# A Climatology of the California Underwater Glider Network


Katherine (Kasia) Zaba

Dan Rudnick • Bruce Cornuelle • Ganesh Gopalakrishnan • Matthew Mazloff


EGO Meeting

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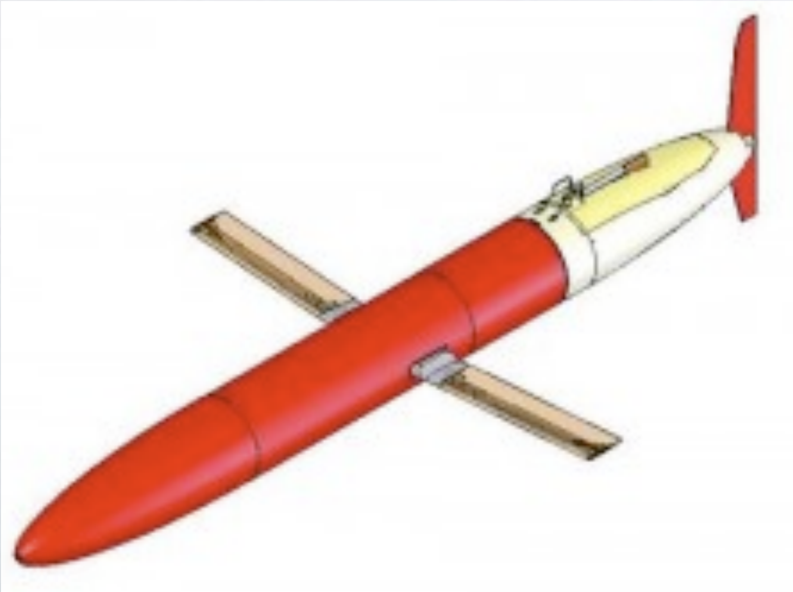


ECCO@Scripps

# Outline

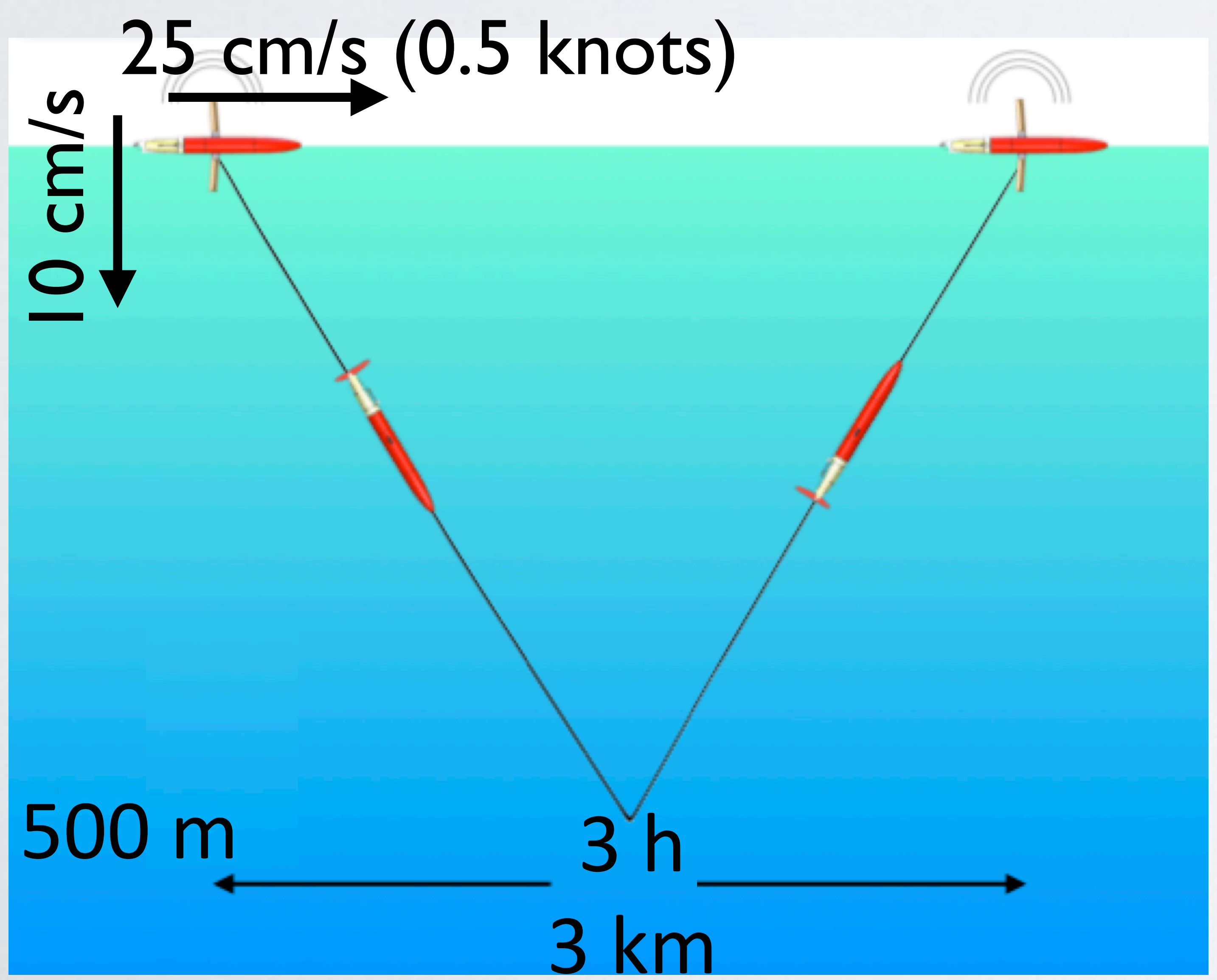
## California Underwater Glider Network (CUGN)

- *CUGN climatology (**3D**)*
- *high resolution baseline (mean and annual cycle)*
- *continuous monitoring (interannual anomalies)*

## Assimilation of CUGN data into California State Estimate (CASE)

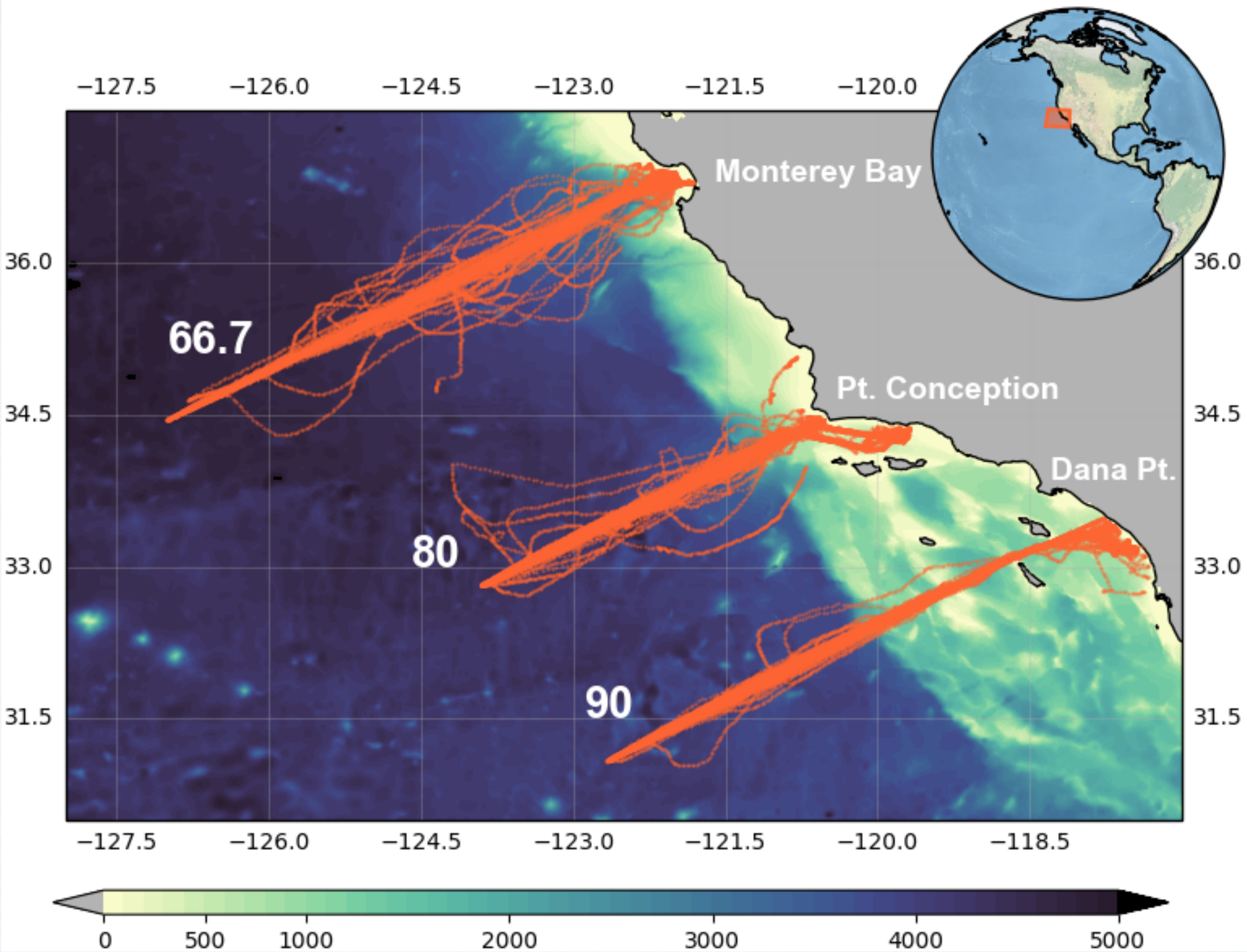
- *provides cross-shore and vertical transports*
- *provides full fields (**4D**), filling data gaps*
- *provides closed physical budgets for anomaly attribution*

