DFS Deutsche Flugsicherung

WakeNet3-Europe

Wake Vortex & Wind Monitoring Sensors Workshop

Long-term Radar Wind Profiler and Windline Measurements for the Wake Vortex Warning System at Frankfurt Airport

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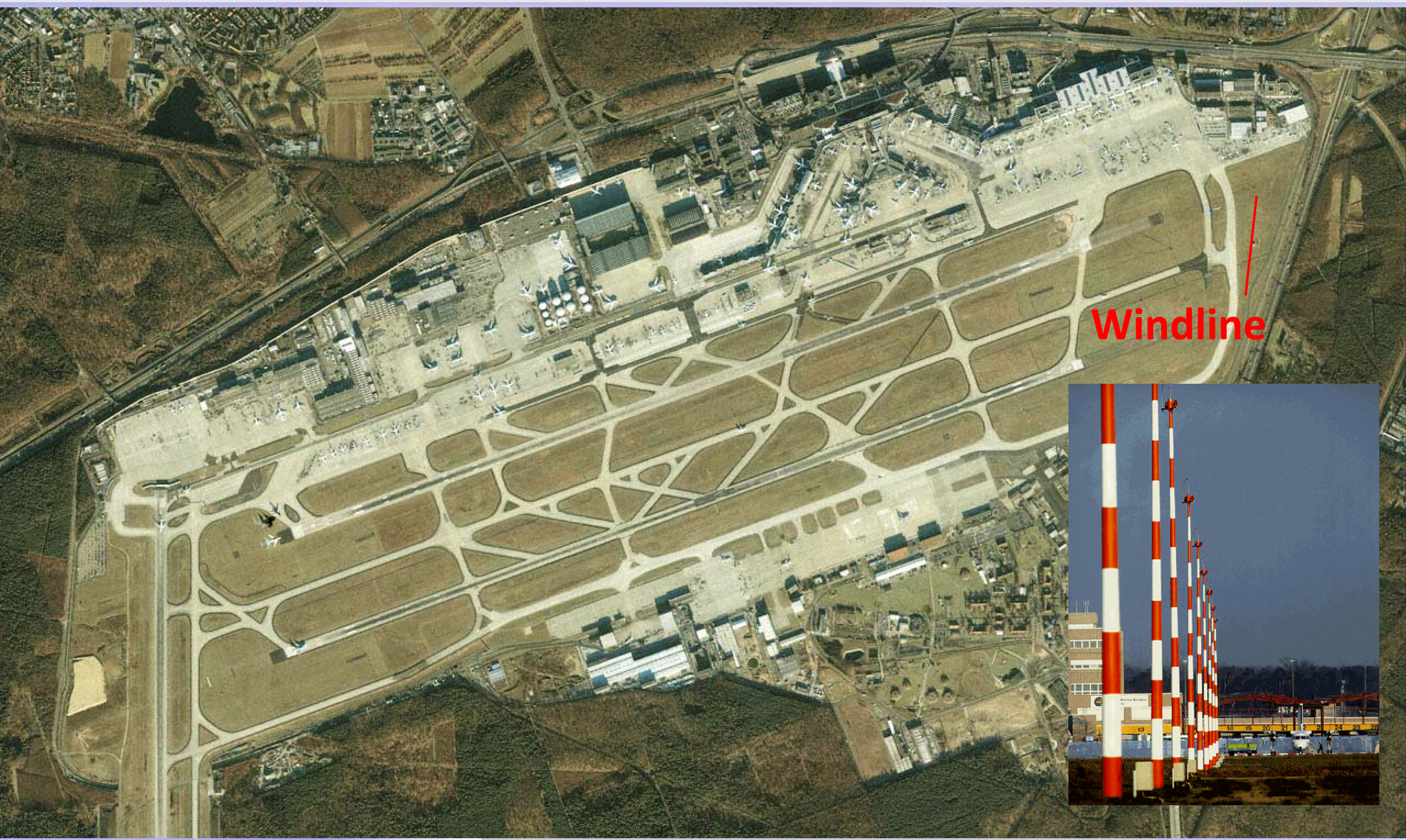
Requirements for Wake Vortex Applications

- Meteorological parameters with influence on wake behaviour like e.g.
  - wind-speed and –direction
  - turbulence
- Different requirements for purely meteorological applications and wake vortex applications
- Meteorological wake applications require spatial and temporal resolution on subscales of the phenomenon itself
  - temporal resolution ~ vortex lifetime ~ minutes
  - spatial resolution ~ few meters - few10 meters
- Wake vortex detection and characterisation is even more demanding

