Wind jump in extra-tropical cyclones

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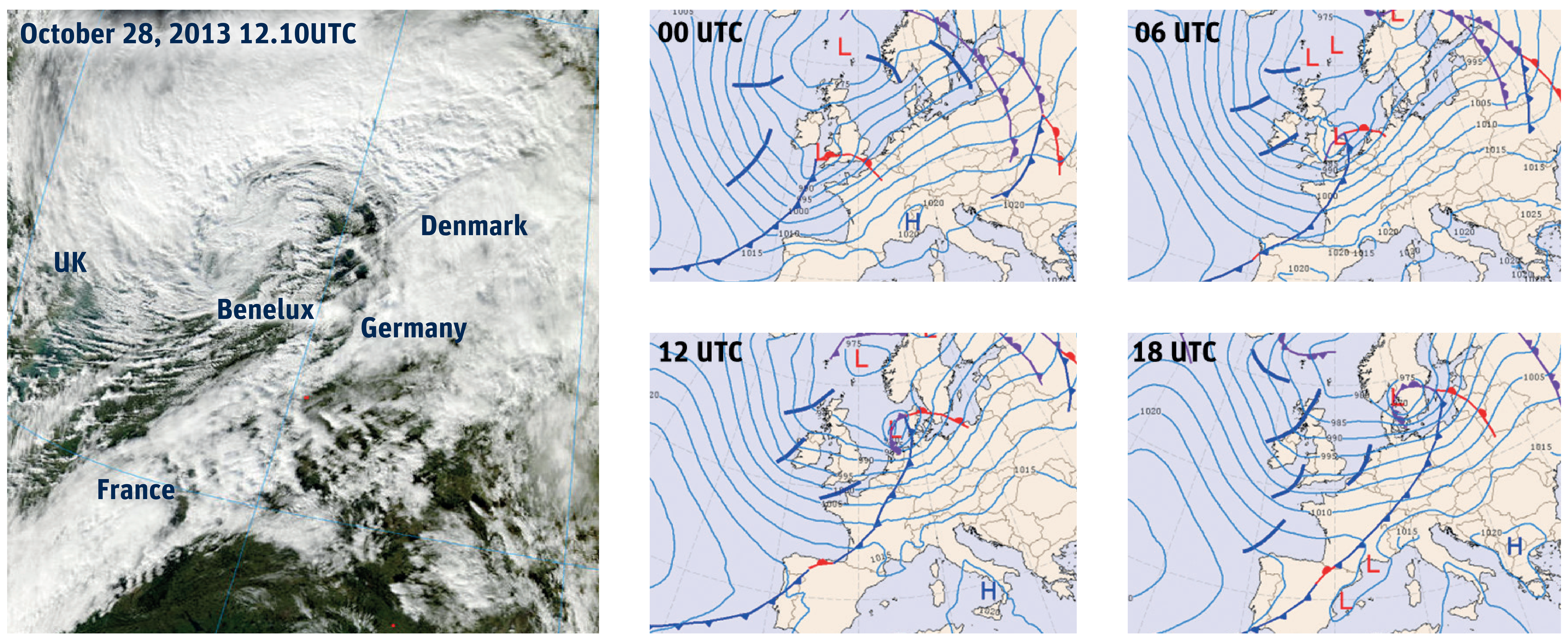
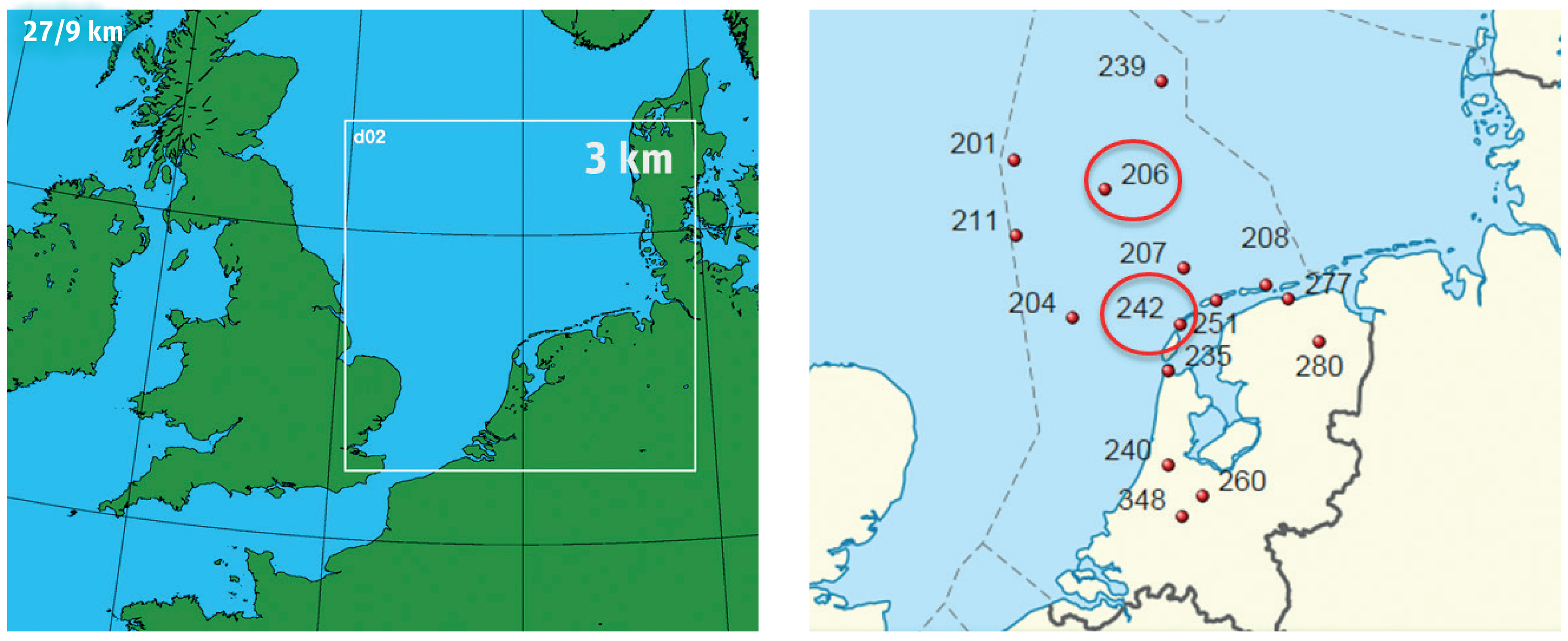
Fast moving extra-tropical cyclones frequently contain a small area in the wake of the cold front where severe non-convective winds (wind jump) occur. In this area, the pressure suddenly increases significantly from its minimum value. It is not clearly known which processes are responsible for the “wind jump” and information from literature is lacking. It is clear that these extreme winds are influenced by ageostrophic effects, but the question is which effect(s) is (are) responsible for the “wind jump”. Numerical weather prediction models have problems with resolving the “wind jump”, because of its small-scale character. The simulated severe winds (averaged over a short time range) can be underestimated up to 1 Beaufort, and as a consequence, forecasters usually add 1 Beaufort when issuing wind warnings. MeteoGroup has investigated whether WRF is able to resolve the “wind jump”, and to uncover the underlying physical processes. The simulation results confirmed that a horizontal resolution of ~10 km or finer, resolves the “wind jump”, but only when the storm is present in the model parent domain at initialization time. A detailed analysis revealed that the development of the wind jump can only be explained by a combination of ageostrophic winds.

