SPRING PRECIPITATION IN INLAND IBERIA: LAND-ATMOSPHERE INTERACTIONS AND RECYCLING-AMPLIFICATION PROCESSES

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EGU2012-10132
CL5.10
XY272

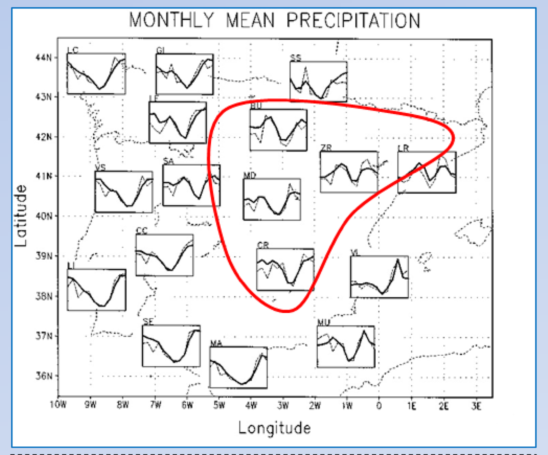
MOTIVATION and GOALS

❑ The interior of the Iberian Peninsula has a distinct precipitation regime with respect to the more coastal areas, with a relative maximum of precipitation in late spring. This peak is more prominent in the East and North-East, where it becomes the annual maximum of precipitation.

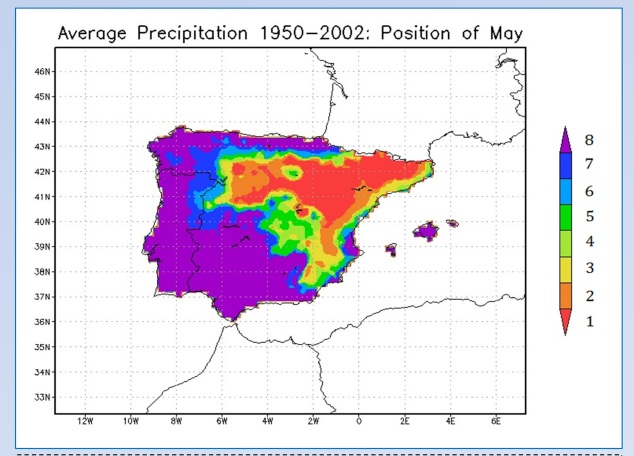
The Iberian Peninsula is an area where land-atmosphere interactions may strongly affect the precipitation regime (Koster *et al.*, 2004)

Hypothesis: The soil moisture – precipitation feedback plays a key role in the intensification of the hydrological cycle in spring and is responsible for this maximum of rainfall.

❑ Understanding the precipitation regime in the water-stressed interior of Iberia is critical for agriculture and hydrological planning.



*Monthly mean annual evolution of precipitation for 17 stations and two periods: solid line, 1949-1995, dashed line, 1986-1995 (from **Rodriguez-Puebla** et al., **1998**)*



Position of May in the climatological (1950-2002) monthly ranking of precipitation over the Iberian Peninsula: May sees the absolute maximum of precipitation in large areas in the East and North-East.

METHODS and VALIDATION

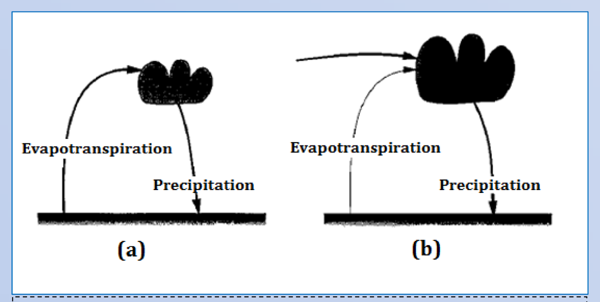
❑ High-resolution (5km) simulations were performed using the WRF model (version 3.0.1.1).

