Dynamics and forcing of interannual regional steric sea level variability

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Interannual RMS variability from altimetry*

...what processes underlie these patterns?

*Merged TOPEX/Poseidon/Jason data ‘93-’04, smoothed in space (5°) and time (1 yr)
• Mechanisms of sea level variability
  – **Forcing:** external atmospheric driving (i.e., winds and buoyancy) and intrinsic ocean processes.
  – **Dynamics:** density advection, wave propagation, local Ekman pumping, mixing, etc.

• An ocean state estimate
  – ECCO-GODAE v2.216 (1993-2004)*
  – MITgcm, 80°S-80°N; 1°×1° grid; 23 vertical layers
  – Fit to altimetry, hydrography and other datasets
  – Satisfies governing thermo/dynamics and conservation laws (momentum, energy, etc.)

*Wunsch, Ponte & Heimbach (2007) J. Climate 20
Hydrostatic condition:

\[ \zeta = \zeta_p + \zeta_{bp} \]

...what governs the steric changes?
Forcing experiments*

<table>
<thead>
<tr>
<th>Wind forcing</th>
<th>Buoyancy forcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully Variable</td>
<td>Fully Variable</td>
</tr>
<tr>
<td>Climatological</td>
<td>Climatological</td>
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</tbody>
</table>

- Influence of interannual forcing mechanisms:
  - Full: \( \zeta^F = \zeta^{VWVB} \)
  - Wind: \( \zeta^W = \zeta^{VWCB} - \zeta^{CWCB} \)
  - Buoy.: \( \zeta^B = \zeta^{CWVB} - \zeta^{CWCB} \)
  - Intr.: \( \zeta^I = \zeta^{CWCB} \)

- Assume linearity:
  - \( \zeta^F = \zeta^W + \zeta^B + \zeta^I \)

*Forcing represents NCEP/NCAR fields adjusted via ECCO optimization*
Forcing of steric variability

Full Forcing $\zeta^F$

Wind Forcing $\zeta^W$

Buoyancy Driving $\zeta^B$

Intrinsic Generation $\zeta^I$

0 2 4 6 8 10 cm
Wind-forced variability

Steric height budget:

\[ \zeta_\rho = A + M + F \]

Piecuch & Ponte (2011) GRL 38
Tropical Pacific
15°S-5°S; 130°W-90°W

\[ \zeta_p \text{ FULL} \]
\[ \zeta_p \text{ WIND} \]
\[ \zeta_p \text{ BUOY.} \]
\[ \zeta_p^F - (\zeta_p^W + \zeta_p^B) \]
\[ \zeta_p \text{ BUOY.} \]
FORCING
ADVECTION
MIXING
Subtropical Indian intrinsic variability

Time series @ 27.5°S, 69.5°E

\( \zeta_\rho \) FULL \( \zeta_\rho \) INTRINSIC
\( \zeta_\rho \) BUOYANCY+ \( \zeta_\rho \) WIND
\( \zeta_\rho \) RESIDUAL
Summary

- Interannual $\zeta$ variability mostly represents steric changes resulting from wind variations and associated large-scale advection patterns.
- However, other forcing mechanisms and dynamics can be important regionally:
  - Local and remote buoyancy signals in tropics/subtropics.
  - Parameterized sub-grid-scale fluxes in extratropics.
  - Intrinsic variability in subtropics.
- Need better understanding and accurate modeling of all these processes to simulate and project low frequency changes in regional sea level:
  - Errors incurred if buoyancy forcing is assumed to have no remote or dynamical effect.
  - Realism of parameterized sub-grid-scale mixing in coarse resolution models.
Comparison interannual RMS variability

**ECCO**

**Altimetry**

![Comparison of ECCO and Altimetry](image)
Checking decomposition

Residual RMS $\zeta_\rho$

Wind Forcing $\zeta_\rho^W$

Buoyancy Driving $\zeta_\rho^B$

Intrinsic Generation $\zeta_\rho^I$
Mixing Components

Laplacian Diffusion (LAP)

G Gent-McWilliams/Redi (GMR)

Nonlocal K profile (KPP)

Mixing terms:

\[ M = \text{LAP} + \text{GMR} + \text{KPP} \]
Buoyancy-driven changes

Total Variability $\zeta_p^B$

Surface Buoyancy Exchange $F^B$

Advective Transport $A^B$

Diffusive Transport $M^B$
Tropical Atlantic
20°S-5°N; 30°W-10°E

\[ \zeta_\rho \text{ FULL} \]
\[ \zeta_\rho \text{ WIND} \]
\[ \zeta_\rho \text{ BUOY.} \]
\[ \zeta_\rho^F - (\zeta_\rho^W + \zeta_\rho^B) \]
\[ \zeta_\rho \text{ BUOY.} \]
FORCING
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Graph showing variability in meters over years from 1993 to 2005.