Technische Universität Braunschweig

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UAS Measurements of the Boundary Layer Late Afternoon Transition

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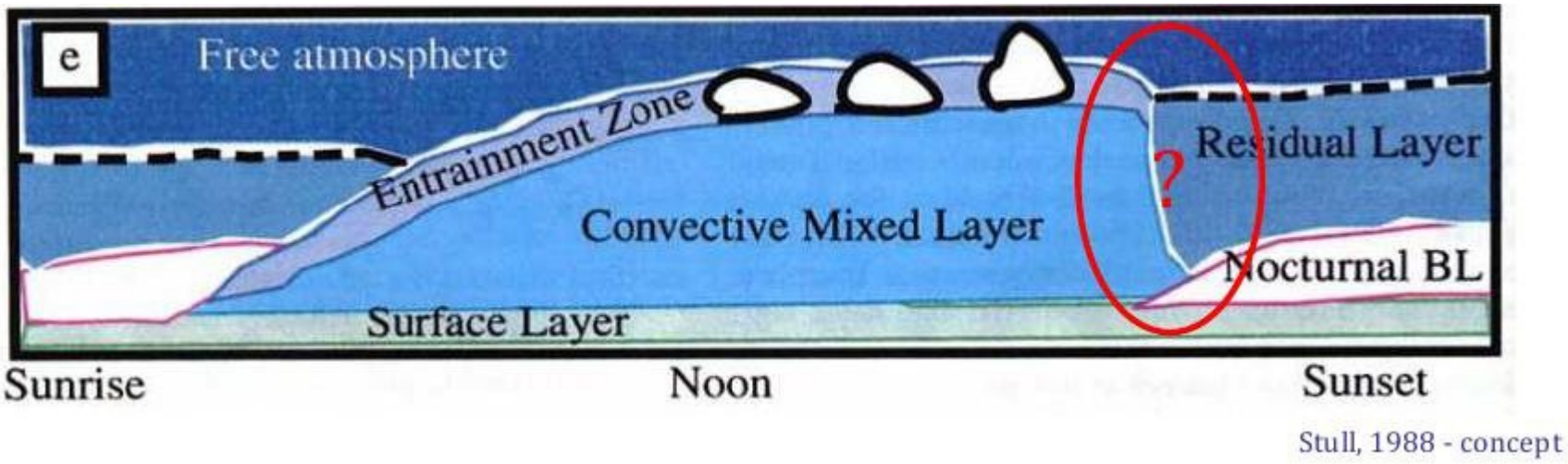
Outline

- BLLAST campaign
- M²AV technology
- Flight patterns
- Initial results
- Conclusion and Outlook

BLLAST: acronym and objective

- **B**oundary **L**ayer **L**ate **A**fternoon and **S**unset **T**urbulence
- Improve understanding of afternoon transition from convective boundary layer to nocturnal and residual layer by means of ...
  - → … modelling and **observations**



