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Nonlinear Processes in Geophysics
Discussions
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Interactive comment on "Seasonal predictability of the winter precipitation over Iberian Peninsula and its relationship with finite-time Lyapunov exponents" *by* Daniel Garaboa-Paz et al.

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We would like to thank the Referee for his/her valuable comments and critics that we tried to take into account in the revised version of the manuscript. Hopefully, all the major and minor corrections pointed out by the reviewer have been corrected now. A detailed answer follows below. We provide replies to the reviewer' comments in bold. As well, corrections included in the manuscript are marked in red.

Answer to Referee 1

The manuscript calculates the local atmospheric mixing using finite time Lyapunov exponents and finds that summertime changes in this field are correlated with winter

changes in precipitation over the Iberian Peninsula. Thus, they suggest this field could be used as a predictor of precipitation in this region.

The topic is very relevant and important because seasonal prediction is still a very active area of research. Thus, any advance in this area will be welcome. However, I am not convinced about the interpretation and the mechanism that connects mixing in summer with rainfall in winter. As the authors mention other works have already found a connection between summertime north Atlantic SST and winter rainfall in Europe. Here, the authors try to explain their results expanding on those based on composites.

But, I could not follow the reasoning of the authors: what is the causality link between changes in mixing in summer and rainfall in winter? Through changes in the SST? Does the SST somehow force a certain teleconnection pattern during winter, which in turn changes rainfall?

The interaction between the ocean and atmosphere is complex. Heat and momentum flux at the interface modify currents and winds near the surface. On the other hand, Cayan showed that vast regions of the middle-latitude ocean surface temperature variability is forced by the atmospheric variations. He showed a strong dependence between heat flux, SST anomalies and the SLP modes on spatial scales that often span major portions of the North Atlantic. The heat flux anomalies, derived from bulk formulations, exhibit large-scale patterns of variability which are related to patterns of sea level pressure (SLP) variability and also to patterns of SST anomalies.

In our case, we showed that FTLE anomalies correspond to patterns of SST and SLP variability. In our opinion, large-scale tropospheric mixing drives summer SST anomalies that lead to changes in the next seasons storm tracks, and consequently changes in the location of action centers (low and high pressures centers).

âĂć Cayan, D.R. Latent and sensible heat flux anomalies over the northern oceans: Driving the sea surface temperature. J. of Phys. Ocean. 22, 859-881, 1992.

Also, changes in mixing are very small, close to 3%... are they significant? Moreover, are the SST, geopotential height, and wind anomalies statistically significant for positive and negative cases of FTLE? Authors need to quantify this, maybe through a test of differences between positive/negative years and neutral years.

Although the changes in the values of positive phase and negative phase of FTLEs are small, the Wilcoxon rank sum test shows that these differences between positive and negative phase of FTLEs are significant. The same is found between the differences of the positive and negative anomalies of the other variables.

Lines 285-287 and 292-295 imply that climatological winds are westerly between the Caribbean and the Iberian Peninsula, but south of 25N the easterly trade winds dominate. Thus, these sentences are incorrect.

We agree with the reviewer, perhaps in the manuscript we describe Figures 5c and 5d in such a way that they were misunderstood. We have rewritten the corresponding paragraph in the manuscript.

For some particular years, weaken easterlies are displaced to lower latitudes reinforcing westerlies between the Caribbean area and the Iberian Peninsula, meaning that rainfall may be stronger associated with the enhancement of the poleward transport of moisture (see for example, figure for January 2001, a month corresponding to a particularly rainy winter). This situation is a particular case of Fig.5d. However, for other years, easterly winds predominate as they are displaced towards North. Low wind speed values are then observed in the trajectory between Caribbean area and the Iberian Peninsula related to a less frequent arrival of cold fronts and their associated baroclinic structures (see for example, figure for January 2005, a month corresponding to a particularly dry winter). This situation is a particular case of Fig.5c.

The sentence “less wind than normal” does not sound right. Please change to “weaker winds” or similar.

The reviewer is right. The sentence has been modified.

Why did you choose the 850 hPa level, which is usually just above the boundary layer (PBL)?

We want to focus on the troposphere, but at the same time we wanted to avoid the atmospheric events close to the surface within the PBL. We are interested in the large-scale tropospheric mixing. To that end, we start the advection at the intermediate level of 850hPa so the observed coherent structures are not perturbed by turbulence effects coming from the PBL.

Does mixing change significantly depending on the level?

We perform integrations at different levels 850 hPa, 500 hPa and 300 hPa. In some cases, the main synoptic coherent structures remain qualitatively the same (see for example 3D simulations in Garaboa-Paz et al, 2015) at different levels; the strength of the FTLE ridges diminishes as pressure decreases. We notice that some structures become weaker and the integration time should be modified to capture these structures. However, in some other cases, due to the different flow dynamics occurring at different pressure levels, the observed coherent structures do not coincide. However, we expect the climatological means and anomalies calculated at different levels to behave similarly.

If the deformation due to vertical movement is not taken into consideration, shouldn’t you pick a level where the atmosphere tends to behave in 2D? Maybe upper levels?

The particles are advected in 3D, but, only the deformation due to 2D horizontal movement is considered. We want to focus on the horizontal spatial deformation instead of vertical deformation.

The vertical-horizontal scales are completely different in the atmosphere, so considering the deformation due to vertical movement will lead to define a 3x3 Cauchy Green tensor. The eigenvalues of this matrix only take into account the relative deformation of an ellipsoid respect to their initial conditions, without distinction between horizontal or vertical movement. If the vertical deformations have the same weight than horizontal deformation, this could lead to mask the FTLE values.

Why did you chose tau=5 days? Is it to capture the mixing due to synoptic variability? Have you performed a sensitivity test by changing tau within 1 or 2 days?

Yes, the reviewer is right. We want to capture the main synoptic scales. Five days is about the mean length of the typical synoptic time scale in mid-latitudes. For larger time scales, observed coherent structures are smeared out, while for smaller tau values those structures are not well shaped, and multiple patterns arise.

Please also note the supplement to this comment:
http://www.nonlin-processes-geophys-discuss.net/npg-2016-79/npg-2016-79-AC1-supplement.pdf

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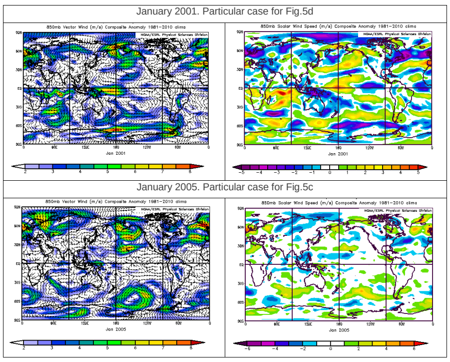

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Fig. 1. Examples for wind behavior