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Observability of wake vortex relevant quantities based on actual wake vortex behaviour

Shanna Schönhals, WakeNet-3 Europe Specific Workshop on Short Term Weather Forecasting, DLR-Oberpfaffenhofen, 11.05.2010

Outline

- Key meteorological quantities
- Effect on wake vortex behaviour and prediction
- Observability - methods
- Added value for probabilistic wake prediction
- Implementation issues (questions, priorities)

MET quantities with relevance to wake vortices

- wake vortex behaviour = *f*(aircraft characteristics) → deterministic
  = *f*(local atm. conditions) → random, variable
- **key MET parameters**
  - headwind
  - crosswind
  - turbulence
  - stratification
  - (wind shear)

  headwind, crosswind, turbulence, stratification: vertical profiles → $u(h)$, $v(h)$, $\varepsilon(h)$, $\Theta(h)$

- provided as 10 min averages and eventually variations around the mean
- data sources:
  - measurements with local sensors (anemometers, SODAR, LIDAR)
  - forecasts with meteorological models

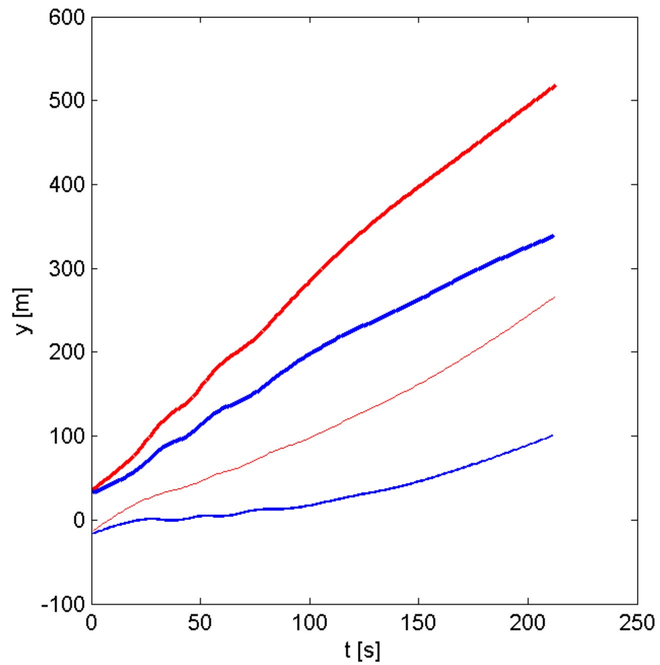
Effect on wake vortex behaviour

- headwind: vortex sink rate and horizontal path
- crosswind: lateral transport, influence on rebound altitude (IGE)
- turbulence and stratification: descent rate reduction, decay acceleration

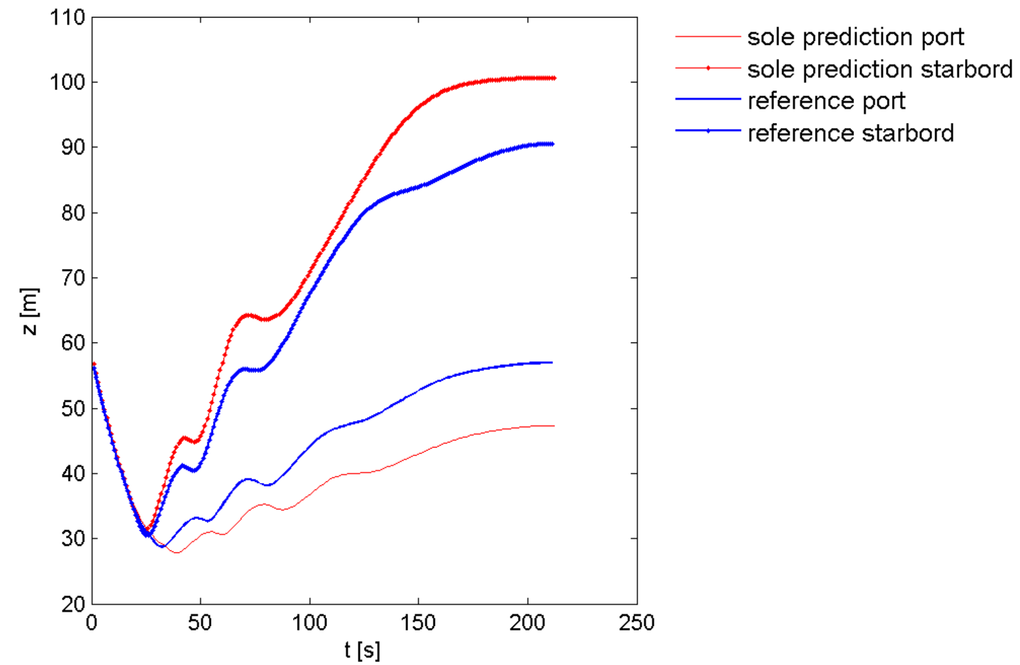
→expected wake vortex behaviour is basis for observability
→has been formulated and validated by existing models

