
Representation of Model Uncertainties in COSMO-DE-EPS

Susanne Theis

Deutscher Wetterdienst (DWD)



Overview



Overview



Hans Ertel Centre
for Weather Research

Development
at DWD

**Operational
at DWD**

**Stochastic scheme
targeted at tendencies**

**Parameter
perturbations**

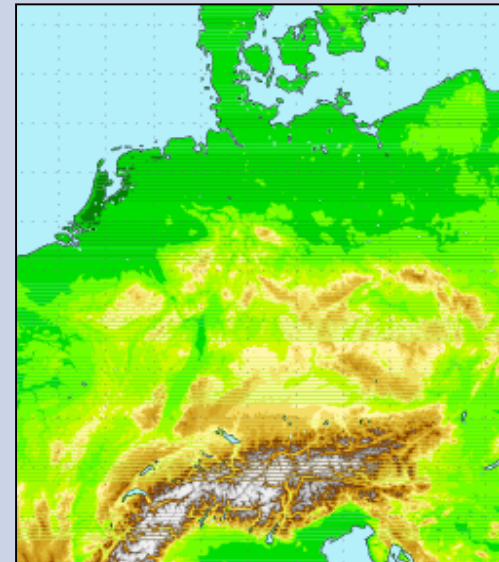
E. Machulskaya
R. Keane

M. Buchhold
R. Kohlhepp
A. Röpnack
C. Gebhardt
S. Theis

Operational at DWD

COSMO-DE-EPS

- 20 members based on COSMO-DE
- grid size: 2.8 km / 50 vertical layers
convection-permitting
- forecast range: 0 - 27/45 hours,
8 model runs per day (00, 03, 06, ... UTC)
- EPS operational since
May 2012

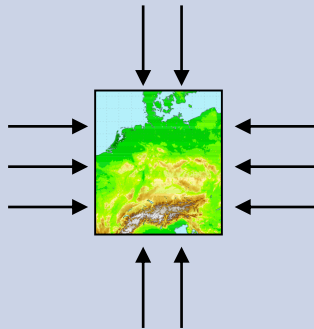


model domain:

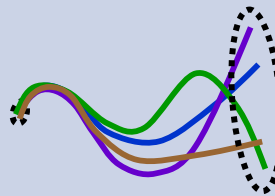
Germany and neighbours

Perturbation Methods

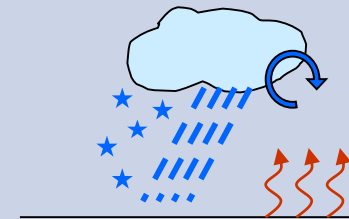
Lateral Boundaries



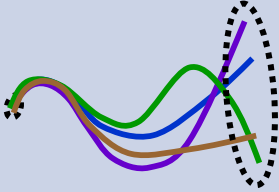

Initial Conditions




Model Physics



Perturbation Methods

Lateral Boundaries	Initial Conditions	Model Physics
<p data-bbox="131 701 454 743">“multi-model”</p> <p data-bbox="131 786 517 886">driven by different global models</p> <p data-bbox="131 1205 469 1243"><i>(future: ICON-EPS)</i></p>		

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Parameter Perturbations



Parameter Perturbations in COSMO-DE-EPS

- alternative values for selected parameters
- based on expert knowledge



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- space and time:
 - constant during lead time (27h / 45h)
 - constant within domain (~1300 x 1200 km²)



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- alternative values for selected parameters
- based on expert knowledge

- space and time:
 - constant during lead time (27h / 45h)
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- “similar” forecast bias in every member



Parameter Perturbations in COSMO-DE-EPS

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entr_sc	0.0003 m ⁻¹	0.002 m ⁻¹	precipitation
q_crit	1.6	4.0	precipitation
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↓ since 2012



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since 2012

added 2014

now in test phase



Criteria for the Selection



Criteria for the Selection of Perturbations

1. Ensemble Spread / Sensitivity

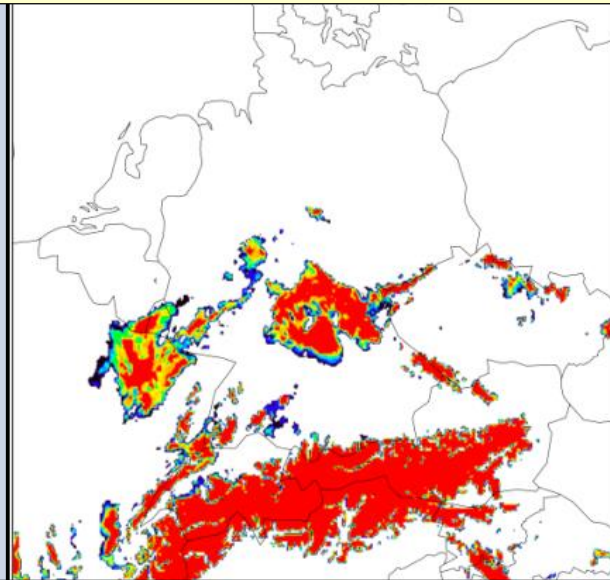


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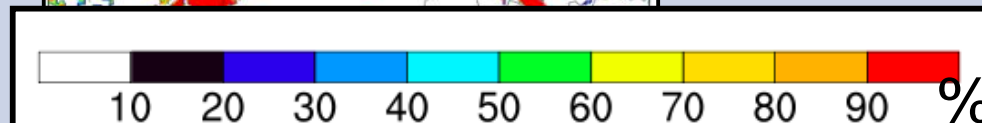
1. Ensemble Spread / Sensitivity

