FIRST EXPERIENCES ABOUT WORKING WITH DATA FROM CLIMATE MODELS

Behavior in the past of the position and intensity of Azores anti-cyclone

Grant Project nº 15: Training in diagnosis and validation applied to reanalysis and integrations of climate models. Centro Meteorológico de Málaga

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1. Acquisition of theoretical knowledge

General climatology:

- Cuadrat, J.M. y Pita, M. F., 2009: *Climatología.*
- Deliang C., 2007: *The Atmosphere: an introduction to meteorology*.

African climatology:

- Jury, M. R. y Mpeta, E.J., 2005: *The annual cycle of African climate and its variability*

Revision of basic concepts about climate models and climate change:

- Documents from IV Assesment Report of the IPCC:
  - *Cambio climático 2007: Base de Ciencia Física (IPCC. PNUMA)*
  - *Cambio climático 2007: Informe de Síntesis (IPCC. PNUMA)*
- Document from AEMET: *Generación de escenarios regionalizados de cambio climático para España*.
- Several presentations and documents for the adquisition of knowledge related to AOGCM and RCM.

2. Familiarization with the use of specific software tools

- Use of the web page of ECMWF, to get the data.
- CDO software and other utilities (ncview, ncdump, etc.).
- Metview software.
- Installation of Magics++ and associated libraries (NetCDF, GribApi, EmosLib, etc).
- R package.
- First basic scripts in linux.
- First steps in Fortran (gFortran).
- First steps using Magics++ with Fortran.

3. Work with data of climate models

STUDY OF THE AZORES ANTICYCLONE

Objective: familiarization with the use of models data and study of the behavior in the past of the Azores anticyclone: changes in intensity and position.

3.1. Bibliography

Wenhong Li., Laifang Li., Rong Fu, Yi Deng, Hui Wang., 2011: *Changes to the North Atlantic Subtropical High and Its Role in the Intensification of Summer Rainfall Variability in the Southeastern United States*. Journal of Climate, 24, 1499–1506

They find a rise along the time, of the influence of the Azores Anticyclone on the climate at southeast of USA.

- They first establish:

  a) A raise of the maximum intensity.

  b) A westward displacement of the 1560 gpm isohypse. This is related to the raise of the maximum.

- Then, they correlate this change with other variables, like the normalized precipitation index.

3.2. Objectives

Study of the behavior of three significant points of the Azores Anticyclone in summer time (JJA), from 1958 to 2002 (ERA40 data):

1. **Anticyclone maximum**.
2. **Easternmost point (EP)** of two isohypses.
3. **Northernmost point (NP)** of two isohypses.

From these two points, we observe their:

Longitude

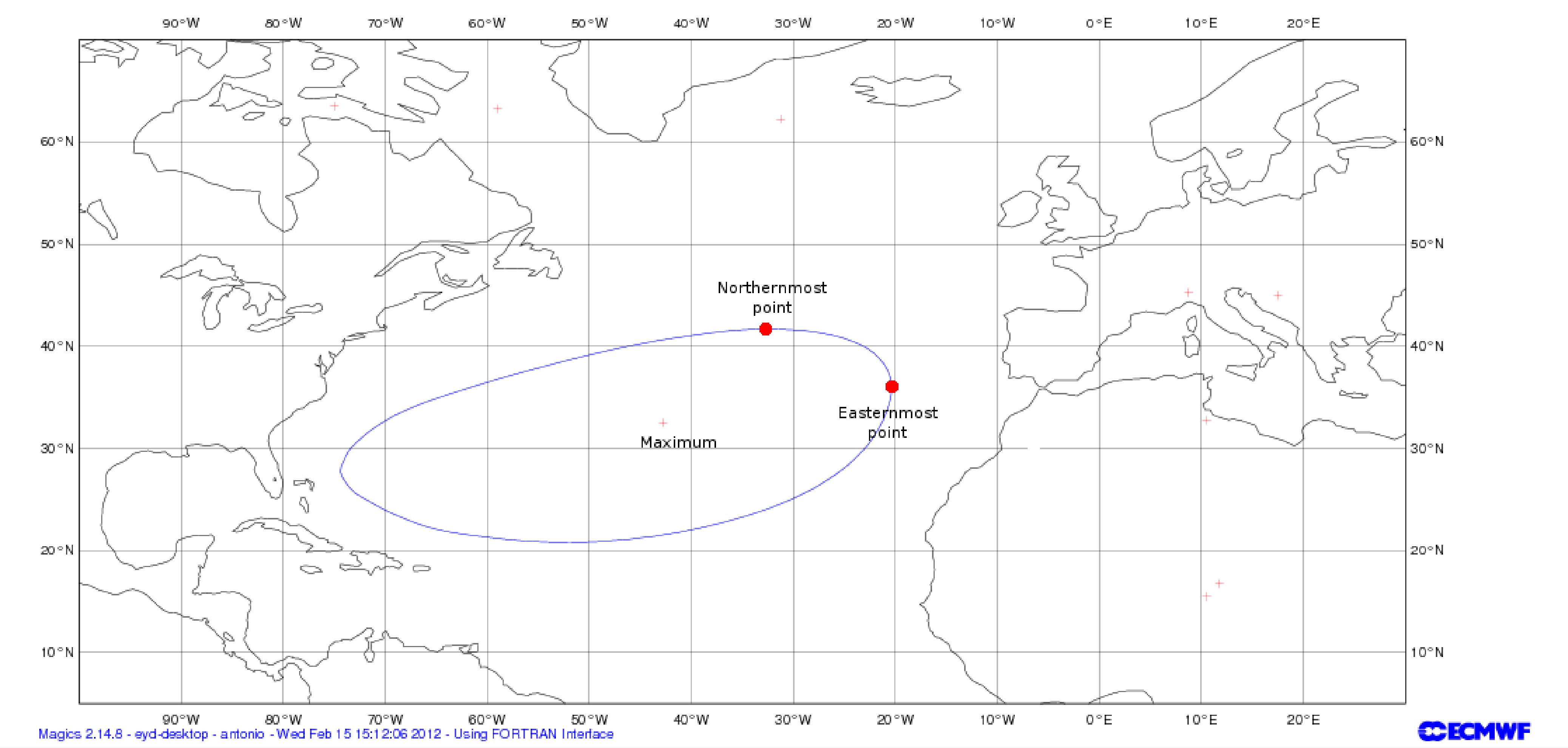
Latitude

In the case of the maximum, also its value (intensity).

Then, the time series of these variables, is studied.

3.2. Objectives

The three significant points



3.3.-Data source

- ERA-40 reanalysis data provided by ECMWF.
- Variable: Geopotential (parameter 129 table 128).
- Level: 850 hPa.
- From Sep-1957 to Aug-2002 (the whole available period).
- Monthly means of daily means.
- Area: 65°N 80°W / 15°N 20°E
- Grid has been interpolated to 0,25ºx0,25º.
- Grib format.

3.4.-Methodology and Results

Steps to observe tendencies:

- Retrieval of data from numerical models.
- Calculations using programs and macros based on cdo and MetView.
- Use of the R package to represent graphics and statistics.

