Hans-Ertel-Zentrum
für Wetterforschung

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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Stochastic parameterization of shallow convection – applications, performance and limitations

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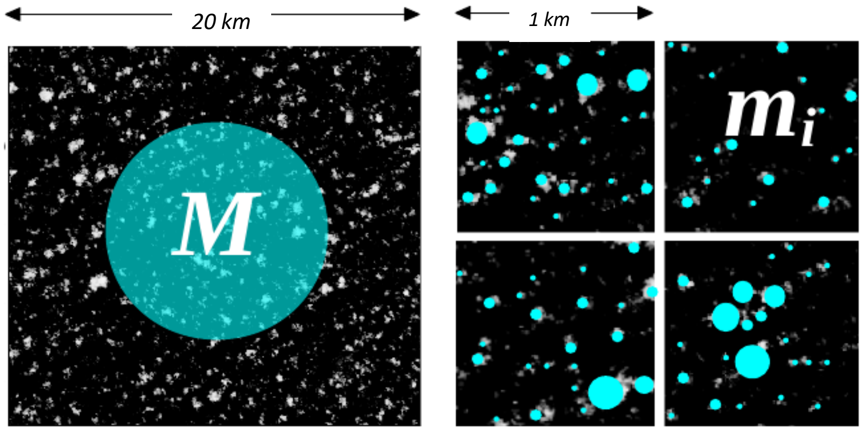
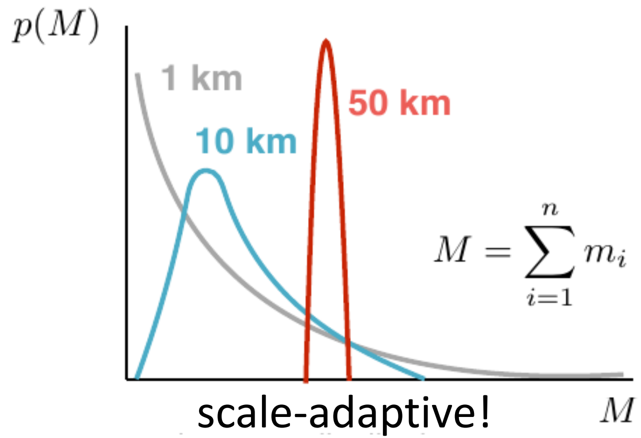
A km-scale grid box is too small to contain a representative shallow cloud ensemble

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



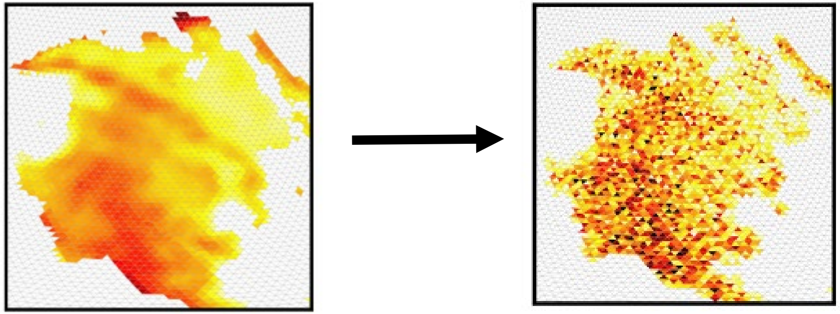
M: mass flux of the ensemble *mi: mass flux of an individual cloud*



