Deep convection and downdraught in Alaro-1

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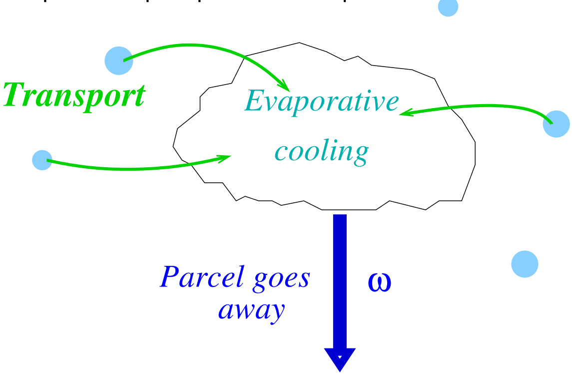
Why downdraught is subsaturated

Air parcel in precipitation: Evaporation of condensate



Evaporative cooling

- increases ω_d
- reduced by $\omega_d >$

Adiabatic heating rate

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- reduces ω_d
- increases q_{sat}

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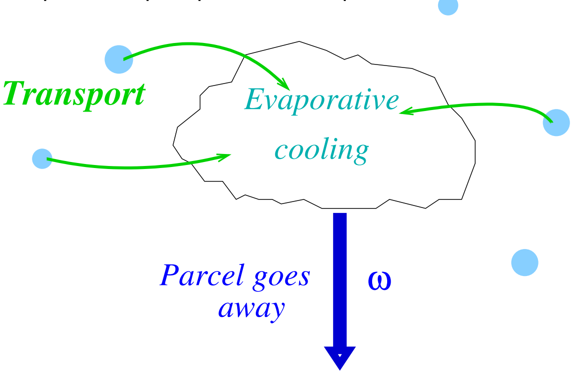

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The downdraught buoyancy results from a balance between evaporative cooling limited by ω_d and adiabatic heating increased by ω_d.
Saturation requires the parcel to move very slowly ($\omega_d \sim 0$).

Non saturated downdraught profile

LNSDO=T, lcddevpro=F

- Prognostic vertical velocity ω_d computed together with the descent (3rd degree equation) (tentrd, tddfr, gddfp[1:2]).
  Braking towards surface (gddbeta, gdddp).
  Evaporation enhanced where downdraught detrains (gddfp[3]).

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- Compatibility with CSD approach when $\overline{\omega} > 0$ (lcddcsd=T);
- Starting level: minimum of θ_{eq} below 500hPa.
- Account for precipitation inhomogeneity: effects of evaporation and melting computed in microphysics are larger over the downdraught area than in the rest of $\sigma_{\mathcal{P}}$ (gddsde=2).

$$\delta T_d = G\delta T_e = \frac{G}{1+\sigma_d(G-1)}\left[-\frac{g\triangle t}{c_p}\frac{\triangle F_{h\mathcal{P}}}{\triangle p}\right], \qquad G = G_0(1-\sigma_d)+1$$

Non saturated downdraught 'closure'

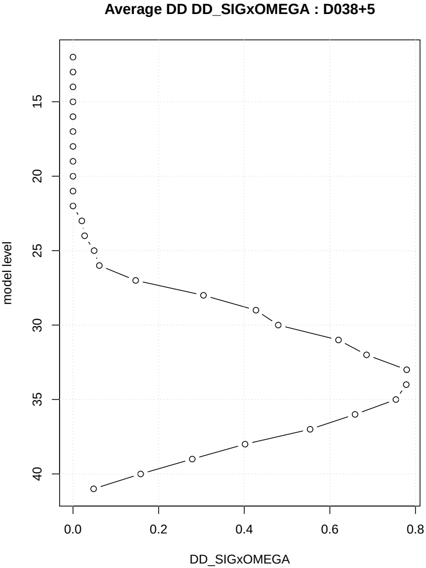
Either diagnostic σ_d or evolving in time.