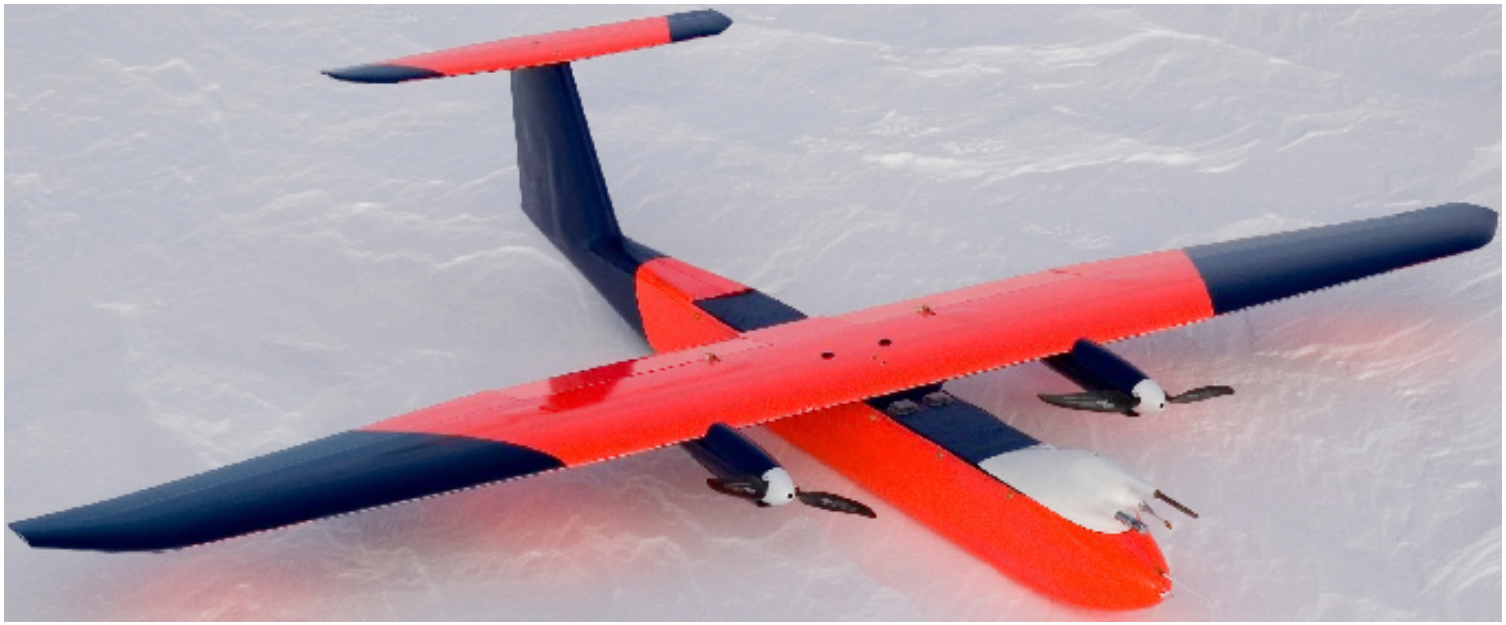
Stull, 1988 - concept

BLLAST 2011 field experiment at a glance

- International campaign in southern France
- Scientists from nine different countries
- Many different measuring technologies, among them …
  - ➔ ... **Unmanned Aircraft Systems (UAS)**

Meteorological Mini Aerial Vehicle (M²AV)

- 2 m wingspan, 6 kg take-off weight
- 22 m/s cruising speed, up to 50 min flight duration
- Telemetry link to ground station up to 5 km
- Automatic flight with autopilot
- Measuring temperature, humidity and **wind vector**



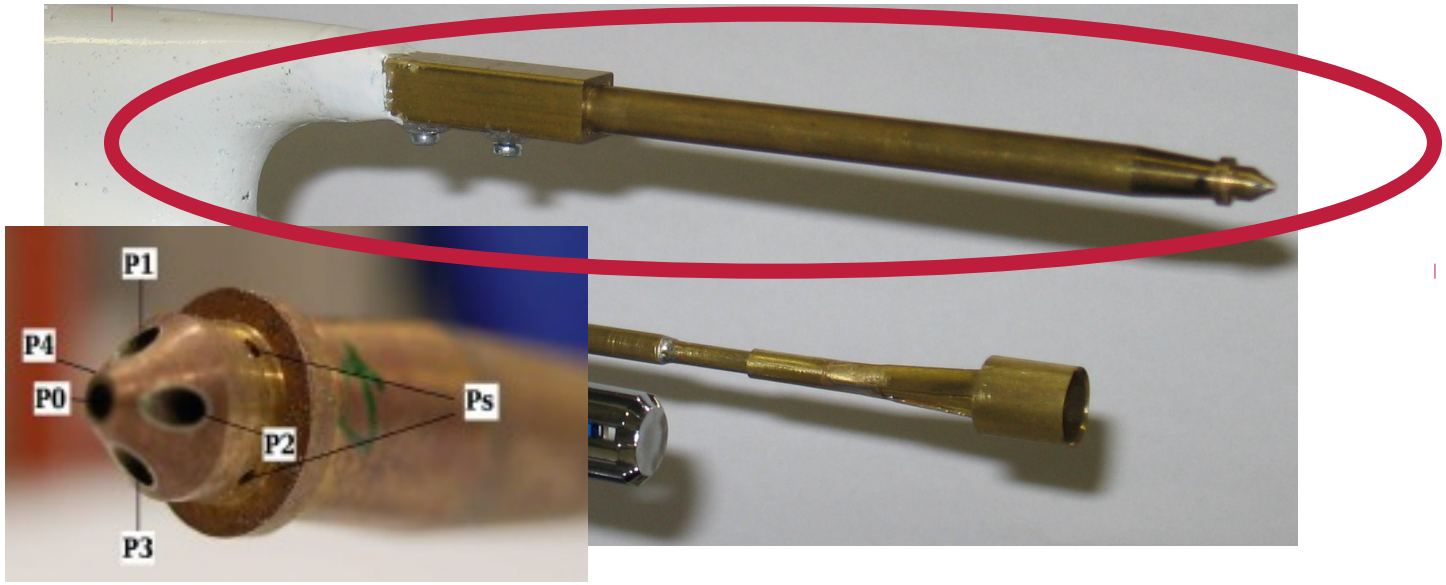
Meteorological Sensors: 3d wind vector

Five-hole probe

- Angles of attack and sideslip: ± 20° (airframe coordinate system)
- Fast response (~ 30 Hz)
- Small (Ø 6 mm) and lightweight (22 g)

Wind vector calculation

- GPS and inertial measurement unit (IMU)
  - ➔ Precise location and attitude
  - ➔ Converting angles of attack and sideslip from airframe coordinates to wind vector



