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Hans-Ertel-Zentrum für Wetterforschung
Deutscher Wetterdienst

DWD

Initial conditions for convection-permitting ensemble forecasting with the COSMO-DE model

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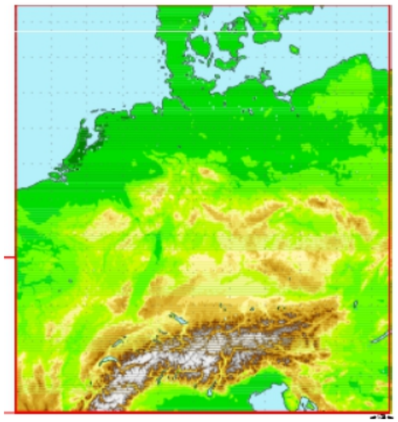
Why ensemble forecasting?

- **convection-permitting limited area model (LAM) forecasts:**
  → improve forecast of severe convective events (rain, wind, …)
- **predictability of convection has short timescales (~ few hours)**
  → probabilistic forecasts rather than deterministic

COSMO-DE-EPS Δx = 2.8 km

~ 1250 x 1150 km

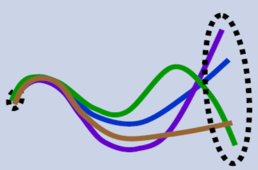
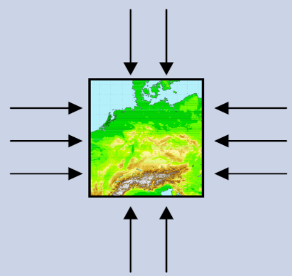
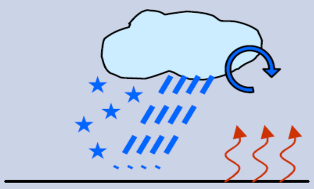


- No parametrization of deep convection
- 20 ensemble member
- 21 hours forecast length, initalized every 3 hours
- Operational since May 2012

→ Good results for precipitation forecasts
(e.g. Gebhardt et al. 2011, Peralta et al. 2012, Kühnlein et al. 2013)

Setup of a LAM ensemble prediction system (EPS)

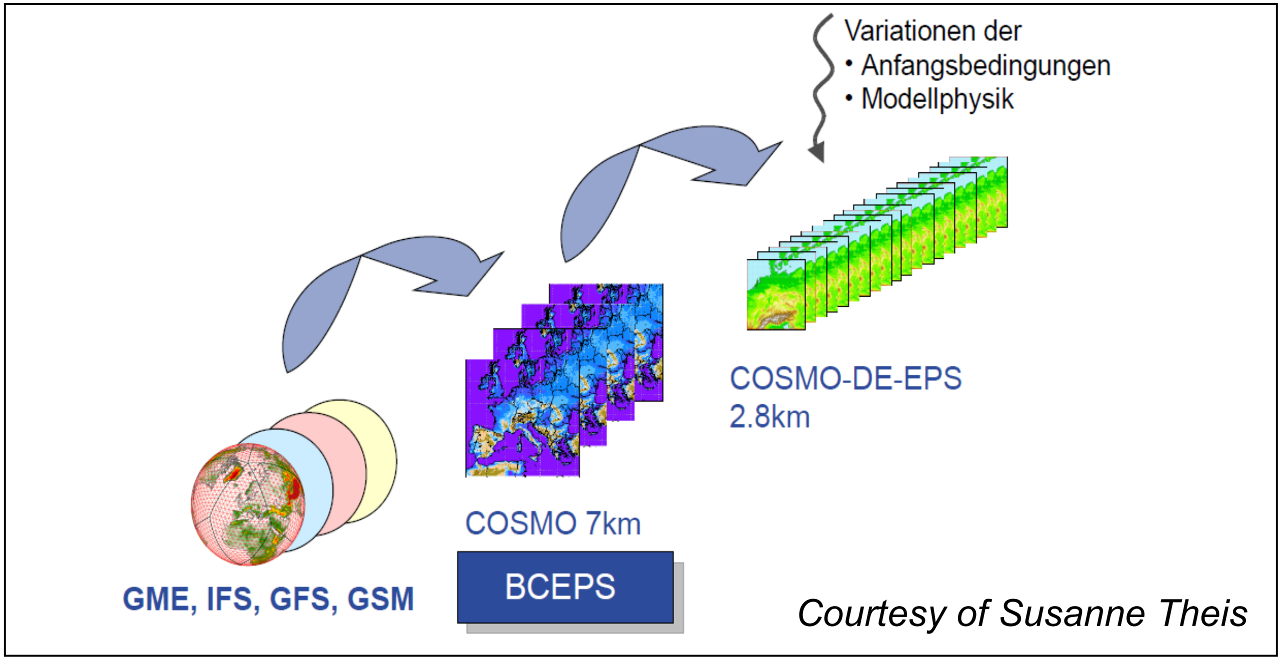
Three different sources of uncertainty in convection-permitting LAM-EPS:

initial conditions (ICs)	lateral boundary conditions (LBCs)	model formulation
		

Graphic courtesy Christoph Gebhardt

→How create an analysis ensemble on convection-permitting scale?

Setup of operational COSMO-DE-EPS



4 x 5 = 20 ensemble members

(1) ensemble of 4 LBCs (multi-model)

(2) ensemble of 4 ICs (multi-model)

(BCEPS perturbations + deterministic COSMO-DE nudging analysis; vertical filter)

(3) 5 perturbations of model physics parametrization

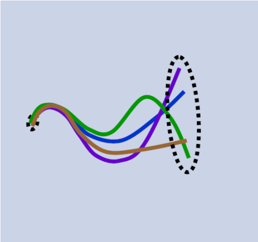
Ensemble data assimilation for COSMO-DE-EPS

- **So far: no data assimilation component in COSMO-DE-EPS**

KENDA: Kilometer-Scale Ensemble Data Assimilation
→ Lokal Ensemble Transform Kalman Filter (**LETKF**) *(Hunt el al. 2007)*

- **Experimental setup for data assimilation of conventional observations**
- **LETKF yields an analysis ensemble (+ optional deterministic analysis)**
  → Provides initial conditions for COSMO-DE-EPS forecasts
  → Improved representation of IC uncertainty in COSMO-DE-EPS

→ What effect do different initial conditions have on ensemble forecasts?



Overview of experiments

Period of interest: 12 UTC 10 June – 00 UTC 12 June 2012

KENDA: - 3-hourly LETKF data assimilation of conventional data (TEMP, AIREP, PILOT and SYNOP)

- **3-hourly analysis ensemble with 20 ensemble members**
- **20 member ECMWF EPS boundary conditions (Δx =16 km)**
- **No physics parametrization perturbations (PPP)**
- **21 h forecasts at 00 UTC 11 / 12 June 2012**

OPER: - COSMO-DE-EPS (boundary conditions: BCEPS)

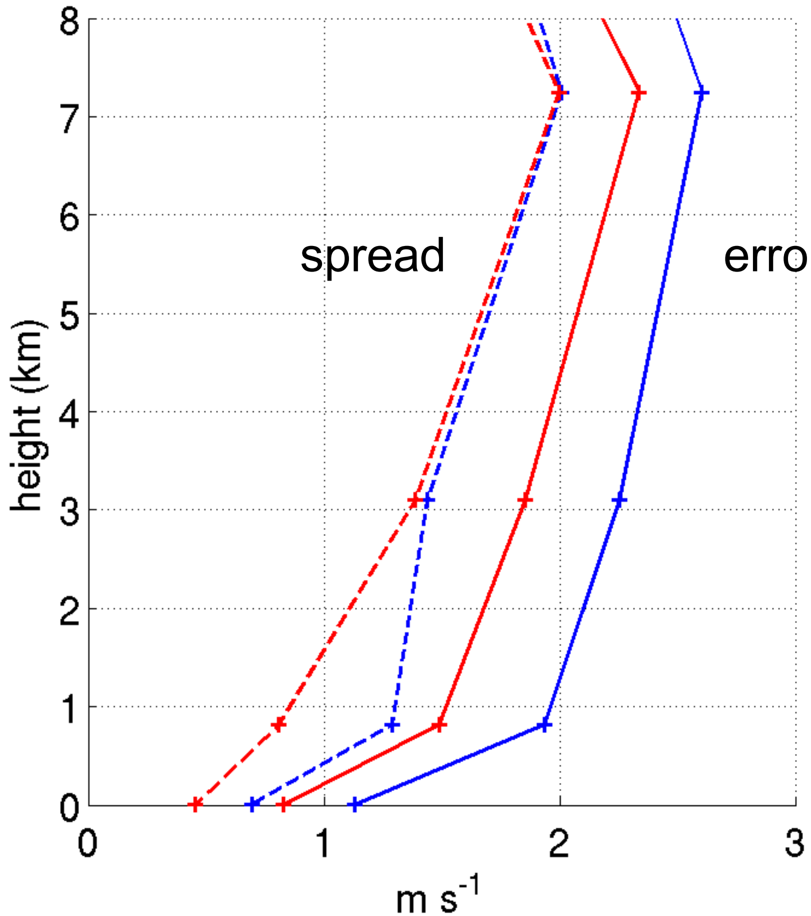
- **ICPs from downscaled BCEPS + nudging analysis, vertical filter**
- **5 model physics parametrization perturbations**

