An Assessment of the Observing System for the California Current

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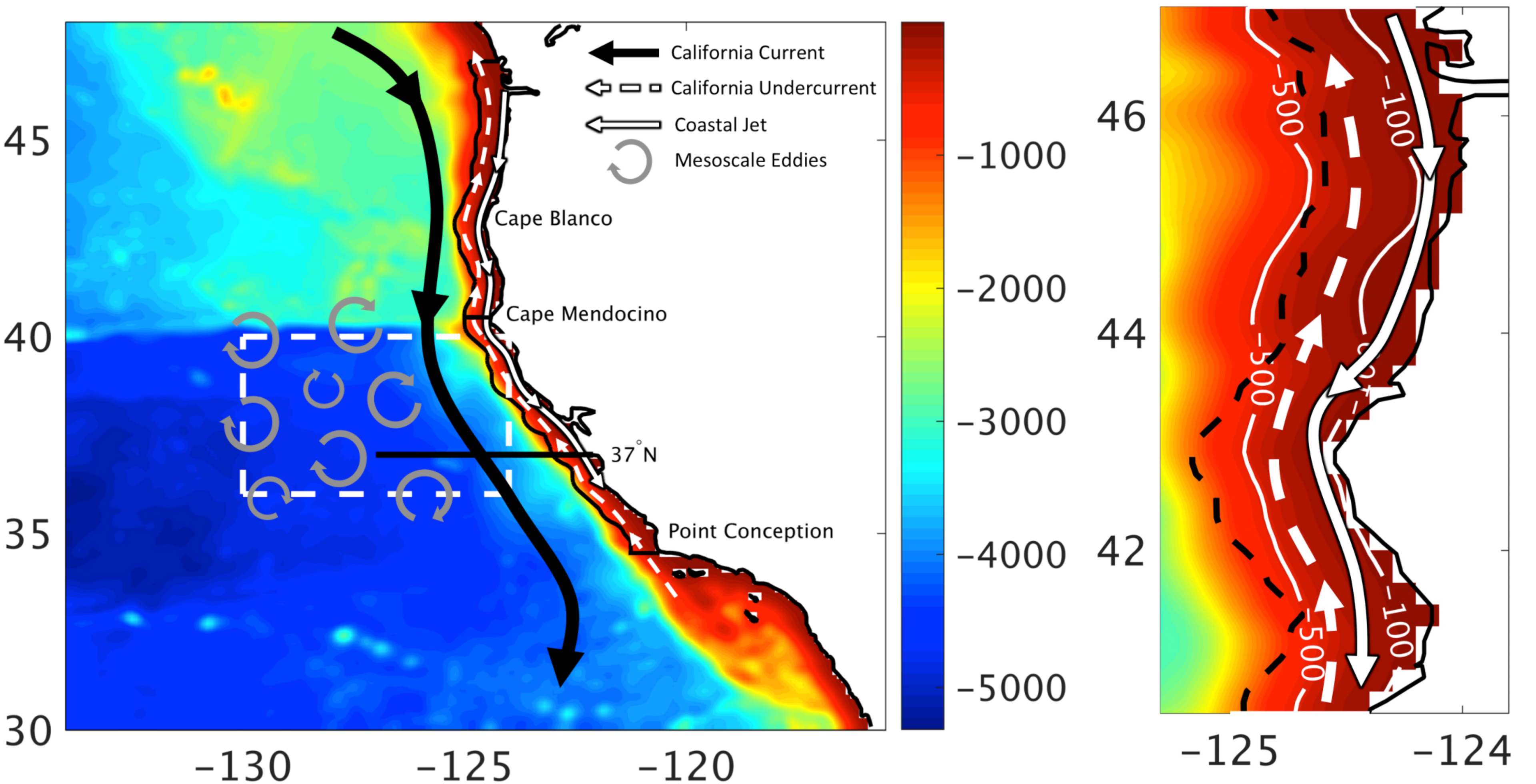
Two Questions Posed by West Coast COMT Group

- What is the impact of the current observing system on the CCS circulation?
  - Observation impact studies (presented previously)
  - Metrics: upwelling transport
    undercurrent transport
    CCS transport along specific section
    eddy kinetic energy
    thermocline depth
    climate variability (NEW)

- How well do existing assets "observe" the CCS?
  - Array modes (NEW)

The California Current System (CCS)



ROMS CCS 30 Yr Analysis

CCMP+ERA (1980-2010)

