Why are stochastic parameterizations appealing?

Workshop on Parameterization of Moist Processes for

next-Generation Weather prediction

Jan 27-29, 2015

Judith Berner

Why are conventional parameterizations dicey?

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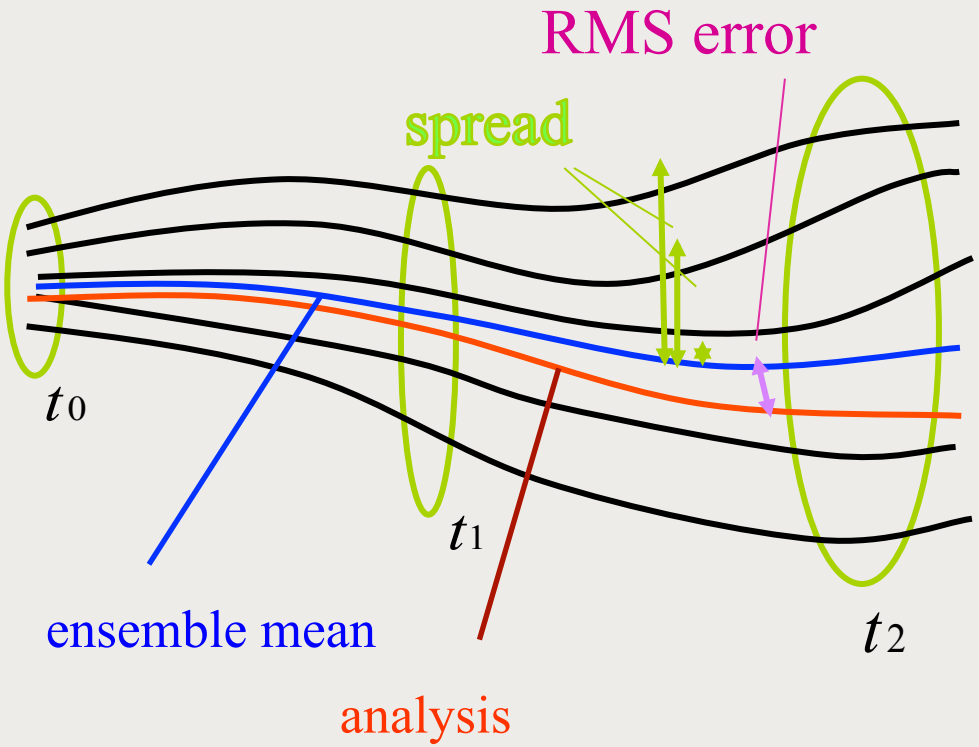
Motivation for stochastic parameterizations

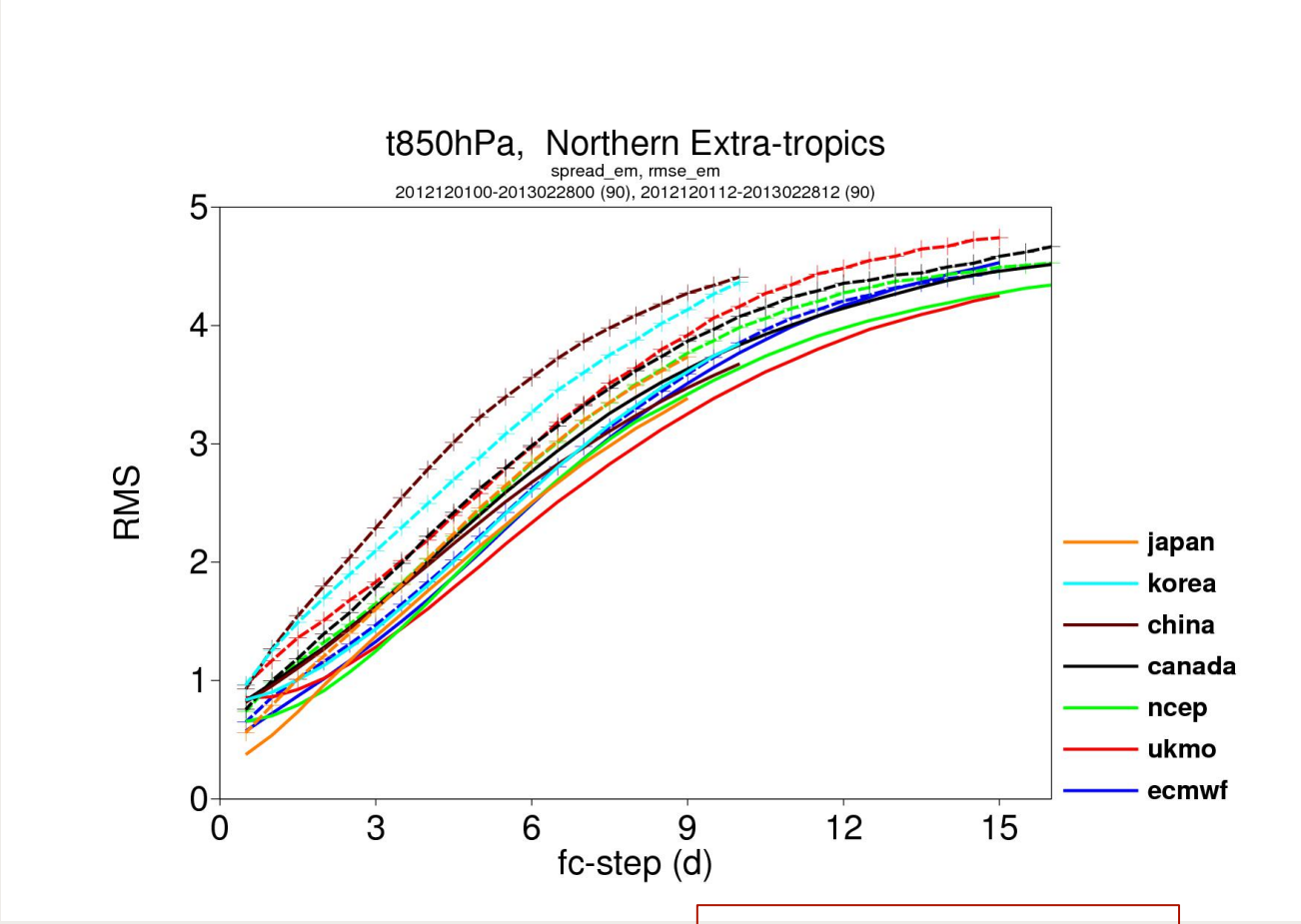
- Unreliable and over-confident ensemble forecasts
- Breakdown of quasi-equilibrium assumption at small scales
- Persistent systematic errors (e.g. blocking)
- Scale-aware parameterization

