Short-term variability in the atmosphere seen by recent regional hindcasts

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Motivation

Within the project openFRED a long-term feed-in time series shall be created based on a Renewable Energy Database. openFRED provides input data for so-called energy system models, i.e. models which simulate the current flow within the power grid considering different types of power plants, substations, … (Fig. 1). The scientific use of long-term energy system simulations is to determine a strategy for optimal grid and storage expansion (other projects).

Energy system models require weather data from which the feed-in of wind energy, solar energy and hydro-power is determined. The demands are so manifold that we decide a) to use regional hindcasts to extract the data needed for openFRED, and b) to perform own simulations to fulfill needs on input parameters.

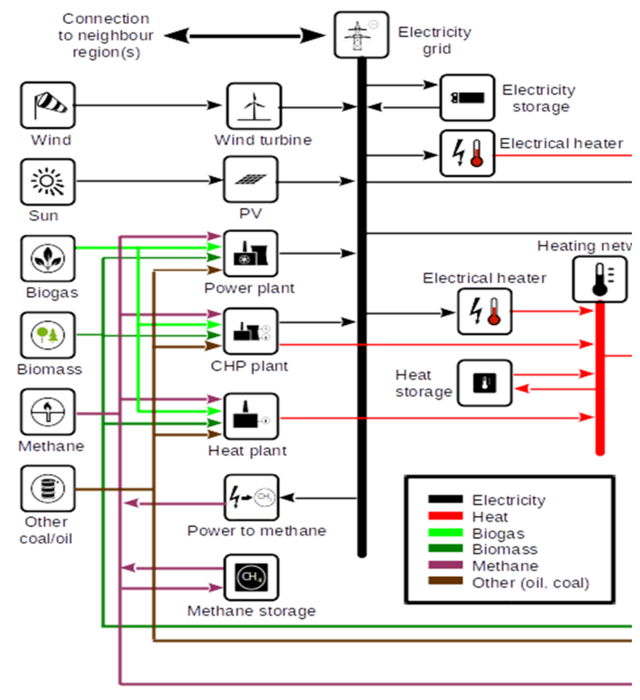


Figure 1: The energy system model oemof (community open-source model). @RLI, simplifed

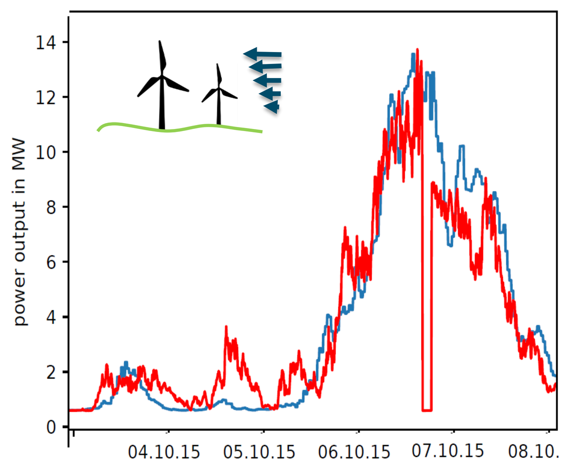


Figure 2: Application of openFRED data, Simulated (blue) and observed feed-in (red) at Nordstrand (Schleswig-Holstein)

Scientific scope

The planetary boundary layer is the most crucial part to investigate for the renewables, but also for learning about model deficits. We focus mainly on evaluation of

- levels located above surface,
- quantities not suitable for assimilation.

The questions that should be answered are

1. What is the impact of assimilation and nudging techniques on model's performance,
2. to what extend forced runs outperform runs without forcing in the interior domain? Are there systematic errors in both?

The short-term variability is of particular interest for the feed-in (Fig.2). Thus, correlation performance is examined.

Zoo of regional hindcasts

Regional reanalyses (Table 1) were established within the UERRA project (SMHI, Météo France, DWD) using an ensemble approach with at maximum 0.11° resolution. The University of Bonn provides the **COSMO-REA 6** reanalysis with 0.06° (Bollmeyer, 2015). At the HZG a COSMO-CLM run with spectral nudging (**oF-Merra-SN**) and without spectral nudging (**oF-Merra-NoSN**) is performed. In addition, data from coastDatII and III are available.

