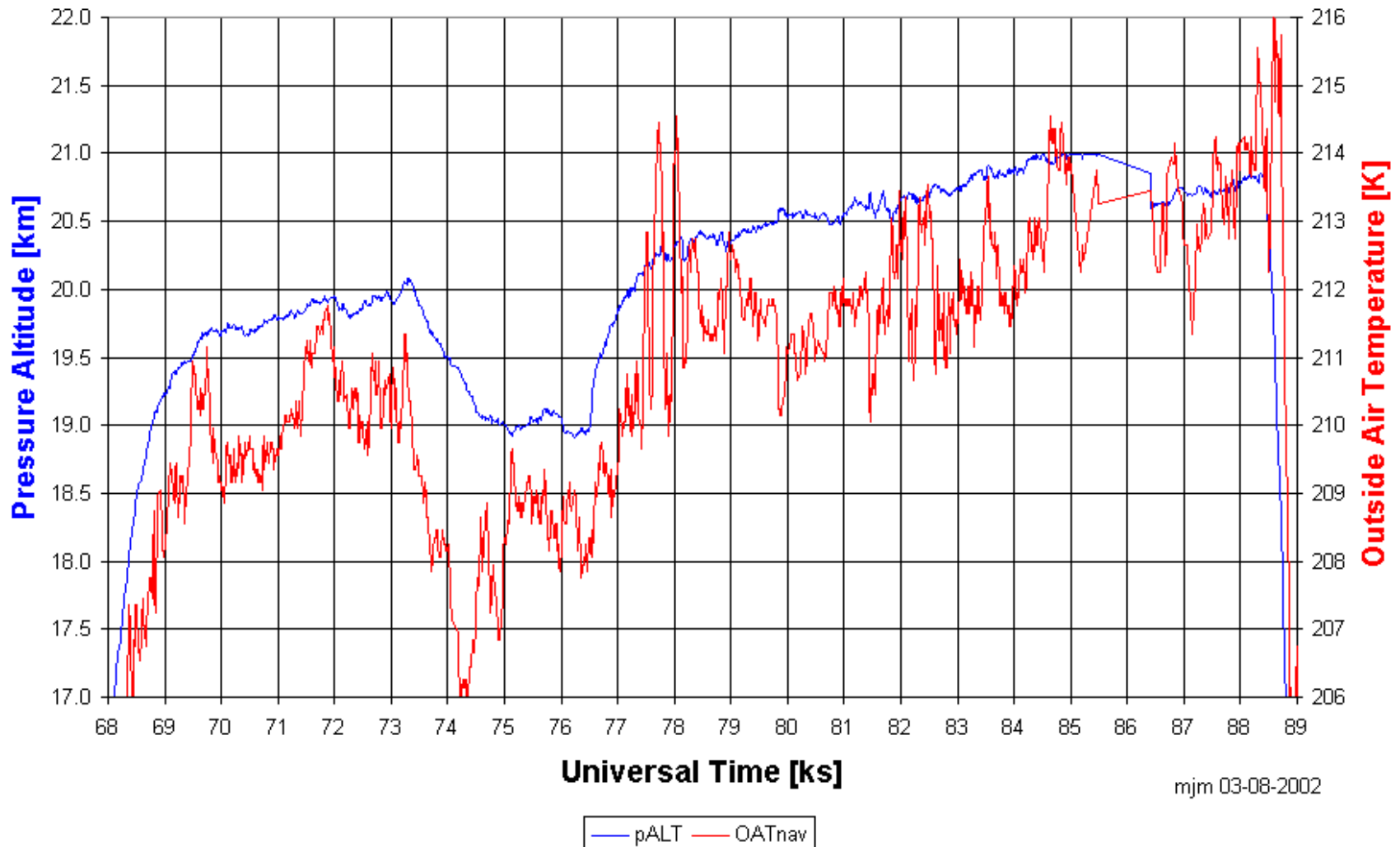
Simulated ER-2 MTP Total Retrieval Error for Flight at 20 km (Observables Calculated at 20.0, 19.9, 19.7 & 19.4 km using 195 RAOBs)



A 600 meter error in Z_p significantly degrades MTP retrievals (green)

Microwave Temperature Profiler (MTP)