Representing initial uncertainty by an ensemble of states

- Represent initial uncertainty by ensemble of states
- Flow-dependence:
  - Predictable states should have small ensemble spread
  - Unpredictable states should have large ensemble spread
- ***Ensemble spread should grow like RMS error***
- True atmospheric state should be indistinguishable from ensemble system



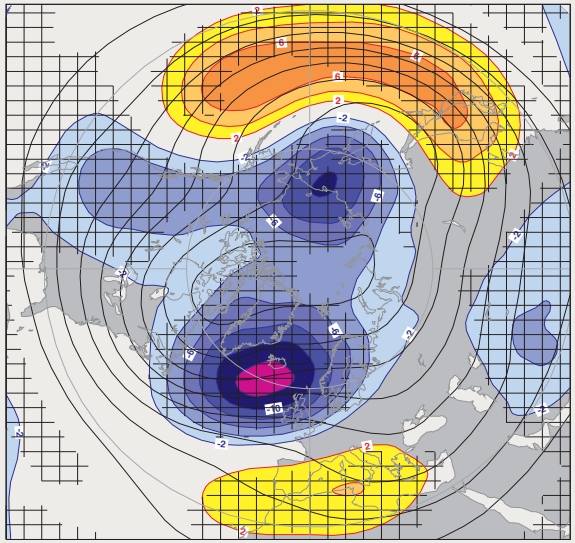
Spread and error, T850 over NH, for winter 2012-13 (90 cases)



TIGGE Curtousy Buizza

Mean systematic error of 500 hPa geopotential height fields

z500 bias in IFS
CY31R1, T95



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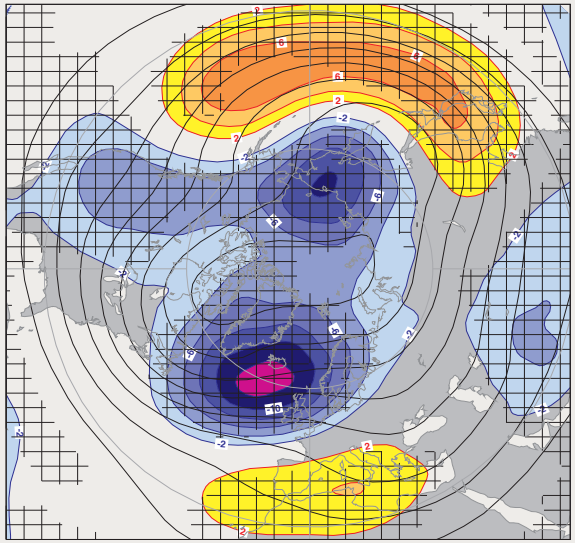
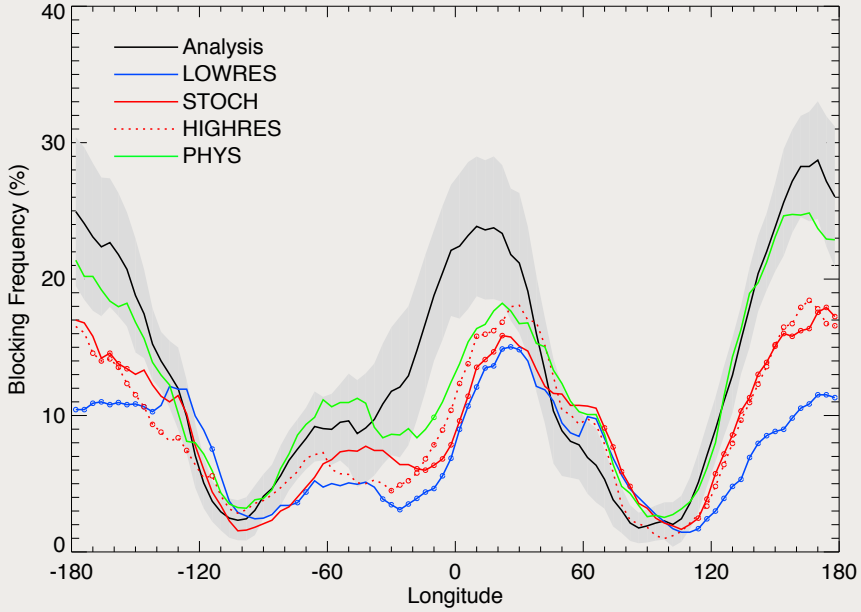
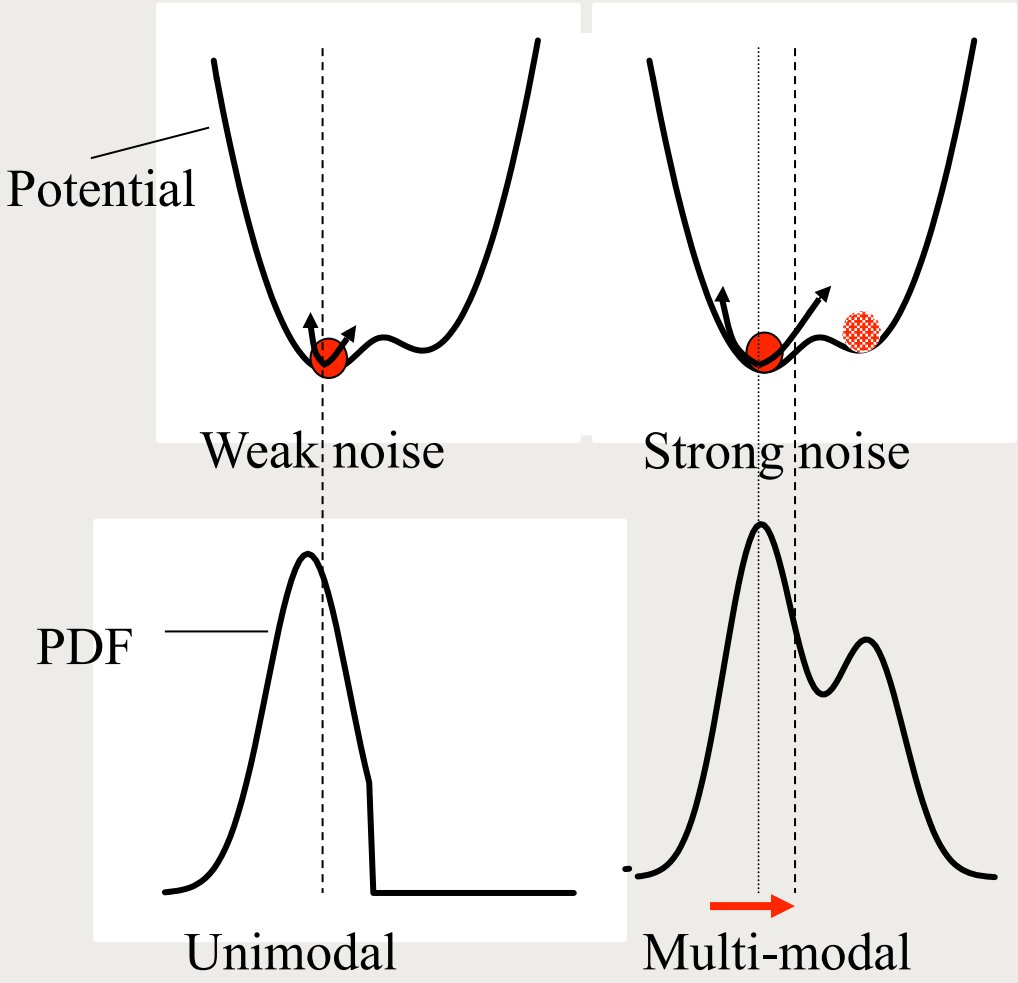