# California Underwater Glider Network (CUGN)

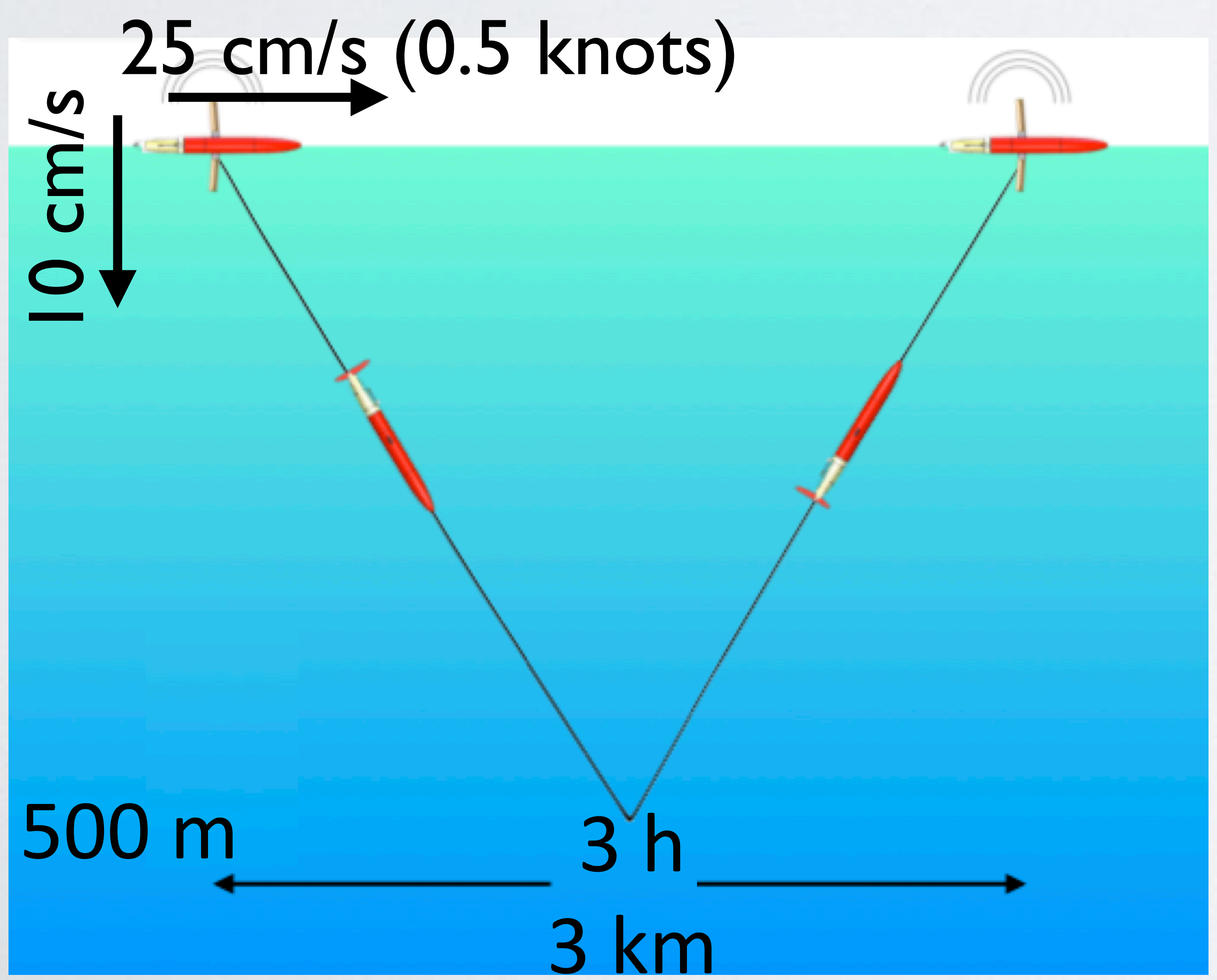

Established in **2006**:
continuous surveillance along **CalCOFI lines 66.7, 80, 90**.

**Longest** sustained glider time series, to our knowledge.




G. Castelão

# California Underwater Glider Network (CUGN)


| Sensors | Measured Variables |
|---|---|
| CTD | p, t, s |
| ADP | u & v (depth-dependent), abs |
| Fluorometer | chl-*a* fluorescence |
| $O_2$ Optode | dissolved oxygen |

