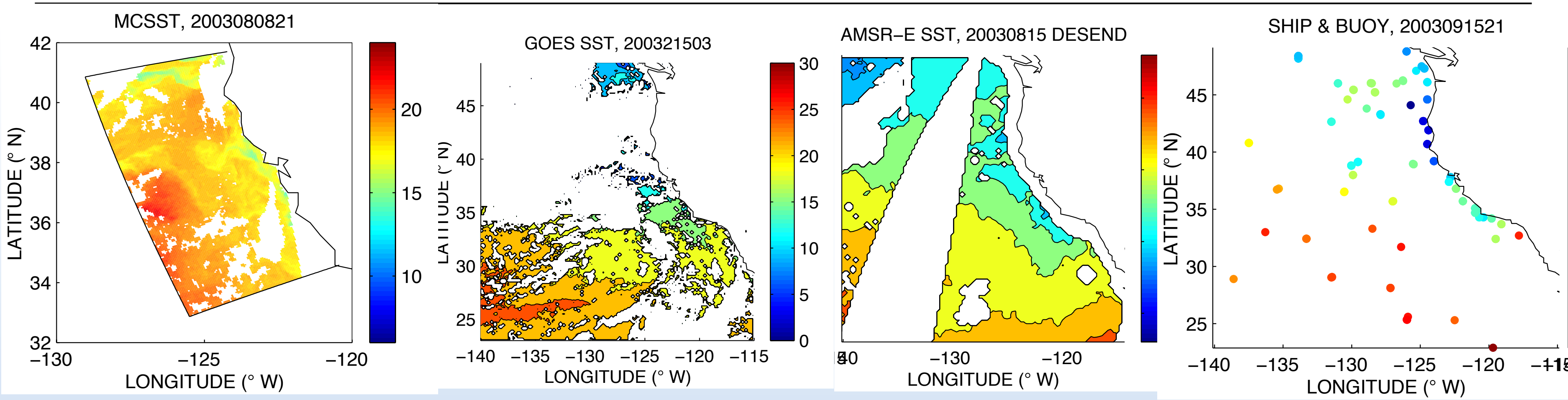
Physical Models (and Data): From Global Climate to Coastal Upwelling and Eddies

- A new approach to blend measurements from multiple sensors and platforms (*in situ* and satellite)
  - SST
  - Wind
- Numerical modeling to enable forecast
  - Current state-of-the-art in ocean modeling: from global climate to coastal upwelling and eddies
  - Data assimilation: Enable forecasting
    - Models to fill in the data gaps
    - Data to reduce the model uncertainties
    - Forecast uncertainty as important as forecast itself
- Concluding remarks

Motivation and Approach for SST Blending



$$J = \frac{1}{2}(T - T_b)^T B^{-1}(T - T_b) + \frac{1}{2}\sum_{s=1}^{S}(H_s T - T_s)^T R_s^{-1}(H_s T - T_s)$$

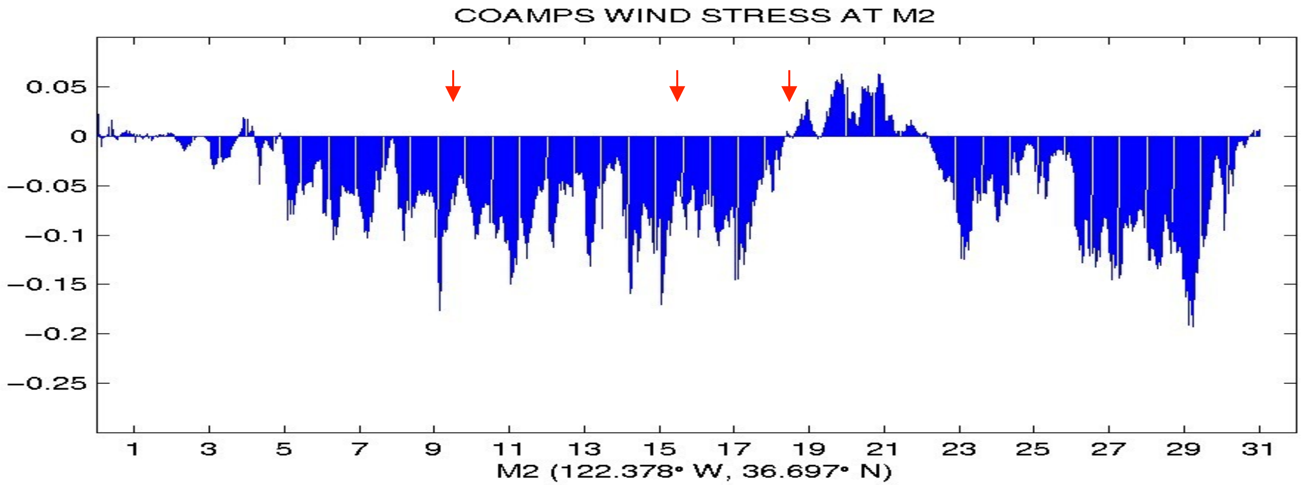
Input: T_b (1st guess), B (1[st] guess error), T_s (Obs), R_s (Obs error), s=1,S (number of sensors/platforms)

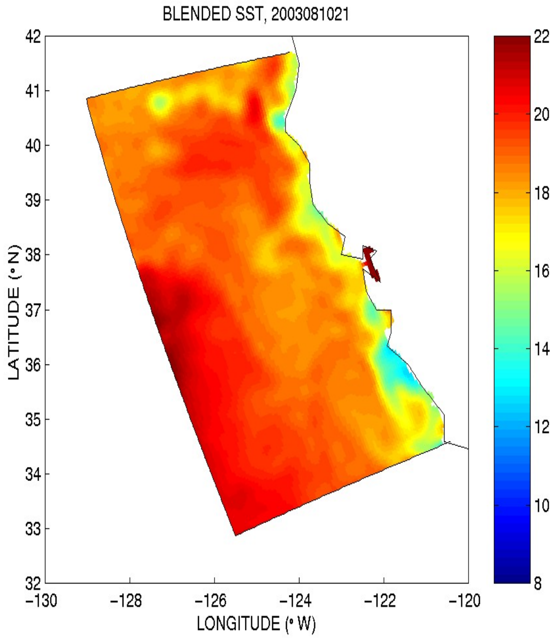
Problem: Min(J), what is T? (Chao et al., GRL, 2003)

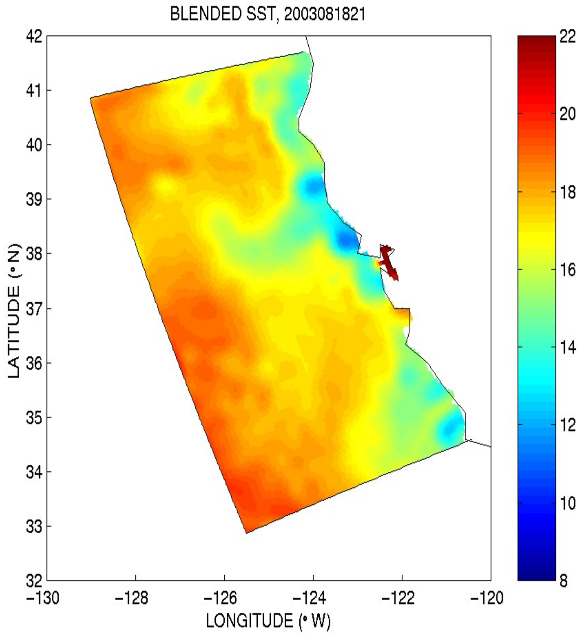
Output: T (blended SST; essentially a weighted average)

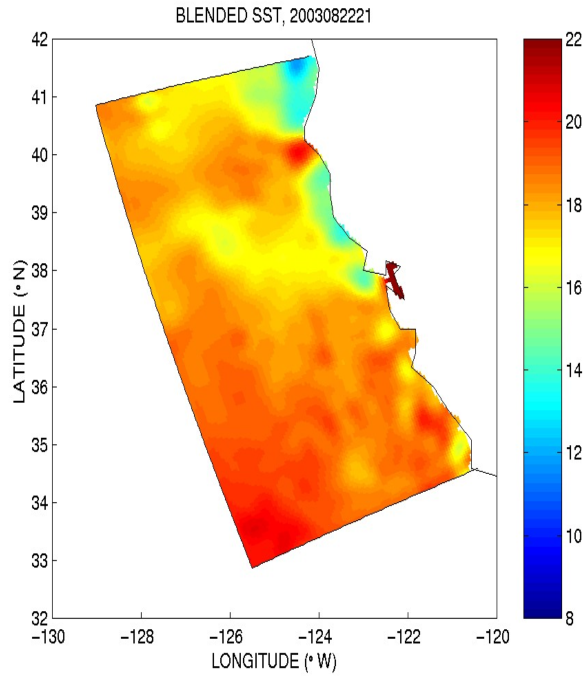
Unique features: multiple measurements with different resolutions; weighted by data errors; uncertainty estimate for the blended SST