Potential to reduce model error

- Stochastic parameterizations can change the mean and variance of a PDF
- Impacts variability of model (e.g. internal variability of the atmosphere)
- Impacts systematic error (e.g. blocking precipitation error)



Stochastic parameterization schemes

Stochastic kinetic-energy backscatter scheme (SKEBS)	Stochastically perturbed parameterization scheme (SPPT)
Rationale: A fraction of the dissipated kinetic-energy is scattered upscale and acts as forcing for the resolved flow (Shutts, 2005,Berner et al. 2009,11,12,14)	Rationale: Especially as resolution increases, the equilibrium assumption is no longer valid and fluctuations of the subgrid-scale state should be sampled (Buizza et al. 1999, Palmer et al. 2009, Berner et al. 2014)

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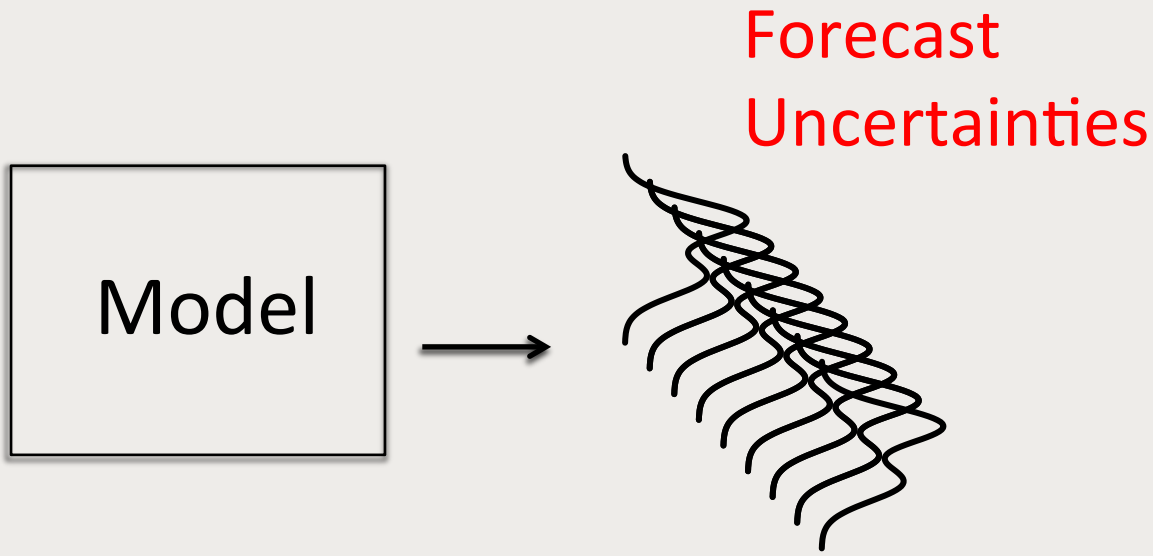
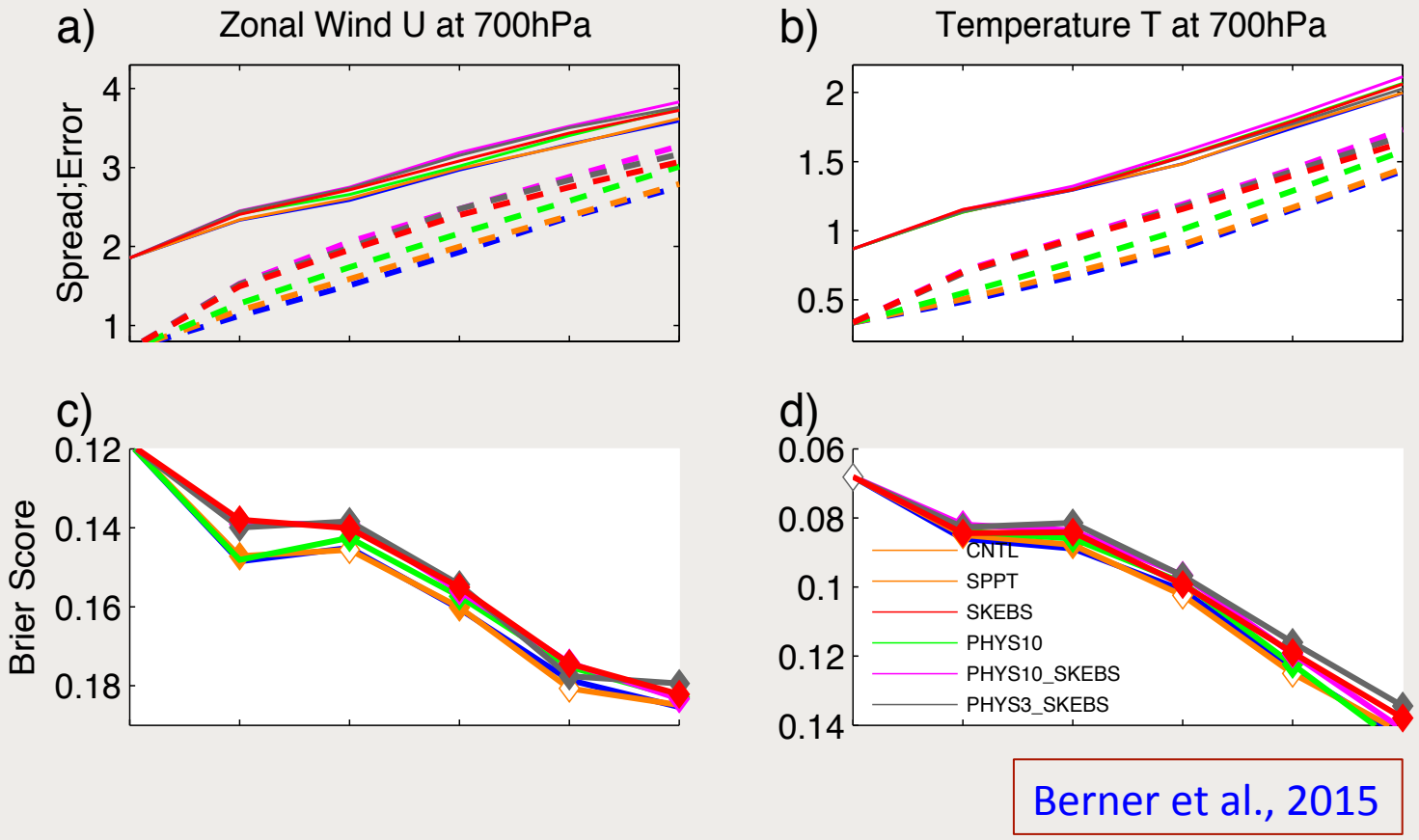
Operational at ECMWF, UK Metoffice, Tested in WRF, CMC	Operational at ECMWF, UK Metoffice Tested at DWD, Swiss Met service, Spanish Metservice

