



GOBIERNO  
DE ESPAÑA

MINISTERIO  
DE AGRICULTURA, ALIMENTACIÓN  
Y MEDIO AMBIENTE



# Statistical cloud scheme research with HARMONIE.

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ASM BUCHAREST 07/04/2014

## 0. OUTLINE

1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE
2. SATURATION DEFICIT VARIANCE
3. PDF FUNCTION PROPOSED
4. SUMMARY



## 0. OUTLINE

1. Statistical Scheme for clouds in HARMONIE (Short introduction).
2. Dependence of the saturation deficit variance with the vertical gradient. Modification of the variance.
3. PDF function proposed.
4. Summary.

## 0. OUTLINE

### 1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE

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## 1. Statistical Scheme for Clouds in HARMONIE

In the Statistical Scheme theory, a PDF (probability density function) is used to obtain the cloud water content and the cloud fraction, that depends on the saturation deficit.

In HARMONIE no PDF is used, but the expressions obtained from several test cases. (*src/mpa/micro/internals/condensation.f90*)

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The subgrid condensation in the HARMONIE Model is based on the relations suggested by Cuijpers and Bechtold (1995).

The cloud fraction is given by:

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

While the condensation content is given by the relations:

$$\frac{\bar{r}_l}{\sigma_s} = e^{(1.2Q_1 - 1)} \quad Q_1 < 0,$$

$$\frac{\bar{r}_l}{\sigma_s} = e^{-1} + 0.66Q_1 + 0.086Q_1^2 \quad 0 \leq Q_1 \leq 2$$

$$\frac{\bar{r}_l}{\sigma_s} = Q_1 \quad Q_1 > 2.$$

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These relations depend on the **saturation deficit normalized** by the variance,  $\sigma_s$

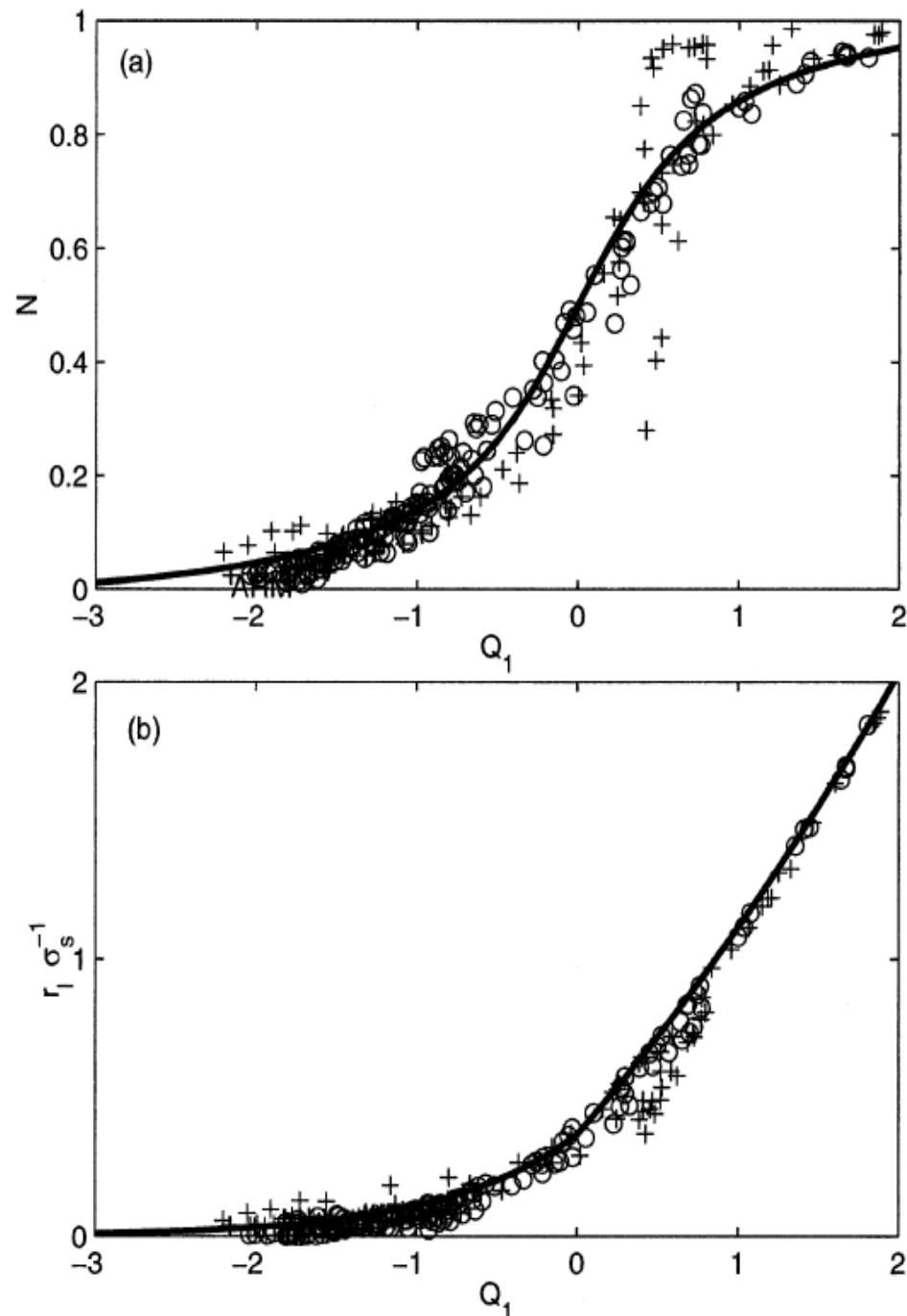
$$Q_1 = \bar{a} [ \bar{r}_w - r_{sat}(\bar{T}_l) ] / \sigma_s$$

The variable  $s$  is defined as

$$s = ar_w - bT_l$$

with  $a$  and  $b$  depending on the latent heat and the water vapour saturation mixing ratio.

*Cloud fraction and cloud water content  
(Chaboureau and Bechtold, 2002)*



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## Explored ways for improving the statistical scheme for clouds

1. Include a term in the variance of the saturation deficit that takes into account the vertical gradient of the saturation deficit.
2. Check a pdf that could fit, more or less, the expressions used in HARMONIE for the cloud water and the cloud fraction.

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$$Q_1 = \bar{a} [\bar{r}_w - r_{sat}(\bar{T}_1)] / \sigma_s$$

The variable  $s$  is defined as

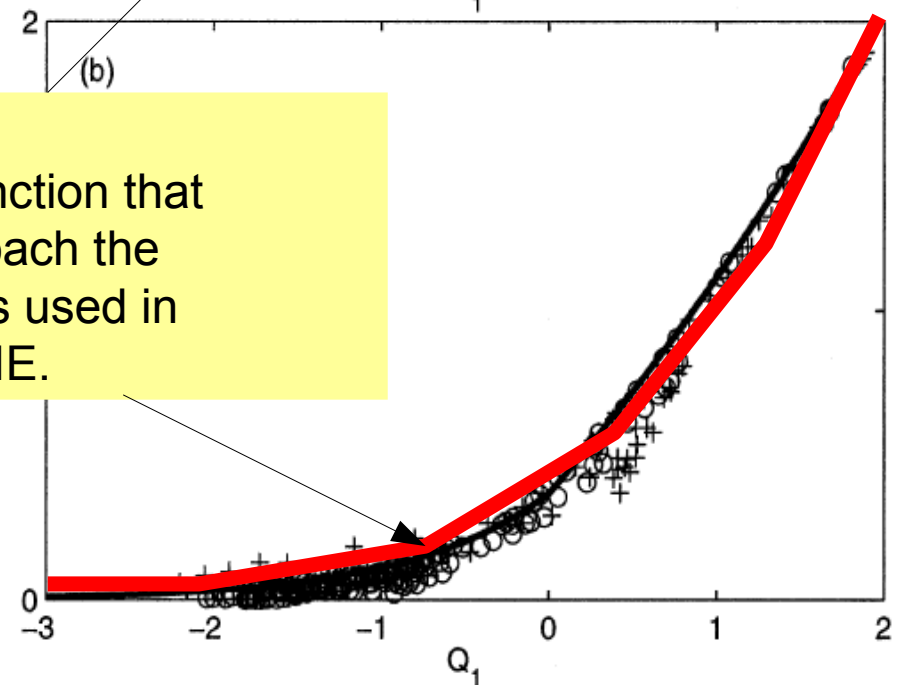
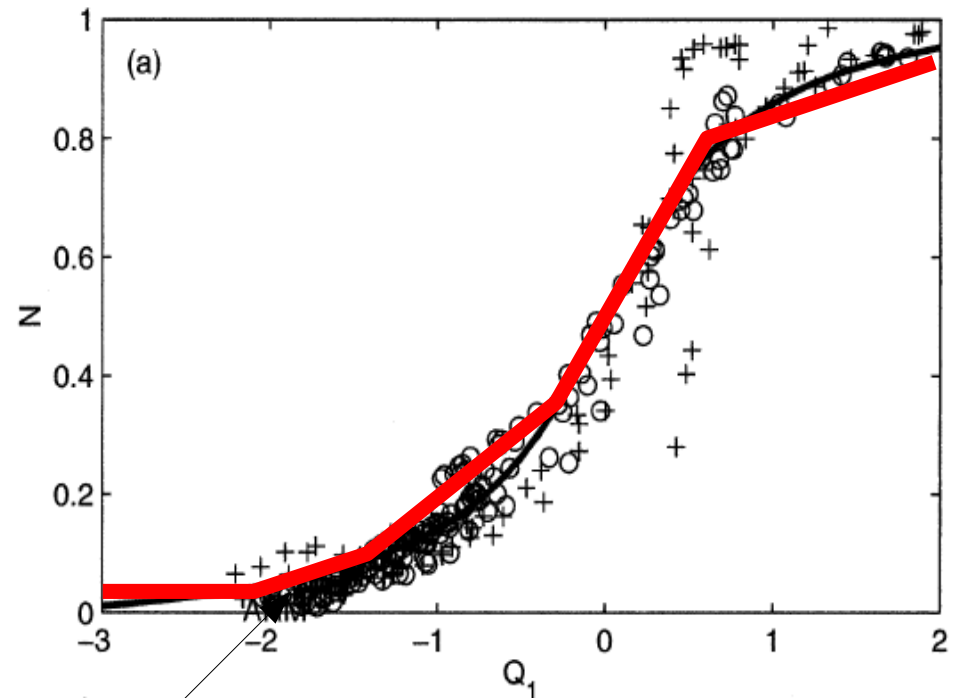
$$s = \frac{r - r_{sat}}{hT}$$

1. Introducing a new term in the variance of the saturation deficit.

the sat

2. PDF function that could approach the expressions used in HARMONIE.

*Cloud fraction and cloud water content (Chaboureau and Bechtold, 2002)*



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## 2. Saturation deficit variance

$$\sigma_s = 2 \sigma_{turb, conv} - 0.02 a r_{sat}$$

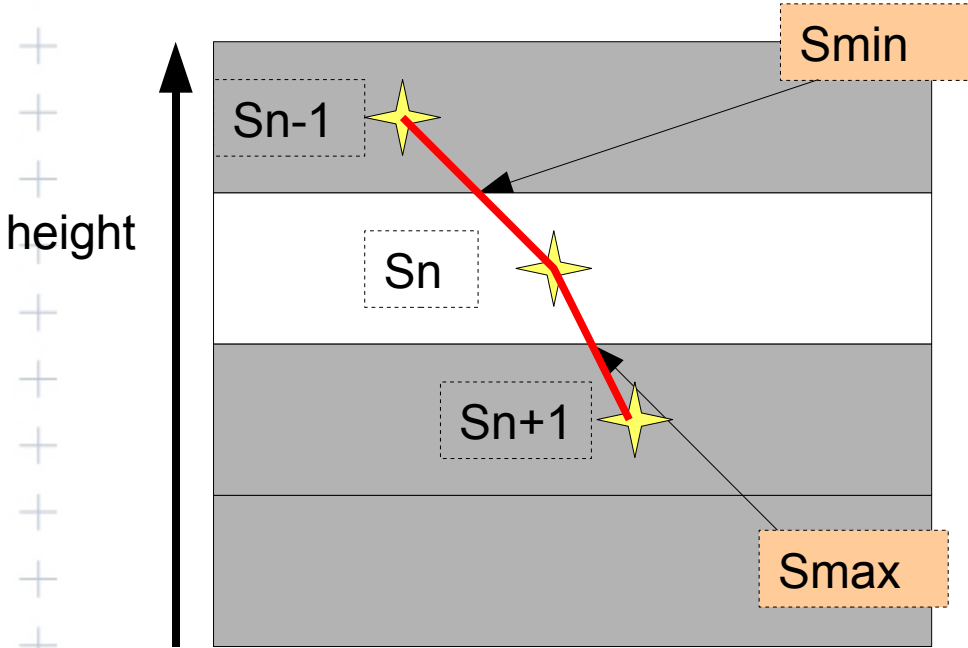
Turbulence and convection term

Term introduced at KNMI

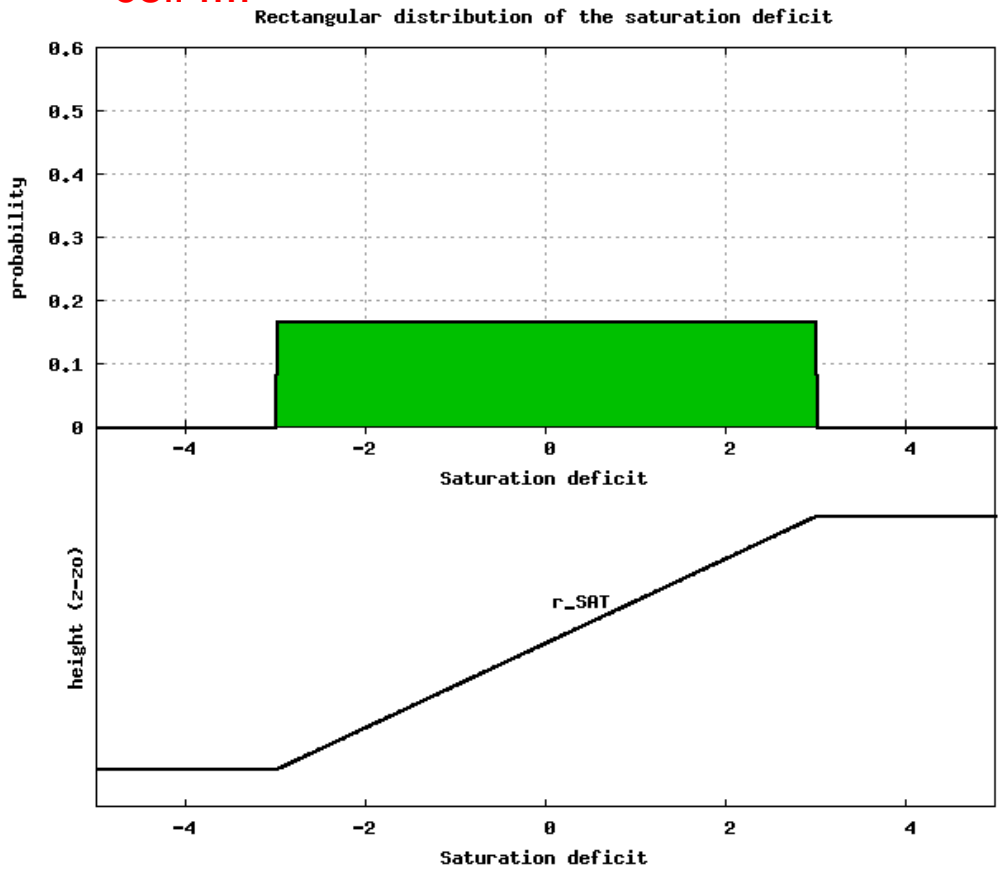


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## Vertical variation of the saturation deficit.



Considering a linear vertical variation of the saturation deficit inside the cell !!!!



