Microwave Temperature Profiler (MTP) Status Report for CAMEX-4

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During the CAMEX-4 campaign, JPL Microwave Temperature Profilers (MTPs) flew aboard the NASA DC-8 and ER-2 research aircraft. Because MTPs measure the temperature profile above, below and at flight level, MTP data can be used for several purposes: to study the mesoscale structure of hurricanes, to derive parameters such as the temperature anomaly, lapse rate, tropopause height, relative humidity (with absolute humidity measurements) and isentrope levels, and to initialize numerical forecast models. This was the first time that MTPs flew on a hurricane research campaign, and it resulted in the first time ever observation of the two-dimensional, mesoscale, temperature anomaly associated with transects through the eye of a hurricane. This report summarizes the current status of the analysis of the MTP data for CAMEX-4.

ER-2 Data Analysis

The ER-2 MTP data analysis was challenging for two reasons. First, there was an excessive amount of interference (up to 25% on some flights), and second, the ER-2 Navigation Data Recorder (NDR) data was seriously in error: pressure altitude by as much as 600 meters, and outside air temperature by 1.5 K.

1. Interference

What made editing the data for interference particularly difficult was that most of it was at a very low level. The solution was to develop a multi-pass algorithm that compared each data sample to successive moving averages of the edited data. This technique is described in detail elsewhere[1]. The ER-2 MTP has never experienced this level of interference in the past, and it was not present on the transit flights. Its source was never identified, but it might originate from ground-based radars. Low-level interference was also seen in the DC-8 MTP data, but much less frequently.

2. Nav Data Recorder Pressure Altitude Errors

The second problem -- errors in the ER-2 NDR data -- was perhaps more serious. MTP data is normally calibrated by comparison with radiosonde data near the ER-2 flight track. When these comparisons were made for CAMEX-4, larger-than-normal differences in temperature were noticed. Based on past experience, it was suspected that this might be because the ER-2 pressure altitude was in error, which would cause the temperature comparisons to be made at different, rather that the same, altitude. This turned out to be the case, and the error in pressure altitude ranged from 200-600 meters. Errors this large would have a significant impact of MTP retrievals, and presumably this will affect other ER-2 experiments as well. Examination of SOLVE data from the winter of 1999-2000, showed that these errors have existed for at least two years. The basic problem is that no one is responsible for maintaining the ER-2 NDR sensors.

