AUTOMATIC IDENTIFICATION AND CLASSIFICATION OF RED SEA TROUGHS

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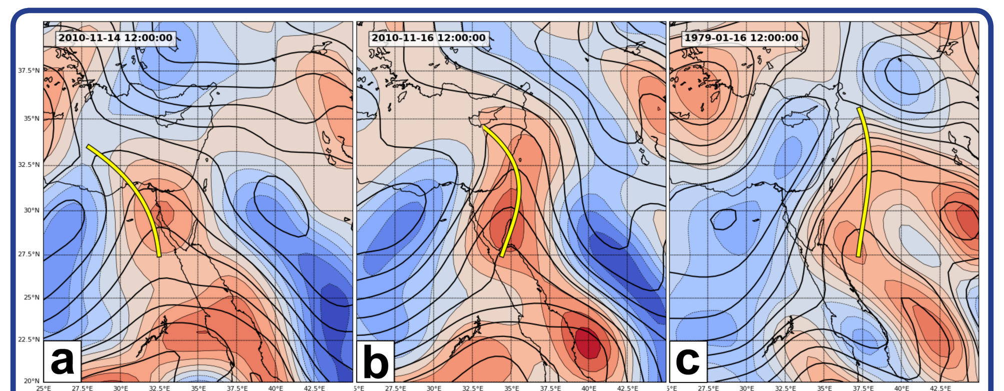

Fig. 1 - Three types of RST axes

(a), (b) and (c) show examples of RST axes to the west, center and east of Israel, respectively.

Introduction

The Red Sea Trough (RST) is a low-pressure system extending from the south toward the Levant. RSTs are most frequent in the fall and the winter, fading out by mid-spring. This system is the most frequent among all troughs, which extend from the North African Monsoon toward the Eastern Mediterranean and is attributed to the lee effect of mountain ridges east of the Red Sea.

Our algorithm aims at explicitly identifying RSTs on sea-level pressure (SLP) maps and classifying them as one of three types, according to the location of the trough axis; to the west, east or over Israel (Fig. 1).

The algorithm is flexible and is not confined to any specific spatial resolution, so it is applicable to a variety of reanalysis datasets, operational forecast model results and climate model outputs.

Methodology

Input and pre-processing

To permit input data from different sources with various resolutions, data is first interpolated to a common basis, i.e., grid of 0.5°X0.5° resolution, which is found optimal for identifying and locating the trough axis.

Locating the trough axis

The algorithm seeks for an initial local SLP minima, which can be regarded as the core of an RST, extending north, north-east or north-west. If a local minimum is found, the algorithm looks for a local minimum in its immediate neighborhood (while the SLP rises in the direction of searching). As long as such minima are found, the algorithm keeps looking further for the next points in the trough.

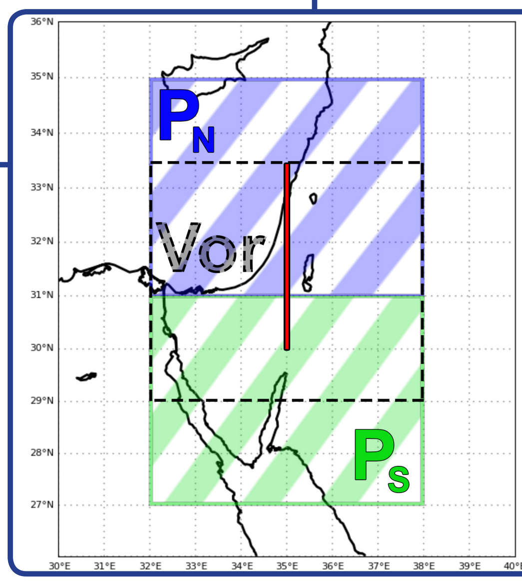

Fig. 2 - Region of interest

SLP is averaged over areas P_N and P_S to verify pressure drop from north to south. Vorticity is averaged over the 'Vor' area (dashed line box). 35°E is used to determine where the RST axis is located relative to Israel.

