Anatomy of a windstorm in the light of a Doppler lidar

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Waves to Weather

1. Introduction

Windstorms associated with low-pressure systems
- Most destructive natural hazards for central Europe
- Due to short-lived but intense peak winds = **gusts**

Challenges for modelling and observing gusts
- Models rely on subgrid-scale parameterizations
- Surface observation networks are too sparse

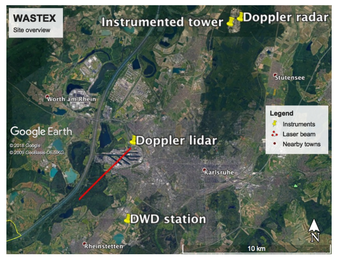
→ **Wind and Storms Experiment (WASTEX)**
= field campaign during winter 2016-17 in Karlsruhe
See overview paper: Pantillon et al. (2018)

2. Instrumentation

Lockheed Martin WindTracer scanning **Doppler lidar** of the KITcube observation platform *(Kalthoff et al. 2013)*
- Range up to 8 km with 70 m along-beam resolution
- Range-height-indicator (RHI) scans 0-15° elevation

KIT Campus North
- **Instrumented 200 m tower**
- **Doppler radar**

DWD surface station
- 10-min observations
- Since 1 Nov 2009



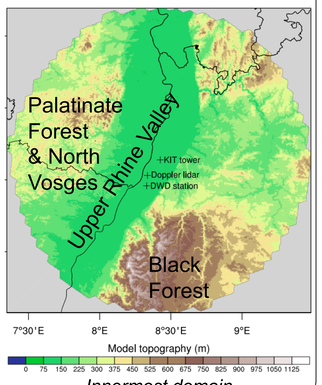
Overview of the WASTEX site

3. Large-eddy simulations

ICON Large Eddy Model based on HD(CP)^2 setup *(Heinze et al., 2017)*

Nested circular domains over Upper Rhine Valley
- Decreasing grid mesh 623 > 311 > **156 m**
- Decreasing diameter 220 > 180 > **150 km**

Init. 00 UTC 23 Feb 2017 from COSMO analysis

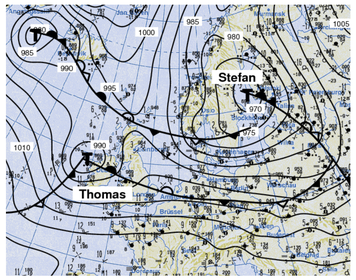


Innermost domain

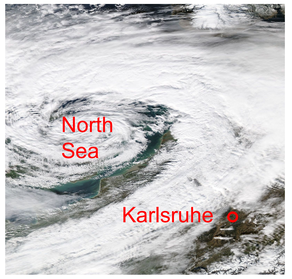
4. Case study

Windstorm *Thomas* on 23 Feb 2017
- Part of a storm series as secondary cyclone of *Stefan*
- First hits Ireland and the UK (known there as storm *Doris*)
- Cold front crosses Germany while centre remains over sea

→ **3rd most severe storm** in Karlsruhe and 2nd most severe over Germany during WASTEX in winter 2016-17



Berliner Wetterkarte at 00 UTC 23 Feb 2017

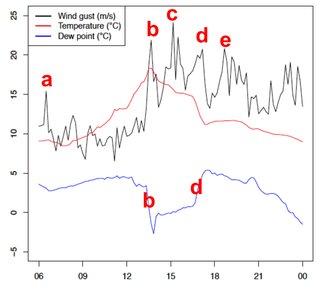


MODIS at 12:25 UTC 23 Feb 2017

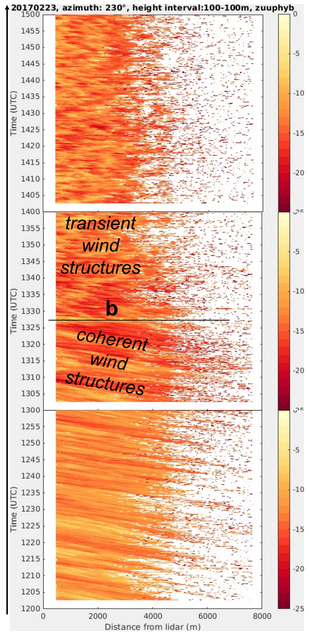
5. Observations

Chronology of peak wind gusts

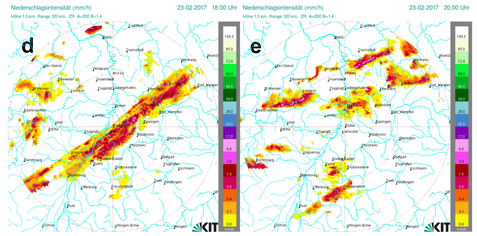
a) 06:30 UTC Sunrise
b) 13:30 UTC Foehn breakthrough
c) 15:30 UTC Passage cold front
d) 17:00 UTC Postfrontal precipitation
e) 19:00 UTC Scattered precipitation



