GOBIERNO DE ESPAÑA
MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO
AEMet Agencia Estatal de Meteorología

Variable Mercator Map Factor at the HARMONIE Model

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Outline

- Projections. Map Factor
- Variable Map Factor at the HARMONIE Model
    - Mercator Map Factor using Fourier Series
    - Working Area
    - Truncation (Arpege vs HARMONIE)
- Code Flow
- Code Modifications
- First Results
- Future Work

Projections – Map Factor

- Conformal projections: planar (stereographic), conical (Lambert) and cylindrical (Mercator)
- Map Factor (**m**): rate of reduction of a line in the projection with respect to a curve on the sphere

$$\mathbf{m}(\varphi) = \frac{dx}{ds} = \left(\frac{1-K^2}{1-\sin^2\varphi}\right)^{\frac{1-K}{2}} \left(\frac{1+K}{1+\sin\varphi}\right)^{K}$$

K = sine of the tangency point latitude

φ = latitude

Map Factor in the Model

- **m** appears in the model equations in projection coordinates
- The easiest way to treat it in the linearized model of the SI scheme is considering its maximum value at the working domain

$$\mathbf{m}_* = \max_{Domain}\{\,\mathbf{m}\}$$

- Good solution when **m** remains close to the unity (small domains)
- Instabilities at the semi-implicit scheme for large domains and greater problems in NH cases (vertical pseudo-divergence)
- A variable treatment of the map factor is considered for "large" domains (similarly to the stretched ARPEGE treatment)

Variable Map Factor at the HARMONIE Model

MERCATOR MAP FACTOR USING FOURIER SERIES

- Mercator map factor

$$\mathbf{m}(\varphi) = \frac{1}{\cos\varphi} \qquad \mathbf{m}(x,y) = \cosh\frac{y}{a}$$

- **m**(x,y) can be written as a linear combination of low-order Fourier harmonics

$$\mathbf{m}(y)^2 = \frac{1}{2}a_0 + \sum_{n=1}^{n=\infty} a_n \cos\left(\frac{2n\pi}{L}y\right)$$

$$a_0 = \frac{1}{2f}\left(e^f - e^{-f}\right) + 1$$

$$a_n = \frac{(-1)^n f}{2\left((n\pi)^2 + f^2\right)}\left(e^f - e^{-f}\right), \qquad n = 1,2,\ldots$$