Demonstration of the Blended SST Product during August 2003

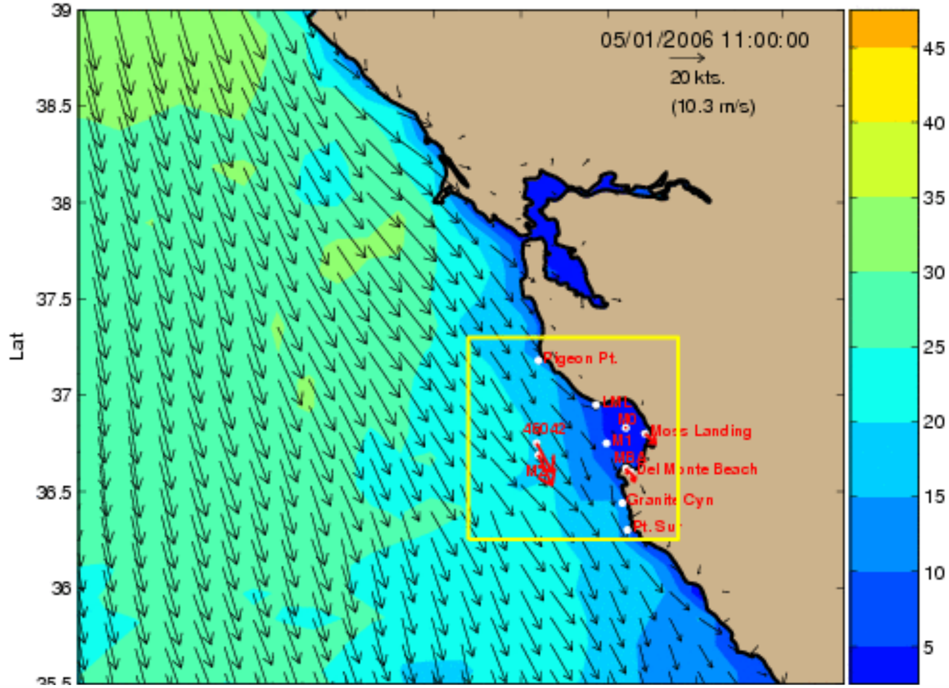


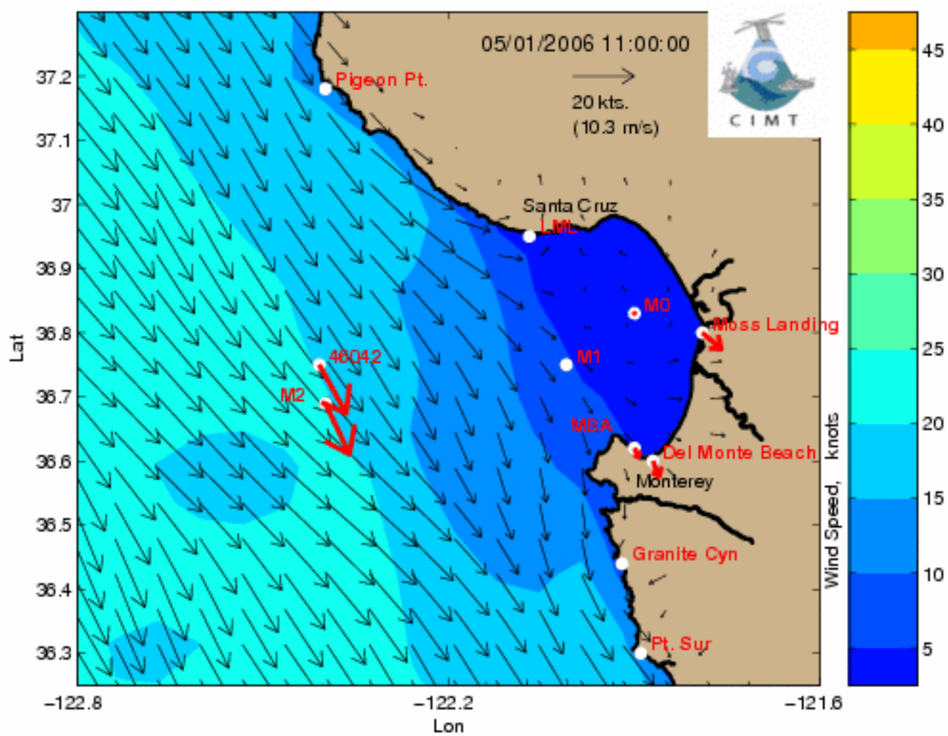


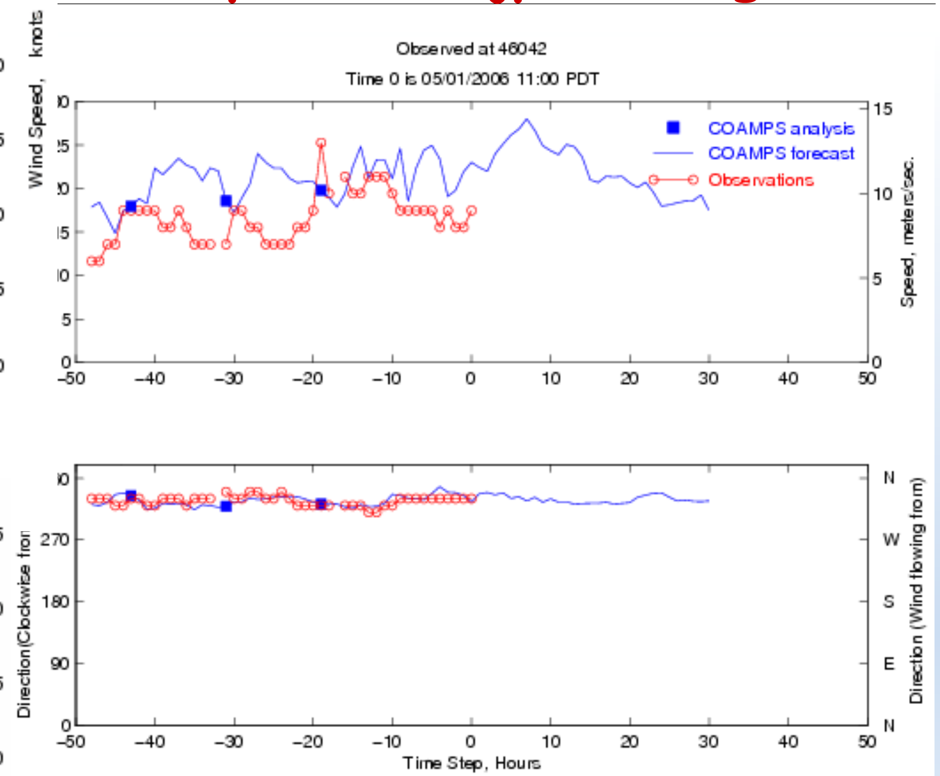




A Real-Time Wind Demo for Monterey Bay (http://cimt.jpl.nasa.gov)



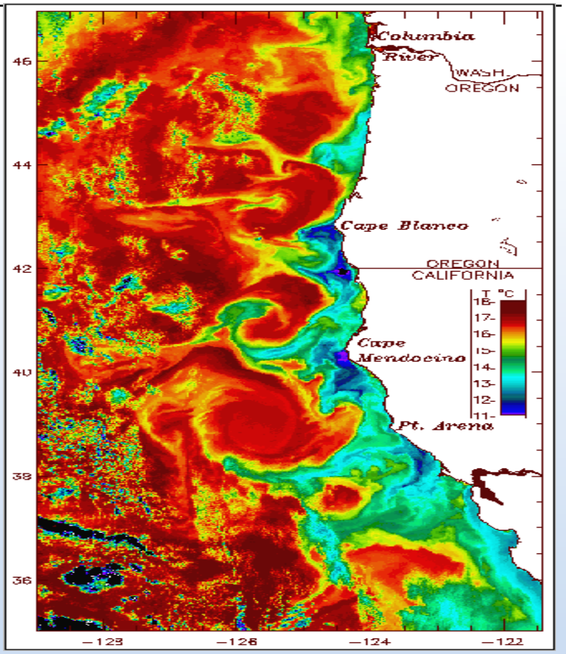




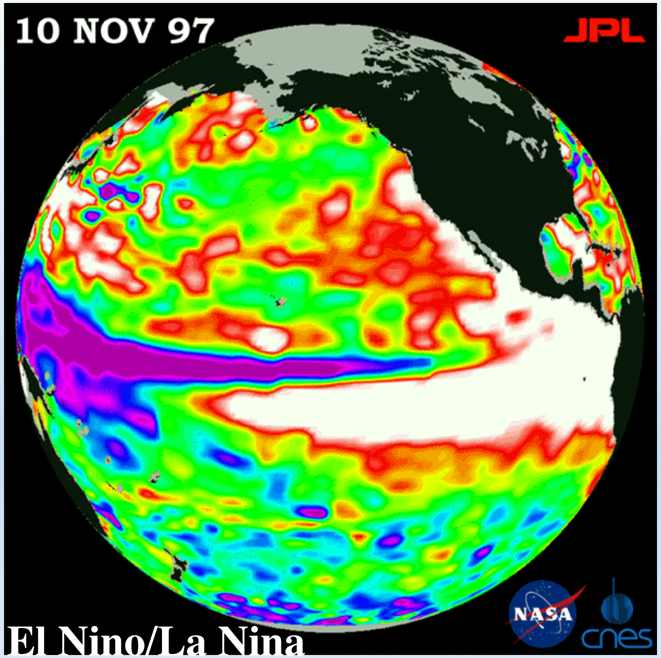
Unique features:

