Deutscher Wetterdienst
Wetter und Klima aus einer Hand

A stochastic convection scheme for ICON: Recent development and evaluation

COSMO WG3a session 2020-09-02

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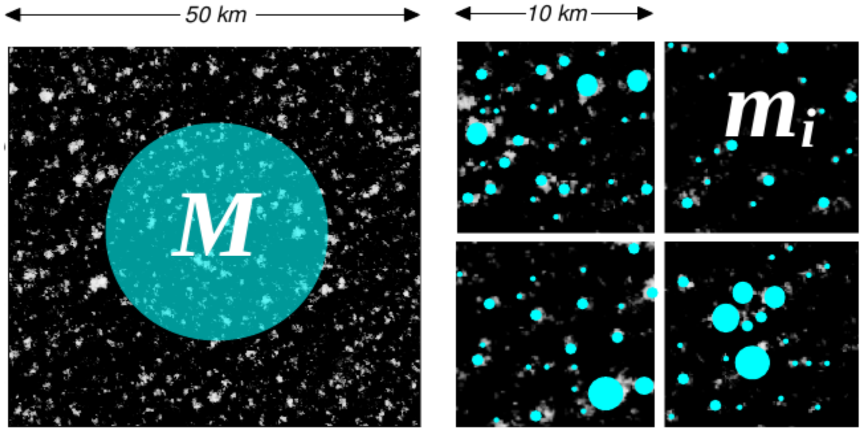
MODIS Aqua 20130505

Quick recap: Why stochastic convection?

- Traditional closure assumptions for convection no longer hold at high resolution

- Grid box area **too small** to contain a complete ensemble of convective clouds



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

- Convection is **not** in equilibrium with the large-scale state (closure)

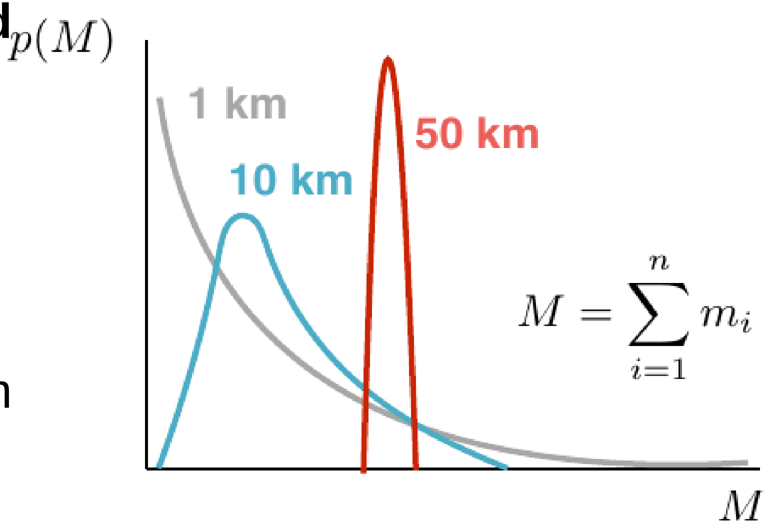
- The resolved atmospheric state no longer predicts a **unique** (deterministic) convective state – there are many possible realisations!

The idea: Predict the cloud ensemble

- The **mass flux on large scales** (where traditional assumptions are a good approximation) is determined with the **classical parameterisation** (Tiedtke-Bechtold/IFS)

- At **individual grid points**, a **stochastic cloud ensemble** is generated whose mass flux (averaged across larger scales) converges to that of the classical parameterisation

- Bonus: The **ensemble automatically adapts to the grid resolution**. The smaller the grid spacing, the greater mass flux departures from the cloud ensemble mean



Two flavours of the stochastic scheme

Explicit stochastic scheme

- up to 5000 individual clouds tracked through their lifetime at each grid cell
- each cloud's cloud base mass flux and lifetime are saved
- easy to extend the scheme (e.g. to include updraft fraction, cloud height)
- slower (x3 nwp-dev convection)
- cloud ensemble is memory-intensive and not saved for restart

Stochastic differential equations (SDE)

- Approximation to the explicit scheme
- 4 prognostic variables of grid cell mean mass flux, cloud number (active/passive)
- restart with saved cloud ensemble properties possible
- cheaper (x2 nwp-dev convection)
- cannot be easily extended

What's new?

