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Optimizing Ocean Observing Networks in the Tropical Pacific

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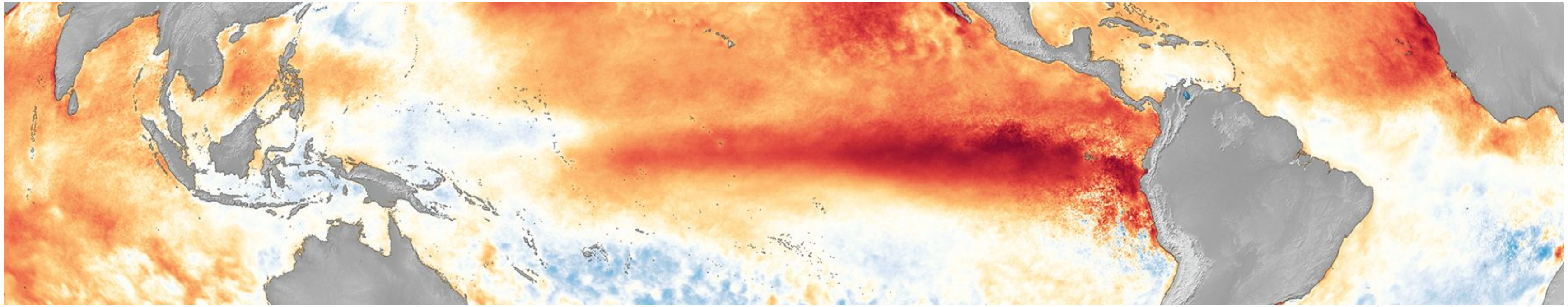
Background; why ocean observations?



- **ENSO**: warming and cooling of ocean surface in Tropical Pacific Ocean on a multi-year time scale; global weather implications
- **Upwelling**: cold, nutrient-rich water rising to surface from deep ocean
- Ocean observations can help forecast ENSO variability and improve numerical models.
- Modeling changes in ocean heat distribution helps in studying evolution of weather patterns.

NOAA's TEPEX-E field campaign

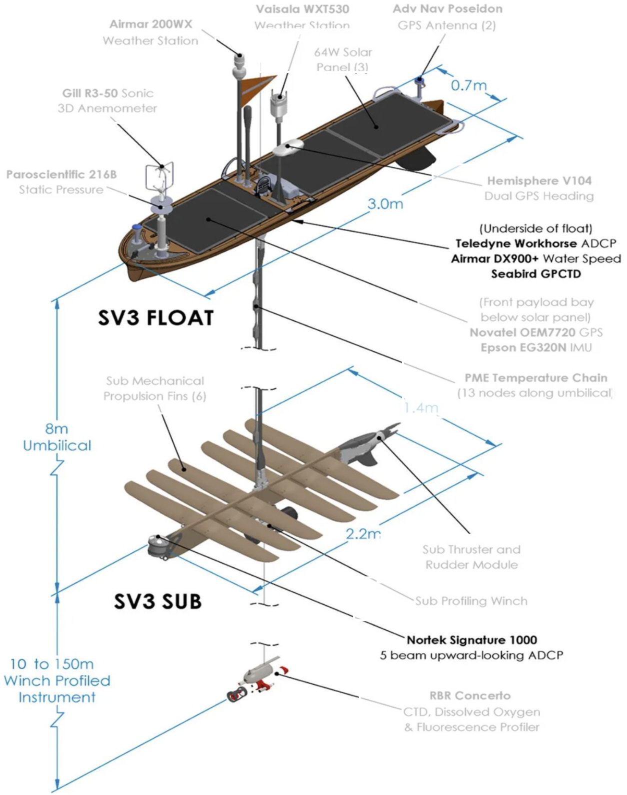
Ship *Ronald H. Brown* (Credits: NOAA)

Location: (at 2S-5N, 140W)

6 Wave Gliders to be deployed;

Observations from Fall 2026 to 2027 including ship cruises

Where to put them?