- In situ & Model
- Real-time monitoring
- Validation of models
- Forecast (2-day)

Ocean has multiple scales in both time and space: From Global Conveyor Belt to El Nino, PDO & Coastal Ocean

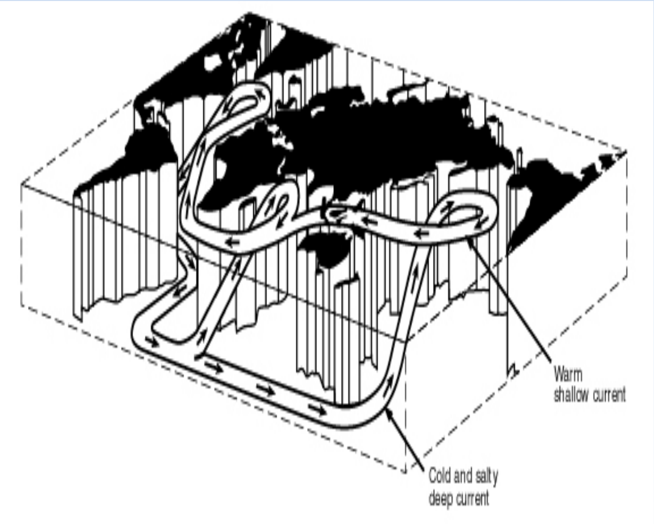


10-km; hours/days



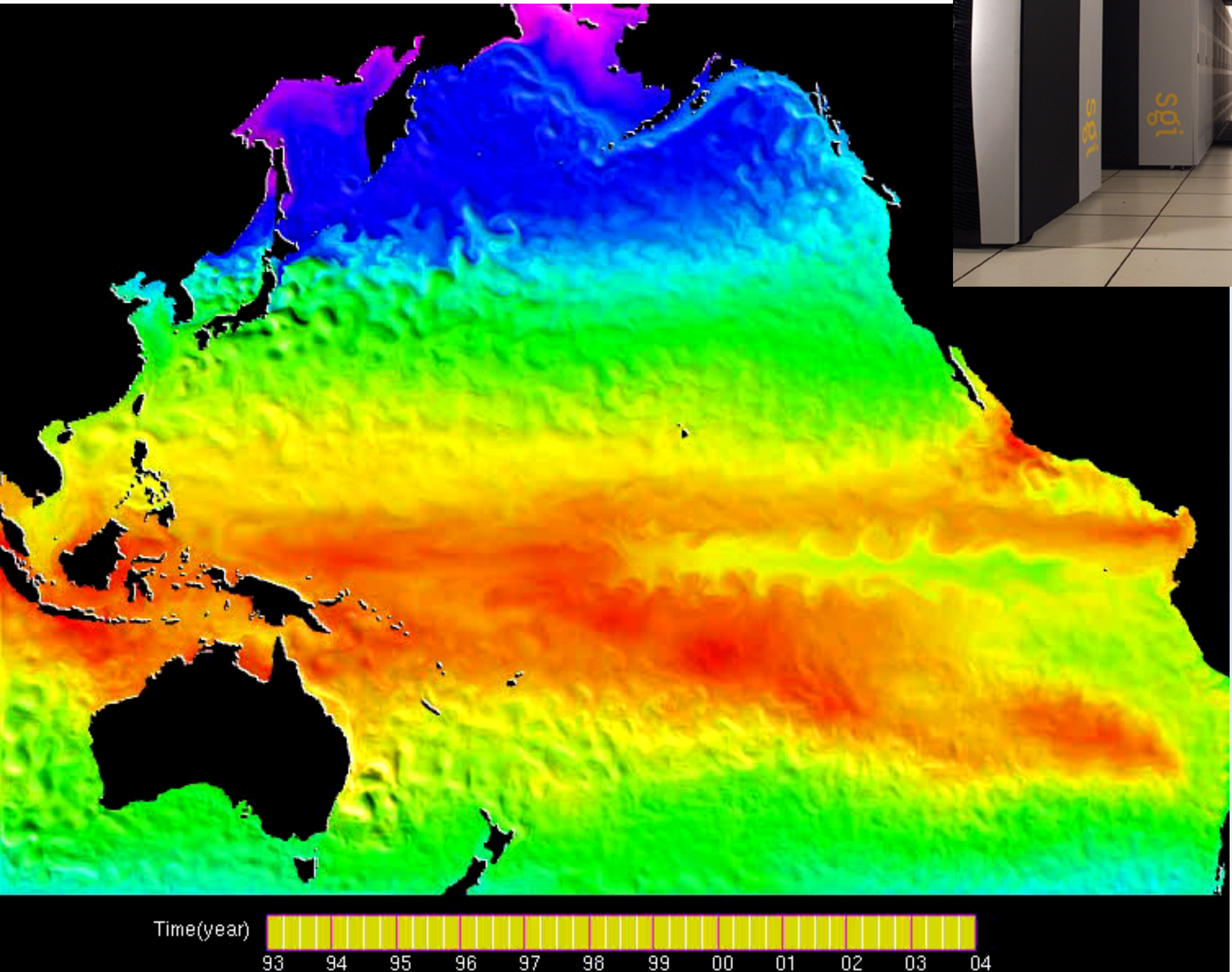
El Nino/La Nina

100-km; years



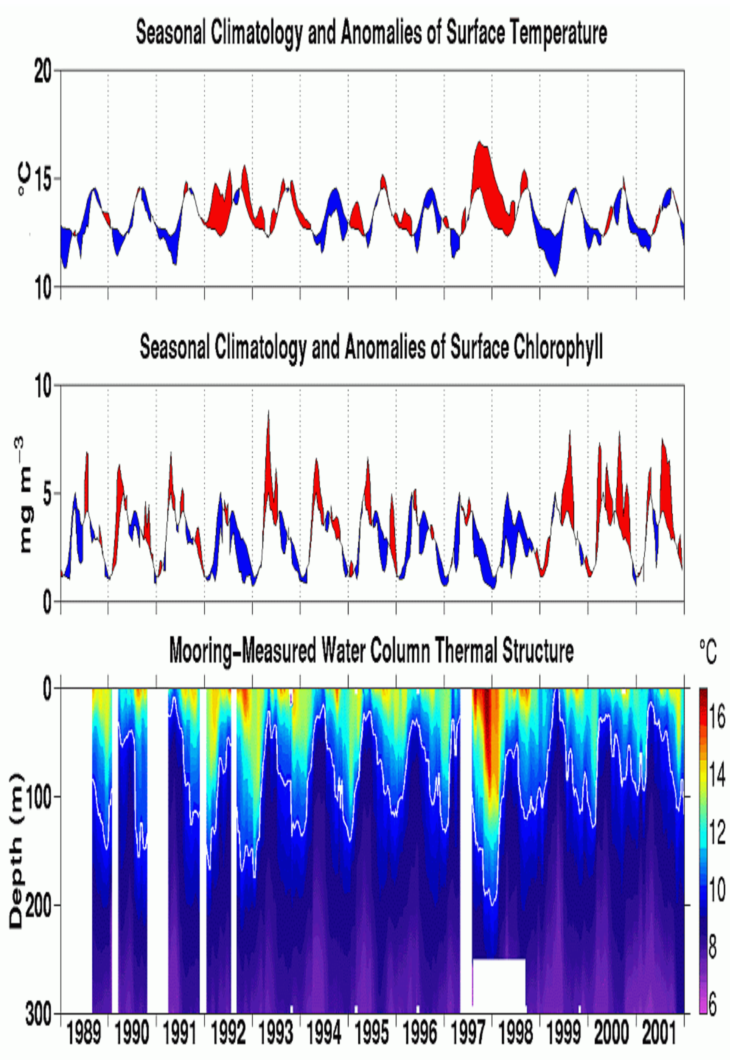
1000-km, decades

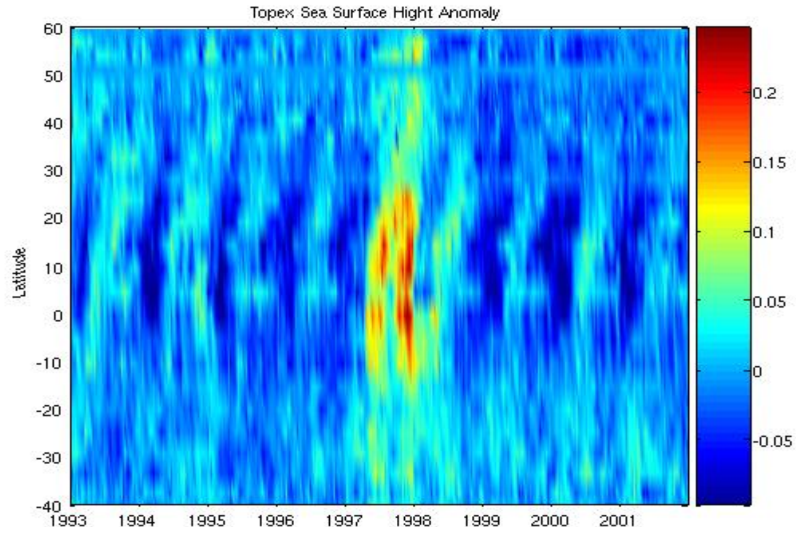
Eddy-Resolving Ocean Modeling at 12.5-km

