Stochastic treatment of cloud related processes in non-hydrostatic NWP models

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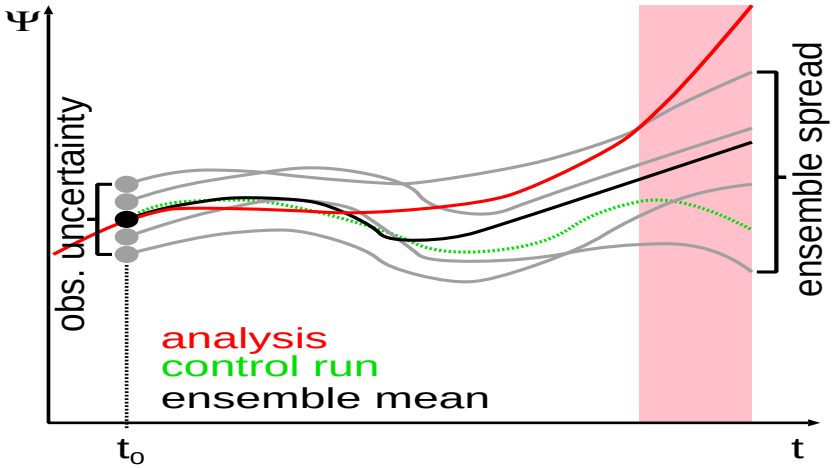
Motivation

ensemble forecast:

- uncertainty of observations: vary initial/boundary conditions



→ ensemble
often underdispersive...

- model uncertainties: variation of model physics
  - multimodel ensemble (e.g. part of COSMO-DE-EPS, DWD)
  - vary output tendencies of phys. schemes (Buizza, 1999)
  - stoch. parameters in phys. schemes (e.g. MOGREPS, UKMO)

perturbed / stochastic physics:

→ parameter value uncertain

→ parameter highly variable in space / time (subgrid scale var.)

Stochastic processes from DNS

direct numerical simulation (DNS): ensemble of particles in turb. flow

$\rightarrow$ Langevin equation for stationary, homogeneous, isotropic turb. turb. velocity $u(t)$ (Pope, 2000):

$$du = -\underbrace{\frac{3}{4} C_0 \frac{e}{K}}_{1/\tau;\text{autocorrel. time}} u\,dt + \sqrt{C_0 e}\, z(t) \sqrt{dt}$$

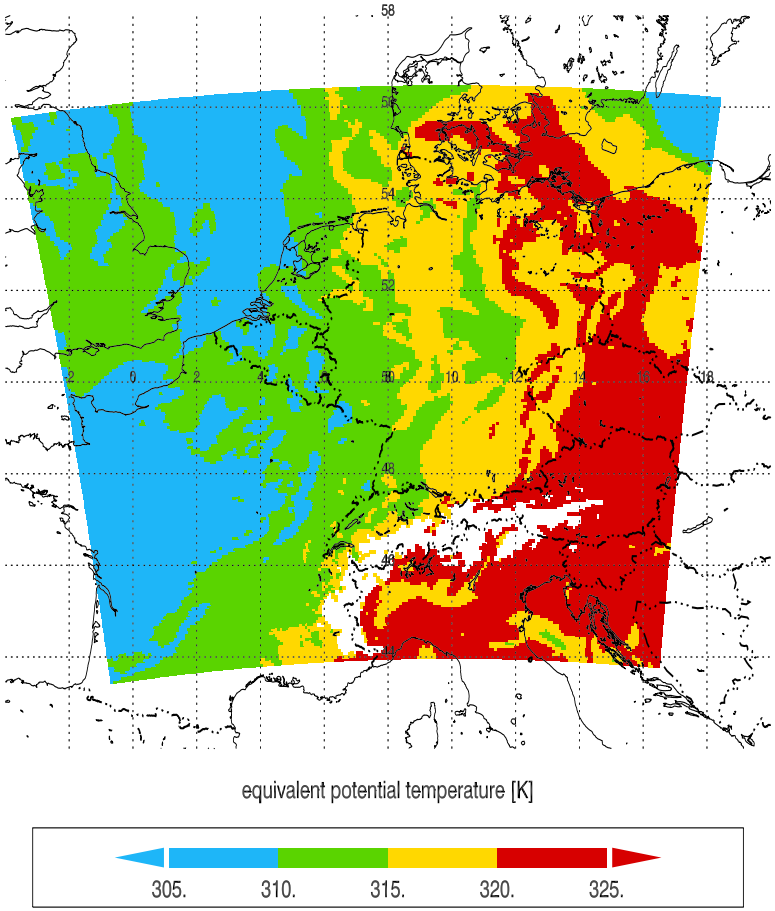
K=TKE, e=EDR, C_0=6, z(t) uncorrel. Gaussian noise

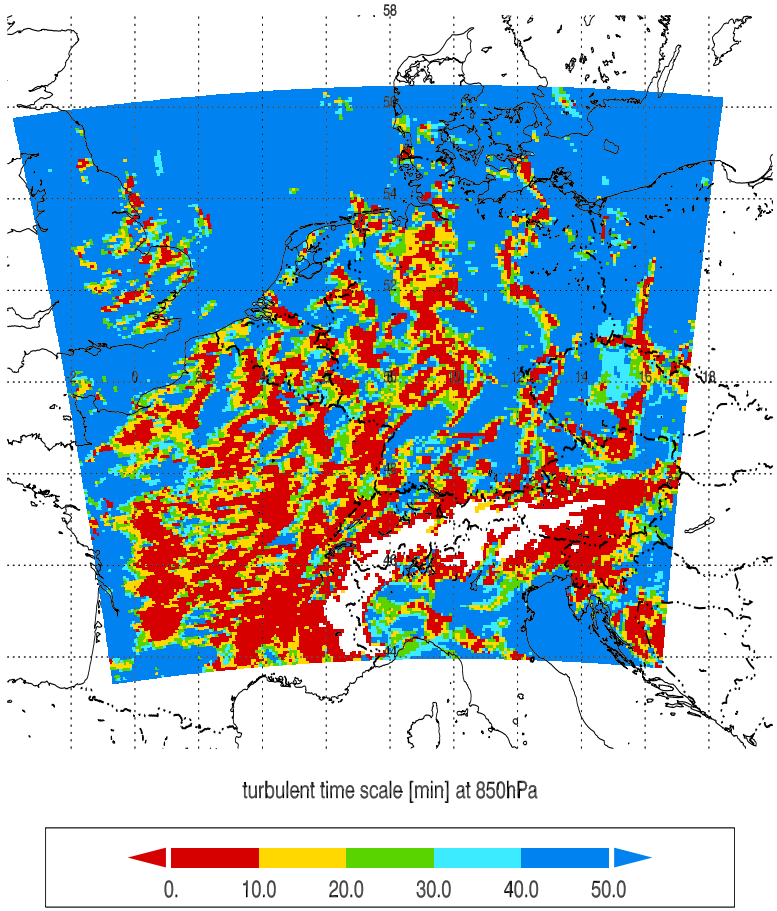
new approach:

