Forecast Sensitivity-Based Observation Impact (FSOI) in an Analysis-Forecast System of the California Current System

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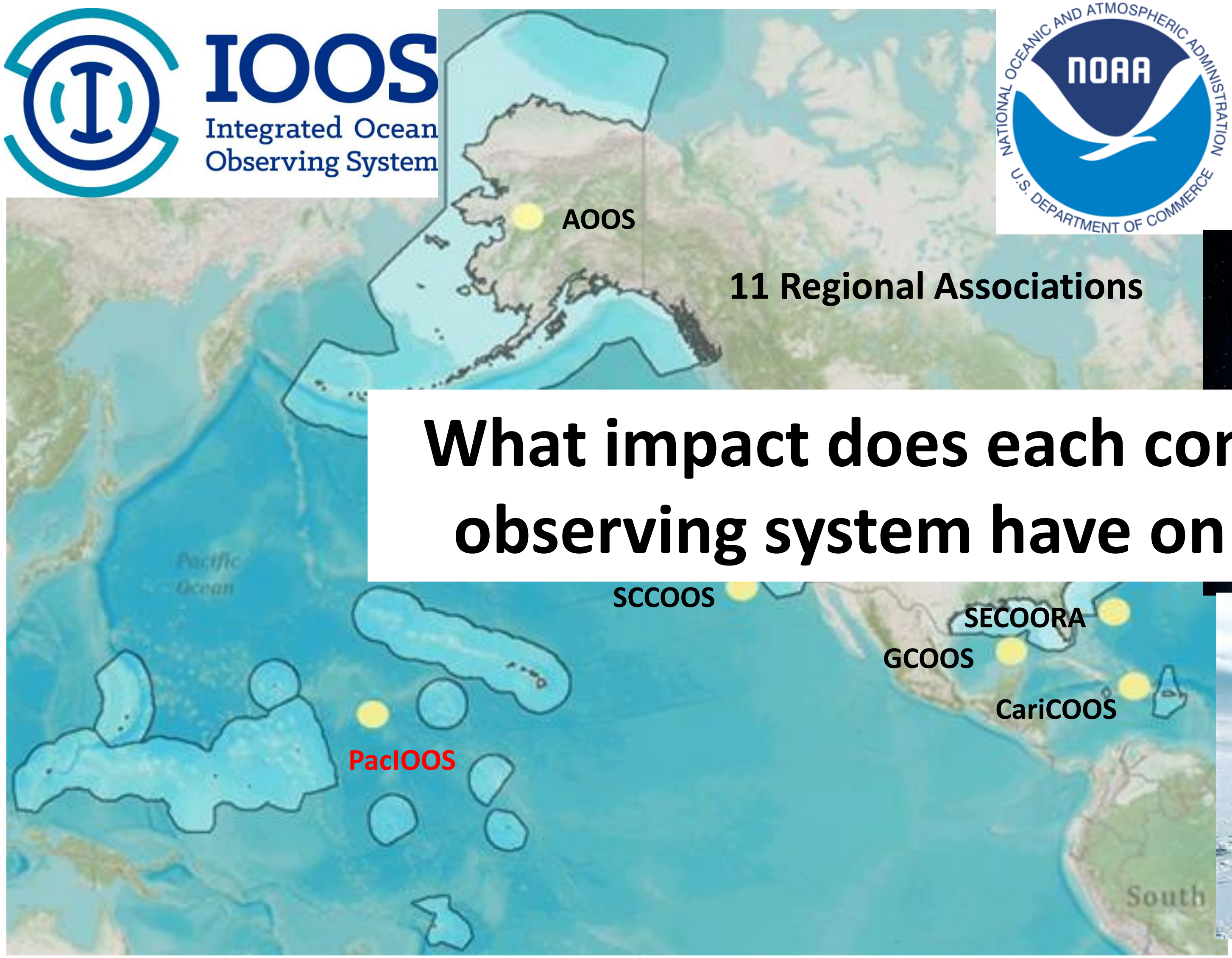
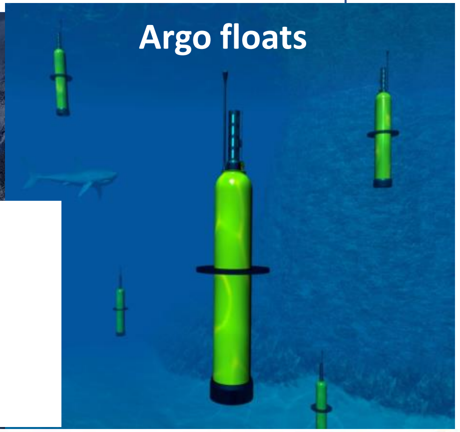
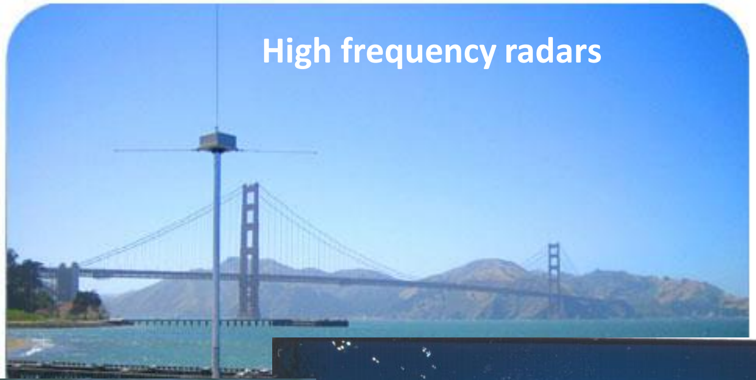
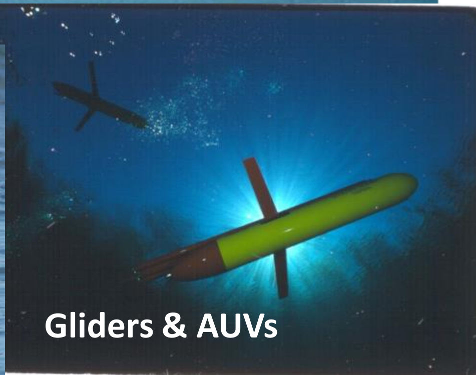
CenCOOS, MARACOOS & PacIOOS near real-time analysis-forecast systems are all based on Regional Ocean Modeling System (ROMS) 4-dimensional variational (4D-Var) data assimilation.