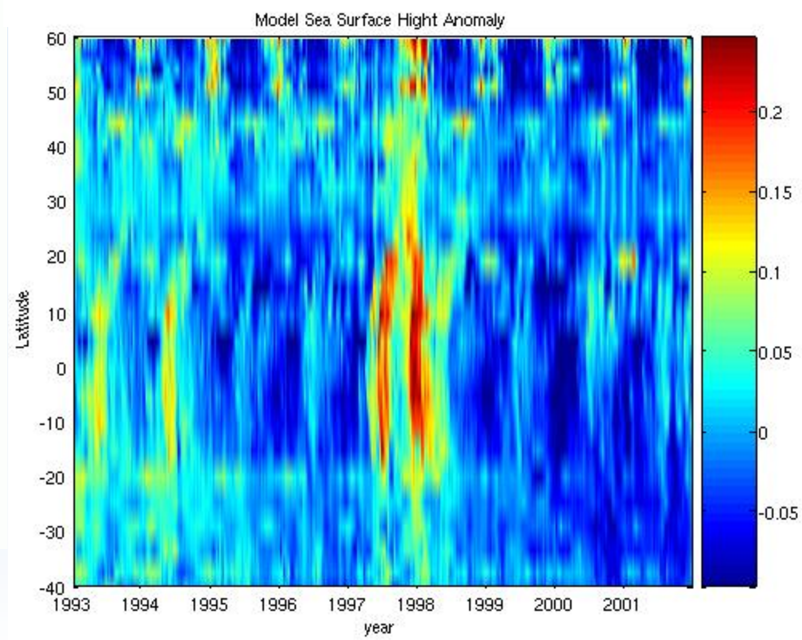


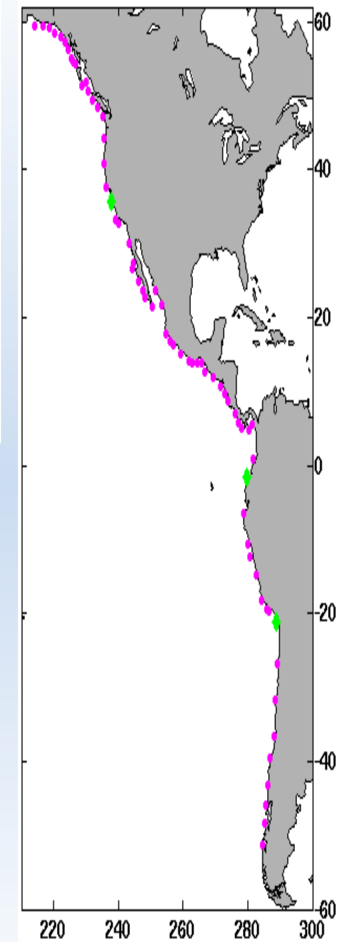
Columbia Computer
(NASA Advanced Computer System)
SGI Altix
10,000+ processors
ranked #4 the fastest supercomputer on Earth

"Remote" Forcing:
El Nino's influence on the California Current System



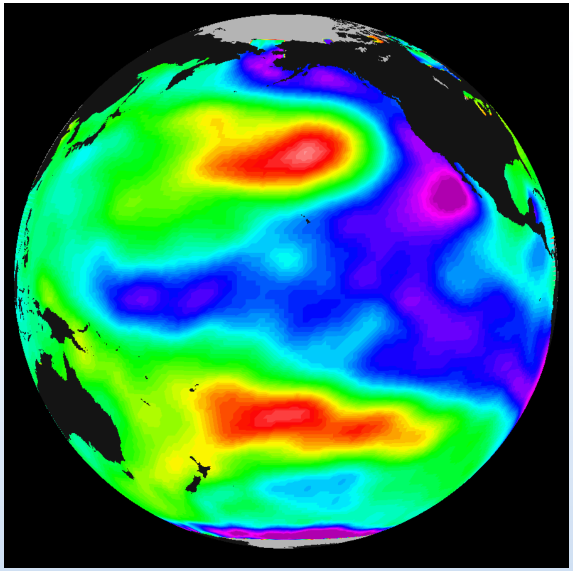




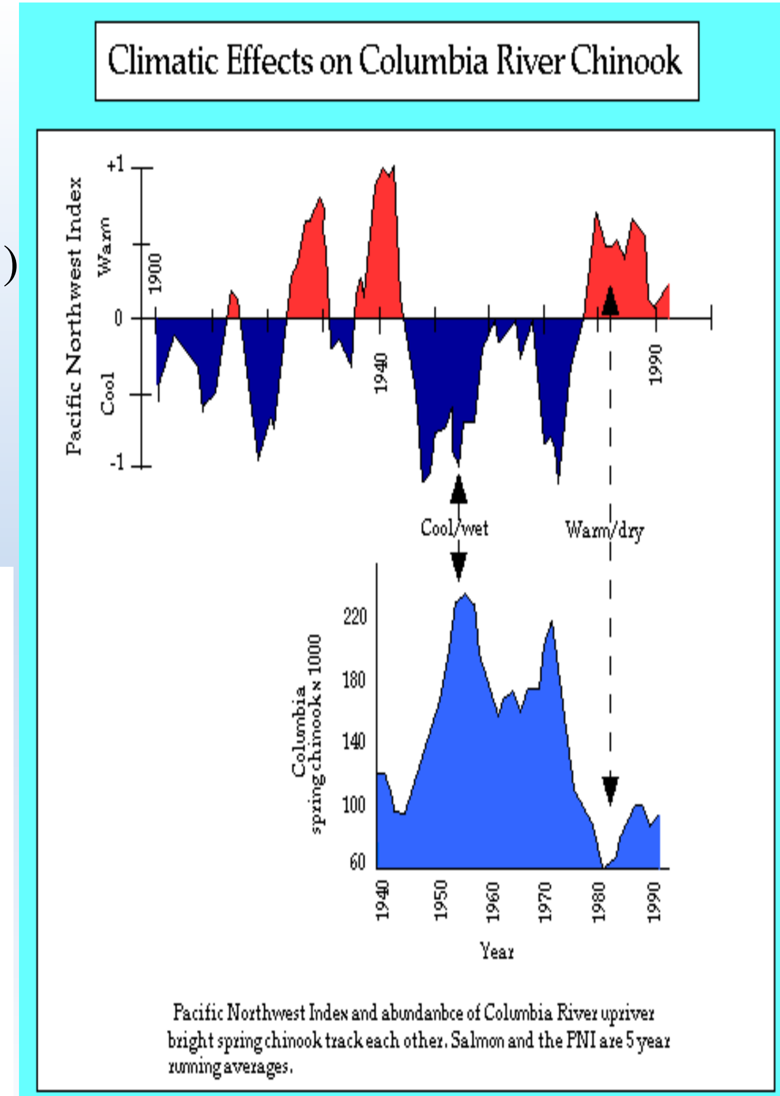


(MBARI)

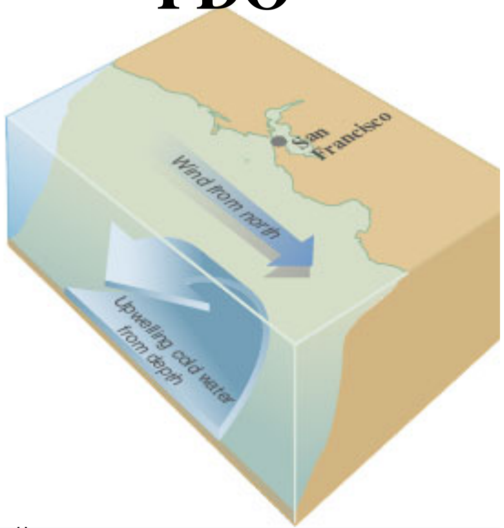
Pacific Decadal Oscillation (PDO)'s Impact on California Coastal Ocean Circulation & Fishery



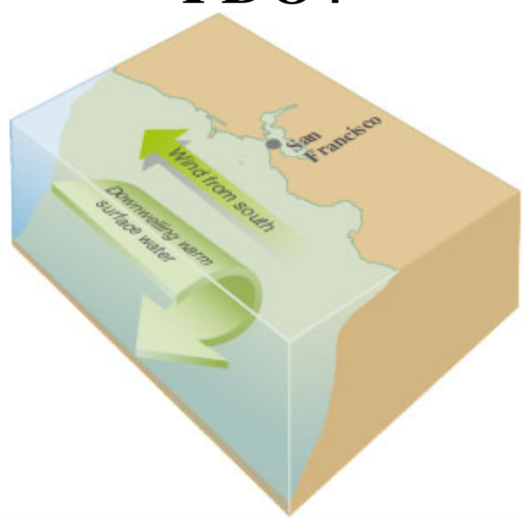
(Chao et al., GRL, 2001)

