Scientific Report ESF-Exchange Grant 2007

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Activity Title: A Lagrangian Identification of Major Sources Of Mediterranean Region Moisture

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A LAGRANGIAN IDENTIFICATION OF MAJOR SOURCES OF MEDITERRANEAN REGION MOISTURE

1. Purpose of the visit

It is now widely accepted that there are different approaches to identify geographical sources or sinks of moisture over a given region, however, in general, these method present some limitations and caveats. Generally speaking, previous studies are capable of providing full 2D or 3D details of where the air mass originated (e.g. Eltahir and Bras, 1996; Tremberth, 1999; Numaguti, 1999; Bosilovich et al., 2003; Chen et al., 1994; Liu and Stewart, 2003; Fernández et al., 2003; Crimp and Mason, 1999 or Knippertz and Martin, 2005). Nevertheless most of these methodologies provide no information on how the moisture increases and decreases along the trajectory affects the moisture in the target region, so the identification of sources is qualitative. Inter-comparison studies of different techniques are rare and difficult to undertake. At least one dozen of papers were published using different methodologies and input data and those results can vary significantly among authors according to the specific methodology applied (Mariotti et al., 2002). Most of these studies were done using some type of Eulerian methods.

In this preliminary work the applicant of this MedClivar grant applied a new sophisticated and robust 3-D Lagrangean method to determinate and rank, the major moisture sources and sinks affecting the Mediterranean area. This work applied the Lagrangian diagnosis method developed by Stohl and James (2004, 2005) and adapted recently by Nieto et al. (2006, 2007) to identify the main net uptake of moisture in air masses residing over an extended Mediterranean area and the main sinks of moisture over Mediterranean Basin.

Mariotti et al., (2002) performed a budget analysis to study contributions to the freshwater flux into the Mediterranean Sea, including atmospheric as well as river discharge inputs, during the last 50 years using recent atmospheric reanalyses and observational datasets. Their analysis reveals a moisture flux from west to east year-round, but with a southward component during summer, from the eastern Mediterranean into northeast Africa and the Middle East. A different approach was employed by Fernández et al. (2003) that have based their approach on integrating the atmospheric moisture fluxes across the region boundaries. These authors have clearly shown that the precipitation variability within the Mediterranean basin is closely related to the structure of the vertically integrated moisture transport fluxes, inside the domain and at the borders.

It is evident that this type of analysis with Eulerian methods or using moisture divergence flux are capable to identify preferable directions of moisture advection but they are not able to locate them with high precision, in part because they do not imply real trajectories of atmospheric particles. This lack of information can be solved through the use of Lagrangean methods. In order to address the differences between these two methodologies we will perform both here. The Lagrangian approach used in the numerical methodology will contrast with the Eulerian approach, and comparisons will provide interesting information. It gives a complementary approach to the simulation of the atmospheric transport on the Mediterranean basin.

2. Description of the work carried out during the visit and first results

2.1 Method

The method is based on the calculation of a large number of trajectories with the Lagrangian particle dispersion model FLEXPART [Stohl et al., 1998; Stohl and James, 2005]. FLEXPART uses data from the European Centre for Medium-Range Weather Forecasts [ECMWF, 2002] (P. W. White (Ed.), IFS documentation, European Centre for Medium-Range Weather Forecasts, Reading, UK, 2002, available at http://www.ecmwf.int) to calculate both the grid-scale advection as well as the turbulent and convective transport of so-called particles. The atmosphere is divided homogeneously into a large number of particles and then these particles are transported by the model using 3D winds, with their positions and specific humidity (q) being recorded every 6 hours. The increases (e) and decreases (p) in moisture along the trajectory can be calculated through changes in (q) with time (e-p = m dq/dt), (m) being the mass of the particle. When adding (e-p) for all the particles residing in the atmospheric column over an area, we can obtain (E-P), where the surface freshwater flux (E) is the evaporation and (P) the precipitation rate per unit area. The method can also track (E-P) from a region backward in time along the trajectories, choosing particles appropriate for finding sources of moisture and precipitation.
In this work I used the tracks of 1,398,801 particles over a 5-year period (2000–2004) computed using ECMWF operational analysis available every six hours (00, 06, 12 and 18 UTC) with a 1ºx1º resolution and all 60 vertical levels.

A data base with the trajectories was performed from the model FLEXPART for several sub-regions within the extended Mediterranean basin. The integration of the data from ECWMF analysis determined the spatial and temporal position of the particles and the value of their moisture was computed.

I've traced (E-P) backwards or forwards from the extended Mediterranean region (50ºN–28ºN lat, 10ºW–40ºE lon). It must be stressed that the Mediterranean sea varies considerably between the west and east parts as well as between the northern European shore and its African counterpart. Therefore any serious study on the location of major moisture sources must take this variability into consideration. I assessed the location of the most important sources of moisture for eleven sub-regions (Fig. 1) for the period with available data (2000-2004). I've tracked the origin of air-masses residing over 7 continental sub-areas surrounding the Mediterranean Basin and, additionally, I've tracked also the forward trajectories over 3 areas over the Mediterranean Sea. All the particles residing over these 7 + 3 regions were identified every 6 hours and tracked limiting the transport times to 10 days.

