OPTIMIZATION OF THE SPECTRAL OROGRAPHY CONSIDERING THE FRACTION OF WATER

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CONTENTS

1. Introduction

The purpose of the present work was to improve the spectral orography for ALADIN model, by the introduction of the fraction of water in the expression of the cost function.

Configuration e923 is a procedure which interpolates climatic and topographic informations from global fields into a chosen limited domain. This configuration has 6 steps, and for each step is used another routine. The routine EINCLI1 defines the orography for ALADIN model. So we were using only the first step of this configuration.

This paper is arranged as follows: in section 2 we describe the domains on which we worked to improve the orography, in section 3 a description of the experiments with different formulations of the cost function is presented. The section 4 is devoted for the conclusions of this report, and the section 7 contains some details about namelists and a list of the modified routines. There is also the section 8, with the most representative figures.

2. Running configuration e923 on the chosen domains

In this section we present the domains on which we tested new formulations of the cost functions. We tried to chose those domains, which have some parts with ocean or sea, to follow the influence of the fraction of water on orography.

The first chosen domain for the optimization of the spectral orography was one from French Polynesia. There is the Pacific Ocean, and there are a lot of islands. First we chosed a domain at a resolution of 82.53 km, and then another one with a finer resolution (32.75 km), and then a finer one (13 km), until the finest resolution of 5.15 km. The points that we focused, were the Tahiti and Bora-Bora Islands. Most tests were done on the last domain with the finest resolution. The details about the coordinates of the domain could be found in the technical appendix (section 7).

The first step was to obtain the orography running the configuration e923, with the two datasets (GLOB95, GTOPO30), using the Bouteloup's cost function , and then Jerczynski's one. All the tests have been done using cy22t1 (of ARPEGE), and al12 (of ALADIN).

GLOB95 is the first global dataset at 2'30'' resolution, produced in 1996, combining the US-NAVY 10' dataset, the NOAA 5' TerrainBase and the NOAA 30'' (but with partial coverage of the Earth). All files contain 8640x4320 values. These data files can be found on Kami: /u/gp/mrpe/mrpe603/923/RELIEF_G/GLOB95/

The GTOPO30 dataset, produced in 1998, uses a real global 30'' mean altitude description, plus some informations on the oceans. The resolution is the same as in GLOB95. To describe fraction of urbanization, we used the UrbaMixte file, combining data from US-NAVY (at 10' resolution) and from the University of Maryland (at 1 km resolution). These files are on delage: /cnrm2_a/mrpe/mrpe603/RELIEF_G/edc.

Comparing the results obtained using the GLOB95 dataset (Fig. 1 a, 1 b), we can see that the orography is better represented, in the case of the Bouteloup's cost function. Also the Jerczynski's function gives a good orography over land, especially for the Bora-Bora Island, but the values along the coasts are too big.

In Fig**.** 2 are represented the orographies obtained using the GTOPO30 dataset, without spectral fit (Fig. 2 a), with the Bouteloup's function (Fig. 2 b), and with the Jerczynski's function (Fig. 2 c). Comparing the results, we chosed again the Bouteloup's cost function, in the case of this domain, even if the Bora-Bora Island is a little to much smooth.

After that, we tried to see which dataset represent better the orography. At the first look over the orography, it seems that the GLOB95 dataset gives the best values. But when we looked at the representation of the land/sea mask from the GLOB95 dataset, we can see that the Bora-Bora Island isn't represented like being land, and just water (Fig. 3 a, 3 c). In this case, our option was to work with the GTOPO30 dataset, preferring to have some small values over land, but to be represented as land.

After a few tests on this domain, we discovered that the spectral orography were calculated including the extension zone, where it has no significance. We modified the routines, but we considered also that we need another one domain. The reasons were that our points of land are in the center of the domain (or almost) and all the points from the boundaries represent water, so with our modifications we couldn't see well the differences.

The new domain includes the west side of the Mediterranean Sea, some parts from France, Spain and Italy, at the resolution of 10.7 km. The namelists NAMDIM, NEMGEO, are given in technical appendix (section 7).

