Empirical Representation of AKRD

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RAF Presentation 14 November 2016

OVERVIEW

The topic addressed here:

AKRD is calculated using a standard empirical representation.
That representation seems to be project-dependent.

- It is hard to understand why it should vary.
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The standard representation:

$$\alpha = c_0 + \frac{\Delta p_\alpha}{q}(c_1 + c_2 M)$$

Fit to a reference that assumes zero vertical wind:

$$\alpha^* = \theta - \frac{w_p}{V}$$

SOME WORRIES

Adjustment of the mean value:

$$\langle \alpha \rangle = c_0 + c_1 \left\langle \frac{\Delta p_\alpha}{q} \right\rangle + c_2 \left\langle \frac{\Delta p_\alpha}{q} M \right\rangle$$

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This affects sensitivity to $\Delta p_\alpha / q$

The sensitivity to radome-pressure fluctuations is now:

$$\alpha' = (c_1 + c_2 M) \left(\frac{\Delta p_\alpha}{q} \right)'$$

- Response to radome fluctuations is then altitude dependence.
- There does not appear to be support for this.
- c_2 is project-dependent, depending on flight patterns.

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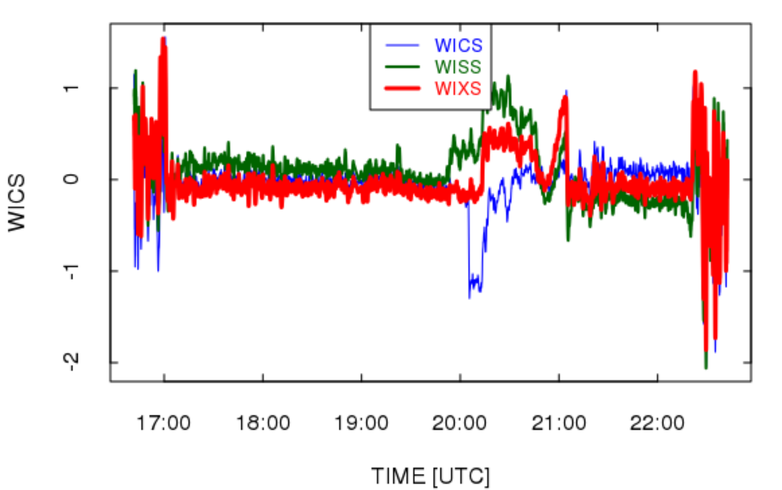
The fluctuating component may be universal, while the slowly varying component is likely project-dependent.

EXAMPLE TO USE: ORCAS Flight 6

Green: standard formula; Red: new fit for ORCAS



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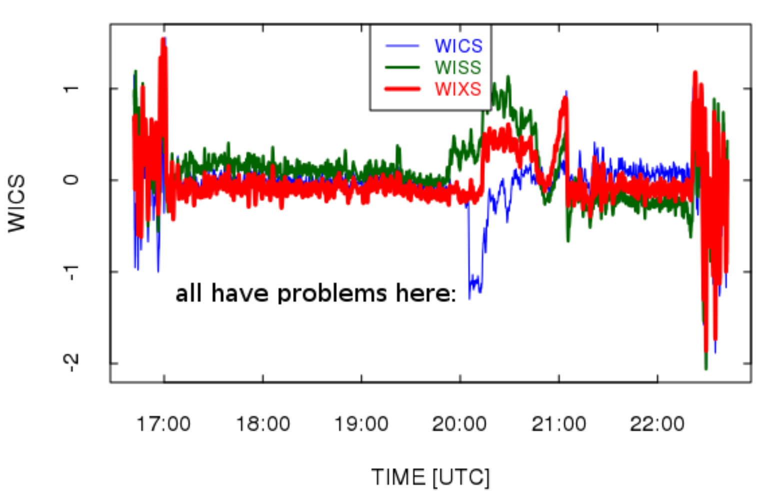