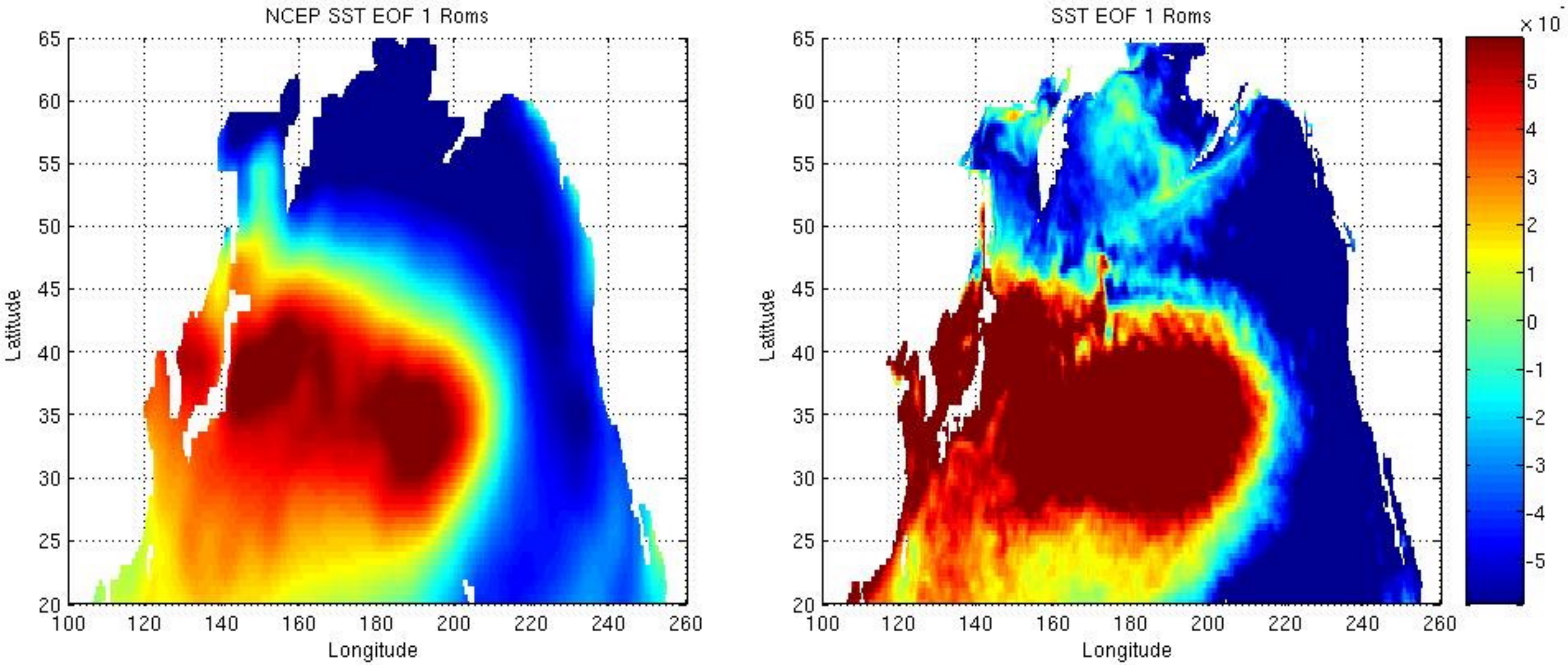


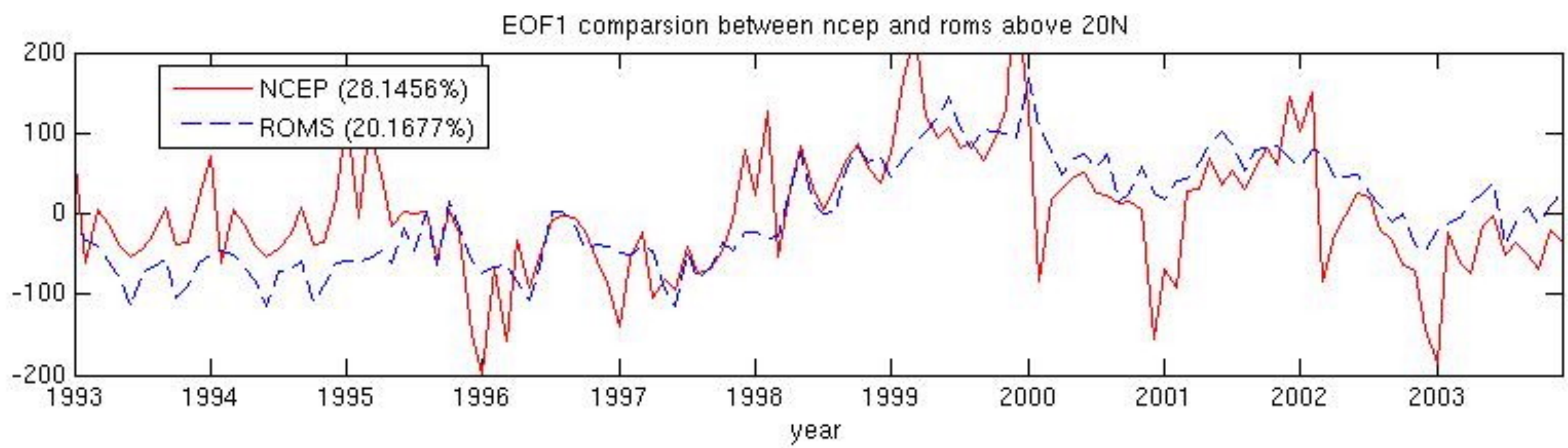
PDO-



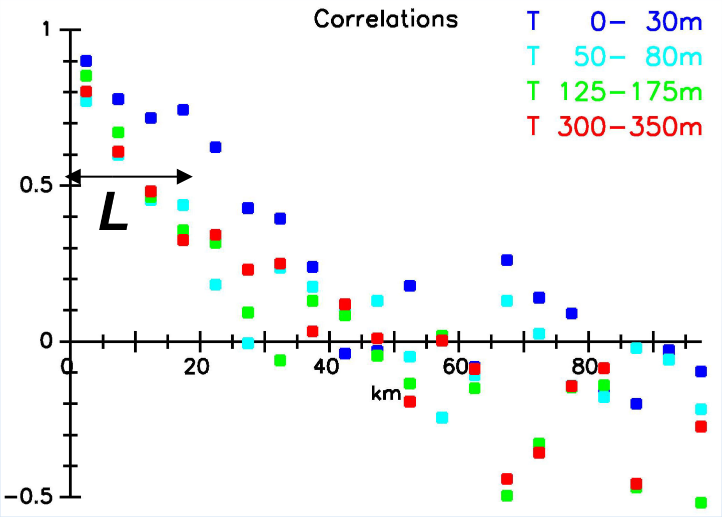
PDO+

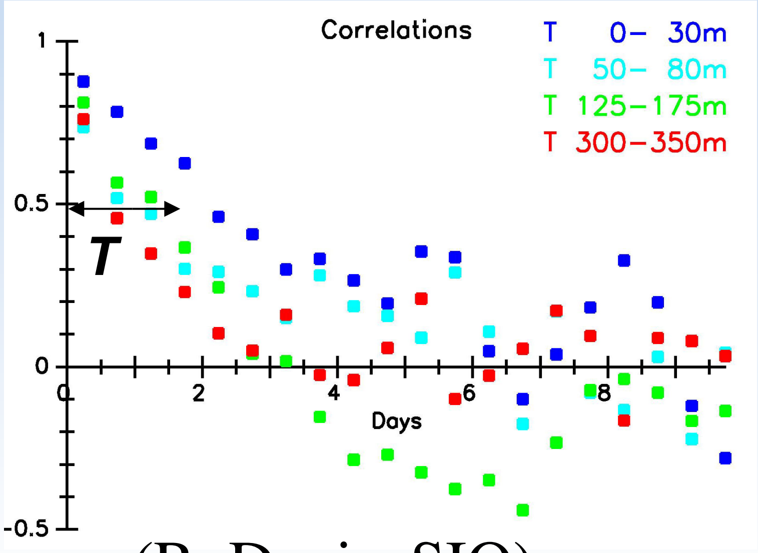


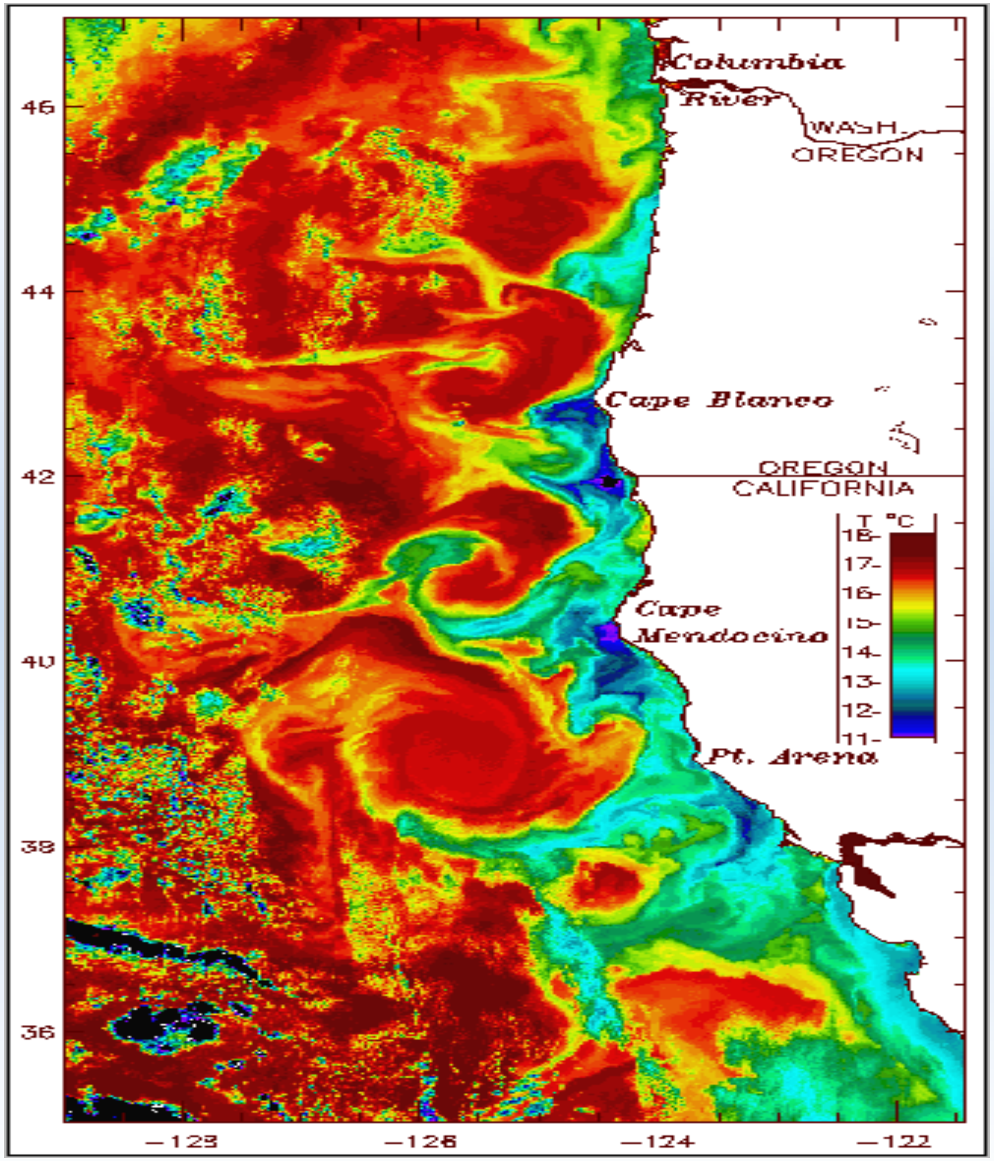

NCEP SST EOF 1 Roms
Latitude
Longitude