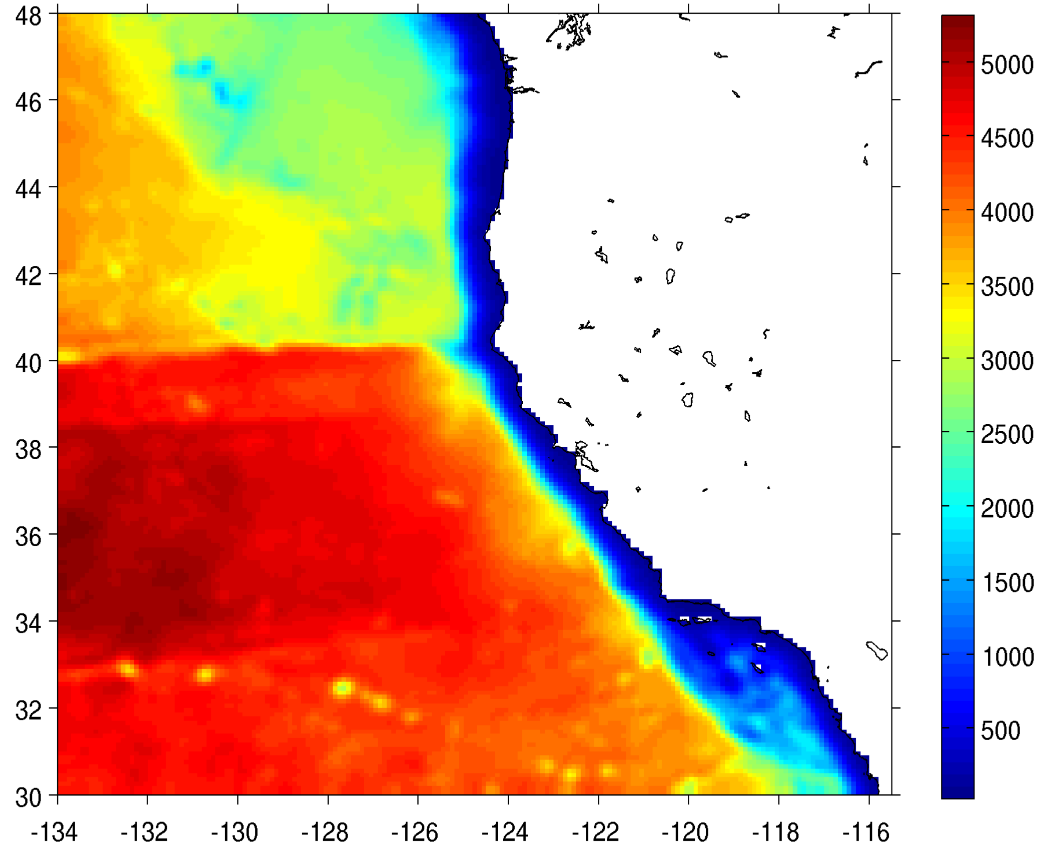
$f_b(t), B_f$

SODA open boundary conditions

$b_b(t), B_b$

$x_b(0), B_x$

Previous assimilation cycle (8 day overlapping cycles)