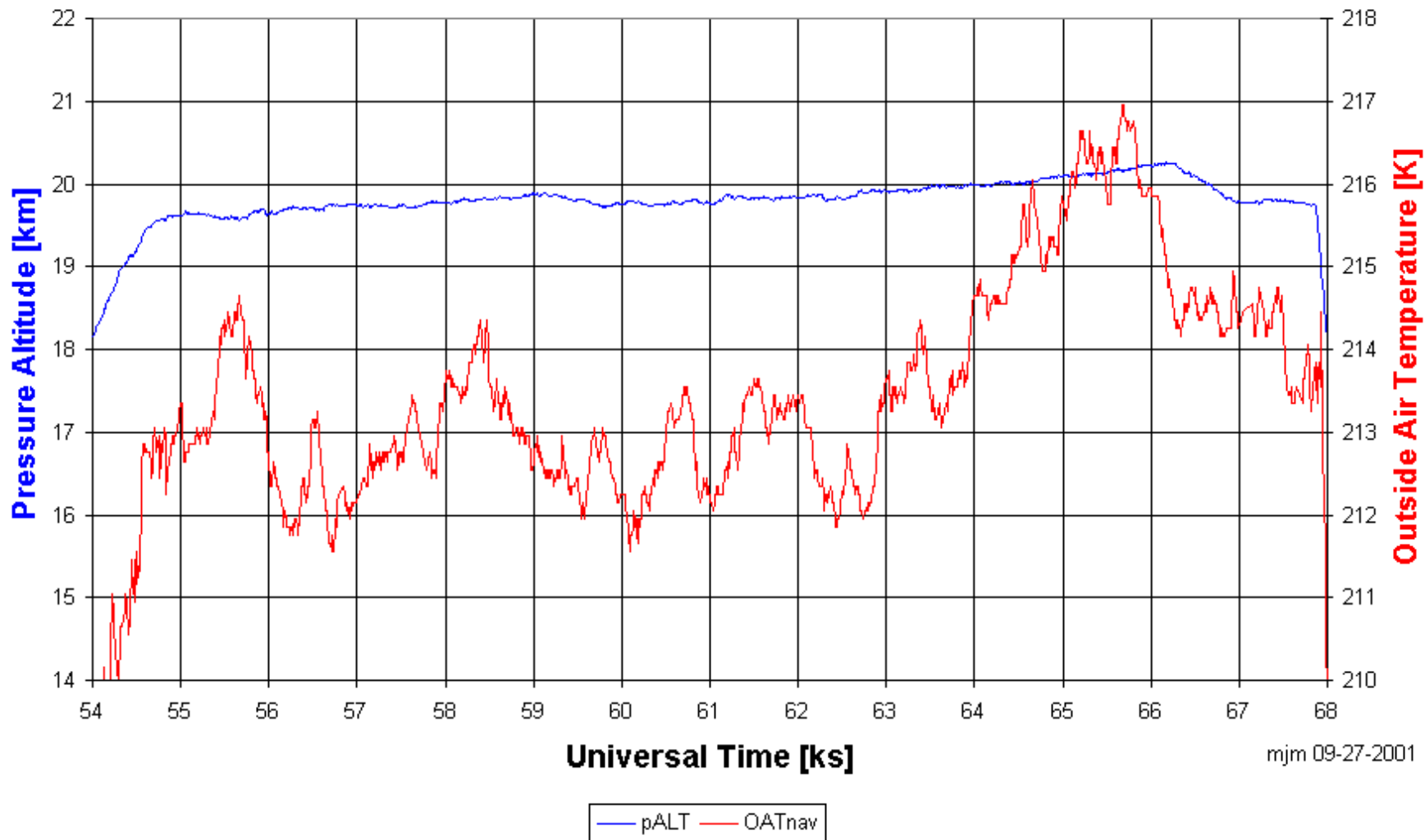
Some science results



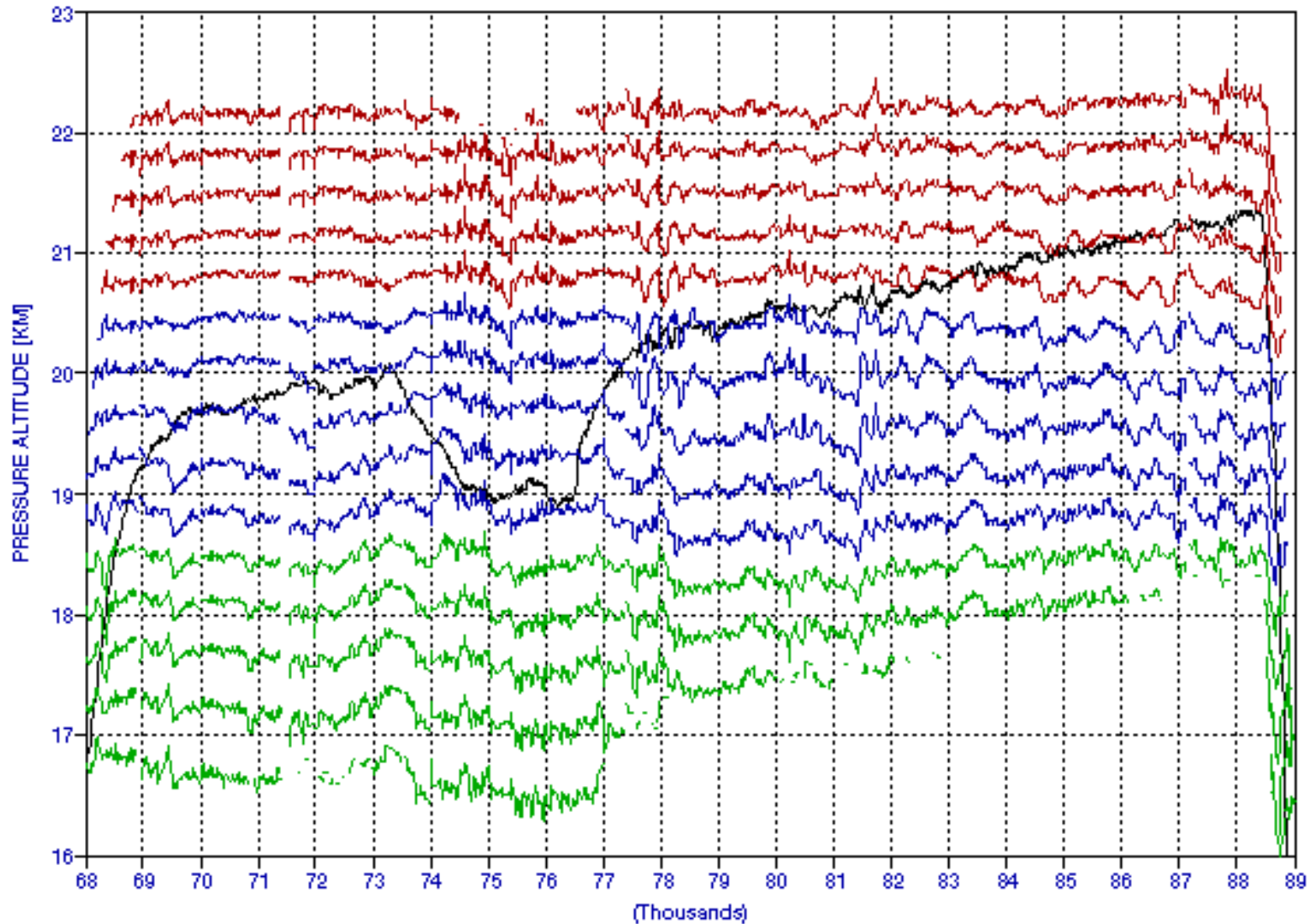
A goal for the MTP observations is to study mesoscale wave phenomena

- Waves appear to be present in the MTP horizon TBs (77 ks & 82 ks)
- Mesoscale fluctuations appear to be greater than on transit flight (next slide)

CAMEX4 - ER2 20010926



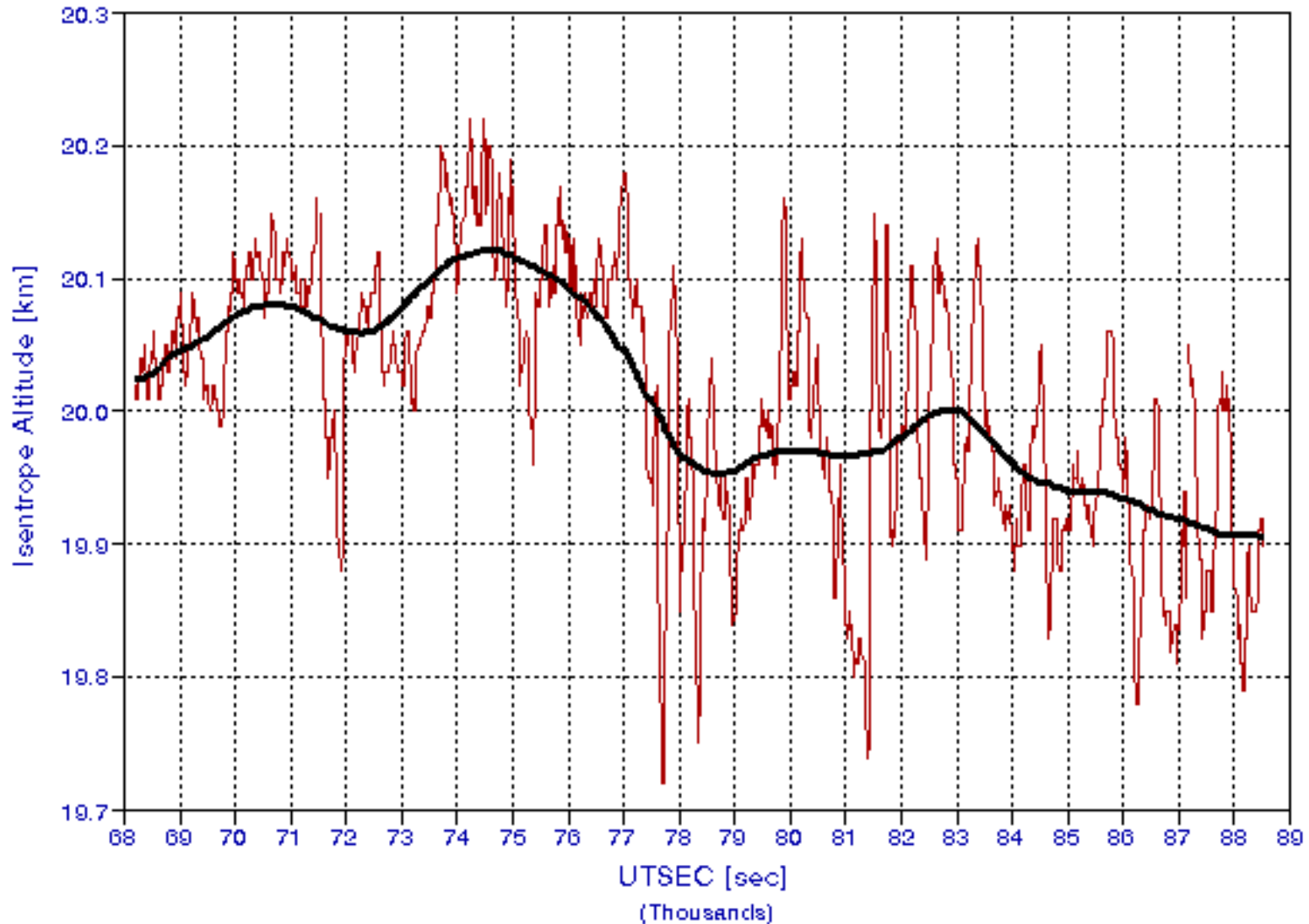
MTP Isentrope Altitude Cross-Section
ER010924



