ACNEBCOND Documentation

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1 Purpose

The routine ACNEBCOND is computing the critical relative humidity and cloud cover for resolved condensation processes. This can be realized by using a modified Xu-Randall-scheme (LXRCDEV=.TRUE.) or the Smith-Gerard scheme (LSMGCDEV=.TRUE.).

2 Preliminary computation of ice proportion

For preliminary computation of α_i (PRMF, representing the ice fraction of the resolved condensate) exponential function FONICE is used. FONICE calculates the partition of ice and liquid water for a given temperature T (PT), taking into account the difference between T and freezing point temperature T_f (RTT)

$$\alpha_i = \begin{cases} 1 - \exp\left\{ -\left(\frac{T-T_f}{2\Delta T}\right)^2 \right\} & \text{for} \quad T < T_f \\ 0 & \text{for} \quad T \geq T_f \end{cases} , \tag{1}$$

where ΔT is chosen in a way to allow liquid and solid cloud condensate to coexiste at temperatures T below T_f $(= 273.16K)$.

3 Computation of condensation-evaporation

For the calculation of the critical humidity profile, there are two options. They are defined through namelist parameters LXRCDEV and LSMGCDEV.

3.1 Switch LXRCDEV=.TRUE.

The computation of critical relativ humidity RH_c (PHCRICS), the threshold for producing cloud condensate, is done by applying a Smith-typed-scheme, which is inspired by the adaption of the Smith-scheme done by Lopez. The critical humidity profile is calculated taking into account the dependency of RH_c on the model mesh-size. While Lopez is using an exponential approach, a homographical one was chosen here. The initial profile of RH_c is calculated in routine APLPAR, here the modification is done according to model-mesh-size and mapping factor (PGM).

3.2 Switch LSMGCDEV=.TRUE.

The calculation of critical relative humidity RH_c (PHCRICS) is done via formula used in the Lopez-scheme. Based on Smith (1990) RH_c varies smoothly in vertical between a maximum value $RH_{c_{max}}$ (RHCRIT2) in the lowest and highest model levels and a minimum value $RH_{c_{min}}$ in mid-troposheric levels.

$$RH_c = f\left(RH_{c_{max}}, RH_{c_{min}}, \eta\right), \tag{2}$$

with

$$RH_{c_{min}} = \mathsf{RHCRIT1} + f\left(\Delta x\right). \tag{3}$$

The minimum value $RH_{c_{min}}$ is considered to be dependent on the model horizontal resolution (Δx), ranging from RHCRIT1 (e.g. 0.4) at low resolutions up to RHCRIT2 (e.g. 0.99) for high resolutions. Beside RHCRIT1 and RHCRIT2, RETAMIN can be used to have namelist-control on critical humidity profile, being the level η (PVETAV) where RH_c is set to $RH_{c_{min}}$.

4 Computing cloud cover

For the calculation of stratiform cloud cover n (PNEBCOND) and specific humidity for saturation q_{sat} (PQSATS), again two options are implemented:

4.1 Switch LXRCDEV=.TRUE.

Cloud cover n (PNEBCOND) is diagnosed using a modified Xu-Randall scheme. The original Xu-Randall formula is replaced by

$$n = \left(\frac{q_v}{q_w}\right)^r \frac{\alpha q_c}{\alpha q_c + (q_w - q_v)^\delta}, \tag{4}$$

with $\alpha = 100$, $r = 0.25$ and $\delta = 0.5$. Fullfilling the conditions

$$q_v = q_w(RH_c(1-n)+n) \quad \text{and} \quad q_c = q_t - q_v, \tag{5}$$

for total water content q_t, critical humidity RH_c and q_w (PQW), representing the equilibrium water contant for exact saturation, where with exact saturation is meant that in contrast to q_{sat}, q_w takes into account latent heat release and storage. One can find following formulation $x(s)$ (ZXN)

$$x_{ref} = x(s) = \underbrace{d_c}_{\text{ZDC}} \overbrace{(1-\frac{1}{s})}^{\text{ZNI}} \left(1 + \frac{A}{\underbrace{d_c s^\delta}_{\text{ZFAC}}} \overbrace{\frac{1}{\underbrace{(1-\frac{d_c}{s})^r}_{\text{ZNPI}} - (1-\frac{1}{s})}}^{\text{ZDNII}}\right) \tag{6}$$

for x_{ref} being the deficit to saturation

$$x_{ref} = \frac{q_t}{q_w} - RH_c. \tag{7}$$

The root of function $x(s)$ is found through a Newton loop. Starting from a first guess $x^0 = 0$ and $s^0 = 1$. One can write the relation for the iterating variable ZSITER ($s = \frac{1}{1-n}$)

$$\overbrace{s^{n+1}}^{\text{ZSITER}} = \overbrace{s^n}^{\text{ZSITER}} + \frac{1}{2}\left(\frac{\overbrace{x_{ref}}^{\text{ZX0}} - \overbrace{x(s^n)}^{\text{ZXN}}}{\underbrace{\frac{\partial x(s^n)}{\partial s}}_{\text{ZDXN}}}\right)^2 \frac{1}{s^n} \quad . \tag{8}$$

The number of iteration steps is defined by IITER$(=3)$. Finally one can write for cloud cover n (PNEBCOND) and saturation specific humidity q_{sat} (PQSATS):

$$n = 1 - \frac{1}{\text{ZSITER}} \quad \text{and} \quad q_{sat} = q_w. \tag{9}$$

4.2 Switch LSMGCDEF=.TRUE.

Cloud cover is computed by using Smith-Gerard scheme. In the first step saturation with respect to ice and liquid water q_{sat} (PQSATS) is computed. Through the namelist parameter NSMTBOT it is possible to treat the lowest level (JLEV=KLEV) independently from the layers above by recomputation of ice phased fraction α_i (PRMF). Instead of level temperature T, an average value of T and surface temperature T_s (PTS) serves as input argument for FONICE. For this NSMTBOT has to bet set equal 0. In the case NSMTBOT is set to another value, no recomputation is done. Specific saturation humidity q_{sat} is computed making use of thermodynamical functions FOEW and FOQS,

$$q_{sat} = \text{FOQS}\left(\frac{e_s}{p}\right), \tag{10}$$

where FOEW is calculating saturation vapour pressure e_s. Function FOQS returns the saturation specific humidity q_{sat}.