Waveglider with ADCPs (Credits: Grare et al., 2021)

OSSE = Observation System Simulation Experiment

Simulate ocean circulation using a numerical ocean model

↓

Create synthetic observations by sampling the model like Wave Gliders

↓

Compute "estimated upwelling" from synthetic observations and compare to true upwelling

Estimated Upwelling

True Upwelling

MOM6 Configuration for the Nature Run

Generate model truth

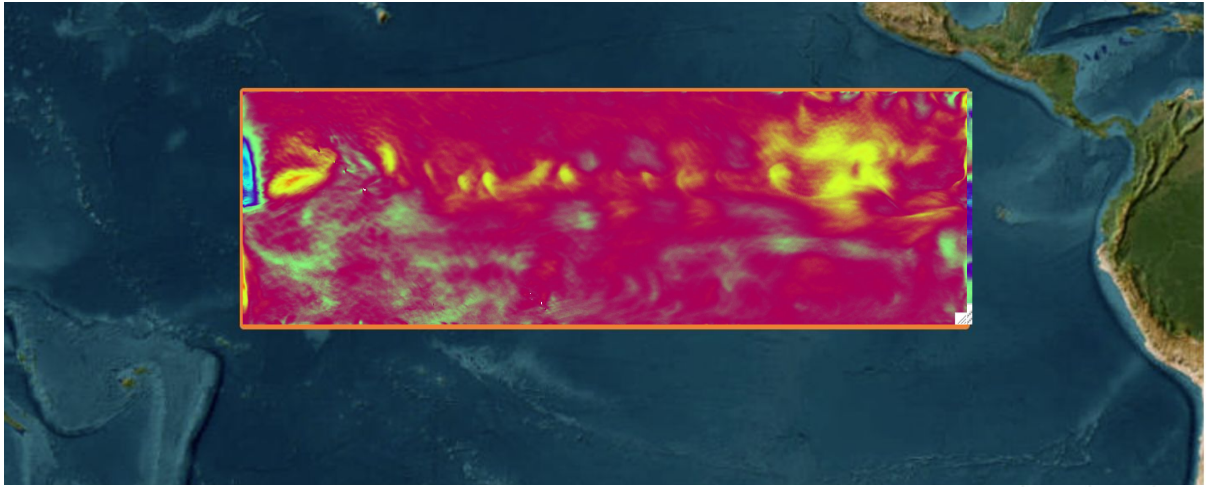
CESM MOM6

Create synthetic observations by sampling model

Compute area-averaged upwelling from observations and compare to upwelling from the model

