Karlsruhe Institute of Technology

The impact of 1-way and 2-way nesting on the simulation of European windstorms

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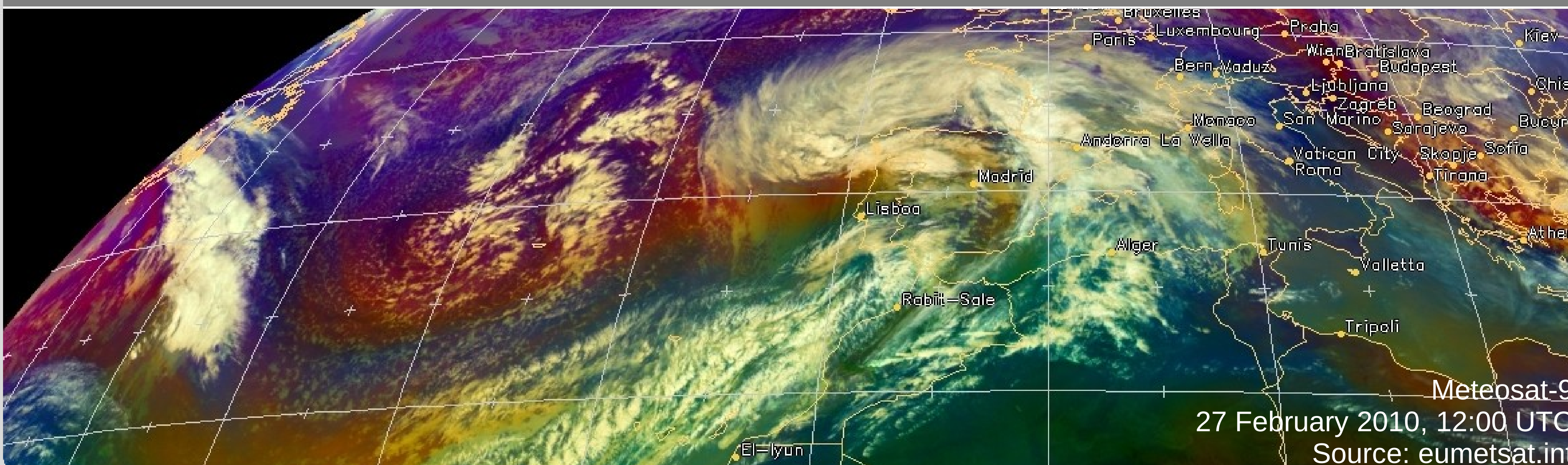
KIT – IMK-TRO – Working Group: Regional Climate and Weather Hazards



Meteosat-9
27 February 2010, 12:00 UTC
Source: eumetsat.int

Motivation

- In nature there is an interaction between large- and small-scale processes. In regional downscaling, often not.

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- Therefore small-scale processes are not represented (well) in low-resolution simulations, like e.g. global climate models

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- 2-way nesting includes small-scale processes on coarse domains

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- Can we improve the development and footprint of wind storms?
- What do we learn from this in terms of process understanding?

Motivation

Examples of the use of 2-way nesting:

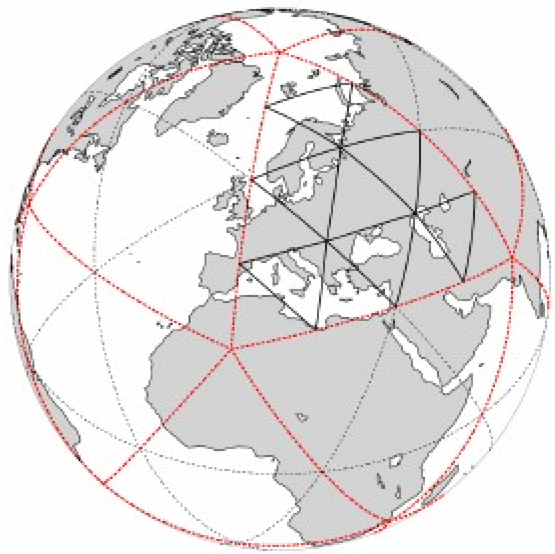
- Many studies about hurricanes (e.g. WRF model, tropics)
- Pante & Knippertz (2019, Nature Communications):

  Resolving Sahelian thunderstorms improves mid-latitude weather forecasts (ICON model, tropics to extra-tropics)

➡ We investigate the impact of 2-way nesting with the **ICON model** for **midlatitude windstorms**

Method

- ICON model
- Limited area modelling
- Driven by ERA5
- Horizontal resolutions:
  - 13.2 km
  - 6.6 km
  - 3.3 km (explicit deep convection)