- ➔ Some initial forecast scores from month-long hindcasts (using Alberto's hindcast setup)
- ➔ Evaluation against TOA SW for maritime shallow Cu regime
- ➔ Porting to (and optimization for) NEC
- ➔ Testing of alternative mass flux closures
- ➔ Extending scheme to include representation of updraft core

Forecast scores from month-long Hindcast

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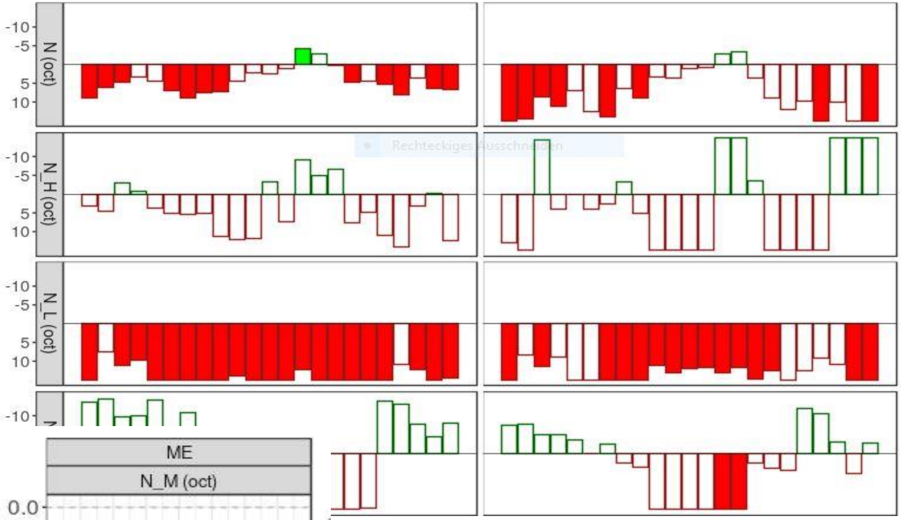
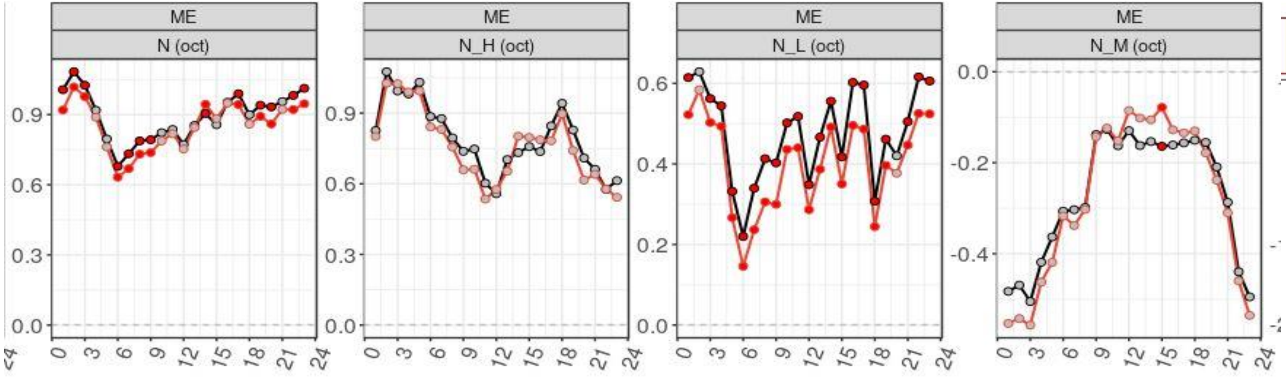
- ➔ Thanks to Alberto!
- ➔ D2 domain, 2.5km resolution

