Year-to-year Great Whirl meridional shifts: role of oceanic internal instabilities

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ABSTRACT

The Great Whirl (GW) is a quasi-permanent anticyclonic eddy that forms off the horn of Africa in the western Arabian Sea during the summer monsoon (Fig. 1). While the annual cycle of the GW has been described by past literature, its year-to-year variability has not yet been thoroughly explored. Satellite observations reveal that the leading mode of interannual sea-level variability (half of the interannual summer variance, Fig. 2) is associated with a ~200-km northward or southward shift of the GW. This meridional shift is associated with coherent sea surface temperature (SST), with warmer (colder) SST in regions with positive (negative) sea level anomalies (Fig. 3). Eddy permitting (25-km resolution) simulations with an ocean general circulation model capture those observed patterns reasonably well (Fig. 4). Those GW meridional shifts are also reproduced in experiments with climatological surface forcing, although with weaker amplitude (Fig. 5). Ensemble simulations reveal the the GW year-to-year interannual shifts has both internal, chaotic (ensemble spread) and external, deterministic (ensemble mean) sources, of comparable magnitudes (Fig. 6). We are currently investigating the forcing mechanism for the deterministic component of the GW year to year variations.

The Great Whirl

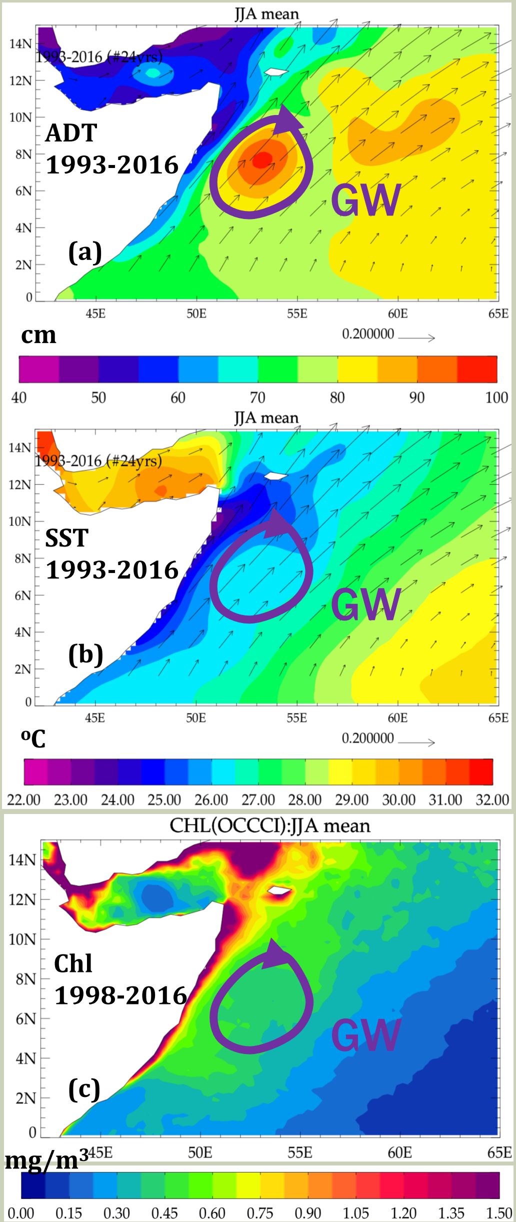


Fig 1: Summer climatology (JUN-AUG; JJA) of observed (a) absolute dynamic topography; ADT (b) sea surface temperature; SST, with wind-stress vectors and (c) surface chlorophyll (Chl)

- **Prominent signatures of Great Whirl (GW) in summer sea level, and associated signals in SST and Chl**
- **Offshore spreading of colder SST and high Chl along the northern flank of the GW**

