# Can we unify clouds representation throughout Alaro physics ?

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# Cloud production line

- Prognostic water variables: $q_v^-$, $q_i^-$, $q_\ell^-$ $\longleftrightarrow$ $q_s^-$, $q_r^-$
- TOUCANS including mass-flux-type shallow convective transport: estimates
  - turbulent transport coefficients
  - a shallow cloud fraction but *no* explicit condensation/evaporation
- Turbulent diffusion
- Statistical *cloud scheme*: Xu-Randall based, completed by pragmatic closure $\Longrightarrow$ compute an equilibrium between $\overline{q_t}, \overline{q_{cs}}, N_s$
  - Based on a state resulting from resolved and turbulent motion $\Rightarrow$ normally includes condensation due to
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    - the resolved part of deep convective motions

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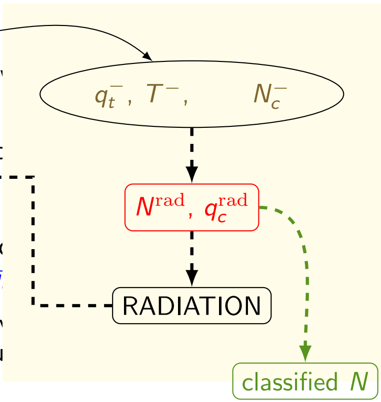

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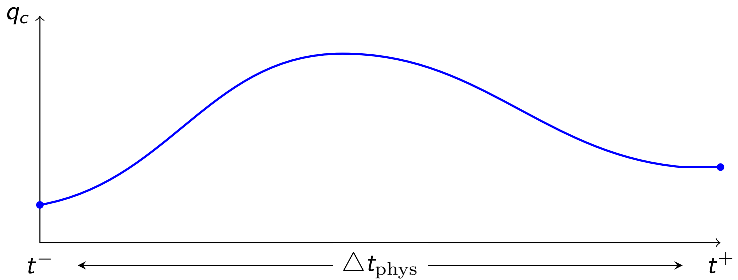

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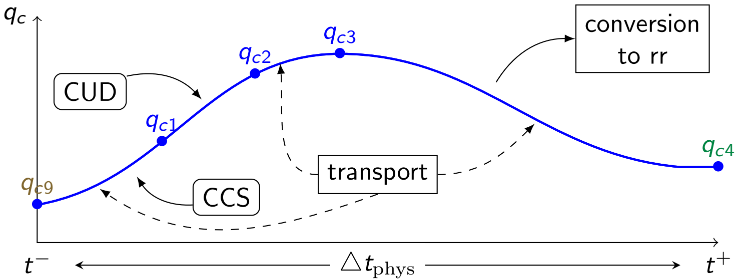

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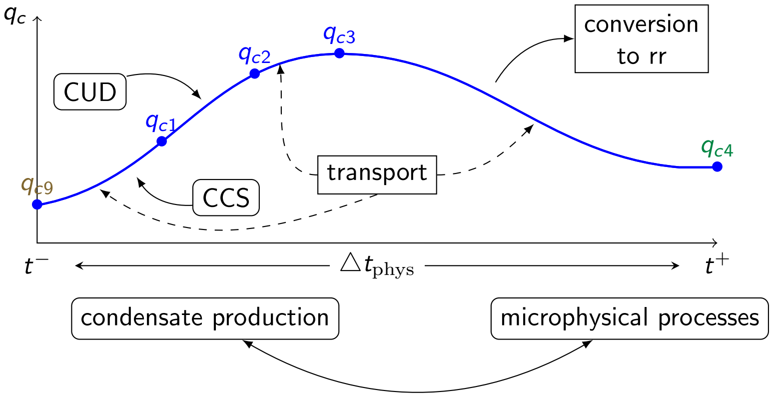