*Oct 21, 2011
00 UTC + 12h
daytime*

Probability of $T_{2m} < 278 \text{ K}$



*source:
A. Röpnack (DWD)*

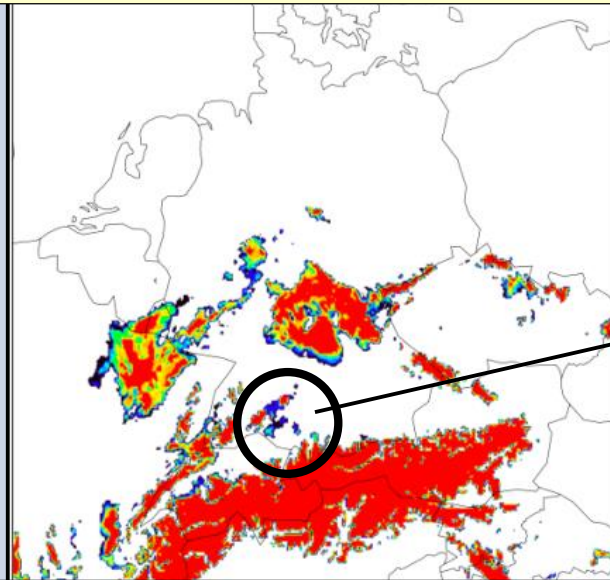


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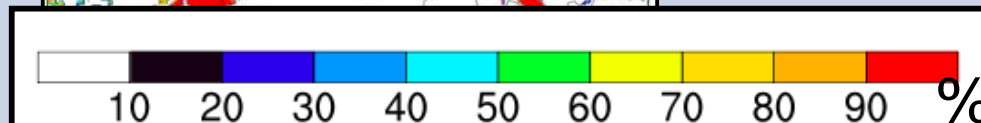
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clouds missed
by forecast

zero probability
of cold temperatures

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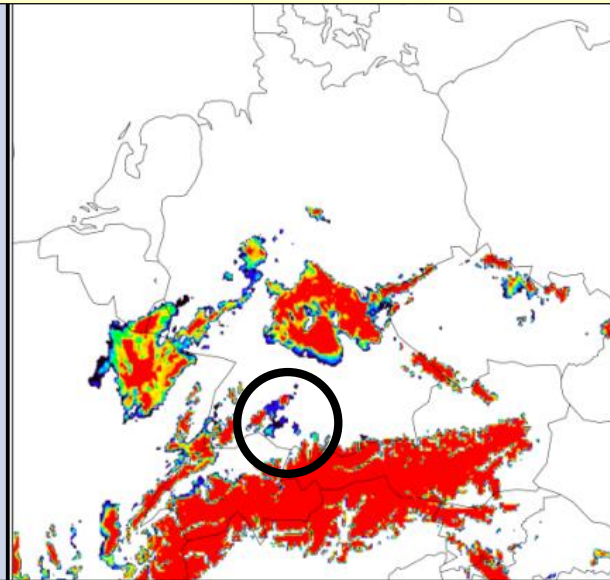


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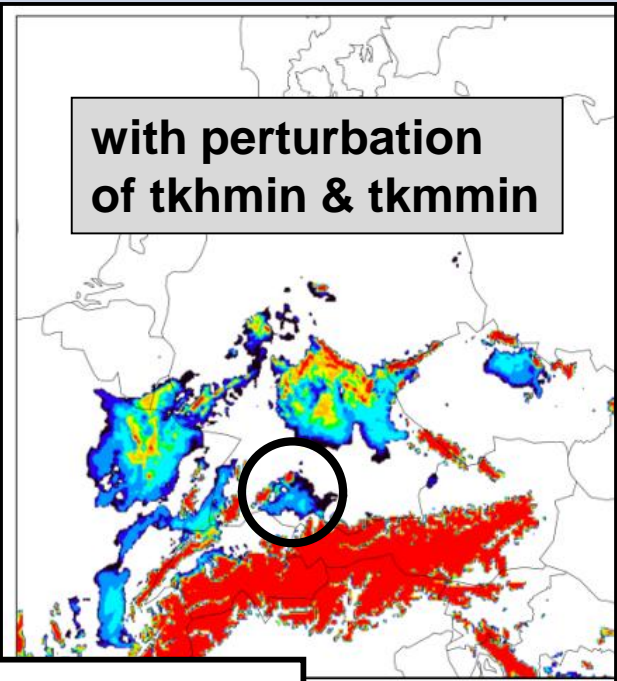
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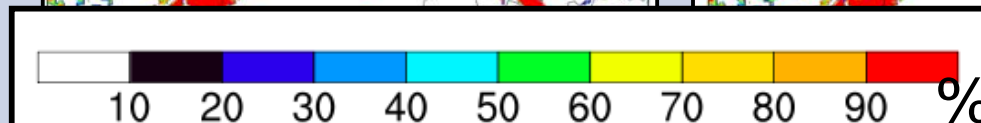
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with perturbation
of t_{khmin} & t_{kmmin}



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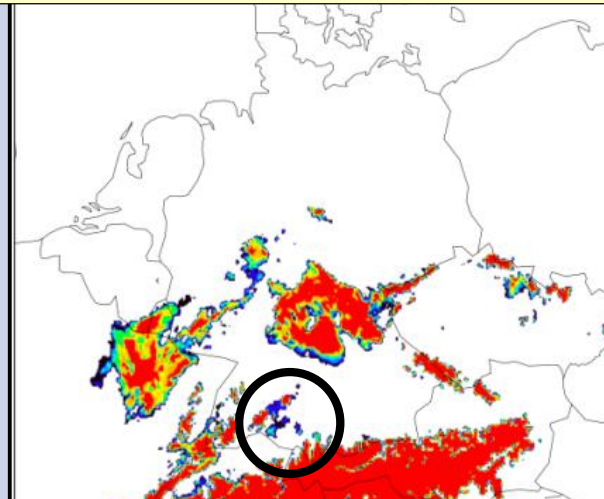