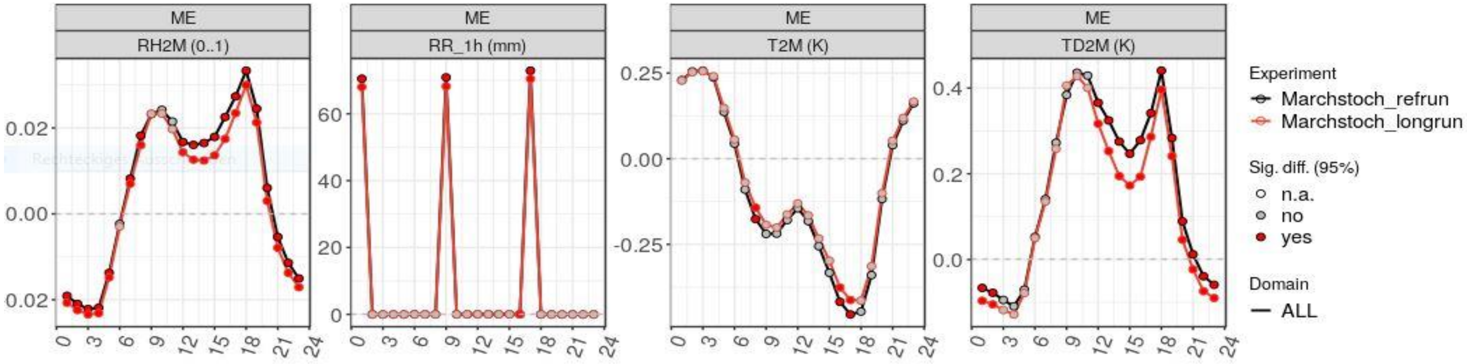
Mean error cloud cover improved (esp. low)

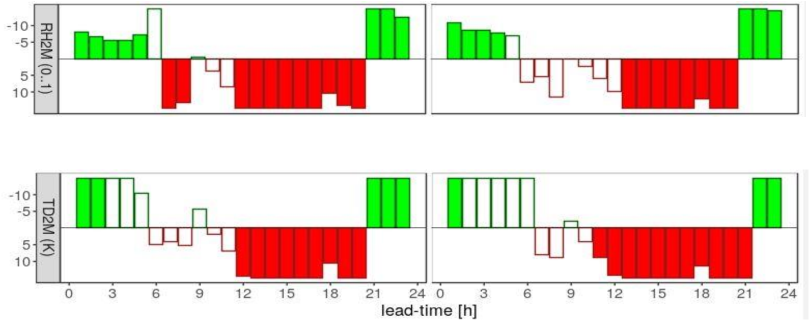




Red is improved relative to reference

Forecast scores cont.





RH2m

TD2m

Hint that precip might also improve (few obs, but in ME and RMSE, significant)

Mean error 2m humidity improves during the day, slightly worse at night.

Forecast scores cont.

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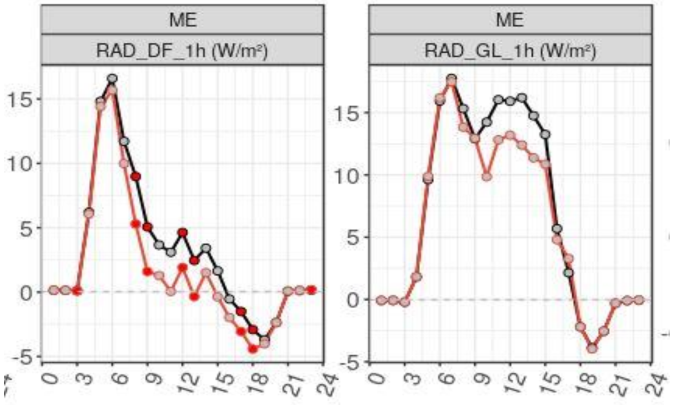
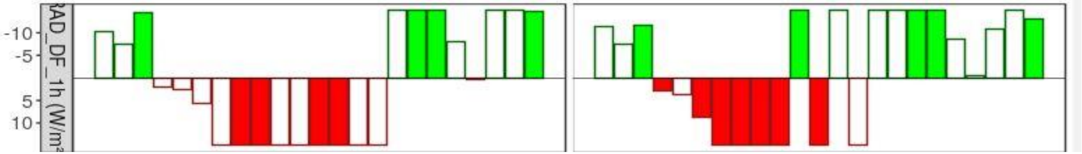