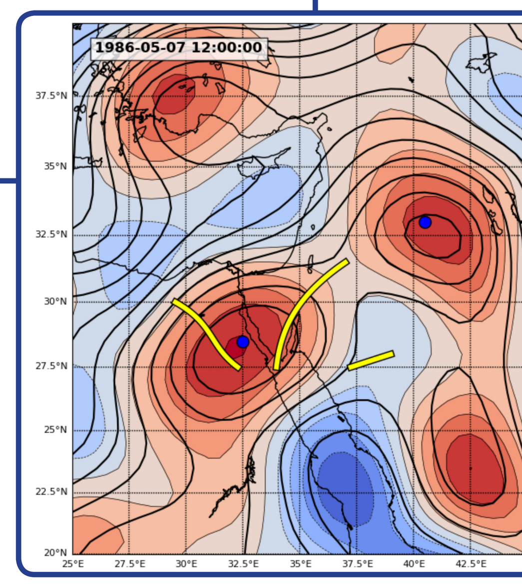

Fig. 3 - Nearby pronounced low

SLP (contours) and geostrophic vorticity (colors, in s^{-1}) for May 7, 1986. Three of the conditions for RST identification were met, but the one concerning nearby pronounced lows, indicates an incidental passage of a Sharav Low. The case is classified as 'No RST'.

Conditions for RSTs

A few conditions are specified to be met, in order for an RST to be identified:

- The 'SLP gradient' condition, i.e., the SLP decreases from north to south across the Levant region (Fig. 2);
- The 'vorticity condition', i.e., the average geostrophic vorticity over the region of interest is positive (Fig. 2);
- No nearby pronounced cyclone (such as 'Sharav' or 'Cyprus' Lows) exists in the proximity of the area of interest (Fig. 3).
- At least one RST trough axis is been identified within the region of interest.

RST classification

If the conditions above are met, the algorithm classifies the RST according to its **relative location** with respect to 35°E (Fig 2.). If the axis is locate east or west of this longitude, the RST is regarded as RST to the East/to the West. If the axis crosses this longitude, it is regarded as a central RST.

If more than one axes exist for a given map, all axes receive a Geostrpohic Vorticity score (GV score). A GV score is the total of GV values in each grid point along the axis. The axis with the highest GV score is selected as the RST axis for that map (Fig. 4).

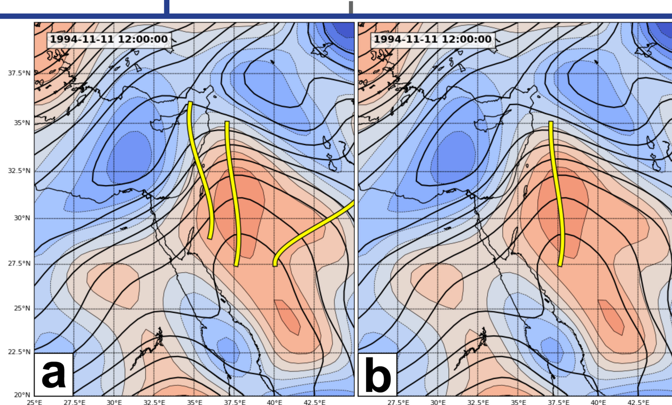

Fig. 4 - Geostrophic Vorticity score example

Multiple axes were found on the map (a). The axis with the highest GV score was chosen (b).

Results

An evaluation of the automatic classification, done for randomly selected 200 days, shows that for 96% of them the subjective classification is similar. For 100 days, identified subjectively as RSTs, the automatic classification agrees on 85%.

		ERA 2.5°×2.5° No RST	East	Central	West
NCEP 2.5°×2.5°	No RST	9916	251	206	90
	East	1222	592	630	78
	Central	195	65	404	61
	West	100	22	34	14
Agreement: perfect match 79% and misidentification 15%					

		ERA 0.75°×0.75° No RST	East	Central	West
NCEP 2.5°×2.5°	No RST	9926	283	156	98
	East	870	785	729	138
	Central	143	55	364	163
	West	80	27	38	25
Agreement: perfect match 80% and misidentification 12%					

		ERA 0.75°×0.75° No RST	East	Central	West
ERA 2.5°×2.5°	No RST	10658	419	240	116
	East	163	521	199	47
	Central	143	171	773	187
	West	55	39	75	74
Agreement: perfect match 87% and misidentification 8%					

Table 1 - Datasets comparison

Comparison of RST identification and classification between NCEP reanalysis (2.5°×2.5° resolution) and ERA Interim (2.5°×2.5° and 0.75°×0.75° resolutions).