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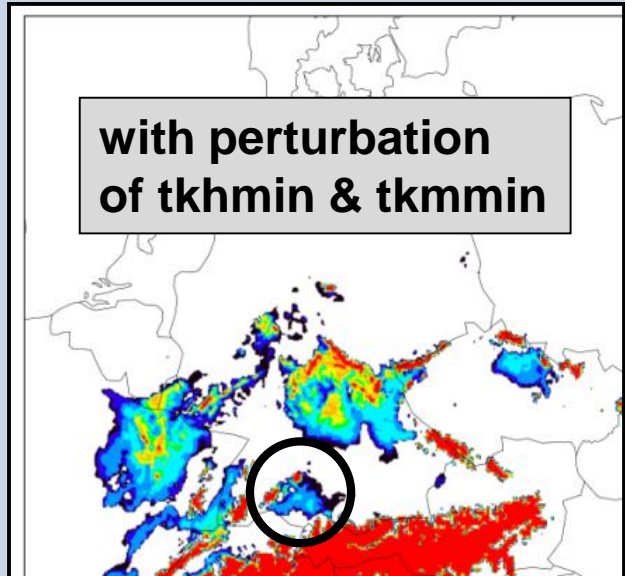
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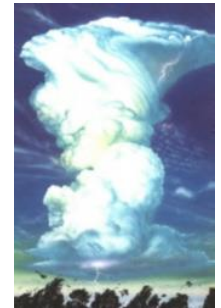
with perturbation
of tkhmin & tkmmin



capture events that are missed otherwise

Criteria for the Selection of Perturbations

1. Ensemble Spread / Sensitivity: **convective precipitation**



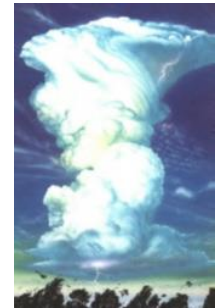
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→ regime-dependent:

high sensitivity for weak synoptic forcing

(Keil and Craig, Meteorol. Z., 2011)



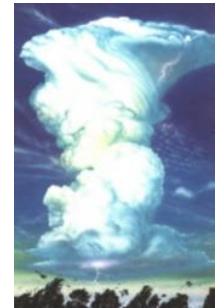
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→ useful to look at

spread in amplitude and location

(e.g. „correspondence ratio“)

(Gebhardt et al., Atmos. Res., 2011)

Criteria for the Selection of Perturbations

2. Quality check



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→ for each member:

- „similar“ quality
- „similar“ bias



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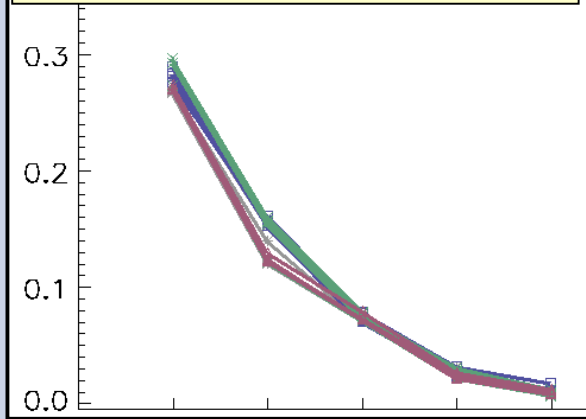
SYNOP verification

1h-precipitation

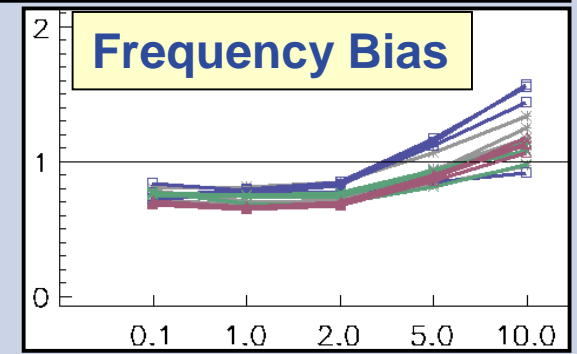
*summer 2015
6 UTC run, 1-21h*

*Colors:
driving global model*

Equitable Threat Score



Frequency Bias



precipitation threshold (mm/h)



Criteria for the Selection of Perturbations

2. Quality check

→ „plausible“ fields

- individual members
- spread
- etc



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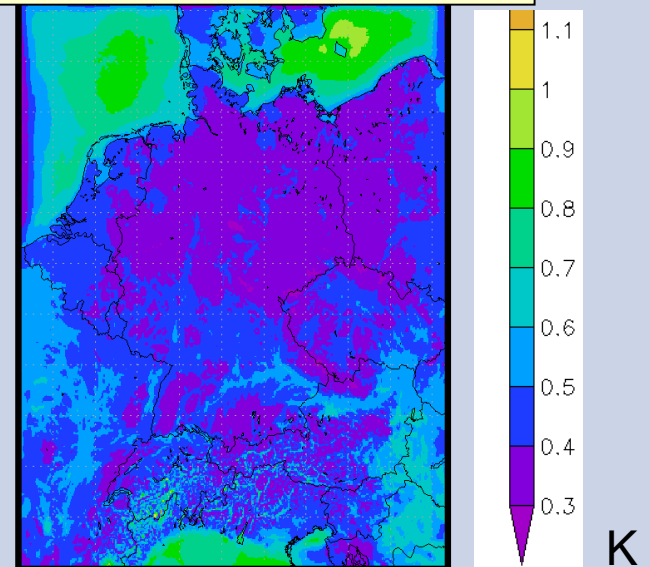
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Example:

*Nov 15, 2015
00 UTC + 12h*

*source:
C.Gebhardt (DWD)*

Ensemble Spread T2m



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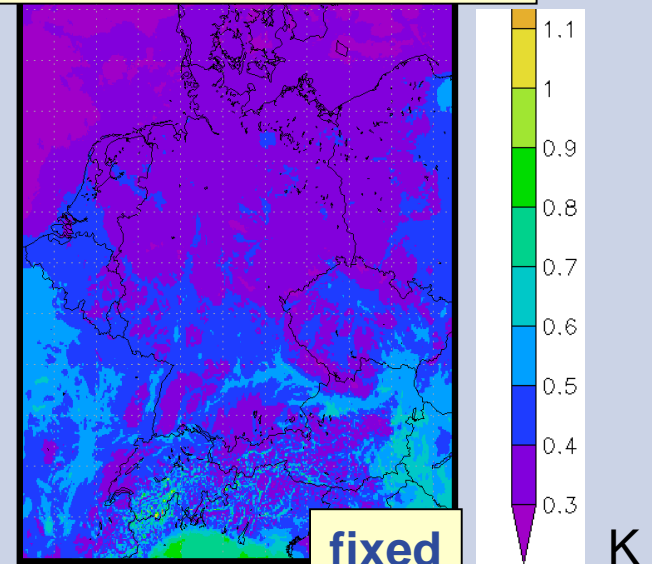
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Ensemble Spread T2m