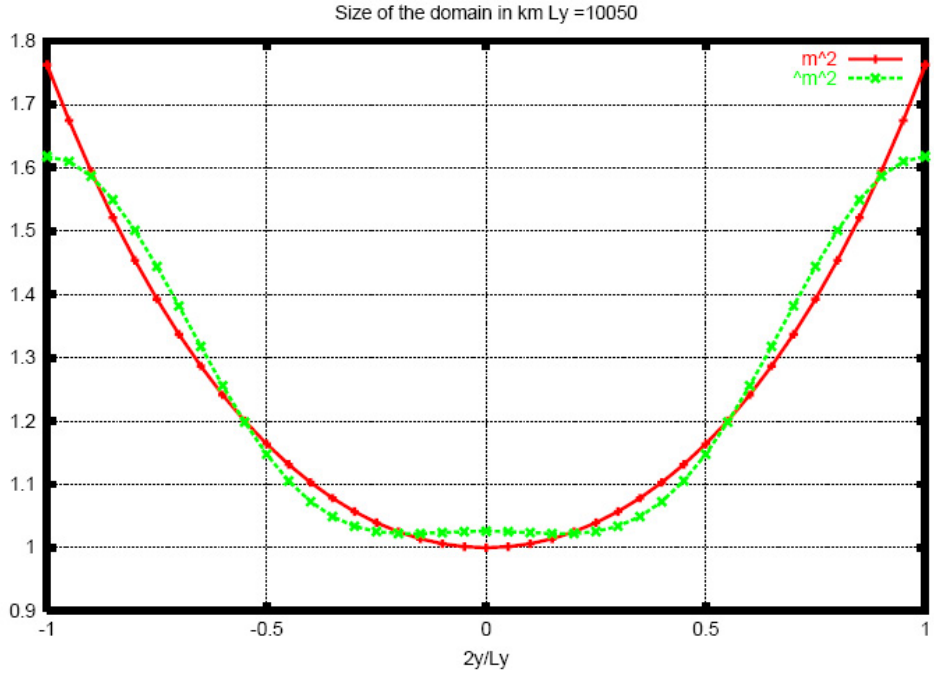
L, domain size

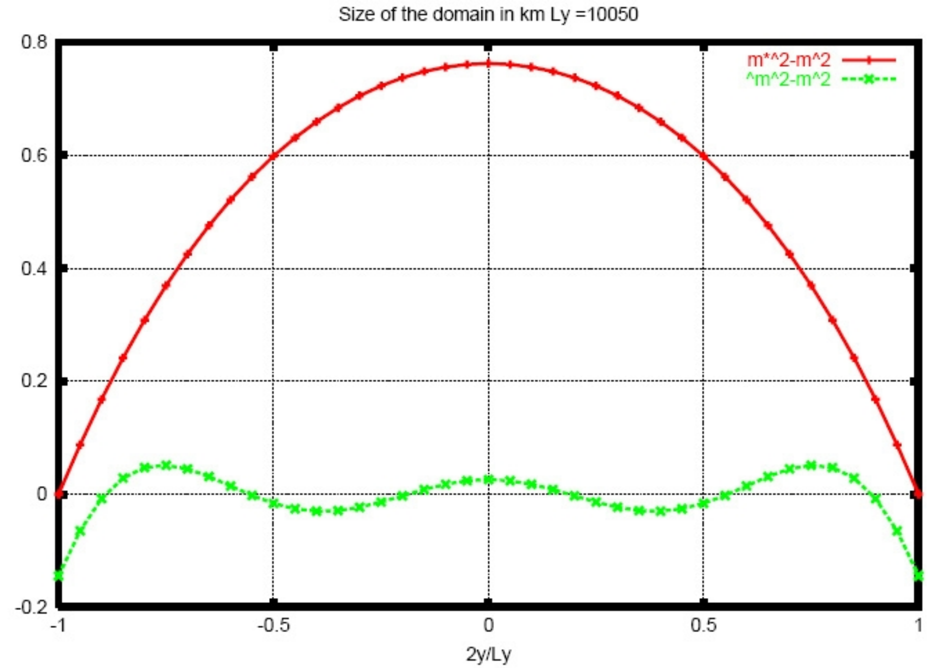
a, Earth radius

$$f = \frac{L}{a}$$

- A truncation with three coefficients will be included at the HARMONIE model codification for “large” domains

Variable Map Factor at the HARMONIE Model



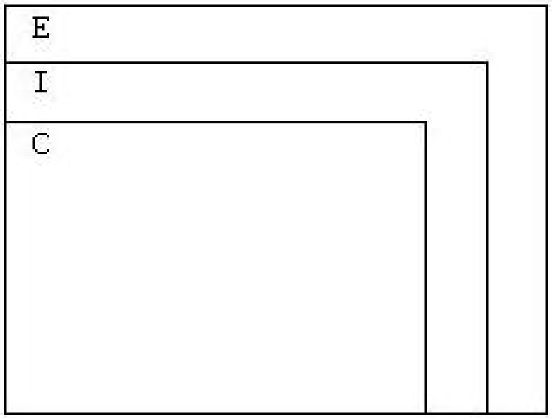


Fourier estimation of the square map factor with three coefficients (a_0, a_1 and a_2) in comparisson to the square **map factor real value**. L_y = 10.050km

Approximation to the square **map factor real value** of the **Fourier estimation** with three coefficients (a_0, a_1 and a_2) and of its **maximum value** in the domain. L_y = 10.050km

