MAJOR MID-WINTER WARMINGS AND IBERIAN PENINSULA RAINFALL

European Geosciences Union
General Assembly 2006
Vienna, Austria, 02 – 07 April 2006

Freie Universität Berlin

Joan A. Lopez-Bustins (1), Pere Esteban (1), Karin Labitzke (2) and Ulrike Langematz (2)

(1) Group of Climatology, University of Barcelona, Catalonia, Spain (**jlopezbustins@ub.edu**)

(2) Dynamik der mittleren Atmosphäre, Institut für Meteorologie, Freie Universität Berlin, Germany

Group of Climatology UB

UNIVERSITAT DE BARCELONA

AS1.06-1FR3P-**0011**

Variability and predictability of the coupled stratosphere-troposphere system

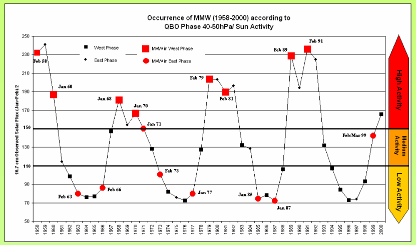
EGU06-A-03493

Abstract: An indirect solar forcing in Iberian rainfall is pursued by means of the occurrence of Major Mid-Winter Warmings (MMW) in the middle-low stratosphere in the North Pole during January and February, according to the role of the Quasi-Biennial Oscillation (QBO) / Solar activity relationship (Labitzke, 1987, 2005). MMW are the warmings which break down the polar vortex (PV). Consequently, a wind anomaly is produced in the north polar stratosphere which is connected with a lagged tropospheric anomaly through stratosphere-troposphere coupling in winter (Baldwin and Dunkerton, 1999, 2005). A T-mode Principal Component Analysis is used as an objective pattern classification method for identifying the main daily surface level pressure patterns for January, February and March for the reference period 1961-1990. Afterwards, those winter months with a MMW influence are identified in the whole study period 1958-2000 by means of the Arctic Oscillation Index (AOI). Thus, performing the same analysis for the selected months, new principal patterns are obtained for detecting changes in the surface circulation frequency and morphology. The results show a significant decrease of the westerlies and a southward shift of the storm tracks some weeks after the MMW occurrence. These changes are reflected in the Iberian rainfall anomalies with a precipitation increase in its west part and a slight decrease in the Mediterranean façade.

Key words: QBO / Solar Activity Relationship, Major Mid-Winter Warmings (MMW), Stratosphere-Troposphere Coupling, Principal Component Analysis (PCA), Circulation Patterns and Iberian Rainfall Anomalies.

1

The solar influence should be understood through the MMWs. As their occurrence usually happens when the QBO phase is west in a high solar activity, and when the QBO phase is east in a low solar activity (Labitzke, 1987, 2005). 16 MMWs are detected. 14 (87.5%) of them fit well with the QBO / Solar activity relationship; only two cases are wrong situated in east phase.



2

Baldwin and Dunkerton (1999, 2005) analysed the prediction of the PV in surface level. The monthly-mean Arctic Oscillation Index (AOI) (Thompson and Wallace 2000) was used to analyse the behaviour of the Northern Annular Mode (NAM) at surface level. They detected that **NAM at higher levels (150hPa) predicts much better AO than itself in winter**, mainly in January and February. Furthermore, using an average of the weak and strong anomalies of the middle-low stratosphere in winter in the North Pole, they noticed a transmission of the anomaly from upper levels to the surface. Nevertheless, a lag was fixed between 2 weeks and 2 months approximately when they performed composites of time-height development of the NAM. Not all the MMWs are well transmitted from the stratosphere to the troposphere. The AO must be taken into account. **Therefore, an analysis of each case individually is carried out in order to check if there is transmission or not.**

(FU Stratospheric Temperature Data)