Configured and ran Regional MOM6 in TEPEX region

Weekly water velocities output from 1/1/2015 to 6/31/2015



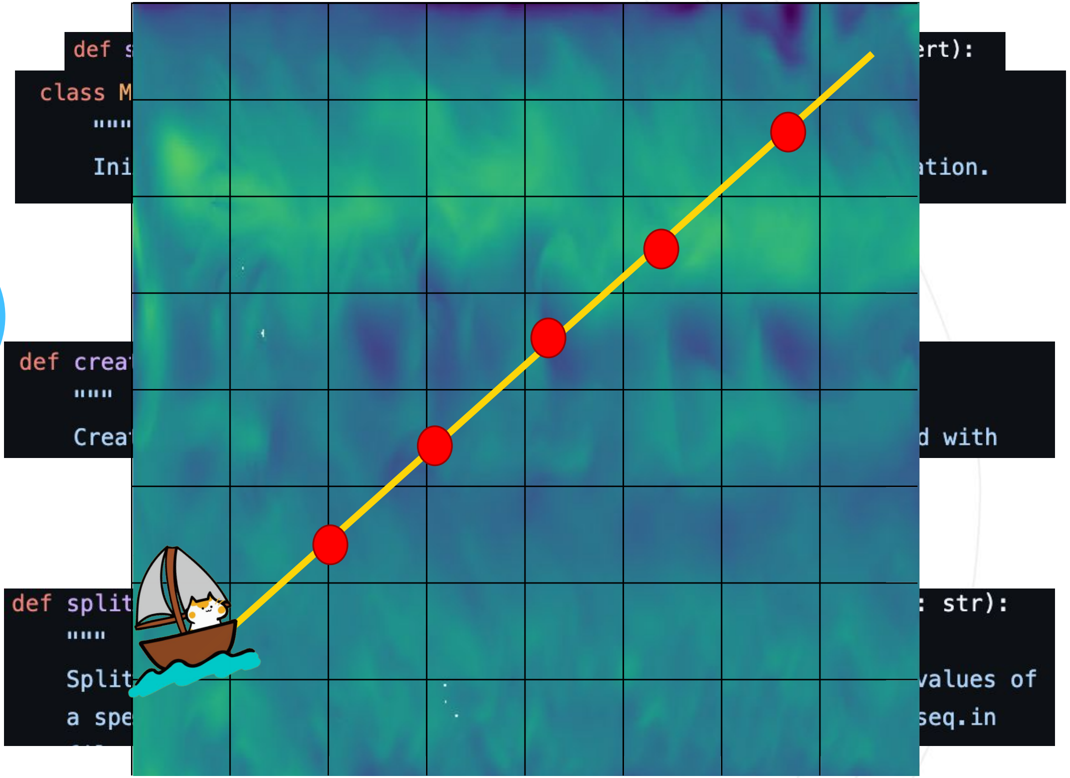
Obs generator

Generate model truth

Create synthetic observations by sampling model

Compute area-averaged upwelling from observations and compare to upwelling from the model

Data Assimilation Research Testbed (DART)



Compute area-averaged upwelling from observations and compare to upwelling from the model

split into two steps

Compute area-averaged upwelling from synthetic observations

Compare computed upwelling to model truth

Estimated Upwelling

Generate model truth

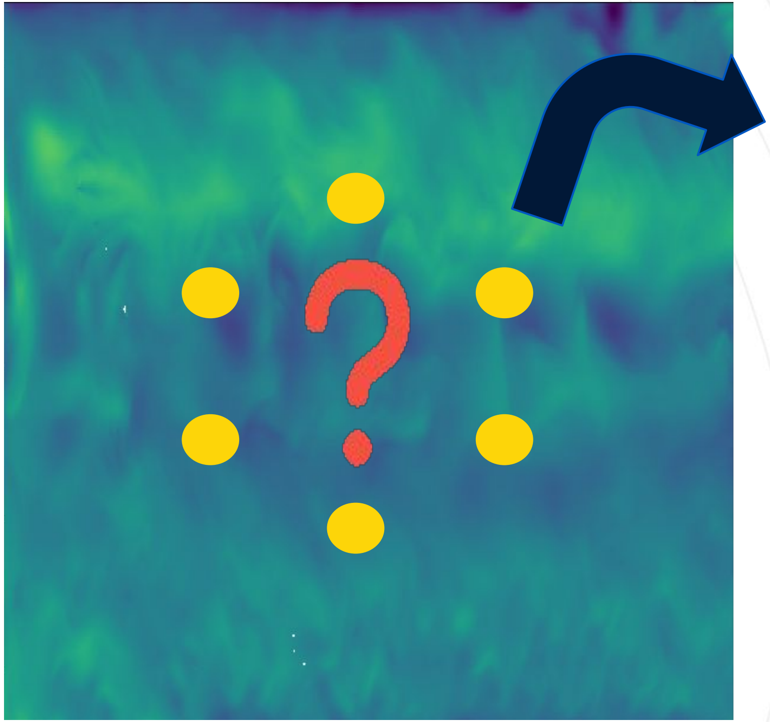
Create synthetic observations by sampling model

Compute area-averaged upwelling from synthetic observations

Compare computed upwelling to model truth

ESTIMATE: area-averaged weekly mean vertical profiles of upwelling in the area bounded by the 6 points

