19 August 2015

TO: Reprocessing File
FROM: Al Cooper
SUBJECT: Vertical wind for HIPPO flights, circuits 2–5

1 General comments

The measurements of vertical wind from HIPPO flights appear to need different sensitivity coefficients for HIPPO-2/3 vs HIPPO-4/5, and the reason for that is not evident. Projects HIPPO-2 and HIPPO-3 are consistent and could use the same coefficients without serious error, but projects HIPPO-4 and HIPPO-5 each need significantly different coefficients and, even with those changes, the results for vertical wind appear to produce significant errors that can't be removed by AKRD calibration. Prior to January 2012, when the radome was changed, the "standard" coefficients expected to apply to the radome, determined from the PREDICT project, which was in August 2010 and so between HIPPO-3 and HIPPO-4, are listed in the following table. The suggested coefficients are also listed, and it is clear that the standard coefficients do not apply well to any of the HIPPO circuits (all flown before the 2012 radome change). There is significant difference also vs. the DC3-TEST project, flown just before the last two HIPPO circuits. There was some evident change between HIPPO-3 and HIPPO-4 (between April 2010 and June 2011), and the results from PREDICT are still different. Furthermore, the resulting vertical wind in HIPPO-2 and HIPPO-3 looks satisfactory, while there are evident problems in HIPPO-4 and HIPPO-5 that do not appear to be correctable by calibration coefficients, as discussed in the next section.

There were apparently no speed runs in the test or research flights leading to HIPPO-4 and HIPPO-5, but there were several in flights 1, 2, and 4 of DC3-TEST. Therefore there may be some argument for using these coefficients in preference to those determined from HIPPO-4/5, in case some frequent radome problems affect the results from those projects. This will be discussed further in the "Suggested choice" section below.

Project	**Dates**	c_1	c_2	c_3
"standard"	before 2012	5.516	19.07	2.08
HIPPO-2	Nov. 2009	5.151	15.651	7.303
HIPPO-3	Mar/Apr 2010	5.112	14.016	8.291
HIPPO-4	Jun/Jul 2011	4.876	9.882	12.275
HIPPO-5	Aug/Sept 2011	5.044	9.746	9.567
DC3-TEST	May 2011	5.389	20.172	0

2 Illustration and study of the HIPPO-4/HIPPO-5 problem

Flight 3 of HIPPO-5 illustrates the problem that is present in vertical-wind measurements from HIPPO-4 and HIPPO-5. If the coefficients listed in the above table, determined from the full-project measurements combining all flights, are used the result is the vertical wind shown in Fig. 1.

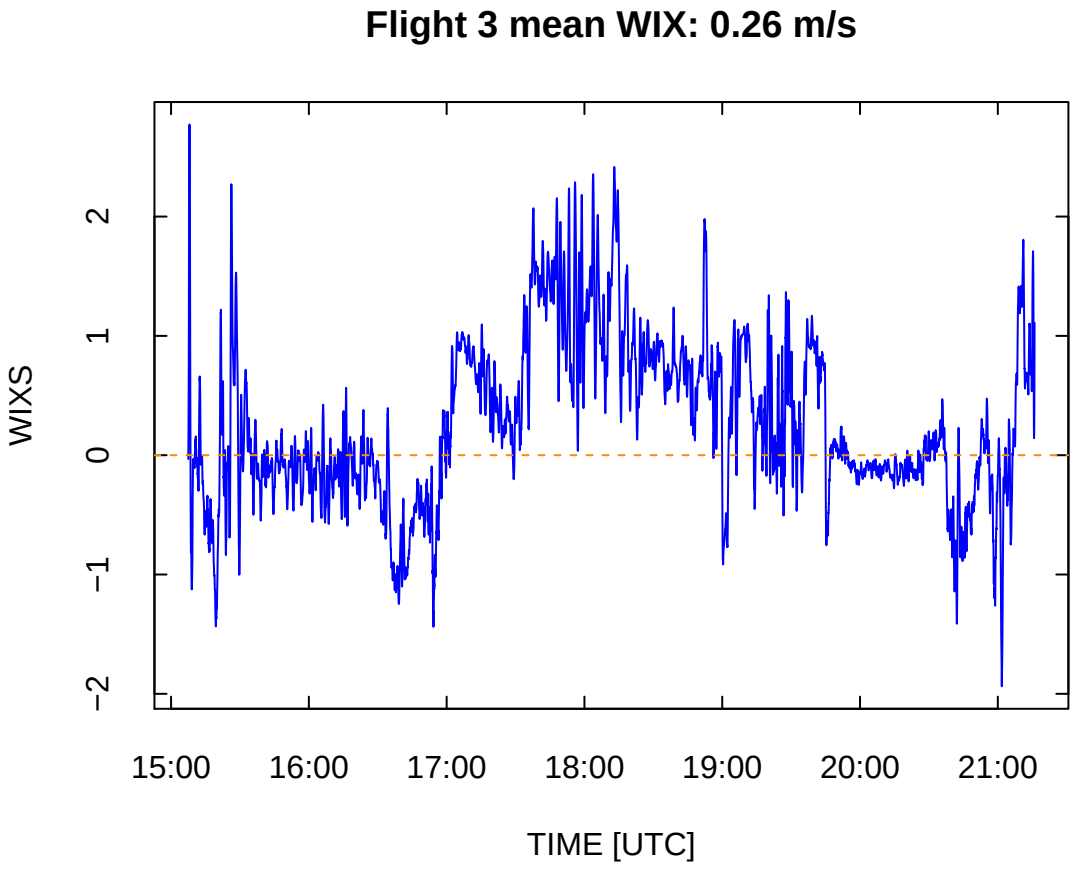

Figure 1: Vertical wind measurements WIC for HIPPO-5 flight 3.

If fit coefficients are determine from only this flight, to avoid the possibility that other flights might have different radome characteristics and so distort the results, the coefficient are {4.76, 7.80, 15.00}. The resulting fit has only minor improvement in the residual standard deviation (0.182 vs 0.188) in comparison to using the full-project coefficients as listed in the above table. It does not appear to improve the vertical wind, however; it lowers the central portion where there appears to be too-high vertical wind, but it accomplishes this by lowering the level portions near the start and end of the flight. Examination of the components entering the vertical wind shows that everything appears normal except ADIFR, which has enough offset in the central portion of the plot to account for the excess vertical wind.

Figure 2 shows that a similar but even more problematic deviation occurs for Flight 4. Because these features occur throughout HIPPO-5, and have both signs, it seems implausible that they are real. More likely is that the radome suffers from some problem, like some accumulation of dirt or a bug near the ports or a partial obstruction in the lines or a leak. To check for this, the measurements of ADIFR were considered as functions of altitude or Mach number to see if there

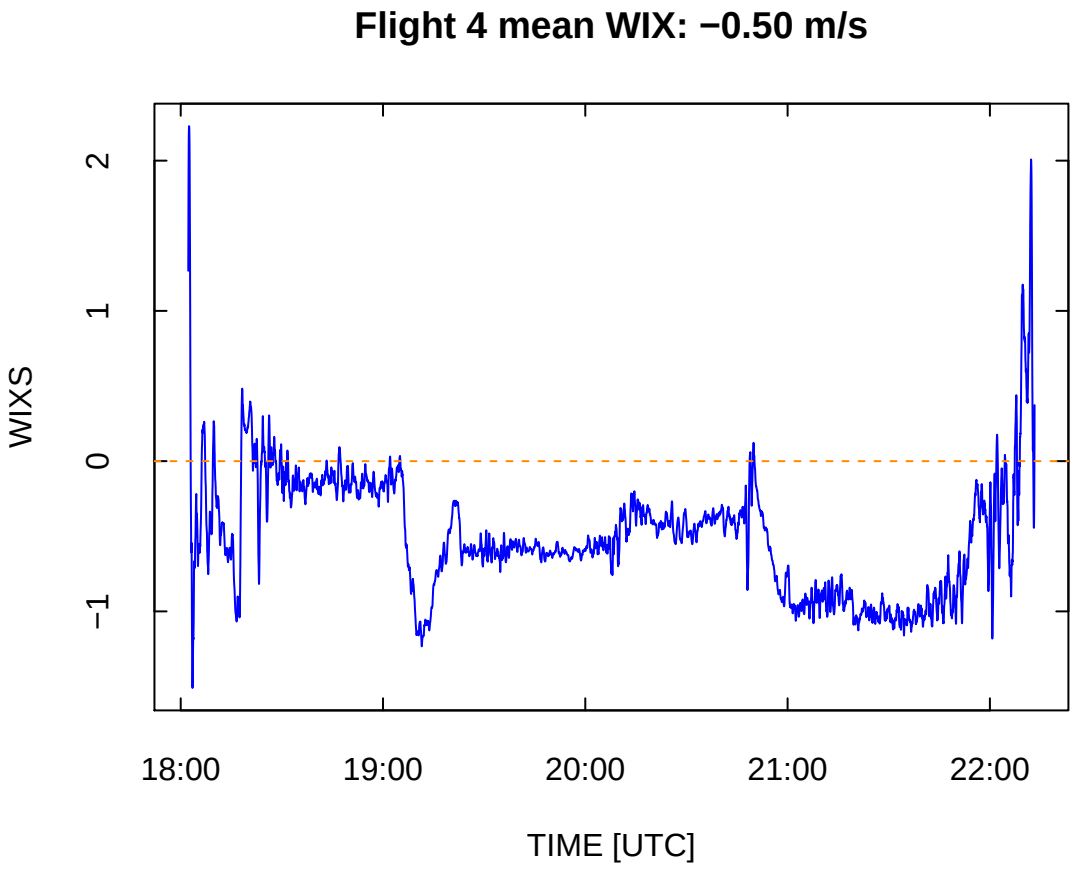

Figure 2: As in the preceding figure but for HIPPO-5 flight 4.

is a normal pattern for level flight and if there is unusual variance in HIPPO-5. Figure 3, comparing the measurements of ADIFR from flight 4 to those from all other HIPPO-5 flights except 1, 3, and 4, shows that flight-4 measurements are clear outliers. Of course, this would be the case if the vertical wind is really low as shown in Fig. 2, but that seems unlikely over such an extended distance. It seems more likely that there was some problem affecting the radome on this flight and perhaps also others in HIPPO-4 and HIPPO-5.

3 Suggested choice

For this reason, we propose a different solution for HIPPO-4 and HIPPO-5:

1. Determine a fit using only a two-coefficient fit, to obtain the best estimate of the second coefficient relating ADIFR/QCF to AKRD: AOAREF = c[1] + c[2]ADIFR/QCF. It appears