For the backward trajectories for the first time step, all the target particles resided over the Mediterranean region and (E-P) is the region-integrated net freshwater flux. For subsequent trajectory time steps, (E-P) represents the net freshwater flux into the air mass travelling to each sub-region. It was calculated (E-P) on a 1ºx1º grid and averaged over seasonal, annual and five year periods. (E-P) values for specific days are labelled

$(E\text{-}P)^n$ here, so $(E\text{-}P)^2$ shows where the moisture over each sub-region as received or lost on the second day of the trajectory. Additionally the total (E-P) integrated over days 1 to n is labelled $(E\text{-}P)^{1,n}$, so $(E\text{-}P)^{1,10}$ is the sum of days 1 to 10. The analysis of (E-P) values tells where and when the moisture over the Mediterranean was received or lost. For the forward trajectories the nomenclature is done using sub-indices in the same way, i.e. $(E\text{-}P)_2$ shows where the moisture over each sub-region as received or lost on the second day of the forward trajectory and the total (E-P) integrated over days 1 to n is labelled $(E\text{-}P)_{1,n}$, so $(E\text{-}P)_{1,10}$ is the sum of days 1 to 10.

The analyzed areas are represented in figure 1, where the backward trajectories (red) are the Iberian Peninsula (IbP), France (F), the Italian Peninsula (ItP), the Balcanic Peninsula (BP), Eastern Mediterranean (EM), and three regions over North Africa, Western, Central and Eastern Africa (WA, CA and EA). The complementary analysis with forward trajectories (blue) correspond to the Western, Central and Eastern Mediterranean Sea basins (1, 2, and 3, respectively). These three oceanic regions were selected based on those selected by Mariotti et al., (2002) work (see their FIG. 8 that provides the climatological atmospheric moisture flux and moisture divergence).

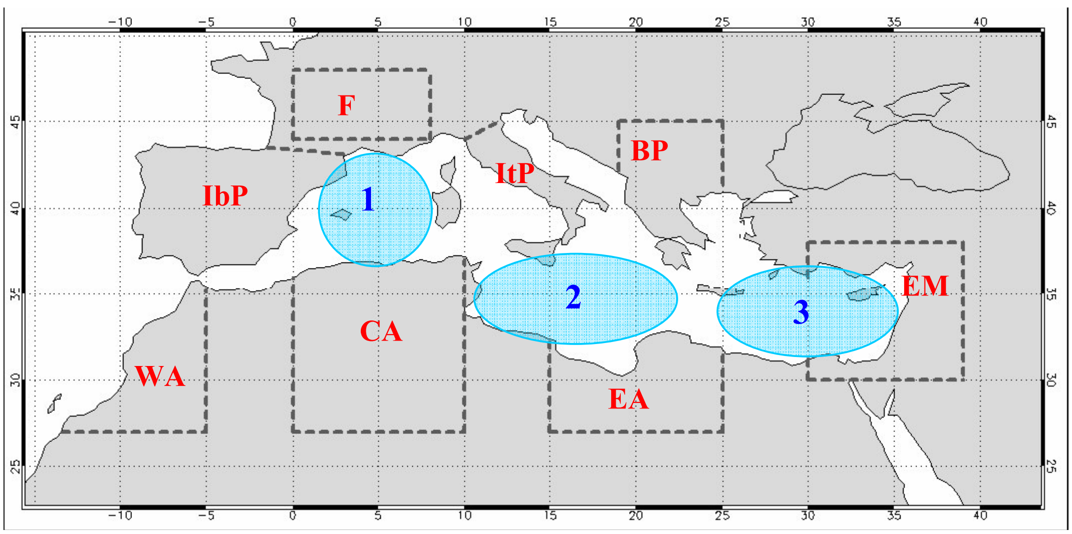


Figure 1: Selected areas over the Mediterranean region to calculate (E-P) backward (in red) and forward (in blue).

2.2 Results:

A large amount of time was spent to track the air masses residing over the regions indicated in figure 1, both backward and forward in time to see where the moisture originated. As an example I present the result for the Iberian Peninsula with more detail (figure 2). This figure shows the annually $(E\text{-}P)^n$ fields for the Iberian Peninsula on the first, third, fifth, and tenth days of transport, and figure 3 the averaged over all 10 days $(E\text{-}P)^{1,10}$. These patterns of the (E-P) fields were very robust, in such way that very similar structures appeared when the analysis was done on a seasonal basis. Figure 4 shows the seasonal $(E\text{-}P)^{1,10}$ averaged over all 10 days of transport (winter, January–

March; spring, April–June; summer, July–September, and autumn, October– December) for the Iberian Peninsula.

For all continental regions surrounding the Mediterranean Sean the difference (E-P) was calculated backward in annual and seasonal basis. Figures 5 to 11 show the annual (E-P) averaged over all 10 days for the remaining sub-areas identified in figure 1.
In the same way for the three sea areas (figure 1 in blue) the forward tracks were calculated. Figure 12 to 14 show the annual $(E-P)_{1,10}$ averaged over all 10 days forward.