Effect of errors in parameters on wake prediction uncertainty

- greatest effect results from crosswind
  - example: moderate wind variation causes significant deviation from actual wake vortex position (Δv = 0,5 m/s)



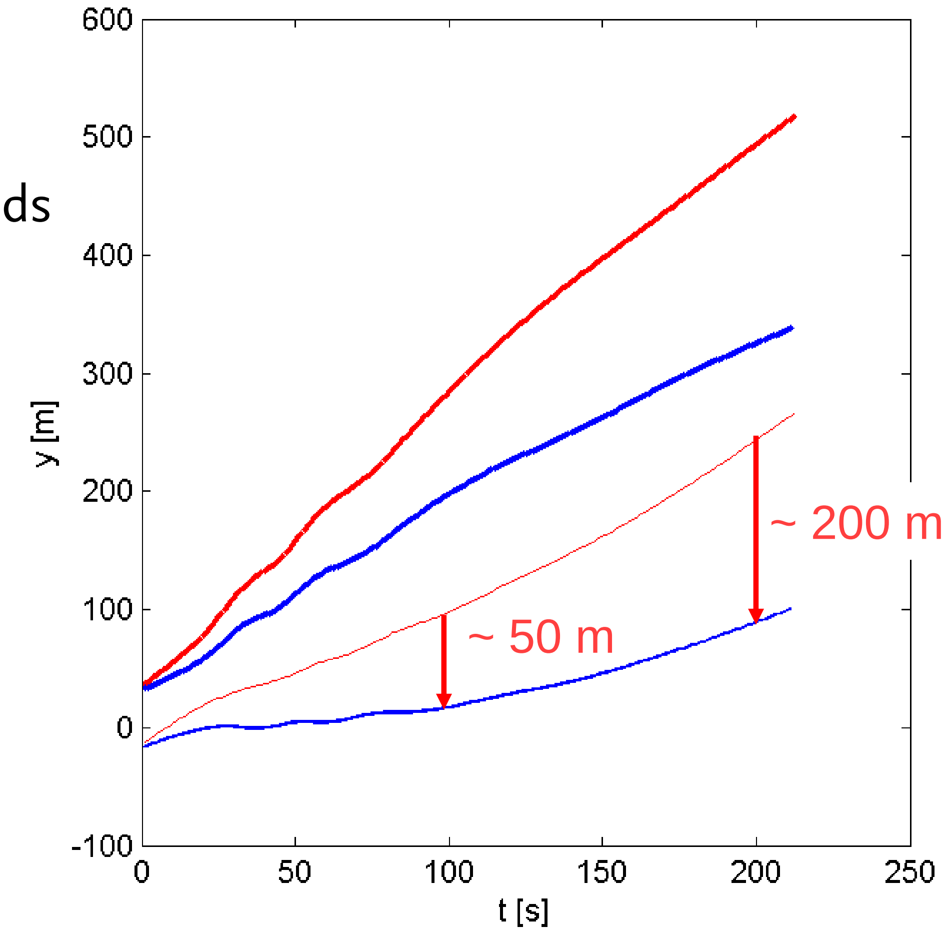
deviation of lateral position



rebound altitude affected

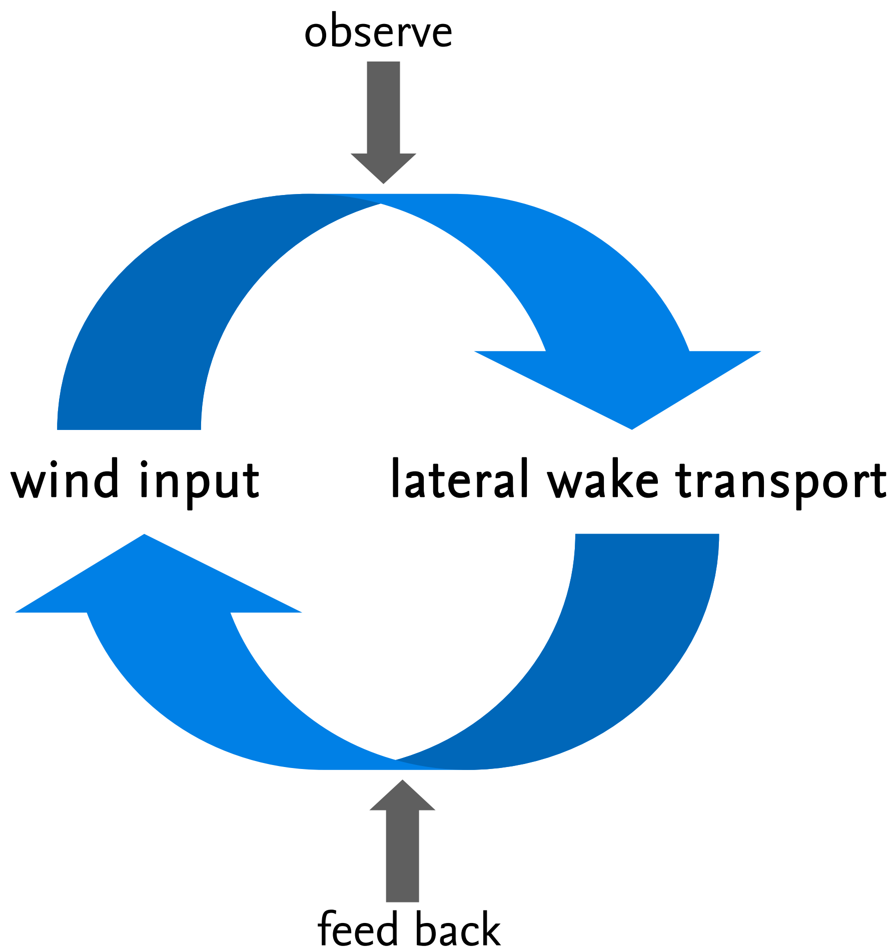
Mitigation of erroneous MET input parameters

- error source can not be located
  - measurement/prediction error
  - natural wind variation
- solution: predicted uncertainty bounds must be increased to account for possible wind input errors
- additionally: constant monitoring required



Estimating meteo quantities from wake vortex behaviour

- **estimate** (predict) wake vortex behaviour with nominal conditions
- **monitor** (measure) real behaviour
- **compare** expected behaviour to actual behaviour
- ***estimate actual meteo parameters*** from known relations to corresponding wake vortex quantity
  - example: crosswind from lateral wake transport