30 hPa North Pole

T (ºC)	J	F	AOi	<-0.50	>0.50
X (58-00)	-72	-67	J	F	M
	≤-75	≤-70			
1958	-71	-49	-0,95	-1,73	-2,55
1959	-74	-73	-1,89	3,15	1,90
1960	-60	-70	-2,22	-1,85	-1,53
1961	-65	-73	-0,92	1,20	0,53
1962	-79	-67	1,96	0,10	-2,88
1963	-74	-52	-2,86	-1,07	0,78
1964	-78	-77	1,12	-0,34	-0,33
1965	-76	-73	-0,70	-1,87	-0,73
1966	-76	-60	-2,90	-1,36	-0,90
1967	-80	-78	-0,02	1,73	2,04
1968	-58	-68	-0,32	-1,57	2,24
1969	-72	-74	-3,08	-2,91	-1,40
1970	-49	-62	-2,10	-0,87	-2,01
1971	-54	-66	0,01	-0,77	-0,88
1972	-79	-70	0,54	0,25	0,13
1973	-73	-44	2,03	1,20	0,98
1974	-78	-79	0,54	-0,34	-0,13
1975	-65	-68	1,93	0,85	0,42
1976	-80	-78	0,51	2,22	0,86
1977	-60	-69	-3,38	-1,47	0,45
1978	-74	-66	0,44	-2,37	0,84
1979	-75	-60	-1,85	-0,48	-0,62

30 hPa North Pole

T (ºC)	J	F	AOi	<-0.50	>0.50
X (58-00)	-72	-67	J	F	M
	≤-75	≤-70			
1980	-80	-70	-1,72	-0,07	-1,22
1981	-81	-56	0,78	0,24	-1,32
1982	-71	-69	-0,59	1,35	1,24
1983	-79	-62	2,04	-0,85	0,02
1984	-80	-65	1,16	0,25	-1,93
1985	-53	-66	-2,22	-1,49	0,73
1986	-76	-74	0,01	-2,05	2,59
1987	-60	-49	-0,31	-1,02	-1,43
1988	-77	-80	0,85	-0,67	-0,07
1989	-82	-57	3,62	3,60	1,74
1990	-80	-63	1,35	3,41	3,55
1991	-70	-57	1,17	-0,09	-0,36
1992	-66	-59	1,64	1,76	1,38
1993	-80	-68	4,06	1,12	1,33
1994	-66	-77	-0,14	-0,48	2,03
1995	-70	-57	0,54	1,79	0,53
1996	-81	-75	-0,61	0,78	-1,11
1997	-79	-83	0,35	2,53	1,30
1998	-67	-64	-1,56	0,72	0,17
1999	-67	-69	0,41	0,95	-1,47*
2000	-84	-74	1,38	1,82	0,04
* March 1999 (-52) >	X March (-57)				

Mid-Winter Warmings
Coolings
Transmission MMW
NO Transmission MMW

13 MMWs of the 16 detected in the study period (81 %) are well-propagated from the stratosphere to the troposphere The months with a MMW influence are:

January (4): 1960, 1970, 1977 and 1985

February (10): 1958, 1960, 1963, 1966, 1968, 1969, 1970, 1971, 1977, 1985 and 1987

March (9): 1958, 1960, 1966, 1970, 1971, 1979, 1981, 1987 and 1999

20 Coolings of the 26 detected in the study period (76.9 %) are well-propagated from the stratosphere to the troposphere. The months with a Cooling influence are:

January (13): 1962, 1964, 1972, 1974, 1976, 1981, 1983, 1984, 1988, 1989, 1990, 1993 and 2000

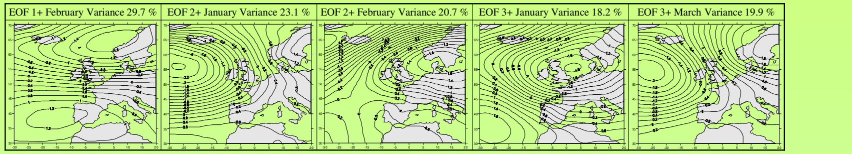
February (10): 1959, 1961, 1967, 1976, 1989, 1990, 1993, 1996, 1997 and 2000