Perturbations added a posteriori



Stochastic parameterizations increase skill

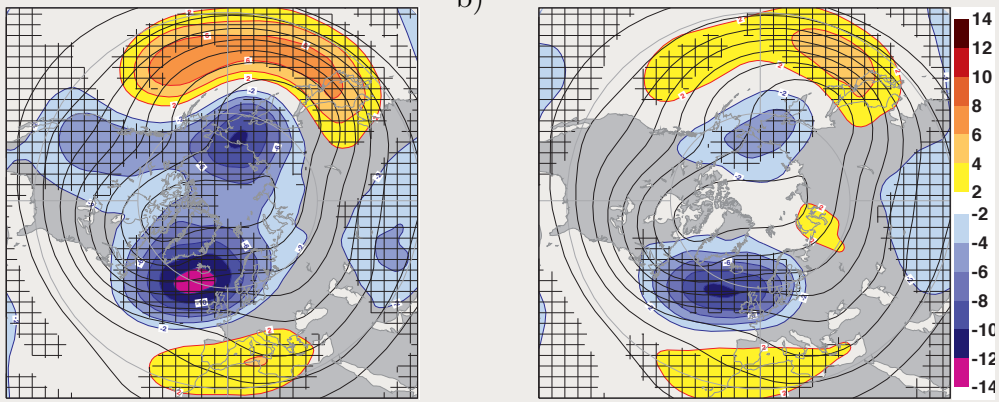


Berner et al., 2015

Mean systematic error of 500 hPa geopotential height fields

LOWRES

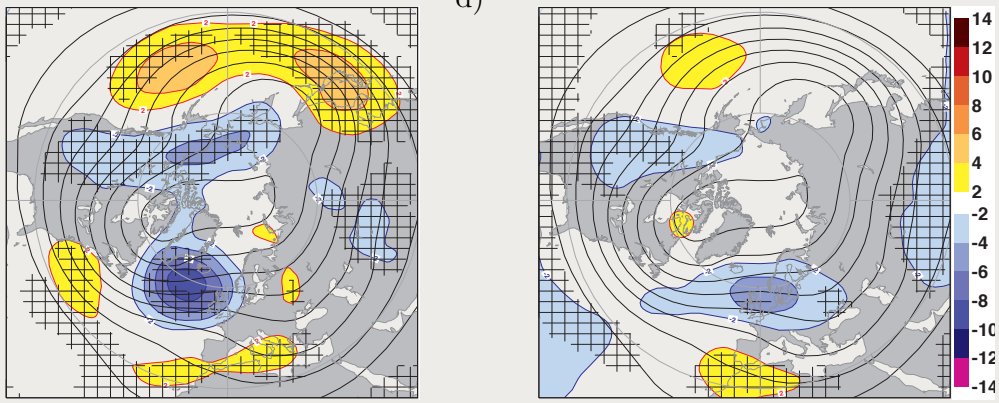
b)



SKEBS

HIGHRES

d)

