11 January 2015

TO: WINTER data-processing file
FROM: Al Cooper
SUBJECT: Data review: Using the 'Review.R' program

1 General description

This program uses a set of functions to make plots that are designed to provide a starting point for quality assessment for C-130 projects, esp. WINTER. This structure makes it easy to change the set of plots for a particular project, to refine the time range for plots, to re-generate a subset of the plots, to add new plots, and otherwise to tailor the output to project and personal needs. This memo shows typical output from the program, suggests how each plot should look and how to spot problems, and provides a record of how output should look when systems are functioning properly

The program can be used in different ways. The simplest is to source("Review.R") from an R console, including the console in RStudio. The program asks for a project and flight, uses a standard set of plots or allows a user to change that set interactively, and then produces a PDF file that is a concatenation of the plots produced. PNG files could also be produced and would provide a much smaller output size, but PDFs have the advantage of maintaining quality when magnified (and are also easier to concatenate) so that has been selected even though that format produces large files (of typical size 10 MB).

Other ways to use the Review.R script and routines include:

1. After running the script, the individual plot functions are available and the assignment of plots to the PDF file has been cancelled, so you can re-generate any selected plots for console or RStudio display, optionally with variable or time-segment modifications.
2. 'Review.R' can be incorporated into an Rnw document where comments can be added to provide a record of problems identified or needing further study, and this might be useful documentation to preserve and distribute. This document is an example of that use.
3. It may be useful to make the plot functions in this routine available as a package so they can be used easily without needing the full structure of 'Review.R'

2 Running the program

When the program is run as an R script, it will interactively ask for a flight name, and description of the plots desired. The flight name should have the format "rf09" (without quote marks). The plot description can be 0 (all plots), -1 (project default set), or a series of plots in the format "c(3,5,7)" (without quotes). The start-up should look like this:

```
## [1] "Project is FRAPPE"
## Flight is rf09; CR to accept or enter new flight name (rfxx format):
## [1] "Flight is rf09"
## [1] "Plots desired: CR to accept, or enter new spec"
## new spec: (0 => all, -1 => project set, n => plot n, can be a sequence):
##  [1]  1  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 19 20
## [1] "/home/Data/FRAPPE/FRAPPErf09R.nc"
```

3 Interpreting the plots

These are short descriptions of the plot functions. In each case, functions generate the plots, often with multiple plots per function:

plot 1: construct flight track with map
plot 2: construct one-per-hour track plots
plot 3: plot all temperatures, one plot
plot 4: plot differences, individual pairs of temperatures
plot 5: humidity
plot 6: ambient pressures
plot 7: dynamic pressure; also TAS and MACH
plot 8: total pressure (static + dynamic)
plot 9: wind
plot 10: Schuler oscillation
plot 11: attack, sideslip
Plot 12: IRU comparisons
plot 13: IRU continued, ACINS, VSPD
plot 14: UHSAS
plot 15: CN, FSSP, CDP, F300, CONCP
plot 16: DBAR (mean diameters) and PLWC (liquid water content)
Plot 17: all-flight Skew-T
plot 18: plot skew-T for individual climbs and descents:
plot 19: potential-temperature plots
plot 20: CDP/SP100 size distributions

It is also possible to generate a subset of the plots, and that will also affect the plot numbering. In the following description of the plots, proper figure numbers are used for this example, but the numbering may change. The sequence, however, should remain the same.

The plots in this memo are reduced in size compared to the PDF file that is generated by running Review.R. When using this guide, it may be useful to use the full-scale plots because some of the legends and other features are hard to read at this reduced size. For each plot, a few-paragraph description is provided. The intent of those descriptions is to suggest how to interpret the plot as an indicator of potential problems. Therefore, most of the descriptions give expected tolerances for differences among sensors or other quantifiable departures from expected behavior that should trigger further investigation of the measurements. That is the intent of these plots: To provide quick indications of problems so that they can be investigated further, usually with other tools. Users should pay particular attention to the tolerances denoted on many plots by dashed lines and to the titles where mean differences between redundant measurements are listed. Once a “good” set of plots is obtained for a project, that set should be used as a reference for future flights because changes in the patterns, even more than tests against specified tolerances, are the best indicators of problems.

Note that, because this memo is written before the start of WINTER, FRAPPE measurements are used for the illustrations. In particular, FRAPPE rf09 was used to generate these plots. An undated example will be needed once WINTER data become available.

Flight track: The first plot function generates two flight-track plots, Fig. 1 a plan-view and Fig. 2 showing height-vs-time. These provide general context that may be useful when looking at the remaining plots, but they can be suppressed if desired because they usually don’t indicate problems with data quality. In some cases the flight track becomes overlaid to such an extent that it is hard to use, so for such cases it may be useful to enable nplot=2, which plots separate flight tracks for each hour of flight. Normally this is disabled as not particularly useful for quality-review of the data.

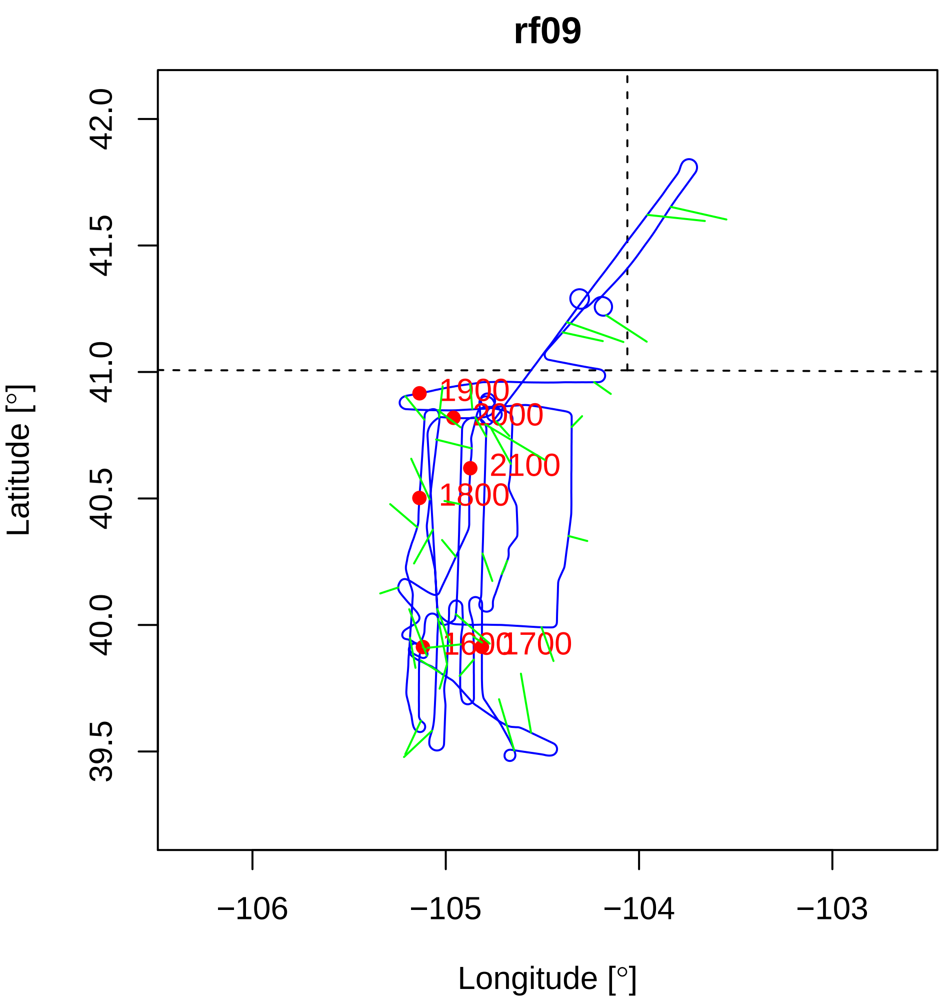

Figure 1: Flight track for FRAPPE flight rf09 on 2014-08-07, 152619–212740 UTC

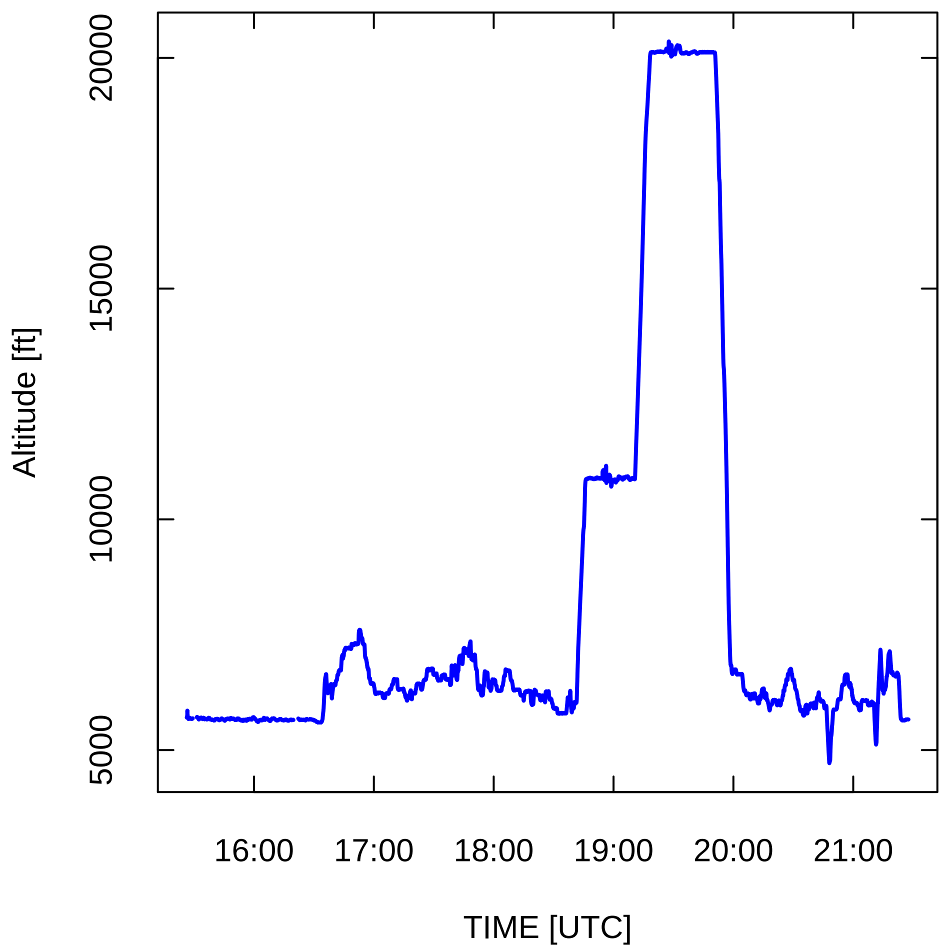

Figure 2: Height vs. time for FRAPPE flight rf09 on 2014-08-07, 152619–212740 UTC

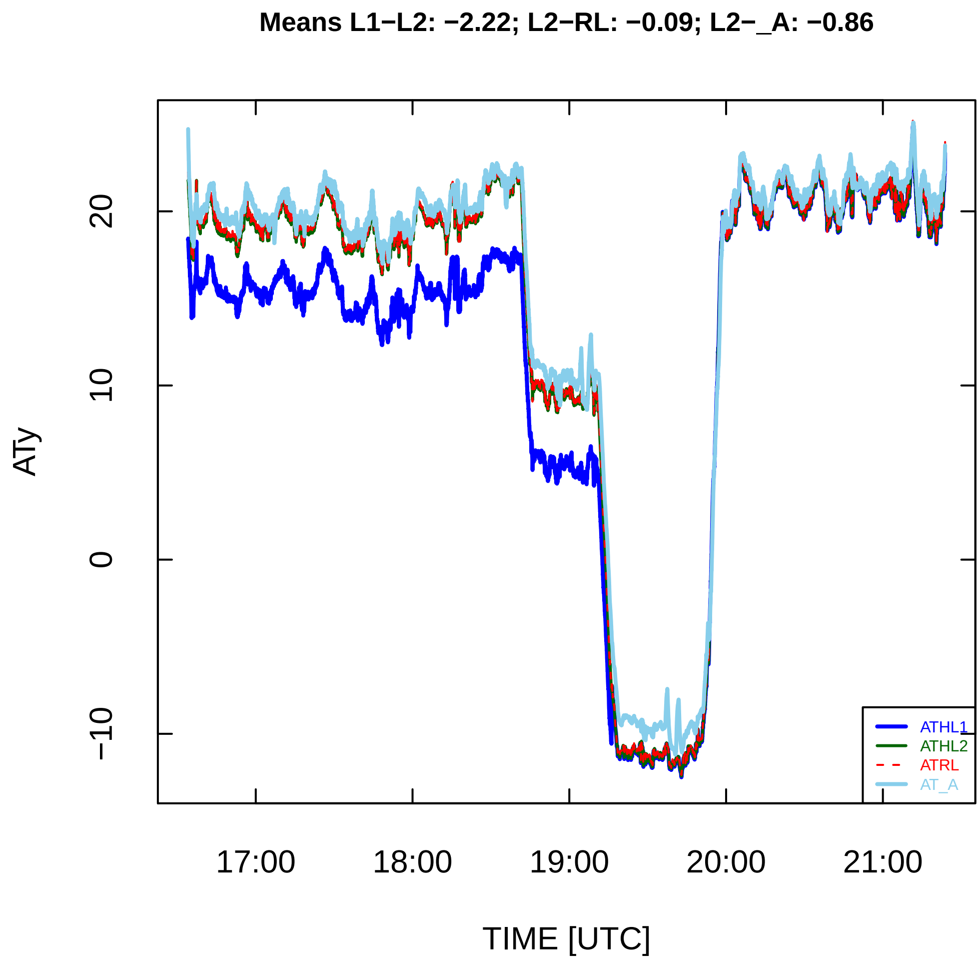

Figure 3: Air temperature (ATy) determined from the different temperature sensors.

Air temperature: Figure 3 shows the time history of measured air temperature from the various temperature sensors, and Fig. 4 compares these sensors in pairs of measurements. After all corrections, these should agree to within about 1°C; claimed uncertainty is about 0.3°C. In particular, ATHR1 and ATHR2 should agree to within about 0.3°C. AT_A, the temperature from the aircraft avionics system, will often show larger scatter; this should not be considered a problem unless it exceeds about 2 C. It appears mostly because that measurement has slow response, either from filtering or delays or both, and this usually accounts for the errors. It is common to see two lines on the AT_A-vs-ATHL2 plot for the same reason; one is from measurements during climb and the other from those during descent. [1]

[1] For this FRAPPE flight, the plot of ATHL2 vs ATHL1 and the history plot both indicate problems with ATHL1 during the first part of this flight, with the problem resolved about midway through the flight. Also, AT_A is clearly offset from the other measurements for measurements around -10°C.

