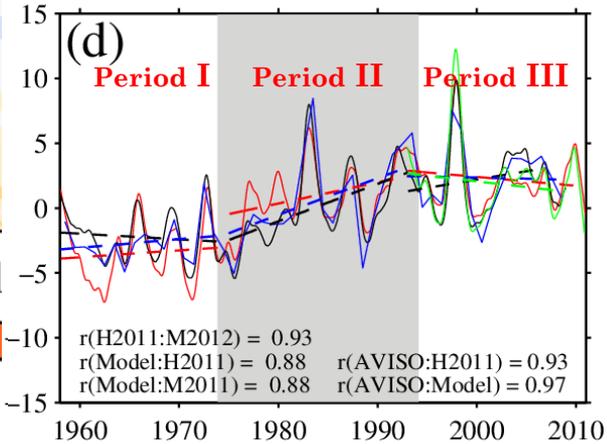
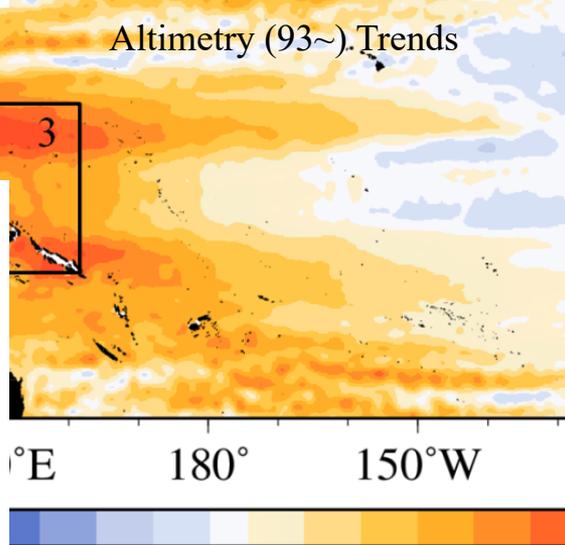
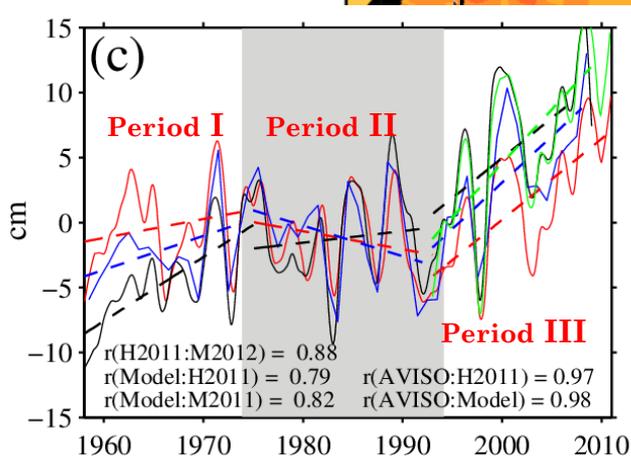
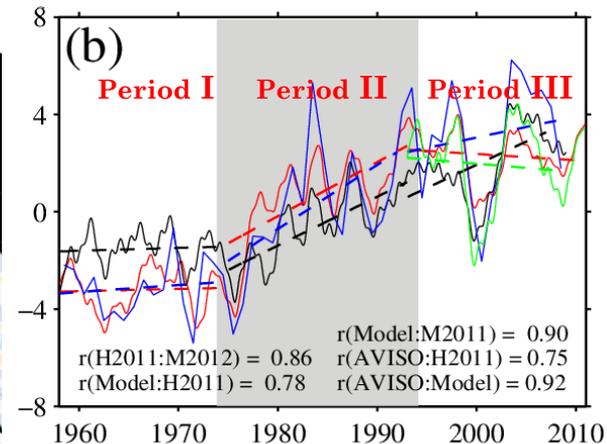
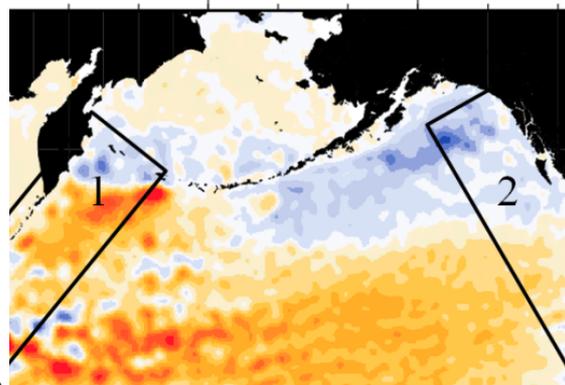
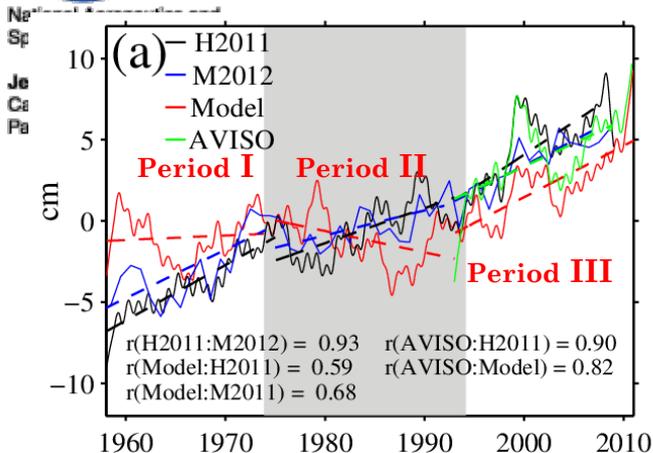