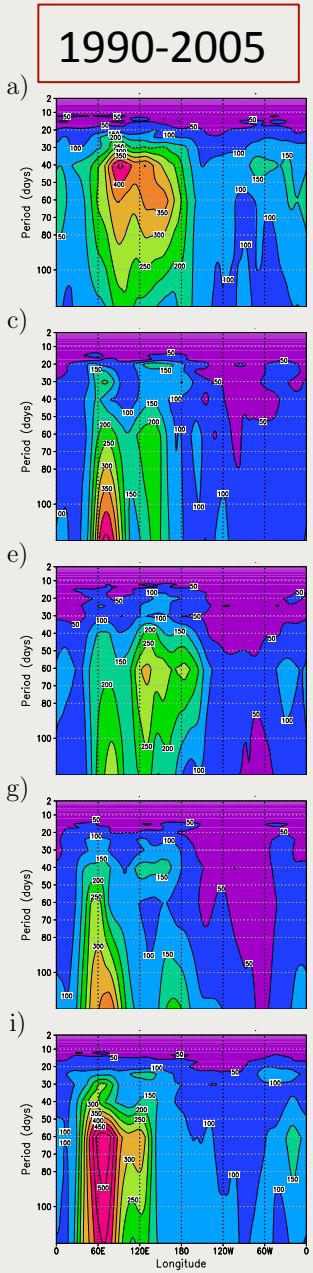


PHYS

- Reduction of z500 bias in all simulations with model-refinement
- Degenerative response

Berner et al., 2012

1990-2005



Obs

LOWRES

SKEBS

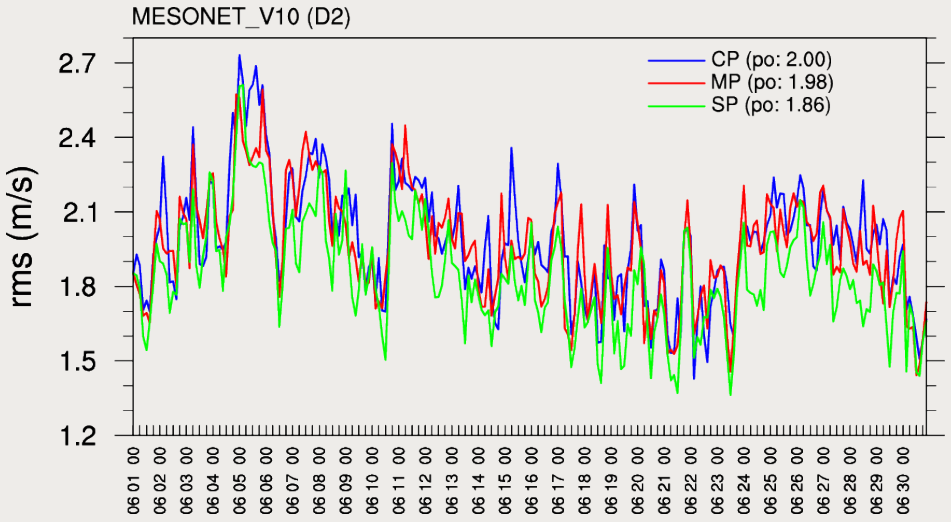
HIGHRES

PHYS

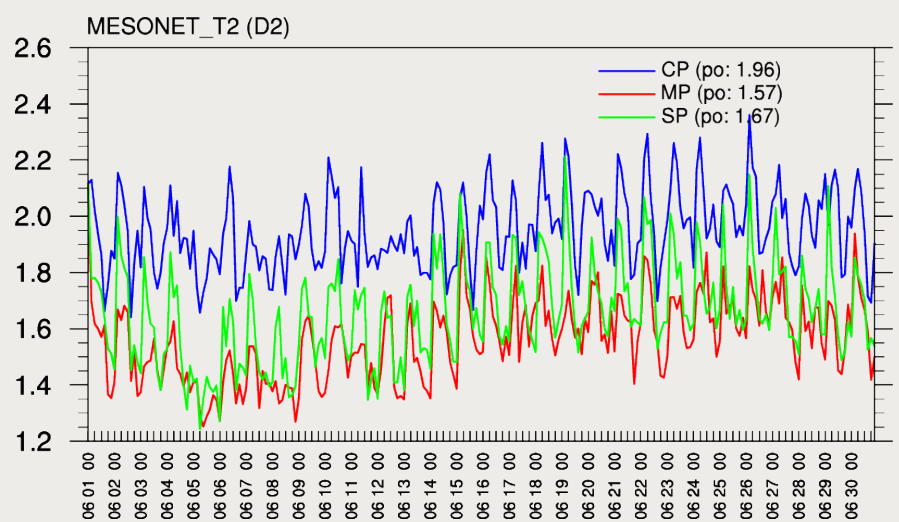
Power spectra of tropical velocity potential anomalies at 200 hPa