Variable Map Factor at the HARMONIE Model

WORKING AREA



- HARMONIE grid areas:
  - computational part of the domain (C+I)
  - biperiodization extension zone (E)

- **m** does not take the value 1 at the centre of the computational domain

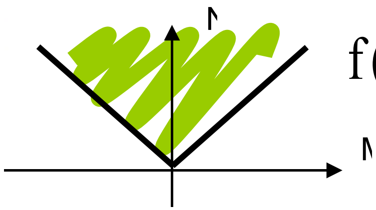
- The improvement of the new map factor treatment should be noticeable anyway

- Other options imply big coding effort for a small improvement

Variable Map Factor at the HARMONIE Model

TRUNCATION (ARPEGE vs HARMONIE)

- Spherical Harmonics vs Bi-Fourier decomposition



$$f(x,y) = \sum_{m=-\infty}^{m=\infty} \sum_{n=|m|}^{n=\infty} a_m^n e^{i(mx+ny)}$$

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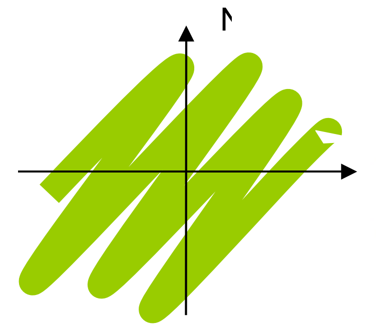
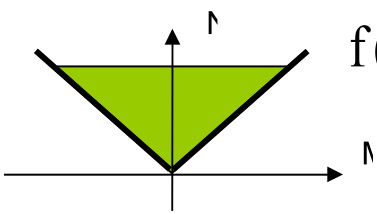