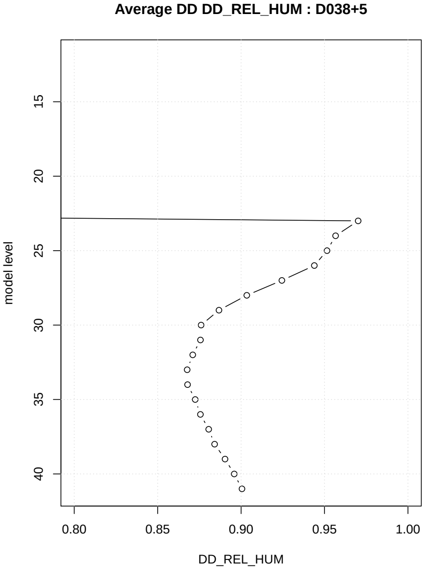
- Guess fraction at the top $\sigma_{d0} = \min\{\sigma_{\mathcal{P}}, \max[\sigma_d^-, \kappa\sigma_{\mathcal{P}}]\}$;
- Along the descent, estimate maximum viable fraction σ_{dx} for evaporating
  - less than $\frac{1}{3}$ of remaining precipitation flux in the higher part, less than 99% in the detraining part, and
  - less than $\frac{1}{2}$ to 1x the evaporation produced in the microphysical scheme (gddevf ~ 0.8).
- limit $\sigma_{d0} = \min(\sigma_d, \sigma_{dx}) \Rightarrow$ precipitation never exhausted, single downdraught along the vertical.
- Evolution by relaxation: $\sigma_d^+ = \sigma_{d0} e^{\frac{-\triangle t}{\tau_d}} + \sigma_{dx}(1 - e^{\frac{-\triangle t}{\tau_d}})$

$\kappa =$ gddfrac: 0.33(diagnostic) or 0.02(prognostic), $\tau_d =$ gddtausig$\sim$20 min.