Wind and Wake Sensor Installations at Frankfurt Airport

1. Windline (Anemometer Array)

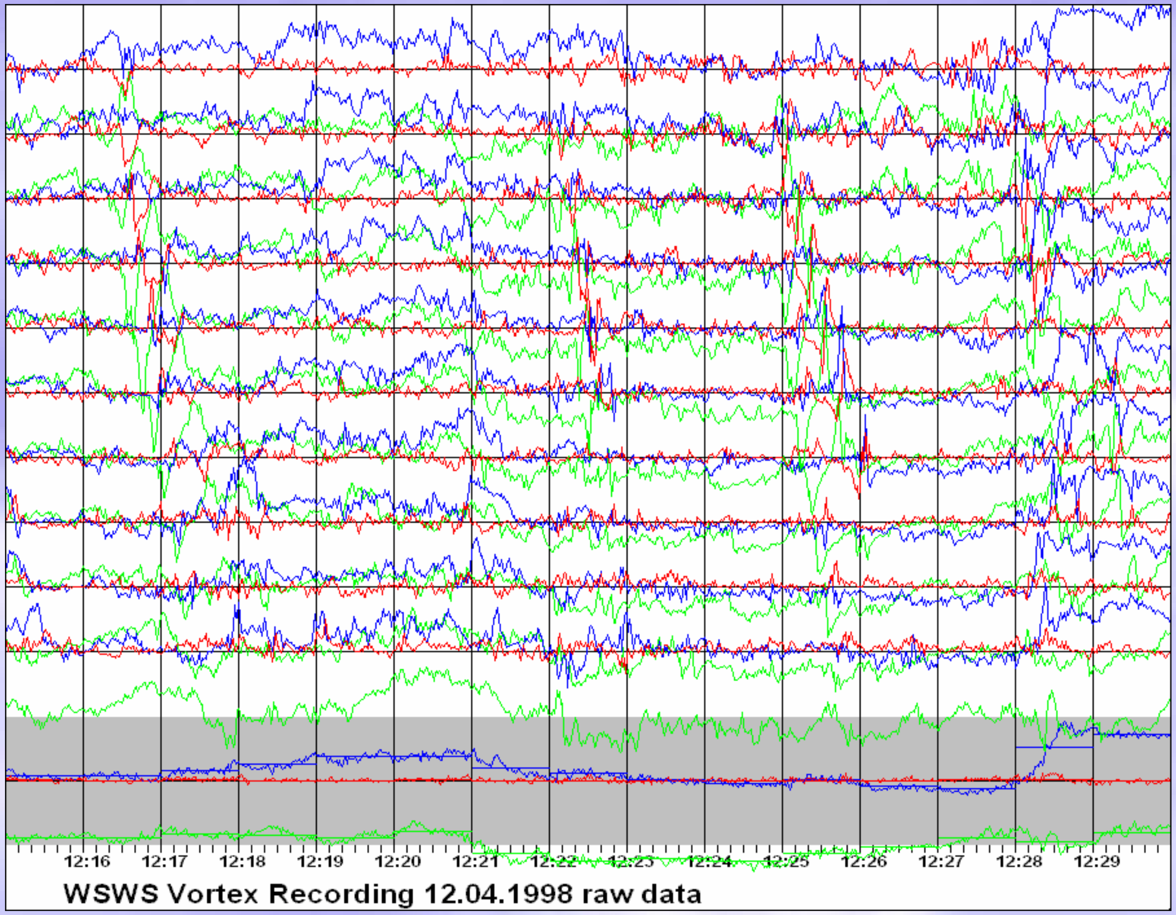


Frankfurt Windline 1996 – 2008

- 10 ultrasonic anemometers (Metek USA-1) at 15 m height
- 3-dimensional wind vector + temperature at a rate of 25 Hz
- intended for accurate characterization of the local wind field at high frequency

