Recent Decadal Changes in Tropical Pacific Sea-Surface Height due to Wind-Driven Sea-Surface Temperature Variability

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Introduction: Pacific SSH Variability

- Sea-surface height (SSH) over the western tropical Pacific has risen more rapidly than over the eastern tropical Pacific during the altimeter era.

- Many studies interpret this spatial pattern of SSH trends in terms of heat redistribution and adiabatic response to winds (Lee and McPhaden 2008; Feng et al. 2010; Timmermann et al. 2010; Merrifield 2011; Qiu and Chen 2012; Merrifield and Maltrud 2011; Merrifield et al. 2012, etc.).
Introduction: Pacific SSH Variability

- Others explicitly reason that diabatic effects and atmospheric exchanges might also be important to SSH trends (e.g., Fukumori and Wang 2013).


- Pacemaker experiments show that coupling between winds and sea-surface temperatures over the eastern equatorial Pacific contributed crucially to the recent surface warming slowdown (Kosaka and Xie 2013; England et al. 2014; Watanabe et al. 2014; Delworth et al. 2015, etc.).
The relative impacts of oceanic redistribution and atmospheric exchanges of buoyancy on decadal tropical Pacific SSH changes remain to be clarified.

As such, the nature of a recently reported reversal in Pacific SSH trend patterns (Hamlington et al. 2016) is unclear.

- Due to change in the winds, or damping surface heat flux, or both?
This Study

- Question here:
  - What are the roles of oceanic heat redistribution and atmospheric fluxes in observed decadal changes in tropical Pacific SSH?

- Research tool—ECCO Version 4 Release 3:
  - Constrained to most ocean data over 1992–2015;
  - Agreement with data achieved via iterative optimization procedure;
  - State estimate is a physically consistent ocean model solution.

- To understand the contributing processes we:
  - Perform additional model experiments with modified forcing.
  - Use model diagnostic output to evaluate closed property budgets.
• We examine the Equatorial Pacific region (7.5°S–7.5°N, 105–175°W).

• ECCOv4 is an excellent fit to the altimeter data over this region.
• Decompose sea-surface height ($\zeta$) using the hydrostatic equation into mass ($\zeta_M$), thermosteric ($\zeta_T$), halosteric ($\zeta_S$), and nonlinear contributions ($\zeta_N$):

$$\zeta = \zeta_M + \zeta_T + \zeta_S + \zeta_N.$$ 

• Sea-surface height changes ($\zeta$) in this region are mainly thermosteric in nature—due to changes in ocean heat storage ($\zeta_T$).
• Perform forcing experiments to separate $\zeta_T$ contributions due to variable momentum forcing ($\zeta_T'$) from buoyancy and mass flux contributions ($\zeta_T\overline{T}$):

$$\zeta_T = \zeta_T' + \zeta_T\overline{T}.$$ 

• Thermosteric SSH changes ($\zeta_T$) are almost entirely related to variable momentum (wind) forcing ($\zeta_T'$).
Results: Thermosteric Budget Diagnosis

- Diagnose wind-driven thermosteric changes ($\zeta_T^{\tau'}$) due to ocean advection ($A^{\tau'}$), diffusive mixing processes ($M^{\tau'}$), and local surface heat flux ($F^{\tau'}$):

$$
\zeta_T^{\tau'} = A^{\tau'} + M^{\tau'} + F^{\tau'}.
$$

- The $\zeta_T^{\tau'}$ budget reflects a complex interweaving between ocean advection ($A^{\tau'}$) and heat flux ($F^{\tau'}$) contributions.
• Partition the surface heat flux term ($\mathcal{F}^{\tau'}$) into latent ($\mathcal{F}_{E}^{\tau'}$), sensible ($\mathcal{F}_{H}^{\tau'}$), longwave ($\mathcal{F}_{L}^{\tau'}$), shortwave ($\mathcal{F}_{S}^{\tau'}$), and freshwater ($\mathcal{F}_{P}^{\tau'}$) contributions:

$$\mathcal{F}^{\tau'} = \mathcal{F}_{P}^{\tau'} + \mathcal{F}_{E}^{\tau'} + \mathcal{F}_{H}^{\tau'} + \mathcal{F}_{L}^{\tau'} + \mathcal{F}_{S}^{\tau'}.$$ 

• Latent (evaporative) heat fluxes ($\mathcal{F}_{E}^{\tau'}$) make most important contributions to the overall surface flux.
In a state estimate, interannual and longer equatorial Pacific SSH changes are due to wind-driven changes in advection and latent surface heat fluxes.

These results establish that the decadal adjustment in this region involves important diabatic processes.

What sets the damping time scale of the heat flux?

What are the relative influences of diabatic and adiabatic mechanisms in controlling the advection?

How do sea-surface height changes over this region relate to other tropical or extratropical Pacific regions?
Thank you

Questions?