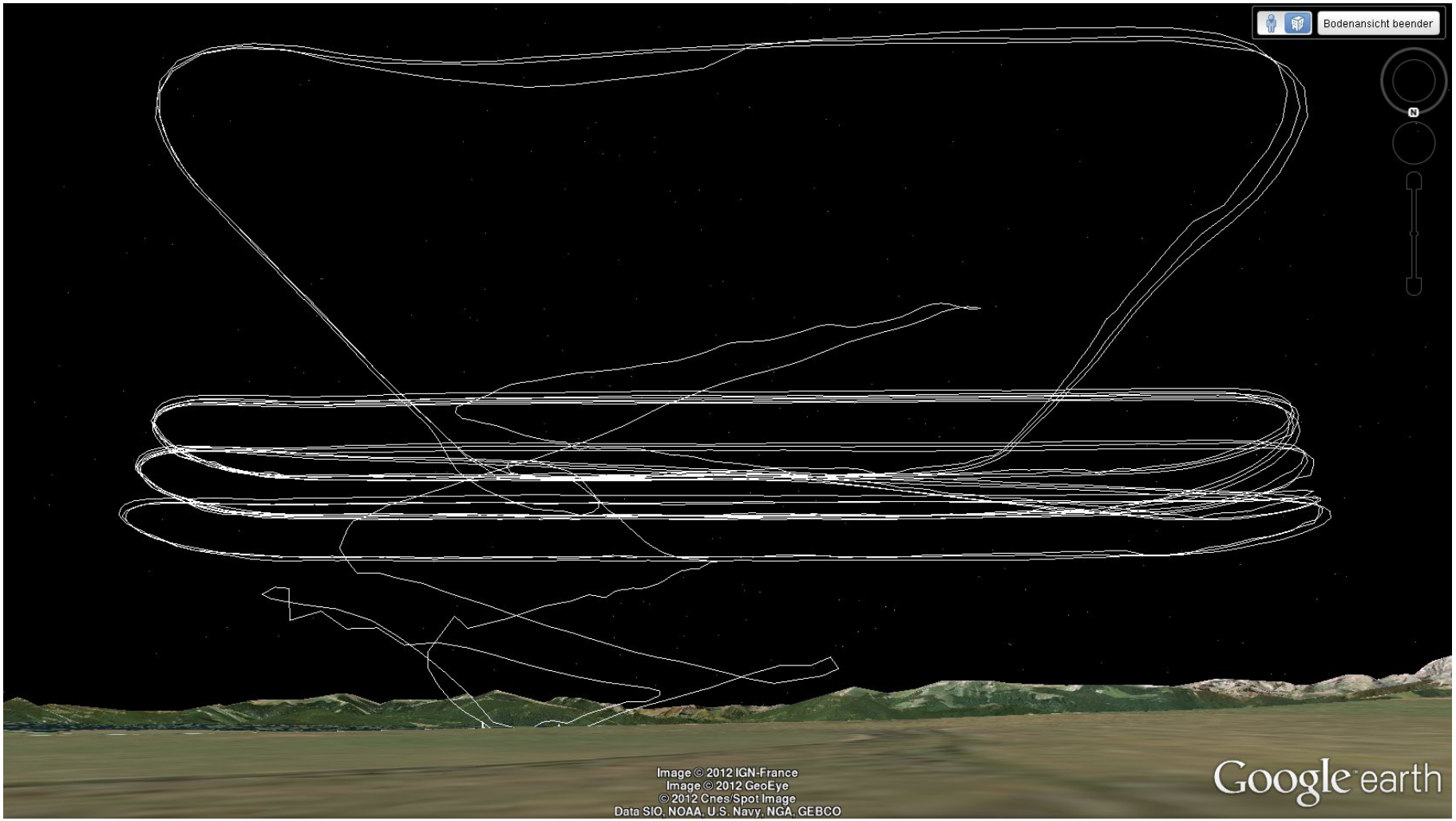
M²AV flights during BLLAST 2011

Date	Takeoff (UTC)	Altitudes (m agl)
30 June	17:22	200, 400
30 June	18:44	200, 400
01 July	14:27	300
01 July	18:47	200, 250, 300
02 July	**14:19**	**200, 250, 300**
02 July	**16:27**	**200, 250, 300**
02 July	**18:13**	**200, 250, 300**
02 July	**20:20**	**150, 200, 250**
05 July	12:25	200, 250, 300
05 July	14:25	250, 325, 400
05 July	15:40	250, 325, 375, 400, 500
05 July	17:10	250, 375, 500
05 July	18:30	250, 375, 500