Ellen: upwelling from sparse obs



Estimated Upwelling

True Upwelling: Small Signal, Lots of Variability

Generate model truth

Create synthetic observations by sampling model

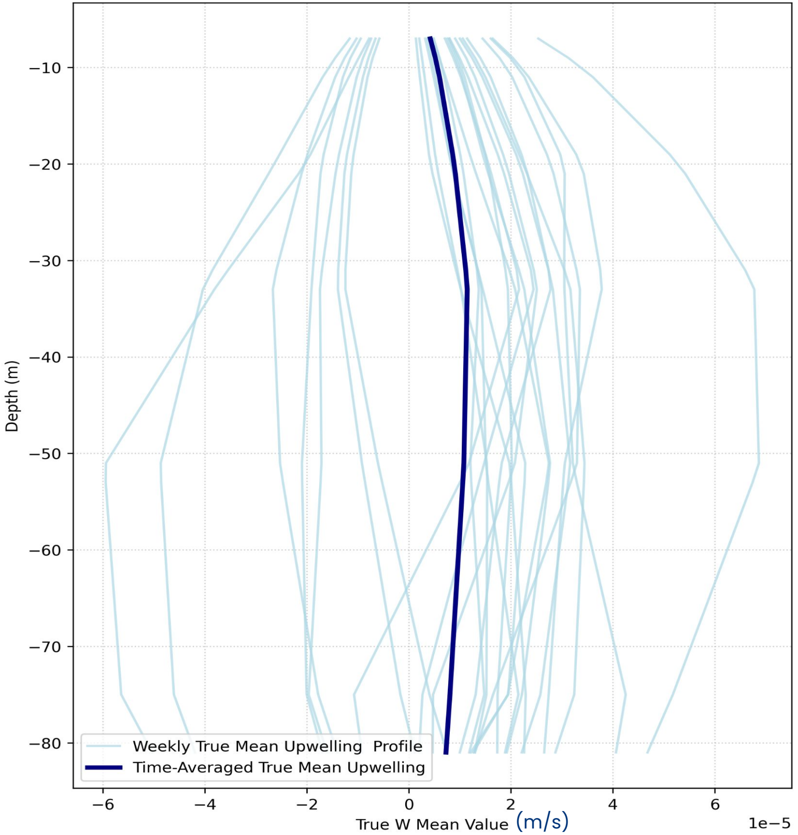
Compute area-averaged upwelling from synthetic observations

Compare computed upwelling to model truth

Frank: upwelling from the model

TRUTH: weekly averaged upwelling profiles for a 1 degree area centered at 0.5N, 140W

Profiles of weekly-averaged, area-averaged upwelling



Optimization

Optimization: Process of making a system as effective as possible.

Generate "true upwelling" using a numerical ocean model

Create synthetic observations by sampling model

Compute area averaged upwelling from synthetic observations

Compare computed upwelling to model truth

Repeat until observation locations that give best estimate of true upwelling are found

L2 Norm = RMSE * sqrt(38*25)

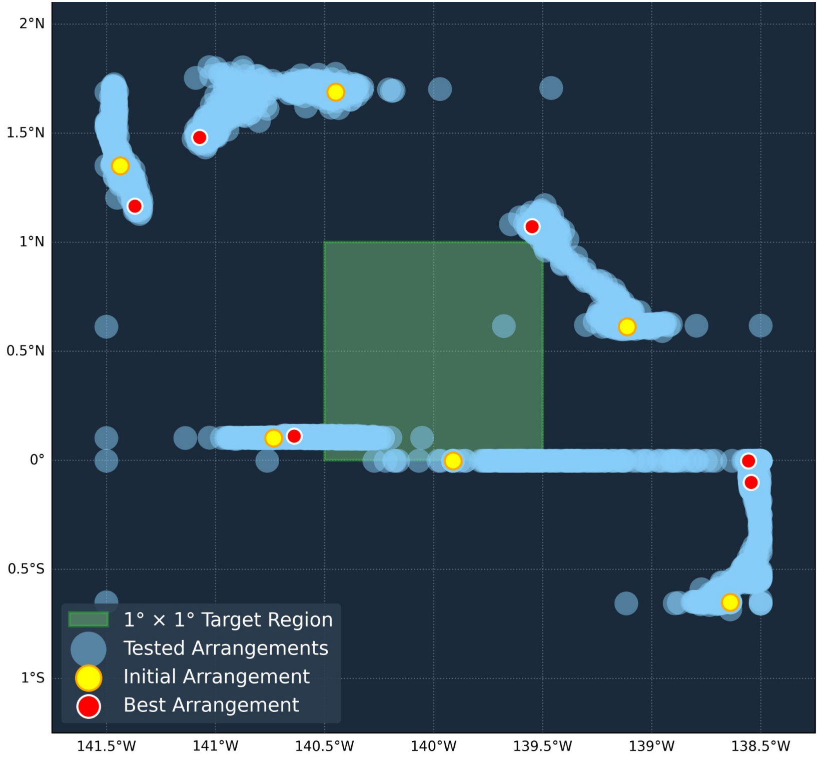
Mechanism to evaluate a single observing network

New Problem: Evaluate and find the best observing network

Try different configurations and minimize the L2 Norm between the true upwelling and estimated upwelling.