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

Example: Southern Ocean, deep convection

large-scale MF stochastically perturbed MF



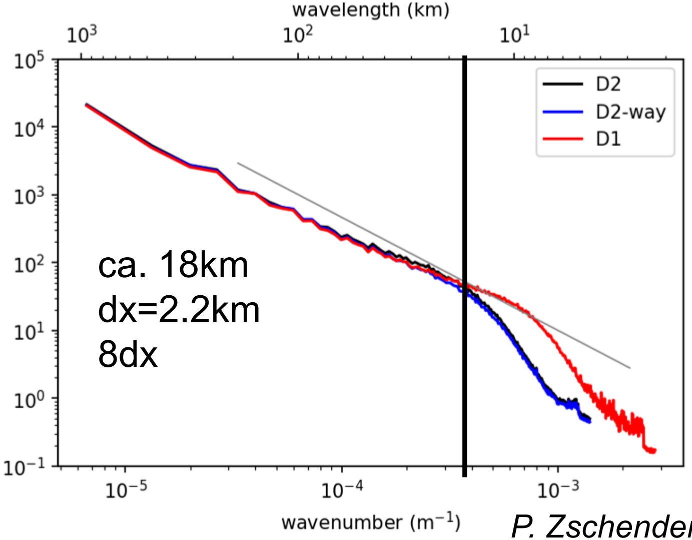
smooth random

T. Selz

- ➔ What is an appropriate size for the cloud ensemble to be represented?
  - ➔ Closure assumptions should be met (updraught fraction small, quasi-equilibrium of subcloud moist static energy)
- ➔ Greyzone perspective:
  - ➔ What scales are explicitly resolved? Scales below parameterised

- ➔ Overall magnitude of mass flux conserved – redistributed in space

2D kinetic energy (lev 50), 15UTC



P. Zschenderlein

"Marrying" the stochastic scheme to Tiedtke-Bechtold convection param.

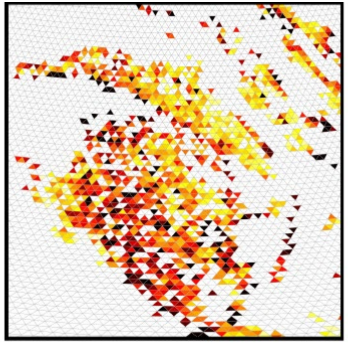
- Easy advantages:
  - Mass flux scheme
  - TB scheme calculates first guess MF, then scales fluxes and tendencies to final MF -> allows implementation with just one call to convection
  - Fast! Convection scheme 30% slower with stochastic scheme added (3.3 vs 3% of ICON D2 runtime)

- Challenging:
  - Test parcel ascent determines whether grid point is convective *before* stochastic scheme is called
  - Shallow/deep convection not clearly separated
  - Closure is directly coupled to dynamics

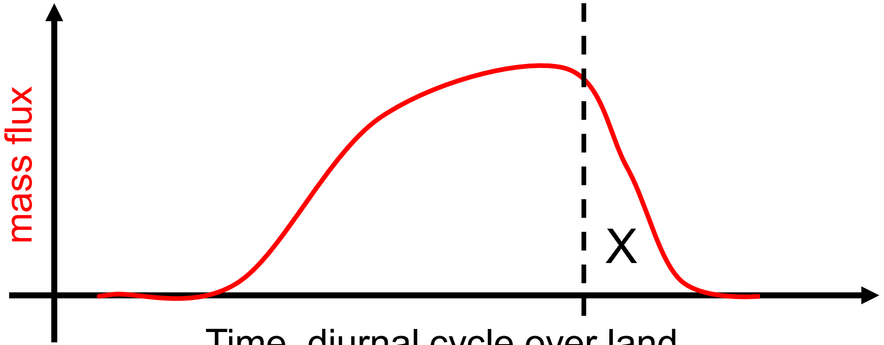
Relationship trouble!

- 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

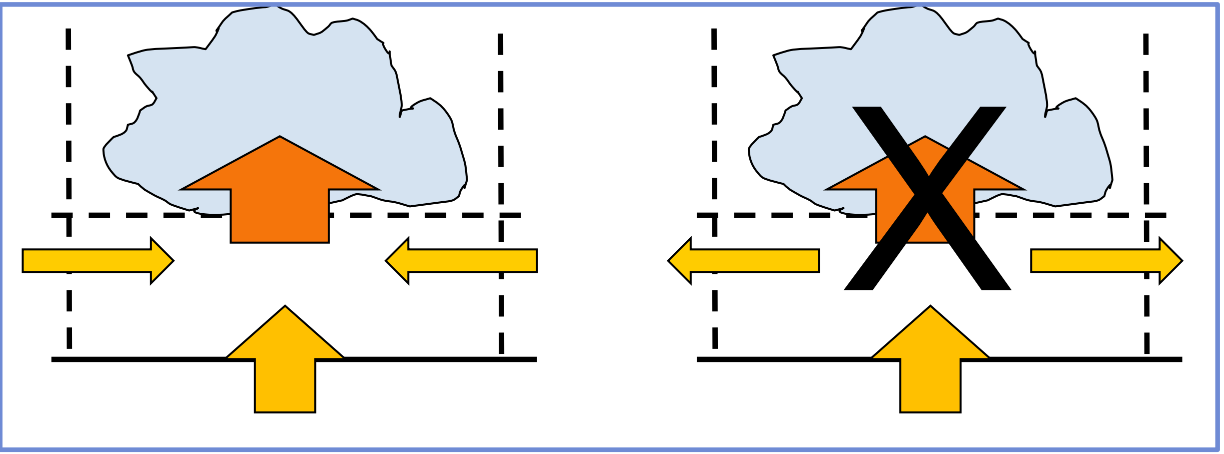
large-scale MF in ICON



not smooth!