Ensemble mean error and ensemble spread

- **Average over 11 cycles**
- **Verification against COSMO-DE analysis**
- **OPER has smaller error:**
  → choice of verification

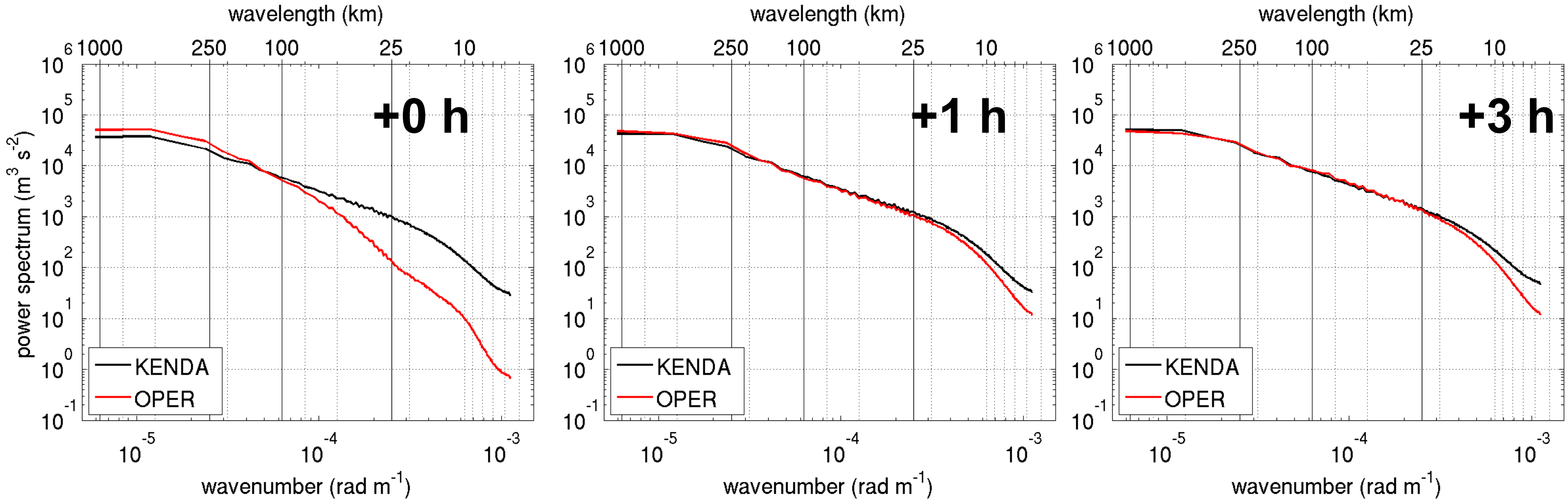
  → initial ensemble constructed around COSMO-DE analysis
- **Both experiments are under dispersive (spread < error)**