MTP-derived isentrope surfaces for Hurricane Humberto flight of 2001.09.24

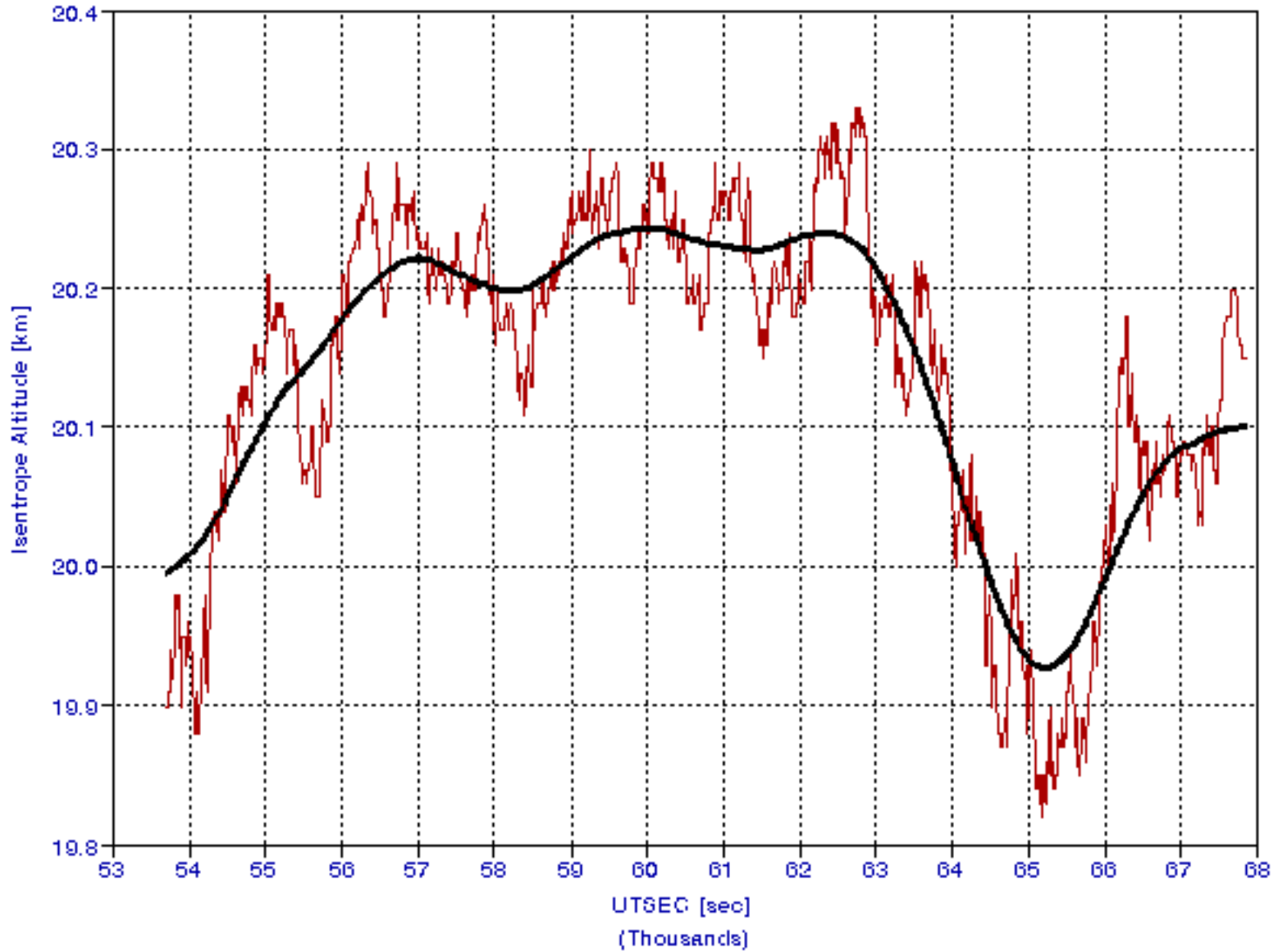
- Note low amplitude waves at ~77 ks and 82 ks

ER2001.09.24, 490 K Isentrope
DOUBLE-BOXCAR 400 KM MOVING AVG



Focussing on 480 K isentrope clearly shows low-amplitude mesoscale waves over Hurricane Humberto; solid black trace shows synoptic scale isentrop surface

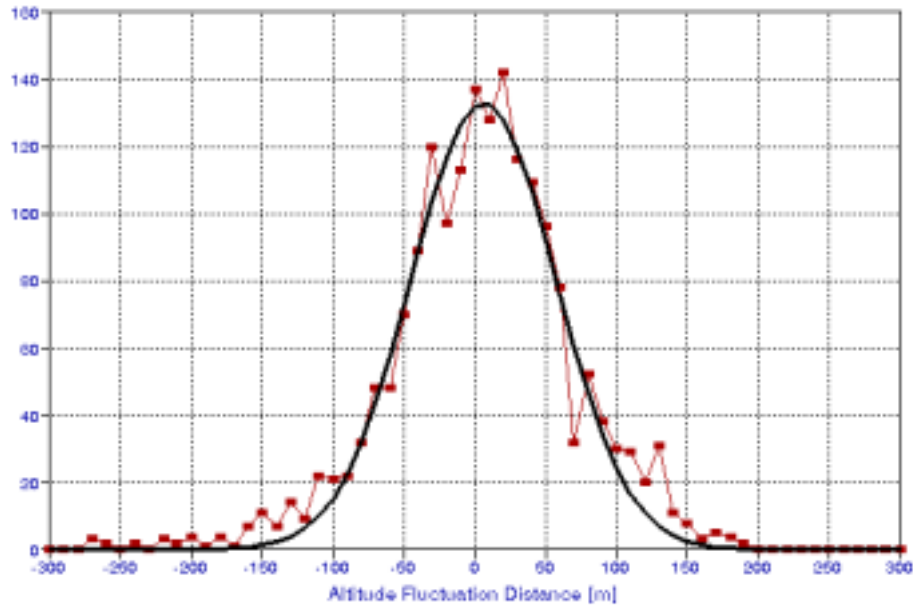
ER010926, 490 K Isentrope



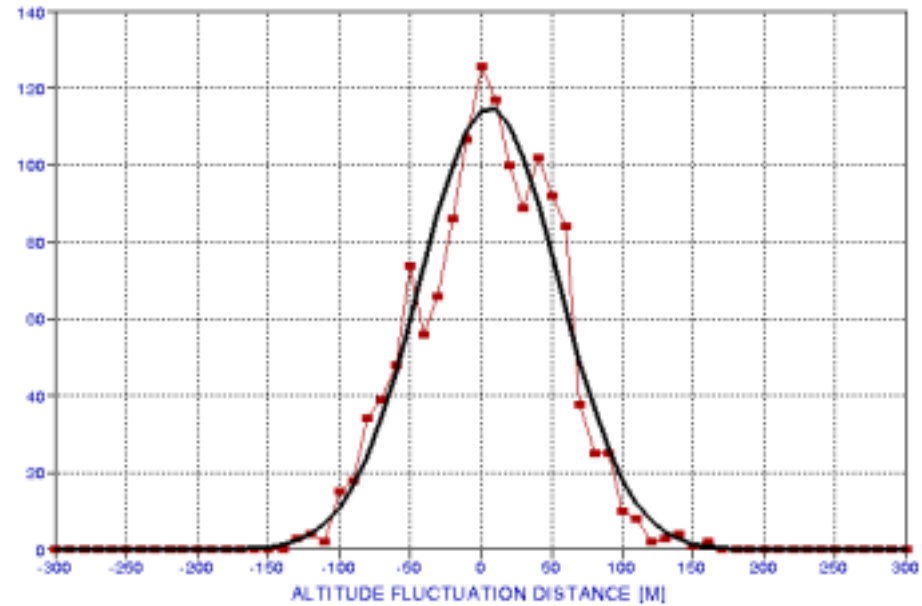
There do not appear to be any mesoscale waves present in the ER-2 transit flight

ER-2 Microwave Temperature Profiler (MTP)

MFA Histogram, ER010924
MFA = 120 meters



MFA HISTOGRAM, ER010926
MFA = 115 meters



The **Mesoscale Fluctuation Amplitude** (MFA) is the full-width at half-maximum of the histogram of mesoscale temperature fluctuations in meters. It depends on altitude, latitude, season and topography, and can be expressed as:

$$MFA = \left[137 - 1.61 \cdot \text{Latitude} + 97 \cdot \left[1 + \sin \left[2\pi \cdot \left(\frac{\text{DOY} - 292}{365} \right) \right] \right] \cdot \left(\frac{\text{Latitude}}{80} \right)^2 + 43.6 \cdot \text{Topography} \right] \cdot \left(\frac{58.85}{P(\text{mb})} \right)^{0.39}$$