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## Saturation deficit variance modified

$$\sigma_s = 2 \sigma_{turb, conv} + 0.02 a r_{sat} + \frac{1}{2\sqrt{3}} (S_{max} - S_{min})$$

Turbulence and convection term

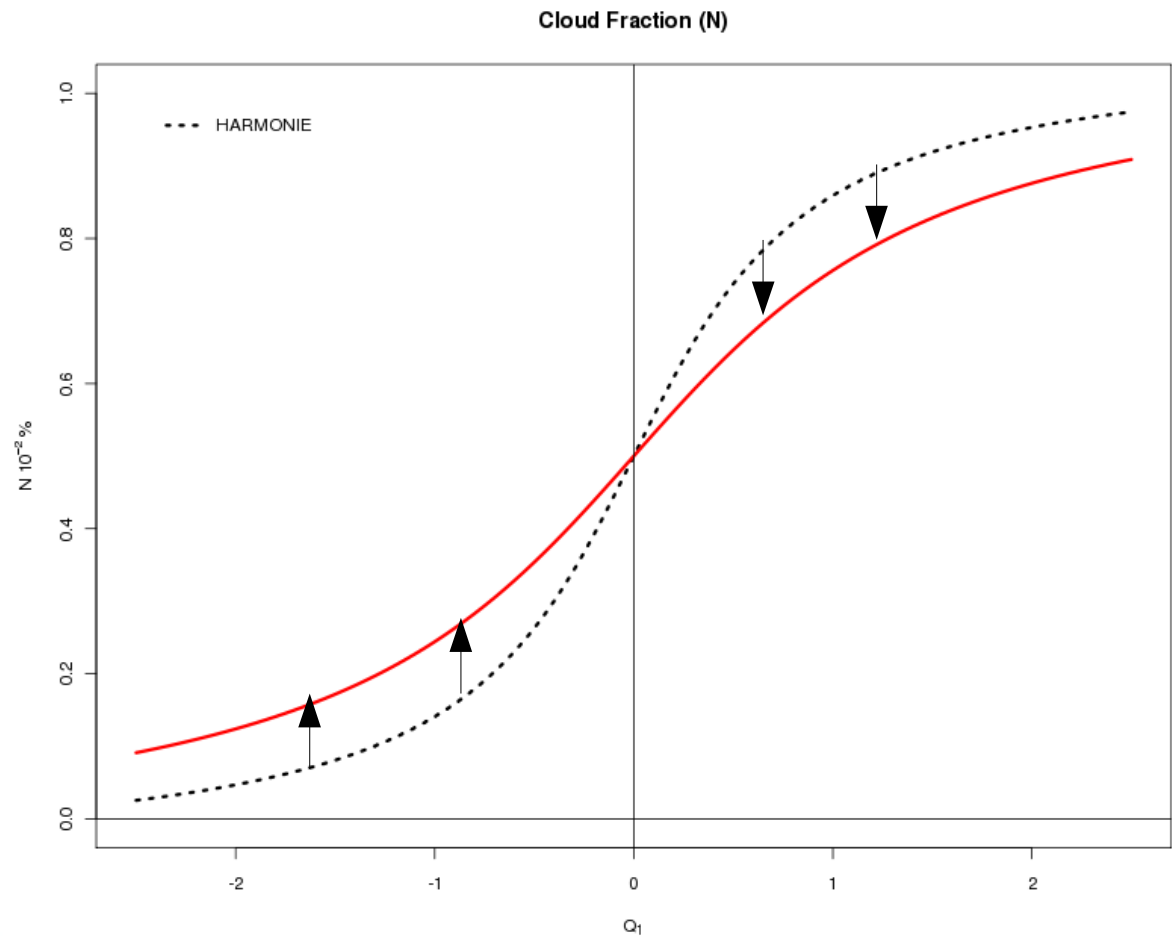
Term introduced at KNMI

Term proposed. It depends on the difference between the maximum and minimum of the saturation deficit inside the cell (considering a linear vertical variation).

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## Influence in the cloud fraction:

When adding a positive term to the variance, it is expected, in general, an increment of the cloud fraction for  $N < 50\%$  and a decrease for  $N > 50\%$ .



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## Variance of saturation term has been tested:

1. MUSC model: ARM case (1997/06/21) to show when the modification is more important.
2. 3D Harmonie cases.
3. Verification has been done for two weeks.

## ARM Case (1997/06/21). Run with MUSC 37h12

The variance modification have been tested in the ARMCu Case (Shallow convection) with MUSC37h12, and compared with the LES results.

*With the EDMF configuration it gives higher values of cloud water content and cloud fraction in the base of the clouds and the vertical extension is much lower than for the LES results*

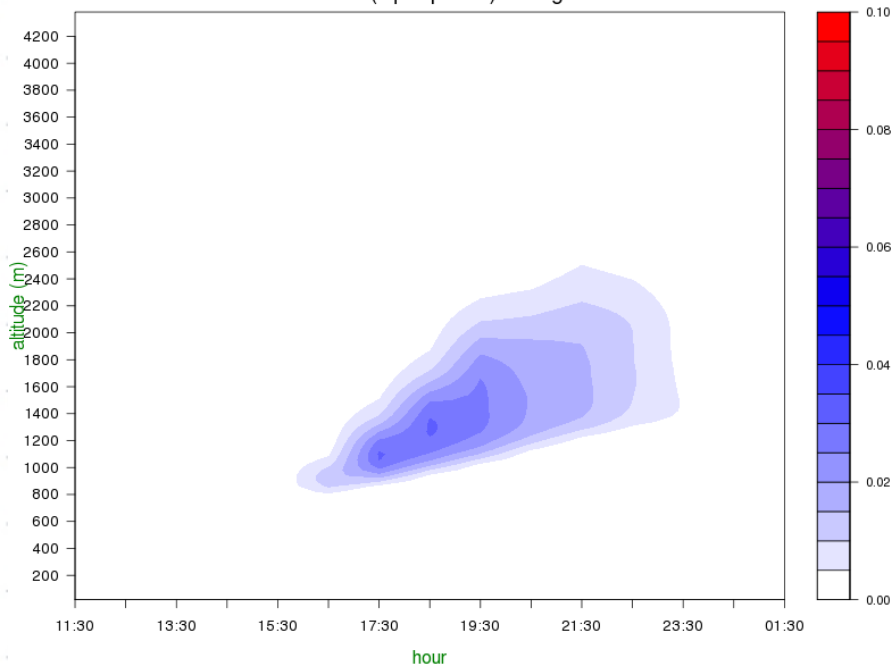
It is going to be showed where the new term of the variance can be relevant

## *Configuration of the experiment:*

```
LOSUBG_COND=.TRUE.,  
LOSIGMAS=.TRUE.,  
LMIXUV=.TRUE.,  
CMF_UPDRAFT='DUAL',  
CMF_CLOUD='STAT',  
LHGT_CLDVAR=.TRUE.,
```

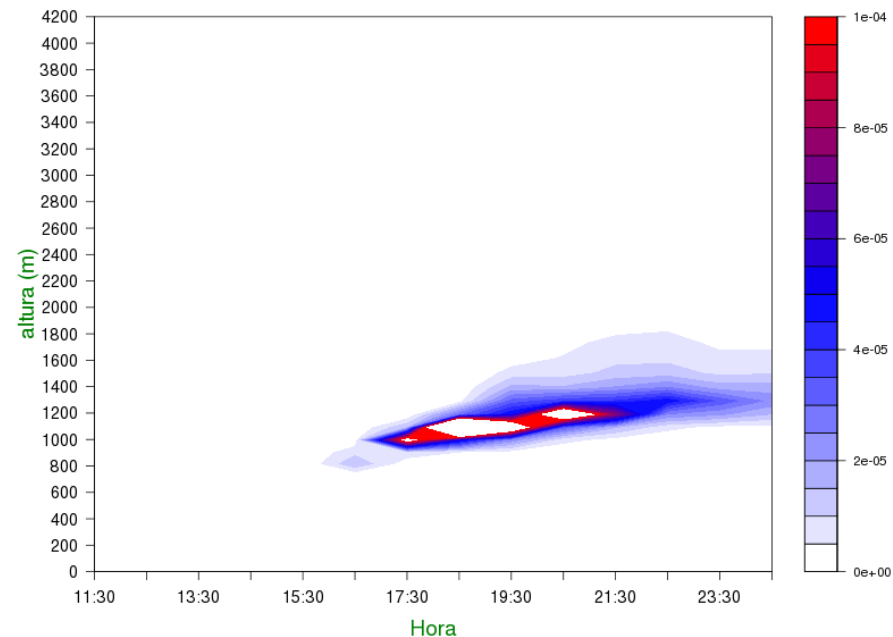
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ARM Cumulus case 21-06-1997  
LES. Water (liquid phase) mixing ratio



*LES.  
Cloud water content.  
ARM Cu case 21/06/1997*

ARM Cu case. MUSC EDMF  
Agua de nube Fecha 21-06-1997 HORA: 11



*MUSC v37h12. EDMF.  
Cloud water content.  
ARM Cu case 21/06/1997*

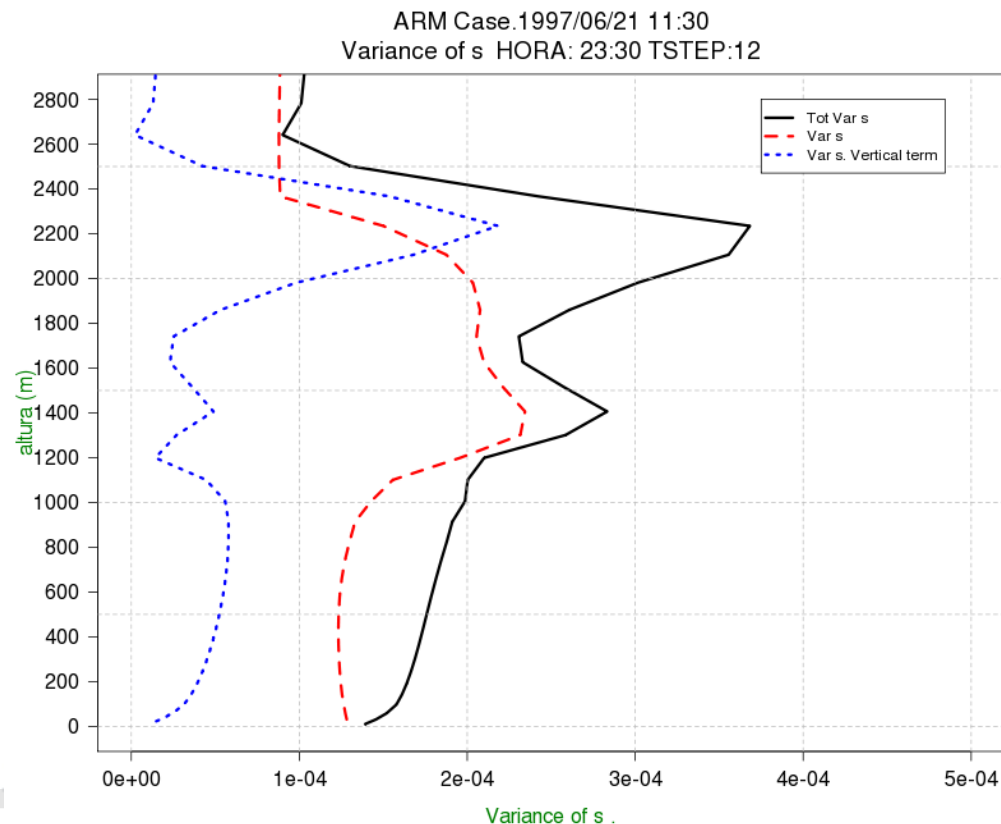
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## ARMCu Case. Variance of $s$

In **red** the variance due to the turbulence, the convection and the KNMI term.

In **blue** the variance due to the vertical gradient.

Two relative maximum are observed



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## ARMCu Case (1997-06-21). Variance of saturation deficit

Fig. Cloud water. H+12.  
LES (black), MUSC ref.(red), MUSC modif. (green)

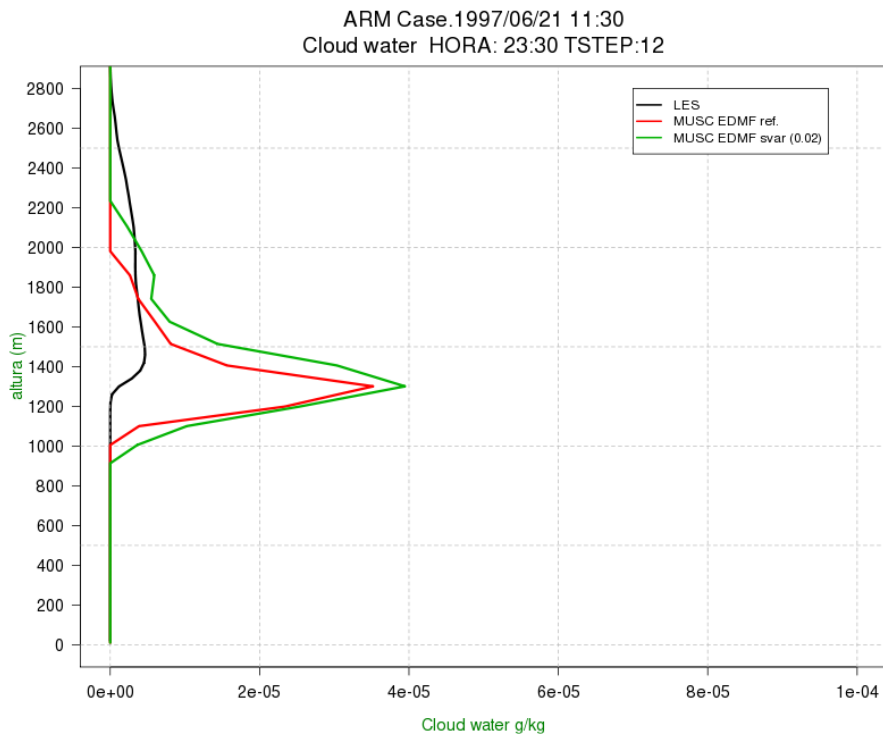
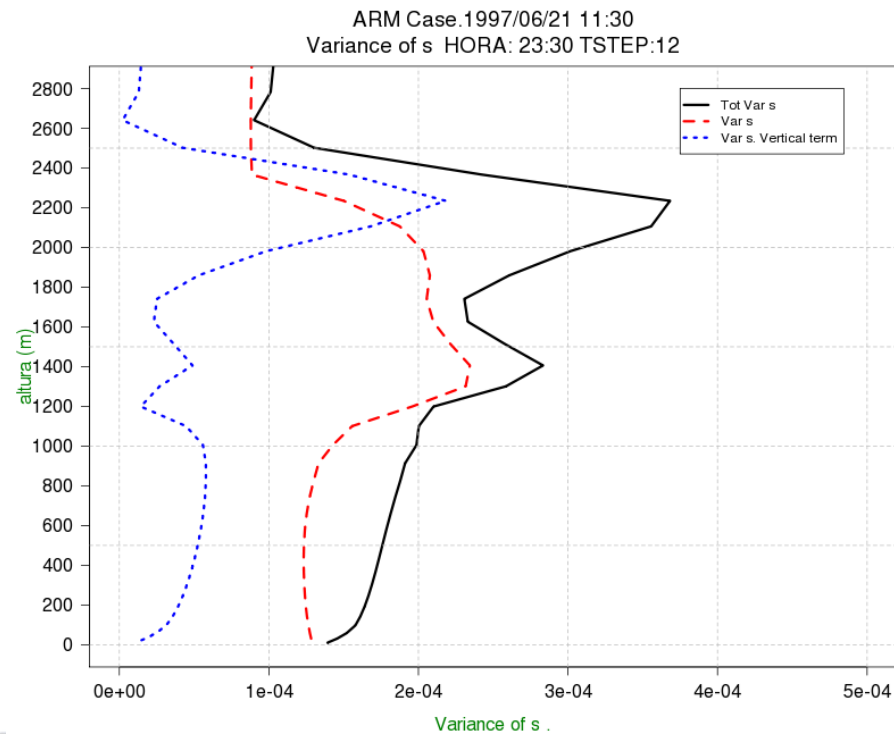


Fig. Variance of s. H+12.  
Var of s (red), New term (blue), Sum (black)