- TKE, EDR from NWP model $\rightarrow$ fix τ by model physics
- integrate Langevin equation
- normalize turb. velocity $u(t) \rightarrow$ Var[u] = 1
- derive stoch. processes for turb.-driven parameters from $u(t)$

Autocorrelation time τ from model physics

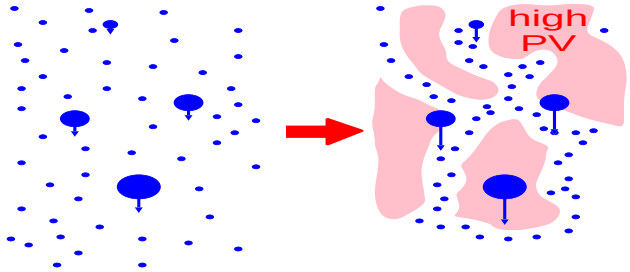
passage of frontal system on July 2, 2007





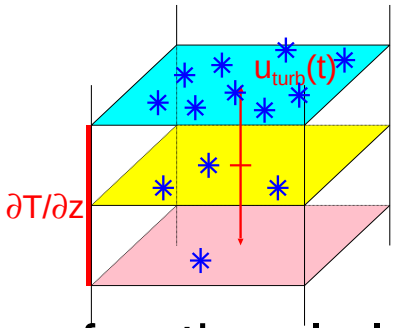
Stochastic parameterizations

grid scale precip., turb. collection kernel:



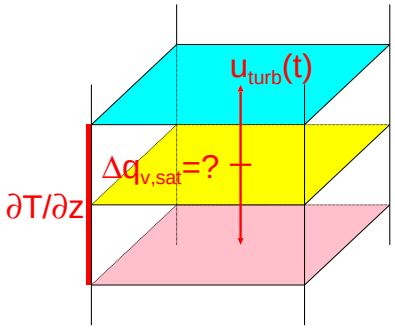
$|u(t)|$, EDR $\rightarrow$ turb. enhancement factor (param. by Pinsky, 2008)

grid scale precip., init. ice concentration:



u(t) $\rightarrow$ turb. vert. displacement $\rightarrow \Delta T$ $\rightarrow q_{i,init}(T)$

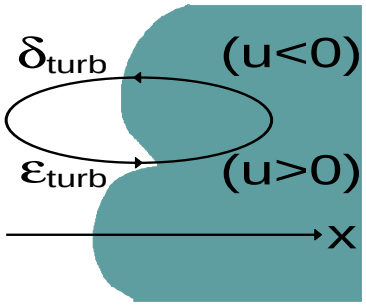
radiation, fractional cloud cover:



cloud fraction $= f(q_{tot}, q_{v,sat}, p/p_{surf})$
u(t) $\rightarrow$ turb. vert. displacem. $\rightarrow \Delta q_{v,sat}$
$\rightarrow$ *switched off (weak influence, CFL crit.)*

Stochastic parameterizations

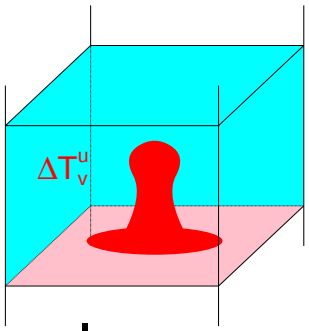
convection, mixing:



turbulent entrainment/detrainment

$$\epsilon_{turb} = \delta_{turb} \sim |u(t)|$$

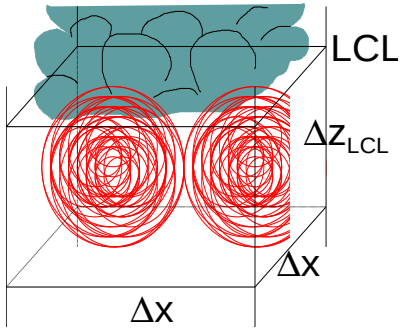
convection, trigger:



Fritsch-Chappell trigger

$$\Delta T_v^{up} = \gamma \sqrt[3]{w} - w_0 + w^* u(t)$$

convection, closure:



$$M^u_{LCL,turb} \sim u(t) \Delta z_{LCL} \sqrt{\Delta x \Delta y}$$

Model simulations

COSMO 4.21 (DWD) with HYMACS
(also applicable, e.g., to Tiedtke or Kain-Fritsch scheme)

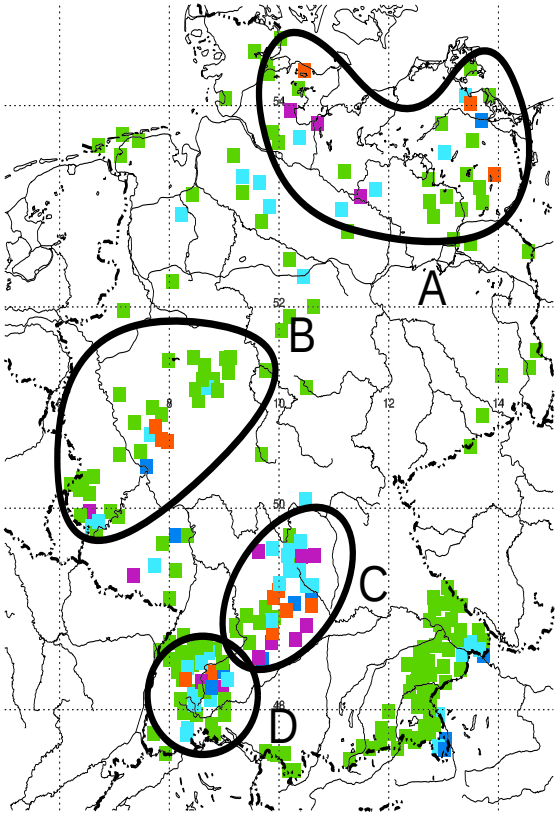
case study:
2.7.-4.7.2007: frontal system, postfrontal showers over several days

compare 1h precip. sums from

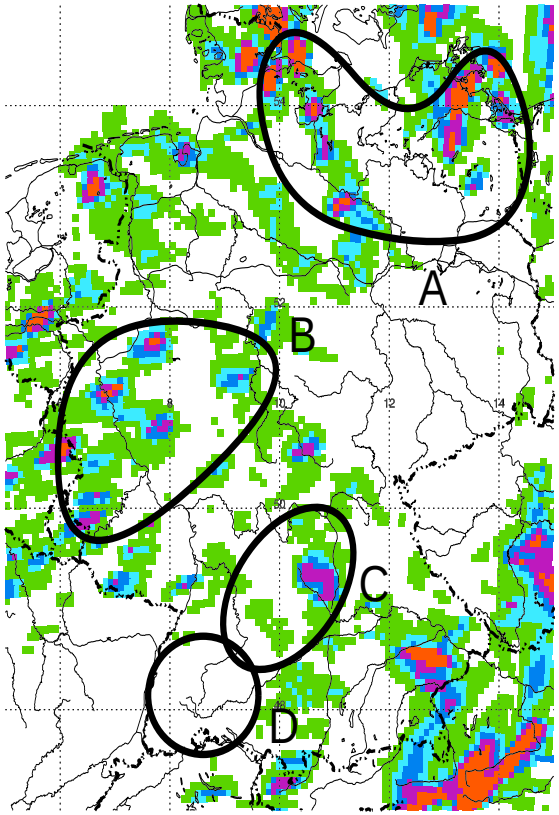
- deterministic control simulation
- ensemble with 24 members (stoch. phys.)
- SYNOP data (DWD network; $\approx$1000 stations in Germany)