+3 h forecast of U-Wind: KENDA OPER



Power spectrum of ensemble perturbations

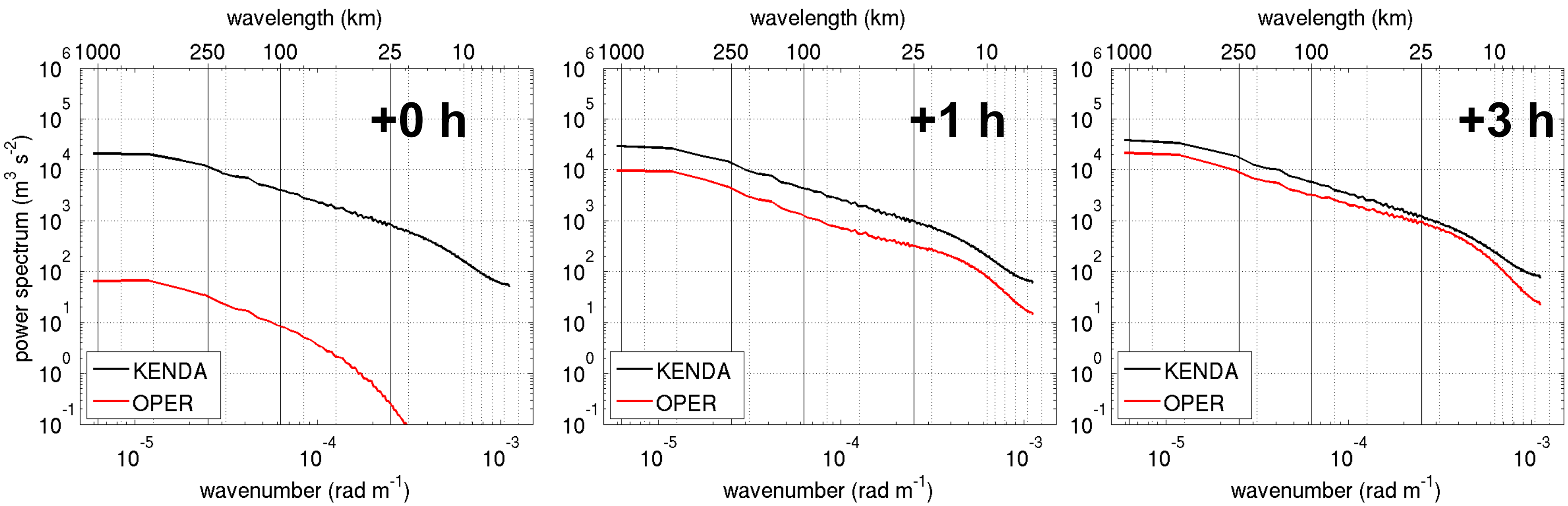
Horizontal wind, model level 30 (~3.1 km)



- **Variance at small scales (<100 km) is reduced OPER**
- **Most of the missing variance at small scales developes within 1 hour**

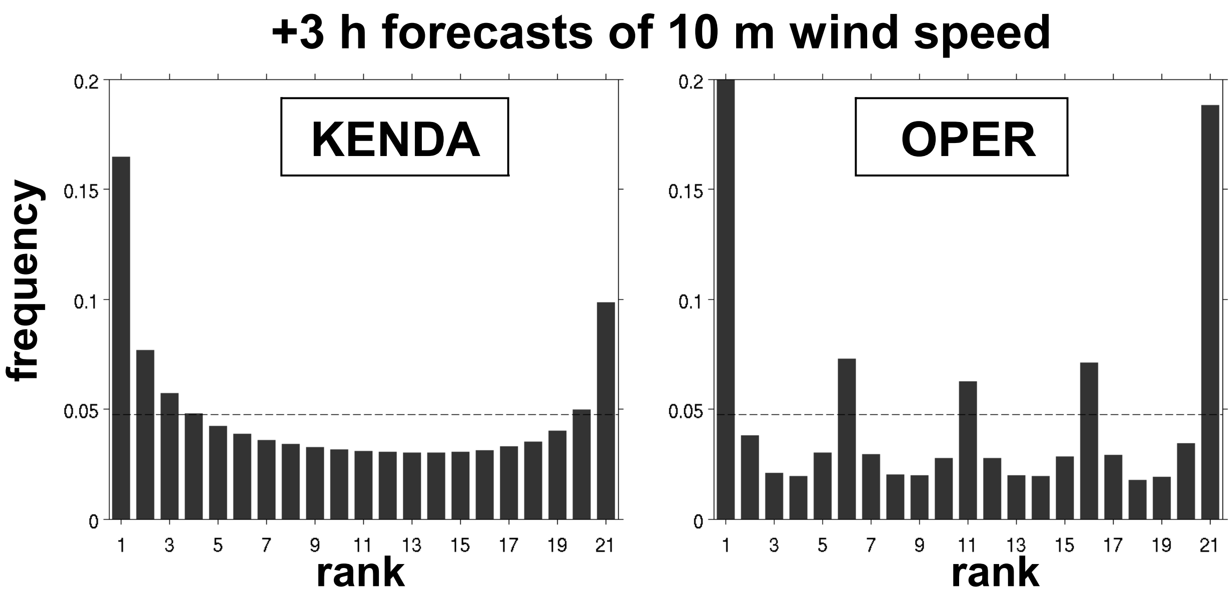
Power spectrum of ensemble perturbations