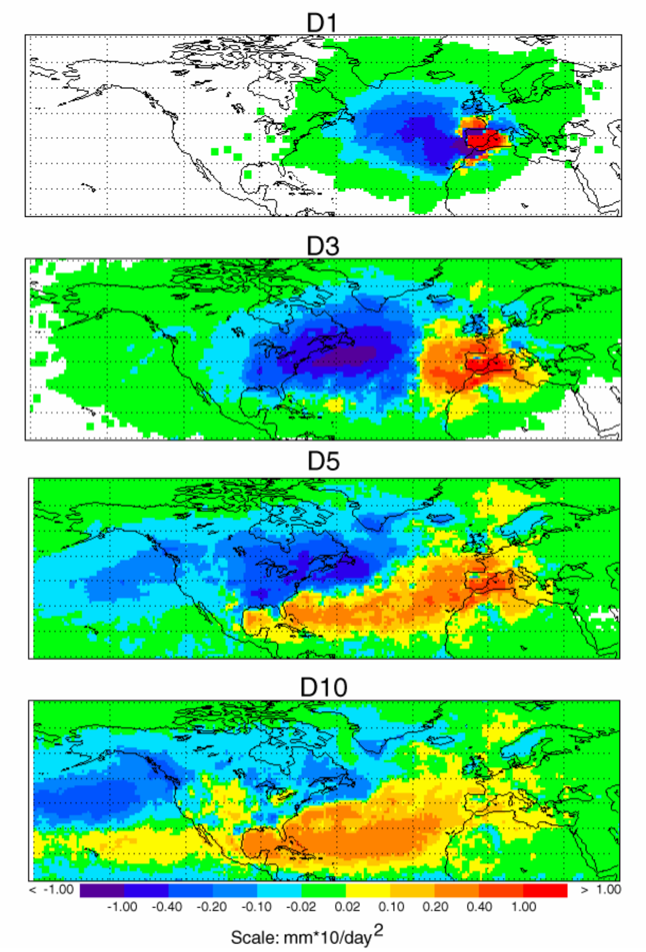


Figure 2: Annually average $(E-P)^n$ fields of the Iberian Peninsula region from the backward tracking: $(E-P)^1$, $(E-P)^3$, $(E-P)^5$ and $(E-P)^{10}$.

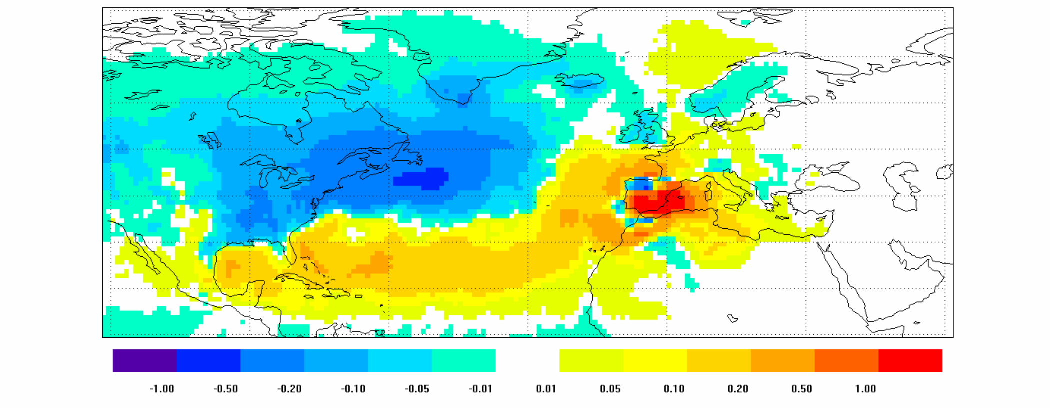


Figure 3: Annually average $(E\text{-}P)^{1,10}$ field of the Iberian Peninsula region from the backward tracking (averaged over 10 days back).

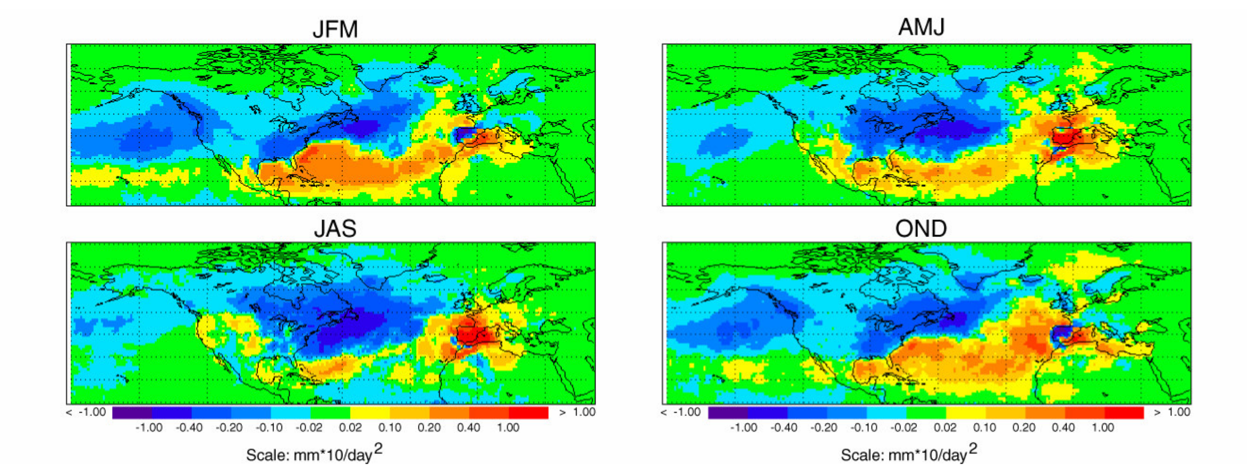


Figure 4. Seasonal average $(E\text{-}P)^{1,10}$ fields of the Iberian Peninsula region from the backward tracking (winter, January–March; spring, April–June; summer, July–September, and autumn, October-December).