Case study: St. Jude storm, October 28, 2013



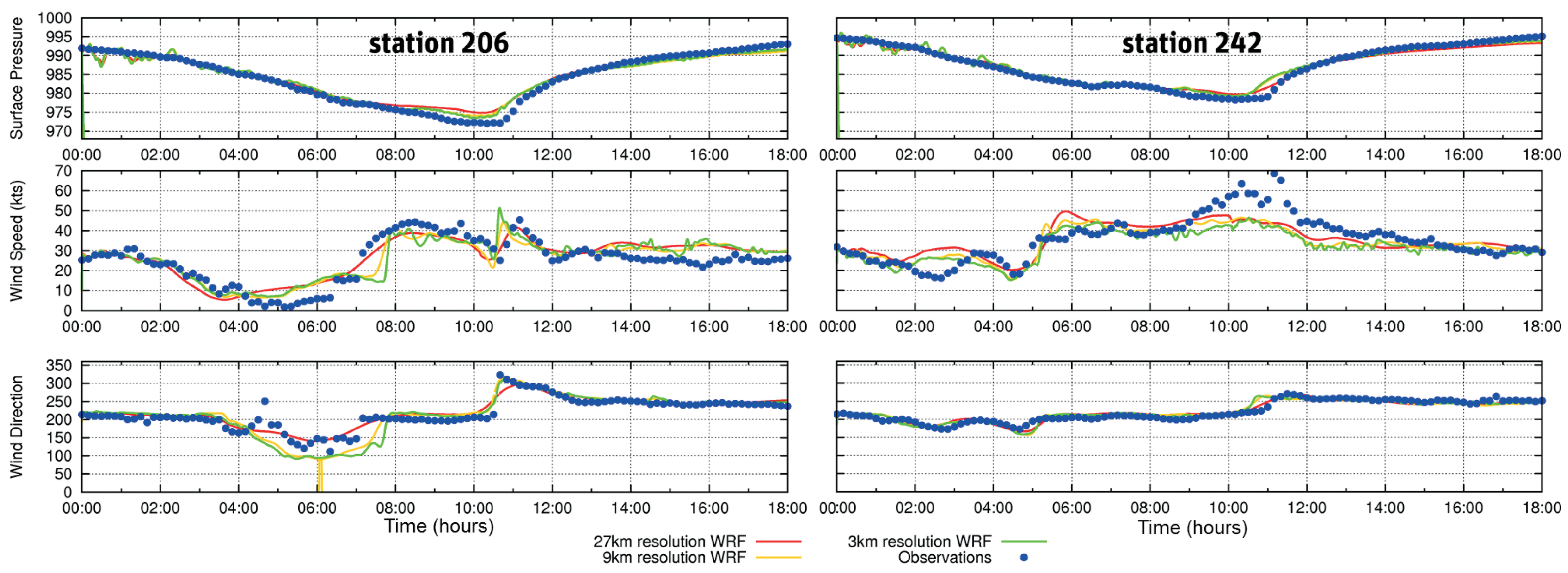
The St. Jude storm of 28 October 2013 over the North Sea induced extreme high wind speeds over a large area with hourly averaged winds of 10 Bft. On the Dutch island “Vlieland” a 10 minute average wind force of 12 Bft was observed. The Dutch national weather institute KNMI issued a weather alarm for this storm. Despite this warning, the storm caused three fatalities in the Netherlands, and more than 100 million dollars of damage.