Retrieval of Azores data

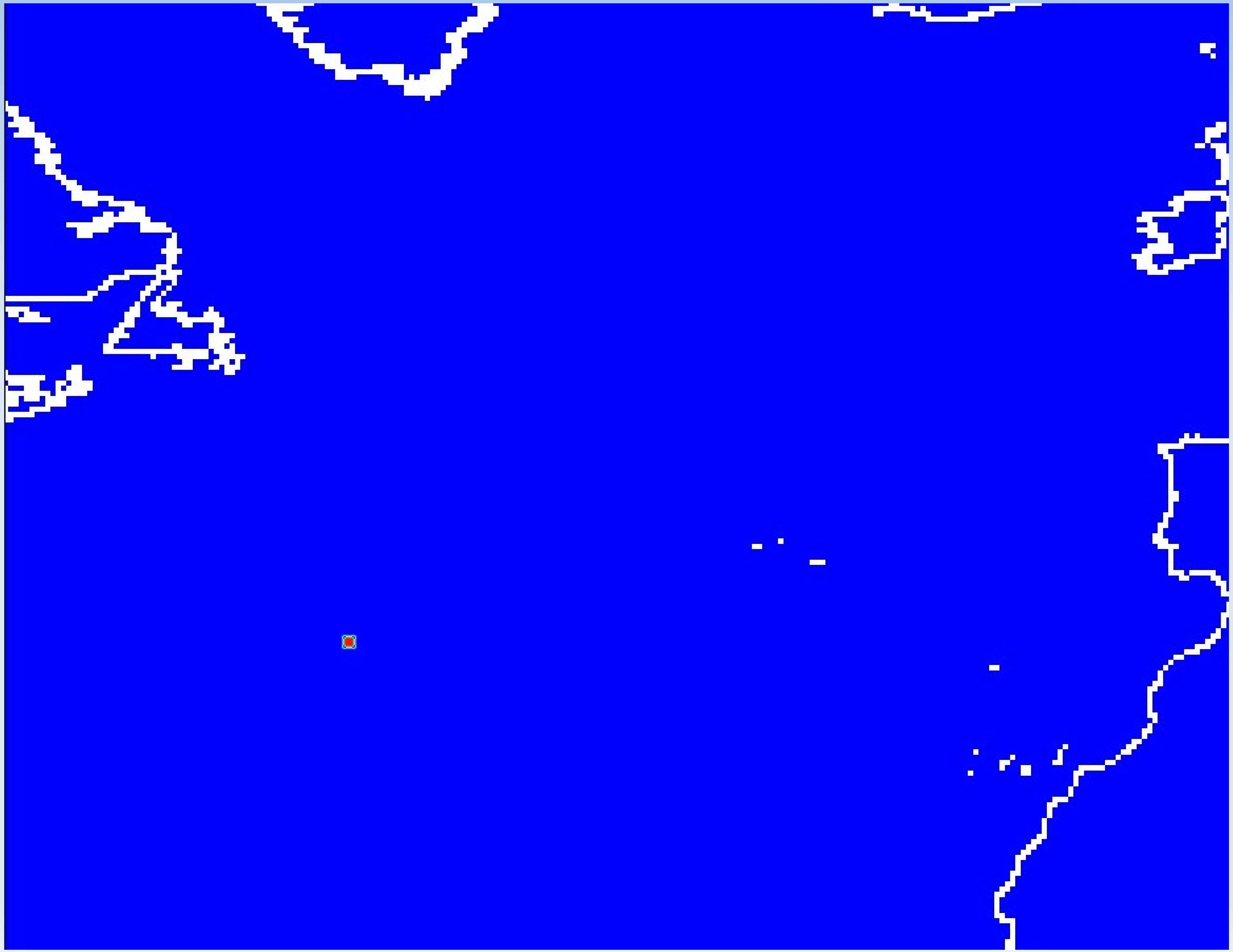
1. Initial treatment: Selection of JJA and calculation of their average in each year (Metview).
2. The value of the maximum (intensity) is provided by the function *maxvalue* (Metview).
3. The position of the maximum is provided by the function *find* (Metview).
4. Position of EP and NP of an isohypse:
   - We choose regular isohypses (to avoid topographic effect).
     - Manual method (only for EP): Display of Metview.
     - Automatic method (for EP and NP): Metview macro using numerical methods.