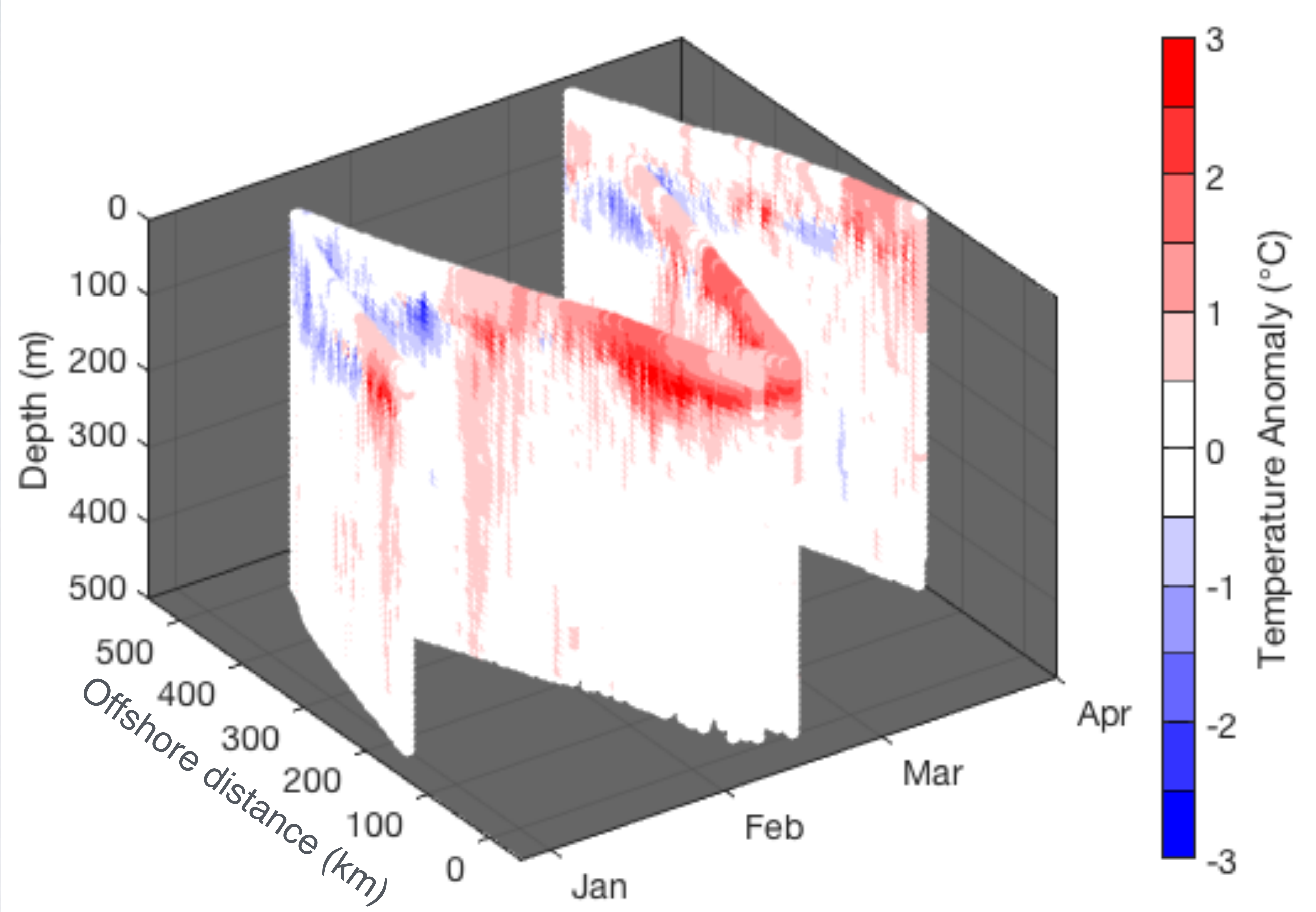
*Gui Castelão*: talk

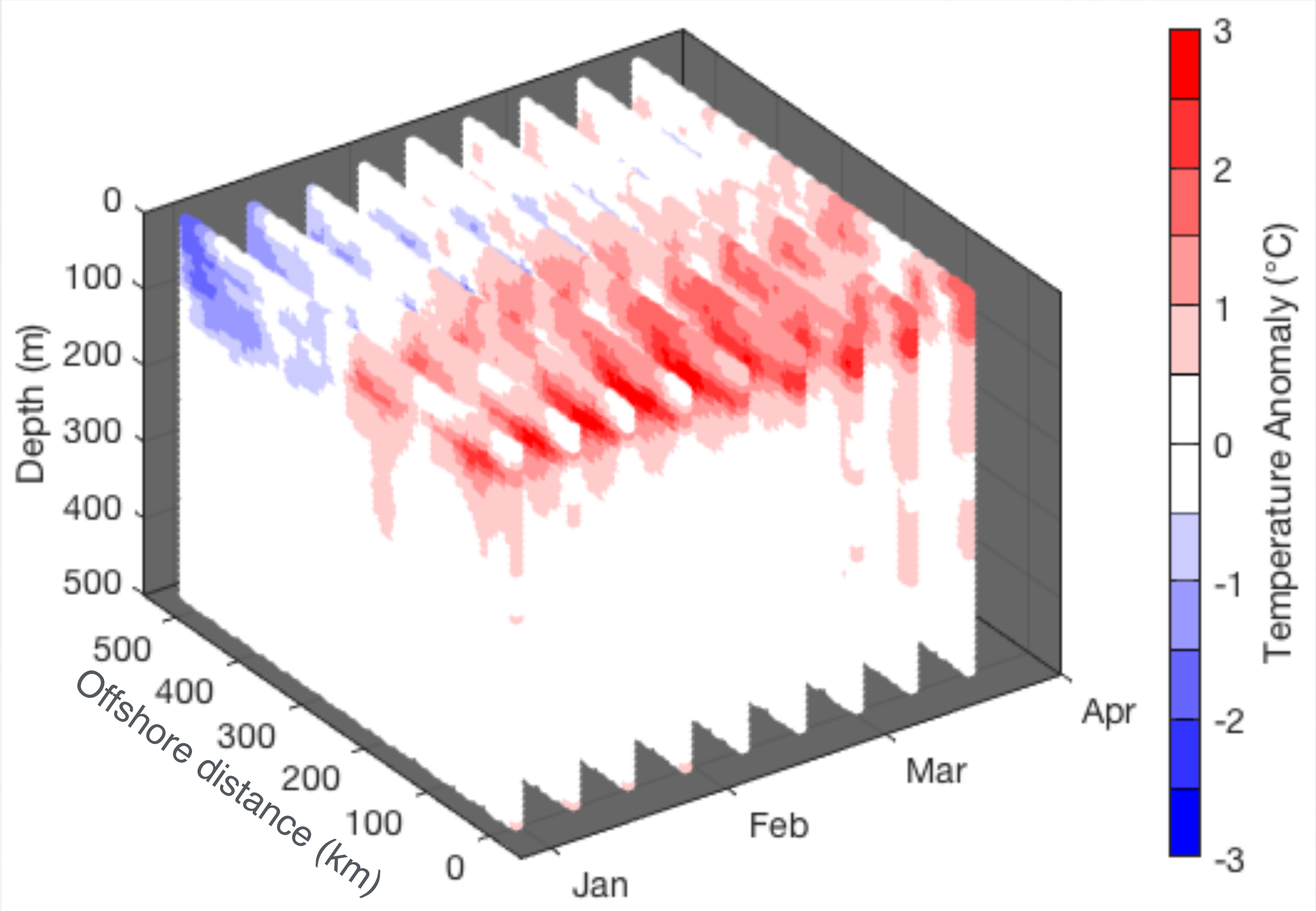
*Alice Ren*: poster

Depth-averaged currents (0-500m)
from dead-reckoning.

# CUGN Climatology

Irregularly sampled glider data are processed into ***uniformly gridded 3D data product***.




- Profile every ~ 3km, 3hrs
- Section over 2-3 weeks

- dx = 5 km
- dt = 10 days
- dz = 10 m

*Rudnick et al., 2017*

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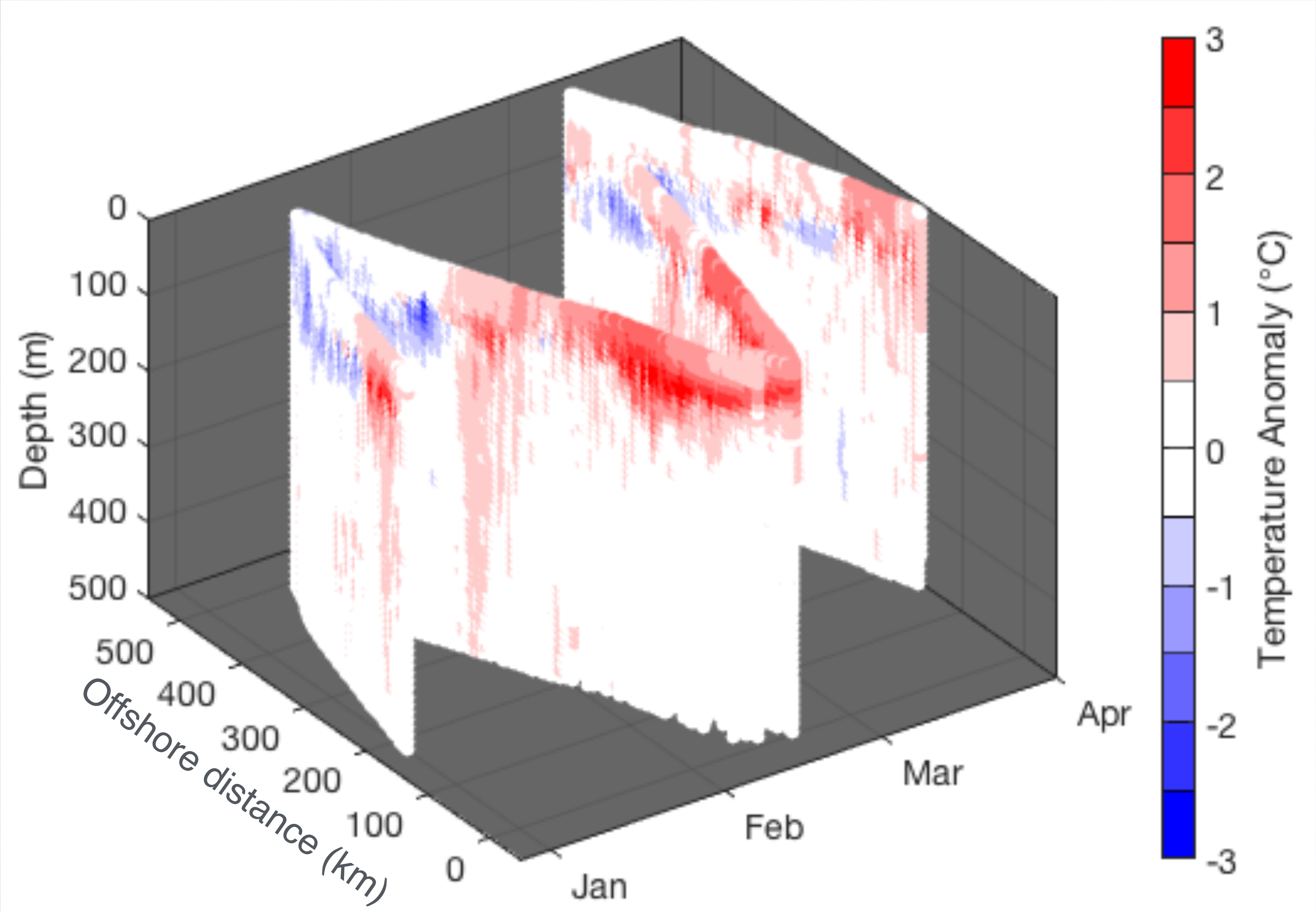
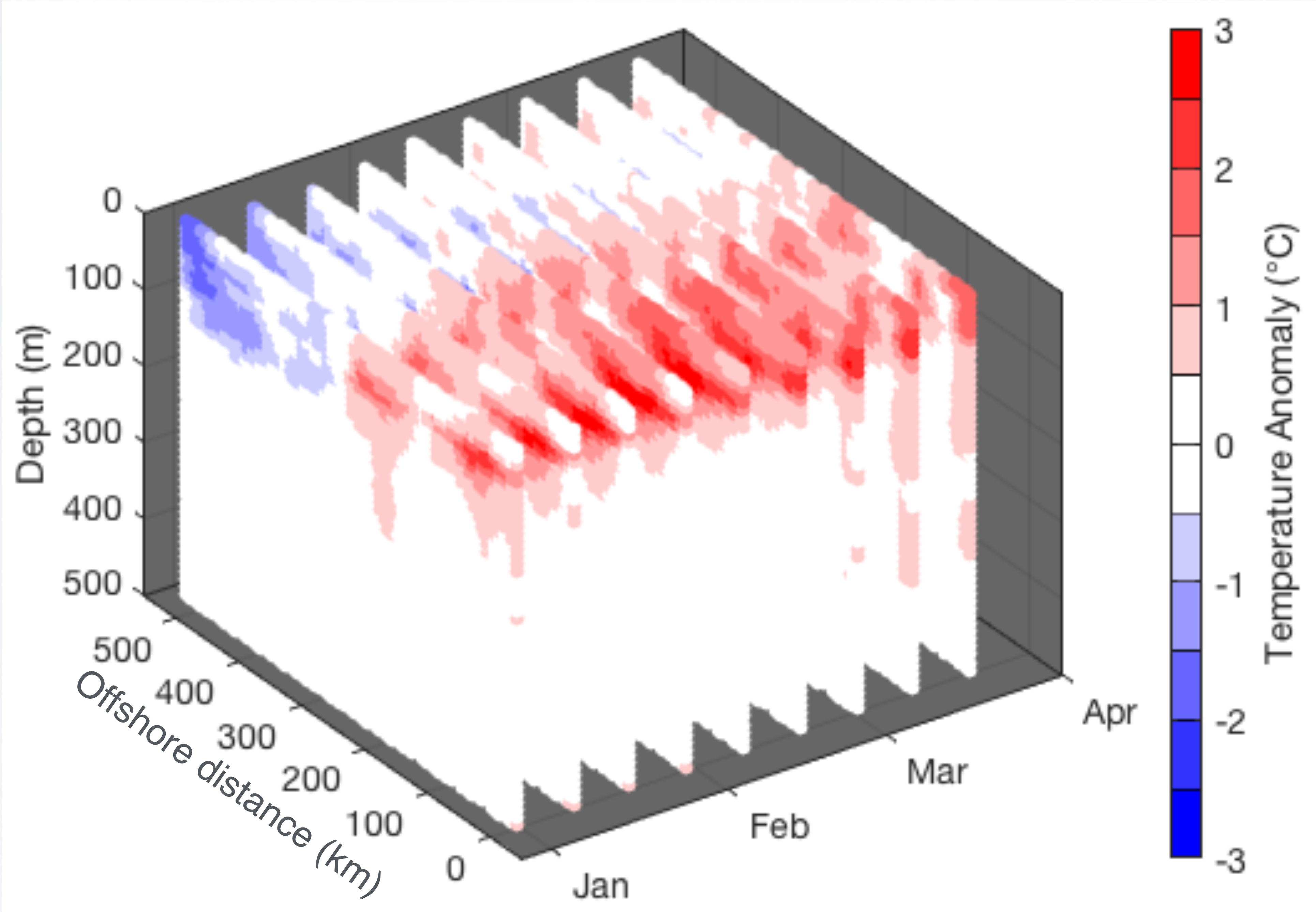



| Mapped Variables | Derived Variables |
|---|---|
| temperature | potential temperature |
| salinity | density |
| u & v (depth-averaged) | potential density |
| | geostrophic velocity |