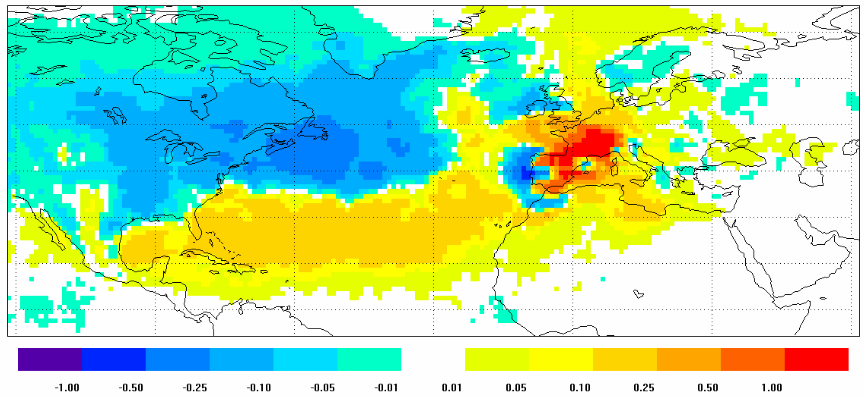


Figure 5: Annually average $(E\text{-}P)^{1,10}$ *field of the France (F) region from the backward tracking (averaged over 10 days back). Scale mm/day.*

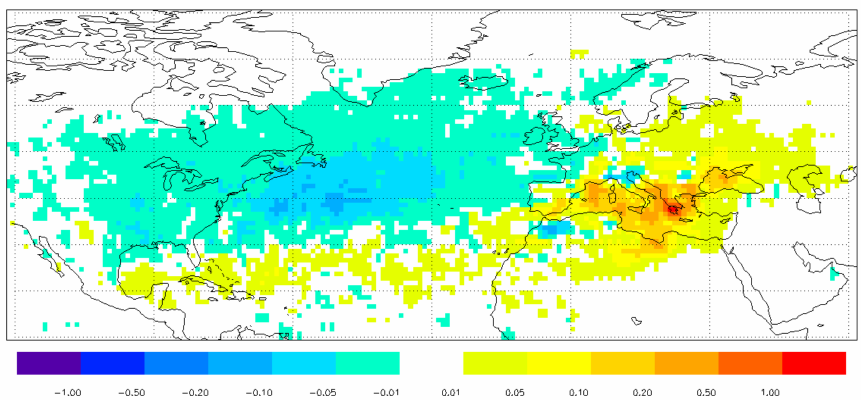


Figure 6: Annually average $(E\text{-}P)^{1,10}$ *field of the Italian Peninsula (ItP) region from the backward tracking (averaged over 10 days back). Scale mm/day.*

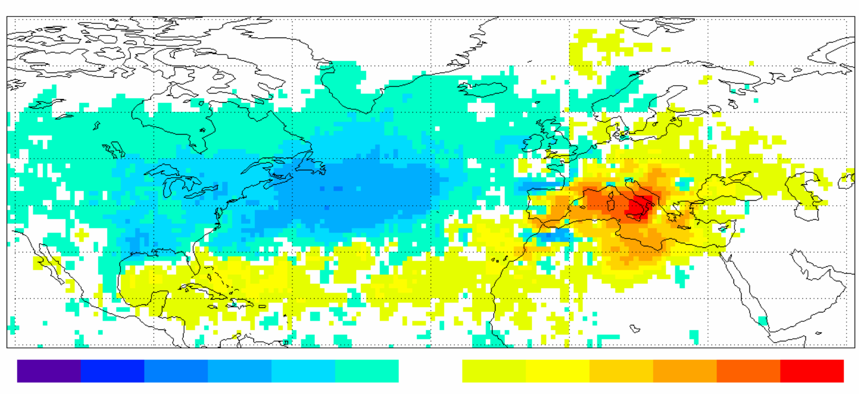


Figure 7: Annually average $(E\text{-}P)^{1,10}$ *field of the Balcanic Peninsula (BP) region from the backward tracking (averaged over 10 days back). Scale mm/day.*

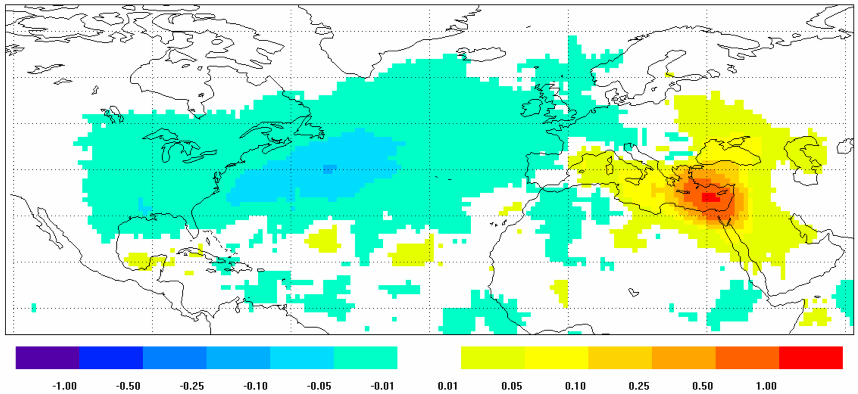


Figure 8: Annually average (E-P)^{1,10} field of the Eastern Mediterranean (EM) region from the backward tracking (averaged over 10 days back). Scale mm/day by 10.