Visualization of Azores maximum

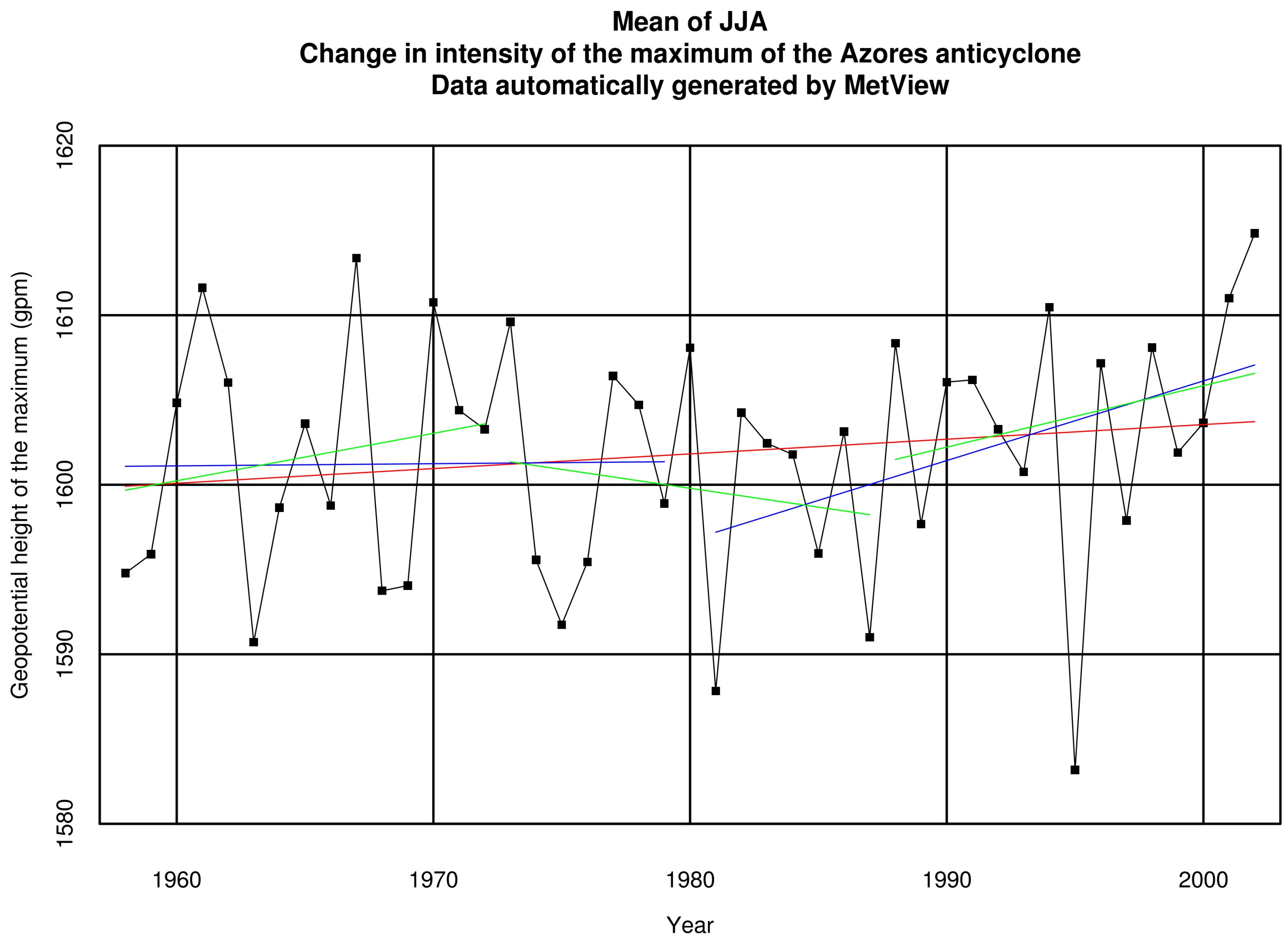
It is achieved by using ncview on files treated with CDO. A bash script facilitates the task.

```
#!/bin/bash
#cd /home/antonio/Documentos/TemasBeca/Azores/meses/5meses

#  Este script actúa sobre ficheros creados a partir del bajado del ECMWF con información de geopotencial a 850 hPa para todos los años de ERA40.
#  Dicho fichero se ha dividido en uno por cada mes del año, usando la orden:
#                     cdo splitmon Z850_Azores_0.25x0.25.grib Z850_Azores_0.25x0.25_Mes
# lo que ha generado doce ficheros, cada uno conteniendo información de un mes a lo largo de los 45 años de ERA40, y llmandose
#  Z850_Azores_0.25x0.25_Mes??.grb, donde ?? es substituído por el número del mes.

for filein in Z850_Azores_0.25x0.25_Mes??.grb   # esta es la plantilla para los nombres de fichero que debe encontrar.
do
#               CREACIÓN DEL FICHERO CON LA PRESIÓN MÁXIMA
fileMax=${filein:0:(${#filein}-4)}'_Max.grb'
cdo fldmax $filein $fileMax     # si no se pone entre llaves, las concatena insertando un espacio en blanco.

#               CREACIÓN DEL FICHERO DE DESCRIPCIÓN DE LA MALLA
# Basta con crear uno porque todos los ficheros tienen la misma malla. Por tanto, detectamos si el fichero de malla ya existe y sólo lo creamos si
# no existe.
fileGridDes='grid.txt'                          #${filein:0:(${#filein}-4)}'_GridDes'
if [ ! -e $fileGridDes ]        # O sea, si no existe el fichero grid.txt.
        then
        cdo griddes $filein > $fileGridDes      #De hecho lo creamos a partir de la malla del primer fichero de mes que encontramos.
fi


#              AMPLIACIÓN DEL FICHERO QUE CONTIENE LA MÁXIMA PRESIÓN
# Primero, el fichero que contiene el máximo de presión, lo ampliamos a una malla igual a la malla del fichero original.
# El fichero resultante es como el original, pero con todos los puntos de la malla con el mismo valor de presión (el máximo).

                # le quita los cuatro últimos caracteres al nombre del fichero, es decir, la extensión '.grb'
fileMaxAmpliado=${fileMax:0:(${#fileMax}-4)}'_Ampliado.grb'     # si no se pone entre llaves, las concatena insertando un espacio en blanco.

cdo enlarge,${fileGridDes} $fileMax $fileMaxAmpliado

#              CREACIÓN DE LA MÁSCARA COMPARANDO ORIGINAL CON MÁXIMO AMPLIADO
# Ahora, creamos el fichero que tendrá un uno en cada punto de malla cuyo valor de geopotencial sea máximo, y que servirá de máscara más adelante
```

Visualization of Azores maximum



Results for intensity of Azores maximum



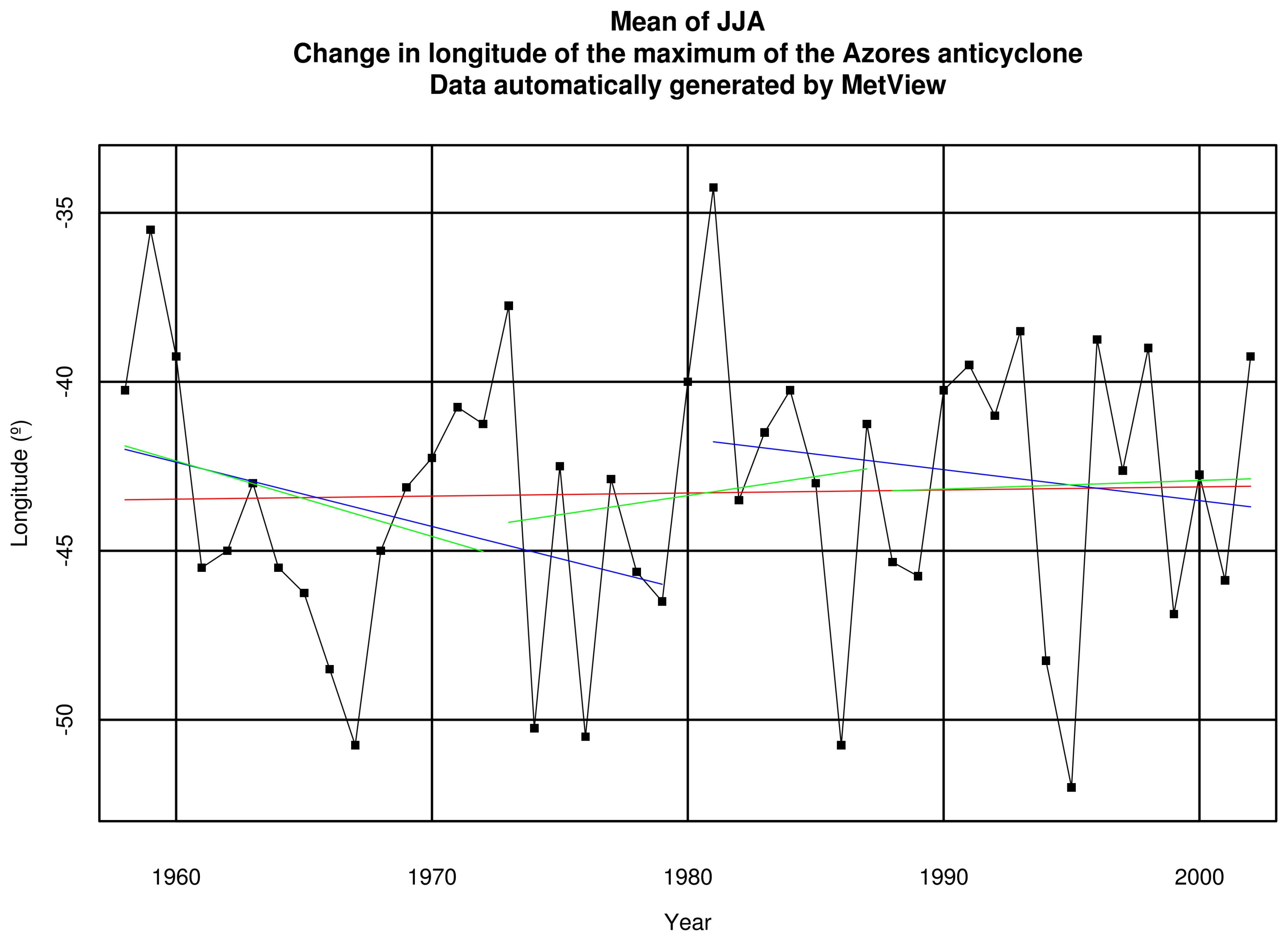
Results for intensity of Azores maximum

Observed tendencies:

	Whole data	*First 1/2 of the data*	*Second 1/2 of the data*	*First 1/3 of the data*	*Second 1/3 of the data*	*Third 1/3 of the data*
Point of maximum geopotential height. Intensification (mgp/decade)	0,87	0,13	4,70	2,80	-2,23	3,63

- Value obtained by Wenhong Li, etc.
(for the whole period): 0,87 mgp/decade
- The tendency is upward in almost all of the sub-periods.
- **Altogether, there is a clear intensification of the maximum.**

Results for longitude of Azores maximum



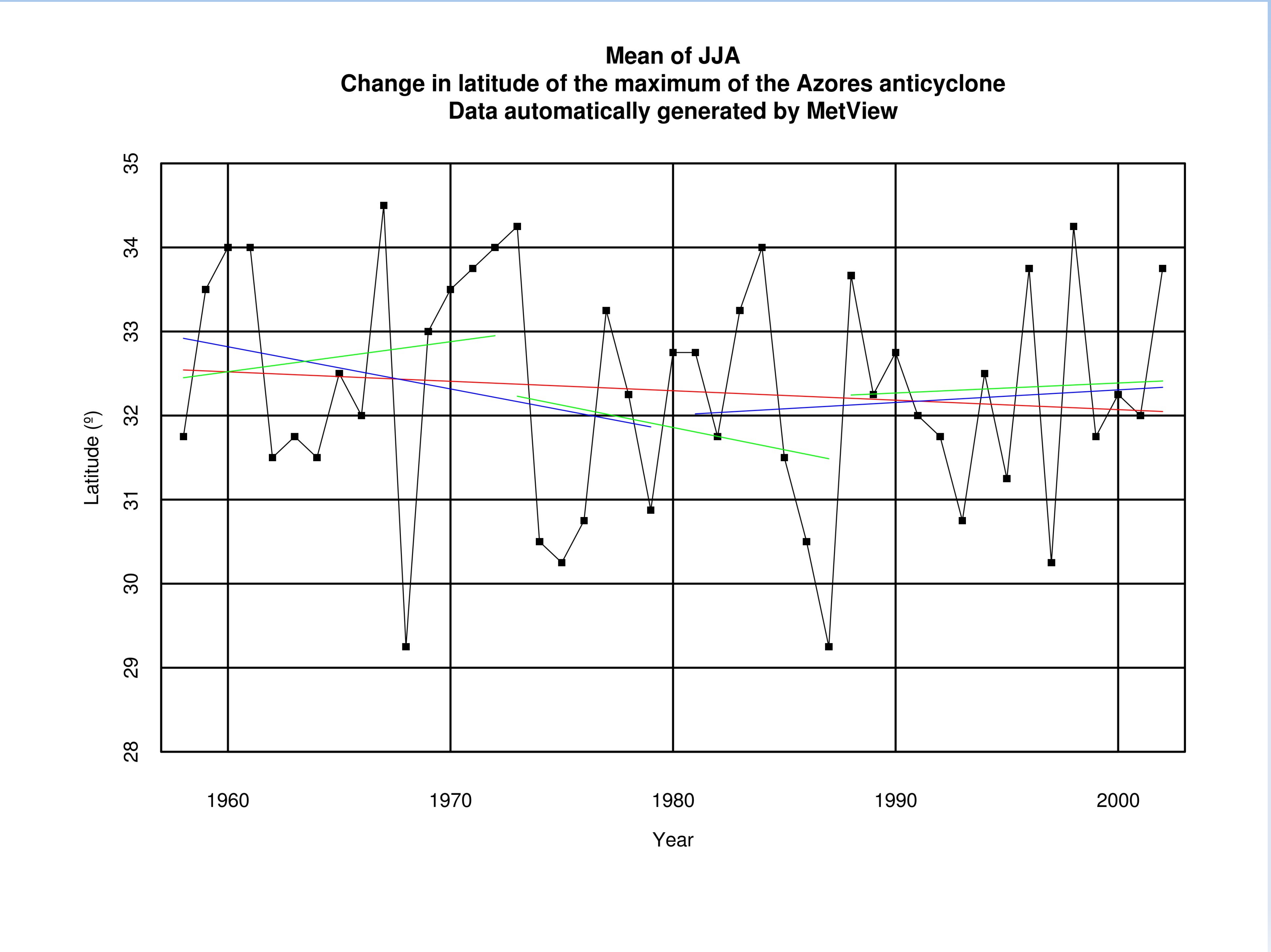
Results for longitude of Azores maximum

Observed tendencies:

	Whole data	*First 1/2 of the data*	*Second 1/2 of the data*	*First 1/3 of the data*	*Second 1/3 of the data*	*Third 1/3 of the data*
Point of maximum geopotential height. Displacement (ºE/decade)	0,09	-1,90	-0,92	-2,23	1,13	0,25

1. Westward movement in the first half of the period.
2. Abrupt eastward movement in the middle of the period.
3. And it moves again westward in the last half of the period.
4. **Altogether results a slight tendency to the east.**

Results for latitude of Azores maximum



Results for latitude of Azores maximum

Observed tendencies:

	Whole data	*First 1/2 of the data*	*Second 1/2 of the data*	*First 1/3 of the data*	*Second 1/3 of the data*	*Third 1/3 of the data*
Point of maximum geopotential height. Displacement (ºN/decade)	-0,11	-0,50	0,15	0,36	-0,53	0,12

Southward movement of the maximum, although over the last years of the period, it moved northward.

Conclusions Azores maximum

We can establish:

- A **rise of the intensity of the maximum** (this piece of data coincides with the one calculated by Wenhong Li, etc.), **more marked in the last sub-periods of time.**
- A southward movement of the maximum, although it moved northward in the last years of the period.
- An **eastward movement of the maximum**, more marked in the last sub-periods of time.

