Stochastic Boundary Layer Perturbations in COSMO-KENDA

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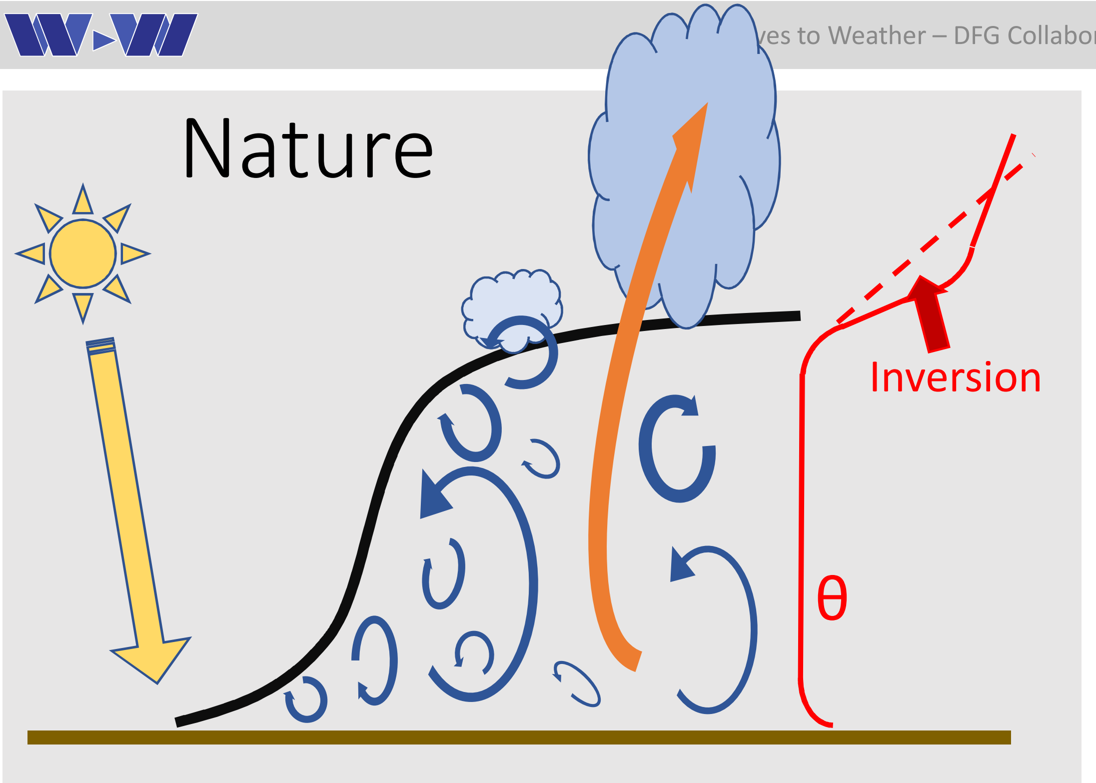
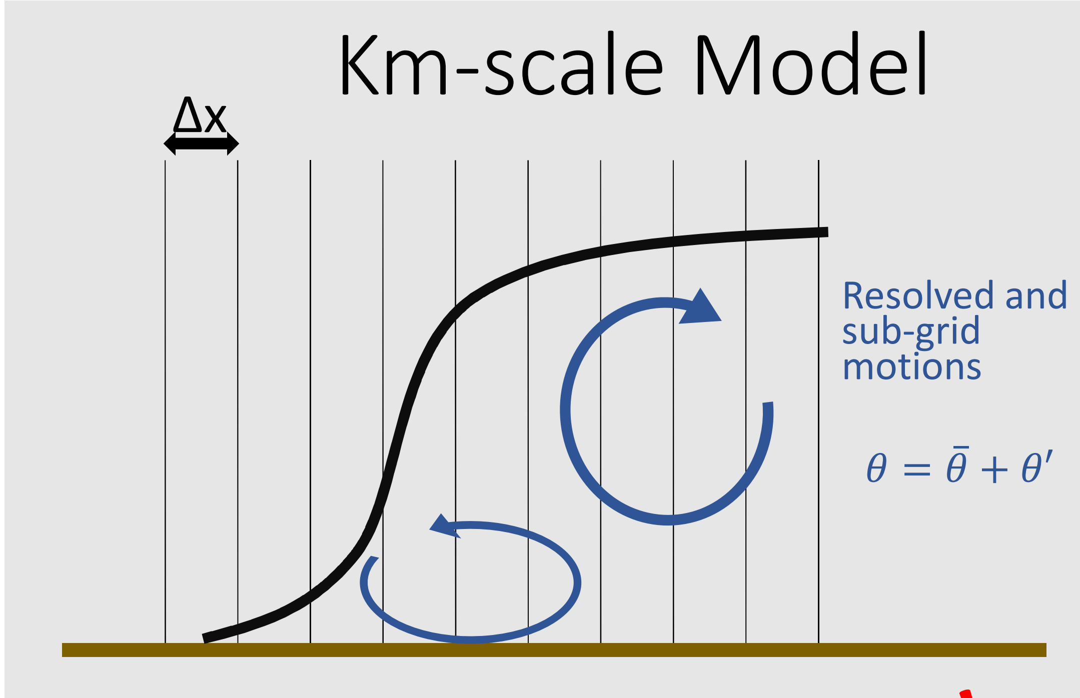
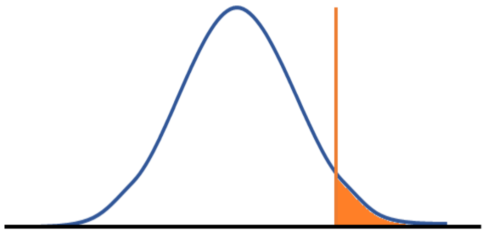