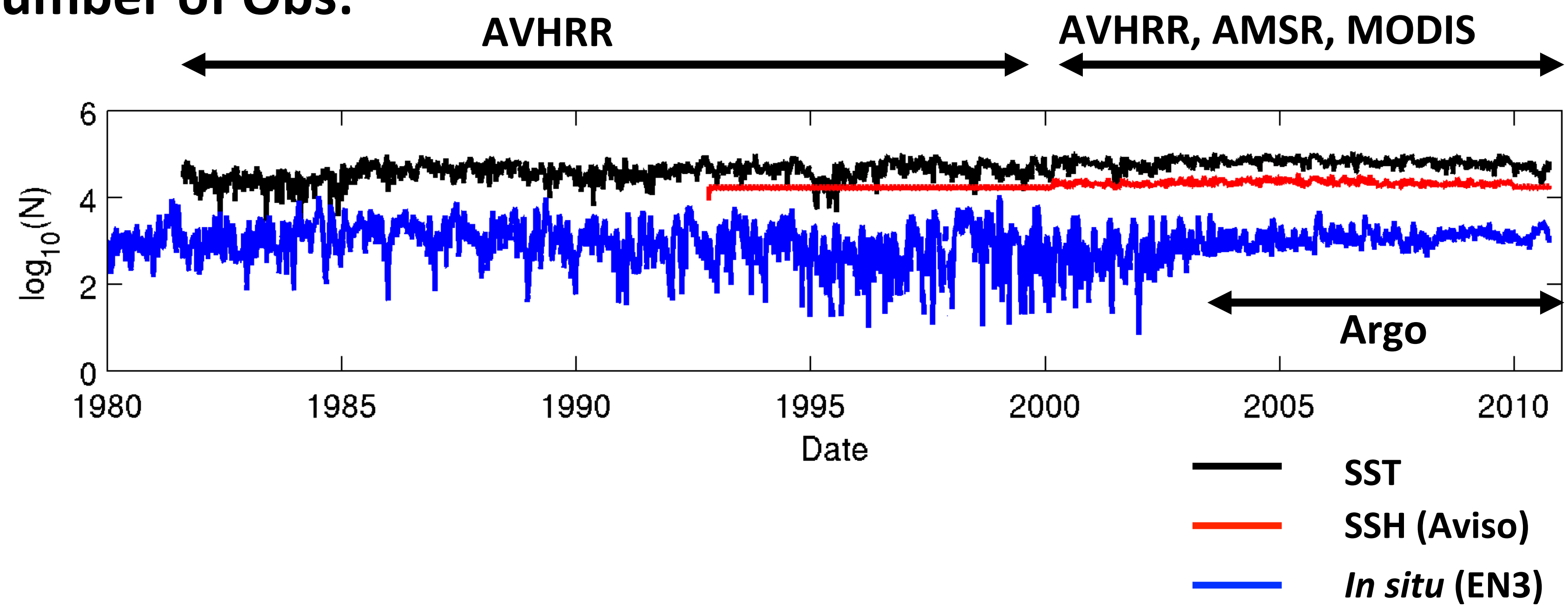


1/10° horizontal resolution, 42 levels

Veneziani et al (2009)
Broquet et al (2009)
Moore et al (2010)

Observation Summary

Number of Obs:



DA Summary

- **ROMS dual-space 4D-Var**
- **8 day overlapping cycles**
- **Control vector: x, f, b.**
- **1 outer-loop**
- **15 inner-loops**
- **Strong constraint**

(Neveu et al., 2015)