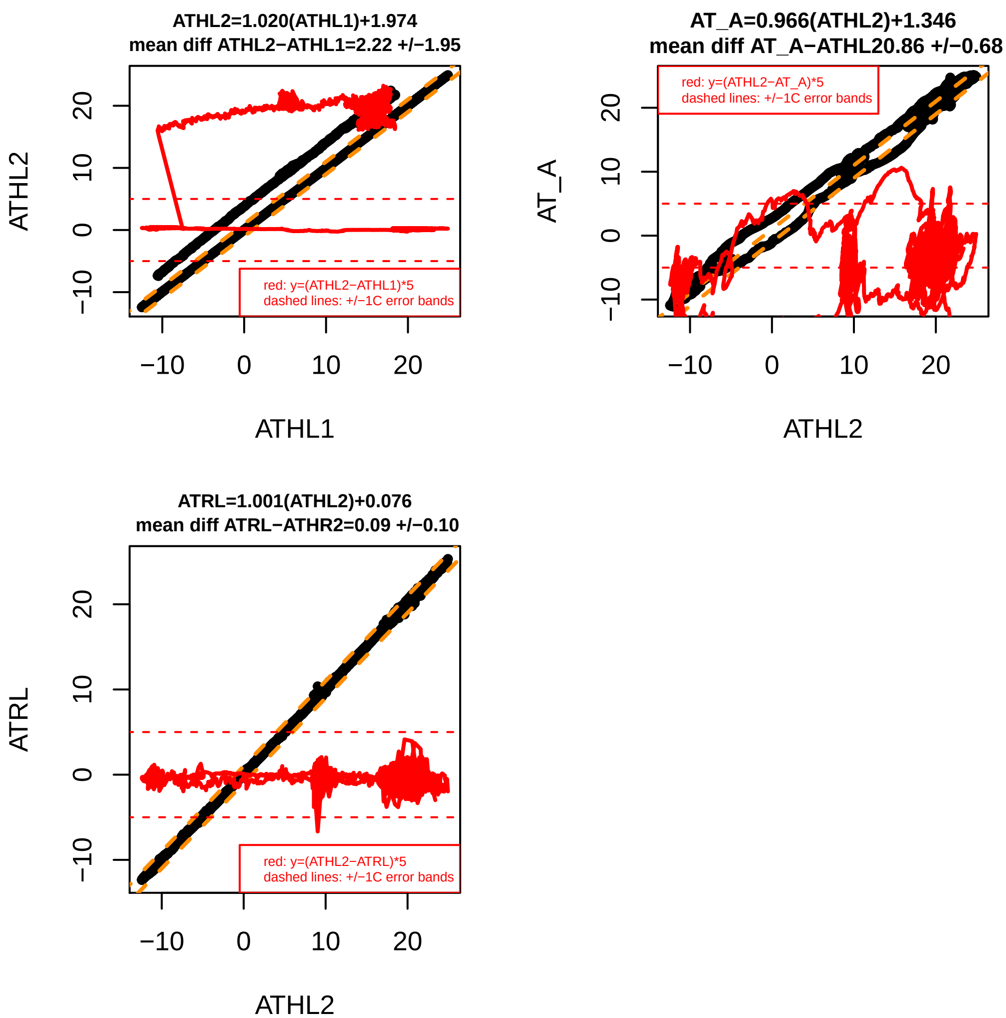

Figure 4: Air temperature (ATy) determined from the different temperature sensors.

Humidity: Four plots are generated by function RPlot5 (). The first (Fig. 5) shows the history of various measurements of dew point, including those from sensors like the UV hygrometer or the VCSEL for which dew point must be calculated from the direct measurements.

Agreement among these measurements to within about 1°C is good. It is common to have problems during and after descent, like that shown near 20:00 on this plot, where the dew-point sensors overheat in an effort to remove thick condensate that forms when the temperature increases rapidly. ATX is also plotted on this history to provide a reference: When the dew point temperature exceeds the temperature, even by a few degrees, there is very likely a problem because this almost never occurs in reality. There are some significant differences also at maximum altitude and lowest dew point (about 19:25), mostly in this case because of disagreement between the UV hygrometer and the dew-point sensors. The UV hygrometer does not show the over-heating problem that the dew-point sensors have at about 20:00. The differences between the mean values for the dew-point sensors (listed in the title of the plot) should usually be less than about 0.5°C.

The second plot (Fig. 6) compares the measurements to one selected as a reference, here DP_DPB. The measurements from the UV hygrometer are shown in this plot in small transparent symbols to avoid complete obscuration of DP_DPT. The overshoot problem appears in this plot in the extension to high dew point, above 15°C, values that appear unrealistic and are above anything measured by the UV hygrometer. The differing rates of recovery of these two sensors lead to the rectangular pattern of blue dots in this plot becayse DP_DPT recovers earlier than DP_DPB. The departure from the ± 1°C error band at high level is not meaningful and not a concern because both sensors are malfunctioning here. Other related errors where the dew-point sensors are slow to respond may result in horizontal lines like those for DPy=-5 and -8 in this plot. This is fairly typical behavior for the dew-point sensors on the C-130.

Figure 7 shows the cavity pressures in the dew-point hygrometers. These are typically close to the ambient pressure (within about 10 hPa) and slightly above PSFC, as for this case. They are not necessarily the same because the sensors are oriented slightly differently, but departure from the behavior shown may indicate that the entrance holes are plugged or the pressure sensors are malfunctioning.

The final humidity plot, Fig. 8, shows the history of water vapor pressure, mixing ratio, and relative humidity. Excursions above relative humidity of 100% should be rare except in over-heating events like that near 20:00. The dashed cyan line in the top segment of this plot shows the water vapor pressure that corresponds to equilibrium at the air temperature measured by ATX. In the top two plots, the traces will usually overlap at the plot resolution for normal operation. In this case, the perfect overlap between MR and MR_UVH is false because MR_UVH was calculated with erroneous dependence on EWX instead of EW_UVH.

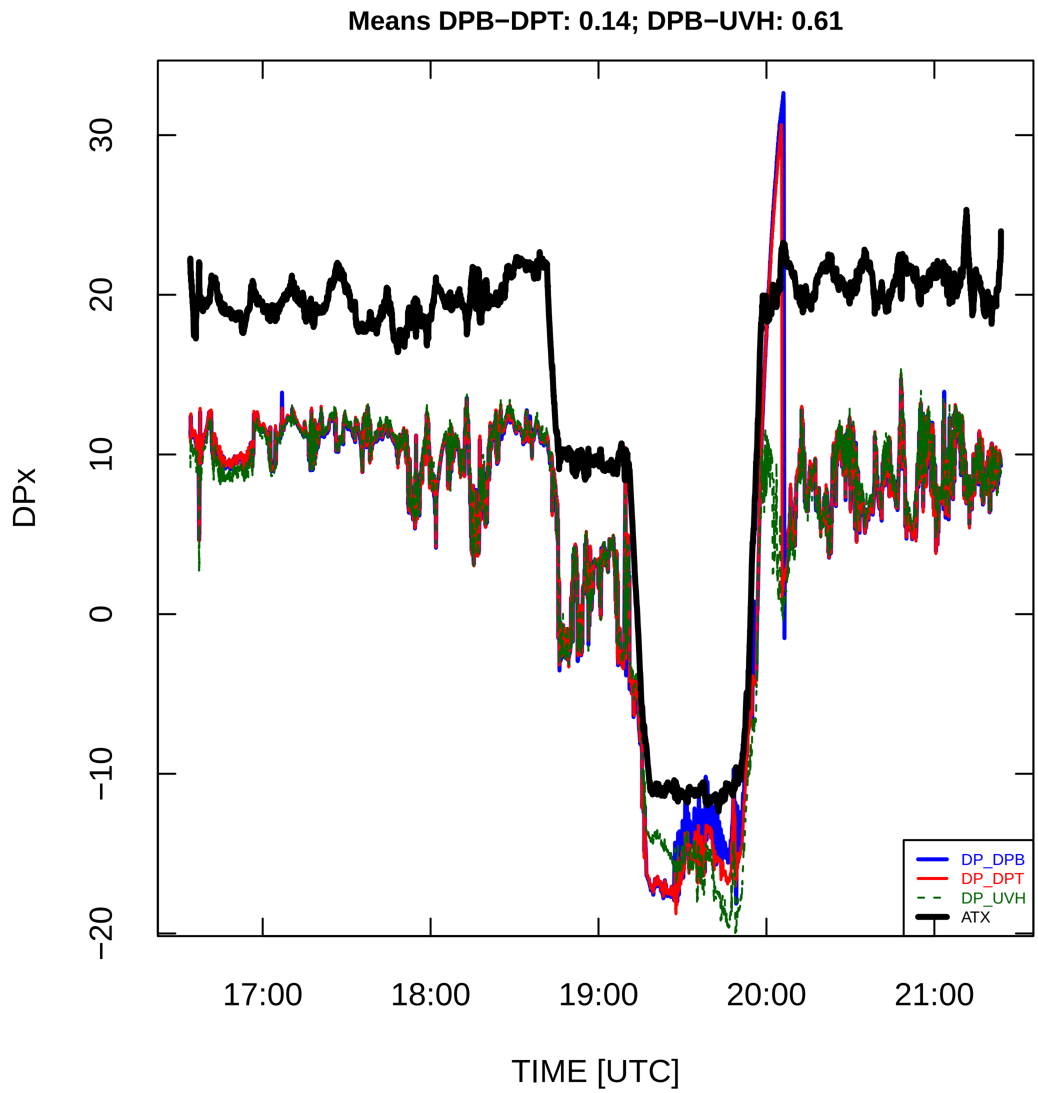

Figure 5: Measurements of dew point from the available measurements.

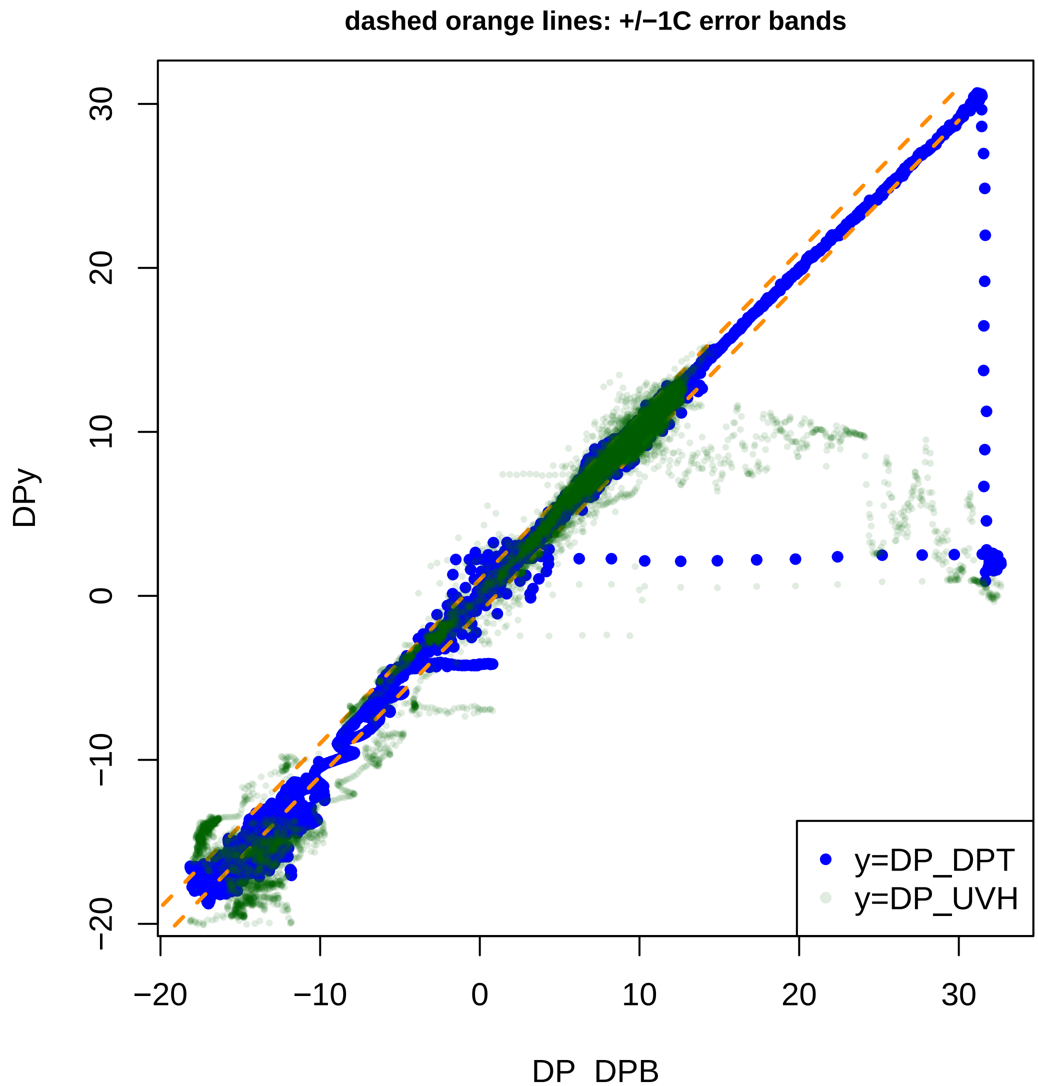

Figure 6: Comparison of available measurements to DP_DPB as a reference.