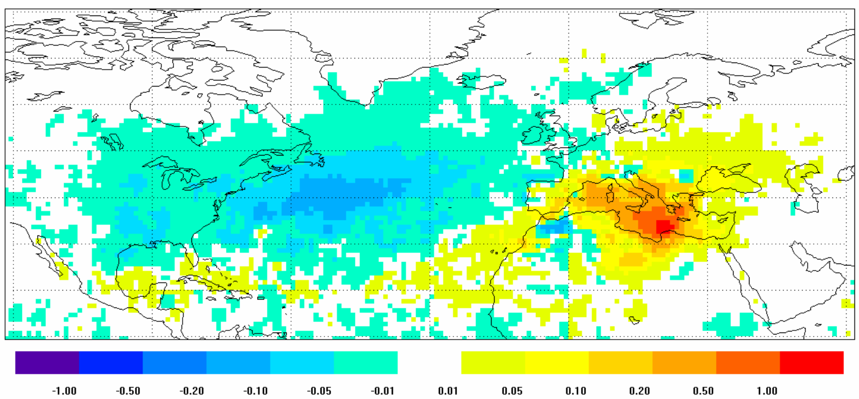


Figure 9: Annually average (E-P)^{1,10} field of the Eastern Africa (EA) region from the backward tracking (averaged over 10 days back). Scale mm/day by 10.

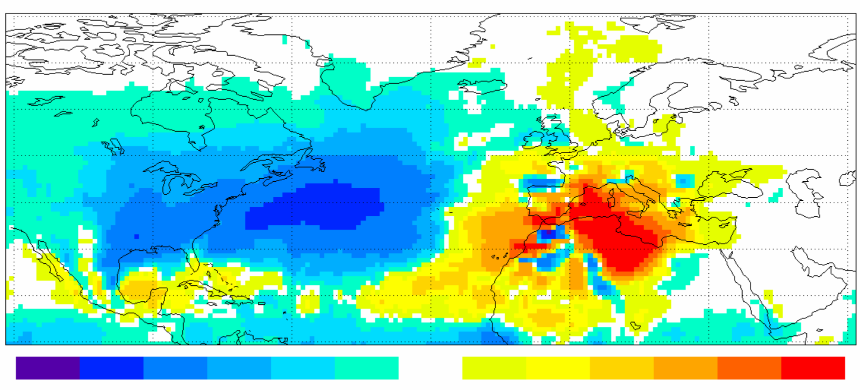


Figure 10: Annually average (E-P)^{1,10} field of the Central Africa (CA) region from the backward tracking (averaged over 10 days back). Scale mm/day.

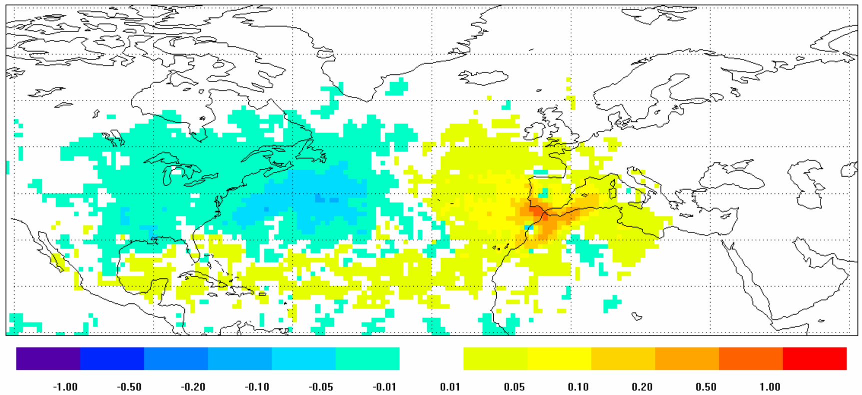


Figure 11: Annually average $(E\text{-}P)^{1,10}$ field of the Western Africa (WA) region from the backward tracking (averaged over 10 days back). Scale mm/day by 10.

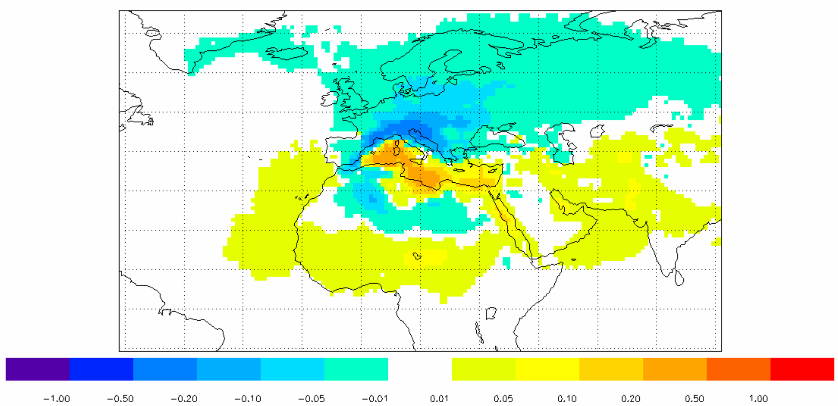


Figure 12: Annually average $(E\text{-}P)_{1,10}$ field of the Western Mediterranean Sea (1) region from the forward tracking (averaged over 10 days forward). Scale mm/day.