March (10): 1959, 1961, 1967, 1976, 1986, 1989, 1990, 1993, 1994 and 1997

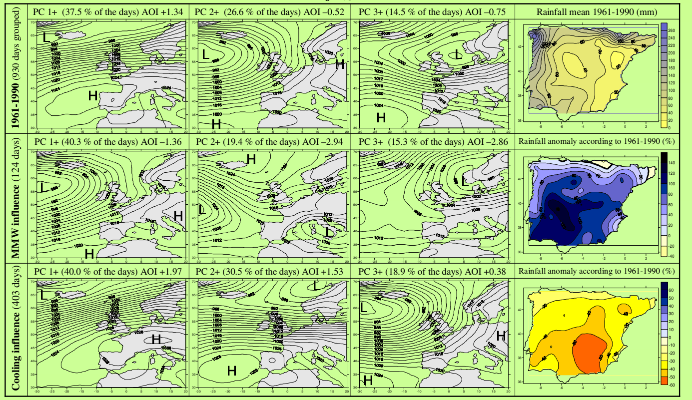
3

OBJECTIVE: After having the anomalous months selected, a daily objective circulation pattern classification is carried out for January, February and March separately at surface level in order **to detect the MMW influence in the troposphere**.

STATISTICAL ANALYSIS: The period **1961-1990** is taken as a reference to define the most frequent circulation patterns for each month. The analyses performed are Principal Component Analysis (PCA) and Clustering // **PCA:** It is used a surface level pressure grid at 2.5° * 2.5° resolution for the window (70ºN: 30ºN; 30ºW: 20ºE), 357 grid points (NCEP/NCAR Reanalysis Project data, CRU). The matrix employed is T-mode where the days are the variables and the grid points are the cases (Huth 1996). 6 PCs are extracted (± 90 % variance) with CORRELATION matrix and VARIMAX rotation (Esteban et al., 2005) // **Clustering:** Using each PC, two possible real patterns are derived, one in its positive phase, and other in its negative phase. Each real day (variable) is correlated with each PC. All the real days of the reference period 1961-1990 are grouped according to the best correlation with one PC in a positive or negative sign. The real days of each group are averaged in order to map a real circulation pattern. The groups are differently sized, and only the most frequent are considered as the representative circulations // The AOIs of each real day are also averaged // The EOFs are quite similar to the real patterns. This fact demonstrates how well the use of a T-mode matrix works (some of them are displayed) // The **rainfall means** are calculated for the reference period 1961-1990. The rainfall data are 51 meteorological stations spread throughout the entire peninsula at a monthly resolution (*Look section 4*) // Afterwards, the same analysis is applied just for the months of January, February and March separately with a MMW influence previously detected by means of the AOI. The rainfall anomalies are calculated according to the reference period 1961-1990. It is performed identically for the months with a Cooling influence. (Only the first three most frequent patterns are shown).