2.7.2007: 1h precip. sums

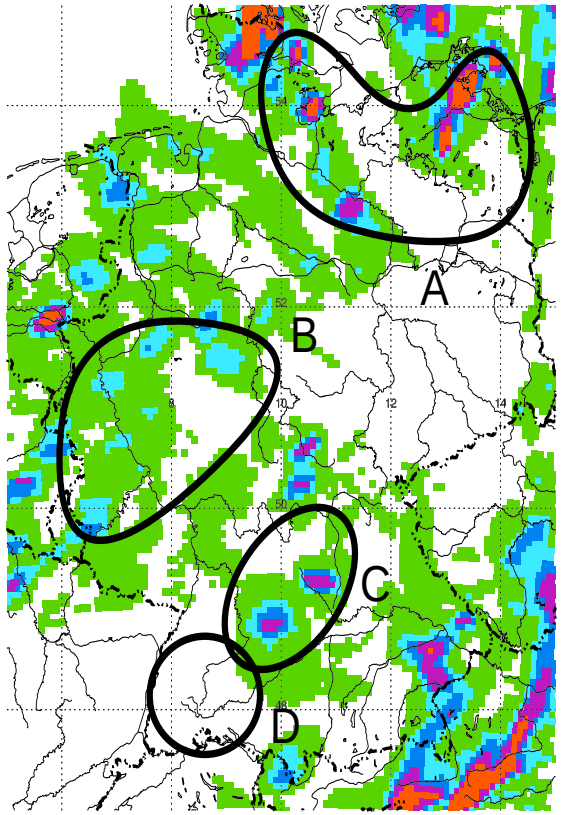
observations



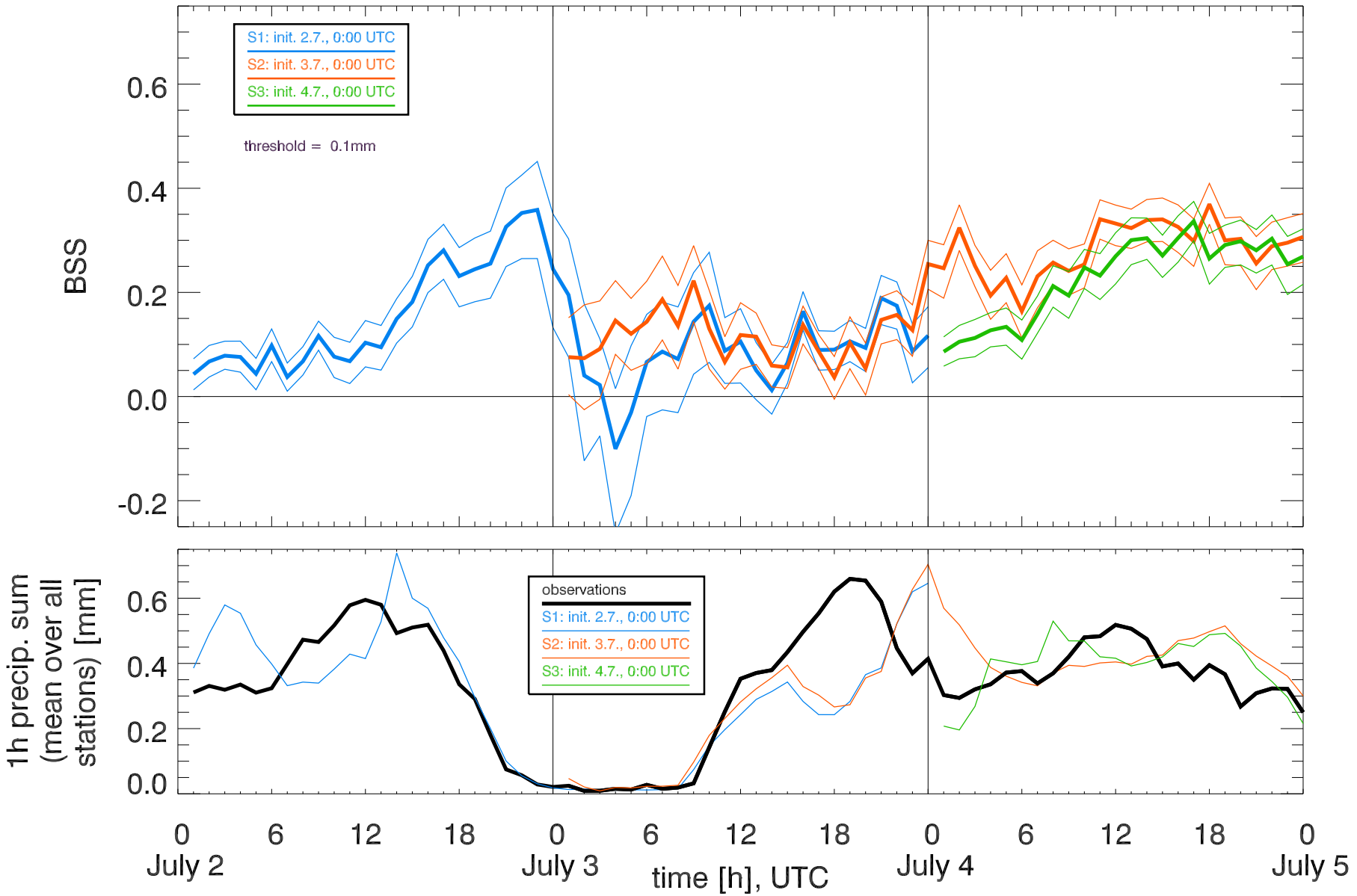
determin. ctrl. sim.



