Karlsruhe Institute of Technology

WAVES TO WEATHER

Observing and forecasting wind gusts in winter storms over Germany

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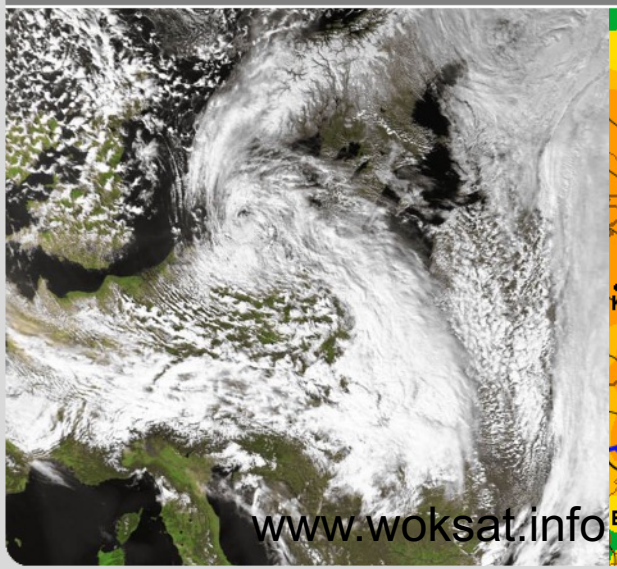
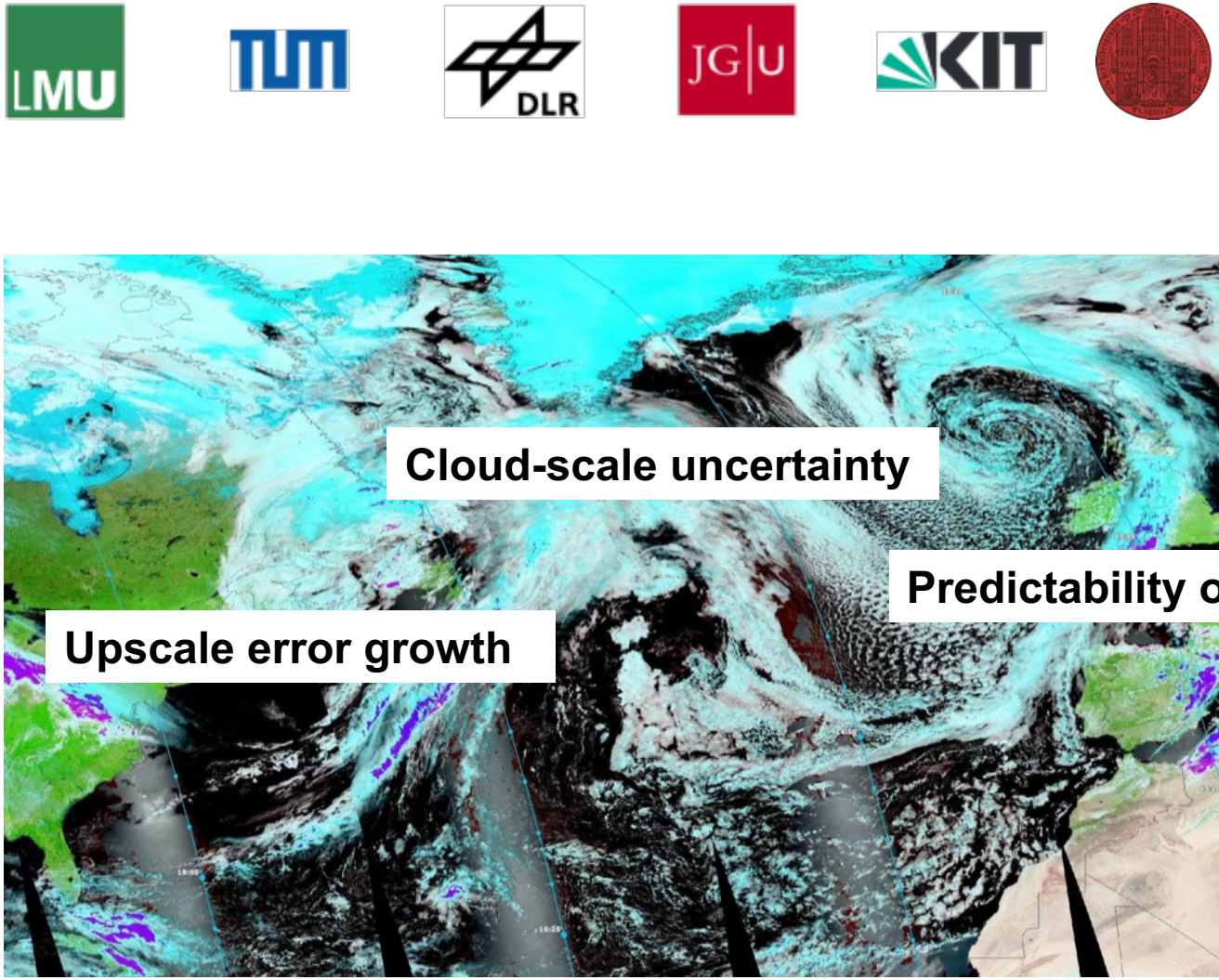
Institute of Meteorology and Climate Research – Troposphere Research (IMK-TRO)



Collaborative Research Center "Waves to Weather"