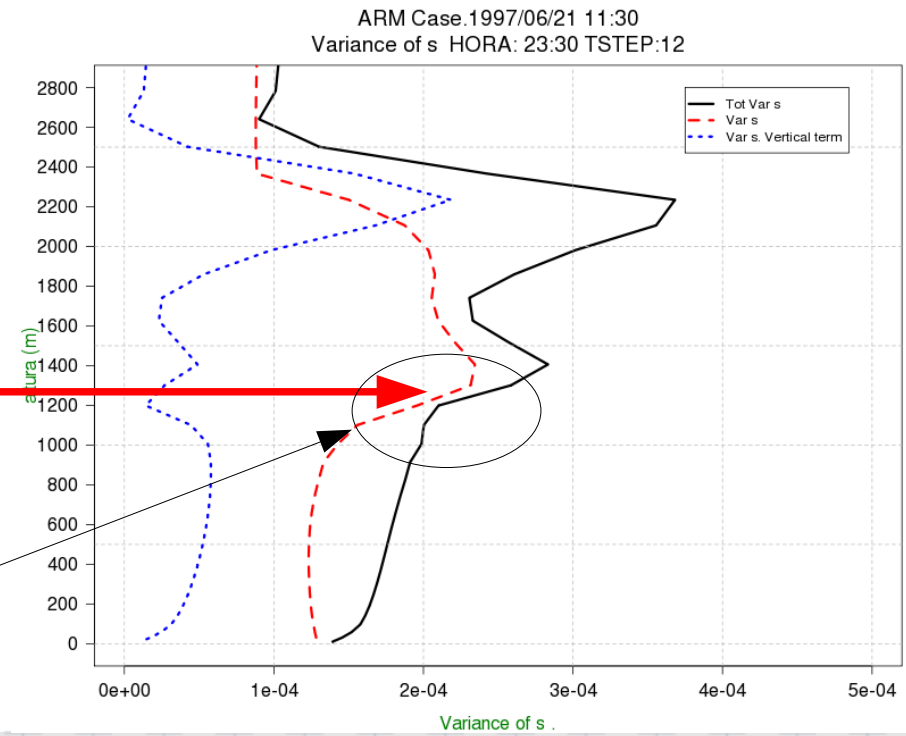
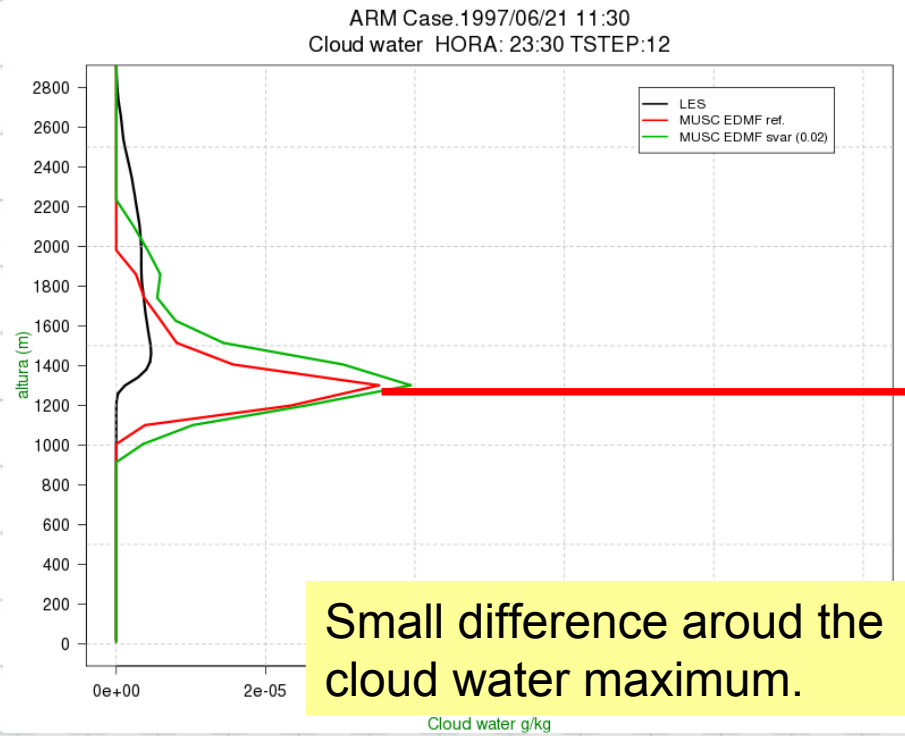


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## ARMCu Case (1997-06-21). Variance of s

Fig. Cloud water. H+12.  
LES (black), MUSC ref. (red), MUSC modif. (green)

Fig. Variance of s. H+12.  
Var of s (red), New term (blue), Sum (black)

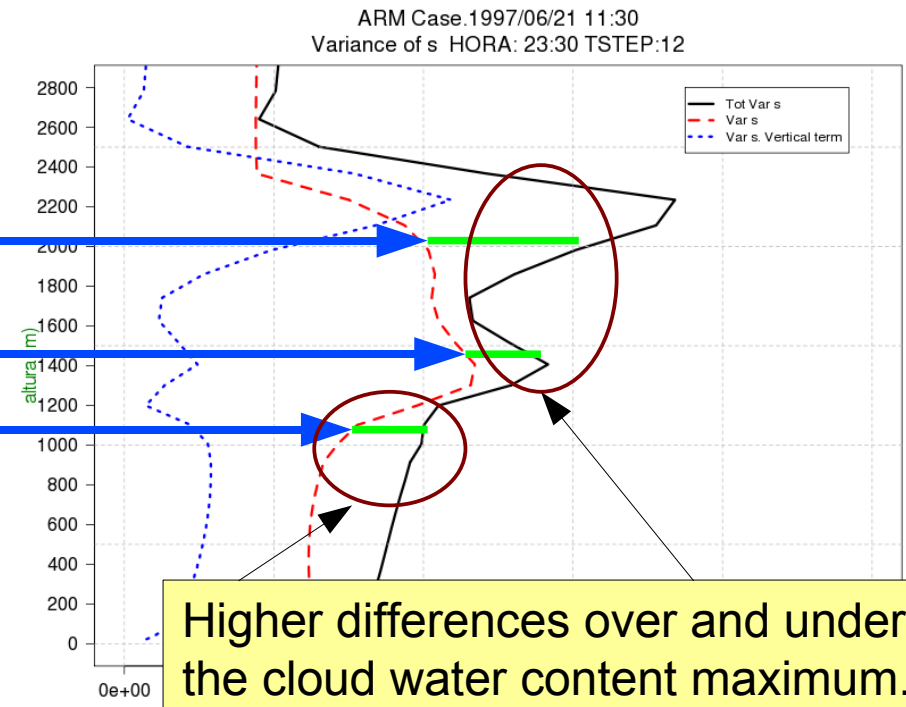
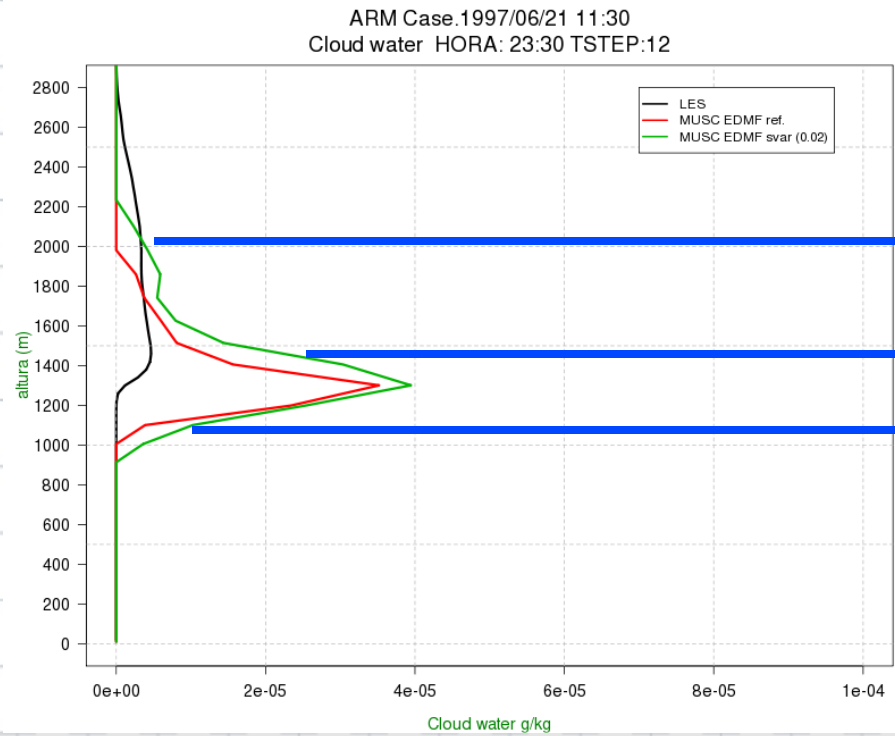


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## ARMCu Case (1997-06-21). Variance of s

Fig. Cloud water. H+12.  
LES (black), MUSC ref.(red), MUSC modif. (green)

Fig. Variance of s. H+12.  
Var of s (red), New term (blue), Sum (black)



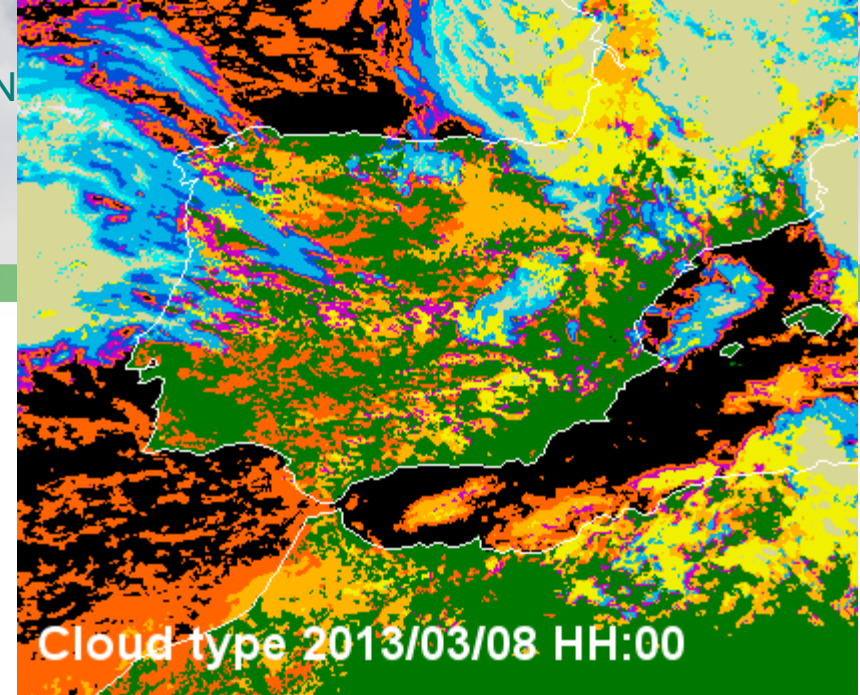
Higher differences over and under the cloud water content maximum.  
Larger vertical extension of clouds

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## Cases from the 3D HARMONIE

Clouds will have a larger extension, in general, with “smoother” contours.

It is not easy to find significant differences.



*Fig: image from SAF-Nowcasting*

*In orange the low clouds  
In white and blue, high clouds*

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## 3D HARMONIE. 07/03/2013 H+24

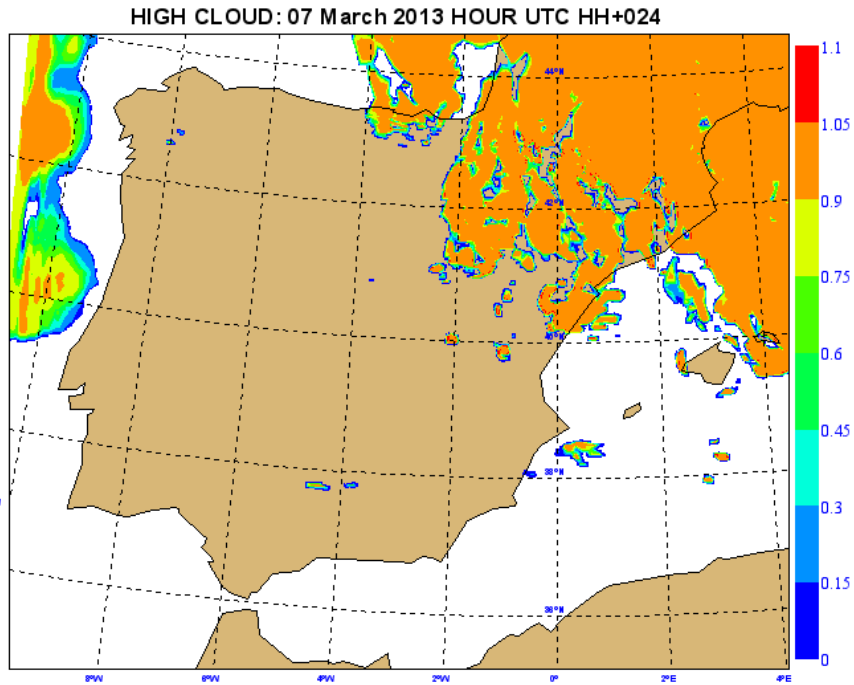
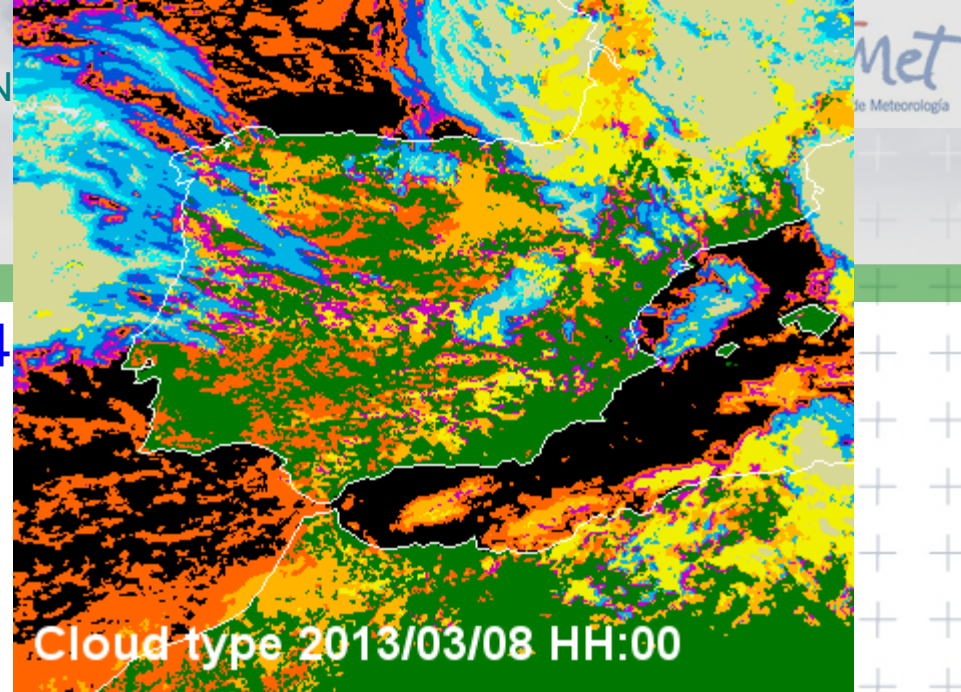


Fig. Cloud fraction. High clouds.

*HARM reference*

STATISTICAL CLOUD SCHEME RESEARCH WITH HARMONIE

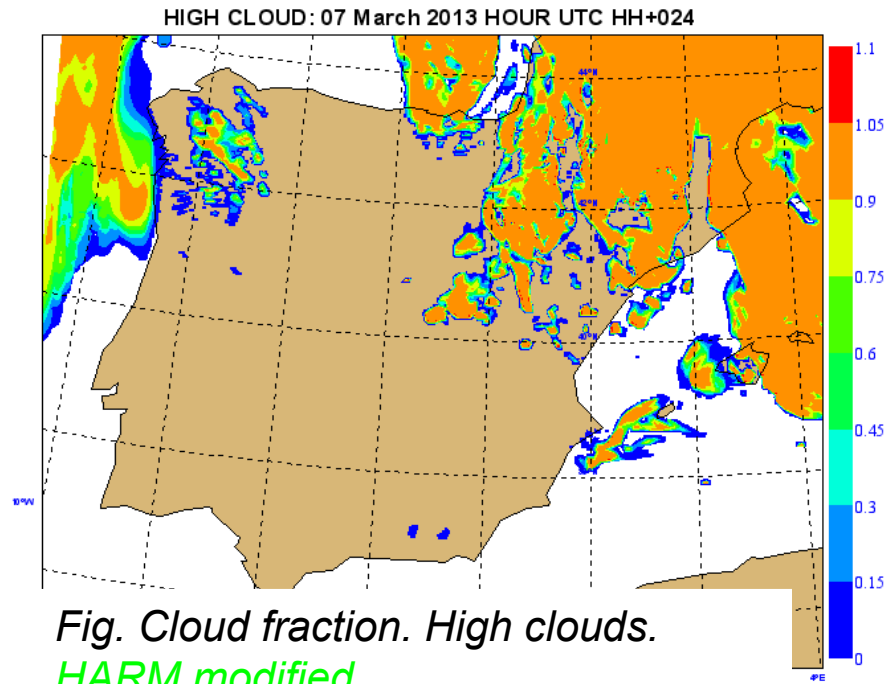


Fig. Cloud fraction. High clouds.