Horizontal wind, model level 40 (~0.8 km)



- **Variance at small scales (<100 km) is reduced OPER**
- **Most of the missing variance at small scales developes within 1 hour**
- **Vertical filter: dampening at lowest levels exists for more than 3 hours**

Ensemble rank histogram

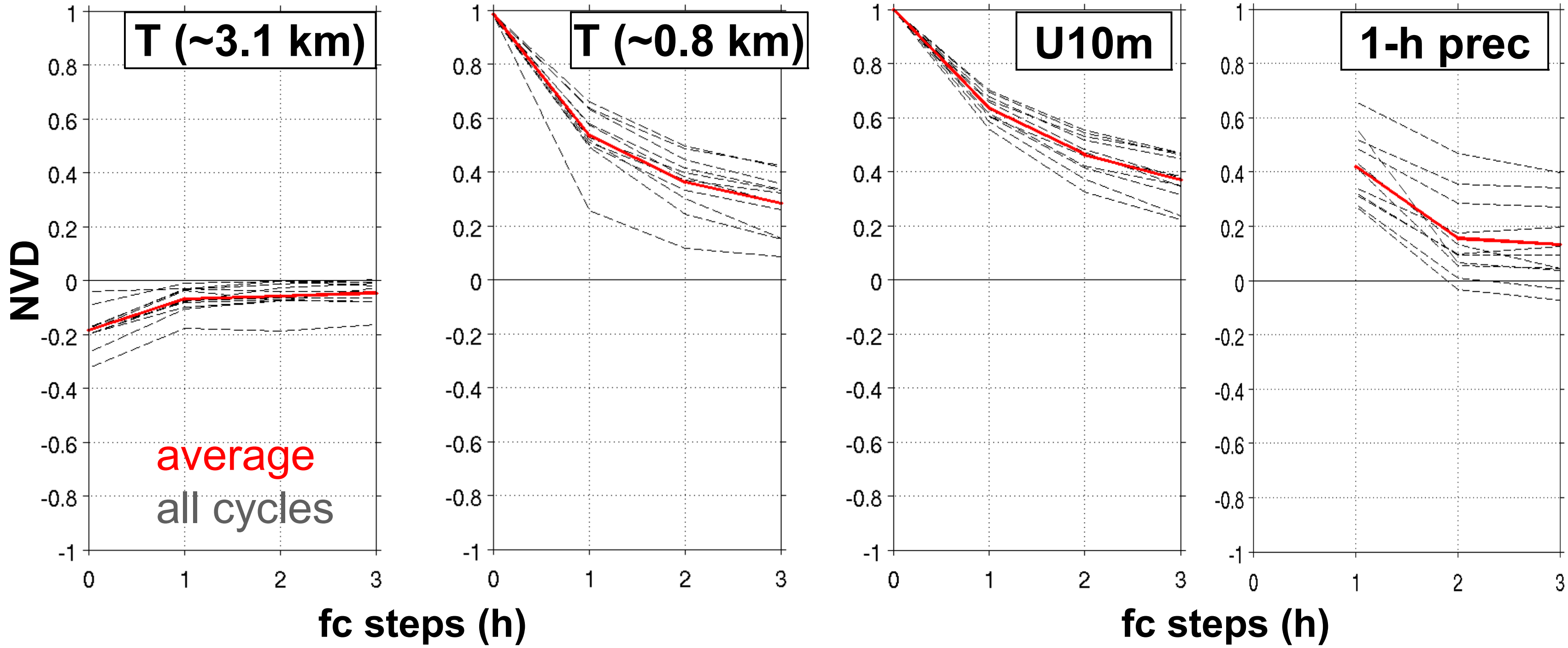


- Verification against COSMO-DE analysis
- All ensemble forecasts are under dispersive
  → analysis / observation lies outside the ensemble
- Signal of 4 global models dominate in OPER