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Motivation and strategy

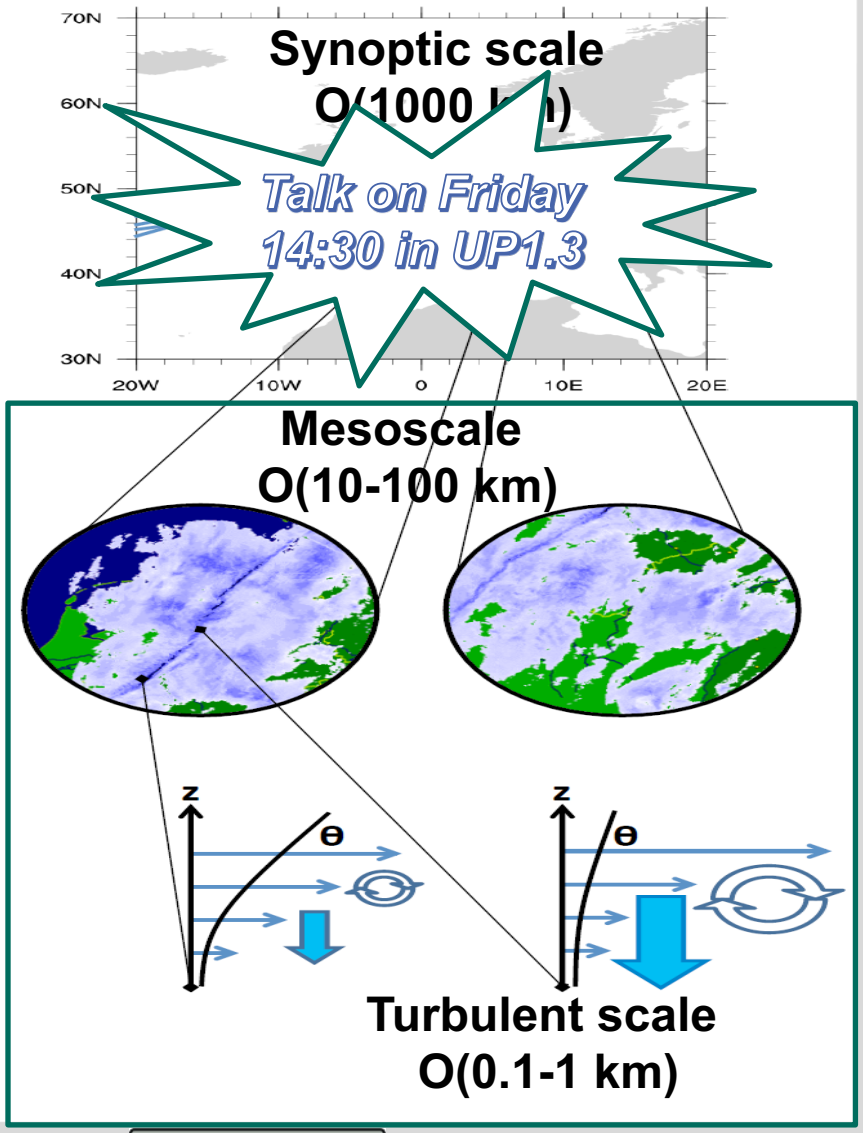
Predictability of wind gusts
in winter storms over central Europe

- Storms = destructive natural hazard
- Predictability = **multi-scale** problem

1. **Synoptic scale**
   → global ensemble forecasts

2. **Mesoscale**
   → regional ensemble forecasts

3. **Turbulent scale**
   → Doppler lidar observations



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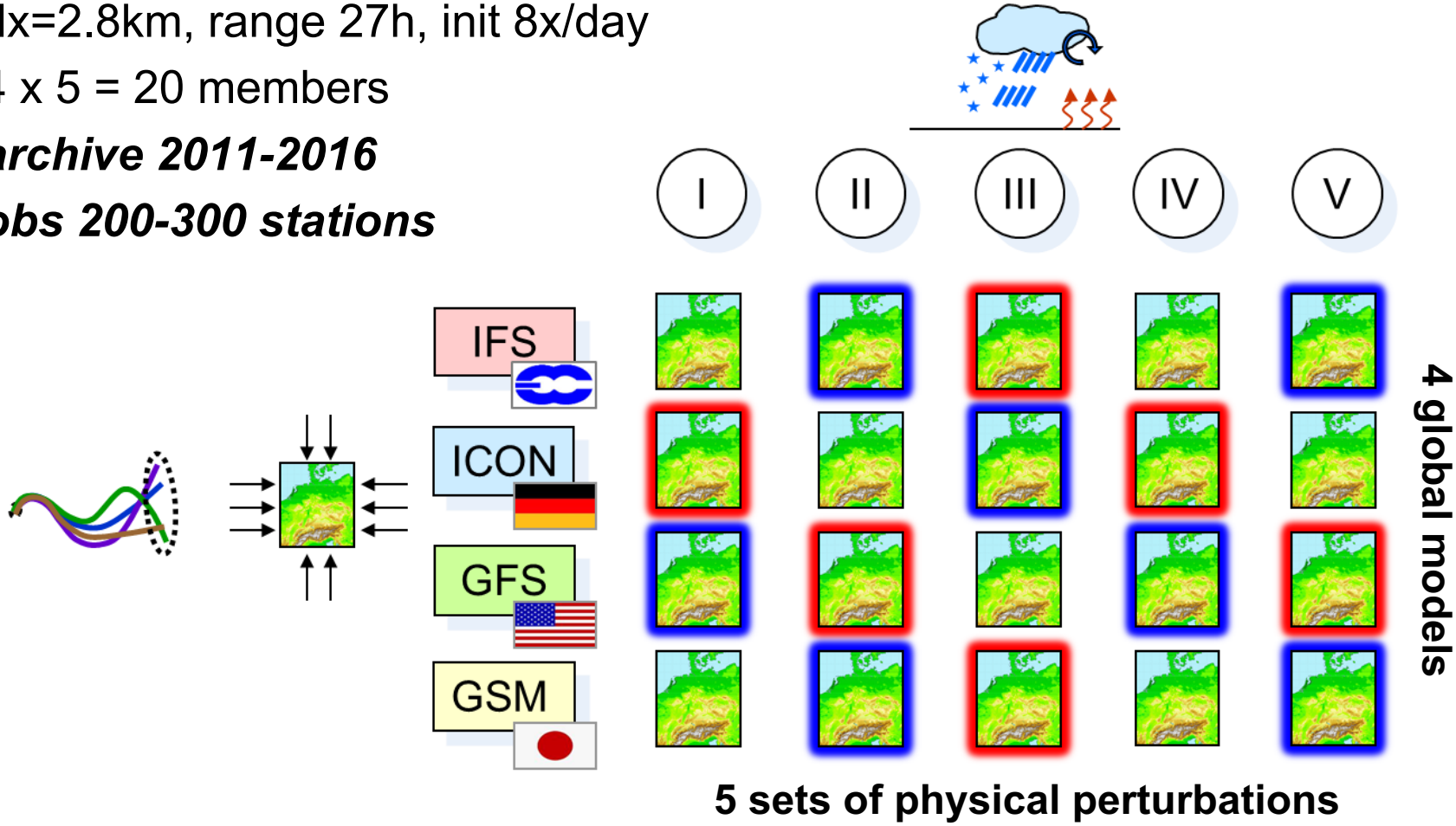
Mesoscale: COSMO-DE-EPS forecasts