SST EOF 1 Roms
× 10^-3


EOF1 comparsion between ncep and roms above 20N
NCEP (28.1456%)
ROMS (20.1677%)
year

What is the resolution requirement for coastal models?

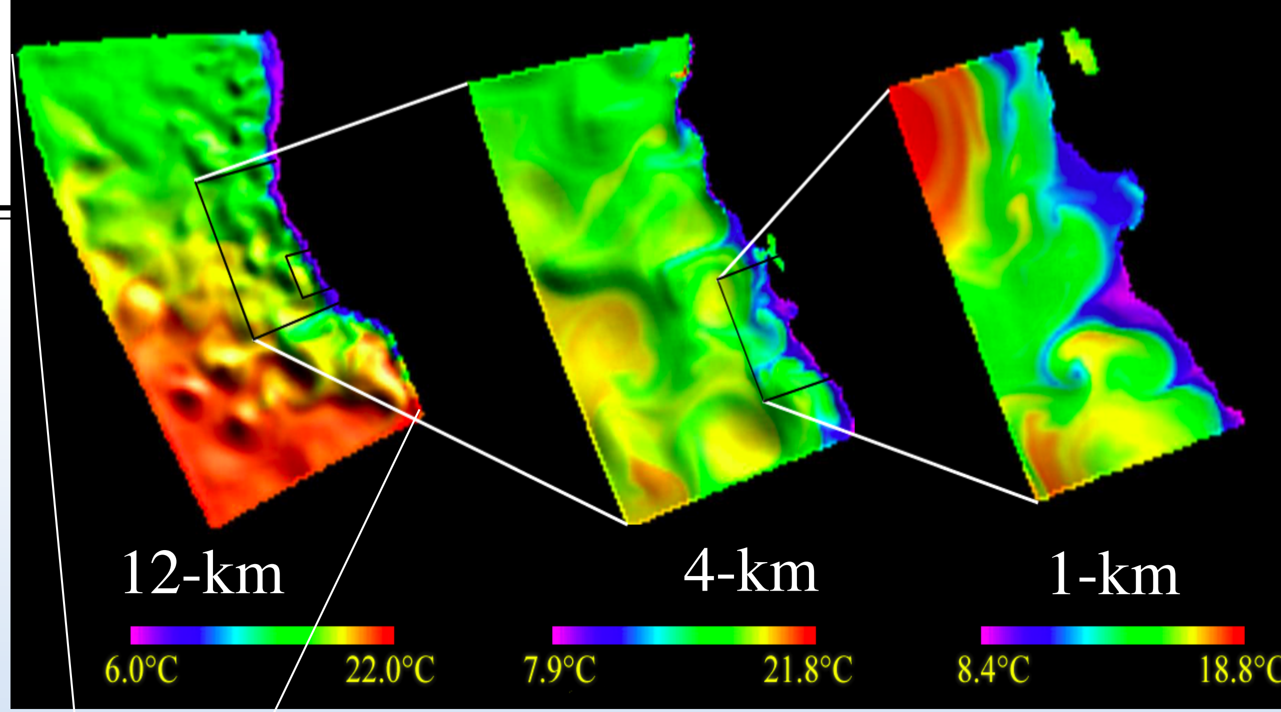


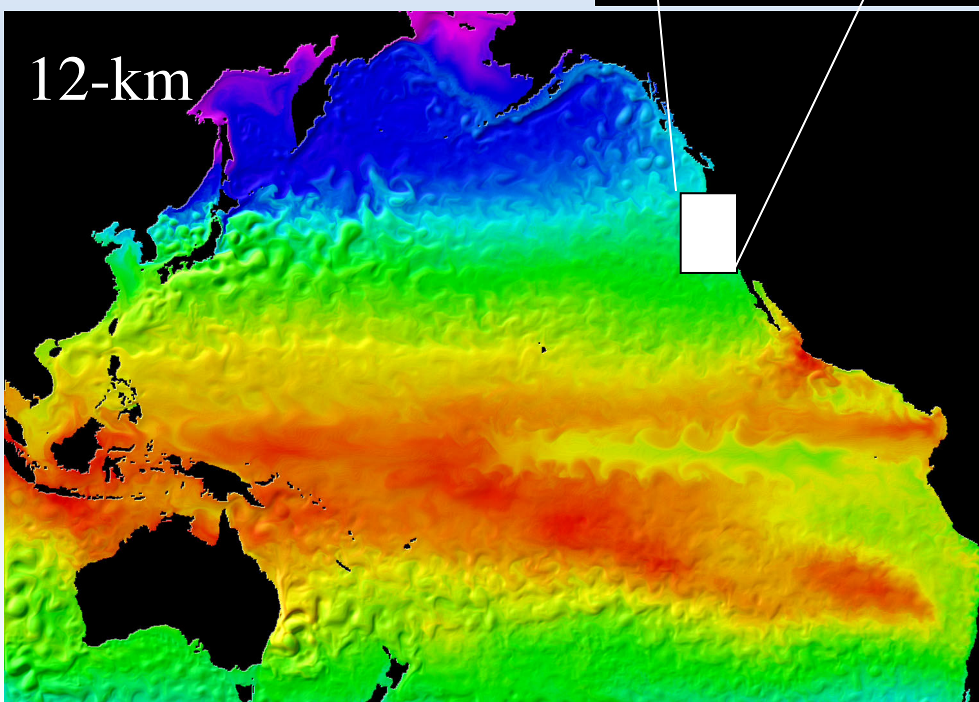




(R. Davis, SIO)

