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Untangling the Mistral and Seasonal Atmospheric Forcing Driving Deep Convection in the Gulf of Lion: 1993–2013

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Key Points:

- The seasonal atmospheric change is the main driver of destratification
- Winters with deep convection have below average levels of stratification that the atmospheric forcing has to overcome
- The Mistral winds have a low frequency signature that elevates the seasonal wind speeds in the winter

Supporting Information:

Supporting Information may be found in the online version of this article.

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Abstract

Deep convection occurs periodically in the Gulf of Lion, in the northwestern Mediterranean Sea, driven by the seasonal atmospheric change and Mistral winds. To determine the variability and drivers of both forcings, multiple 1 year ocean simulations were run, spanning from 1993 to 2013. Two sets of simulations were performed: a control and seasonal set, the first forced by unfiltered atmospheric forcing and the other by filtered forcing. The filtered forcing was bandpass filtered, retaining the seasonal and intraday aspects but removing the high frequency phenomena. Comparing the two sets allows for distinguishing the effects of the high frequency component of the Mistral on the ocean response. During the preconditioning phase, the seasonal forcing was found to be the main destratifying process, removing on average 46% of the stratification needed for deep convection to occur, versus the 28% removed by the Mistral. Despite this, each forcing triggered deep convection in roughly half of the deep-convection events. Sensible and latent heat fluxes were found to be the main drivers of the seasonal forcing during deep-convection years, removing 0.17 and 0.43 m^2s^{-2} of stratification, respectively. They were themselves driven by increased wind speeds, believed to be the low frequency signal of the Mistral, as more Mistral events occur during deep-convection winters (34% vs. 29% of the preconditioning period days). An evolving seasonal forcing in a changing climate may have significant effects on the future deep convection cycle of the western Mediterranean Sea.

Plain Language Summary

Deep convection occurs periodically in the Gulf of Lion (located in the northwestern Mediterranean Sea), when water at the surface of the ocean is cooled enough to mix freely with the deeper water below, sometimes reaching the sea floor. It's an important part of the overall circulation of the Mediterranean Sea that leads to an explosion in the phytoplankton population in the following spring. In the gulf, the surface cooling is caused by the atmospheric transition from summer to winter and the Mistral winds. The latter is a cool, dry northerly wind that flows through the Rhône Valley out over the gulf. In our study, we ran ocean simulations that included and excluded the non-seasonal effects of the Mistral to determine the importance of the seasonal and Mistral forcing on deep convection. The seasonal forcing was found to have a larger role, and contained a low frequency part of the Mistral, elevating the average wind speeds during the winter. Changes in the seasonal forcing and ocean water composition will need to be studied to understand the evolution of deep convection in the Gulf of Lion and its consequences on the Mediterranean Sea dynamics and biology in a changing climate.

1. Introduction

Deep convection, or open-ocean convection, occurs in the higher latitude regions of the world and is an important ocean circulation process (Marshall & Schott, 1999). It is formed when the stable density gradient along the ocean column is eroded by surface buoyancy loss, leading to an overturning that can span the entire depth of the water column. In the western basin of the Mediterranean Sea, this process can occur in the Gulf of Lion and assists in the thermohaline circulation of the sea (Robinson et al., 2001) by forming the Western Mediterranean Deep Water (WMDW). When it does occur, the WMDW produced spreads out along the lower layers and bottom of the northwest basin (MEDOC, 1970). Figure 13 in Testor et al. (2018) illustrates this process, additionally showing the submesoscale coherent vorticies that are produced and aid in the lateral transport (Bosse et al., 2016). Some of the WMDW is transported along the northern boundary current toward the Balearic Islands (Send & Testor, 2017), and some of it completes the general circulation by flowing down toward the Algerian Basin and the Strait of Gibraltar (Beuvier et al., 2012; Testor & Gascard, 2003). In the Gulf of Lion, deep convection also plays an important role in the marine biology of the region, as the springs following deep convection events also