*HARM modified*

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## 3D HARMONIE. 07/03/2013 H+24

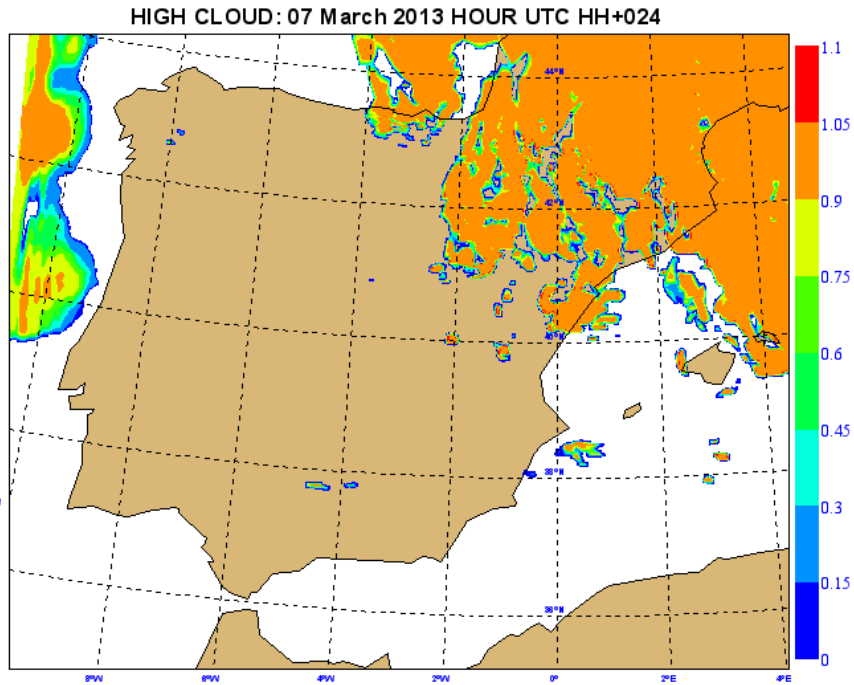
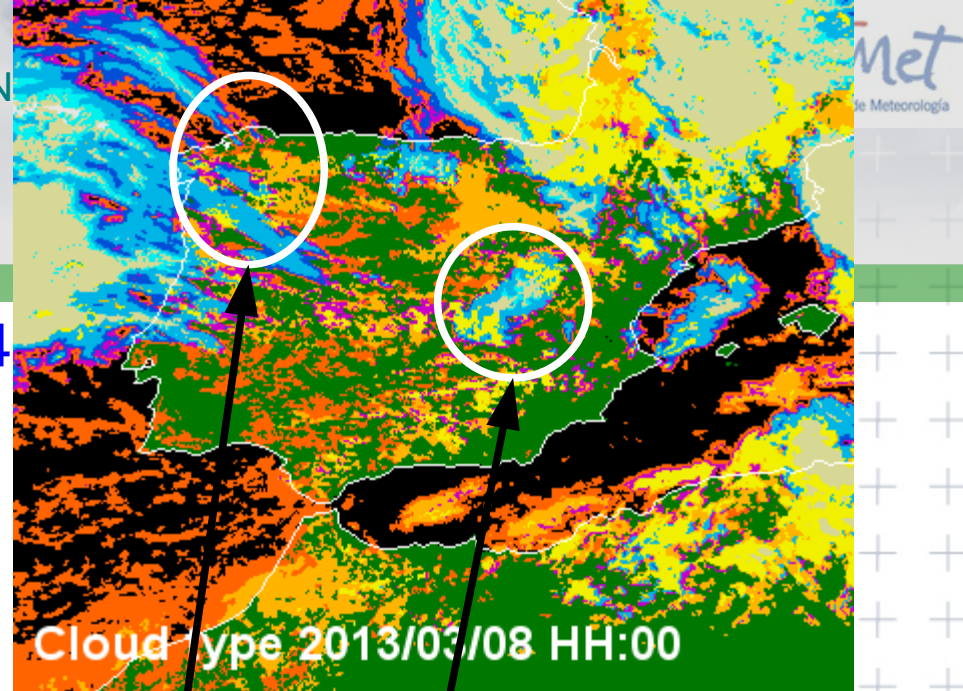


Fig. High clouds. *HARM reference*

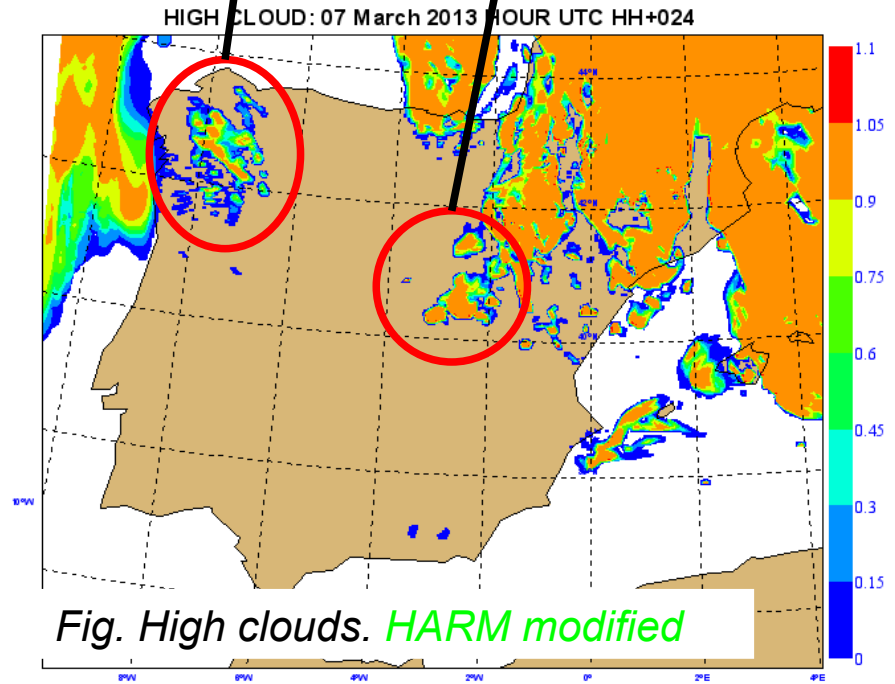
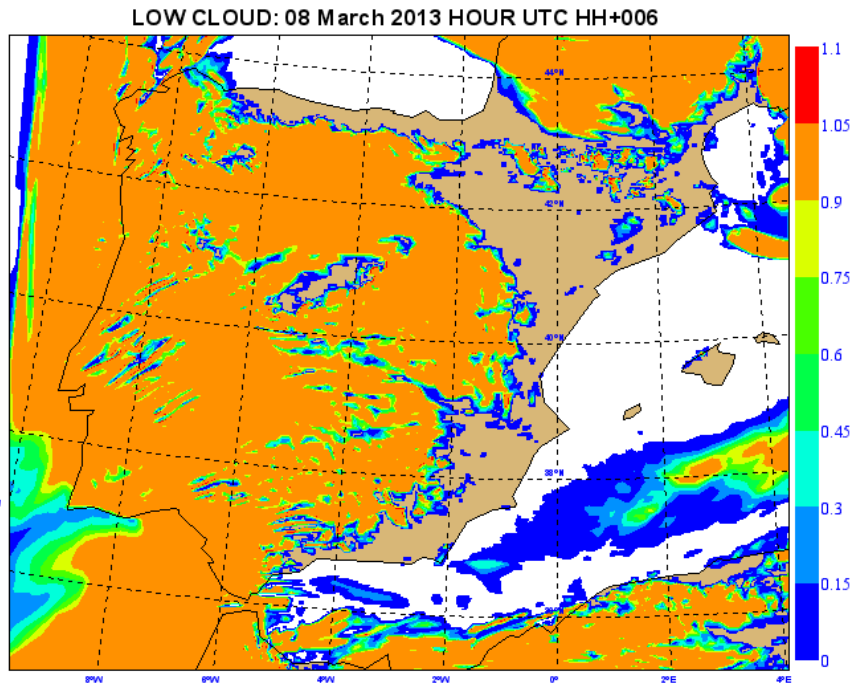
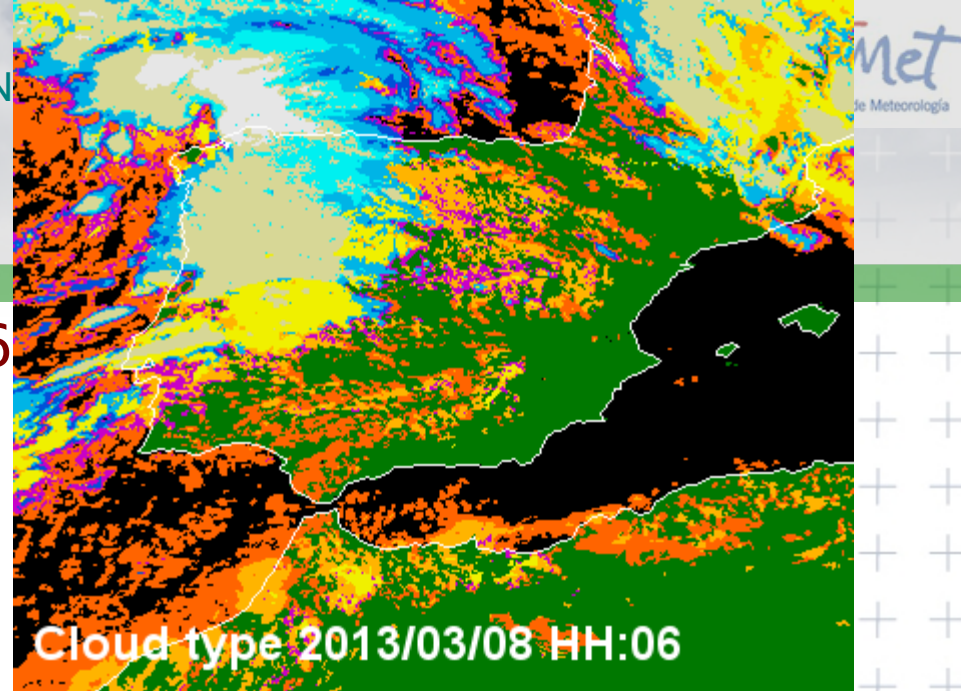


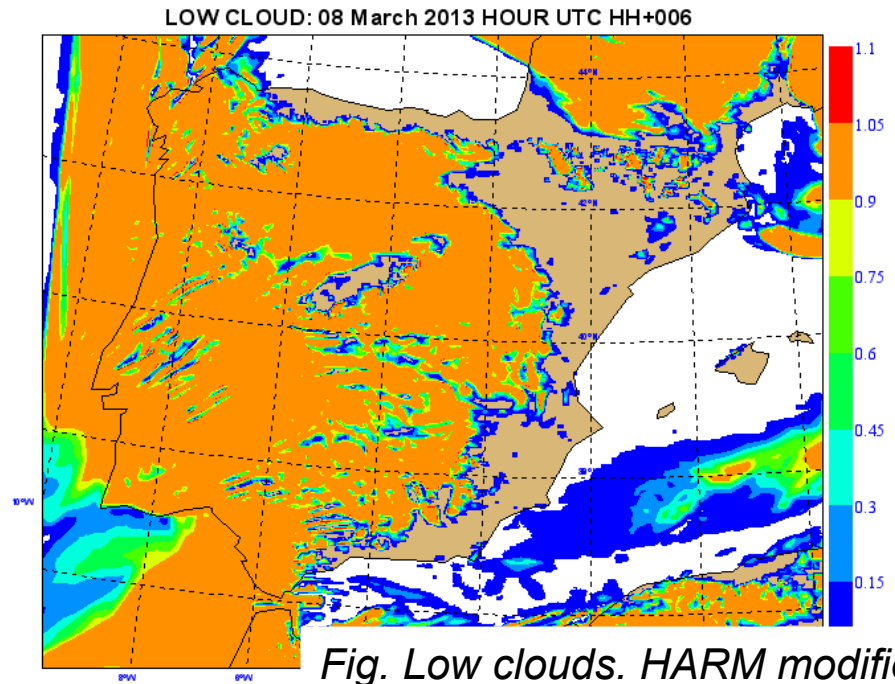
Fig. High clouds. *HARM modified*

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## 3D HARMONIE. 08/03/2013 H+06



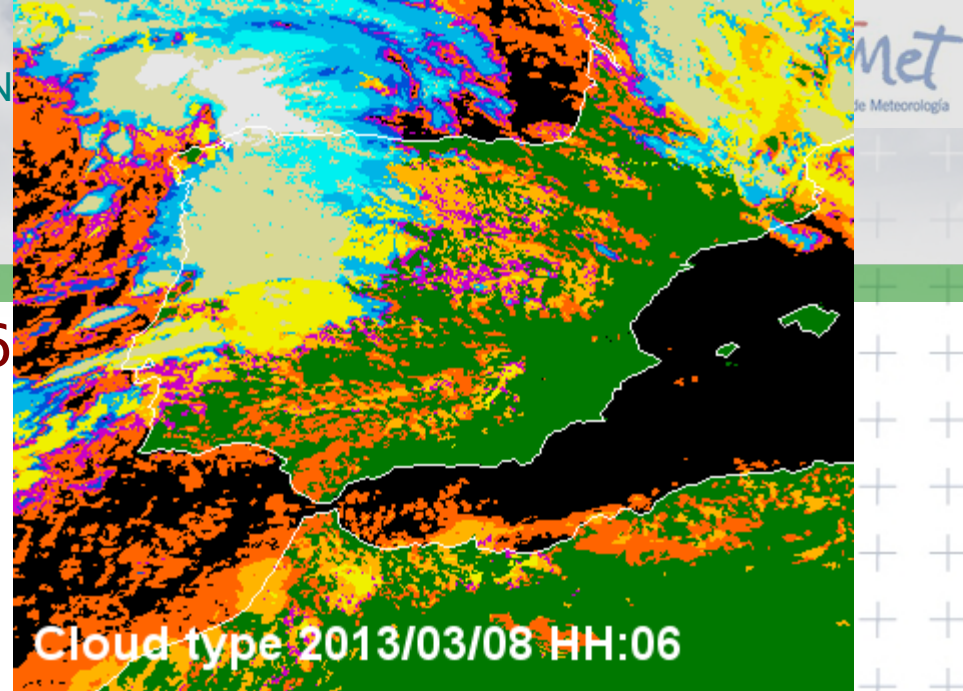
*Fig. Low clouds. HARM reference*



*Fig. Low clouds. HARM modified*

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## 3D HARMONIE. 08/03/2013 H+06



LOW CLOUD: 08 March 2013 HOUR UTC HH+006

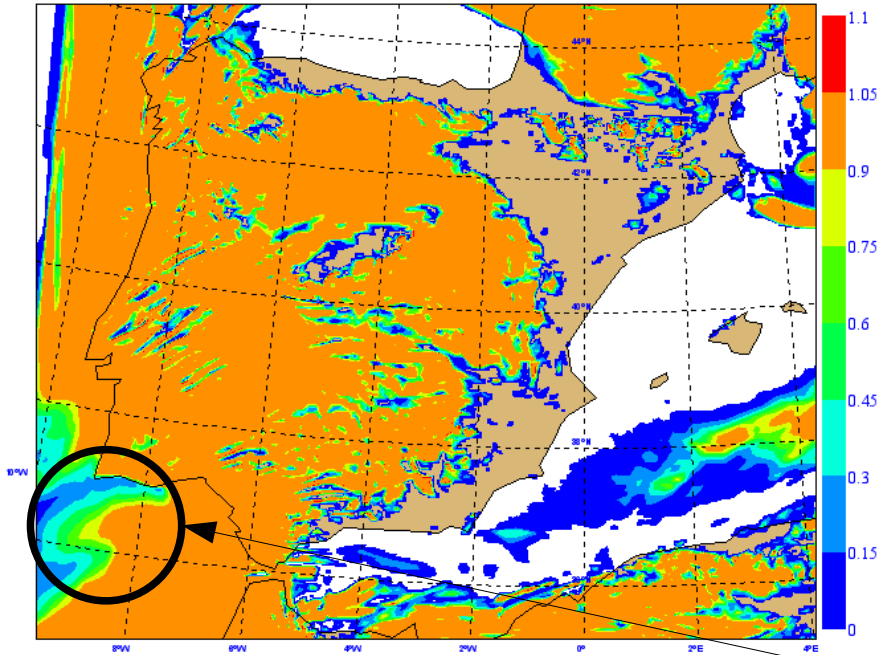


Fig. Low clouds. *HARM reference*

LOW CLOUD: 08 March 2013 HOUR UTC HH+006

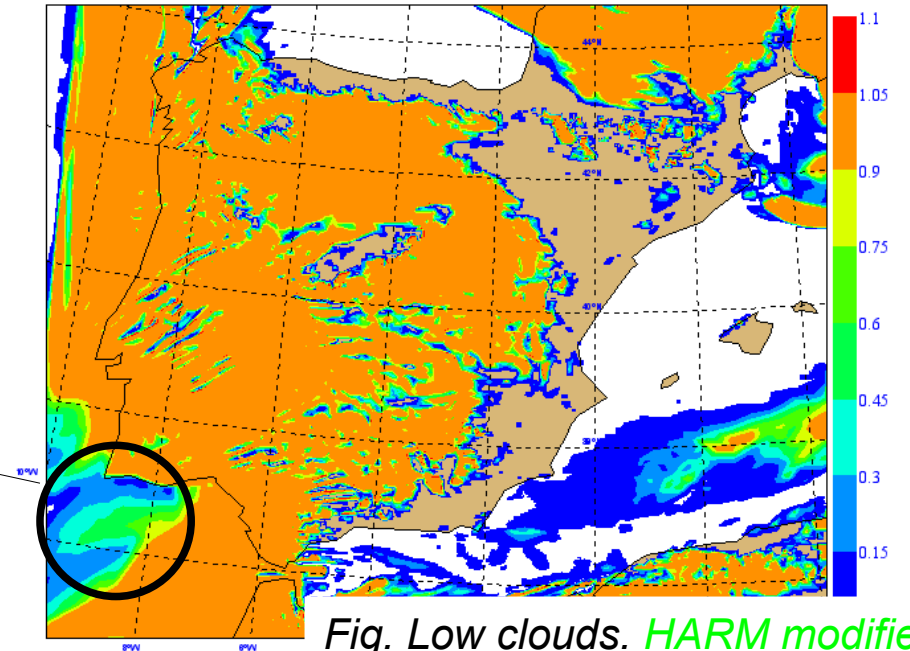


Fig. Low clouds. *HARM modified*

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## Verification.

