

Great Whirl non-seasonal variability: a combination of oceanic internal variability and wind-forced signals

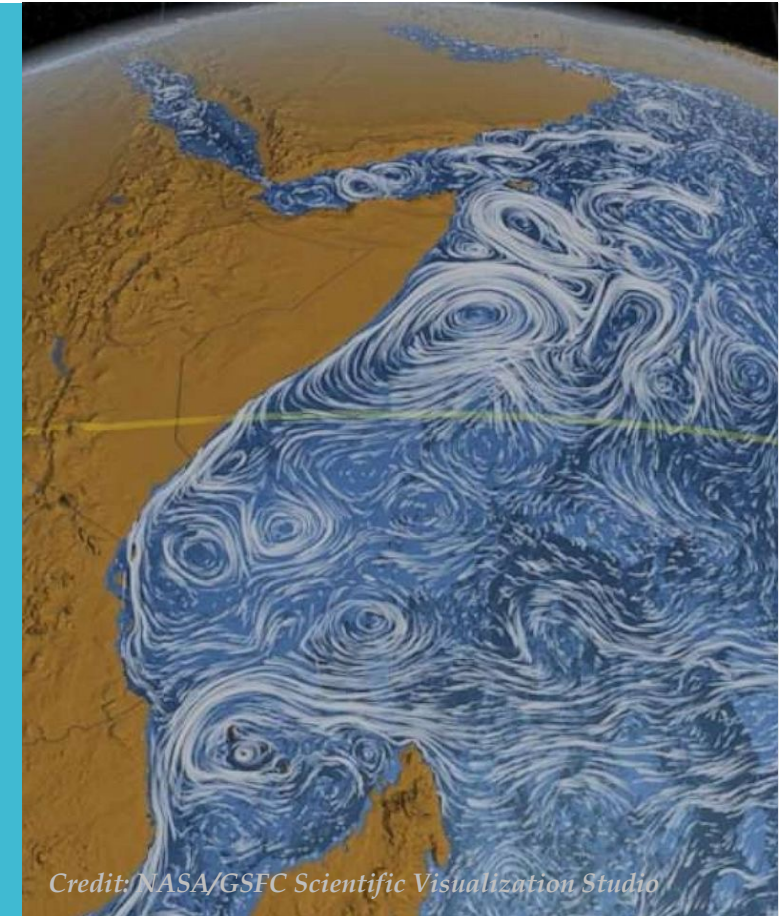
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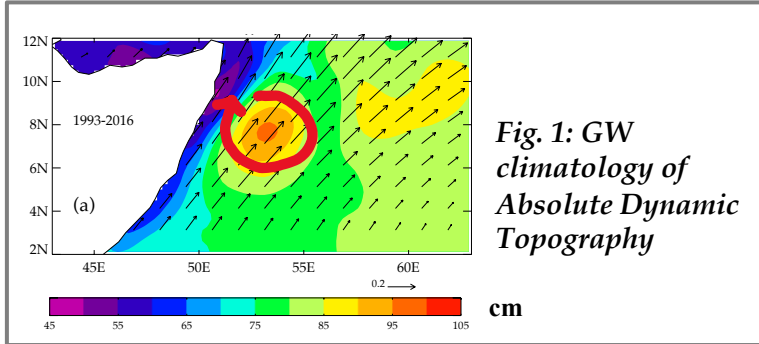
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Credit: NASA/GSFC Scientific Visualization Studio

• The Great Whirl (GW)

- A quasi-permanent anticyclonic eddy in the western Arabian Sea (first referenced in 1866 in Findlay's Directory of navigation of Indian Ocean)



- Appears in June, peaks in July-August, and dissipates in September-October
- Many studies have focused on deciphering its generation mechanism, life cycle, and collapse, with some emphasizing the role of local and remote forcing and others pointing to the role of internal instabilities
- Studies on forced variability (Schott and Quadfasel, 1982; Schott, 1983; Luther and O'Brien, 1989; McCreary et al., 1993; Kim et al., 2001; Rao et al., 2010; Beal and Dunhoe, 2012, 2013; Vic et al., 2014)
- Studies on the role of internal instabilities (Jensen, 1993; Fischer et al., 1996; Wirth et al., 2002)
- Past literature mainly describe GW seasonal variability