Operational DWD regional ensemble

- dx=2.8km, range 27h, init 8x/day
- 4 x 5 = 20 members

→ ***archive 2011-2016***

→ ***obs 200-300 stations***



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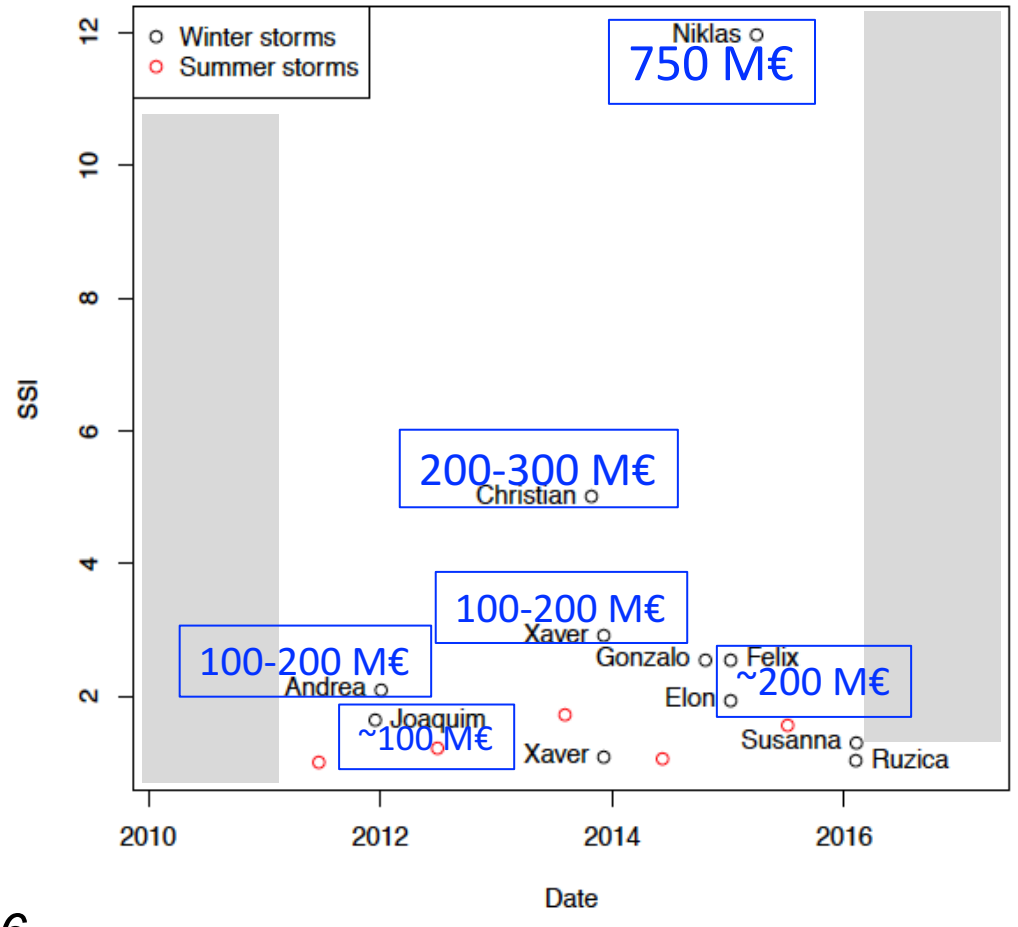
Selection of winter storms

Storm Severity Index (SSI)
(Klawa and Ulbrich 2003)

$$SSI = \underbrace{\left(\frac{v_{max}}{v_{98}} - 1\right)^3}_{daily\ maximum\ wind\ gust} \Big/ \underbrace{v_{98}}_{local\ 98^{th}\ clim.\ percentile}$$

- SSI ~ insurance losses
- Troubles never come alone
  - *Elon-Felix 9-10 Jan 2015*
  - *Ruzica-Susanna 8-9 Feb 2016*
  - *…*
- Also summer storms

→ *10 strongest storms 2011-2016*



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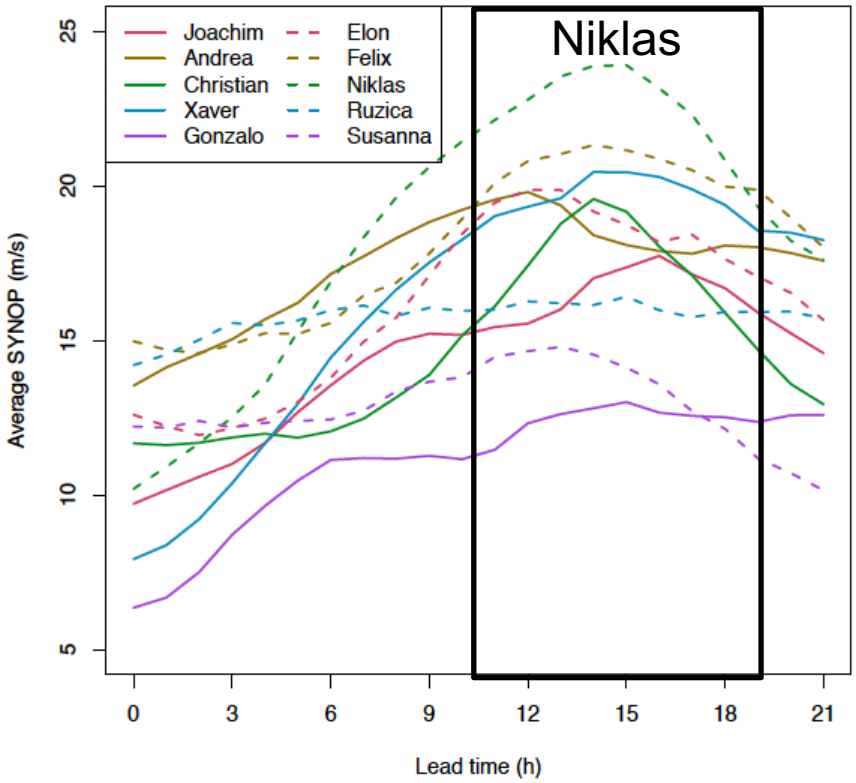
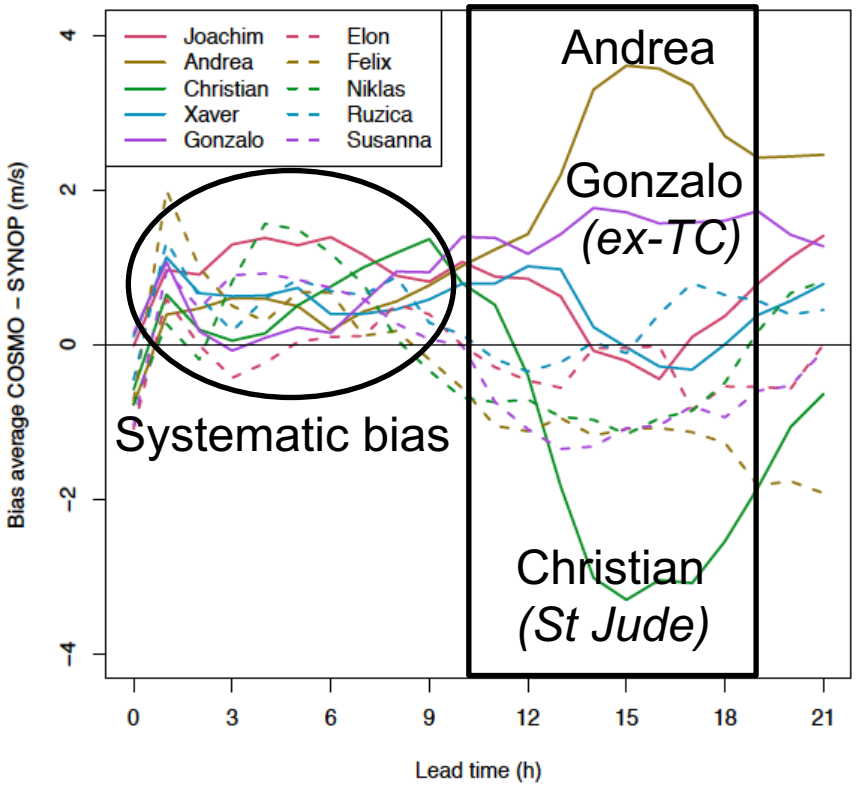
Gusts COSMO vs. SYNOP

