# A13G-0330: Evaluation of 3-dimensional winds measured by the Aircraft Integrated Meteorological Measurement System (AIMMS) Christopher G Kruse, David J Delene, and Cedric Grainger, University of North Dakota (christopher.kruse@und.edu)

## Objective

To analyze and evaluate atmospheric winds derived from measurements taken by the Aventech Research Inc. Aircraft Integrated Meteorological Measurement System (AIMMS). These AIMMS data analyzed are from a King Air 200 aircraft during a field project in Saudi Arabia from 15 March 2009 to 15 April 2009.



**In-Situ Airborne Measurements** 

The Research King Air 200 aircraft with the AIMMS probe installed. The components of an AIMMS are an air data probe (ADP), commonly referred to as a gust probe, a differential GPS, an inertial measurement unit (IMU), and a central processing unit (CPU). The CPU uses data from the ADP, GPS, and IMU to derive the winds. The IMU and CPU were mounted in the cabin, the ADP was mounted under the right wing, and the GPS antennas were mounted on the top of each wing.



To evaluate the performance of the AIMMS probe, special maneuvers were performed on the 23 March 2009 flight. Flight legs were flown in one direction and then flown in the opposite direction at the same altitude and speed. Each set of maneuvers was conducted at three speeds and two altitudes. The performance of the horizontal winds is evaluated by comparing level flight legs in two directions.

| Horizontal Winds   |          |     |            |          |               |               |  |  |  |  |
|--|----------|-----|------------|----------|---------------|---------------|--|--|--|--|
| Maneuver   | Altitude | TAS | Start Time | End Time | Mean E/W Wind | Mean N/S Wind |  |  |  |  |
|  | ft       | m/s | HH:MM:SS   | HH:MM:SS | m/s           | m/s           |  |  |  |  |
| Straight Level 1   | 15000    | 85  | 12:04:00   | 12:06:33 | -18.9148      | -5.5972       |  |  |  |  |
| Straight Level 2   | 15000    | 85  | 12:16:18   | 12:19:04 | -17.9790      | -4.4799       |  |  |  |  |
| Straight Level 3   | 15000    | 105 | 12:21:40   | 12:25:40 | -18.8049      | -4.8901       |  |  |  |  |
| Straight Level 4   | 15000    | 105 | 12:35:00   | 12:37:48 | -18.9550      | -4.9917       |  |  |  |  |
| Straight Level 5   | 15000    | 130 | 12:40:00   | 12:43:10 | -18.4975      | -6.4552       |  |  |  |  |
| Straight Level 6   | 15000    | 130 | 12:51:30   | 12:54:26 | -18.2004      | -7.6485       |  |  |  |  |
| Straight Level 7   | 21000    | 85  | 13:00:00   | 13:03:10 | -29.8412      | -0.7875       |  |  |  |  |
| Straight Level 8   | 21000    | 85  | 13:10:20   | 13:13:40 | -29.1538      | 0.9123        |  |  |  |  |
| Straight Level 9   | 21000    | 105 | 13:18:20   | 13:21:10 | -31.1230      | 0.1342        |  |  |  |  |
| Straight Level 10  | 21000    | 105 | 13:28:40   | 13:31:10 | -32.2279      | 1.1015        |  |  |  |  |
| Straight Level 11  | 21000    | 130 | 13:36:20   | 13:39:30 | -31.1968      | 1.4192        |  |  |  |  |
| Straight Level 12  | 21000    | 130 | 13:48:00   | 13:51:20 | -28.2079      | -0.3109       |  |  |  |  |
| The time intervale and mean magnitude of East/Meat and North/South wind components during th |          |     |            |          |               |               |  |  |  |  |

straight and level maneuvers at 15,000 feet and 21,000 ft MSL during the wind validation flight conducted on 23 March 2009 in Saudi Arabia. Each consecutive straight and level maneuver was flown in the opposite direction. This was repeated at three different speeds and two different altitudes.



The horizontal components of the wind (m/s), true airspeed (m/s), and altitude (ft MSL) during the different legs are shown. The AIMMS processing code was used. The 5, 25, 50, 75, and 95 percentiles are given by the box-and-wiskers while the stars denote the mean values.