# Sea-Level Swings in the Pacific—A Review



## Tony Song



Moon, J.-H., Y. T. Song, P. D. Bromirski, and A. J. Miller (2013), Multidecadal regional sea level shifts in the Pacific over 1958–2008, *J. Geophys. Res. Oceans*.



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# Sea-Level swings Intensified ! (focusing on the tropics)



Moon, Song, Lee, *JGR* (2015):

Over the past 60 years, regional sea-level changes in the tropical Pacific have been intensified.

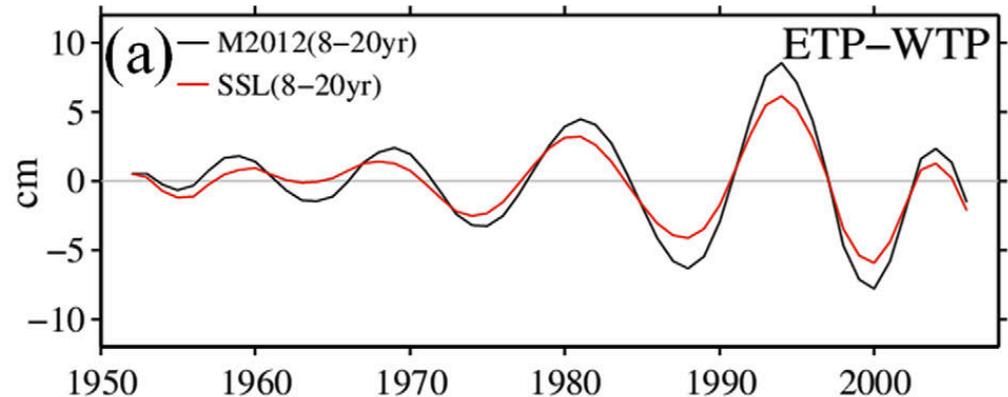
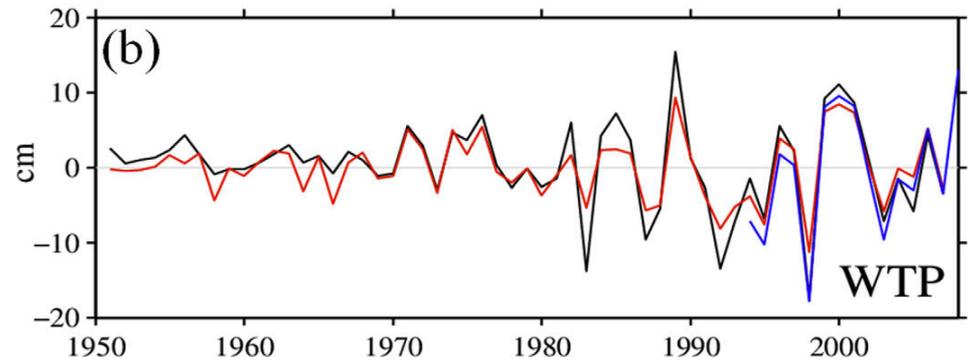
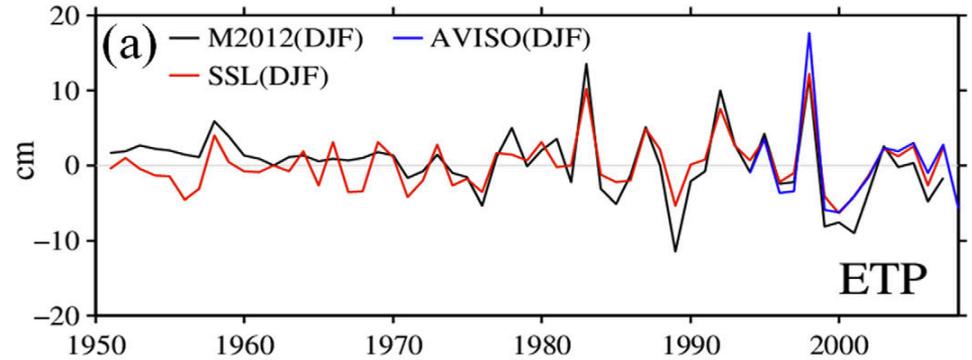
Han et al. (2014): *Intensification of decadal and multi-decadal sea level variability in the western tropical Pacific during recent decades. Clim. Dyn.*