*Rudnick et al., 2017*

# CUGN Climatology

spraydata.ucsd.edu

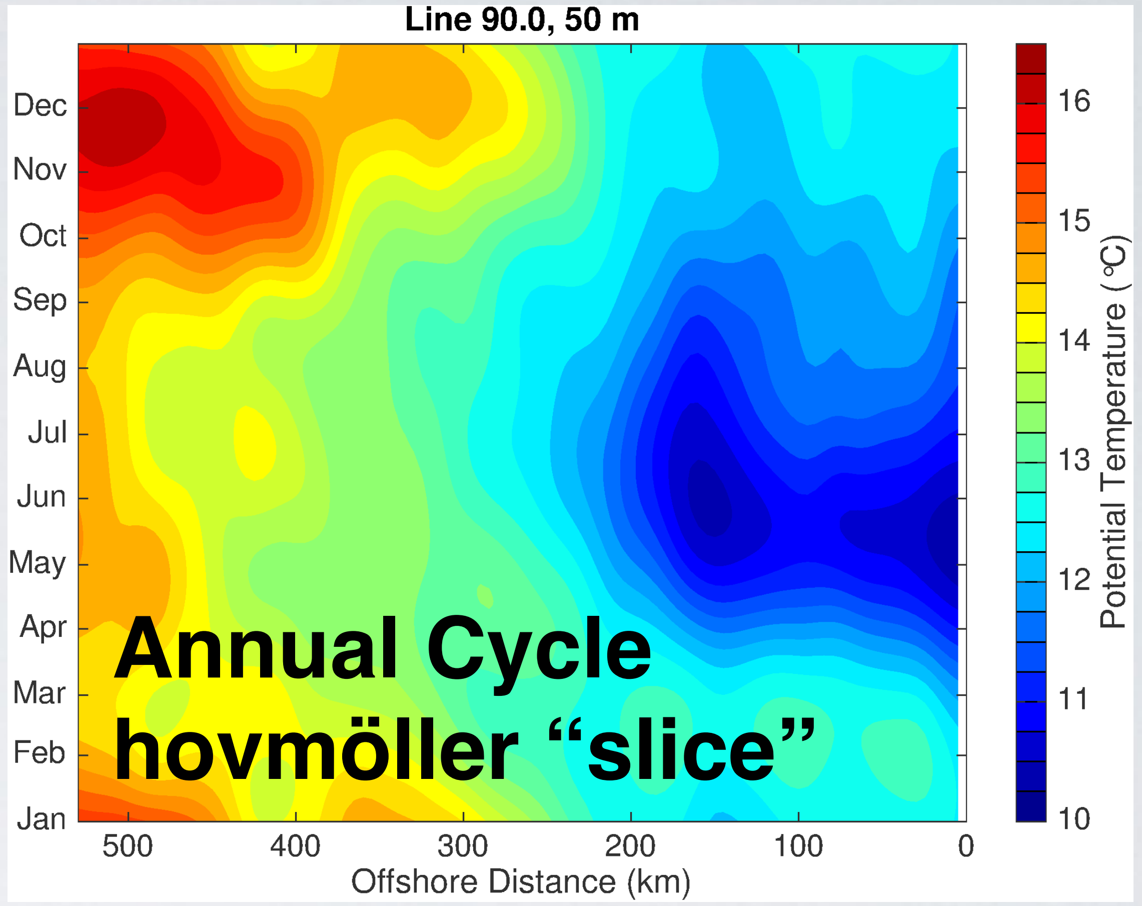
Several ***3D gridded products*** along each glider line for each variable:

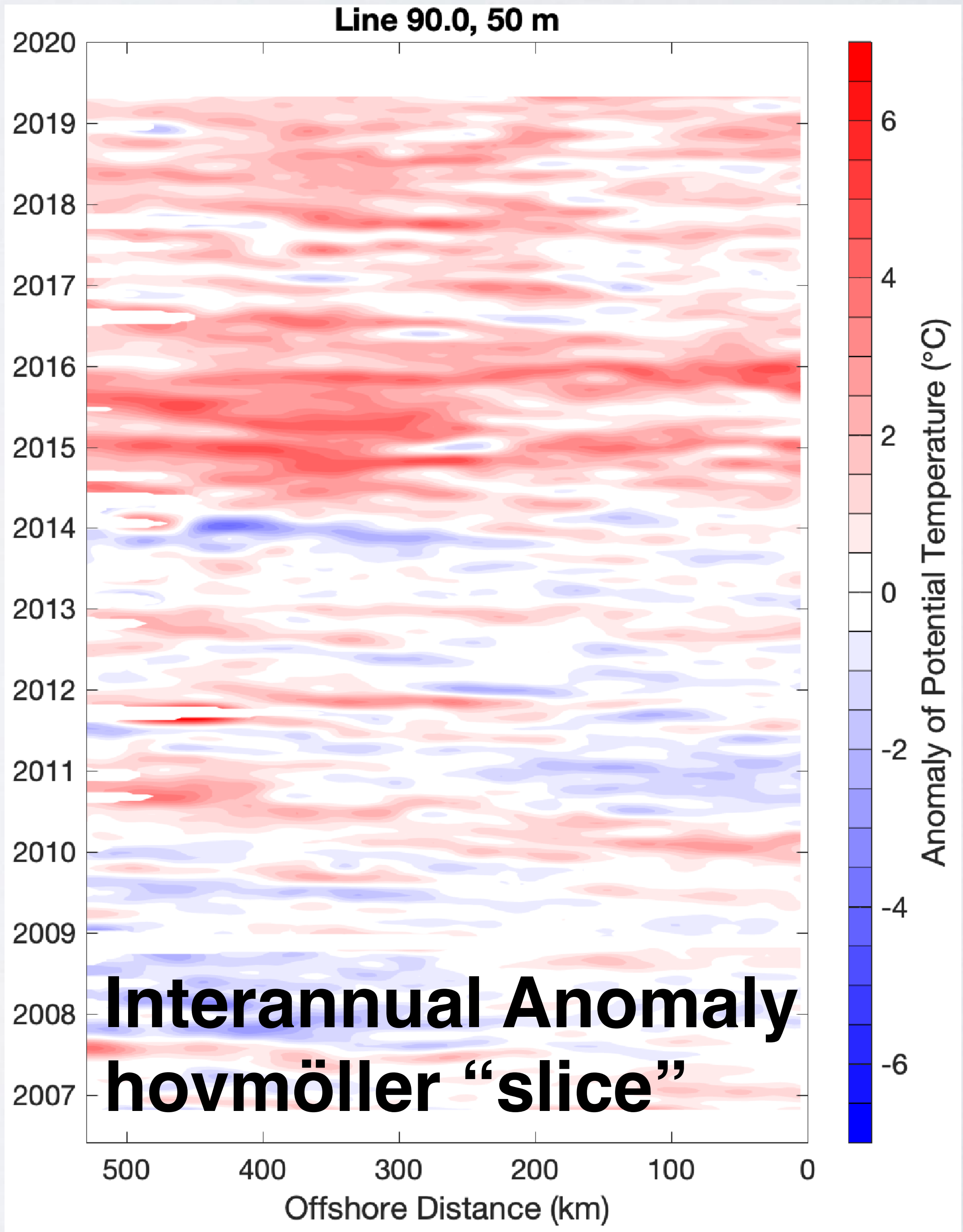
1. **Mean**
2. **Annual Cycle**
3. **Interannual Anomaly**
4. **Total**

Mean, Annual Cycle → Least-Squares Fit (*2007 - 2013*)

Interannual Anomaly → Objective Map

Total → Reconstruction (annual cycle + anomaly)

