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Changes in the contribution of moisture from the Mediterranean Basin to the continental precipitation from 1980 onwards: a Lagrangian analysis

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Abstract

In this work we use an objective 3-D Lagrangian method to identify possible changes in the moisture contribution from the Mediterranean basin to the continental precipitation during the extended winter season (October-April) for the 1980-2012 period. We tracked air parcels from the Mediterranean forward in time along the 10-day trajectories to investigate the role of the basin as source of moisture. Climatologically, the contribution of moisture from the basin to the winter precipitation occurs over a domain expanding from the northern Africa towards Europe and the western Asia. The differences of the decadal composites point out that the 90's was characterized by enhanced moisture contribution from the basin towards central/western Europe.

Keywords: moisture transport, Lagrangian analysis, decadal changes

Introduction

Observational analysis suggests increasing in the evaporation averaged over the Mediterranean basin during the extended winter for the last three decades (Gomez-Hernandez *et al.* 2013 and references therein).

In this work we use an objective 3-D Lagrangian method to identify possible changes in the moisture contribution from the Mediterranean basin source to the continental precipitation during the extended winter season (October-April) for the 1980-2012 period.

Materials and Methods

We used the method developed by Stohl and James (2004), based on the Lagrangian model FLEXPART v9.0 forced by the 1º ERA-Interim reanalysis (Dee *et al.* 2011) available every 3 hours.

The method divides the atmosphere into air parcels, which are transported using the wind field. The changes of the specific moisture of an air parcel (of mass m) along its trajectory can be expressed as: $e - p = m\ dq/dt$, where (e-p) can be interpreted as the freshwater flux in the parcel (the difference of evaporation and precipitation). By adding (e – p) for all the parcels in the vertical atmospheric column over an area, we obtain the surface freshwater flux (E – P).

The lagrangian data set used comes from a global simulation in which the atmosphere was divided into approximately 2.0 million parcels. We track (E-P) from the Mediterranean basin (MED) forward in time along the 10-day trajectories (the average residence time of water vapour in the atmosphere). We analyse negative values of (E-P) integrated over the 10-day trajectories at the seasonal scale. They indicate the sinks of moisture that, under the necessary dynamical conditions, can be converted into surface precipitation.

Differences of the 90´s (1991-2000) and 80´s (1981-1990) and of the 2000´s (2001-2010) and 90´s were calculated for the precipitation (GPCP; 2.5º; Huffmann *et al*. 2009), the vertically integrated moisture flux (VIMF; ERA-INTERIM) and the (E-P) fields. A bootstrap test with 90% of significance was applied in the decadal differences of the (E-P).

Results

Climatologically, the rainy season for most of Europe occurs during October-April, when higher precipitation and convergence of VIMF are observed (fig 1, left and central top panels, respectively). Divergence of VIMF over Mediterranean suggests its role as a moisture source. The contribution of moisture from MED to the precipitation occurs towards the northern Africa, Europe and the western Asia (Figure 1, right top panel).

The 90's - 80's differences (Figure 1, central panels) show a dipole over MED and Europe: reduced (increased) precipitation and higher divergence (convergence) of VIMF over MED (central/north Europe). The moisture contribution from MED increased towards western and central Europe.

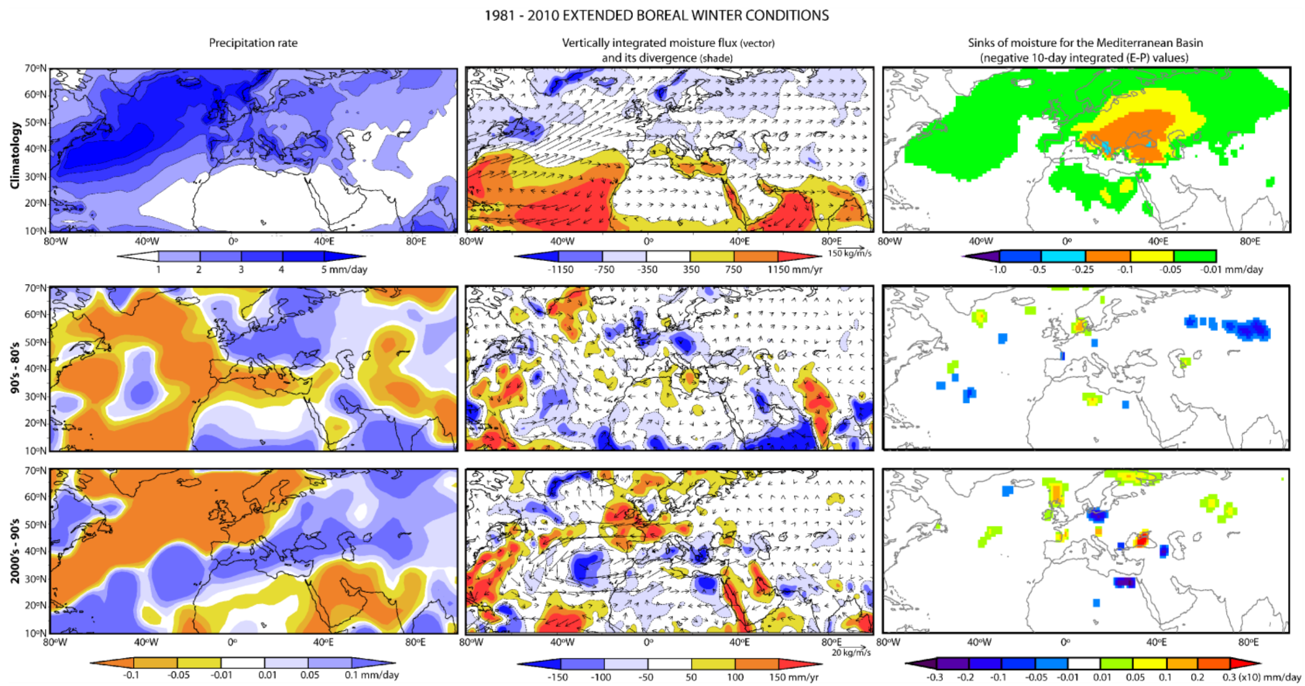

Figure 1. Top (from left to right columns): 1981–2010 extended boreal winter climatology of the precipitation rate (mm/day, GPCP), of the Vertically Integrated Moisture Flux (vector; kg/m/s) and its divergence (mm/year, Era-Interim), and of the negative E-P (sinks of moisture) (mm/day). Central: same as top, but for decadal differences of 90's and 80's. Bottom: same as top, but for 00's and 90's. Only decadal differences of sinks of moisture significant at the 90% confidence level are plotted (Bootstrap Test).

The dipolar structure of precipitation and VIMF over MED and Europe observed in the 90's - 80's was inverted during 00's – 90's (Figure 1, bottom panels). In comparison to the 90's, enhanced moisture contribution from MED towards Egypt and areas of Turkey was configured during the 00's. However, the moisture contribution from MED was reduced towards Black Sea and regions of western/Central Europe.

Discussion

The differences of the decadal composites suggest that the patterns over the Mediterranean basin and Europe have changed during the last thirty years. It seems that the 90's was characterized by the enhancement of the divergence of the VIMF over the basin and by the intensified moisture contribution from this source towards central/western Europe.

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