RISk of deep CONvection indices (RISCON): a new diagnostic tool

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1. Motivations

- **To calculate a diagnostic tool which evaluates the *risk of deep convection* in short range forecasting.**
- **To verify if the new tool is able to complement the forecasted precipitation in convective situations.**

2. Definition of RISk of deep CONvection index

A RISk of deep CONvection index (RISCON) is a composite of diagnostic fields derived from an atmospheric model that includes one stability index, one field associated to vertical motion and three fields associated to humidity (Table 1). This new index can be used to determine if there exists or not favourable mechanisms for deep convection. Moreover, RISCON provides an intensity of risk that varies between 0 and 6, corresponding the minimum value to the inexistence of two essential mechanisms for convection, humidity in low levels and atmospheric instability, and the maximum value to the existence of those mechanisms and upward vertical motion.

Table 1. Different diagnostic fields used to calculate the RISCON and the estimated stability thresholds for those fields. In this work the thresholds were estimated by the comparison of the diagnostic fields obtained from analysis and forecasts of the ALADIN–Portugal model with the observations in 11 cases of deep convection.

Stability Indices (ºC)				*Moisture Fields*	*Upward Motion Fields*		*RISCON* (derived from ω or $div\vec{Q}$)
TT	*Jeff*	*Mod TT*	*CI*	*R* / *CONVq* ($10^{-1} g\, m^{-2} s^{-1}$) / conq ($10^{-4} g kg^{-1} s^{-1}$)	ω ($Pa\, s^{-1}$)	$div\vec{Q}$ ($10^{-13} K\, m^{-2} s^{-1}$)	
<48	<29	<57	<5	------	------	------	0
---	---	---	---	If none of the following conditions is fulfilled: (a) $R_{850hPa} \geq 65\%$ (b) $CONVq \geq 0.3$ (c) $conq_{v\,850hPa} > 0.1$	----	---	
≥48	≥29	≥57	≥5	If one or two of the last conditions is (are) fulfilled	$\omega_{850hPa} \leq -0.2$	$div\vec{Q}_{850hPa} < -0.6$ + OROG < 550m $div\vec{Q}_{700hPa} < -0.6$ + OROG ≥550m	1 – 3
≥48	≥29	≥57	≥5	(a) + (b) + (c)	$\omega_{850hPa} \leq -0.2$ + $\omega_{700hPa} \leq -0.2$	$div\vec{Q}_{850hPa} < -0.6$ + $div\vec{Q}_{700hPa} < -0.6$ + OROG < 550m $div\vec{Q}_{700hPa} < -0.6$ + $div\vec{Q}_{500hPa} < -0.6$ + OROG ≥ 550m	4 – 6

Legend:

TT	:	*Total Totals index*
Mod TT	:	*Modified Total Totals index*
Jeff	:	*Jefferson index*
CI	:	*Convective Instability index*
$conq_{850}$	:	*water vapour convergence at* 850hPa
CONVq	:	*water vapour convergence in low troposphere*
R_{850}	:	*relative humidity at* 850hPa
OROG	:	*orography of the atmospheric model*
$divQ_{850}/_{700}/_{500}$	:	*Q vector divergence at* 850hPa /700hPa /500hPa
$\omega_{850}/_{700}$	:	*vertical velocity at* 850hPa /700hPa

◆ Definition of the diagnostic fields associated to RISCON

Stability indices

Total Totals index considers static stability in the layer 850–500 hPa (*VT*) and the contribute of humidity to parcel bouyancy (*CT*).

$$\text{Total Totals} = (VT + CT) = (T_{850} - T_{500}) + (T_{d850} - T_{500})$$ (*stability threshold: 48ºC*)

Modified Total Totals index is a modification of the Total Totals index to include the profile of humidity and temperature in the PBL

$$\text{Modified TT} = (T_{2m}+T_{925}+T_{850})/3 + (T_{d2m}+T_{d925}+T_{d850})/3 - 2T_{500}$$ (*stability threshold: 57ºC*)

Convective Instability index estimates the potential instability of a low/medium troposphere layer by considering the values of θ_e in some particular levels of that layer

$$\text{Convective Instability} = 0.5(\theta_{e2m} + \theta_{e925}) - \theta_{e500}$$ (*stability threshold: 5ºC*)

Jefferson index estimates the bouyancy of a parcel by considering its original temperature at 500hPa. Moreover, the possible reductions in bouyancy produced by *entrainment* (*T700-Td700*) are taken into account on this index.

$$\text{Jefferson} = 1.6\theta_{sw850} - T_{500} - 0.5\,(T_{700} - T_{d700}) - 8$$ (*stability threshold: 29ºC*)

Water vapour convergence in low troposphere (CONVq)

$$CONVq = -\int_{p_o}^{p} \nabla \cdot (q\vec{V}) \frac{dp}{g}$$

q – *specific humidity*
V – *horizontal wind*
p_o – *lower level*
p – *highest level*

OROG > 550 m => p_o= 925hPa , *p*=700hPa
OROG ≤ 550m => p_o=1000hPa , *p*=850hPa

(*stability threshold:* $0.1 \times 10^{-4}\ g\ m^{2}\ s^{-1}$)