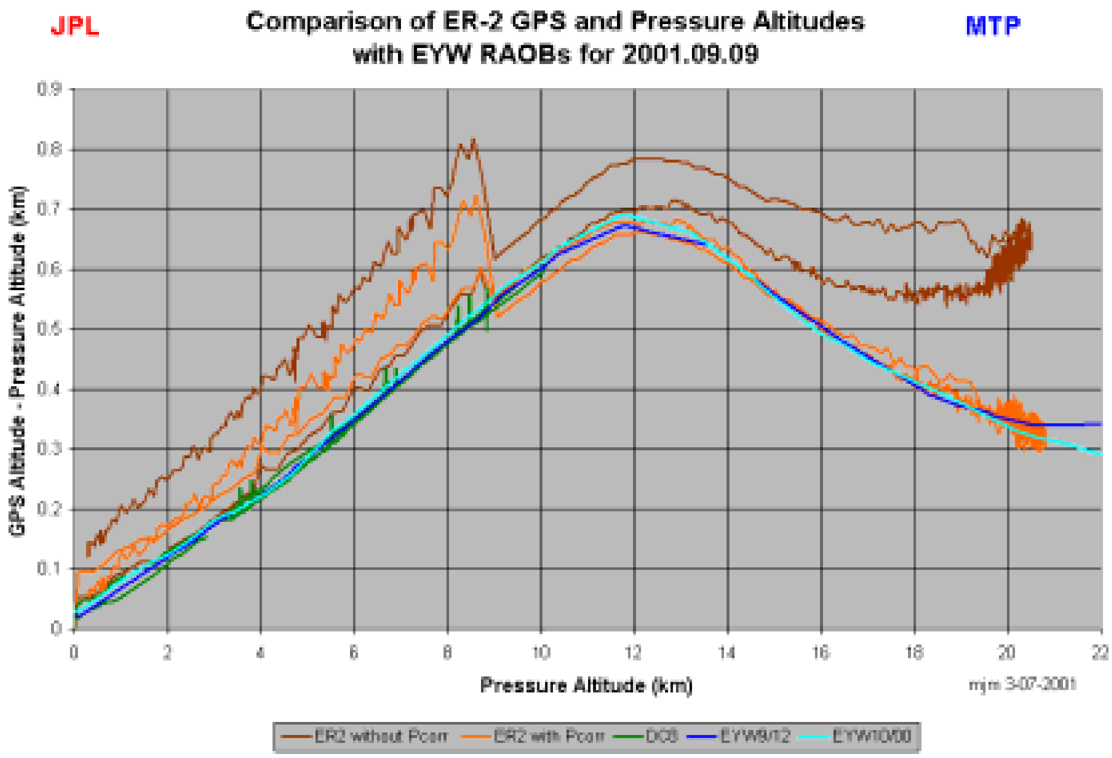

Figure 1. An example of how radiosonde data can be used to correct the ER-2 NDR pressure altitude. The brown trace is the uncorrected ER-2 NDR data, and the orange trace is the corrected data. Key West, FL, radiosondes launched before and after the ER-2 flight are shown in the two shades of blue.

By studying the behavior of the difference between geometric altitude (**Zg**) and pressure altitude (**Zp**), (that is, **Zg-Zp**), for the NDR compared to radiosondes and dropsondes, the following expression was been derived for the corrected pressure altitude (**Zp'**) in terms of the NDR pressure altitude (**Zp**):

Zp' = *fPtoZ*(*fZtoP*(**Zp**) + **Pcorr**) + **UTcorr** * (**UT**(s) - **UTtakeoff**(s))/3600 + **Zoffset**

where the pressure correction (**Pcorr**), the temporal correction (**UTcorr**), and the pressure altitude offset (**Zoffset**), vary from flight to flight, and are summarized on another web page[2] for each flight . **UTtakeoff** is the Universal Time that the ER-2 launches, **UT** is the Universal Time of the current NDR sample, and *fPtoZ*(p) and *fZtoP*(Z) are functions that convert between pressure and pressure altitude, and pressure altitude and pressure, respectively, using the US Standard Atmosphere 1976[3] . (All altitudes are in km and all pressures are in hPa.)

Although this technique of using the difference between geometric (**Zg**) and pressure (**Zp**) altitude to correct the NDR data might be expected to work on relatively localized flights, such as the KAMP flights, it is somewhat questionable on flights over large distances, such as most of the hurricane flights. In the latter case, the offset between **Zg** and **Zp** almost certainly changes. Fortunately, dropsondes were available for most of the hurricane flights and reasonably good corrections could be derived for at least the portion of the flight spent over the hurricane.

3. Nav Data Recorder Temperature

Based on radiosonde comparisons[4], the error in the reported NDR temperature is: -1.51 +/- 0.36 K; that is, the NDR temperatures are too warm.

It cannot be emphasized enough how important it is that a reliable and accurately calibrated meteorological system be flown on all atmospheric research missions, since so many instruments, if not all, rely on these fundamental parameters for their data analysis and interpretation. Accurate temperatures and pressures are also essential for assimilation of aircraft measurements into various meteorological models.