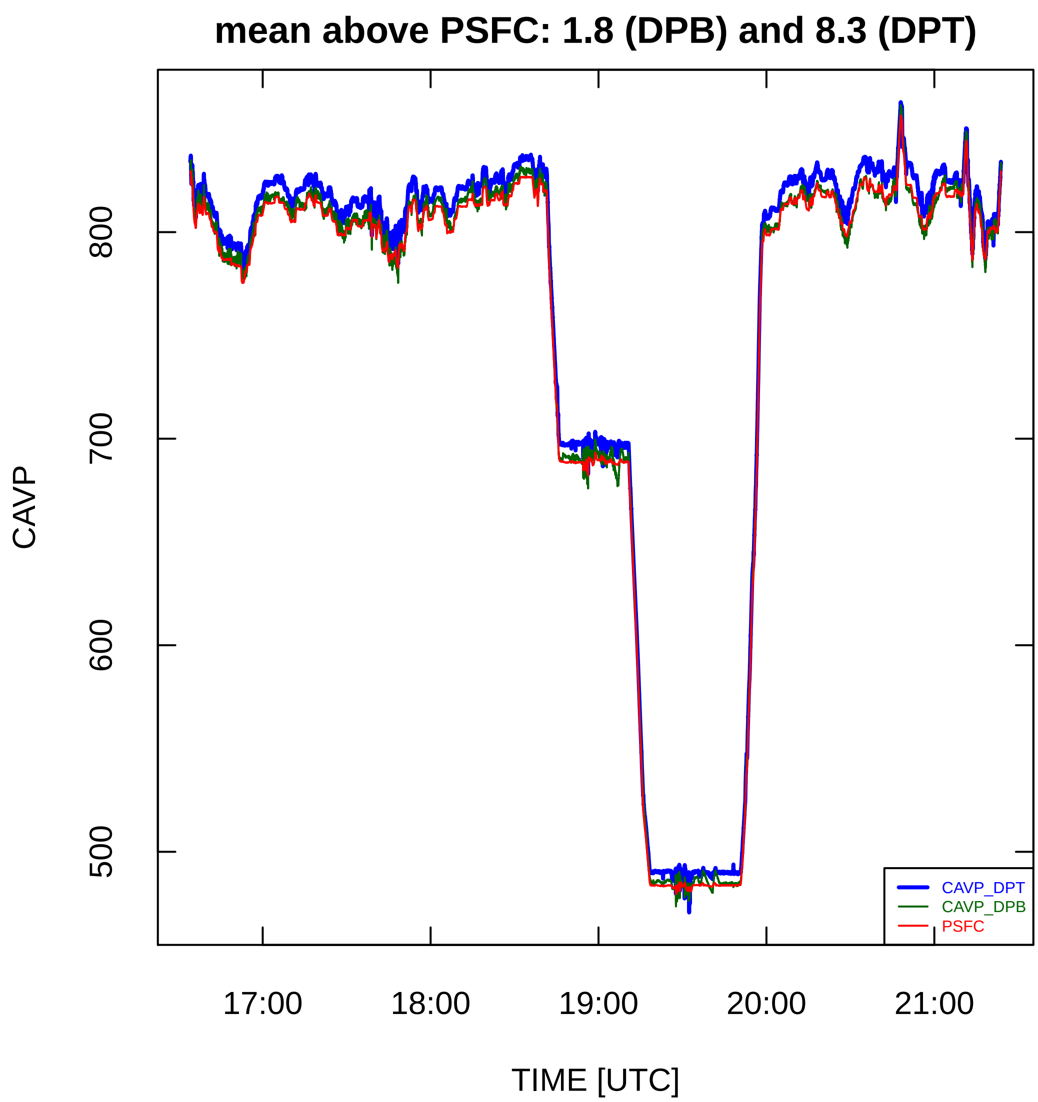

Figure 7: Measured pressures in the cavities of the dew-point sensors, plotted with the ambient pressure (PSXC) for reference.

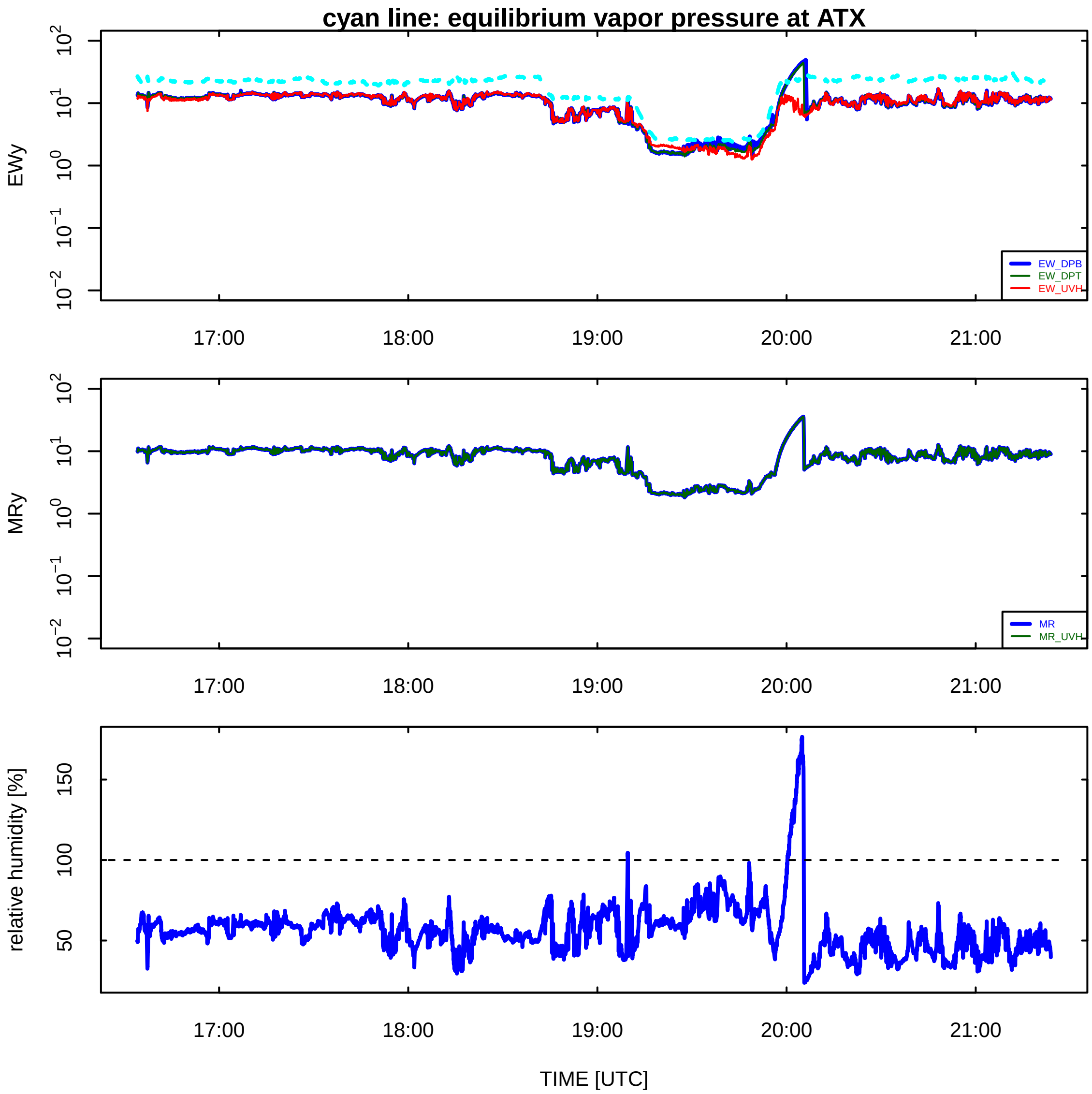

Figure 8: Measurements of water vapor pressure, mixing ratio and relative humidity.

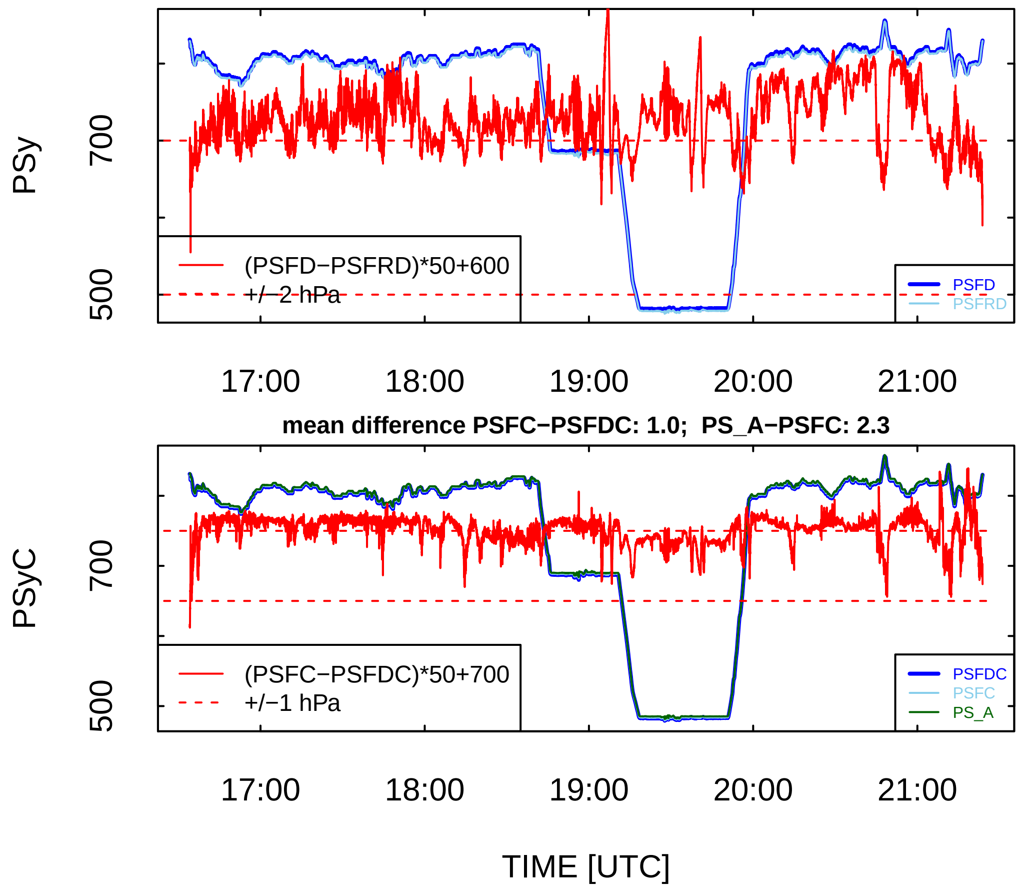

Figure 9: History of available pressure measurements, both uncorrected (top) and after application of the LAMS-derived pressure corrections (bottom).

Ambient or static pressure: Figure 9 compares the redundant measurements of ambient pressure, uncorrected (top panel) and corrected. The estimated uncertainty in pressure measurements is about 0.3 hPa, so PSFDC and PSFC (the redundant pressure measurements after correction) should agree to within about this tolerance.[2] A somewhat larger but still 1–2 hPa difference may be present for PS_A; the LAMS calibration consistently indicated a small error in that measurement. The difference between mean PSFC and PSFDC, the corrected measurements, should be less than about 0.3 hPa when all systems are working properly. The uncorrected measurements (top panel) are expected to differ because correction for different static defects are applied to different sensors. Therefore a better indicator of problems is departure from the typical offset shown here.

[2]In this example from FRAPPE flight 9, the differences are well outside that tolerance and indicate a problem.

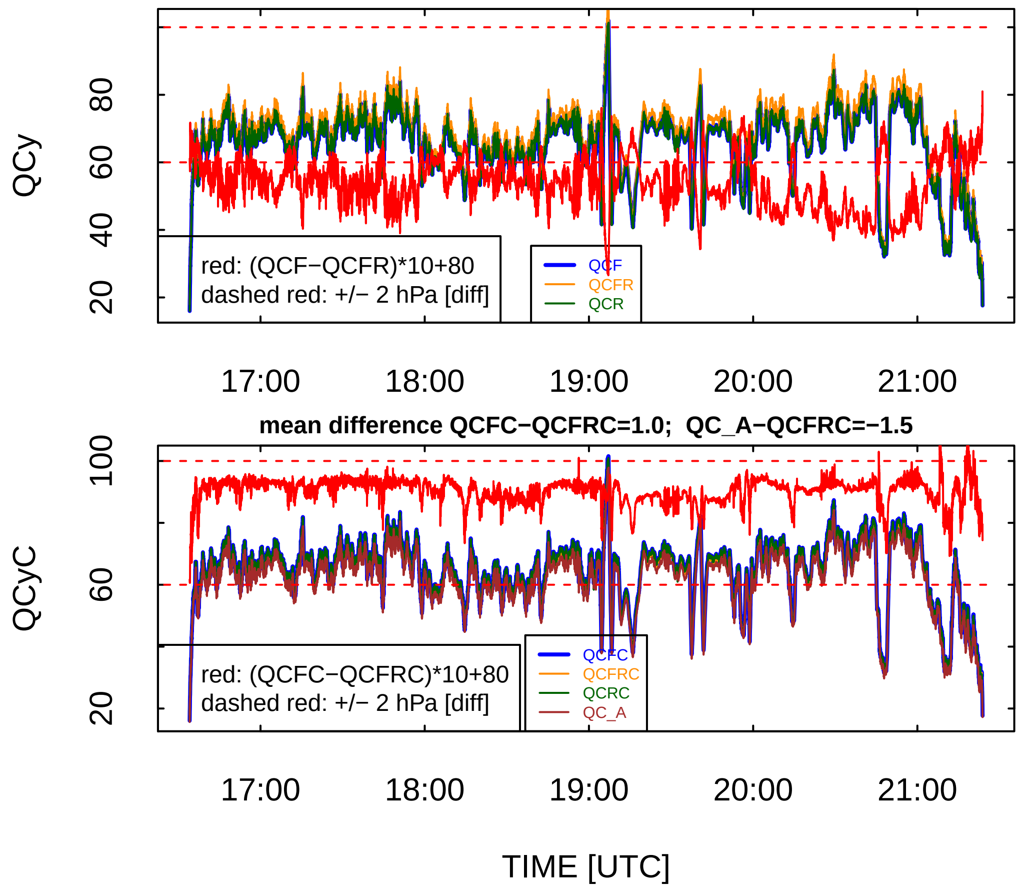

Figure 10: History of available measurements of dynamic pressure, both uncorrected (top) and after application of the LAMS-derived pressure corrections (bottom).

Dynamic pressure: Measurements of dynamic pressure, similar to those from the ambient pressure, are shown in Fig. 10. The uncertainty in these measurements should be about 0.3 hPa, so the redundant sets QCFC and QCFRC (bottom panel) should agree within about this tolerance. As for PSFD and PSFRD, an offset is expected but that offset should remain consistent. Any significant change should be an indicator of a problem.[3] An additional plot, Fig. 11, shows two measurements dependent on the dynamic-pressure measurements, TAS and MACH. Only one TASF is available from the pair of measurements QCF and QCFR, so these aren't compared here, but TASR and TAS_A are redundant measurements that, although of lower quality compared to TASF, should remain without about a hPa of it.

[3]In this case, FRAPPE flight 9, the difference in the bottom panel (1.0 hPa) is outside expectations and indicates some problem with either QCFC or QCFRC.