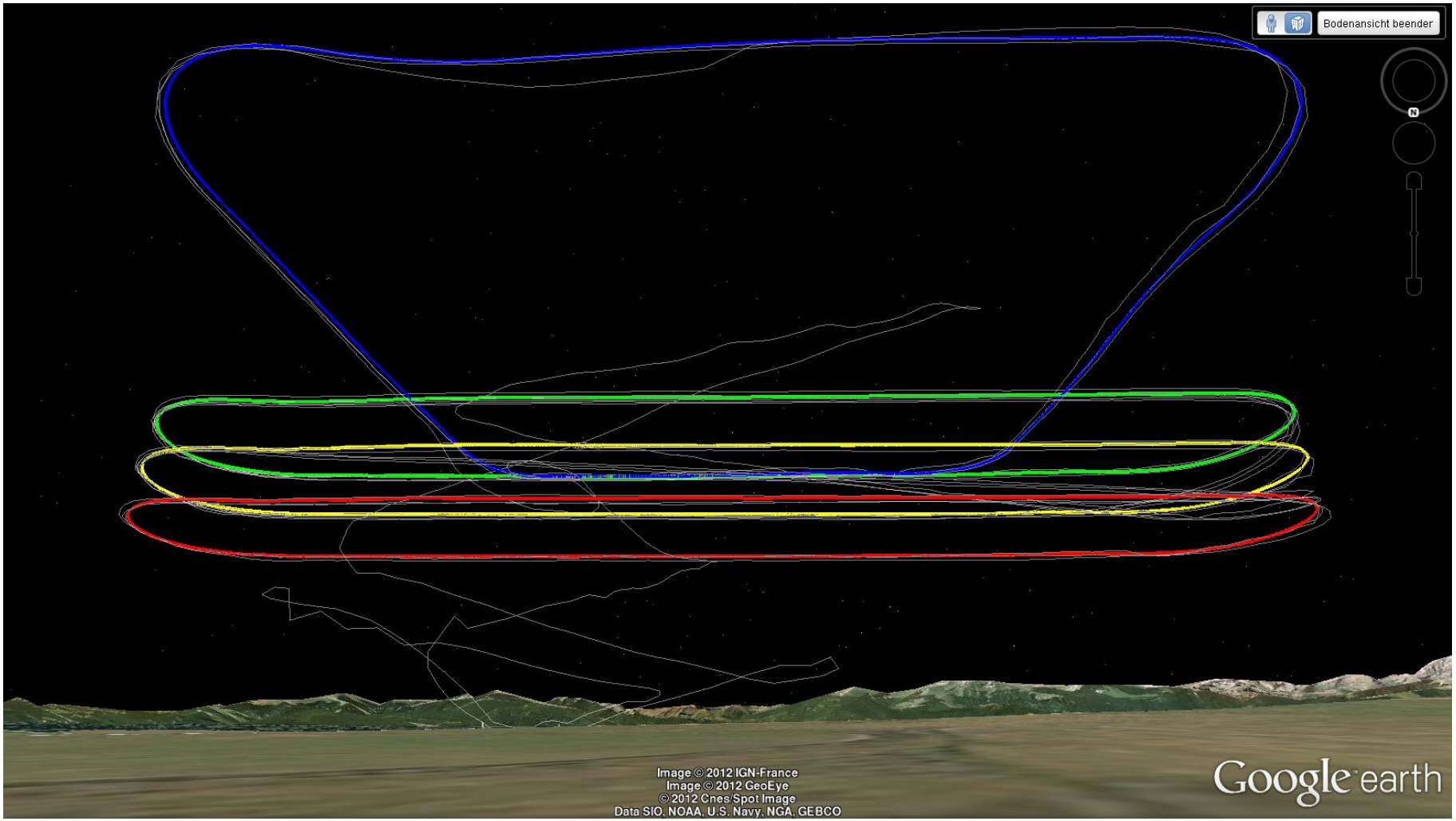
Flight pattern seen from above

Flight pattern seen from above

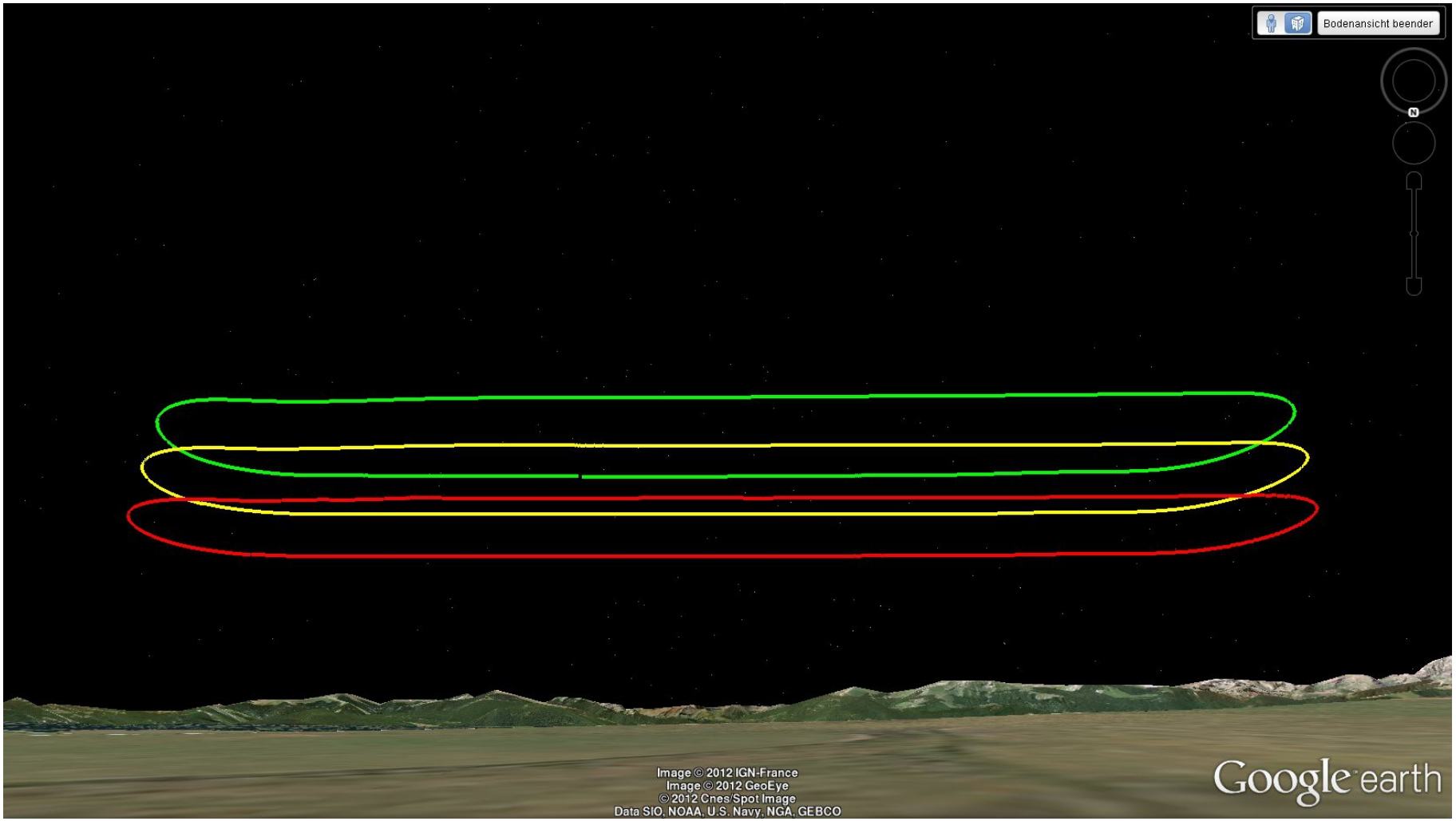