Observations (average 177 stations)



Ensemble mean – observations



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Statistical post-processing

Correct biases + calibrate forecast

- Ensemble Model Output Statistics (EMOS)
- e.g. truncated normal distribution

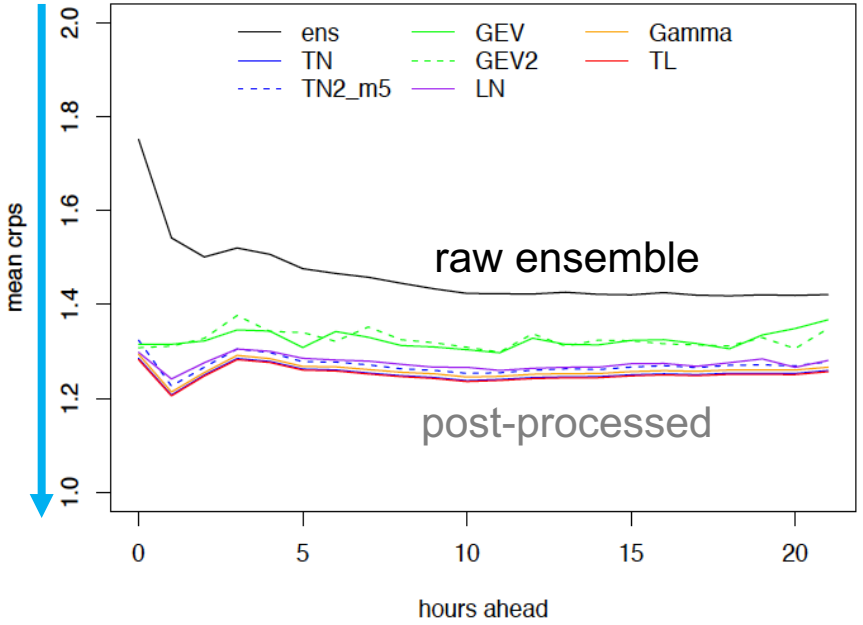
$$Y|X_1,\ldots,X_m \sim \mathcal{N}_{[0,\infty)}(\mu,\sigma^2)$$

gust — *ensemble members*

$$\mu = a + b\,\bar{X}$$
$$\sigma^2 = c + d\,S^2$$

→ 4 parameters *a, b, c, d*

- 1-month training with observations
- Minimize Continuous Ranked Probability Score (CRPS)



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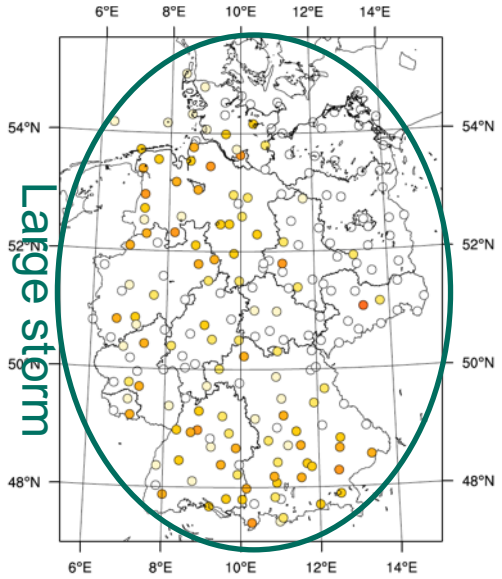
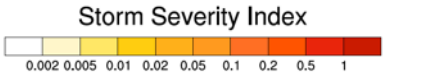
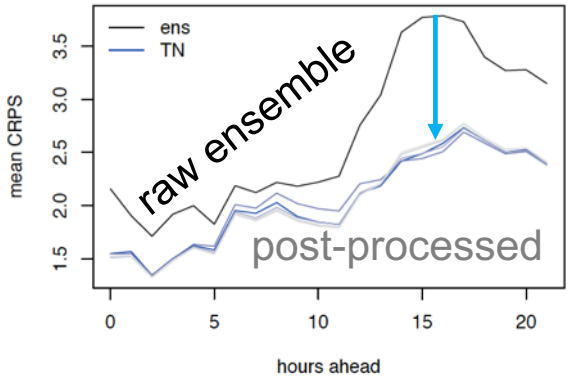
Comparison 3 storms