• **What is the impact of the current observing system on the CCS circulation?**

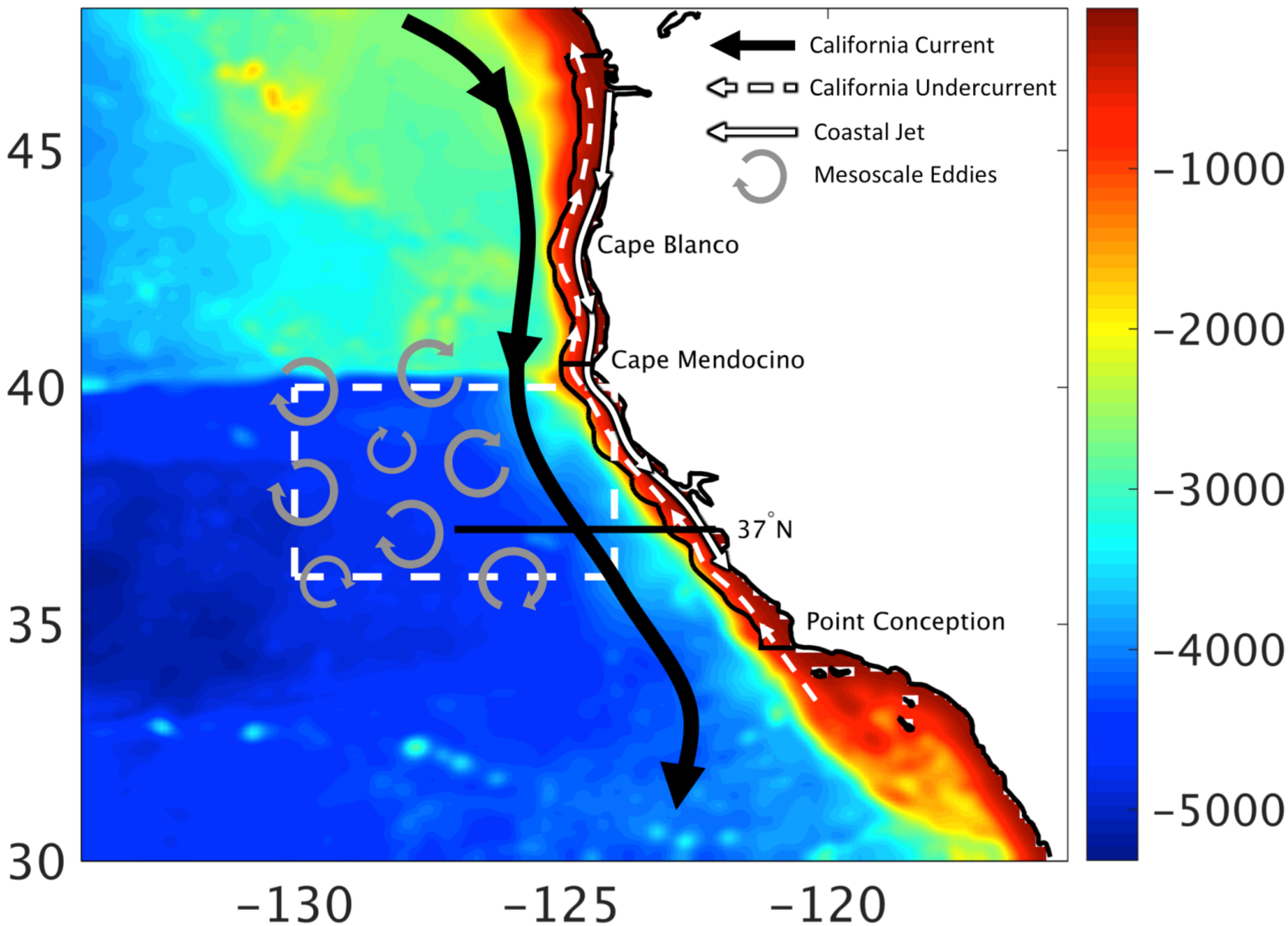
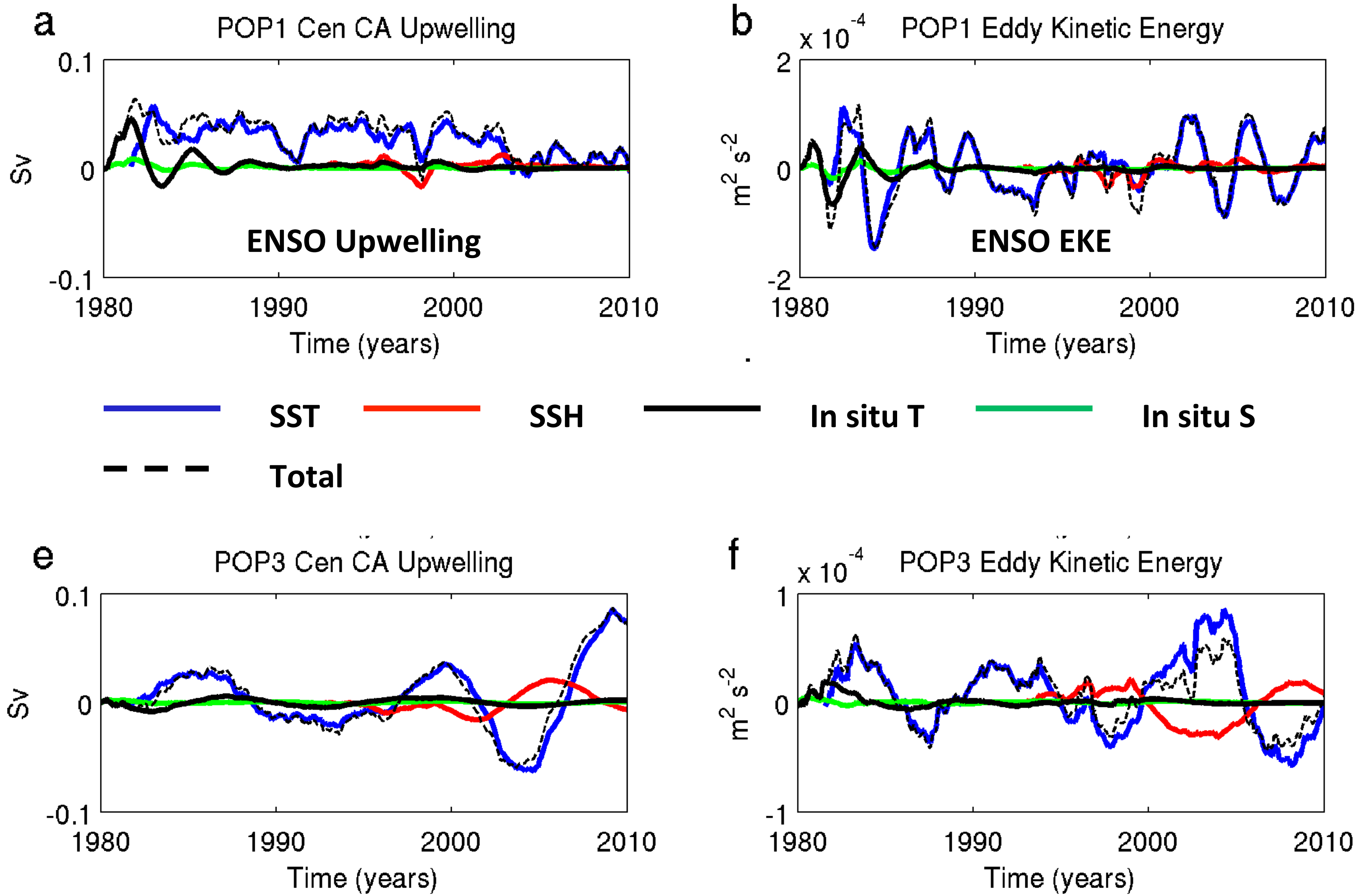