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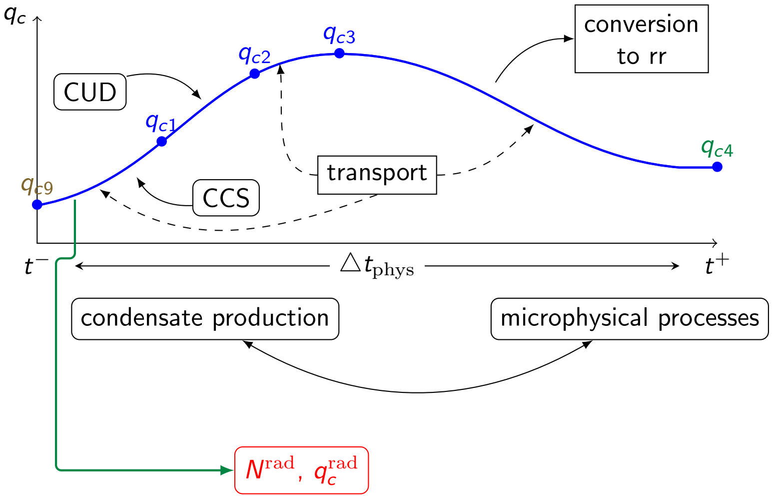

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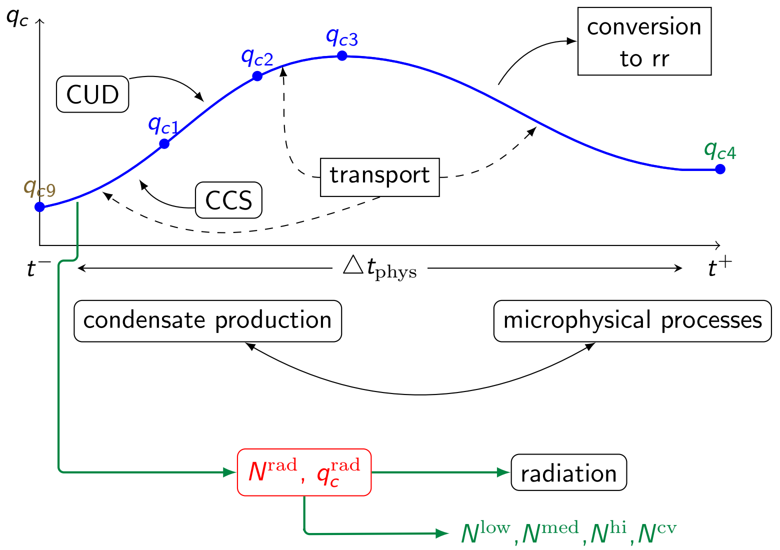
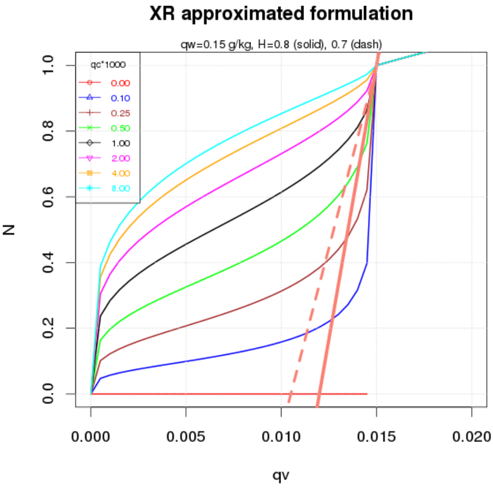


# Xu-Randall *diagnostic* formula in cloud scheme




$$N \approx \left(\frac{q_v}{q_w}\right)^{\frac{1}{4}} \frac{\alpha q_c}{\alpha q_c + (q_w - q_v)^{\frac{1}{2}}},$$

$$q_t = q_c + q_v,$$

$$q_v = q_w N + H \cdot q_w (1 - N)$$

$\alpha \sim 150$, $q_t$, $H(z)$, $q_w$ fixed

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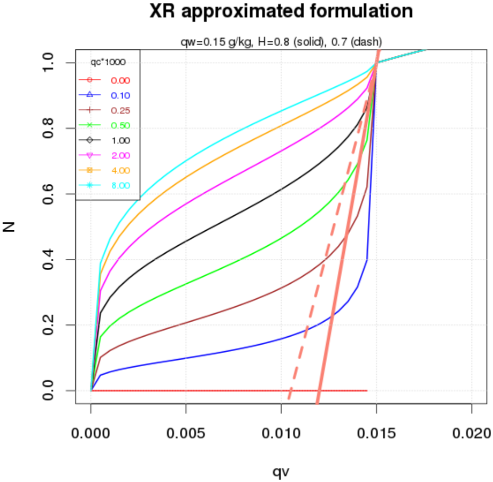