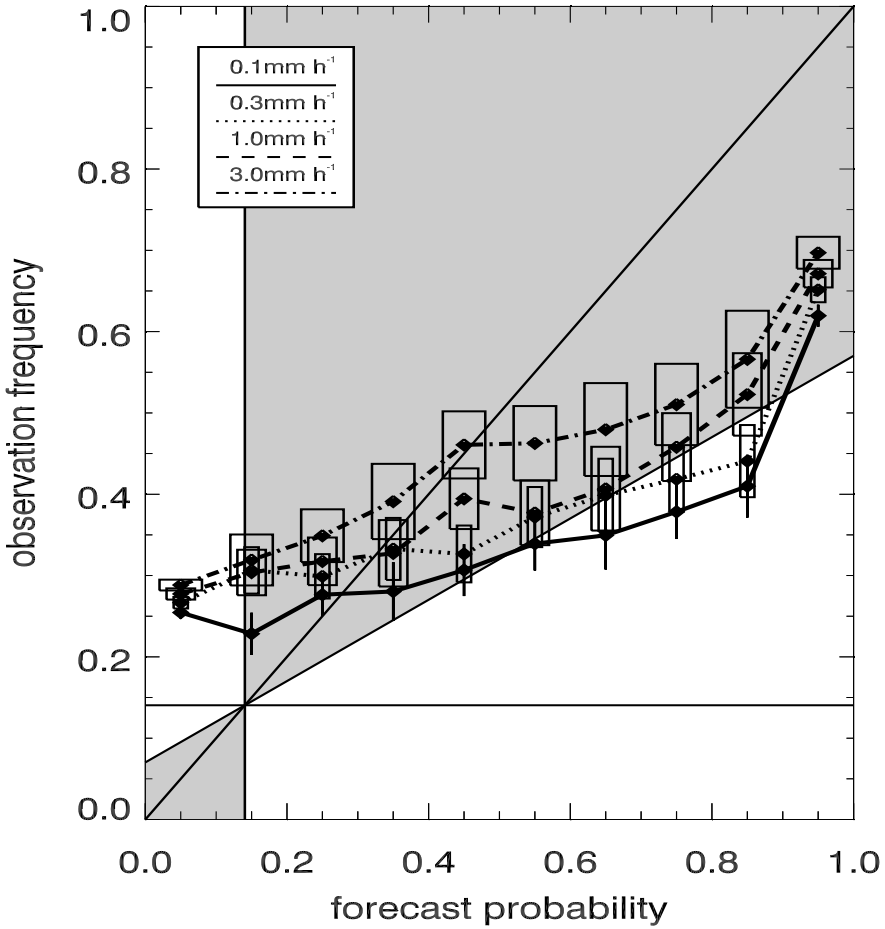
ensemble mean

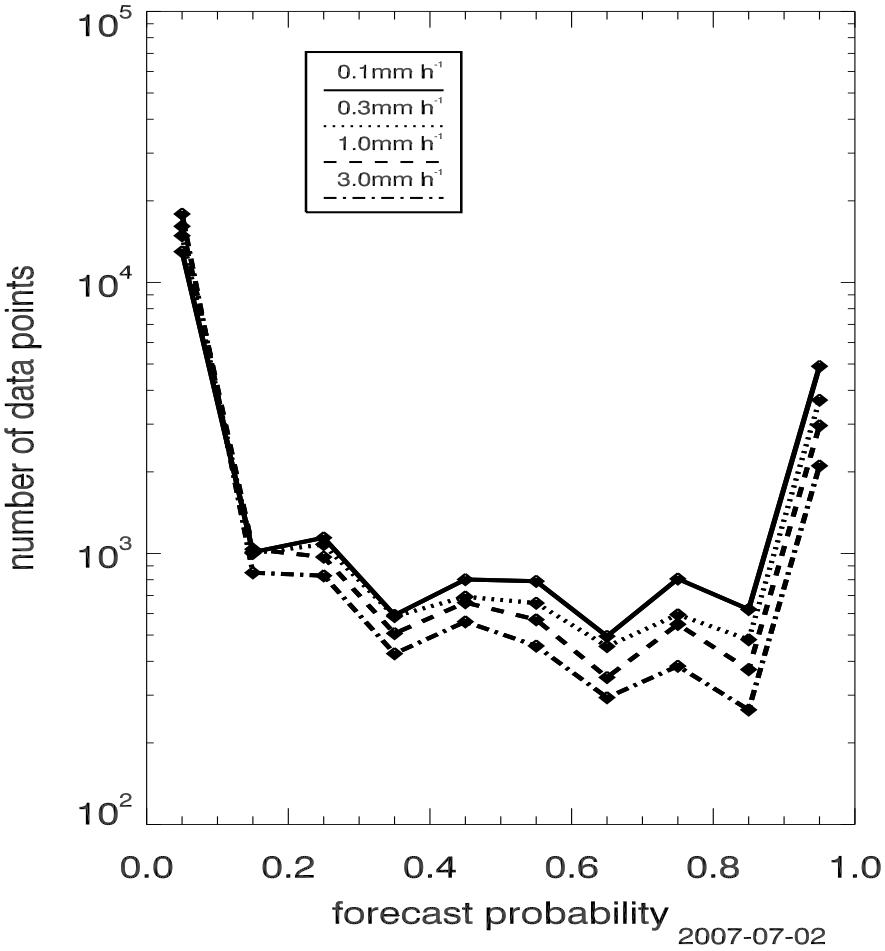


BSS and spin up effects



Attributes diagram, 2.7.2007





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