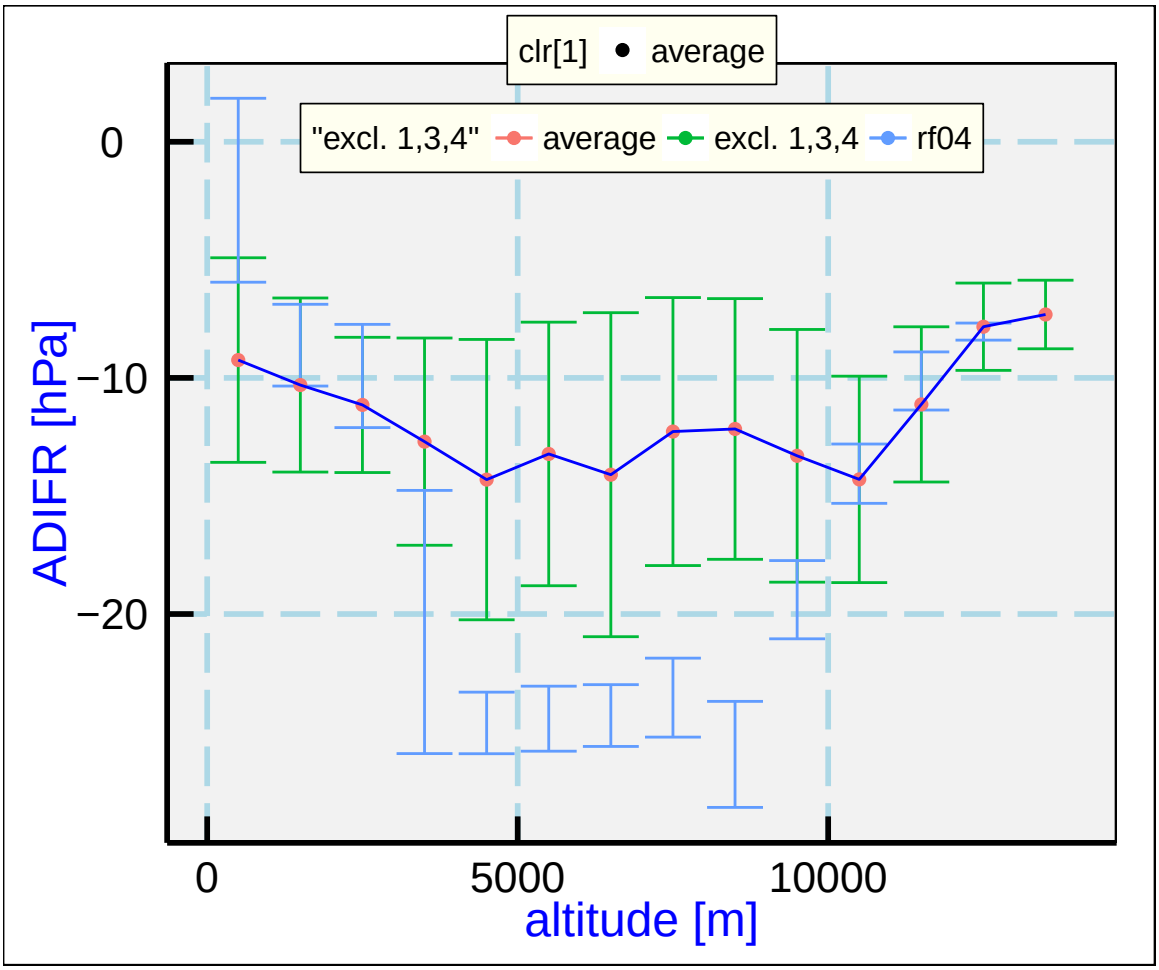

Figure 3: Distribution in ADIFR in altitude bins, for all measurements in HIPPO-5 except those in flights 1, 3, and 4 (green), and for those from flight 4 (blue).

preferable to use the fit to DC3-TEST data because this program included several speed runs suitable for determining these coefficients. Therefore, the suggested fit coefficients for HIPPO-4/5 are {5.389, 20.172, 0}.

2. Use a high-pass filter with long time constant, perhaps 600 s, to adjust the resulting vertical wind to remove the offset.

This avoids the danger that a fit like those shown for HIPPO-4 and HIPPO-5 will distort the sensitivity to the radome pressures from periods of faulty radome performance, keep what appears to be a reasonable sensitivity to the ratio ADIFR/QCF, and ensure that the resulting vertical wind will remain near zero in the mean. A 600 s time constant will correspond, at a flight speed of 180 m/s, to a wavelength of at least 100 km, so only vertical motion persisting at least this far will be affected.

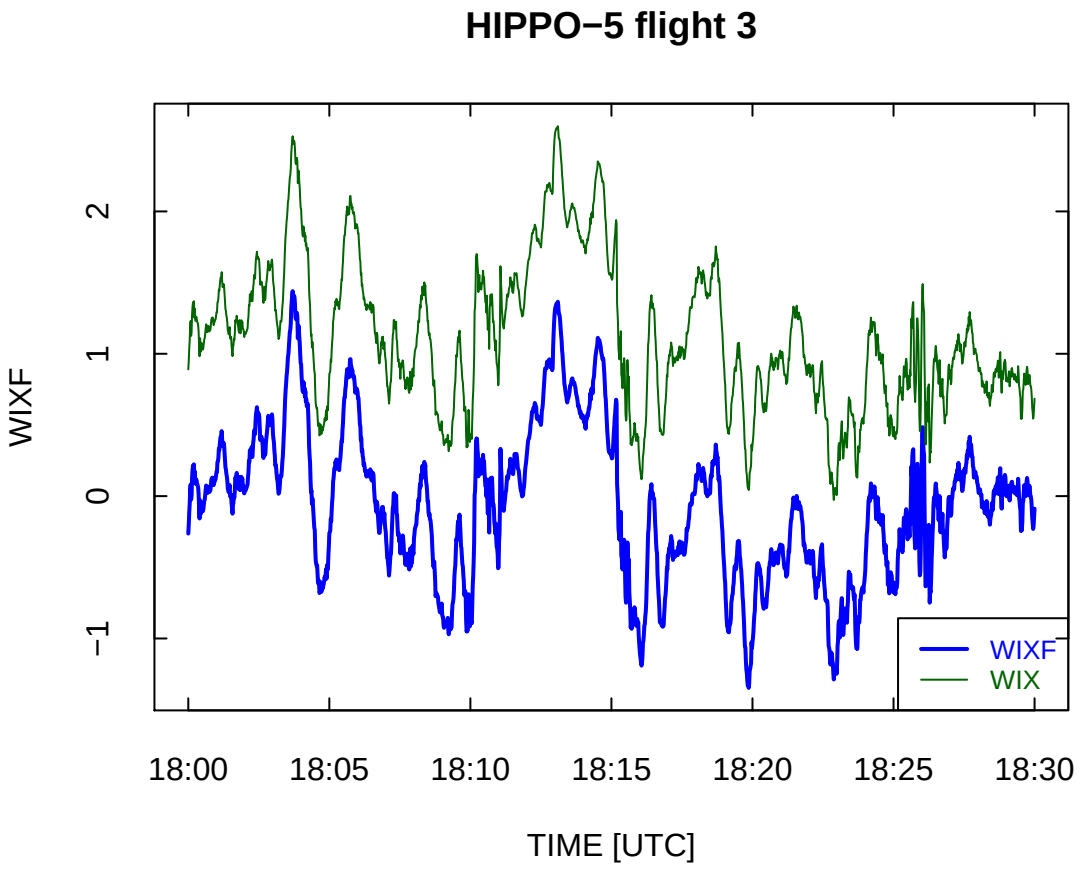

Figure 4: Example of the effect of a 600-s high-pass filter (WIXF) applied to the vertical wind measurement (WIX), from HIPPO-5 flight 3, 18:00:00–18:30:00.

4 Resulting vertical wind

An example of the result of applying this approach, with 600-s high-pass filtering, is shown in Fig. 4. The high-frequency structure is mostly preserved well while the significant offset is removed. For reference, the full-flight plots of the unfiltered and filtered wind that results from this approach are appended, for both HIPPO-4 and HIPPO-5. See the sequence of figures starting with Fig. **??**.

– End of Memo –

Reproducibility:

PROJECT:	WICforHIPPO
ARCHIVE PACKAGE:	WICforHIPPO.zip
CONTAINS:	attachment list below
PROGRAM:	WICforHIPPO.Rnw
ORIGINAL DATA:	/scr/raf_data/HIPPO/HIPPO-5/rf08.nc, etc. Aug 19)
GIT:	git@github.com:WilliamCooper/WICforHIPPO.git