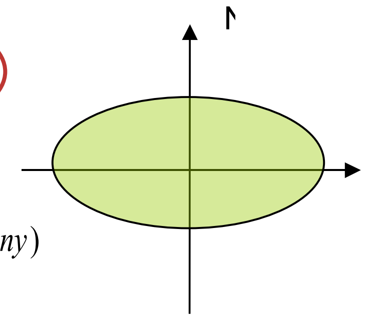
- Triangular vs Elliptical truncation



$$f(x,y) = \sum_{m=-MMAX}^{m=MMAX} \sum_{n=|m|}^{n=MMAX} a_m^n e^{i(mx+ny)}$$

$$P = \frac{NMAX}{MMAX}\sqrt{MMAX^2 - m^2}$$

$$f(x,y) = \sum_{m=-MMAX}^{m=MMAX} \sum_{n=-P}^{n=P} a_m^n e^{i(mx+ny)}$$



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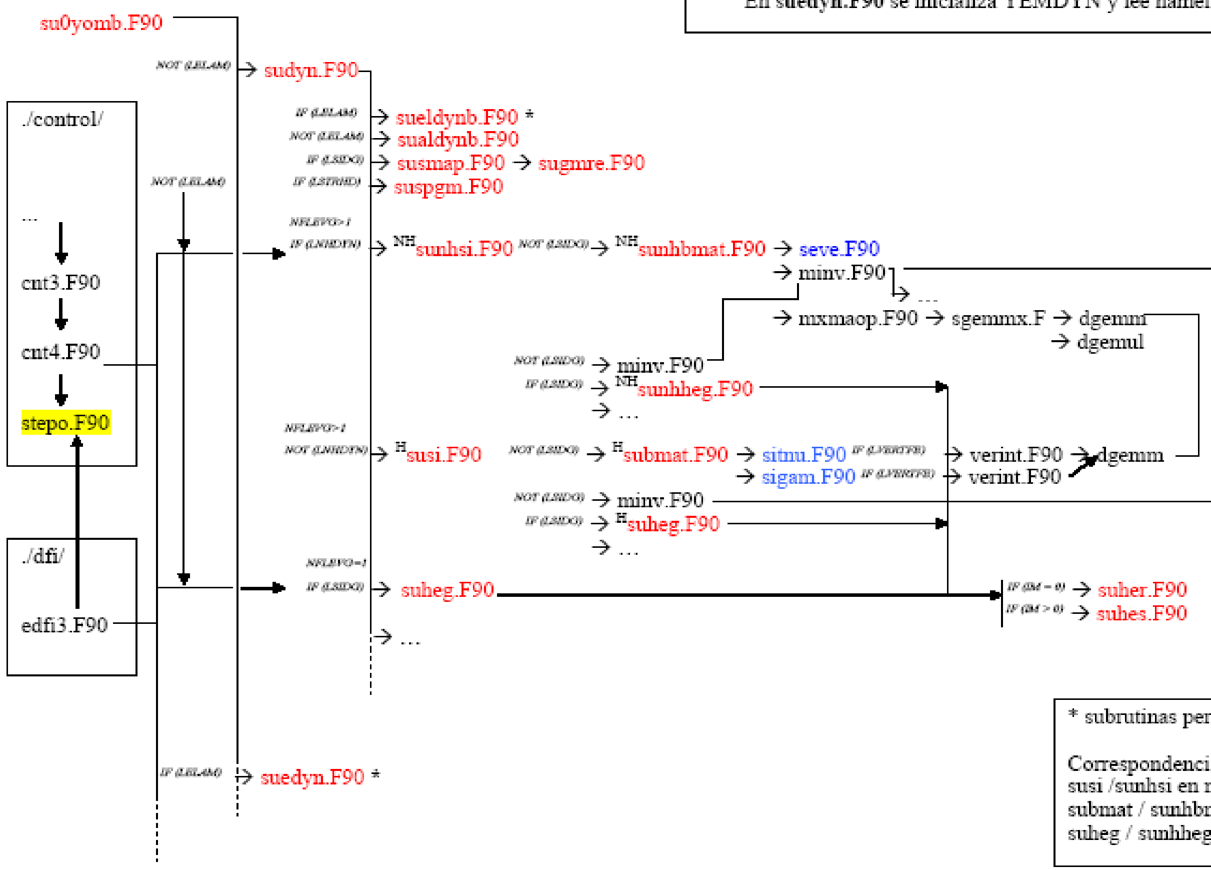
Code Flow (1)

ARPEGE – SETUP (./main/arp)

En **sudyn.F90** se inicializa YOMDYN y lee namelist NAMDYN
En **suedyn.F90** se inicializa YEMDYN y lee namelist NEMDYN