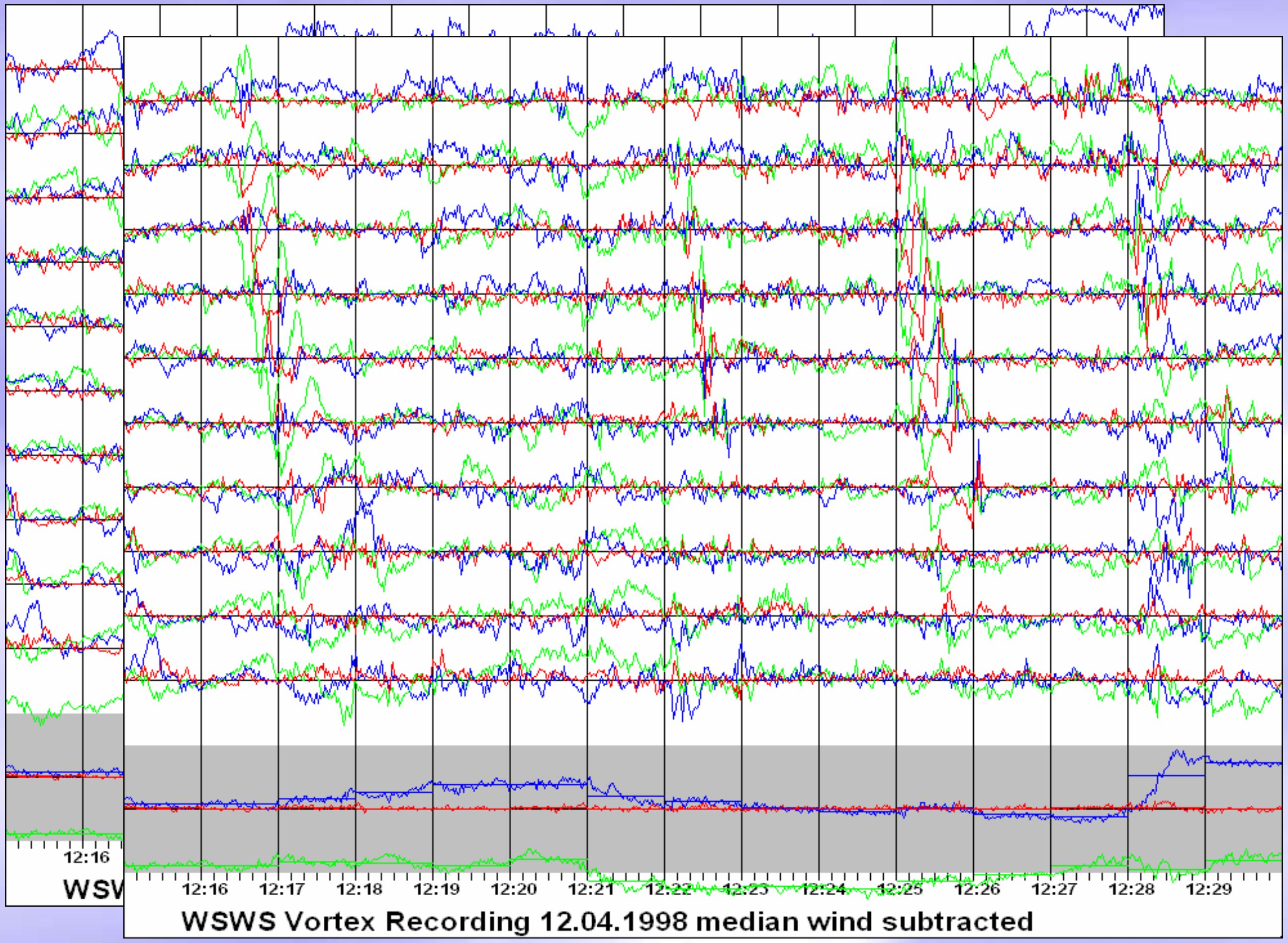
Vortex Tracking using Windlines

Step 1: get raw data



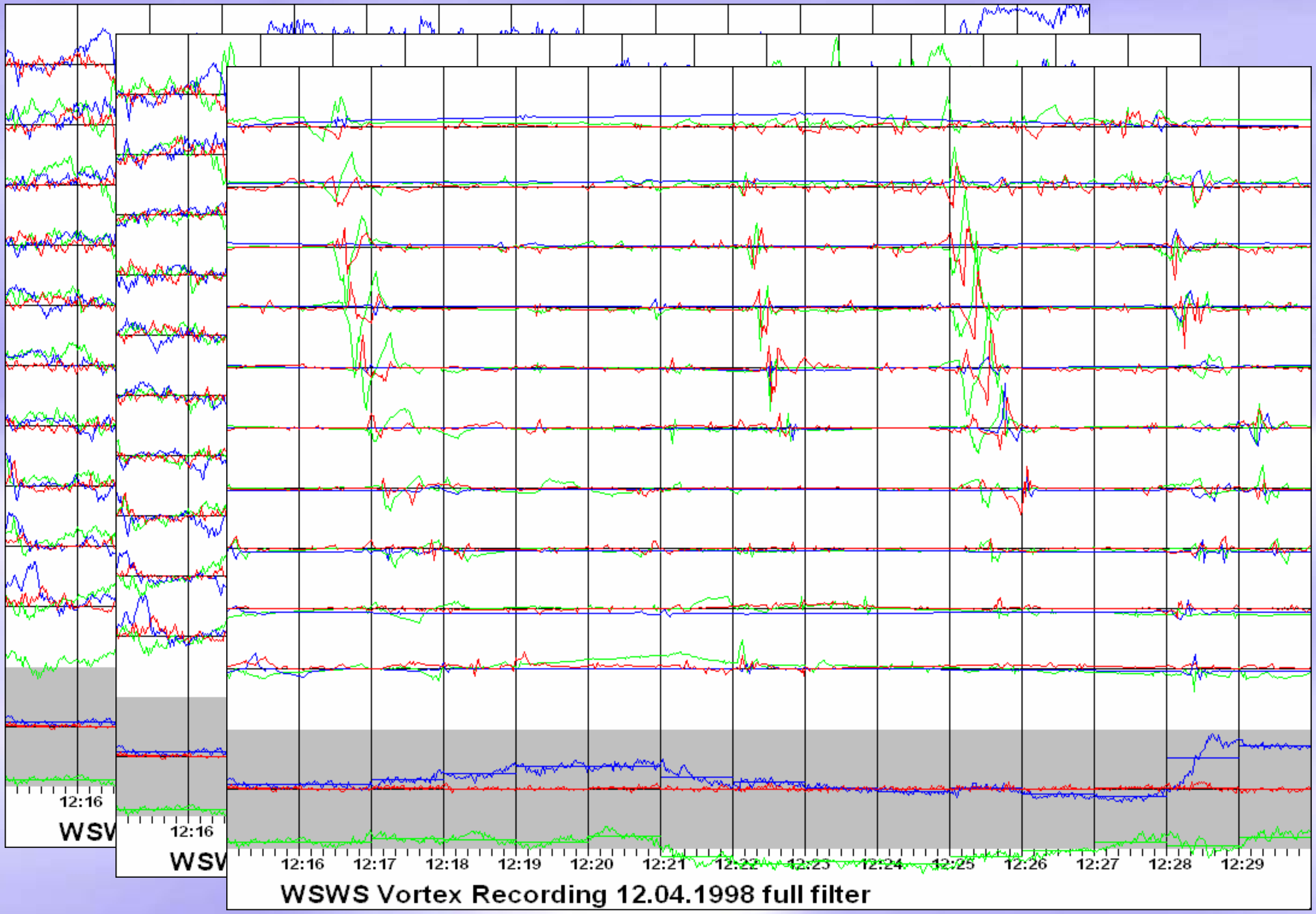
Vortex Tracking using Windlines

Step 2: remove ambient (=median) wind in all components



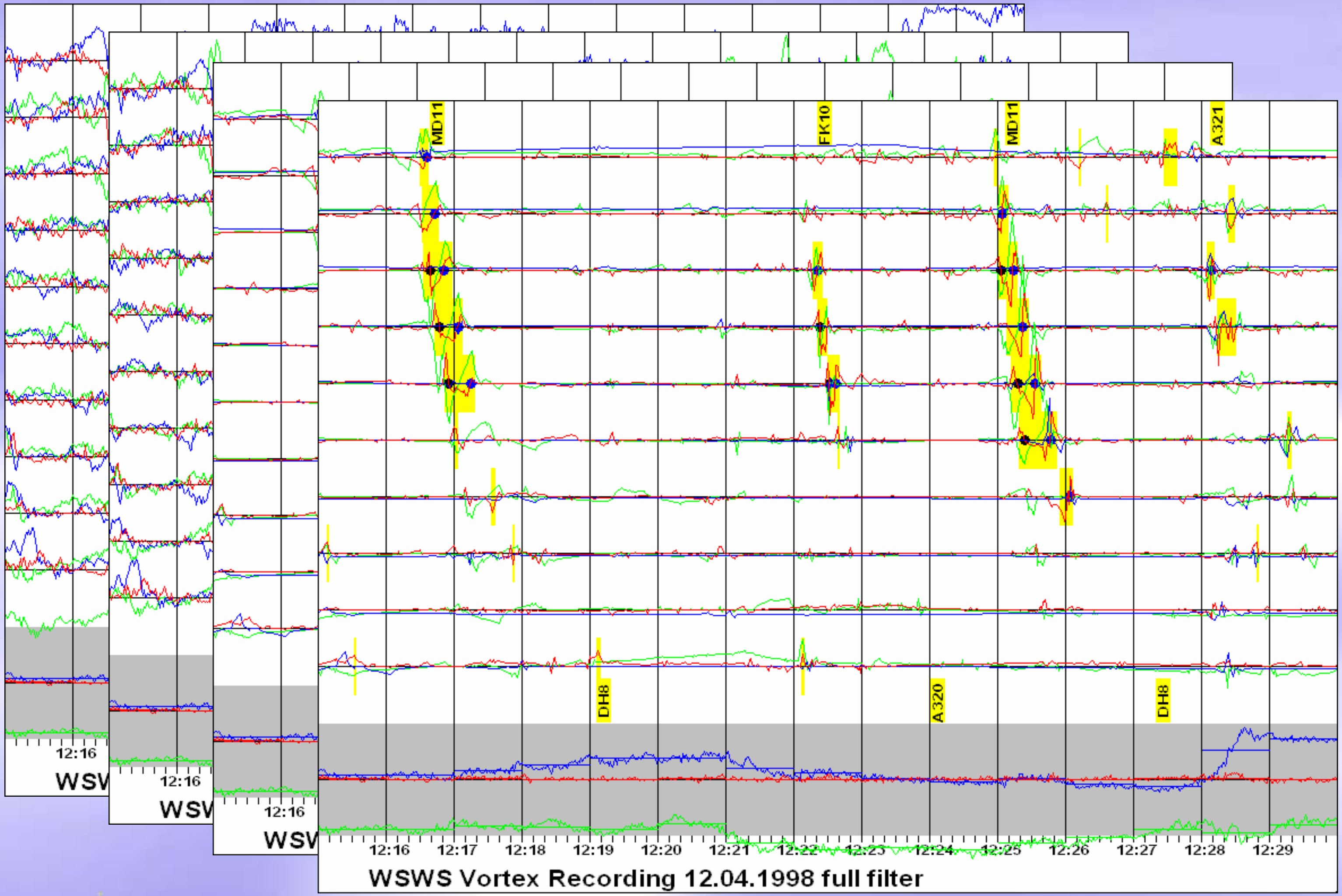
Vortex Tracking using Windlines

Step 3: remove ambient turbulence

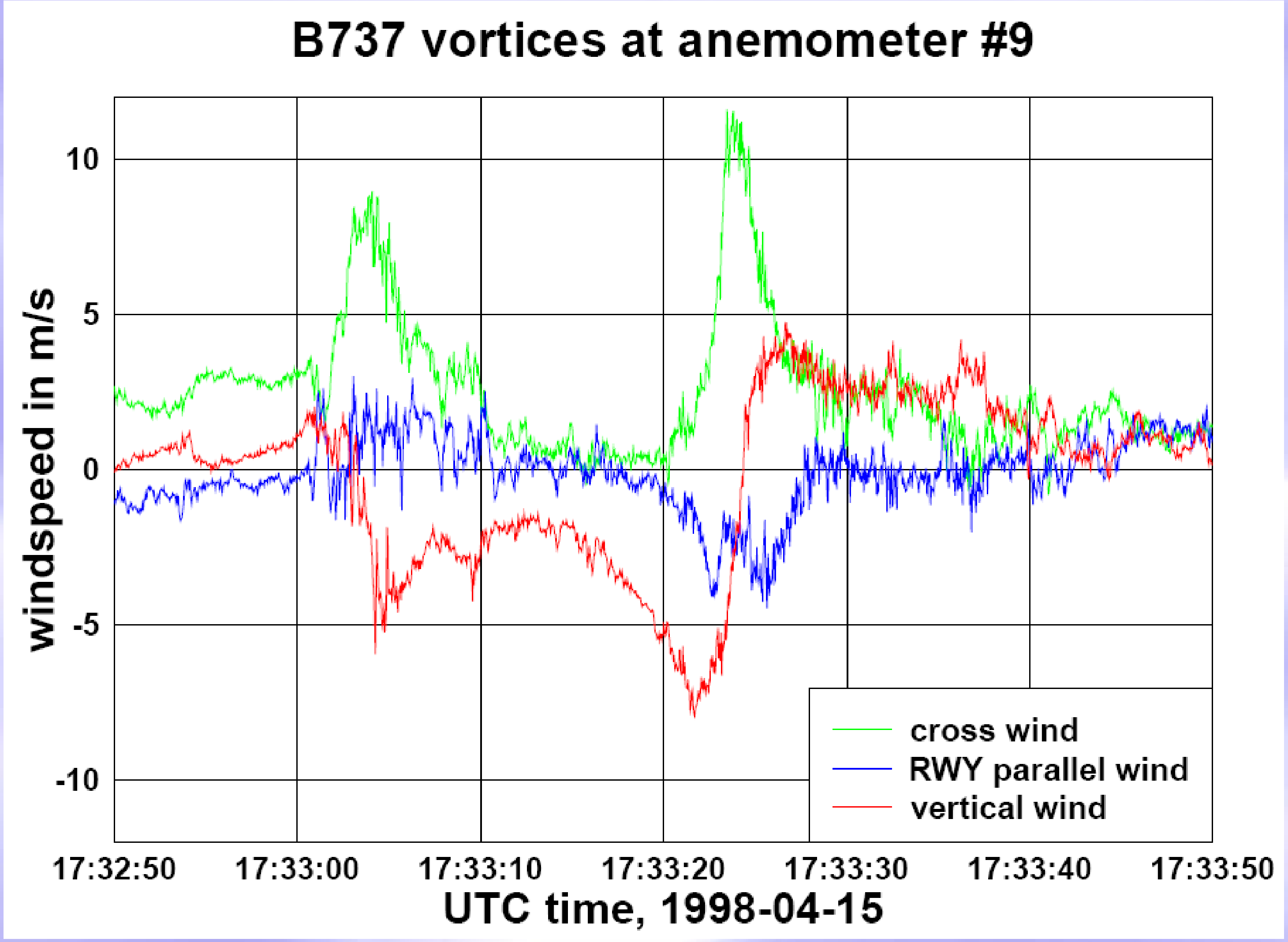


Vortex Tracking using Windlines

Step 4: identify vortices, build vortex tracks, correlate with landing a/c



One out of Million Examples



Windline Summary

+ extremely robust and very accurate and cost efficient sensor
+ very high temporal resolution
+ works under all weather conditions
+ can run for years in the field with very little maintenance
+ can be used for vortex tracking in ground effect
– can be used near the ground only
– obstacle clearance
– vortex strength cannot be measured
– vortex height cannot be measured either
– vortices that are too high might even be missed

