Uncertainty Limits for Wind Measurements

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DEEPWAVE Workshop Short Presentation
4 May 2015

SUMMARY TABLE FOR VERTICAL WIND – Nov 2014

#	measure-ment	bias	random error	δw bias $\mathrm{m\,s^{-1}}$	δw, random
1	radome ADIFR	0.07 hPa	0.002 hPa	–	–
2	AOA: fit	0.03°	0.001°	0.12	0.04
3	sideslip	0.07 hPa	0.002 hPa	–	–
4	dynamic pressure QCF	0.34 hPa	0.01 hPa	<0.02	0.001
5	pitch	0.05°	0.02°	0.19	0.08
6	GV vertical velocity	0.03 m/s	<0.03 m/s	0.03	<0.03
7	GV u, v motion	0.03 m/s	<0.03 m/s	–	–
8	pressure PSF	0.10 hPa	0.001 hPa	–	–
9	temperature ATX	0.3°	0.1°C	–	–

DEVELOPMENTS RE VERTICAL WIND

At the Nov 2014 workshop:

Estimated σ_w (standard uncertainty) $\simeq 0.2\,m\,s^{-1}$.
Pitch is the primary cause of uncertainty in w.
->Provided by an inertial reference unit, specs $\pm 0.05^\circ$.

Two subsequent studies of the pitch measurement:

1. Compared the duplicate inertial reference units onboard

   full-project standard deviation: 0.02°, better than specs
   difference when high-pass filtered (1000 s): 0.007°

   Suggests contribution to uncertainty is:

   - slowly varying bias: 0.08 m/s
   - faster-varying random error: 0.03 m/s

2. New correction procedure: Detect the Schuler oscillation

   project-average correction: 0.02°, consistent with above

NEW ESTIMATE. UNCERTAINTY IN PITCH

Without Schuler-correction procedure (standard output):

bias: 0.02°, varying slowly compared to 1000 s
random error: $<0.01^\circ$

Effect on the vertical wind: ± 0.08 m/s

A correction procedure can be applied based on the Schuler oscillation:

Bias is negligible.
Residual error contribution: 0.03 m/s!

NEW ESTIMATE, UNCERTAINTY IN ANGLE OF ATTACK

- The calibration of angle of attack relies on the pitch measurement.
- The Schuler-correction procedure removes the main error in pitch.

Result:

Significant reduction in bias estimate for angle of attack:
0.01° or 0.04 m/s

Relies on assumed zero vertical wind for calibration data!

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NEW ESTIMATE, UNCERTAINTY IN VERTICAL WIND

Standard (radome-based) system

Standard processing: bias limit ± 0.1 m/s,
random uncertainty 0.04 m/s

With pitch correction: bias limit ± 0.05 m/s *[special processing]*
random uncertainty 0.04 m/s