What impact does each component of the observing system have on forecast skill?



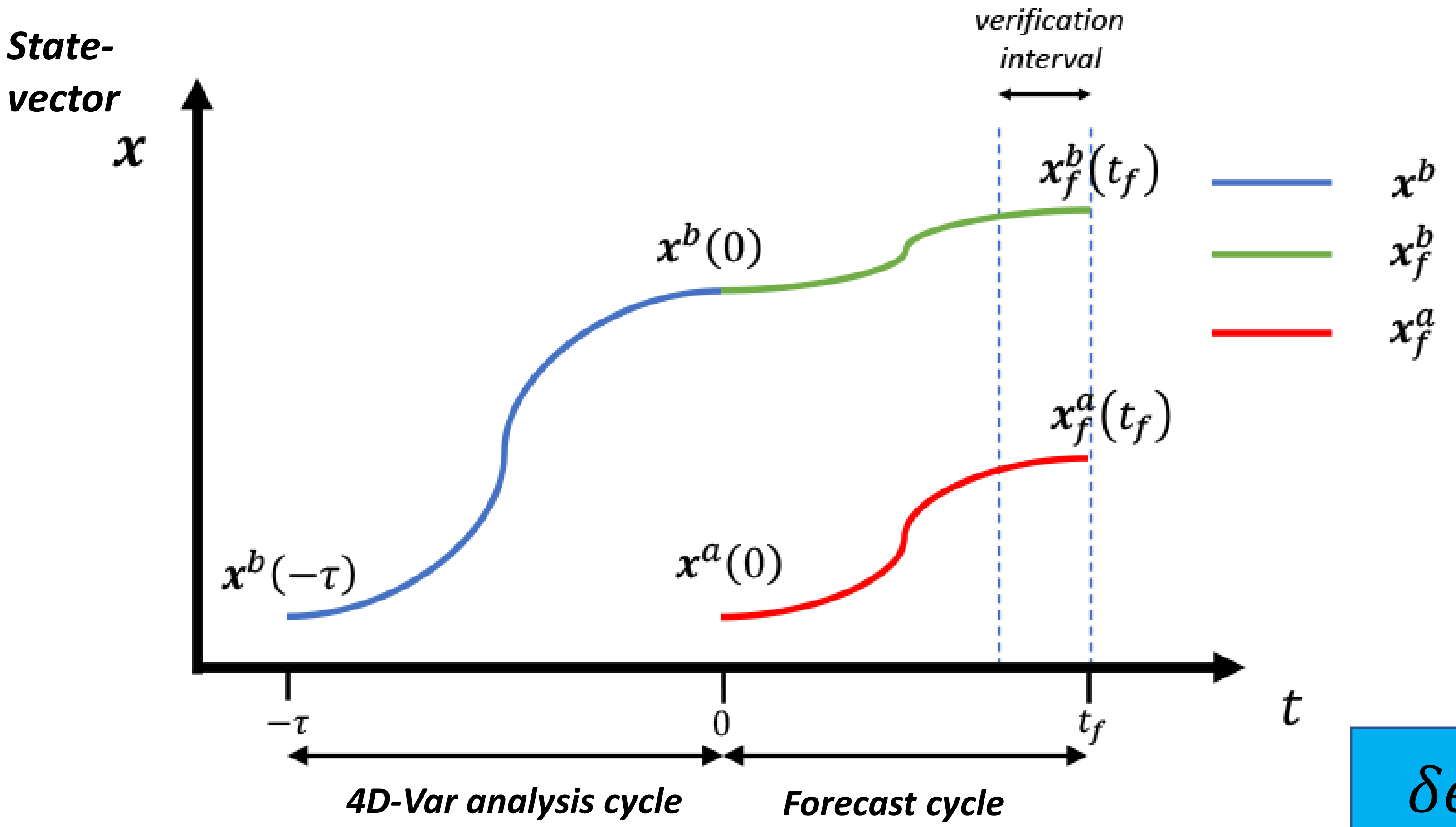




CeNCOOS = Central and Northern California Ocean Observing System
MARACOOS = Mid-Atlantic Regional Association Ocean Observing System
PacIOOS = Pacific Island Ocean Observing System