Nelder-Mead

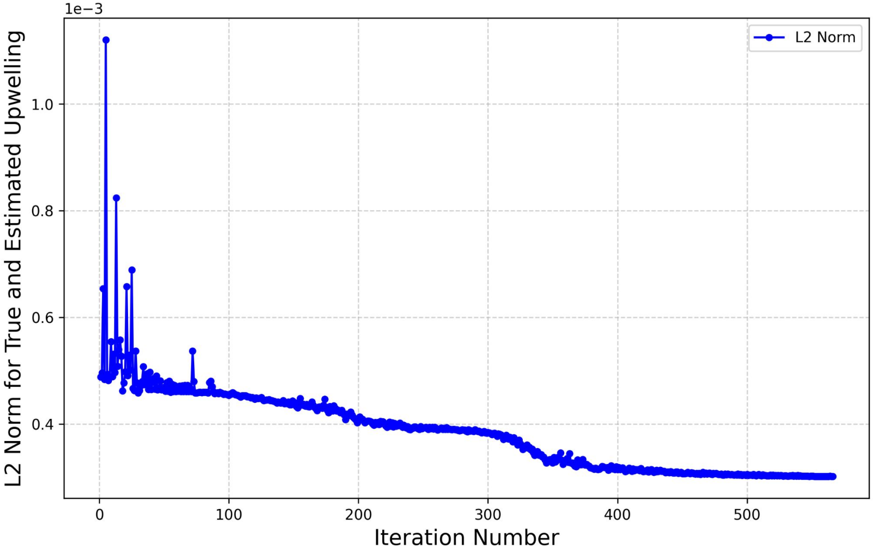
Map of Tested Arrangements



RMS of true upwelling = 2.54×10^{-5} m/s

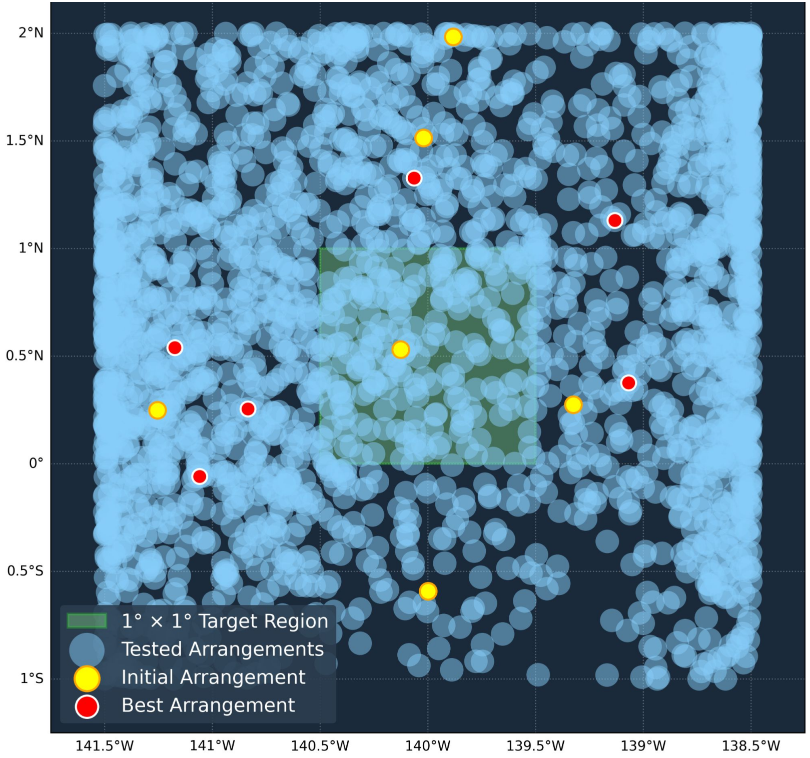
RMSE = 9.79×10^{-6} m/s

L2 Norm of All Depths and Times (True vs Est)