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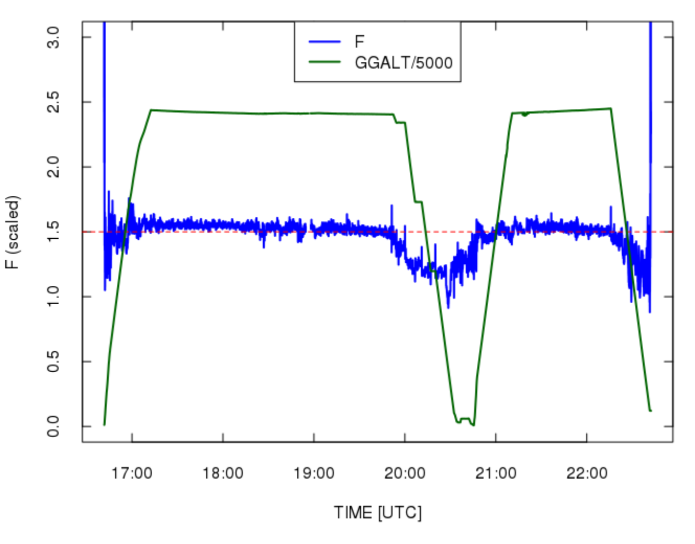
Variations in F then can be used to identify unusual flight conditions like use of flaps, etc.

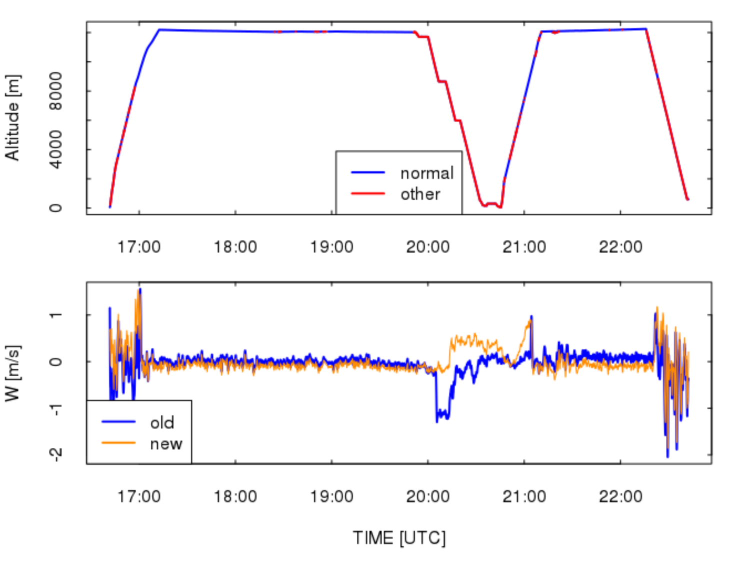
PLOT F FOR A REPRESENTATIVE FLIGHT:

ORCAS Flight 6: Vertical Wind Errors Near 20:00



FLAG ERRORS USING $F < 1.45$:

Good vertical wind for normal flight:



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COMPLEMENTARY FILTER:

1. Split variables representing α (like $\Delta p_\alpha / q$) into two components:
   (a) high-frequency component, 10-min cutoff
   (b) low-frequency component, variable minus high-frequency component
2. Fit these components separately so as to avoid mixing primary sensitivity and representation of the long-term mean. Fit to similarly filtered reference values.
3. Add the two contributions to obtain a final α.

THE COMPLEMENTARY FILTER

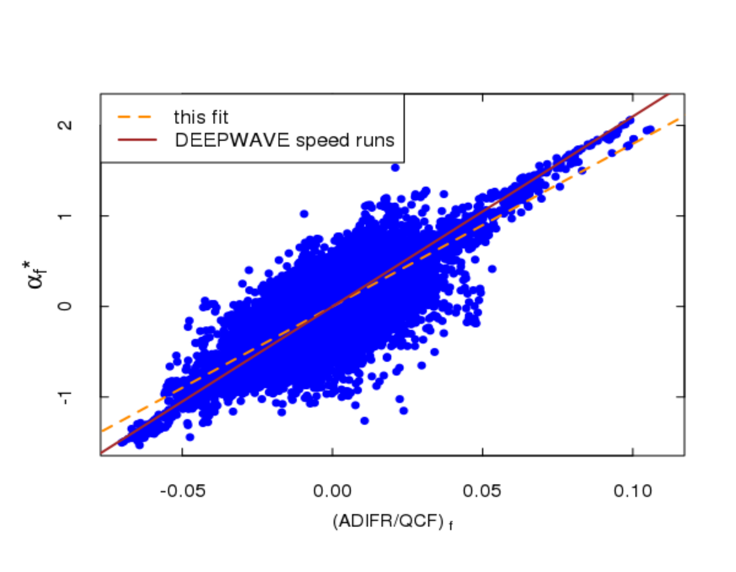
Advantages:

- This provides separate representation of the fast and slow components.
  $\rightarrow$ *This avoids having to use a single formula for both.*
  $\rightarrow$ *The most important fast component will not be distorted.*
- The result can be a reference to which to compare other approaches that might be easier to implement.
- The slow component is not removed, so valid larger regions of updraft can be measured.

Disadvantage:

- This implementation requires a second-pass calculation.
- It will require further exploration to see if this can be implemented in nimbus instead.

THE HIGH-FREQUENCY COMPONENT:
Combined ORCAS and CSET flights



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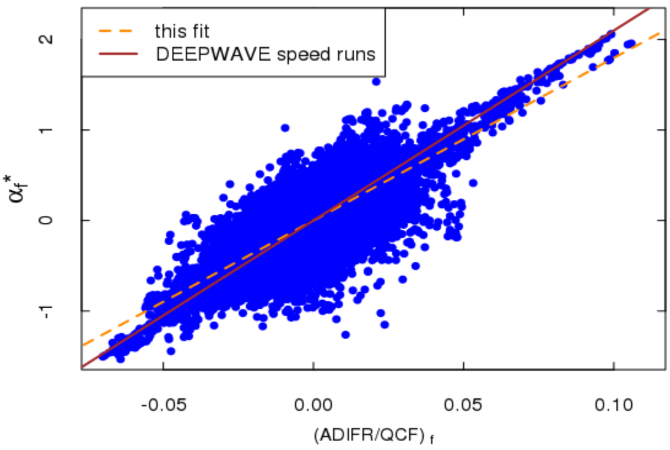
what is wrong with "this fit"? (next slide)



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Speed runs are best:

- Usually, little vertical wind, so no error in α^*
- DEEPWAVE value of c_1 was 20.986. Result for many projects is similar when speed runs are used.
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Regression fitting: A problem can arise from measurement errors.

- With spread-out scatterplots, there is often an apparent bias toward a more level result.
- Because there is a limited range represented in these composite fluctuations, the correlation coefficient is small even though the residual error is $<0.1^\circ$.
- If we are to assume a universal value for all projects, it should be based on speed runs. The DEEPWAVE value is perhaps best.

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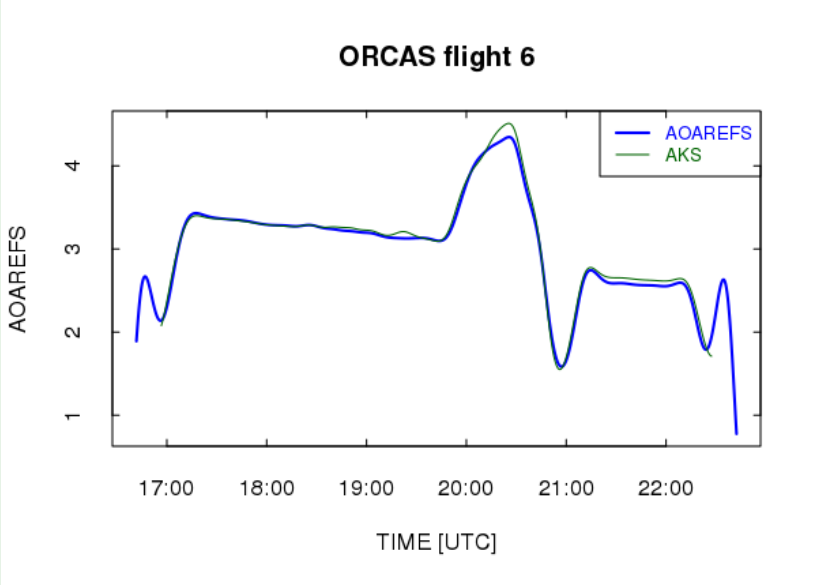
A simple fit works well:

$\alpha_s^* \sim d_0 + d_1 \left(\frac{\{\mathrm{AKRD}\}}{\{\mathrm{QCF}\}} \right)_s + d_2 \{\mathrm{QCF}\}_\mathrm{s}$

Two-project residual: 0.061°, $R^2 = 0.99$

THE LOW-FREQUENCY COMPONENT - ORCAS FLIGHT



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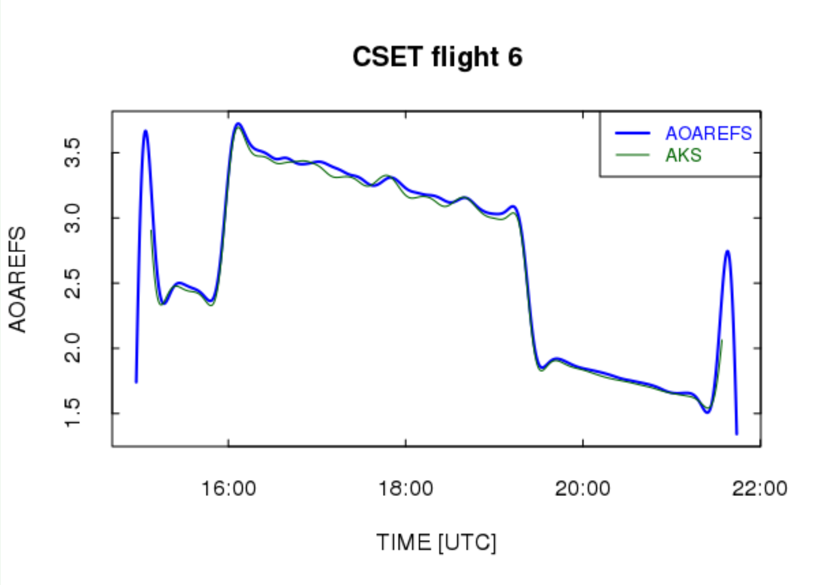