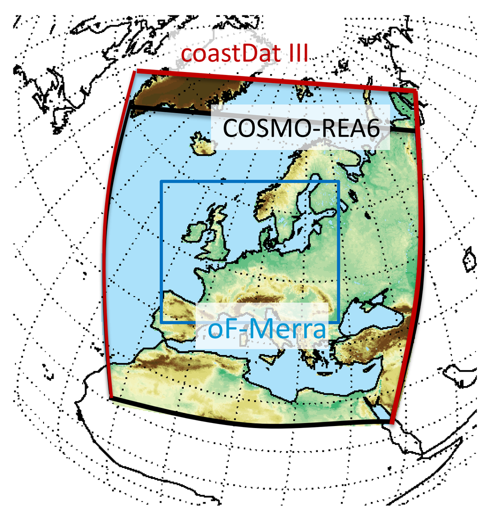


Figure 3: Model domains.

oF-Merra	COSMO-REA6	UERRA-SMHI	UERRA-UKMO
Helmholtz-Zentrum G.	Deutscher Wetter-dienst / Uni. Bonn	SMHI	UKMet-Office
Large-Scale constraint / no nudging	Continuous nudging / OI	OI / 3D-VAR	4D-VAR
DOF: ++ and +++	DOF: +	DOF: + - ++	+ - ++
MERRA2 / ERA inter	ERA inter	ERA inter	-
0.06°	0.06°	0.11°	0.11°

Table 1: Regional hindcasts / reanalyses considered for the project openFRED. First row indicates data provider, the second the assimilation / nudging technique, third the degrees of freedom, the fourth the forcing and the fifth the horizontal resolution.

Impact of interior forcing on coastal wind

October 2013 is analyzed where Low Chistian was crossing the North Sea coast. Parts of the high-level winds were transfered in strong downdraft near to surface (radio sounding Emden: 160 km/h at 500 m AG). The COSMO-REA6 and the oF-Merra-SN run perform nearly similar whereas the unforced run is far north and development starts later. The coastal winds are BIAS-corrected with the COSMO-REA6, but this can be achieved also by a higher vertical resolution (Figure 5).

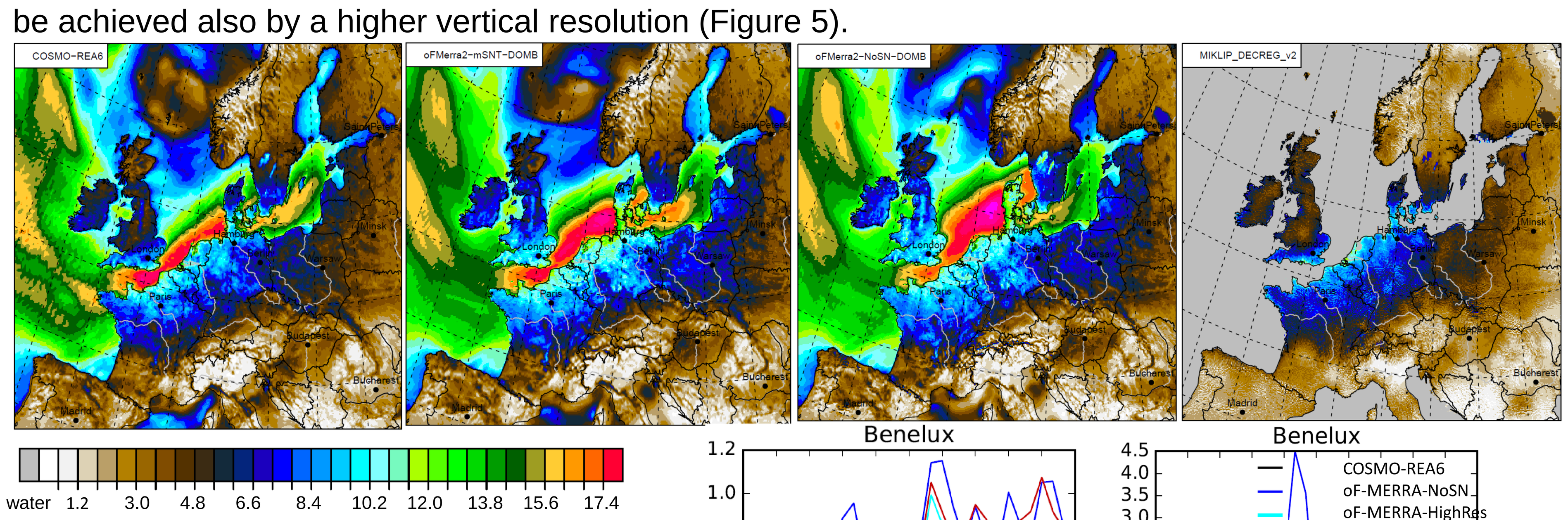


Figure 4 (above): Daily near surface wind at the 28th of October 2013 [m/s]: COSMO-REA6, oF-Merra2-SN, oF-Merra2-NoSN MIKLIP-DECREG v2.

