Forcing Mechanisms of Sea Level Variations in Shelf Waters off the coast of British Columbia

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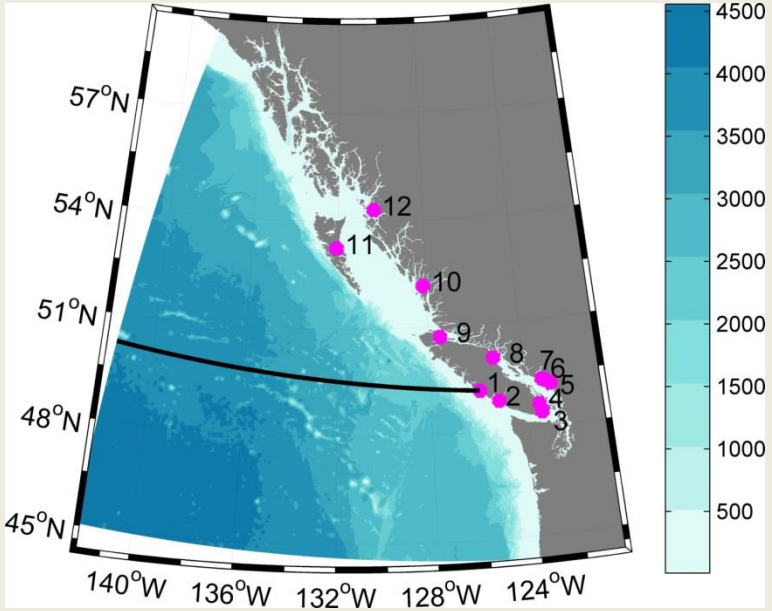
Outline

- Northeast Pacific 1/36 degree (NEP36) model setup
- Focusing on analysis with monthly time series of sea levels: seasonal, intra-seasonal & inter-annual variations
- Evaluation with altimeter & tide gauge data
- Calculation of steric height; decomposing halo & thermo contributions
- Regression analysis to wind forcing, heat and fresh water fluxes?
- Local vs remote forcing: Climatology OBC test
- Conclusions

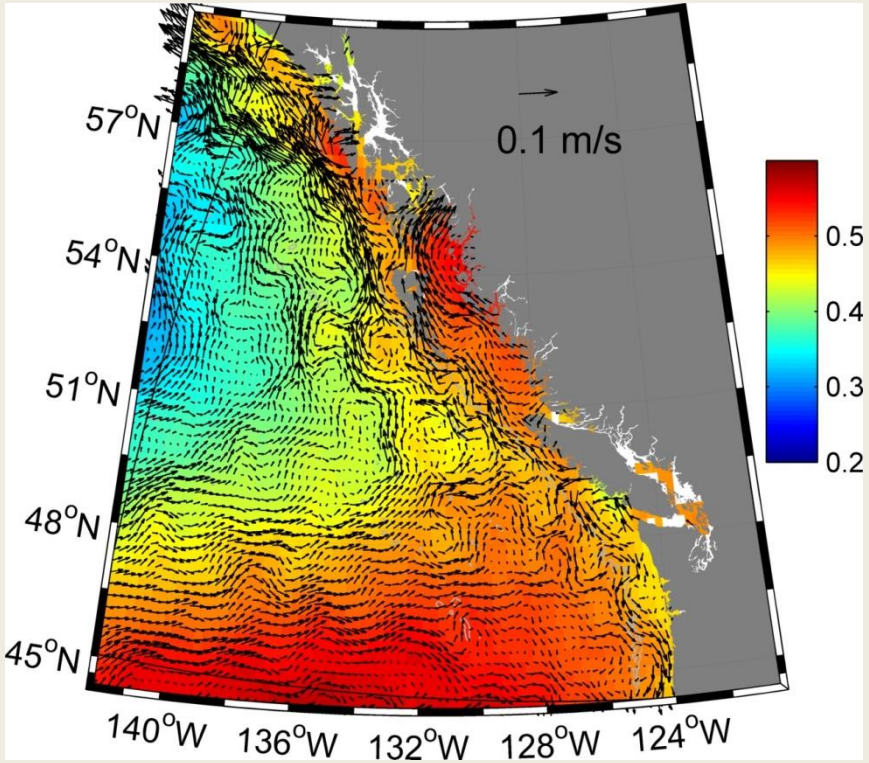
NEP36 Hindcast (2007-2016)

- Based on NEMO3.6
- Use 558 oceanic processors, 18 processors for XIOS in detached mode
- Runtime: 15 days to complete 10-year simulation, time step 60 s
- Resolution: 1/36 degree (1.7 km), 50 levels
- Initial conditions: T/S, U/V & SSH from daily PSY4
- Open boundaries: T/S, U/V & SSH from daily PSY4; 8 constituents of tidal heights & depth-averaged currents from WebTide
- Surface forcing: hourly CFSR wind, air pressure & air T, specific humidity; 0-n hour averaged precip/radiation
- Monthly climatology of river runoff (Morrison et al., 2012)
- Smagorinski horizontal mixing scheme