Grayzone problems
Example: Convective rolls



Moist static energy closure: MSE convergence in subcloud layer balanced by mass flux transport through cloud base (equilibrium assumption)

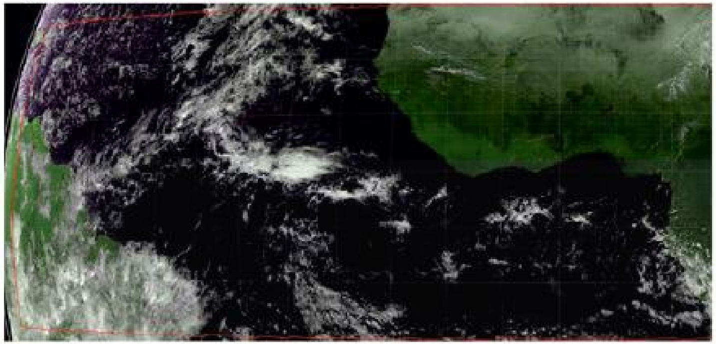
When there is a mass divergence in the subcloud layer, the horizontal m.s.e. divergence must be more than cancelled by the surface fluxes

Is this interaction "correct"? Often, not on the correct spatial scale, but on whatever scale the model can resolve

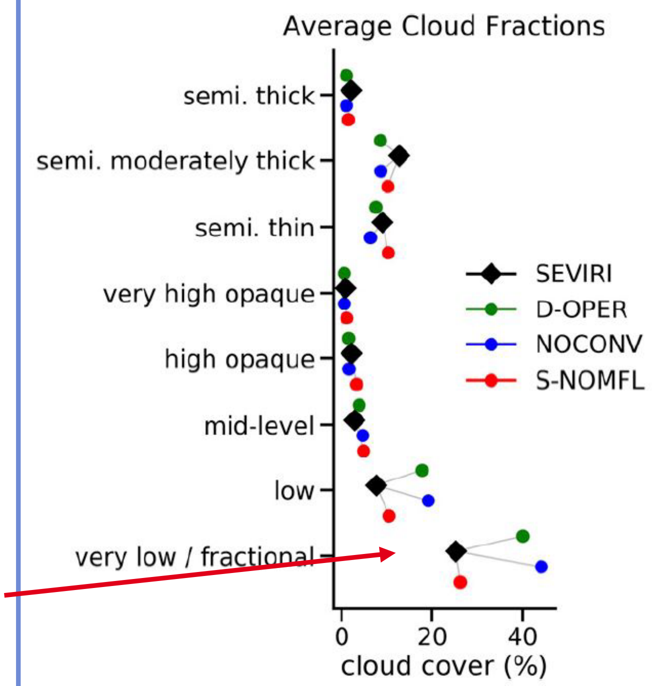
- Apply averaging over 8dx -> no rolls
- Lots of structure in low clouds – TB scheme does a good job
- Problematic for boundaries (coast, land use)

Improved convection/dynamics interaction in Tropical Atlantic

- Single-day simulation of tropical Atlantic
- Comparing:
    - SEVIRI/TRMM obs
    - operational ICON
    - no shallow parameterization
    - stochastic shallow convection