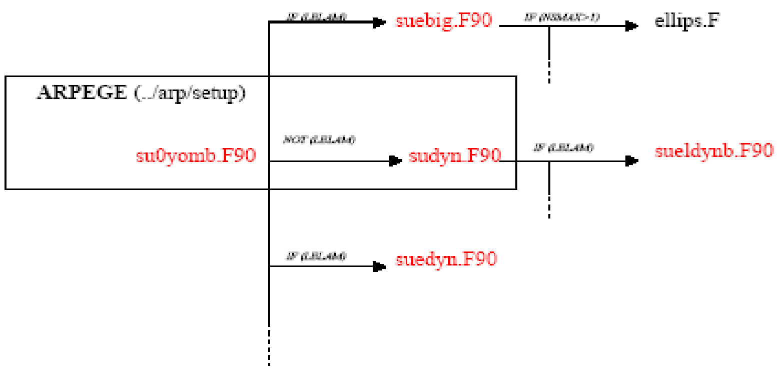


* subrutinas pertenecientes a ALADIN

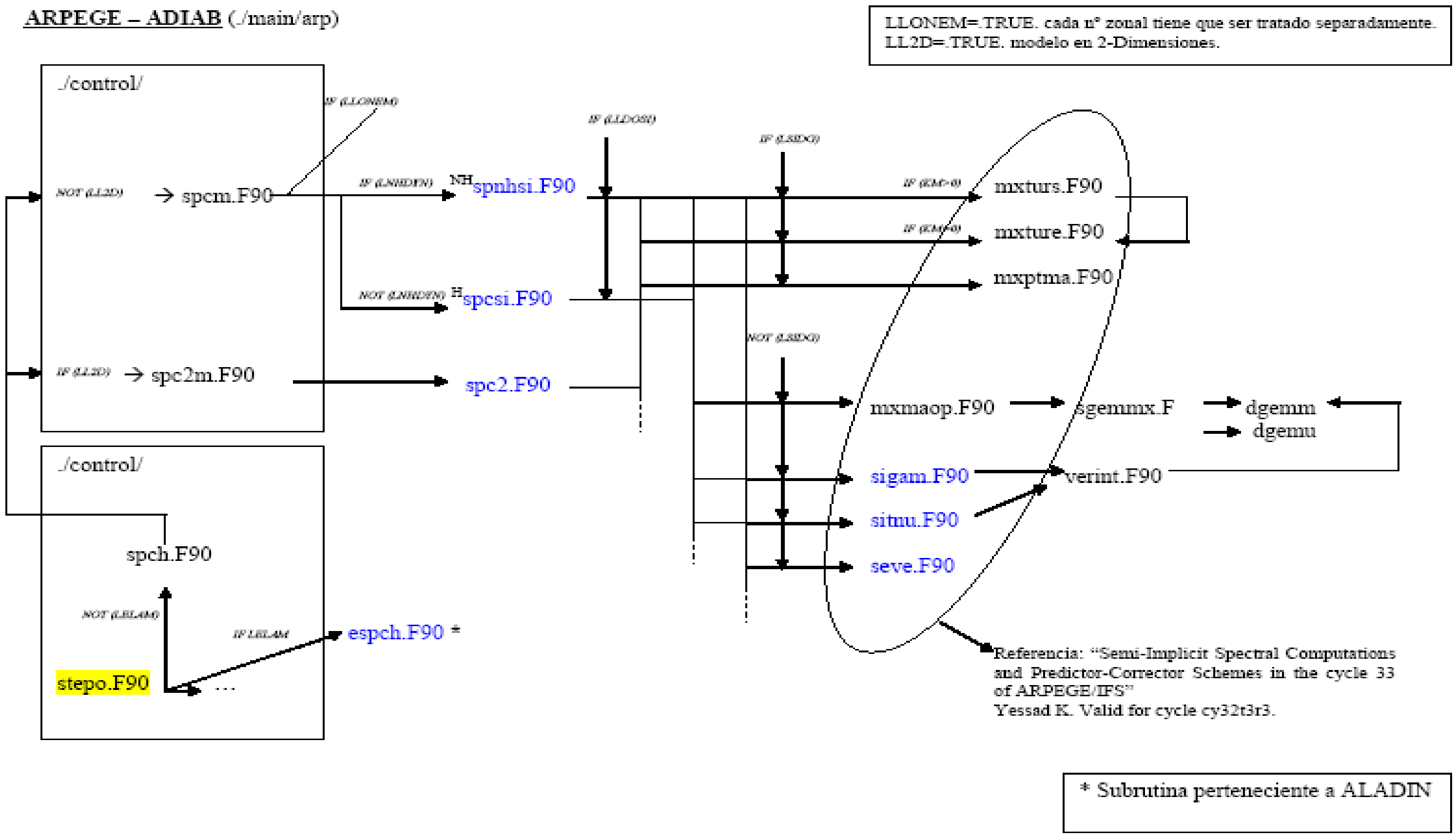
Correspondencias:
susi /sunhsi en minv
submat / sunhbmat en dgemm
suheg / sunhheg en suher / suhes

Code Flow (2)

ALADIN – SETUP (./main/ald)



Code Flow (3)