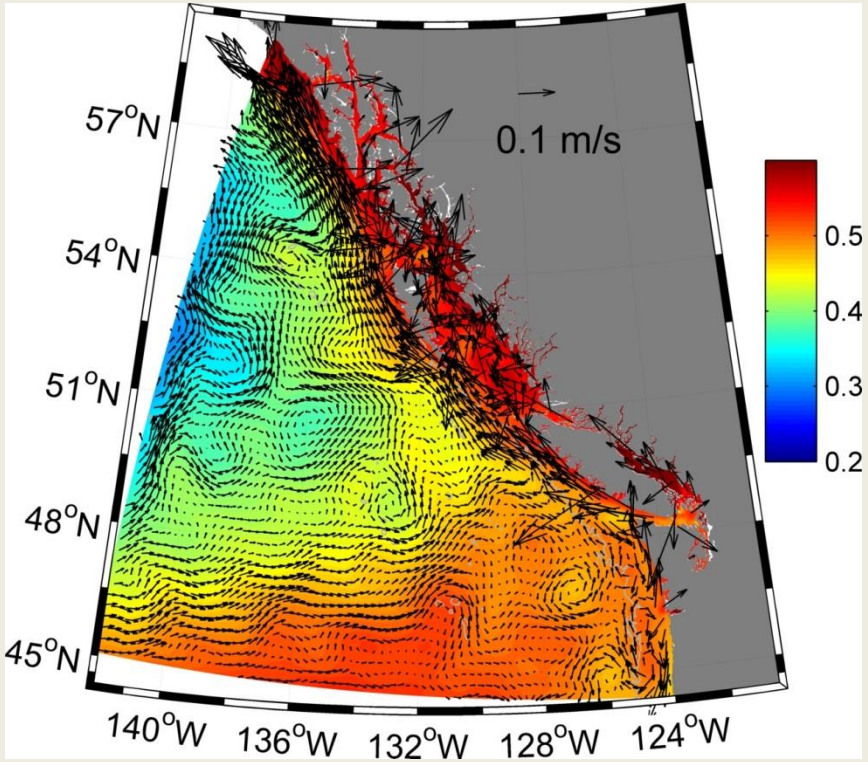


Mean Sea Level & Surface Geostrophic Currents (2008-2016)

Altimeter



NEP36



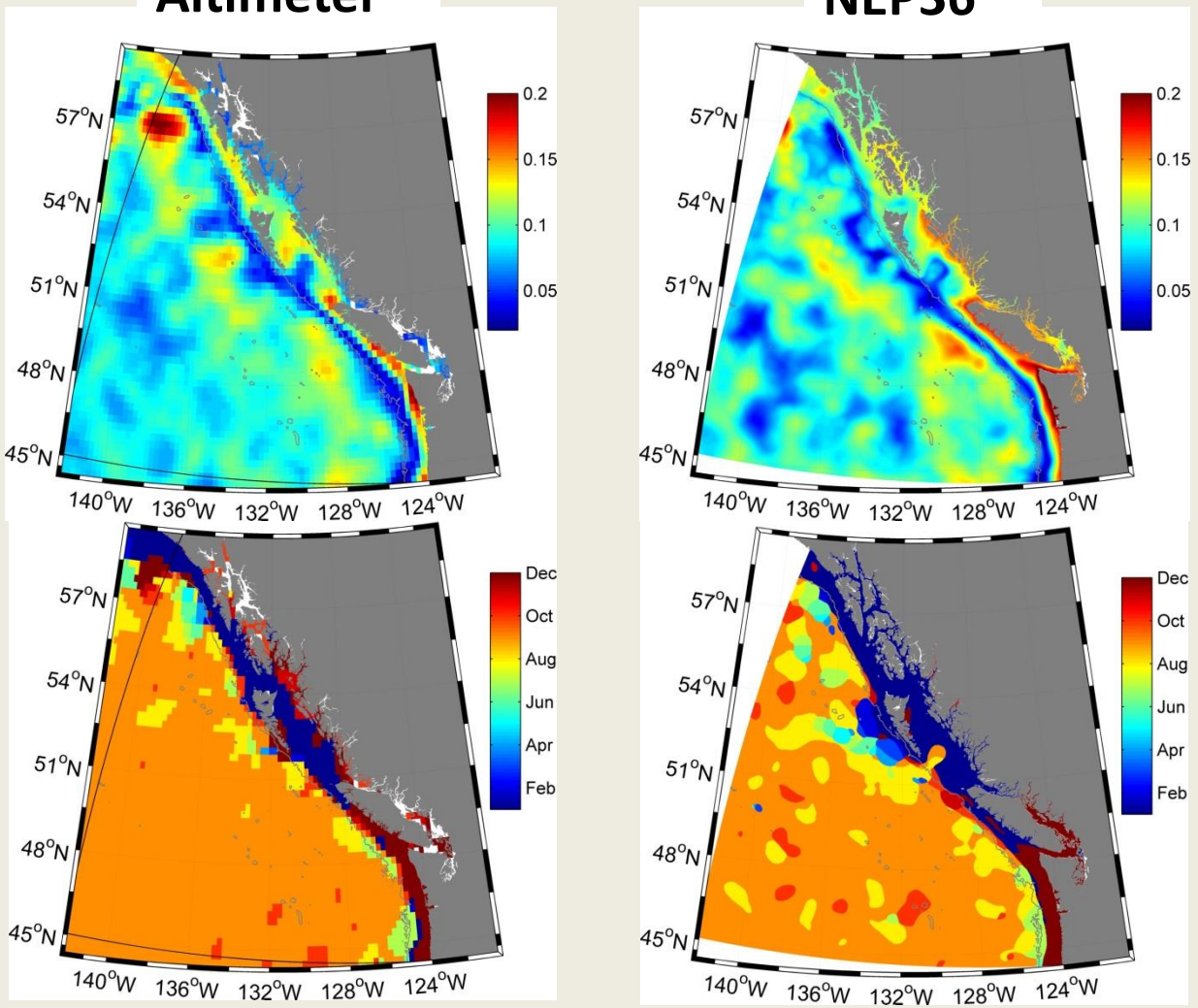
Compared to altimeter data, NEP36

- **Captures large scale features of surface geostrophic currents**
- **Generates higher coastal sea level and stronger coastal currents**
- **Produces less small-scale eddies than altimeter data**