Flight pattern seen from the ground



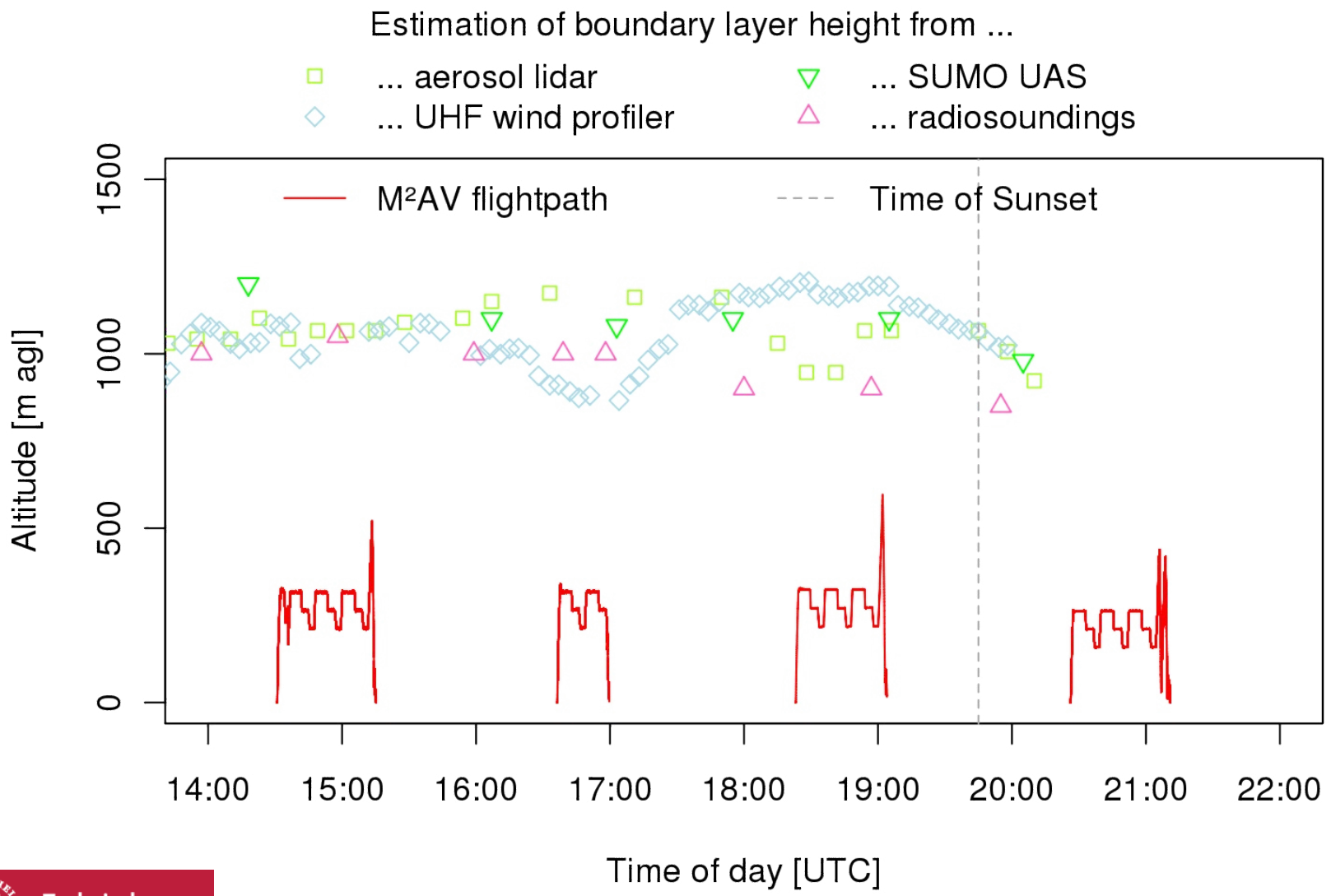
Flight pattern seen from the ground