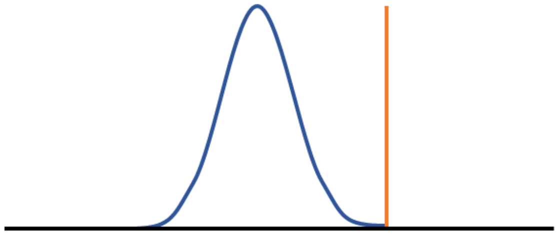


Joint PDF
$P(w, q, \theta)$



Lucky parcels
trigger convection

Resolved PDF
$P(\bar{w}, \bar{q}, \bar{\theta})$



+

Sub-grid variability
Missing!
$\overline{w'^2}, \overline{q'^2}, \overline{\theta'^2}$

Goal: Bring it back on the grid-scale

Reintroducing missing variability on the resolved scales
Physically–based Stochastic Perturbations (PSP)

$$\frac{\partial \Phi}{\partial t} = \text{Advection} + \text{Physics} + \boxed{\eta \ \alpha_c \ \frac{l_\infty}{5\Delta x} \ \frac{1}{\Delta t} \ \overline{\Phi'^2}}$$

Stochastic perturbations

$$\Phi \in \{w, q, \theta\}$$

`wtens, qvtens, ttens`

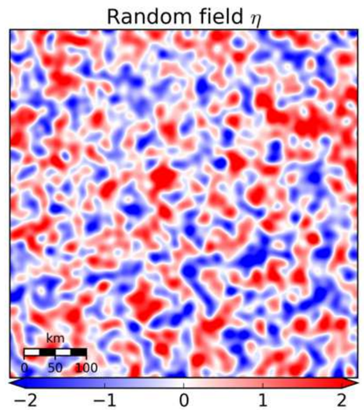
Formulation of PSP with case studies: Kober and Craig, 2016. JAS.

Physically–based Stochastic Perturbations (PSP)

Constant (tuning) factor

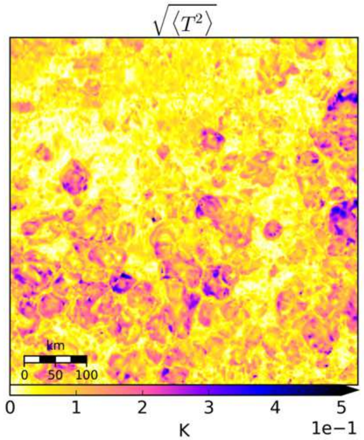
$$\eta \; \alpha_c \; \frac{l_\infty}{5\Delta x} \frac{1}{\Delta t} \; \overline{\Phi'^2}$$

Adapts to grid spacing and time step



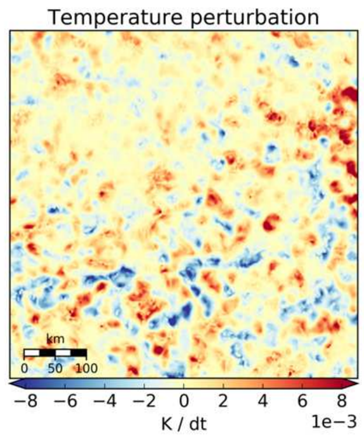
Random field

- $N(0, 1)$
- Correlated in *x*-*y* (5Δ*x*), constant in *z*
- New field every 10 minutes



Sub-grid variances

- Computed in BL parameterization: local 1.5 order (Mellor and Yamada 1982)



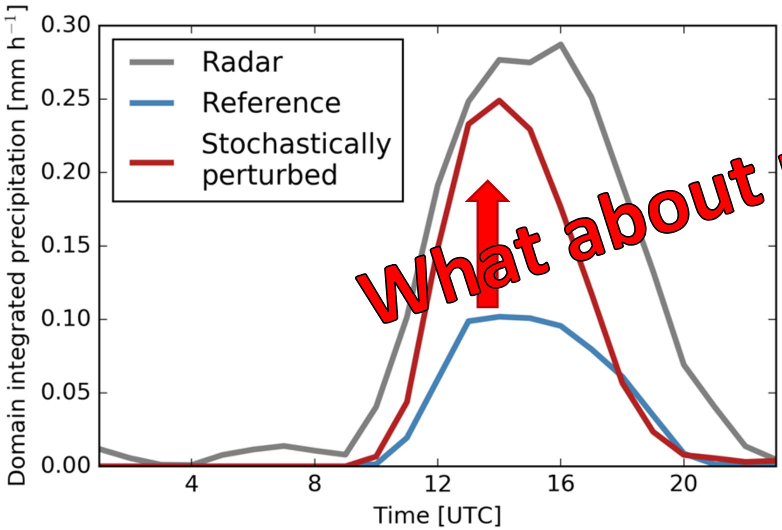
Total perturbation

- Small scale, physically reasonable
- For temperature: around 0.1K per 10 minutes