Spatial pattern of interannual variability in GW region

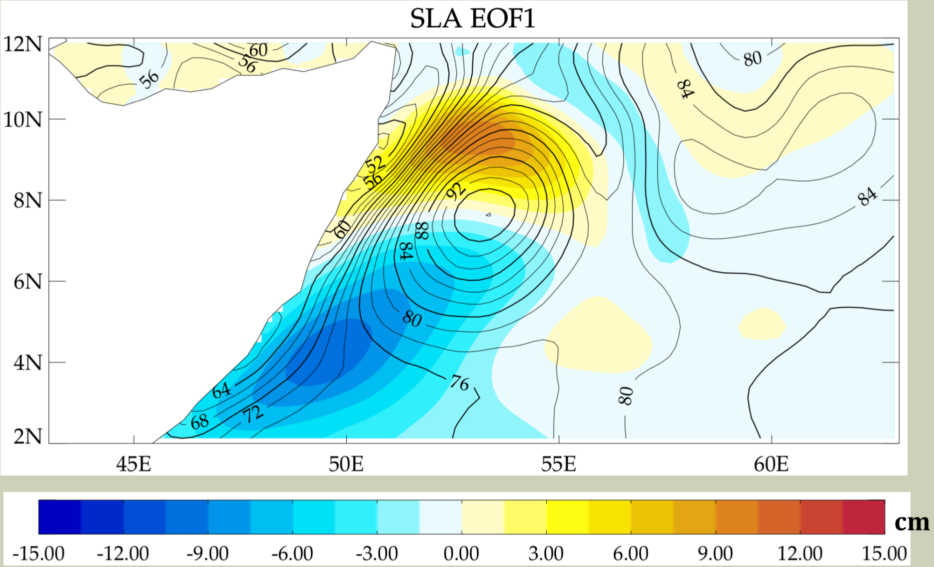


Fig 2. Spatial patterns of leading empirical orthogonal function mode (EOF1) of interannual observed sea level anomalies, with climatological ADT as contours

- **The leading mode of summer interannual sea level anomalies (48% of the total variance in the region) is a dipole with opposite anomalies North and South of the GW climatological location**
- **The main mode of GW interannual variations is associated with ~200-km GW northward / southward shifts**

Northward and southward shift events

Northward shift | **Southward shift**

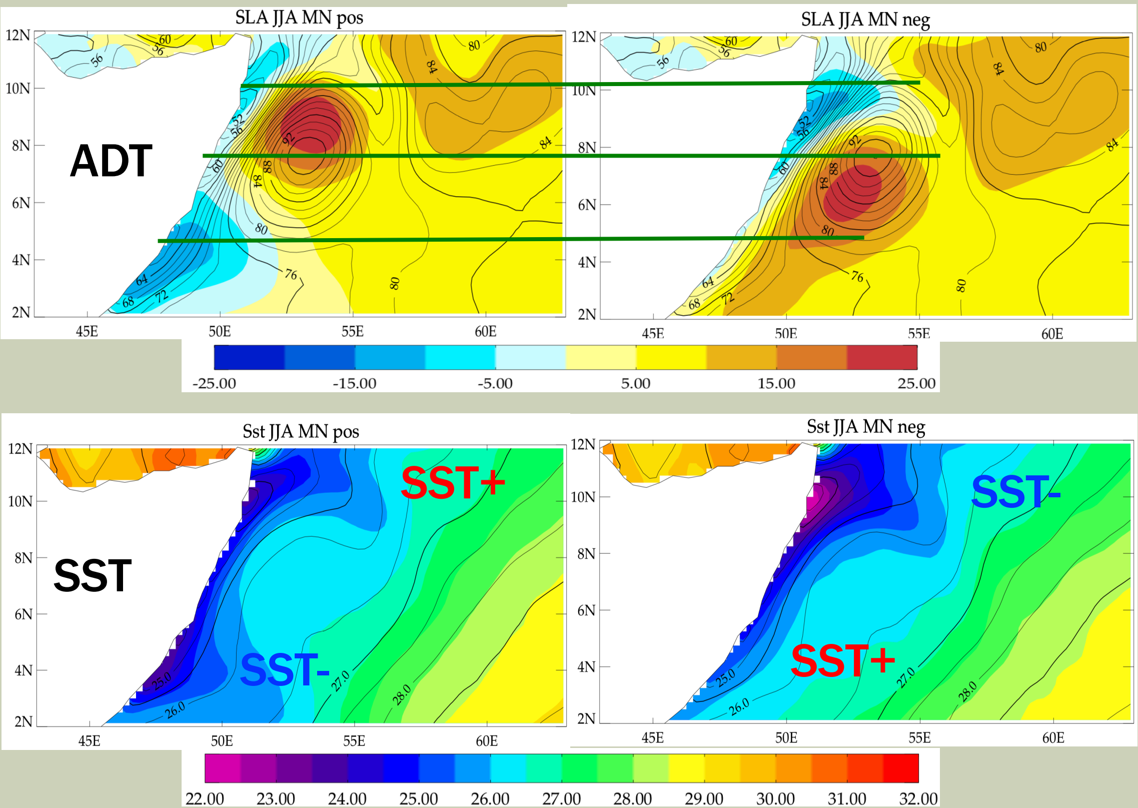


Fig 3. ADT and SST composites of observed northward and southward GW shift events