HARMONIE cy37h12. Forecast length: 36

**Red:** reference

**Green:** modified

Period chosen: 07/03/2013-20/03/2013 (2 weeks) with high number of precipitation events.

Area: Iberian Peninsula.



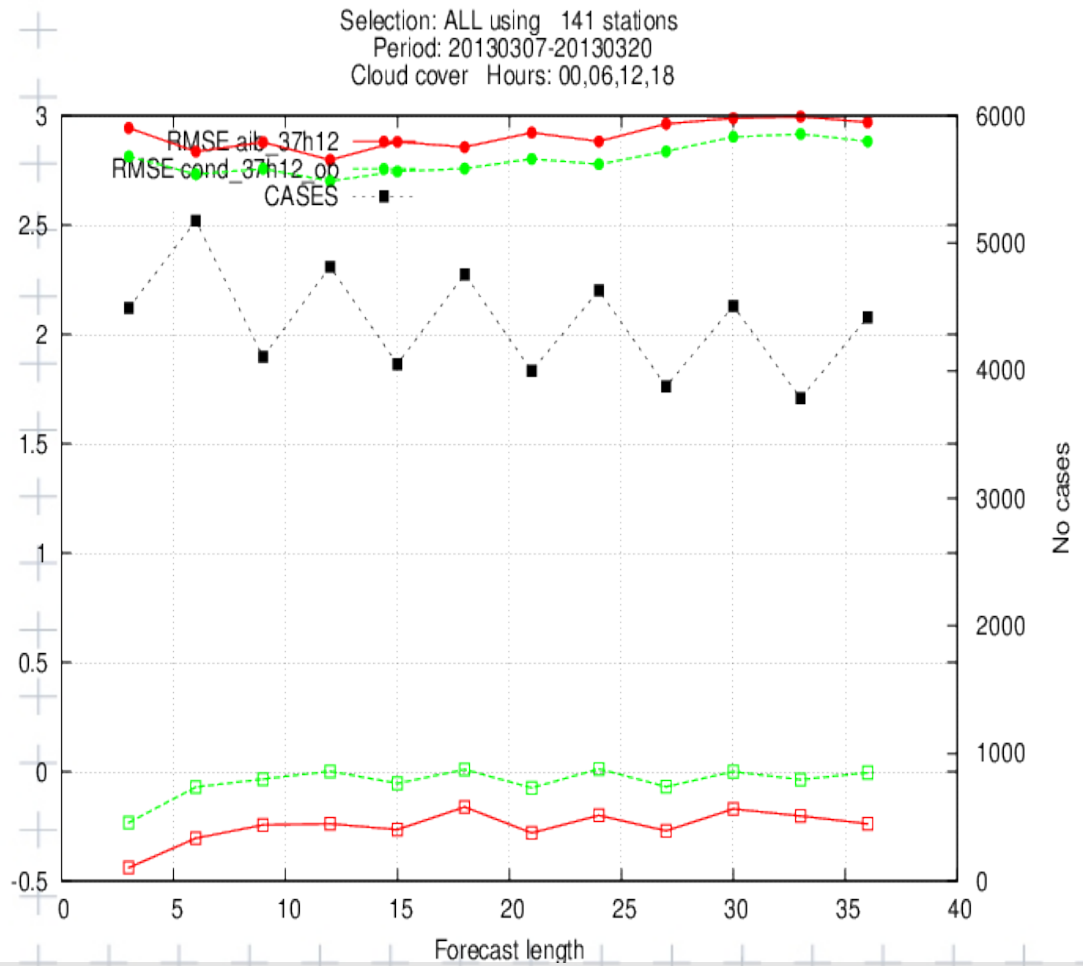
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## Cloud cover verification.



ALL stations

Better rmse (small difference) and bias for all the forecast lengths



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Red: ref.  
 Green: mod.

## 0. OUTLINE

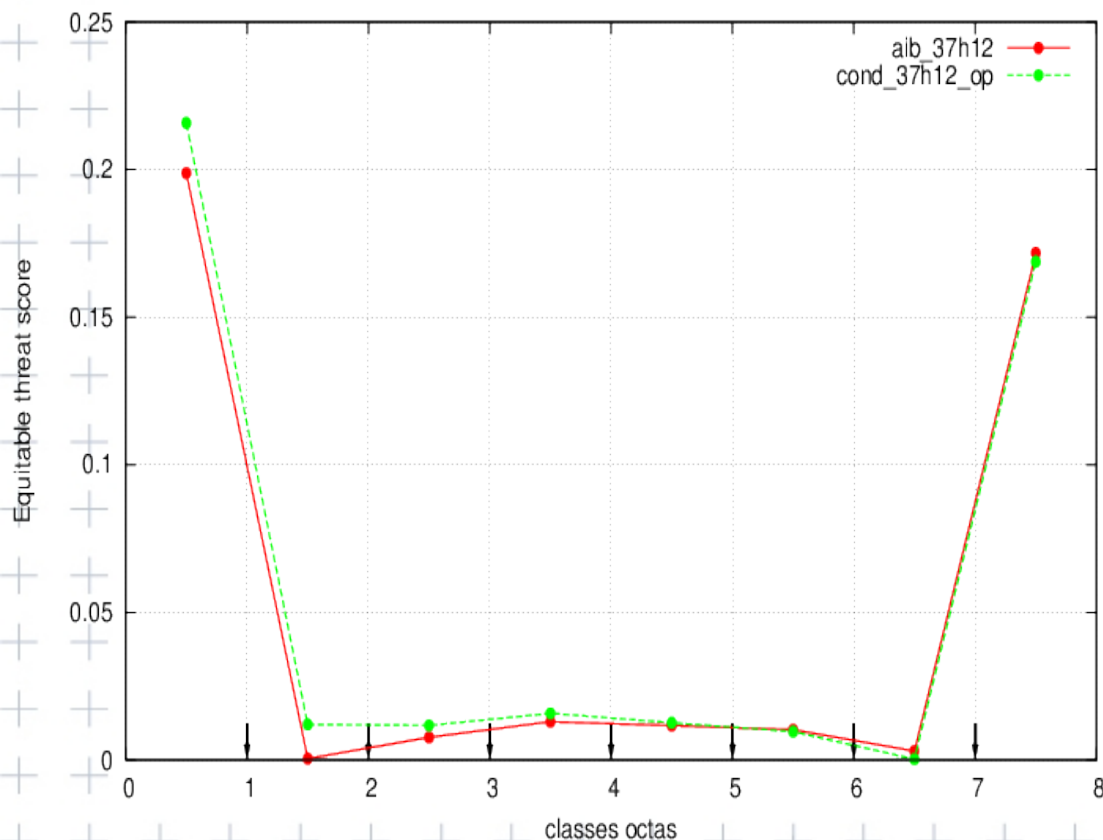
### 1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE

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Equitable threat score for Cloud cover (octas)  
Selection: ALL 141 stations  
Period: 20130307-20130320  
Used 00,06,12,18 + 06 12 18 24 30



## Cloud cover. Equitable threat score.

Classes.

ALL stations

small improvement for low number of octas cases.

No improvement for high number of octas.

STATISTICAL CLOUD SCHEME RESEARCH WITH HARMONIE

## 0. OUTLINE

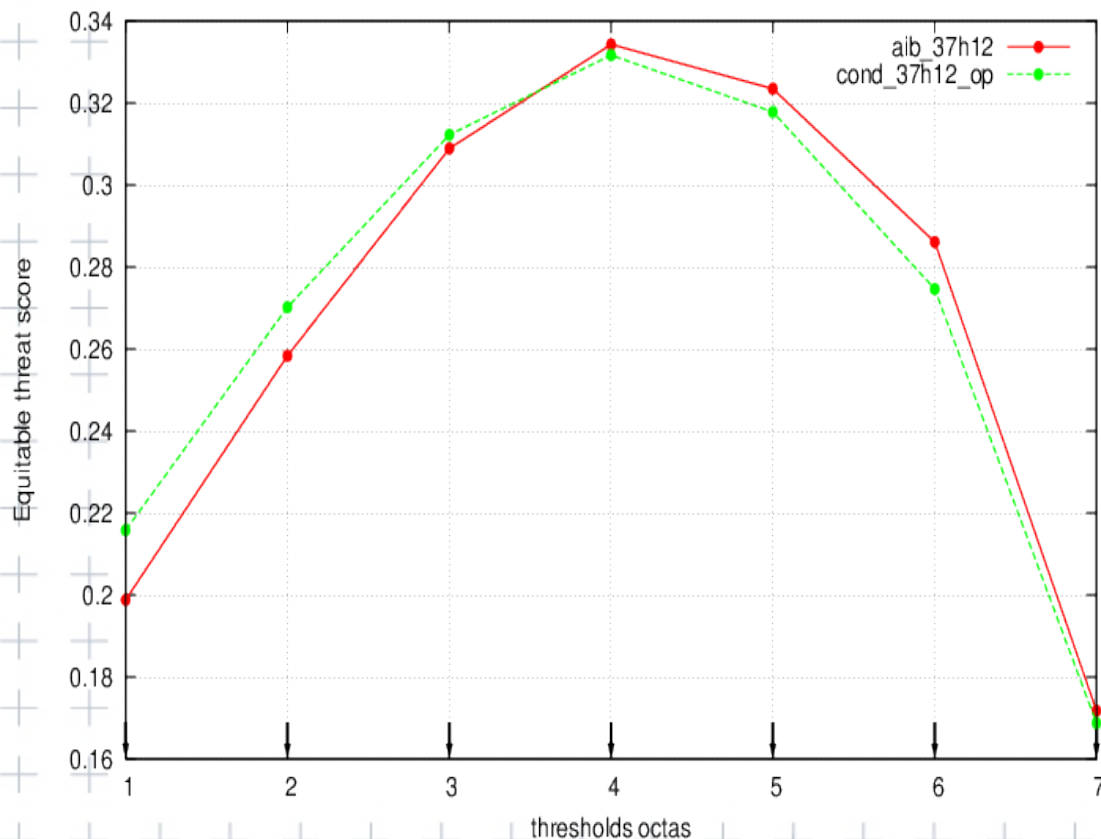
## 1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE

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## 4. SUMMARY

Equitable threat score for Cloud cover (octas)  
Selection: ALL 141 stations  
Period: 20130307-20130320  
Used 00,06,12,18 + 06 12 18 24 30



## Cloud cover. Equitable threat score.

Thresholds.

ALL stations

small improvement for low number of octas thresholds.

worse for high number of octas.

STATISTICAL CLOUD SCHEME RESEARCH WITH HARMONIE

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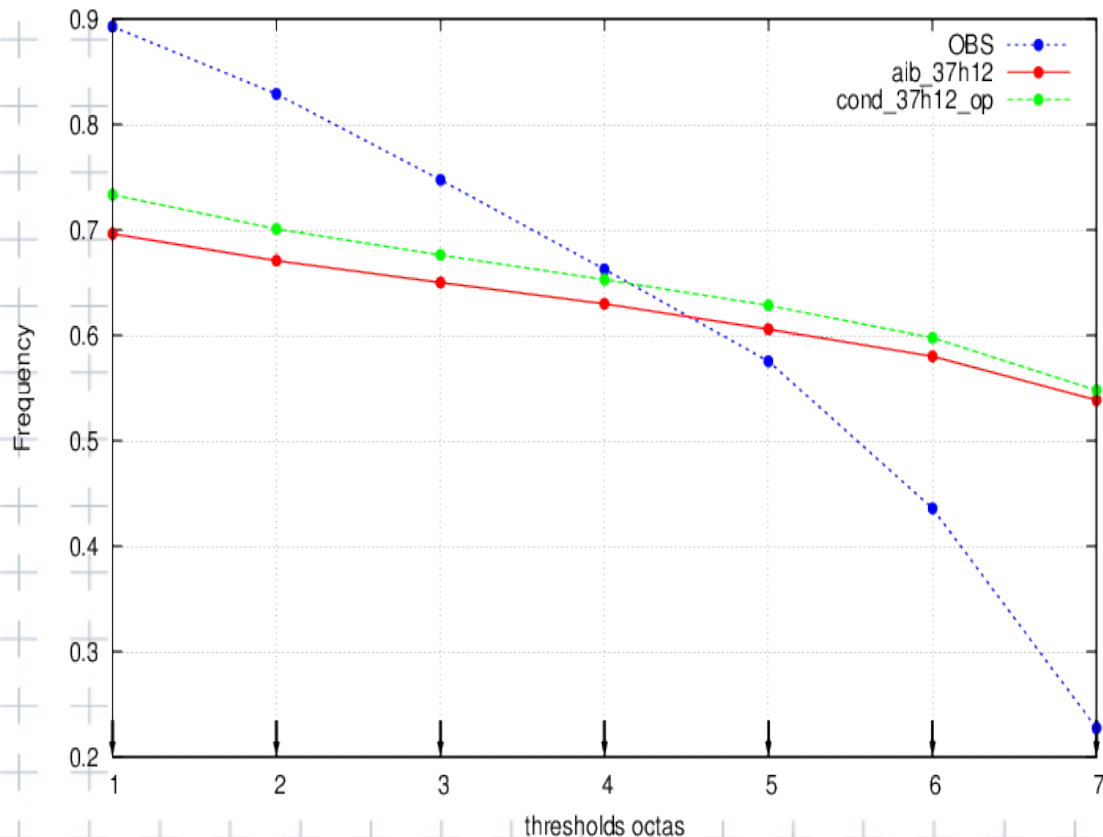
## 1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE

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## 4. SUMMARY

Frequency for Cloud cover (octas)  
Selection: ALL 141 stations  
Period: 20130307-20130320  
Used 00,06,12,18 + 06 12 18 24 30



## Cloud cover. frequency.

Thresholds.

ALL stations

small improvement for low number of octas cases.

worse for high number of octas.