Ensemble dispersion

- **Normalized variance difference (NVD):** $\dfrac{\text{var(eps 1) - var(eps 2)}}{\text{var(eps1) + var(eps 2)}}$

KENDA vs OPER

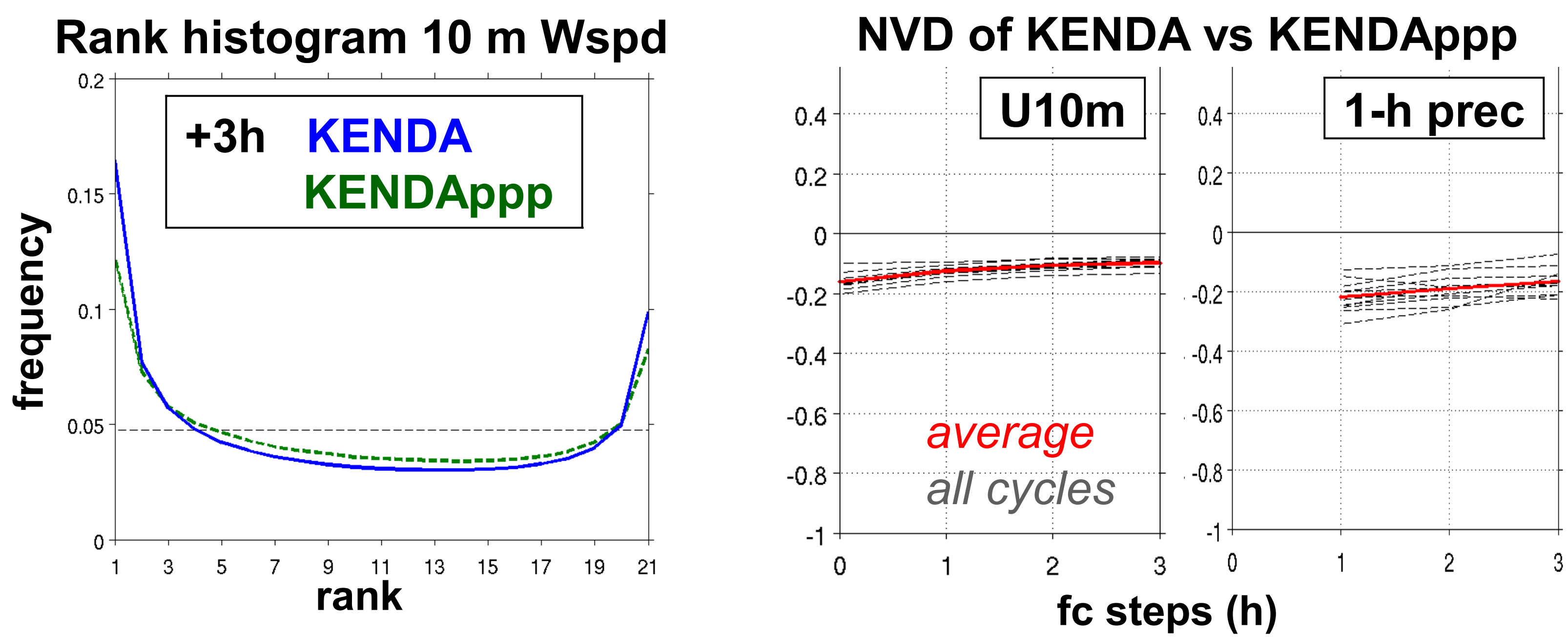


