Hans-Ertel-Zentrum
für Wetterforschung

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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A stochastic shallow convection scheme for operational use
- impact on ensemble spread

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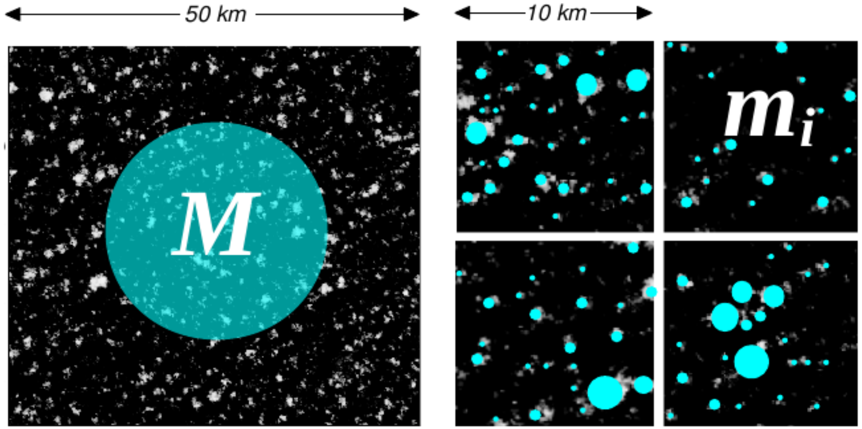
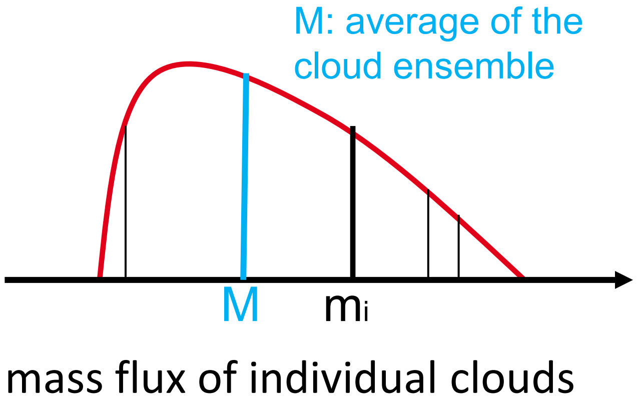
A brief history

- Prime **motivation**: scale-adaptivity in the convective greyzone (km-scales)
- Mirjana Sakradzija (MPI, HErZ) and colleagues develop an **„explicit“ stochastic shallow convection scheme**, based on LES simulation – implementation and testing in ICON (also an attempt at IFS)
- Ekaterina Machulskaya & Axel Seifert (DWD) derive an **approximation using stochastic differential equations** (SDE) to the (simpler) Plant & Craig (2008) stochastic scheme for deep convection, and Mirjana‘s shallow scheme
- Since 2019: **full implementation and testing** in ICON with a view towards operational use
  - updating SDE version, porting to NEC, general speed-up, implementing restart capabilities
- To demonstrate: scale-adaptive characteristics, forecast performance, computational performance, **benefits to ensemble spread**?

A km-scale grid box is too small to contain a representative shallow cloud ensemble

→ The resolved atmospheric state no longer predicts a **unique** (deterministic) convective state – there are many possible realisations!