Criteria for the Selection of Perturbations

2. Quality check

→ RMSE of ensemble mean

→ CRPS

→ Brier score

- Reliability
- Resolution



Combining the Perturbations



Combining the Perturbations

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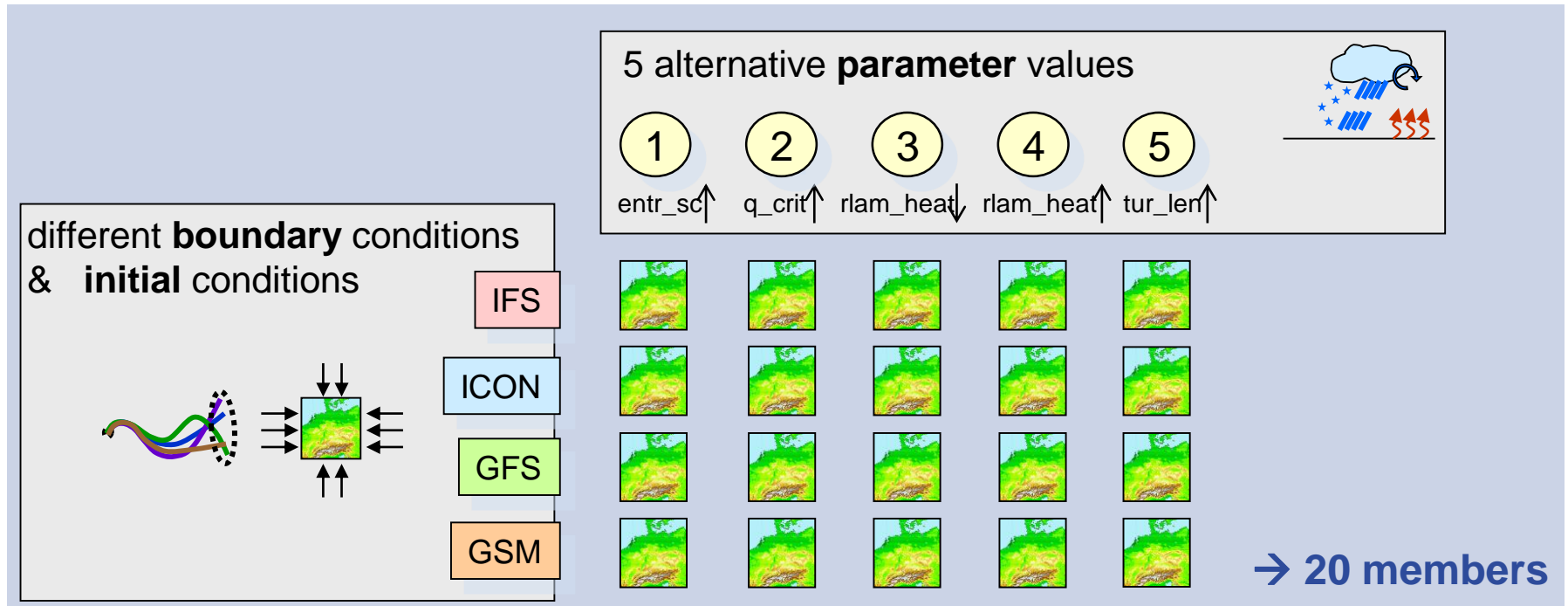
↓ since 2012

→ 5 alternative values



Combining the Perturbations

→ **in 2012**: applying the alternative values **in isolation**,
combining each alternative with each driving model



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added 2014

→ 7 alternative values

→ new perturbations combined with existing



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search for an optimum combination?



Combining the Perturbations

→ **Idea:**

randomize the combinations

(M. Buchhold, DWD)



Combining the Perturbations

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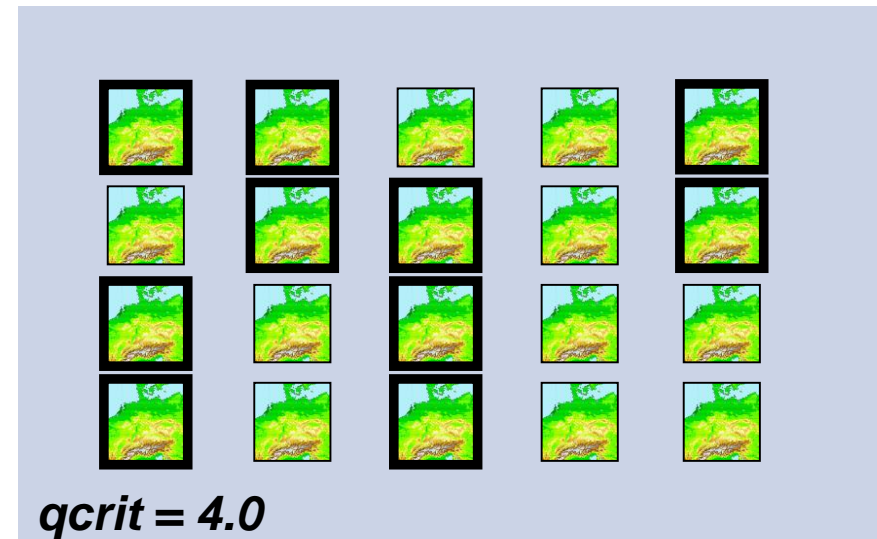
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(M. Buchhold, DWD)

→ Method (in test phase):