Figure shows target regions of interest

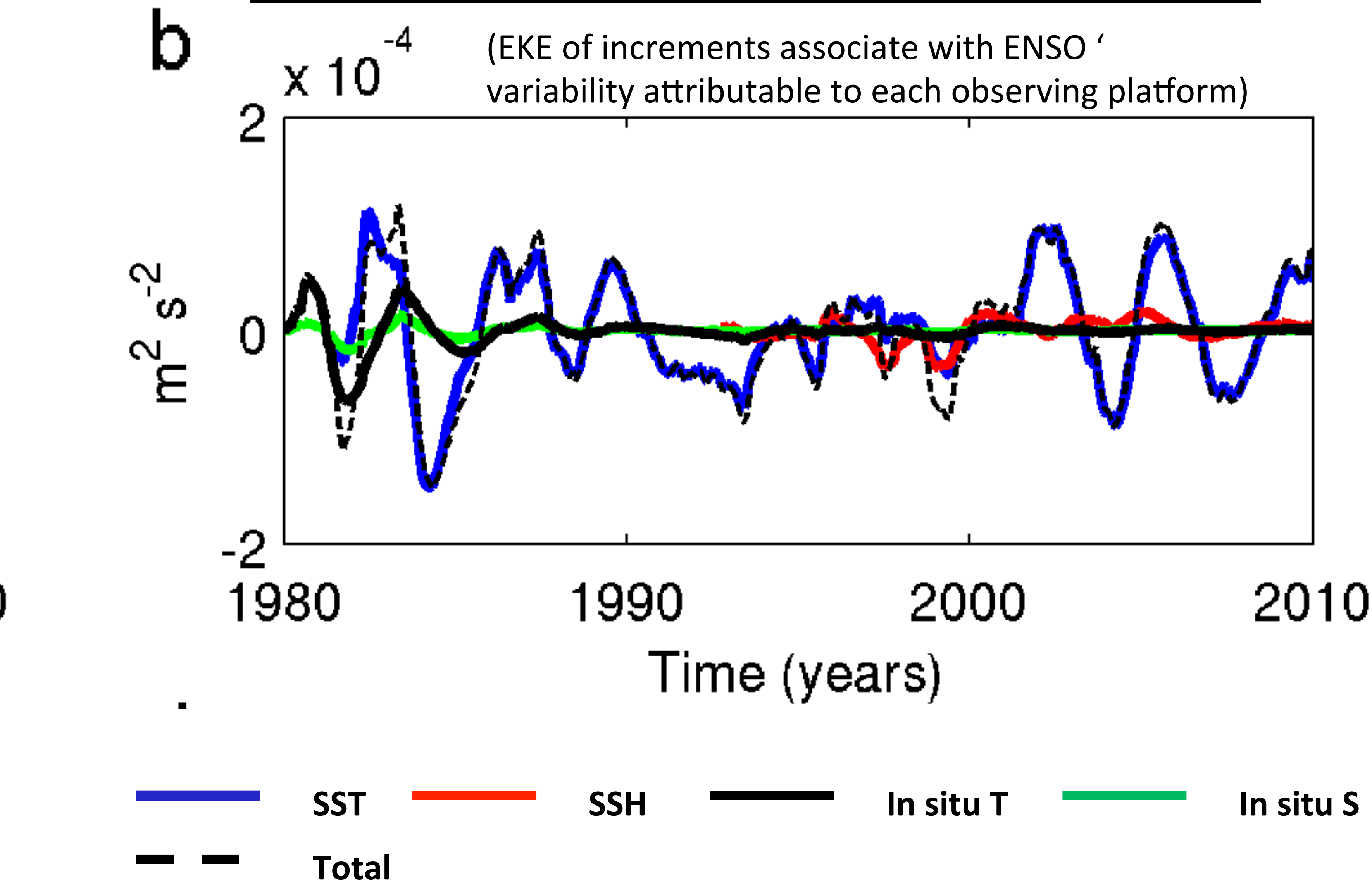
The principal oscillation pattern (POP) analysis is a multivariate technique used to simultaneously infer the characteristic patterns and times cales of a vector time series. The POPs may be seen as the normal modes of a linearized system whose system matrix is estimated from data.