Mesoscale Temperature Fluctuations and Convectively-Excited Gravity Waves

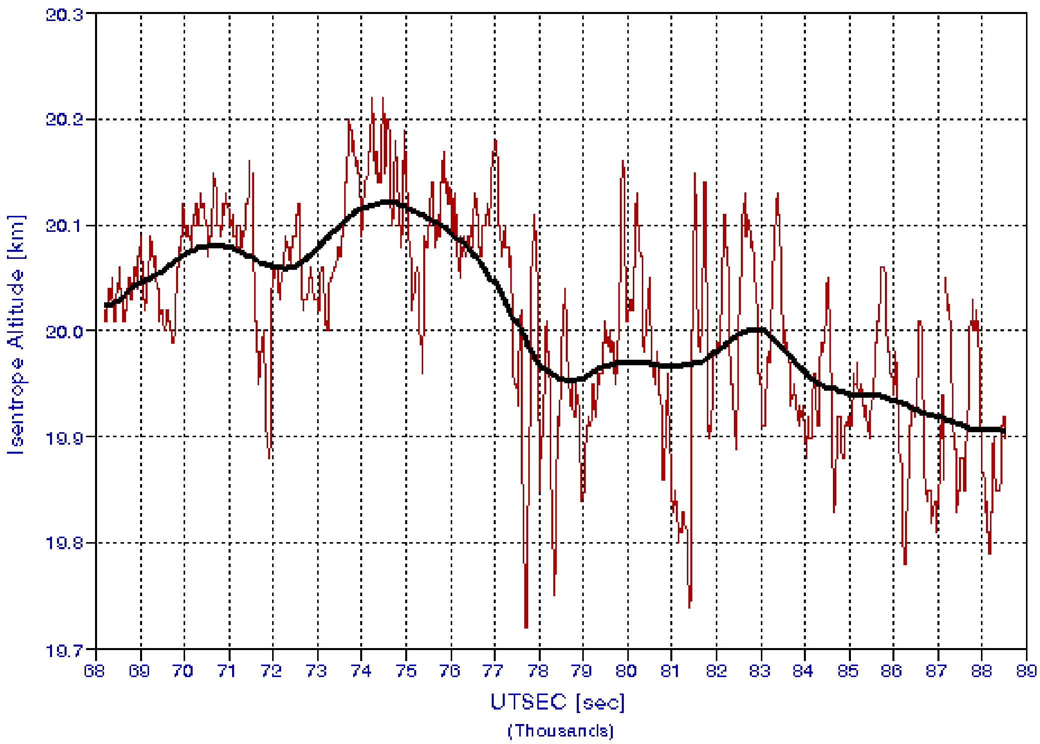

Figure 2. The 480 K isentrope surface during the ER-2 flight of 2001.09.24 over Hurricane Humberto.

Particular interests of the MTP team are the parameterization of mesoscale temperature fluctuations and the study of wave phenomena associated with convection. **Figure 2** shows the 480 K potential temperature (or isentrope) surface during the September 24, 2001, ER-2 flight through Hurricane Humberto. Low-amplitude waves are clearly present at ~77, ~82 and ~88 ks UT, the approximate times that the ER-2 transected the eye of this hurricane. The solid black trace is a 400 km double boxcar moving average used to simulate the synoptic scale structure. To study mesoscale structure, we define the Mesoscale Fluctuation Amplitude (MFA) as the full-width at half-maximum of the histogram of mesoscale fluctuations from the synoptic scale structure. For flights in summer over tropical oceans, we expect MFA = 100 meters, based on more than a decade of MTP observations. During this flight MFA = 120-130 meters, which is significantly larger than what is expected in the absence of hurricanes. Although the waves show up in the wings of the MFA histogram, they do not significantly affect the MFA value itself because statistically they represent only a small fraction of a flight. Currently, most numerical weather models do no include any parameterization for this mesoscale structure, but such structural parameterization can be important in some situations.