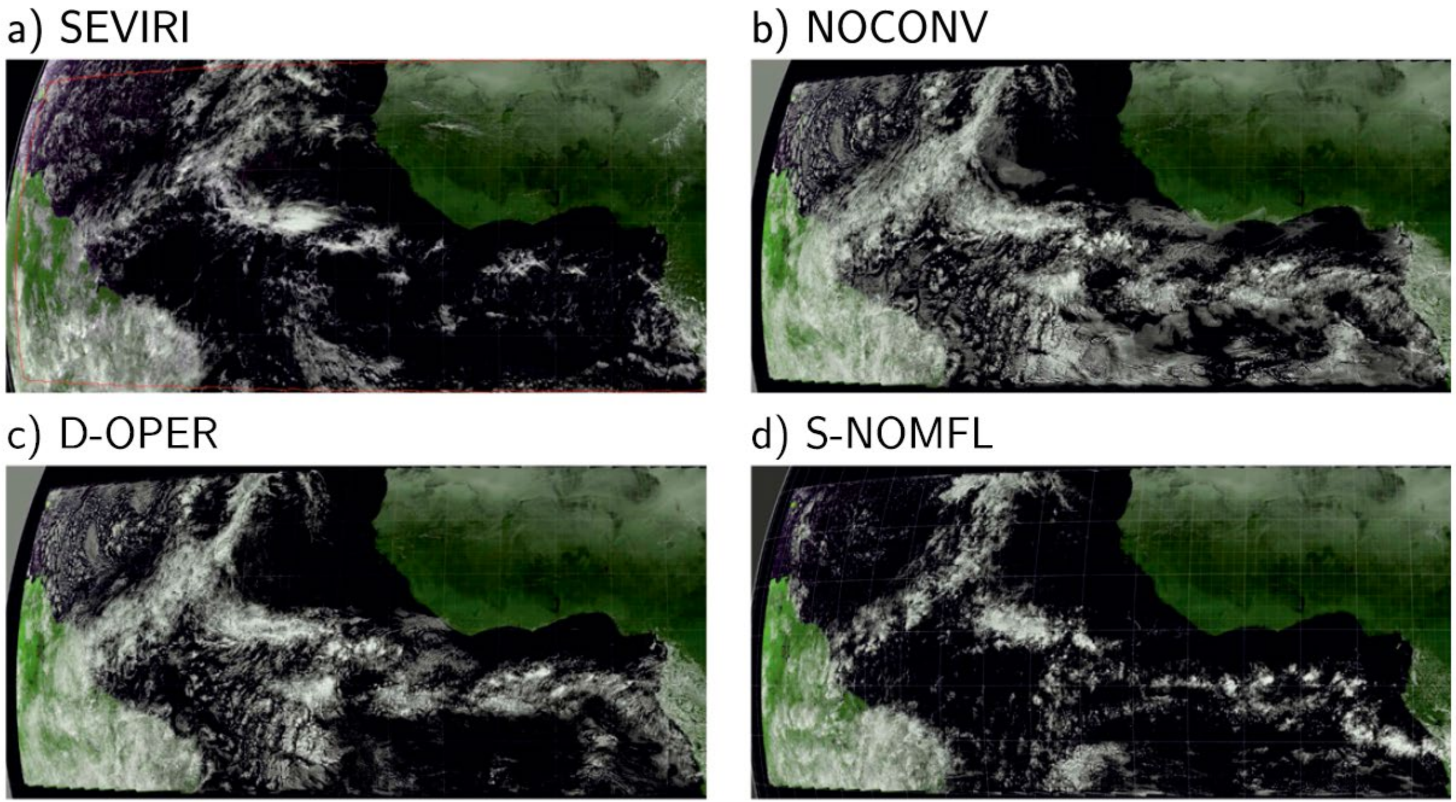


Improved low-cloud occurrence – also seen in EUREC4A simulations for North Atlantic (improved SW)