Downdraught mean vertical profiles

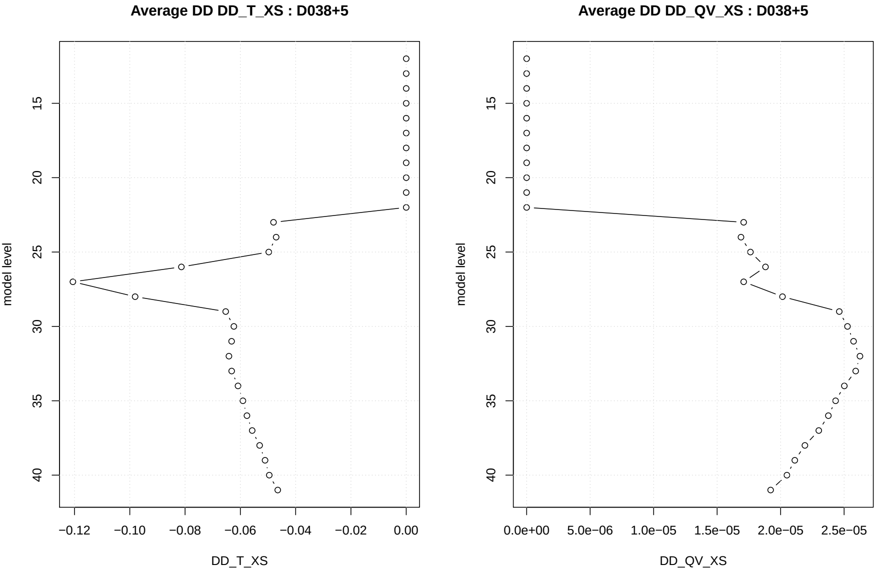
Mass flux and relative humidity





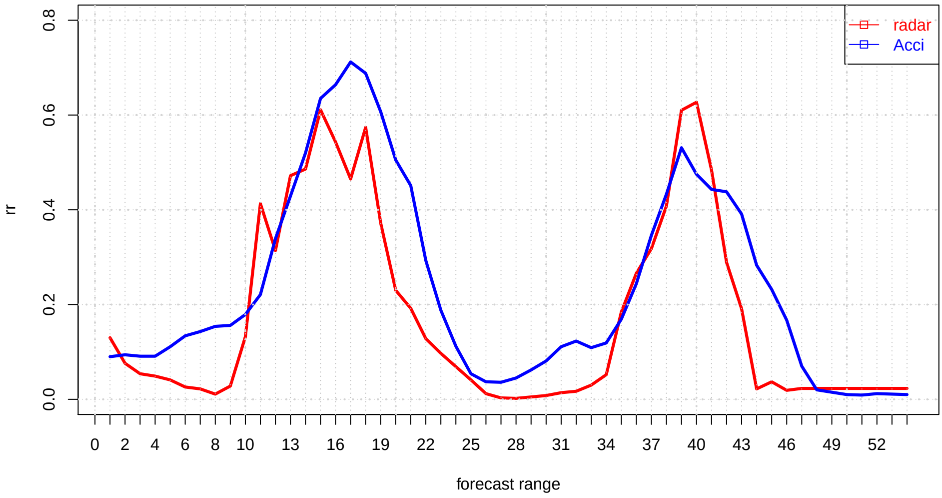
Downdraught mean vertical profiles

Additional cooling/moistening by inhomogeneity



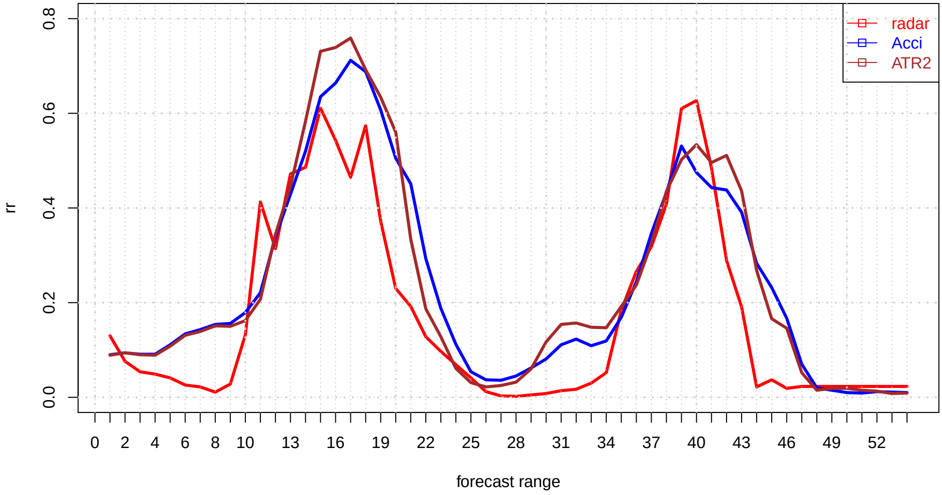
Diurnal cycle

Acci: initial TR tests



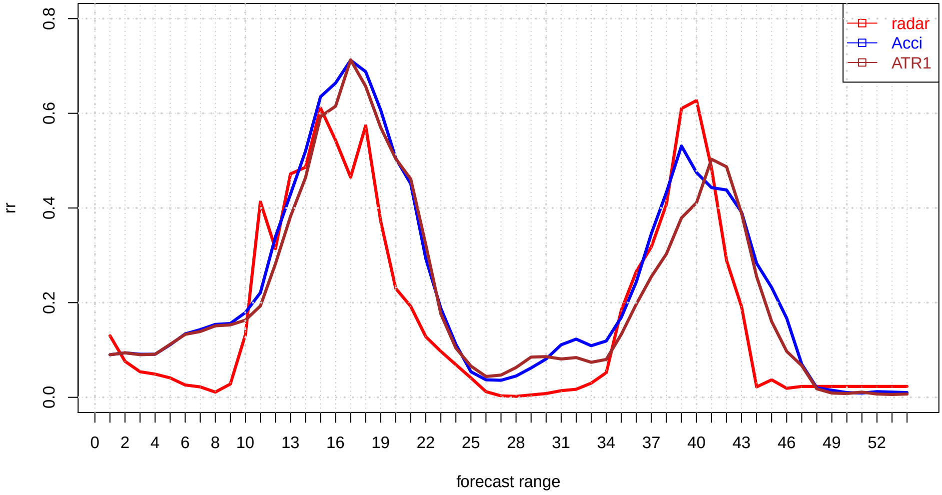
Diurnal cycle

ATR2: Last adaptations in RAD, QSMODC=1 et QSSUSV=500



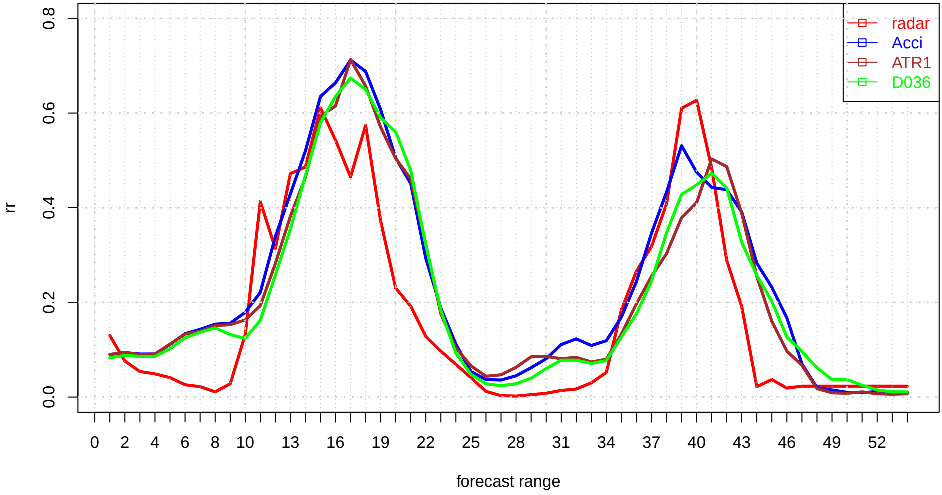
Diurnal cycle

ATR1: Retuning QSMODC=4,QSSUSV=250

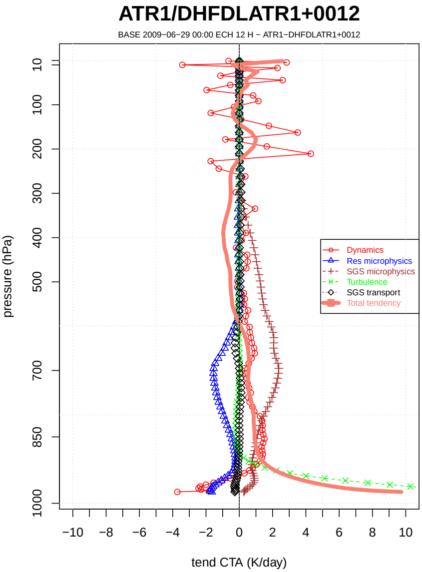


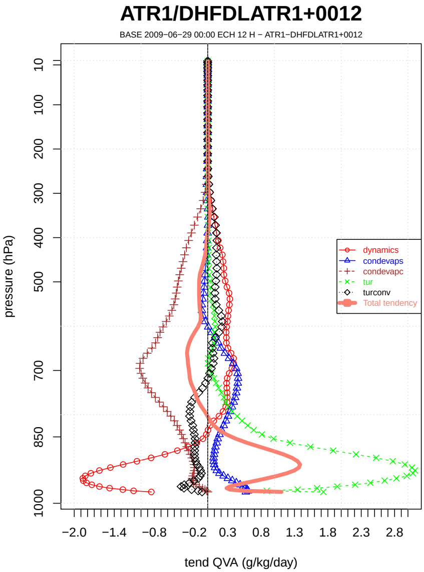
Diurnal cycle