Dealing Climate Cycles to Increase Sea Level Swings

NASA



The tropical Pacific Ocean isn't flat like a pond. Instead, it regularly has a high side and a low side. Natural cycles such as El Niño and La Niña events cause this sea level seesaw to tip back and forth, with the ocean near Asia on one end and the

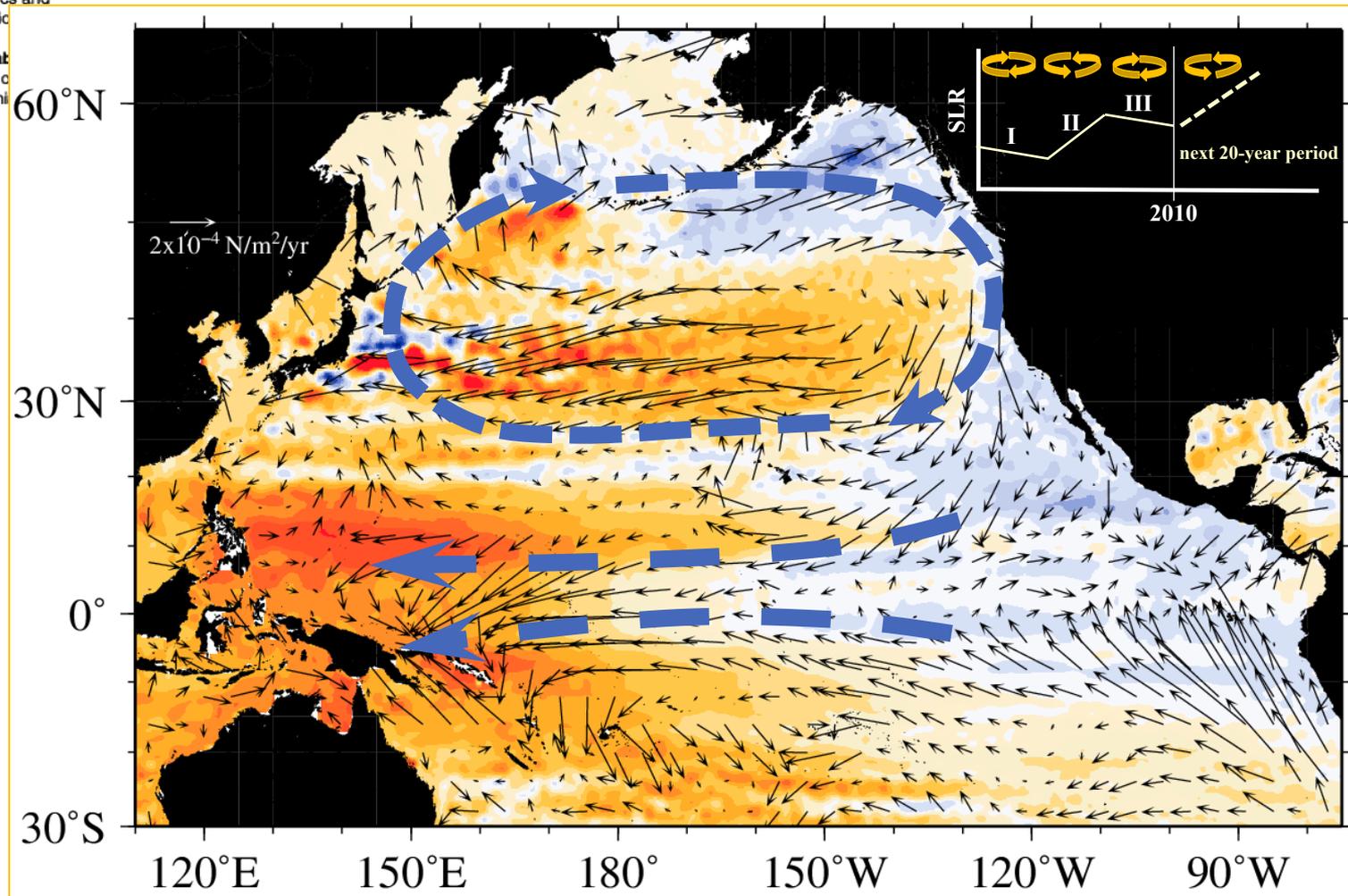




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Pasadena, California

# Why? The Role of Wind Forcing



- [Lee, T., and M. J. McPhaden \(2008\)](#), Decadal phase change in large-scale sea level and winds in the Indo-Pacific region at the end of the 20th century, *Geophys. Res. Lett.*