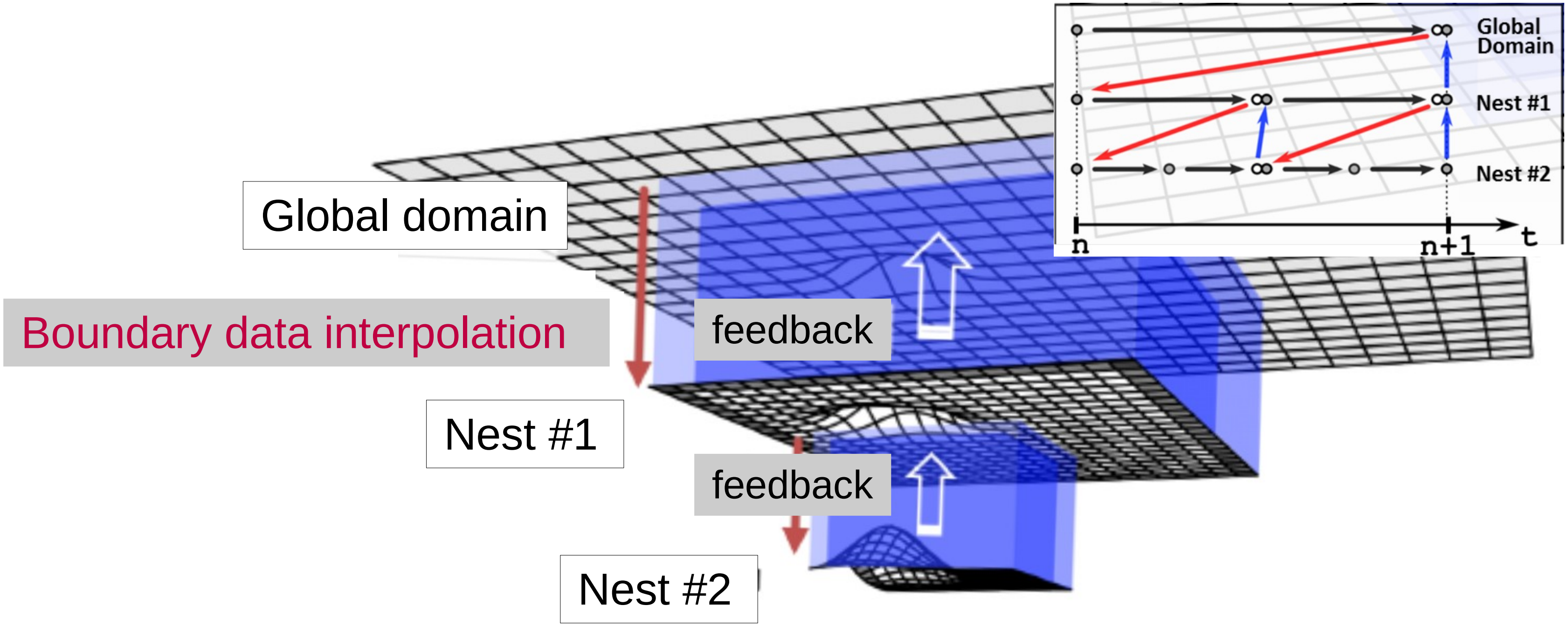


(Source: ICON model tutorial 2019)

Method

1-way nesting: nested domains with only boundary data interpolation

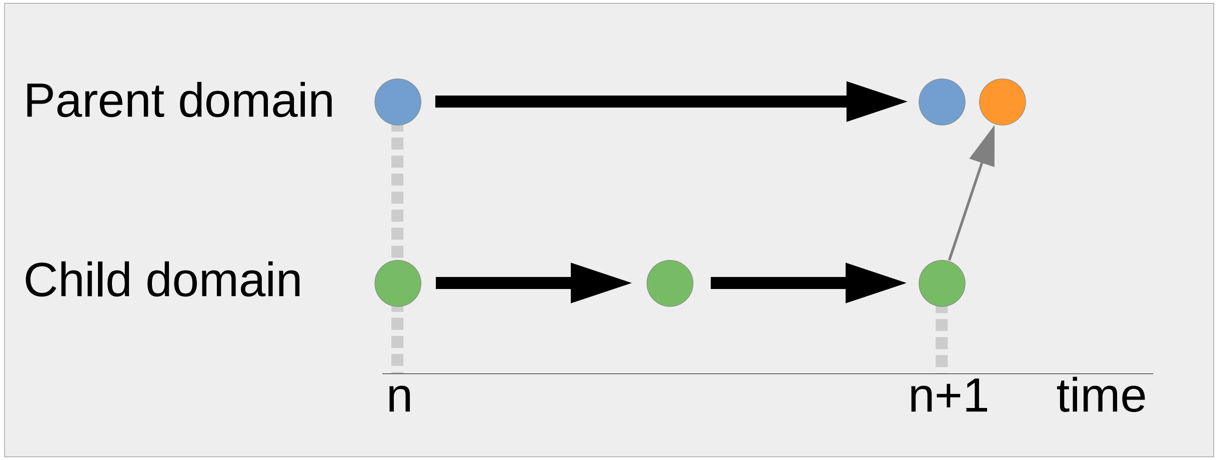
2-way nesting: additonal feedback into the coarser domain



(Figure adapted from the ICON model tutorial 2019)

Method

- Child-to-parent information transfer
- Feedback of the prognostic variables $v_n,\ w,\ \theta_v,\ \rho\,,\ q_v,\ q_c,\ q_i$



$$\rho_p^* = \rho_p^{n+1} + \frac{\Delta t_p}{\tau_{fb}} \left(\mathcal{I}_{c \rightarrow p}(\rho_c^{n+1}) - \rho_p^{n+1} \right)$$