Mean error in diffuse radiation improved during day, slightly worse at night

Generally not a lot of signal in RMSE, upper air scores are mixed/not significant

Changes seen are directly related to cloud cover/radiation/BL transport – make sense.

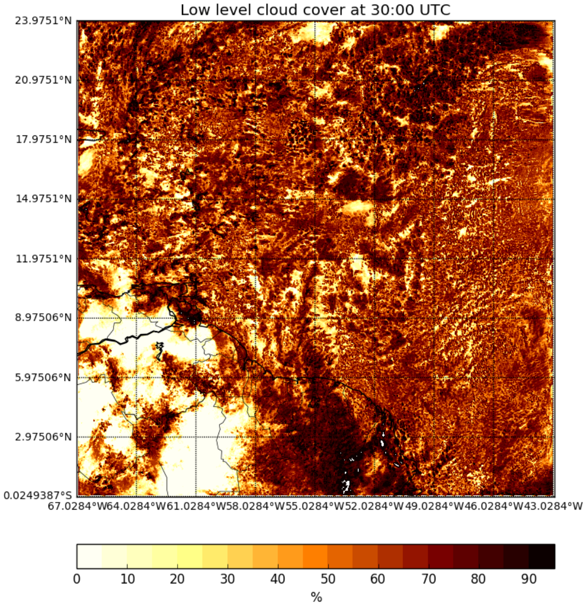
Largely neutral

All resolution-dependent tuning disabled in convection, no new attempts at tuning!

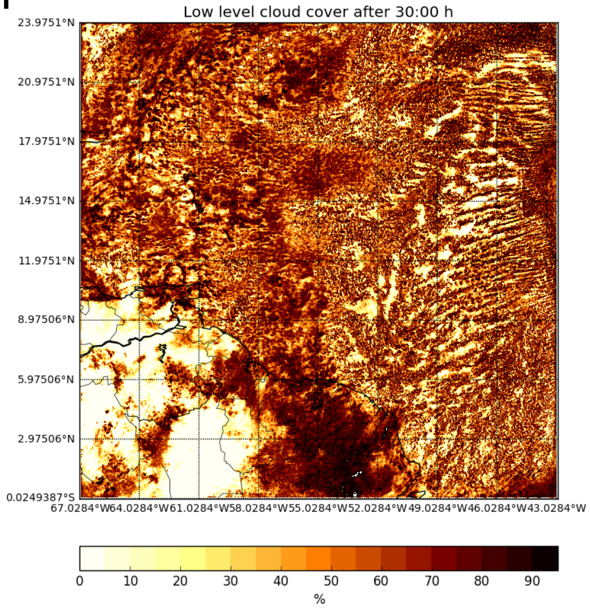
What is the “right” amount of convective cloud?

- EUREC4A field campaign in the north Atlantic
- About a week of daily 48hr forecasts at 1.2km (first 24hrs discarded)