Forecast Sensitivity-Based Observation Impact (FSOI)

Baker & Daley (2000); Langland & Baker (2004); Errico (2007); Trémolet (2008); Zhu & Gelaro (2008)



Forecast error: $e(\boldsymbol{x})$

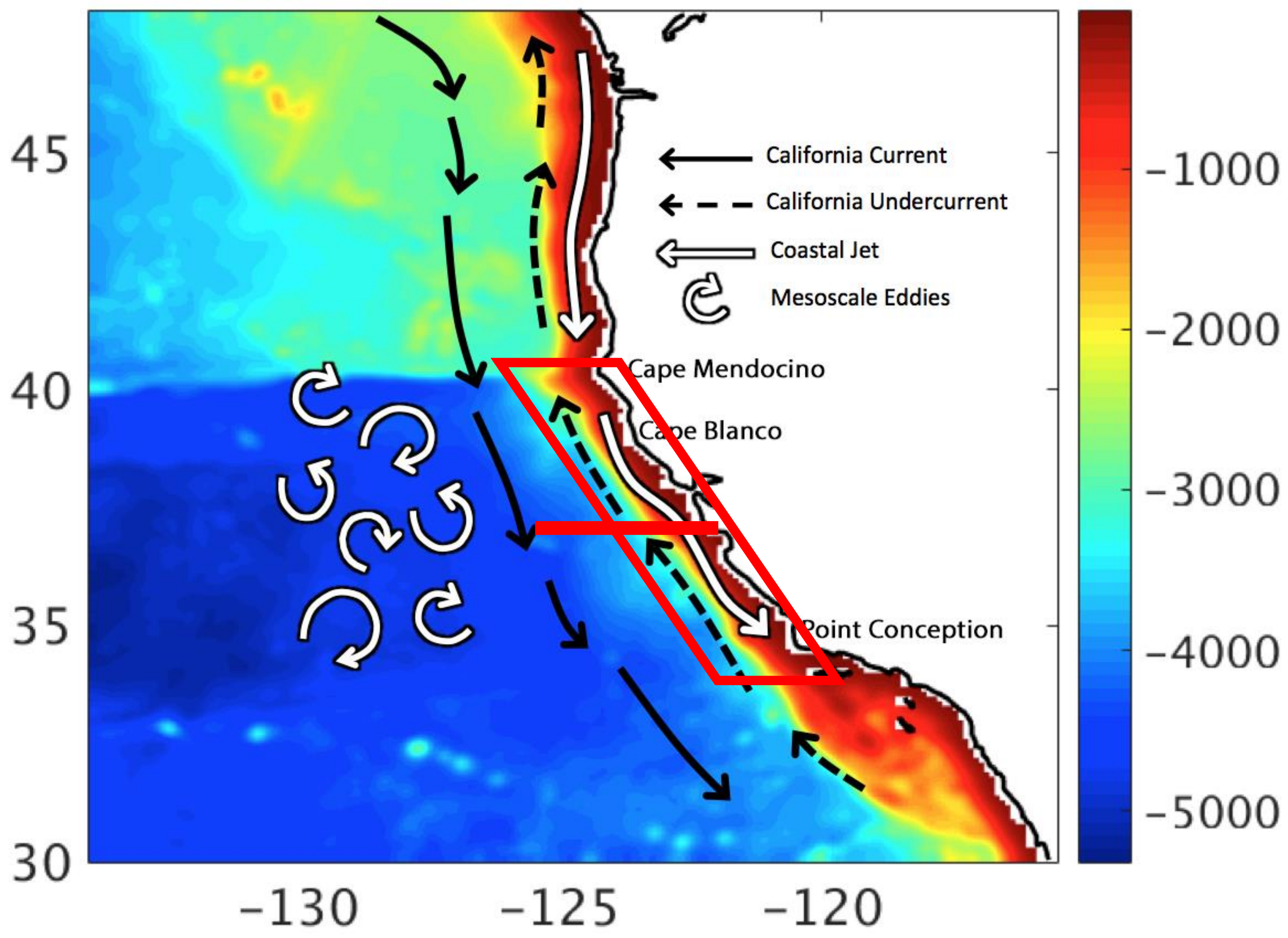
The change in forecast skill due to assimilating observations:

$$\delta e = e^a(t_f) - e^b(t_f)$$

Adjoint -> impact of each obs

$\delta e < 0$	**Obs *improve* forecast skill**
$\delta e > 0$	**Obs *degrade* forecast skill**

The California Current System & CeNCOOS



ROMS Grid & Bathymetry

- **ROMS & 4D-Var**
- **1/10th degree resolution, 42 σ-levels**
- **COAMPS surface forcing**
- **Global HYCOM open boundary conditions**
- **Observations (2018 & 2019):**
  - **- satellite SST**
  - **- Aviso altimetry**
  - **- Argo profiling floats**
  - **- gliders**
  - **- HF radar surface radial currents**
- **Background quality control of obs**
- **4-day 4D-Var windows (1 outer-loop, 9 inner-loops)**
- **4-day forecasts ("*hindcasts*")**
- **Forecast metrics:**
  - **- central CA SST MSE e_{SST}**
  - **- central CA surface current MSE e_V**
  - **- central CA upwelling transport MSE e_W**

- 37N transport MSE e_{37N}

Directly observed **Indirectly observed**

Day-4 Forecast Error Differences

$\delta e < 0$

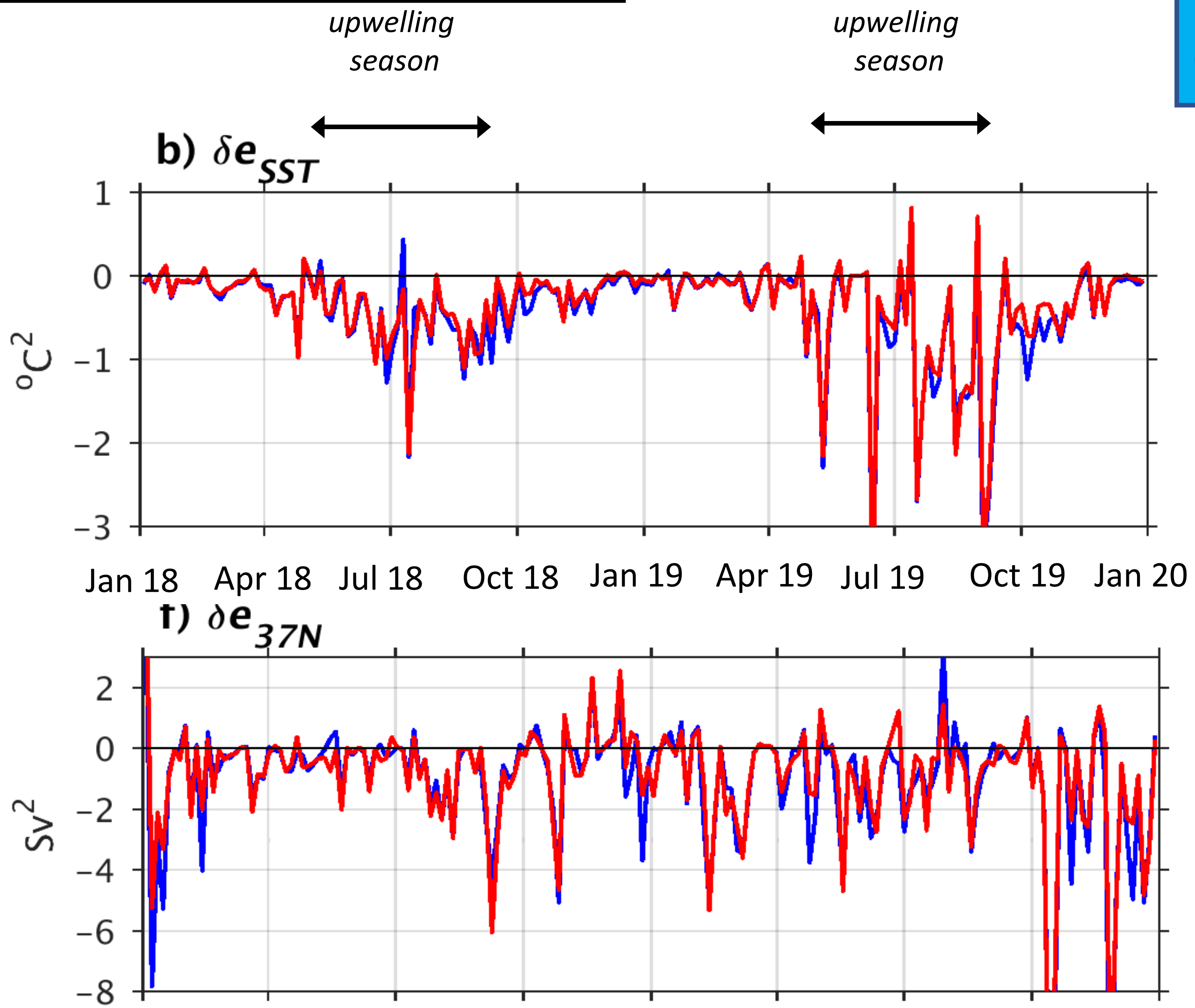
Obs improve forecast skill

Central CA SST MSE

Directly observed

37N transport MSE

Indirectly observed



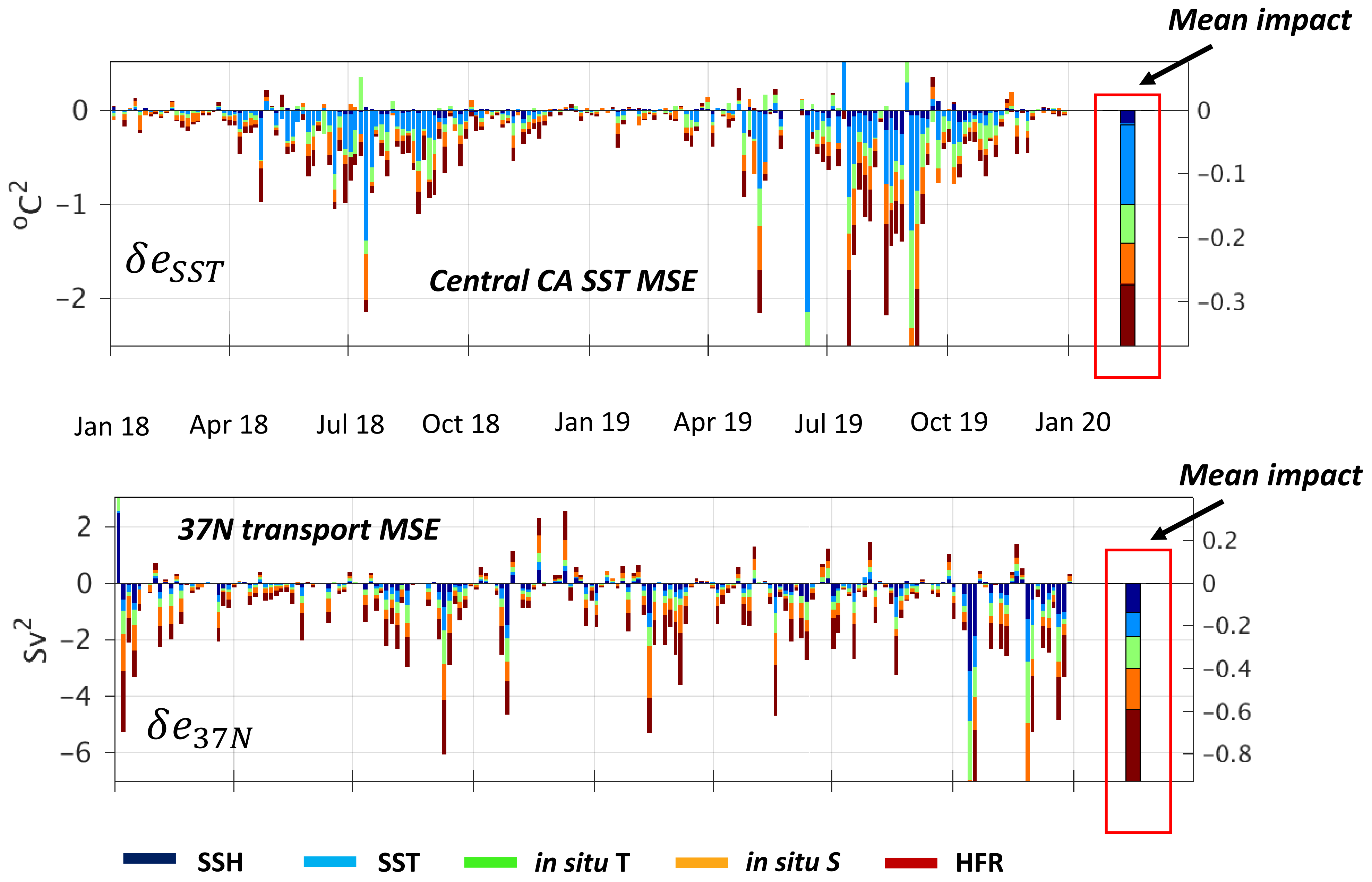
δe_{SST}

δe_{37N}

$\delta e = e^a - e^b$

δe 3rd-order approx

Forecast Sensitivity-Based Observation Impact (FSOI)



