Normal Modes of the South Indian Ocean in a Shallow-Water Model

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South Indian Ocean Bathymetry





South Indian Ocean Bathymetry





South Indian Ocean Bathymetry





• Warren et al. (2002): current meter data from Mascarene Basin





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• Warren et al. (2002): current meter data from Mascarene Basin

- Strong oscillations with approx. 60-day period
- Westward propagation @ 7cm/s
- WWL suggested barotropic Rossby Basin Mode





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- Study whether basin modes exist that could explain observations
- Calculate normal modes of motionless solution in barotropic Shallow-Water (SW) model
 - Spherical coordinates
 - Bathymetry based on ETOPO-2
 - 0.25° x 0.25° resolution
 - Horizontal viscosity: A_h = 10³ m²s⁻¹
 - Bottom friction: $r = 10^{-7} s^{-1}$





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System of discretized equations:

$$\frac{dx}{dt} = F(x)$$

Assume small perturbation:

 $x' = \hat{x} e^{\sigma t}$

• Linearize:

$$\frac{dx'}{dt} = F(x') \rightarrow \sigma \hat{x} = \left(\frac{\partial F}{\partial x}\right) \hat{x}$$



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Solving the eigenvalue problem gives you:

- A set of eigenvalues/eigenmodes: {(σ_i, x_i) j=1,N}
- Eigenvalues: $\sigma = \sigma_r + i \sigma_i$
- Eigenmodes: $x = x_r + i x_i$

 σ_r = growth rate; σ_i = oscillation frequency

(complex) spatial pattern

Jacobi-Davidson QZ (JDQZ) method

• Finds eigenvalues close to a pre-specified target τ

MRILU preconditioning

Multi-level Renumbering Incomplete LU factorization



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T = 58.7 days



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T = 59.6 days



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RATORY

EST. 1943



Decaying mode found in altimeter data/models



LARGE SCALE 20-100 DAY SEA SURFACE HEIGHT VARIABILITY



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Decaying mode found in altimeter data/models



Webb & de Cuevas (2002)



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- Webb & de Cuevas (2002): decay time of only 3.45 days in OCCAM
 - "Energy leaks away along Southeast Indian Ridge"
- Fu (2003): damping time scale longer than 20 days



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T = 4.97 days



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T = 5.94 days



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T = 7.52 days



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• Can we find evidence in mooring data?

- Current meters (AUSSAF array)
- Horizontal Electric Field (HEF) recorders (SAFDE array)
- Look for:
 - Coherence among individual moorings at specific frequencies (POPs?)
 - Polarization of velocity vector consistent with dynamical modes
- Work in progress, in collaboration with Helen Phillips (U. Tasmania)



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Conclusions

- South Indian Ocean houses large variety of topographically-trapped wave modes
- Observed 60-day variability in Mascarene Basin due to barotropic normal mode: can be described as Rossby basin mode in tilted basin
- Decay rate of Australia-Antarctic Basin mode enigmatic
- Spectrum of wave modes on Southeast Indian Ridge



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