Seasonal Cycle of Sea Level

Amplitude
= maximum minus minimum

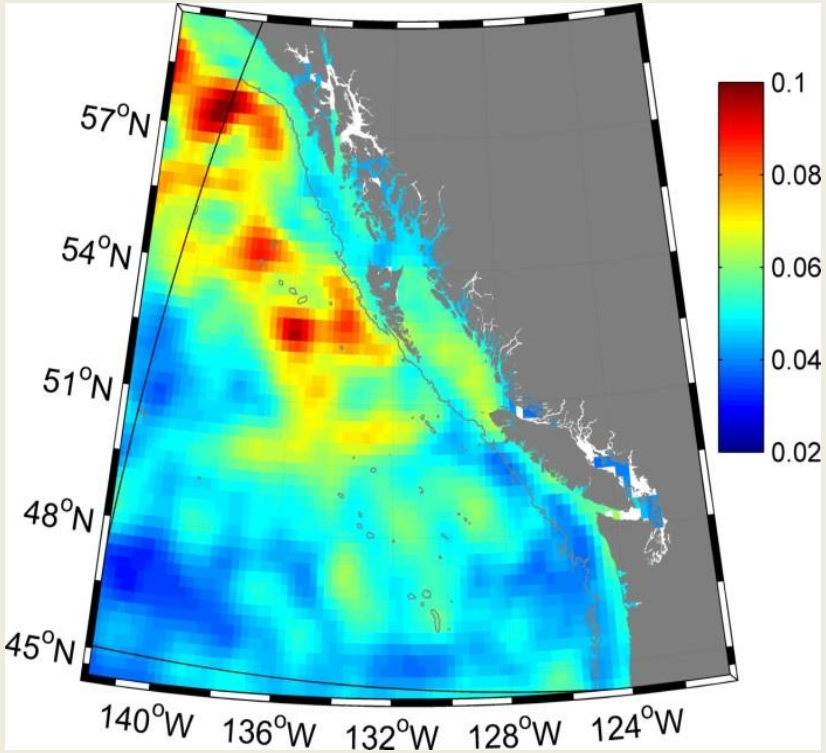
Phase
= month when maximum occurs



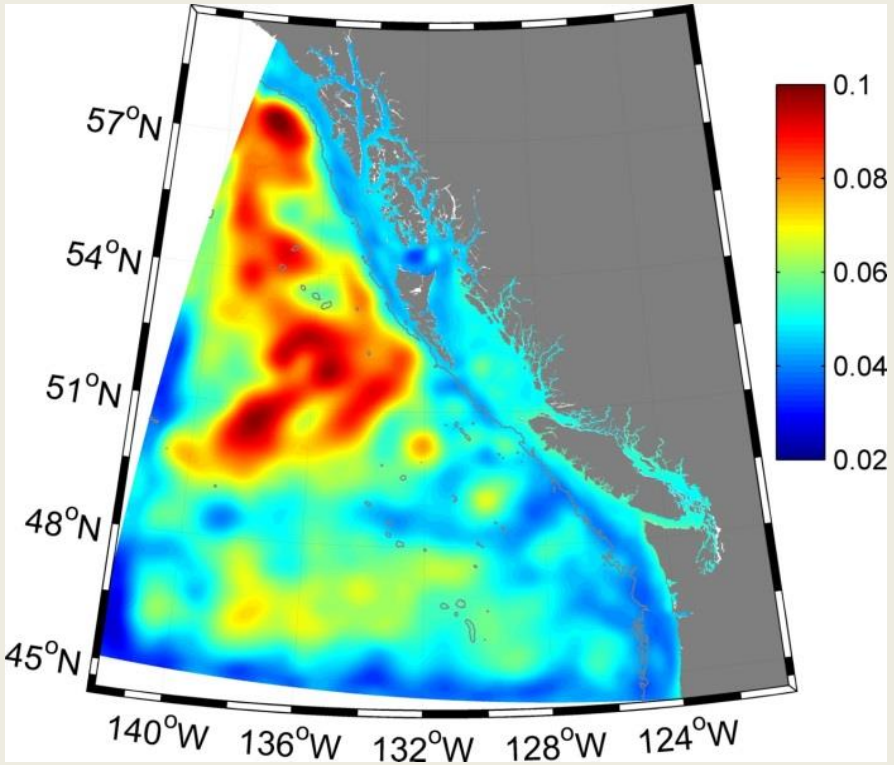
- **Amplitude: Large spatial variations**
- **Phase: out of phase between shelf & deep waters**