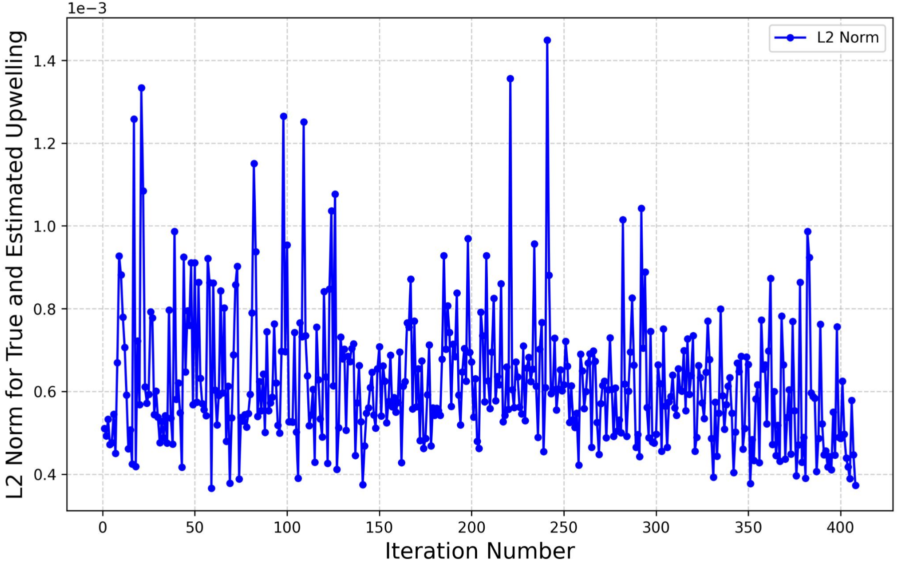
Another method: CMA

Map of Tested Arrangements



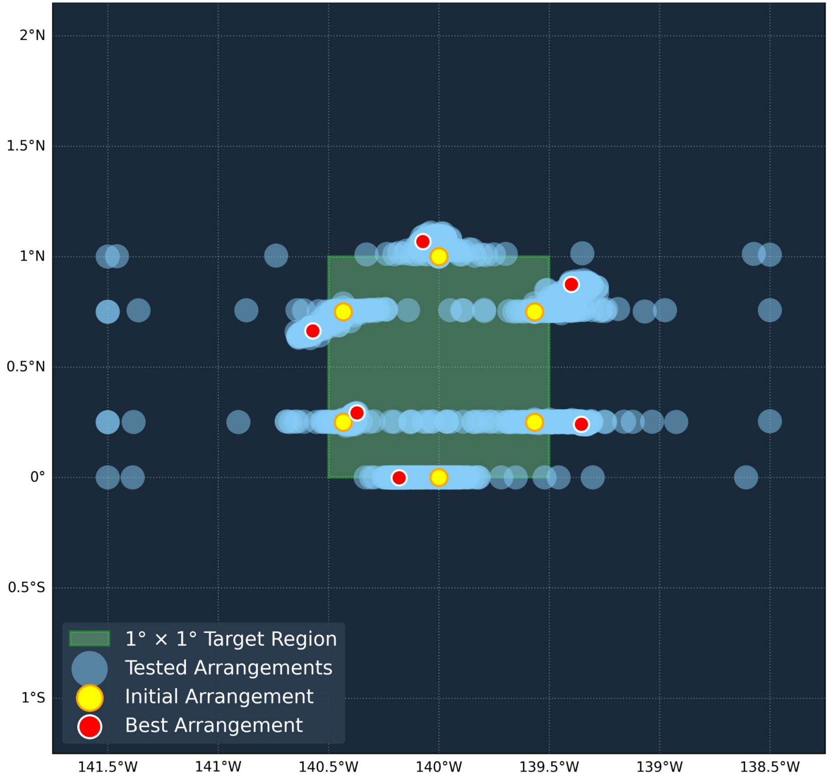
RMSE = 1.19×10^{-5} m/s

L2 Norm of All Depths and Times (True vs Est)