Attachments: WICforHIPPO.Rnw
WICforHIPPO.pdf
SessionInfo

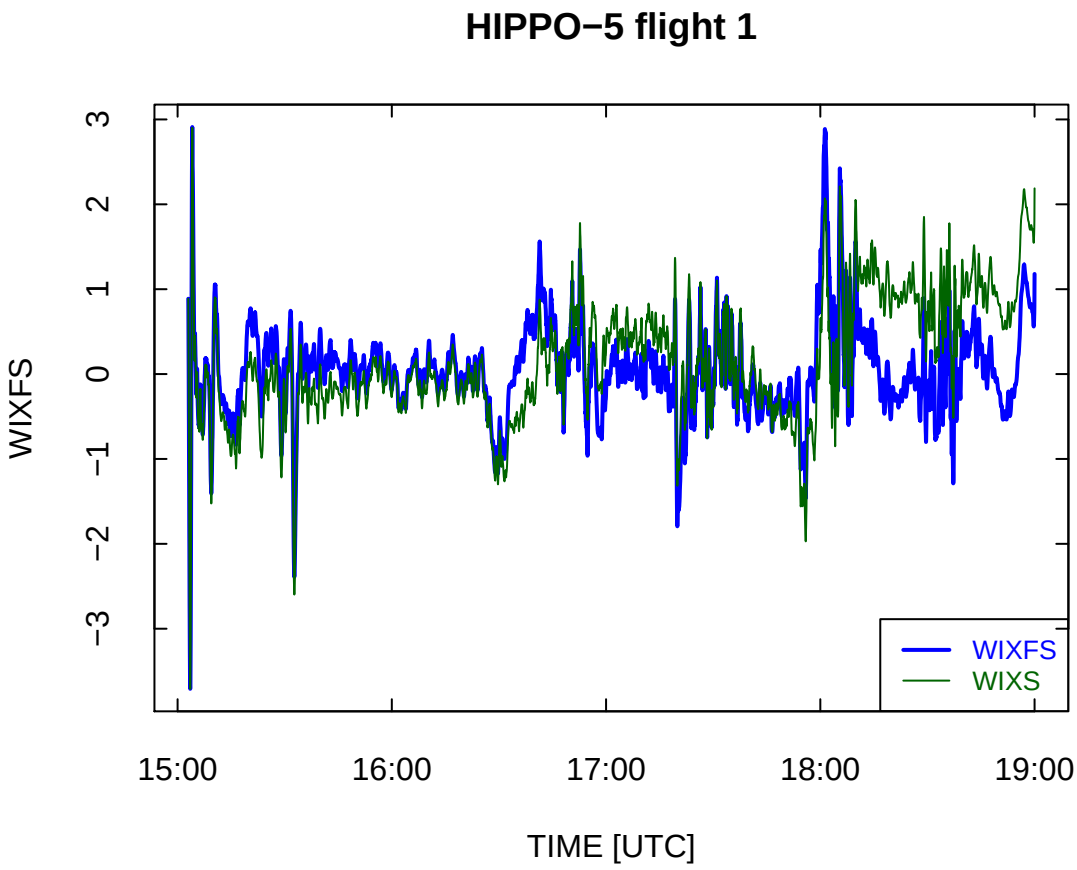

Figure 5: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

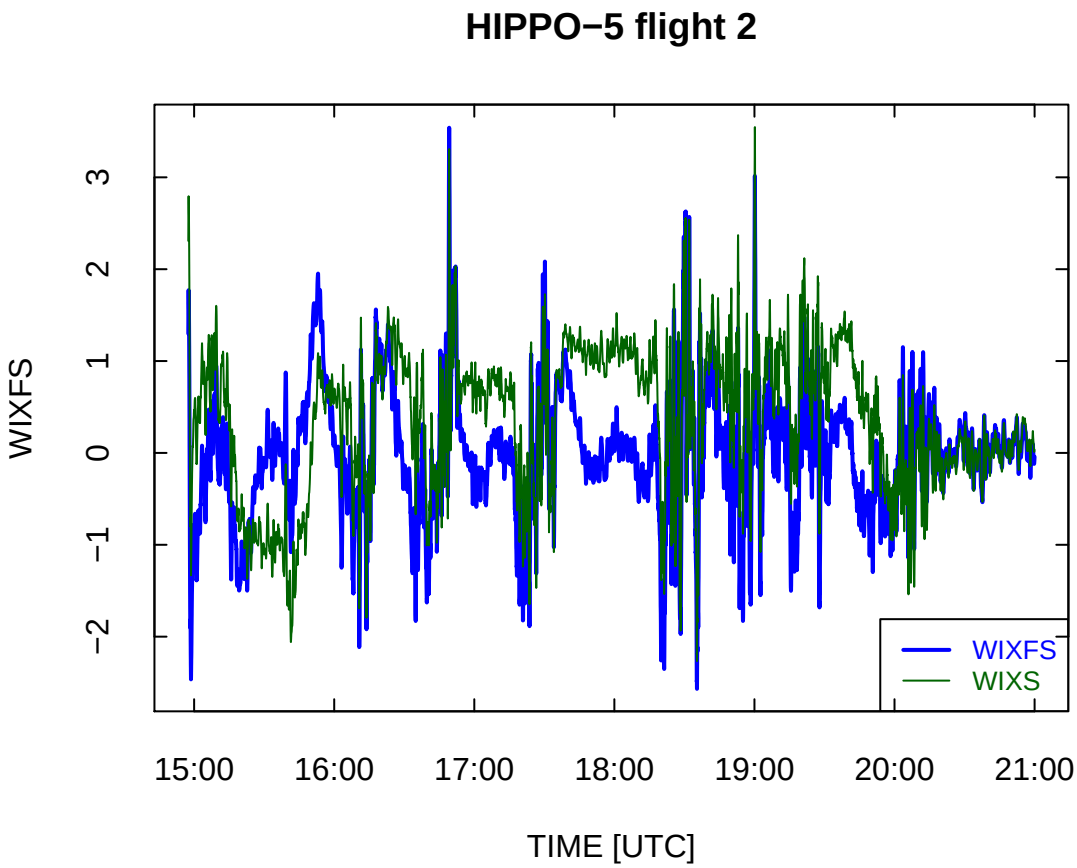

Figure 6: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

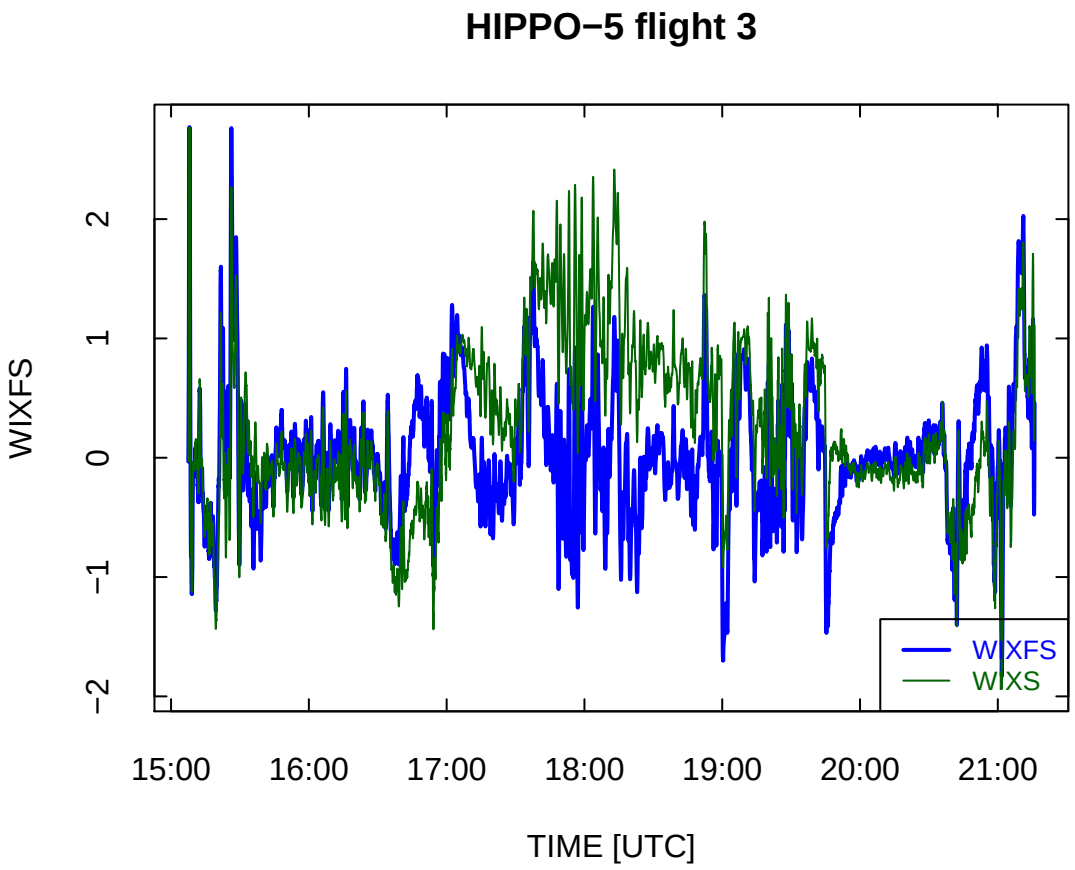

Figure 7: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

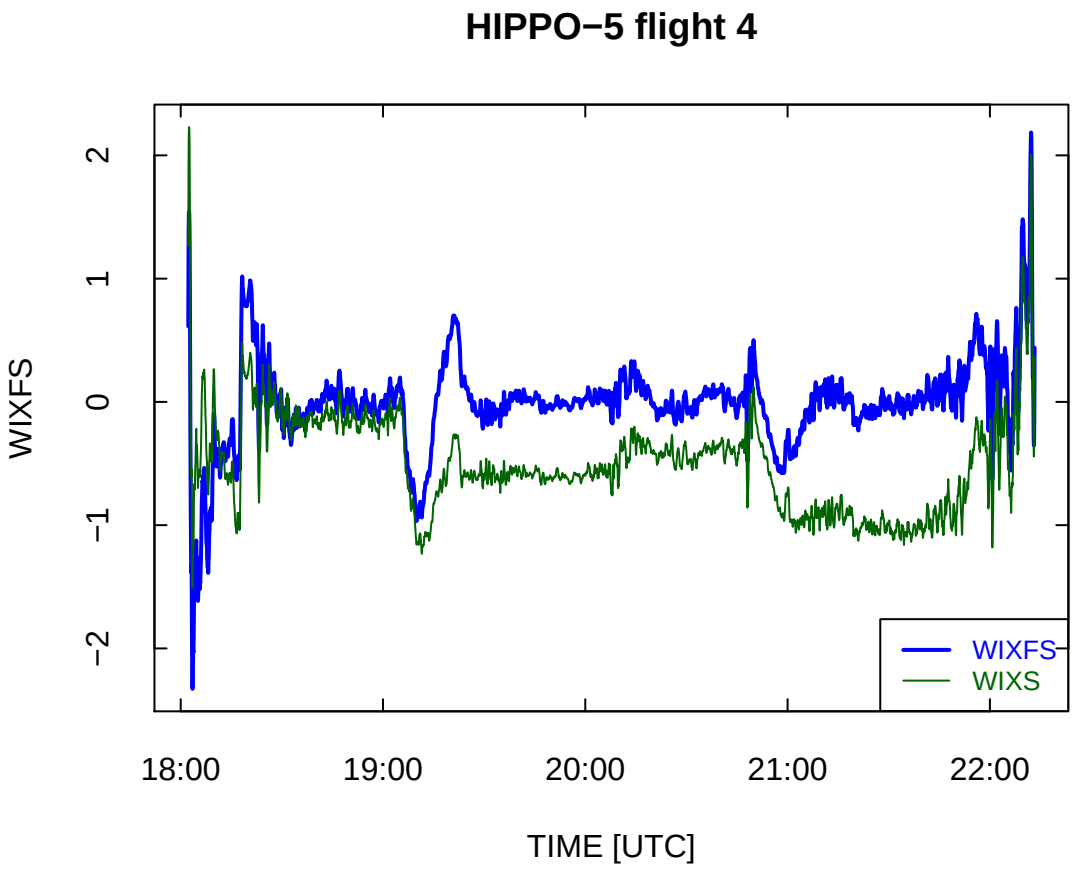

Figure 8: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