We were running the first step of the configuration e923, using in turn, the both datasets, and the two cost functions. After that, we compared the results and we chosed that the GTOPO30 dataset and the Bouteloup's cost function represent better the orography for this domain (Fig. 4, 5). There are some points that are well represented by Jerczynski's function and the GTOPO30 dataset (Fig. 4 c), like the Central Massif, the north of Algeria and the eastern part of Spain, but along the coasts of the Mediterranean Sea, the values are too big.

So until now, we have two domains which orography is better represented using the Bouteloup's cost function.

For the case of Jerczynski's function, we considered the choice of the coupling and operational domains of Romania, as a good one. The details about the namelists NAMDIM, NEMGEO, for both domains, can be found in the section 7.

The coupling domain of Romania includes the Black Sea and the eastern part of Europe, at a resolution of 24.79 km. So there are enough points on land and on sea. The idea to chose the operational domain of Romania, was to see how the tests influence the representation of the orography and of the coasts of the Black Sea at a finer resolution (10 km).

In the case of these domains, we chosed also the GTOPO30 dataset, after we compared the orography obtained with both datasets. For the representation of the orography we chosed the Jerczynski's cost function, because of the good values for the Carpathians Mountains, the Balkans, the Tatry Mountains, even if along the coasts of the Black Sea, the values are quite bad. (Fig. 6, 7, 8, 9)

Over these domains, we tried to improve the spectral orography.

3. Testing new formulations of the cost functions

The two cost functions from ARPEGE model, are proposed by Bouteloup and Jerczynski. For ARPEGE model, the Bouteloup's function is used. For ALADIN model, the choice either of the Bouteloup's function, or the Jerczynski's one, depends on the domain.

In the configuration e923, for ALADIN model, the calling tree is:

```
INCLI0 -> EINCLI1 (if LELAM=T)
              -> ERELSPE
                    -> INIPZ  (calculates the weights of the grid points)
                    -> SIMREL (calculates the function and its gradient)
```

According to the choice of the cost function, our experiments might be divided in two parts. In the first one, we describe the tests performed for improving the orography using the Bouteloup's function, while in the second part, the Jerczynski's function have been chosen.

In the case of the French Polynesia and the Mediterranean Sea domains, we used the Bouteloup's function (the option LNEWORO=T). The expression of this function is:

$$F = \sum_i \omega(i) * \left[\frac{\left| R(i) - R_s(i) \right|}{HDIM} \right]^{W(i)}$$

$$W(i) = QMIN + (QMAX - QMIN) * \exp\left| \frac{-R}{HMIN} \right|$$

where R is the grid-point orography, R_s the spectrally fitted grid-point orography to obtain, ω the field of Gaussian weights (constant for ALADIN), HDIM a dimensioning factor, W a field of weights allowing a geographical modulation of the cost function, QMAX, QMIN maximum, minimum of the field of weights, HMIN a scaling factor.

The idea to improve the spectral orography was to introduce the fraction of water in the expression of weight. As we can see there isn't any dependence on the fraction of water. But when we introduced the fraction of water, we have problems, because it has values only for the central and intermediate zones. So we discovered that the spectral orography is calculated including the extension zone. First we tried the biperiodization of the fraction of water, but the time for running it was almost 5 times more. Afterwards we chosed another variant, to multiply the cost function with zero in the extension zone. For that we introduced a bi-dimensional array XEXT to multiply the cost functions, which in the case of ALADIN, it takes the value zero, for the extension zone, and one for central and intermediate zones.

The first test was quite simple. We kept QMAX=4, QMIN=2 and then we multiplied the weight thus:

$$W(i) = \left(1 + ZOCE(i)\right) * W(i)$$

where ZOCE is an unidimensional array which contains the fraction of water, for central and intermediate zones, and it has the value zero for the extension zone.

The results were not spectacular. In some points there were some improvements, but the coasts were even worse represented. In the case of French Polynesia we observed some noise over ocean, a better value for Bora-Bora Island (but not too much), and a smoothing of the Tahiti Island (Fig. 10). For the Mediterranean Sea domain, we can see the worse representation of the coasts and the smoothing of the most mountains (Fig. 11).

Another idea was to make QMIN=1 and to keep QMAX=4, in the expression of the weight written above and then to multiply thus:

$$W(i) = \left(1 + ZOCE(i)\right) * W(i)$$

As we can see in the Fig. 12, 13, no good results are shown. The noise was increased, the coasts are worse represented, the Tahiti and Corsica Islands were smoothed. The only good result was the increase over land of some points: for Bora-Bora Island (Fig. 12 b), and for Majorca Island (Fig. 13 b). So this formulation doesn't work.

