Microwave Temperature Profiler and Sea Surface Temperature Measurements

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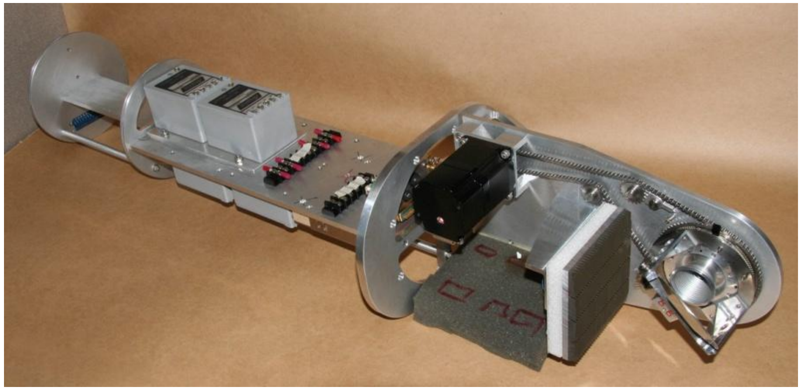
Overview of Presentation

- Temperature Profiles from GV
  - MTP description
  - Retrieval method
  - Data set quality
  - Data examples
- Sea Surface Temperature from GV
  - KT-19 description and limitations
  - Altitude-induced errors
  - Correction method
  - Data example

Microwave Temperature Profiler

- Measures radiance on three oxygen absorption lines
  - 56.363, 57.612, 58.363 GHz;
- Rotating mirror scans ±80º from horizontal
  - 10 viewing angles
- Scan completed every 17 seconds
- Internal calibration system
  - heated blackbody target
  - in situ ambient temperature measurement
  - calculate gains

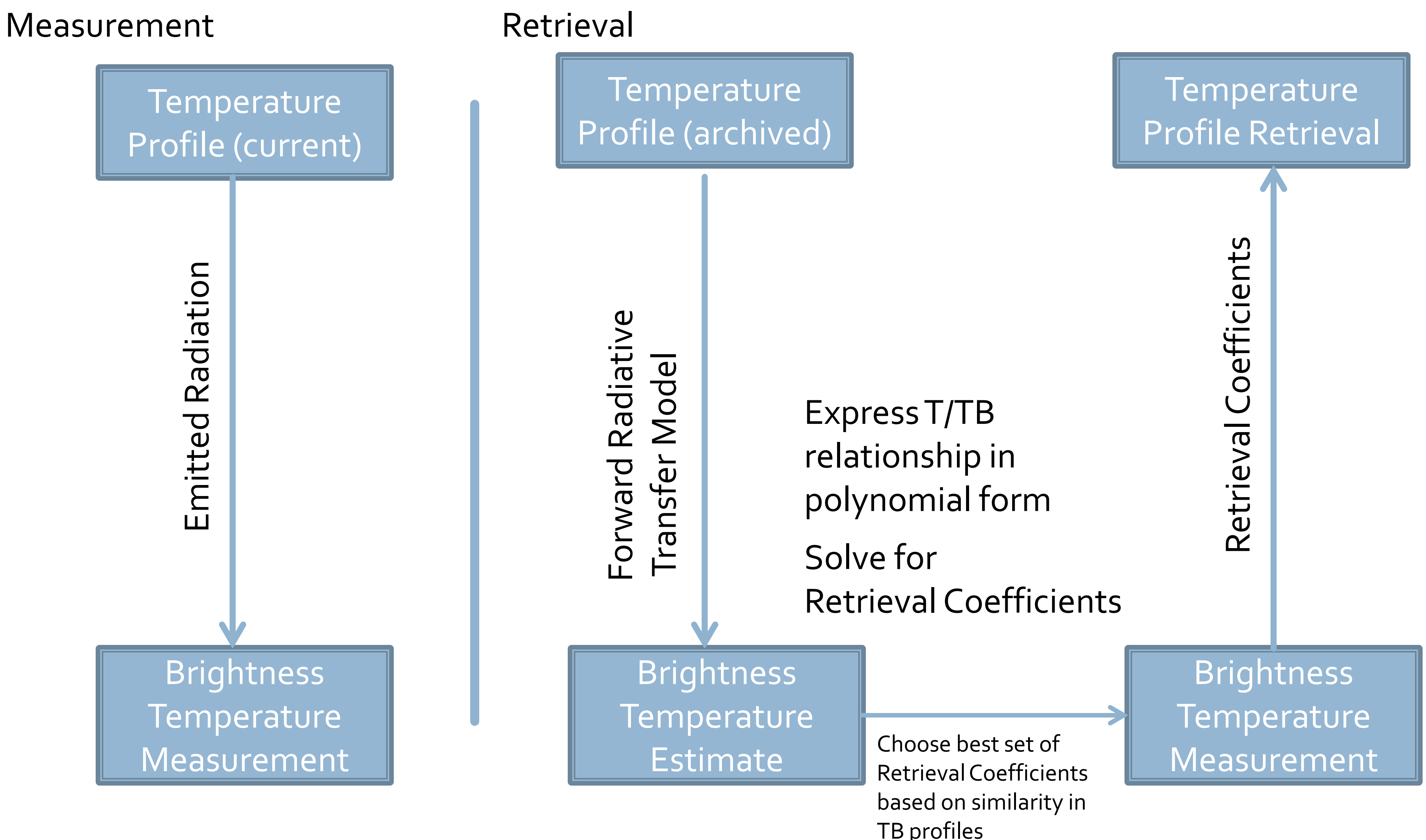


Statistical Retrieval of Temperature Profiles from MTP Measurements

- MTP measures brightness temperature (TB) or radiance from thermal emission by oxygen molecules
- TB is related to T via the radiative transfer equation; TB does not have a one-to-one mapping to a physical temperature (T)
- Even in simplified form, the radiative transfer equation is underconstrained
- Retrieval problem is ill-posed unless we include constraints
- a priori statistics are commonly used to provide constraints on atmospheric behavior