Easternmost and northernmost points (EP and NP)

Two methods are used:

- Manual (only for EP. Laboriousness)
- Automatic. (for both EP and NP)

On two isohypses at level 850 hPa:

- 1560 gpm
- 1570 gpm

Results EP longitude

Manual method:

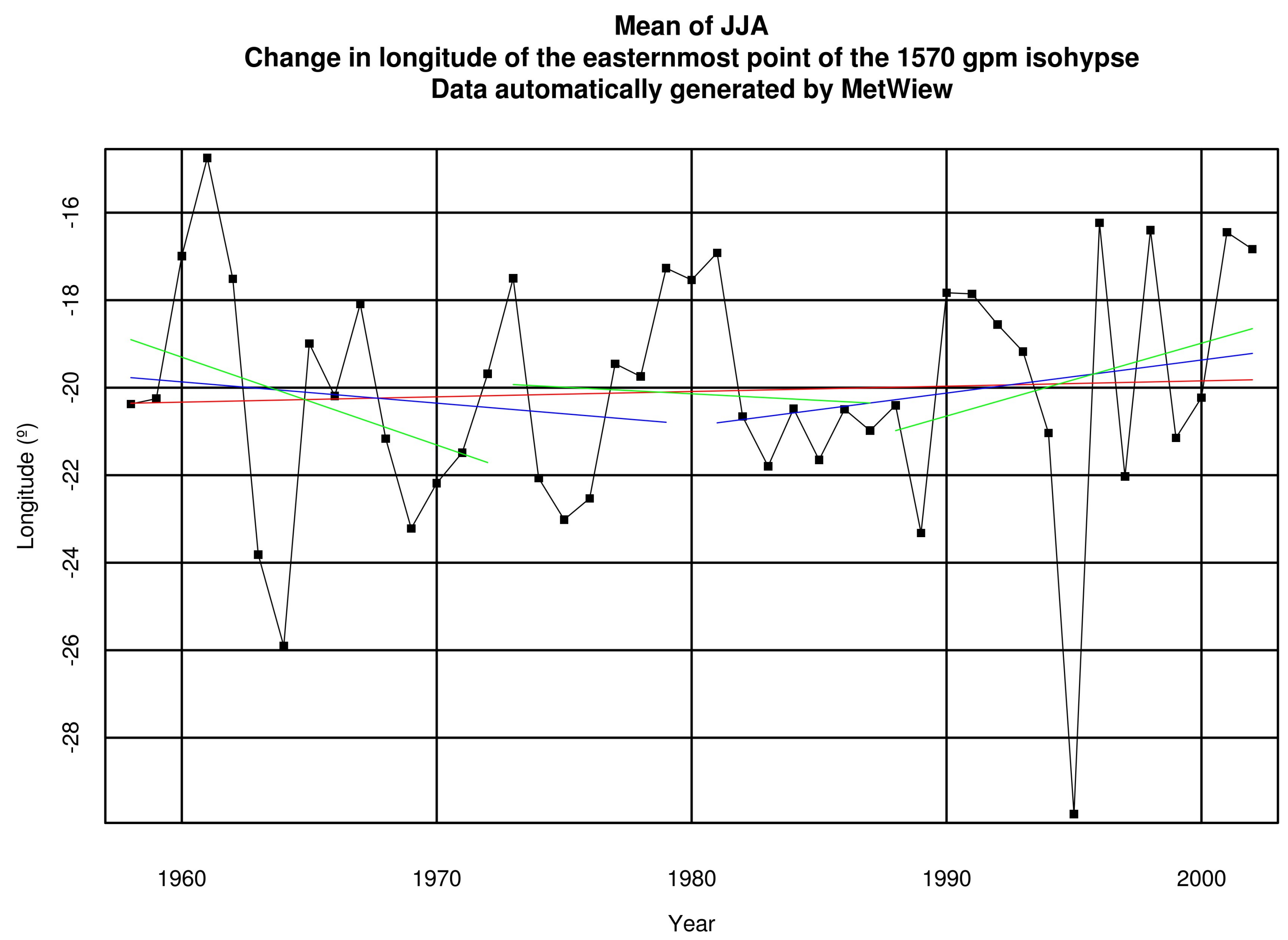
	Whole data	*First 1/2 of the data*	*Second 1/2 of the data*	*First 1/3 of the data*	*Second 1/3 of the data*	*Third 1/3 of the data*
Isohypse 1560 gpm Displacement of EP (ºE/decade)	0,05	-0,43	0,78	-2,14	-0,70	1,29
Isohypse 1570 gpm Displacement of EP (ºE/decade)	0,12	-0,48	0,76	-2,00	-0,32	1,66

Automatic method:

	Whole data	*First 1/2 of the data*	*Second 1/2 of the data*	*First 1/3 of the data*	*Second 1/3 of the data*	*Third 1/3 of the data*
Isohypse 1560 gpm Displacement of EP (ºE/decade)	0,04	-0,43	0,76	-2,16	-0,67	1,30
Isohypse 1570 gpm Displacement of EP (ºE/decade)	0,12	-0,49	0,76	-2,01	-0,30	1,67

- Both methods are practically equivalent
- The 1560 gpm isohypse is too irregular to provide reliable data.