Hurricane Humberto - 2001.09.24

Expect: MFA = 100 meters

Measure: MFA = 120 -130 meters

Transit: JAX to DFRC - 2001.09.26

Expect: MFA = 118 meters

Measure: MFA = 115 meters

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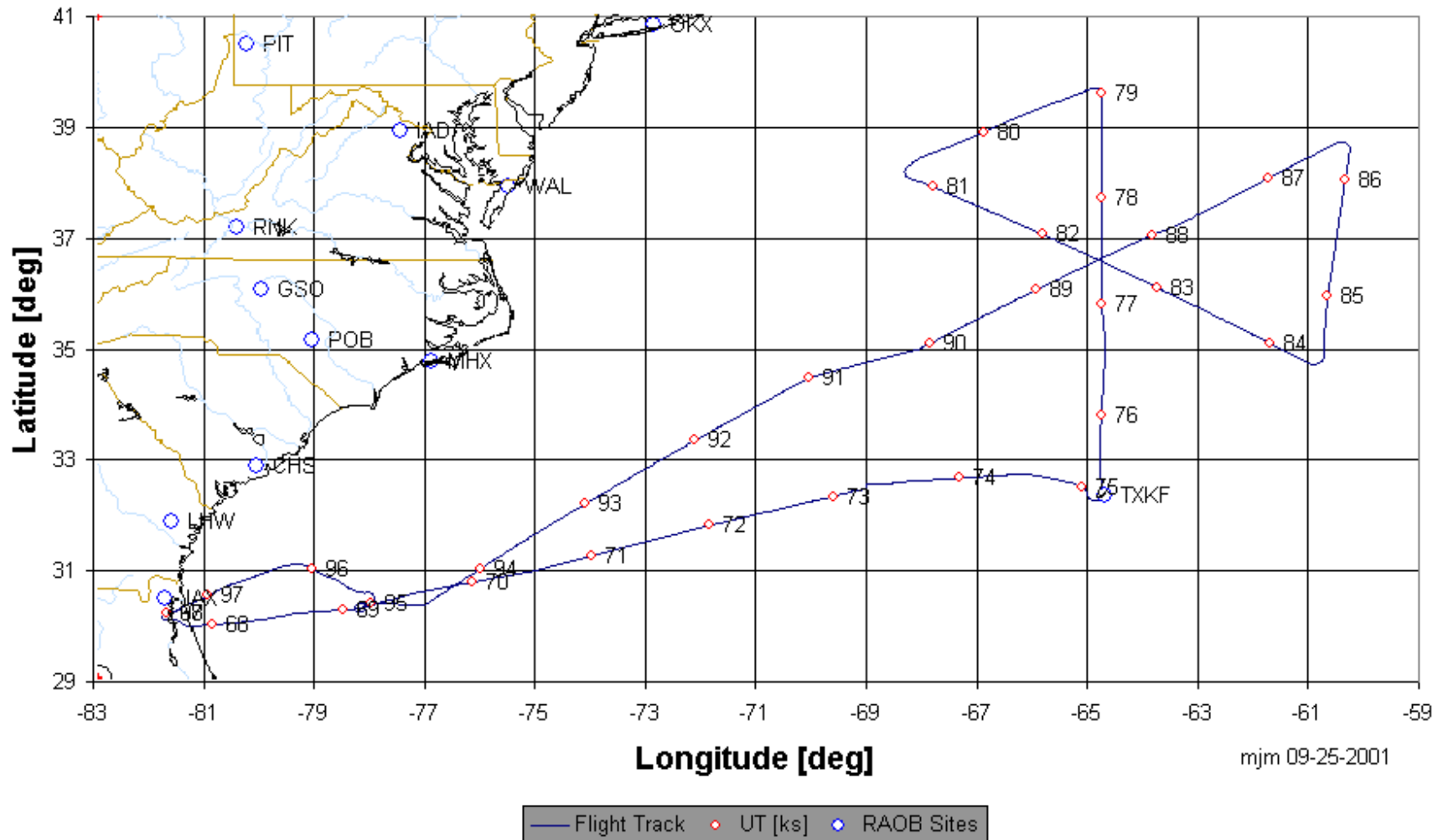
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http://mtp.jpl.nasa.gov/missions/camex4/Science/NDR_Corrections.html

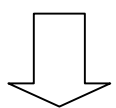
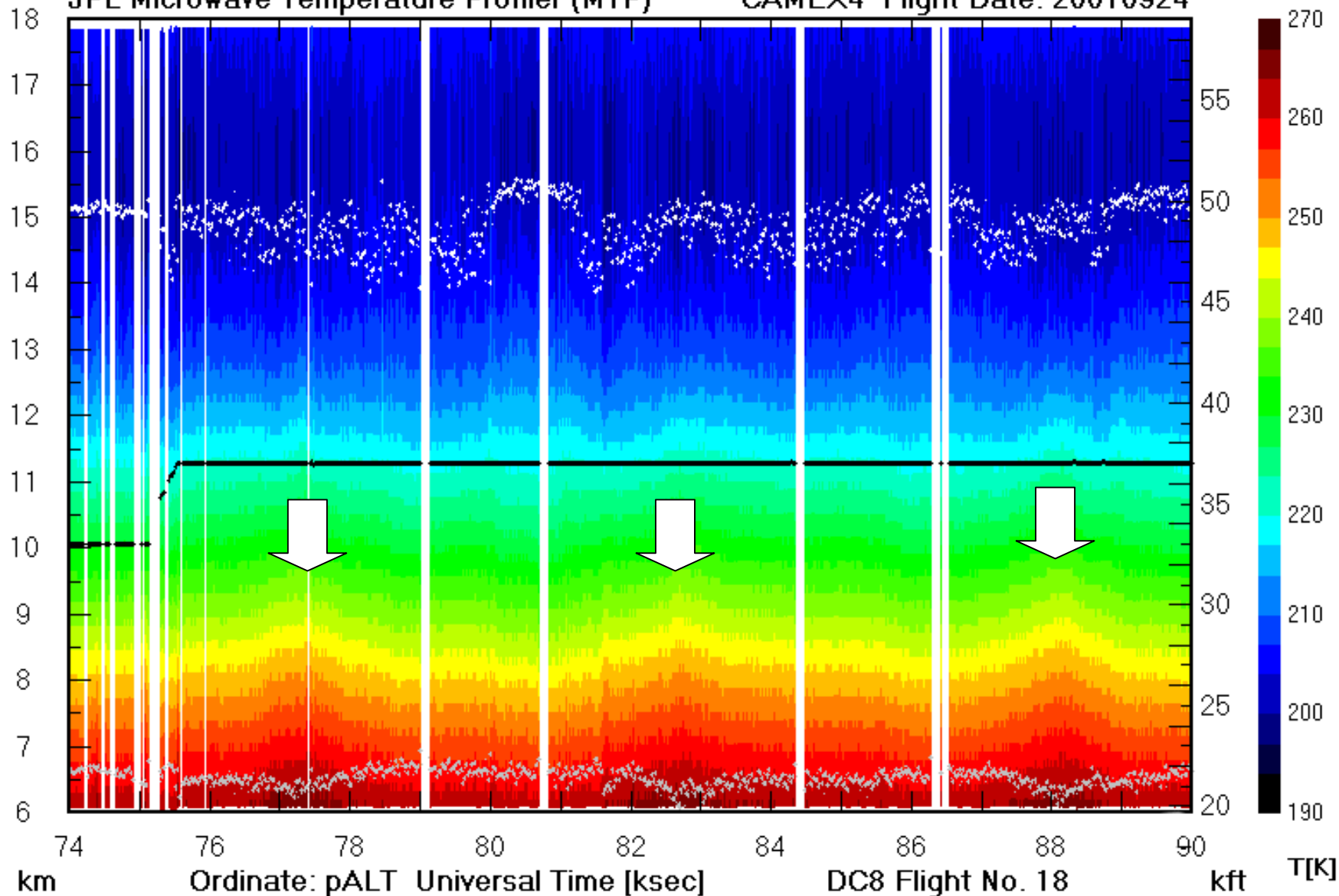
Report on DC-8 MTP Data and Data Analysis