Model setup and observations



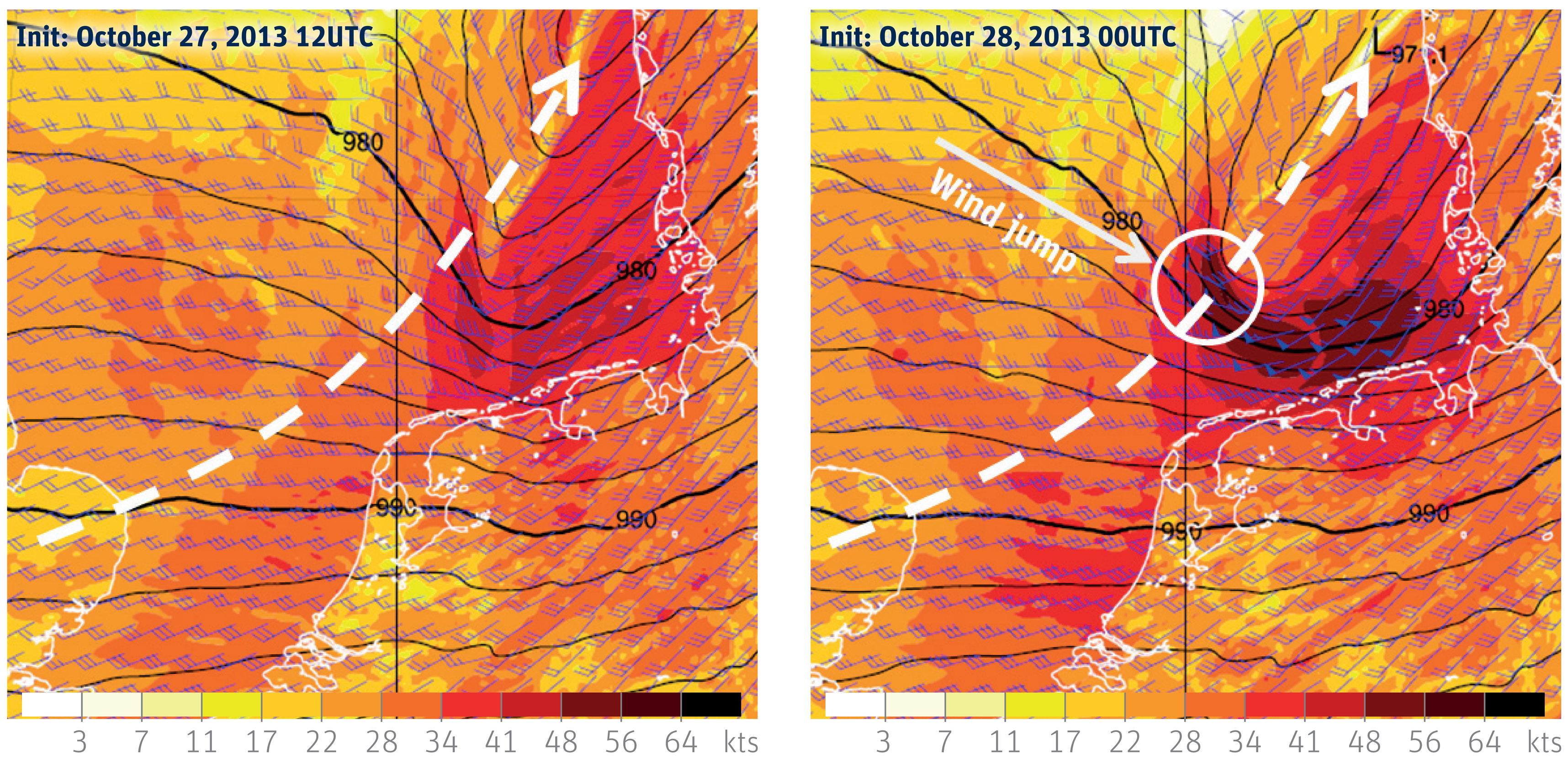
- Horizontal resolution: Run 1: 27 km (d01); Run2: 9 (d01) and 3 km (d02)
- Number of vertical levels: 39
- Forcing: ECMWF 0.25° (27 km run), ECMWF 0.125° (9/3 km run)
- Initialization: October 27, 2013 12 UTC / October 28, 2013 00 UTC
- Parameterization schemes: YSU PBL sch., Noah LSM, WSM6 mp, RRTM lw sch., Goddard sw sch. and Grell-Devenyi cumulus sch. (27/9km only)