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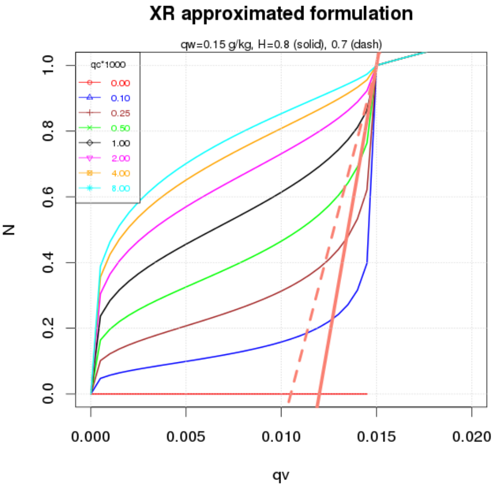


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*actually $H(z)$ – prescribed RH in clear part – should be affected by evaporation*

# Survival kit within the XR-based scheme

- Cloud fraction diagnosed from XR is related to hanging condensates
- First estimation of an equilibrium: $E0 \equiv \{ q_t^0 = q_t^-, q_c^{(0)}, N_s^{(0)} \}$
  *output cloud fraction based on* $N^{\mathrm{rad}}$ *built on this* $N_s^{(0)}$

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  *(associated heat exchanges ignored while computing E0, E1)*
- conversion to precipitation further perturbs this equilibrium:
  $\longrightarrow q_c^+ < q_c^{(1)}$ and $q_t^+ < q_t^- \ldots$
  *(conversion local $q_c \rightarrow (q_r, q_s)$, variation $q_t$ ignored in E0, E1)*
  ($\leftrightarrow$ more elaborated budgets in RK98 ?).
- the final value of condensates advected by the large-scale flow are smaller than the $E1$ values fulfilling the XR formula.

The actual tuning of $H(z)$ and of $\alpha$ tries to compensate the different inadequacies.

# Critical relative humidity profile $H(z)$

Closure used by Smith (1990) (constant values 0.85/0.925, $\triangle x \sim$300km) as a way to represent the subgrid variability.

$$RH_{\mathrm{crit}} = 1 - \sqrt{6}\frac{\sqrt{\overline{q_t'^2} - 2\alpha_S\overline{T_L' q_t'} + \alpha_L^2\overline{T_L'^2}}}{q_{\mathrm{sat}}(T_L)}, \qquad \alpha_L = \frac{\partial q_{\mathrm{sat}}(T_L)}{\partial T}$$

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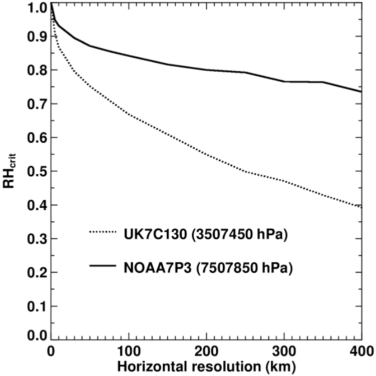
  - Vertical dependency
    $\rightarrow$ 1 at bottom and top
    to prevent spurious clouds
  - Grid-box length dependency
    *estimated with subgrid variances computed from aircraft FASTEX measurements*