Effect of PSP

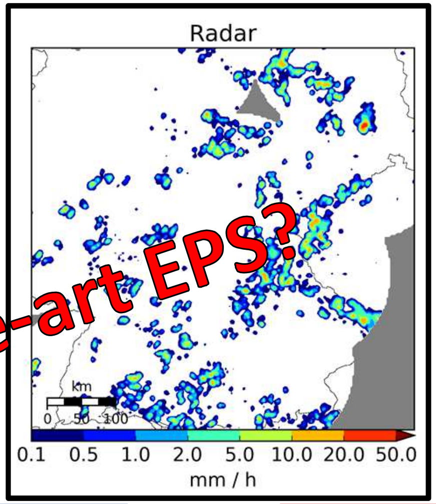
Case study: Diurnal convection

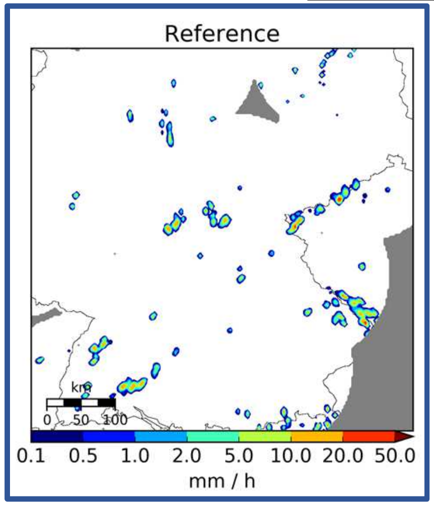
- 1 June 2009
- Driven by ECWMF initial and boundary conditions

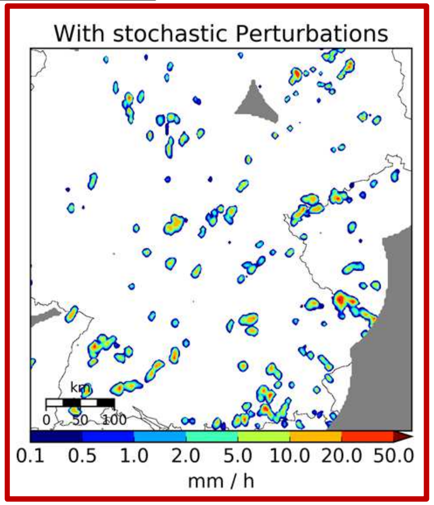


→ Earlier and more convection!

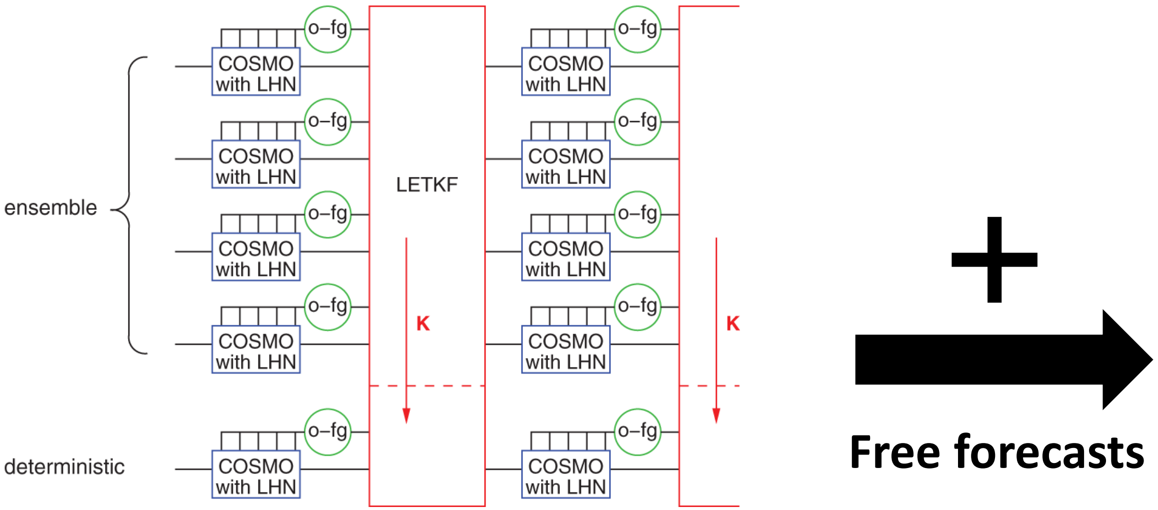
What about real, state-of-the-art EPS?







Testing PSP in COSMO-KENDA



- 1h cycling
- 40 Members plus deterministic run
- ICON Ensemble BC
- Latent heat nudging
- ID: 6000.04

Description of KENDA: Schraff et al., 2016. QJRMS.

REF

- No PSP

PSP

- PSP with original settings

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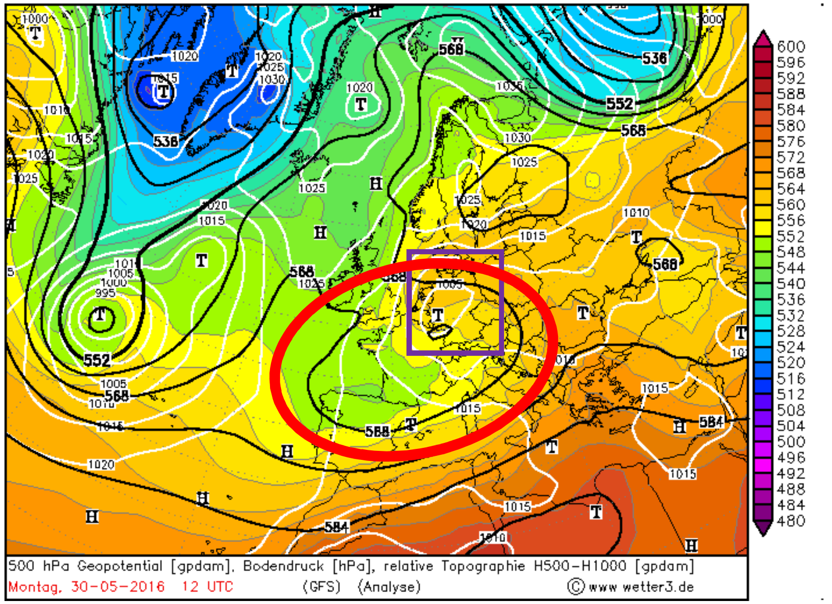
HIWeather Period May/June 2016