- Excellent data set, some interference but very much less than on ER-2
- Analysis not funded

CAMEX4 - DC8 20010924

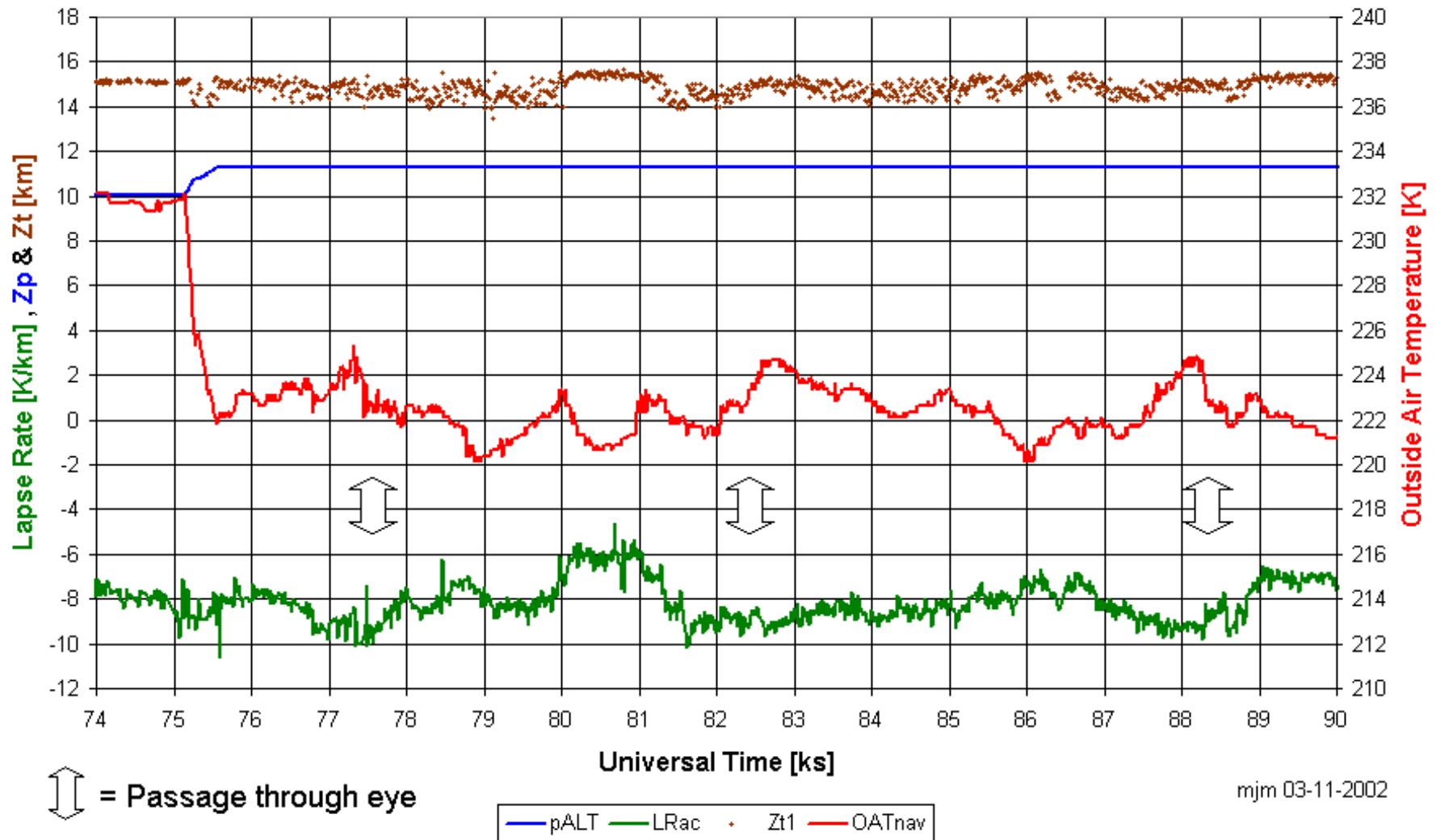


DC-8 MTP clearly sees a temperature anomaly associated with transects of Hurricane Humberto on 2001.09.23 and 2001.09.24 (next slide)



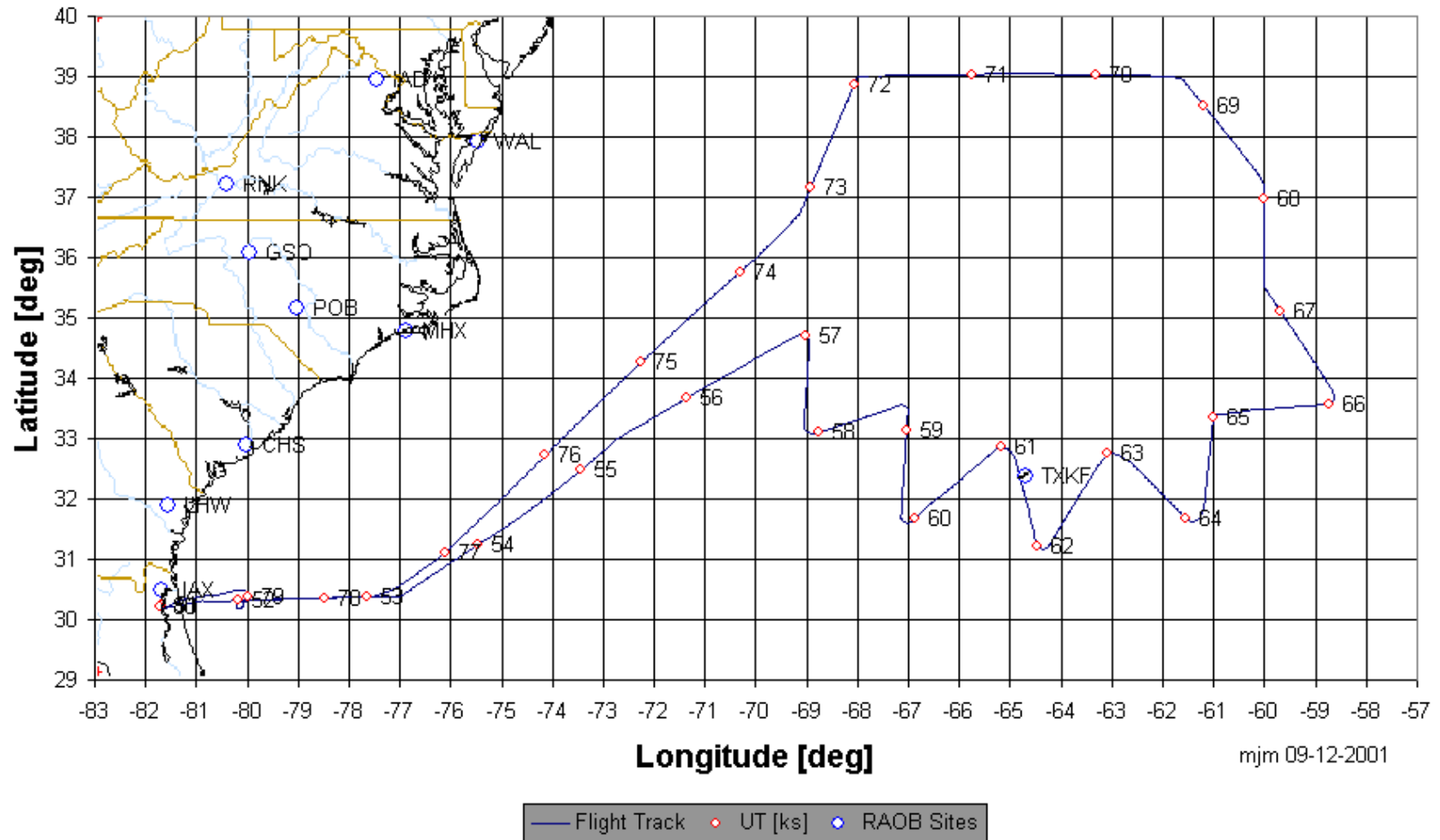
= Temperature anomaly associated with passage through the eye of Hurricane Humberto on 2001.09.24