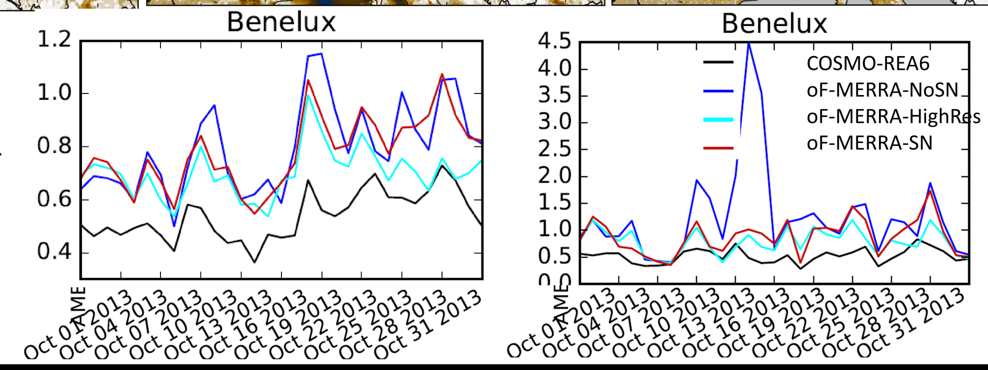


Figure 5 (right): daily BIAS and AME for Benelux states

Investigation of the PBL

Reference data

Long-term reference data of high-quality are very rare (Figure 4). We plan to use them to investigate the stratification, the wind and the humidity profiles in the atmosphere. All data were converted to netcdf format with predefined metadata structure. For many of them a mast correction has to be considered for the wind speed measurements.

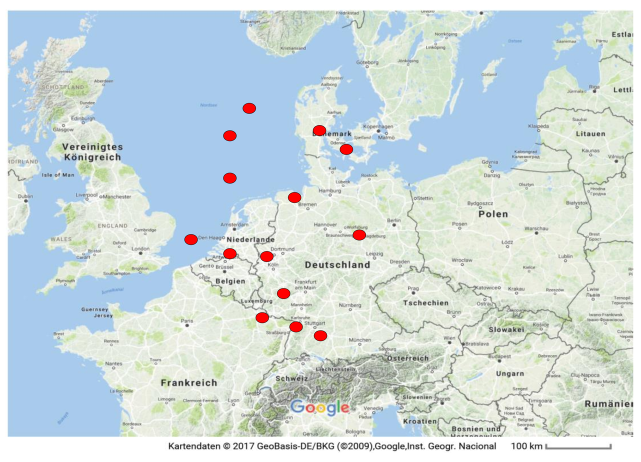


Figure 6: Measurement towers providing realiable data over more than 10 years (@googlemaps)

PBL at Hamburg

Measurement data are taken since 15 years and at different heights from 50 m up to 280 m. The daily cycle can only be captured by continuous nudging or non-forced runs, whereas the highest correlation is achieved with 4D-Var. The temperature gradients separate the various PBL schemes.