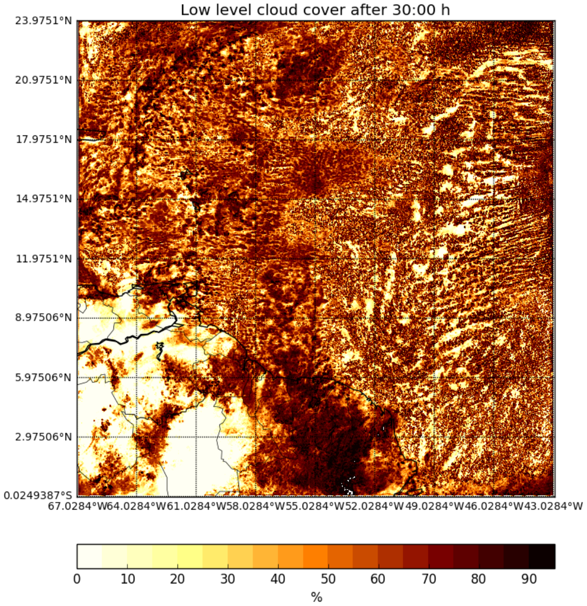
Snapshot: low cloud cover at fc hour 30



nwp-dev

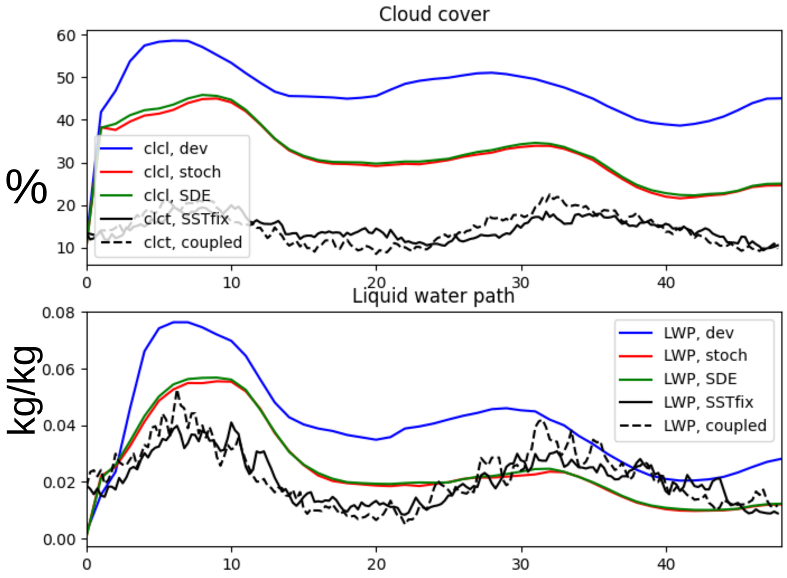


explicit stochastic



SDE

Quick overview



1. Significant spin-down of moisture during the first 24hrs
2. Both stochastic versions very similar
3. Stochastic scheme has about 2/3 of low cloud cover and ½ of LWP compared to nwp-dev
4. Similar LWP as DYAMOND runs (2.5km), but cloud very dissimilar (D. Klocke)

Expect less upwelling SW at TOA!