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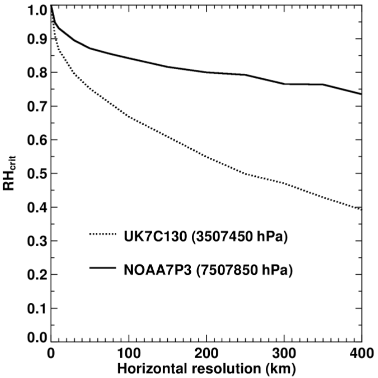
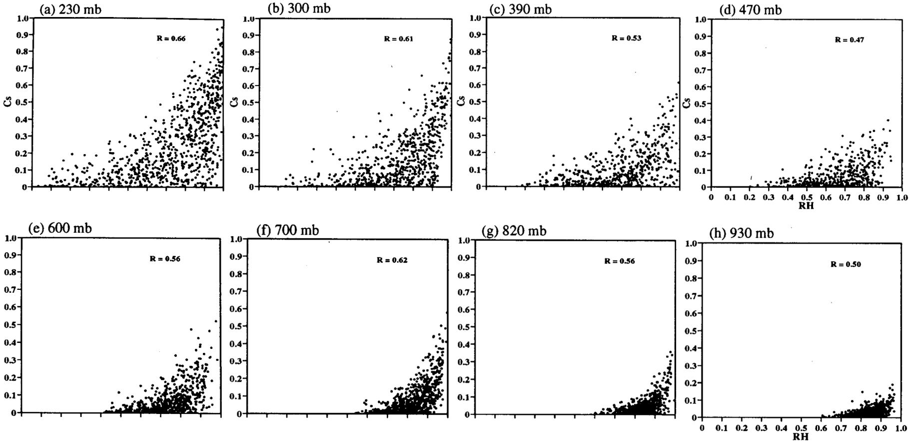
  - assumes triangular distribution
  - Right formula ?



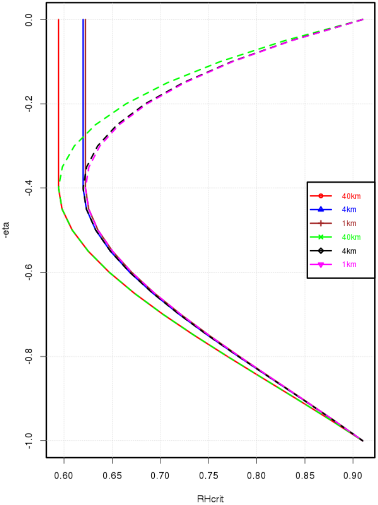
# Xu-Randall 1997 Fig 5

Scatterplot: stratiform cloud amount vs large-scale RH (GATE 64km subdomain)




*...there is no unique threshold RH for zero $C_s$ at any level !*

# $H(z)$ as implemented in the code

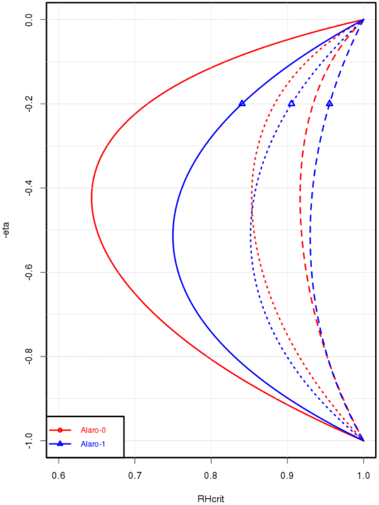



LSMITH_CDEV || LSMGCDEV

- minimum value much smaller than presented by Lopez
- ... but did he use the correct formula ?

# $H(z)$ as implemented in the code

- Explicit phase dependency (dot=ice, dash=liquid)
- Values for ice and droplets closer to Lopez's suggestion in XR...
- but anyway no triangular distribution !
- Smaller $H$ used in radiation (solid line) but further reduction of condensate by coefficient $c_1/\sqrt{1+(c_2 \cdot \overline{q_{\rm sat}})^2}$ with $c_1$ =0.4, $c_2$ cste (500) or increasing upwards (250→1000).