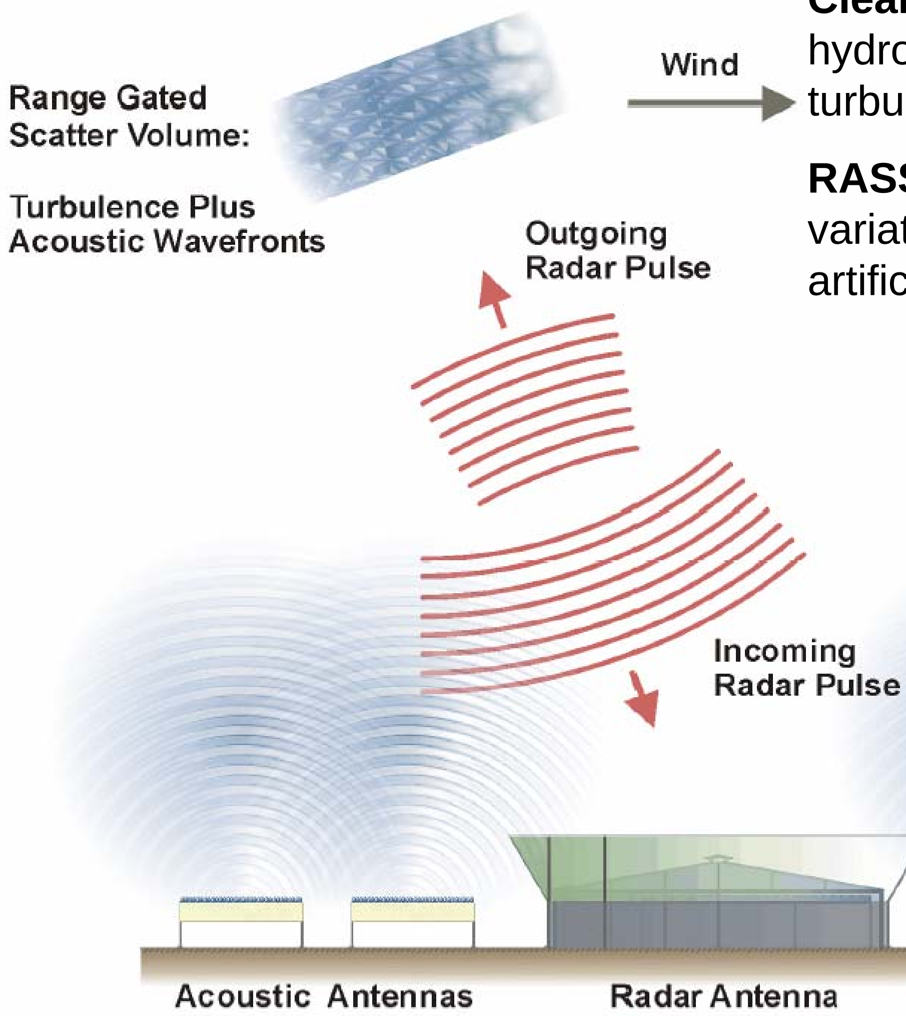
2. Radar Wind Profiler WTR/RASS

Wind-Temperature Radar 2004 –

- Octagonal shape, diagonal 24 m
- RASS: 20 acoustic sources with 1024 elements each
- 2,5 kW pulsed radar
- Peak power consumption 80 kW

- Radar (1290 MHz) and acoustic beams steerable (5 beams)
- Designed for routine operation in an adverse environment
- RASS also for wind measurements

Clear Air & RASS Measurement Techniques

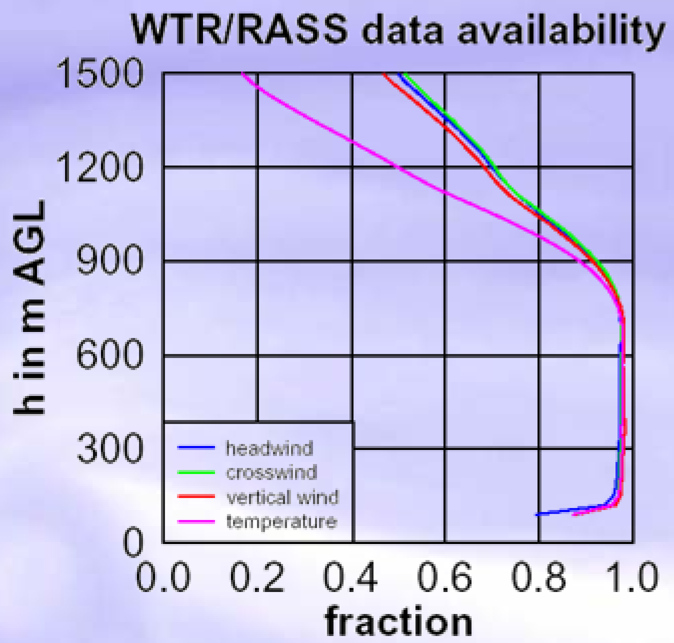


Clear Air: Radar reflection at hydrometeors like water droplets and turbulent eddies

RASS: Radar reflection at periodic variations of the refractive index artificially generated by acoustic waves