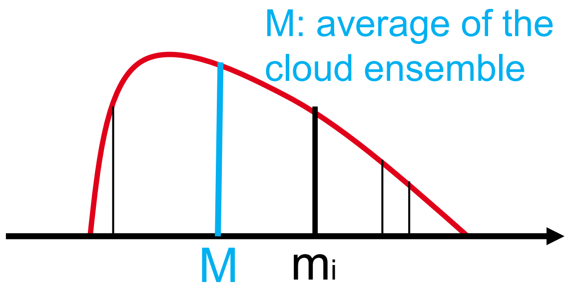


M: mass flux of the ensemble *mi: mass flux of an individual cloud*

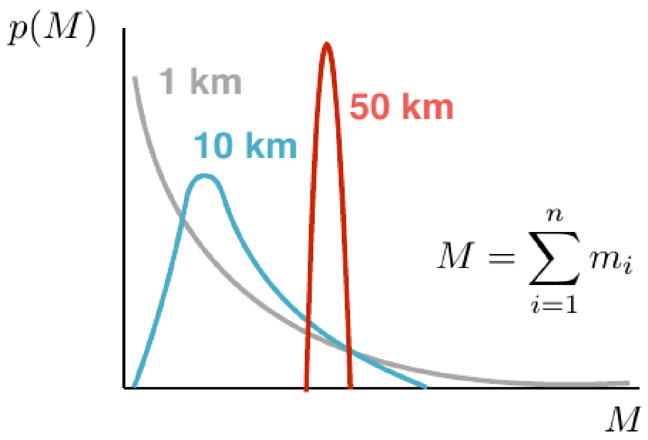
→ **The stochastic convection scheme adresses this particular limitation of conventional convection parameterizations**

Scale-adaptivity

- The scheme **adapts to the grid resolution**. The smaller the grid cell, the greater the mass flux departure from the large-scale „bulk“ mass flux
- “Bulk” mass flux representative of a larger area is stochastically **re-distributed in space**, memory of individual grid points* on time scales of shallow convective clouds (~1hour)
- By construction, mass flux averaged over larger area **converges** back to “bulk” mass flux from Tiedtke-Bechtold closure



mass flux of individual clouds



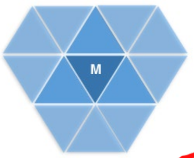
Stochastic scheme + Tiedtke-Bechtold

Tiedtke-Bechtold

1) Average input profiles over neighbourhood

2) Do test-parcel ascent (trigger!), plume calculation and mass flux closure to get **bulk MF <M>**

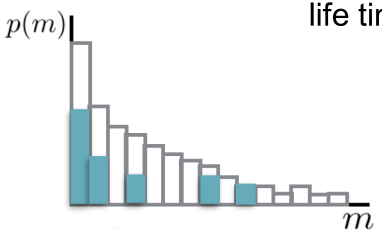
6) Finish Tiedtke-Bechtold calculations, **replacing the bulk MF with the stochastically perturbed MF** to generate convective tendencies
7) Check cloud depth and **decide whether grid point is shallow** or deep – switch off deep points



3) Construct the mass flux distribution. Distribution parameters include **<M>** and the **Bowen ratio**

$$p(m) = \frac{k}{\lambda^k} m^{k-1} e^{-\left(\frac{m}{\lambda}\right)^k}$$

4) Stochastically **generate clouds** (Poisson) within each grid cell, and assign each a **„perturbed“ MF** and life time.



5) Add up mass flux (m) of individual clouds to get the **grid box mean mass flux (mi)**

(Craig and Cohen 2006; Plant and Craig 2008; Sadkradzija et al. 2015, 2016; Sakradzija and Hohenegger 2017, Sakradzija and Klocke 2018)

How does the stochastic scheme impact spread?

… and how do we best measure it?

- First step: Consider spread of ensemble forecast only
- BACY LAM ENS forecast experiments:
  - Identical initialisation of 20 members
  - Spread **only** from stoch conv, or convection parameter perturbations (PPconv)
    - PP: +/- sigma (additive/multiplicative) – constant in time and space
    - *Buoyancy of test parcel, dilution of test parcel, cloud depth*
  - Analyse tendencies of qv, T from convection parameterization from single case, 10-12UTC (when parameterised convective activity peaks)
- Question: Could the stochastic scheme replace PP for the convection process?