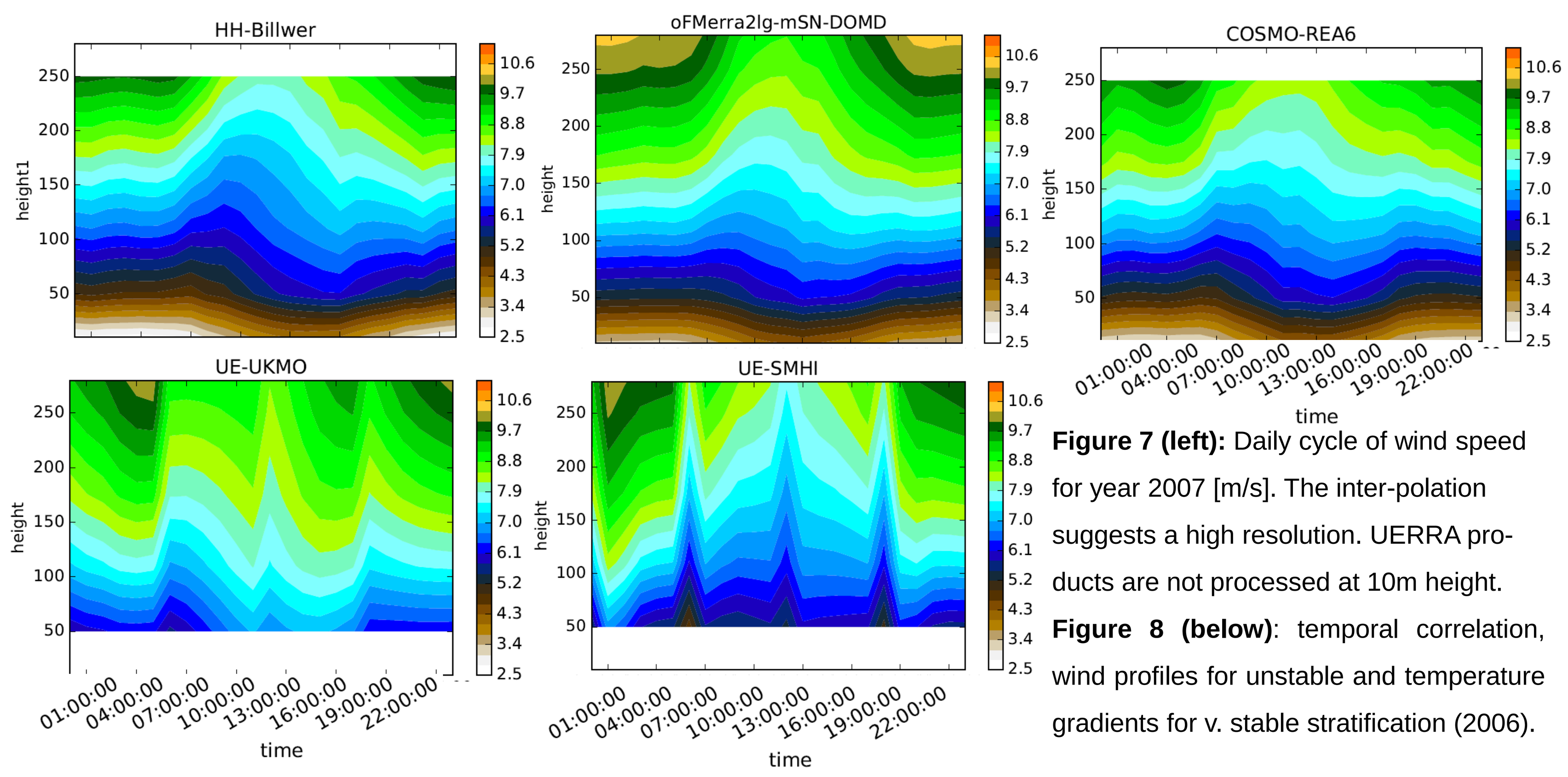
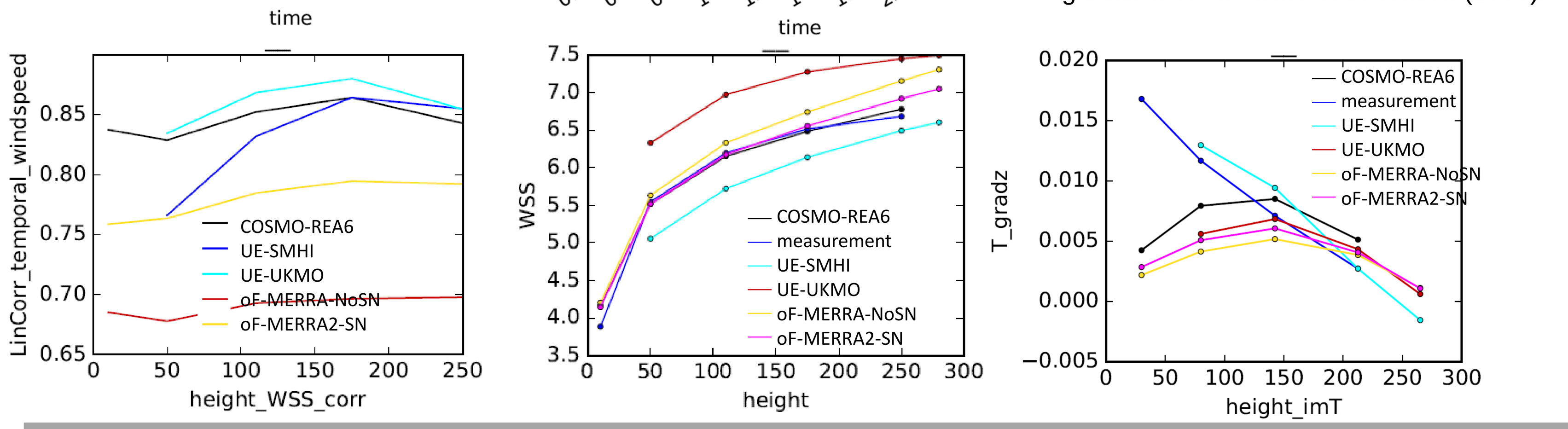