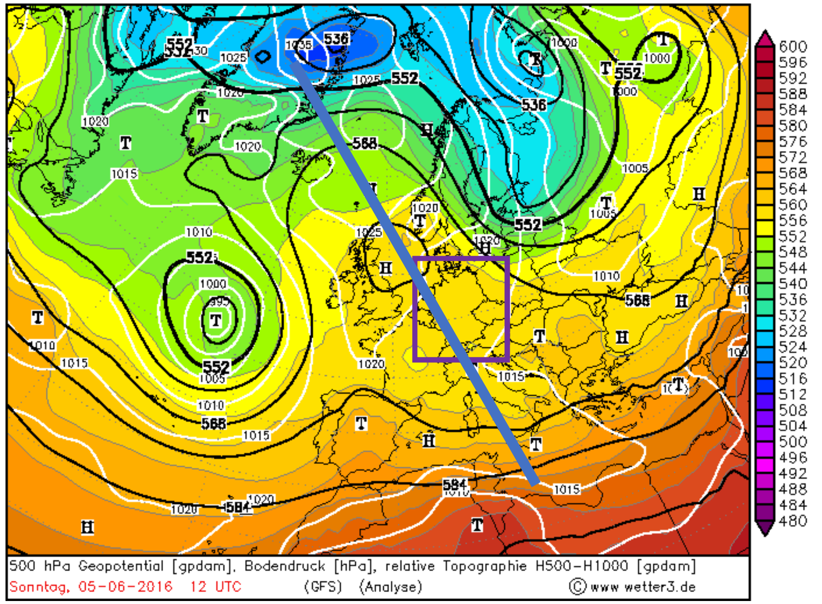
1st phase (roughly 26 May to 2 June)

- Cut-off low
- Strong synoptic lifting
- Example day: 29 May (Braunsbach flooding)

2nd phase (roughly 3 – 9 June)

- Stationary ridge
- Weak gradients
- Example days: 4 and 5 June (diurnal convection)

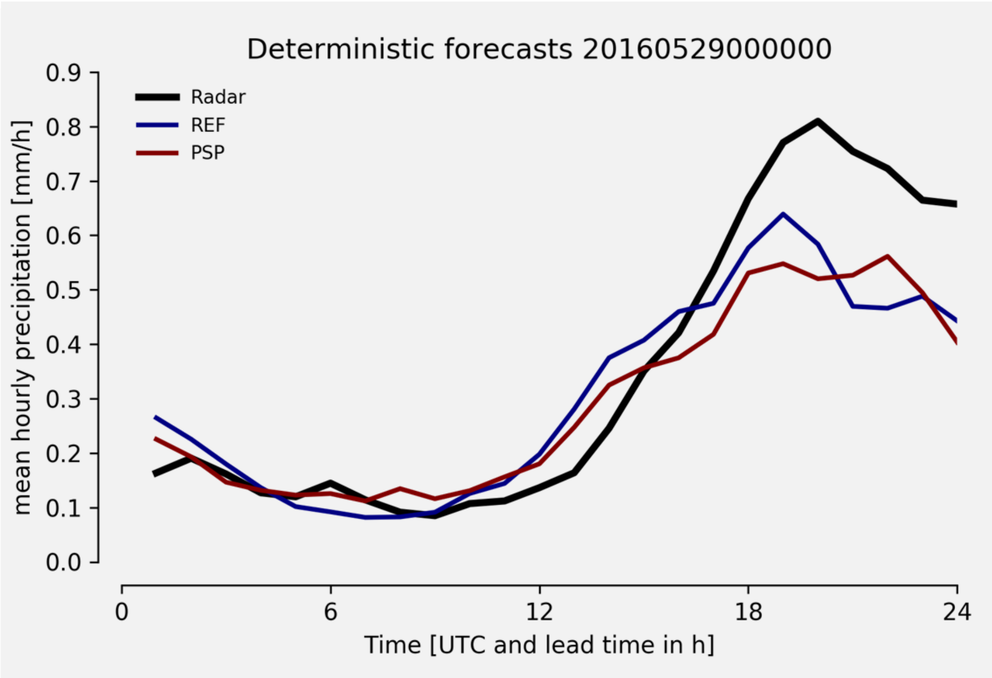




Summary of extreme weather and meteorological situation: Piper et al., Nat. Hazards Earth Syst. Sci., 2016