D036: ATR1 + NS downdraught



DDH components





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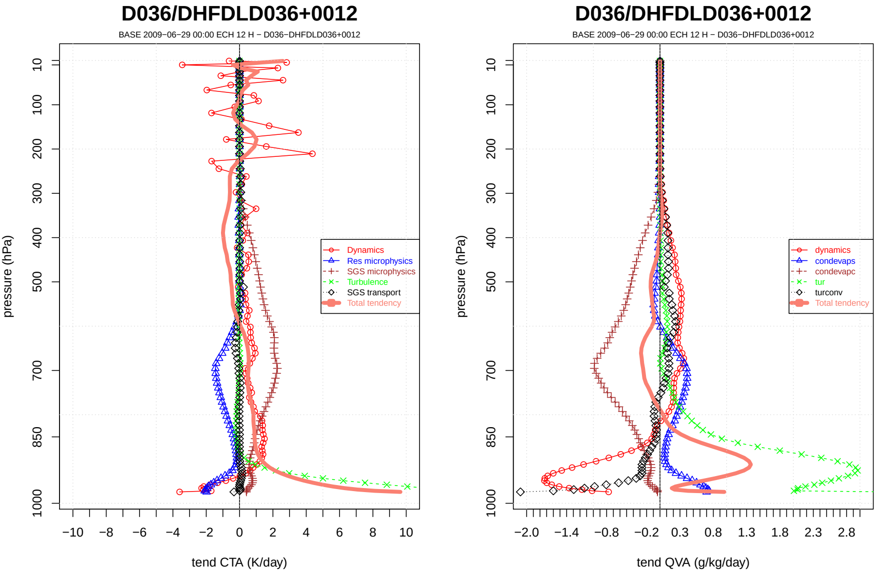

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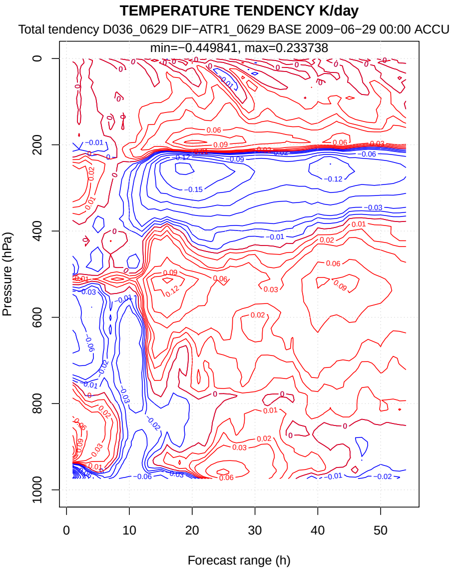

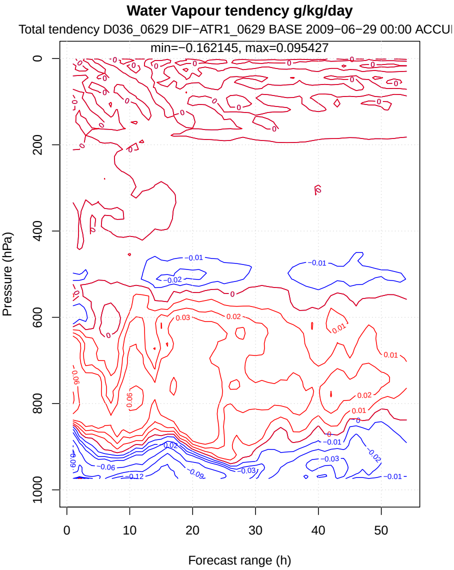

3MT Convection scheme main features

Handles complementarity, evolution and mesh fraction

- Sequential organization of parameterizations, one single microphysics.
- Cloud scheme prevented to affect condensates in convective part.
- Evolution in time with prognostic variables
- Direct expression of DC effects through convective condensation and transport fluxes.

3MT Convection scheme main features

Handles complementarity, evolution and mesh fraction

Ignores direct effects of resolved updraught

- DC scheme ignores $\overline{\omega}$, assumes $\omega_e \equiv 0$.
- DC scheme pretends to represent the absolute updraught.

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Moisture convergence closure, no explicit triggering

- Extremely cheap.
- A CAPE closure cannot be used.
- Reducing the forcing at small mesh fraction appears to improve the diurnal cycle (slowing down the onset of convection, hence leaving more CAPE accumulate).