Spatial Variations of Sea Level Anomaly (SLA) with Seasonal Cycle Removed

Altimeter



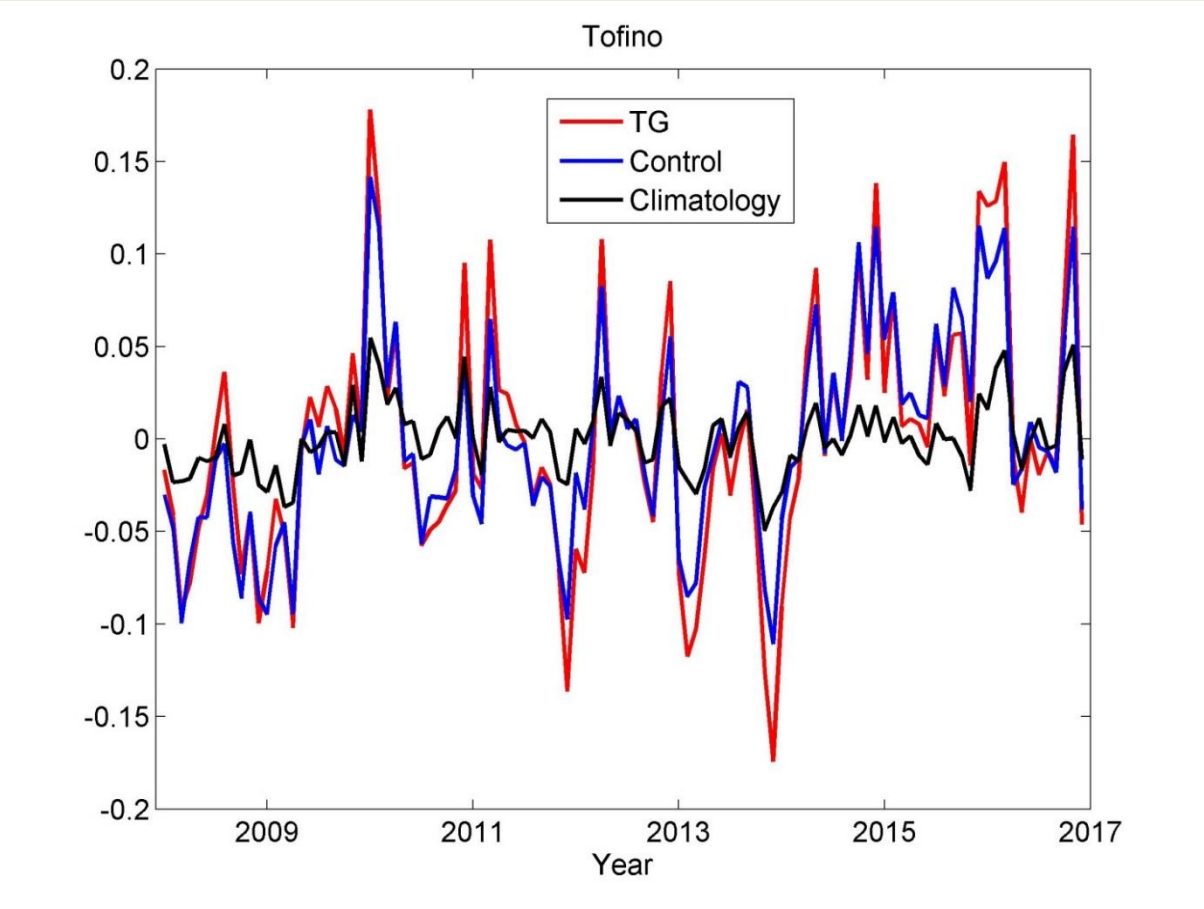
NEP36



Standard deviation of SLA shows

- **Minimal amplitude near shelf break.**
- **Interior eddies: model too strong or altimeter too weak?**