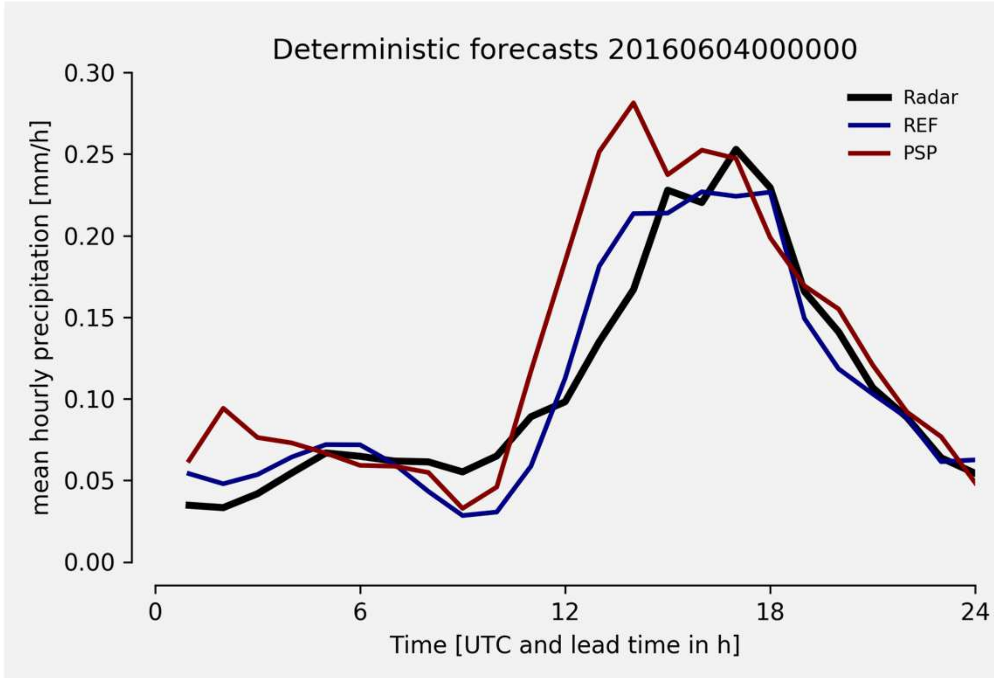
REF vs. PSP Precipitation Forecasts

Strong forcing: 29 May



- Small impact of PSP in strong synoptic forcing situations

Weak forcing: 4 June

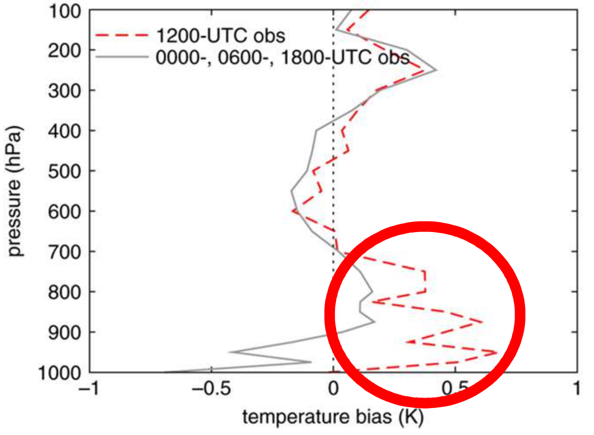


- REF already captures CI well

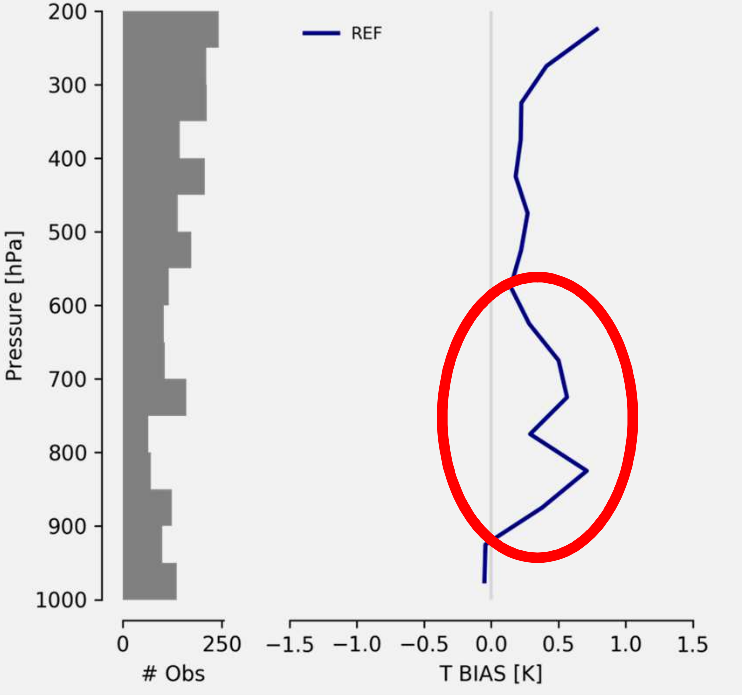
→ Trying to fix a non-existent problem?

tur_len Tuning

- tur_len = turbulent mixing length scale
- Determines efficiency of mixing in BL parameterization
- Used to be 500 m, now is 150 m



Temperature bias of 12h forecasts verified against 12UTC TEMP for weak forcing period