References: Rodgers, 2000: Inverse Methods for Atmospheric Sounding
Janssen, 1993: Atmospheric Remote Sensing by Microwave Radiometry
Method Implemented by MJ Mahoney (JPL)

Temperature Retrieval Overview



A Priori Statistics for MTP Retrievals

- Radiosonde profiles, together with a forward radiative transfer model, provide the a priori statistics

- Large database of representative radiosonde profiles acquired for each project
  - ~5000 profiles from region and season
  - South and Central American stations
  - Ticosondes and raobs from Hakuho Maru

- Radiosonde profiles close to flight track selected as template profiles
  - Database search for profiles similar to template
  - Similar groups of ~200 profiles are compiled
  - Provides information for numerical solution of retrieval coefficients

MTP Data Attributes

- Best retrievals within ± 6km of flight level
  - Provide data farther away when needed
- Temperature uncertainty range ~0.5-1.5 K
- Vertical resolution near aircraft ~100 m
- Profiles retrieved at 17 sec intervals
- Limited retrievals during steep ascents/descents
- Tropopause height defined using WMO definition

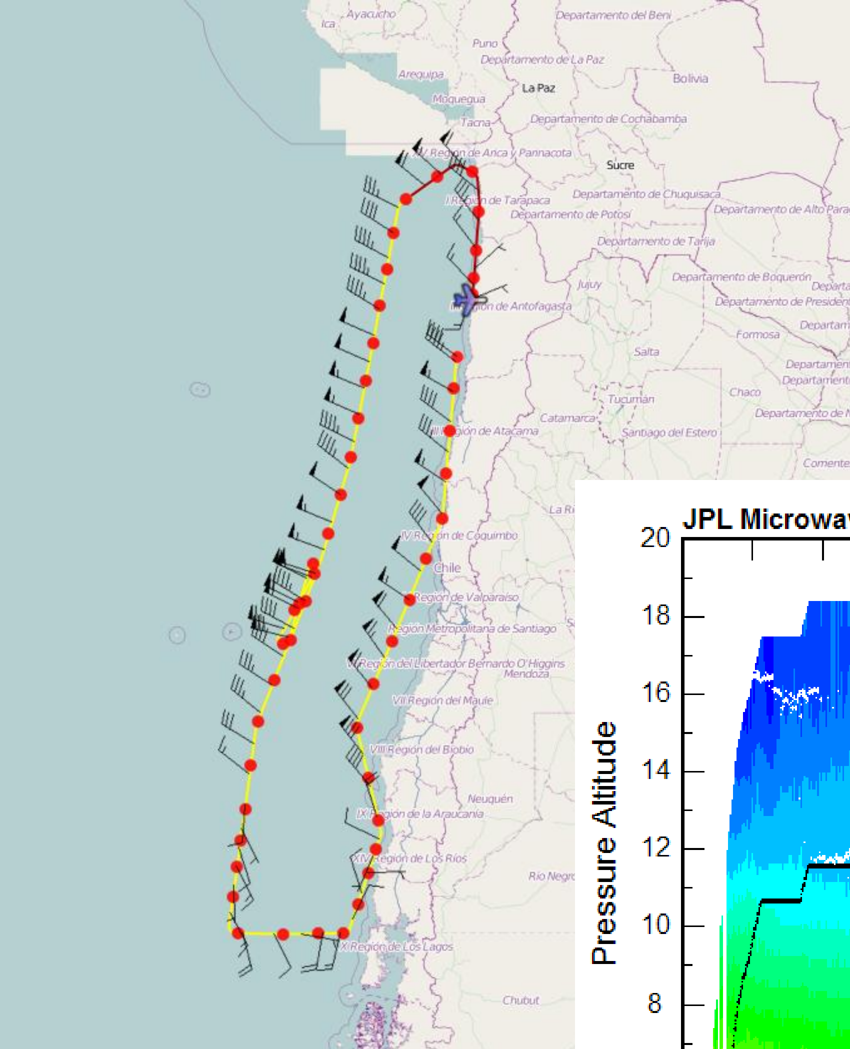
MTP Data Set from TORERO

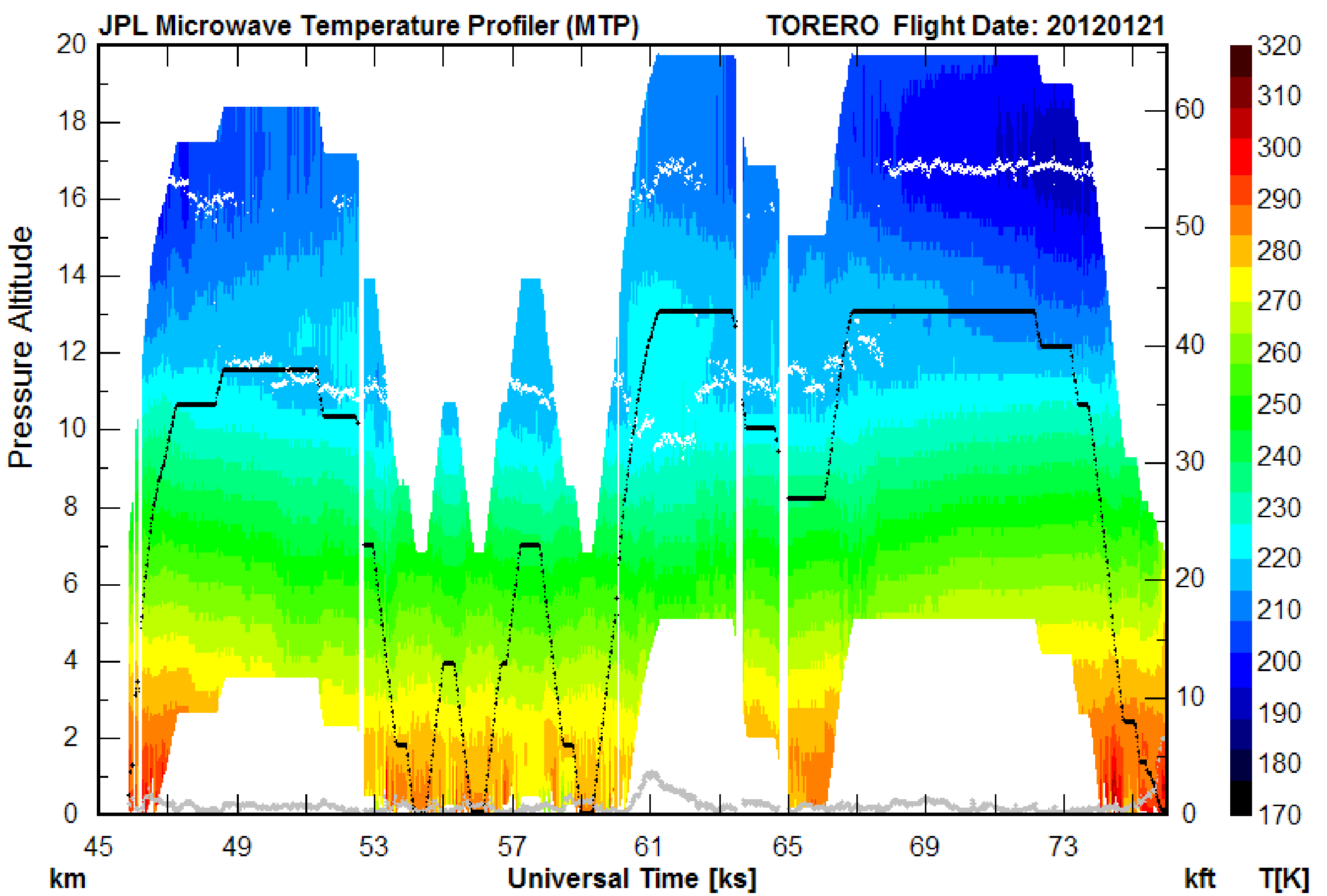
- Processed Data
  - RF01 -- problem with sensor configuration resulted in no useful data from this flight
  - RF02-RF17 -- good quality data
- Steep ascents/descents
  - Gain calculation assumes level flight for duration of scan
  - Data gaps during rapid altitude changes
  - Data preserved where consistent with level flight