Comparison observations - simulations, October 28, 0 - 18 UTC



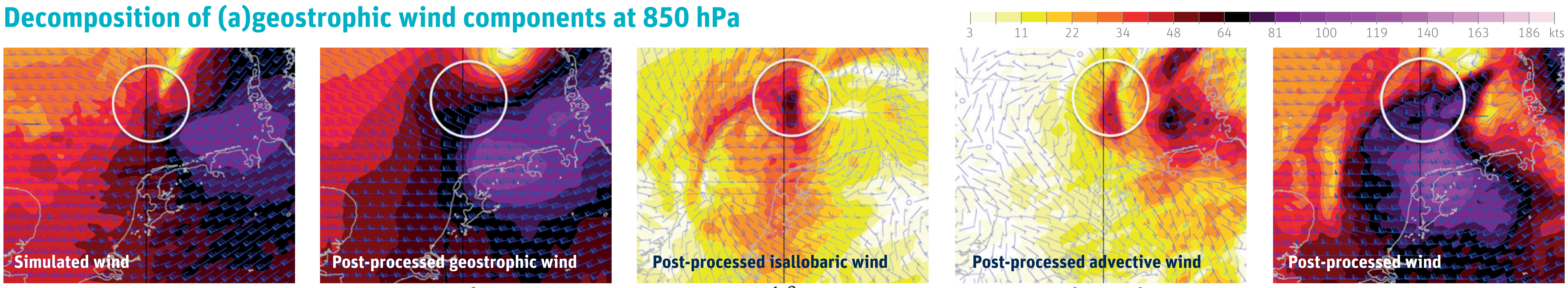
- Wind jump resolved at horizontal resolutions < ~10 km
- Offshore location 206: Wind jump resolved in simulations with a slight difference in timing
- Onshore location 242: Wind jump not resolved in simulations due to a simulated storm path shifted slightly to the north

Effect of initialization time at surface, October 28, 12 UTC



Wind jump is better resolved when the storm is within the parent domain at initialization time.

Decomposition of (a)geostrophic wind components at 850 hPa



October 28, 2013 12 UTC

The wind jump is a result of a combination of ageostrophic wind components.

$$-\frac{g}{f}\frac{\partial z}{\partial y} \quad -\frac{1}{f}\frac{\partial v}{\partial t} \quad -\frac{u}{f}\frac{\partial v}{\partial x}-\frac{v}{f}\frac{\partial v}{\partial y} \quad = \quad u$$

$$\frac{g}{f}\frac{\partial z}{\partial x} \quad +\frac{1}{f}\frac{\partial v}{\partial t} \quad +\frac{u}{f}\frac{\partial u}{\partial x}+\frac{v}{f}\frac{\partial u}{\partial y} \quad = \quad v$$

Conclusion

The wind jump occurs in a small area, and this study has proven that numerical weather prediction models need a horizontal resolution of < 10 km to capture this extreme wind event. It is also essential to note that the storm itself has to be present in the model domain at initialization time. This study also showed that the wind jump can for a large part be explained by the most important ageostrophic wind components, being the isallobaric wind and the advective wind. A second case study of the Xaver storm (December 5, 2013; not shown) confirmed these conclusions.

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