→ Positive temperature bias in lower troposphere

Experiments

REF

- No PSP
- tur_len = 150m

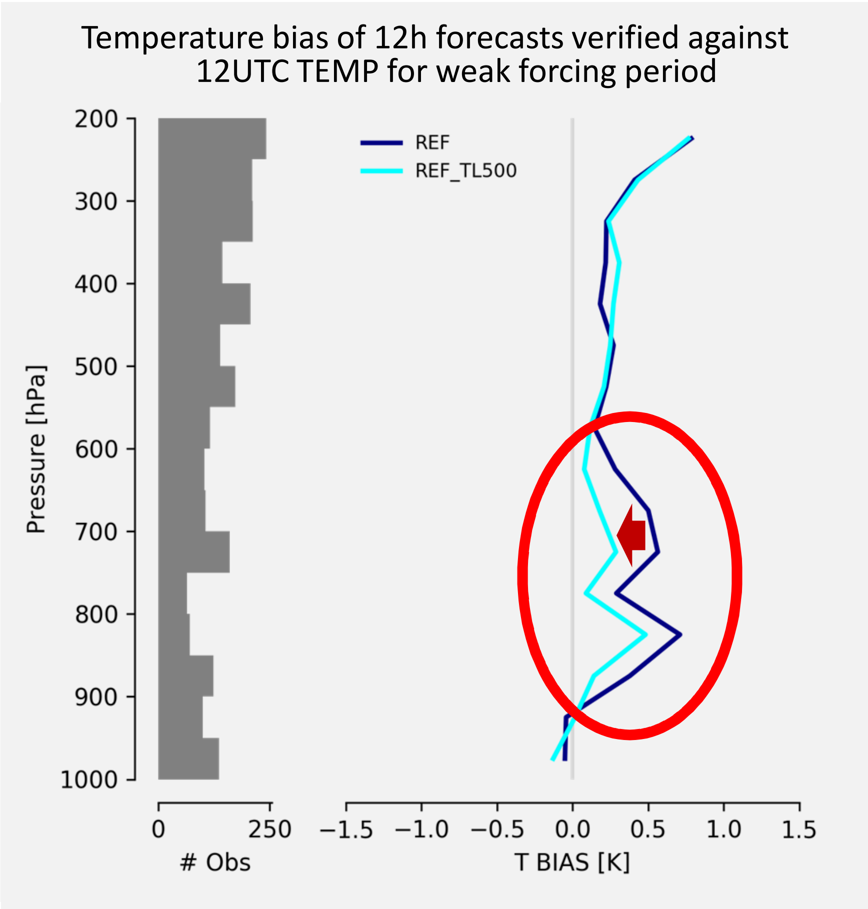
PSP

- PSP with original settings
- tur_len = 150m

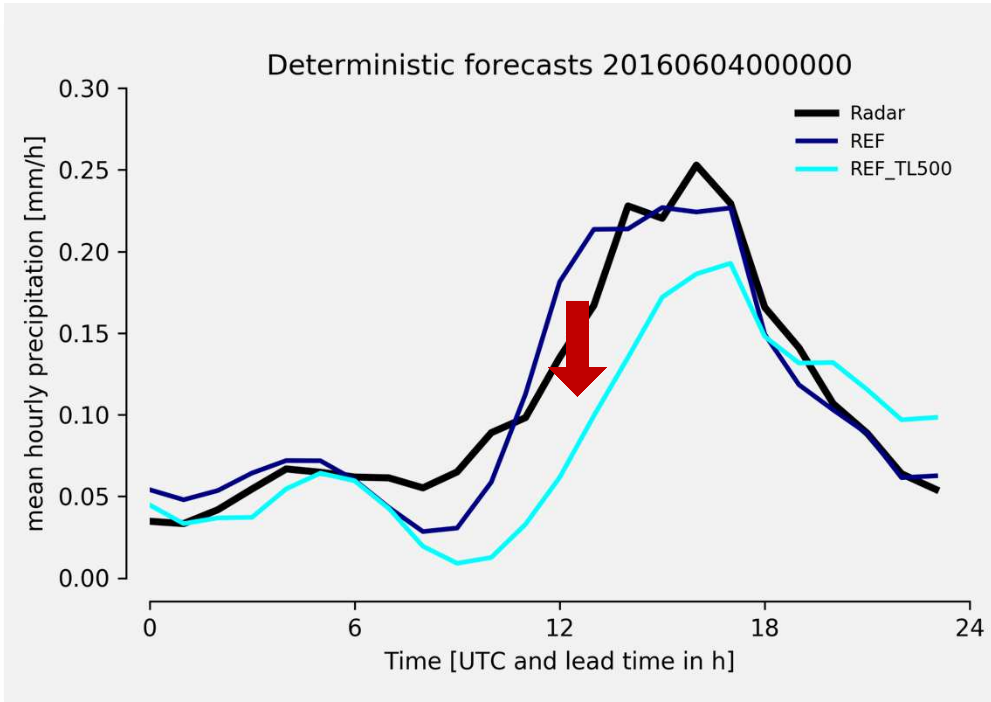
REF_TL500

- No PSP
- tur_len = 500m

Impact of changing tur_len



Weak forcing: 4 June



→ Potentially reduce temperature bias by increasing mixing

Experiments

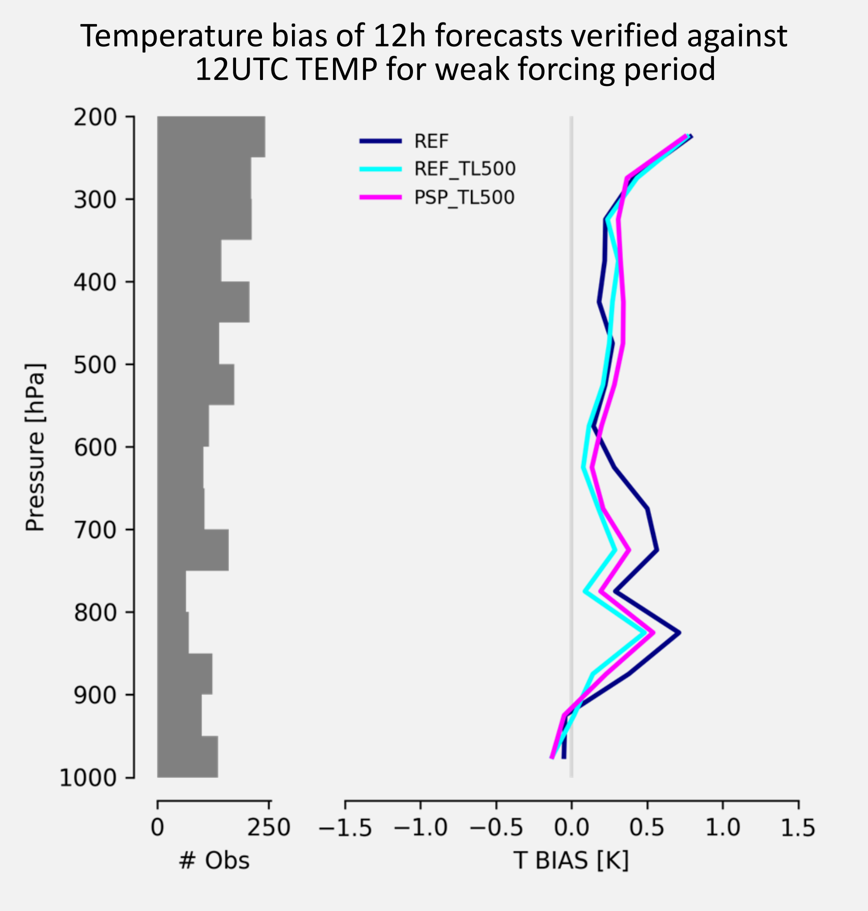
REF
- No PSP
- tur_len = 150m

PSP
- PSP with original settings
- tur_len = 150m