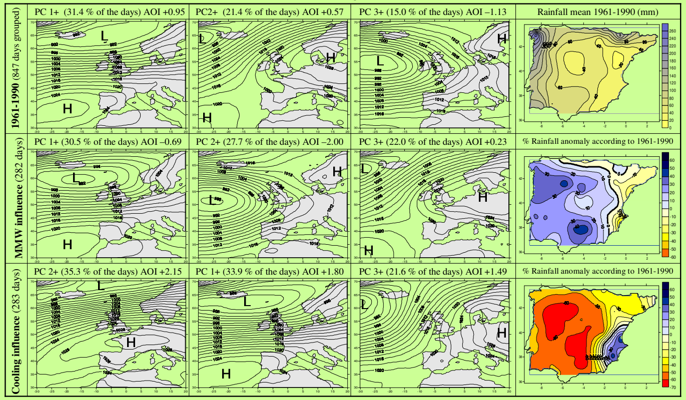


JANUARY



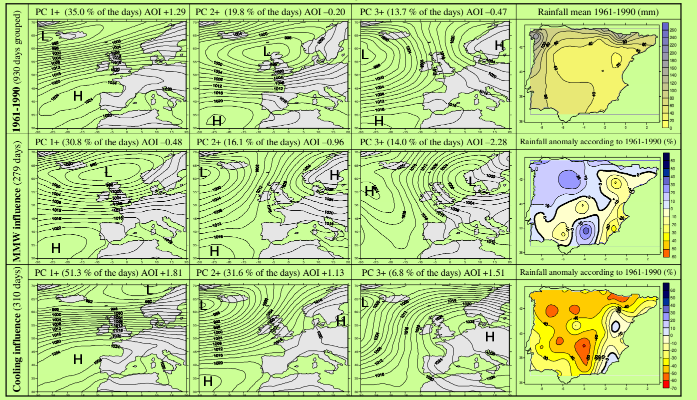
➢The second pattern 1961-1990 is the most frequent in MMW analysis. SW flows are frequent over Iberian Peninsula leading to an important rainfall increase in the SW Iberian area.
➢The first pattern 1961-1990 is the most frequent in Cooling analysis. The anticyclone is perceptibly strengthened and shifted northward leading to a general pluviometric decrease.
➢Both Cantabrian and NE areas do not vary their precipitation because no wet conditions are favoured in these zones with SW flows and the appearance of the Liguria low in MMW conditions.

FEBRUARY



➢The first pattern 1961-1990 is weakened and southward shifted in MMW, so that the storms travel southward leading to a rainfall increase in W Iberia, but dry conditions in the E fringe.
➢The first pattern 1961-1990 is strengthened and northeastern shifted in Cooling conditions leading to a strong rainfall decrease in western Iberia and a increase in the southeastern area.
➢ The central European anticyclone pattern does not vary under either of the influences, but it remains in a third position due to the frequency increase of other patterns.

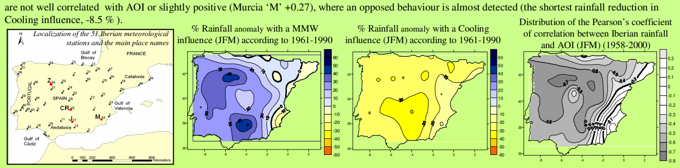
MARCH



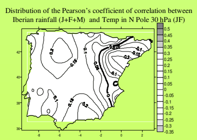
➢ The first pattern 1961-1990 disappears under the MMW influence, but it is absolutely predominant in Cooling conditions leading to a rainfall decrease in most of the Iberian Peninsula.
➢The second and third patterns 1961-1990 are predominant in MMW influence. The southward shifting of the storms tracks (PC1+, MMW) favours a slight increase in the northwestern area.
➢Under MMW, the increase in the north area is also related to the north advections (PC3+, MMW). In Cooling, Mediterranean fluxes lead to a very slight increase in the E fringe (PC3+, Cooling)

4

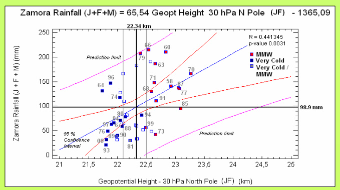
The MMW average map of rainfall anomalies of the three months shows the largest increase in northern Iberian Plateau (Zamora 'Z' +48.7 %) and in the eastern inland area of Andalusia (Jaén 'J' +53.0 %). The Cooling average map is quite different as the most important decrease is in south Iberian Peninsula (Ciudad Real 'CR' -40.7 %). (*The maps are weighted average according to the number of cases in each month*). The rainfall area best correlated with the AOI in its negative phase is Zamora (-0.76). The coefficient distribution with the AOI is quite similar to the MMW average map. Those zones best negatively correlated with AOI are sensitive to have an increase with a MMW influence. The eastern façade remains with a slight increase as well as the Cantabrian area. These zones are not well correlated with AOI or slightly positive (Murcia 'M' +0.27), where an opposed behaviour is almost detected (the shortest rainfall reduction in Cooling influence, -8.5 %).