- ~200 km shift between northward and southward events compared to GW mean position
- Consistent changes in SST

Simulated Great Whirl interannual variability

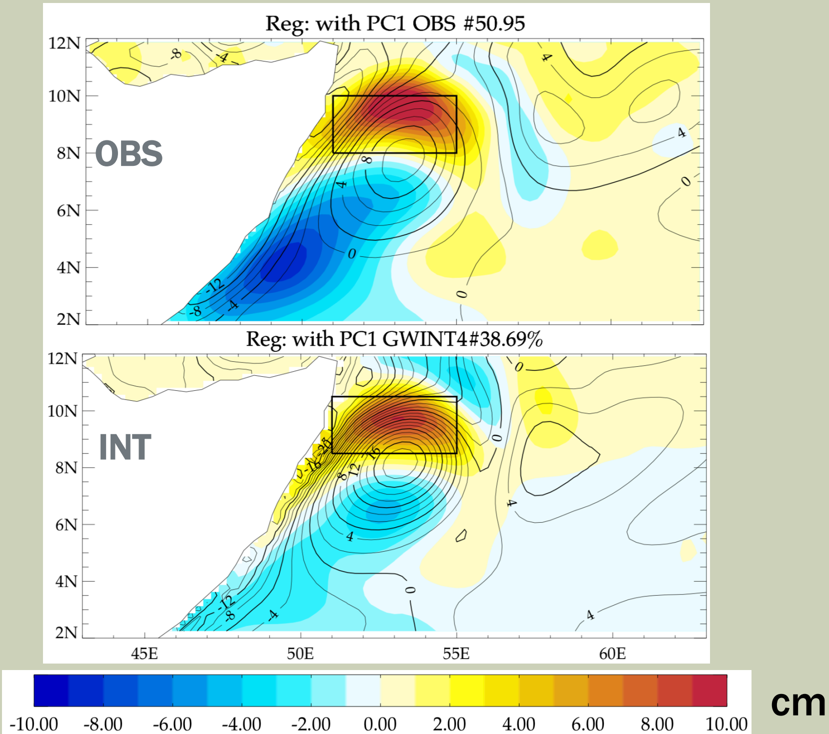


Fig 4. Sea-level first EOF in observations (OBS) and in a ¼° Nemo OGCM simulation with interannual forcing (INT) (normalized to show 1 std amplitude)

- **¼° resolution OGCM interannual simulations capture the GW interannual variability reasonably well**
- **(1/12° slightly better capture the observed amplitude; not shown)**