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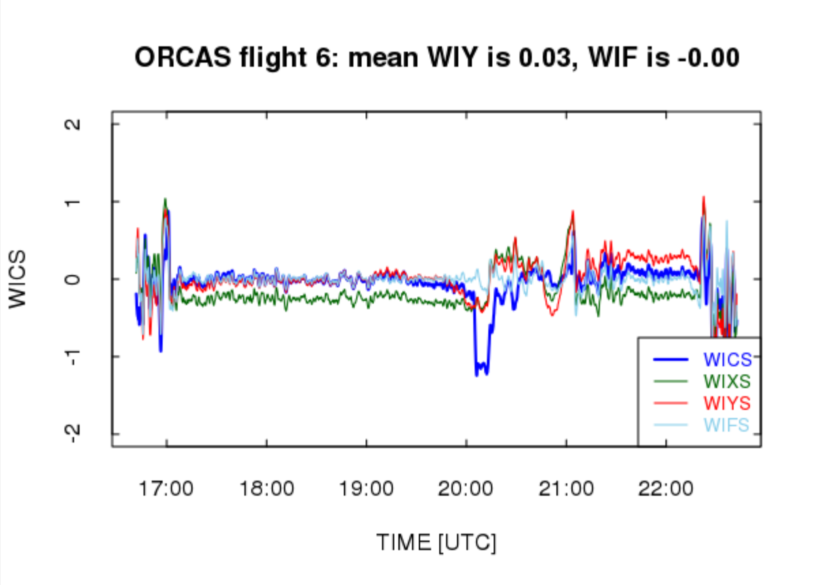
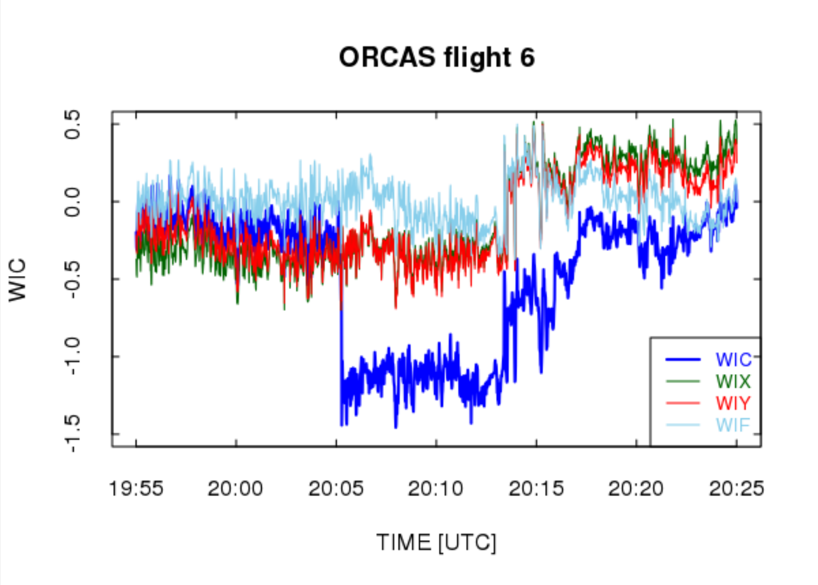
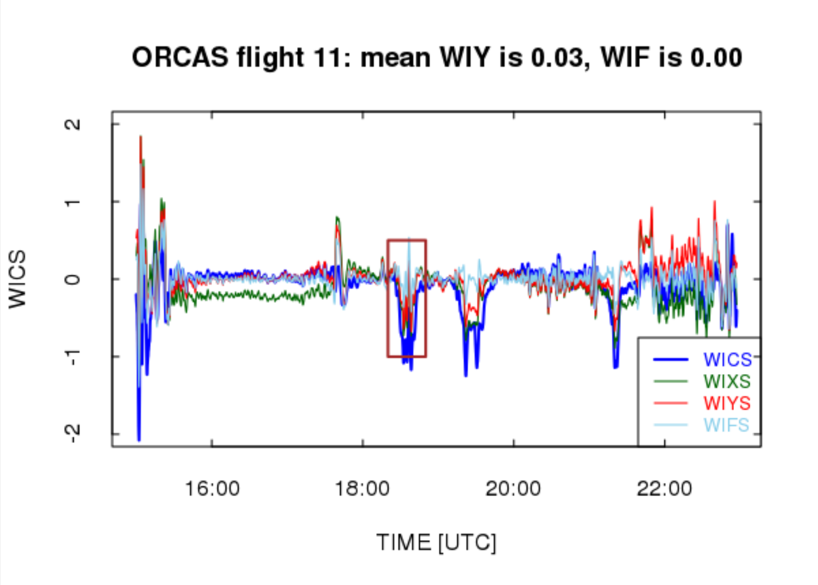
ALL VERTICAL WIND VARIABLES



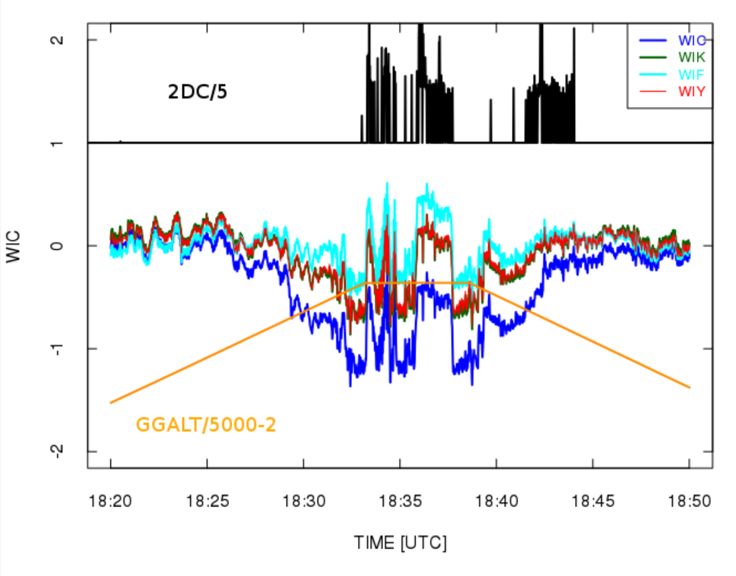
(SHORTER PERIOD)