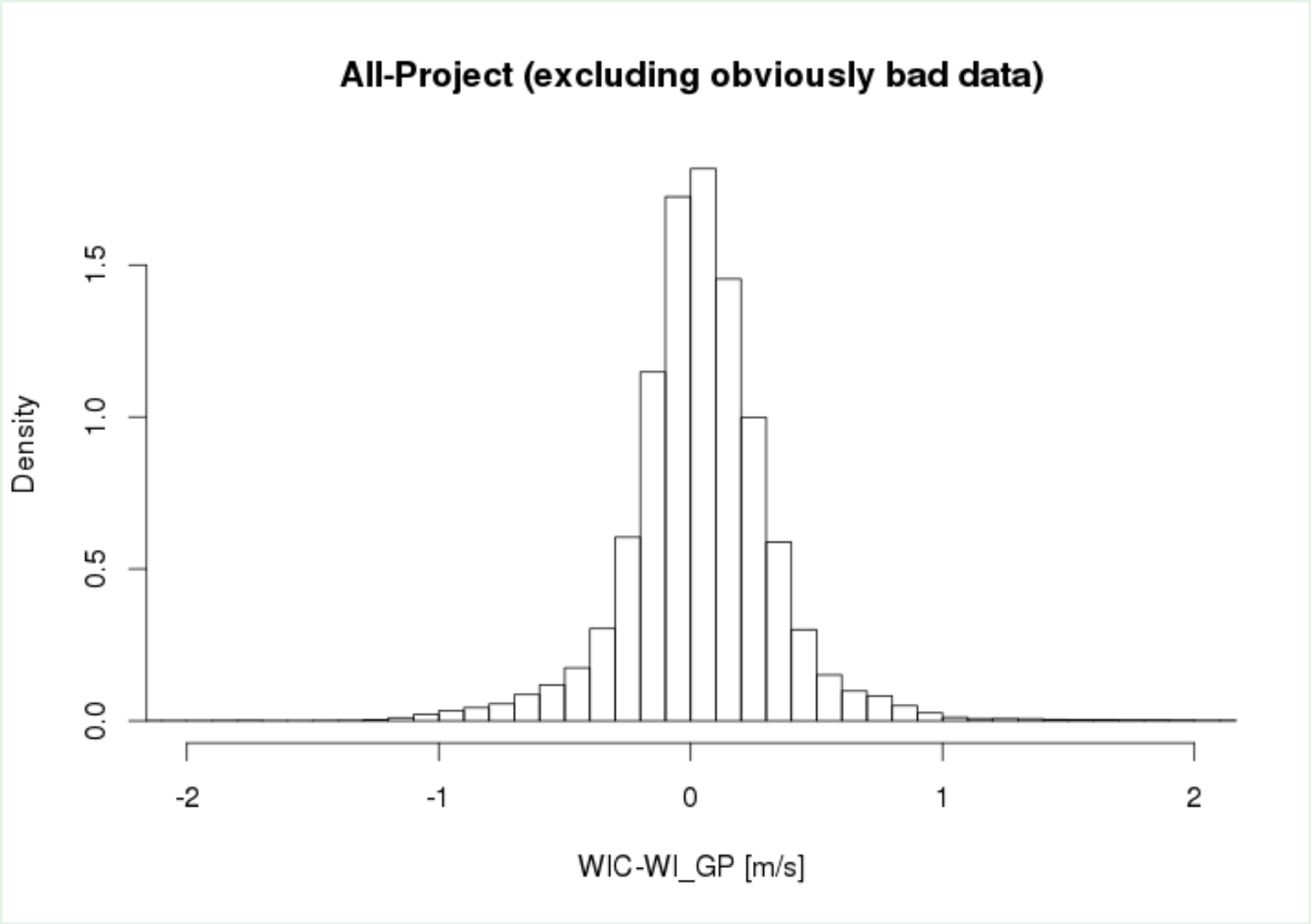
Gust-pod system

bias limit ± 0.2 m/s,

random uncertainty 0.2 m/s

Critical test: Compare standard vs gust-pod vertical wind,
vs. predicted 0.3 m/s from the above

Standard Deviation for the Project: 0.34 m/s



UNCERTAINTY IN HORIZONTAL WIND

Similar approach with tabulation of error sources

longitudinal wind: dominant error source is airspeed
calibration via LAMS:
bias limit$\pm$0.3 m/s
random uncertainty: 0.2 m/s

lateral wind: dominant error sources are heading and sideslip angles
best evidence: circle maneuvers:
bias limit $\pm$0.4 m/s
random uncertainty: 0.2 m/s

Gust Pod

longitudinal wind: as above for standard processing
(0.5 m/s for TAS_GP calculated independently)

lateral wind: *use is not recommended, standard is always available*
bias limit: $\pm$0.7 m/s
random uncertainty: 1.7 m/s

IMPORTANT LIMITATIONS

Limits valid for:

- $|\text{Roll}| < 5^\circ$
- TAS > 130 m/s
- Gust pod: flight levels above 5000 m

for flight below about 18,000 ft,
an important limitation applies to high-rate (25 Hz) measurements:

- Resonance in pressure lines affects the variance spectrum of the longitudinal wind.
- A correction procedure is available: contact cooperw@ucar.edu for information.

OTHER UNCERTAINTY LIMITS IN DEEPWAVE

Pressure: LAMS-based corrections applied

bias limit 0.3 hPa
random uncertainty: 0.1 hPa
reference available:
Atmos. Meas. Tech., 7, 3215–3231

Temperature: LAMS-based validation

bias limit: $\pm 0.3^{\circ} C$
random uncertainty: $0.3^{\circ} C$
same reference as above

TECH NOTE: Uncertainty in Wind Measurements...

A long and detailed document (>160 pp) describing the wind measurement systems and characterizing uncertainty in them is in draft form, now undergoing continued editing but complete in regard to analysis and presentation of results.

Send a request to cooperw@ucar.edu for access to the current draft,