Random number generator
assigns a perturbation to members

For each forecast start,
then fixed during forecast



Combining the Perturbations

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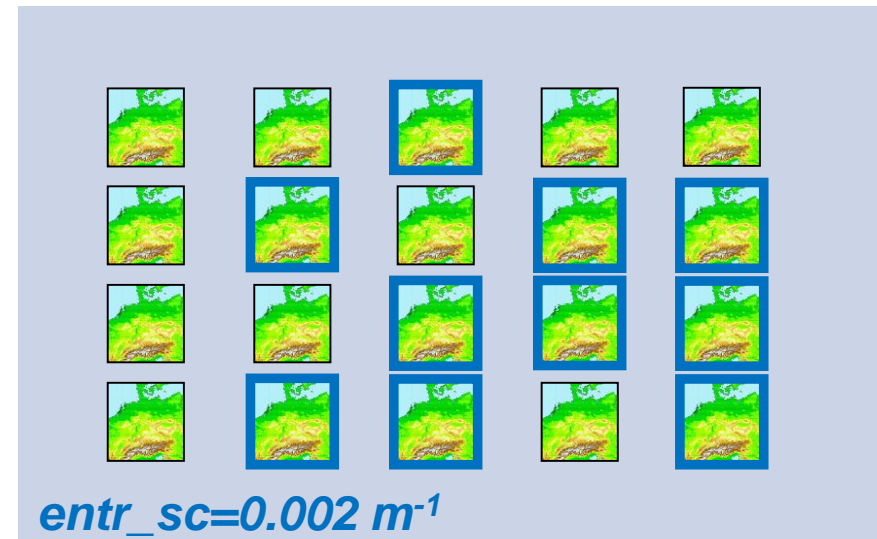
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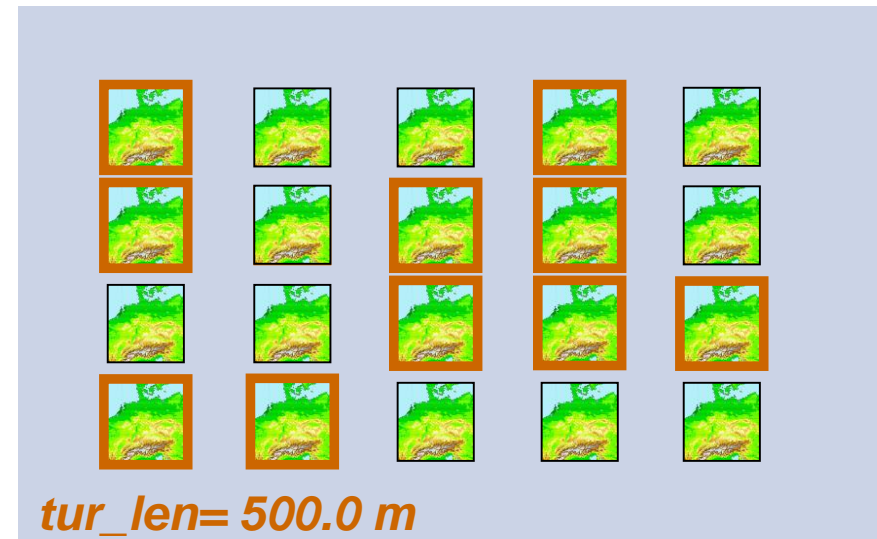
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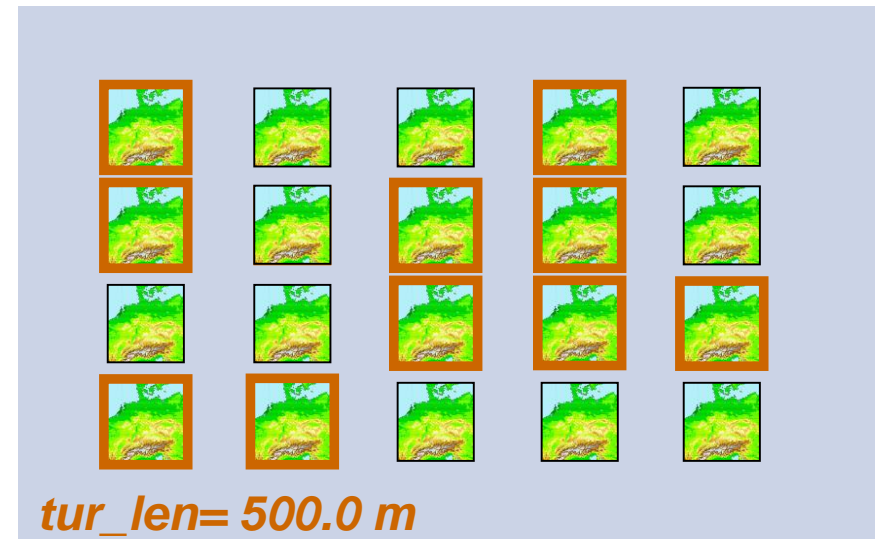
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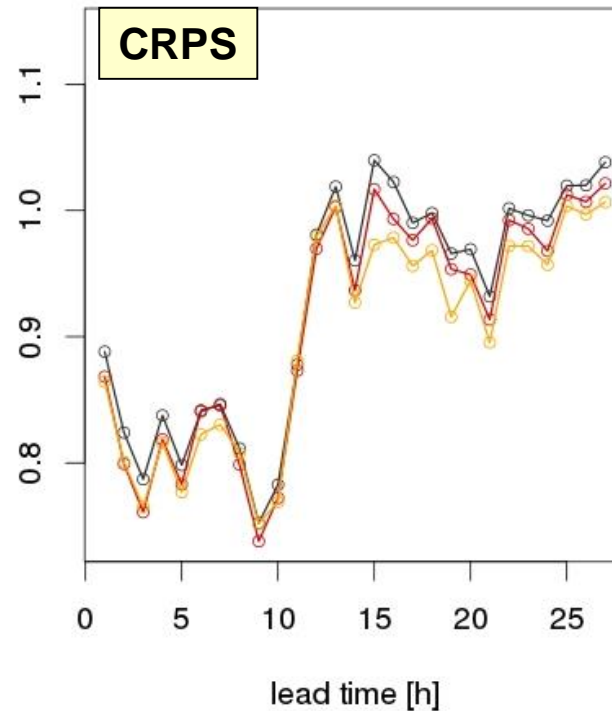
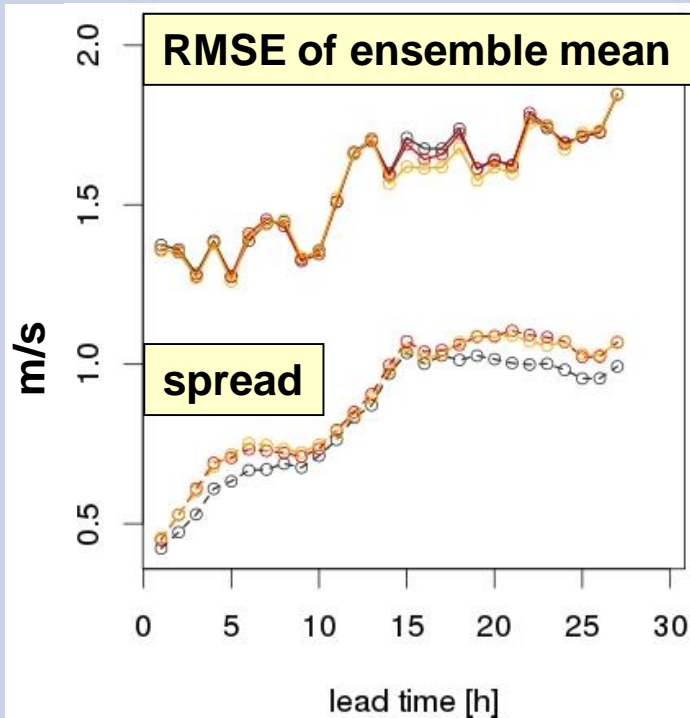
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Indication that all sorts of combinations are OK