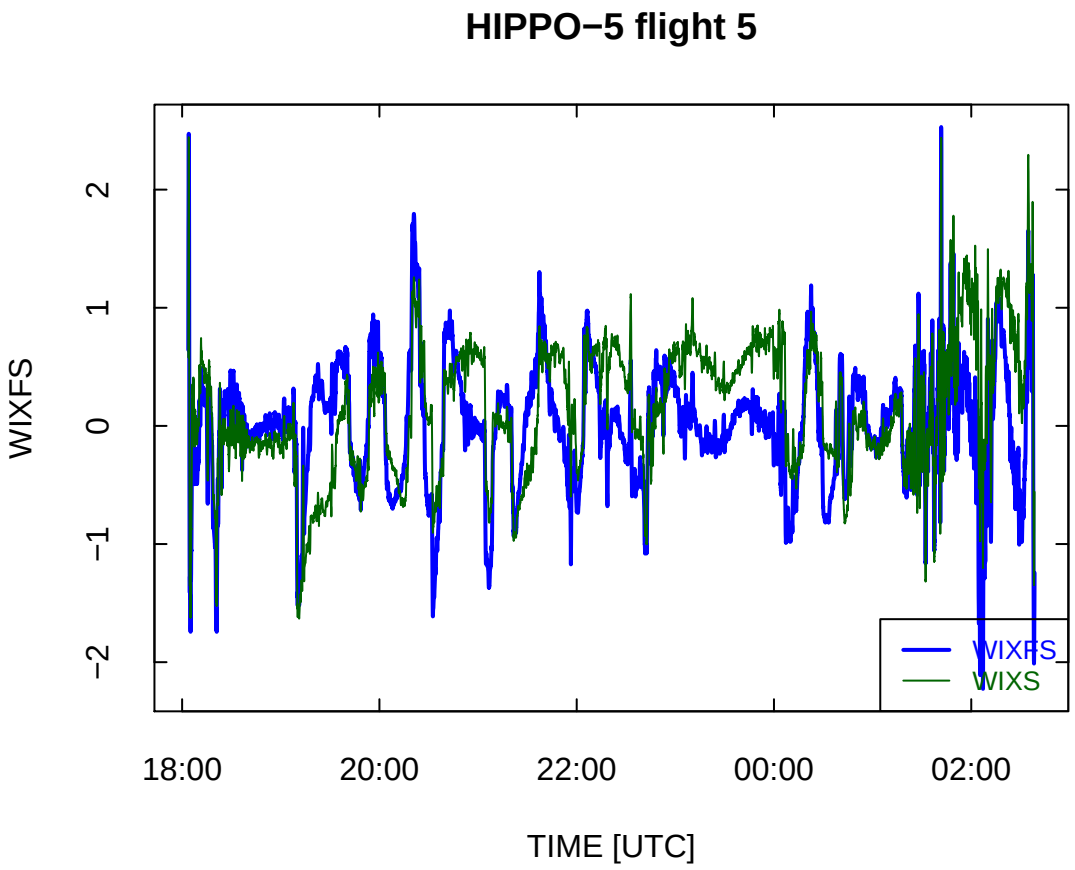

Figure 9: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

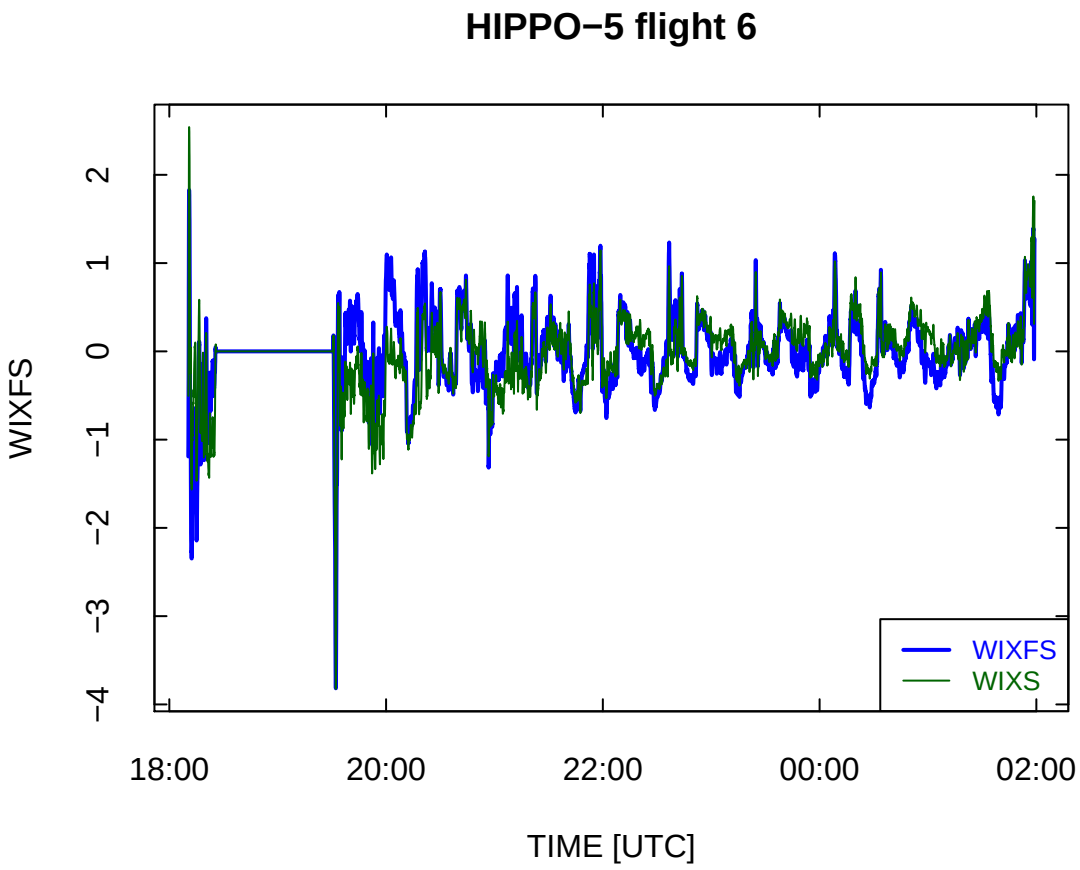

Figure 10: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

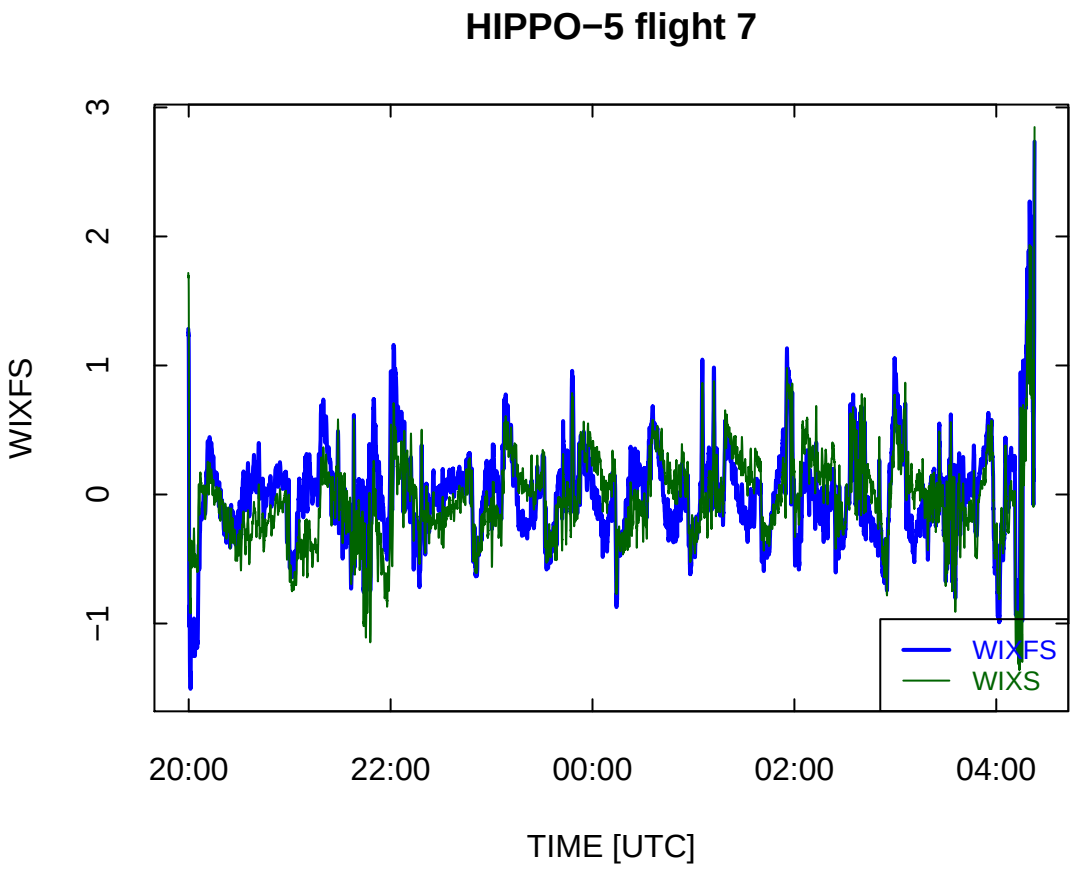

Figure 11: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

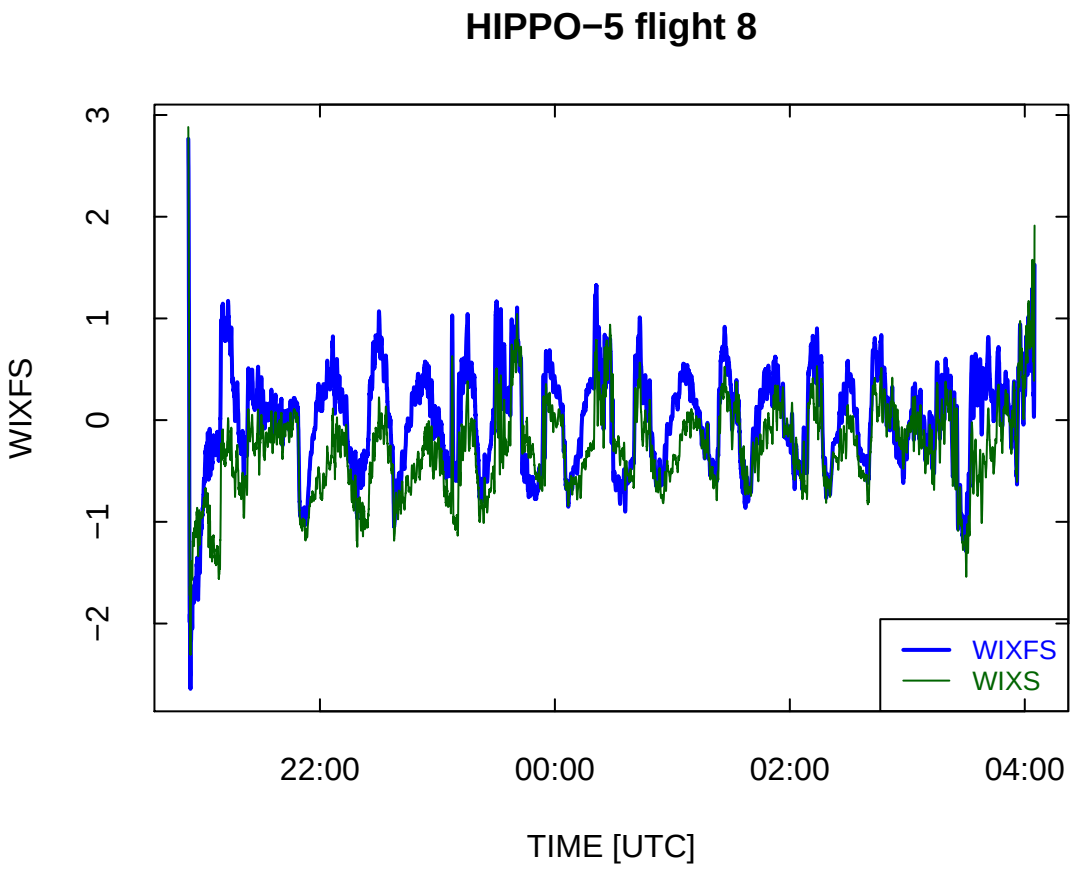

Figure 12: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

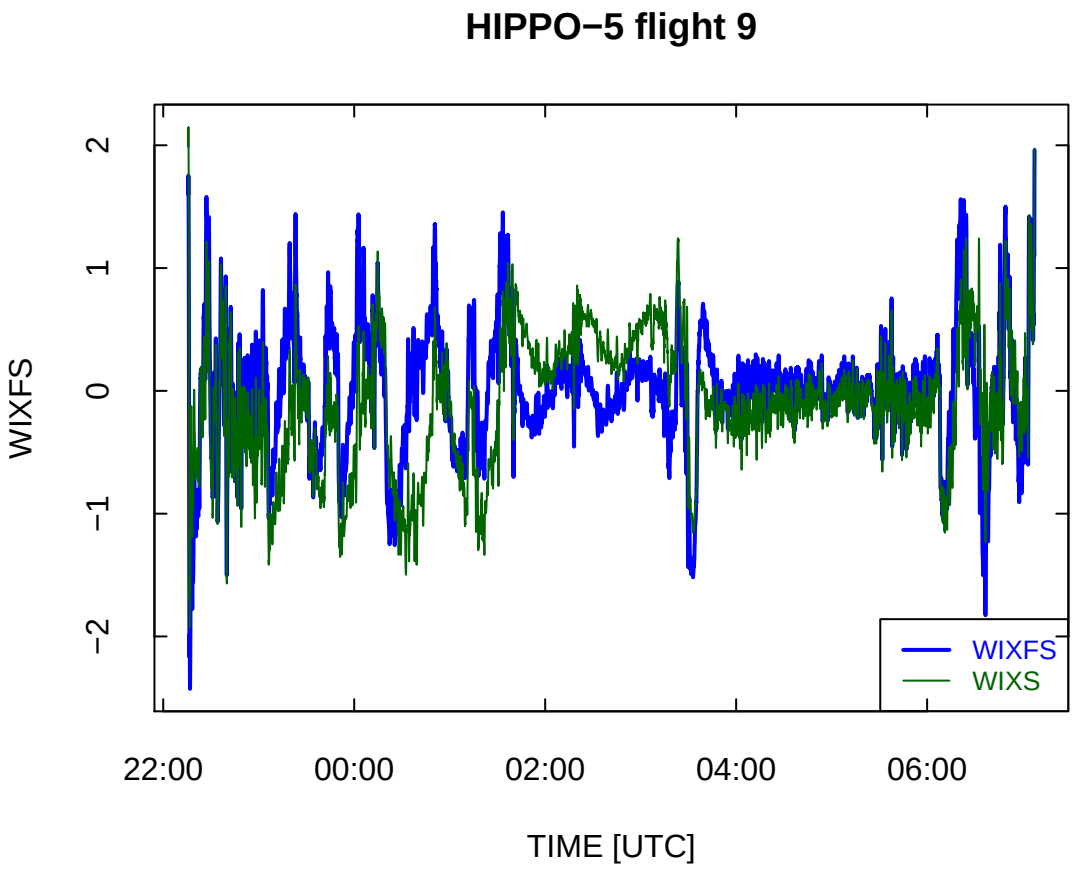

Figure 13: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