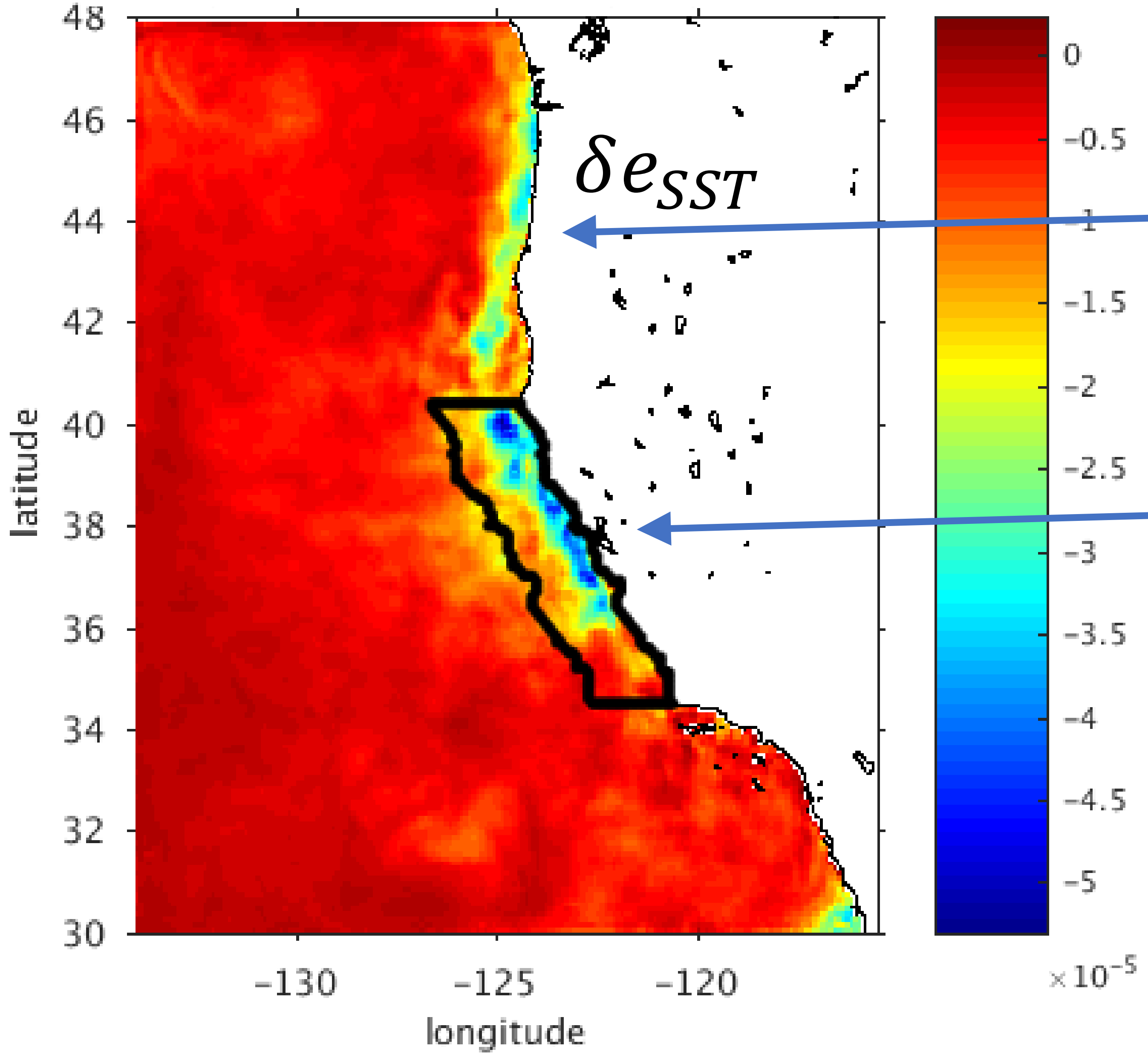
Percentage of obs that <u>improve</u> forecast skill