*verification
August 2013*

*wind speed
up to 200 m*

- reference
- with new perturbations and fixed combination
- with new perturbations and randomized combination

*source:
R.Kohlhepp (DWD)*



Maintenance



Maintenance of Parameter Perturbations

Selection of perturbed parameters depends on...

→ the specific model configuration

model version, grid size, domain, lead time, default values of parameters,...

→ the target

precipitation, T2m, low level clouds, low level jet,...



Maintenance of Parameter Perturbations

Selection of perturbed parameters depends on...

→ **the specific model configuration**

model version, grid size, domain, lead time, default values of parameters,...

→ **the target**

precipitation, T2m, low level clouds, low level jet,...

need to revisit the perturbations from time to time



Summary

(Operational Method)



Summary: Parameter Perturbations in COSMO-DE-EPS

- **manual selection**, using expert knowledge
- depends on **target variable and model configuration**



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- **manual selection**, using expert knowledge

- depends on **target variable and model configuration**

- **selection criteria:**
 - ensemble spread
 - quality check
 - individual members (quality & bias)
 - plausible fields
 - standard scores



Development at DWD

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for Weather Research

Development
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**Operational
at DWD**

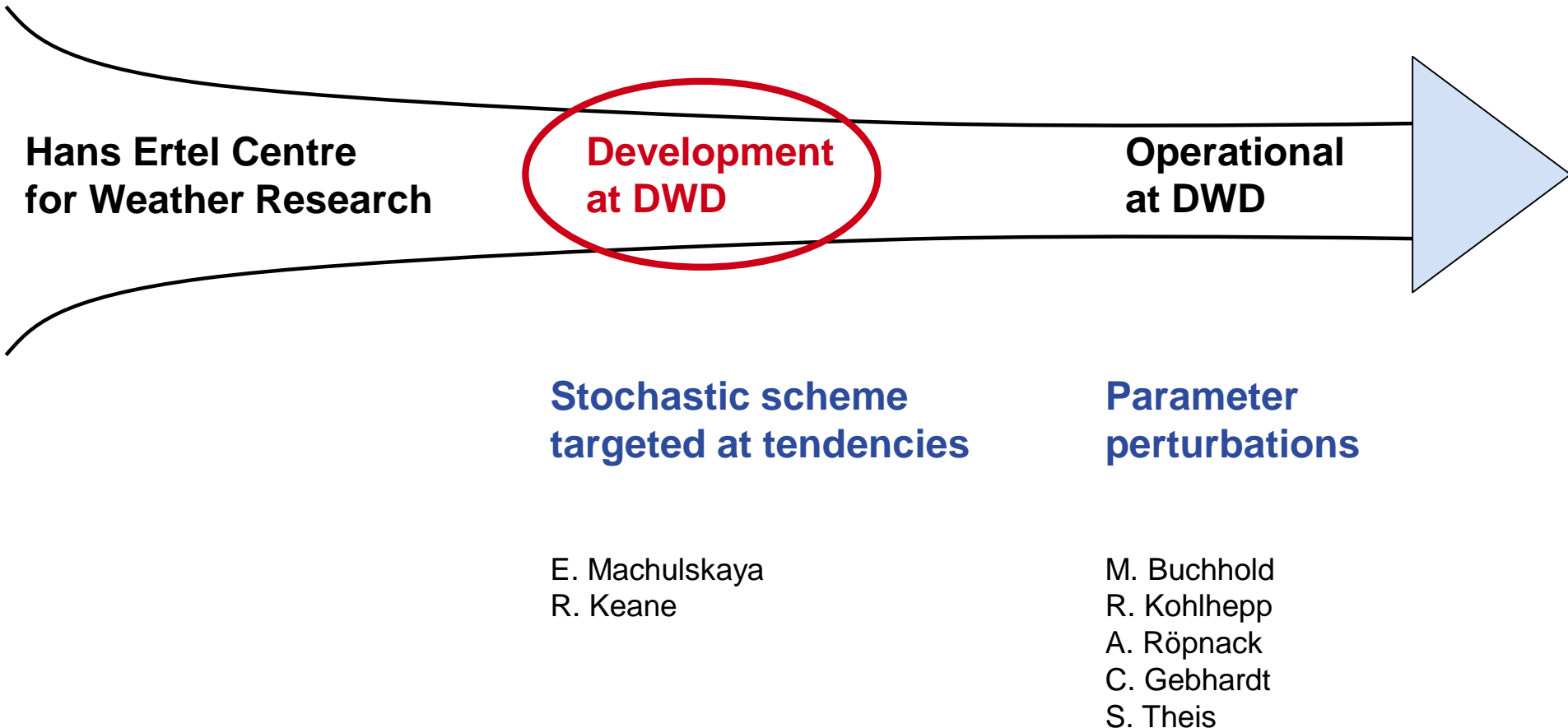
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**Parameter
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Stochastic scheme targeted at tendencies