- [Qiu, B., and S. Chen \(2012\)](#), Multidecadal sea level gyre circulation variability in the Northwestern tropical Pacific Ocean, *J. Phys. Oceanogr.*



# Ocean Mass (E-W pressure gradient) Contribution



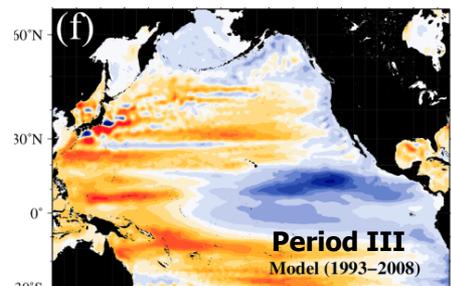
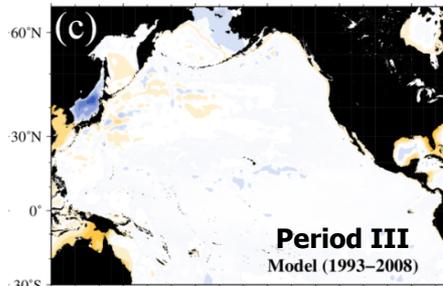
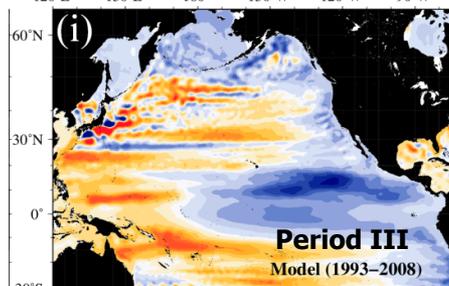
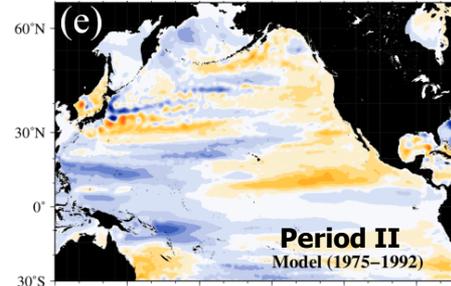
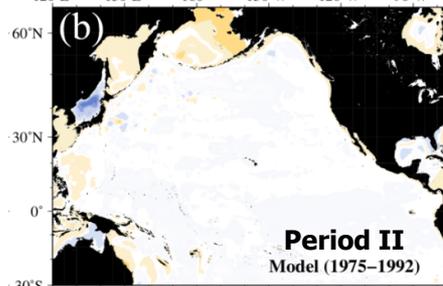
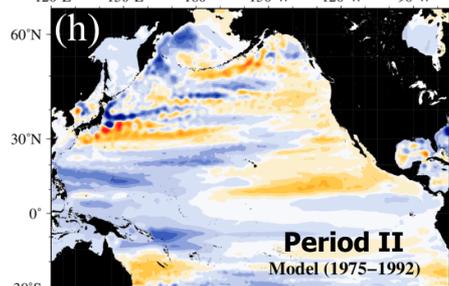
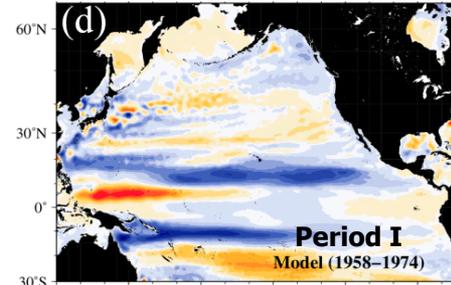
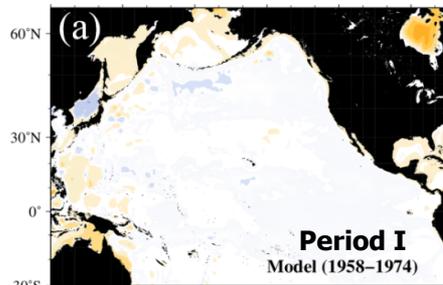
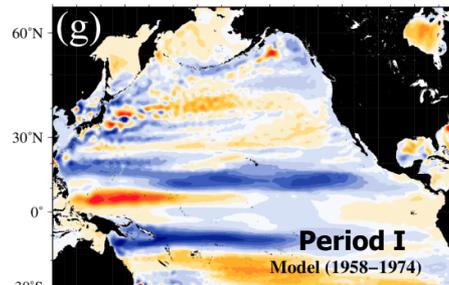
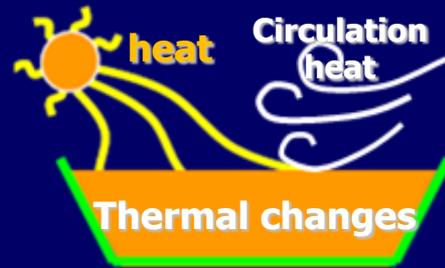
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**Regional  
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-10 -5 0 5 10 mm/yr