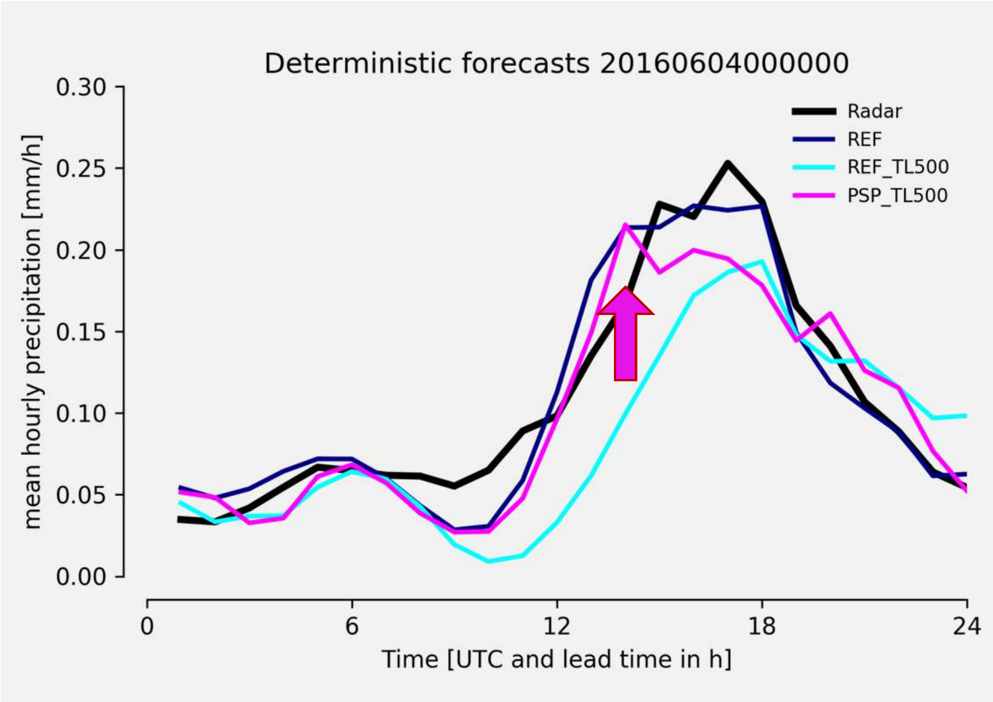
REF_TL500
- No PSP
- tur_len = 500m

PSP_TL500
- PSP with original settings (adjusted)
- tur_len = 500m

Changing tur_len plus PSP



Weak forcing: 4 June

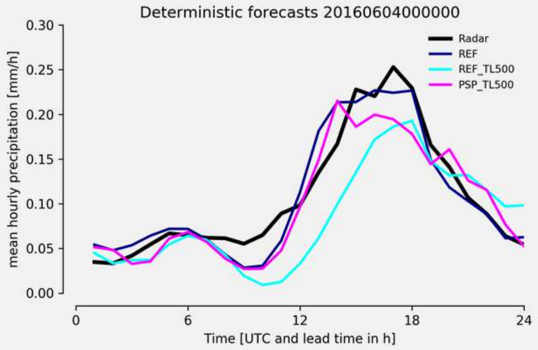


→ TL500 + PSP could produce similar precipitation amounts

Summary, Part I

Systematic impact of PSP

- Stochastic perturbations in the BL with physically-based amplitudes
- Earlier and more convection
- REF already does will in terms of CI
- Combination of increased mixing and PSP could be used to reduce T bias