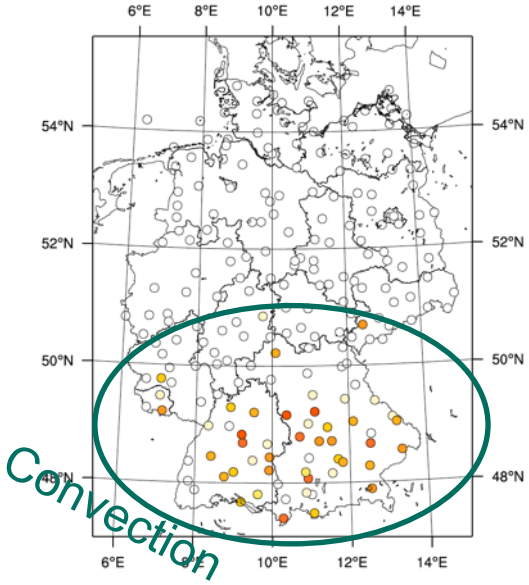
Andrea 5 Jan 2012

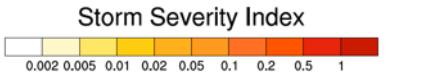


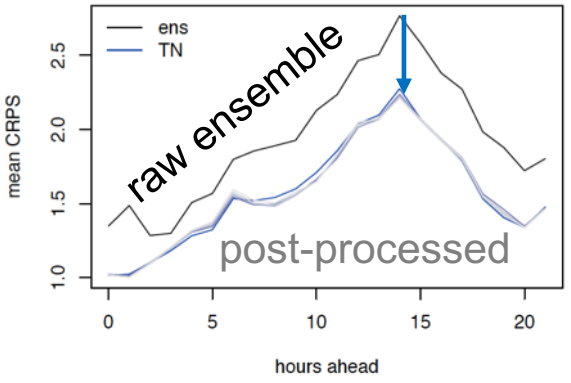




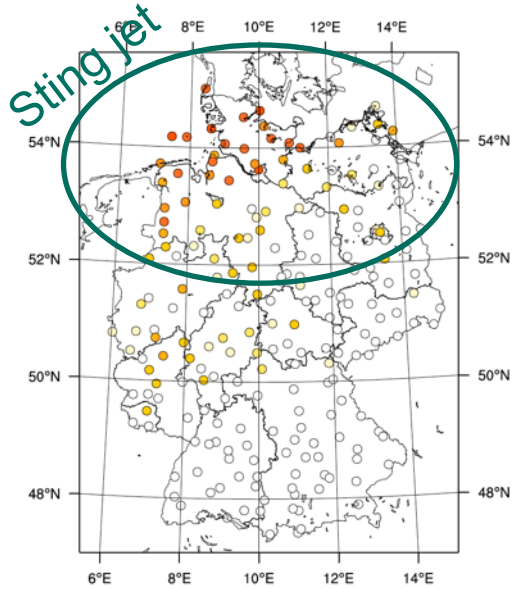
Gonzalo 21 Oct 2014

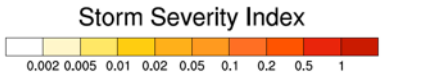


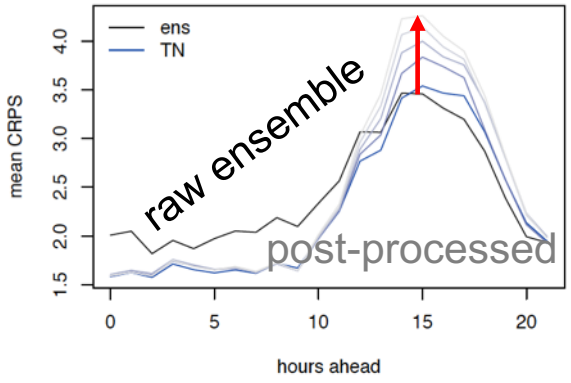




Christian 28 Oct 2013







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Turbulent scale: lidar observations

Field campaign winter 2016/17
WASTEX *(Wind and Storms Experiment)*

- **Doppler wind lidar**
  - High resolution ~80 m
  - Range up to 8 km
  - Vertical scans (RHI) in wind direction
  - 1 scan 0-15° elevation every 5-10 s

- KIT C-band Doppler radar
- 200-m instrumented mast

→ *6 Intense Observation Periods (IOPs) during passage of storms*

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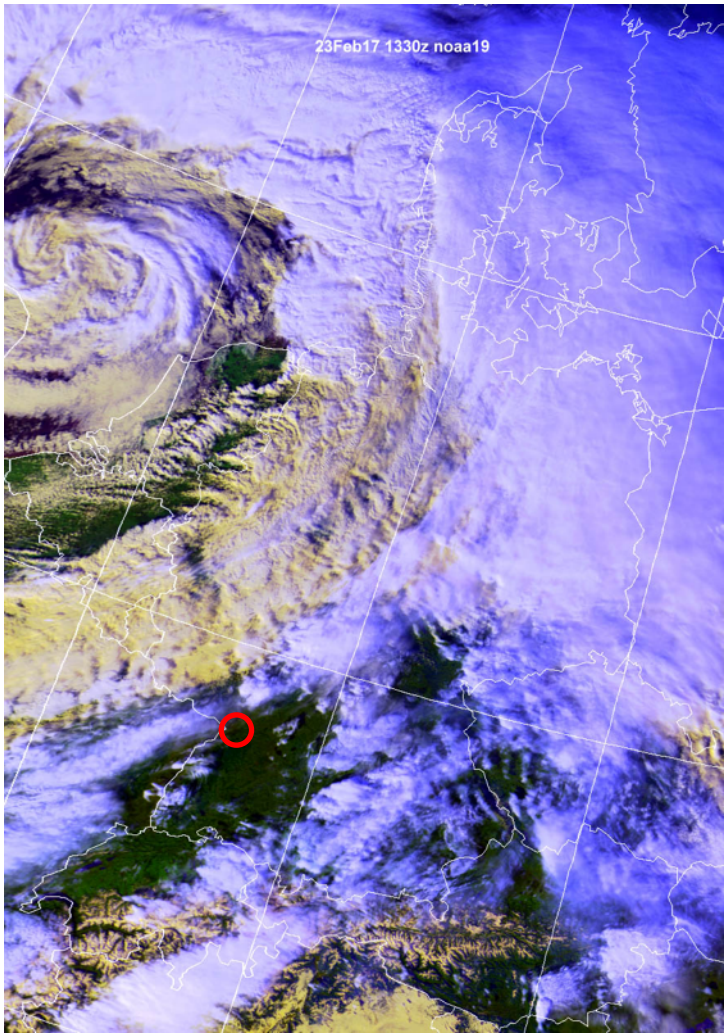
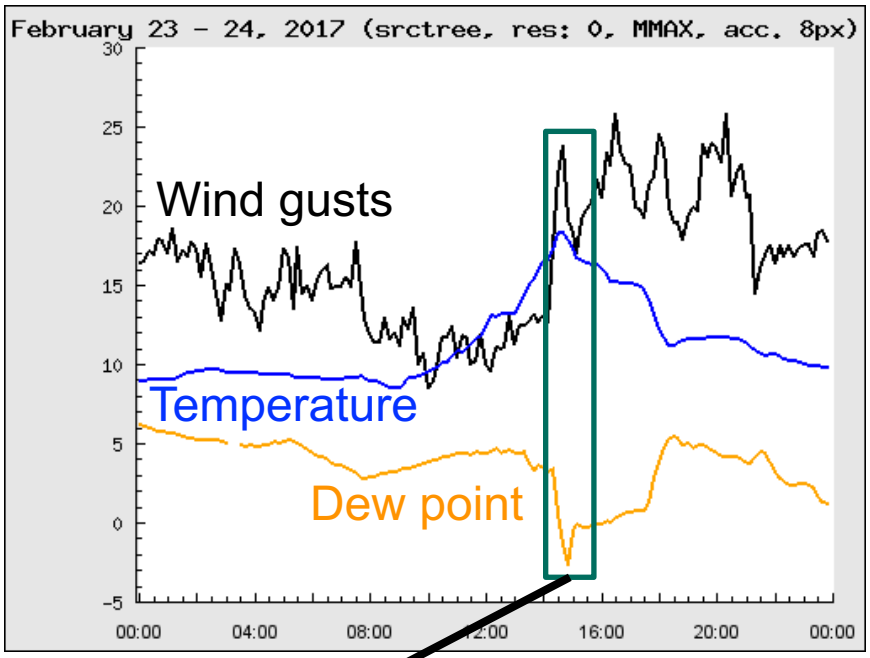
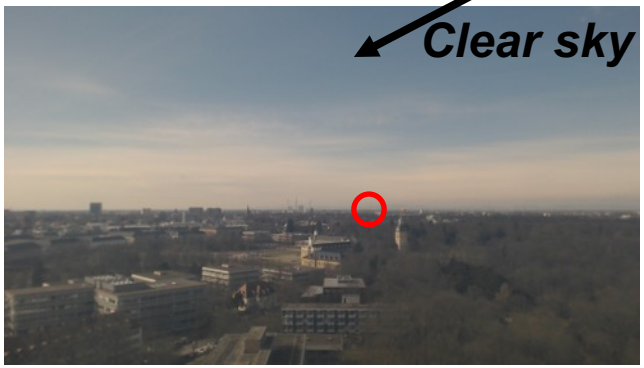
IOP5 23 Feb: storm Thomas
(IRL&UK: Doris!)