MTP Data Set from TORERO

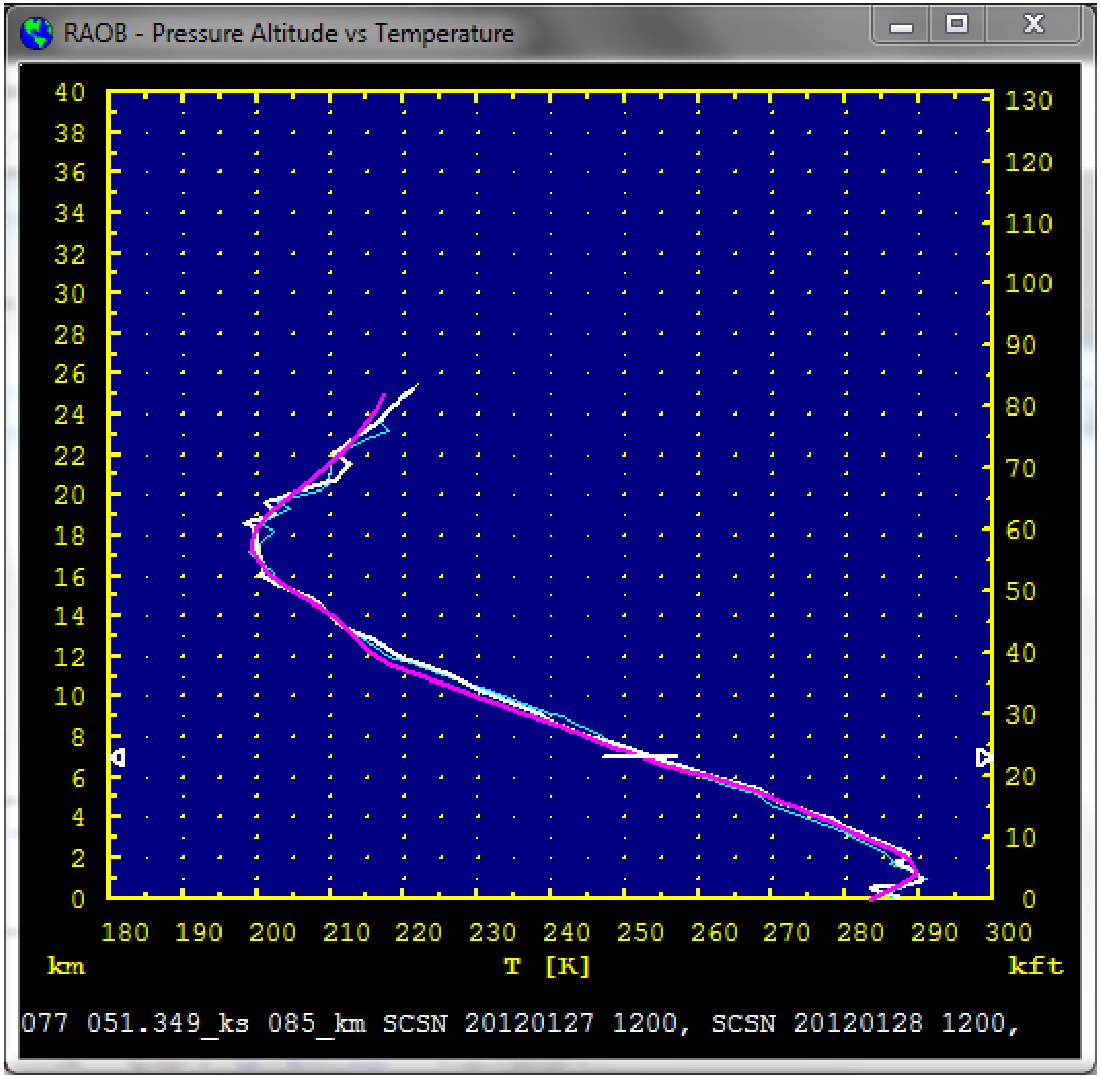
- Surface inversion layer
  - Detected by MTP in Antofagasta flights
  - Not represented in a priori data, so retrieval coefficients are not optimal to resolve this feature
  - Surface emissivity not accounted for in retrievals
- Data files
  - NASA Ames format
  - Available via CODIAC
- Website summarizes data quality and shows quicklook images
  - http://mtp.mjmahoney.net/www/missions/torero/torero.html