Flightlegs relevant for turbulence measurements



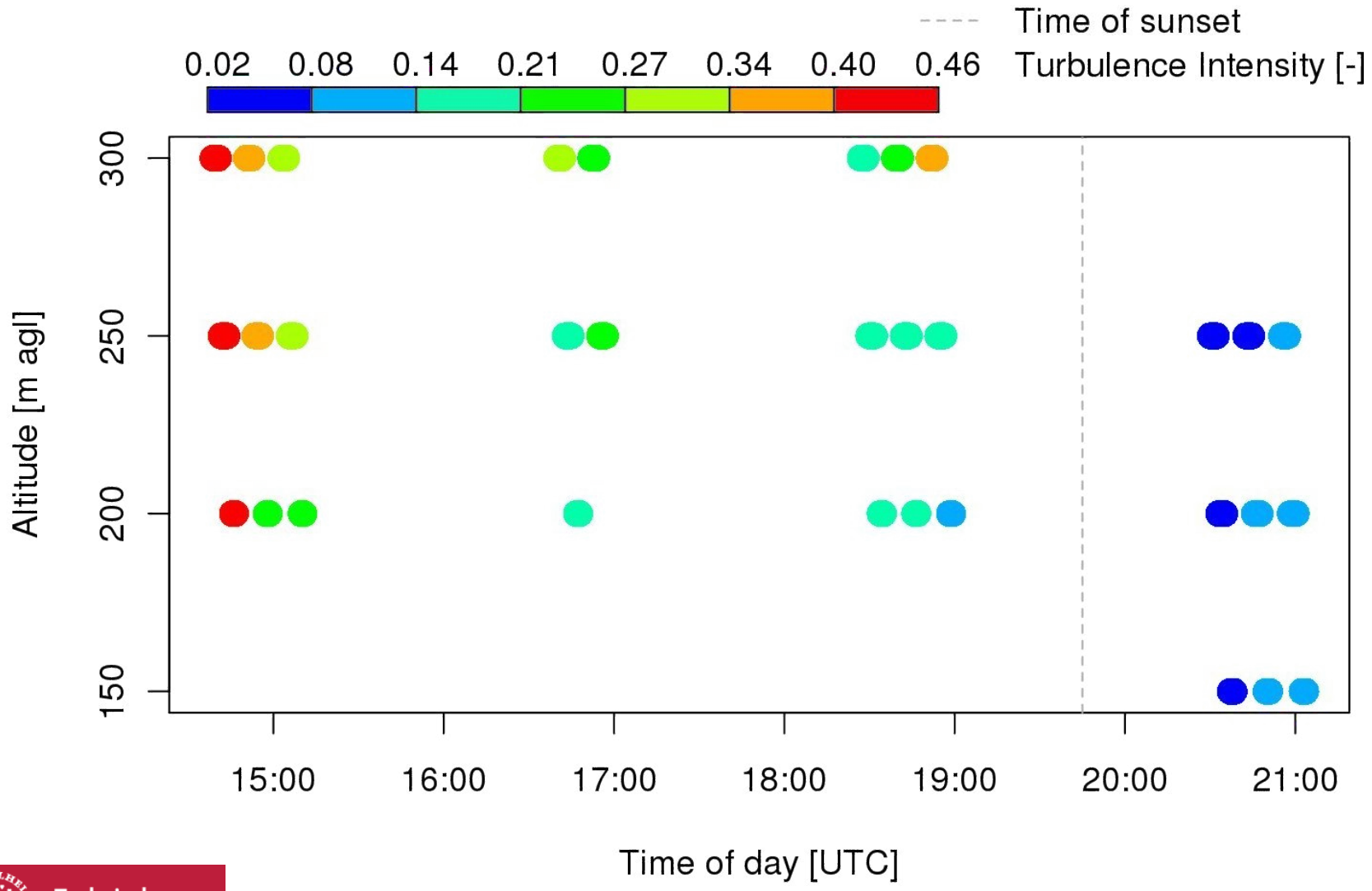
Flightpaths in relation to boundary layer height