ARPEGE – ADIAB (./main/arp)
LLONEM=.TRUE. cada nº zonal tiene que ser tratado separadamente.
LL2D=.TRUE. modelo en 2-Dimensiones.
./control/
spcm.F90
spc2m.F90
NH spnhsi.F90
H spcsi.F90
spc2.F90
mxturs.F90
mxture.F90
mxptma.F90
mxmaop.F90
sgemmx.F
dgemm
dgemu
sigam.F90
verint.F90
sitnu.F90
seve.F90
./control/
spch.F90
stepo.F90
espch.F90 *
Referencia: "Semi-Implicit Spectral Computations and Predictor-Corrector Schemes in the cycle 33 of ARPEGE/IFS"
Yessad K. Valid for cycle cy32t3r3.
* Subrutina perteneciente a ALADIN

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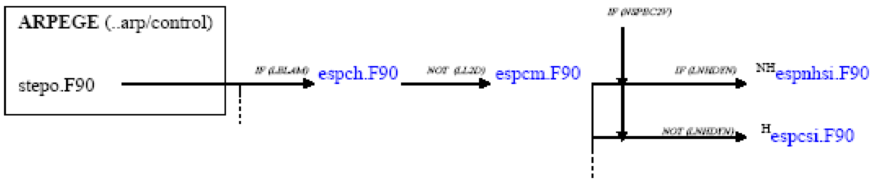
Code Flow (4)

ALADIN – ADIAB (./main/adiab)

NSPEC2V: nº of spectral columns treated by this process for SI calculations and other vertical transforms.



Code Modifications (1)

- *ESUSMAP* → Calculus of the map factor Fourier coefficients, ESCGMAP
- *SUDYN* → Definition of logical LLESIDG
  Calling to *ESUSMAP* function
- *YEMDYN*
  SUELDYNB → Initialization of variables LLESIDG and ESCGMAP and variables for future semi-implicit calculus, SIHEG, SIHEG2, SIHEGB and SIHEGB2
- *SUSI*
  SUNHSI → Calling to the semi-implicit scheme calculus at *ESUHEG* and *ESUNHHEG* when LLESIDG

Code Modifications (2)

- *ESUHEG*

  ESUNHHEG → Solver of the Helmholtz equation (SIHEG,…)

  Use of the new map factor coefficients ESCGMAP

  Use of the laplacian operator in the new spectral coordinates (bi-Fourier), RLEPDIM and RLEPINM

- *ESPCM* →

  Interface to the semi-implicit step

  Introduction of the LLESIDG option

  Introduction of the parallel calculus by zonal number (LLONEM)

  Array dimensions adapted to the new elliptical truncation

```
END=START+4*(ELLIPS(M)+1)-1
```

Code Modifications (3)

- *ESPCSI* Semi-implicit step
  - *ESPNHSI* → Introduction of the LLESIDG option

Use of the new map factor coefficients ESCGMAP

Use of the laplacian operator in the new spectral coordinates (bi-Fourier), RLEPDIM and RLEPINM

Dimensions adapted to the new elliptical truncation

- Use of four matrix, one per quadrant, instead of two, just for the first and second quadrant
- Adapted array dimensions

```
DO JN=0,ELLIPS(M)
  ISE=START+4*JN
  AUX_ARRAY(:,ISE:ISE+3)=WORK_ARRAY(:,JN,1:4)
ENDDO
```

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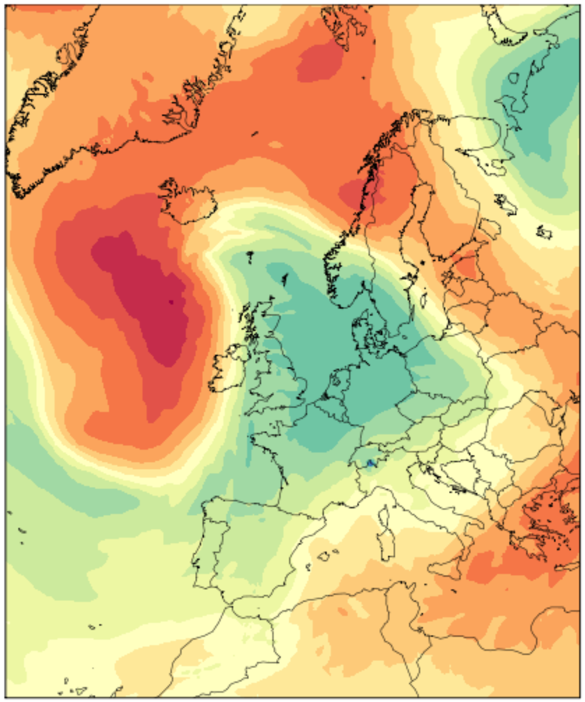
First Results (Hydrostatic)