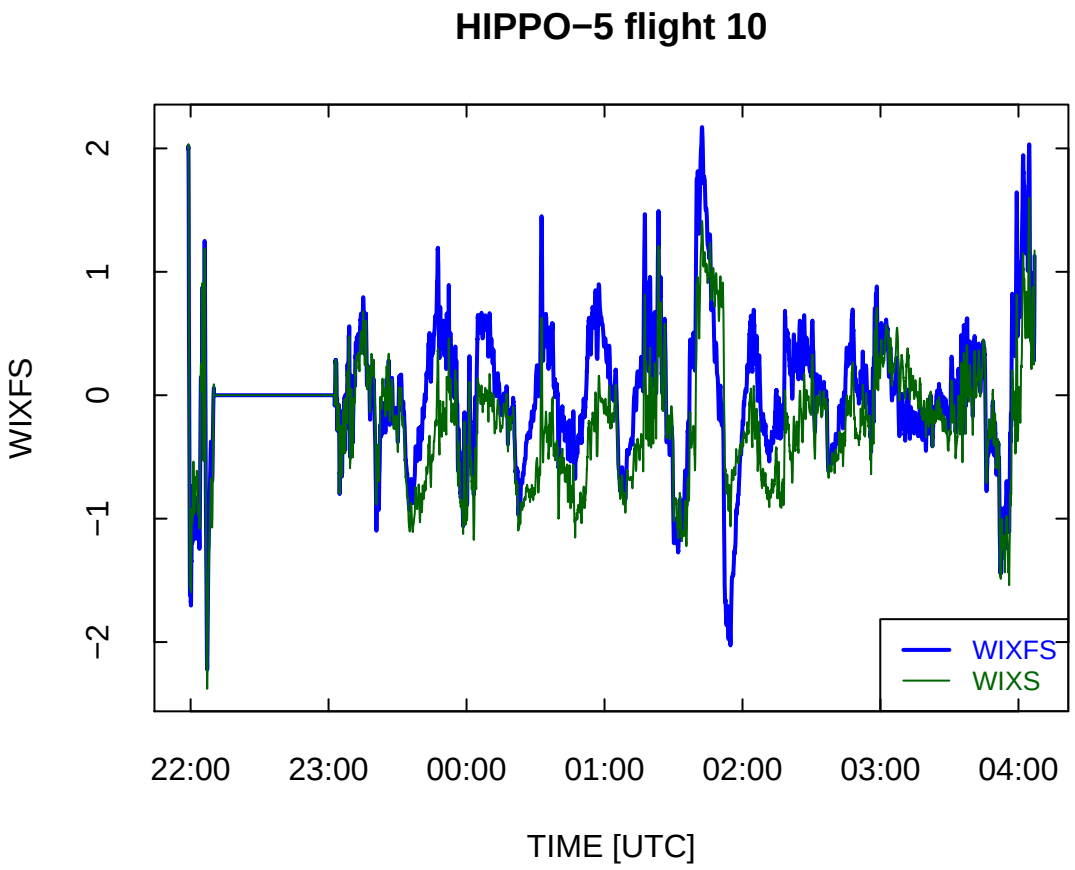

Figure 14: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

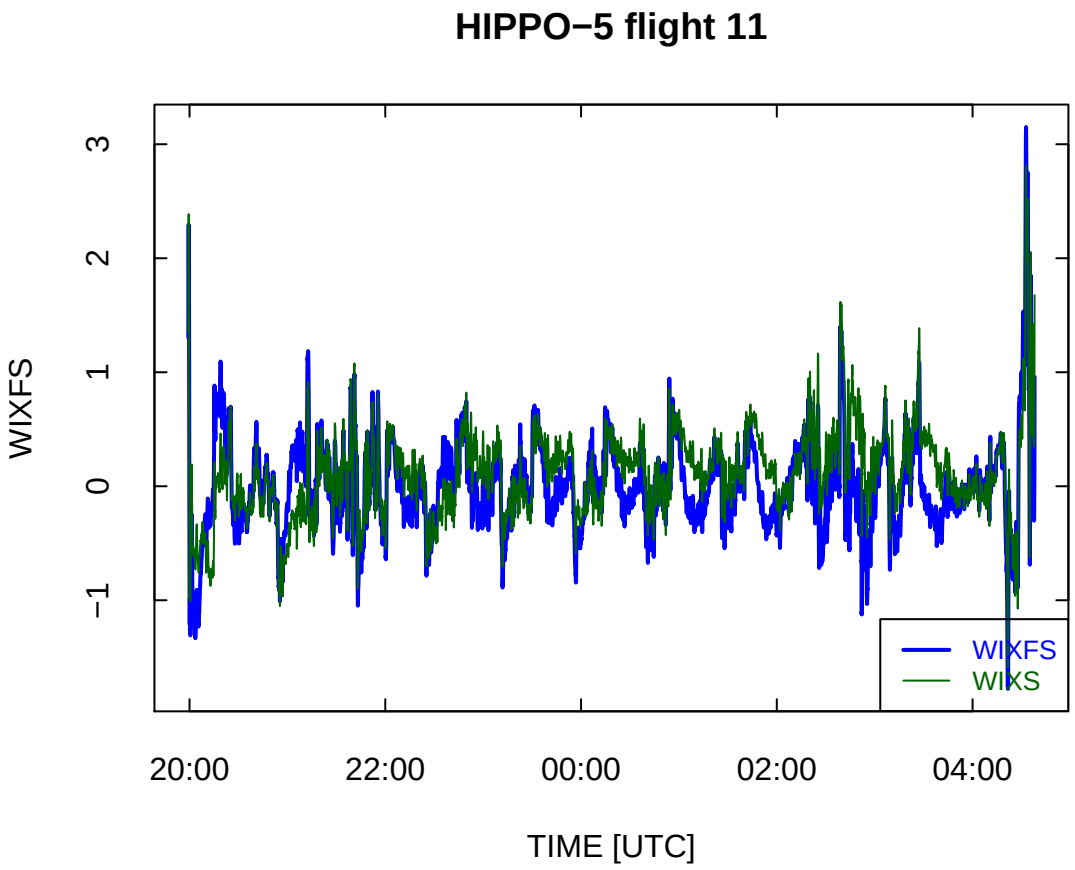

Figure 15: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

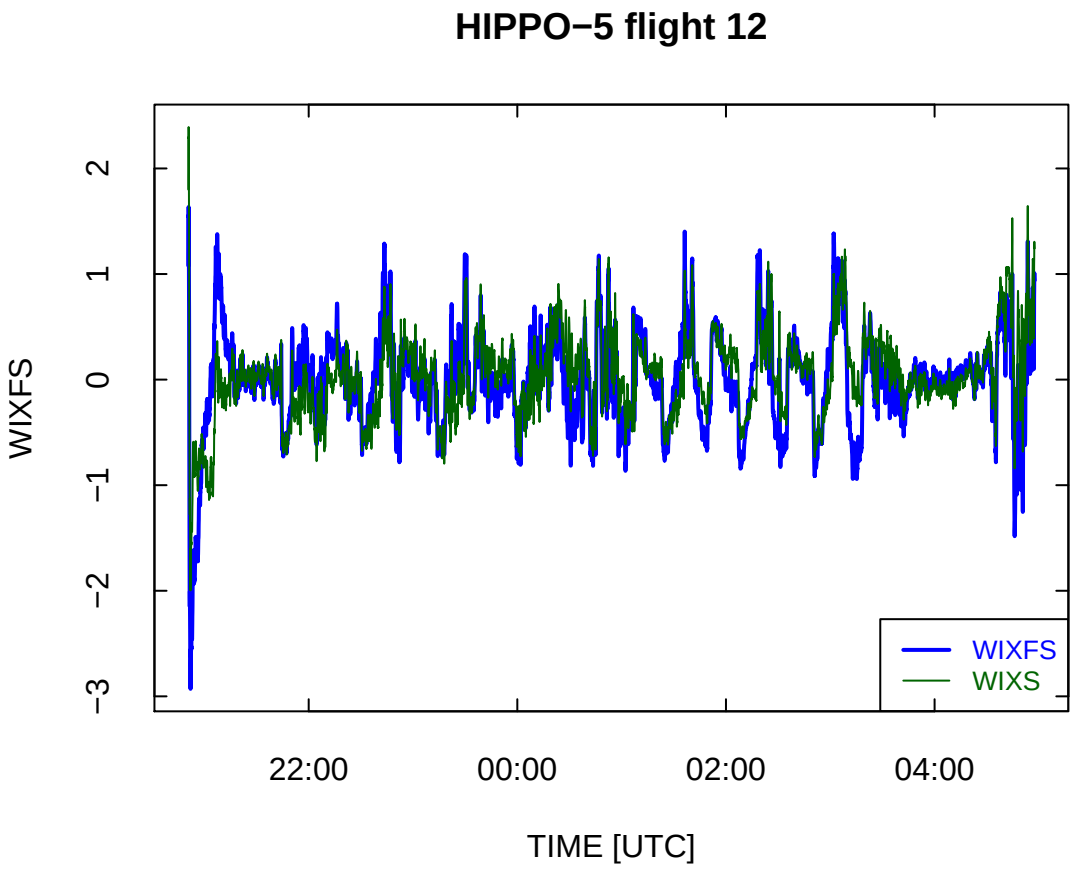

Figure 16: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

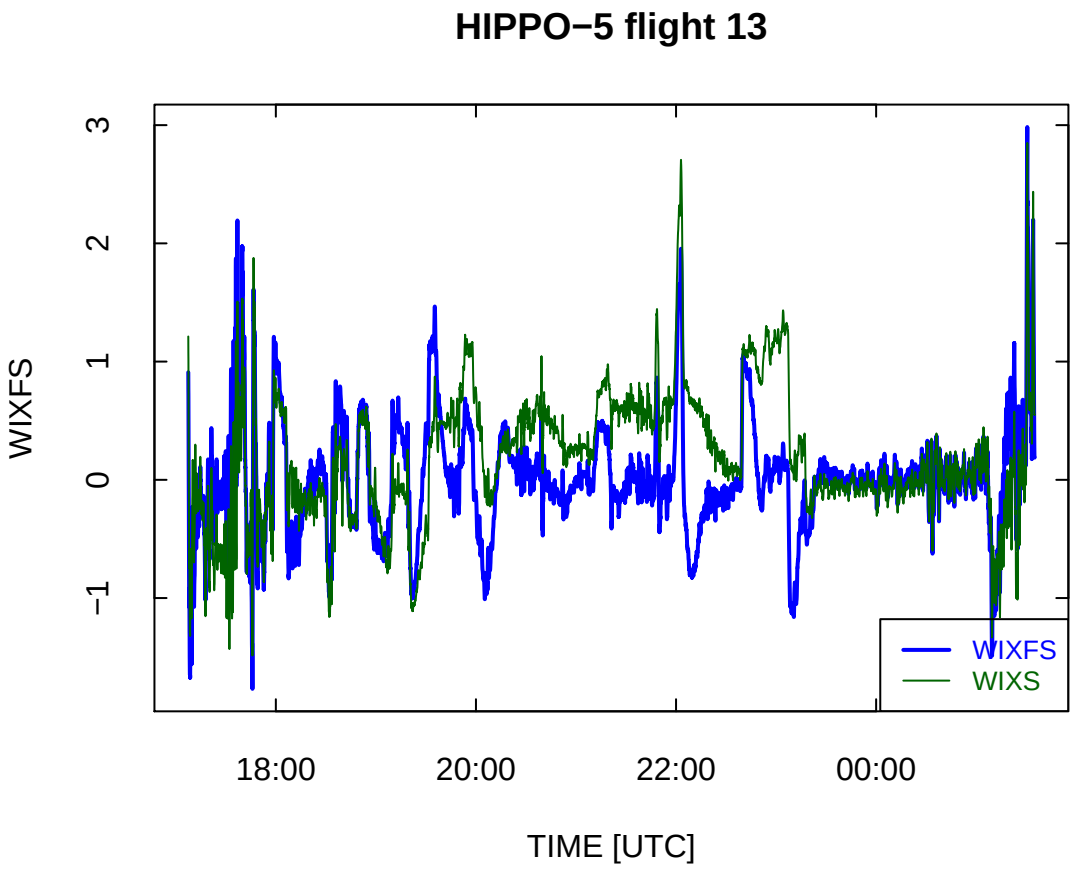

Figure 17: Result for unfiltered and filtered vertical wind for HIPPO-5 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