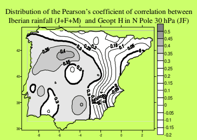
After having detected some influence of the middle-low stratospheric behaviour in Iberian precipitation variability, it is worthy to confirm this relationship by means of the stratospheric temperature and geopotential height in the North Pole 30 hPa. The stratospheric temperature is not significantly correlated with the Iberian rainfall, however, the Mediterranean area is negatively correlated and the western part positively. The results are enhanced using the geopotential height, being significantly correlated at 0.05 % in the western part (shaded area). The maximum is in Zamora (+0.44). The shaded area fits closely with the area delimited by the contour line 20 % in the average map of rainfall anomalies under a MMW influence.



The lineal regression between Zamora Rainfall (J+F+M) and the geopotential height in North Pole 30 hPa (JF) shows a precipitation rise when a MMW takes place increasing the geopotential height, and viceversa for those years when January or February is very cold (when $T_{30hPa\ N\ Pole}$ Jan ≤ -80ºC or $T_{30hPa\ N\ Pole}$ Feb ≤ -75 ºC) (*Look at the table in section 2*)

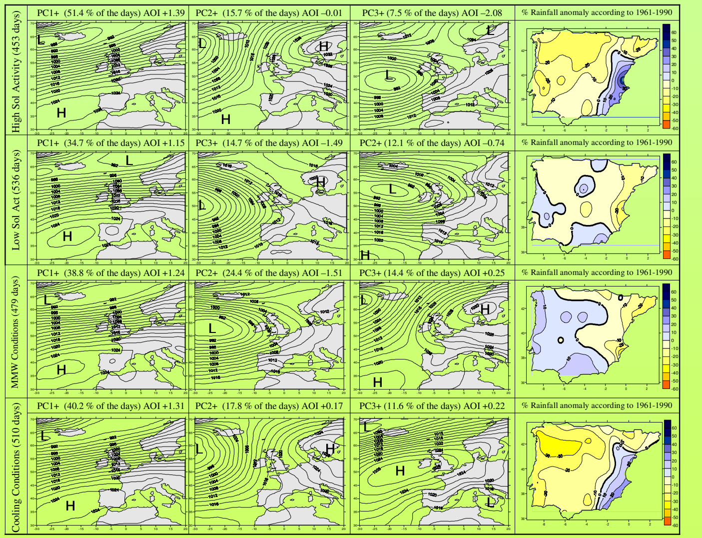


If the mean geopotential height in JF is under 22.1 km, a very cold vortex is almost ensured with a consequent Zamora rainfall (J+F+M) under the mean; and viceversa when the geopotential height in JF is above 22.5 km



5

Checking the analysis. In order to ensure a solar signal through the occurrence of MMW, a new analysis has been carried out without taking the AOI into account. The chosen month is February because it is when a largest solar signal is more probable (Baldwin 2005, Labitzke 2005). Firstly, following the same method like in section 3, an analysis has been performed separating the years with a high solar activity from those with a low solar activity.
➢High Activity (16): 1958, 1959, 1960, 1968, 1969, 1970, 1971, 1979, 1980, 1981, 1982, 1989, 1990, 1991, 1992 and 2000.
➢Low Activity (19): 1962, 1963, 1964, 1965, 1966, 1973, 1974, 1975, 1976, 1977, 1985, 1986, 1987, 1988, 1994, 1995, 1996, 1997 and 1998.
Afterwards, the years according to the role QBO / Solar Activity relationship will be separated.
➢MMW conditions are favoured (QBO W with High Solar Activity and QBO E with Low Solar Activity) (17): 1958, 1960, 1963, 1966, 1968, 1970, 1973, 1975, 1977, 1979, 1981,1985, 1987, 1989, 1991, 1997 and 1998.
➢Cooling conditions are favoured (QBO E with High Solar Activity and QBO W with Low Solar Activity) (18): 1959, 1962, 1964, 1965, 1969, 1971, 1974, 1976, 1980, 1982, 1986, 1988, 1990, 1992, 1994, 1995, 1996 and 1998.