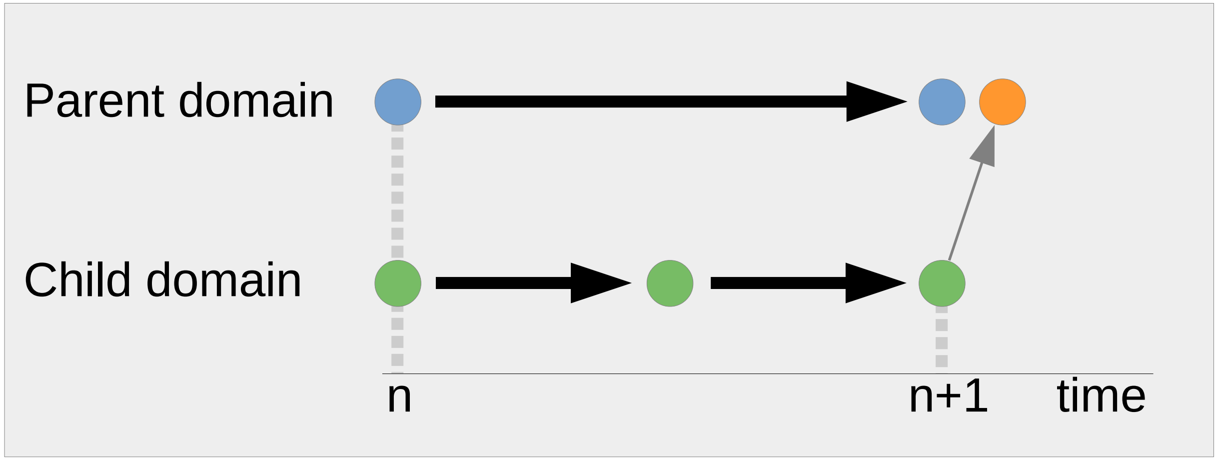
final solution of the parent domain (p)

solution of the parent domain (p) based on dynamics and physics

solution of the child domain (c) based on dynamics and physics

Method

- Child-to-parent information transfer
- Feedback of the prognostic variables $v_n,\ w,\ \theta_v,\ \rho,\ q_v,\ q_c,\ q_i$



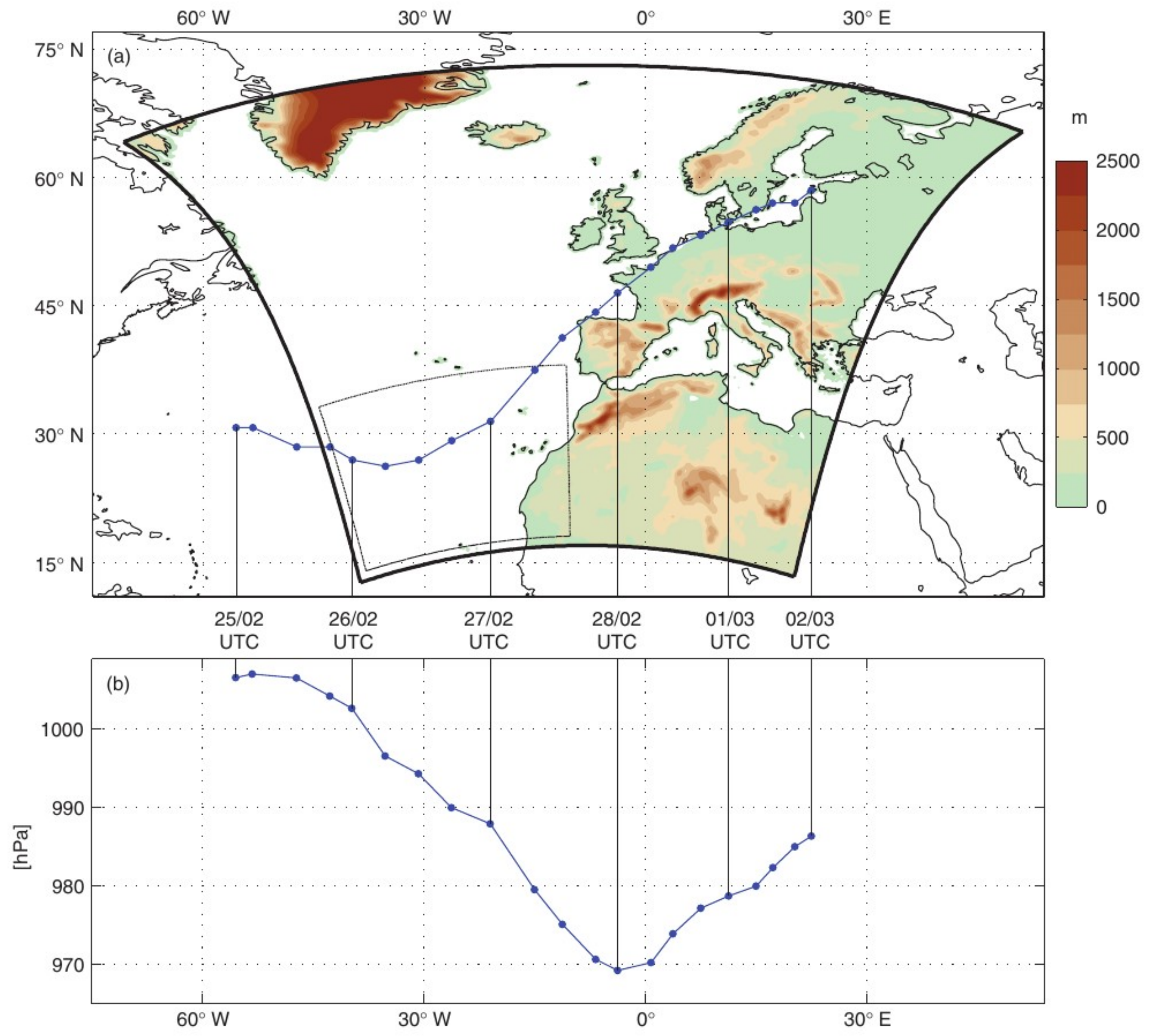
$$\rho_p^* = \rho_p^{n+1} + \frac{\Delta t_p}{\tau_{fb}} \left(\mathcal{I}_{c \rightarrow p}(\rho_c^{n+1}) - \rho_p^{n+1} \right)$$

feedback factor

Relaxation time step τ_{fb}
default = 3 hours, motivated by the wish to exclude small-scale transient features from the feedback, but to capture synoptic-scale features