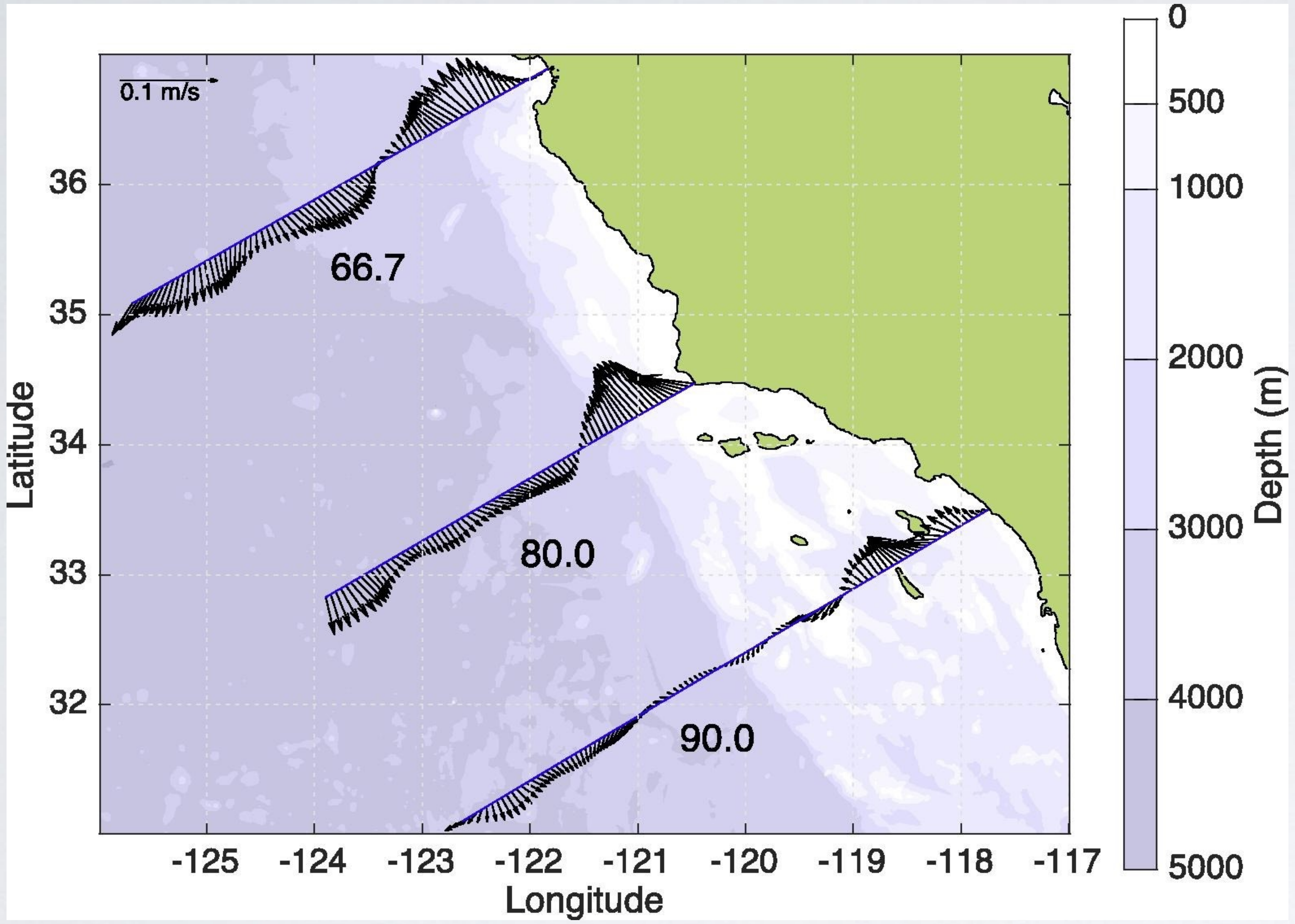



*Rudnick et al., 2017*

# Regional Circulation: Mean and Annual Cycle

***High resolution basis***, necessary for understanding variability.




*Rudnick et al., 2017*

Measured variable: depth-avg velocity

Poleward California Undercurrent

Equatorward California Current

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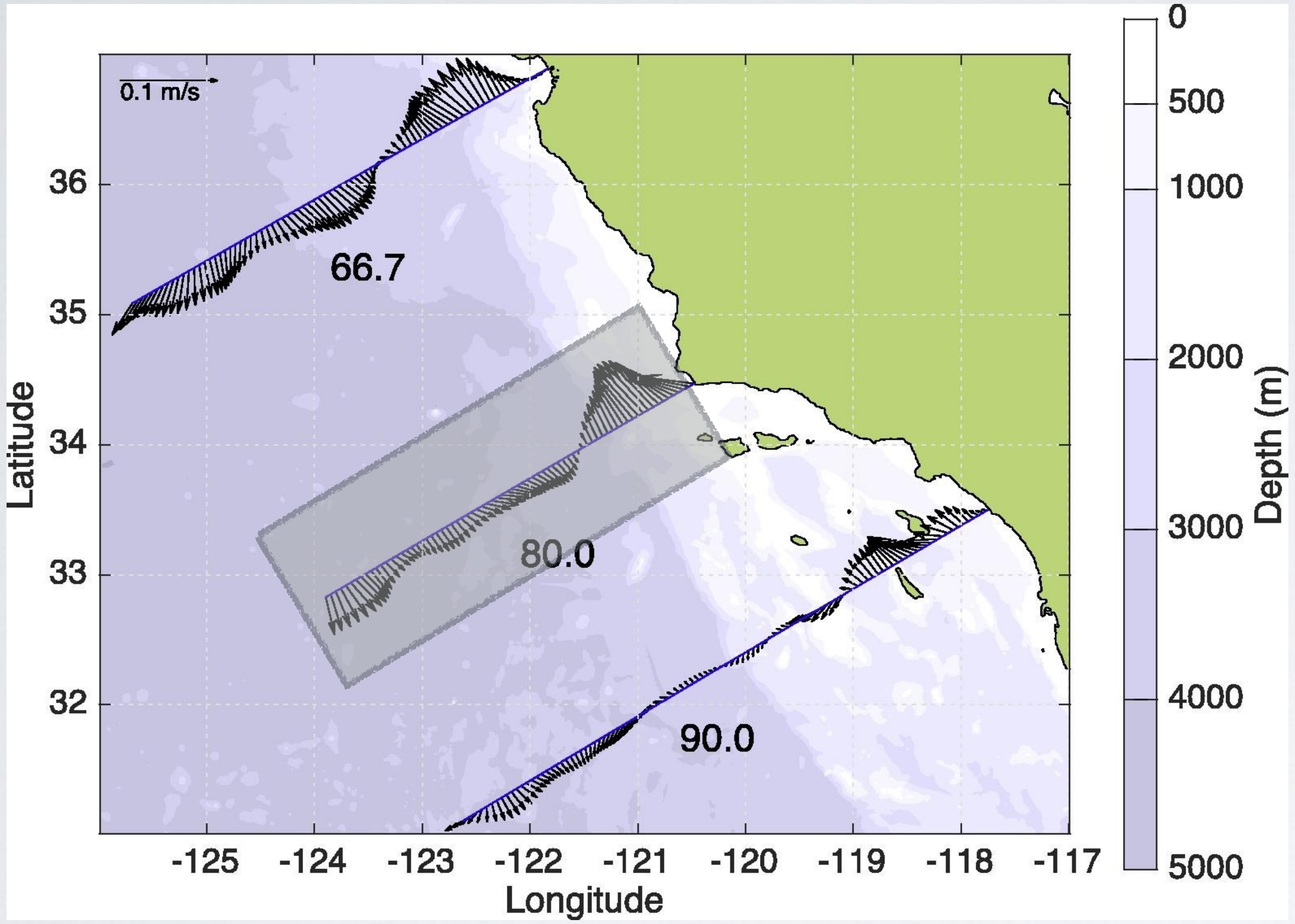
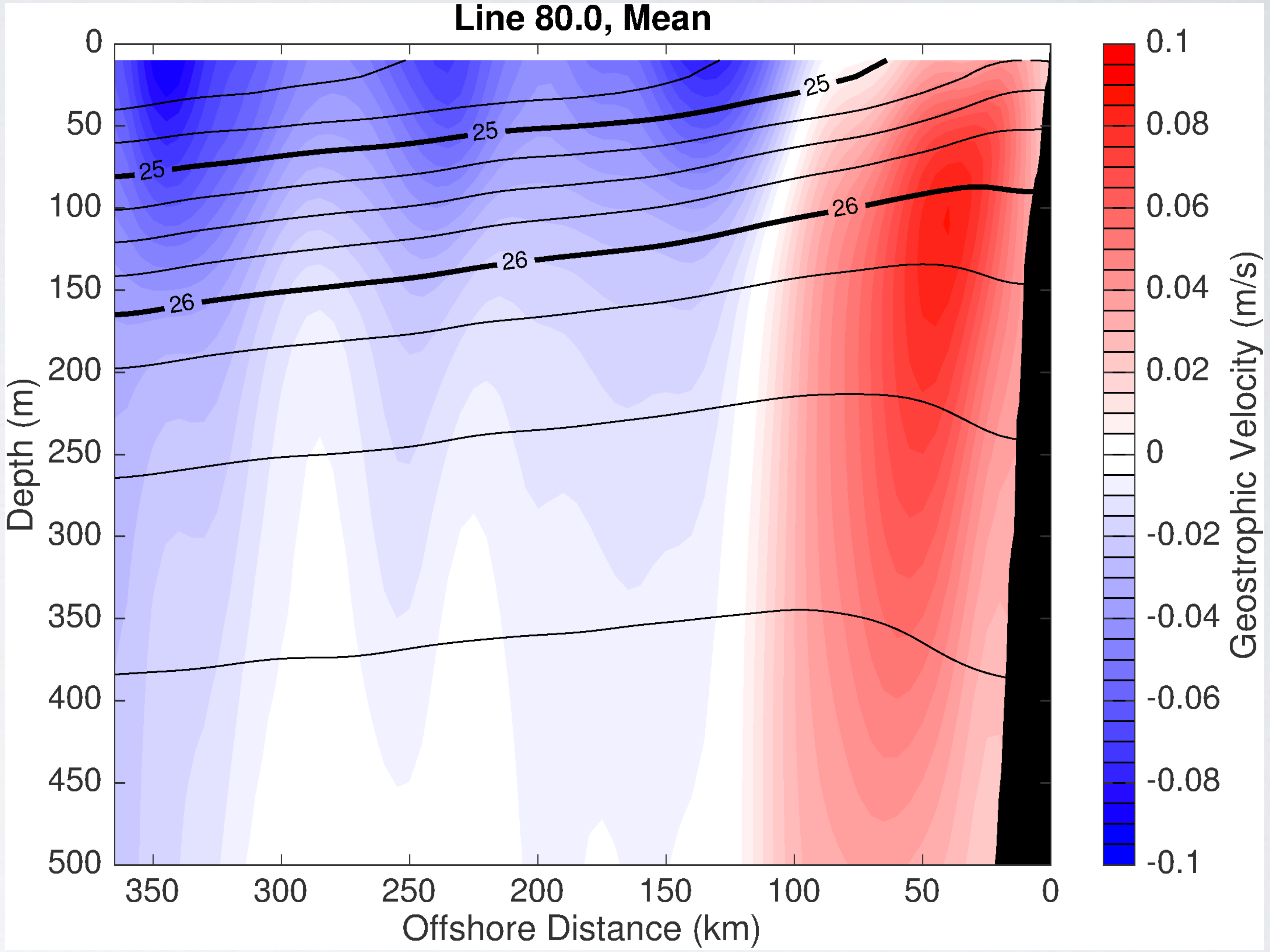