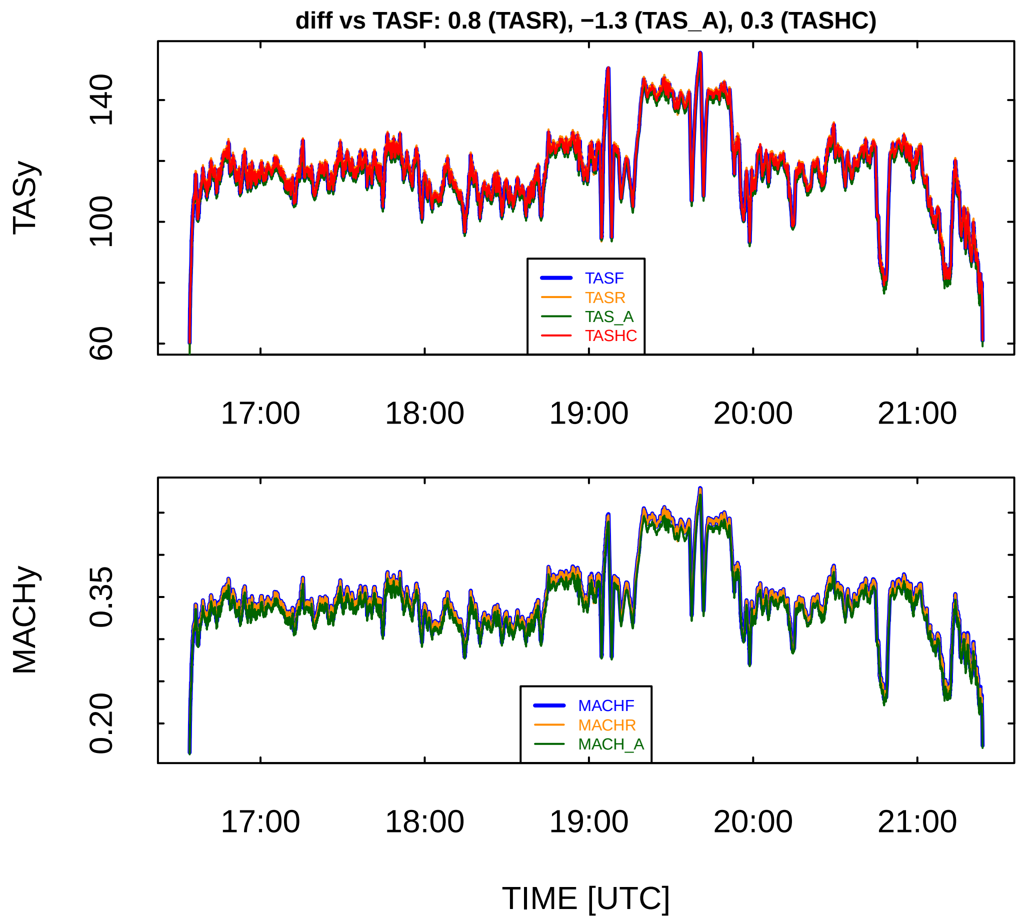

Figure 11: History of redundant measurements of true airspeed and Mach number.

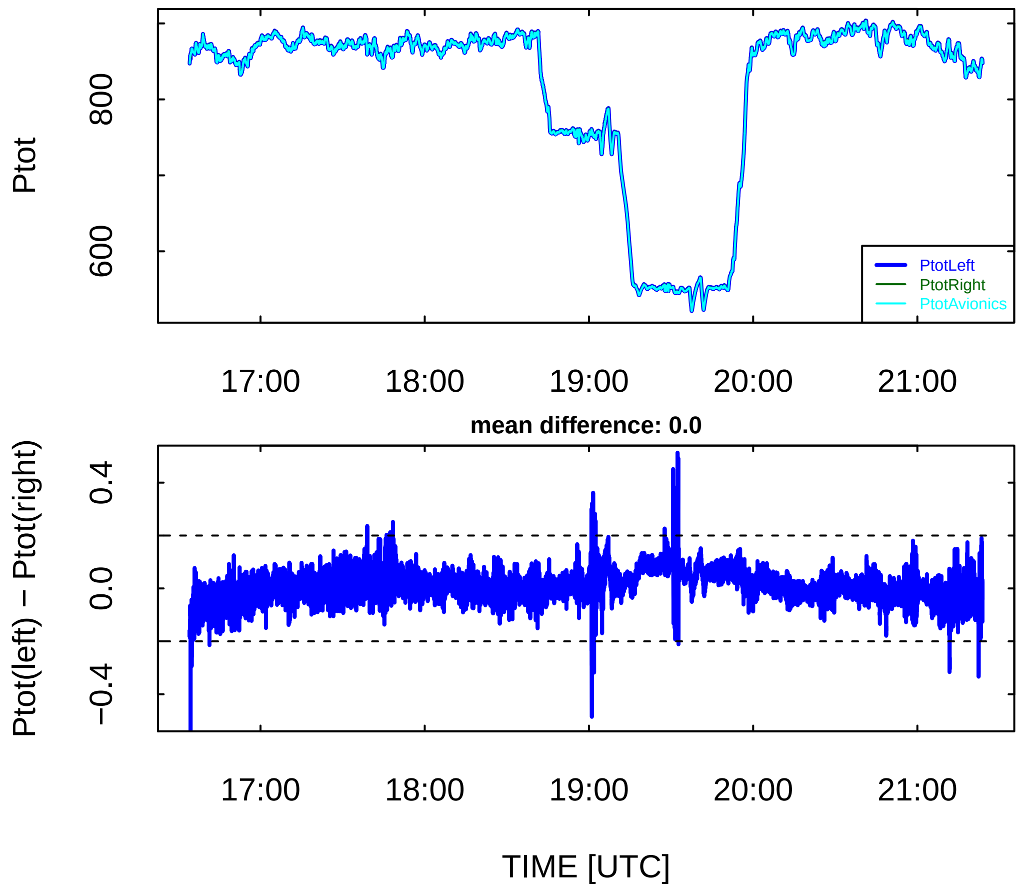

Figure 12: Total pressure measurements obtained by adding the independent pairs of measurements PSFD+QCF and PSFRD+QCFR (i.e., the uncorrected measurements). Exactly the same plot is obtained for the corrected measurements because the pressure-correction function is applied to pairs of PS and QC measurements with opposite sign, positive for PS and negative for QC.

Total pressure: Adding the measurements of dynamic and ambient pressure gives the total pressure measured at the input of a pitot tube. Two independent systems provide this measurement on the C-130, and the avionics system provides a third measurement. These are compared in Fig. 12. The difference between research-system measurements in the bottom panel should be mostly less than 0.2 hPa and, on average, less than 0.1 hPa, as is true of the measurements used for this plot.

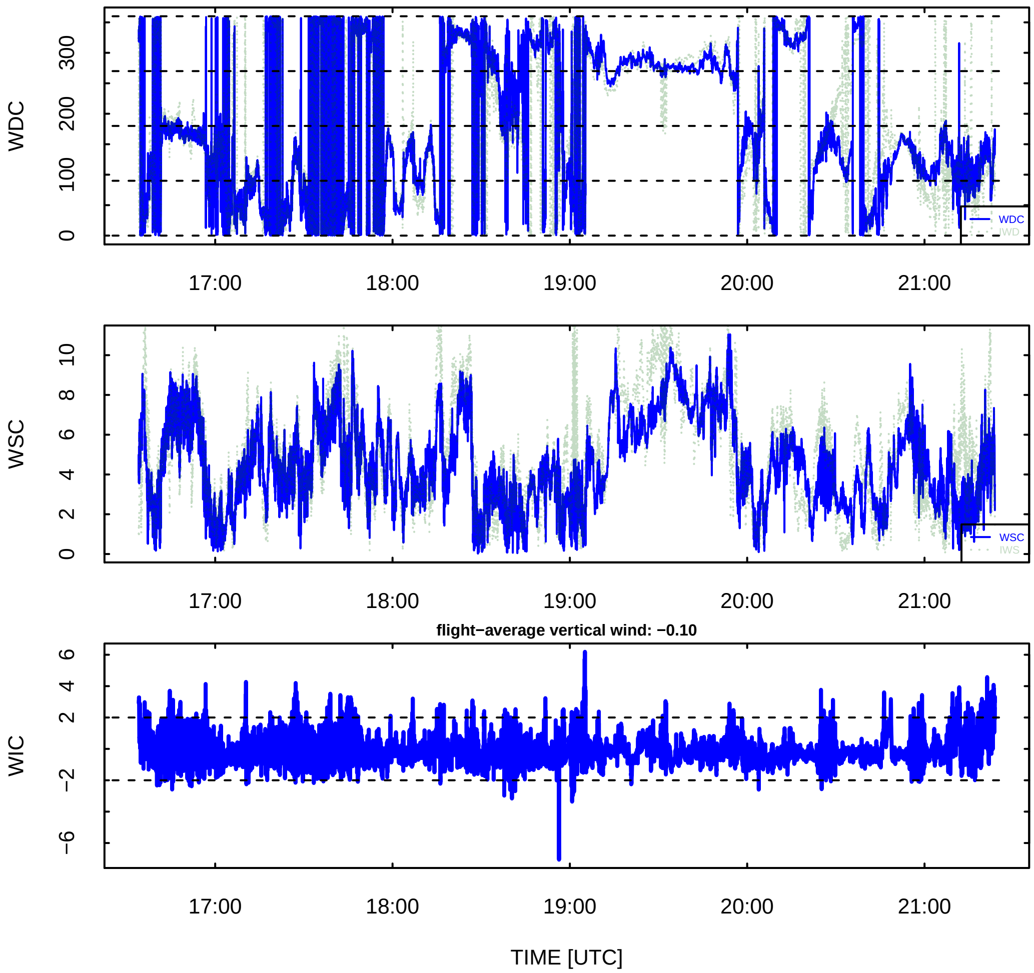

Figure 13: Wind measurements, horizontal (WDC/WSC) and vertical (WIC). See the next plot for the horizontal wind plotted in terms of easterly and southerly components.

Wind: The measurements of horizontal and vertical wind are shown in Fig. 13, and also in terms of easterly and southerly components in Fig. 14. Mean vertical wind averaged over the full flight should be close to zero, usually with absolute magnitude less than 0.3 m/s. The horizontal wind measurements can be used to check for reasonable continuity without excessive noise, although when the wind speed is weak there may be substantial noise in the WDC measurements. Wrap-around from 0 to 360 causes vertical lines in this plot that can be more frequent when the wind direction is near 0 or 360. For this reason, the second plot, showing easterly and southerly components, can be a better indicator of continuity.[4]

[4] The components are calculated from WDC and WSC. When UXC and VYC were used, results were significantly different although these should be the same components. Calculation of these variables needs to be checked.

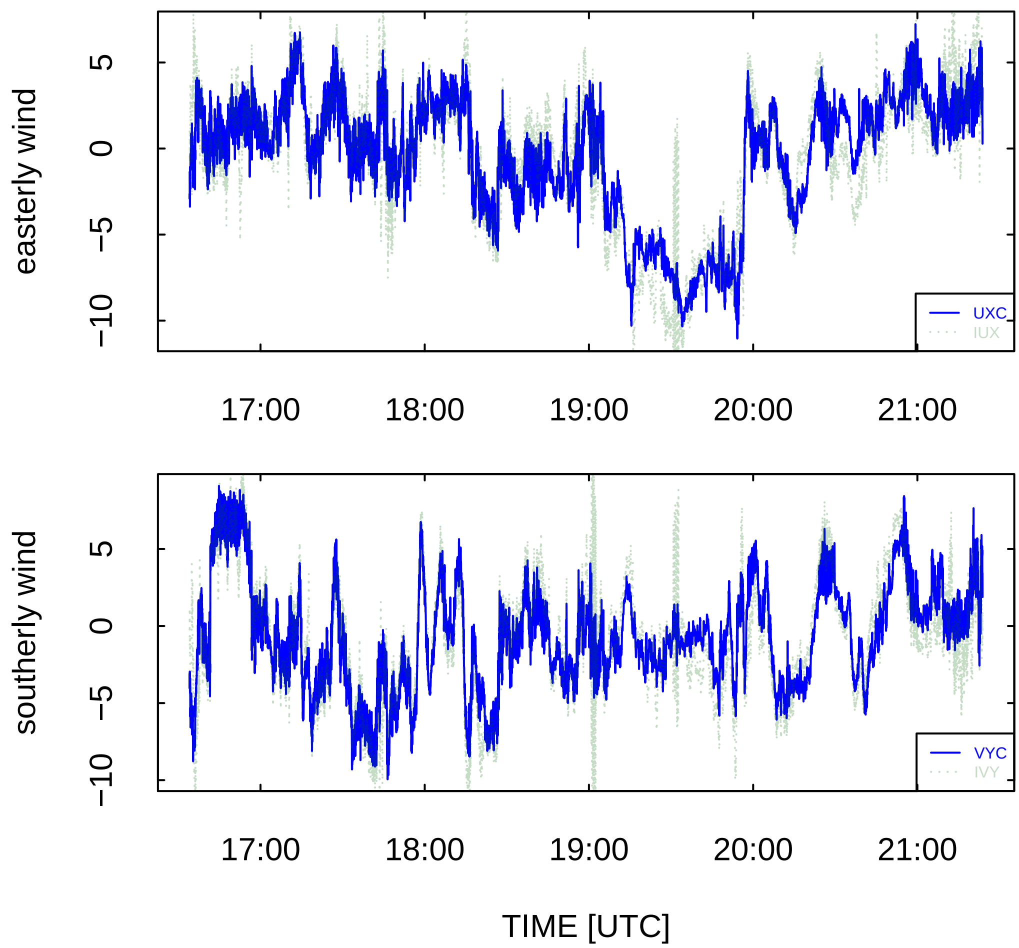

Figure 14:]
Easterly and southerly components of the horizontal wind [m/s]. The preceding plot shows the wind in terms of direction and speed.