Von Storch (1995)

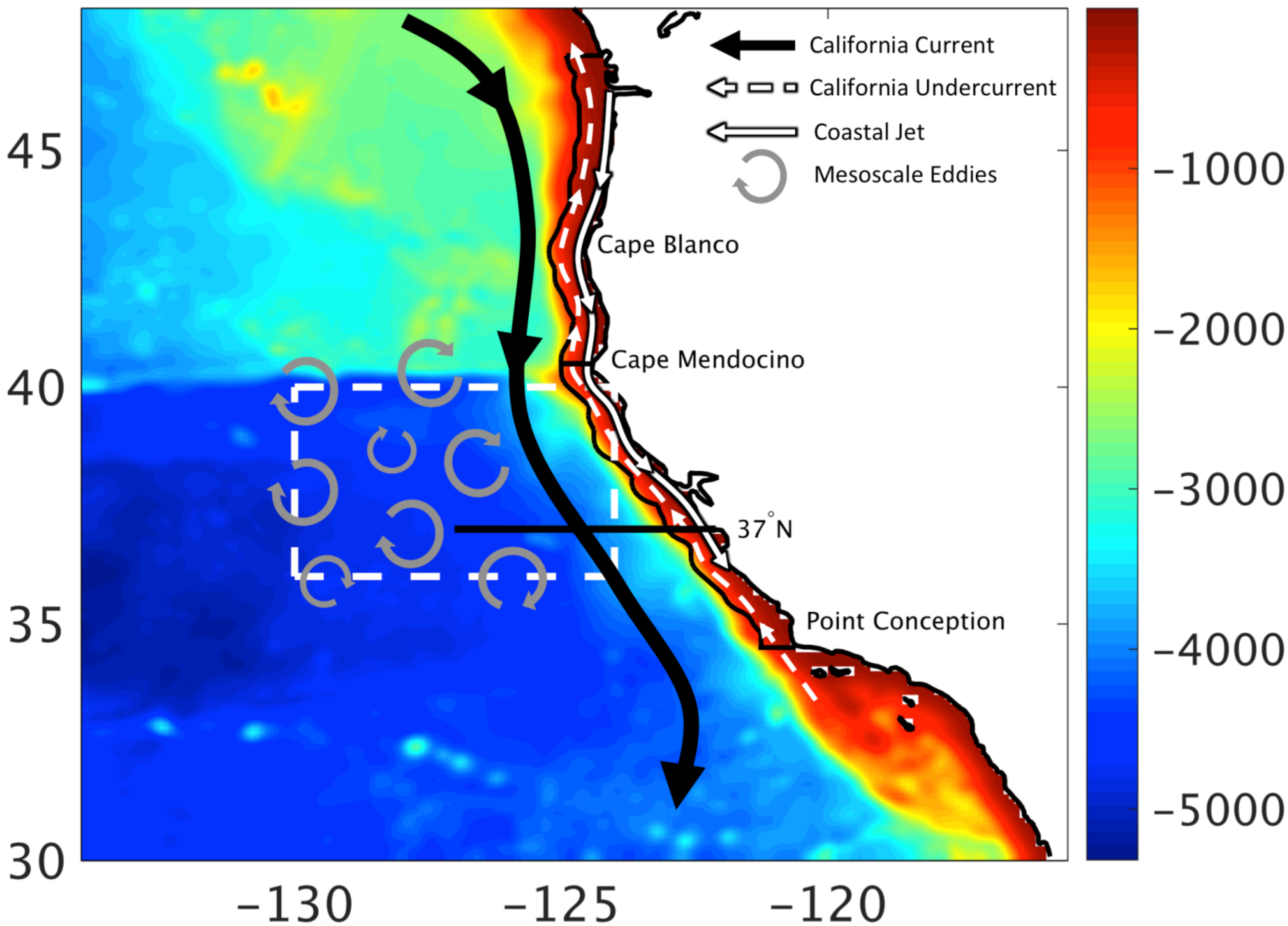
Principal Oscillation Patterns (POPs)



Observation Impacts on ENSO-related EKE



- **How well do existing assets "observe" the CCS?**



The Importance of the Background Error Covariance Matrix

$$\mathbf{x}_a = \mathbf{x}_b + \mathbf{B}\mathbf{G}^T\left(\mathbf{G}\mathbf{B}\mathbf{G}^T + \mathbf{R}\right)^{-1}\left(\mathbf{y} - H(\mathbf{x}_b)\right)$$

- analysis: $\mathbf{x}_a$
- background: $\mathbf{x}_b$
- adjoint obs operator: $\mathbf{G}^T$
- background error cov matrix: $\mathbf{B}$
- obs error cov matrix: $\mathbf{R}$
- obs: $\mathbf{y}$
- obs operator: H