Case study Xynthia

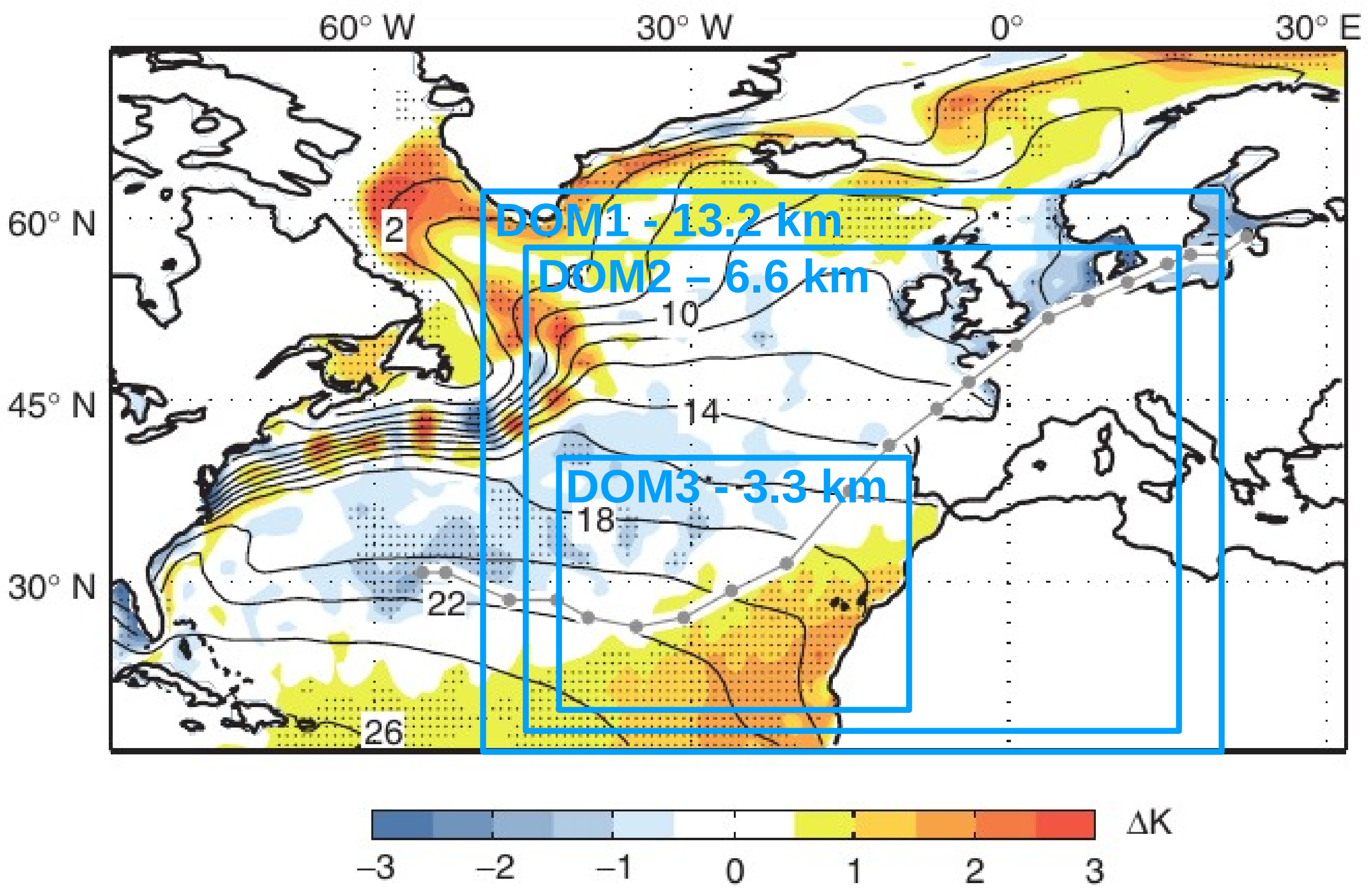
- Several fatalities
- Dyke bursts, flooding
- Losses (Munich Re)
  - €3.10 billion (France)
  - €250 million (Spain)
  - €750 million (Germany)



(Source: Ludwig et al. (2014), QJRMS)

Case study Xynthia

- Shaded: SST anomalies for February 2010



(Source: Ludwig et al. (2014), QJRMS)