Results EP longitude
Automatic method, 1570 gpm



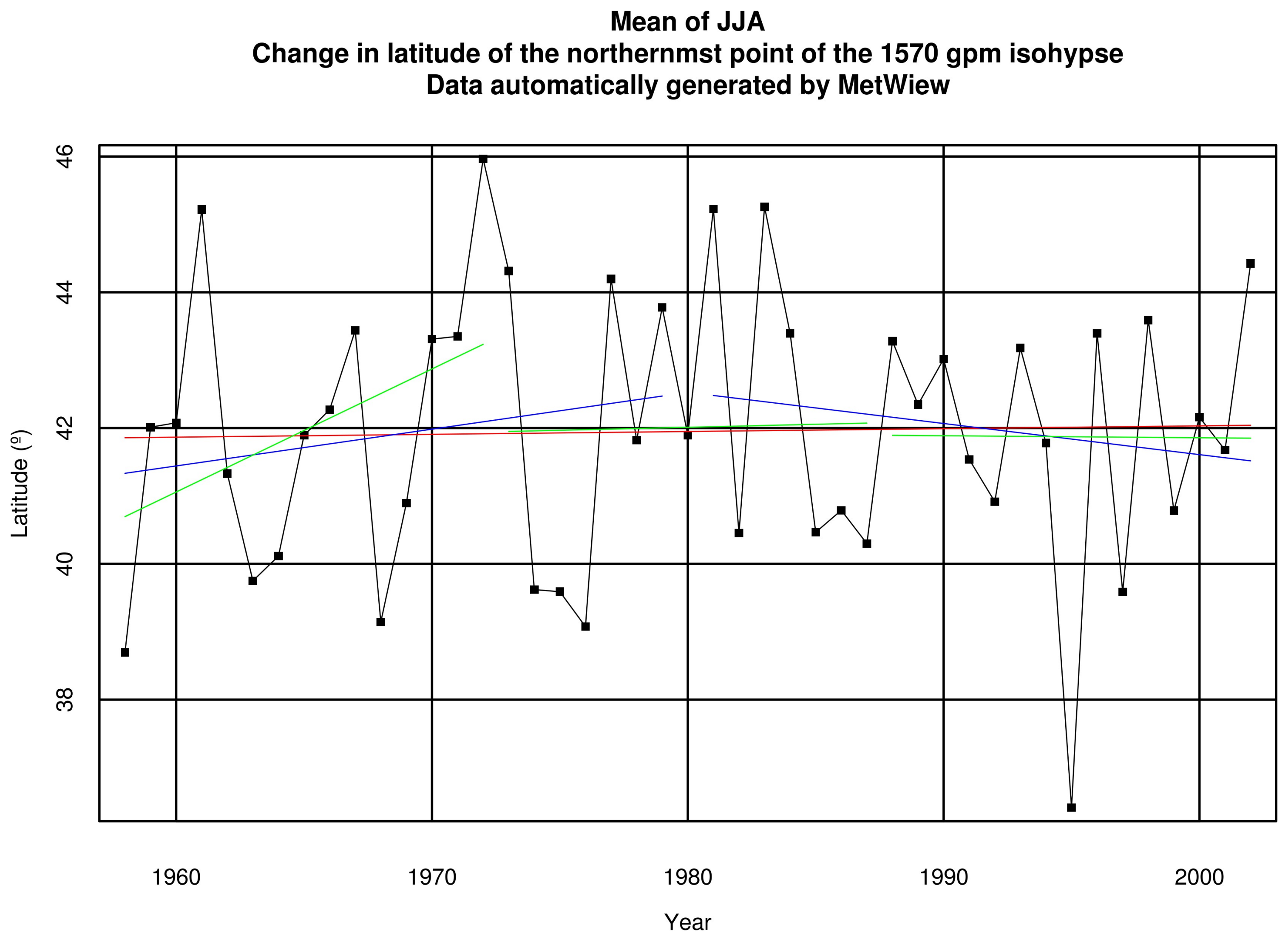
Results EP longitude

Observed tendencies:

	Whole data	*First 1/2 of the data*	*Second 1/2 of the data*	*First 1/3 of the data*	*Second 1/3 of the data*	*Third 1/3 of the data*
Isohypse 1570 gpm Displacement of EP (ºE/decade)	0,12	-0,49	0,76	-2,01	-0,30	1,67

- We observe an **eastward movement**, more marked as we advance in time.
- This movement (0,12 ºE/decade) is much lower than the observed on the western part of the 1560 gpm isohypse by Whenhong Li, etc. (-1,22ºE/decade).
- Could the greater continental mass act as a brake on the expansion?.

Results NP latitude



Results NP latitude

Only determined by the automatic method:

	Whole data	*First 1/2 of the data*	*Second 1/2 of the data*	*First 1/3 of the data*	*Second 1/3 of the data*	*Third 1/3 of the data*
Isohypse 1570 gpm Displacement of NP (ºN/decade)	0,04	0,54	-0,46	1,81	0,09	-0,03

- We observe a **swinging movement of the NP, moving northward early in the period, and then southward late in the period.**
- Altogether, there is a very slightly movement northwards.

Conclusions EP and NP

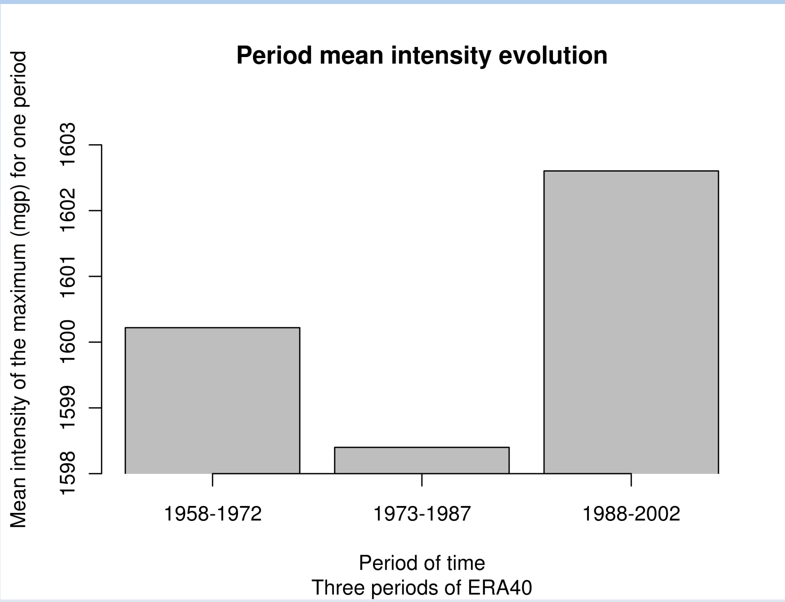
We observe an eastward movement of the easternmost point of the 1570 gpm isohypse, which is more marked as we advance in time. This movement (0,12 ºE/decade) is much lower than the one observed on the west part of the 1560 gpm isohypse by Whenhong Li, etc. (-1,22ºE/decade). Could the greater continental mass act as a brake on the expansion?.

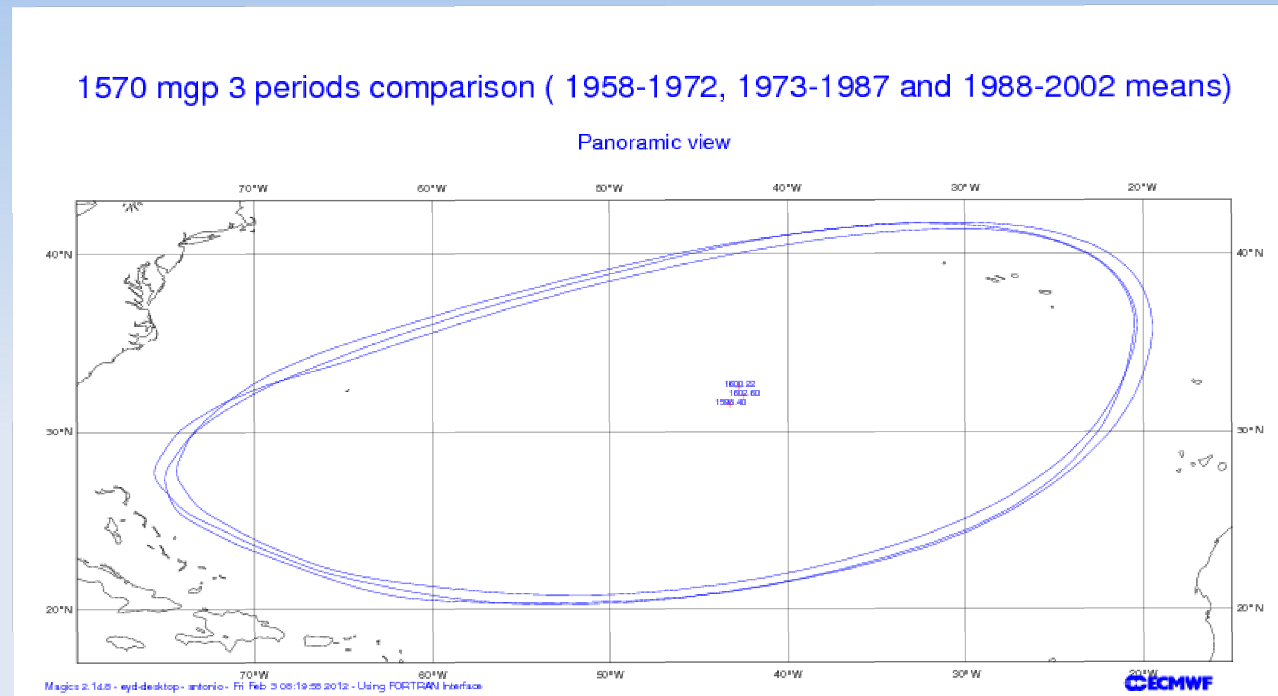
In the article by Li et al. (2011), they attribute a 38% of the westward displacement of the westernmost point of the 1560 gpm isohypse of the anticyclone, to the rise in the intensity of the maximum, and this can also contribute to the eastward displacement of the EP that we have observed.