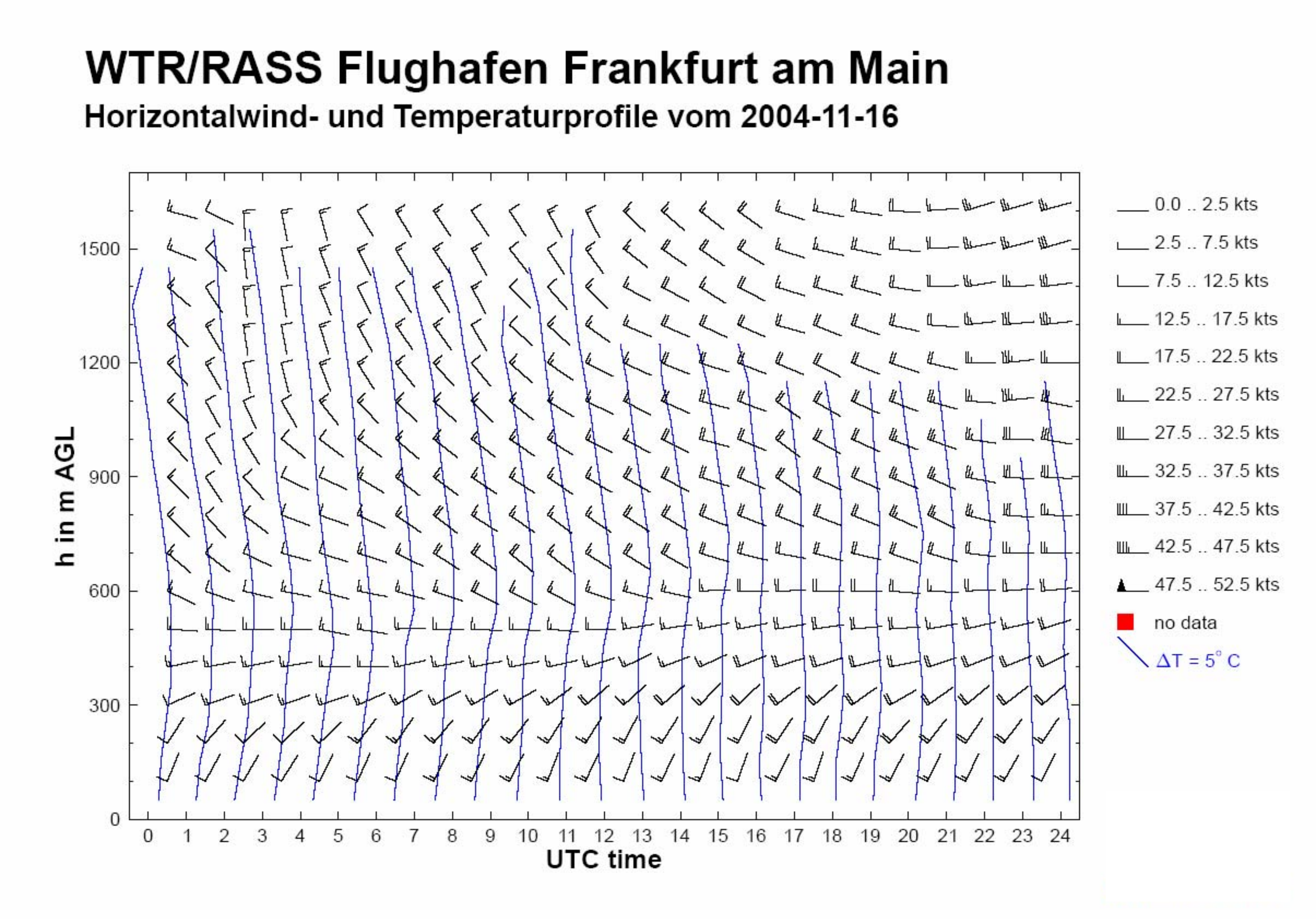
Source: Scintec AG

WTR/RASS Measurements

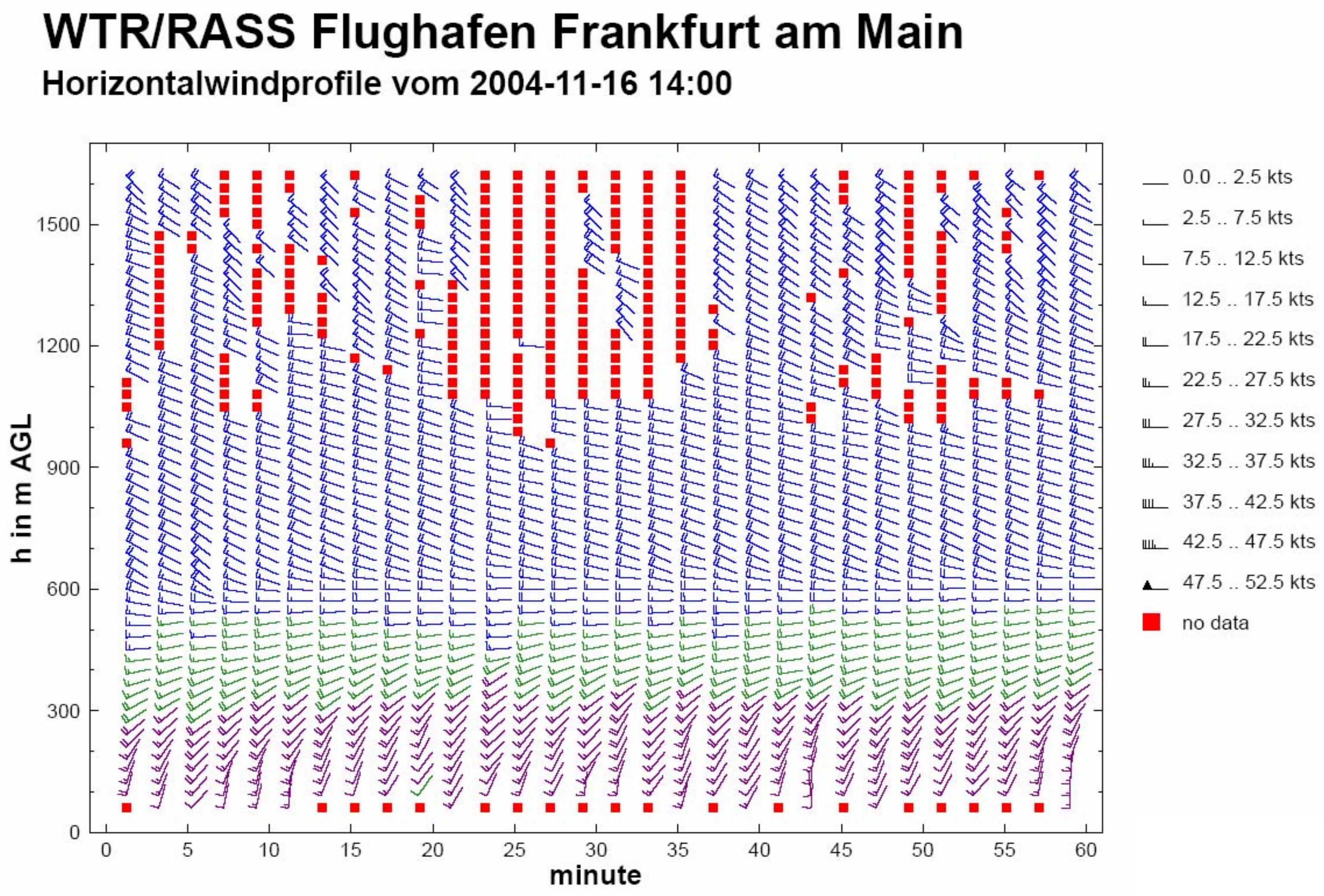


- Data availability of high confidence 2 minute averages exceeding 95% are routinely achieved up to 800 m.
- Reduced data availability and accuracy during certain periods and due to several reasons:
  - Due to the extreme sensitivity of the radar, echoes of birds contaminate the wind-trace even when the birds are flying through the side-lobes.
  - Very strong reflections from high altitudes can be aliased in the height range of interest.
  - Convective motion deteriorates the accuracy of the measurement of horizontal wind.