Verification of surface analysis against independent observations

V-10m



T-2m



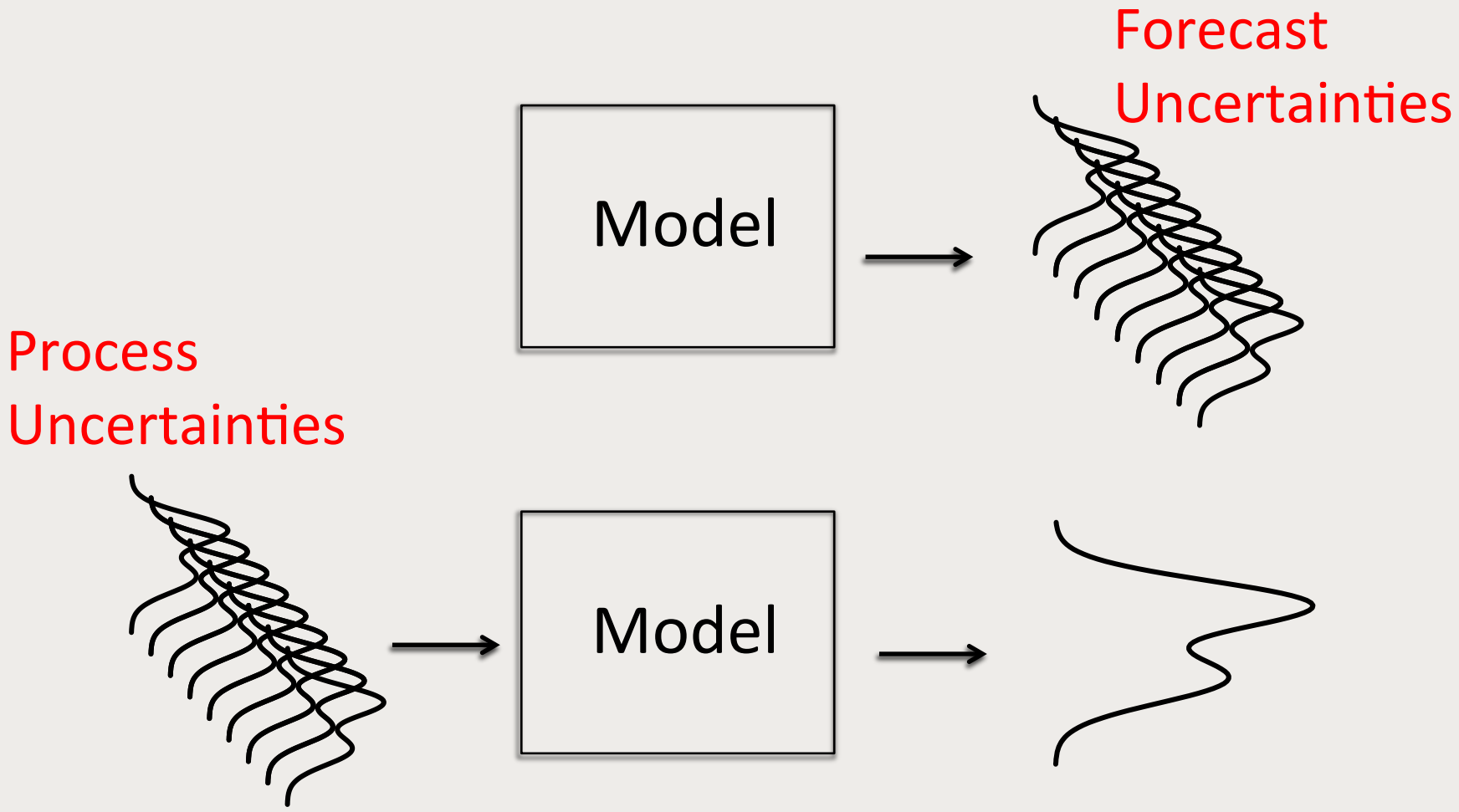
CNTL
SKEBS
PHYS

- Including a model-error representation reduces the RMS error of the surface analysis
- SKEBS has smallest error for 10m-wind; PHYS for 2m temperature

Ha et al 2014, submitted

- Chris Bretherton “Computational efficiency is not an afterthought”
- “Uncertainty assessment is not an afterthought”

A priori vs a posteriori



A priori vs a posteriori

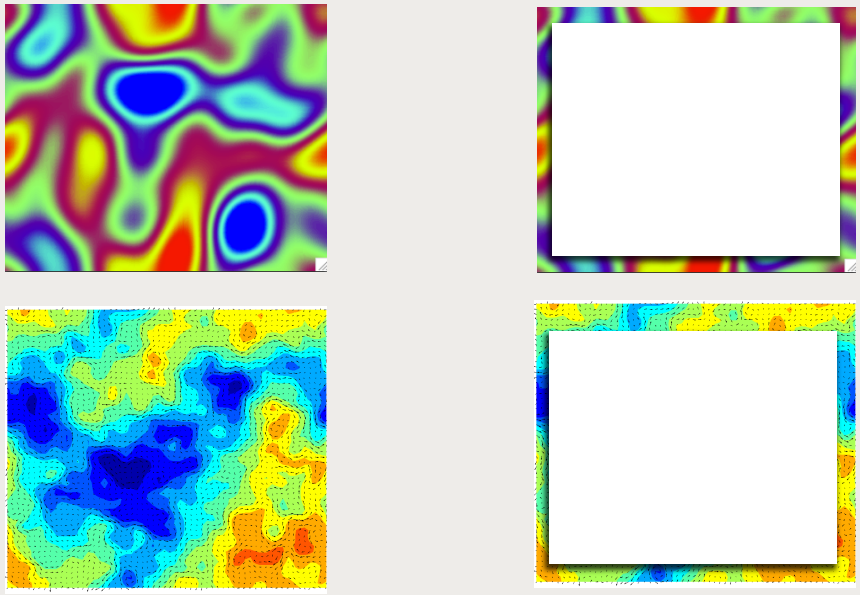
- If you develop a parameterization, I urge you to develop an uncertainty scheme alongside – OTHERWISE I WILL …

… and you don’t want that!