Temperature Curtain Plot
Costal Upwelling Flight
21 Jan 2012 - RF02



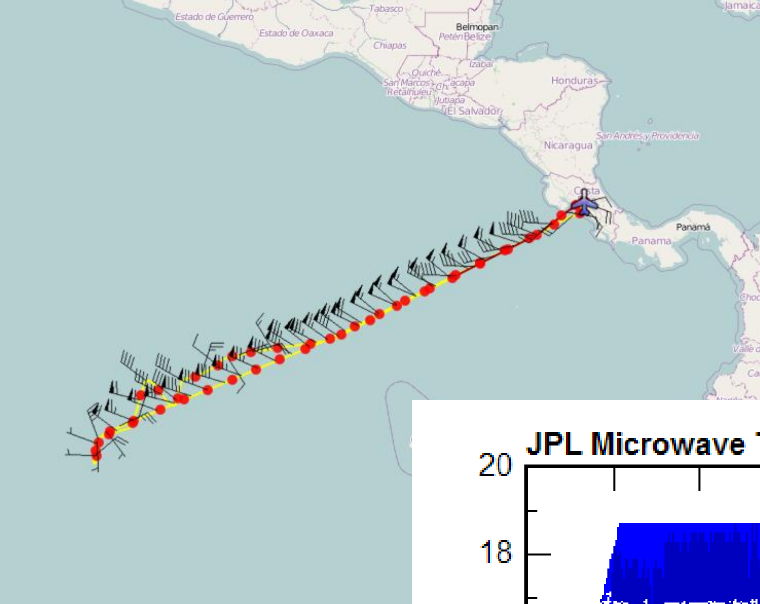


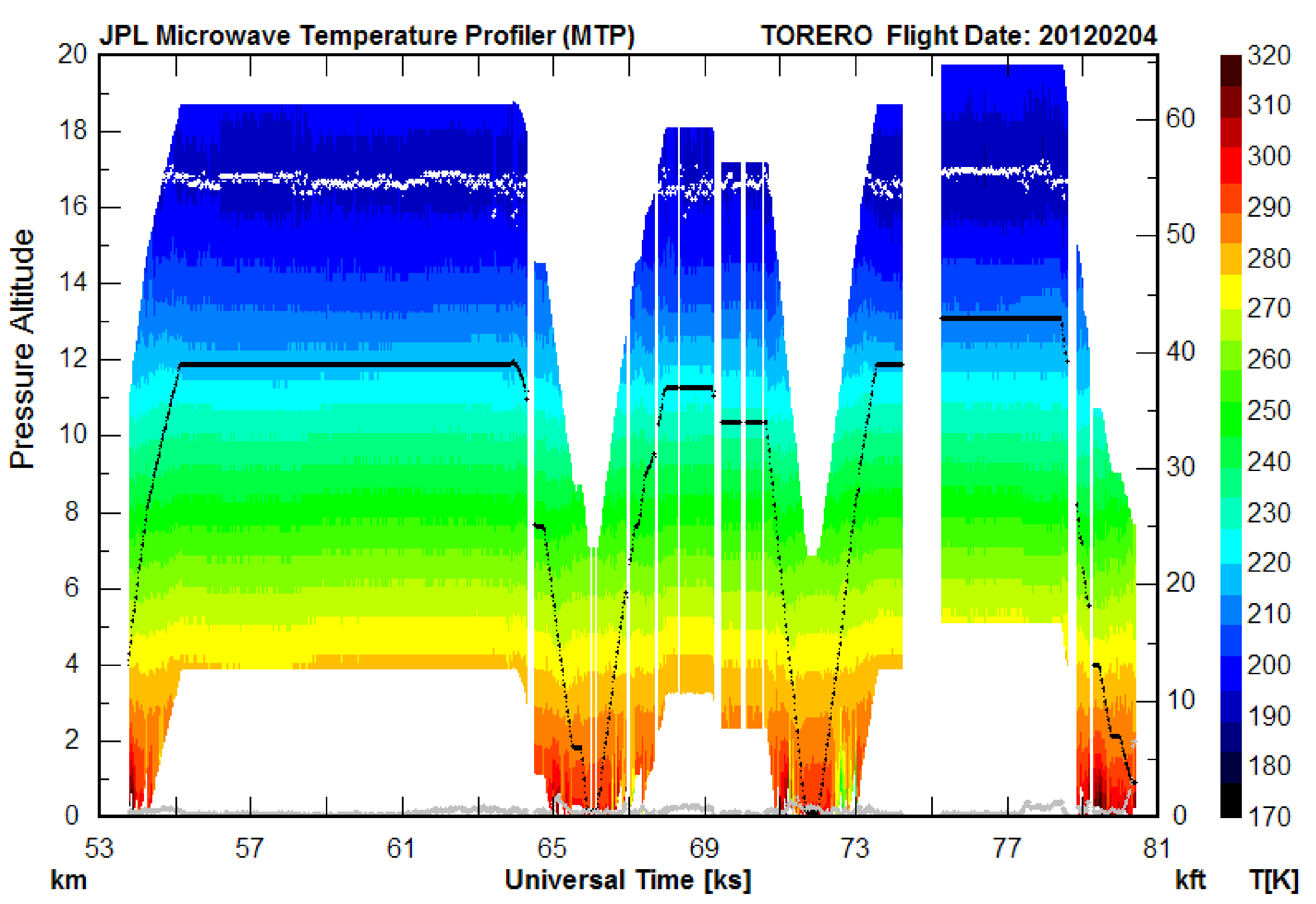
Single Profile Retrieval
27 Jan 2012 – RF04