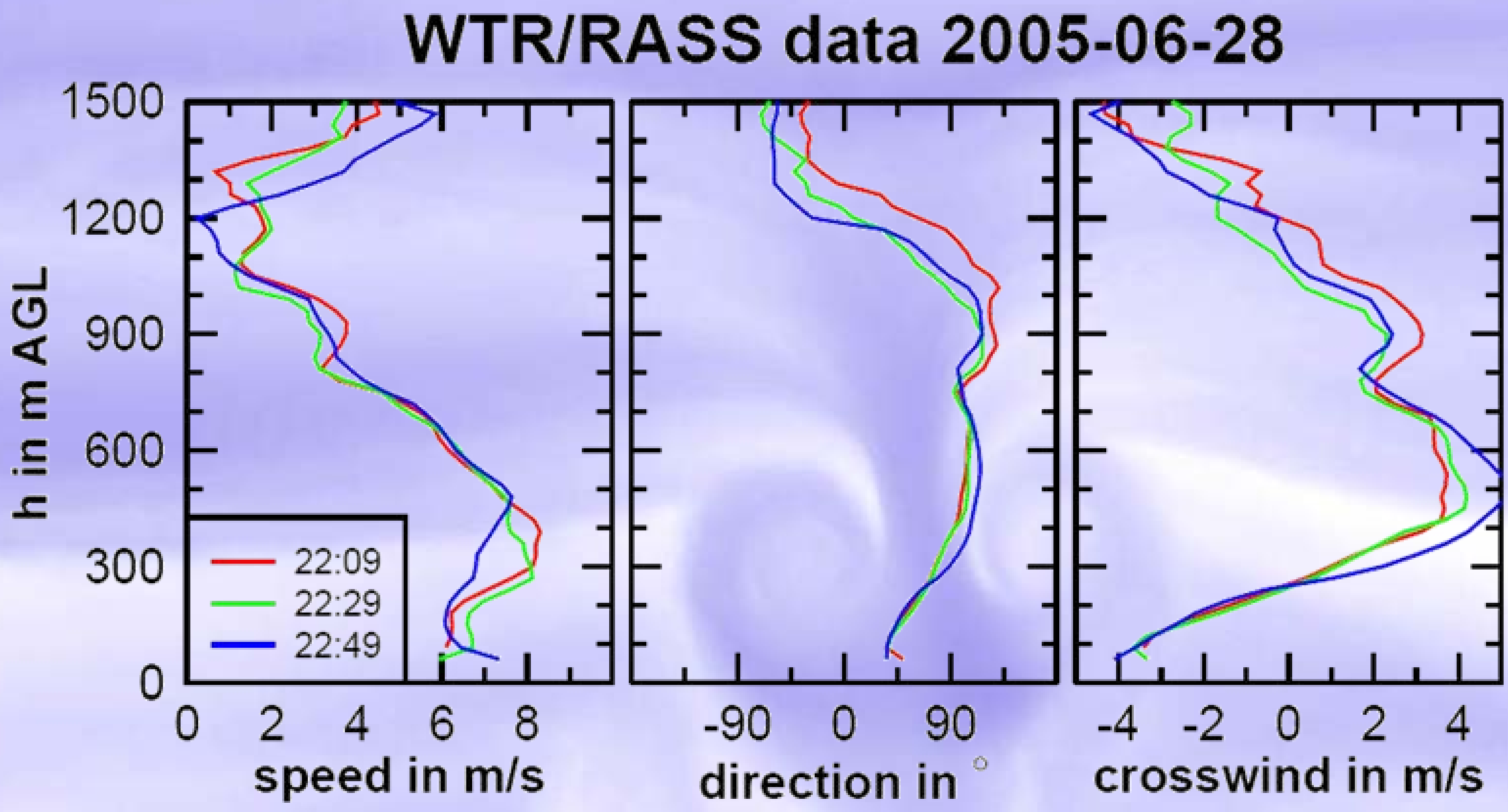
Measured Wind (Low Resolution)



Measured Wind (High Resolution)