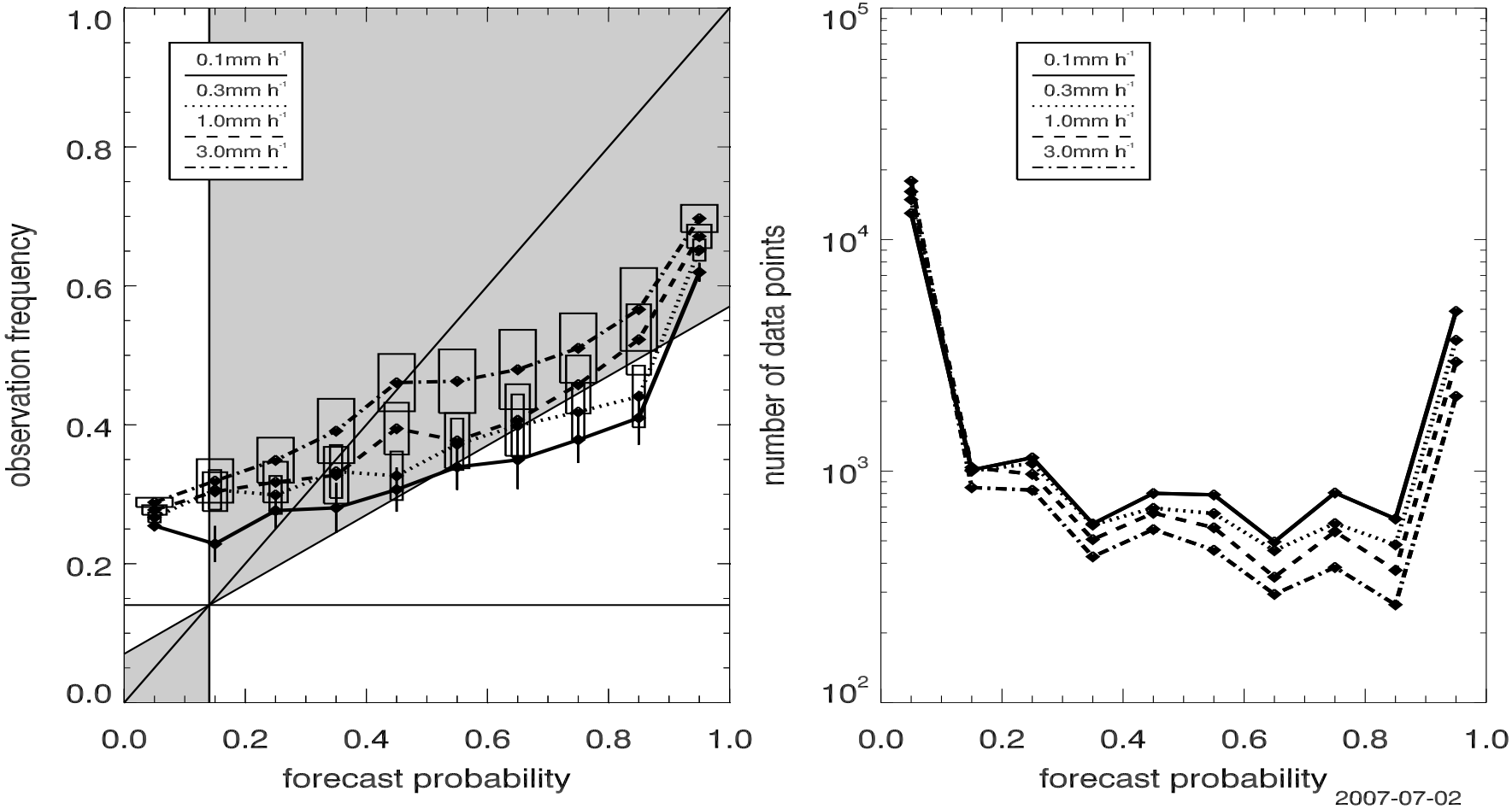
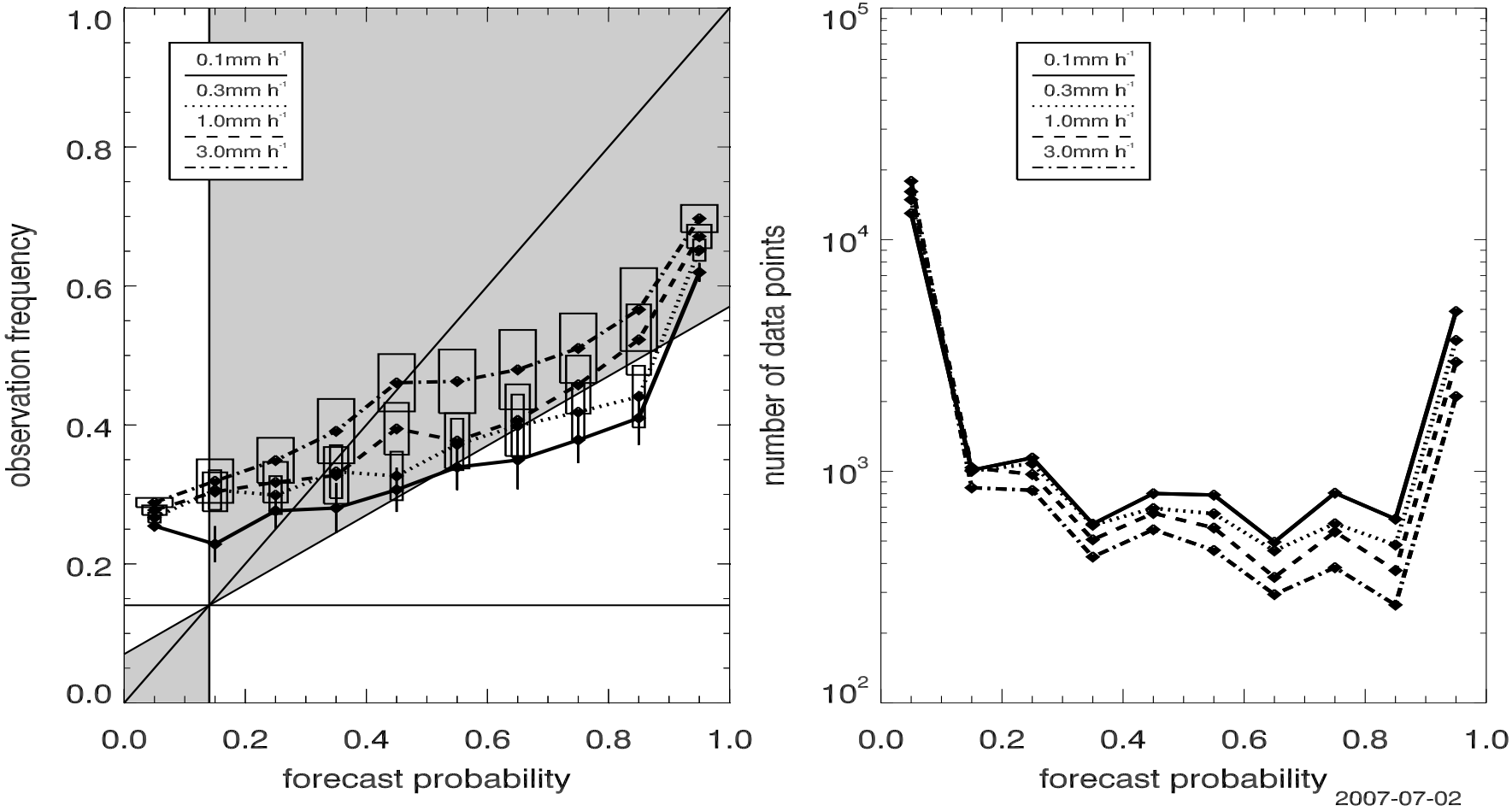


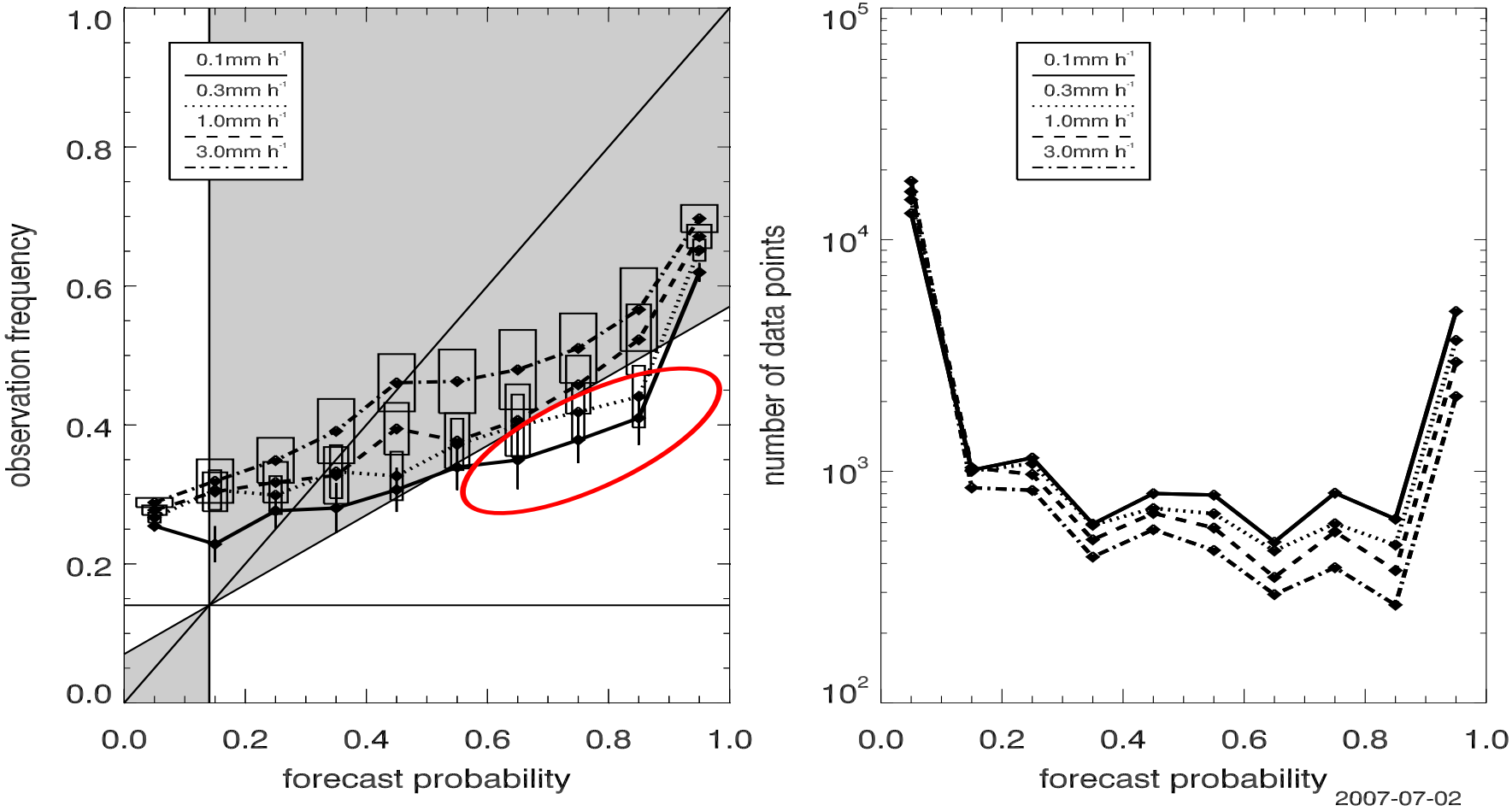
more data below diagonal → small model wet bias