TOA upwelling SW radiation as target

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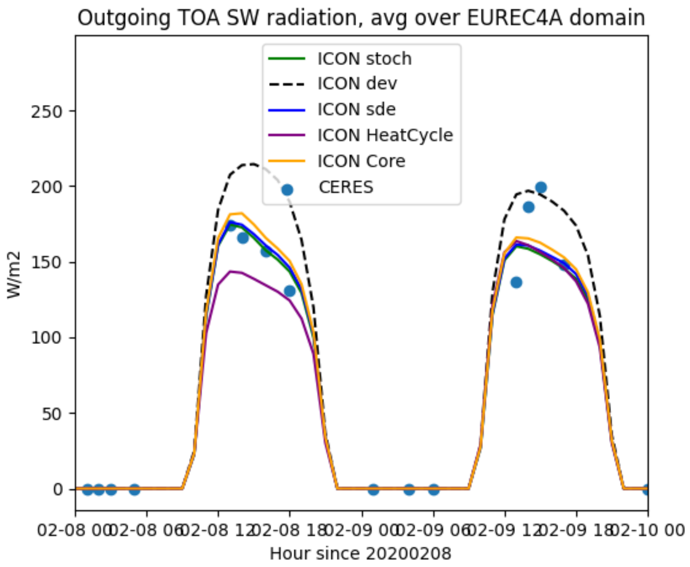
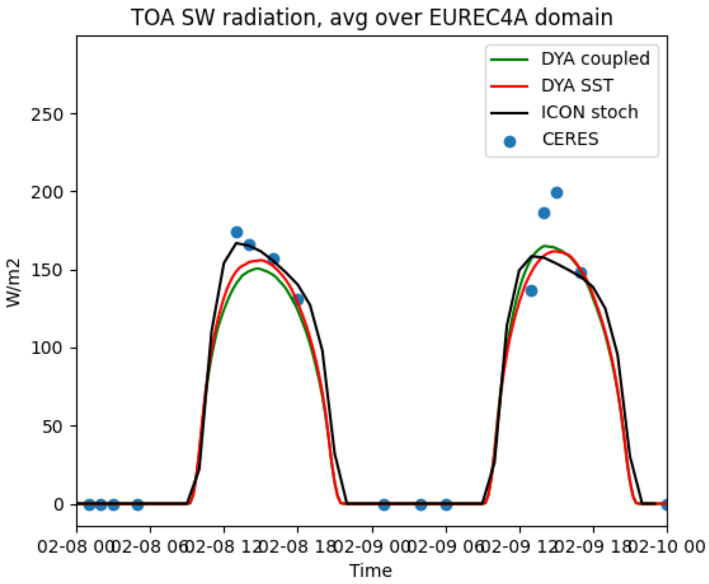
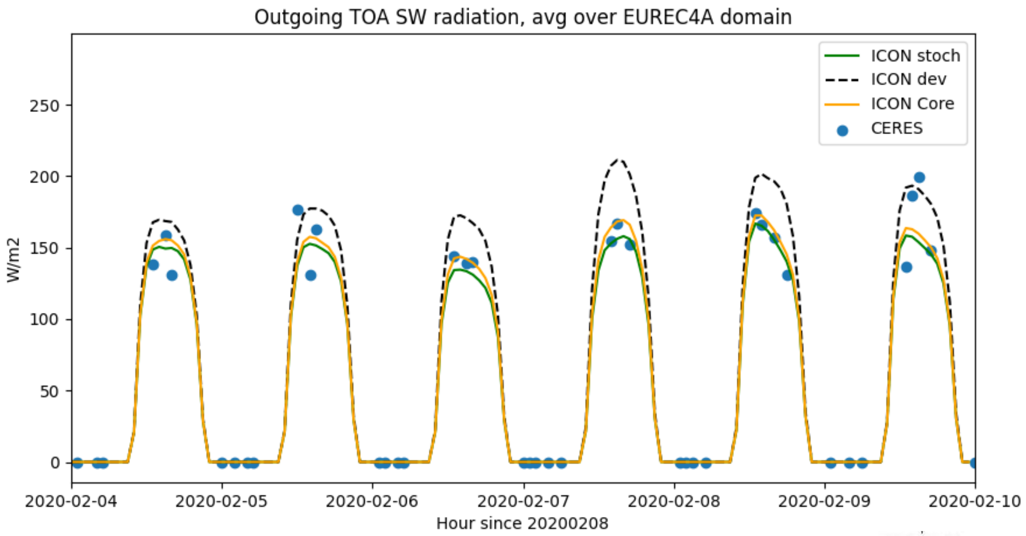




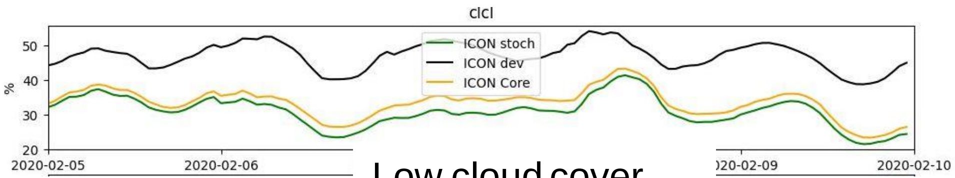
Averaging CERES FlashFlux over EUREC4A domain

Upwelling SW reduced for stochastic scheme – as expected.
DYAMOND similar to stochastic scheme – issue with cloud cover in DYAMOND

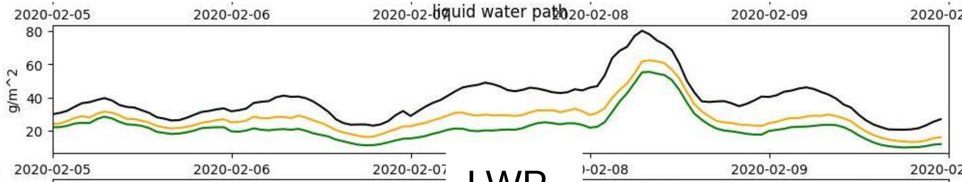
TOA SW cont.