- 11 months of May (from May 2000 to May 2010) and 11 months of January (from January 2000 to January 2010) were simulated, in order to account for seasonal variations.
- For each month, we perform two simulations: a **CONTROL** one, where all land-atmosphere fluxes are normally set up, and the corresponding **EXPERIMENT**, where evapotranspired water (ET) over land in the nested domain is not incorporated into the atmosphere.

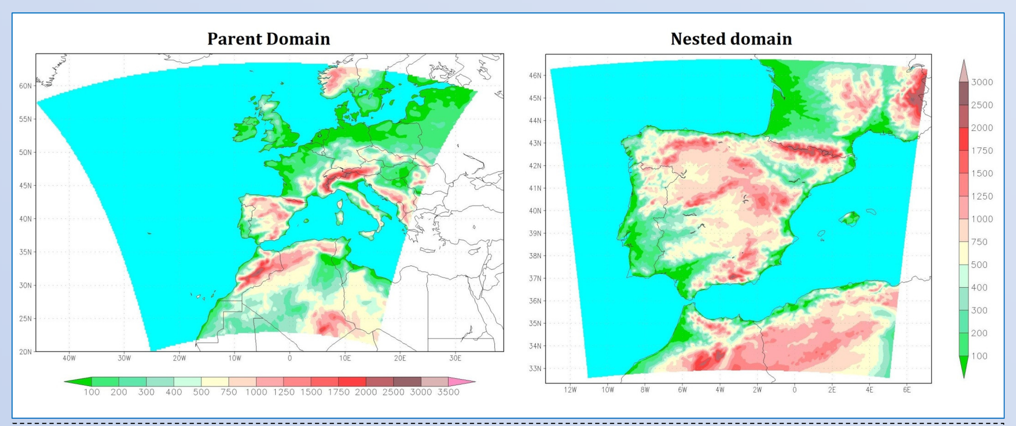
❑ There are two physical ways of activating the soil moisture – precipitation feedback (Schär *et al.*, 1999):

(a) Recycling
- Precipitation coming from ET within the study region.

(b) Amplification
- Extra moisture coming from advection which precipitates as a result of the indirect effect of land-atmosphere interactions on the thermodynamic structure of the lower atmosphere.



*Scheme of (a) recycling and (b) amplification processes (from **Schär et al., 1999**)*



Height above the sea level (m) for the parent and nested domains used in our simulations.

❑ We developed a new method for the separation of both recycling and amplification contributions using the no-ET experiments:

→ *Origin of precipitation:* $P = P_a + P_m = (P_{ad} + P_{ai}) + P_m$

$P_{ad} \equiv$ *Precipitation coming directly from advection.*

$P_{ai} \equiv$ ***Moisture coming from advection which is retained and added to precipitation as a consequence of the indirect effect of land-air interactions on the thermodynamics of the Planetary Boundary Layer .***

$P_m \equiv$ *Precipitation coming from evapotranspiration within the study region.*

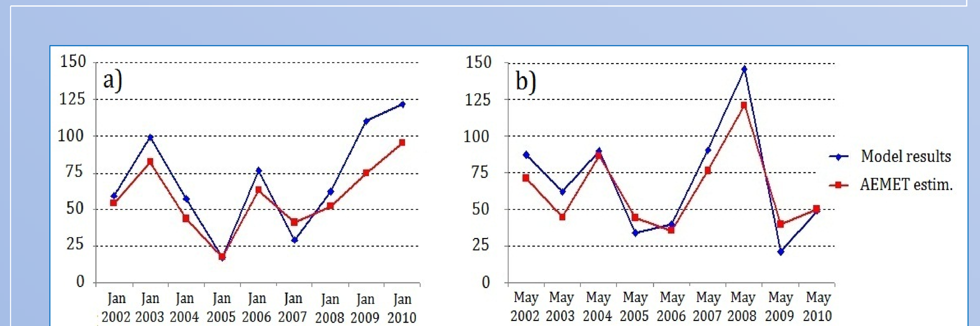
→ *In the control and experimental runs :* $P_C = (P_{ad} + P_{ai}) + P_m \qquad P_E \approx P_{ad} \qquad \Delta P = P_C - P_E$