→ perturb physics tendencies using additive noise

→ **noise amplitude & space-time correlation:**
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→ proxy for model uncertainty:
“forecast – analysis” as frequent as possible

→ detect **dependencies**, e.g.

amplitude of model uncertainty $\leftarrow |dT/dt|$

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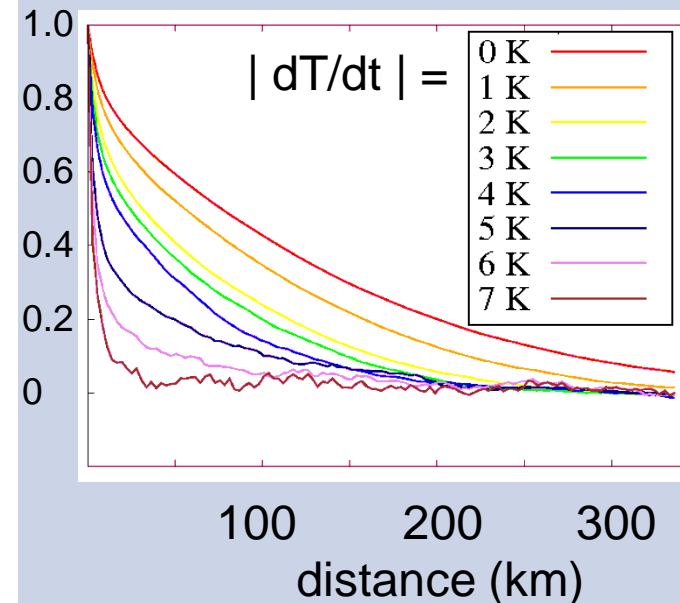
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spatial correlation of
model uncertainty

near the surface



source: E. Machulskaya (DWD)



Stochastic scheme targeted at tendencies

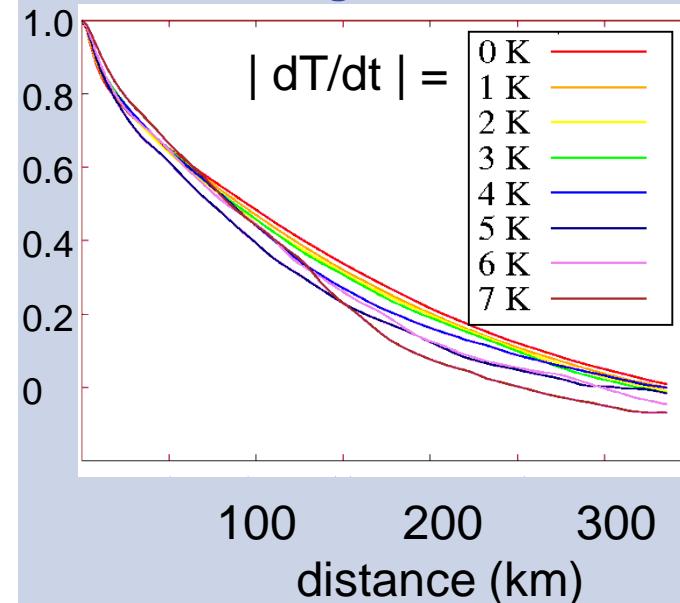
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spatial correlation of
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at 5 km height



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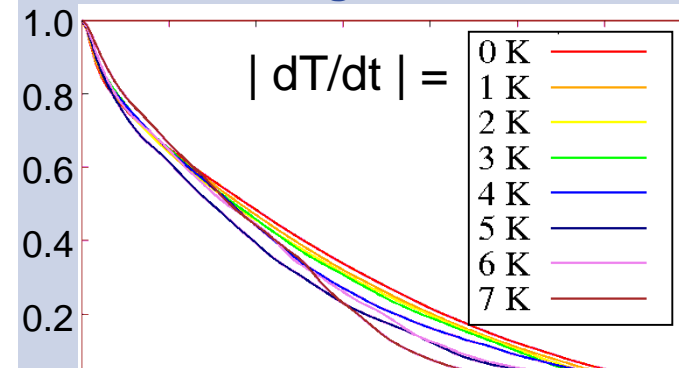