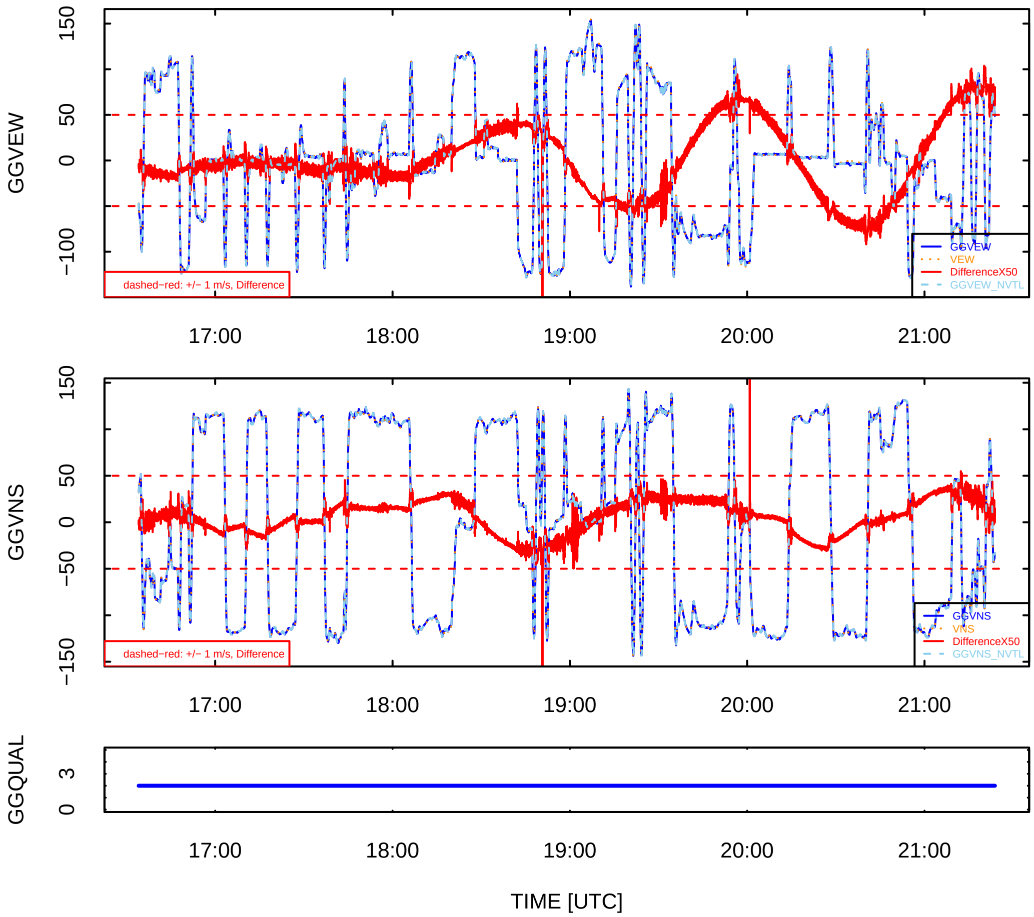

Figure 15: Comparison of ground-speed components measured by the GPS and IRU units (blue and dashed orange lines), along with the difference (red line). Dashed red lines show ±1 m/s limits.

Schuler oscillation: The IRU measurements of ground speed will usually have some error that varies in a Schuler oscillation with a period of about 84 min. The magnitude of this oscillation is usually less than a few m/s, and in the wind calculations this oscillation is removed by adjustment to the GPS measurements, but excessive amplitude or unexpectedly noisy measurements can indicate a problem worth investigating. Figure 15 shows the difference between ground-speed measurements from the IRU and the GPS and will usually show an oscillation similar to that in this example. The lowest panel in this plot shows the value of GGQUAL, which will be 5 for OmniStar reception from the Novatel GPS receiver, indicating highest-quality measurements.

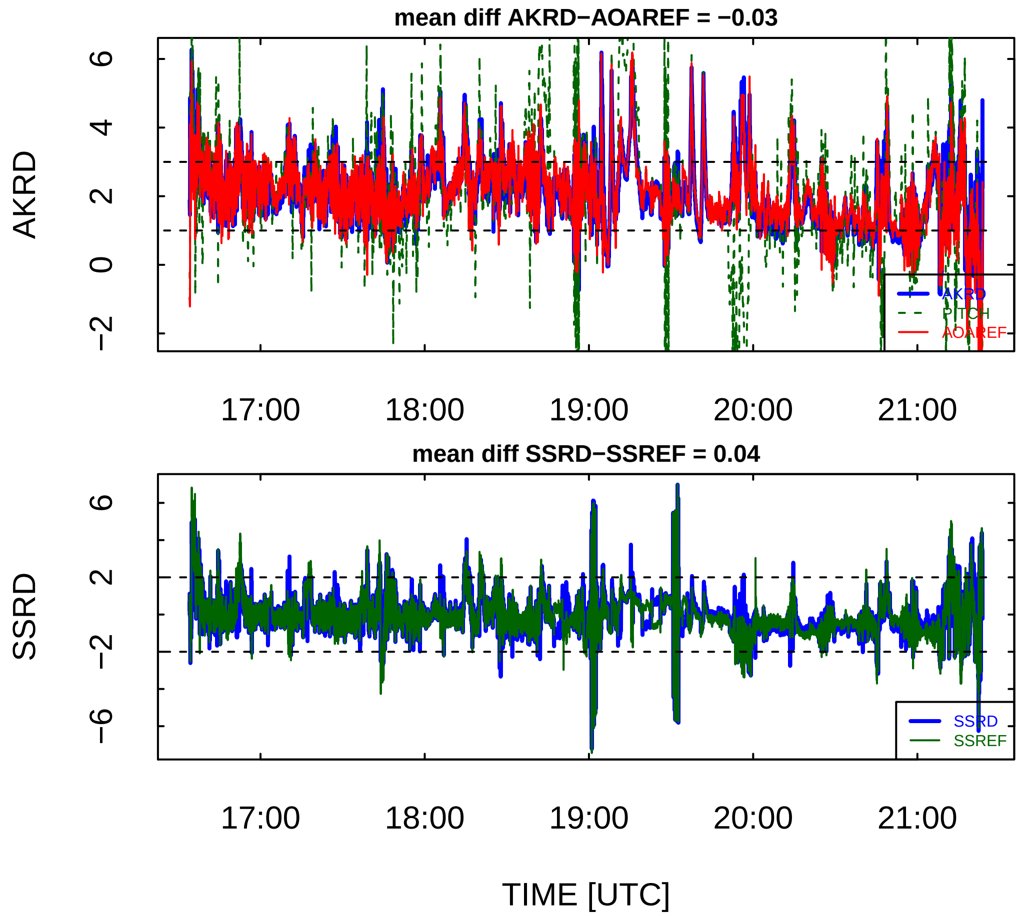

Figure 16: Measurements of the angles of attack and sideslip (blue traces, [deg.]), plotted with the reference values used for calibration that depend on the assumption of zero vertical wind or zero real sideslip not caused by wind gusts.

Angles of attack and sideslip: The sensitivity coefficients relating pressure differences on the radome to angle of attack and sideslip have been described in a separate memo (FRAPPEprocessing.pdf). That calibration used reference values of attack and sideslip (here plotted as AOAREF and SSREF) that would be valid measures of the angles of attack and sideslip if there were respectively zero vertical wind and zero sideways wind gust.

Figure 16 shows a comparison of the measurements to the reference values. If the calibration is valid, the blue and red traces in the top plot and the blue and green traces in the bottom plot should match in the mean, with occasional fluctuations caused by real wind gusts. PITCH is also shown in the top plot because, in the absence of both vertical wind and aircraft climb or descent, the pitch would match the angle of attack. For the C-130, the usual angle of attack is about $2\pm1^{\circ}$, so these limits are denoted on the top panel. Notice the gradual decrease in angle of attack during the course of the flight; this is normal behavior as the weight of the aircraft decreases. Plots like these are good indications that the radome calibration is valid. This is useful to monitor because there have been some unexplained changes in C-130 radome behavior, perhaps from changes in mounting alignment or from flow interference from small accretions of dirt near the radome ports.

Aircraft attitude angles: pitch, roll, heading The research IRUs provide redundant measurements of the attitude angles, so comparing them tests if they remain consistent. They should agree to within about 0.05° except for possible errors in alignment when the units are installed in the aircraft.

Figure 17 shows the measurements from the two inertial systems and also a magnified (red) plot of the differences between the two units (IRS1 value minus IRS2 value). Dashed red lines show the expected tolerances for these magnified differences. For pitch, typical values are about 2° as expected and the offset is about 0.03° between the two systems. Because this is so steady for this flight, it is probably an indication of a real difference in alignment, which should be considered if the primary unit used for wind calculations is changed. For roll, the mean difference is near zero. No average value is shown for the heading offset because the average is dominated by occasional large positive excursions, producing a large positive mean even though it appears that the baseline is about -0.25°as indicated by the dashed green line. This offset likely arises from misalignment to this extent on installation. When monitoring these measurements, consistency of these offsets is the primary criterion to use; the magnitude of the heading offset, for example, is not a problem unless it become necessary to use the alternate IRU in wind measurements.

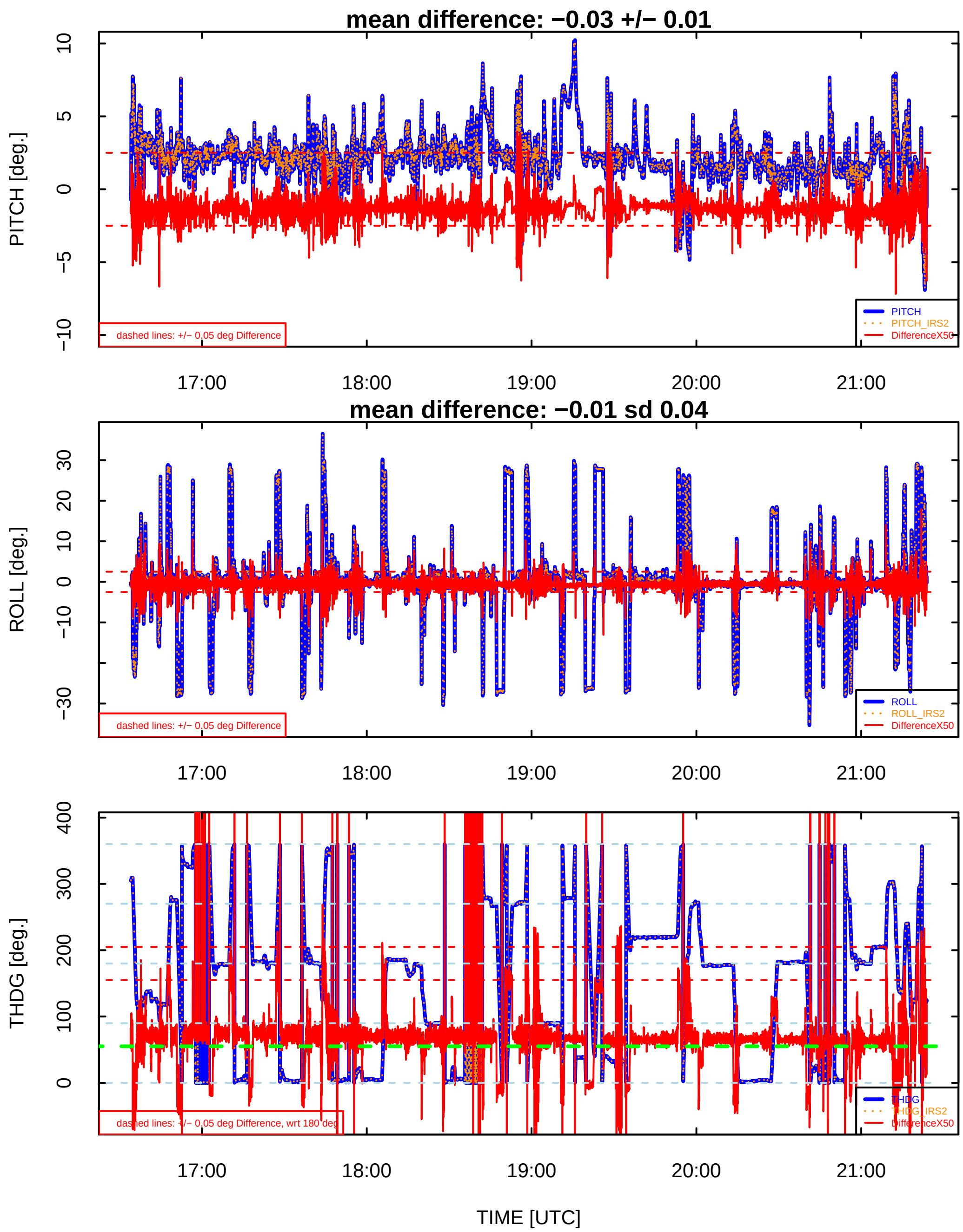

Figure 17: Comparison of attitude angles measured by the two duplicate research inertial systems on the C-130, with dashed reference lines indicating the uncertainty limits quoted by the manufacturer for the angle measurements. The red lines show the differences multiplied by 50 for pitch and roll and by 500 for heading, with a further offset of 180° for heading to center the difference plot.

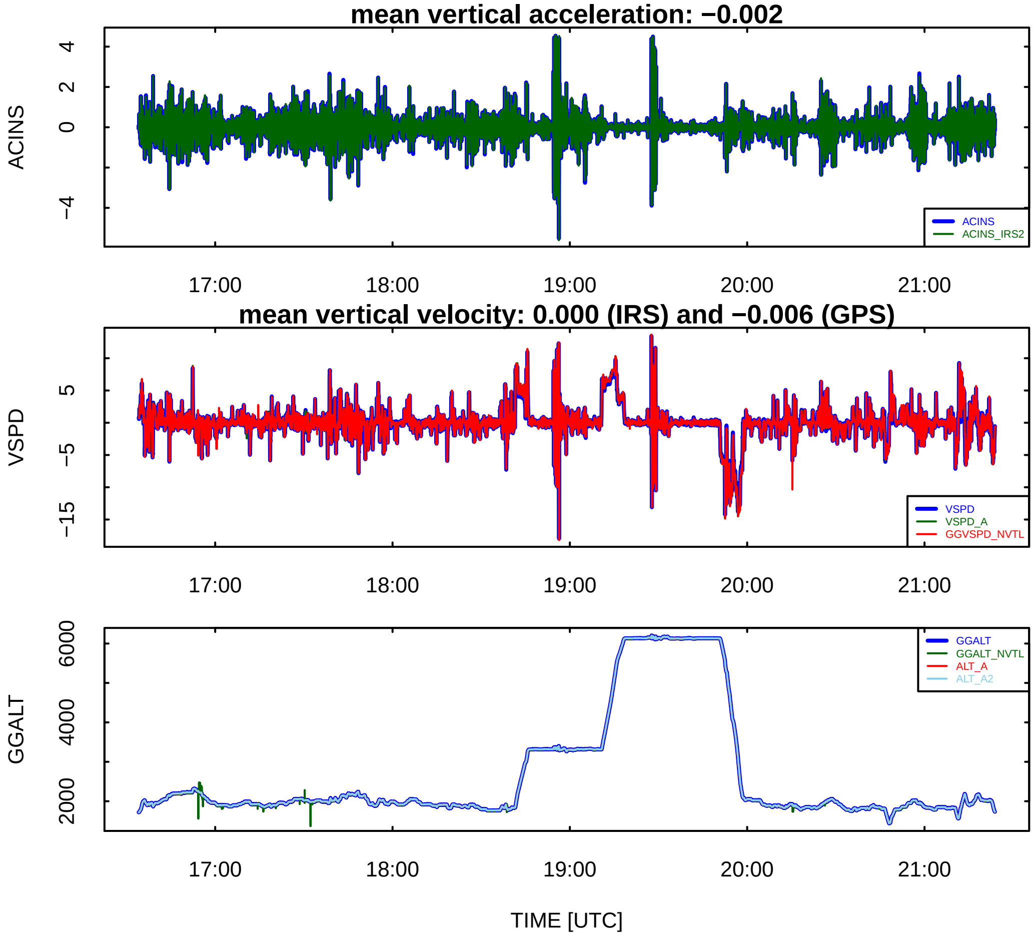

Figure 18: Vertical acceleration (top), vertical aircraft velocity (middle), and aircraft altitude (bottom) for the available redundant measurements.