Results – on 13.2 km

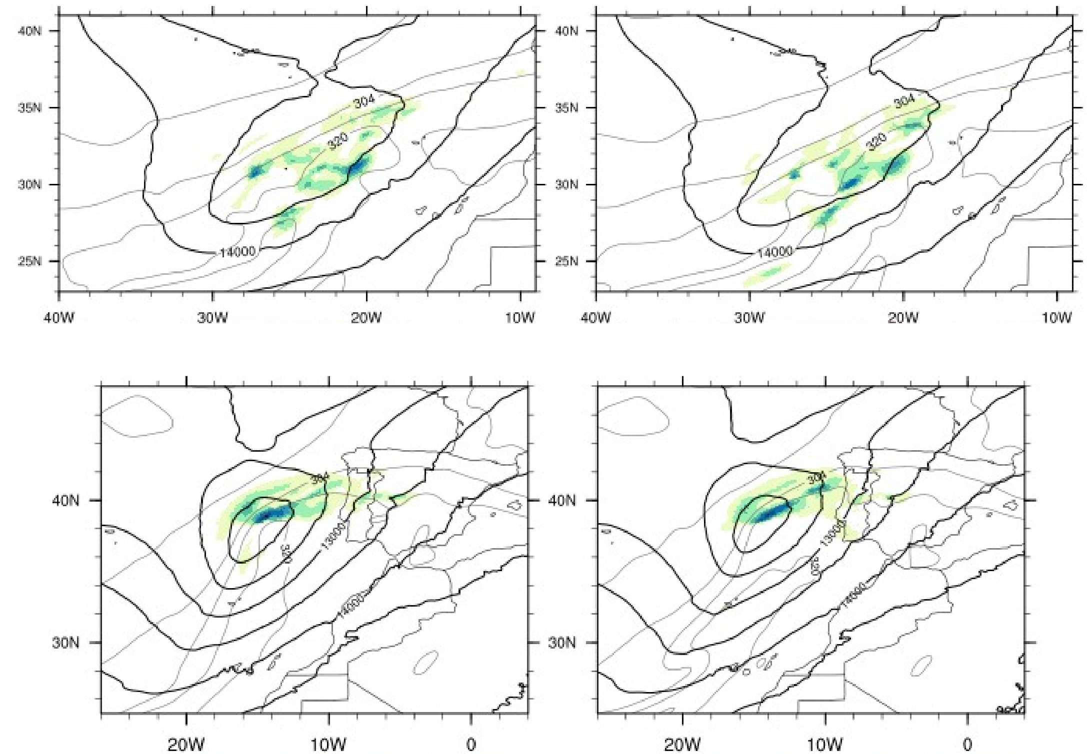
- Bias in precipitation due to feedback of single convective cells
- Differences become smaller when the influence of high-res becomes negligible and/or when frontal precipitation starts

1-way

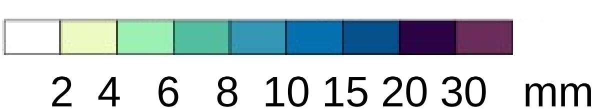
2-way

26th, 16 UTC

27th, 05 UTC



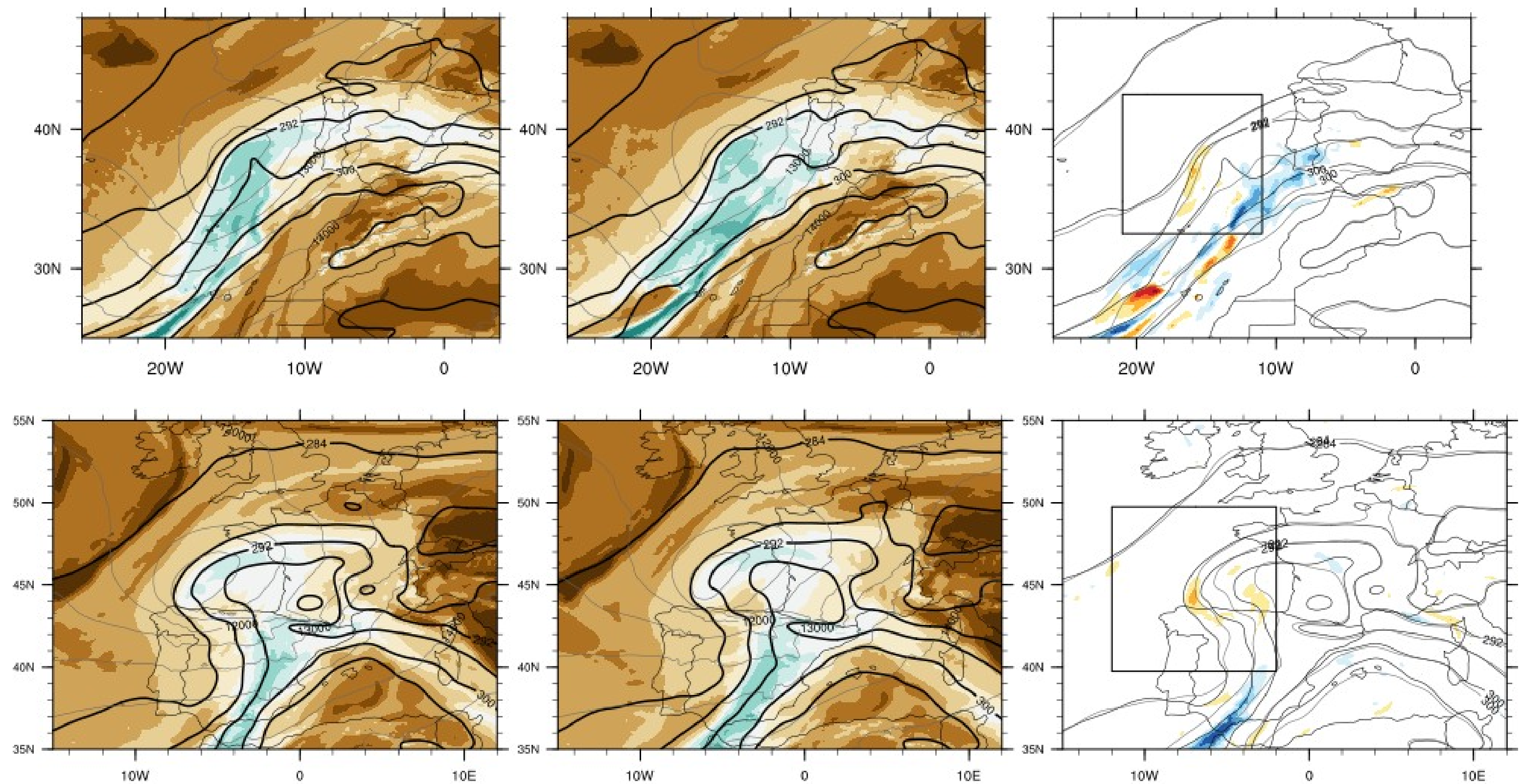
Shaded: hourly precipitation
Black contours: geop @ 850 hPa
Grey contours: θ-eq @ 850 hPa