First-time Measurement of the 2-D Temperature Anomaly in a Hurricane

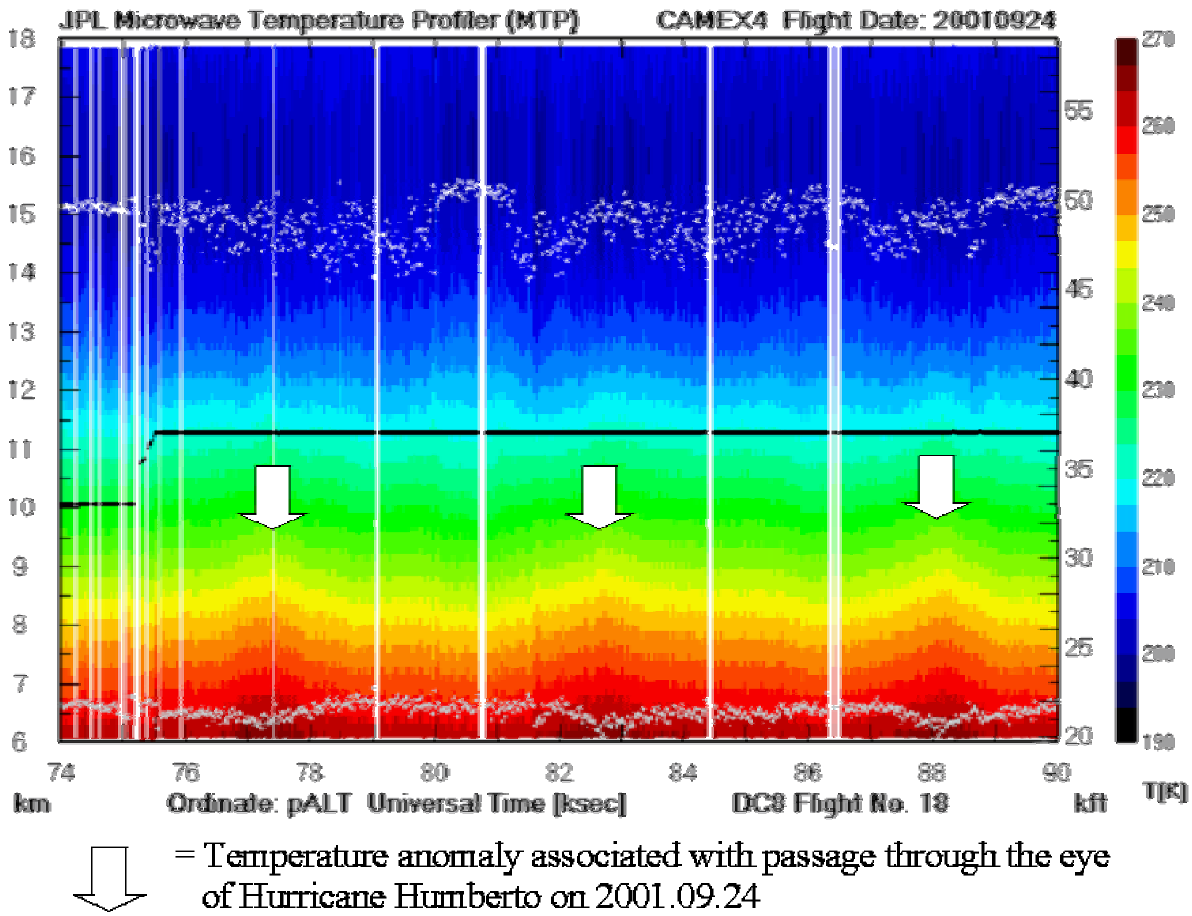

Figure 3. An example of a DC-8 MTP temperature curtain obtained during the Hurricane Humberto flight of September 24, 2001. The solid black trace is the DC-8 pressure altitude in km (left axis) and kft (right axis). The color bar to the right shows the temperature scale, and the tropopause altitude is shown as the upper white dots. The lower gray dots are a metric for the retrieval quality. It has a relative range of 2 km, and values less than 1 km are very good.

Figure 3 illustrates a DC-8 MTP temperature curtain taken during the September 24, 2001, DC-8 flight through Hurricane Humberto. The temperature anomaly of ~3 K associated with three transects through the eye of this hurricane are clearly evident, and this represents the first time ever that the two-dimensional temperature anomaly has been measured with such high spatial resolution. Stronger temperature anomalies were also seen on the flight a day earlier. The DC-8 data will be useful for converting LaRC/LASE absolute humidity measurements to relative humidity. Past experience has shown that this greatly improves the quality of the relative humidity determinations, in particular for sub- and super-saturation studies. These data will also be very useful in initializing numerical forecast models, and assessing their performance improvement.

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References

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