NOAA19 13:30 UTC *(www.woksat.info)*

Mast observations at 100m height





Webcam KIT westward view

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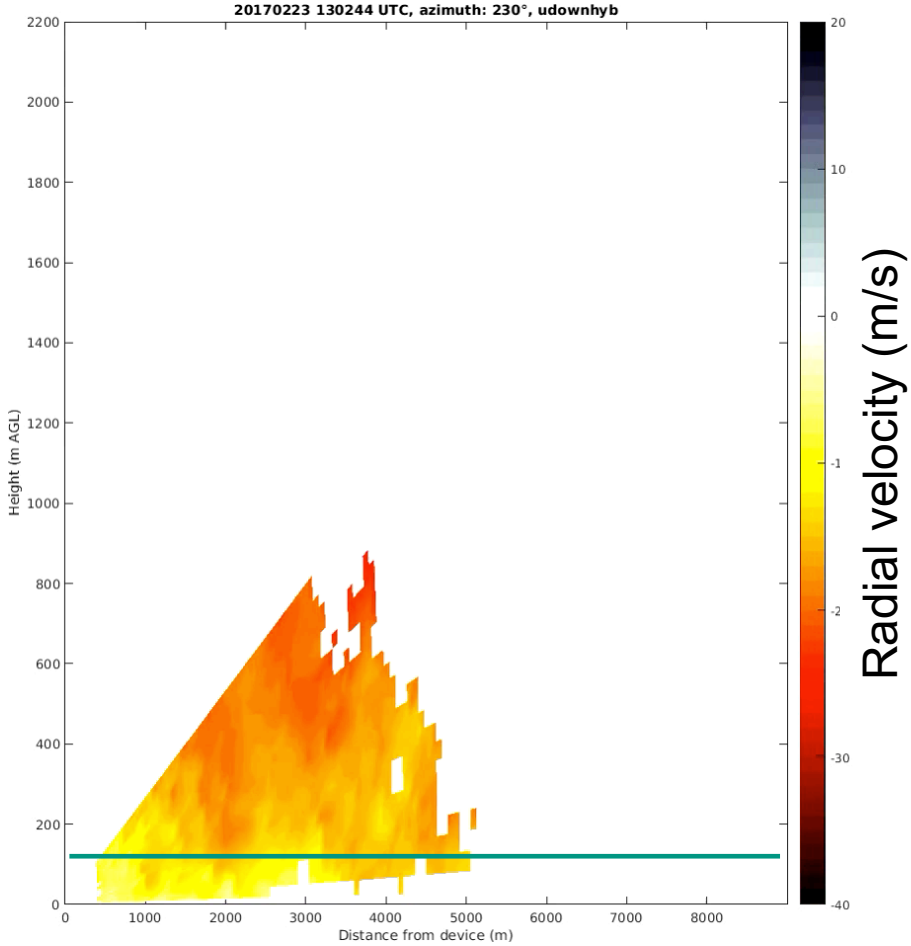
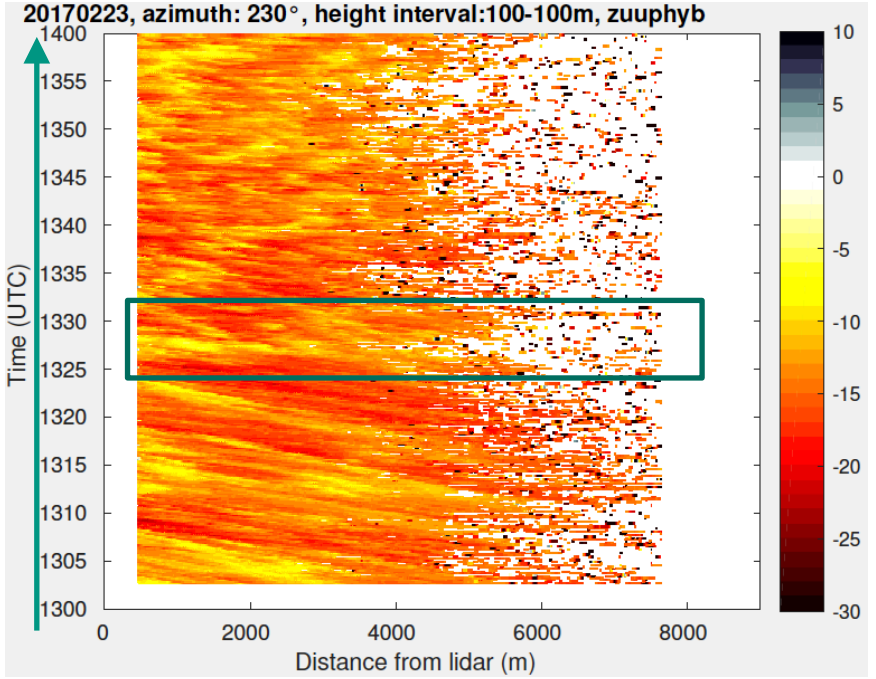
Regime change at 13:30 UTC