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T and qv tendencies from convection (domain average)

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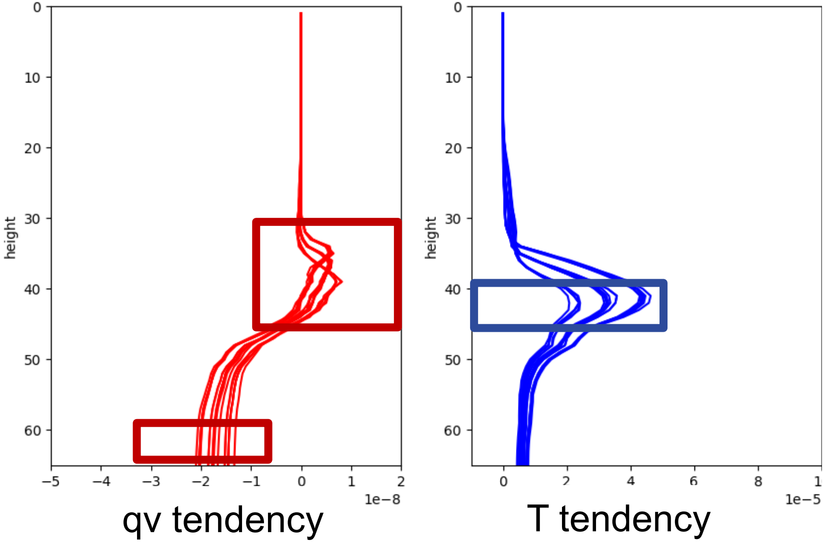
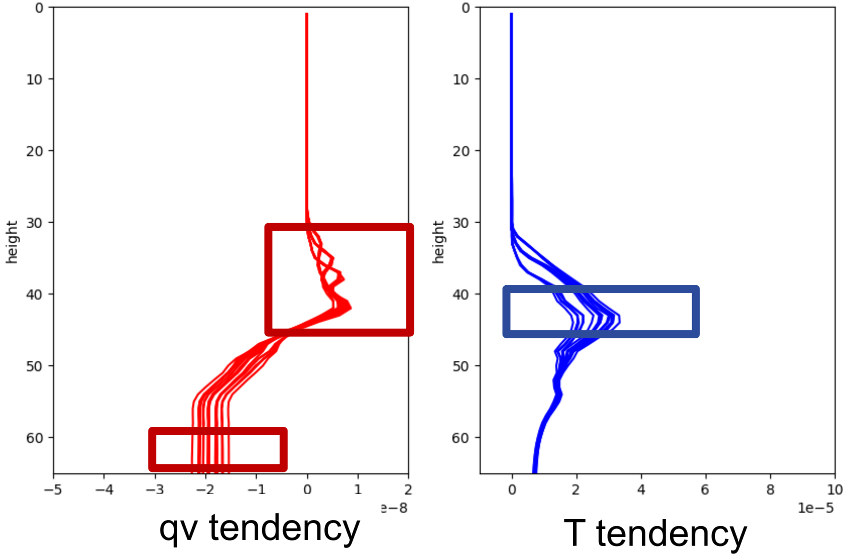
Oper (grayzone tuning off) + PPconv