# 0. OUTLINE

## 1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE

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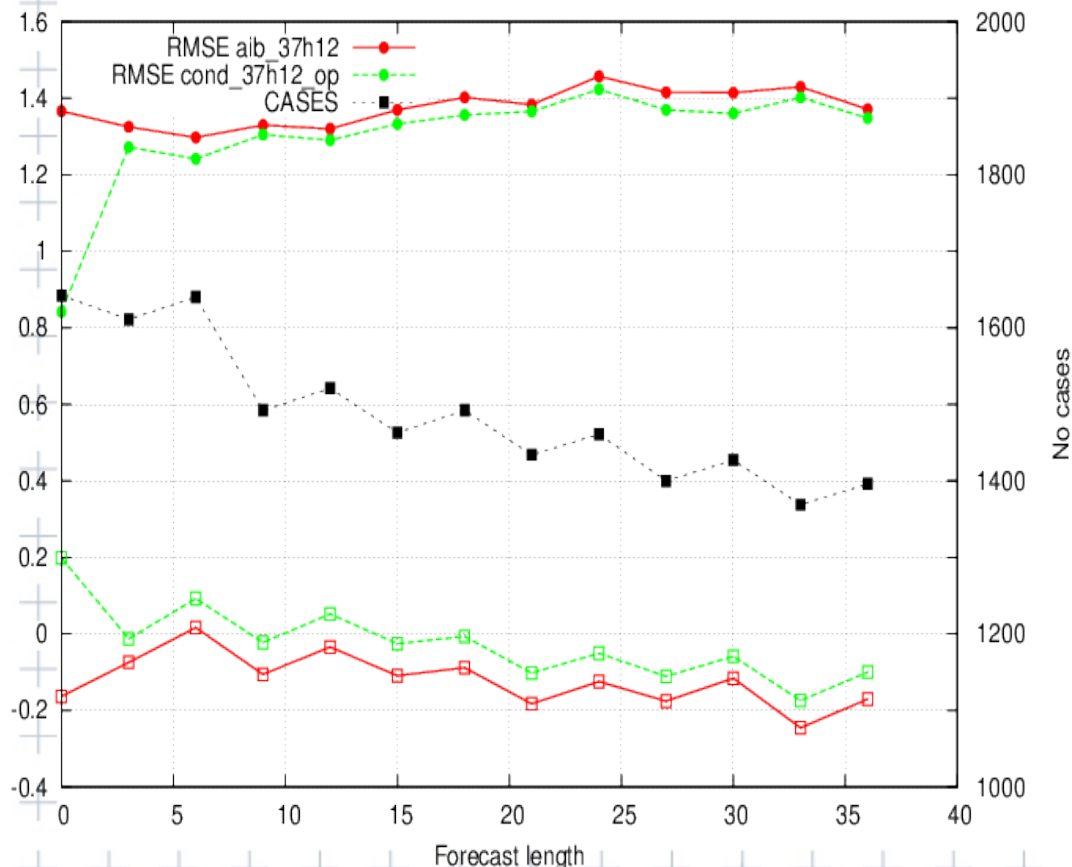
## 2m temperature verification.



EWGLAM stations

small difference in the rmse, better bias.

Selection: EWGLAM using 31 stations  
Period: 20130307-20130320  
T2m Hours: 00,06,12,18



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Red: ref.  
Green: mod.

# 0. OUTLINE

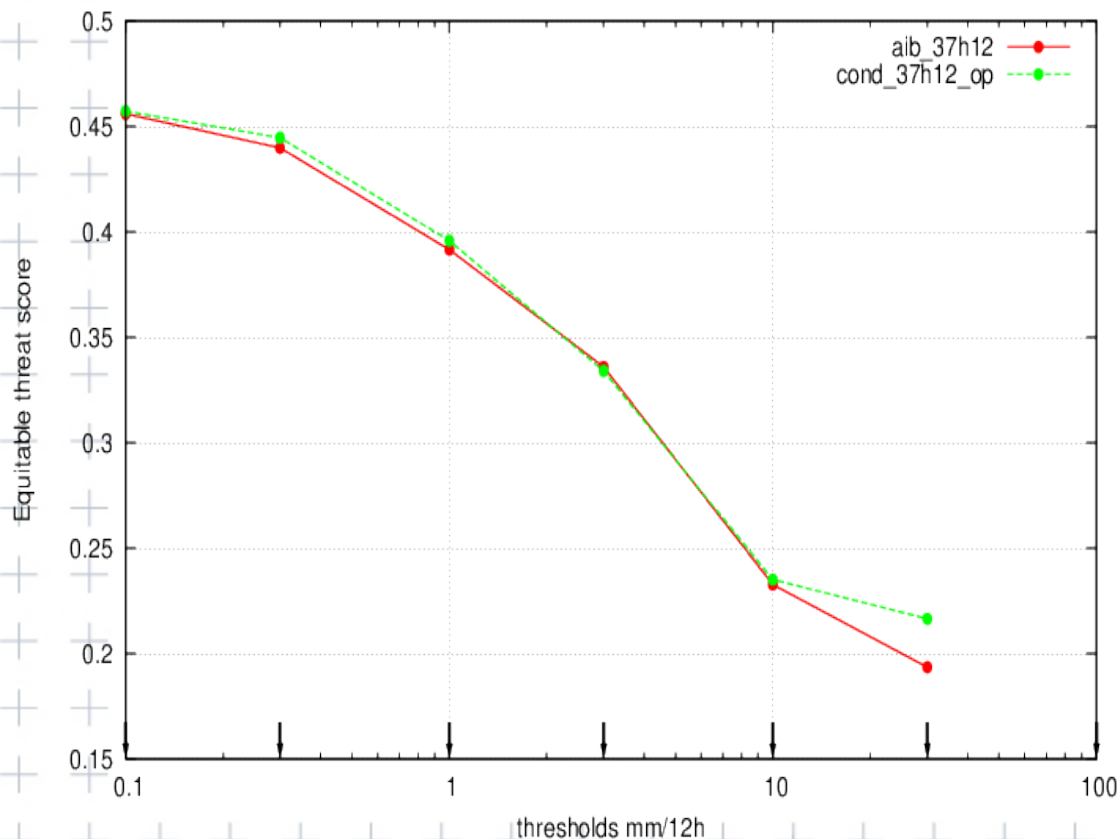
## 1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE

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Equitable threat score for Precipitation (mm/12h)  
Selection: ALL 206 stations  
Period: 20130307-20130320  
Used 00,06,12,18 + 12-00 18-06 24-12 30-18



## Precipitation. Equitable threat score.

ALL stations

neutral impact

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## 10 m. wind speed. Equitable threat score

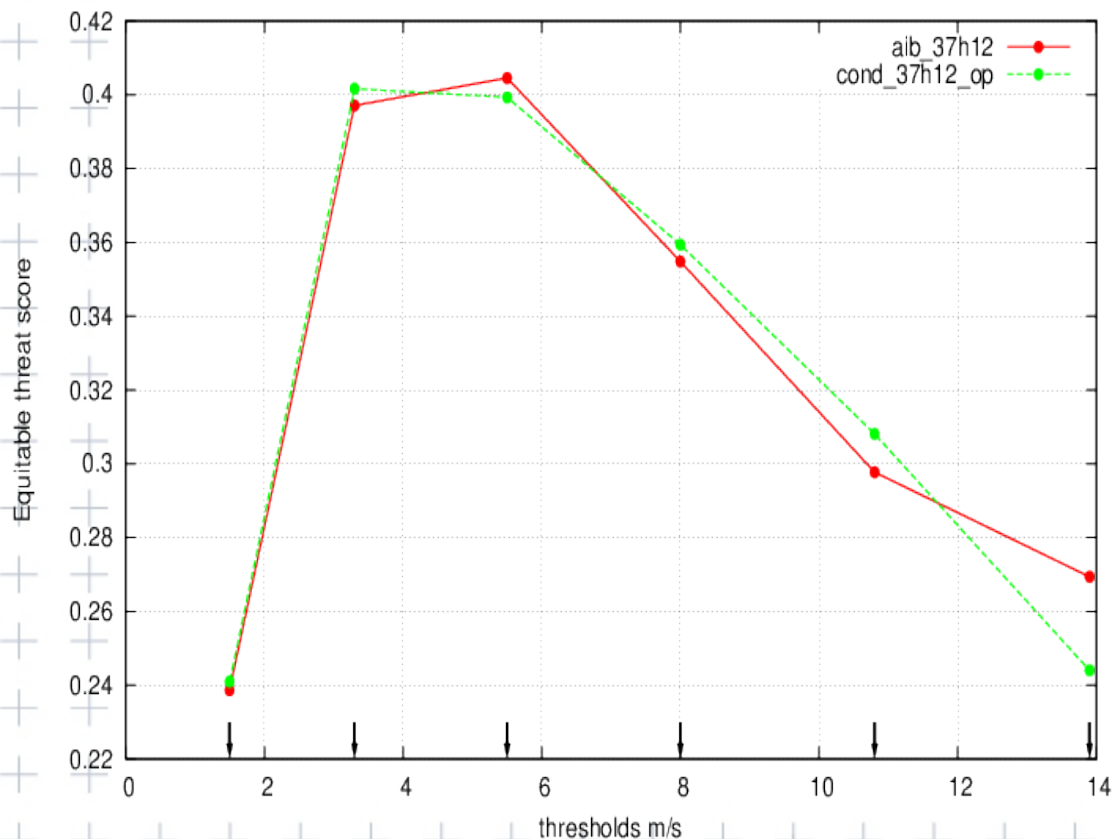


thresholds

EWGLAM stations

Neutral impact

Equitable threat score for U10m (m/s)  
Selection: EWGLAM 31 stations  
Period: 20130307-20130320  
Used 00,06,12,18 + 06 12 18 24 30



STATISTICAL CLOUD SCHEME RESEARCH WITH HARMONIE

## Conclusions

- ★ The vertical gradient of saturation can be a source of variance specially important for  $N < 4$  octas.
- ★ In general, adding this new term supposes an increment of the cloud cover extension.
- ★ The verification shows small impact but positive for the cloud cover, specially for low number of octas. Also for 2m temperature can be considered that there is an improvement.
- ★ Neutral impact for the precipitation and 10 meters wind speed.



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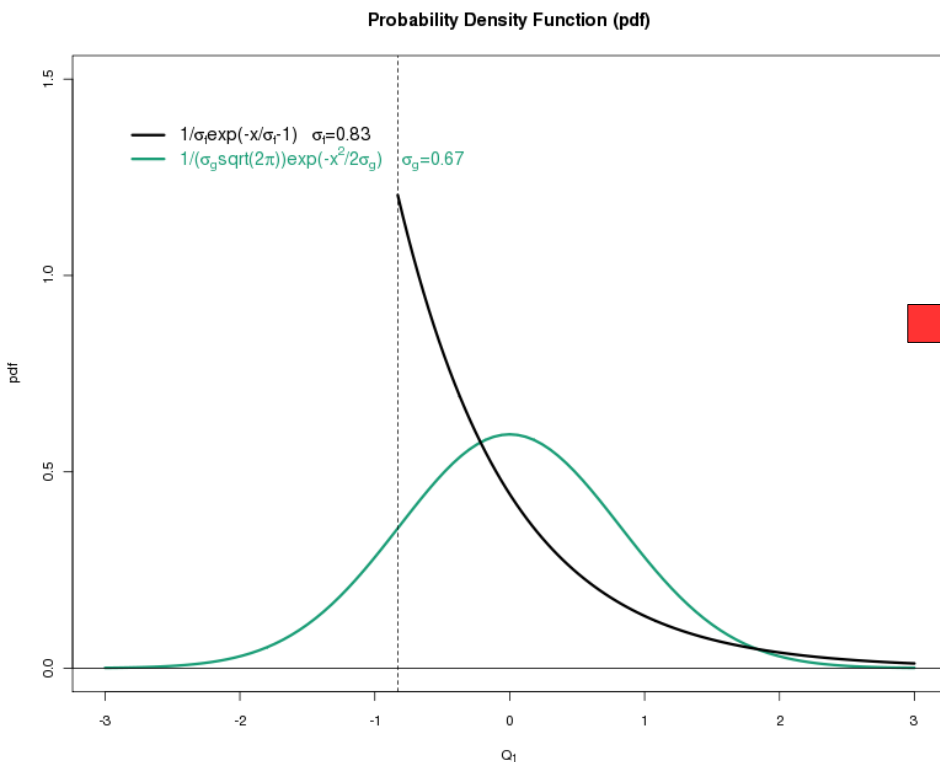


## 3. PDF function

- ★ A PDF function is going to be proposed that it could fit approximately the cloud fraction and the cloud water expressions used in HARMONIE.
- ★ It is going to be obtained from the **convolution of a gaussian and an exponential function.**
- ★ The pdf depends on three parameters, these are going to be chosen so that the result **approach the HARMONIE expressions**

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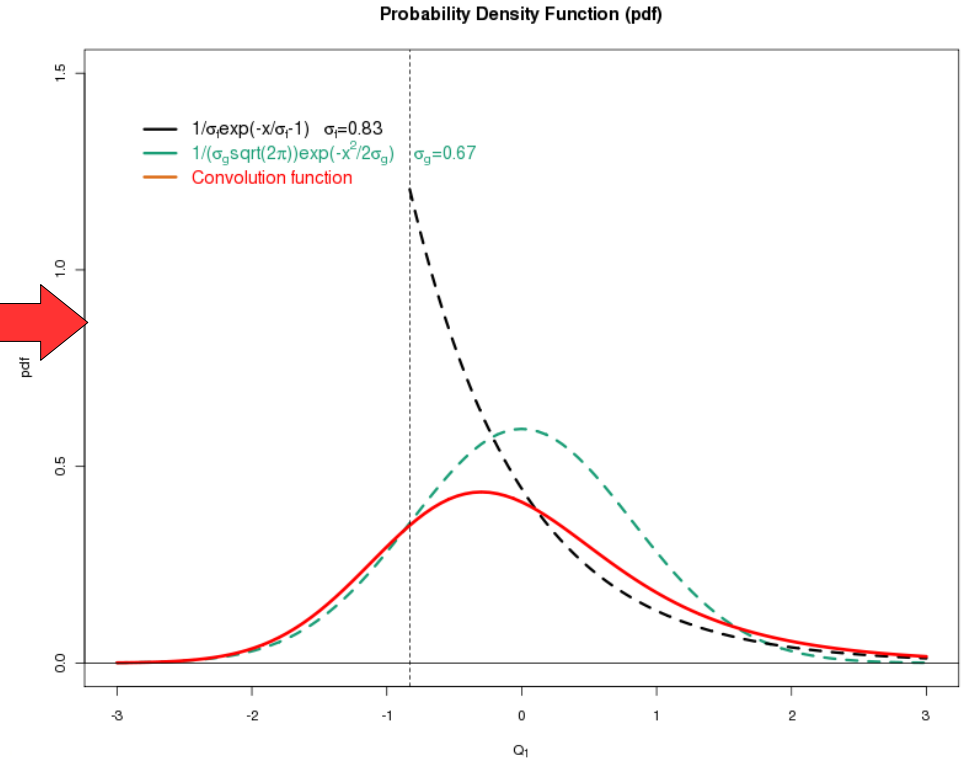
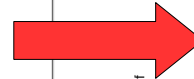
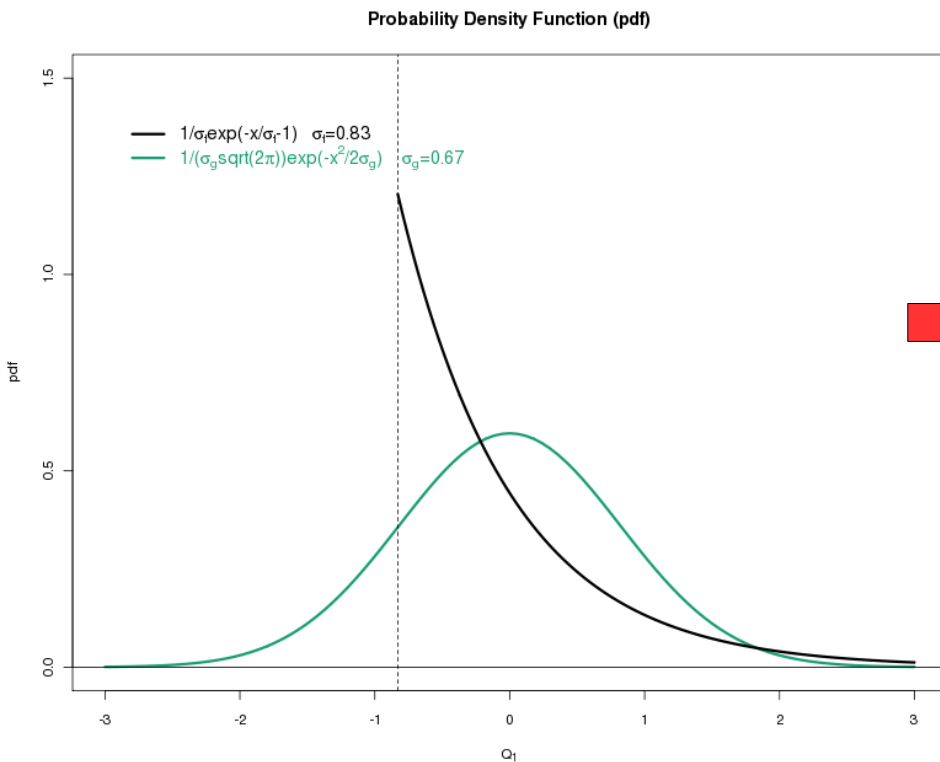
The pdf function is obtained from a **gaussian** and an **exponential** functions



$$\Phi(x) = (\rho_1 * \rho_2)(x) = \int_{-\infty}^{\infty} \rho_1(x-x') \rho_2(x') dx'$$

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The pdf function is obtained calculating the **convolution** of a gaussian and an exponential function.