Obs	e_{SST} (MSE SST)	e_V (MSE Velocity)	e_{37N} (MSE 37N)	e_W (MSE W)
SSH	60%	67%	60%	49%
T	49%	52%	49%	42%
S	50%	53%	51%	45%
HF radial	58%	62%	59%	50%
SST	61%	58%	55%	50%

- **Only ~ 40-50% of *in situ* observations *<u>improve</u>* the forecast skill**
- **~60% of remote sensing obs *<u>improve</u>* forecast skill**
- **~50-60% of all obs improve forecast skill, similar to experience in NWP**

Local versus Remote Impacts

Mean Impact of SST obs on Central CA SST MSE

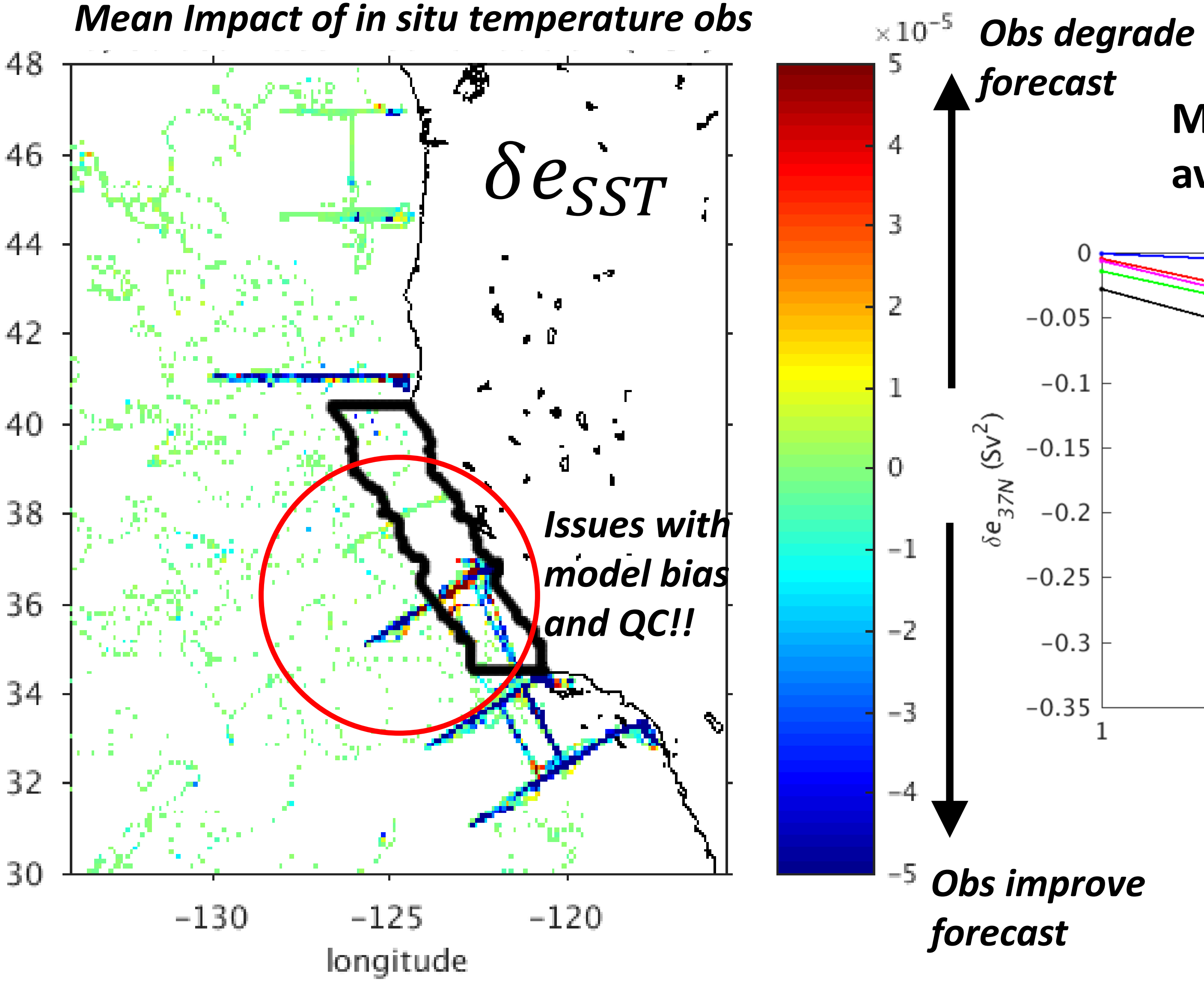


- **Significant remote influence on forecast skill of SST obs upstream along the coast of N. CA, OR and WA**
- **Local SST obs have largest impact on central CA SST forecast skill**