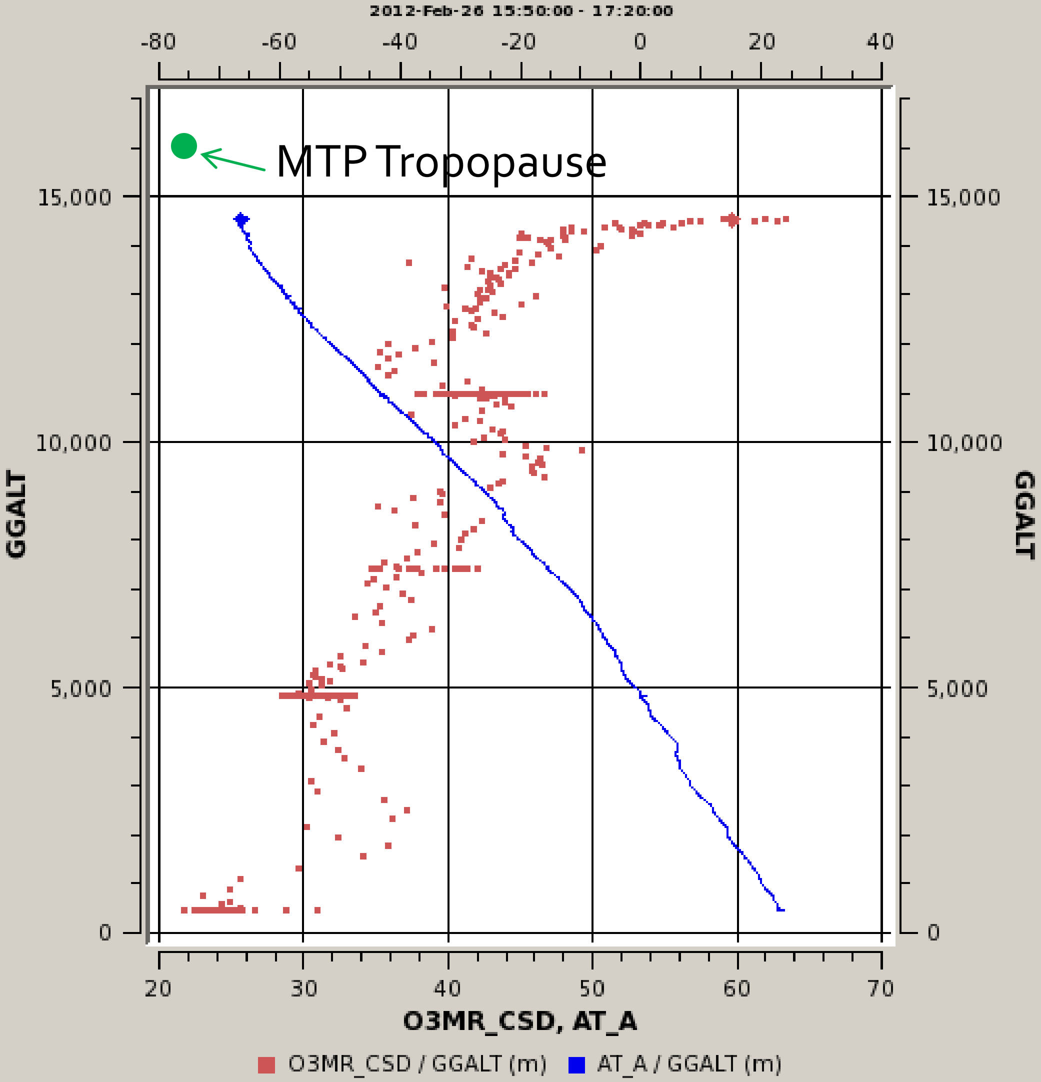
- MTP profile vs. Santo Domingo radiosondes
- Separation
  - 2+ hours later
  - aircraft 85 km west

Tropical Convective Flight
4 Feb 2012 – RF08
Hakuho Maru overpass





O3 Mixing Ratio and Temperature Profiles – 26 Feb 2012 (RF17)



Preliminary ozone data shown (R. Gao)