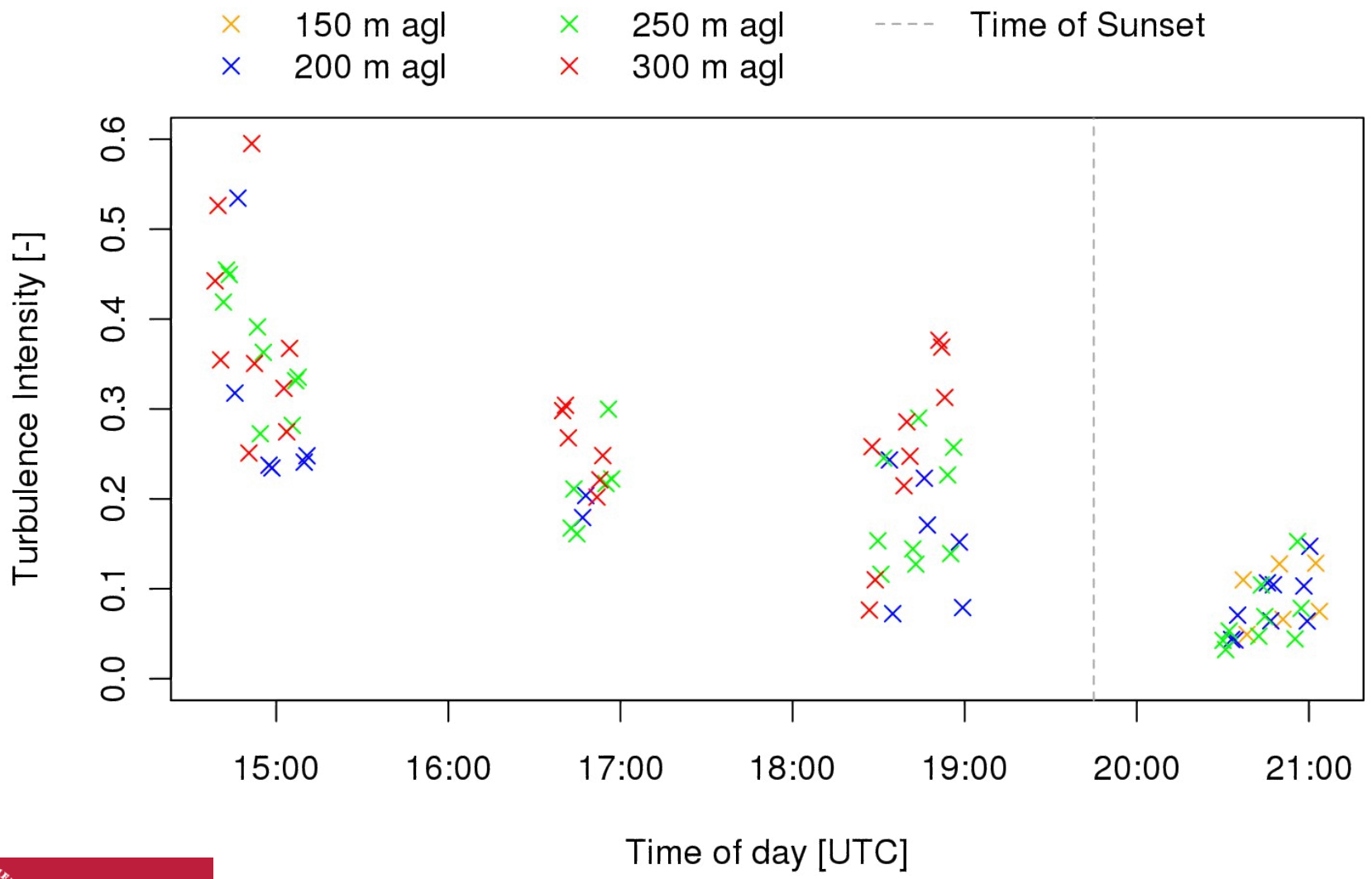
Turbulence Intensity

- Split wind speed (ff) into mean ($\overline{ff}$) and turbulent (ff ') parts
  - $ff' = ff - \overline{ff}$
- The average of the square of the turbulent part ff ' is known to be the variance σ_{ff}^2
  - $\sigma_{ff}^2 = \overline{ff'^2}$
- The square root of the variance is defined as the standard deviation σ_{ff}
  - $\sigma_{ff} = (\overline{ff'^2})^{1/2}$
- σ_{ff} relative to the mean wind $\overline{ff}$: dimensionless measure of **turbulence intensity I**
  - $\mathbf{I = \sigma_{ff} / \overline{ff}}$
- Averaged for straight flight legs (~ 1 km)
  - (+/-) 45 sec. averaging time