Analysis increment

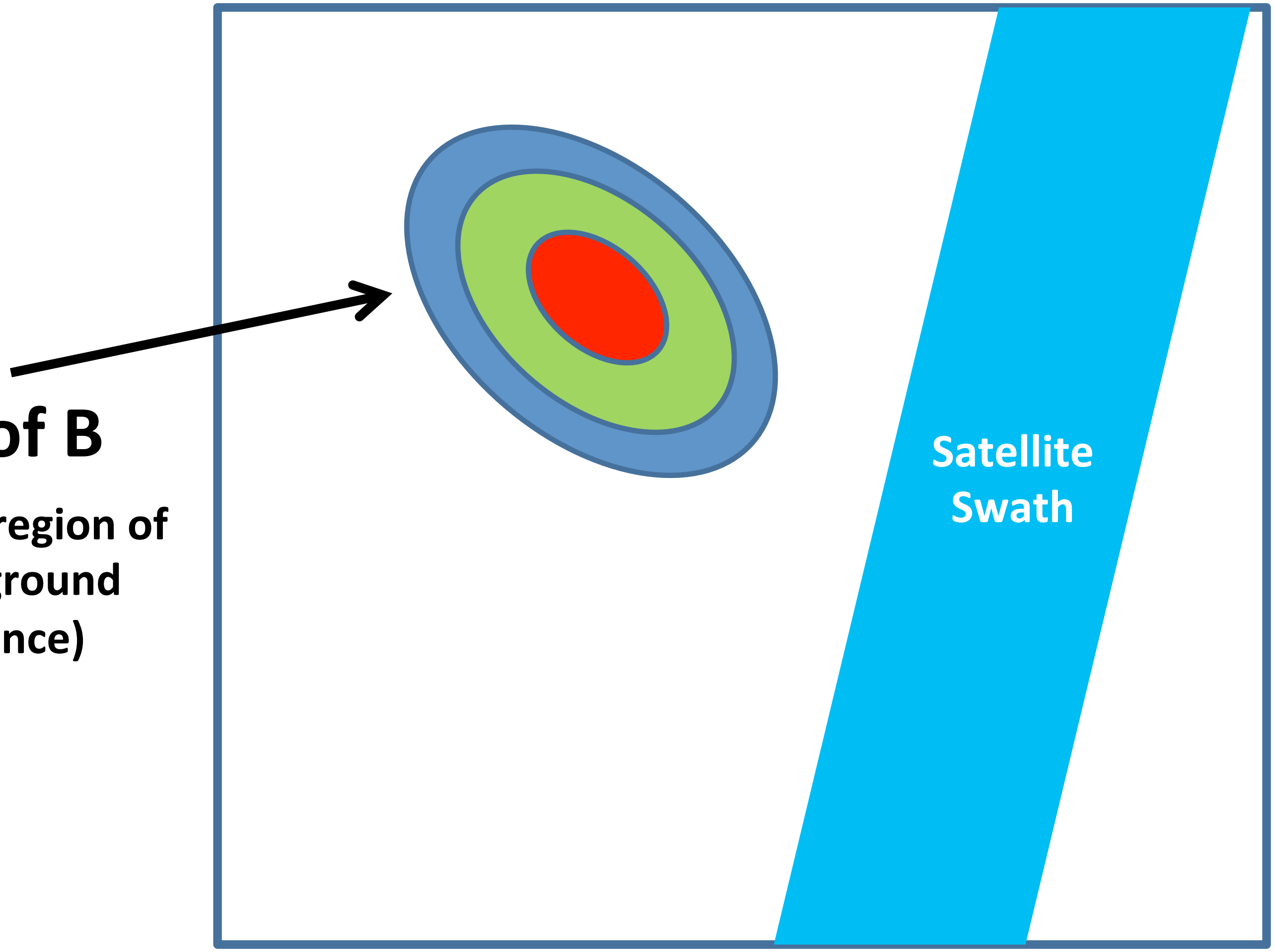
The analysis increment "lives" in the space spanned by B !!!

Therefore, to reduce errors in x_b, the observing system must effectively observe (directly via G or indirectly via G^T) the dominant EOFs of B.