Role of internal variability

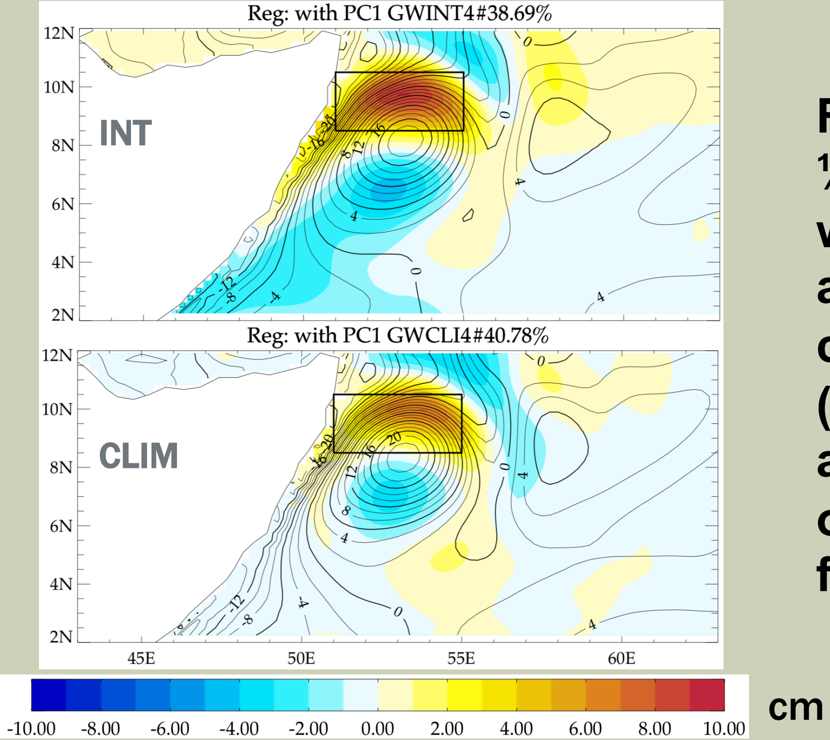


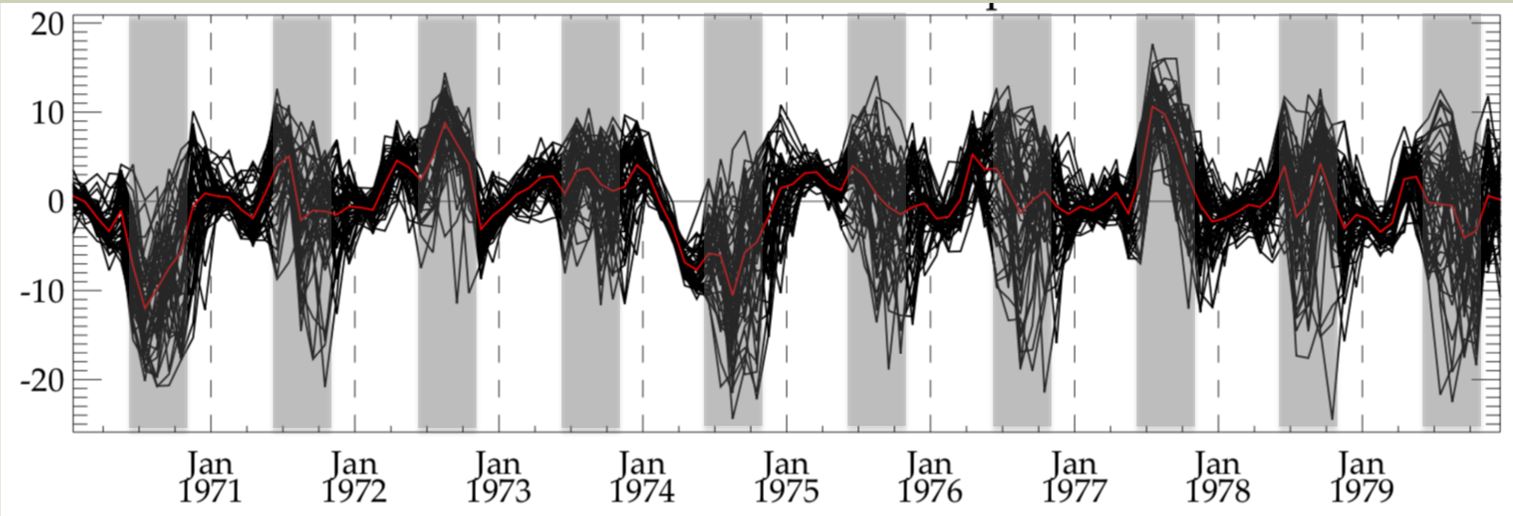
Fig 5. Sea-level first EOF in a ¼° Nemo OGCM simulation with interannual forcing (INT) and in a simulation with climatological forcing (CLIM) (normalized to show 1 std amplitude). The black frame on the positive node is used for Fig. 6

- **¼° OGCM simulations with climatological forcing also reproduce the GW interannual meridional displacements, but with smaller amplitude than in simulations with interannual surface forcing**

=> Suggests that part of the GW year-to-year variability is internal, and part is forced

Role of deterministic processes

Fig 6. Sea-level time series in the GW interannual anomalies positive node (black frame in Fig. 5) in a 50-member ensemble ¼° NEMO simulation with interannual forcing (black curves) and the ensemble mean (red). Grey shading marks May - October period



- **50-member ensemble indicates that part of the GW year-to-year meridional shifts results from internal variability (ensemble spread), while the other part, of comparable magnitude, results from a deterministic mechanism (ensemble mean)**
- **We are currently investigating the deterministic mechanism responsible for the forced component of the GW year-to-year variability**

Summary

- **Observations reveal that ~50% of the Great Whirl (GW) interannual sea level variability is associated with ~200-km northward or southward shifts, associated with coherent SST signals**

- **A ¼° (eddy-permitting) simulation reproduces this GW interannual variability reasonably well**

- **A 50-member ensemble simulation and a simulation with climatological forcing suggest that those GW meridional shifts have both chaotic internal & deterministic external sources, of comparable magnitudes**

- **We are yet to understand the mechanism of the externally-forced GW variations (local alongshore wind forcing? Remote influences?)**

Thank you