→ *From model simulations, we compute the **ANALYTHICAL RECYCLING RATIO r** (method of Eltahir and Bras, 1994) and the **RELATIVE CHANGE IN PRECIPITATION r***. From both parameters, the recycling and amplification contributions to ΔP can be easily obtained:*

$$r = \frac{P_m}{P} \qquad r^* = \frac{P_C - P_E}{P_C}$$

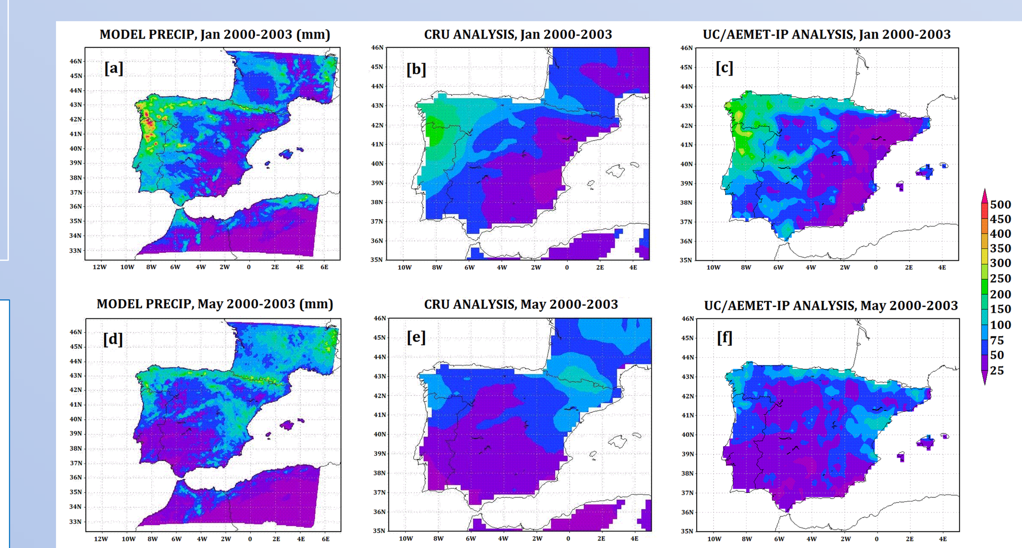
$$\Delta P_{rec} \approx \frac{r}{r^*} \cdot \Delta P$$

$$\Delta P_{amp} \approx \left(1 - \frac{r}{r^*}\right) \cdot \Delta P$$



AEMET area-averaged monthly precipitation over Spain (red) for a) January and b) May 2002 – 2010, together with the corresponding model results in blue (mm).

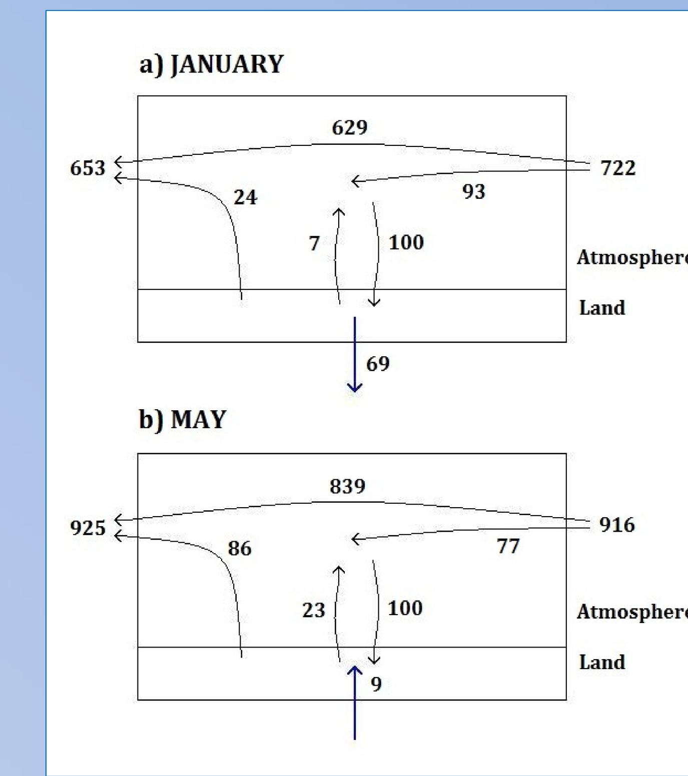
❑ **VALIDATION OF PRECIPITATION**. The observed patterns are well captured by the WRF simulations, showing finer scale structure than those from CRU and UC/AEMET-IP analyses, whose horizontal resolution is 25 and 20 km, respectively.