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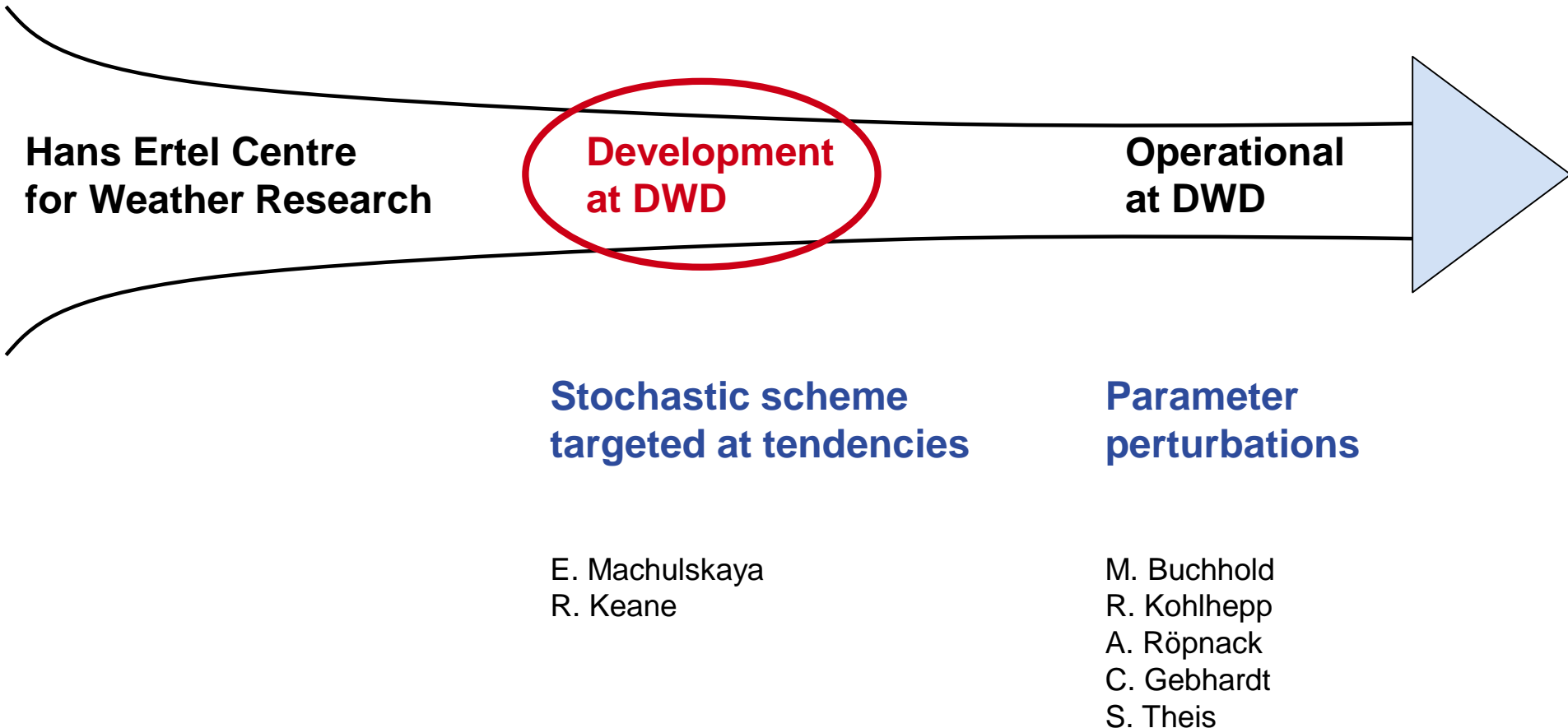


use $|dT/dt|$ and other quantities

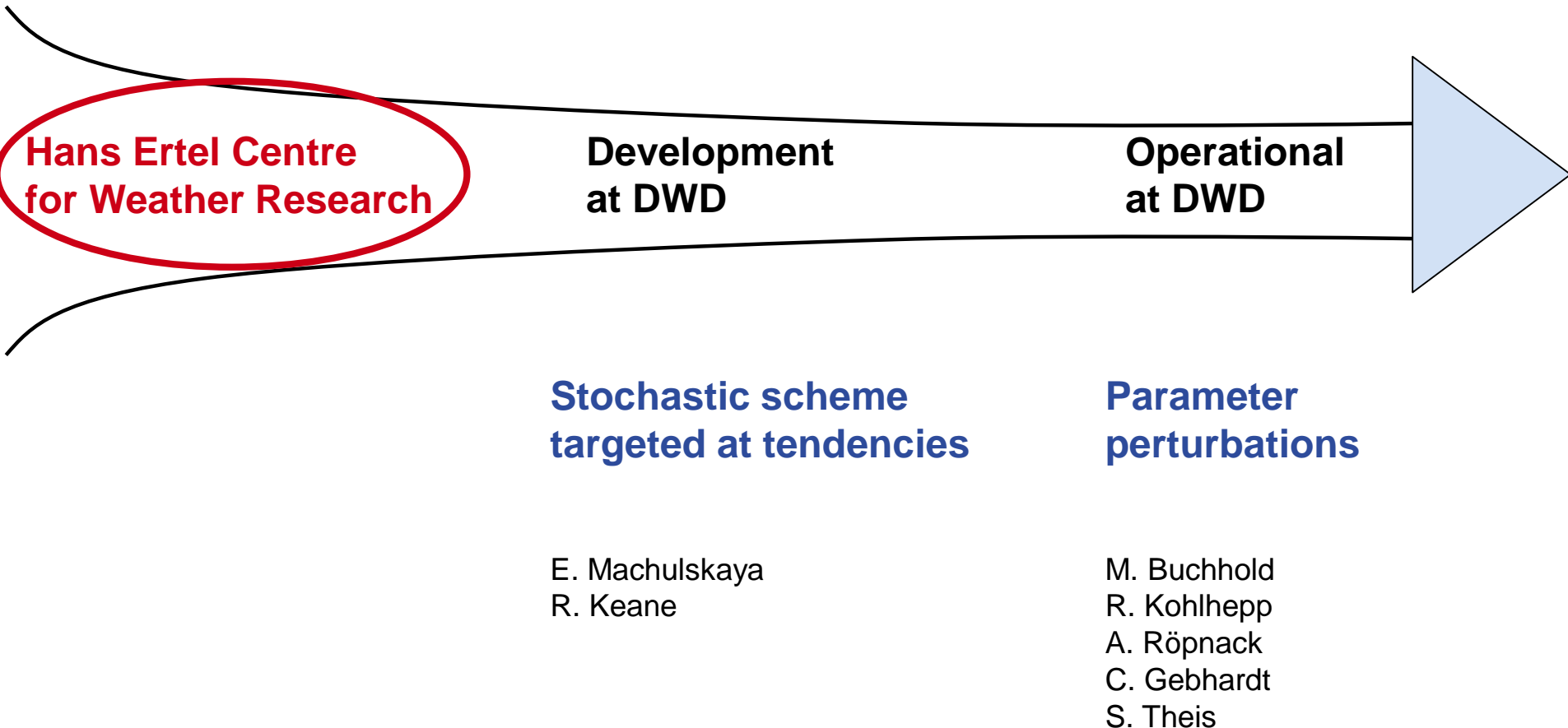
as “predictors” for noise amplitude & correlation



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Hans Ertel Centre for Weather Research

→ Examples:

- **Ensemble based convective scale data assimilation**
and the use of remote sensing observation (**LMU Munich**)



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Mirjana Sakradžija, 2015:

A **stochastic parametrization of shallow cumulus convection** for high-resolution numerical weather prediction and climate models, *Reports on Earth System Science*, Max-Planck-Institute for Meteorology, Hamburg, 144 pp.



Thank you for your attention