- Prominent signatures of GW in summer Absolute Dynamic Topography (ADT)
- Coherent signals in SST and Chl, with cooler SST and increased marine productivity in regions with lower ADT
- Offshore spreading of colder SST and high Chl along the northern flank of GW

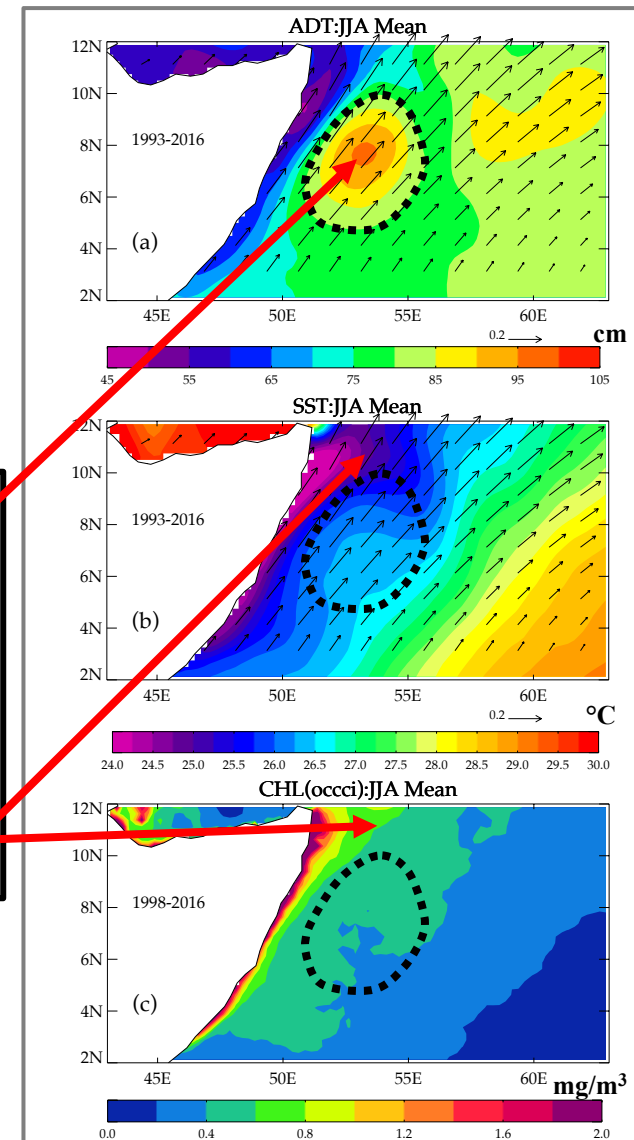
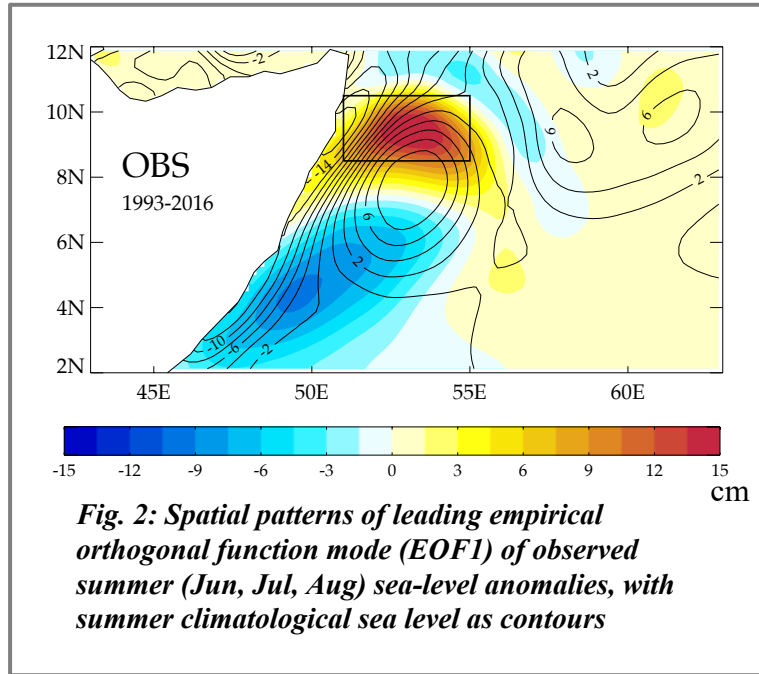