*Rudnick et al., 2017*




*Rudnick et al., 2017*

Measured variable: depth-avg velocity

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Derived quantities:

(1) Potential density (— are isopycnals)

(2) Geostrophic velocity

(thermal shear ref. to depth-avg velocity)

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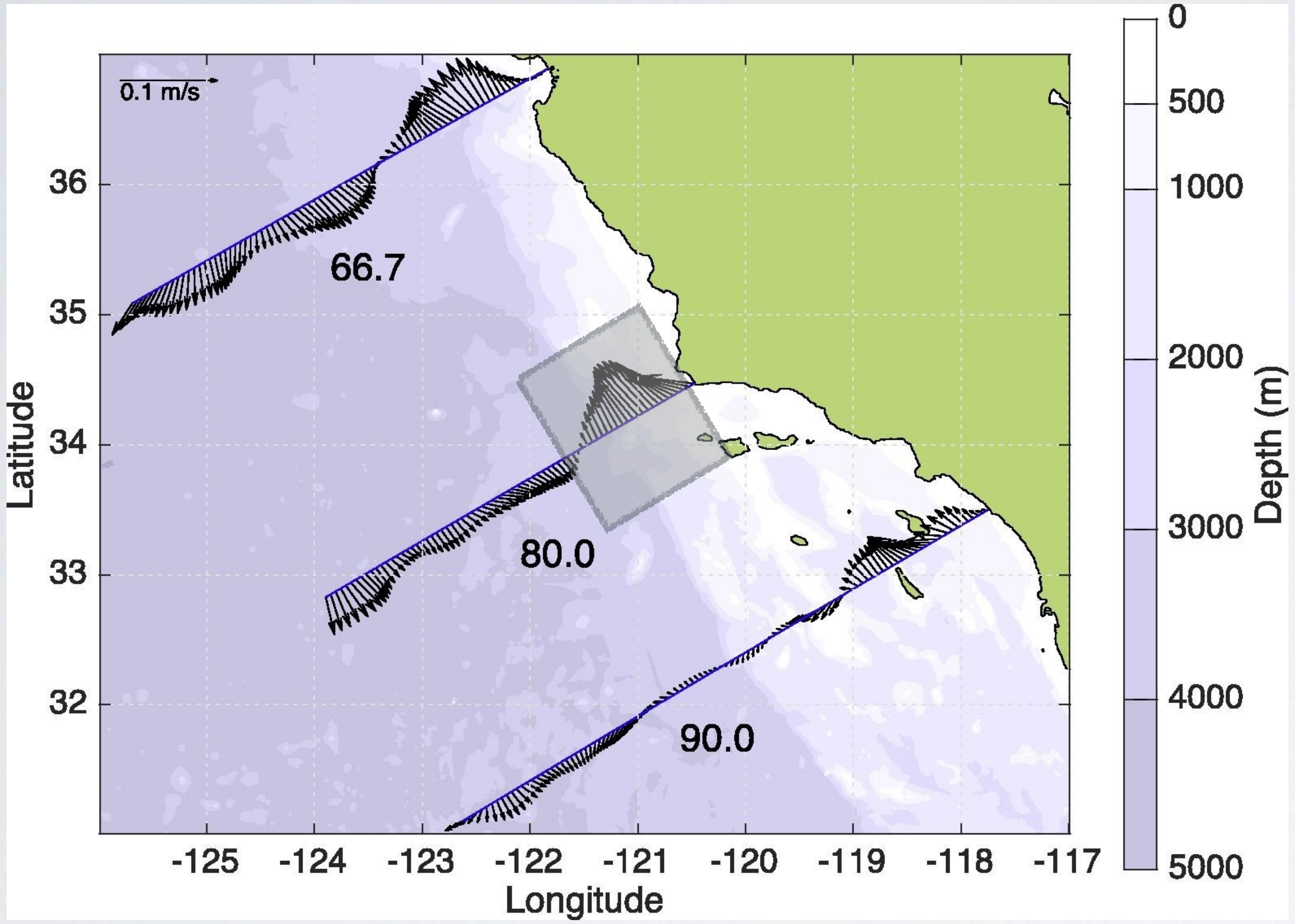
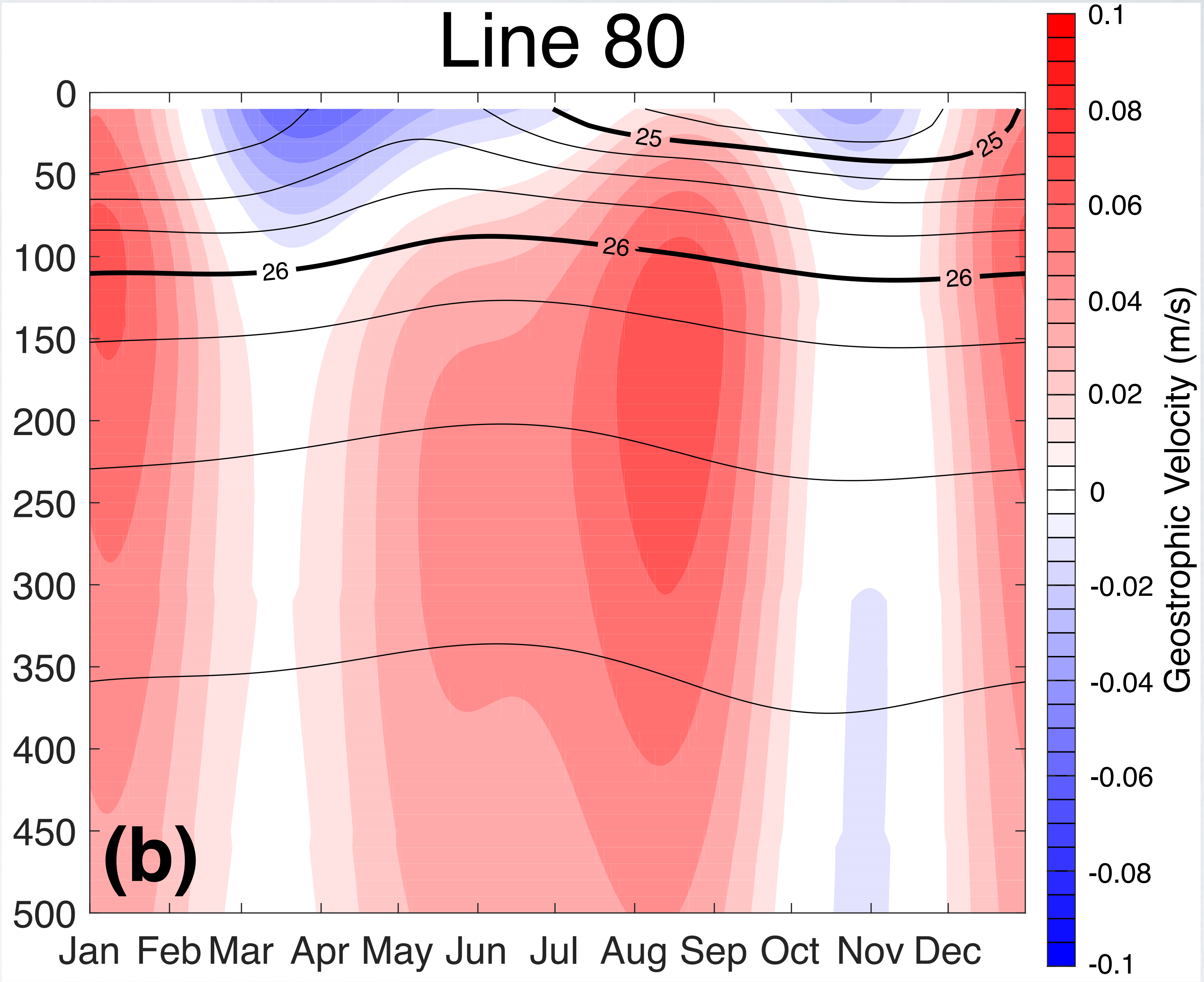



