Calibration of the University of North Dakota's Citation Aircraft Wind System

David J. Delene

Department of Atmospheric Sciences
University of North Dakota
Where it all Started

A long, long, time ago .............. May
In an office, not too far way ...

What? You have to move the IMU!

It shouldn't be a problem. Just redo the calibration.
Why Measure Winds During Flight

- Basic Atmospheric Parameter
- Transport Studies
- Vertical Velocity (updrafts, downdrafts)
- Air Parcel Tracking
Wind Velocity Measurement from an Aircraft

\[ V = V_p + V_a \]

Velocity of the aircraft with respect to the earth - \( V_p \)

Velocity of the air with respect to the air

\( V_p \) – Measured with the Position and Orientation System
\( V_a \) – Measured with pressures transducers on the aircraft nose
Pitot Pressure Ports on Aircraft Nose

- Attack Angle
- Sideslip Angle
- Pitot Nose
Inside of the Citation's Radome
Position and Orientation System

Rack Mount Computer System

Inertial Measurement Unit
Air Velocity with Respect to the Earth

\[ U = -U_a D^{-1} \left[ \sin \Psi \cos \Theta + \tan \beta (\cos \Psi \cos \phi + \sin \Psi \sin \Theta \sin \phi) + \tan \alpha (\sin \Psi \sin \Theta \cos \phi - \cos \Psi \sin \phi) \right] + U_p - L (\text{DIV}(\Theta) \sin \theta \sin \Psi - \text{DIV}(\Psi) \cos \Psi \cos \theta) \]

\[ V = -U_a D^{-1} \left[ \cos \Psi \cos \Theta - \tan \beta (\sin \Psi \cos \phi - \cos \Psi \sin \Theta \sin \phi) + \tan \alpha (\cos \Psi \sin \Theta \cos \phi + \sin \Psi \sin \phi) \right] + V_p - L (\text{DIV}(\Psi) \sin \Psi \sin \Theta + \text{DIV}(\Theta) \cos \Psi \sin \theta) \]

\[ W = -U_a D^{-1} (\sin \Theta - \tan \beta \cos \Theta \sin \phi - \tan \alpha \cos \Theta \cos \phi) + W_p + L \text{DIV}(\Theta) \cos \Theta \]

\[ D = (1 + \tan^2 \alpha + \tan^2 \beta)^{\frac{1}{2}} \]

\[ \Psi - \text{True Heading, measured clockwise (looking down) from north} \]

\[ \Theta - \text{Pitch Angle} \]

\[ \phi - \text{Roll Angle} \]

\[ \alpha - \text{Alpha Angle} \]

\[ \beta - \text{Beta Angle} \]

\[ L - \text{Distance between the inertial navigation system and the air-sensing platform along the x-axis of the aircraft} \]

\[ U - \text{East Wind Velocity} \]

\[ V - \text{North Wind Velocity} \]

\[ W - \text{Upward Wind Velocity} \]

\[ U_p - \text{East Aircraft Velocity} \]

\[ V_p - \text{North Aircraft Velocity} \]

\[ W_p - \text{Upward Aircraft Velocity} \]
Calibration Procedure

- Heading Angle Offset
- Alpha Angle Calibration
- Beta Angle Calibration
- Pitot Pressure Calibration
The aircraft's heading (black line) and track angle (blue line) versus time for taxies segment 3 on July 11, 2003 using the real time data files.
The vertical wind versus time for the time period of the alpha angle calibration on July 11, 2003.
The aircraft's vertical velocity during the October 8, 2003 flight.
The vertical wind versus time during the October 8, 2003 flight.
Beta Angle Calibration

The X (East) component of the wind versus time for the time period of the beta angle calibration on July 11, 2003.
The nose pitot pressure versus the measured pressure transducer voltage for the July 11, 2003 reverse track flight.

Slope = 17.2344
Offset = -3.6440
Reverse Track Flight: May 23, 2003

![Graph showing POS_Lat and POS_Lon]
Reverse Track Flight:  May 23, 2003
Reverse Track Flight: May 23, 2003
Reverse Track Flight: May 23, 2003

Graph showing POS_Lat [degrees] vs. POS_Lon [degrees] with markers at t=64460 Sec, t=64845 Sec, t=64775 Sec, and t=64510 Sec.
Reverse Track Flight: May 23, 2003
Reverse Track Flight: May 23, 2003
COBRA Flight: June 6, 2003
COBRA Flight: June 6, 2003
COBRA Flight: June 6, 2003

![Graph showing wind and time data.](03_06_06_11_16_16.tam)
COBRA Flight: June 6, 2003
**Bismarck Rawinsonde Sounding: July 25, 2003**

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Conclusions

The wind calibration procedure has been validated using independent flight data and by comparison with a rawinsonda sounding.

The wind components have an accuracy of 1 Meter/second.

Robust software routines are available so recalibration of the Wind System is not a “problem”.

More information and further calibration documentation is available at http://cumulus.atmos.und.edu/citation/winds