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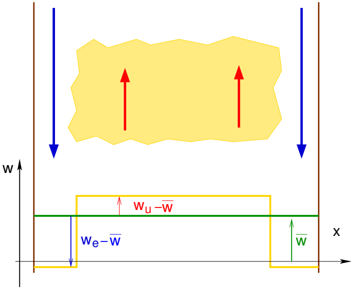
Complementarity seems realized, down to 2km resolution...

but not in a way that the subgrid part would fade out.

Complementary subgrid draught features

Perturbation approach: provide a complement to the partly explicit representation.

- Perturbation draught is a *closed circulation* in the grid column



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Perturbation approach: provide a complement to the partly explicit representation.

- Perturbation draught is a *closed circulation* in the grid column
- Formal derivation from anelastic equation
    - Perturbation updraught properties account for mesh fraction, for grid-column environment vertical lapse rate.
    - Distinction between organized entrainment and turbulent mixing.

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- Formal derivation from anelastic equation
- Closure relations: extrapolated steady state + evolution towards it.
    - grid-column CAPE $\neq$ environmental CAPE
    - Expression of a moisture-convergence closure
    - A mixed closure appears adequate, CAPE at small mesh fraction, moisture convergence at large fractions.

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- Triggering
    - Compulsory with CAPE closure
    - Specific: triggering of subgrid scheme $\neq$ triggering of convective updraught

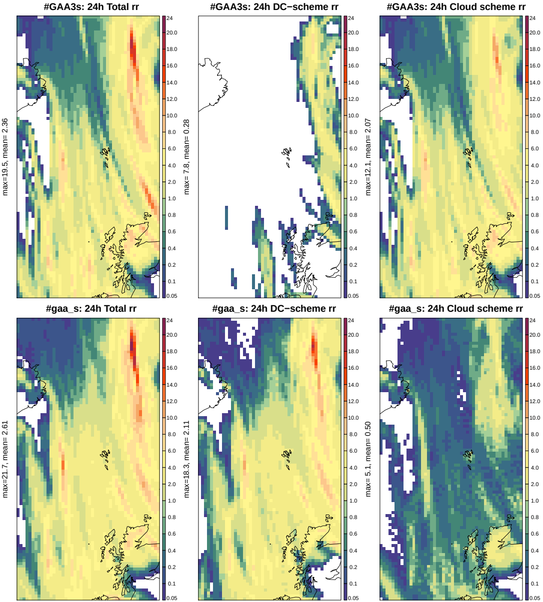
Cold air outbreak: CSD vs 3MT

24-hour accumulated precipitation shares

CSD

$\triangle x = 16$ km

3MT



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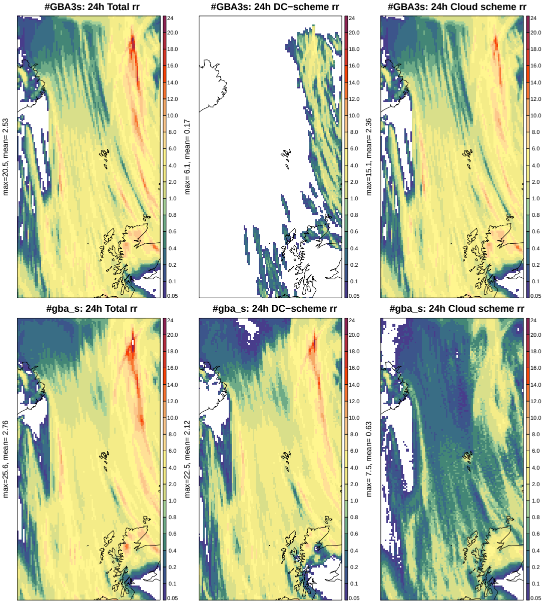
24-hour accumulated precipitation shares