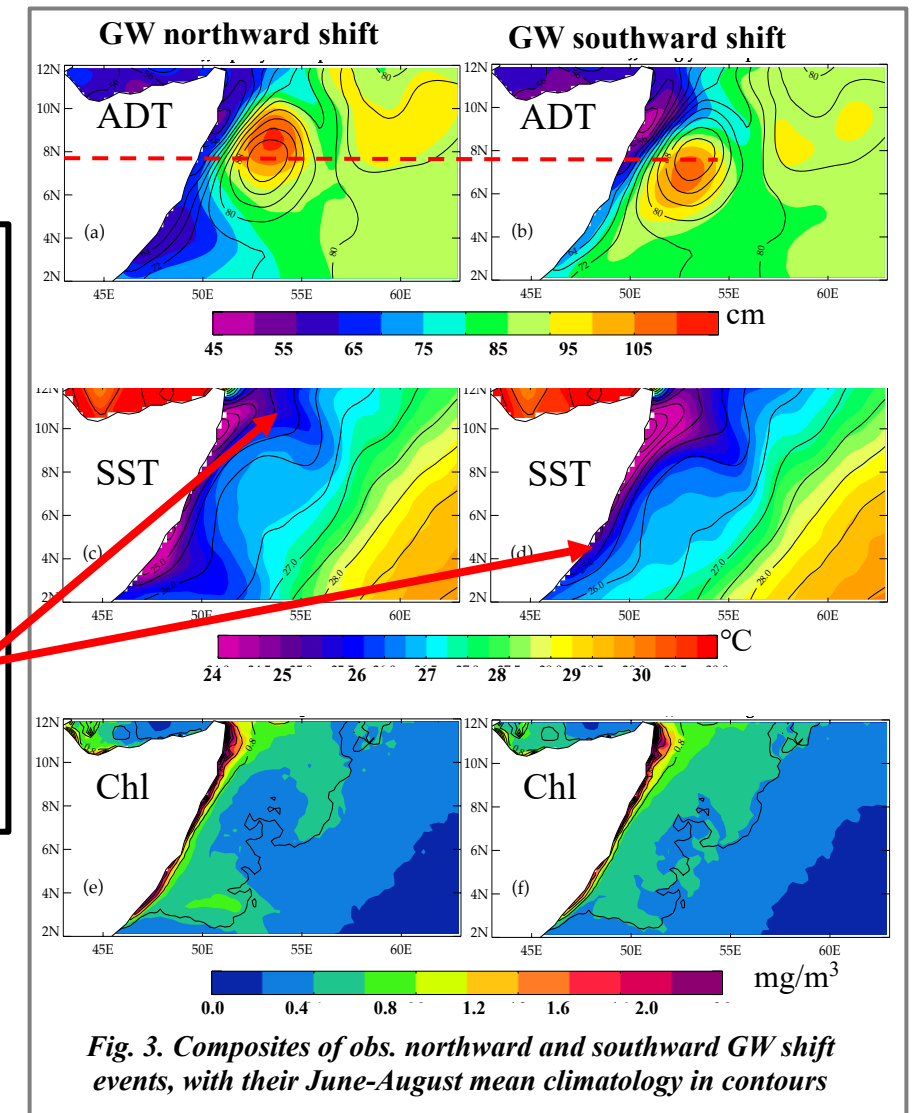
Fig. 2: Summer (June-August, JJA) climatology
 (a) Absolute dynamic Topography (ADT; cm)
 (b) Sea Surface Temperature (SST; °C)
 (c) Chlorophyll (Chl; mg/m³)