Your Parameterization scheme

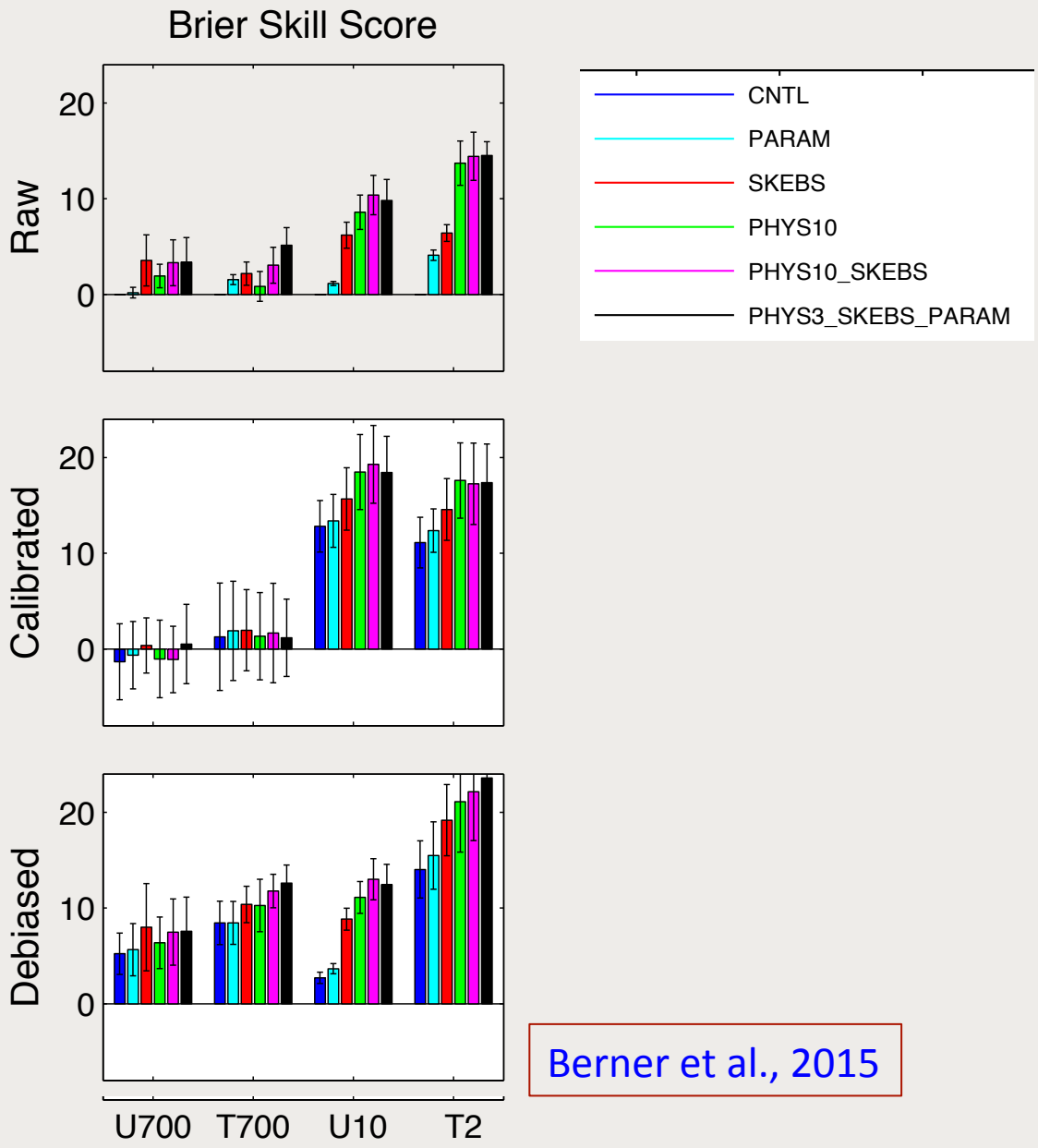
… and you don’t want that!

WRF3.7:Random Fields



- Random pattern can be used to perturb user specific fields, e.g., lower boundary conditions or parameters
- SKEBS or SPPT pattern can now also be used to perturb the lateral boundaries
  - Either in conjunction with interior SKEBS perturbations or just as lateral boundary perturbation

Importance of Bias



Berner et al., 2015

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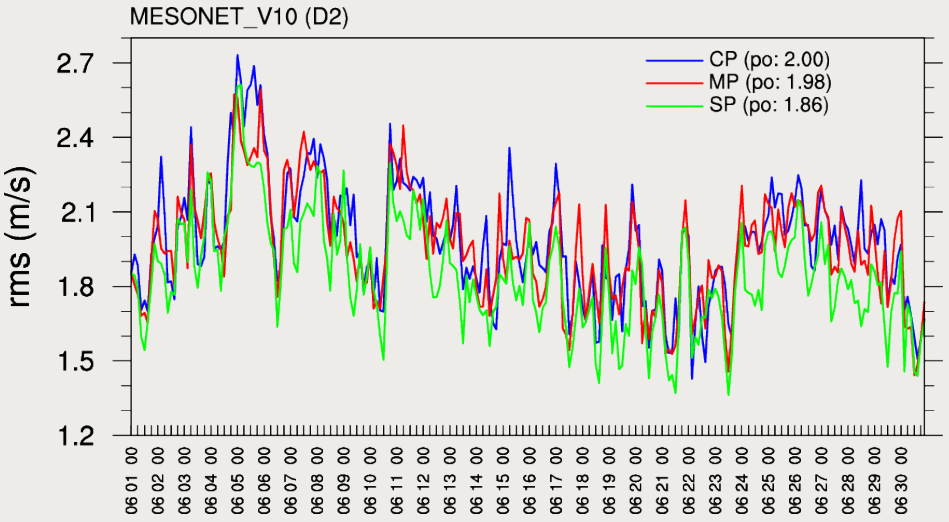
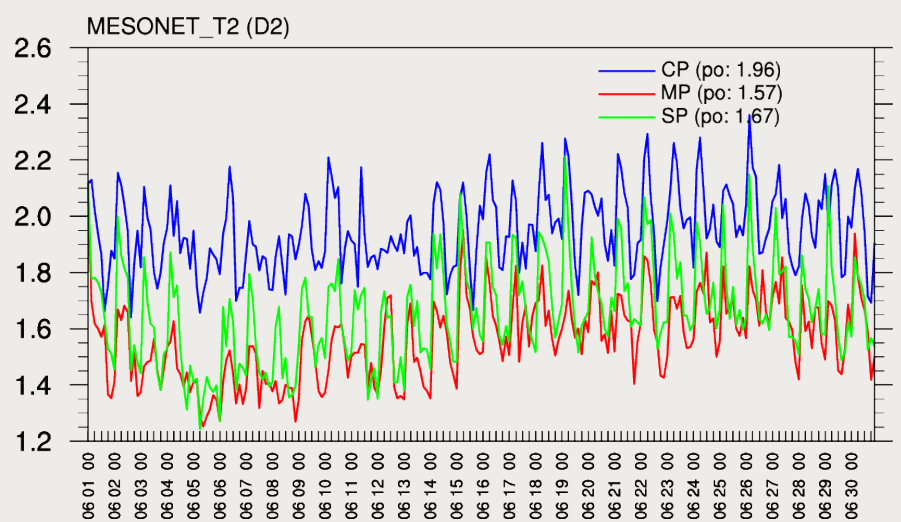