Global/Pacific-Basin to Regional/Coastal





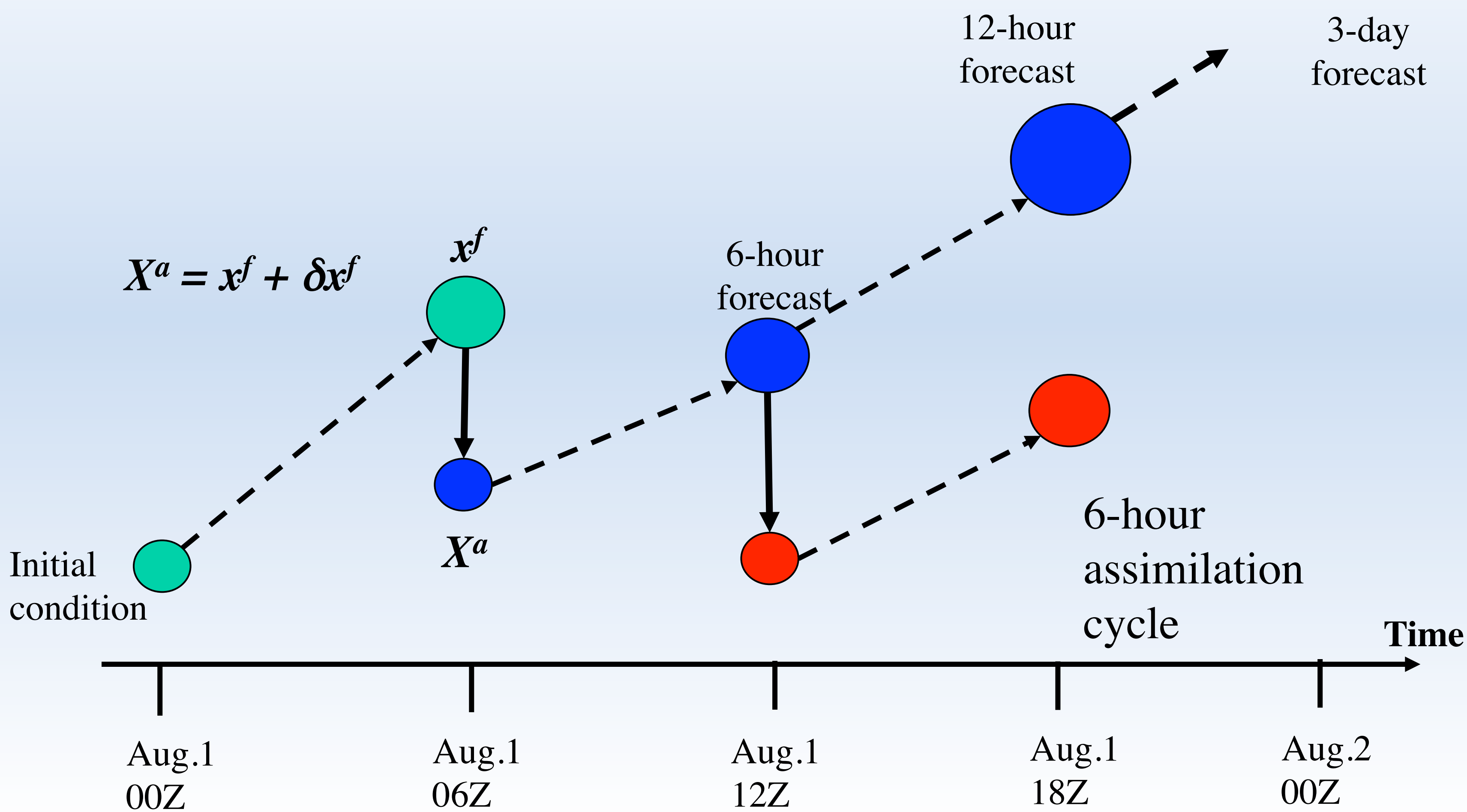
Multi-scale (or "nested") ROMS modeling approach is developed in order to simulate the 3D ocean at the spatial scale (e.g., 1-km) required to resolve coastal upwelling and eddies

Integrating Data with Models (or Data Assimilation) for Retrospective Analysis or Real-Time Nowcast/Forecast

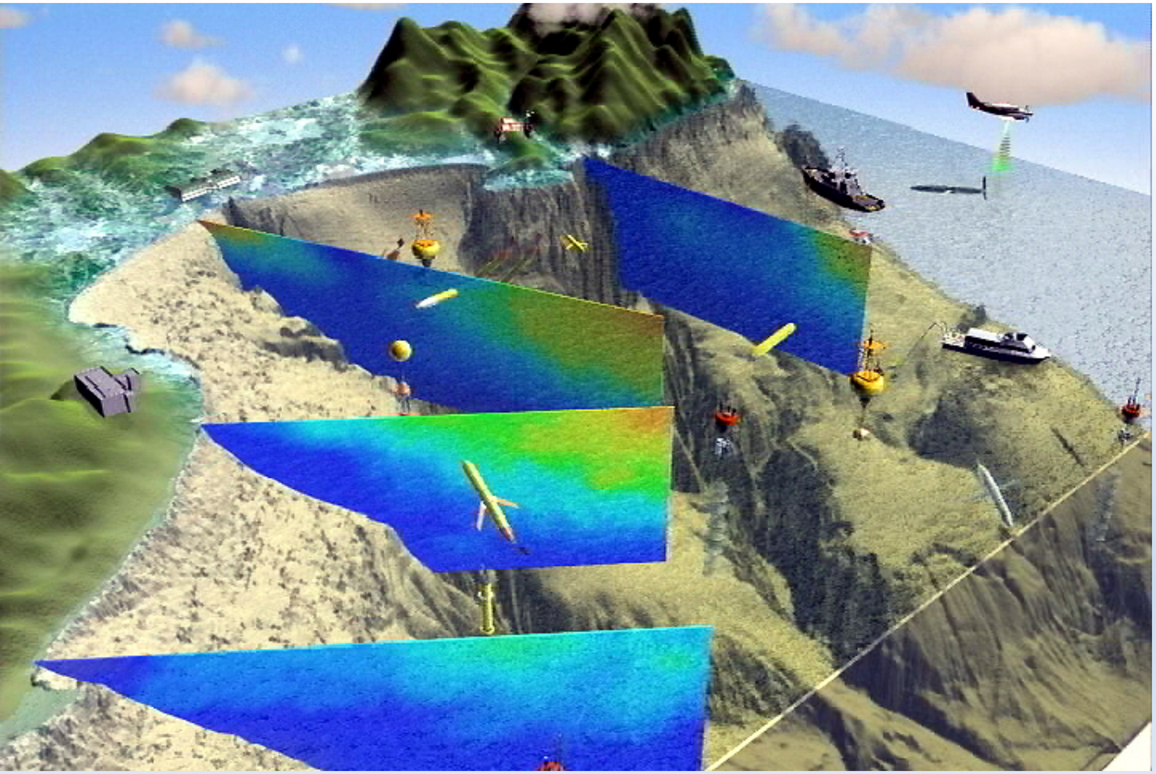
3-dimensional variational (3DVAR) method:

$$J = 0.5\,(x-x^f)^T B^{-1} (x-x^f) + 0.5\,(h\,x-y)^T R^{-1} (h\,x-y)$$

y: observation
x: model



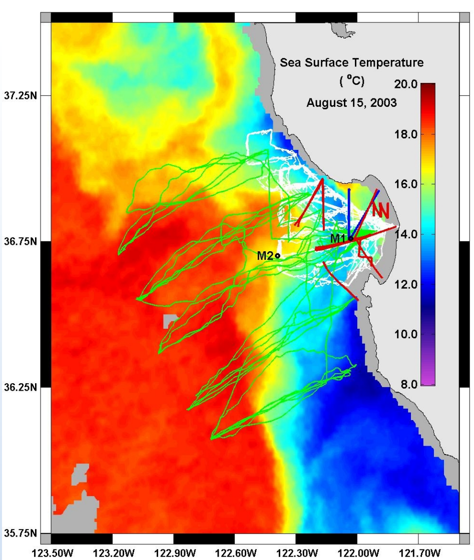
Monterey Bay August 2003 Experiment
AOSN (Adaptive Ocean Sampling Network):

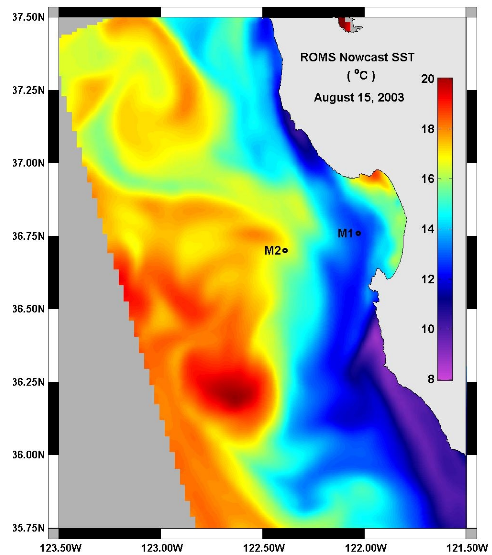


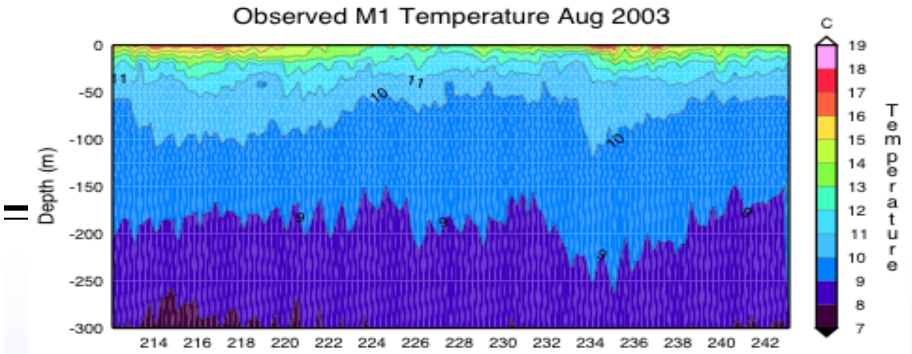
* Platform & Sensors
* Data management
* Modeling & data assimilation

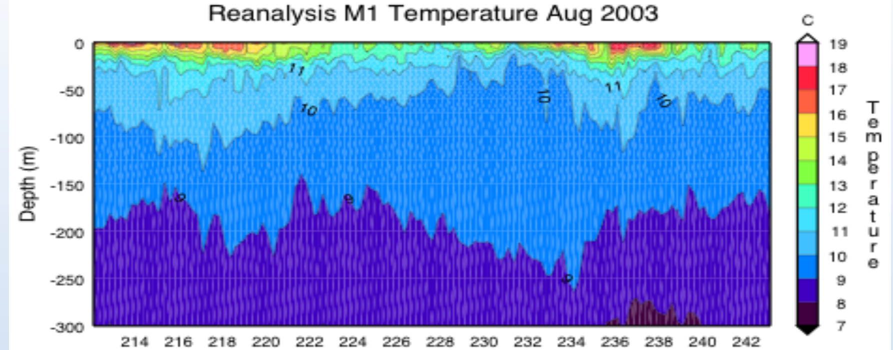
Can we deliver observational data and model predictions in real-time?
Are the model nowcast and forecast any good?
How to sustain such an integrated system?