Results – on 13.2 km

- Bias in moisture, higher availability when using 2-way nesting

	1-way	2-way	diff. 1-way - 2-way
27th, 05 UTC			
27th, 20 UTC			



Shaded: q_v @ 850 hPa
Black contours: θ @ 850 hPa
Grey contours: geop @ 850 hPa

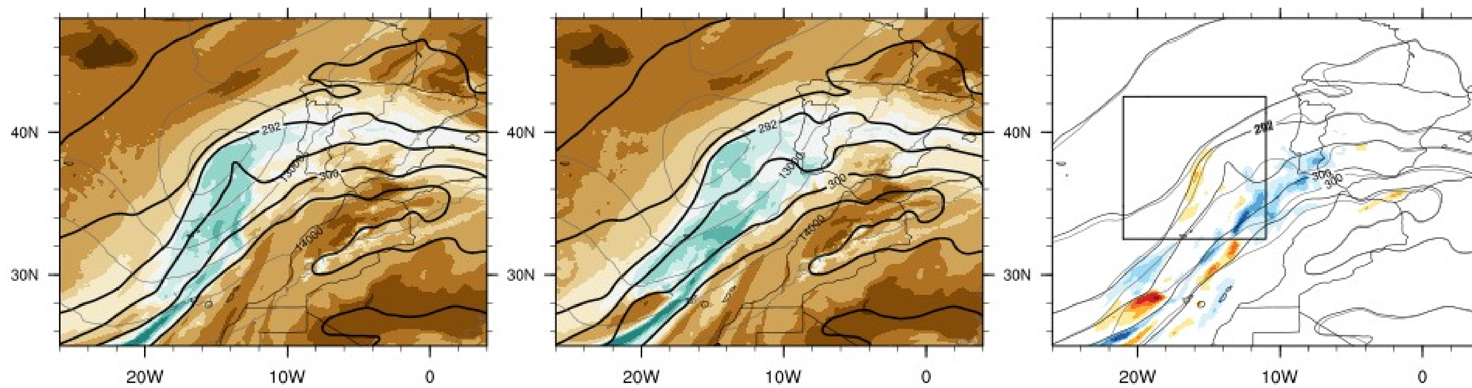
Results – on 13.2 km

- Bias in moisture coincides with an increased wind speed using 2-way nesting

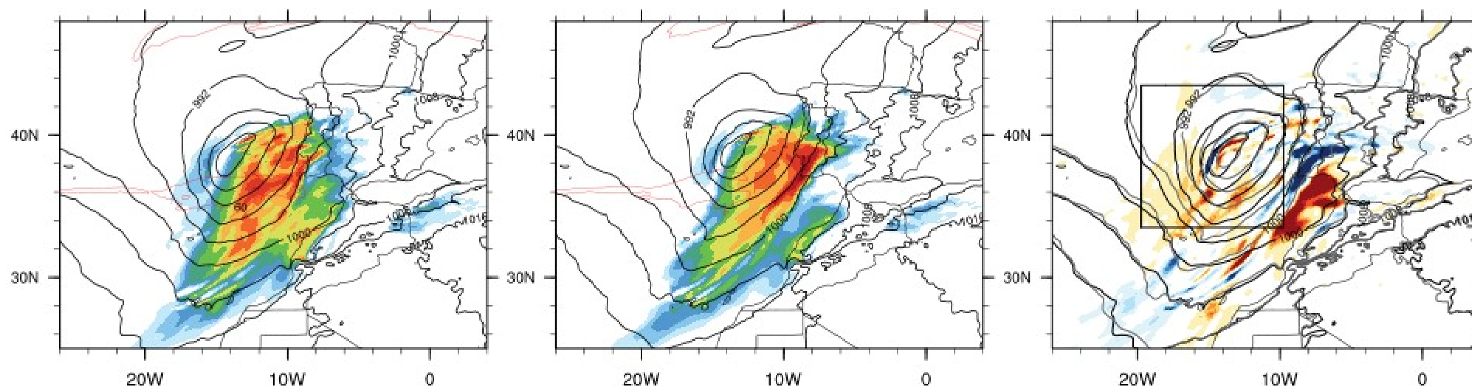
1-way | 2-way | diff. 1-way - 2-way

27th, 05 UTC

Shaded: q_v @ 850 hPa
Black contours: θ
Grey contours: geop



27th, 07 UTC

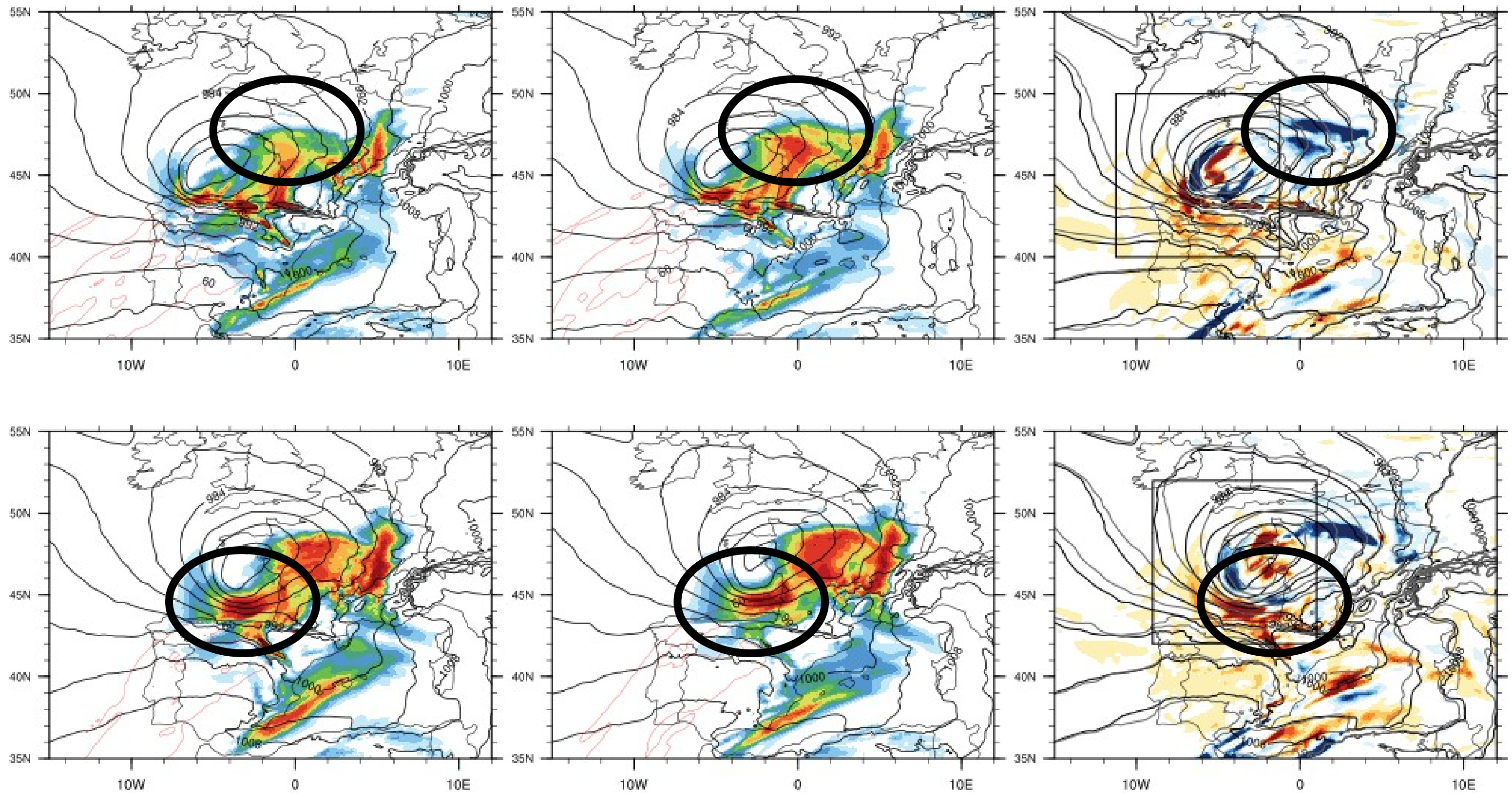


Shaded: wind-speed @850 hPa
Contours: geopotential @850 hPa

Results – on 13.2 km

- Bias in wind speed, more/less in 2-way nesting depending on the feature

