# Optimizing Ocean Observing in the Tropical Pacific


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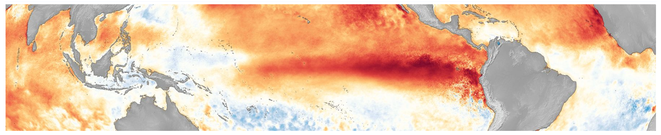
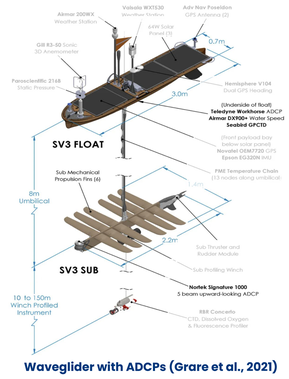
## Ocean Observations for ENSO



El Niño Image (Credits: NOAA)




Waveglider with ADCPs (Grare et al., 2021)

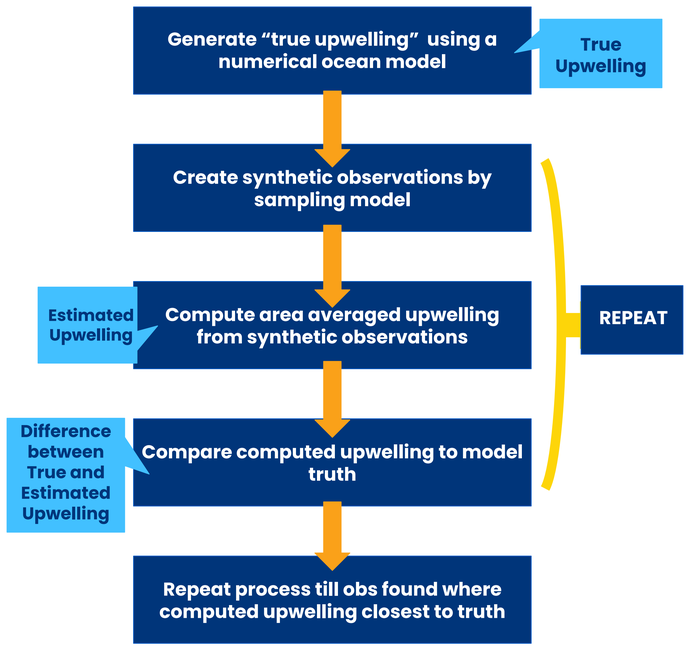
The El Niño Southern Oscillation (ENSO) is the warming and cooling of the ocean surface in the Tropical Pacific.

Observing **upwelling** – when cold, nutrient-rich water rises to the surface from the deep ocean – can help improve numerical models and predict ENSO variability.

NOAA's Tropical Eastern Pacific Experiment - East (TEPEX-E) mission aims to measure upwelling in Fall 2026-27. **Our question: where should NOAA deploy 6 wavegliders for the best upwelling measurement?**

## OSSE Workflow

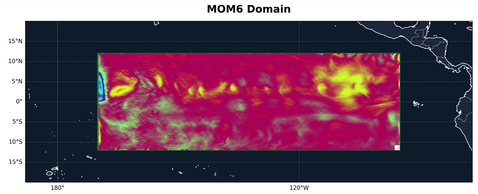
**Observation System Simulation Experiments (OSSEs) evaluate proposed observing systems in a numerical ocean model.**




## New capabilities for synthetic observations

### A novel 1/12° MOM6 Configuration

- **Region**: 12°S to 12°N, 95°W to 170°W
- **Time**: January 1, 2015 to June 31, 2015 (ENSO neutral -> El Nino)
- **Output**: Weekly averages of horizontal and vertical (upwelling) water velocities




Water velocities at one timestamp in configured MOM6 domain

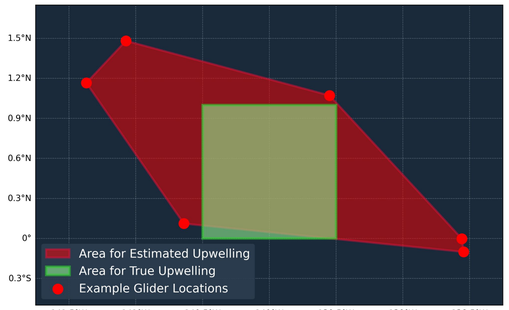
### Synthetic Observations

Observation metadata generated for 6 wavegliders at fixed locations every 3 hours every 2m from 8-80m. Data Assimilation Research Testbed (DART) capabilities interpolate model output to obtain data for synthetic observations.

## True and Estimated Upwelling

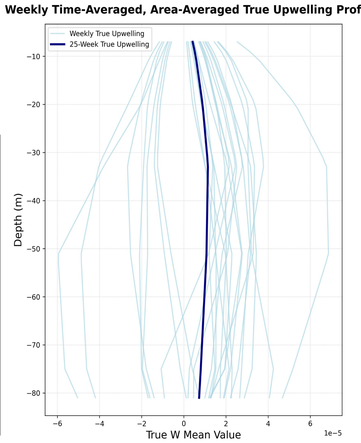
- The **TRUTH**: weekly averaged upwelling depth profiles over a 1° square centered at (0.5°N, 140.0°W).
- The **ESTIMATE**: weekly averaged upwelling depth profiles over the area bounded by the 6 wavegliders.