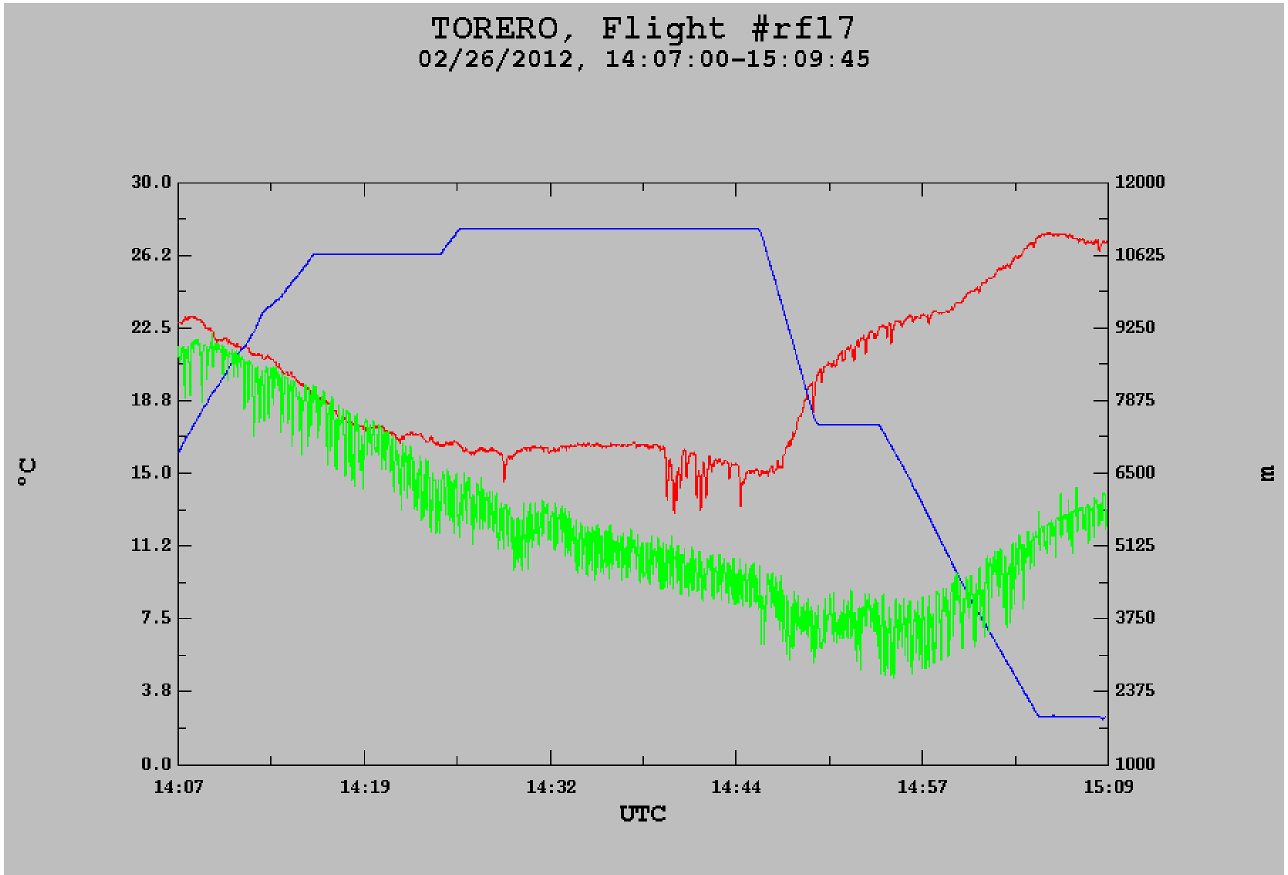
Sea Surface Temperature

- Heitronics KT19.85 infrared pyrometer
- Spectral range 9.6 – 11.5 um
- Field of view 2°
- Sampling rate 5 Hz
- Specified accuracy 0.5 K plus a term dependent on difference between scene temperature and sensor housing temperature
- Temperature variations in sensor housing may be large
- Emission by water vapor in the column also contributes to uncertainty

<u>GV Installation</u>

- Mounted on downward facing aperture plate
- Vertical orientation
- Not heated

Altitude-Induced Variation in SST Measurement

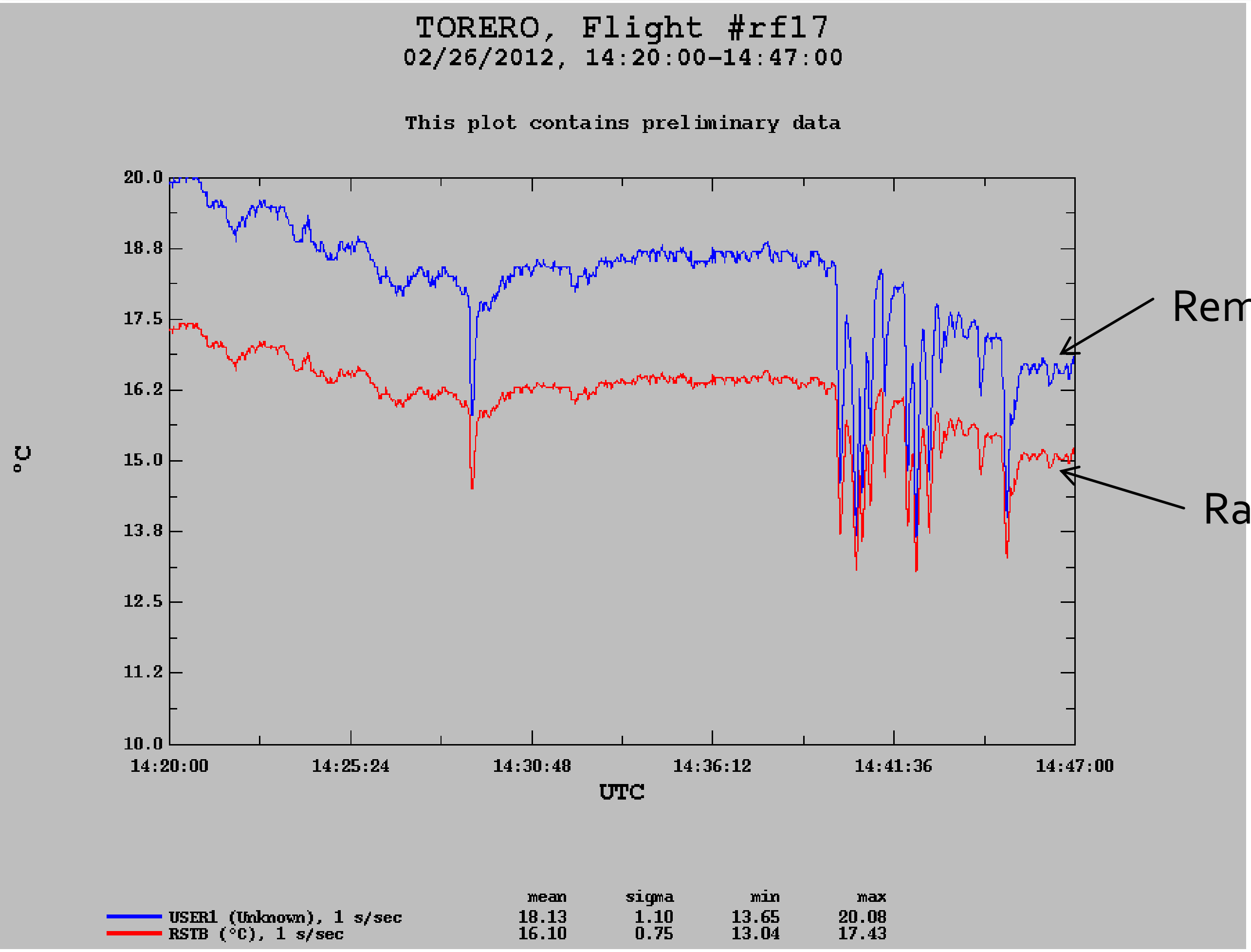


	mean	sigma	min	max
TCABFWDB (°C), 1 s/sec	12.37	4.36	4.42	22.21
GGALT (m), 1 s/sec	8564.53	3098.69	1857.38	11129.60
RSTB (°C), 1 s/sec	19.59	3.89	13.04	27.43