Lidar observations at 100m height

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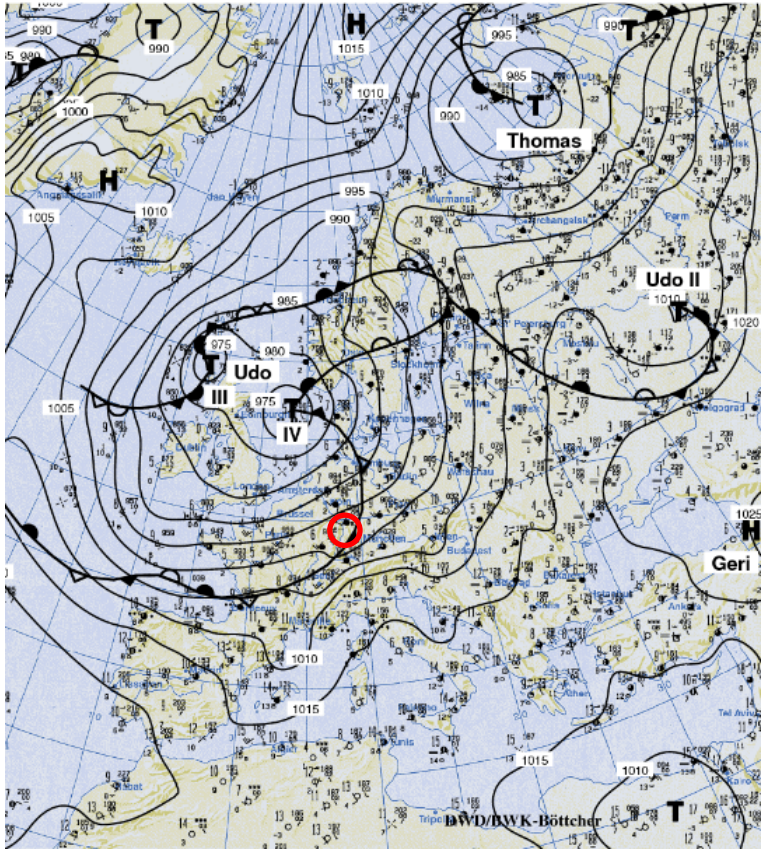
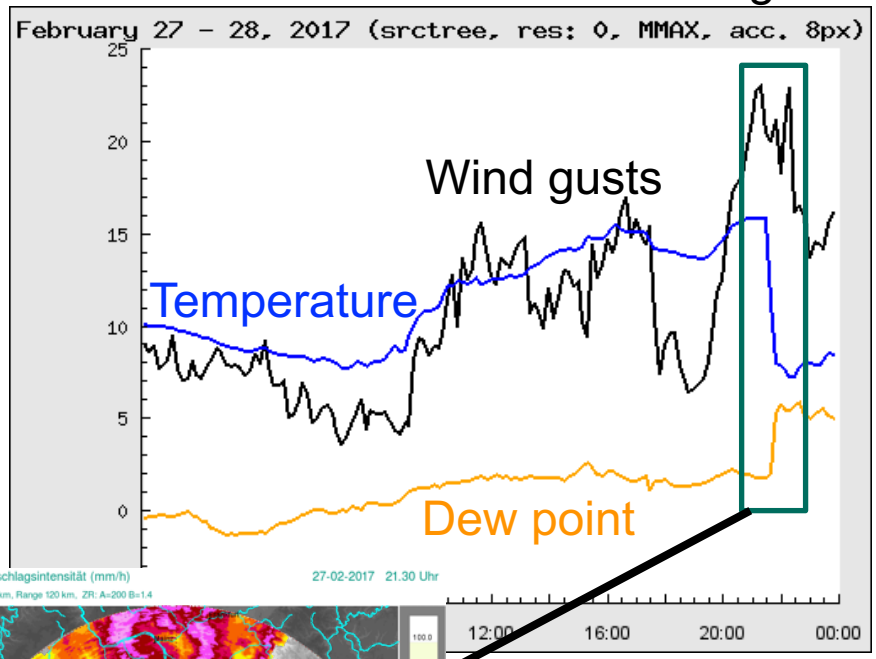
IOP6 27 Feb: storm Udo

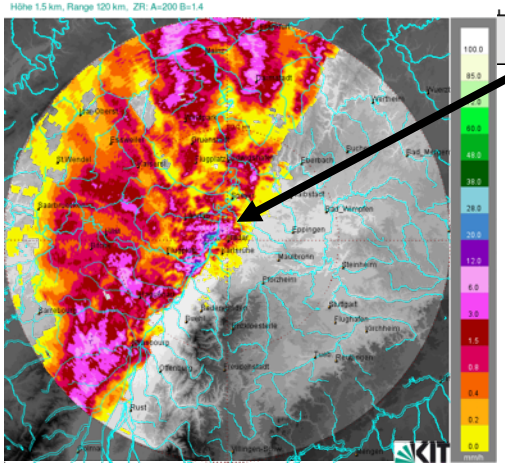
(IRL&UK: Ewan?)



Berliner Wetterkarte 28 Feb 00 UTC

Mast observations at 100m height





Cold front

Radar observation at 20:30 UTC

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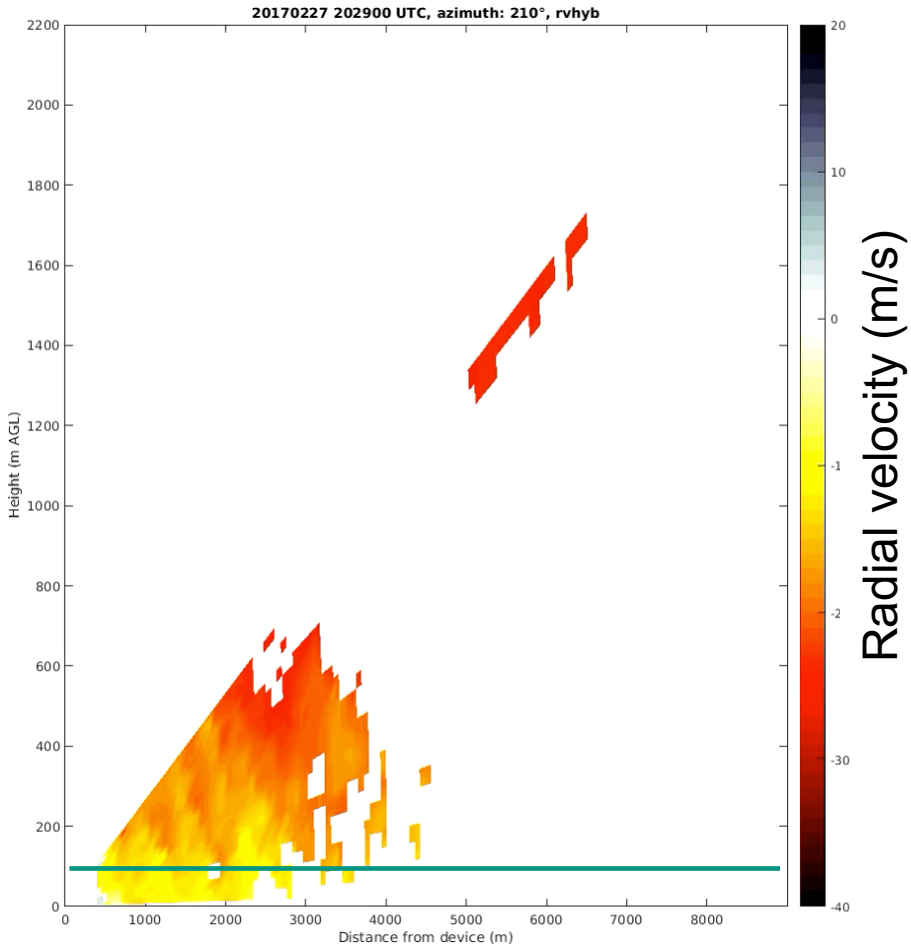
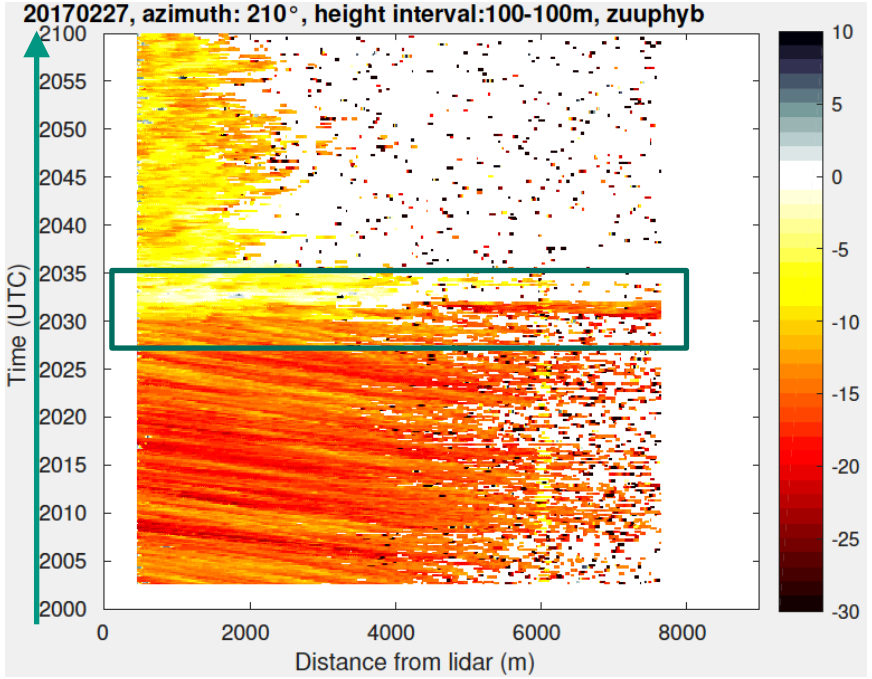
Convective gust at 20:30 UTC