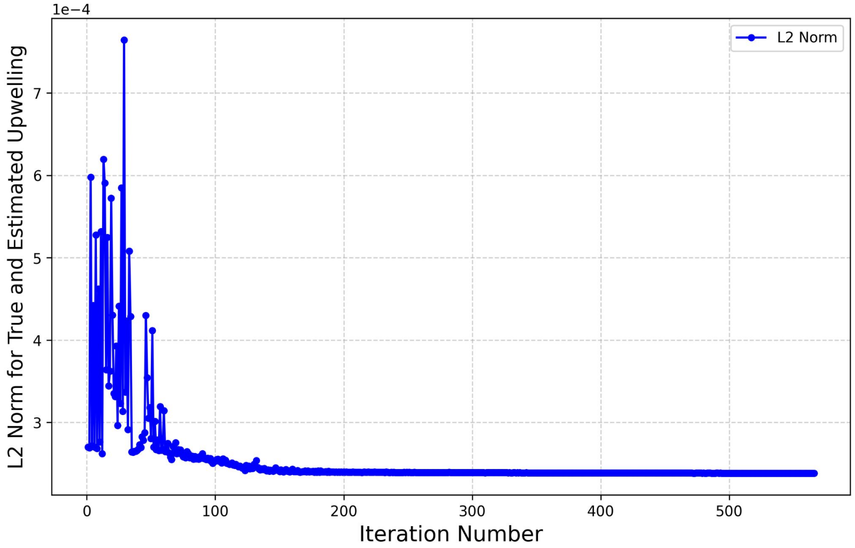
Hexagons are the BESTagons!

Map of Tested Arrangements (Nelder-Mead)



RMSE = 7.73×10^{-6} m/s

L2 Norm of All Depths and Times (True vs Est)