Figure 7 (left): Daily cycle of wind speed for year 2007 [m/s]. The inter-polation suggests a high resolution. UERRA products are not processed at 10m height.

Figure 8 (below): temporal correlation, wind profiles for unstable and temperature gradients for v. stable stratification (2006).



PBL over land (Falkenberg)

The boundary layer at Falkenberg differs in wind climate. The speed-down during morning and evening is not well captured by models. T- and WSS-profiles consistent for SMHI and stable stratification.

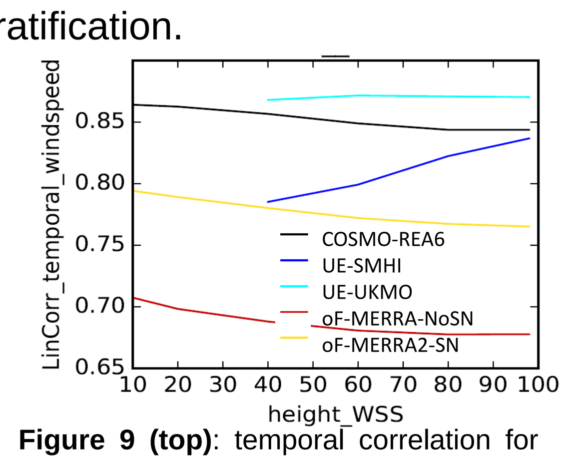


Figure 9 (top): temporal correlation for year 2006

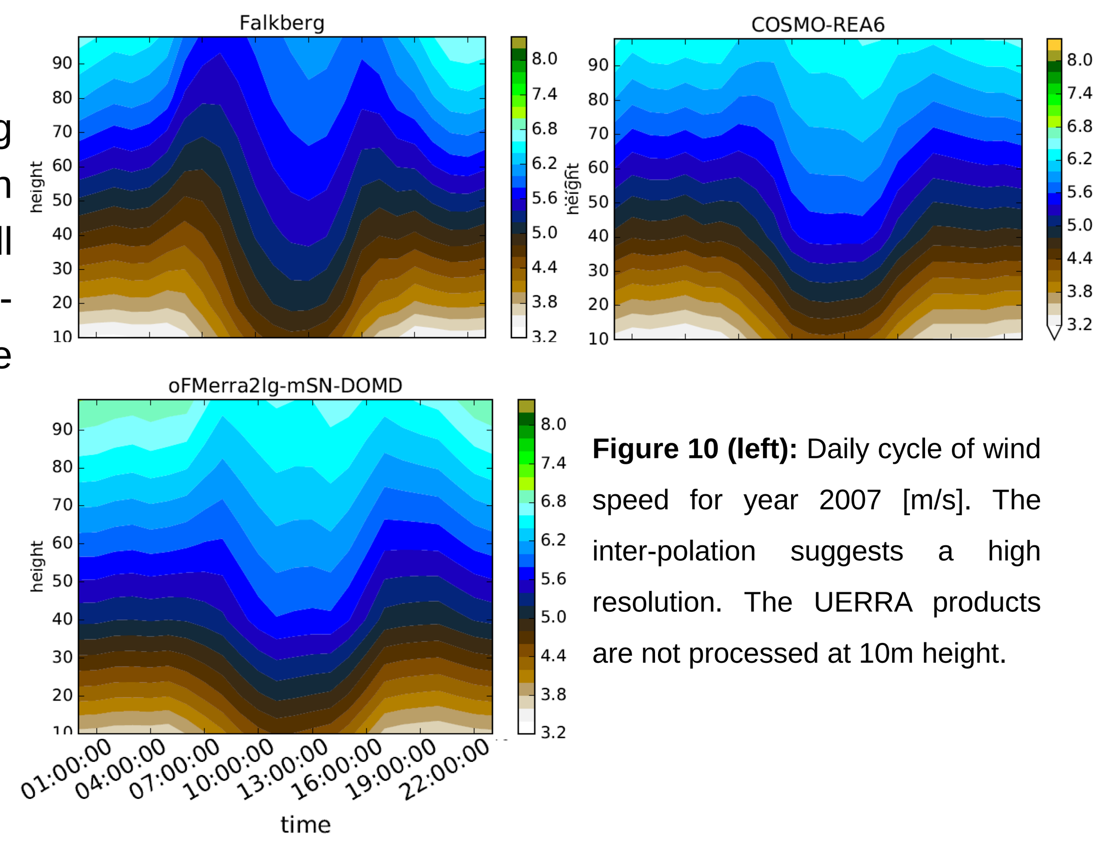


Figure 10 (left): Daily cycle of wind speed for year 2007 [m/s]. The inter-polation suggests a high resolution. The UERRA products are not processed at 10m height.

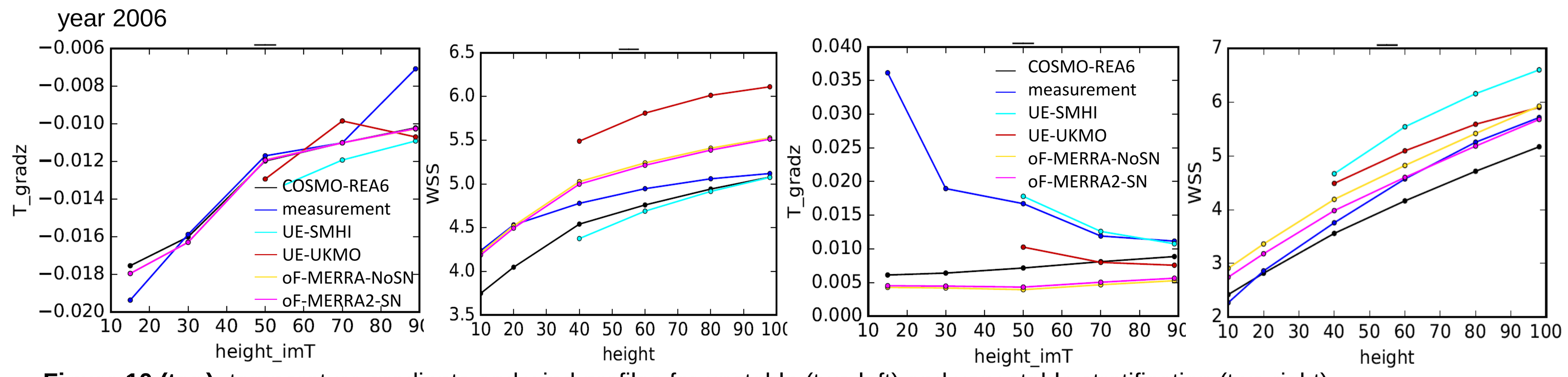


Figure 10 (top): temperature gradients and wind profiles for unstable (two left) and very stable stratification (two right).

Conclusions

- near surface COSMO-REA6 outperforms the others due to exessesive nudging of observations
- near surface: systematic errors detectable using spectral nudging, i.e. overestimation of wind speeds at coast → prevent the problem with higher vertical resolution
- PBL: 4D-Var delivers best temporal correlation to measurements that is not height-dependent, but daily cycle is depicted best with contineous or no nudging (COSMO-REA6, oF-MERRA)
- PBL: runs with COSMO-CLM share the same errors (temperature gradients, daily cycle in wind speed and temperature error); all nudged-runs share nearly the same AME in wind speed (minor advantage for contineous nudging, clear disadvantage for non-nudged run)
- PBL: temperature gradients seperate different PBL schemes with SMHI performing best for very stable stratifications

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