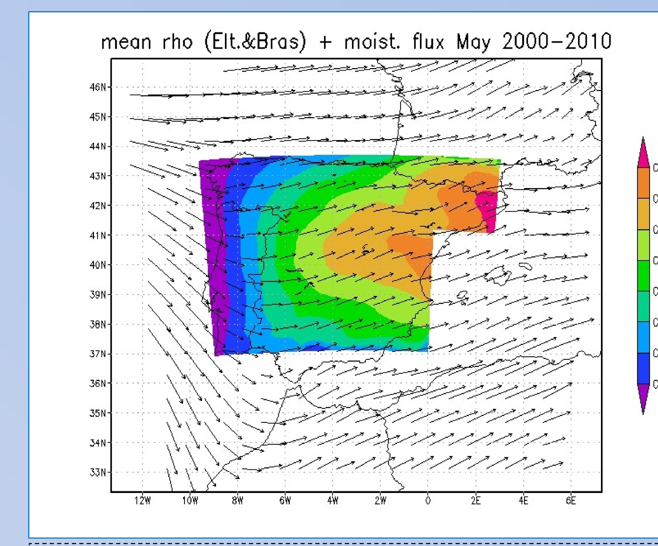
Average precipitation (mm) for the period January 2000 – January 2003 computed via: (a) control simulations; (b) CRU analysis; and (c) UC/AEMET-IP analysis. Panels (d), (e) and (f) show the analogous results for the period May 2000 – May 2003.

RESULTS

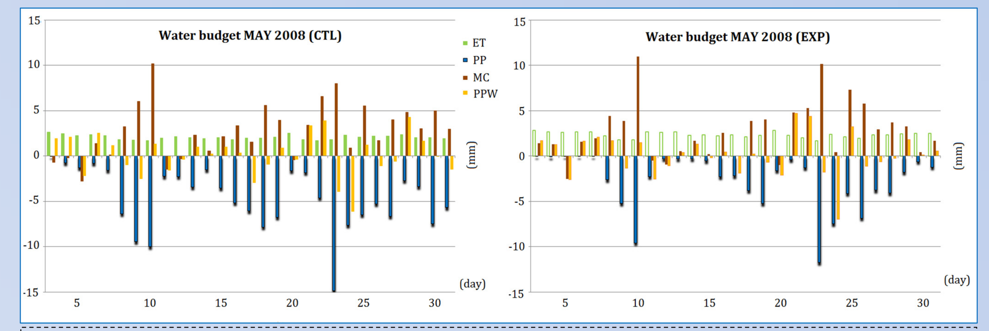
1. In winter, the amount of water into the soil increases. In contrast, there is a net moisture loss from the surface to the atmosphere in spring, when the peak of rainfall inland Iberia occurs.
2. The analytical recycling ratio, computed via the method of Eltahir and Bras, tends to be the highest in the East and North-East, precisely where the annual maximum of precipitation occurs in May.
3. Precipitation is higher in the control simulations than in the corresponding no-ET experiments, and this difference in rainfall substantially exceeds the value of the analytical recycling ratio: in spring, land-atmosphere interactions induce the retention of advected moisture that, otherwise, would be simply blown across Iberia.