**Example Area for True and Estimated Upwelling**




Area for true upwelling and an example glider arrangement

**Weekly Time-Averaged, Area-Averaged True Upwelling Profiles**




The "Truth": weekly depth profiles for area-averaged model upwelling

## Take-home points and next steps

Our new OSSE tools allow us to plan observing systems by pretending the model is real life. Here, we found that:

- Average upwelling velocity in the model truth itself has a small signal with high variability.
- The two optimization routines with initial random points are unable to find the significantly better hexagonal arrangement.

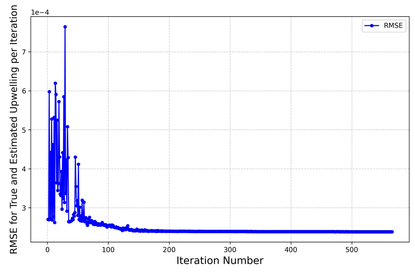
### Future Work

- Include existing observations via CrocoLake.
- Use other optimization methods and approaches.
- Try workflow on new regions, higher resolution models.

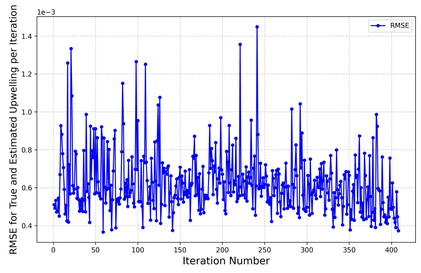
## Finding the Best Positions for Wavegliders

**Optimization** attempts to make a system as effective as possible. Here, we try to find an arrangement of wavegliders that minimizes the RMSE between the true upwelling and the estimated upwelling.
Tried two optimization methods, with 400 iterations and locations bounded to a 3° square centered at (0.5° N, 140.0°W):

**Nelder–Mead converges, but doesn't find global optimum**

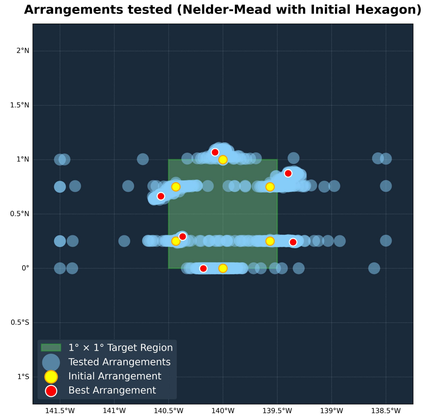



**CMA: Stochastic with better coverage, but still small improvements**

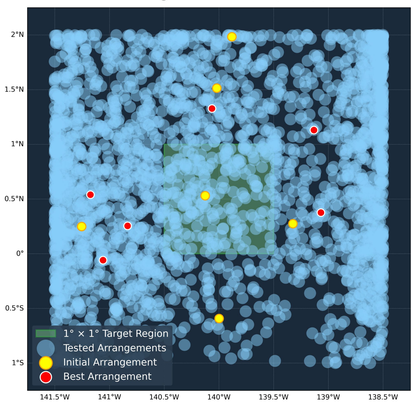



RMSE per iteration (arrangement) for two different optimization methods

**Arrangements tested (Nelder-Mead with Initial Hexagon)**



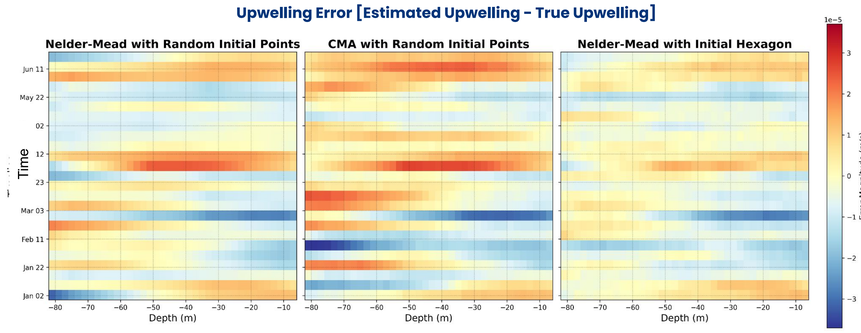

**Arrangements tested (CMA)**




Initial, tested, and best arrangements found by the two optimization routines.

So far, the arrangement with lowest RMSE resembles a hexagon. This arrangement was found using the Nelder-Mead method on a regular hexagon.

**Upwelling Error [Estimated Upwelling - True Upwelling]**




Error comparison between best arrangements found by the two optimization routines.


This material is based upon work supported by the NSF National Center for Atmospheric Research, which is a major facility sponsored by the U.S. National Science Foundation under Cooperative Agreement No. 1852977.
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