Original Codification

S010TEMPERATURE
2008/7/1 z0:0 +12h



Modified Codification

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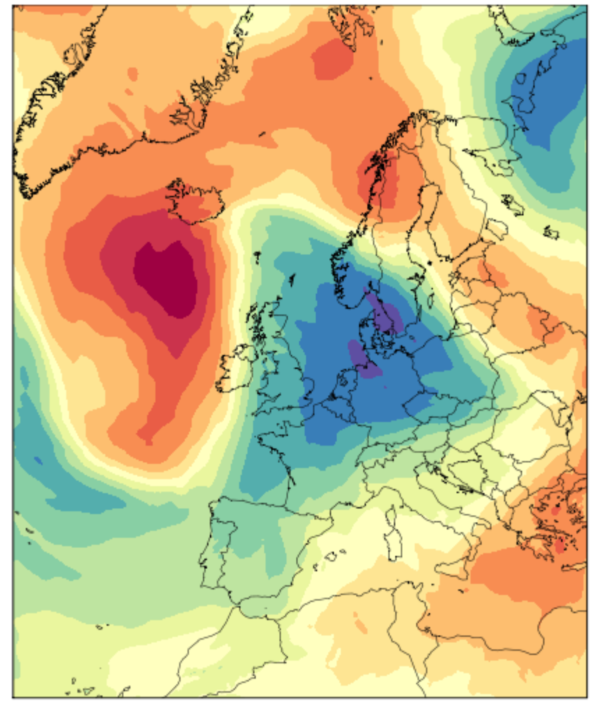

The main differences are at the central part of the maps, where map factor estimations differ the most

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First Results (Hydrostatic)

Original Codification

S020TEMPERATURE
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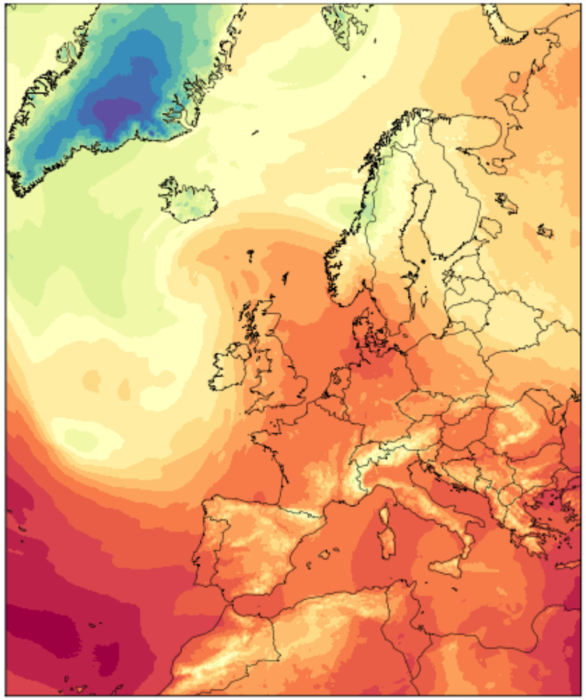