An Illustrative Example

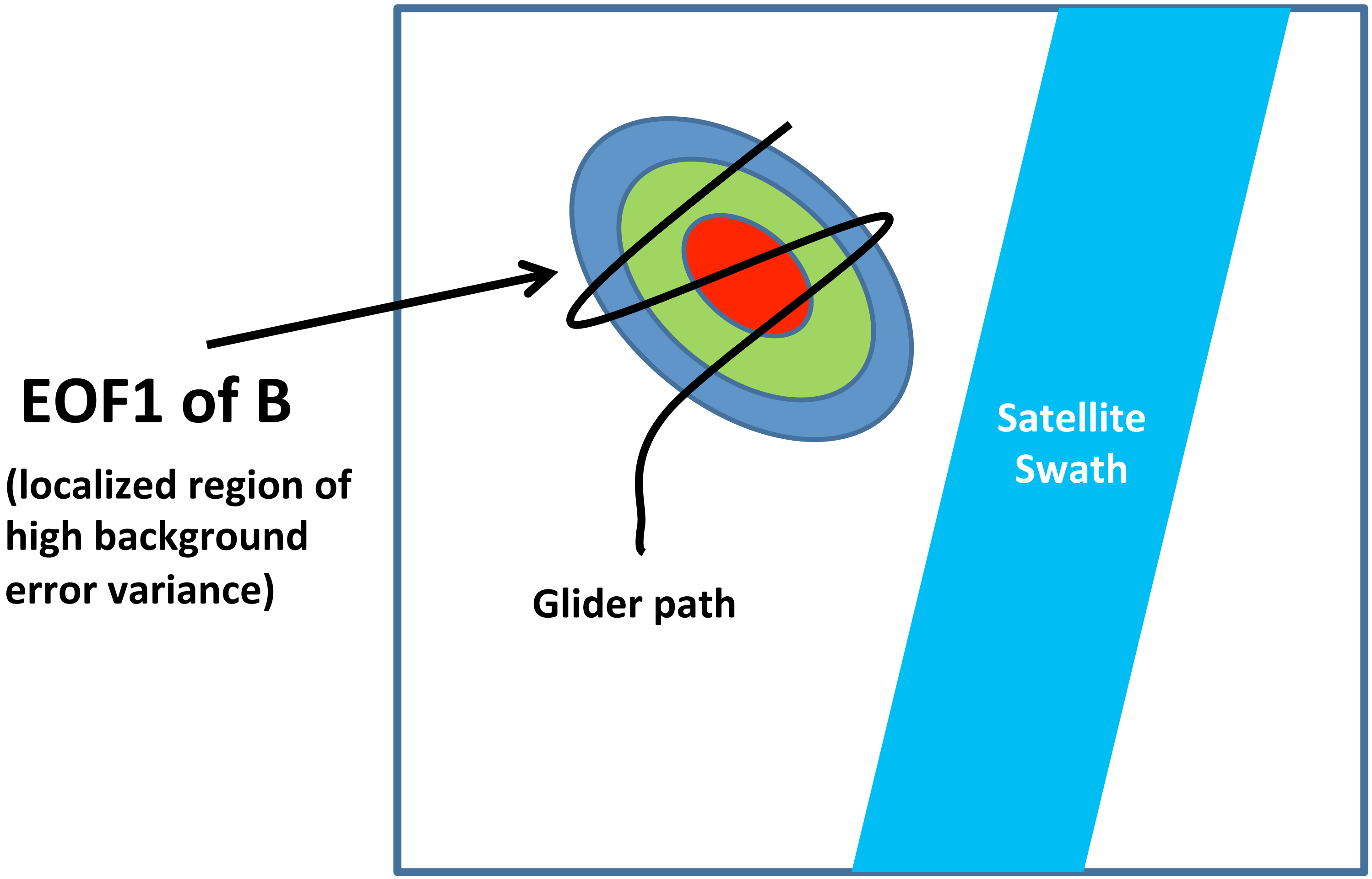
EOF1 of B

(localized region of high background error variance)



The satellite swath does not directly (G) or indirectly (G^T) observe the region of elevated background error variance associated with EOF1 of B, so errors in this regions will not be corrected during data assimilation by the satellite.

An Illustrative Examples



The glider path **does** **directly observe the region of high error background error variance associated with EOF1 of B, so errors in this regions** **will** **be corrected during data assimilation by the glider.**

Array Modes

- The degree to which the EOFs of B are captured by the observing systems is described by the "array modes."

- The array modes depend *ONLY* on the observation locations, not the observation values.

$$\mathbf{x_a} = \mathbf{x_b} + \sum_{i=1}^{N} \alpha_i \Phi_i$$

analysis — $\mathbf{x_a}$

background — $\mathbf{x_b}$

Weights (α_i)
(depend on obs values)

Array modes (Φ_i)

Bennett (1985)

Summary and Conclusions

- We have used observation impact calculations to quantify the influence of the existing observing system on the CCS circulation and climate variability (Moore et al., 2016).
- Analysis of the array modes is currently underway.
- Preliminary results suggest that the current observing system observed rather well the dominant EOFs of the background error covariance matrix.
- Caveat: the analysis will only ever be as good as **B**