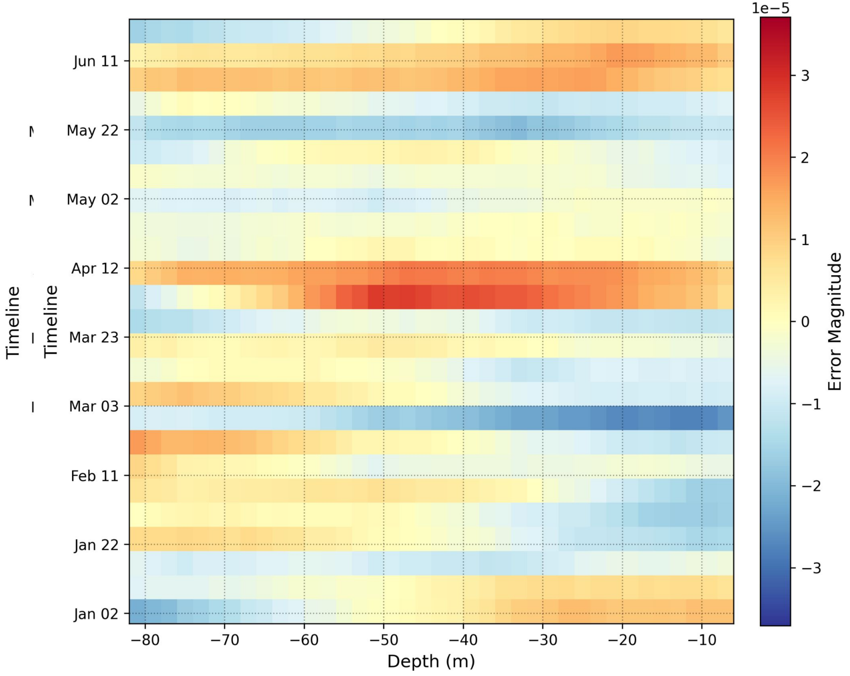


Error Comparisons

RMSE = 1.19×10^{-5} m/s

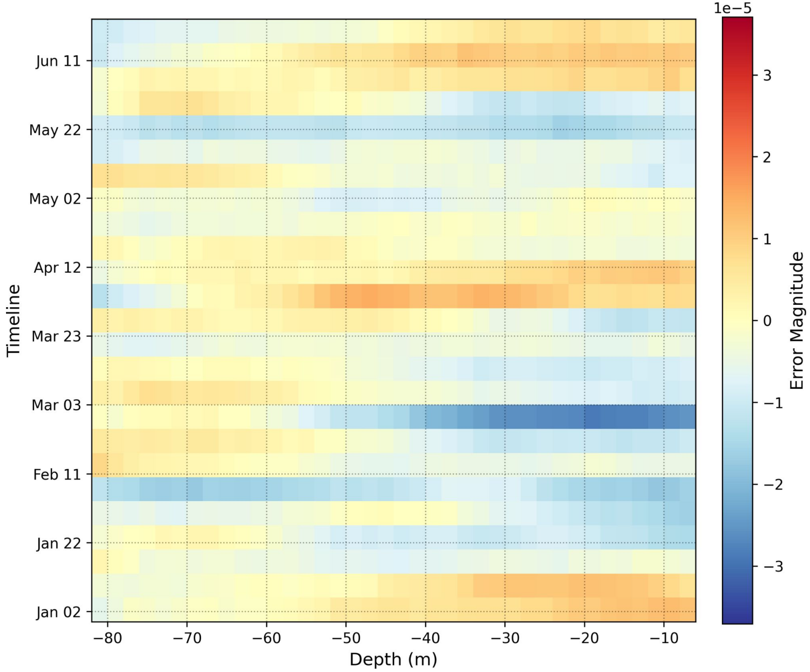
RMSE = 9.79×10^{-6} m/s

Random Initial (NM): (Estimated – True W)



RMSE = 7.73×10^{-6} m/s

Hexagon : (Estimated – True W)



Summary of the Summer

OSSEs allow us to plan observing systems by pretending the model is real life.

In this project:

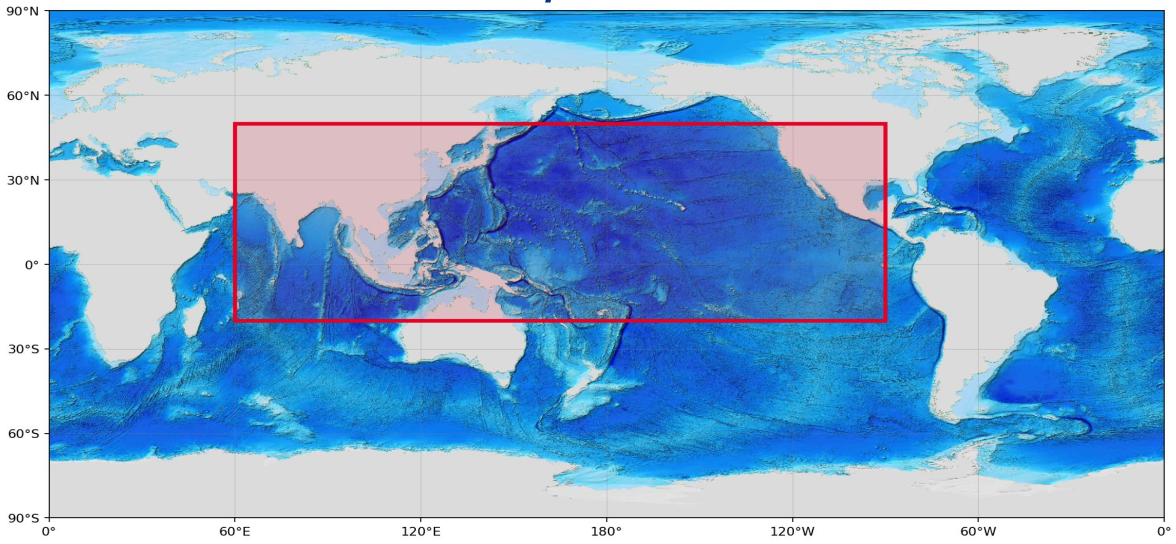
- Configured/ran MOM6 (pretend this is real life)
- Developed tools to sample it like observation instruments
- Showed how we can use this to improve observation network design

Takeaways

- 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.

Up Next

IndoPac 1/36th MOM6



- Include existing observations via CrocoLake.
- Use other optimization methods and approaches.
- Workflow documented in CrocoGallery for others to use.
- Try workflow on new regions, higher resolution models.


THANK YOU

Questions?