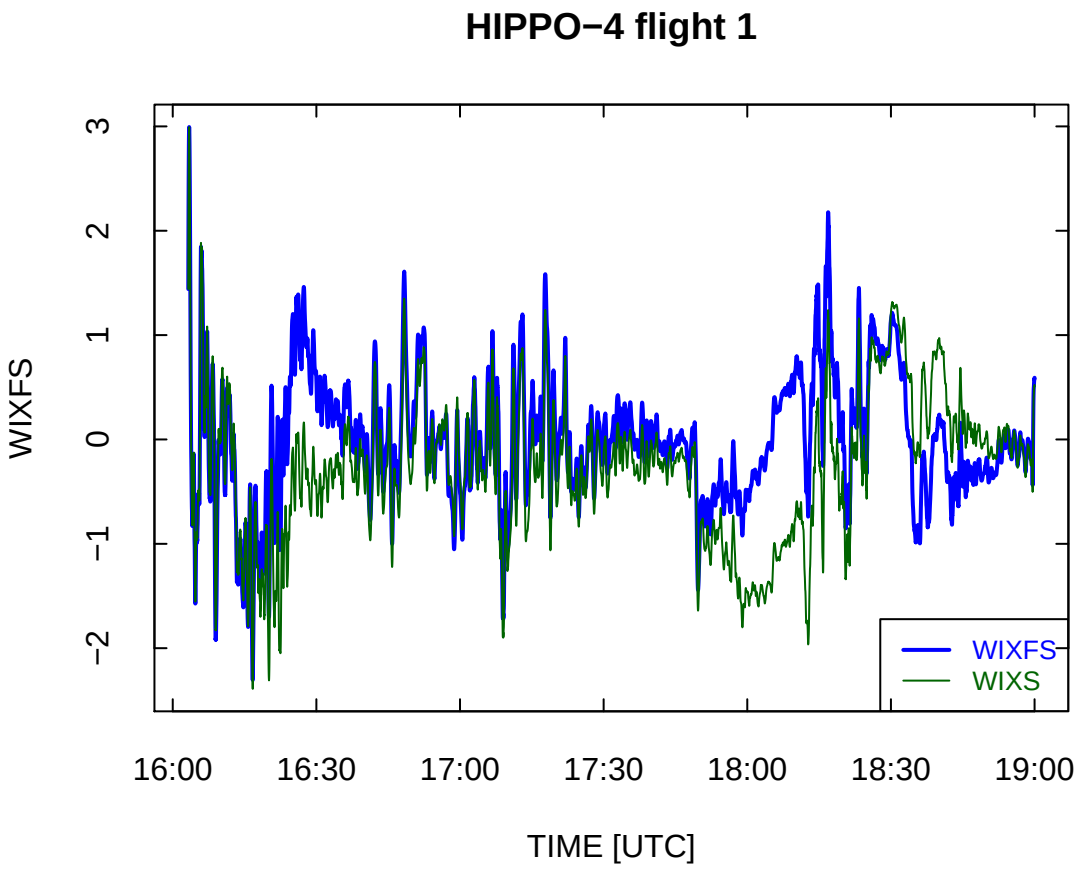

Figure 18: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

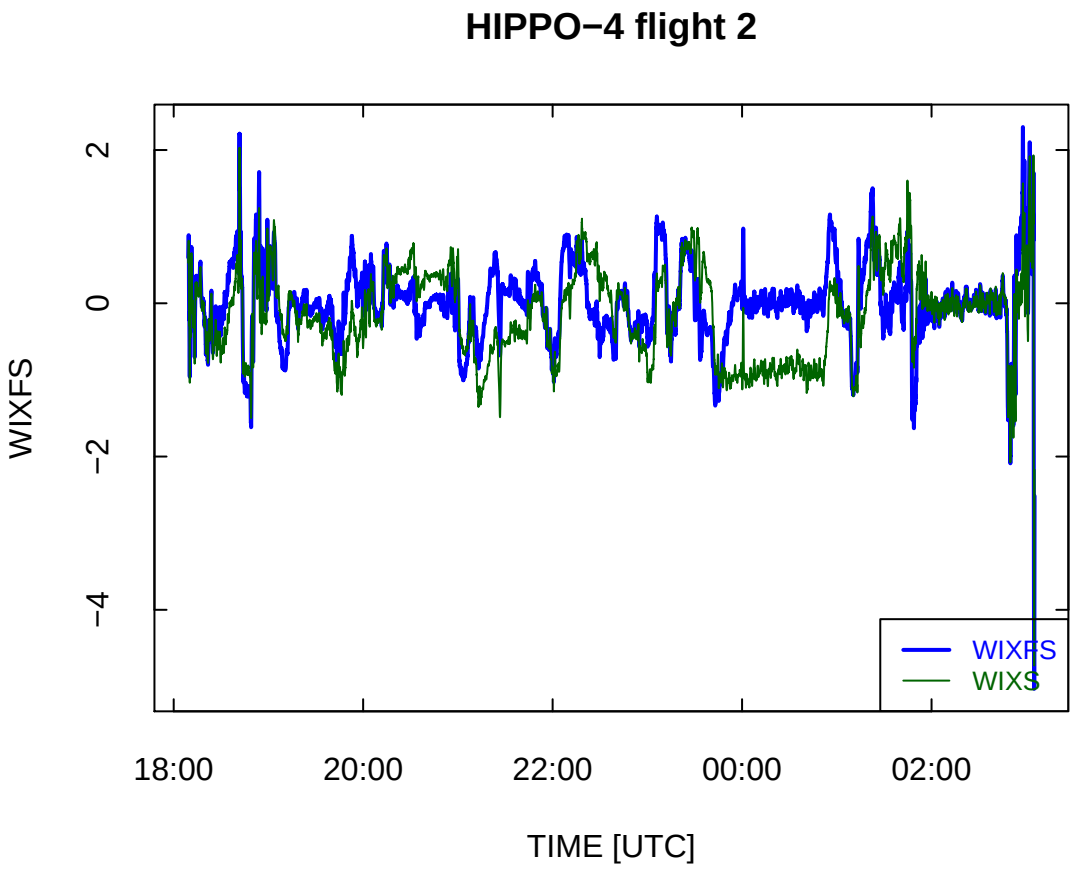

Figure 19: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

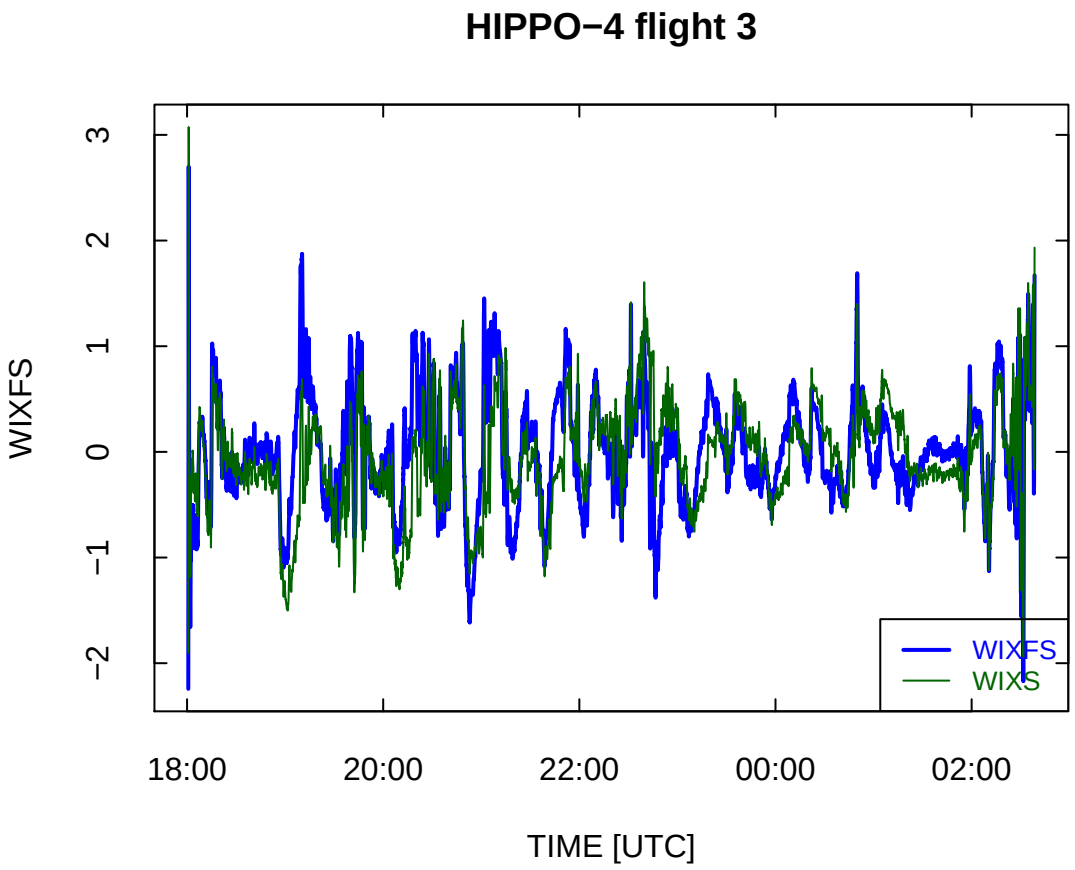

Figure 20: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

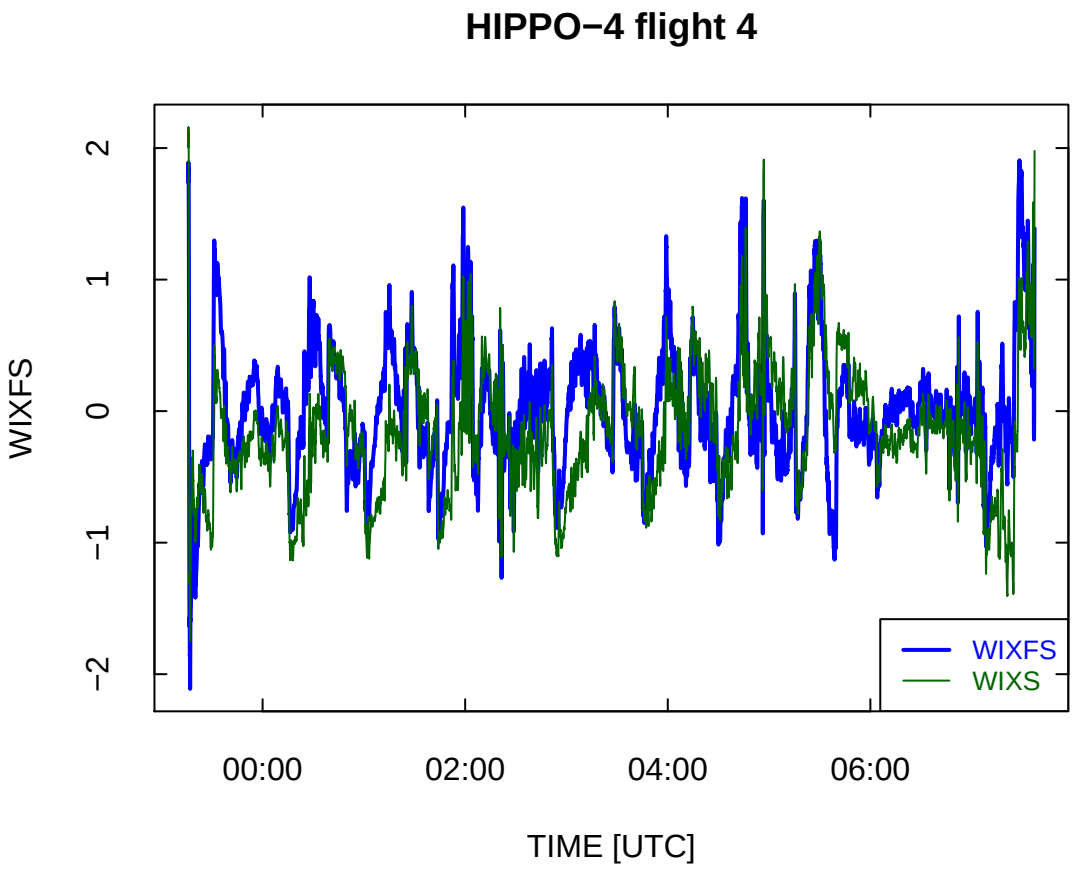

Figure 21: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

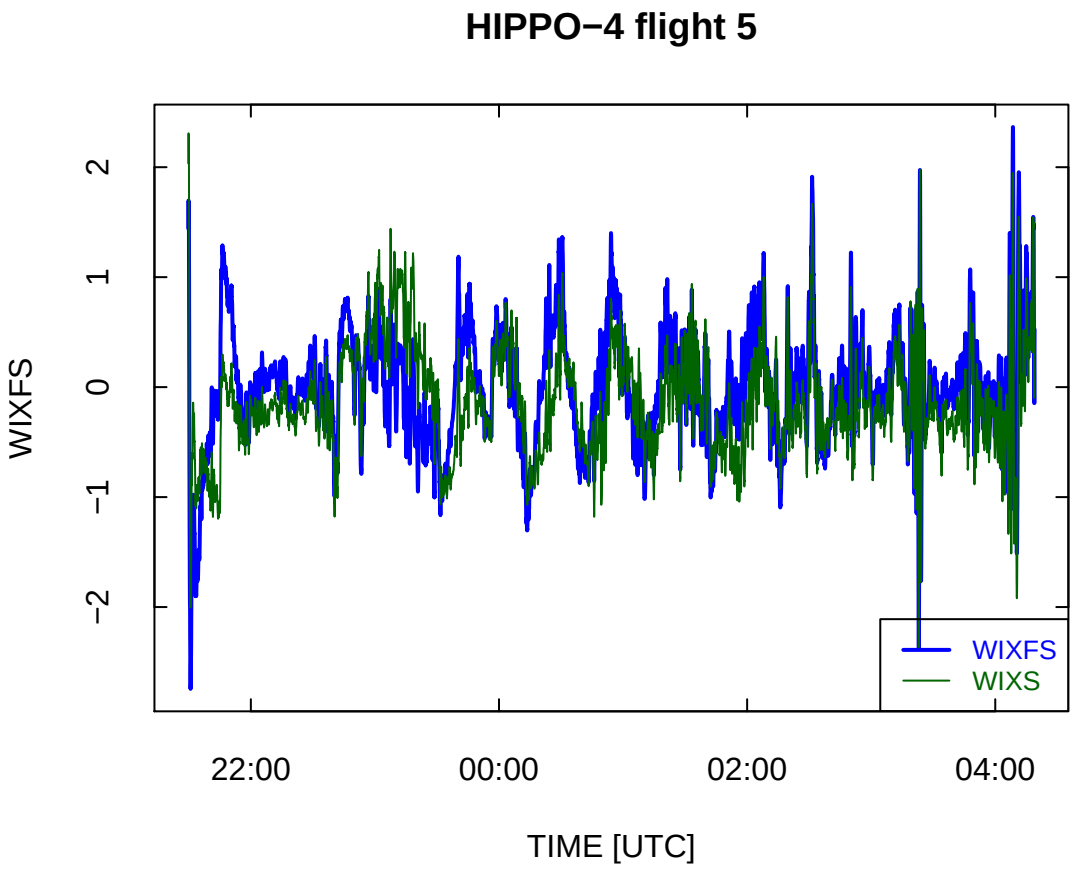