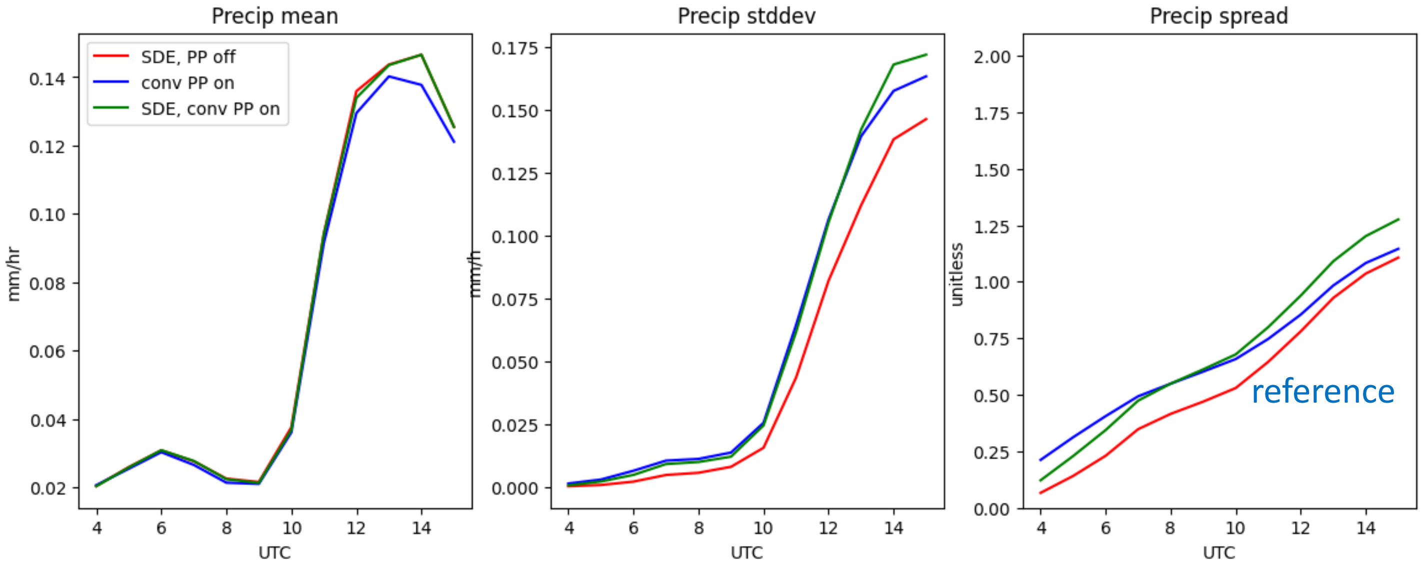


Stochastic schema + PPconv



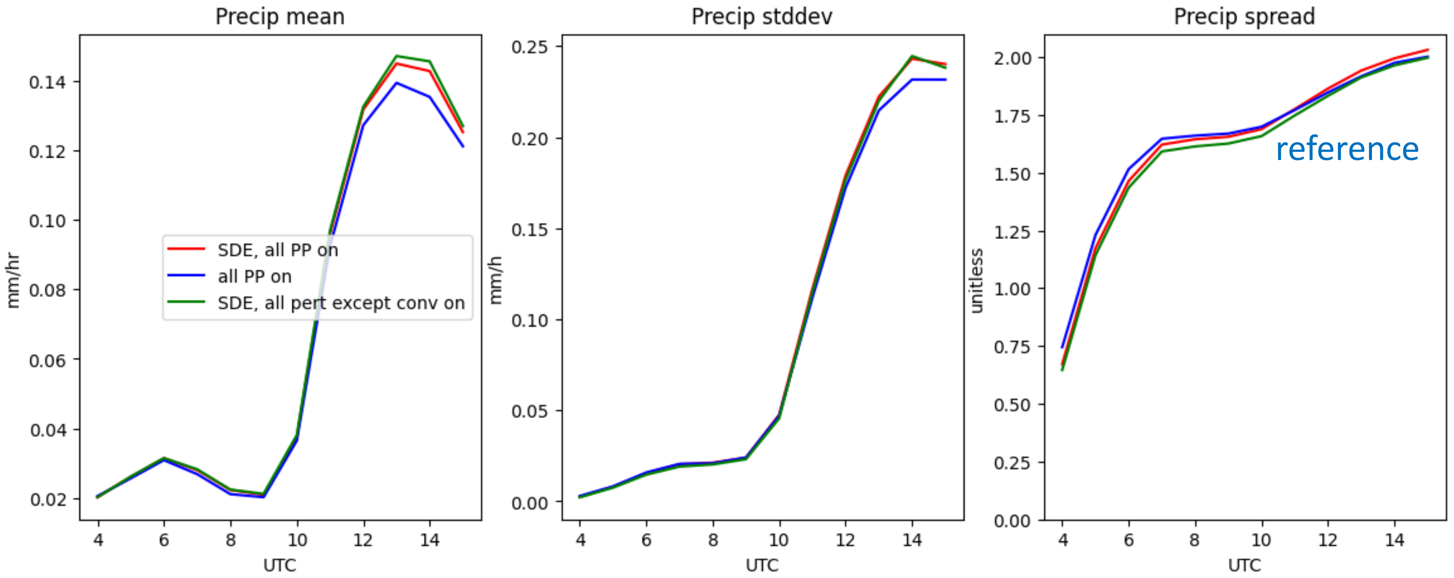
- PP produces "convection loving" and "convection averse" ensemble members: **overall convective activity differs** between ensemble members
- Domain average from the stochastic scheme is **very similar** for all members: by construction, the overall convective activity is similar for all realizations
- PP can be used in conjunction with stochastic convection