Then we have thought to introduce the fraction of water just in the right term of the expression. Something like that:

$$W(i) = QMIN + (QMAX - QMIN) * \left(1 + XINCOC * ZOCE(i)\right) * \exp\left|\frac{-R}{HMIN}\right|$$

where QMIN, QMAX are the weight multiplicators over land in the spectral orography, and XINCOC, weight multiplicator over ocean.

The first value for XINCOC we have chosen 4, with QMIN=1, QMAX=2. We observed that there is an improvement especially in the representation of the coasts. For the French Polynesia domain, we can see an increase of the orography for Tahiti Islands, and a high decrease for Bora-Bora Island (Fig. 14 b). For the Mediterranean Sea domain, the results are illustrated in Fig. 15 b, and there are showing a generally improvement of the orography of the east part of the domain, the Central Massif and the north of Algeria. There are some points not so well represented, like the Sardinia Island, the Alpes.

Other tests were performed, trying for XINCOC values as 5, 3.5, 3, 2. Following the results in this order, we can say that the Majorca Island, the Central Massif are smoothed, and the mountains from the eastern part of Spain and from Italy are increased. But finally, the best choice we concluded that it is for XINCOC=3 (Fig. 14 c, 15 c).

But these were only some experiments, when we varied one parameter. After that we have thought what results would be in the case of variation of three parameters. We have carried out some experiments to study how the combined tuning of QMIN, QMAX, XINCOC, could influence the final results.

QMIN and QMAX took values between 1 and 4, and XINCOC, 3, 3.5, 4. And with these values, we performed many combinations. After we compared all the tests, we concluded that we didn't find a better orography. For the French Polynesia domain, we can see a smoothing of the Tahiti Islands, an increase of the height of the Bora-Bora Islands, a lot of noise over ocean, and a bad representation of the coasts (Fig. 16). For the Mediterranean Sea domain, we observed a decrease of the orography of the Corsica Island, of the Alpes, and of the mountains from Italy, and an increase of the values along the coasts of the sea (Fig. 17). When we increased the values of QMIN, QMAX, the results were worse than the initial orography, obtained with Bouteloup's function (Fig. 16 d, 17 d).

Finally, we said that the best orography is obtained using the next values of the parameters: QMIN=1, QMAX=2, XINCOC=3, i.e. keeping the initial tuning and adding the impact of the sea fraction. Comparing the initial orography with the final one, we can see an improvement over land, and especially along the coasts (Fig. 18, 19).

For the Jerczynski's function (the option LNEWORO2=T), we worked with the coupling and operational domains of Romania. This cost function is used only in the case of ALADIN, and it has the following formulation:

$$F = \sum_i \omega(i) * \left[W(i) * \left(R_s - R\right)^2 + \left(QCONST * \left|R_s - R\right|\right)^{QPOWER} \right]$$

$$W(i) = \left[1 + (XINCOC - 1) * \exp\left|\frac{-R}{HMIN}\right| \right]$$

where XINCOC is here the weight multiplicator in the orography optimization, QCONST constant used in the minimization function, QPOWER exponent used in the minimization function.

We can see again that, even if XINCOC is defined in the comments as the weight multiplicator over the ocean, there isn't any dependence on the fraction of water.

A first set of experiments using a new expression of the weight was performed in order to see how the introduction of the fraction of water could modify the ALADIN orography. So the new weight is:

$$W(i) = \left(1 + ZOCE(i)\right) * W(i)$$

where ZOCE is the same vector, like in the case of Bouteloup's function.

The results from these experiments are illustrated in Fig. 20, 21, which show an improvement of the orography along the coasts of the Black Sea, and of the Carpathians, the Tatry Mountains, the Balkans, and of the mountains from Greece and the north part of Turkey, but also a decrease in the Crimea. We considered this as a good result.