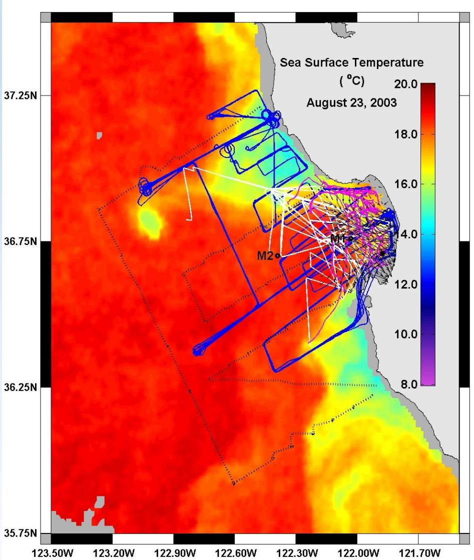
Model Skill Assessments

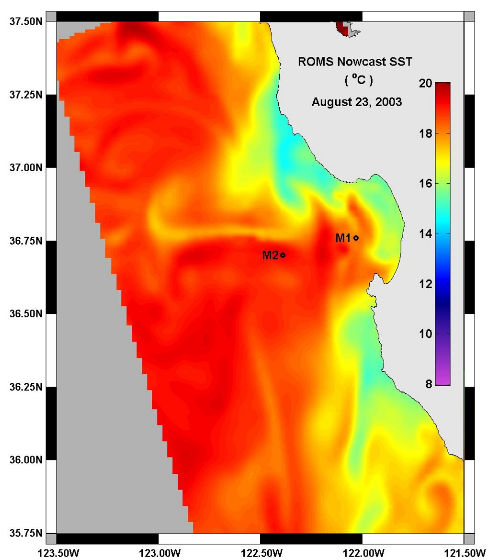


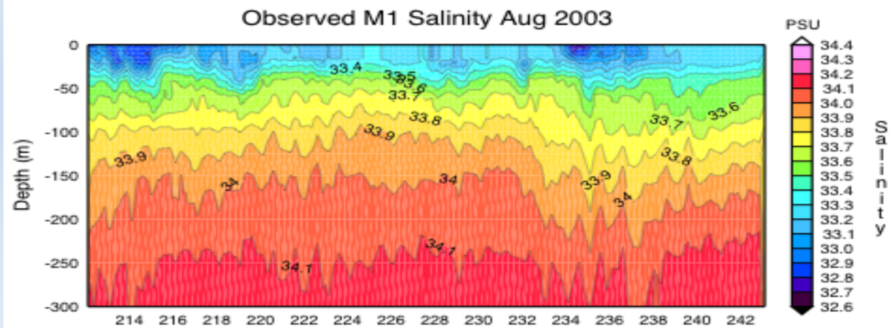


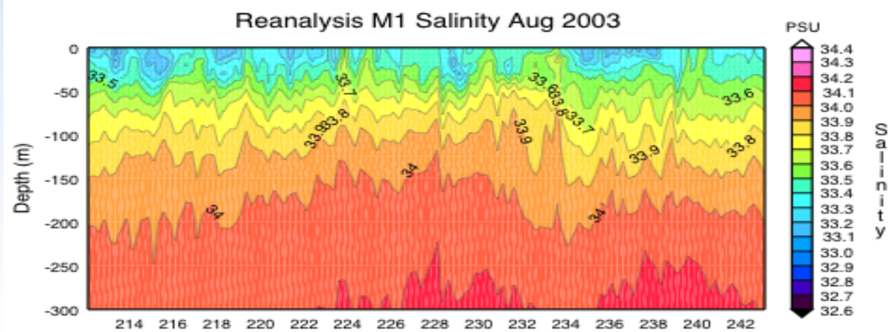








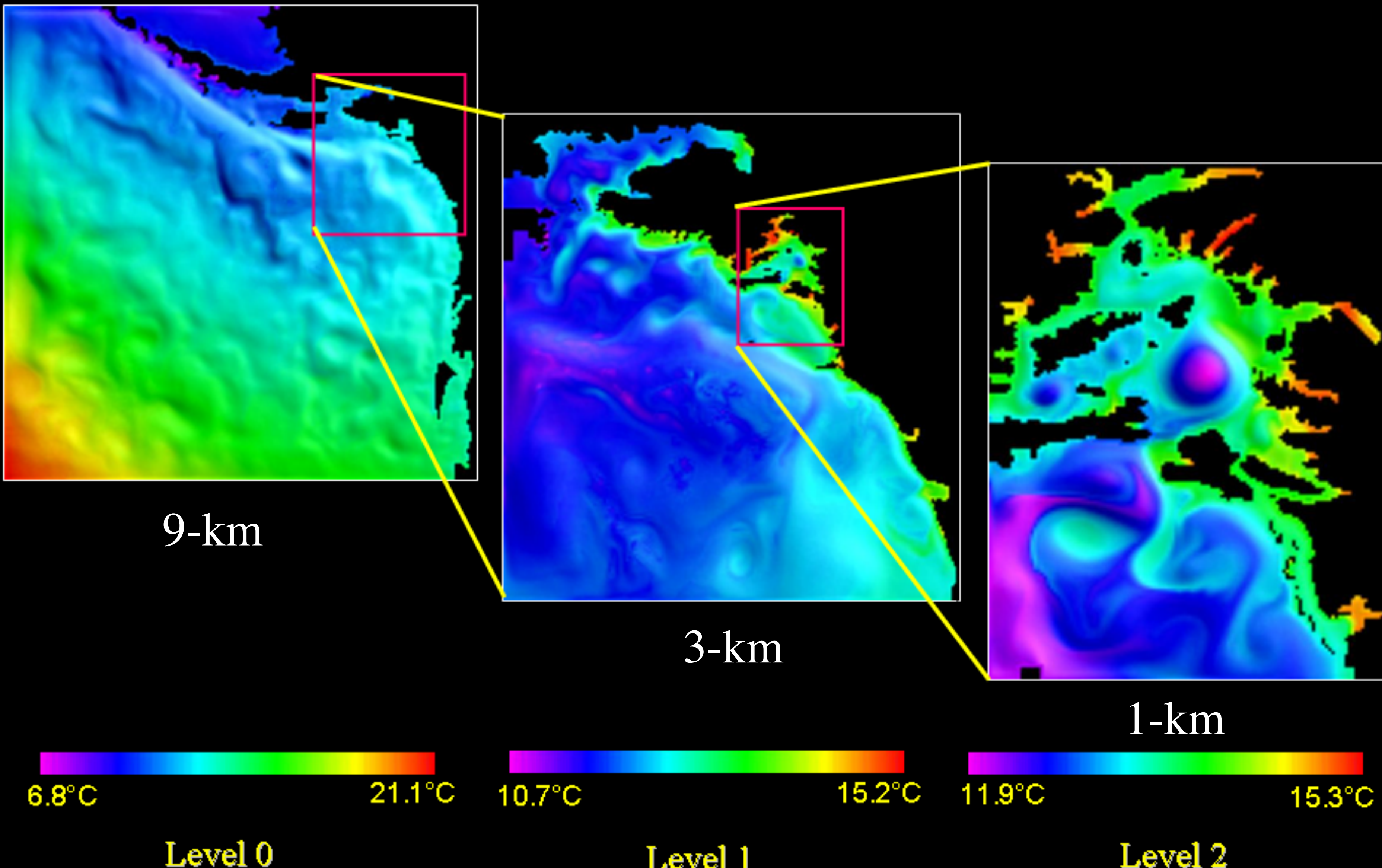




OBS **ROMS**

Three Level Nested Prince William Sound ROMS Model

SST shaded Relieved with SSH



Assessment of Weather Forecast in 2005
(imagine how do we assess Ocean Forecast in 2025)

- **Concept proposed in 1920s, but the major breakthrough was not made until late 1950s when the first electronic computer was used for weather forecast**
- **Very short-range forecasts (0–12 hour)**
  - Considerable skill and utility, especially for predictions of the evolution and movement of large- and medium-sized weather systems
- **Short-range forecasts (12–72 hour)**
  - Forecasts of how much precipitation will fall in the 36-60-hour time frame are now more accurate than 12-36-hour predictions were during the late 1970s.
- **Medium-range forecasts (3–7 days into the future)**
  - Skillful day 7 forecasts will be possible in the future given the steady improvements in computer models, observational approaches, and forecast strategies.
- **Extended-range forecasts (week 2)**
  - The predictability of the day-to-day weather for periods beyond day 7 is usually small. Statistical forecast of the mean conditions for the 8-14-day period might be possible.
- **Monthly and seasonal forecasts**
  - No verifiable skill exists or is likely to exist for forecasting day-to-day weather changes beyond two weeks: “butterfly” effect (or chaos) rules.