Upward vertical motion (inferred by ω or *divQ*)

Quasigeostrophic theory was used to determine vertical motion using omega equation to calculate *divQ* in a form where the components of *Q* vector are expressed as

$$(Q_x, Q_y) = \left[-\frac{\partial \vec{v}_g}{\partial x} \cdot \nabla\left(-\frac{\partial \phi}{\partial p}\right), -\frac{\partial \vec{v}_g}{\partial y} \cdot \nabla\left(-\frac{\partial \phi}{\partial p}\right) \right]$$

It was verified in this study that the divergence of *Q* vector allows, in some cases, a better definition of the areas with upward/downward motion than vertical velocity ω.

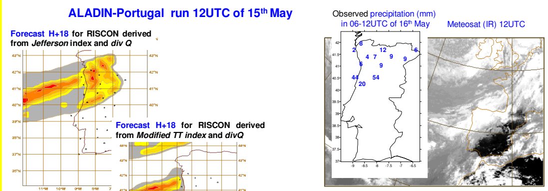
(*stability threshold* for *divQ* : -0.6×10^{-13} K m^{-2} s^{-1})

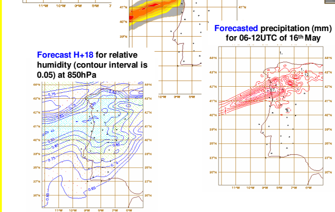
(*stability threshold* for ω: -0.2 Pa s-1)

3. Preliminary validation of the RISCON

In this preliminary validation the forecasted RISCON and 6h precipitation were compared with the observations in 5 cases of *heavy* precipitation occurred in 2001. In this study heavy precipitation was defined by intensities of precipitation above 10mm/1h and/or 30mm/6h. Some results are presented below for 2 of those cases including the reference to the corresponding diagnosed conceptual model. This comparison was very important to evaluate also the performance of ALADIN-Portugal in forecasting precipitation. Further validation work includes the analysis of contingency tables of the observed precipitation in 6h *versus* instantaneous forecast of the RISCON.

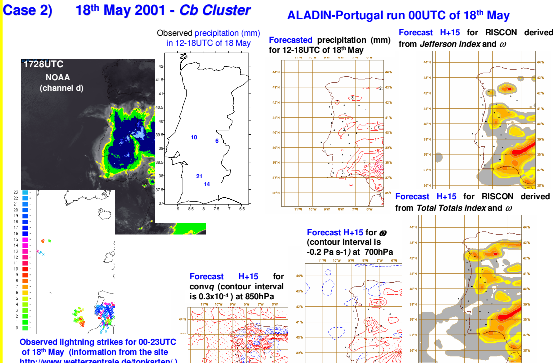
Case 1) 16th of May 2001 - *Thickness Ridge Cloudiness*

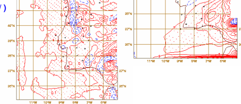




- **Forecast H+18 for RISCON derived from *Jefferson* and div*Q* has a better performance than the other indices defining well the area of precipitation.**
- **ALADIN-Portugal accurately alerts to the occurrence of heavy precipitation and provides a realistic definition of the areas with precipitation for the period 06-12UTC.**
- **However, the model underestimates the maximum quantity of precipitation.**

Case 2) 18th May 2001 - *Cb Cluster*





- **RISCON resulting from *Jefferson* and ω has the best performance of these indices in the forecast H+15 providing a realistic idea of the area with deep convection.**
- **By contrast, RISCON derived from Total Totals and ω produces the worst result by giving false alarm in the northern part of Iberian Peninsula and over sea.**
- **Although the lack of the observations of precipitation, the information of lightning strikes, radar (not shown) and satellite indicated that ALADIN-Portugal underestimates the area with deep convection. Furthermore, the model shifts the area of maximum precipitation by 1 to 2º to East.**
- **Consequently, the forecast H+15 of the RISCON derived from Jefferson and ω complements the forecasted precipitation for the period 12-18UTC.**

4. Some considerations

The preliminary validation of the risk of deep convection indices based on 5 cases of heavy precipitation highlights some interesting results:

◆ **RISCON resulting from the divergence of Q vector usually present similar results to the ones derived from ω.**

◆ **However, the RISCON resulting from the divergence of *Q* vector tends to show a better performance when the convection occurs in the mesoscale-β while the RISCON resulting from vertical velocity, when the convection occurs at larger scales.**

◆ **RISCON derived from the *Jefferson* index has a better performance than those derived from the other stability indices.**

◆ **By contrast, the RISCON derived from the Convective Instability index had the worst performance.**

◆ **ALADIN alerted to the occurrence of heavy precipitation in Portugal in 4 of the 5 cases of heavy precipitation.**

◆ **However, the model tends to underestimated the maximum quantities of precipitation and to shift the regions of maximum precipitation by 1 to 2º.**

◆ **It is essential to continue the validation of the RISCON with the analysis of contingency tables in order to obtain concluding results.**