Method to Remove Water Vapor Emission Signal

- Radiative transfer model runs over a range of hypothetical surface temperatures
- Temperature and humidity profiles from aircraft ascents/descents used as input
- Clear scenes
- Difference between brightness temperature at top of layer and input surface temperature gives the correction
- Generate look-up table of corrections dependent on altitude and measured brightness temperature

Corrected Data Example 26 Feb 2012 – RF17



Remove water vapor emission

Raw measurement

Sensor heating/cooling effect not yet addressed

Summary

- MTP production data files now available
- SST data processing continues

Convection over the Andes, near San Pedro de Atacama

Radiative Transfer Equation:

Discrete approximation
Microwave radiative transfer in the atmosphere

- Non-scattering at these wavelengths (several millimeters)
- Neglect surface emission
- Remaining terms from atmospheric emission:

$$TB(\nu,\theta)=\sec\theta\int_{z1}^{z2}T(z)\cdot\alpha(\nu,z)\cdot\exp((-\tau(z1)-\tau(z2)\sec\theta)dz$$

- Integral can be approximated by a sum:

$$TB(\nu,\theta)=\sum_{i=0}^{N}Ki(\nu,\theta)\cdot T(zi)+\varepsilon$$

- Residual error, ε, denotes quadrature error and can account for instrument noise, etc.

Polynomial Representation

- Alternatively, T can be written as a polynomial in terms of TB

$$T(z) = \sum_{i=1}^{N} a_i \cdot TB(\nu, \theta) + \varepsilon$$

- Then we must estimate the coefficients, a_i, using a priori information

Generating Retrieval Coefficients

For each of N = 200 raobs, at a given altitude:

- Express T_{raob} as a linear combination of TB_{raob}

$$T_{raob} = a_1 TBraob_1 + a_2 TBraob_2 + \ldots + a_{30} TBraob_{30}$$

- Using a system of N equations in M=30 unknowns, solve for a_m at each vertical level L.

Obtain a set of *Retrieval Coefficients* at each vertical level associated with a single template.
Repeat process for all template profiles (usually 20-40 sets).

Relate Temperature to Brightness Temperature

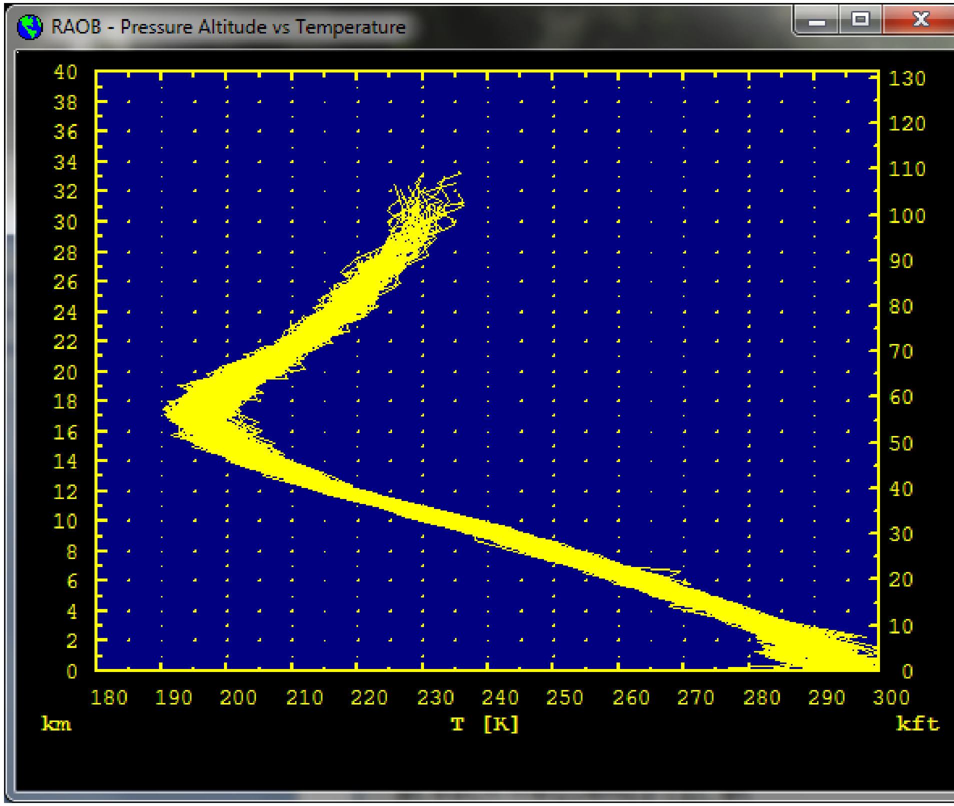
For each template raob, at each frequency (3), at each viewing angle (10), at common flight altitudes

T_{raob} → TB_{raob}

RT Forward Model

Repeat for ~200 similar raob profiles → Regression on results gives a linear polynomial relationship between T and TB