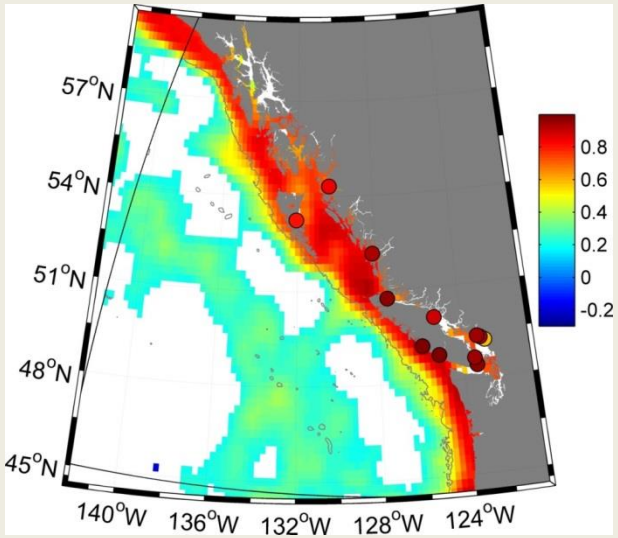
Sea Level Anomaly at Tide Gauge Tofino



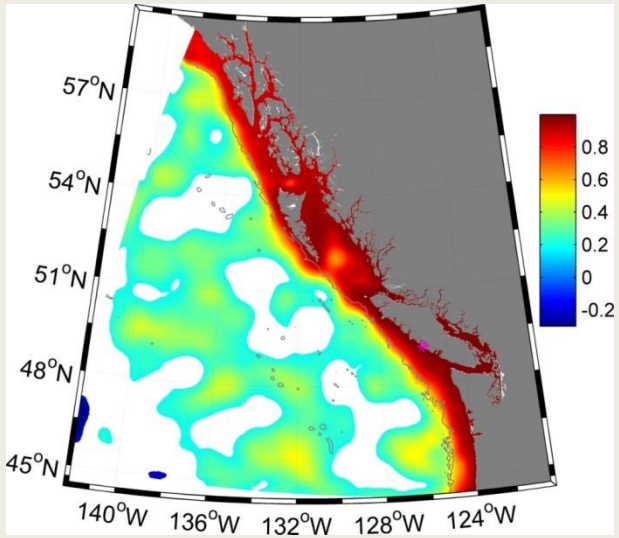
- Model reproduces sub-seasonal & inter-annual variations;
- Remote forcing important: Little variation if OBC set to climatology;
- Large anomalies coincide with El Niño events of 2009-10 &2014-16