T-2m



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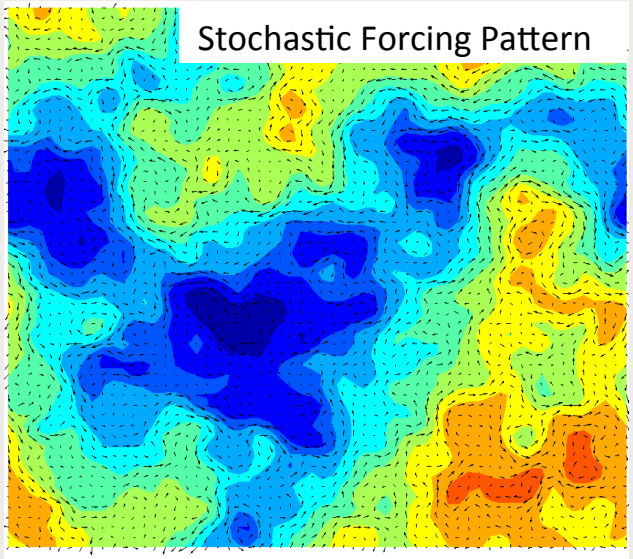
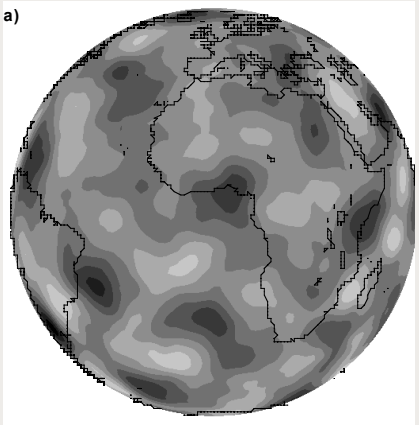
Ha, Berner, Snyder, 2014



Stochastic-kinetic energy backscatter scheme (SKEBS)

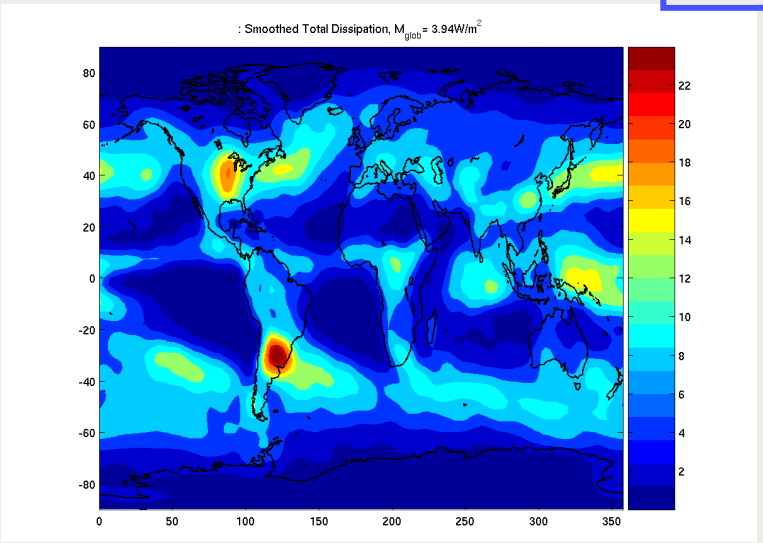
- Rationale: A fraction of the subgrid-scale energy is scattered upscale and acts as random streamfunction and temperature forcing for the resolved-scale flow. Here: simply considered as additive noise with spatial and temporal correlations
- Similar to ECMWF global ensemble system (Shutts 2005, Berner et. al 08,09) but with constant dissipation rate and potential temperature perturbations (Berner et al. 2011).



Stochastic kinetic-energy backscatter scheme

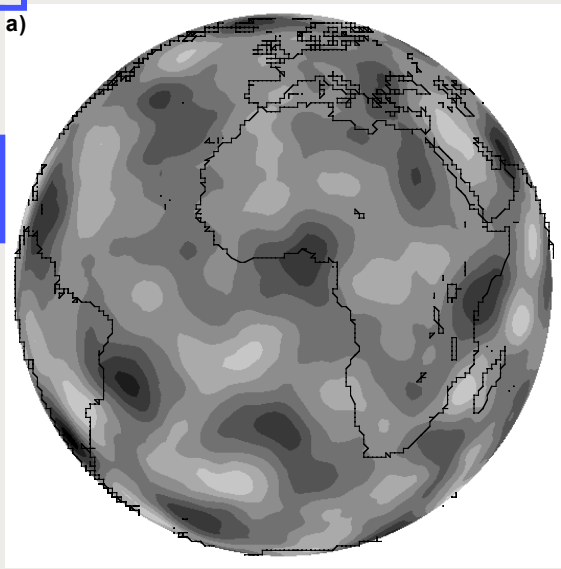
Rationale: A fraction of the dissipated energy is scattered upscale and acts as streamfunction forcing for the resolved-scale flow

$$\Delta\psi^* \propto \sqrt{D}\psi'$$



Total Dissipation rate from numerical dissipation, convection, gravity/mountain wave drag.

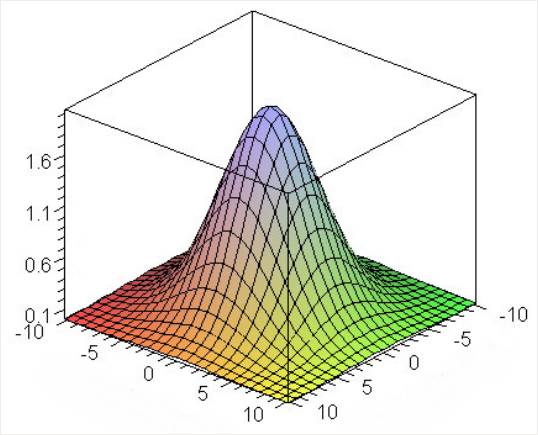
ψ'



Spectral Markov chain: temporal and spatial correlations prescribed

Stochastically perturbed tendency scheme (SPPT)

Rationale: Especially as resolution increases, the equilibrium assumption is no longer valid and fluctuations of the subgrid-scale state should be sampled (Buizza et al. 1999, Palmer et al. 2009, Berner et al. 2014)



$$\frac{\partial X}{\partial t} = D_X + (\mathrm{r}+1)P_X$$

Local tendency for variable X

Dynamical tendencies => Resolved scales

Physical tendencies => Unresolved scales

Other mathematical relevant areas to the parameterization problem

- MMF/Superparameterization
- Emulators
- Stochastic mode reduction (MTV)
- Concept from Statistical Mechanics
- Concepts from Enthropy