Attributes diagram, 2.7.2007



more data below diagonal → small model wet bias
calibration func. flatter than diagonal, U-shaped refinement distrib.
→ only part of spread from stoch. phys.

Attributes diagram, 2.7.2007



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calibration func. flatter than diagonal, U-shaped refinement distrib.

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neg. BSS contrib. → model too active at edges of precip. areas/weak precip.

Summary

stochastic physics for cloud related processes:

DNS $\rightarrow$ normalized turb. velocity
$\rightarrow$ turb. time scale from NWP model (TKE, EDR)
stoch. processes for turbulence-driven parameters

trigger, mixing, closure	in convection scheme,
turb. collect. kernel, init. ice concentr.	in microphys. scheme
(subgrid scale cloud fraction	in radiation scheme)

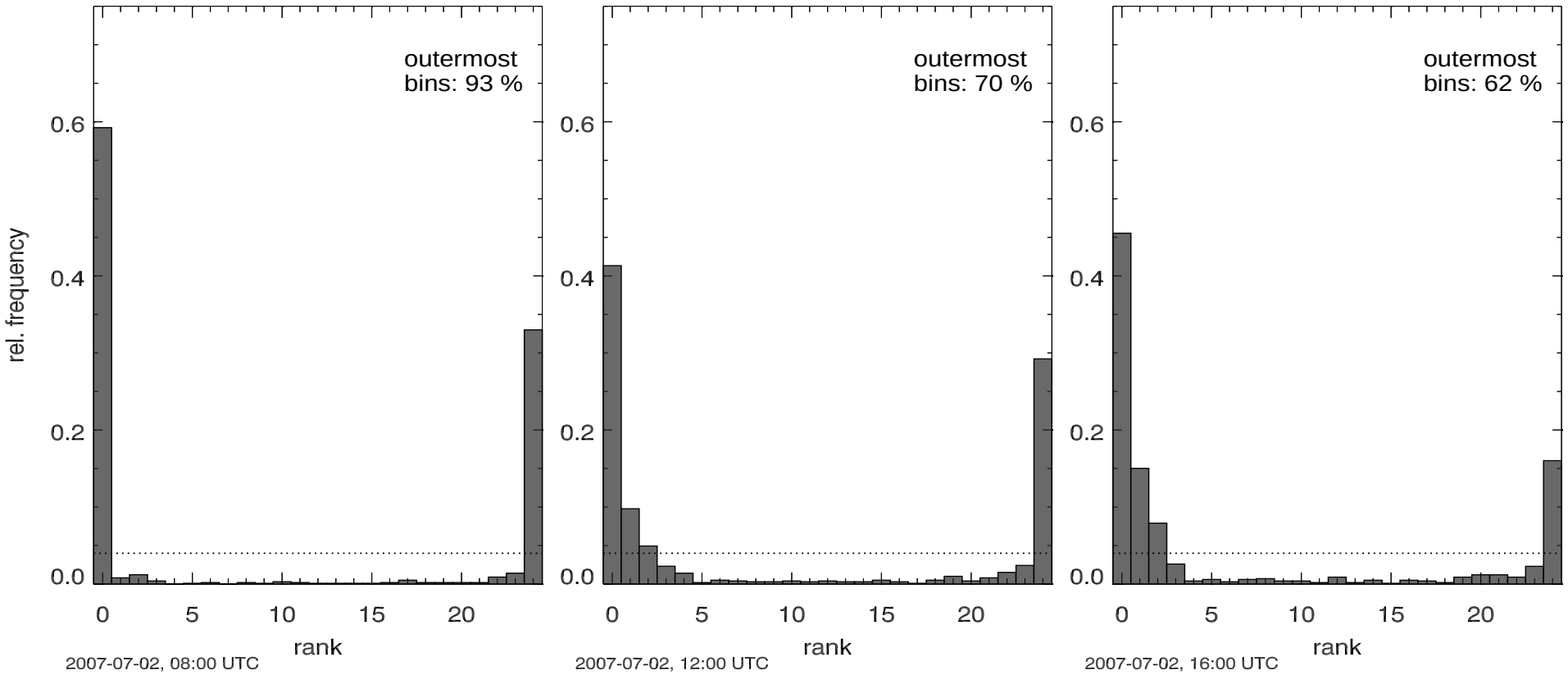
case study 2.7.-4.7.2007:

	showers	frontal precip.
BSS spin-up time	9...15 h	3 h
BSS sat. value	0.3...0.4	0.1

BSS spin-down during dry periods


Thank you for your attention !