	1-way	2-way	diff. 1-way - 2-way
27th, 21 UTC			
28th, 00 UTC			



Shaded: wind-speed @850 hPa
Contours: geopotential @850 hPa

Results – on 13.2 km

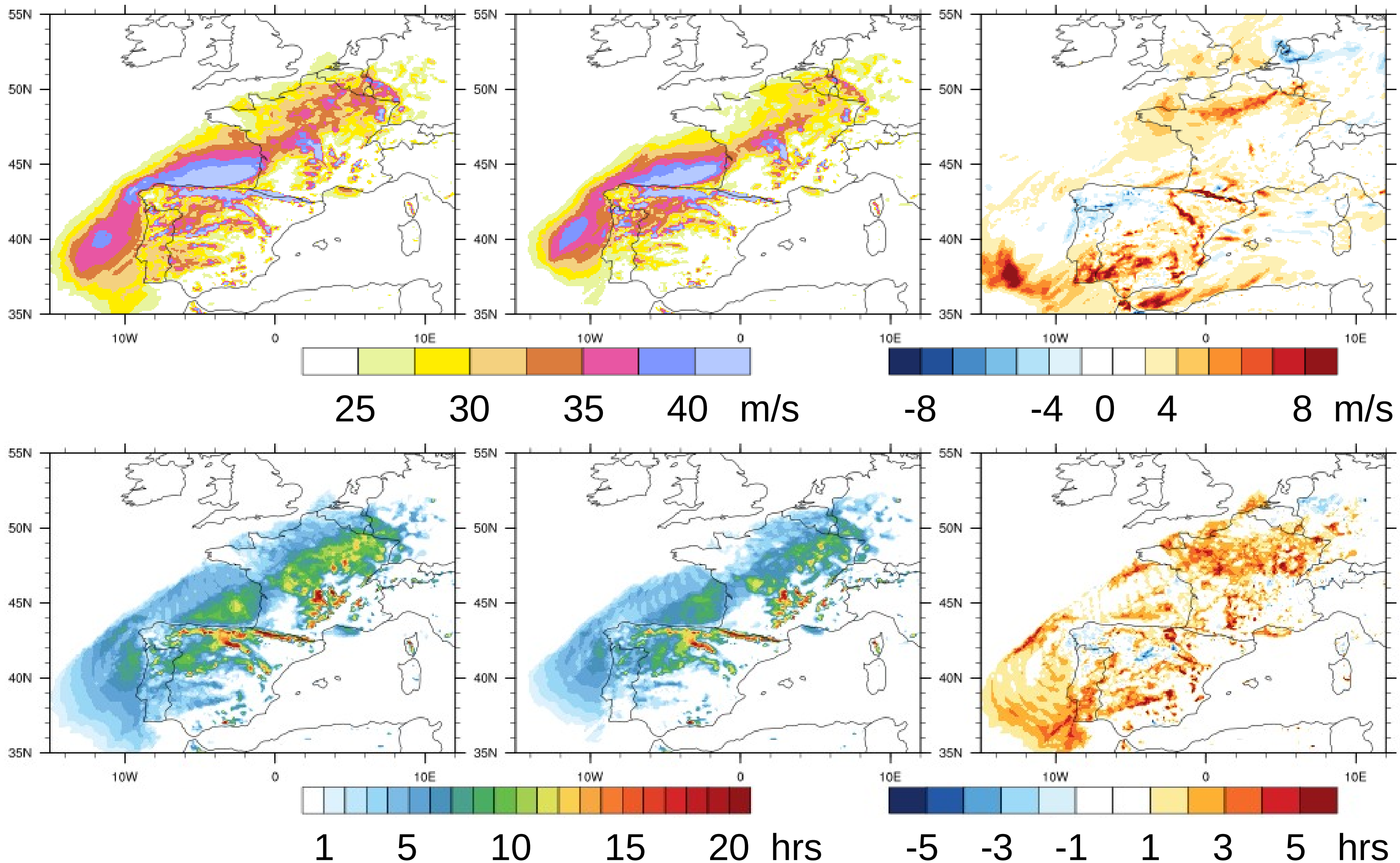
- Bias in the wind gust field, more intense gusts in 1-way nesting

27th, 12 UTC
- 28th, 18 UTC

1-way | 2-way | diff. 1-way - 2-way

Shaded:
max wind gusts footprint

Shaded:
duration of gusts > 25 m/s

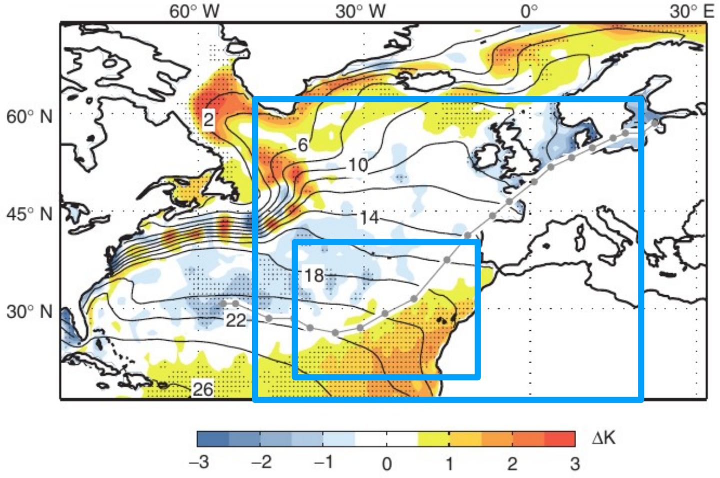


Summary & Outlook – part I

Many questions left:

- Sensitivity to location/timing of the high-res domain?
- Sensitivity to a larger domain?
- Which one performs better? (observations)
- Other storms?

We cannot make clear statements yet.



Work in progress!!

But:

We do see an impact on the representation of the wind field over Europe by the use of a 2-way coupling between high- and low-resolution domains during the development of windstorm Xynthia.

Outlook – part II

Starting in 2 weeks:

Germany-wide research project
- ClimXtreme -
Extreme events in a changing climate

Sub-projec CyclEx
„Intensity and structural changes
of extreme mid-latitude cyclones
change in a warming climate“

Hilke Lentink, Aiko Voigt, Joaquim Pinto

e.g.:

- low-resolution CMIP data versus high-res idealized ICON simulations
- impact of diabatic processes on extreme cyclones in a warming climate
- systematic biases in extreme cyclone projections due to the representation of large- and small-scale processes in climate models

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