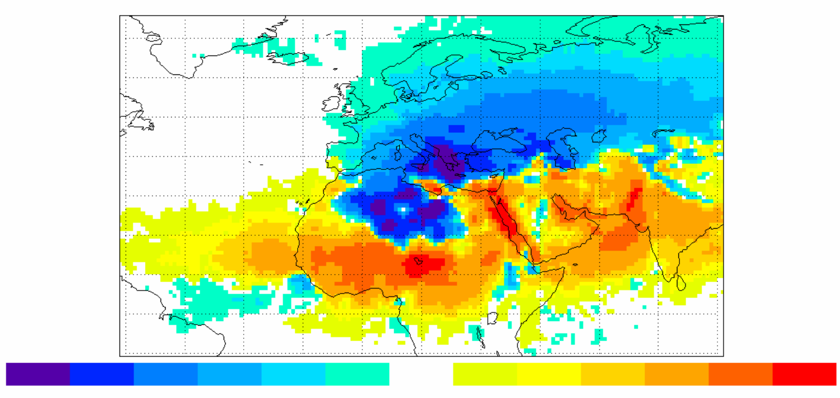


Figure 13: Annually average $(E\text{-}P)_{1,10}$ field of the Central Mediterranean Sea (2) region from the forward tracking (averaged over 10 days forward). Scale mm/day by 10.

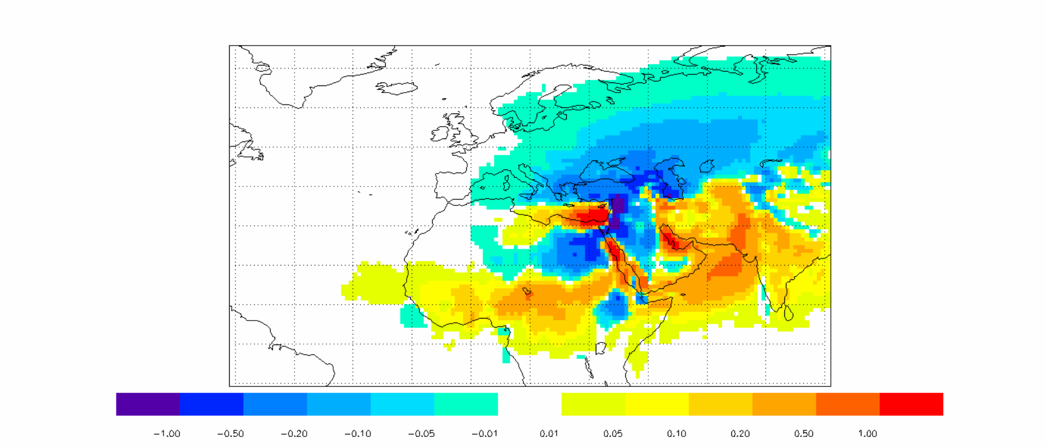


Figure 14: Annually average $(E\text{-}P)_{1,10}$ field of the Eastern Mediterranean Sea (e) region from the forward tracking (averaged over 10 days forward). Scale mm/day.

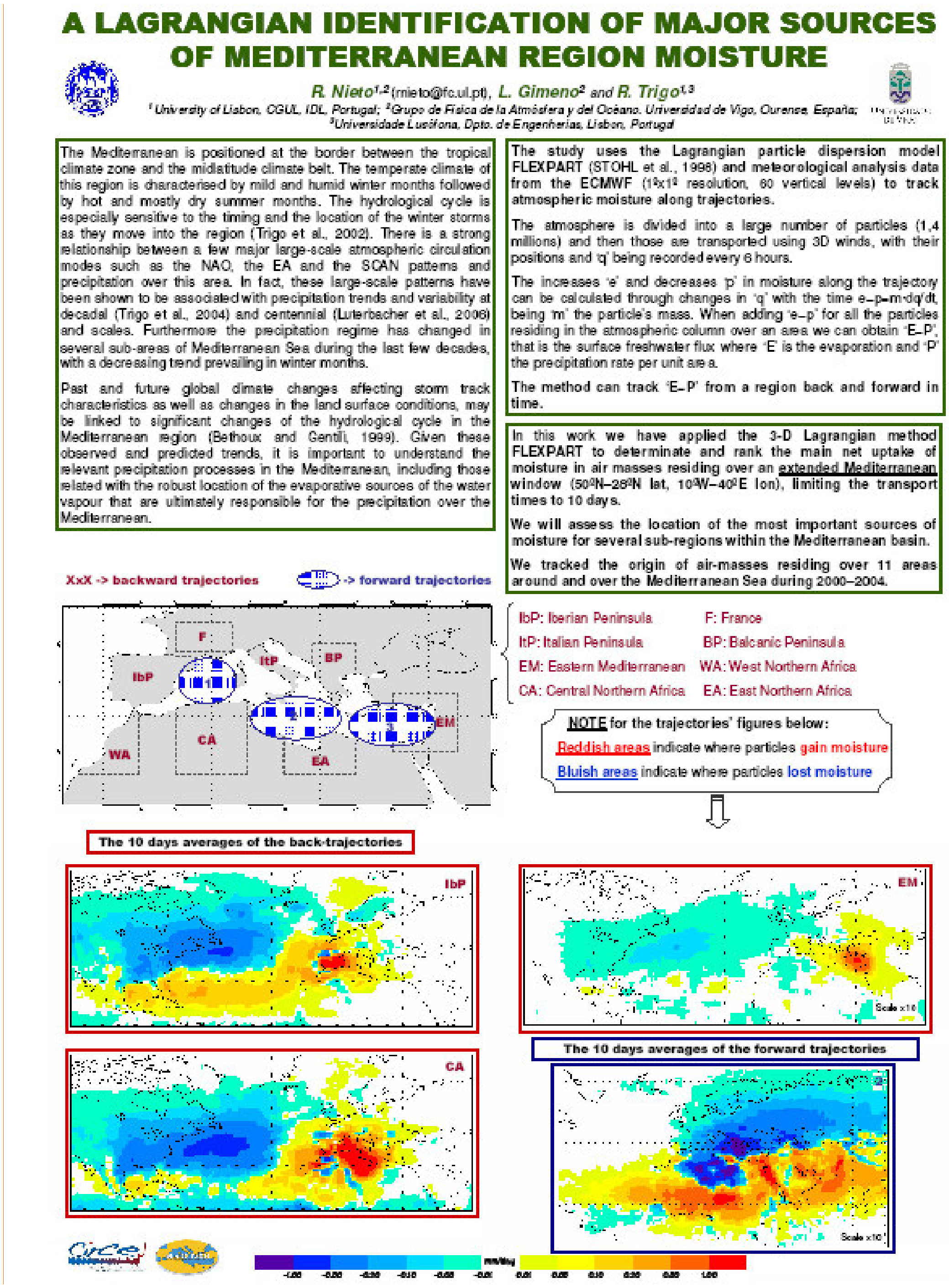
3. Future collaboration with host institute