Vertical acceleration, vertical velocity of the aircraft, and aircraft altitude Figure 18 provides additional information on the performance of the INS and GPS systems. The top panel shows a comparison of the measurements of vertical acceleration; these should match to strict tolerance because the acceleration is integrated twice to get the altitude. The difference, shown here as -0.002, should be less than about 0.01 in magnitude for normal good operation of the inertial units. This does not have to be exactly zero because the data used are qualified to have TASX > 60, so some brief periods near the start and end of flights can be omitted. The middle panel shows the vertical speed of the aircraft as measured by three independent systems. All are in good agreement, and the flight-mean values are <0.001 and -0.006 m/s respectively for the inertial and GPS-Novatel units. The mean velocity should be very close to zero for a flight that takes off and lands at the same airport. The bottom panel will normally show the four traces from independent systems overlapping so much as to be indistinguishable. In this case, there are occasional spikes in the altitude from the Novatel GPS that indicate a problem needing investigation.

UHSAS The UHSAS was not operated on FRAPPE so this section will need to be provided once measurements from WINTER are available.

CN, PCASP, FSSP, CDP, FSSP300 concentrations The plots in this section show measurements from particle and hydrometeor distrometers on the C-130. The top panel of the first figure, Fig. 19, shows CN counts and the CN concentration determined from them, as well as the concentration from the PCASP. The bottom panel shows concentrations from the CDP, FSSP, and FSSP300. The apparent floor on the plot of CDP concentration arises because that is the threshold for a single droplet counted in the 1-s interval used for these measurements. Zero values are reset to missing for these log plots. The FSSP300 measures higher concentrations than the CDP because it extends to a much small size and therefore is sensitive to some large aerosol particles. In this case, there seems to be a significant difference between CDP and FSSP, with the FSSP measuring concentrations orders of magnitude smaller than those from the CDP. This is an indication of a problem, most likely with the FSSP. The CDP particle counts reduce in concentration significantly for the high-level flight segment following 19:00. Except for the FSSP, these are all reasonable-looking measurements. One useful check is to look for correlation among these measurements, as is clearly present here for the top-panel aerosol measurements. The 2DC concentration should remain zero in cases of flight outside cloud, as it does except for a few brief bursts (light blue lines); a steady concentration above zero in clear air may indicate a problem with the uniform illumination of diodes or a bad diode in the instrument.

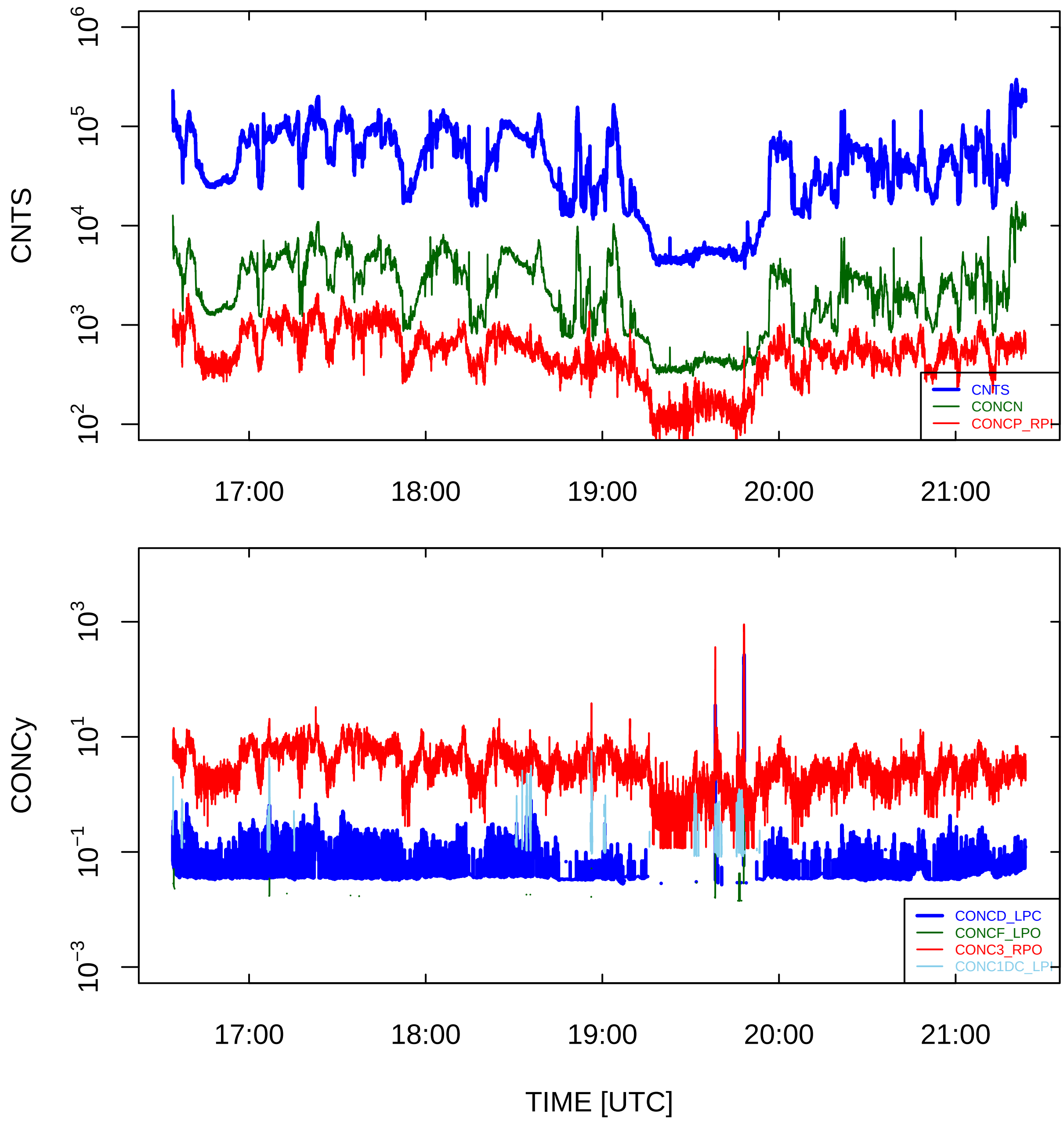

Figure 19: Particle concentrations from the CN counter and PCASP aerosol distrometer (top, [cm^{-3}) and hydrometeor concentrations from the CDP, SPP100, FSSP300, and 2DC (bottom, [cm^{-3}] exc. 2DC [liter^{-}1], bottom).

Mean diameters and liquid water content of hydrometeors Measurements of mean diameter and liquid water content at low levels can be quite noisy and therefore hard to interpret, so the plots in this section have been smoothed over running periods of 61 s using cubic Savitzky-Golay polynomials. That led to much smoother plots that are easier to interpret, as shown in Fig. 20, but at the expense of losing fine resolution in cases of short passage through clouds. For that reason, this plot and the others in this section are likely only useful for data-quality review, not for analysis conclusions.

The mean diameter shown in the top panel of Fig. 20 shows that the CDP and FSSP are only measuring particles in small channels, although the FSSP is barely responding while the CDP produces a suspicious-looking steady mean arount 5 μm diameter except in the region near 19:330 where the aircraft flew near 20,000 ft altitude. There were brief spikes in all measured mean diameters, including that from the 2DC but excluding the PCASP, just before the descent from this altitude, likely from ice that shattered to produce spurious measurements in the droplet and particle spectrometers. This plot seems to display normal behavior except for two related problems, the large disagreement in mean diameter between the CDP and FSSP and the absence of measurable concentrations from the FSSP that prevents meaningful estimation of the mean diameter.

The same smoothing is applied to the liquid water content measurements shown in the top panel of Fig. 21. In the plotted case, there is too little liquid water content to conclude much except that the measurements properly show very small values, with a suspicious offset in the variable PLWCC that may indicate poor removal of the zero value resulting from concentrations above the threshold CDP concentration for calculating the offset. For a case like this, it is worth checking on the offset in use for the King probe zero adjustment. The middle panel in this figure shows the power used by the King probe. This should remain steady during the project unless probe elements are changed. The guidelines on this plot can help detect departures from normal operation. Finally, the bottom panel shows the liquid water content deduced from the 2DC probe. Here it is appropriately quiet outside a few brief passes through cloud elements.

For monitoring purposes, Fig. 22 shows some measurements characterizing the operation of the FSSP. The instrument rejects droplets for two reasons, either because it estimates they are outside the depth of field or because their transit time is shorter than the average and can indicate passage through the edges of the beam. The displayed results are too noisy and the probe was apparently not working properly, so better examples may be obtained from the WINTER test flights and this section will be updated then.

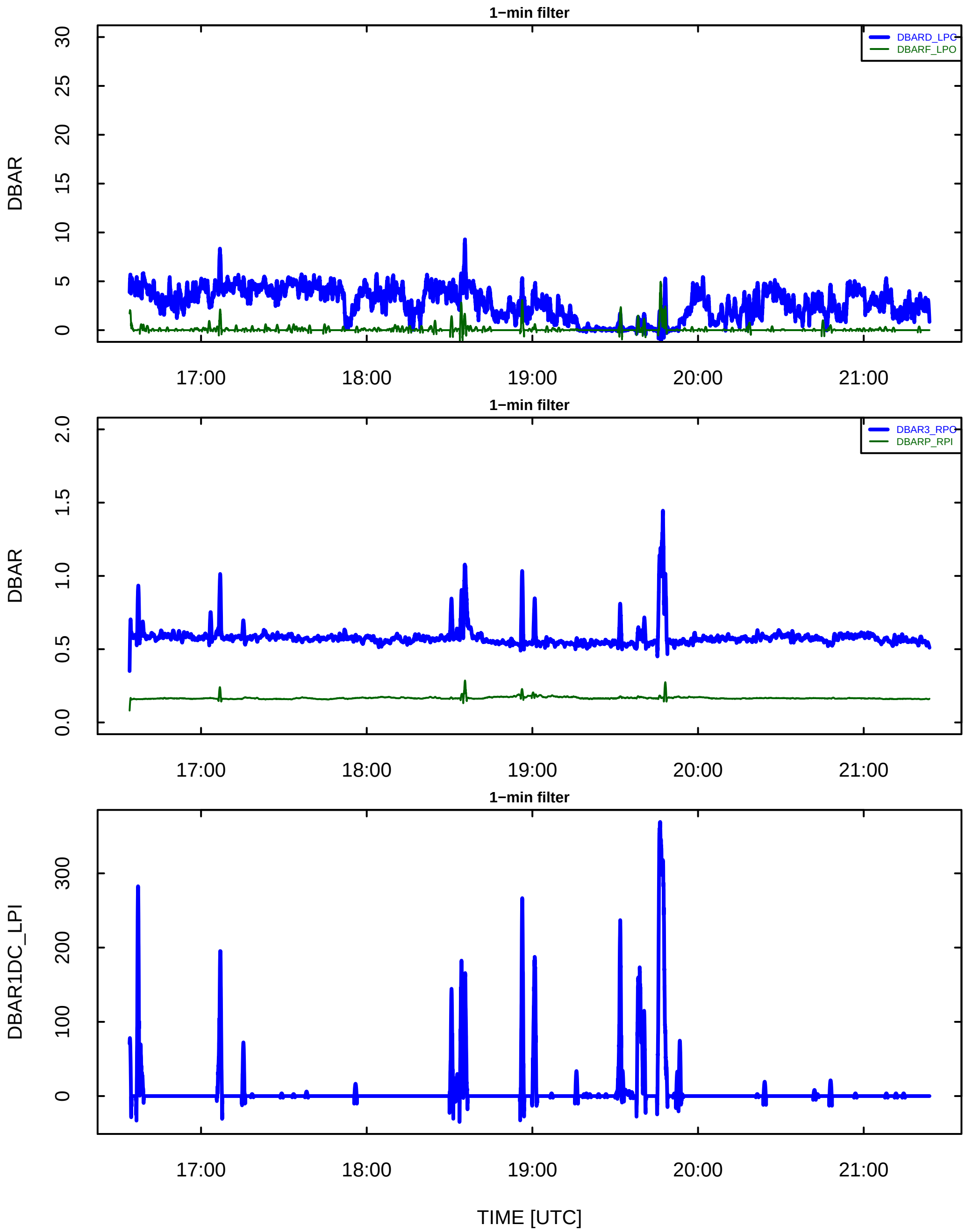

Figure 20: Mean diameters [μm] measured by the CDP and FSSP (top), the FSSP300 and PCASP (middle), and 2DC [bottom].