Template and associated radiosondes from Antofagasta

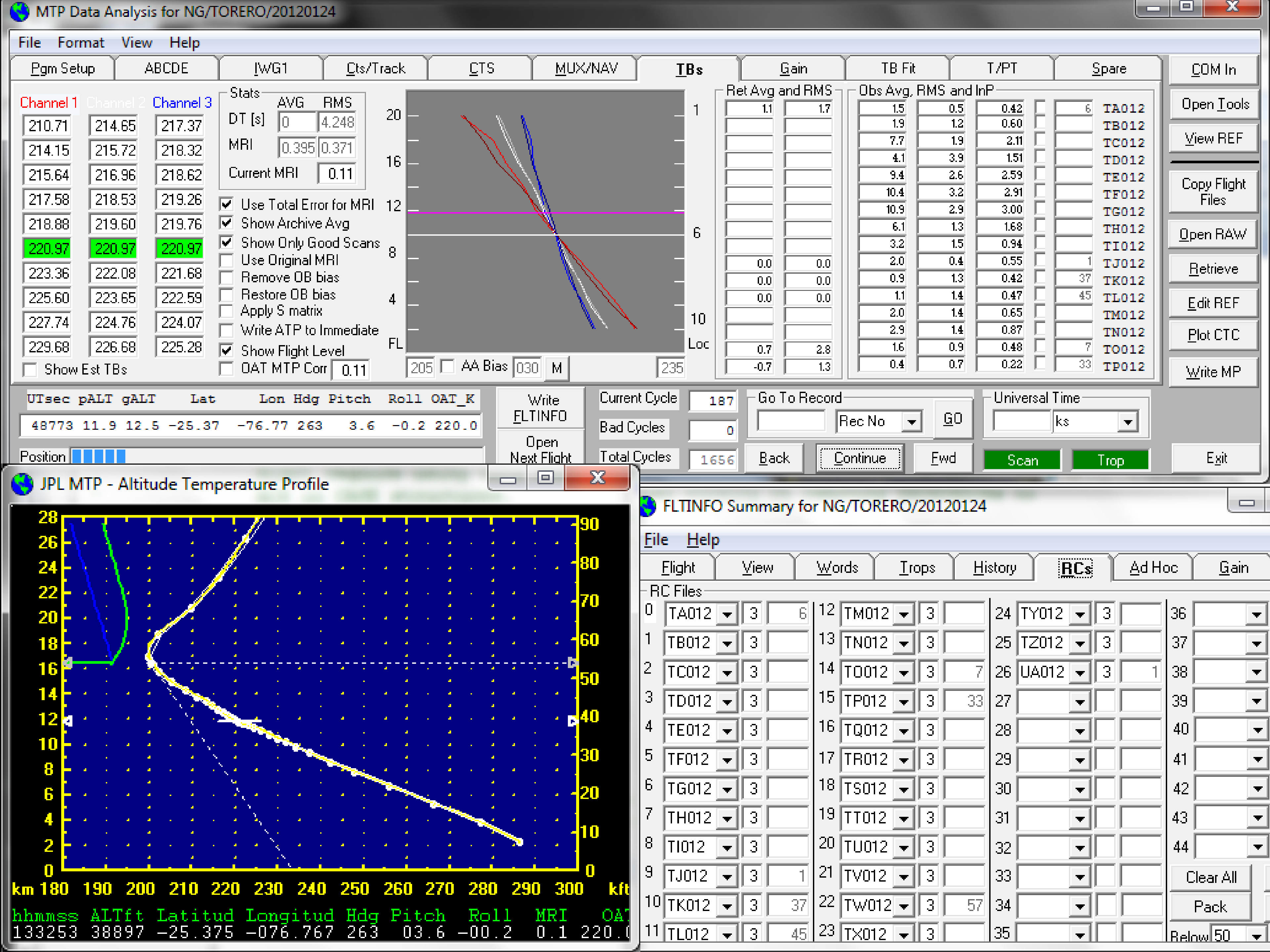


Retrieval Procedure

- For each MTP scan, match (measured) TB_{mtp} profile with most similar (modeled) TB_{raob} profile
- Assume similar TB profiles will have similar relationships to T profiles
- Apply the associated set of RCs to TB_{mtp}
- Calculate T_{mtp} at altitude z:

$$T_{mtp}(z) = \overline{T_{raob}} + \sum_{m=1}^{30} RC(z,m) TB_{mtp}(m))$$

measurement


MTP Data Analysis for NG/TORERO/20120124
File Format View Help
Pgm Setup ABCDE IWG1 Cts/Track CTS MUX/NAV TBs Gain TB Fit T/PT Spare
COM In
Open Tools
View REF
Copy Flight Files
Open RAW
Retrieve
Edit REF
Plot CTC
Write MP
Channel 1 Channel 2 Channel 3
210.71 214.65 217.37
214.15 215.72 218.32
215.64 216.96 218.62
217.58 218.53 219.26
218.88 219.60 219.76
220.97 220.97 220.97
223.36 222.08 221.68
225.60 223.65 222.59
227.74 224.76 224.07
229.68 226.68 225.28
Show Est TBs
Stats
AVG RMS
DT [s] 0 4.248
MRI 0.395 0.371
Current MRI 0.11
Use Total Error for MRI
Show Archive Avg
Show Only Good Scans
Use Original MRI
Remove OB bias
Restore OB bias
Apply S matrix
Write ATP to Immediate
Show Flight Level
OAT MTP Corr 0.11
20
16
12
8
4
FL
1
6
10
Loc
205 AA Bias 030 M 235
Ret Avg and RMS
Obs Avg, RMS and lnP
TA012
TB012
TC012
TD012
TE012
TF012
TG012
TH012
TI012
TJ012
TK012
TL012
TM012
TN012
TO012
TP012
UTsec pALT gALT Lat Lon Hdg Pitch Roll OAT_K
48773 11.9 12.5 -25.37 -76.77 263 3.6 -0.2 220.0
Position
Write FLTINFO
Open Next Flight
Current Cycle 187
Bad Cycles 0
Total Cycles 1656
Go To Record
Rec No
GO
Universal Time
ks
Back Continue Fwd Scan Trop Exit
JPL MTP - Altitude Temperature Profile
km 180 190 200 210 220 230 240 250 260 270 280 290 300 kft
hhmmss ALTft Latitud Longitud Hdg Pitch Roll MRI OAT
133253 38897 -25.375 -076.767 263 03.6 -00.2 0.1 220.0
FLTINFO Summary for NG/TORERO/20120124
File Help
Flight View Words Trops History RCs Ad Hoc Gain
RC Files
0 TA012 3 6
1 TB012 3
2 TC012 3
3 TD012 3
4 TE012 3
5 TF012 3
6 TG012 3
7 TH012 3
8 TI012 3
9 TJ012 3 1
10 TK012 3 37
11 TL012 3 45
12 TM012 3
13 TN012 3
14 TO012 3 7
15 TP012 3 33
16 TQ012 3
17 TR012 3
18 TS012 3
19 TT012 3
20 TU012 3
21 TV012 3
22 TW012 3 57
23 TX012 3
24 TY012 3
25 TZ012 3
26 UA012 3 1
Clear All
Pack
Below 50