STUDY OF THE CONDENSATION IN HIGH VERTICAL SATURATION GRADIENTS

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PALMA DE MALLORCA 19/03/2013
SUMMARY

- Short description of the condensation scheme in AROME
- When high **vertical saturation deficit gradients** in the condensation are considered:
  - What kind of saturation distribution function inside a grid point is obtained.
  - When a gradient is high enough to introduce this change.
  - Equations used for the cloud fraction and the condensed water.
- Some case studies.
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CONDENSATION SCHEME IN AROME

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CONDENSATION SCHEME IN AROME

- It's based on the assumption of a Gaussian distribution for the total specific humidity and the temperature in the grid point.

\[ G(s) = \frac{1}{\sqrt{2\pi \sigma_s}} \exp\left[\frac{-s^2}{2\sigma_s^2}\right] \]  \hspace{1cm} (1) \hspace{1cm} \text{where} \hspace{1cm} s = (aq'_w - b\theta'_l)/2 \hspace{1cm} \text{and sigma is the variance of } s.

The saturation mixing ratio is determined from the average temperature of the grid volume.

\[ \bar{q}_{sl} = q_s(\bar{T}_l) \]

- So the cloud fraction and the mean liquid water specific humidity can be obtained solving some integrals.
The **cloud fraction**

\[
R = \int_{-\alpha \Delta \bar{q}/2}^{\infty} G(s) ds = \frac{1}{2} \left[ 1 + \text{erf}\left( \frac{Q_1}{\sqrt{2}} \right) \right]
\]

While the **condensation** is

\[
\frac{\bar{q}_i}{2 \sigma_s} = \frac{1}{2 \sigma_s} \int_{-\alpha \Delta \bar{q}/2}^{\infty} (a \Delta \bar{q} + 2s) G(s) ds
\]

\[
\frac{\bar{q}_i}{2 \sigma_s} = R Q_1 + \frac{1}{2 \pi} \exp\left[ -\frac{Q_1^2}{2} \right]
\]

where \( \Delta \bar{q} = \bar{q}_w - \bar{q}_{sl} \)

\[
Q_1 = \bar{a} \left[ \frac{r_w - r_{sat}(T_1)}{\sigma_s} \right]
\]

is the **saturation deficit**
A parameterization of sigma was proposed \(^{(3)}\) that is activated in AROME with the switch LOSIGMAS.

\[
\sigma_s = c_o l \left[ \bar{a}^2 \left( \frac{\partial \tilde{r}_w}{\partial z} \right)^2 - 2 \bar{a} \bar{b} C_{pm}^{-1} \frac{\partial \tilde{h}}{\partial z} \frac{\partial \tilde{r}_w}{\partial z} + \bar{b}^2 C_{pm}^{-2} \left( \frac{\partial \tilde{h}}{\partial z} \right)^2 \right]^{1/2}
\]

The actual parameterization is based on the results from a LES model \(^{(2)}\)

\[
N = \max \left\{ 0, \min \left[ 1, 0.5 + 0.36 \arctan \left( 1.55 Q_1 \right) \right] \right\}
\]

\[
\frac{\tilde{F}_I}{\sigma_s} = e^{(1.2Q_1-1)} \quad Q_1 < 0,
\]

\[
\frac{\tilde{F}_I}{\sigma_s} = e^{-1} + 0.66Q_1 + 0.086Q_1^2 \quad 0 \leq Q_1 \leq 2
\]

\[
\frac{\tilde{F}_I}{\sigma_s} = Q_1 \quad Q_1 > 2.
\]
VERTICAL SATURATION DEFICIT GRADIENTS
It is going to be considered a linear variation of the water mixing ratio inside the grid point.

\[ r_w = r_w^* + A_w \Delta z \quad , \quad r_w \in \left[ r_w^* - \frac{A_w \Delta z}{2} , r_w^* + \frac{A_w \Delta z}{2} \right] \]
It is going to be considered a linear variation of the water mixing ratio.

\[
r_w = r_{w0} + A_w \Delta z, \quad r_w \in \left[ r_{w0} - \frac{A_w \Delta z}{2}, r_{w0} + \frac{A_w \Delta z}{2} \right]
\]

The saturation mixing ratio is linear as well

\[
r_s = r_{s0} + A_s \Delta z, \quad r_s \in \left[ r_{s0} - \frac{A_s \Delta z}{2}, r_{s0} + \frac{A_s \Delta z}{2} \right]
\]
It is going to be considered a linear variation of the water mixing ratio.

\[ r_w = \bar{r}_w + A_w \Delta z, \quad r_w \in [\bar{r}_w - \frac{A_w \Delta z}{2}, \bar{r}_w + \frac{A_w \Delta z}{2}] \]

The saturation mixing ratio is linear as well

\[ r_s = \bar{r}_s + A_s \Delta z, \quad r_s \in [\bar{r}_s - \frac{A_s \Delta z}{2}, \bar{r}_s + \frac{A_s \Delta z}{2}] \]

The condensation will be given by the area between the two lines.
We get the difference:

\[ Q_1 = r_t - r_s \]