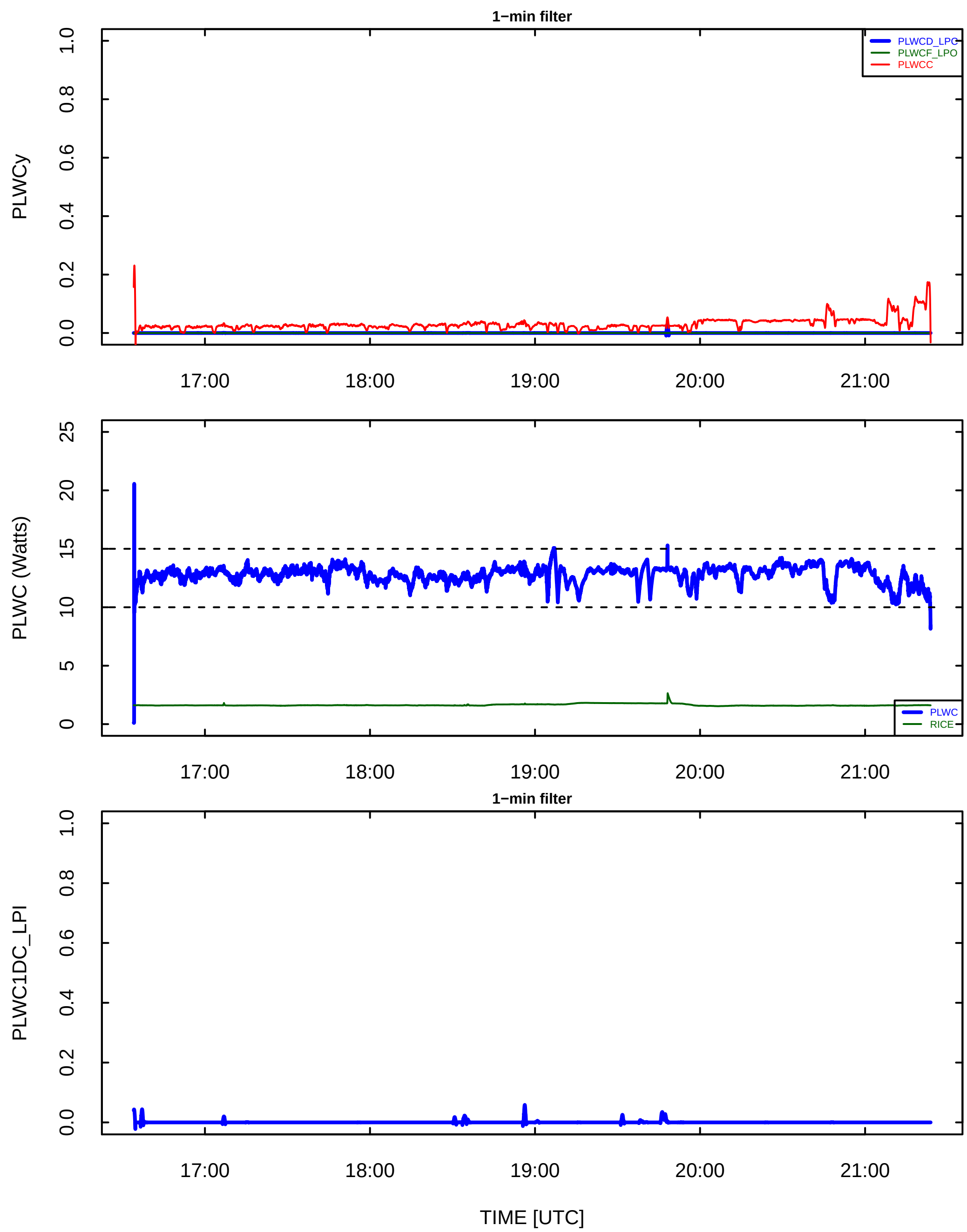

Figure 21: Measurements of liquid water content from the SPP100, CDP, and King probe (top); the power required to maintain King-probe temperature (middle), and the extimated liquid water content from the 2DC probe with the assumption that all particles are liquid.

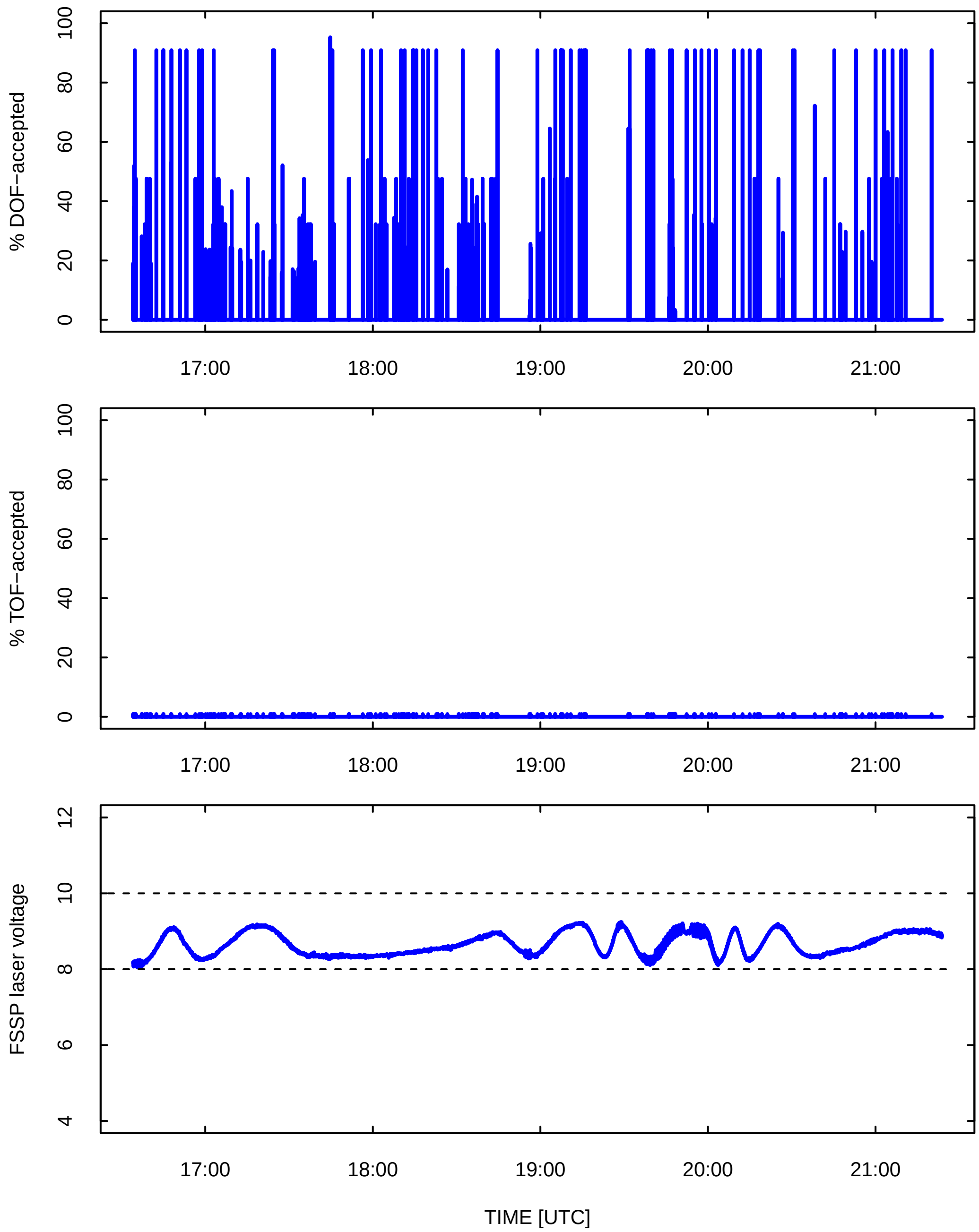

Figure 22: Additional characteristics of the FSSP: percentage of DOF-accepted particles (top), percentage of TOF-accepted particles (middle), and the laser power (bottom).

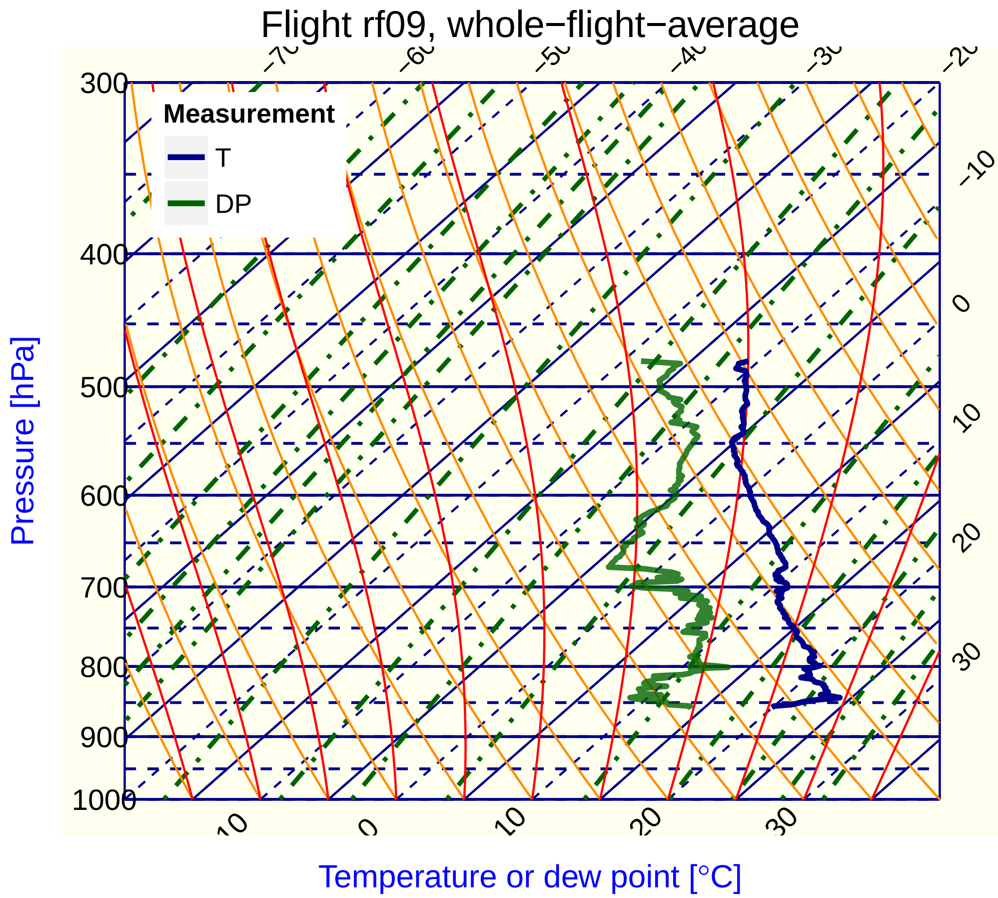

Figure 23: Plot of all temperature and pressure measurements, averaged in 5 hPa intervals, for the flight. The only restriction on data is that only measurements where TASX exceeded 60 m/s were used.

Plots on a thermodynamic (skew-T) diagram Skew-T diagrams can indicate problems if they show regions where the temperature decreases with altitude faster than expected for parcel ascent, and they can also indicate layers of strong stability where boundary-layer pollution may be trapped. They can also indicate the potential for the development of clouds and the potential for severe weather. A skew-T plot is included here (Fig. 23 for information and context, but as long as the appearance remembles this plot it will probably not add to the quality-control information. There is also a section of this program, suppressed in the project configuration, that searches for climbs and descents and constructs separate plots for them. Include 18 in the sequence named 'nplots' to see these individual plots. They are suppressed in this memo.

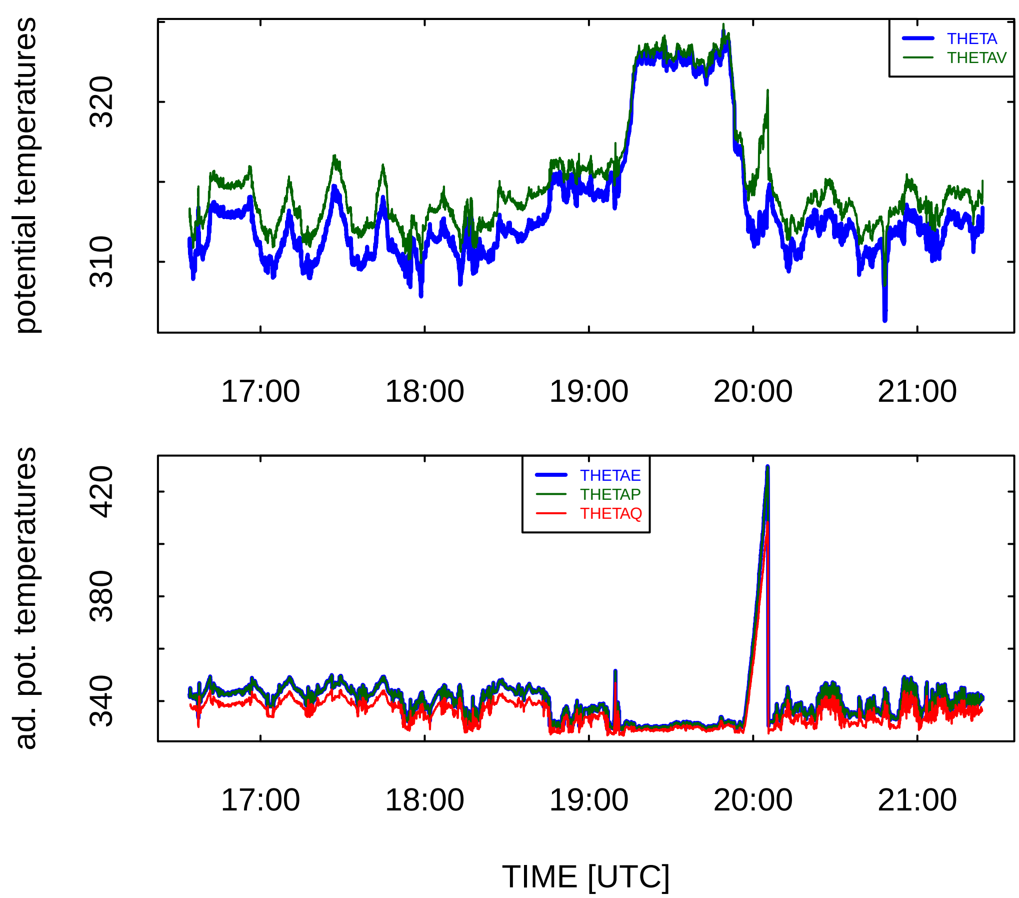

Figure 24: Measurements of potential and virtual potential temperature (top panel) and of Bolton-formula equivalent potential temperature (THETAE), Davies-Jones pseudoadiabatic potential temperature (THETAP), and wet-equivalent potential temperature (THETAQ). All units are kelvin.

Potential temperature profiles Figure 24 shows the history of measurements of various potential temperatures during the flight, and Fig. 25 shows the same measurements in vertical profile. The latter can be useful because it is expected that potential temperature (THETA or THETAV) will normally decrease or remain steady as the altitude increases, and uniform regions indicate possible well-mixed regions such as the Earth's boundary layer, often capped by modest stability reflected in increasing THETA. These profiles often will show multiple lines because all individual measurements are plotted in connected lines, so for example there may be one plot for ascent and one for descent. Much more can be deduced by using profiles like these, but for the purposes of data review the best test is to expect plots resembling these and investigate departures. For example, in these plots there are right-ward excursions near 800 hPa that originate from overheating of the dew-point sensors. Features like these should be investigated if they haven't been understood from the preceding plots.