CAMEX4 - DC8 20010924



mjm 03-11-2002

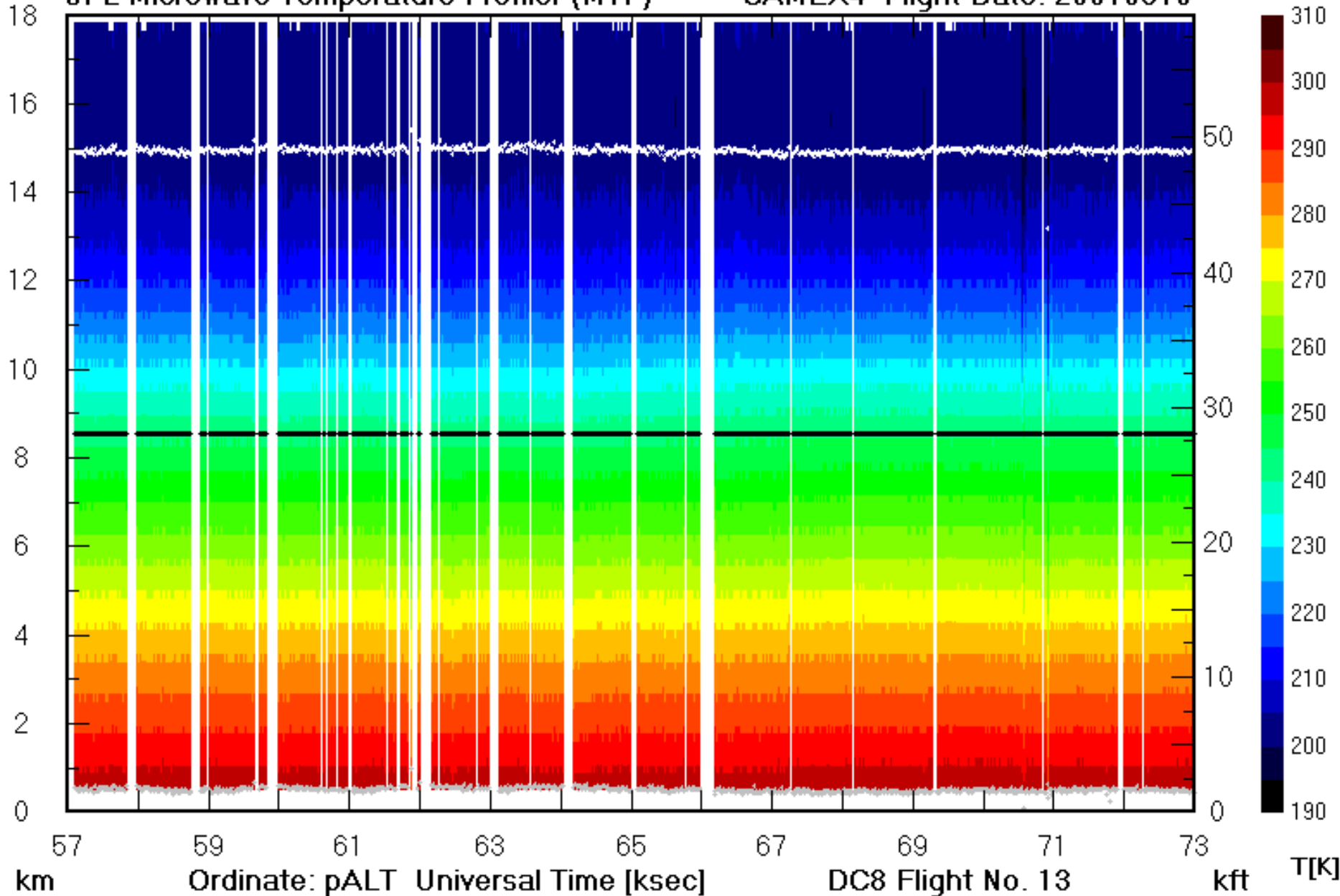
Transects of Hurricane Humberto are associated with ~ 3 K temperature anomaly and decrease in the lapse rate to near dry adiabatic (~ -10 K/km)



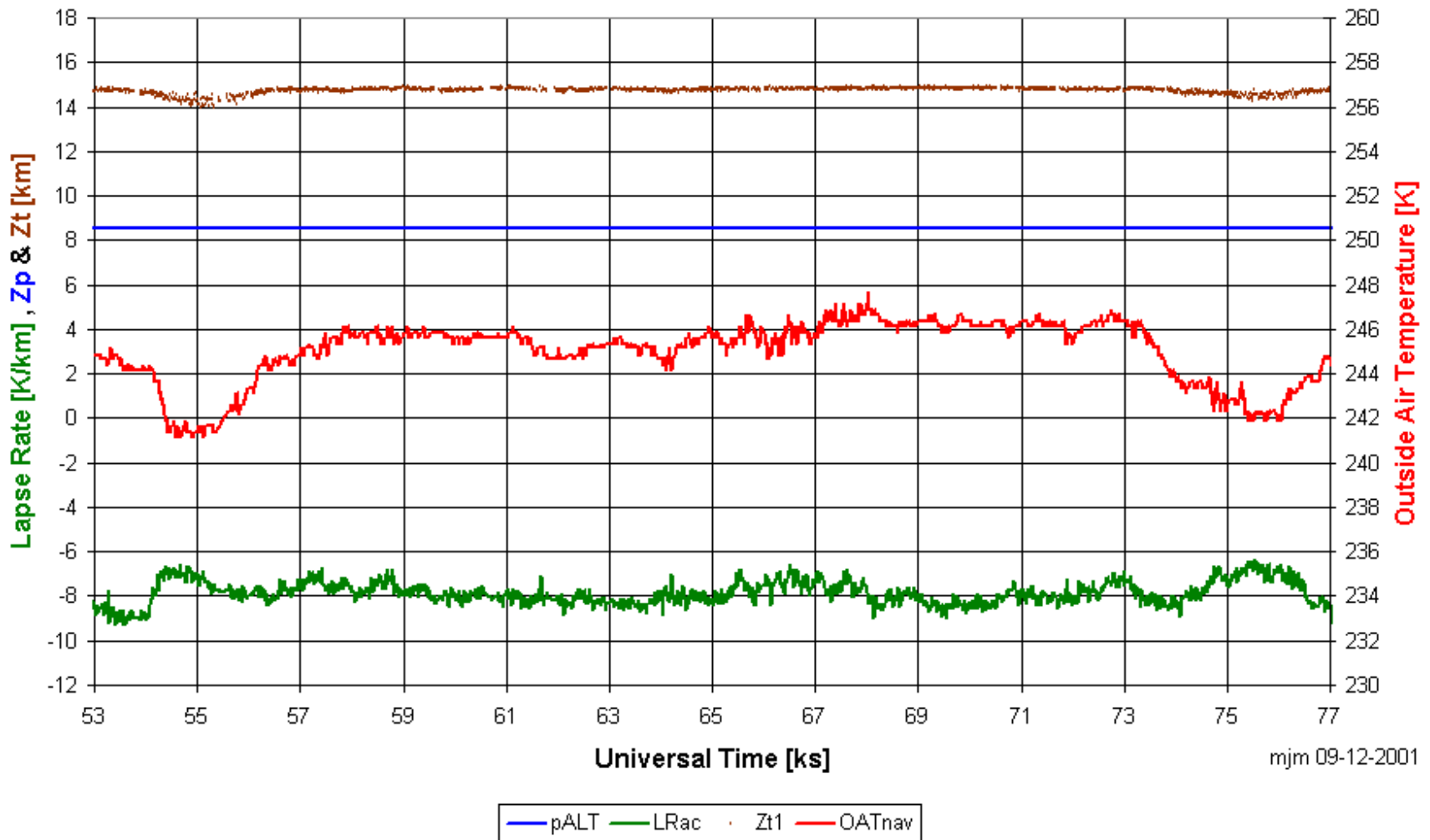
In contrast to the Humberto flights, the DC-8 circumnavigation of Hurricane Erin on 2001.09.10 shows very little variation in temperature and lapse rate

JPL Microwave Temperature Profiler (MTP)

CAMEX4 Flight Date: 20010910



CAMEX4 - DC8 20010910



mjm 09-12-2001

Note increase in temperature and decrease in lapse rate as Hurricane Erin is approached (~55 ks) and departed (75 ks).