The condensation will be given by the area under the positive part of the line.
The distribution that corresponds to this linear dependence is a rectangular function:

\[
\rho(Q_1) = \frac{1}{(A_w - A_s) \Delta z}, \quad r_w \in [\bar{Q}_1 - \frac{(A_w - A_s) \Delta z}{2}, \bar{Q}_1 + \frac{(A_w - A_s) \Delta z}{2}] \quad \rho(Q_1) = 0, \quad \text{otherwise}
\]
The rectangular distribution is going to be compared with a gaussian distribution in order to consider when the first is going to be important.
In order to consider both this distribution and the gaussian due to the turbulence, we calculate the convolution:

\[
\Phi(q') = (\rho * \rho_{gauss})(q') = \int_{-\infty}^{\infty} \rho(x - q') \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}} dx
\]

with \( x = Q_1 - \bar{Q}_1 \)

\[
\Phi(q') = \frac{1}{A_q \Delta z} \left[ \text{erf} \left( \alpha \frac{q' + A_q \Delta z / 2}{A_q \Delta z \sqrt{2}} \right) - \text{erf} \left( \alpha \frac{q' - A_q \Delta z / 2}{A_q \Delta z \sqrt{2}} \right) \right]
\]

Alpha is the ratio:

\[
\alpha = \frac{A_q \Delta z}{\sigma}
\]

and indicates when the vertical gradient is important compared with the turbulence.
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► Comparison of distribution functions for different values of alpha

► For high values of alpha, it is going to be taken the rectangular distribution

► In red the gaussian distribution corresponding to sigma.

► In black the rectangular distribution

► In green the convolution

► In blue a gaussian with sigma=DQ1
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► Comparison of distribution functions for different values of alpha
► For high values of alpha, it is going to be taken the rectangular distribution
Comparison of the rectangular distribution with the convolution distribution for different values of alpha.

In our present study we are going to consider the rectangular distribution for values of \textit{alpha} greater than 5.
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► Parametrization of cloud fraction and condensation.

► We are going to consider the difference between the mixing ratio and the saturation mixing ratio:

\[ Q_{\text{top}} = r_t \text{top} - r_s \text{top} \]
\[ Q_{\text{bottom}} = r_t \text{bottom} - r_s \text{bottom} \]
\[ Q_{\text{MAX}} = \text{MAX} (Q_{\text{top}}, Q_{\text{bottom}}) \]
\[ Q_{\text{MIN}} = \text{MIN} (Q_{\text{top}}, Q_{\text{bottom}}) \]

\[ \rho = \frac{1}{Q_{\text{MAX}} - Q_{\text{MIN}}} \]

\[ N = \int_{0}^{Q_{\text{MAX}}} \rho \, dQ = \frac{Q_{\text{MAX}}}{Q_{\text{MAX}} - Q_{\text{MIN}}} \]

\[ \text{COND} = \int_{0}^{Q_{\text{MAX}}} Q \, \rho \, dQ = \frac{Q_{\text{MAX}}^2}{2(Q_{\text{MAX}} - Q_{\text{MIN}})} \quad \text{if} \quad Q_{\text{MIN}} < 0 \]

\[ \text{COND} = \int_{Q_{\text{MIN}}}^{Q_{\text{MAX}}} Q \, \rho \, dQ = \frac{Q_{\text{MAX}}^2 - Q_{\text{MIN}}^2}{2(Q_{\text{MAX}} - Q_{\text{MIN}})} \quad \text{if} \quad Q_{\text{MIN}} > 0 \]
CASES
Fog in the Alboran sea: Model (Cloud water LEVEL 65) vs. Satellite (Low clouds in orange)

Monday 8 October 2012 00UTC  t+15 VT: Monday 8 October 2012 15UTC Surface:

• 08/10/2012
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- Fog in the Alboran sea: Model vs. Model+changes (Cloud Water model level 65)
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- Precipitation event: Model (SFC ACC PLUIE)

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The difference of the accumulated precipitation shows that although the pattern is similar there seems to be a displacement in the maximum and minimum areas.
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MUSC. With forcing from the 3D model. 08/03/2013 12 H+06

MADRID-BARAJAS AIRPORT

Cloud Fraction

In red the profile given by the model

- In green the output from the MUSC without modification
- In blue with the modifications for the condensation
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MUSC. With forcing from the 3D model. 08/03/2013 12. MADRID-BARAJAS AIRPORT

Cloud Fraction and Cloud water. Increase in the cloud water content and widener of the cloud

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MUSC. With forcing from the 3D model. 08/03/2013 12. MADRID-BARAJAS AIRPORT

Rain. Increase of the precipitation at HH+06 but it decreases at HH+11
CONCLUSIONS
Although no big changes are appreciated, in some areas there are important differences. *(If these differences are due to errors in the parametrization or they represent real events is not yet studied)*

From the MUSC results it seems that in most of the cases the clouds are wider and the cloud water content is increased.

The influence on the precipitation has not a clear sign, it can be observed the same pattern, but with the maxima and minima displaced.

It is not clear that there is any improvement.
BIBLIOGRAPHY


THANK YOU!

QUESTIONS?