Correlation of Sea Level Anomaly: Tofino with large scale

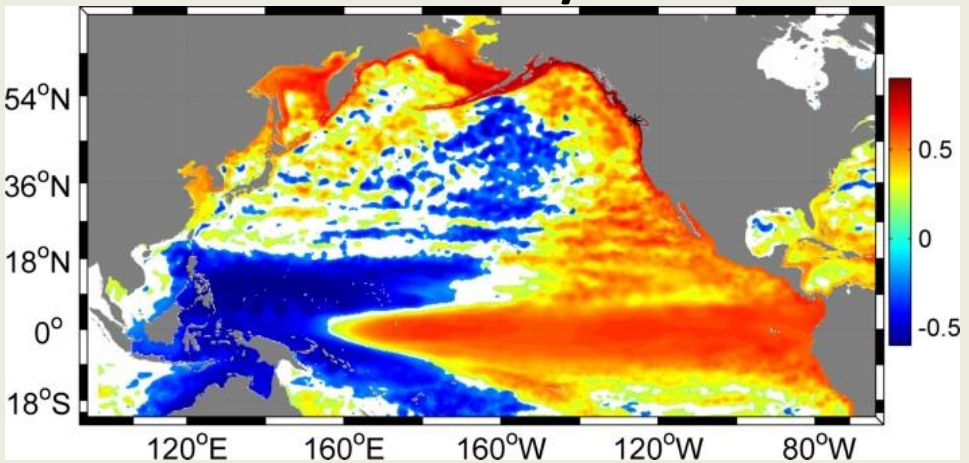
Altimeter

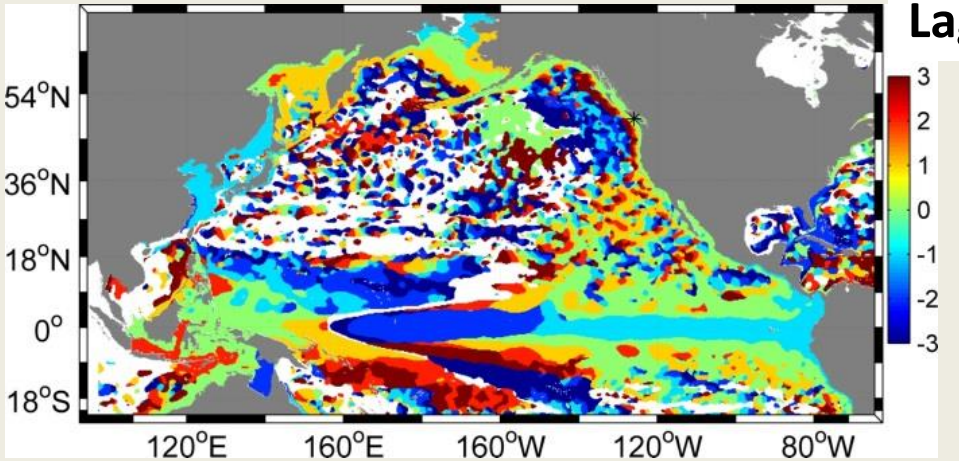


NEP36



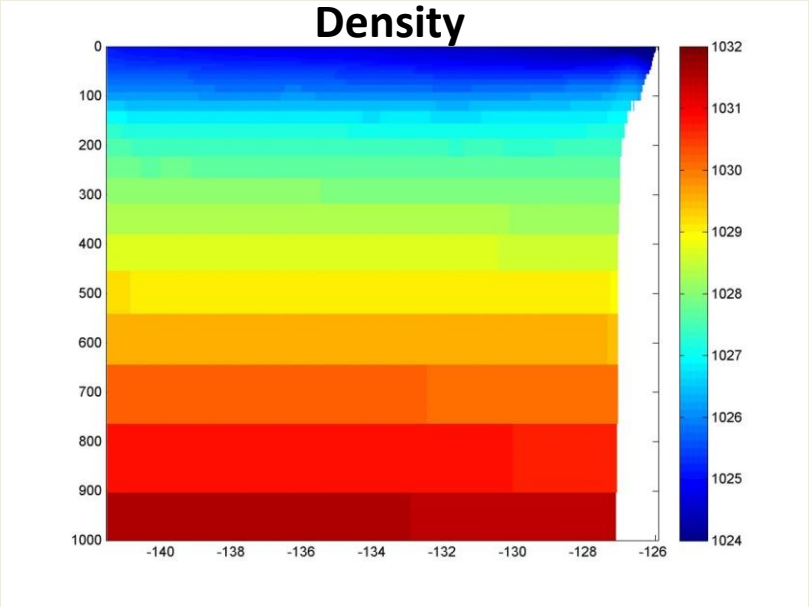
GLORYS 1/4°

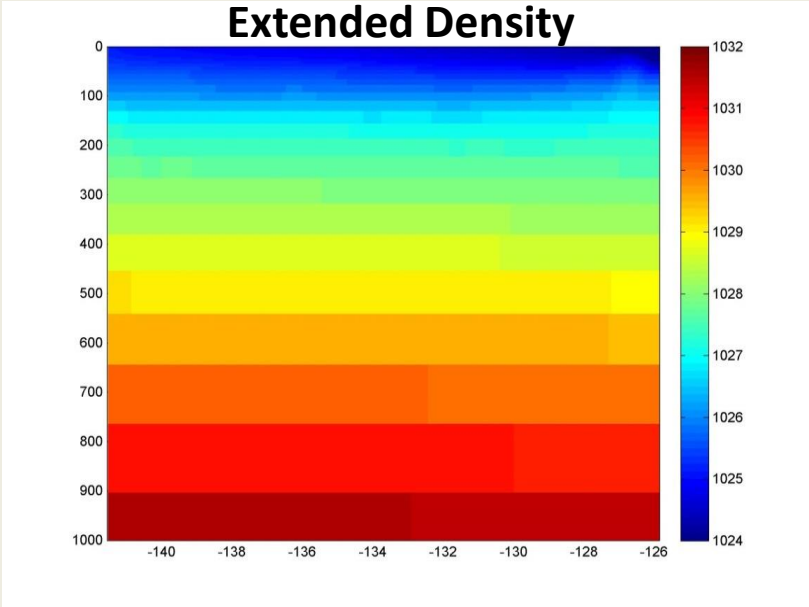


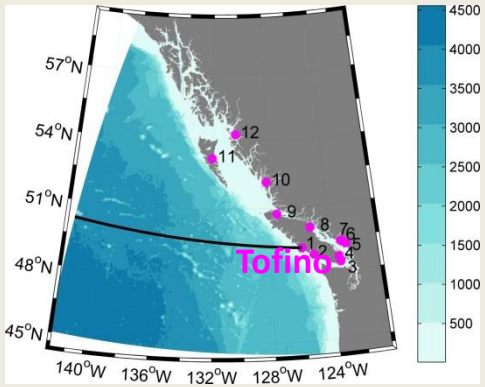


- Large-scale coherence on shelf (zero-lag correlation)
- Remote coherence with tropical Pacific (lagged correlation)