Talagrand diagramms



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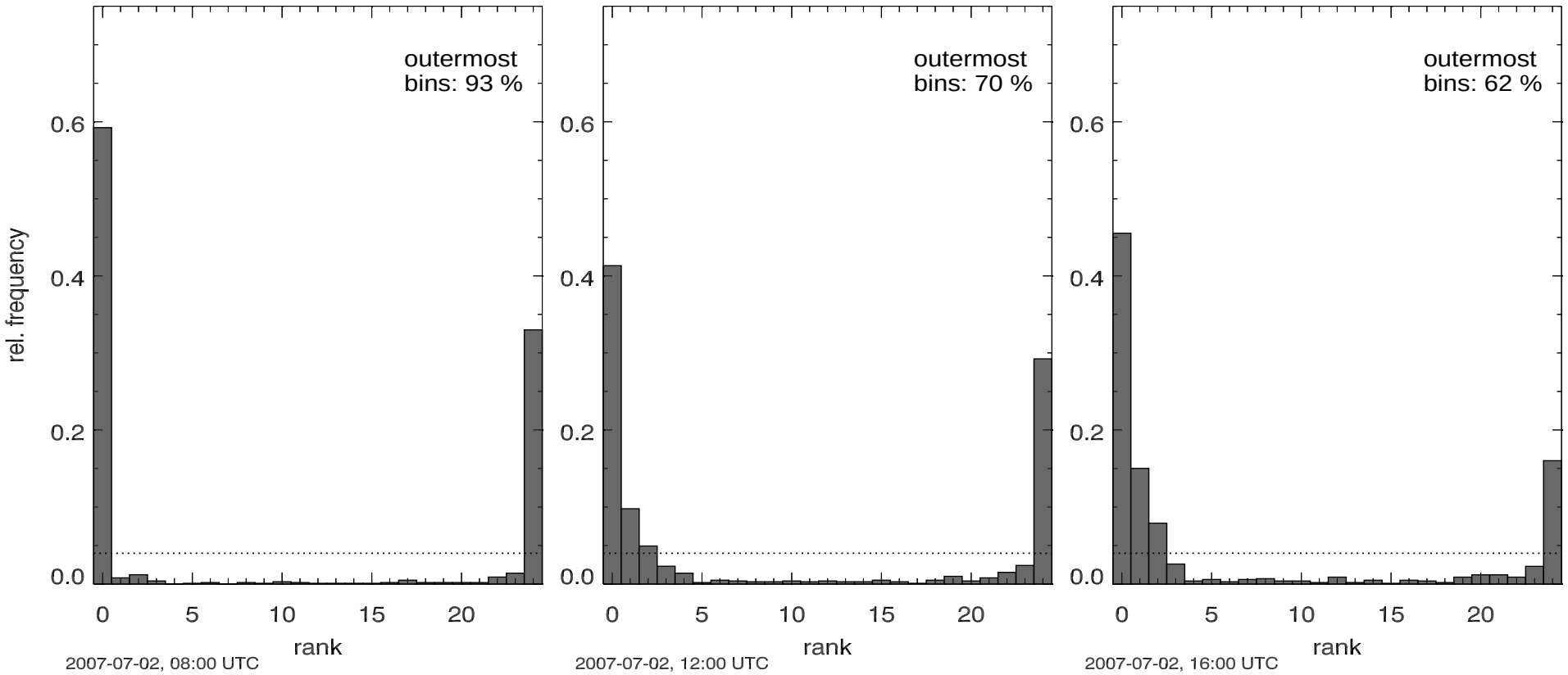
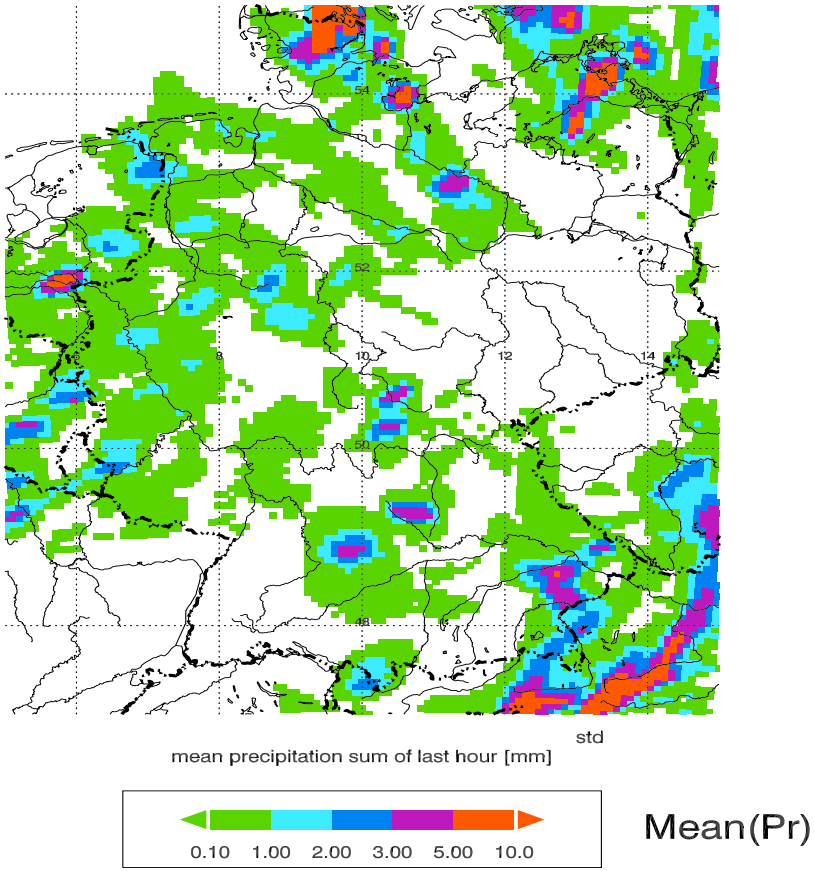


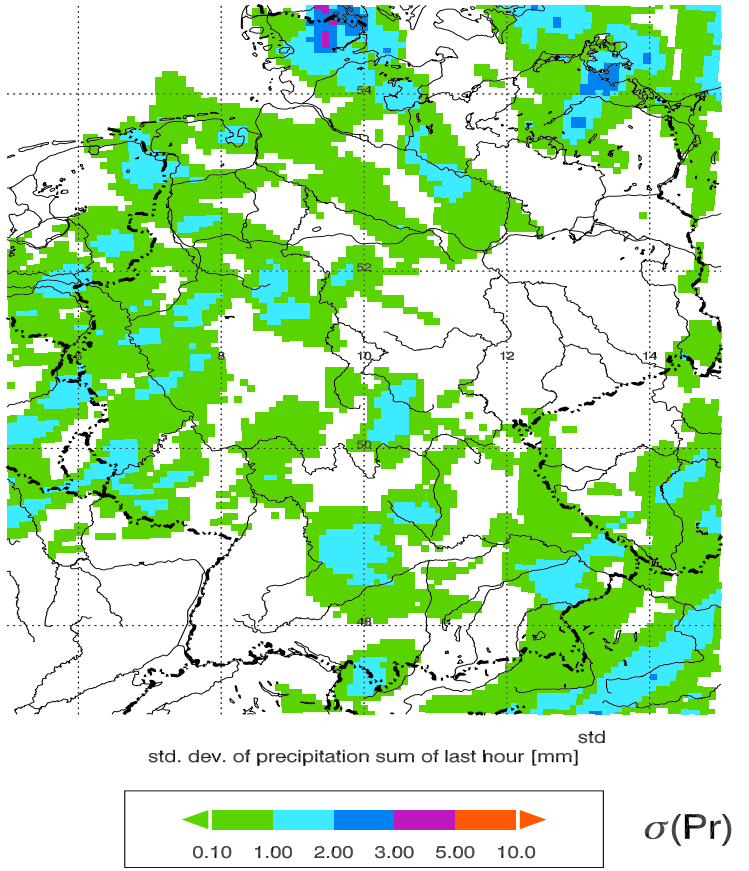
spread increases with time

underdispersive $\rightarrow$ part of spread from stoch. physics

(rest: var. of init.)