A FLIGHT WITH DOWNDRAFT PERIODS



EXPANSION OF BOX ON PREVIOUS SLIDE



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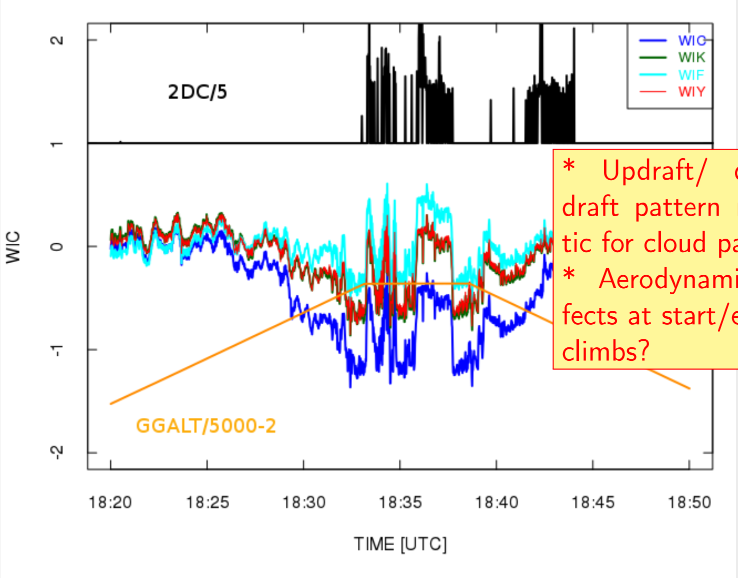
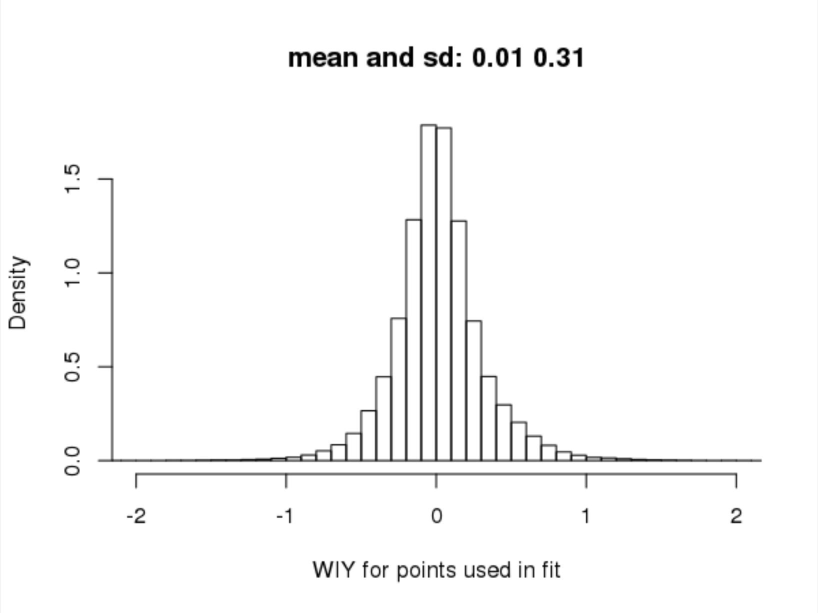


* Updraft/ downdraft pattern realistic for cloud pass?
* Aerodynamic effects at start/end of climbs?

RETURN TO QUESTION OF BIAS IN DATA FOR FIT



RECOMMENDATIONS (BASED ON CSET/ORCAS)

Consider the complementary-filter solution:

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2. "Fast" representation is consistent, all projects.
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4. The combination continues to show suggestions of aerodynamic effects
   (a) lasting a few minutes at start and end of climbs
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Alternatives:

1. Conventional all-two-project fit works fairly well.
2. Even better if QCF dependence is added.
3. Disadvantage: Leads to variable high-frequency sensitivity.

IMPLEMENTATION STRATEGIES:

Second-pass processor:

Advantages: * Can do forward/backward filtering to avoid transient effects;
* Could be combined with other second-pass tasks like height-above-terrain and pitch/heading corrections, maybe someday Kalman filtering.

Disadvantages: Requires extra processing and attention.

Incorporate in nimbus:

Feasibility? Not sure, but probably reasonably straightforward.

Single-pass filtering: Will have a disadvantage; probably very little difference vs forward/backward. Need to test this.