Each item is one day, represented by its 12UTC map. The period is 1979-2016, total of 13,880 days.

Comparison between datasets

Comparing the algorithm's results among the 3 different datasets yields a high agreement rate between them (Table 1).

Climatological aspects of the RST

The distribution of RST days along the year shows the dominance in the fall, with annual maximum in November (Fig. 5, in agreement with Alpert et al., 2004).

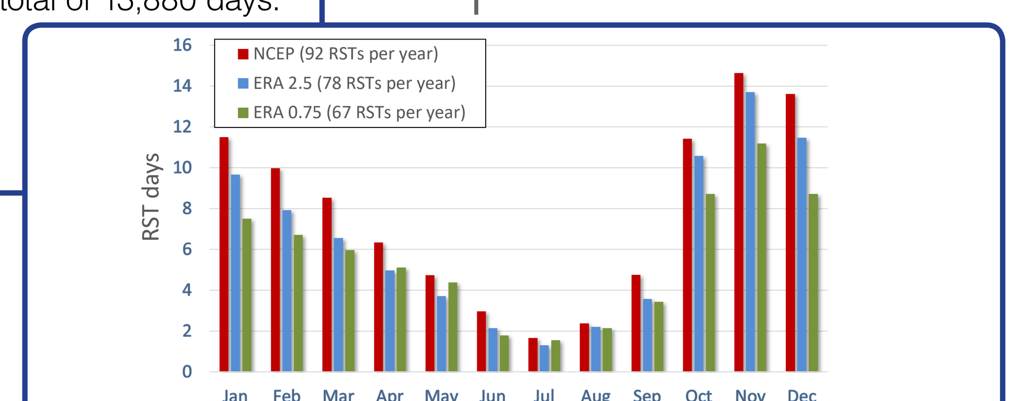

Fig. 5 - RST monthly distribution

Monthly distribution of RST days (%) according to NCEP reanalysis, ERA Interim with 2.5°×2.5° and with 0.75°×0.75° resolution.

A distinct shift in the RST axis is noticed between day and night (Fig. 6). The daytime (12UTC) axes are tilted towards the east, while night time (00UTC) axes are centered over Israel. This is attributed to the effect of land warming during daytime.

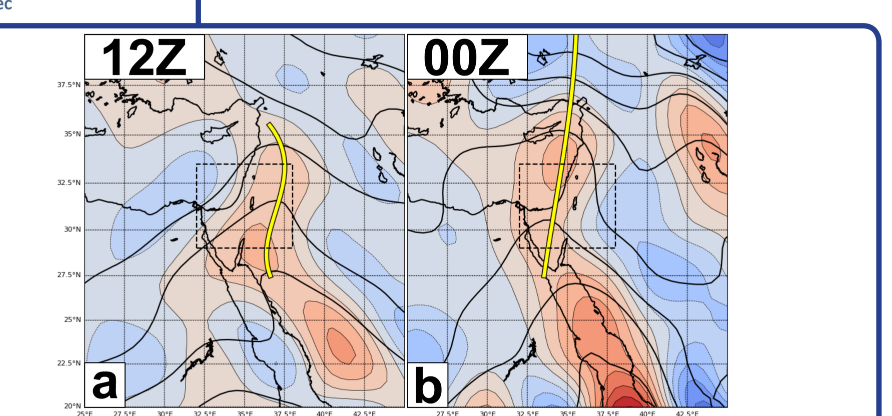

Fig. 6 - Day and night RST axis shift

Composite maps of all RSTs found in NCEP at 12UTC (a) and 00UTC (b) reveal a shift of RST axes to the land (east) during the day.

Conclusions

- The identification methodology proposed here is an 'explicit' one. It intends to identify and classify one synoptic system rather than covering the entire set of prevailing synoptic systems.
- The algorithm was found to accurately identify and classify RSTs (85%=96%).
- Although RST is a synoptic system in size, it responds to the meso-scale factor of sea-land temperature contrast.
- The algorithm is applicable for different data sources with different resolutions, including climate models.

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