Domain-average spread for total precip



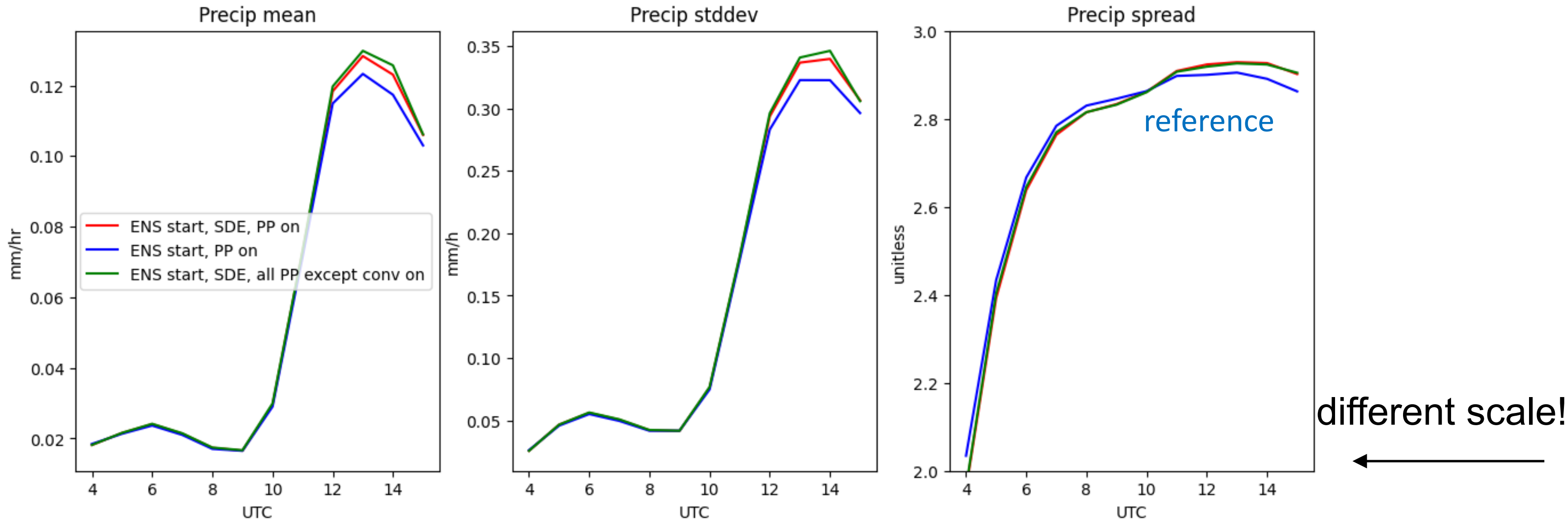
- Spread generated by SDE alone is less effective than PP applied to convective parameters only.
- SDE plus PP applied to convection parameters adds spread later in the day.
- Precip spread **indirect effect** of shallow convection via pre-conditioning (little to no convective precip)

PP active for all parameters



- Sensitivity related to convection perturbations generally fairly small.
- Adding SDE on top of the operational PP increases spread slightly.
- Replacing convective PP with SDE (while keeping other PP unchanged) leads to similar spread from about 11UTC onwards, less previously.