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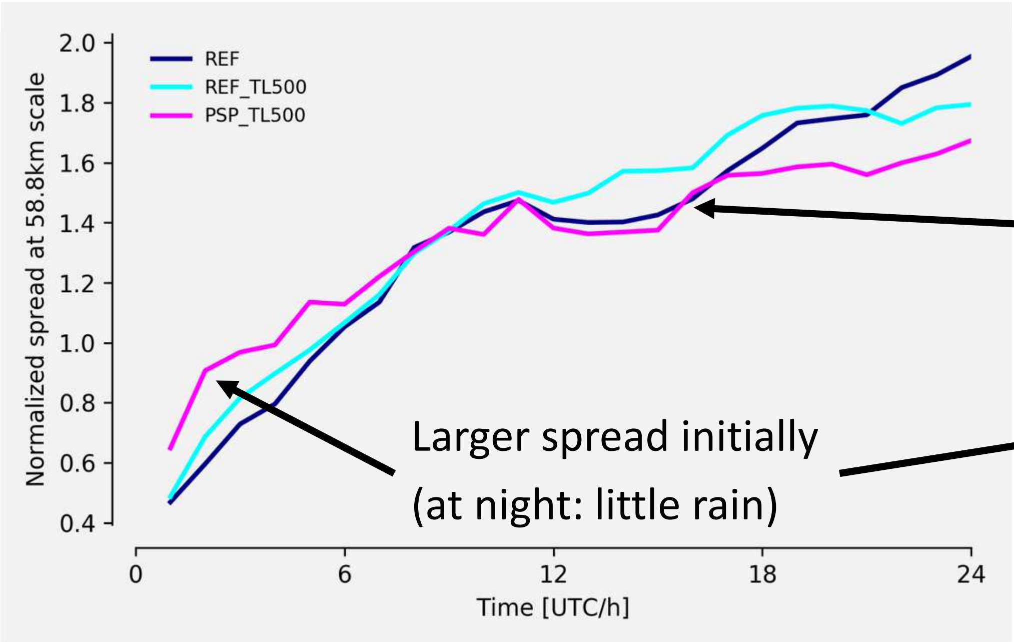
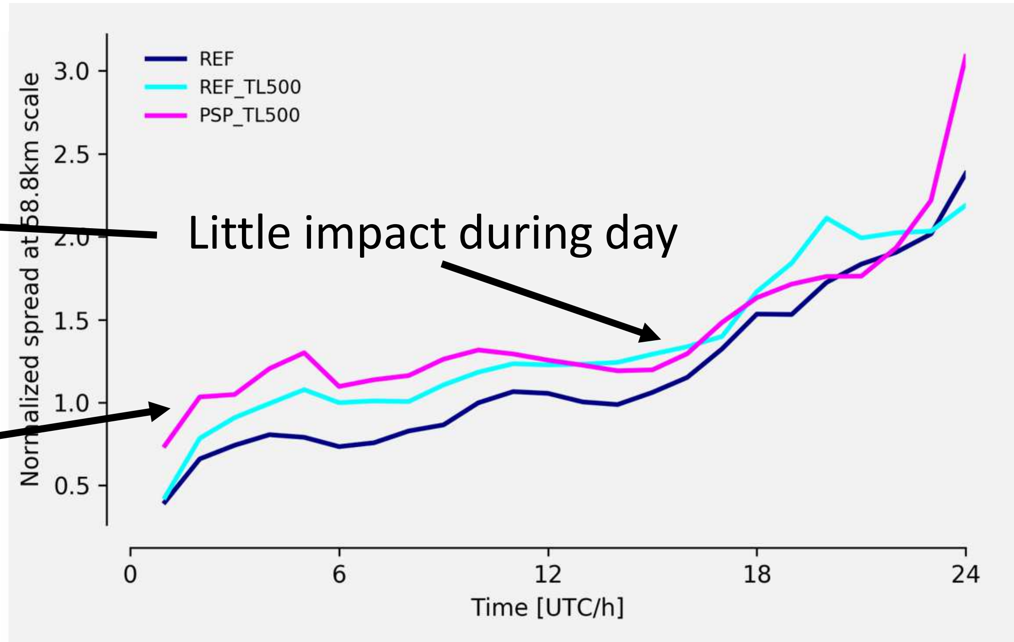
What about Ensemble Spread?

- Can small-scale perturbations increase ensemble spread?
- Metric: Upscaled (ca. 60km) standard deviation normalized by total precipitation amount

Strong forcing: 29 May

Weak forcing: 5 June

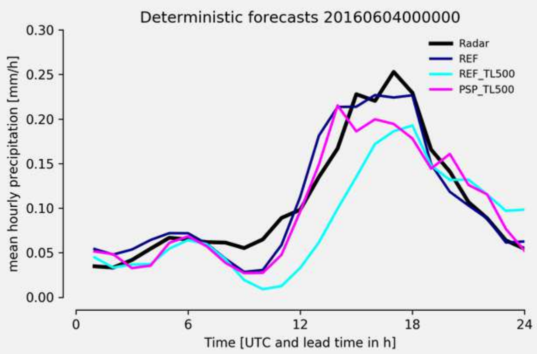




Summary

Systematic impact of PSP

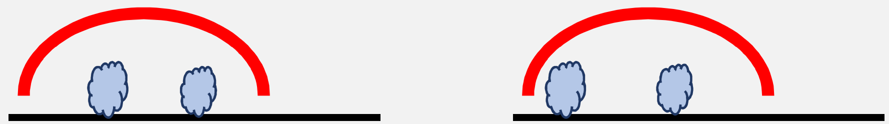
- Stochastic perturbations in the BL with physically-based amplitudes
- Earlier and more convection
- REF already does will in terms of CI
- Combination of increased mixing and PSP could be used to reduce T bias



Dispersive impact of PSP

- Potentially larger spread in initial conditions
- Are small-scale perturbations relevant in the presence of large-scale perturbations?

Only small-scale perturbations



Small and large-scale perturbations