Lidar observations at 100m height

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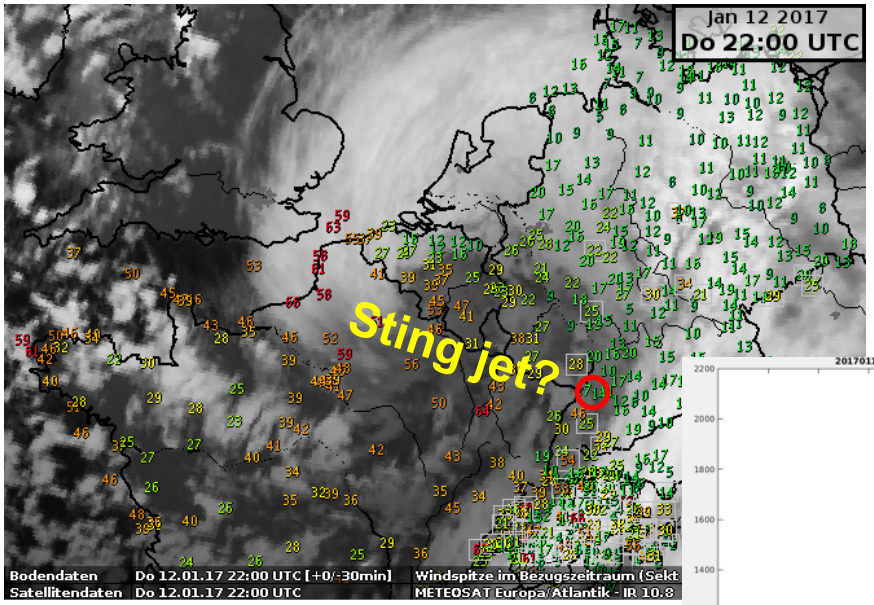
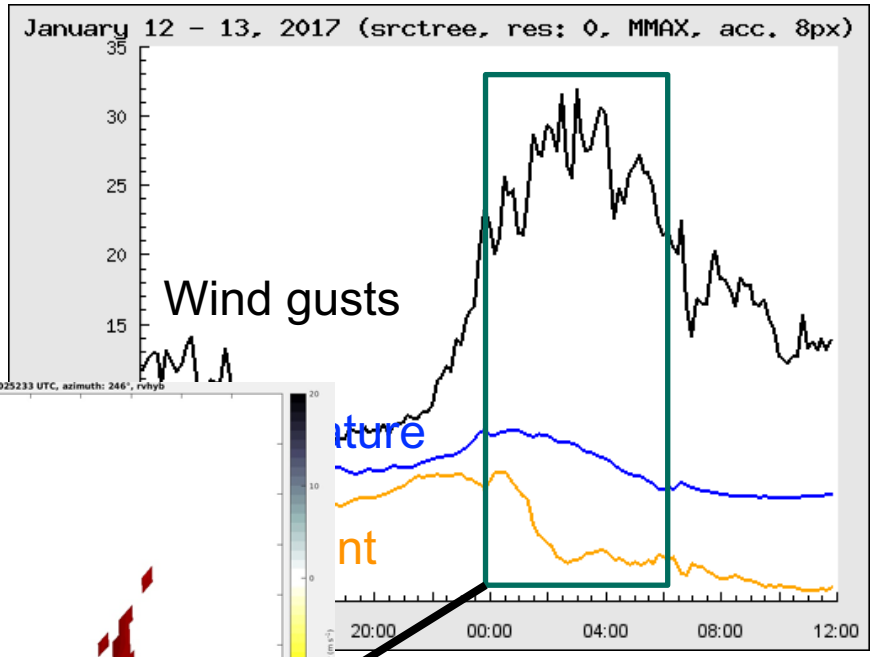
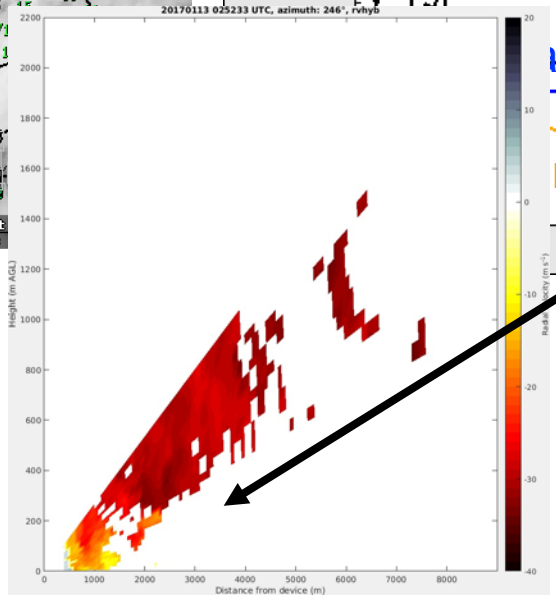
IOP3 13 January: storm Egon

MSG 12 Jan 22 UTC



Mast observations at 100m height





Poor signal ☹

Lidar observation
at 02:52:33 UTC

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Conclusions and perspectives

Multi-scale predictability of wind gusts in winter storms

Mesoscale

- DWD regional ensemble forecast COSMO-DE-EPS
- 10 strongest storms for the 2011-2016 period

→ *Connect forecast skill with storms' dynamics*

→ *Compare models for statistical post-processing*

Turbulent scale

- WASTEX field campaign with Doppler lidar
- 6 IOPs during winter 2016/2017

→ *Understand mixing of momentum in the boundary layer*

→ *Investigate its representation in NWP models*

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