➢Without considering the QBO phase, the rainfall anomalies are not clear in low solar activity years, but those with high solar activity show a rainfall increase in the Gulf of Valencia due to a major frequency of NE flows as it is seen in PC2+ of high solar activity. A general decrease in the northwestern part is detected due to a strengthening of westerlies.
➢Considering the QBO, the 2nd pattern in MMW conditions demonstrates a southward shift of the storm tracks leading to a precipitation rise in western Iberia. But, in the Mediterranean fringe varies contrarily because it is more dependent on the eastern flows displayed in PC2+ and PC3+ of Cooling conditions.

6 CONCLUSIONS

➢We might find an **indirect Solar Signal** in Iberian winter (JFM) rainfall by means of the **occurrence of MMW according to the role QBO Phase / Solar Activity**.
➢After a **MMW** occurrence we should expect an **increase** of precipitation in the **western part** of the Iberian Peninsula in 10 days to 2 months, and a slight decrease in the eastern façade, mainly in February. The **storm tracks are shifted southward**.
➢After a **Cooling** we should expect a **decrease** of the precipitation in the **western part** of Iberian Peninsula in 10 days to 2 months, and no variation or a slight increase in the eastern façade, mainly in February. The **storm tracks are shifted northward**.
➢There is an **opposite influence between the eastern fringe and the western Iberian area**. The favourable western flows after a MMW occurrence arrive very dry at the Mediterranean façade, and NE flows are favoured after a Cooling due to the strengthening and northward shifting of the North Atlantic anticyclone.
➢**February is the most probable month to contain solar signal** because it is when more years are detected to have a MMW or Cooling influence. In February, there is a better correlation between stratospheric temperature in the North Pole 30 hPa and solar flux (Labitzke, 2005). Baldwin and Dunkerton (2005) also proposed the late winter for finding this indirect signal.
➢**The stratospheric influence in Iberian Rainfall is demonstrated regarding the geopotential height in North Pole 30 hPa**. There is a significant correlation at 0.05 % in the western part (excepting the north fringe) between both variables, reaching a confidence level of 99.0 % in Zamora and Jaén.
➢The stratosphere-troposphere coupling is also demonstrated when we perform the analysis again **without taking the AOI into account for February**. The results are very similar to the first ones, however, with some **weakening**. The stratospheric anomaly is not always transmitted to the troposphere. Indeed, we must remember that the AOI has its own variability.

7 MAIN REFERENCES

· Baldwin, M. P., Dunkerton, T. J., 1999. Propagation of the Arctic Oscillation from the stratosphere to the troposphere. J Geophys Res 104 (24), 30937-30946.
· Baldwin, M. P., Dunkerton T. J., 2005. The solar cycle and stratosphere-troposphere dynamical coupling. J Atmos Solar-Terr Phys 67, 71-82.
· Esteban, P., Jones, P.D., Martin-Vide, J., Mases, M., 2005. Atmospheric circulation patterns related to heavy snowfall days in Andorra, Pyrenees. Int J Climatol 25, 319-329.
· Huth R., 1996. An intercomparison of computer-assisted circulation classification methods. Int J Climatol 16, 893-922.
· Labitzke, K., 1987. Sunspots, the QBO, and the stratospheric temperature in the north polar region. Geophys Res Lett 14, 535-537.
· Labitzke, K., 2005. On the solar cycle-QBO relationship: a summary. J Atmos Solar-Terr Phys 67, 45-54.
· Thompson, W. J., Wallace, J. M., 2000. Annular Modes in the Extratropical Circulation. Part I: Month-to-Month Variability. Journal of Climate 13, 1000-1016.