We find a correlation of r = 0.64 between the eastward displacement of the easternmost point of the 1570 gpm isohypse of the anticyclone, and the rise in the intensity of the maximum.

We observe a swinging movement of the northernmost point of the isohypse, moving northward early in the period, and southward late in the period.

Final Conclusions (I)



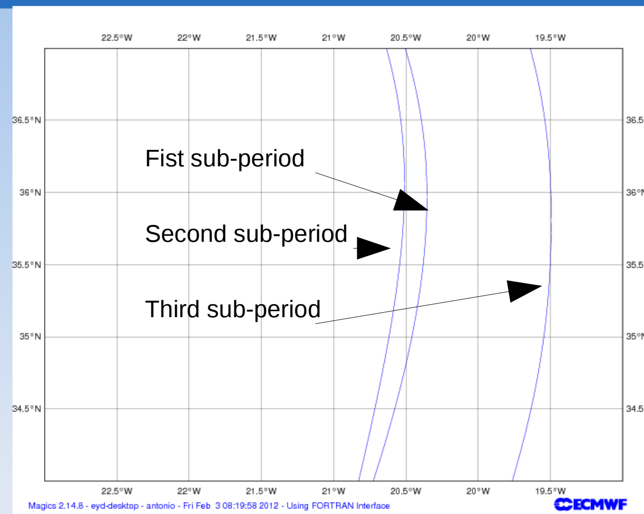


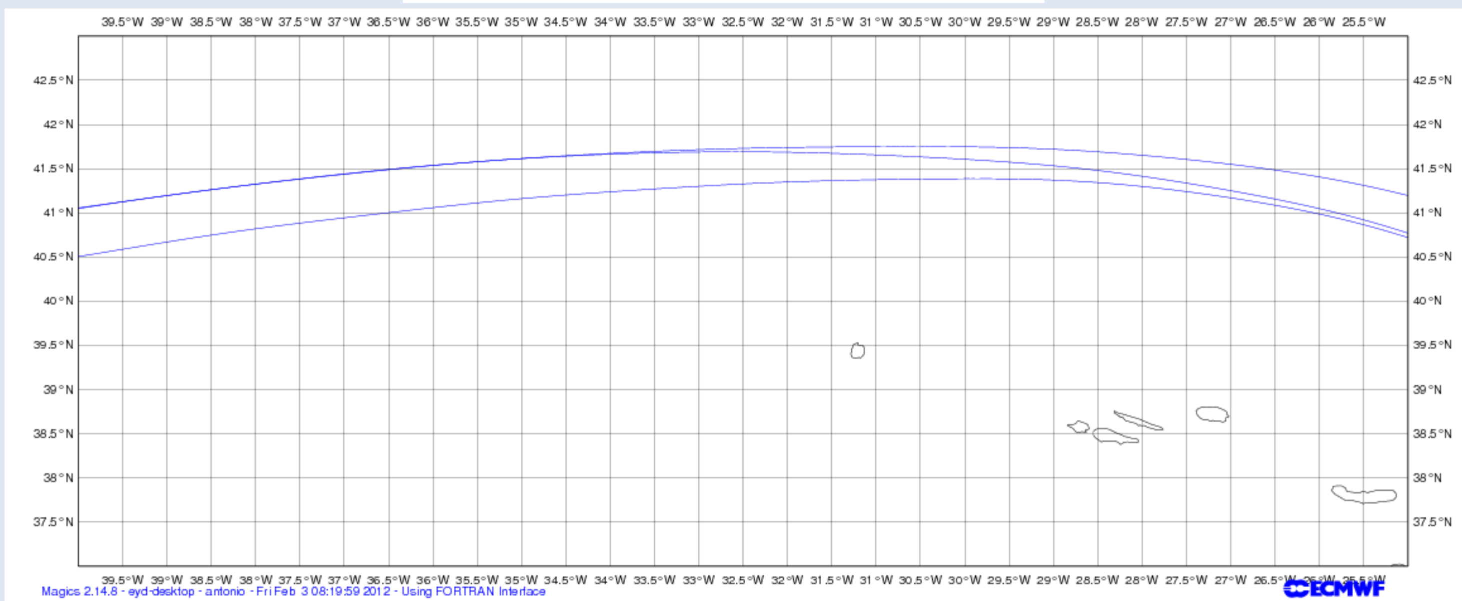
We can see an **intensification of the maximum value of Z850 gpm** between three periods of time.

The **evolution of the position of the Maximum value is not very significant.**

Final Conclusions (II)

Movement of easternmost point and northernmost point





We can see a displacement towards the east of 0,86º, and also a displacement to the south.

Final Conclusions (III)

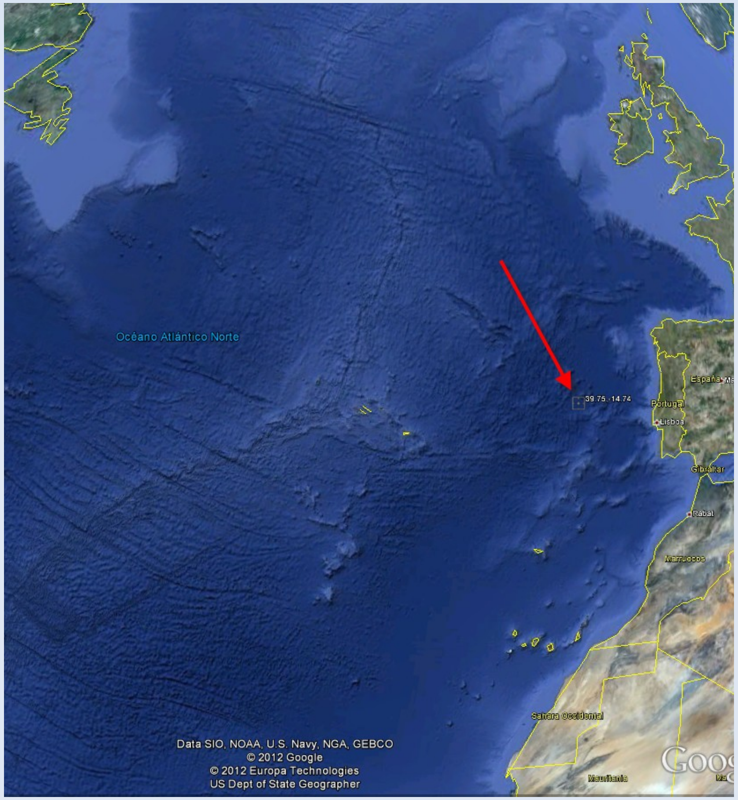
I have observed the **intensification of the Maximum and eastward displacement of the easternmost point of 1570 mgp isohypse in the past, in summer time (JJA).**