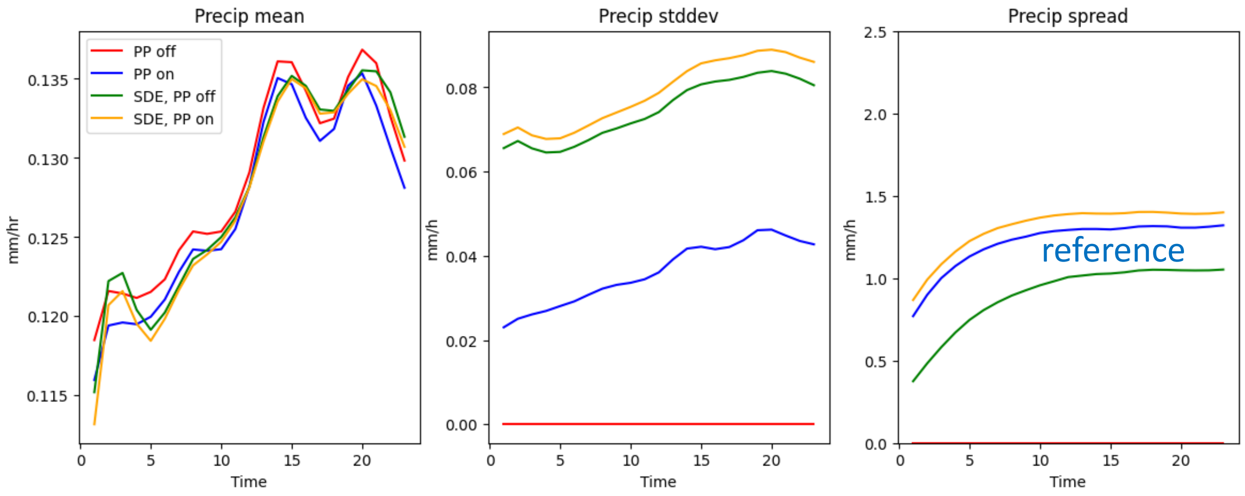
Initialise FC from 20 different members



- SDE still adds extra spread after 10UTC, regardless of whether conv PP is on/off
- Olaf Stiller: little impact on ensemble covariance (2 week RUC-style setup)
- Conclusion: in RUC-style setup, **spread from SDE is pretty negligible**
- Percentage of grid points in time/space with active param. convection is low