• GW non-seasonal variability and the associated signals



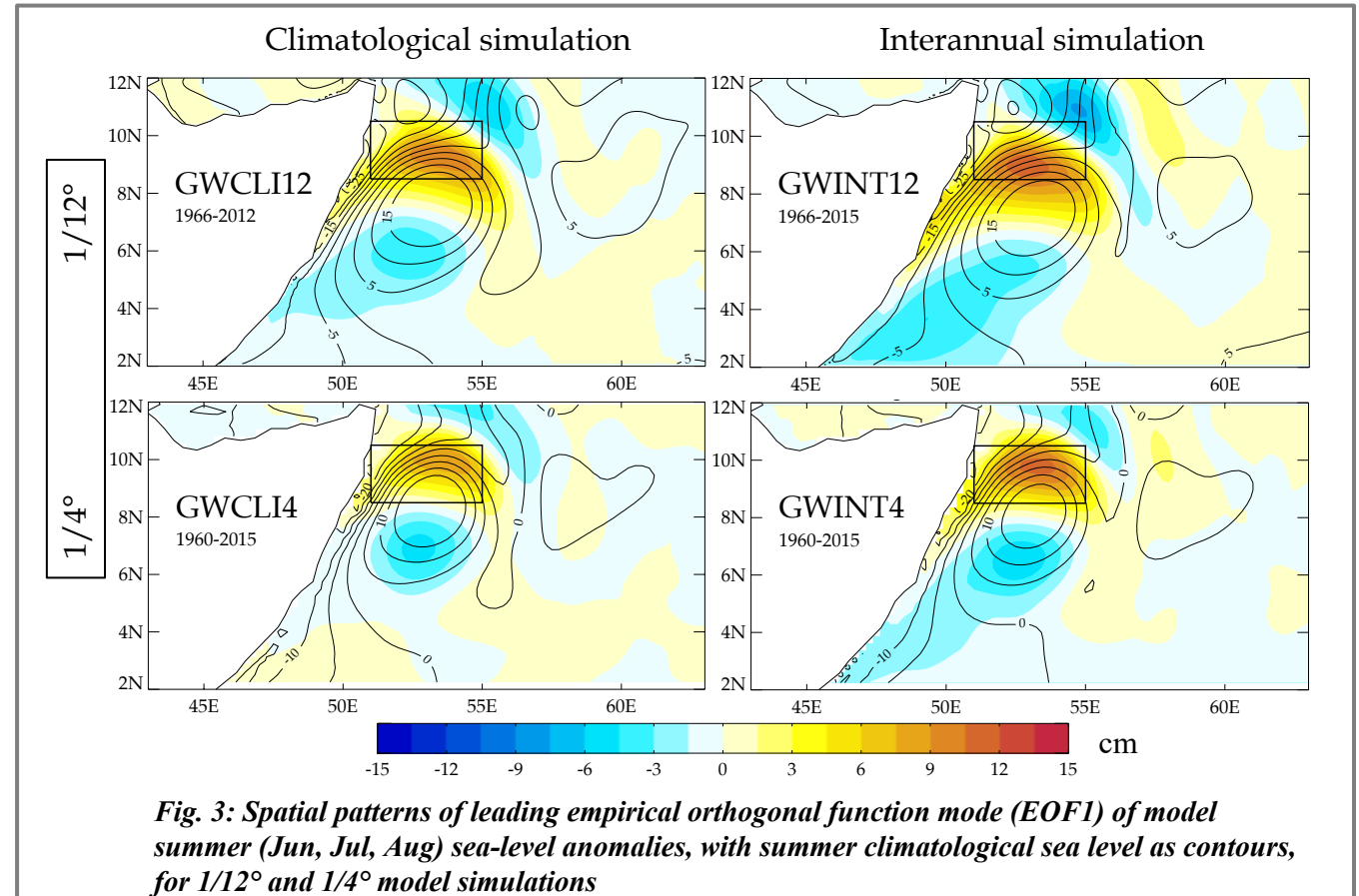
- Clear dipole structure with opposite anomalies north and south of the GW climatological location
- Observed non-seasonal variability is associated with ~100-km meridional shifts
- Typical duration: ~50 days

- Shifts in position of GW from the summer climatological mean position
- Associated changes in the distribution/spread in SST and Chl signatures
- Northward (southward) GW shifts inhibit the upwelling in the northern (southern) cold wedge