*Representation of the Iberian hydrological cycle for a) January 2000-2010; and b) May 2000-2010. <P> is taken as 100 units. (Following **Eltahir and Bras, 1994**).*

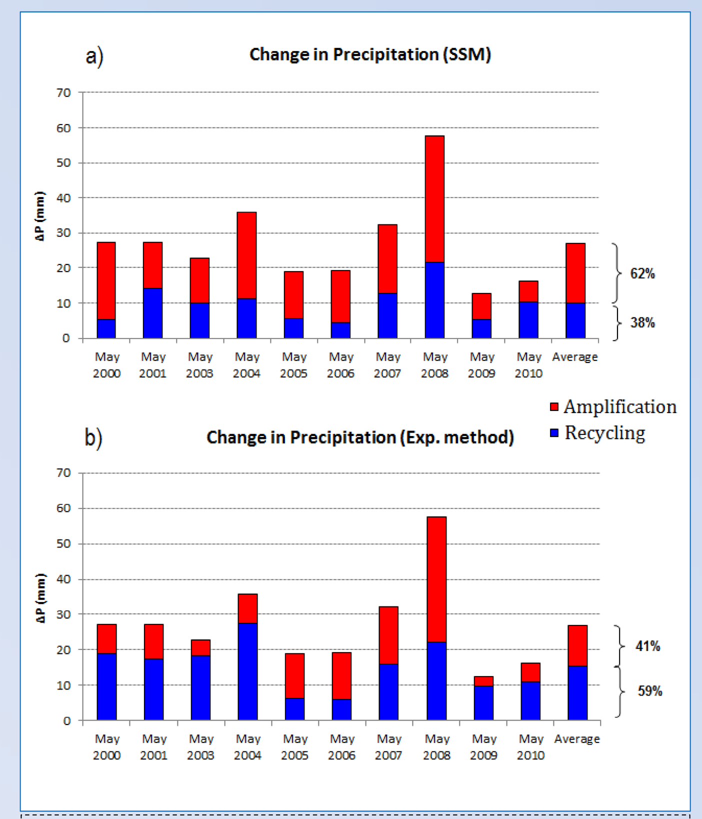


Spatial distribution of the multiannual (May 2000 to May 2010) average of recycling ratio (method of Eltahir and Bras), and correlation with the mean moisture flux.

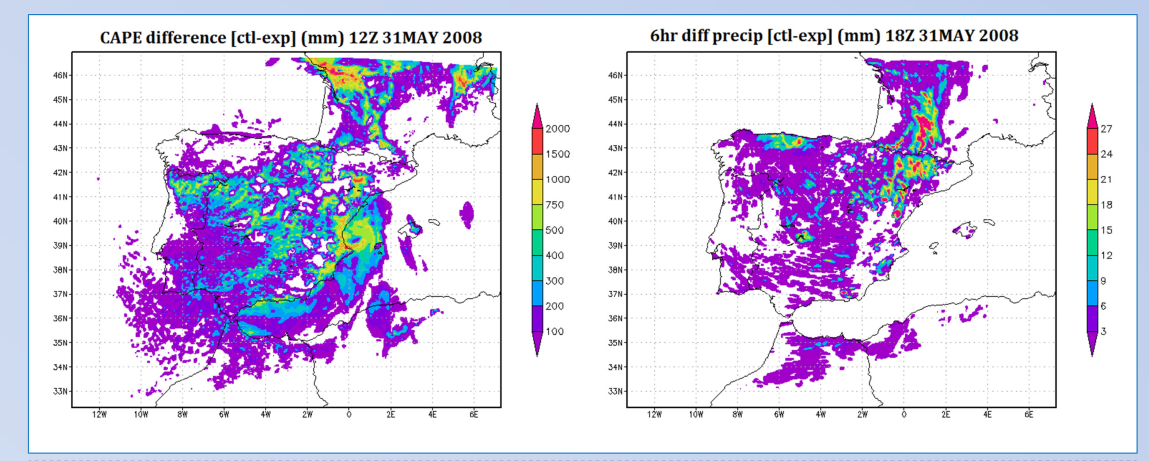


Daily representation of the different terms of the water budget (evapotranspiration, ET; precipitation, PP; moisture convergence, MC; and precipitable water, PPW) in the Iberian Peninsula (May 2008) for both control simulation (left) and no-ET experiment (right). As a result of land-atmosphere interactions, precipitation is intensified and sustained in time.