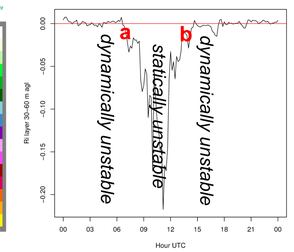
Tower: obs 40 m agl 06-24 UTC



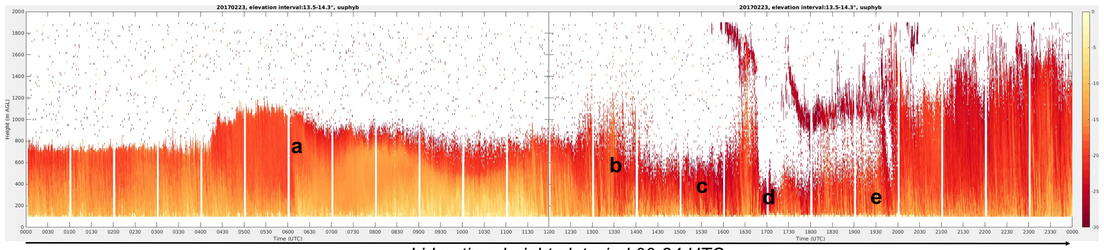
Lidar: Hovmöller plot wind 12-15 UTC



Radar: precipitation rate 17 UTC (left) and 19 UTC (right)



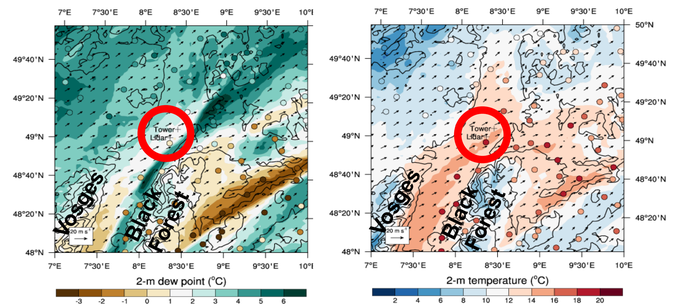
Tower: Ri number 00-24 UTC



Lidar: time-height plot wind 00-24 UTC

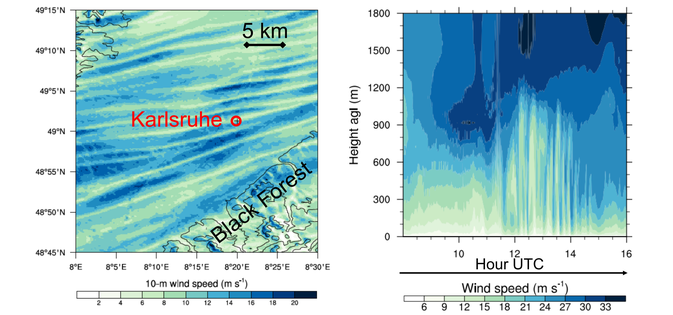
6. Representation in models

Operational 2.8 km COSMO forecasts
- *Deterministic*: fail to capture foehn breakthrough (not shown)
- *Ensemble*: some members perform better!



COSMO: member 17 at 14 UTC (t+14h)

ICON large eddy simulations
- Coherent wind structures in 156m run 11:30-15:30 UTC
- Discernible in 311m but absent in 623m run (not shown)



ICON 156m run: zoom at 13 UTC (left) and time-height plot 08-16 UTC (right)

7. Summary

A Doppler lidar operating during the WASTEX field campaign offers observations at high resolution in space and time of the formation of wind gusts in the boundary layer.

During the passage of storm Thomas on 23 February 2017, the breakthrough of foehn results in a peak in wind gusts and in a change from coherent to transient wind structures.

Operational forecasts poorly predict the breakthrough of foehn while large-eddy simulations with grid spacing of 156-312 m capture–at least partly–the boundary-layer structures.

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