Then we have thought to introduce one parameter to multiply the fraction of water, and in that way to increase the weight over ocean. And to be easier to understand, we unified the notations for the both cost functions. Thus:

$$W(i) = QMIN + \left(QMAX - QMIN\right) * \exp\left|\frac{-R}{HMIN}\right|$$

$$W(i) = \left(1 + XINCOC * ZOCE(i)\right) * W(i)$$

where QMIN, QMAX are the weight multiplicators over land in the spectral orography, and XINCOC, weight multiplicator over ocean (the same meaning as for the Bouteloup's function).

So we made a tuning with XINCOC between 4 and 8. We observed that with more increase of XINCOC, we obtained the better representation of the coasts of the Black Sea, and a certain smooth of the orography over land. The difficulty of the choice, was to make a good compromise between a better representation of the coasts and a higher orography. Finally, we decided that with XINCOC=7, we have a better orography.

A third set of experiments with the Jerczynski's function, was carried out tuning two parameters in the expression of the weight, thus:

$$W(i) = A * \left(1 + XINCOC * ZOCE(i)\right) * W(i)$$

where A is the second parameter that we have been introduced with the value 2, and XINCOC between 5 and 7.

As we can see in Fig. 24, 25, the orography over land was smoothed. The only good result is the decrease of the values along the coasts, but it isn't enough to consider an orography as a good one. These experiments were useful, because they show that the initial orography tuning is still a good choice.

So the final formulation of the weight in the case of the Jerczynski's function, has the next values of parameters: QMIN=1, QMAX=2500, XINCOC=7. For the coupling domain of Romania, we can see a better representation of the Carpathians, the Tatry Mountains, and over the mountains from Turkey, of the coasts of the Black Sea (Fig. 26). For the operational domain of Romania, there is an improvement along the coasts of the sea, for the Tatry Mountains, the Balkans, but not too much differences for the Carpathians (Fig. 27).

4. Conclusions

1. After so many tests, the main conclusion is that the introduction of the fraction of water was a good idea. We have seen that we can obtain a better orography, and especially a better representation of the coasts and islands.

2. For both cost functions we established new formulations, with a new definition of the parameters QMIN, QMAX, XINCOC, and with different values for them. For the Bouteloup's function QMIN=1, QMAX=2, XINCOC=3, and for the Jerczynski's one QMIN=1, QMAX=2500, XINCOC=7.

3. For the French Polynesia domain, we obtained an orography with an increase of the Tahiti Islands, a high decrease for the Bora-Bora Island, and a better representation of the coasts of these islands.

4. For the Mediterranean Sea domain, the results are showing a generally improvement of the orography over land (the Alpes, the Central Massif, the Pyrenees Mountains), and especially along the coasts.

5. For the coupling domain of Romania, we can see a better representation of the Carpathians, the Tatry Mountains, and over the mountains from Turkey, the coasts of the Black Sea.

6. For the operational domain of Romania, there are some improvements along the coasts of the sea, for the Tatry Mountains, the Balkans, but not too much differences for the Carpathians Mountains.

7. We are not saying that the final orographies are the best. There are better than the initial orographies. The values that we established, are not the final. That means that for other domains, these values may not be so good. So we recommend to make first a tuning of these parameters (QMIN, QMAX, XINCOC), and then to chose the best orography. According to our experiments it appears that (QMIN, QMAX) and XINCOC may be tuned independently.

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6. References

- Marek Jerczynski, 1994: "Spectral representation of the LACE domain orography with a variational method"
- Yves Bouteloup, 1994 "Improvement of the Spectral Representation of the Earth Topography with a Variational Method", *Monthly Weather Review,* Vol. 123, No. 5, 1560-1573
- "2'30'' Orography dataset", version 1, 27/08/96
- "2'30'' Orography dataset", version 2, 13/11/98

7. Technical appendix

The namelists for each domain that we are running the first step of configuration e923, are written below:

French Polynesia:

```
&NAMDIM
        NDLUN    = 1,
        NDGUN   = 1,
        NDGUX   = 61,
        NDLUX    = 97,
        NDGL       = 72,
        NDLON    = 108,
        NSMAX    = 23,
        NMSMAX = 35,
/
&NEMGEO
        ELAT1 = -18.525229708,
        ELAT2 = -15.74438100,
        ELON1 = 207.02619605,
        ELON2 = 211.68287269,
        ELON0 = 216.,
        ELAT0 = -17.00093199,
/
```