Turbulence Intensity on July 2, measured by M²AV



Turbulence Intensity on July 2, measured by M²AV



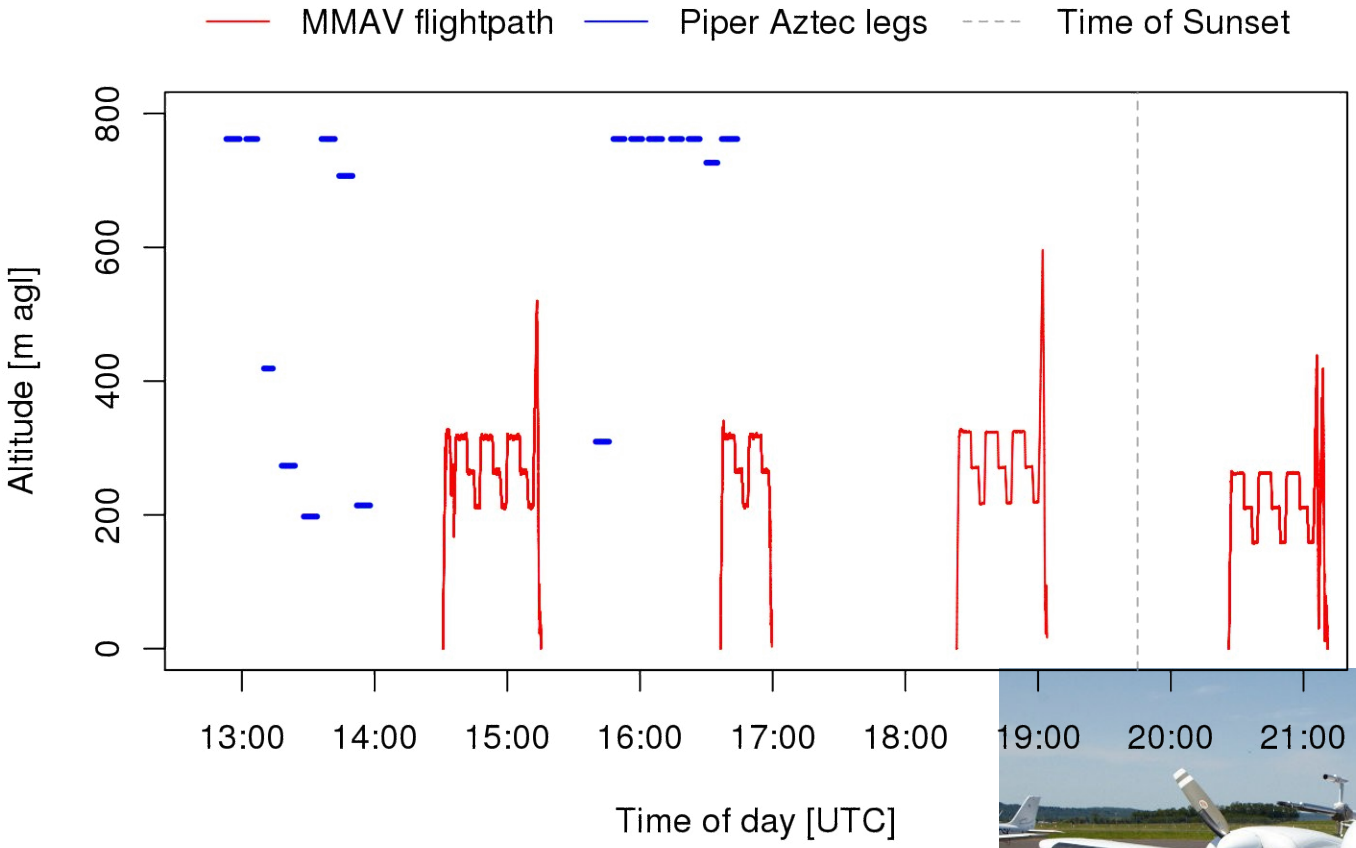
Summary / Conclusion

- M²AV participated in BLLAST campaign 2011
  - ➔ Restrictions on flightpath due to techincal difficulties
  - ➔ Decay of turbulence intensity was observed on small scales

- Resolve existing problems with additional flights → increase available data

- M²AV is a tool well suited for investigation of turbulence ...
  - ➔ … could have been put to better use if it hadn't been for the technical problems

Outlook: e.g. comparison with manned aircraft



Thank you for your attention!

Special thanks to the BLLAST team for data and support!

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