As expected, the three months were a too short time, to finish the entire project. The first results obtained and presented here should be analysed with more detail.
The next steps of this project include a testing of different precipitation data base to analyze moisture sources associated with precipitation, even heavy precipitation events.
During these months a first comparison with previous studies was performed, but we need put more emphasis on the comparison of the new results with Eulerian previous studies.

The collaboration between the University of Lisbon and the Universidad of Vigo in Ourense will therefore continue, first for finishing this project, and thereafter also for future collaboration within this topic, potentially investigating in more detail some aspects arisen by this study.

4. Publications and presentations

During the stay in Ourense (University of Vigo) a poster was presented in the 2nd HyMex (HYdrological cycle in the Mediterranean EXperiment) Workshop in Palaiseau, France (http://www.cnrm.meteo.fr/hymex/) during 2-4 June 2008.
The abstract can be obtained in:
(http://www.cnrm.meteo.fr/hymex/index.php?lang=english&page=view_abstract&num=83) and the poster is attached below.



I'm currently preparing all the material obtained during my period in Ourense. It is expected that, after some further analysis of the results, to submit a scientific paper in a ISI journal in the climatology field containing the main results obtained.

5. References

Bosilovich, Y. et al. 2003: Numerical simulation of the large-scale North American monsoon water sources. J. Geophys. Res. 108, 8614; doi: 10.1029/ 2002JD003095.

Chen, T.C. et al. , 1994: Aspects of the hydrological cycle of the ocean-atmosphere system. J. Phys. Oceanogr. 24, 1827–1833.

Crimp, S.J., S.J. Mason, 1999: The extreme precipitation event of 11 to 16 February 1996 over South Africa. Meteor. Atmos. Phys. 70, 29–42.

Eltahir, E.A.B., R.L. Bras, 1996: Precipitation recycling. Rev. Geophys. 34, 367–378.

Fernandez, J. et al., 2003: Analysis of wintertime atmospheric moisture transport and its variability over southern Europe in the NCEP-Reanalyses. Climate Res. 23, 195–215.

Knippertz, P., J.E. Martin, 2005: Tropical plumes and extreme precipitation in subtropical and tropical West Africa: Part 1. Moisture transport and precipitation generation. Quart. J. Roy. Meteor. Soc. 131, 2337–2365.

Liu, J., R.E. Stewart 2003: Water vapor fluxes over the Saskatchewan River basin. J. Hydrometeor. 4, 944–959.

Mariotti A. et al., 2002: The Hydrological Cycle in the Mediterranean Region and Implications for the Water Budget of the Mediterranean Sea. J. Climate 674–1690

Nieto, R., L. Gimeno, and R. M. Trigo, 2006: A Lagrangian identification of major sources of Sahel moisture. Geophysical Research Letters 33, L18707, doi: 10.1029/2006GL027232.

Nieto, R., L. Gimeno, D. Gallego and R. M. Trigo, 2007: Contributions to the moisture budget of airmasses over Iceland. Meteorologische Zeitschrift 16, No. 1, 037-044, doi: 10.1127/0941-2948/2007/0176

Numaguti, A., 1999: Origin and recycling processes of precipitating water over the Eurasian continent: Experiments using an atmospheric general circulation model. J. Geophys. Res. 104, 1957–1972.

Stohl, A. et al., 1998: Validation of the Lagrangian particle dispersion model FLEXPART against large scale tracer experiment data. Atmos. Environ. 32, 4245–4264.

Stohl, A., P. James, 2004: A Lagrangian analysis of the atmospheric branch of the global water cycle. Part 1: Method description, validation, and demonstration for the August 2002 flooding in central Europe. J. Hydrometeor. 5, 656– 678.