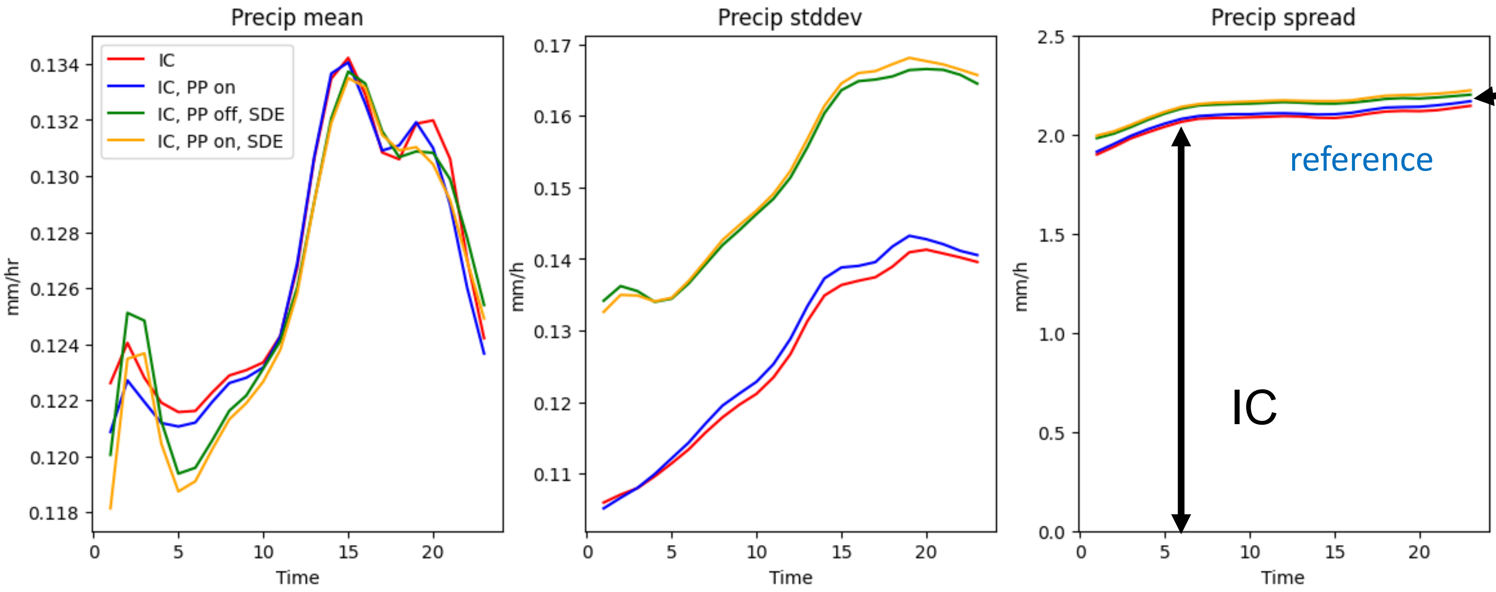
Deep SDE: global ensemble forecast

- No separate switching of convective PP parameters
- Single day, 20 members
- About 10 hours of spinup



Deep SDE alone produces a lot of spread (though less than PP)
Deep SDE plus PP adds more spread than in LAM setting.

How relevant are forecast perturbations vs. initial conditions?



tiny impact from PP

but: SDE more effective than PP (all processes)

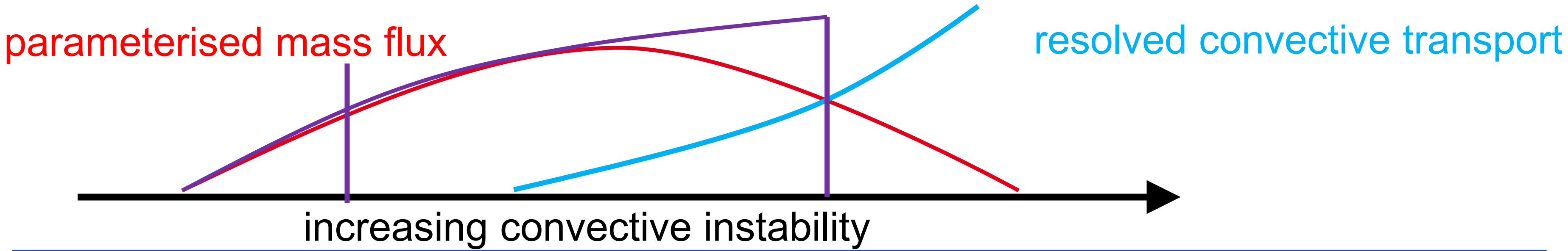
- More relevant in tropics, less in mid-latitudes
- Do we care about precip spread, or rather e.g. geopotential?

See poster: Tobias Selz (LMU)

*(Implementation) Problems:

- ➔ Binary decision on both „ends" of the (parameterised) convective activity:
  - ➔ convection trigger (on/off) decides whether grid point is convective
  - ➔ „rdepths" (cloud thickness) decides whether cloud is shallow (on) or deep (off)
- ➔ The scheme can only perturb active grid points – not possible to make „non-convective" grid points active in a different realisation

See poster: Tobias Selz (LMU)



Summary:

- SDE: scale-adaptive, fast, near-neutral in forecast performance (without tuning!)
- LAM: Shallow SDE has similar impact as PP but parameterised convection generally adds little to overall (precip) spread
- Deep SDE appears to have a more noticeable impact, but also small compared to IC
- Stochastic scheme does not produce the same kind of spread as PP
- Questions:
  - How important is it have an “offset” between members, vs. spread at a single grid point?
  - How important are rare extreme values vs. a broader peak?
  - Is it realistic to expect any/stronger signal from stoch conv in LAM setup if model is cycled for a longer time (instead of RUC setup?)
  - Do we need longer lead times (~5days) for convective perturbations to influence synoptic scales, and will see greater differences then?