Sakradzija et al. 2020, MWR

(Synthetic) Reflectance



The ITCZ in the Tropical Atlantic

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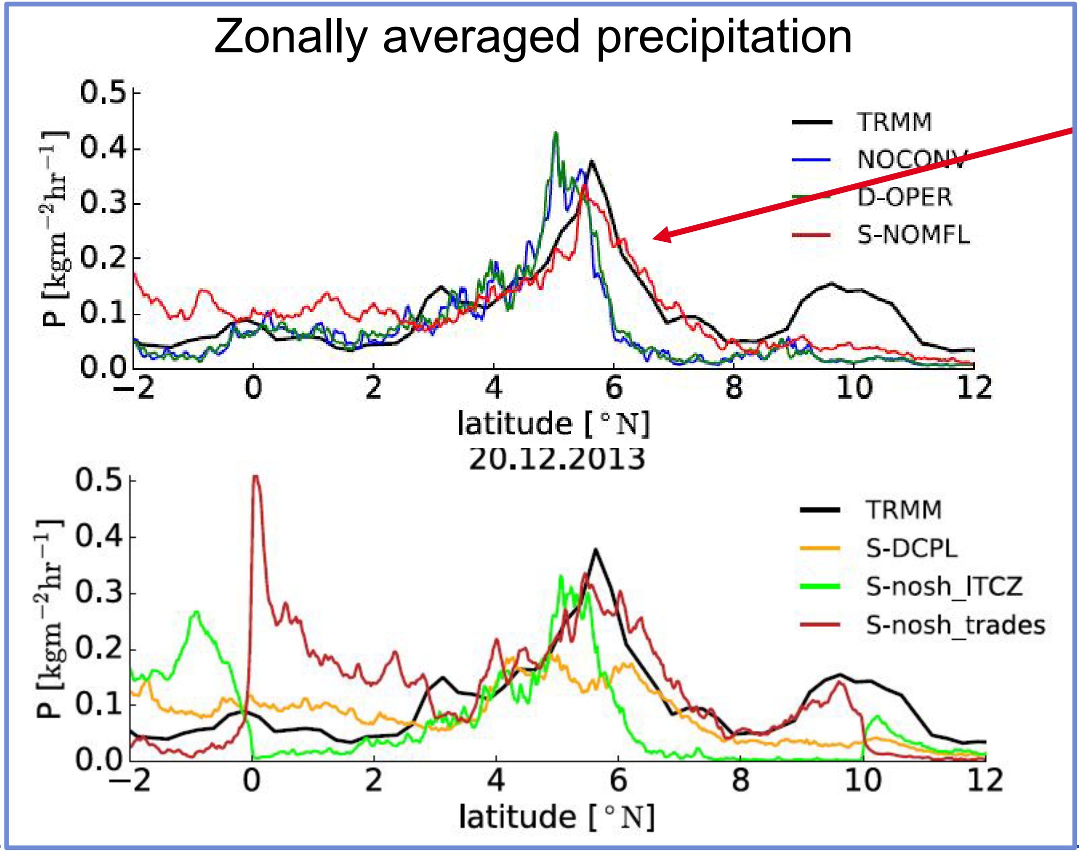
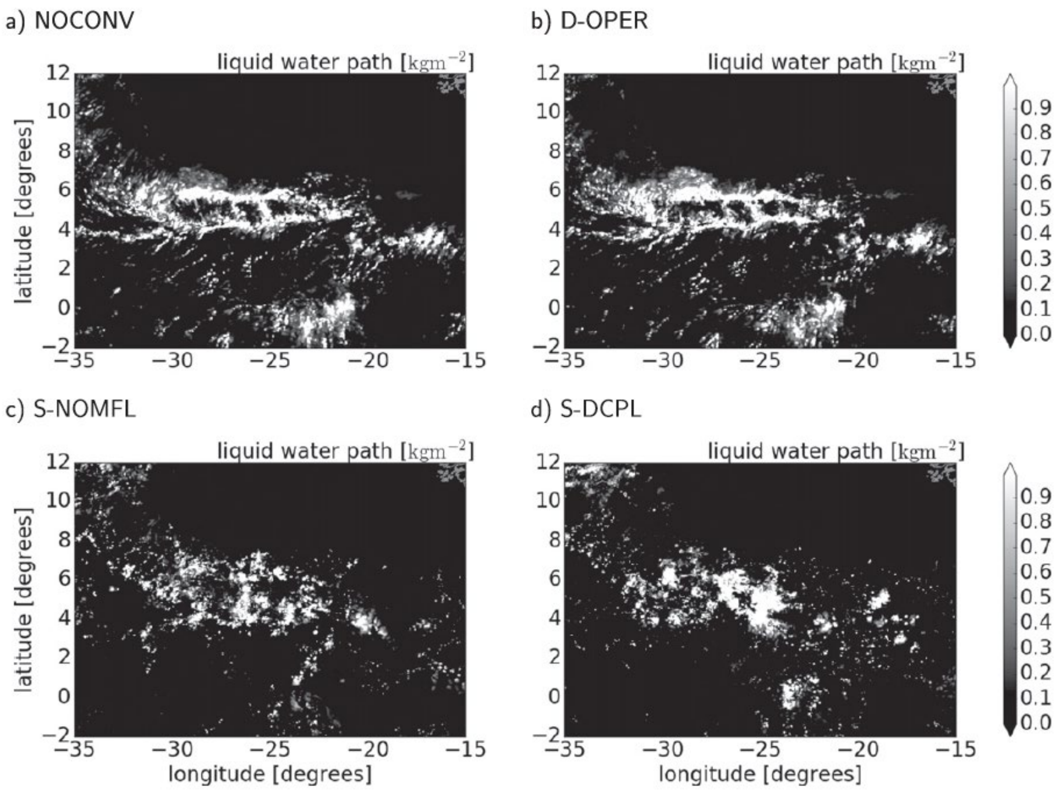


Improved location and width of the ITCZ

No remote effects, local invigoration of vertical velocity by parameterized shallow convection is required!