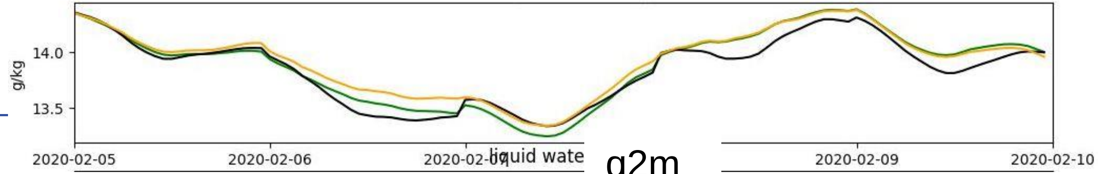
Slightly more representative: stochastic scheme agrees reasonably well with CERES (certainly better than nwp-dev)
Representing the cloud core may bring additional slight benefit



Low cloud cover



LWP



q2m

Alternative closures

- Why? About 10-15% of shallow Cu grid cells do not have proper closure. (This is true in IFS and nwp-dev also.)
- Options tried: Keeping first guess mass flux (various definitions), using CAPE closure (deep convection), modifying m.s.e. equilibrium closure, using Heat Cycle for closure, using modified Grant/Boeing closure.
- Choice for “bad points” acts as tuning knob – can get more/less congestus-like activity depending on choice.
- Completely different closure gives significantly poorer results (updraught calculation remains unchanged)

Updraft core representation

- ➔ Question: can we achieve a better representation of the diurnal cycle by including the temporal evolution of the updraft core?
- ➔ Observations show phase shift in cloud fraction near LCL vs. cloud fraction aloft (under the trade inversion)
- ➔ Idea: Cloud top rises for the first half of the cloud's life time, cloud erodes from base for the second half of lifetime
- ➔ Result: No improvement in phase shift of cloud fraction, probably because lifetimes of individual clouds are much too short. “Memory effect” must be on the level of the cloud ensemble, not the individual cloud.

Practicalities:

Branch based on nwp-dev. If all stochastic switches are set FALSE, nwp-dev is reproduced. NOT including new cp/cv bug fix yet. Runs on NEC (some finishing left to do).

Main namelist switches:

```
&nwp_phy_nml
lstoch_conv     = .true.    ! explicit stochastic scheme
lstoch_sde      = .false.   ! stochastic differential equations
lrestune_off    = .true.    ! switch off resolution-dependent tuning in convection scheme
/
```

lrestune_off MUST be true, else stochastic scheme is unable to function properly, and results will be very similar to nwp-dev.

You can only choose either lstoch_conv or lstoch_sde to be set TRUE, not both. (will default to explicit scheme)

To enable piggy-backing: Choose version to be used actively via namelist switch, and set lpassive=T in mo_nwp_conv_interface.f90

What's left? Next steps

- ➔ NEC branch still failing some buildbot tests (e.g. restart) -> needs cleaning up
- ➔ New ICON reference after removing cp/cv bug, and extensive retuning -> Is the stochastic branch still beneficial relative to new reference?
- ➔ Joint evaluation with other developments (2mom-scheme)
- ➔ Options on closure choices, cloud core treatment can be chosen based on performance of "baseline" version.
- ➔ How much does scheme add to spread, and does this add benefit by allowing additional (situation dependent) assimilation of convective parameters? BACY
- ➔ Still true: cloud cover scheme decides how convective cloud cover/condensate is used, and thus has huge impact on how convective cloud impacts radiation (and related properties)