Modified Codification

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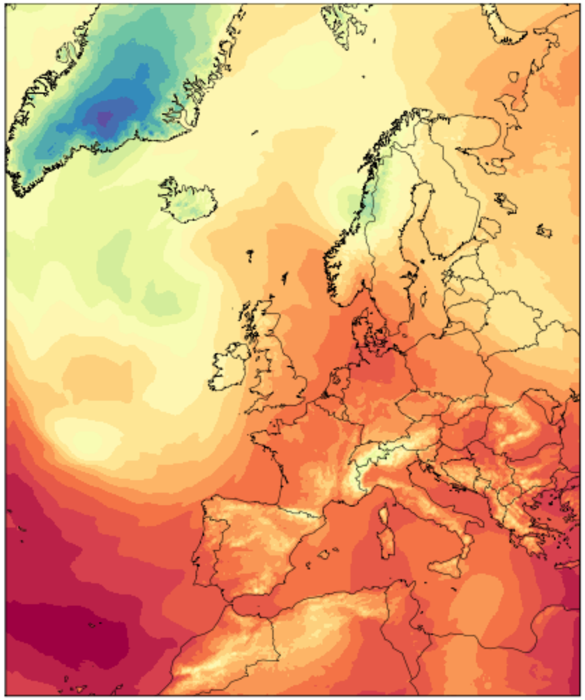

The main differences are at the central part of the maps, where map factor estimations differ the most

First Results (Hydrostatic)

Original Codification

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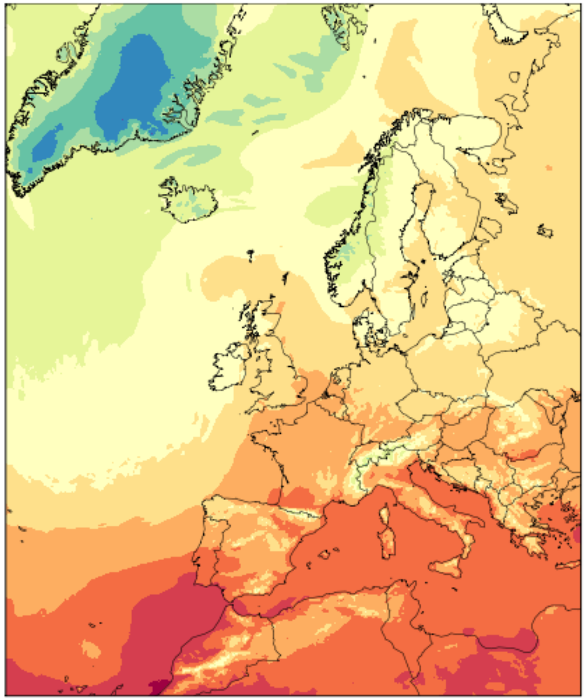

Modified Codification

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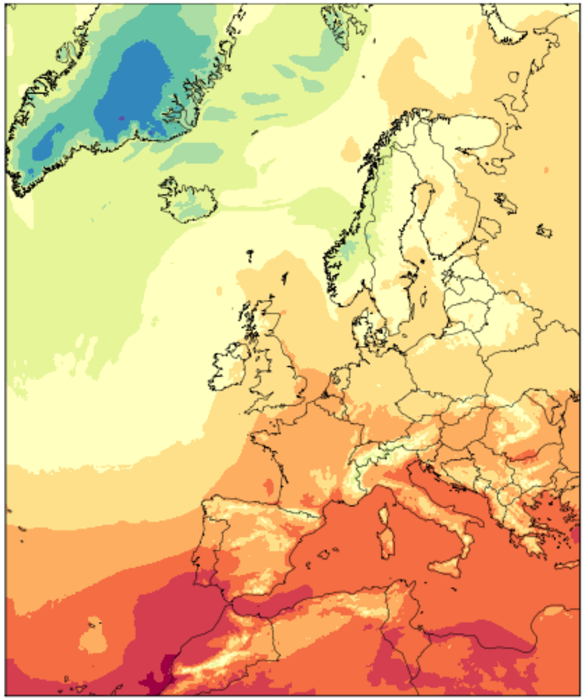

The main differences are at the central part of the maps, where map factor estimations differ the most

Future Work

- Further test should be done for reassuring the stability and reliability of the hydrostatic codification → 10 day forecasting
- The non-hydrostatic codification is under work
  - Stability problems
  - The inclussion of a new diffusion term (as in ARPEGE) is under study