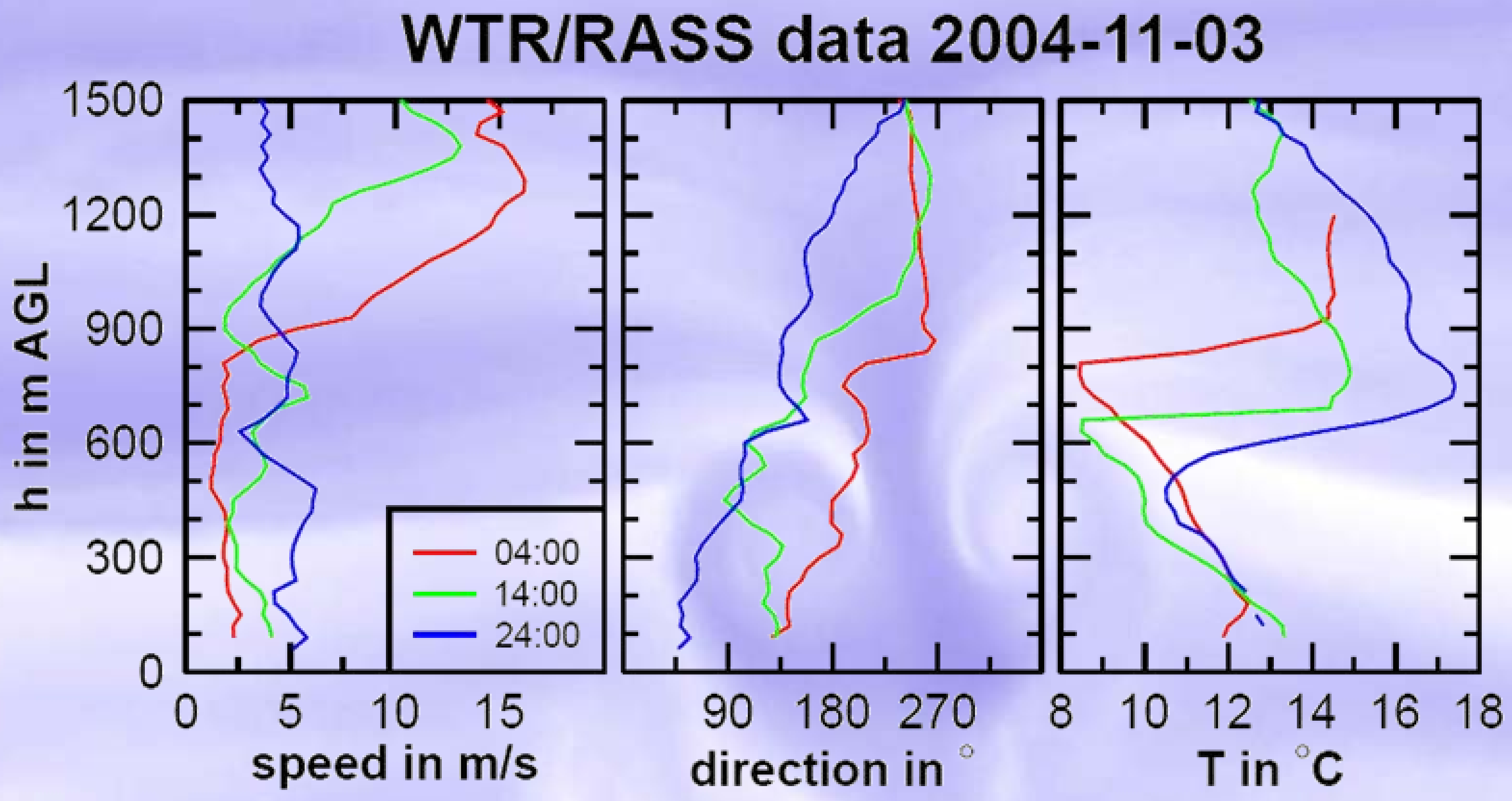


Example of Changing Crosswind



- Crosswind changes sign at 200 m. Direction shear at 1200 m.
- Wake avoidance due to lateral transport not feasible.

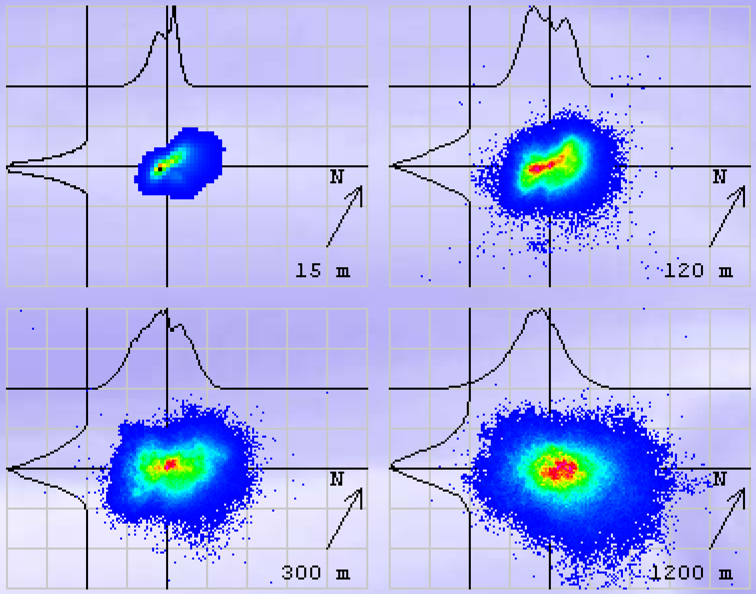
Example of a Strong inversion



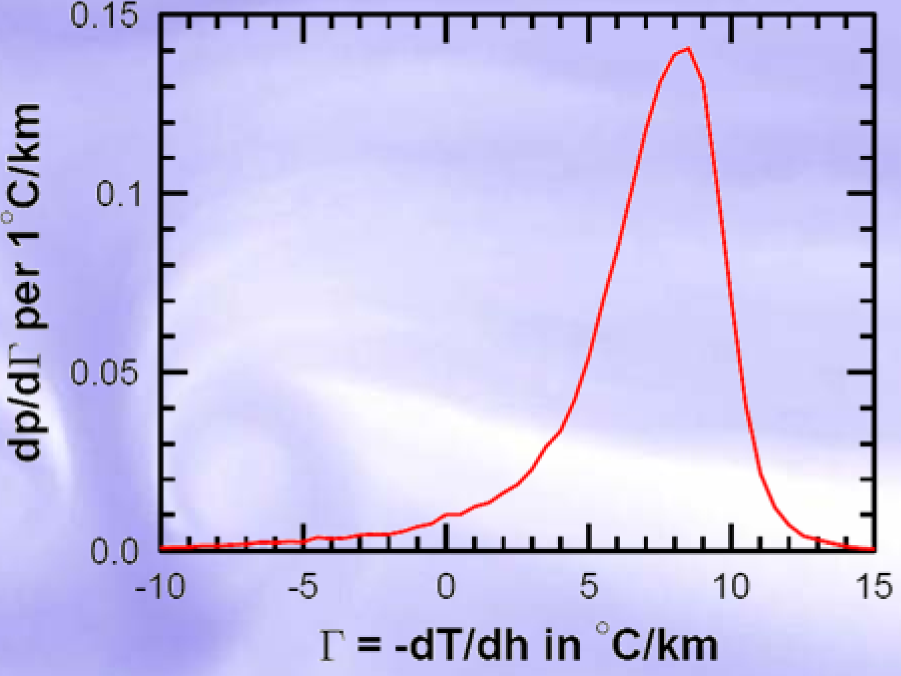
- Strong inversion around 700 m with potential adverse effect on wake descent.

Statistical Quantities Derived from the WTR/RASS data

Wind statistics



lapse rate statistics



- The WTR/RASS data is a valuable data set to study the occurrence of weather situations which may have an adverse or positive effect on the wake vortex evolution.

Radar Windprofiler Summary

+ mature technology for measurements of profiles of ambient wind
+ in-beam wind component accuracy
+ RASS technology for measurement of the lapse rate
+ remote sensing technology: access to high altitudes, where a physical sensor cannot be positioned
+ in combination with RASS: self-control
− not really a handy instrument (other frequencies)
− weather dependent performance of the sensor
− minimum range
− perpendicular-to-beam wind component based on assumptions which are not always valid
− spatial and temporal resolution for wake vortex applications?

... do measurements solve the problem?

"Owing to the variability of meteorological elements in space and time, to limitations of observing techniques and to limitations caused by the definitions of some of the elements, the specific value of any of the elements given in a report shall be understood by the recipient to be the best approximation to the actual conditions at the time of the observation."

ICAO Annex 3 – Meteorological Service for International Air Navigation, Section 4.1.9

Questions?