-10 -5 0 5 10 mm/yr

-10 -5 0 5 10 mm/yr

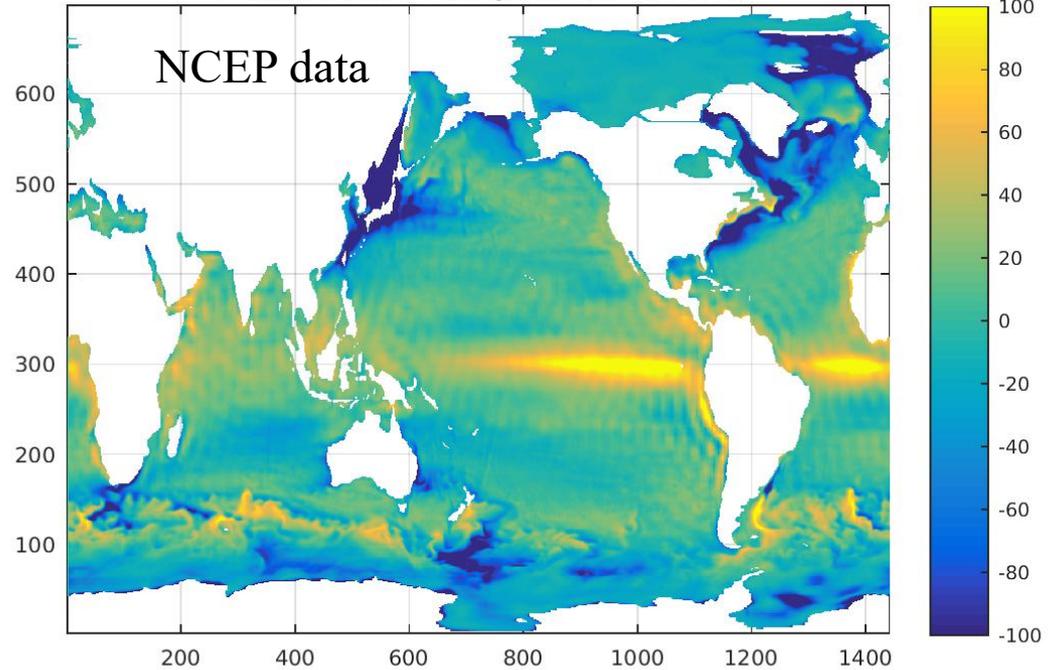


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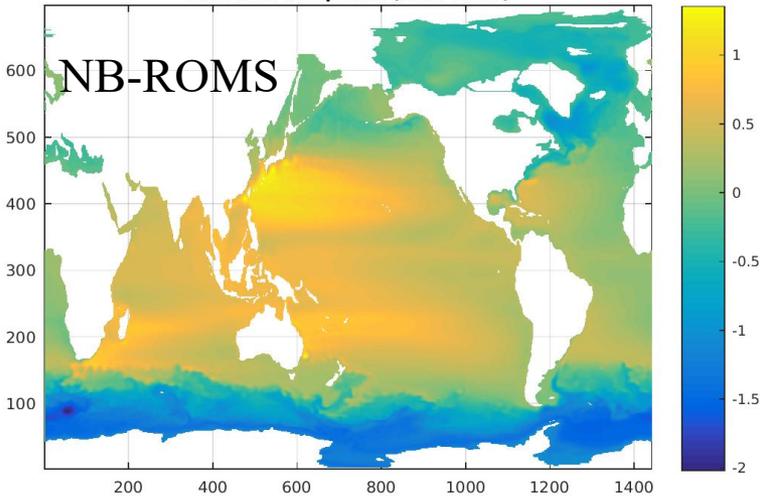
# Heat Flux Contribution