Additional KENDA experiment

- **Investigate the effect of model formulation uncertainty:**

  KENDAppp: same as KENDA, but

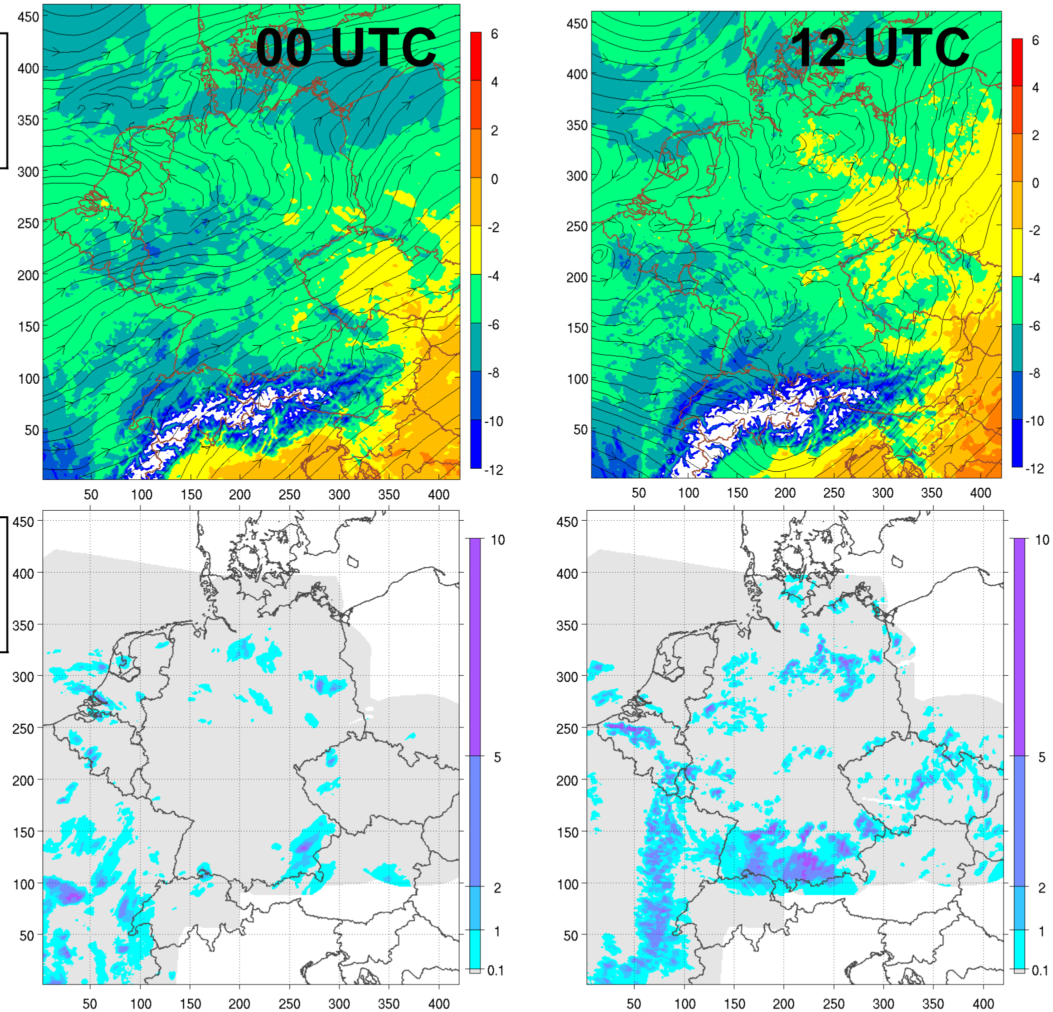
  → including 10 physics parametrization perturbations