Calculation of Steric Contribution

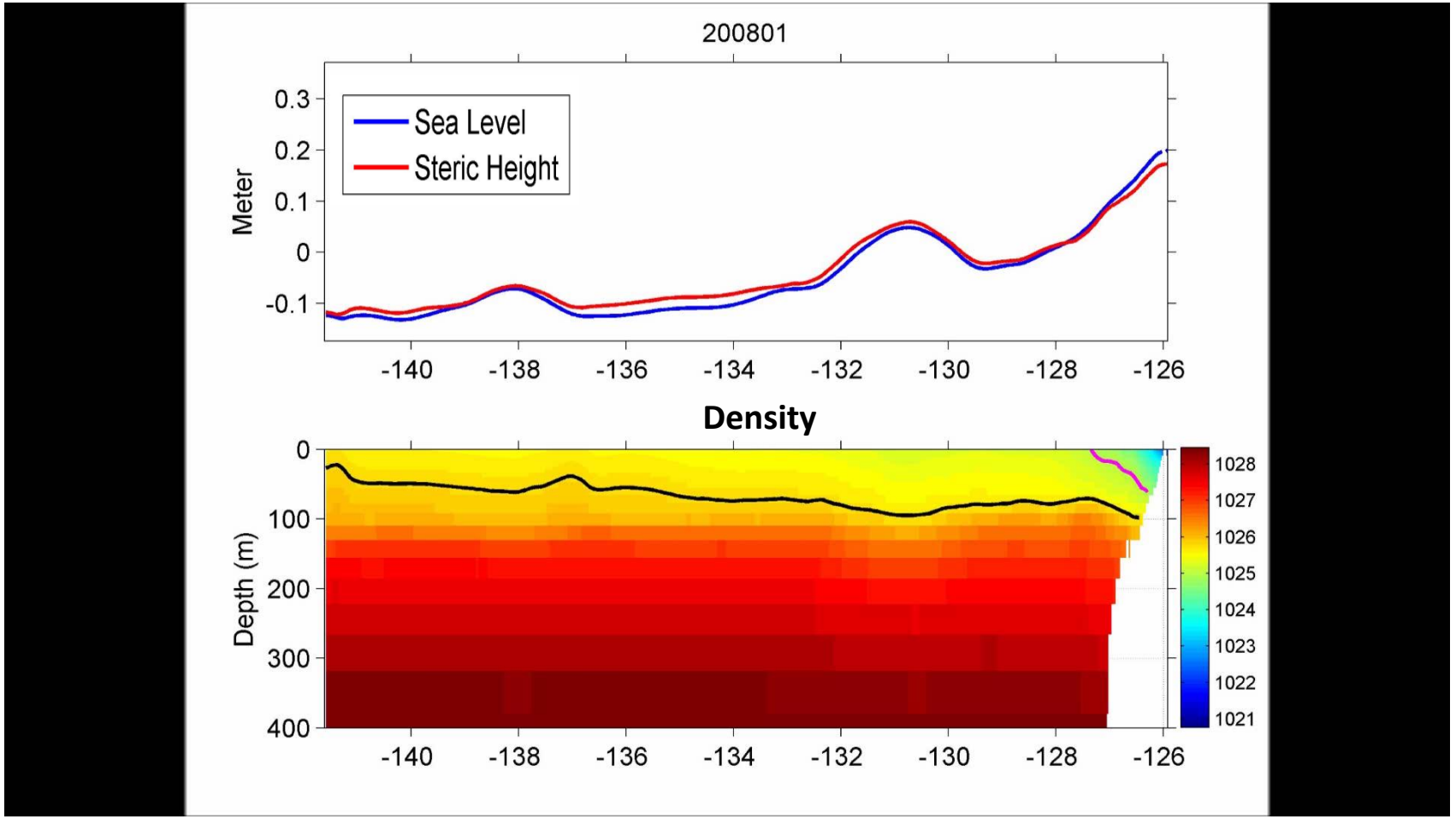






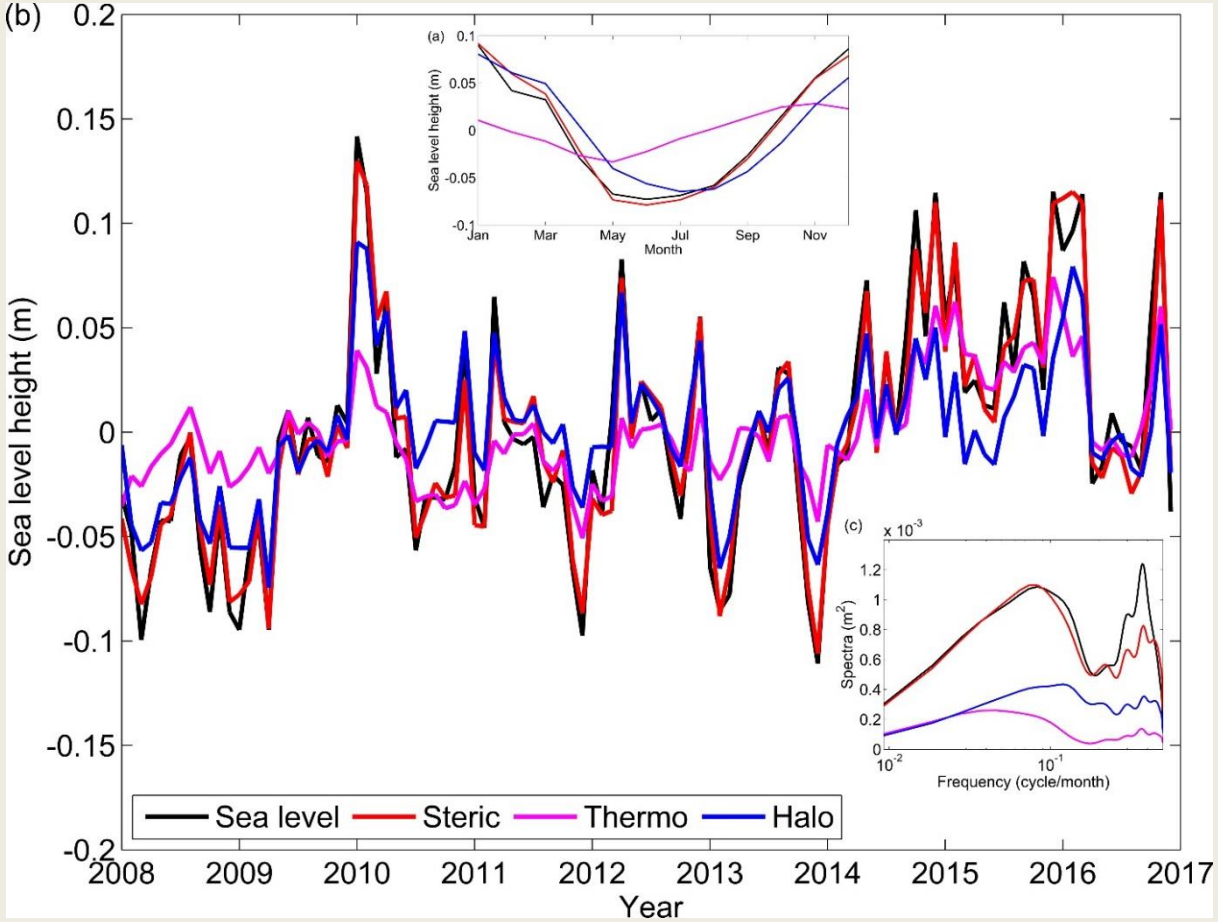
- **Following Helland-Hansen's (1934) to calculate steric height at the coast**
- **Extend bottom density, T/S horizontally under the sea floor from their point of intersection to the coast**

Animation: Sea Level, Steric Height & Density Variations



- **Steric accounts for most sea level variations;**
- **Strong T-S variability in upper 200 m.**