Sakradzija et al. 2020, MWR

Liquid Water Path

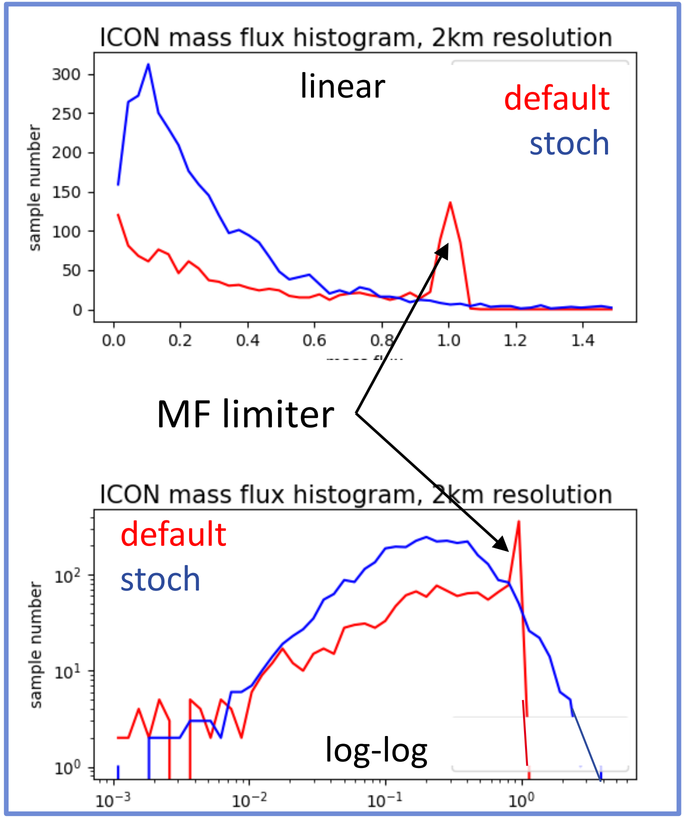


organisation more along narrow lines

organisation more as arcs/clusters

What aspect of the scheme does this?

- By first averaging of a neighbourhood, **first-guess MF** tends to have **lower** values
- **MF limiter** no longer needed at tuning knob
- **Fewer** points with **more intense** convection, randomly distributed in space, but with a certain persistence (**memory**)
- Not sufficient to remove MF limiter without stochastic scheme!



Performance in ICON D2

- Improved low cloud cover and associated SW radiation
- Impacts resolved precipitation (timing, not so much intensity)
- Impacts T/q profiles
- Difficult to show clear improvement in current verification system against SYNOP, TEMP, AIREP
- SINFONY project may deliver tools (neighbourhood or object-based verification methods focussing on precip and/or reflectivity)

Stochastic scheme solves ONE aspect of the grayzone problem

- → Population of clouds in individual grid boxes are not deterministic
- → Scale-adaptive
- → Tapers convective activity for high resolution (partially for the wrong reasons)

- → Stochastic scheme does not offer a complete solution to the questions how convection should interact with the resolved flow in the grayzone - > it inherits assumptions made in closure, momentum transport
- → Imperfect implementation: breaks MF “conservation”, neighbourhood averaging, closure

How does the stochastic scheme impact spread in ensemble forecasting (D2)?

- All ensemble members have same overall convective activity, at least to start
- Shallow convection is localized in space and time – physical process with relatively low impact overall
- Impact is situation-dependent – strongly or weakly forced?
- What sets spatial/temporal scales of perturbations?
  - Spatial smooth “envelope” from first-guess MF -> same for all members
  - Temporal persistence of perturbations on the order of ~1hour -> imperfectly implemented
- So far: small increase in precip spread on top of default parameter perturbations