2.7.2007: ensemble spread





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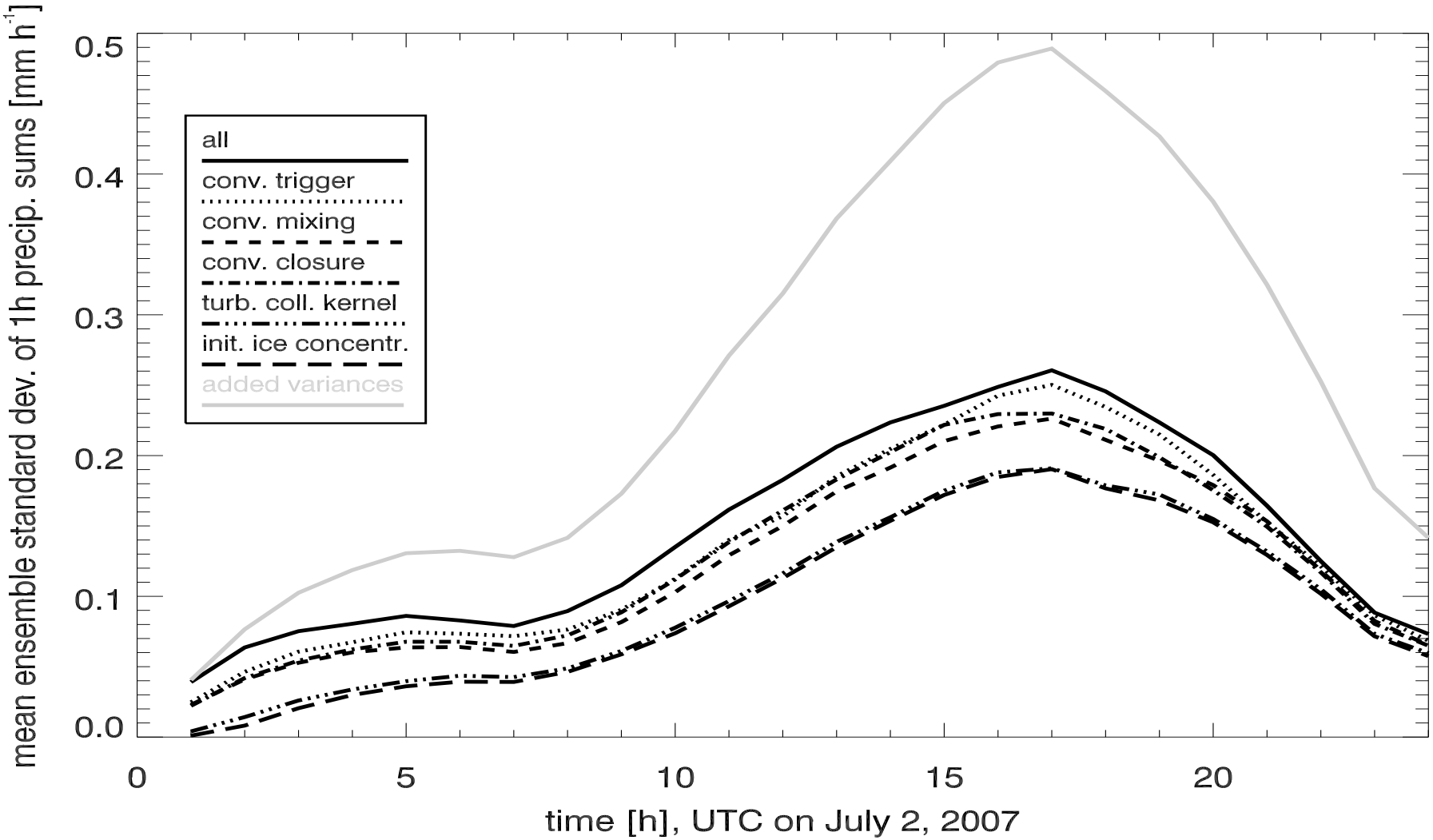

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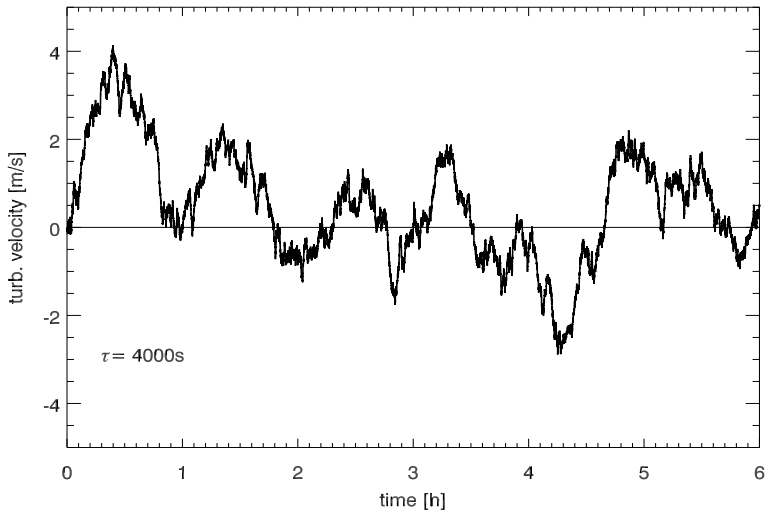
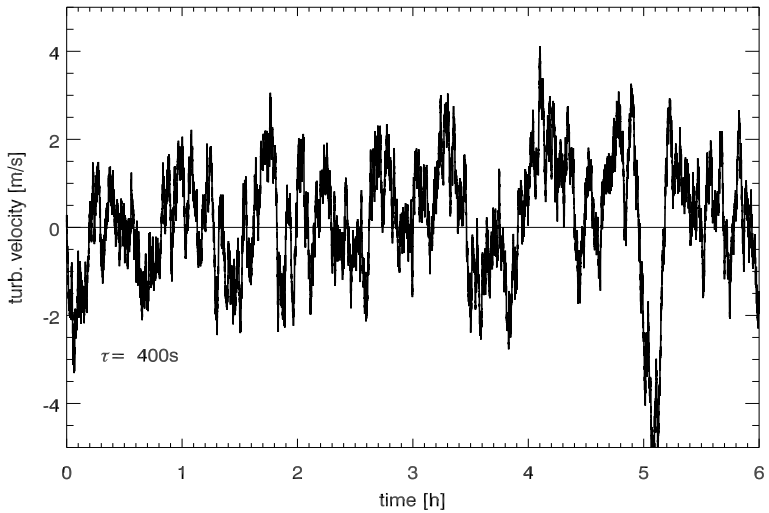
K=TKE, e=EDR, C_0=6, z(t) uncorrel. Gaussian noise

→ velocity $u(t)$ with statistical properties of tubulence





→ derive stoch. processes for turbulence-driven parameters