Case study of 12 June 2012: synoptic situation

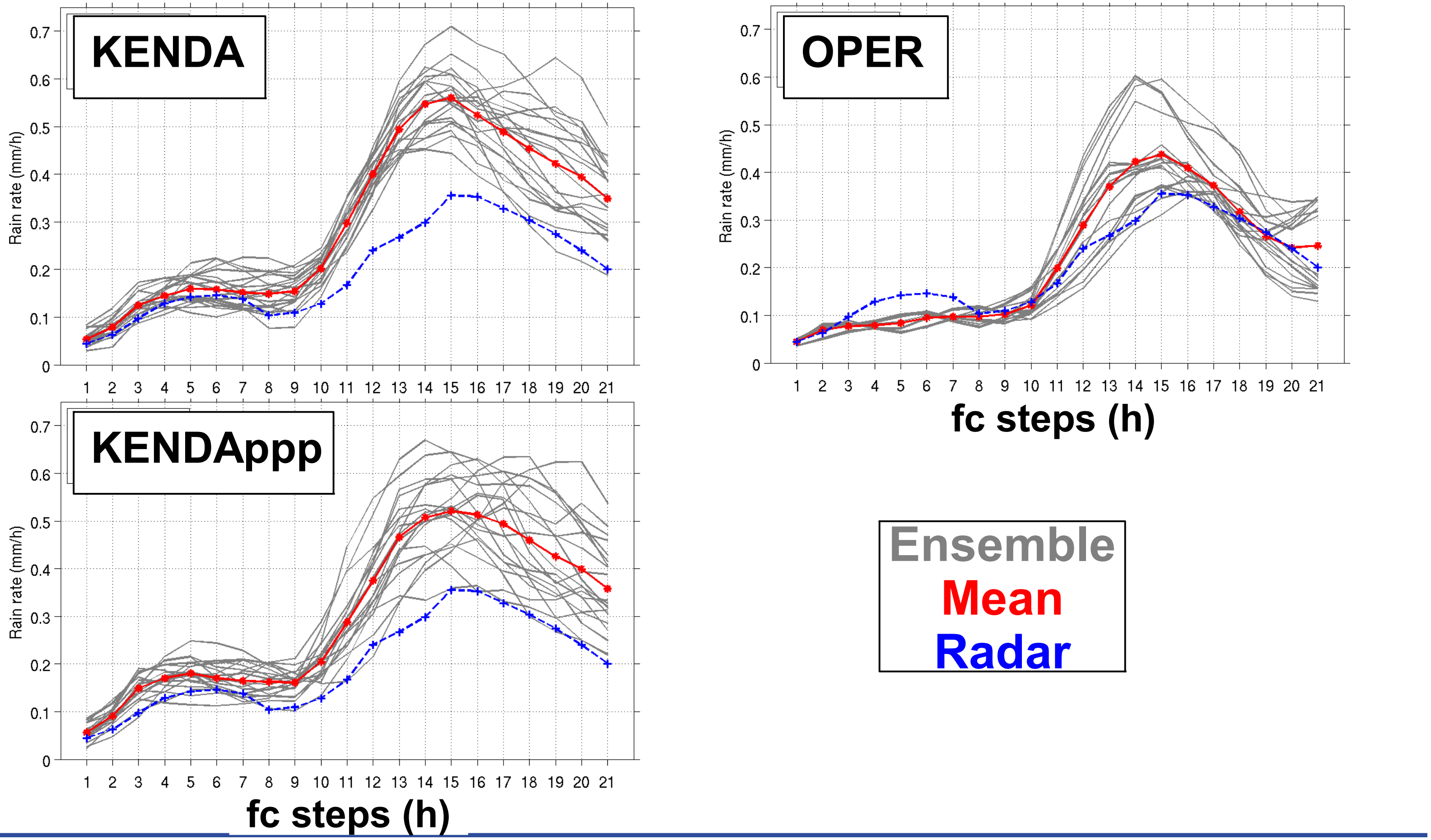
COSMO-DE analysis: T (K), wind at ~3.1 km

Radar derived precipitation (mm/h)



Ensemble forecasts of precipitation

Forecast of precipitation rate averaged over Germany, 00 UTC 12 June 2012



Summary & Outlook

- **Current ICPs in COSMO-DE-EPS based on downscaled perturbations**
- **KENDA: km-scale ensemble data assimilation by means of an LETKF for the COSMO model (experimental system)**
- **KENDA provides consistent ICs for ensemble forecasts**

  → ICPs are present at all scales / all levels from the beginning

  → Represent the approximated probability density function (PDF) around the high-resolution deterministic / ensemble mean analysis

(1) Increase KENDA analysis ensemble spread

→ Modify the raw analysis ensemble

(2) Improve representation of model uncertainty

→ Include stochastic boundary layer perturbations