Tofino – Sea Level and Steric Height



Seasonal cycle

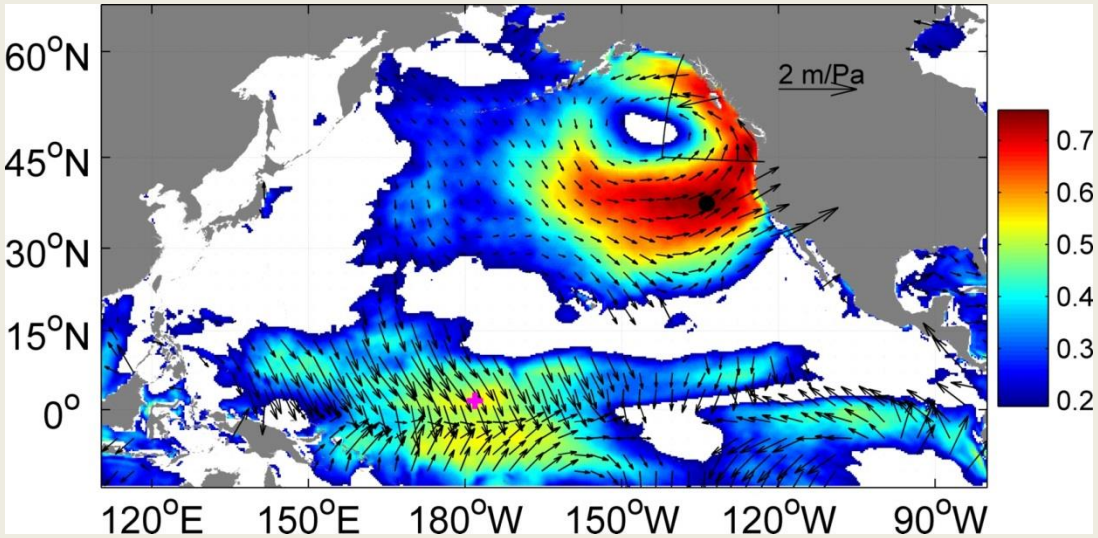
- Steric accounts for seasonal sea level & halo dominant; consistent with Tabata et al. (1986) based on observations.
- Seasonal wind: importance well known. but it must influence halo steric!

Sea Level Anomaly with Seasonal Cycle Removed

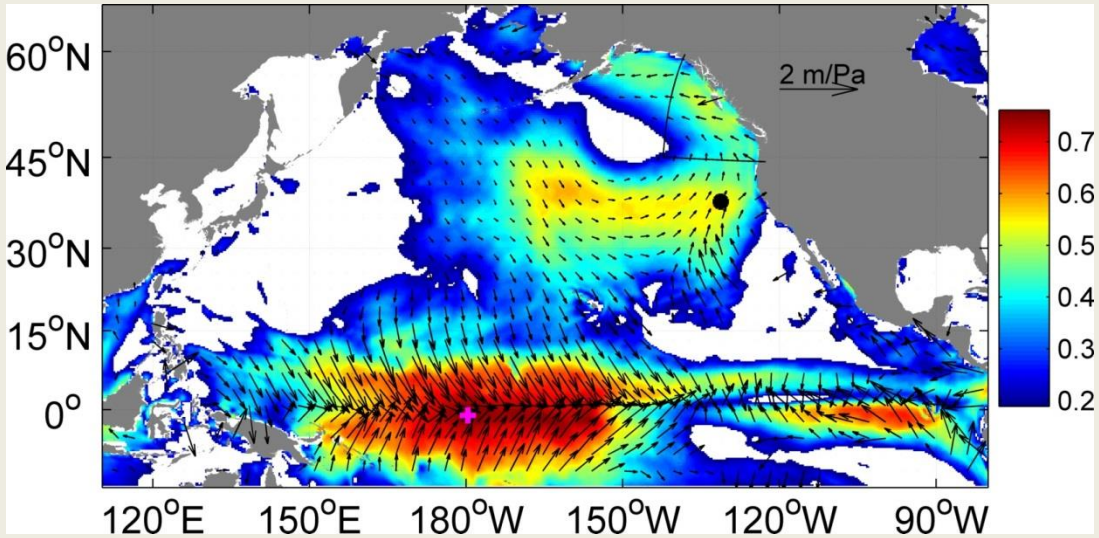
- Steric accounts for sub-seasonal sea level variations;
- Halo is more important than thermo – Note runoff is climatology!
- El Niño events: In 2009-2010, halosteric dominates; In 2014-16, thermo-steric dominates

Regression Analysis:
Steric Height at Tofino vs Wind Stress

Halosteric



Thermosteric



Importance of remote winds:

- **Western tropical Pacific: forced waves along American coast;**
- **38°N off shore: change coastal currents?**
- **38°N: inside NEP domain of Hermann et al (2009) but outside of Masson & Fine (2012)**

Conclusions

- **Both seasonal and interannual variations of sea level can mostly be accounted for by steric height.**
- **On shelf, the halo-steric component is more dominant than thermo-steric component; for seasonal cycle, consistent with Tabata et al. (1986) based on T-S observations.**
- **Role of seasonal winds: drive seasonal halo-steric!**
- **Sub-seasonal & inter-annual variations on shelf: importance of remote wind in western tropical Pacific, and at 38°N offshore; key for prediction!**
- **OBC important: "Climatology OBC test" obtains little variability of monthly mean sea-level variations – winds outside of NEP domain are important!**