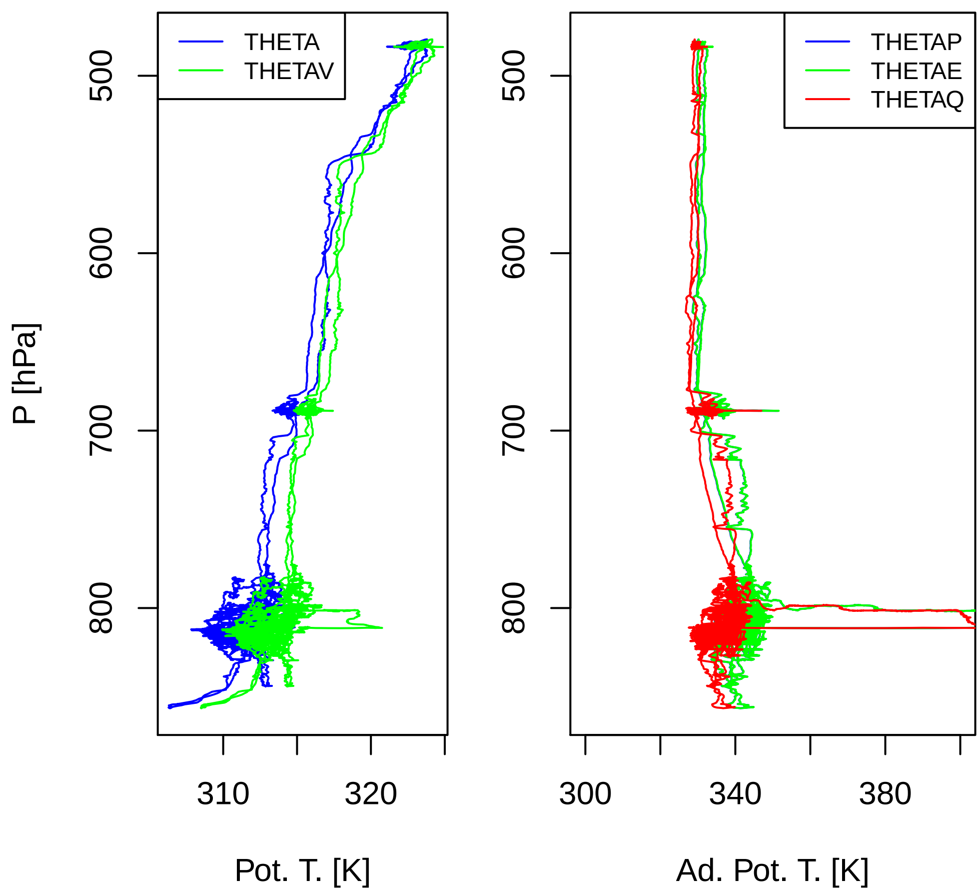

Figure 25: Vertical profiles of the same measurements shown in the preceding figure.

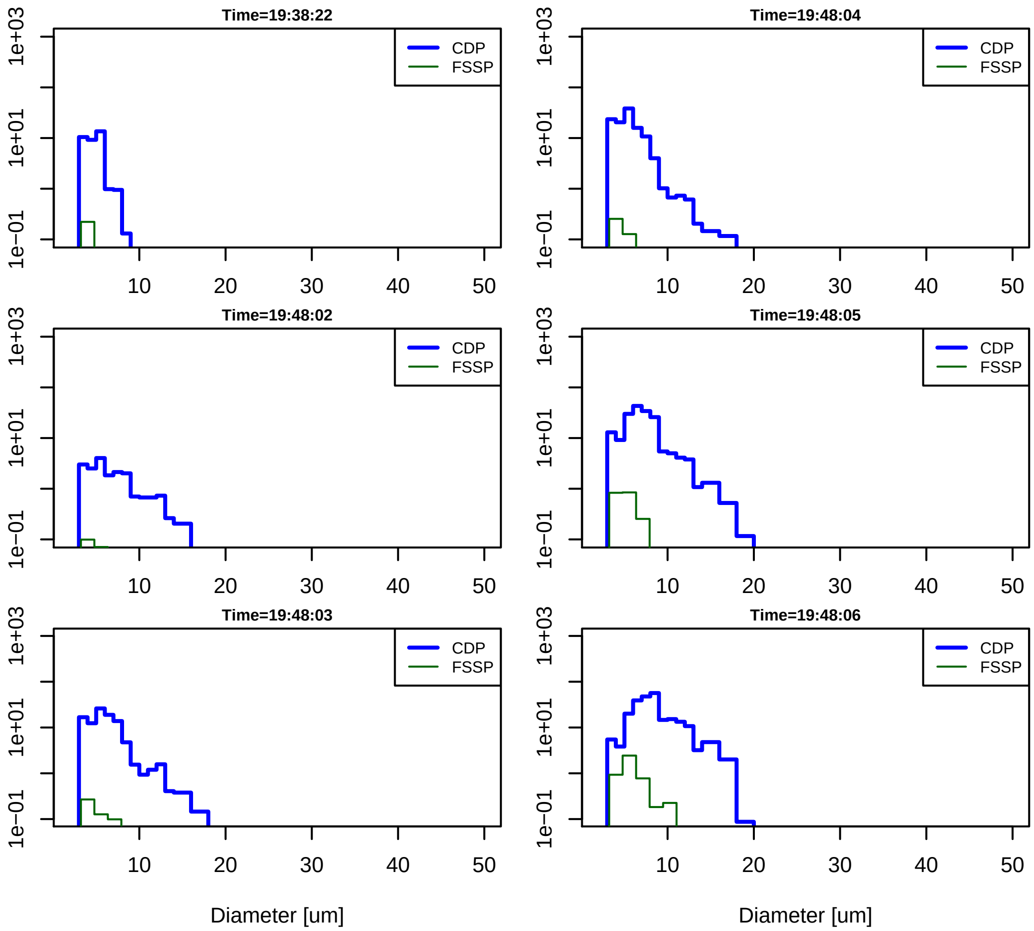

Figure 26: Size distributions measured by the CDP and FSSP, each representing 1-s of measurements.

Hydrometeor size distributions Size distributions measured by the CDP and SPP100 (FSSP) are shown in the next set of plots beginning with Fig. 26. Individual plots show measurements made over 1-s, as labeled at the top of the plots, and plots are only generated when at least one channel in the CDP measures a concentration of more than 1 cm^{-3}. Once three pages of plots are generated, the plotting is suppressed, so this only provides an initial limited sample.

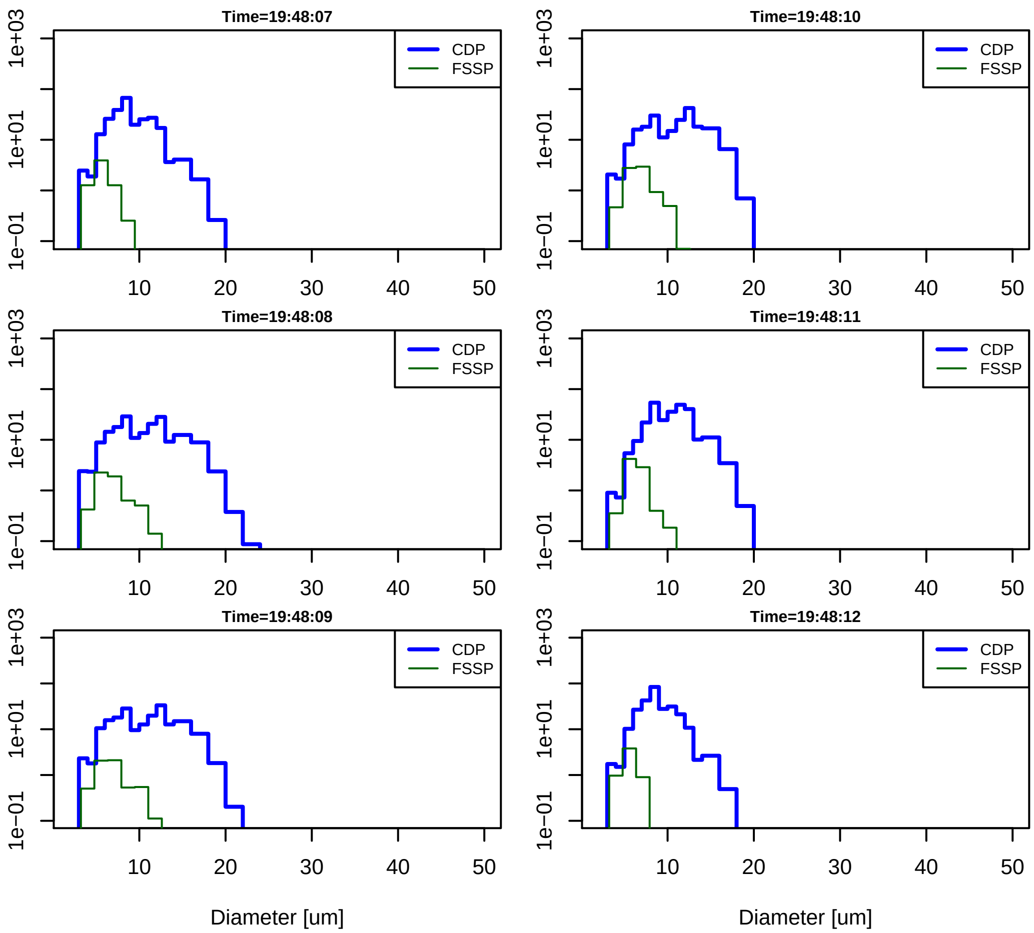

Figure 27: Size distributions measured by the CDP and FSSP, each representing 1-s of measurements.

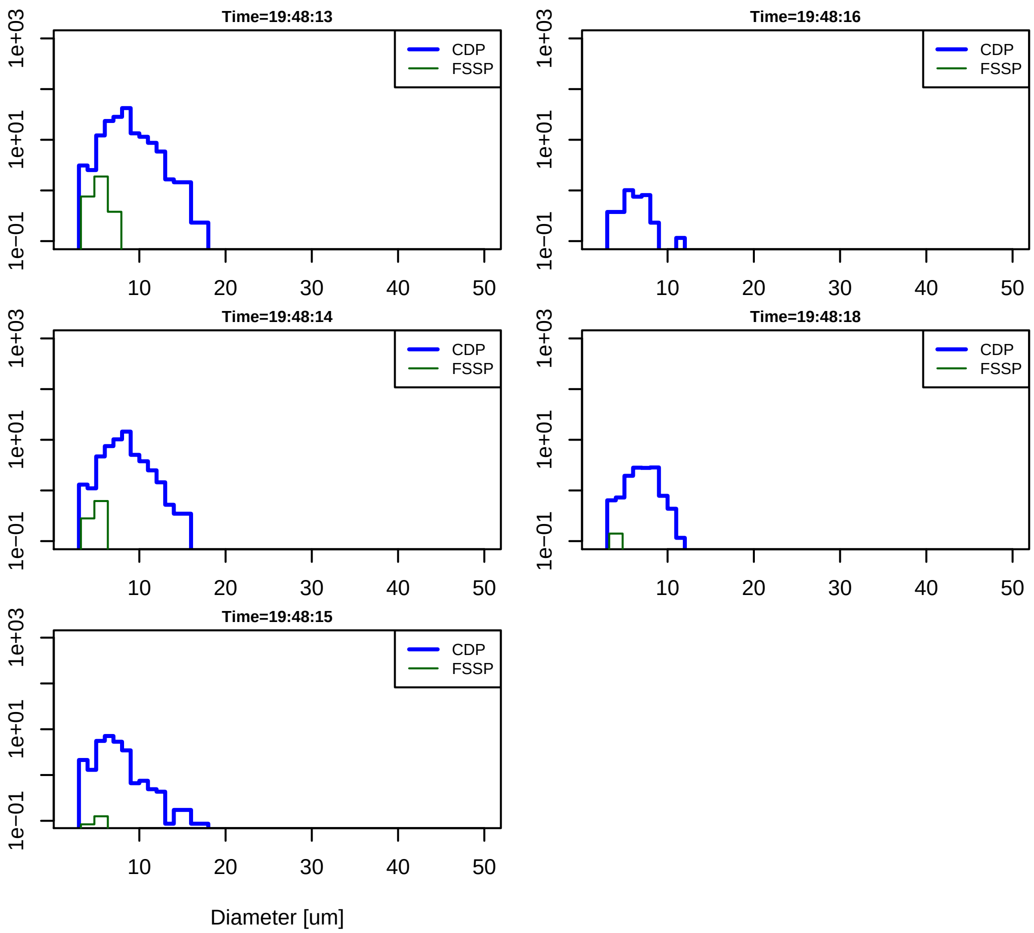

Figure 28: Size distributions measured by the CDP and FSSP, each representing 1-s of measurements.

4 How to add new plots

Here is the procedure for adding a plot to this routine:

1. Copy this code and insert it at the end of Review.R:

```
### This is a model for adding a function:
RPlotN <- function(data) {
  # next just resets geometry, in case previous plot used multiple panes
  op <- par (mfrow=c(1,1), mar=c(5,5,2,2)+0.1)
  ## simplest plot: variables "Var1" and "Var2" vs time
  plotWAC (data[, c("Time", "Var1", "Var2"), ylab="Var"]
}
```

2. Change N in the name RPlotN to some number not in use. The present version uses 1–20, so a good choice might be to use 100; i.e., RPlotN should be replaced by RPlot100 or some other number that it is unlikely anyone else will use.

3. Make sure that the needed variables are in "VarList". If not, add them in the statement where VarList is defined, or alternately follow that statement (immediately below) with this statement: VarList <- c(VarList, "Var1", "Var2") where Var1 and Var2 are replaced by the names of variables you want to use. They must be in the netCDF file or else this program will crash; it is not protected against this error.

4. Then, follow where the above function definition is inserted with this R code:

```
RPlot100 (DataV)   # change '100' to whatever number you have used
```

5. You can then make additional modifications to the function as you see the results and want to change them. Use the functions RPlot[1:20] in Review.R for ideas of ways to tailor the plots. Also, there are some functions available that you may find useful:

   (a) hline (X) will draw a black dashed horizontal line on the plot at ordinate value X.

   (b) SmoothInterp (X) will return a smoothed version of X (which might be a variable like data$TASX) as referenced in your routine). Usage: Xsmoothed <- SmoothInterp (X).

6. Finally, please write a description of how to interpret the new plot and what to look for when reviewing data. Give that to me for incorporation into future versions of this memo.

– End of Memo –

Reproducibility:

PROJECT:	WINTER
PROGRAMS:	Review.Rnw, Review.R
ORIGINAL DATA:	/scr/raf_data/FRAPPE/FRAPPErf09.nc – for testing
GIT:	https://github.com/WilliamCooper/WINTER.git