Figure 22: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

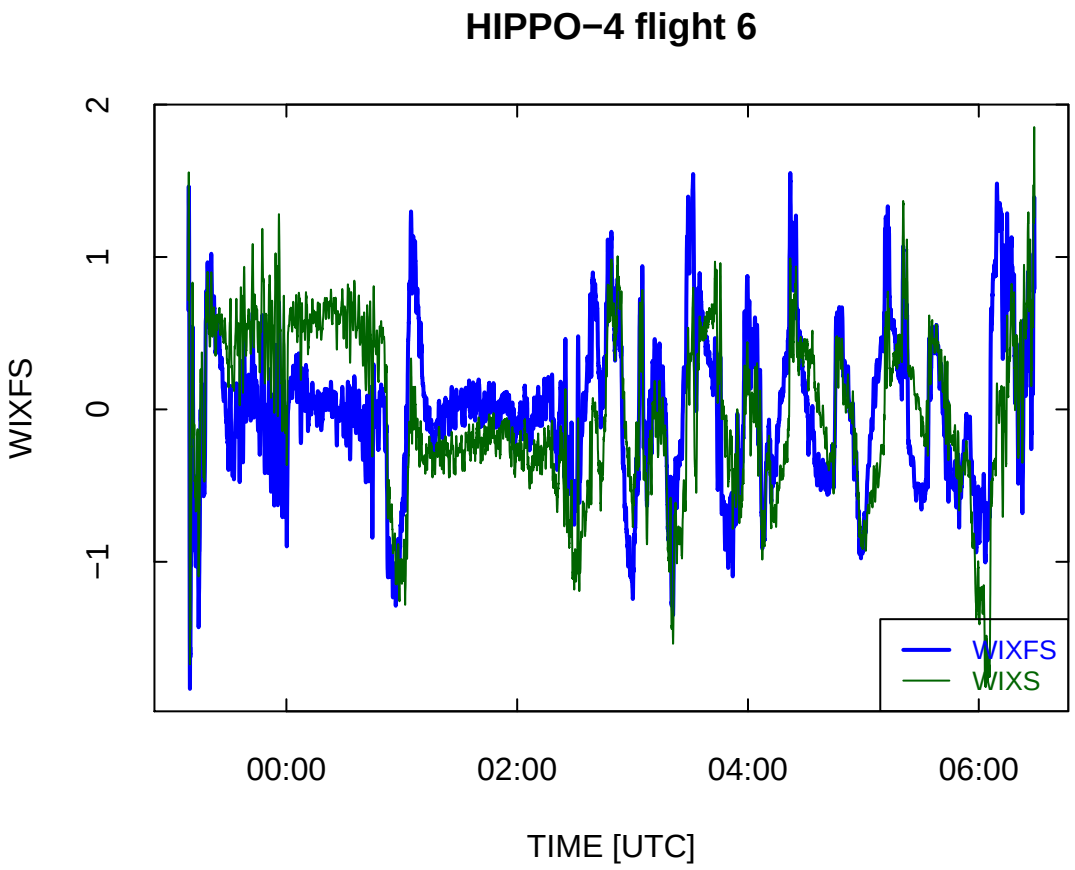

Figure 23: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

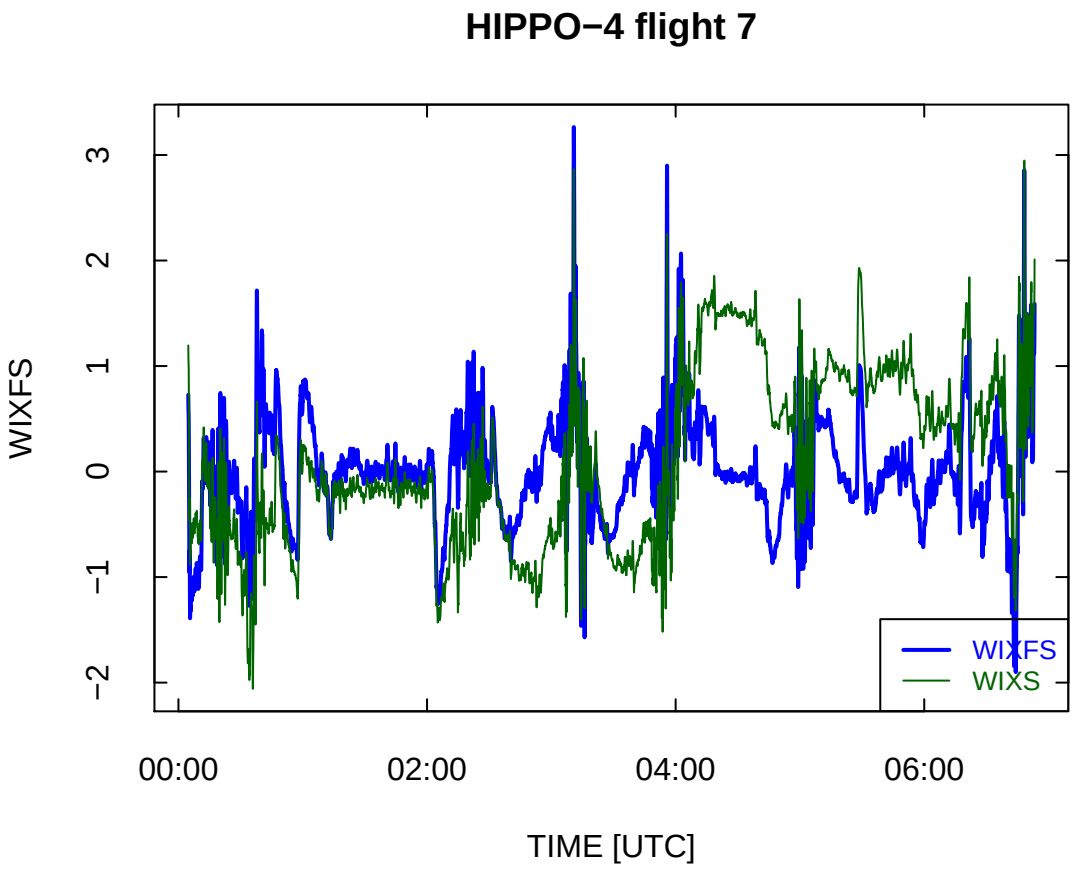

Figure 24: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

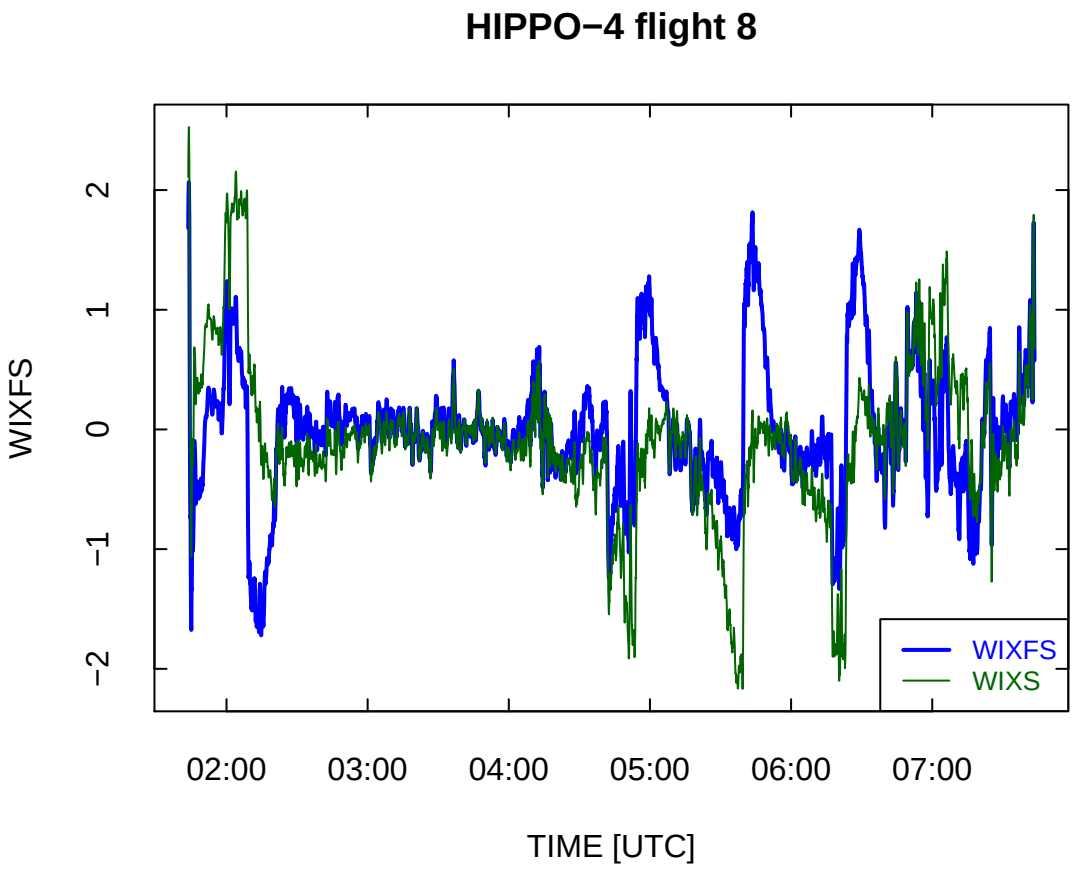

Figure 25: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

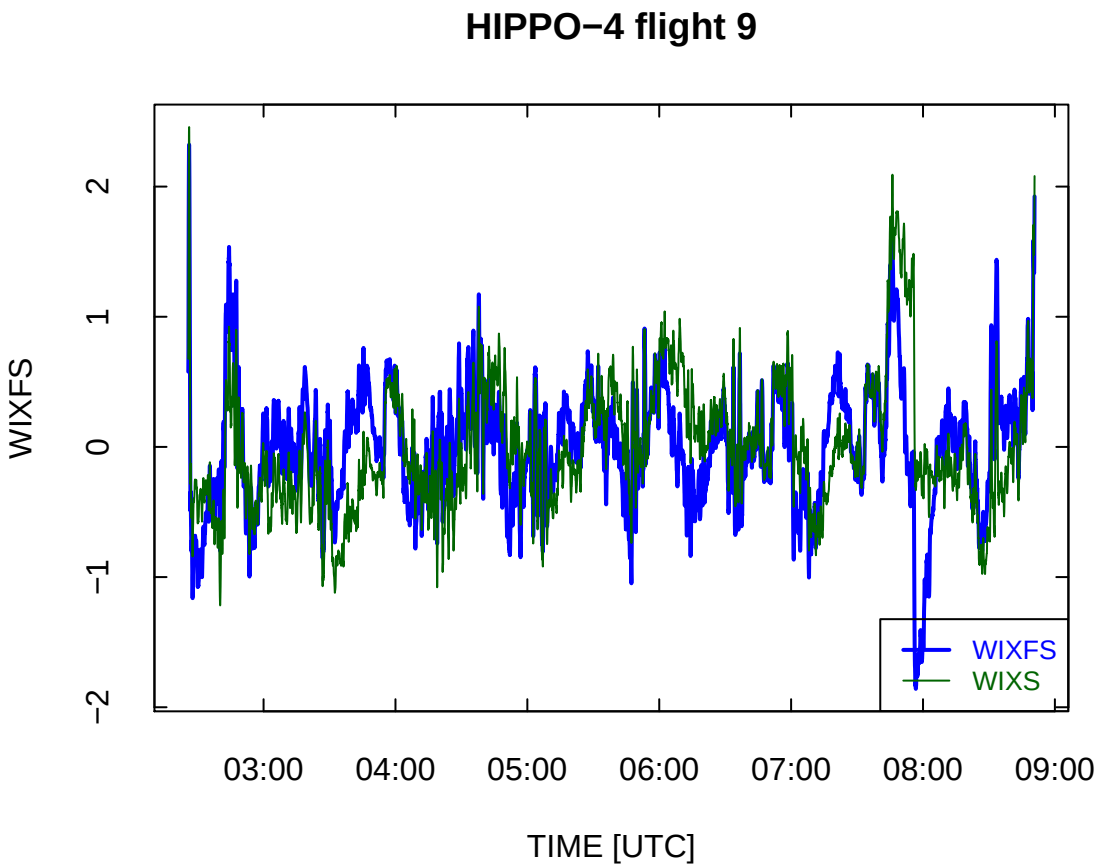