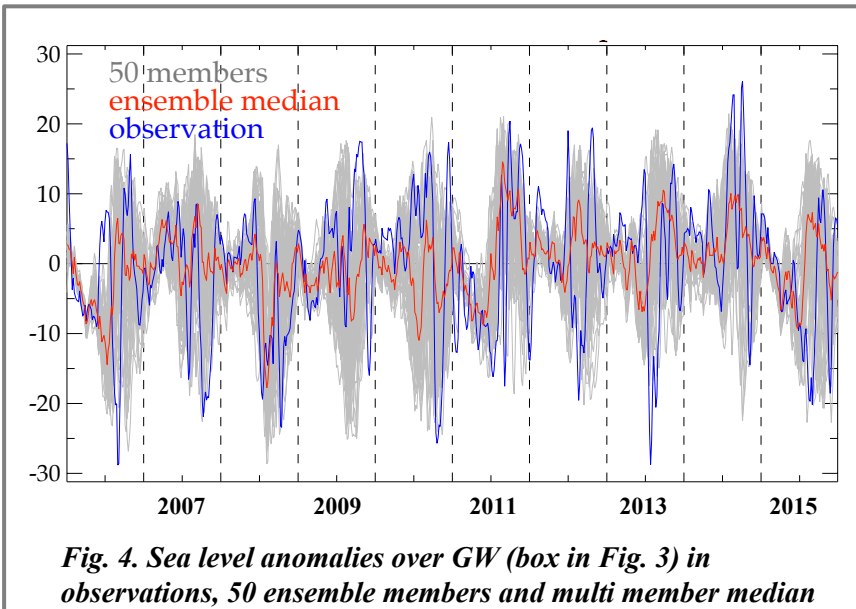
• GW non-seasonal variability in model

- Eddy-permitting simulation also simulates the GW meridional shifts
- Both $1/12^\circ$ and $1/4^\circ$ simulations capture the GW variability, albeit with some underestimation in magnitude
- Climatological simulation also simulates the GW variability $\Rightarrow$ role of internal variabilities

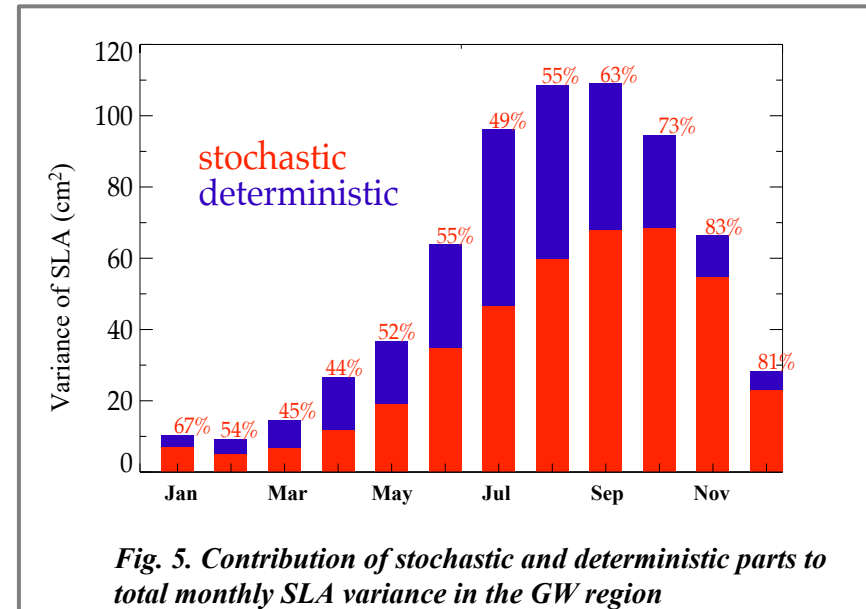


Is the GW variability atmospherically forced or driven internally?

• Contribution of forced and intrinsic variabilities



- Ensemble mean not zero: deterministic ocean response to forcing
- Spread: stochastic intrinsic variability



- Forced and internal processes equally contribute until July
- Stochastic intrinsic variability dominates from August onward

• Mechanism of deterministic response to wind forcing

- Correlation analysis (not shown) indicates that GW shifts are correlated with offshore wind-stress during May
- Those wind signals are likely associated with the ENSO ~6 months before (not shown)
- Consistent patterns of wind stress and sea level in May in observations, the ensemble mean OGCM simulation and simulation from a Linear Continuously Stratified (LCS) model
- Deterministic part of GW non-seasonal variability: oceanic response to offshore wind-stress curl during May

Suggested mechanism:

- Findlater jet forces a negative sea level offshore and positive signal at the coast
- Latitudinal dependence of the Rossby wave phase speed => east/west dipole, which projects onto the GW spatial pattern
- Signals are likely amplified through energy extraction from the background state that allows the GW to grow