Heat flux ( $W/m^2$ ) composite (1993-2017)



Sea Level composite (1993-2017)





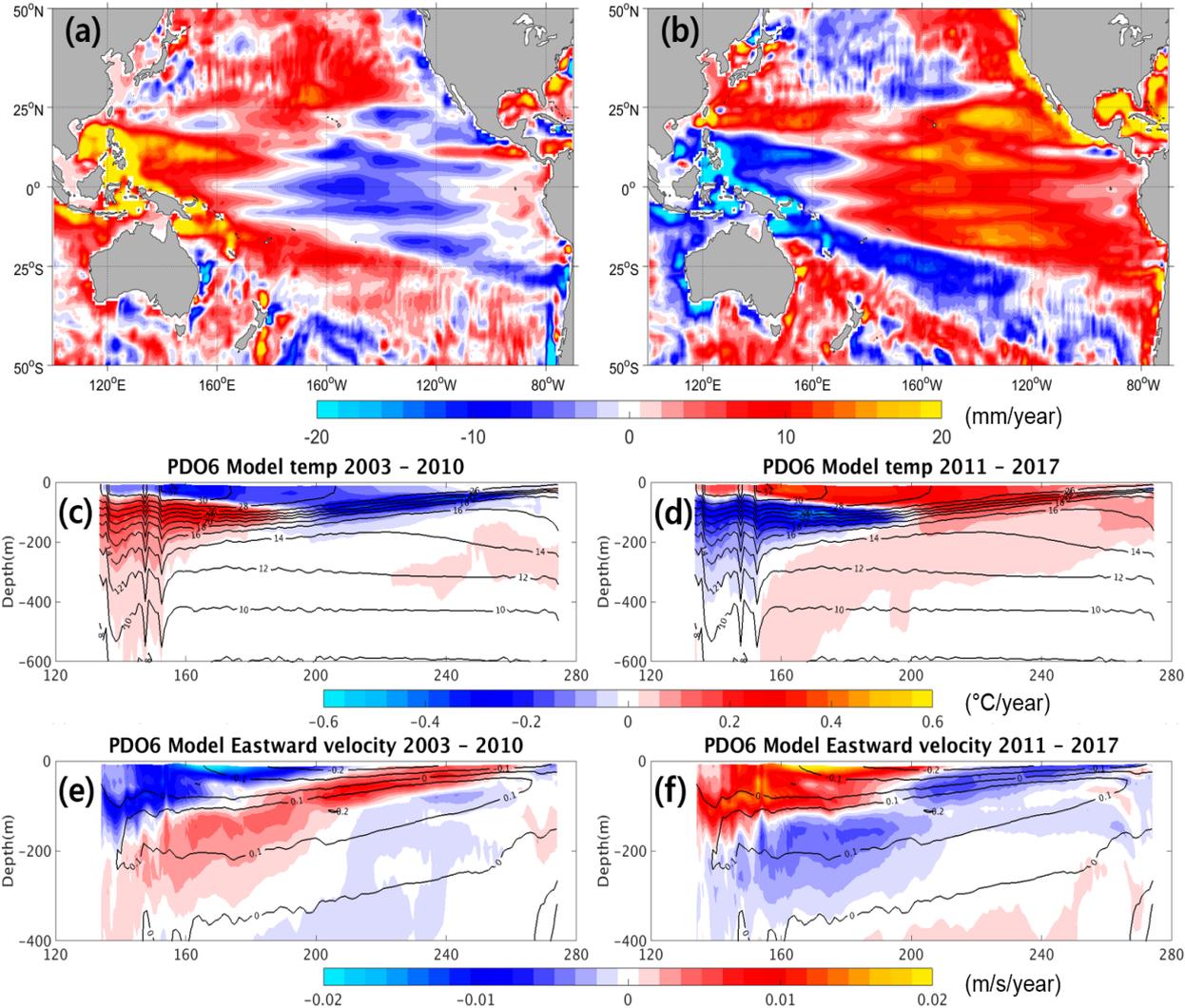
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# How? The Role of Ocean Circulation



**Cha, Moon, Song (2018):**  
A recent shift toward an El Niño-like ocean state in the tropical Pacific and the resumption of ocean warming.  
*Geophysical Research Letters.*



Temperature swing →

Transport swing →

**Result:** Climate modes and wind forcing regulate: the strength of the Equatorial Undercurrent, and the warming rate of upper-ocean temperature.