### Calibration



Each leg flown consisted of a straight and level constant speed maneuver followed by a porpoise and side-slip maneuver. The performance of the vertical winds is evaluated by comparing the level flight legs to the porpoise flight legs.

### **Aventech Calibration**

- Data are obtained from flight maneuvers.
- Calibration coefficients are determined for a linear equation to approximate angle of attack, angle of side-slip, and true air speed.
- •All calibration coefficients are determined simultaneously using the flight data and the assumption that the wind field is uniform over the time period of the flight maneuvers.
- •The coefficients are used in the calculation of the winds and are applied on all project flights.

|                  |     |            | 15,000' MSL |                | 21,000' MSL |          |                |  |
|------------------|-----|------------|-------------|----------------|-------------|----------|----------------|--|
| Maneuver [       | TAS | Start Time | End Time    | Mean Vert Wind | Start Time  | End Time | Mean Vert Wind |  |
|                  | m/s | HH:MM:SS   | HH:MM:SS    | m/s            | HH:MM:SS    | HH:MM:SS | m/s            |  |
| Straight Level 1 | 85  | 12:04:00   | 12:06:30    | -0.1660        | 13:00:00    | 13:03:10 | -0.4270        |  |
| Straight Level 2 | 85  | 12:16:18   | 12:19:04    | -0.1593        | 13:10:20    | 13:13:40 | -0.2508        |  |
| Straight Level 3 | 105 | 12:21:40   | 12:25:40    | 0.0140         | 13:18:20    | 13:21:10 | -0.0440        |  |
| Straight Level 4 | 105 | 12:35:00   | 12:37:48    | -0.0560        | 13:28:40    | 13:31:10 | -0.0477        |  |
| Straight Level 5 | 130 | 12:40:00   | 12:43:10    | -0.3459        | 13:36:20    | 13:39:30 | -0.3471        |  |
| Straight Level 6 | 130 | 12:51:30   | 12:54:26    | -0.3887        | 13:48:00    | 13:51:20 | -0.5112        |  |
| Porpoise 1       | 85  | 12:06:30   | 12:08:20    | -0.1341        | 13:03:10    | 13:04:44 | -0.1416        |  |
| Porpoise 2       | 85  | 12:14:30   | 12:16:18    | -0.2676        | 13:08:45    | 13:10:20 | -0.0166        |  |
| Porpoise 3       | 105 | 12:25:40   | 12:29:09    | -0.0883        | 13:21:10    | 13:22:55 | -0.1439        |  |
| Porpoise 4       | 105 | 12:33:50   | 12:35:00    | 0.0536         | 13:26:50    | 13:28:35 | -0.0343        |  |
| Porpoise 5       | 130 | 12:43:10   | 12:45:25    | -0.4652        | 13:39:30    | 13:40:55 | -0.5394        |  |
| Porpoise 6       | 130 | 12:50:10   | 12:51:30    | -0.5941        | 13:46:45    | 13:48:05 | -0. 4297       |  |

The time intervals and mean magnitude of vertical wind during the straight and level and porpoise maneuvers at 15,000 feet and 21,000 feet MSL. Each consecutive straight and level maneuver was flown in the opposite direction and the same was done with the porpoise maneuvers. This was repeated at three different speeds and two different altitudes.



- horizontal wind components.
- at 21000 ft.
- lower two airspeeds.

- vertical wind component.

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### **Vertical Winds**



and altitude (ft MSL) during the different legs are shown. The AIMMS processing code was used. The 5, 25, 50, 75, and 95 percentiles are given by the box-and-wiskers while the stars denote the mean values.

## Conclusions

• Comparison between three minute northbound and southbound legs agree within the variability of the measurements (1 Hz) which indicates that aircraft maneuvers are not affecting the

• Comparison between the level and the porpoising legs agree within the variability of the measurements which indicates that aircraft maneuvers do not greatly affect the wind measurements; however, there is mean negative bias of 24 cm s<sup>-1</sup> assuming zero vertical velocity

• There is distinct difference between the vertical wind at the highest airspeed compared to the

## **Future Work**

• Analyze different calibration techniques whereby each maneuver type is used independently to determine coefficients related to that aircraft maneuver.

• Fly two AIMMS instruments and compare the resulting measurements.

• Determine if it is possible to calibrate the AIMMS and not have a bias in the

## Acknowledgments