*Rudnick et al., 2017*




*Zaba et al., 2018*

Measured variable: depth-avg velocity

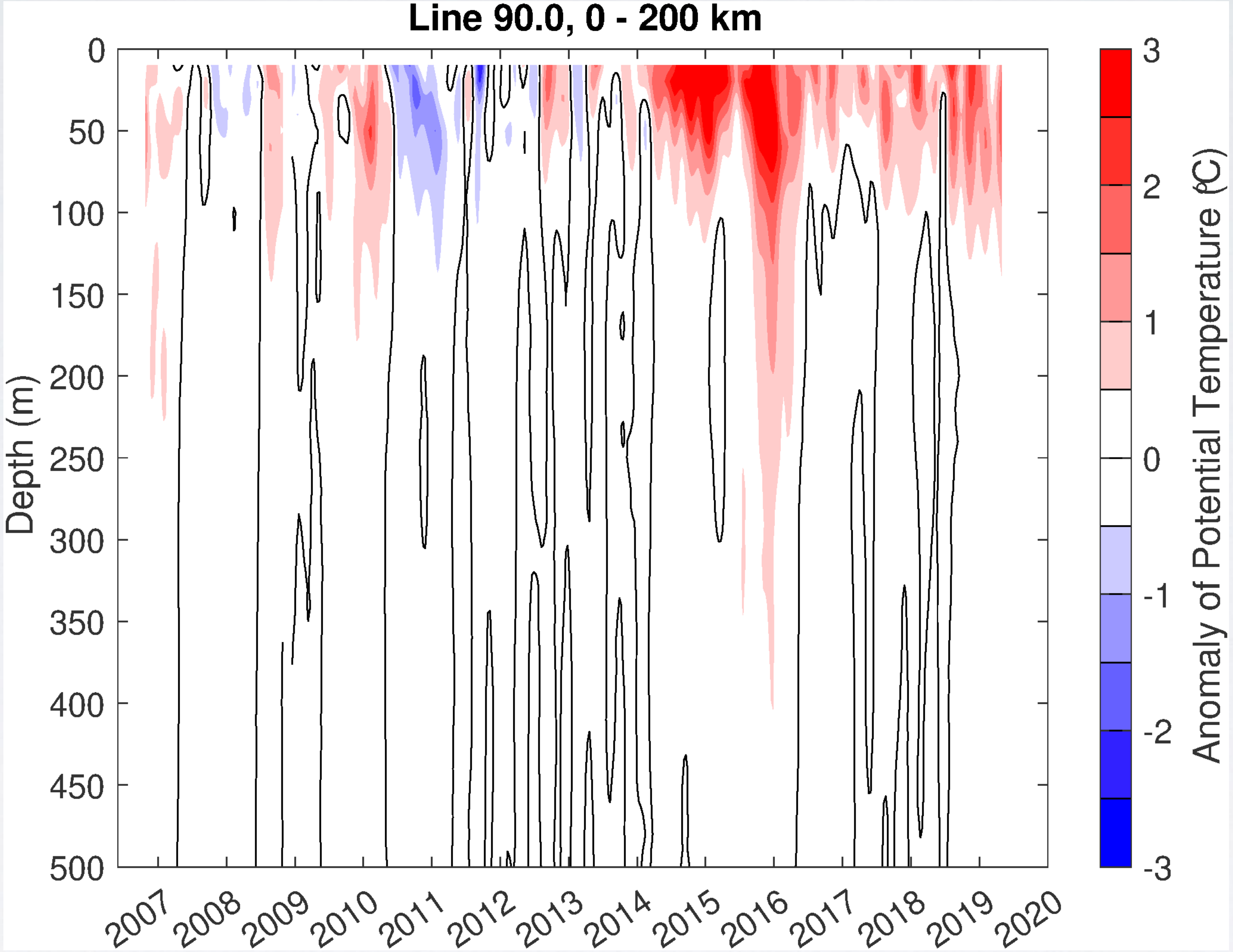
Poleward California Undercurrent

Equatorward California Current

- Springtime transition: **upwelling**
- Summer **heating**: stratification
- **Semiannual intensification** of subsurface California Undercurrent

# Interannual Temperature Anomalies

Continuous ***monitoring*** of the ***regional effects of climate variability.***

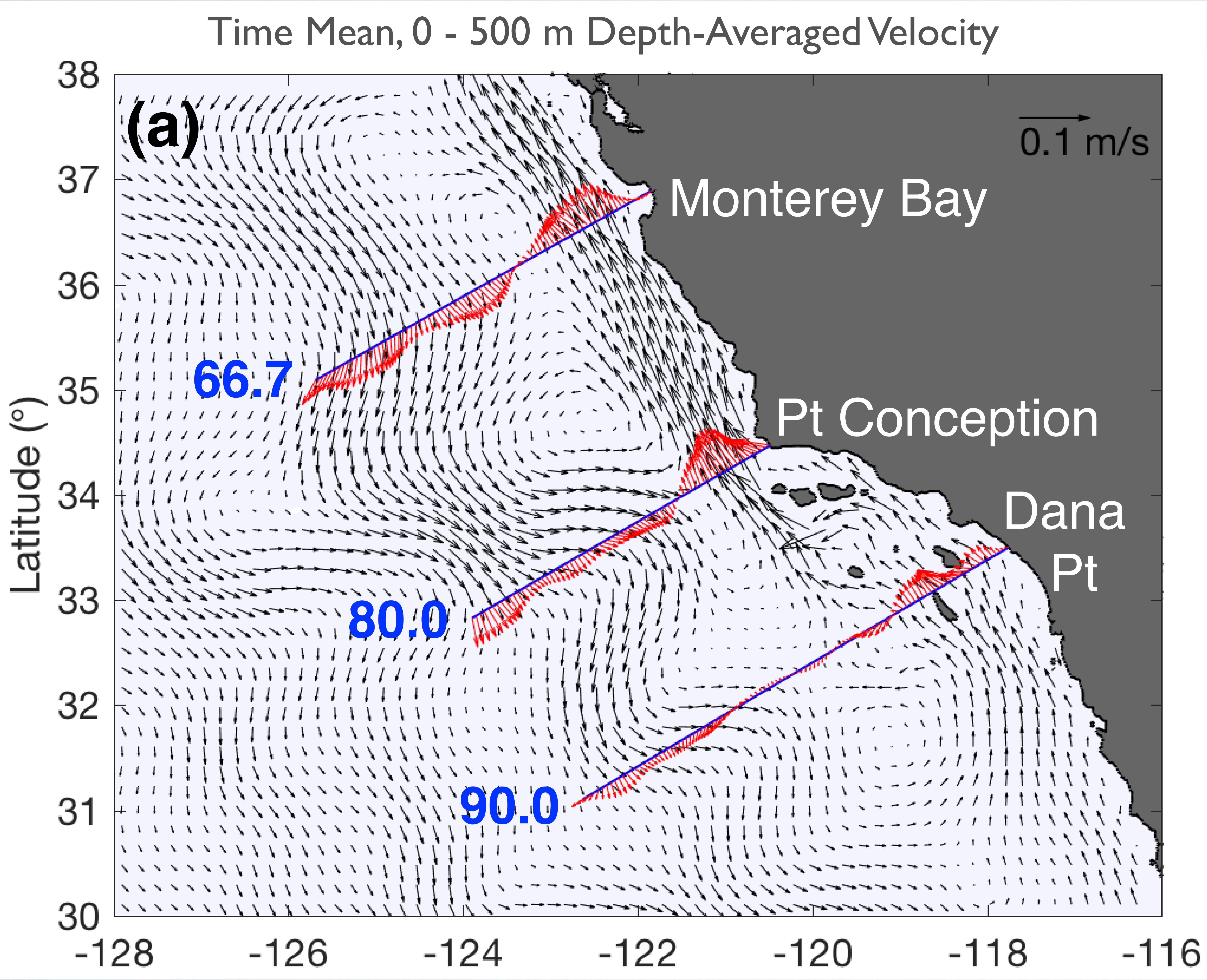



spraydata.ucsd.edu

**Marine Heatwave** warming peaks at turn of year 2014-15 (shallow, surface-intensified)

**El Niño** warming peaks at turn of year 2015-16 (penetrates deeper)

# The California State Estimate (CASE)




*Zaba et al., 2018*

ecco.ucsd.edu/case.html

- Regional version of **MITgcm**
  - $^1/_{16}$ degree (~7km) resolution
- 4-dimensional variational (**4D-Var**) **assimilation**
  - Solutions obey **model physics**
  - Solutions are optimized to **fit data**: glider, SSH, SST, Argo, XBT observations
- model output processed like data
  - "CASE climatology"

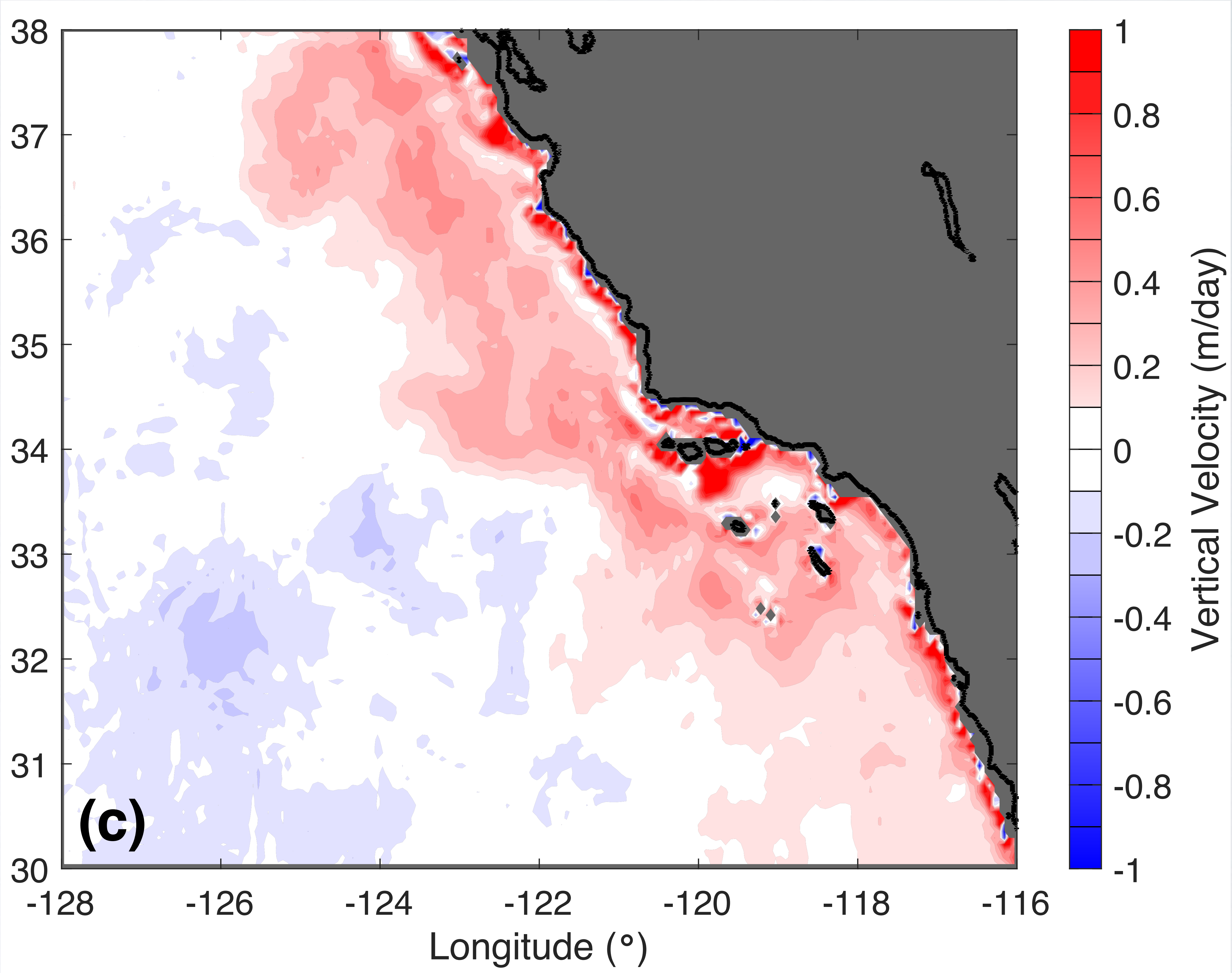
# Model augments data by providing:

1. **Estimates of cross-shore and vertical velocities.**

2. Full four-dimensional (4D) context for observed anomalies.

3. Hypotheses of forcing mechanisms of observed anomalies.

## Mean vertical velocity across z = 50m




*Zaba et al., in prep*

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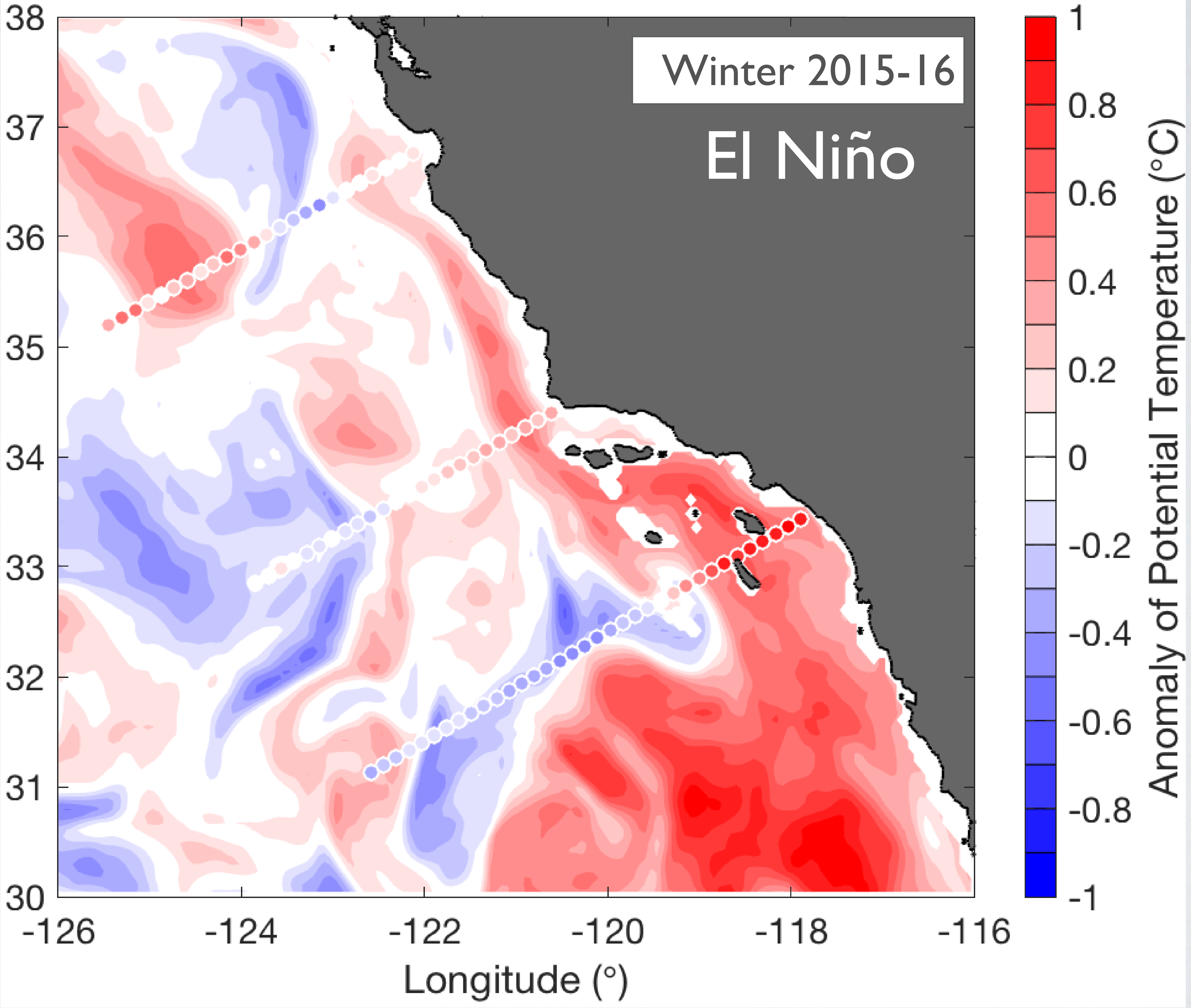
26 kg/m$^3$ isopycnal pot. temp. anomaly




*Zaba et al., in prep*

# Model augments data by providing:

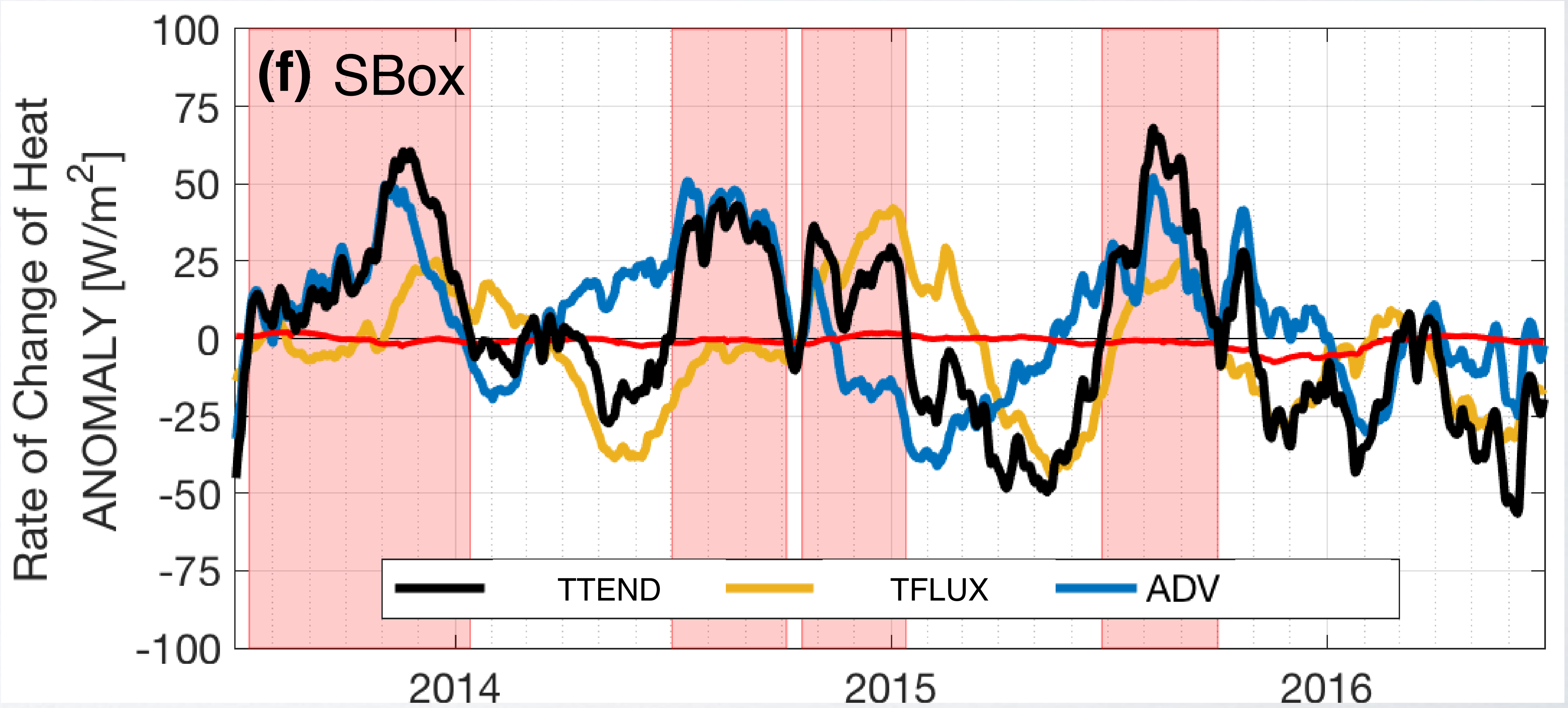
1. Estimates of cross-shore and vertical velocities.

2. Full four-dimensional (4D) context for observed anomalies.

3. **Hypotheses of the forcing mechanisms of observed anomalies.**
   (*via closed physical budgets*)

## Heat Budget

$$\underbrace{\rho_o c_p \frac{\partial T}{\partial t}}_{\text{temperature tendency}} = \underbrace{\frac{\partial Q}{\partial z}}_{\text{air-sea heat flux}} - \rho_o c_p \left( \underbrace{\vec{u} \cdot \nabla T}_{\text{heat advection}} - \underbrace{\left( \kappa_H \nabla_H^2 T + \kappa_Z \frac{d^2 T}{dz^2} + K_T^{turb} \right)}_{\text{heat diffusion}} \right)$$




*Zaba et al., in prep*

# Summary

**CUGN climatology** for 2006-present available at: [spraydata.ucsd.edu]

**CASE model output** for 2007-2017 available at: [ecco.ucsd.edu/case.html]

Complementary use of *glider data* and *data-assimilating model*

- real-time **monitoring**
- improving **realism** of model

- **diagnosing physical mechanisms** that drive the observed anomalies