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# PDO and ENSO Modulation & Prediction



Moon, Song, Lee, *JGR-Oceans* (2015): PDO and ENSO modulations intensified decadal sea level variability

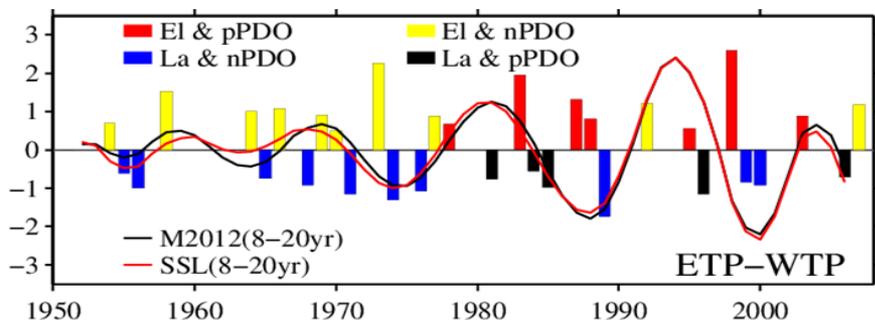


Fig 1: Sea level (black) and SSL (red line) from East-West Pacific.

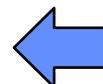
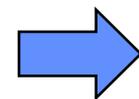


Fig 1: The intensification is modulated by PDO and ENSO cycles.

Hamlington, et al, *JGR-Oceans* (2016):

An ongoing shift in Pacific Ocean sea level.



SL changes due to different climate modes (e.g., PDO and ENSO) can be separated, therefore, are predictable.

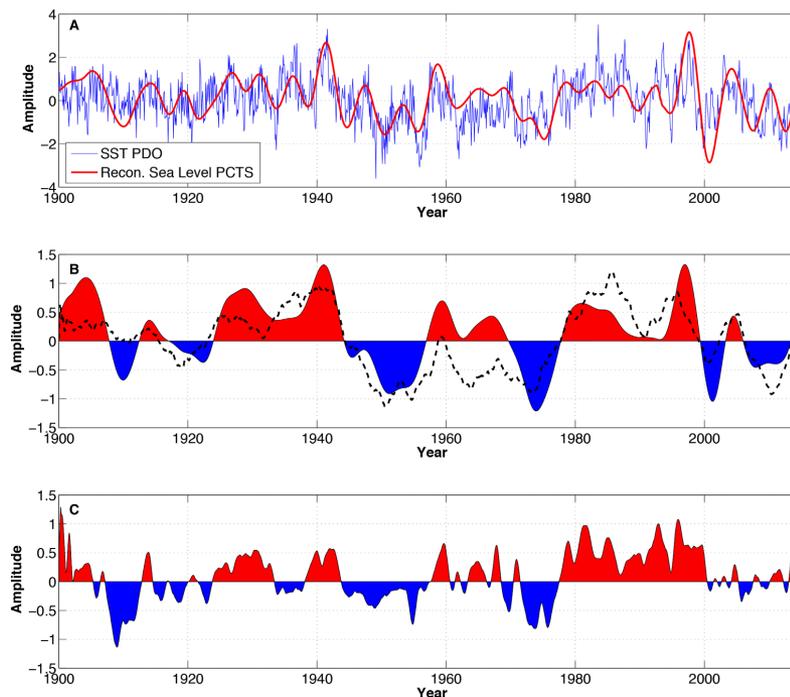


Fig 2: Recent shift to the low-frequency PDO climate signal.