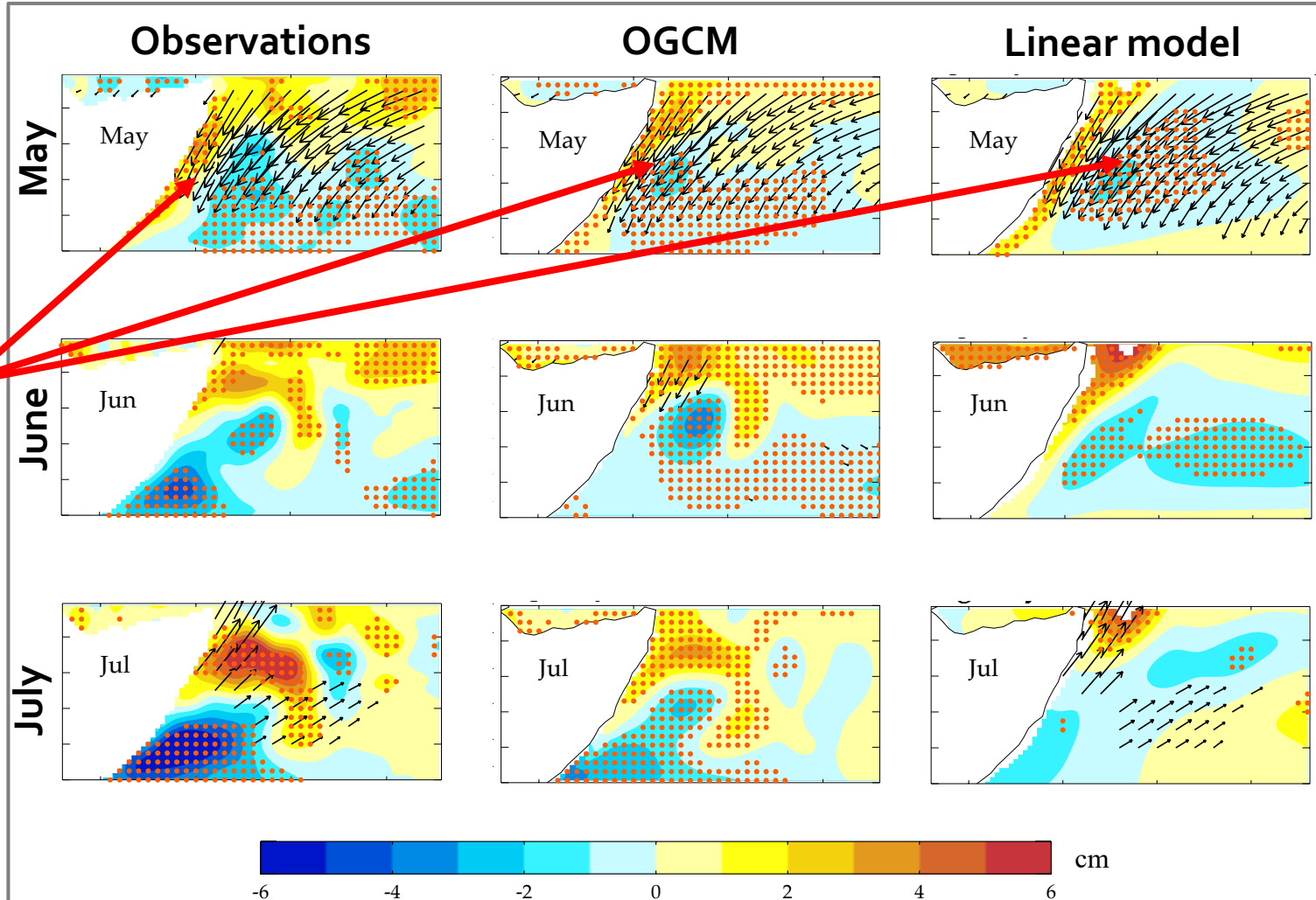


Fig 5. Regression of monthly SLA anomalies (shaded) and wind-stress anomalies (vectors) onto May wind-stress curl index from obs (left), 50-members ensemble mean (middle) and LCS model. LCSmodel sea-level is scaled by a factor of 2 for clarity

- **Summary**

- Great Whirl non-seasonal sea level variability is associated with ~ 100 -km northward or southward shifts, with coherent SST & Chl signals
- Eddy-permitting model simulations reproduce this variability reasonably well
- 50-members ensemble simulations and a simulation with climatological forcing suggest that chaotic internal variability and the deterministic response to external forcing both contribute to GW meridional shifts, with comparable contributions
- Deterministic response is likely associated with the Rossby wave response to the May offshore wind-stress curl, which projects onto the GW and is amplified through nonlinear interaction with the background state

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Thank you