Figure 26: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

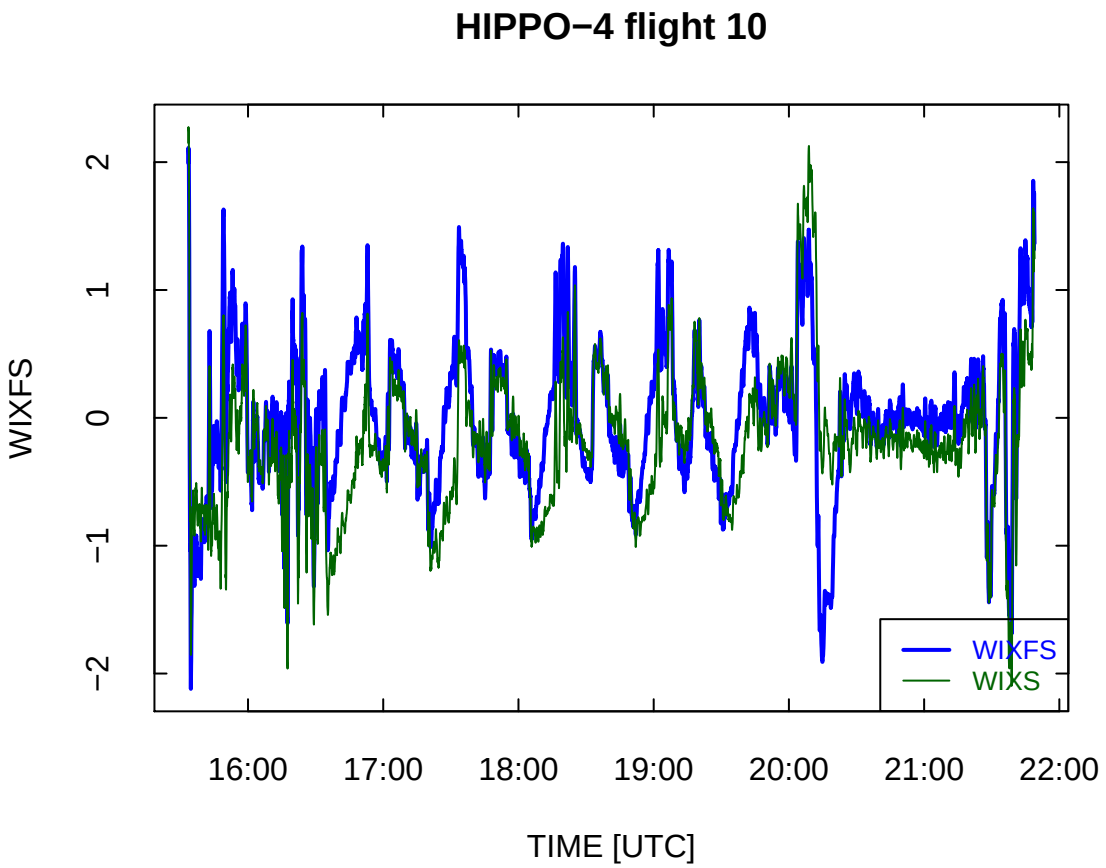

Figure 27: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

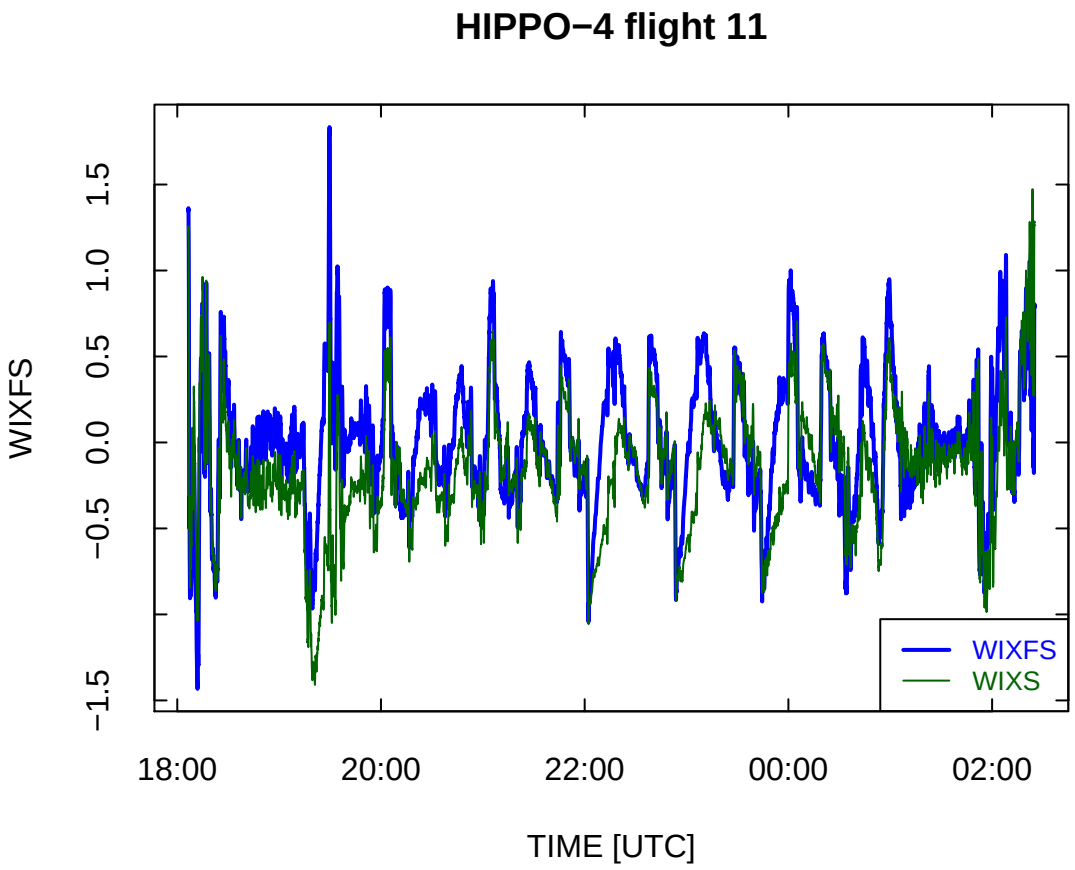

Figure 28: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.

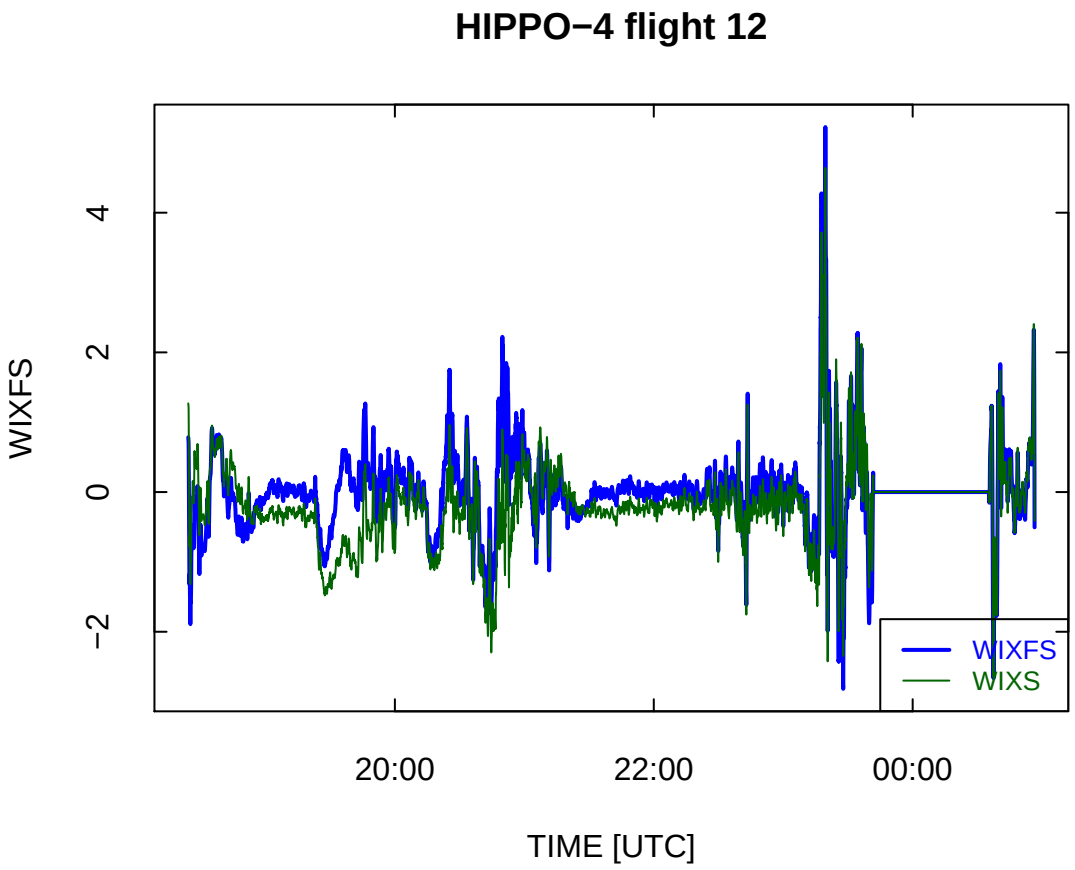

Figure 29: Result for unfiltered and filtered vertical wind for HIPPO-4 flights. All plots have 60-s smoothing to reduce noise in these full-flight plots.