LXRCDEV (4km)

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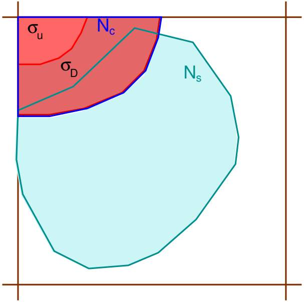
    *(assume uniform $\overline{T}$, $\overline{q_w}$, $\overline{q_v}$, distribute $\overline{q_c}$ in clouds)*

$$N_c = \sigma_u + \sigma_D$$
$$N_t = N_c + N_s - N_c N_s$$



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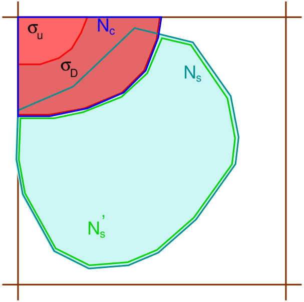
$$N_c = \sigma_u + \sigma_D$$
$$N_t = N_c + N_s - N_c N_s$$
$$e = 1 - N_c$$
$$N_t = N_c + N'_s$$
$$N'_s = N_s(1 - N_c) = N^*_s e$$

where $N^*_s$ is the cloudy fraction of $e$.



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- Underlying hypotheses of the XR formula $N(\overline{q_t}, \overline{q_c}, \overline{q_w})$ somehow opposite to the use of a single $H(z)$;
- XR97: *...deep convection tends to warm and dry the environment; it reduces the clear regions RHs...*
  $\Rightarrow$ try to reduce $H$ where deep convection is active ?

# How to estimate clouds before radiative scheme ?

Starting state:

- 3-D advected prognostic water variables: $q_v$, $q_i$, $q_\ell$, $q_s$, $q_r$
  $\Longrightarrow q_t^-, q_v^-, q_c^-$ *not at equilibrium with a cloudiness*
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- 'diagnostic': less dependent of actual cloud scheme
  1. independent calculation of 'stratiform' condensates $q_{cs}$: estimate over-saturation with respect to a $H'(z)$ profile with no phase or $\triangle x$ dependency, replaced by $q_{\mathrm{sat}}$-dependent attenuation of the condensation.
  2. re-estimate convective condensates with inverted XR formula $q_{cc}(N_c^-, q_t, q_w)$;
  3. $q_c = q_{cc} + q_{cs}$ and direct XR formula $N(q_c, q_t, q_w)$.

  Rem: $q_{cc}$ *has not been subtracted from* $q_t$ *to compute* $q_{cs}$

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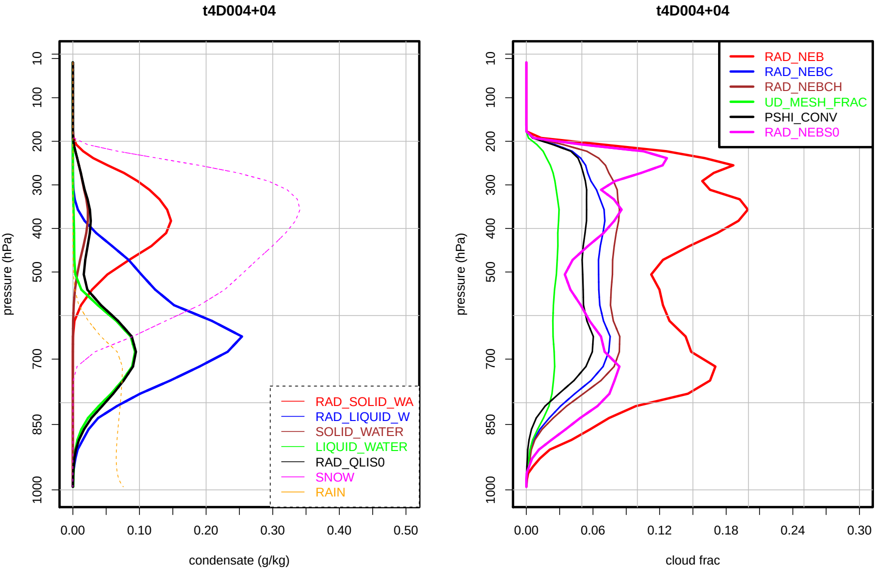
- Other schemes sometimes apply empirical scaling of cloudiness or cloud condensate passed to radiation scheme...

# Example of fractions evaluations



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However – maybe ?

- Trying to use cleaner formulas that are the same in the first evaluation of cloudiness and in the final cloud condensate generation would be an asset, allowing to better identify the sources of errors.