In the next step, setting the logical switch LSMTPS=.TRUE. activates a smoothing of the q_{sat}

profile . Recomputation of q_{sat} is only done for layers containing liquid condensate (ILIQ=1) and in the case of a dry adiabatic unstable stratification. Unstable case is defined through ΔS (ZDS), representing the difference of static energy $S(= c_pT + \Phi)$ (ZS) between two levels. The numbers of levels used below/above the actual layer to search for a dry adiabatic unstable profile is defined by integer values NSMTPB and NSMTPA.
Following q_{sat} the computation of cloud cover n (PNEBCOND) is performed. After Smith cloud fraction depends on the difference of specific total water content q_t (ZQTOT) and the saturation specific humidity q_{sat}. The cloud fraction is retrieved through relative humidity $RH = \frac{q_t}{q_{sat}}$ (ZRATQ) and saturation specific humidity via the relation

$$n = 1 - \frac{1}{2}\left(1 + \frac{\frac{q_t}{q_{sat}} - 1}{1 - RH_c}\right)^2 \quad \text{for} \quad q_t \geq q_{sat} \tag{11}$$

and

$$n = \frac{1}{2}\left(1 - \frac{\frac{q_t}{q_{sat}} - 1}{1 - RH_c}\right)^2 \quad \text{for} \quad q_t < q_{sat}. \tag{12}$$

Additionally n (PNEBCOND) is modified by imposing a minimum of cloud fraction for layers containing liquid or frozen condensate to avoid excessive values for the case that overlapping is performed during radiation computation. This reduction is controlled by RDPHIC. Finally, the retrieved profile of n can be smoothed. There are two methods implemented, the way to compute the smoothing is defined by NSMDNEB. Setting NSMDNEB equal 1 chooses smothing via averaging PNEBCOND in vertical a loop. The modified cloud cover n_{jlev} for the actual level JLEV is retrieved via

$$n_{jlev} = \frac{\frac{1}{2}(n_{jlev-1} + n_{jlev}) + \frac{1}{2}(n_{jlev} + n_{jlev+1}) + 2n_{jlev}}{4}. \tag{13}$$

When entering the bottom layer the formula has to be adopted to

$$n_{jlev} = \frac{\frac{1}{2}(n_{jlev-1} + n_{jlev}) + n_{jlev} + 2n_{jlev}}{4}. \tag{14}$$

Setting NSMDNEB to 2 activates smoothing via limitation of the gradient of cloud cover. The cloud cover n_{jlev} for the actual level JLEV is retrieved via

$$n'_{jlev} = n'_{jlev-1} + \text{min}\left(\text{RSMNDNEBX}, |n_{jlev} - n'_{jlev-1}|\right) \quad \text{for} \quad n_{jlev} \geq n_{jlev-1} \tag{15}$$

and

$$n'_{jlev} = n'_{jlev-1} - \text{min}\left(\text{RSMNDNEBX}, |n_{jlev} - n'_{jlev-1}|\right) \quad \text{for} \quad n_{jlev} < n_{jlev-1}, \tag{16}$$

where RSMDNEBX represents the maximal gradient allowed. The prime indicates a possible modification of original n_{jlev-1} during the preceding iteration of the vertical loop.

Table 1: Subroutine **ACNEBCOND**

Purpose:	COMPUTATION OF CLOUDINESS AND CRITICAL HUMIDITY FOR RESOLVED CONDENSATION
Called by:	APLPAR

Incoming arguments/fields:

0D		
	KIDIA	START OF HORIZONTAL LOOP
	KFDIA	END OF HORIZONTAL LOOP
	KLON	HORIZONTAL DIMENSION (NPROMA)
	KTDIA	START OF VERTICAL LOOP IN PHYSICS
	KLEV	END OF VERTICAL LOOP AND VERTICAL DIMENSION
1D		
	PHUC	CRITICAL MOISTURE FOR EACH LEVEL FOR PNEB CALCULATION
	PVETAF	ETA COORDINATE OF FULL LEVELS
2D		
	PAPHI	HALF LEVEL GEOPOTENTIAL
2D		
	PAPHIF	GEOPOTENTIAL ON FULL LEVELS
	PAPRSF	PRESSURE ON FULL LEVELS
	PCP	SPECIFIC HEAT AT CONSTANT AIR-PRESSURE
	PDELP	LAYER THICKNESS IN PRESSURE UNITS
	PQ	SPECIFIC HUMIDITY OF WATER VAPOUR
	PQW	SPECIFIC HUMIDITY OF THE WET THERMOMETER
	PT	TEMPERATURE
	PQI	RATIO OF SUSPENDED ICE
	PQL	RATIO OF LIQUID WATER
1D		
	PGM	MAPPING FACTOR
	PTS	SURFACE TEMPERATURE

Outgoing arguments/fields:

2D		
	PNEBCOND	STRATIFORM CLOUDINESS
	PHCRICS	CRITICAL RELATIVE HUMIDITY
	PQSATS	SATURATION SPECIFIC HUMIDITY
	PRMF	RESOLVED CONDENSATE ICE FRACTION

Used Modules:

YOMPHY, YOMCST, YOMPHY0, YOMPHY2

References

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