Plans for FY'02 and FY'03

FY'02 Plans:

- Complete analysis of ER-2 MTP data
- Submit to archive within 2 months
- Collaborate with other CAMEX-4 PI's as much as possible
- Carry out independent research to study wave phenomena associated with convection (with collaborator, Dr. Joan Alexander, CoRA)

FY'03 Plans:

- No funding requested for FY'03; therefore, no plans

Acknowledgements:

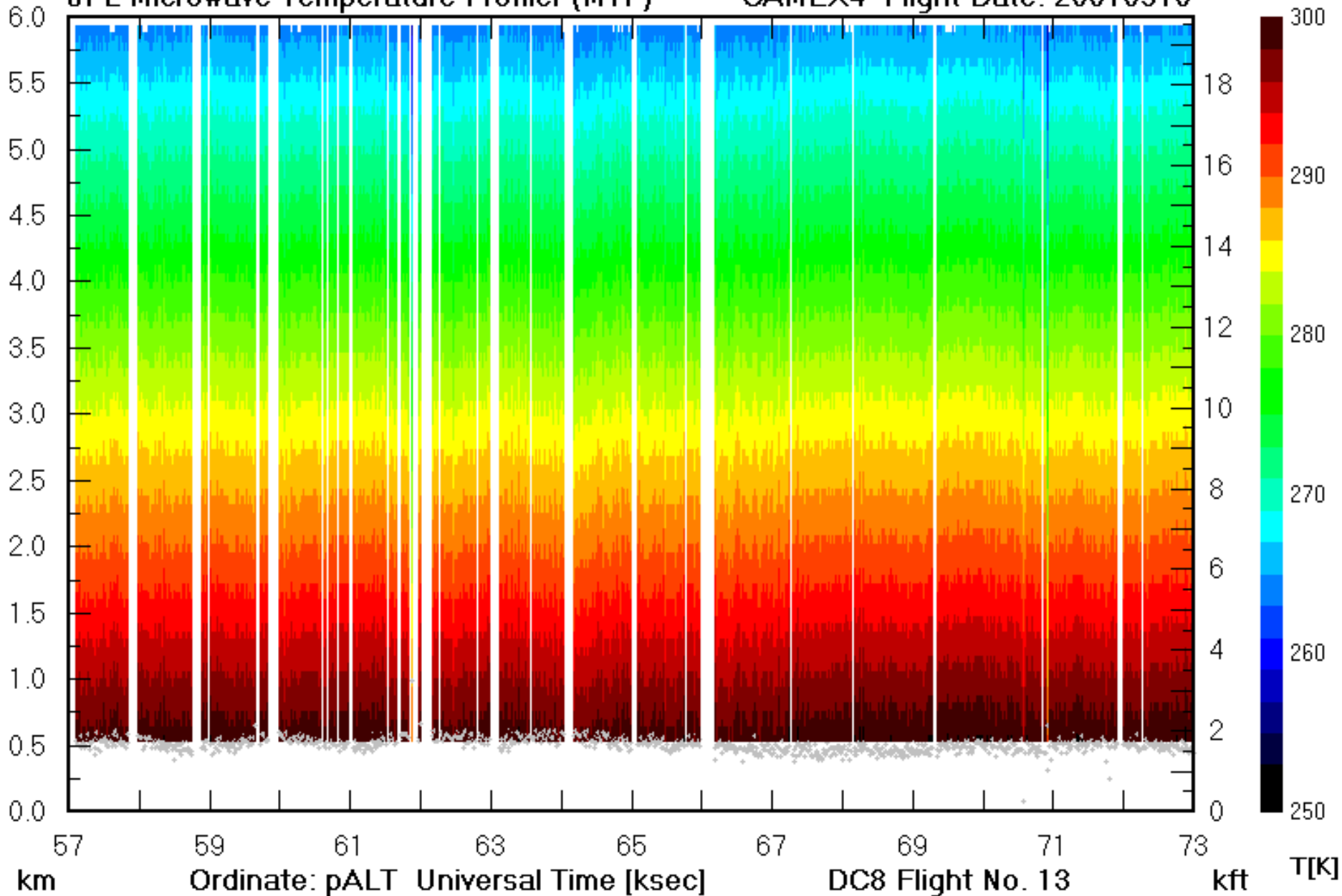
- Dr Ramesh Kakar for ER-2 support, Bruce L Gary for assistance with the data analysis, and Richard Denning for instrument support.

Microwave Temperature Profiler (MTP)

Backup

JPL Microwave Temperature Profiler (MTP)