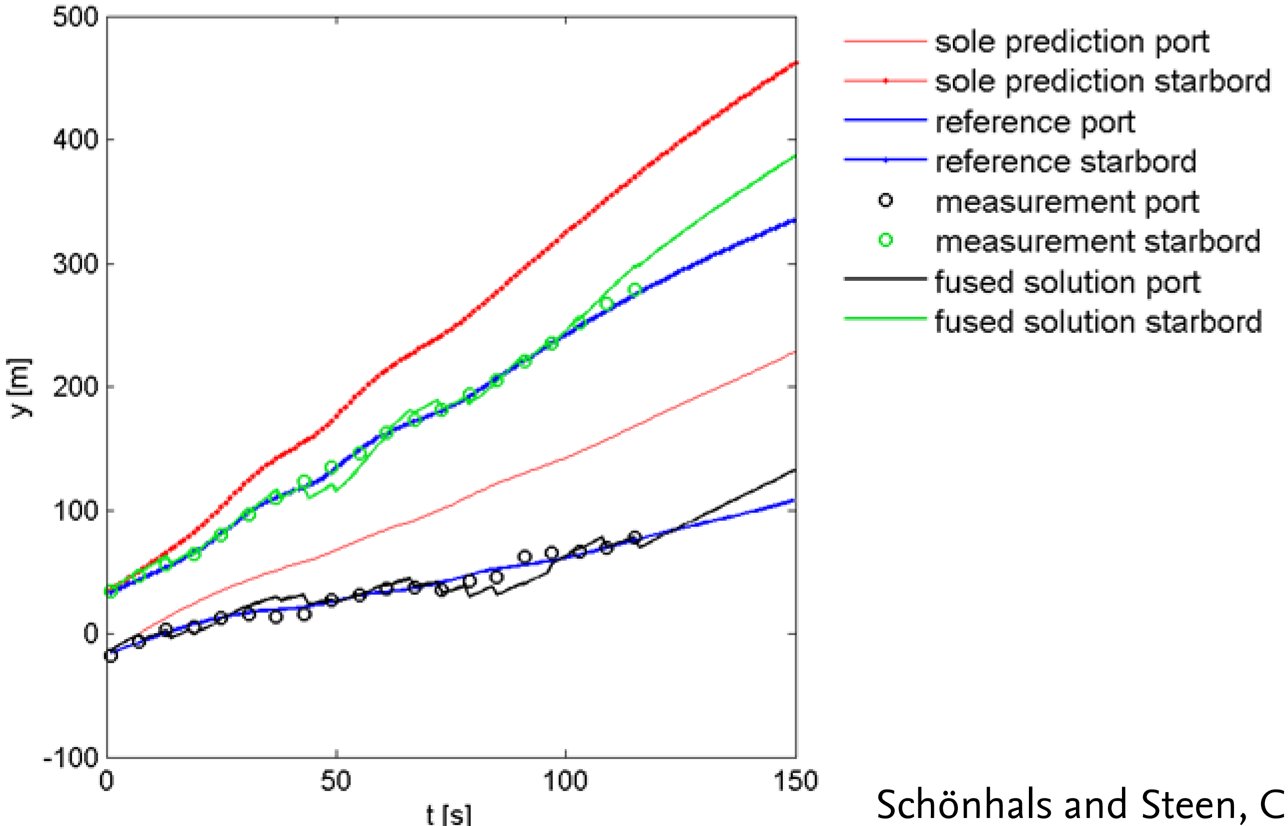


Using the wake vortex monitoring sensors

- almost every Wake Vortex Advisory or Alert System concept foresees a wake vortex monitoring sensor (LIDAR, RADAR or combined)
- wake vortex detection has proved reliable in the operating range of the sensors
  - for LMCT Windtracer, a range of up to 5 km is realistic
- use of wake vortex monitoring today: mainly as safety net
- potential to deliver useful information for enhancing short-term weather information needed by the prediction models
  - improvement in terms of update rate
  - possible accuracy increase

Possible improved solution

- calculation with a fused system provide more accurate results
- the required uncertainty margins can be reduced



Schönhals and Steen, CEAS, 2009

Added value for probabilistic wake vortex prediction

- real-time observations of meteorological quantities provided by wake vortex monitoring can be used by probabilistic prediction in order to:
  - update the currently used calculation parameters (wind, wind shear)
  - detect and correct errors caused by unexpected deviations in MET input
  - adjust the uncertainty values for the observed quantity, more realistic total uncertainty calculation
  - if error behaviour of observed quantity can be observed and modeled, uncertainty predictions can be made (valid for some limited time scale)

    → a possible solution to provide the required σ_{MET}?

Implementation issues

- accuracy limitations
  - wake vortex sensors are also susceptible to errors, need to be taken into account
- range limitations
  - only area in the vicinity of the sensor can be augmented
  - alternative: multiple sensors for critical areas or multiple sensor scanning planes
- weather limitations
  - need for all-weather sensor
- sensor data available on measurement only – "snap shot"
  - need to fill the gaps between single measurements to provide continuous estimates of meteorological quantities

Thank you for your attention!

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