CSD

$\triangle x = 8$ km

3MT



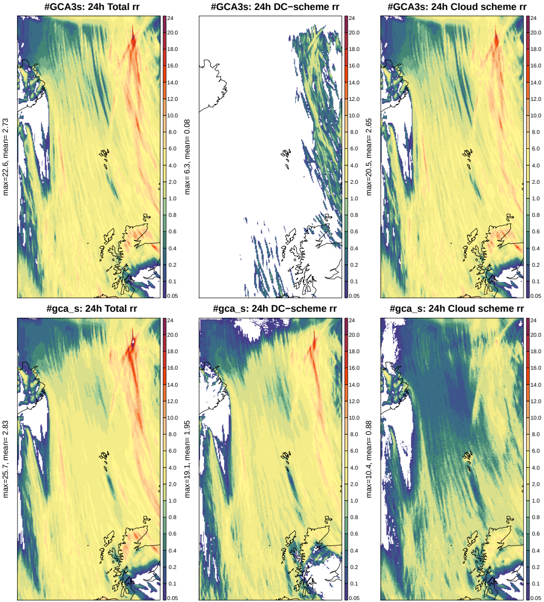
Cold air outbreak: CSD vs 3MT

24-hour accumulated precipitation shares

CSD

$\triangle x = 4$ km

3MT



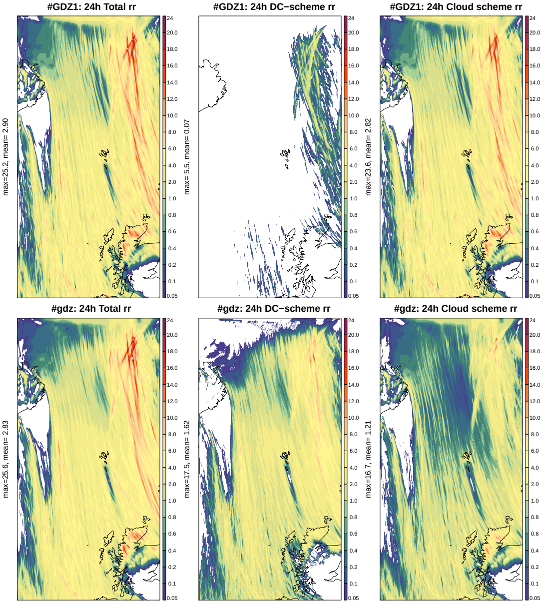
Cold air outbreak: CSD vs 3MT

24-hour accumulated precipitation shares

CSD

$\triangle x = 2$ km

3MT



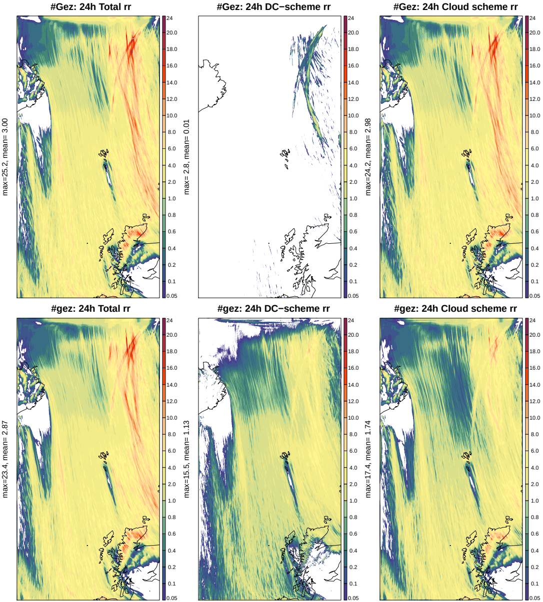
Cold air outbreak: CSD vs 3MT

24-hour accumulated precipitation shares

$\triangle x = 1$ km

CSD

3MT



Prospects

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- Downdraught:
  - New features: increased exchanges at detrainment levels, simple approach of precipitation inhomogeneity and mesh fraction effect.
  - Relaxation in time covers (replaces) gradual descent along several time steps and gradual extension of cold pools.
- Updraught:
  - CSD scheme was shown to improve scores in Alaro-0 but required to retune the critical relative humidity profile.
  - Complete tuning waiting after shallow convection and radiative cloud condensates have been finalized.
  - Multi-resolution tuning becomes an issue.
  - Cost appears reasonable.