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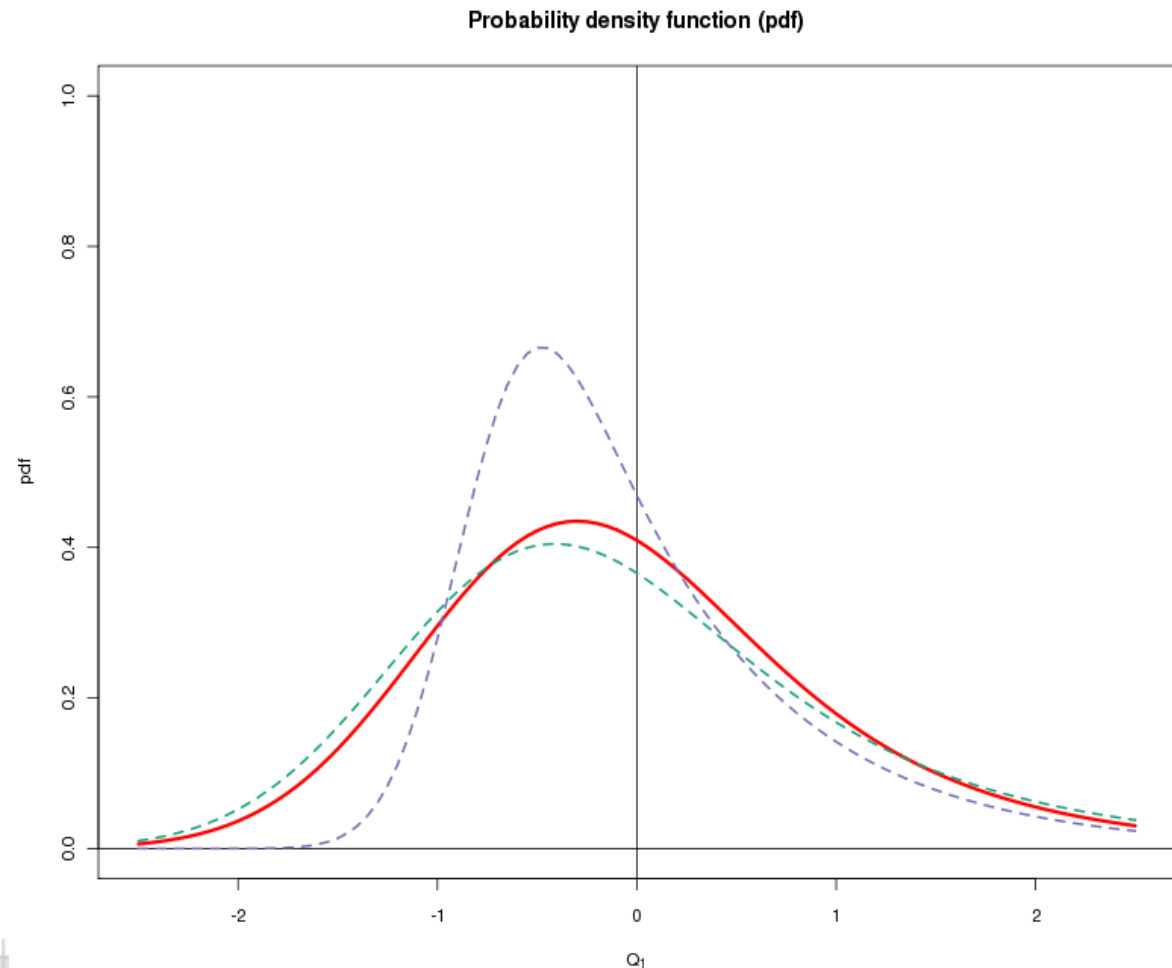
### 2. SATURATION DEFICIT VARIANCE

### 3. PDF FUNCTION

### 4. SUMMARY

The pdf depends on three parameters: variance of the gauss function, scale factor of the exponential function and a displacement factor.

The figure shows different pdf functions.



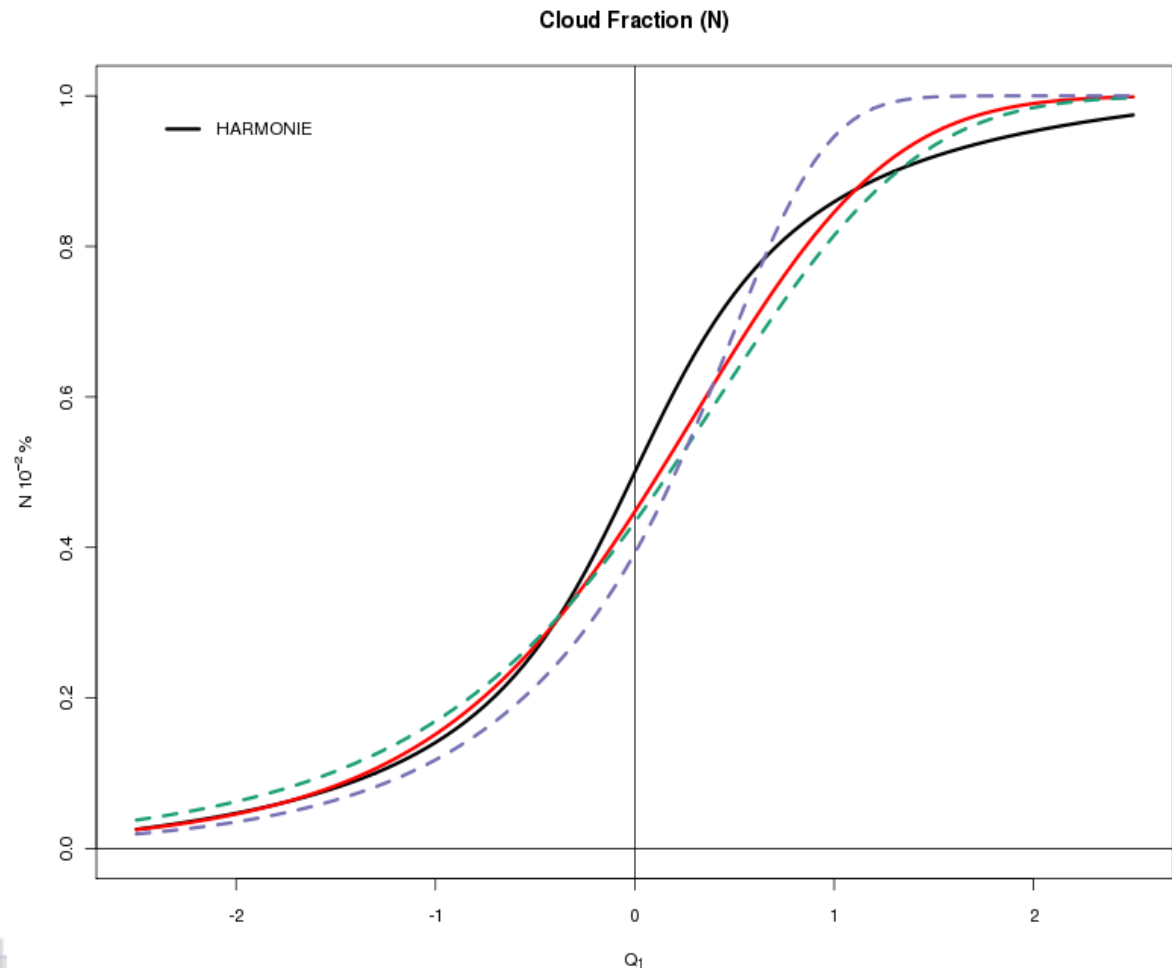
0. OUTLINE
1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE
2. SATURATION DEFICIT VARIANCE
- 3. PDF FUNCTION**
4. SUMMARY

## Cloud fraction

In **black** the expression used in the HARMONIE code. In **red**, from the pdf proposed.

The biggest difference is around 60% (**red-black**)

The total cloud cover is reached for lower values of saturation deficit.



## 0. OUTLINE

### 1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE

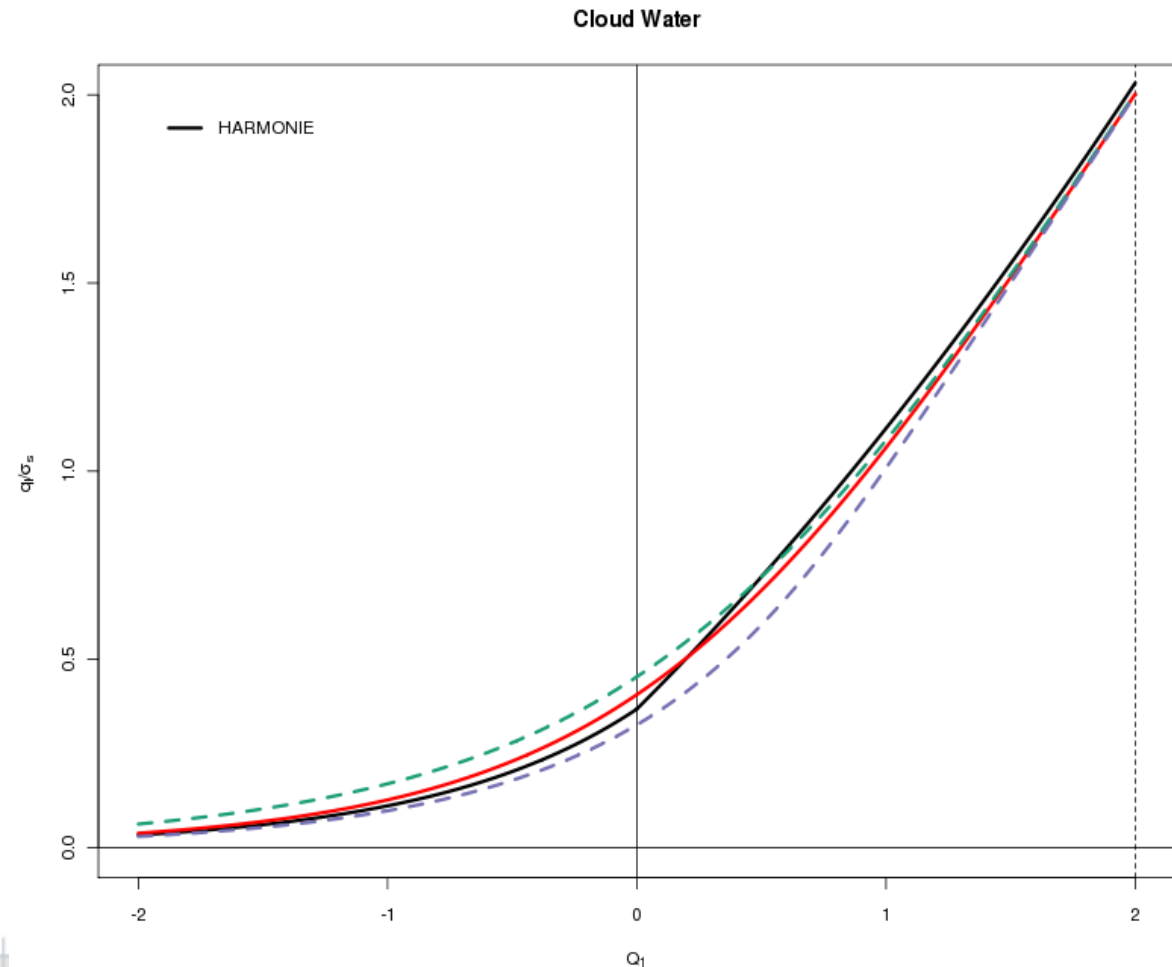
### 2. SATURATION DEFICIT VARIANCE

### 3. PDF FUNCTION

### 4. SUMMARY

## Cloud water content

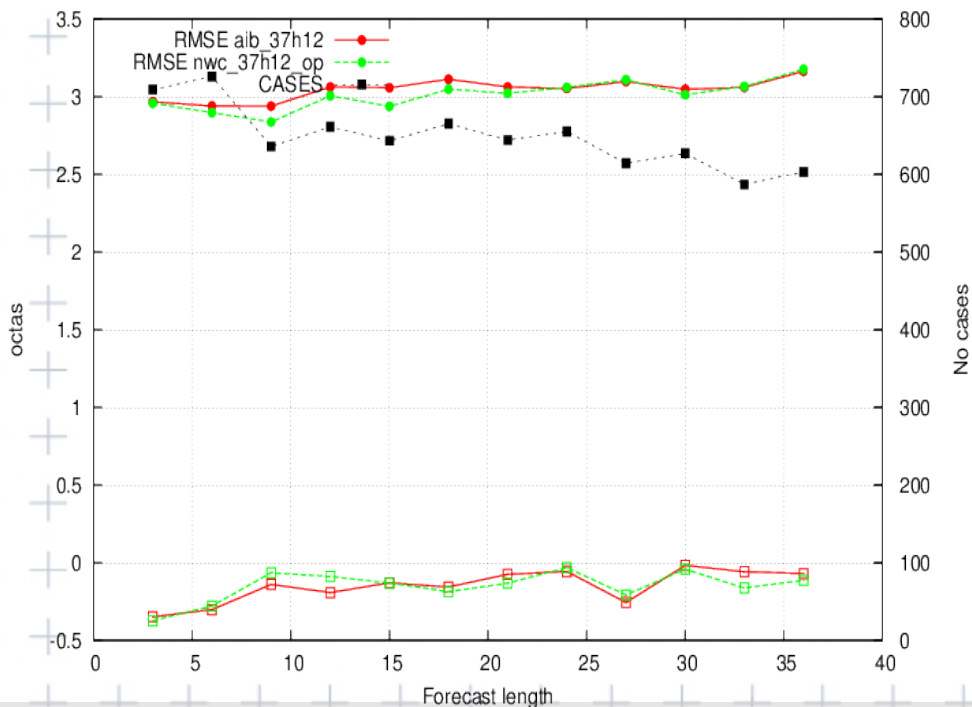
The difference between the formula in HARMONIE and the one obtained with the pdf seems to be less significant for the cloud water content than for the cloud fraction.



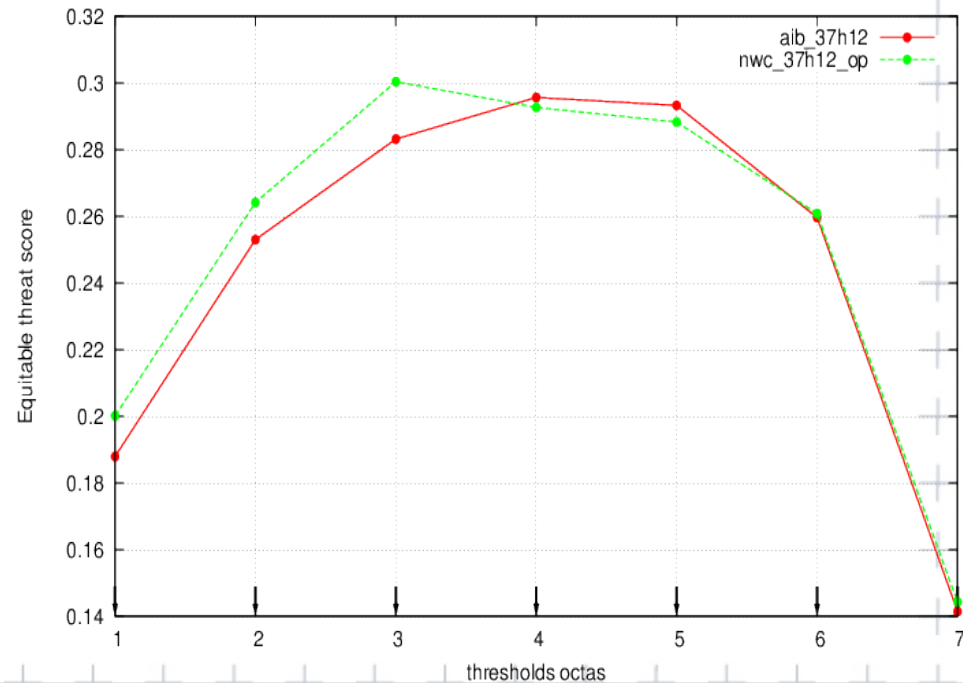
- 0. OUTLINE
- 1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE
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Verification for a short period (1 week) in order to check that there is no negative impact... **Cloud cover**

Selection: EWGLAM using 30 stations  
 Period: 20130307-20130314  
 Cloud cover Hours: 00,06,12,18



Equitable threat score for Cloud cover (octas)  
 Selection: EWGLAM 29 stations  
 Period: 20130307-20130314  
 Used 00,06,12,18 + 06 12 18 24 30