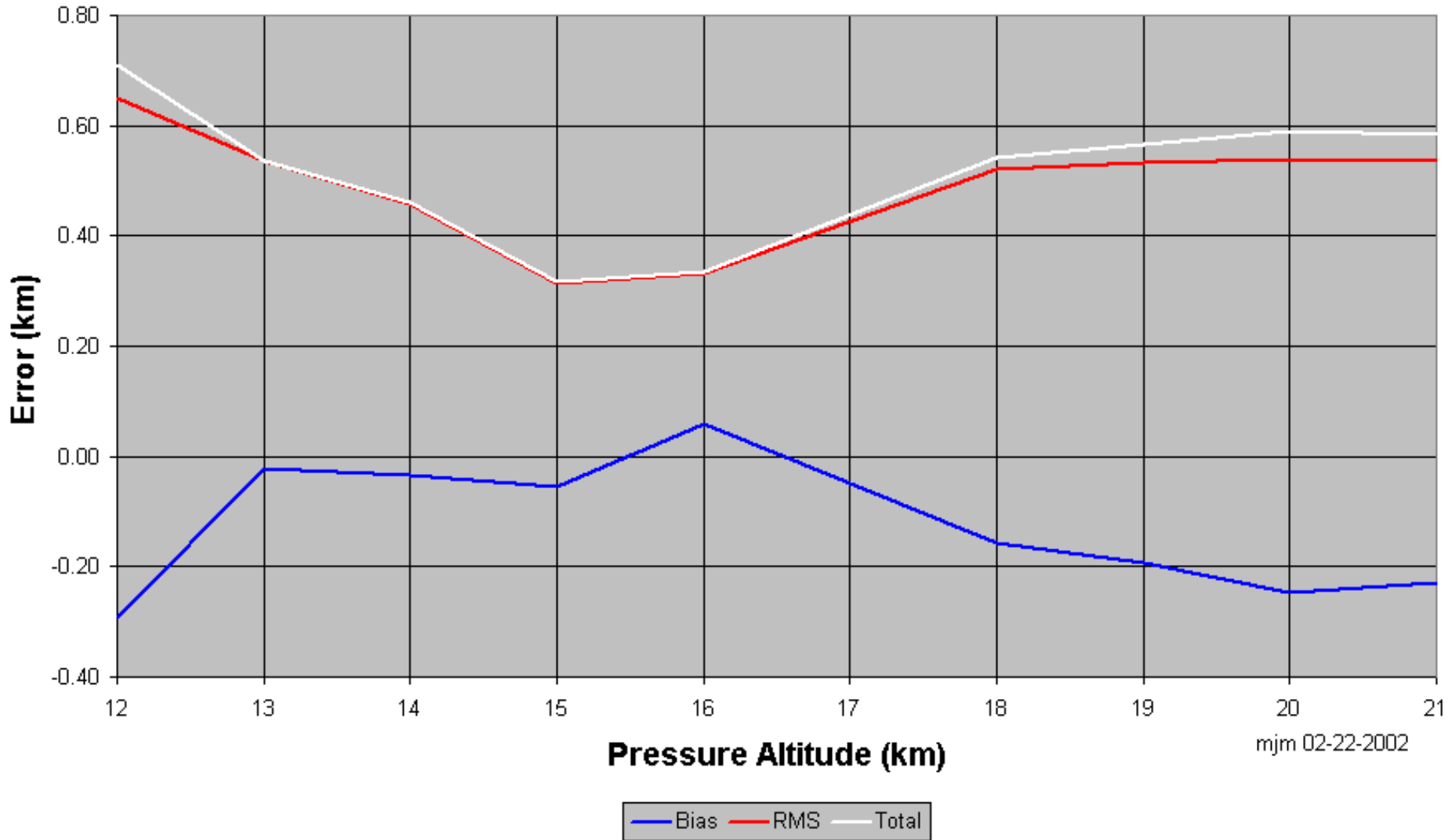
CAMEX4 Flight Date: 20010910

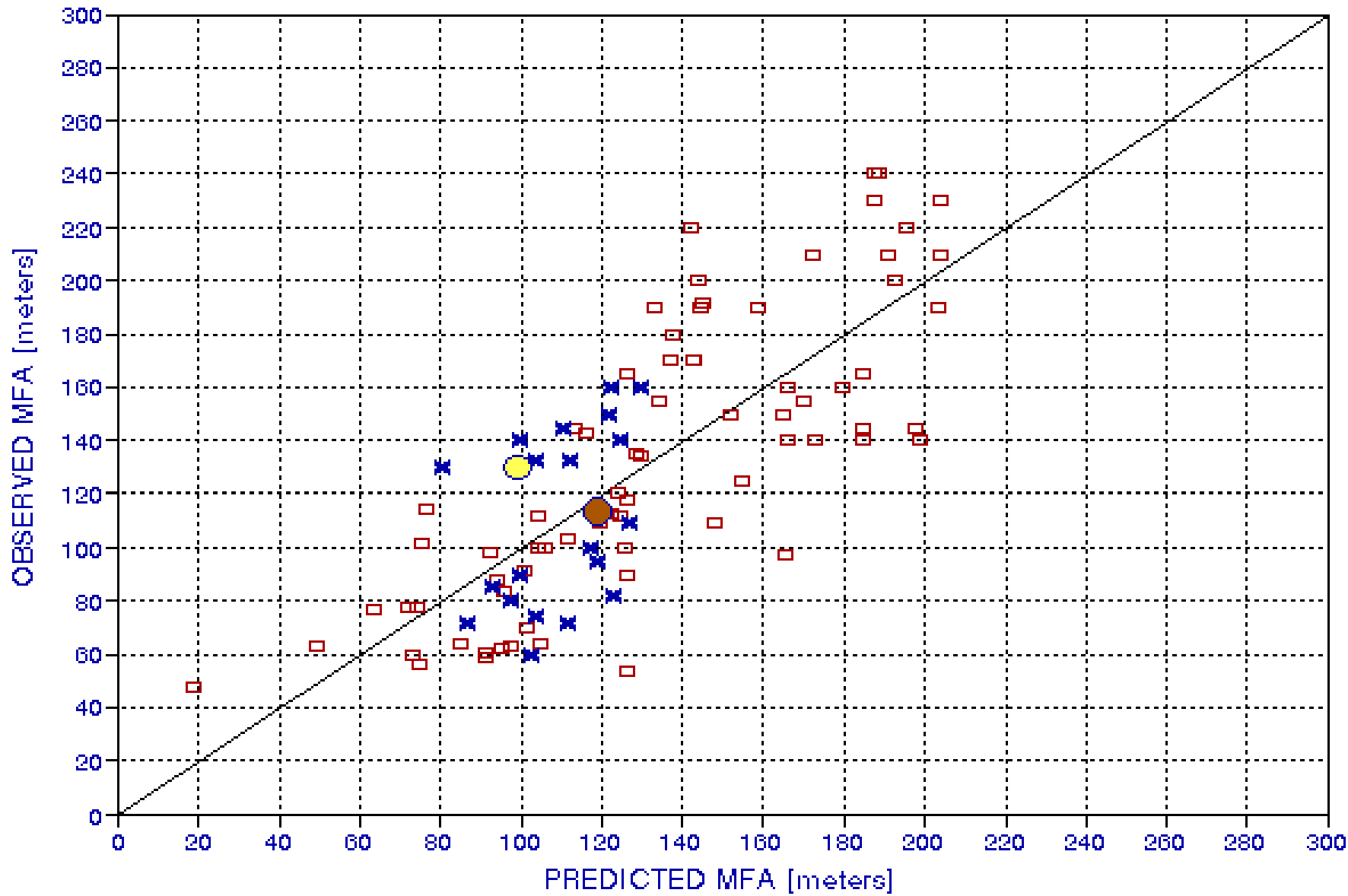


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Tropopause_{MTP}-Tropopause_{RAOB} Errors vs Pressure Altitude Based on Simulated Retrievals of 194 Tropical Radiosondes (Average Radiosonde Tropopause at ~15.5 km)

MTP





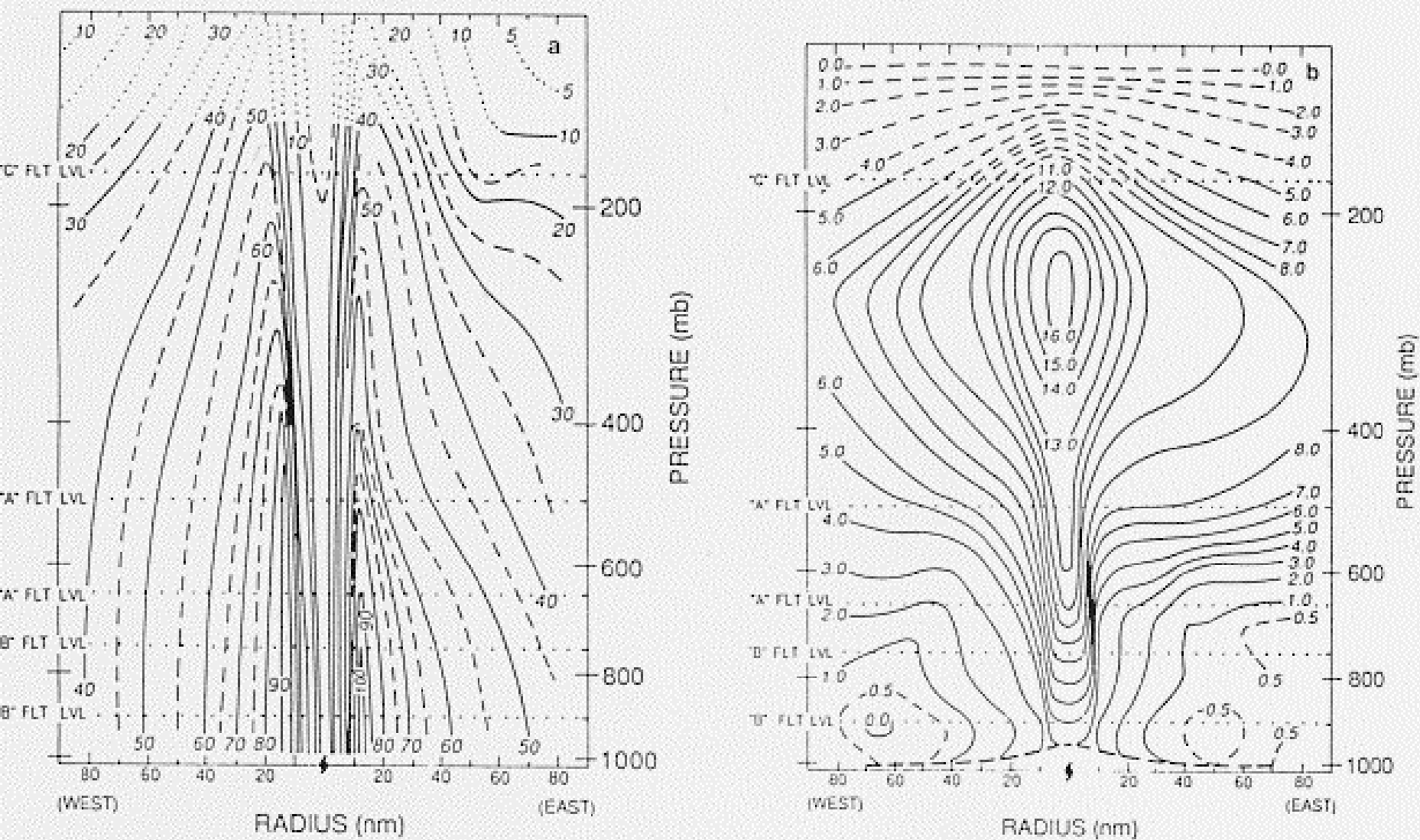


Fig. 2.6 Vertical cross sections of (a) azimuthal wind (kt), and (b) temperature anomaly ($^{\circ}$ K) in Hurricane Hilda of 1964 (Hawkins and Rubsam 1968).