4. On average, for the period May 2000 – May 2010, the average relative change in precipitation between control and no-ET experiments, *r**, reaches 38%, whereas the average recycling ratio *r* is only 23%. This implies that the amplification effect is of the same order as the recycling contribution: the analytical method of separation (Schär et al., 1999) confirms this result.

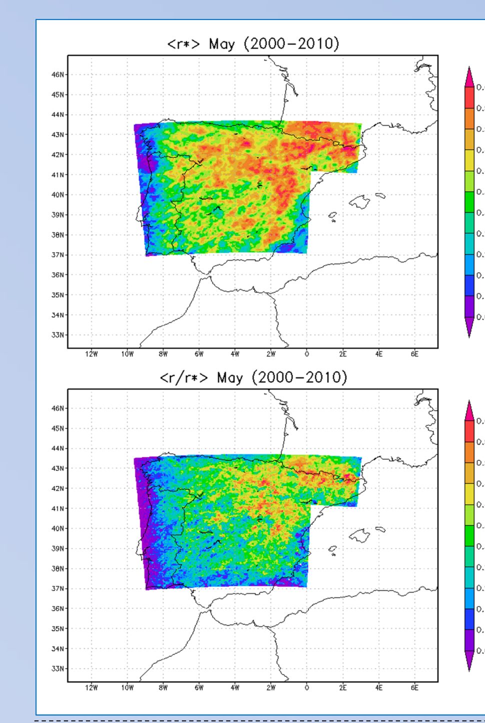


a) According to the Schär's Separation Method (SSM), 62% of the change in precipitation ($\Delta P = P_C - P_E$) comes from amplification processes. b) In constrast, recycling is the main contribution to ΔP (59%) according to our experimental procedure for the period May 2000 – May 2010.



a) Difference in CAPE (J/kg) between control and experiment at 12Z on May 31st 2008; and b) Corresponding difference in accumulated rainfall (mm) from 12Z to 18Z on the same day. (Rios-Entenza and Miguez-Macho, 2012).

5. The role of the extra moisture is twofold: it increases the total water in the column that can be condensed and fall as rain and it enhances atmospheric instability (CAPE) and convection. This surplus of recycled and amplified precipitation plays a key role in the spring rainfall regime in the interior of Iberia.



a) Average relative change in precipitation and b) Fraction of ΔP coming from direct recycling (May 2000 – May 2010). Water recycling is the main physical mechanism responsible for the maximum of precipitation in May in the East and North-East.

SUMMARY and CONCLUSIONS

We study the impact of land-surface interactions on the Iberian precipitation regime. The seasonality of precipitation in the coastal areas follows large-scale forcing and moisture supply, whereas in the interior, away from maritime influences, the peak of rainfall occurs in May. We use high-resolution WRF simulations to quantify the impact of ET fluxes via recycling or amplification mechanisms in rainfall dynamics inland Iberia.

1) Using an experiment where we suppress the incorporation of evapotranspired moisture into the atmosphere, we design a method to calculate the fraction of precipitation coming from recycling or amplification processes. This new procedure shows that in large interior areas the amplification effect can be of the same order as the recycling contribution.

2) In the Eastern and North-Eastern regions of Iberia, where the spring peak of precipitation is more prominent, water recycling is the main physical mechanism responsible. In general, land-atmosphere interactions intensify and sustain convective processes in time all over the interior areas.

References

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