Stohl, A., P. James, 2005: A Lagrangian analysis of the atmospheric branch of the global water cycle: 2. Earth's river catchments, ocean basins, and moisture transports between them. J. Hydrometeor. 6, 961–984.

Trenberth, K.E. 1999: Atmospheric moisture recycling: Role of advection and local evaporation. J. Climate 12, 1368–1381.

White, P.W., 2002: IFS documentation. ECMWF Rep., Reading, United Kingdom. – Available online at http://www.ecmwf.int

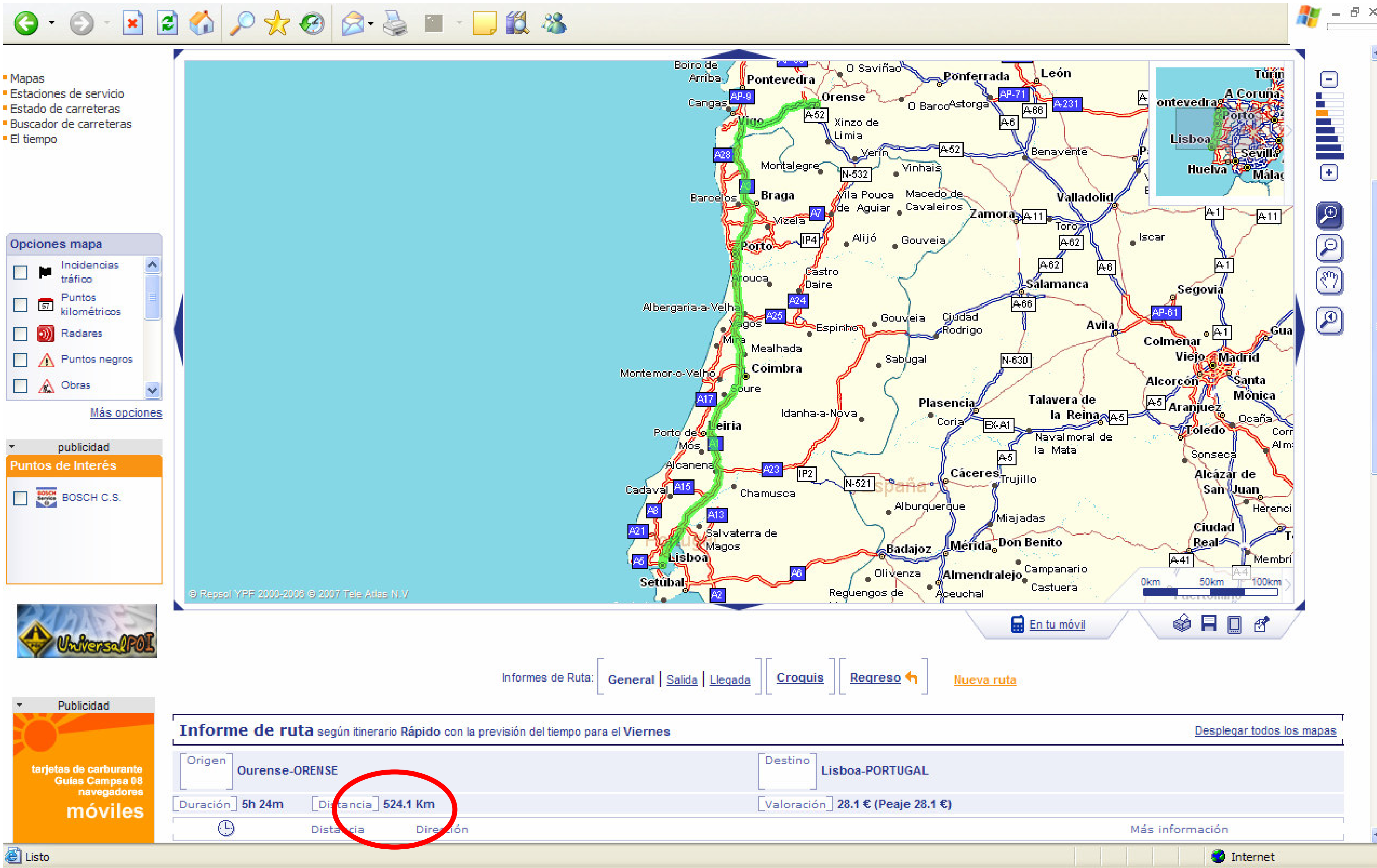
6. Travel Cost

The travel was by car Lisbon to Ourense and Ourense to Lisbon.

The distance between both cities is 524.1 Km (see map below)

Total distance 524.1 x 2 = 1048.2 Km

I assume that the cost of diesel is 0.25 euros/Km, so, the total cost was: **262.05 euros**


Mapas
Estaciones de servicio
Estado de carreteras
Buscador de carreteras
El tiempo
Opciones mapa
Incidencias tráfico
Puntos kilométricos
Radares
Puntos negros
Obras
Más opciones
publicidad
Puntos de Interés
BOSCH C.S.
Publicidad
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Croquis
Regreso
Nueva ruta
Informe de ruta según itinerario Rápido con la previsión del tiempo para el Viernes
Desplegar todos los mapas
Origen Ourense-ORENSE
Destino Lisboa-PORTUGAL
Duración 5h 24m
Distancia 524.1 Km
Valoración 28.1 € (Peaje 28.1 €)
Distancia
Dirección
Más información
Listo
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