Mediterranean Sea:

```
&NAMDIM
        NDLUN     = 1,
        NDGUN     = 1,
        NDGUX     = 152,
        NDLUX     = 152,
        NDGL        = 160,
        NDLON     = 160,
        NSMAX     = 53,
        NMSMAX = 53,
/
&NEMGEO
        ELAT1 = 34.953,
        ELAT2 = 48.5455294,
        ELON1 = -5.831,
        ELON2 = 12.74199999,
        ELON0 = 2.57831001,
        ELAT0 = 41.46884918,
/
```

The coupling domain of Romania:

```
&NAMDIM
        NDLUN     = 1,
        NDGUN      = 1,
        NDLUX       = 79,
```

```
            NDGUX     = 53,
            NDGL        = 64,
            NDLON      = 90,
            NSMAX     = 21,
            NMSMAX  = 29,
    /
    &NEMGEO
            ELAT1  = 38.6201311400000,
            ELAT2  = 50.0609016614889,
            ELON1  = 19.9034267400000,
            ELON2  = 44.5523304000000,
            ELON0  = 31.,
            ELAT0  = 45.,
    /
```

The operational domain of Romania:

```
    &NAMDIM
            NDLUN     = 1,
            NDGUN     = 1,
            NDLUX      = 89,
            NDGUX     = 89,
            NDGL        = 100,
            NDLON      = 100,
            NSMAX     = 33,
            NMSMAX  = 33,
    /
    &NEMGEO
            ELAT1  = 41.91284257,
            ELAT2  = 49.80342137,
            ELON1  = 20.68979003,
            ELON2  = 32.12558703,
            ELON0  = 26.,
            ELAT0  = 46.,
    /
```

The routines have been modified, for the new expressions of the cost functions and for the correction of the spectral orography in the extension zone.

ALADIN:

/utility/deello.F90 - deallocate array XEXT

ARPEGE:

/c9xx/incli0.F90 - new values of QMAX, QMIN, XINCOC
/c9xx/alclia.F90 - allocate array XEXT
/c9xx/inipz.F90 - for modifications of the expression of the weights
/c9xx/simrel.F90 - add XEXT in the expression of the cost functions
/module/ptrspor.F90 - add XEXT

There can be found on Kami:~mrpe734/cy22t1/src
and on delage: ~mrpe734/REPORT_2001/Appendix_7

9. The workstation optimizations of the configuration e923

In Romania, the configuration e923 was implemented on our workstation following the documentation of Neva Pristov and Mehdi El Abed. Technically it was necessary to do some modifications of the code due to the memory limitation on DEC workstation.

First, in eincli1.F90, we changed in the opening of binary files, thus the record length in direct access of them to be divided by 4.

Another problem we have at the first step of the configuration, when we tried to obtain a climatic file using the spectral fit, in the routine grtest.F90. Here it had to calculate a scalar product, but it gave us a message like this:

"ABOR1 CALLED

mpe_barrier should not be called"

We tried to see where is the problem, but we haven't success. Finally we wrote an empty routine, named mpe_barrier.F, and we compiled with all the routines called by m1qn3.F (from xrd/minim)

For the second step of the configuration, we didn't need to modify something.

At the third step, it appears a message about the insufficient memory. So we used allocatable arrays for ZFLD, ZALB, ZEMI, ZGEO, ZLSM, ZITP, ZCMP, ZS, ZTSHT (in eincli3.F90)

For eincli4.F90, it wasn't necessary to change something.

At the fifth step, we have the same problem with the memory, and we used also the allocatable arrays for ZALS0, ZALV0, ZARG0, ZDPR0, ZDPS0, ZEMI0, ZITP0, ZLAI0, ZMSK0, ZRSM0, ZSAB0, ZVEG0, ZVGX0, ZZ0V0, ZALB1, ZALS1, ZARG1, ZDEP1, ZDPS1, ZEMI1, ZGZ01, ZGZR1, ZGZV1, ZGZT1, ZITM1, ZITP1, ZLAI1, ZLND1, ZRSM1, ZSAB1, ZURB1, ZVEG1, ZVGX1 (in eincli5.F90)

For eincli6.F90, we didn't modify anything.

The modified routines, can be found on delage: ~mrpe734/REPORT_2001/Appendix_9