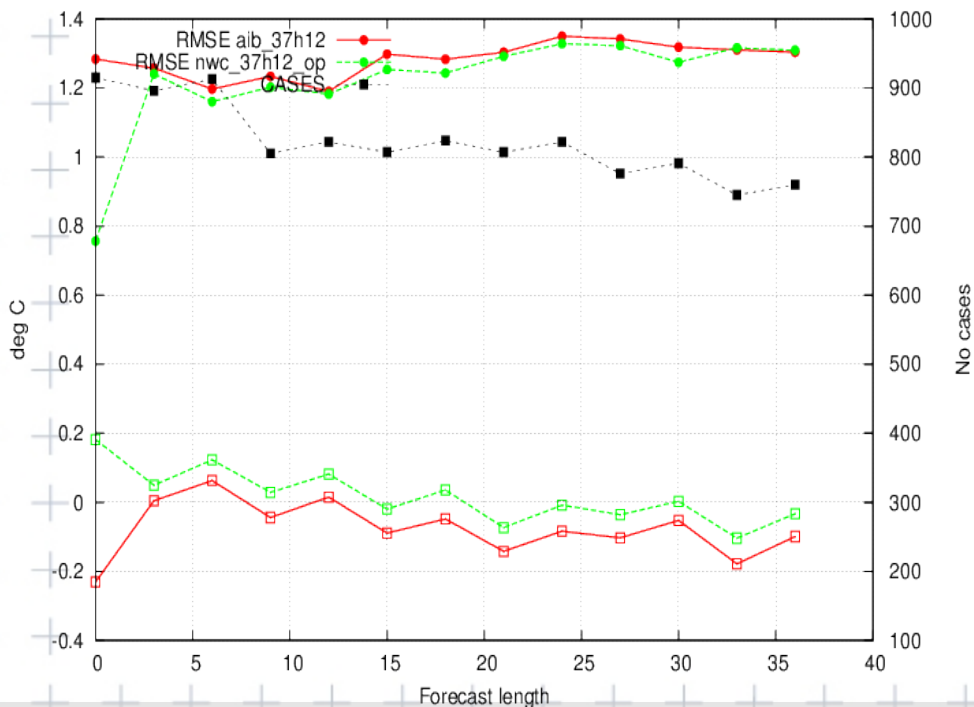
STATISTICAL CLOUD SCHEME RESEARCH WITH HARMONIE

- 0. OUTLINE
- 1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE
- 2. SATURATION DEFICIT VARIANCE
- 3. PDF FUNCTION**
- 4. SUMMARY

## Verification for a short period (1 week)

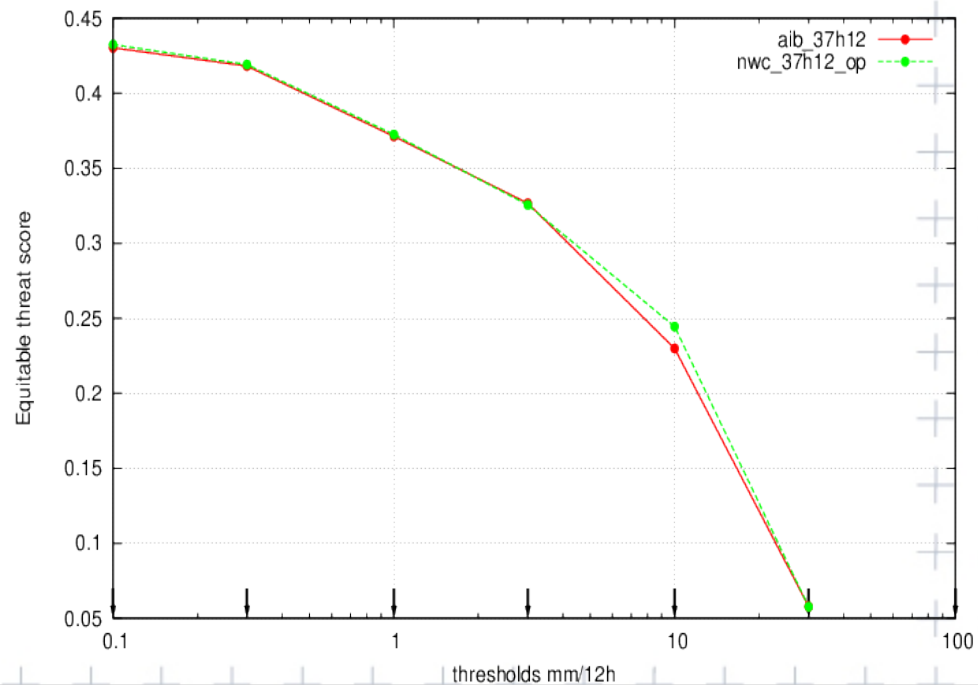
### 2m Temperature

Selection: EWGLAM using 31 stations  
 Period: 20130307-20130314  
 T2m Hours: 00,06,12,18



### Precipitation

Equitable threat score for Precipitation (mm/12h)  
 Selection: ALL 153 stations  
 Period: 20130307-20130314  
 Used 00,06,12,18 + 12-00 18-06 24-12 30-18



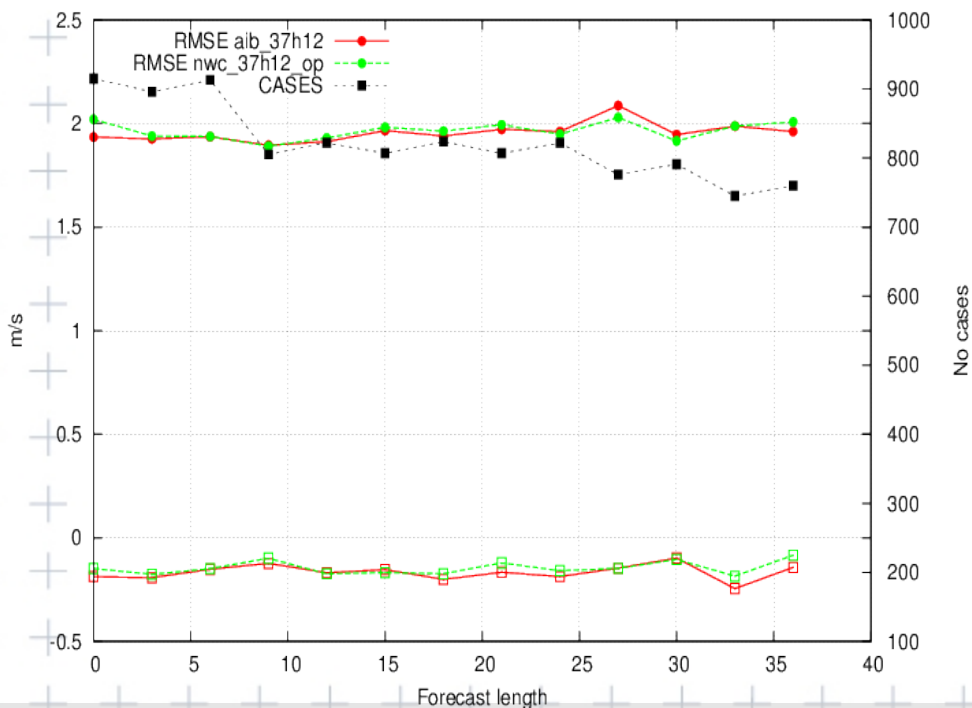


- 0. OUTLINE
- 1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE
- 2. SATURATION DEFICIT VARIANCE
- 3. PDF FUNCTION**
- 4. SUMMARY

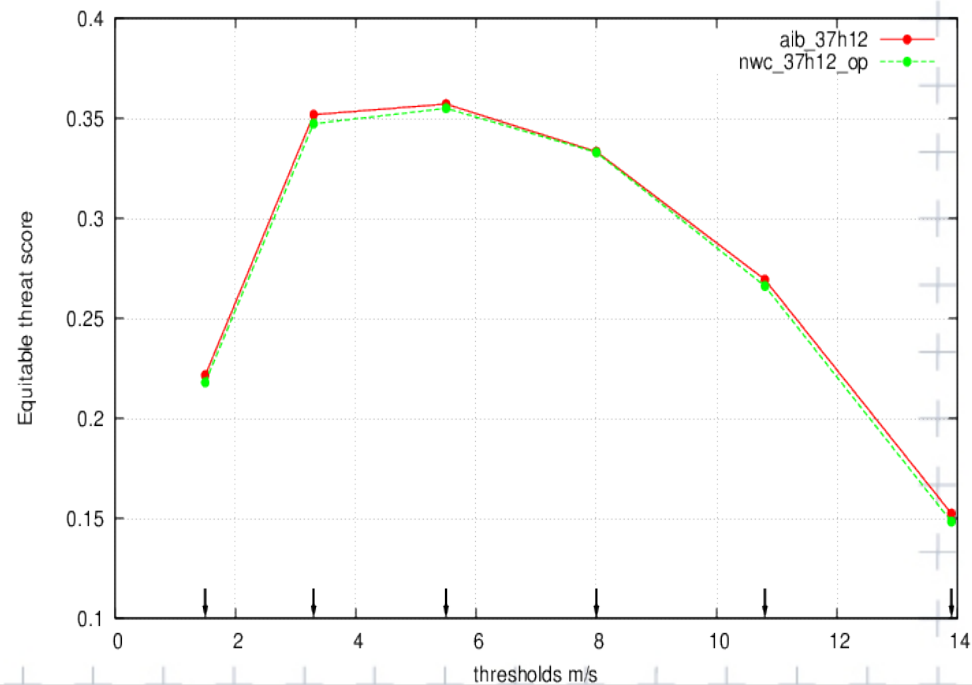
## Verification for a short period (1 week)

### 10m wind

Selection: EWGLAM using 31 stations  
 Period: 20130307-20130314  
 U10m Hours: 00,06,12,18



Equitable threat score for U10m (m/s)  
 Selection: ALL 156 stations  
 Period: 20130307-20130314  
 Used 00,06,12,18 + 06 12 18 24 30



STATISTICAL CLOUD SCHEME RESEARCH WITH HARMONIE

0. OUTLINE
1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE
2. SATURATION DEFICIT VARIANCE
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## Conclusions

- ★ The cloud water content and the cloud fraction obtained from the pdf formula approach to the ones used in HARMONIE, specially well for the first one...
- ★ ...so that verification shows a neutral impact...
- ★ ...as this pdf depends on three parameters, different combinations can be checked for improvement.

## 4. Summary

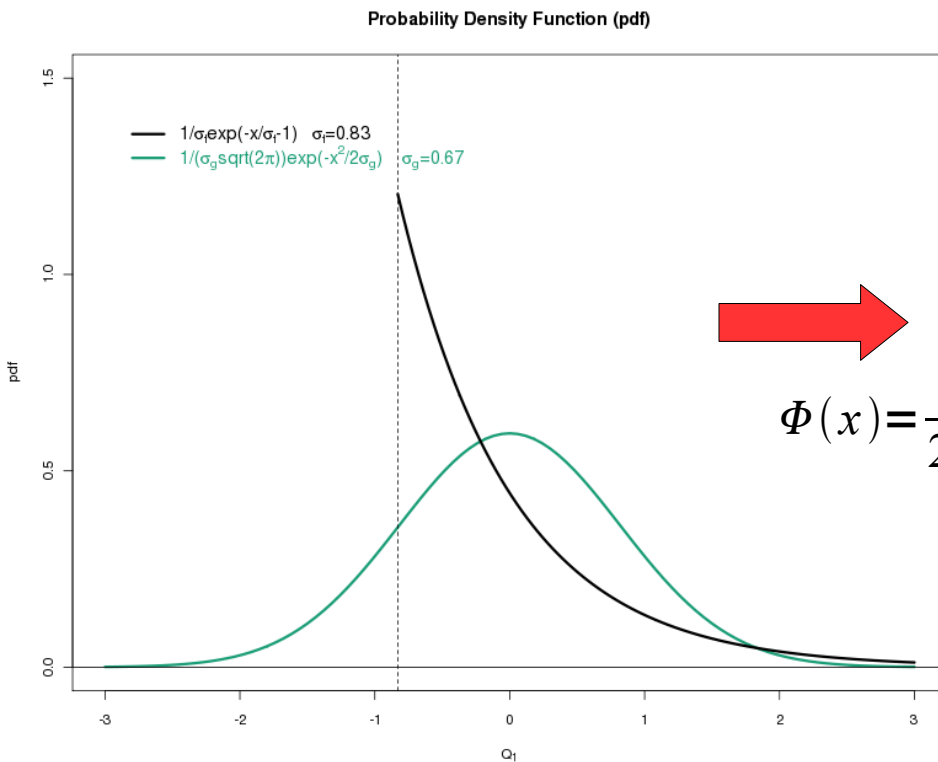
- ★ The vertical dependence of the thermodynamical variables can have a positive impact when considered to calculate cloud water content and cloud fraction.
- ★ Using the formulas from the new pdf doesn't seem to modify the verification, and permits that cloud fraction and cloud water are related through it.

*THANK YOU!*

*QUESTIONS?*

0. OUTLINE
1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE
2. SATURATION DEFICIT VARIANCE
3. PDF FUNCTION (EXTRA MATERIAL)
4. SUMMARY

The pdf function is obtained from a **gaussian** and an **exponential** functions



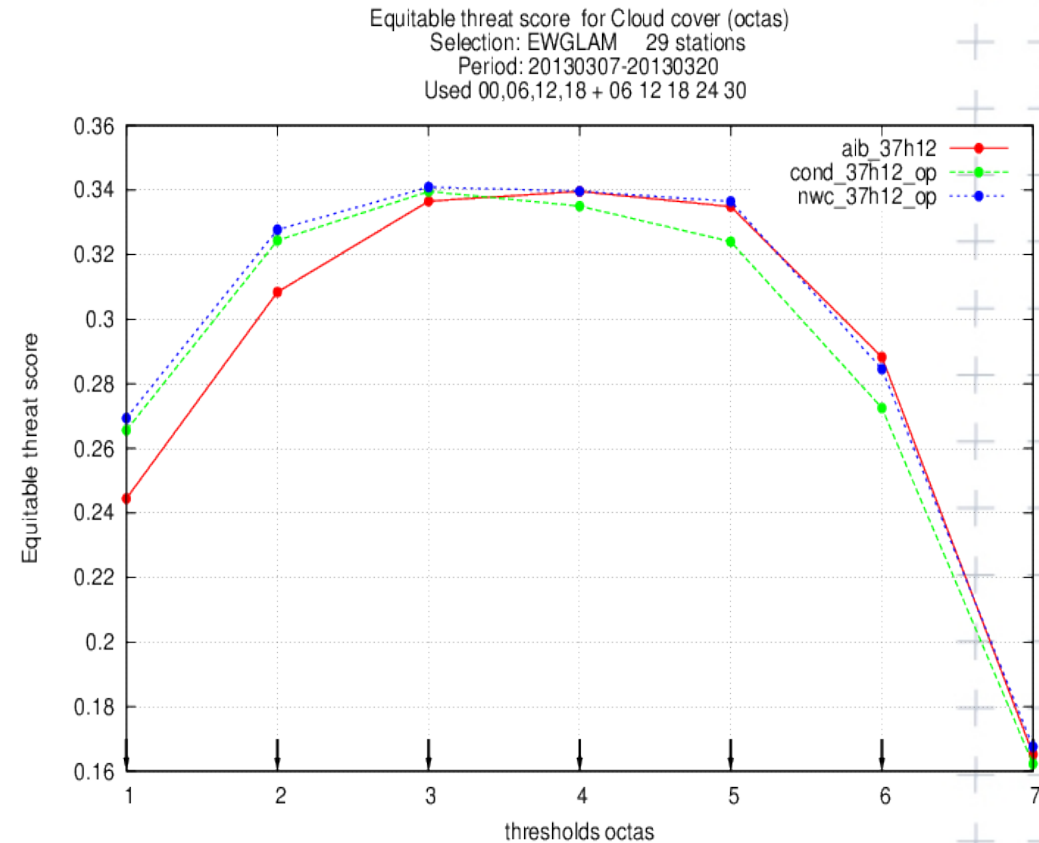
$$\Phi(x) = (\rho_1 * \rho_2)(x) = \int_{-\infty}^{\infty} \rho_1(x-x') \rho_2(x') dx'$$

$$\Phi(x) = \frac{1}{2\sigma_f} \exp\left(-\left(\frac{x-\beta}{\sigma_f}\right) + \frac{\sigma_g^2}{2\sigma_f^2}\right) \left[ 1 - \operatorname{erf}\left(-\left(\frac{x-\beta}{\sqrt{2}\sigma_g}\right) + \frac{\sigma_g}{\sqrt{2}\sigma_f}\right) \right]$$

0. OUTLINE
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## PDF function + variance

When both modifications (pdf+variance) are used together, better results are obtained for the cloud fraction.



0. OUTLINE
1. STATISTICAL SCHEME FOR CLOUDS IN HARMONIE
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4. SUMMARY

## PDF function + variance

Precipitation.

EWGLAM stations