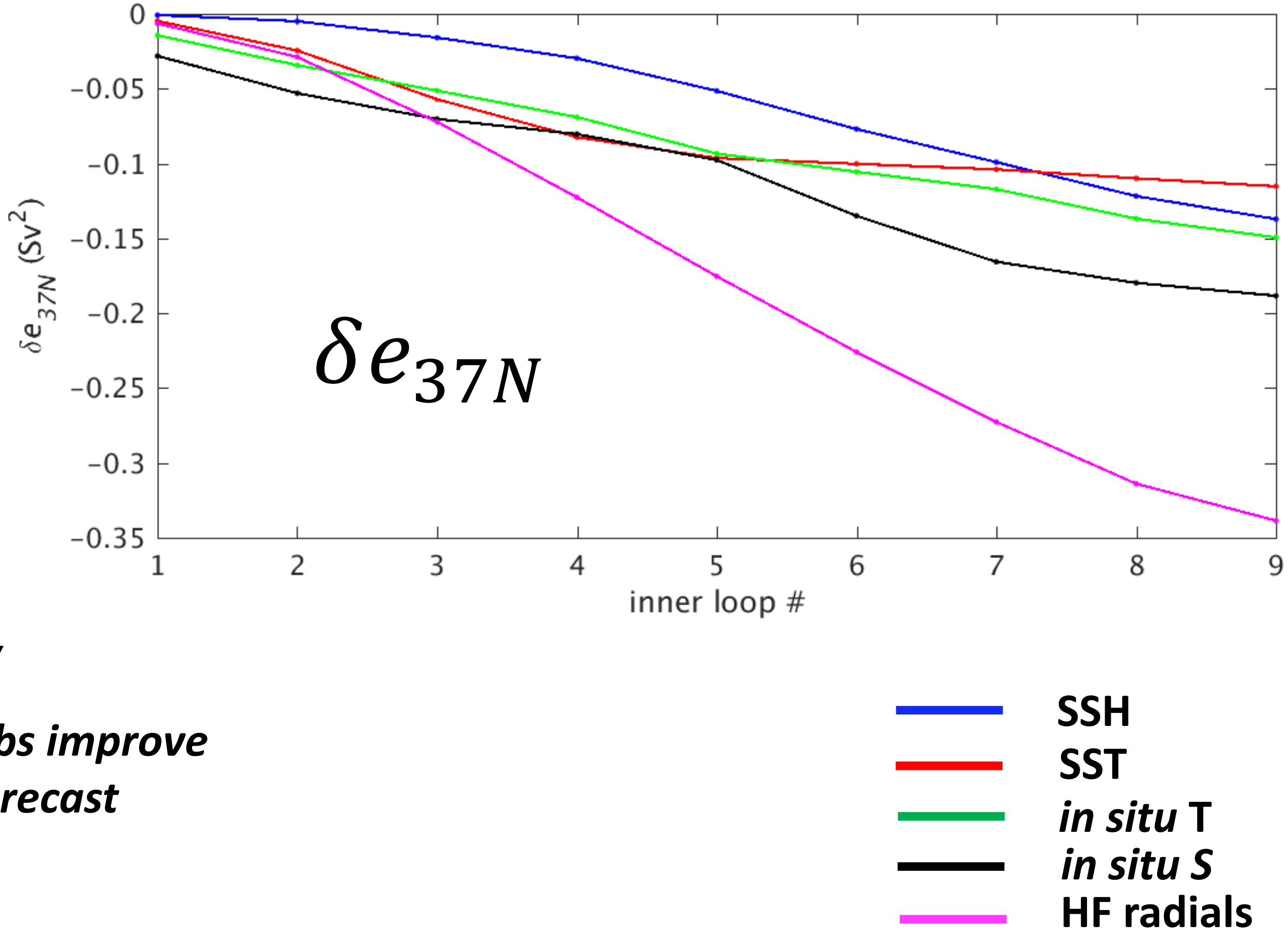
Increasing obs impact that improves forecast skill

Monitoring of Observing System Data Streams and DA System Performance

Mean Impact of in situ temperature obs



Mean impact per data type versus inner-loop averaged over all analysis-forecast cycles



Summary

- Only ~50% of obs improve forecast (agrees with experience in NWP, e.g. THORPEX, JCSDA IOS)
- Should more observations be assimilated (*cf* Gelaro *et al.*, 2010)?
- Can better use be made of existing observations (*i.e.* can more info be extracted from some obs)?
- Data thinning required to reduce relative impact of high volume obs (*e.g.* HF radar, SST – *work in progress*)
- FSOI is useful for monitoring observing system and performance of 4D-Var system
- FSOI reveals local and remote influence of observing system components
- Forecast Sensitivity to Observations (FSO) provides complimentary information