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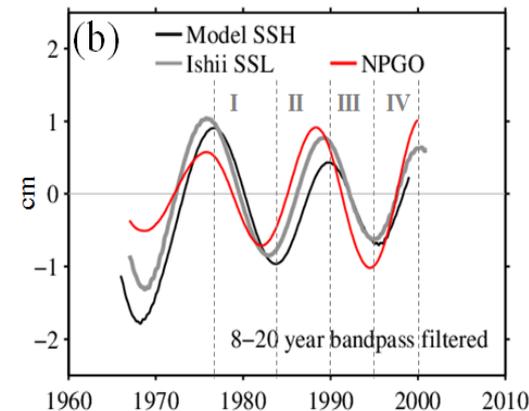
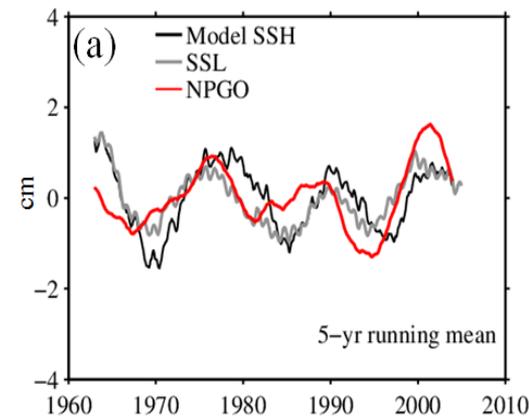
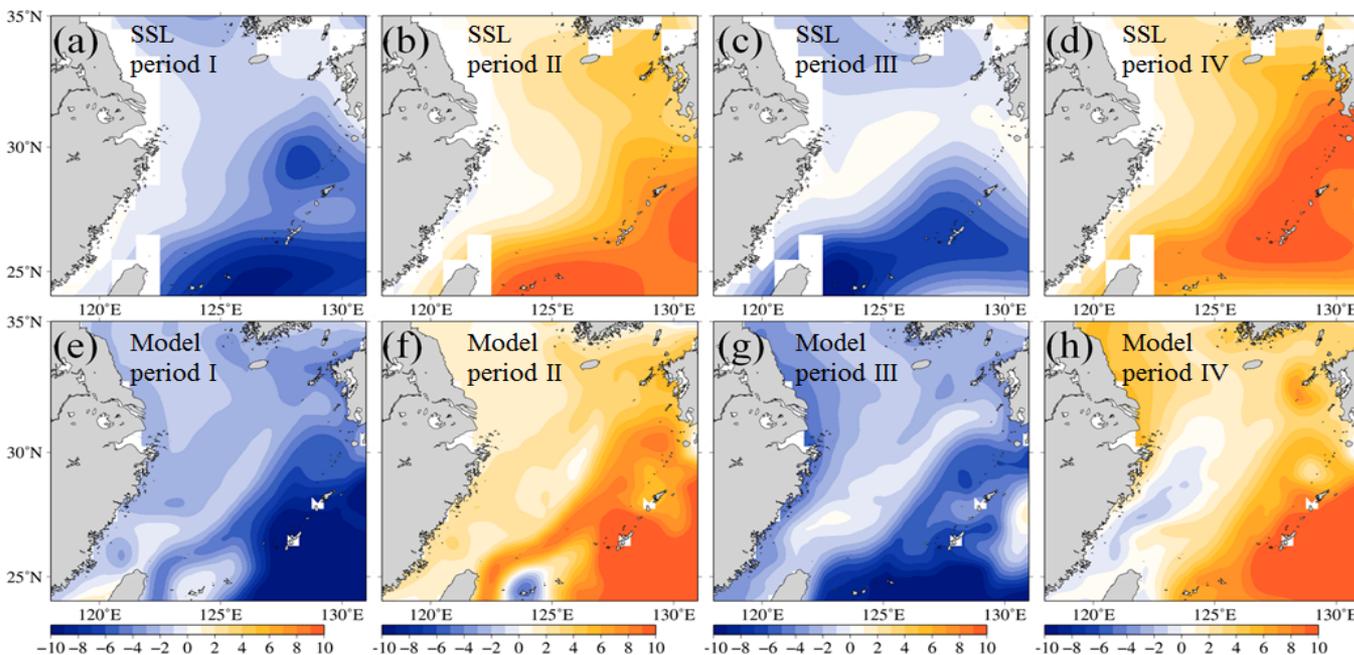
# Effects on Coastal Oceans

## Challenges in understanding and projection



### Coastal sea-level & Slope barrier

I) 1978-1982, II) 1983-1988, III) 1989-1993, IV) 1994-2000



**Moon & Song (2016)**, Decadal sea level variability in the East China Sea linked to the North Pacific Gyre Oscillation, *Cont. Shelf Res.*

**Weiqing Han, Detlef Stammer, Philip Thompson, Tal Ezer, Hindu Palanisamy, Xuebin Zhang, Catia M. Domingues, Lei Zhang, Dongliang Yuan (2019)**, Impacts of basin-scale climate modes on coastal sea level: A review, *Surveys in Geophysics.*



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## Summary

- Observational evidence: The Pacific Sea Levels have been swinging over the last 60 years, modulated by climate modes (e.g., PDO and ENSO), affecting coastal oceans.
- Understanding & Modelling: Wind forcing and Ocean circulation are the two important contributors to the regional sea-level changes.
- Projection & Challenges: Climate modes (e.g., PDO and ENSO) may be separable (by statistical or modeling approaches), indicating projection or prediction of sea level changes is possible (with challenges).