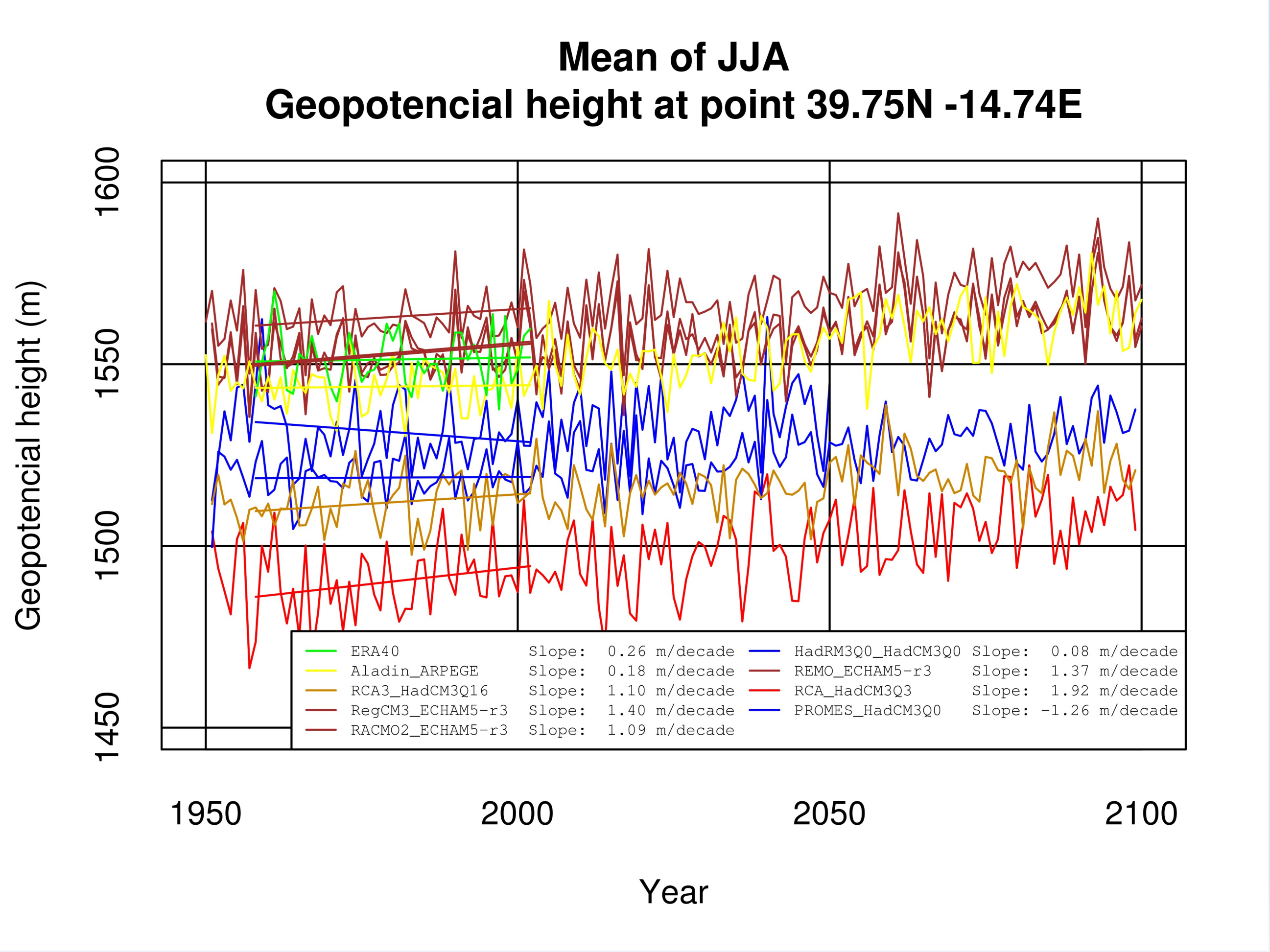
It is interesting to confirm this tendency with climate models projections data.

In the following page, we present an example of three models that show a similar increasing tendency.

Final Conclusions (IV)

For this, we use projections from some RCM of ENSEMBLES PROJECT. RCMs don't have extension enough for containing the whole anticyclone or to properly deal with the 1570 gpm isohypse, so we do not calculate the intensity of the maximum, nor the NP or the EP, but can obtain the geopotential height at a fixed location (39.75 N, -14.74 E) included in the RCMs.





Final Conclusions (V)

Models ordered by absolute value of difference between their slopes and the slope of ERA40, of the tendency line in the period of ERA40 (see last page).

Model	*Slope in ERA40 Period (1958-2002)*	*Slope in the whole period of each model*	*Mean of reference Sub-period (1961-2000)*	*Mean of sub-period 2001-2025*	*Mean of sub-period 2026-2050*	*Mean of sub-period 2051-2075*	*Mean of sub-period 2076-2100*
ERA40	0.26	0.26	1551.05	1558.77	NaN	NaN	NaN
Aladin_ARPEGE	0.18	1.67	1543.90	1549.37	1552.70	1560.93	1563.40
HadRM3Q0_HadCM3Q0	0.08	1.11	1518.76	1521.27	1523.66	1528.45	1531.40
RACMO2_ECHAM5-r3	1.09	1.02	1562.54	1566.04	1566.11	1571.46	1574.99
RCA3_HadCM3Q16	1.10	0.91	1512.04	1514.29	1515.55	1520.99	1521.88
REMO_ECHAM5-r3	1.37	1.03	1552.33	1555.08	1554.69	1561.11	1564.22
RegCM3_ECHAM5-r3	1.40	0.99	1552.67	1556.12	1556.12	1561.16	1564.63
PROMES_HadCM3Q0	-1.26	0.58	1530.22	1533.91	1535.79	NaN	NaN
RCA_HadCM3Q3	1.92	1.61	1489.84	1494.19	1499.47	1503.53	1508.71

Slopes are in m/decade and means are in m, except for ERA40 and Aladin_ARPEGE, which are in gpm/decade and gpm.

- Aladin_ARPEGE seems to be the model that best conforms with the variable we are studying.
- It has also the greatest slope in its whole period.
- All models have a positive slope in their whole period.
- All means of all quarter-centuries are greater than the one in the reference sub-period.
- Each mean of each quarter-century sub-period is greater than the precedent quarter-century sub-period, except for the two last models nested in ECHAM5-r3.
- However, models nested in ECHAM5-r3 predict the highest geopotential heights at the end of the century.

4. Future work

Generation of graphics of evolution for runoff and evapotranspiration in Spain, with data from regional climate models of Ensembles Project