Linking technological and POC advances over the past 25 years

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PICES

Background & Outline

1. Many technological advances but focus on POC research arising from
   a) Bigger & faster computers (better models)
   b) Observations from
      i. Satellites (SST, Chlorophyll, SSH)
      ii. Autonomous platforms (Argo floats, gliders)

2. Examples from 2003-2014 POC-Paper & POC co-sponsored presentations on http://www.pices.int/meetings/past_annual_meetings.aspx

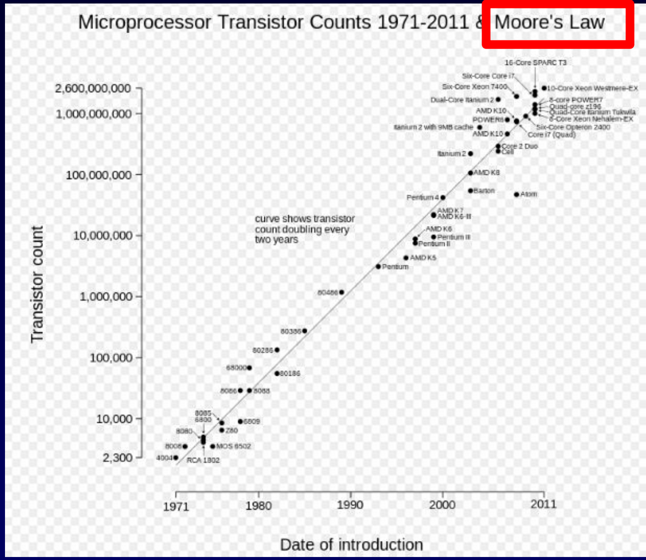
3. What lies ahead

4. Summary


Earth Simulator

Bigger & Faster Computers

1. Earth Simulator in Japan
   - First opened March 2002
   - Replaced 2009 & 2015

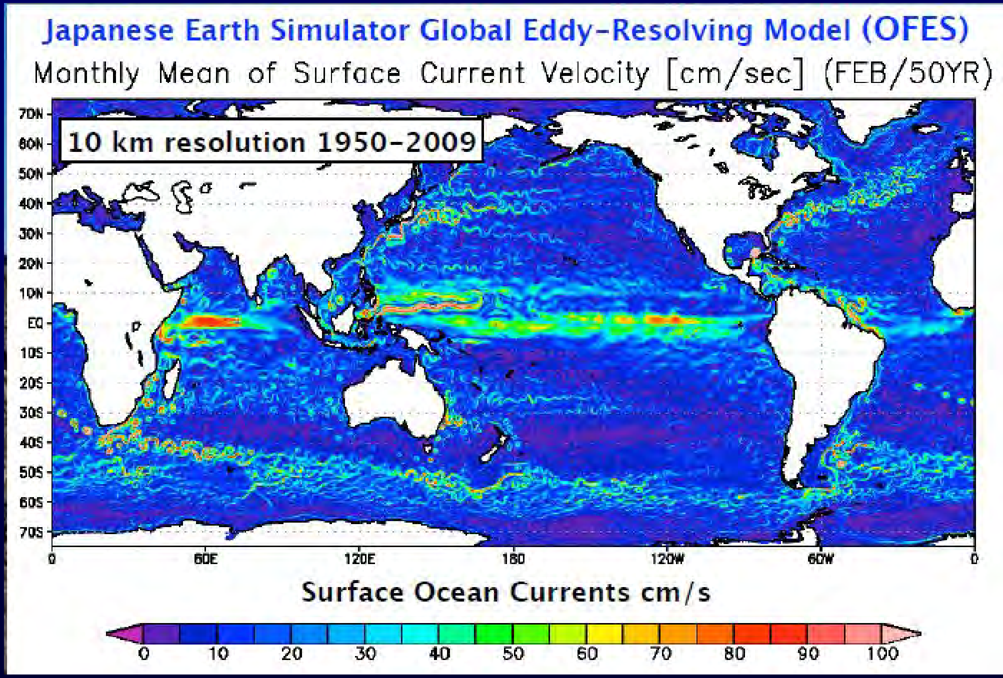


2000 times increase from 1990 to 2011

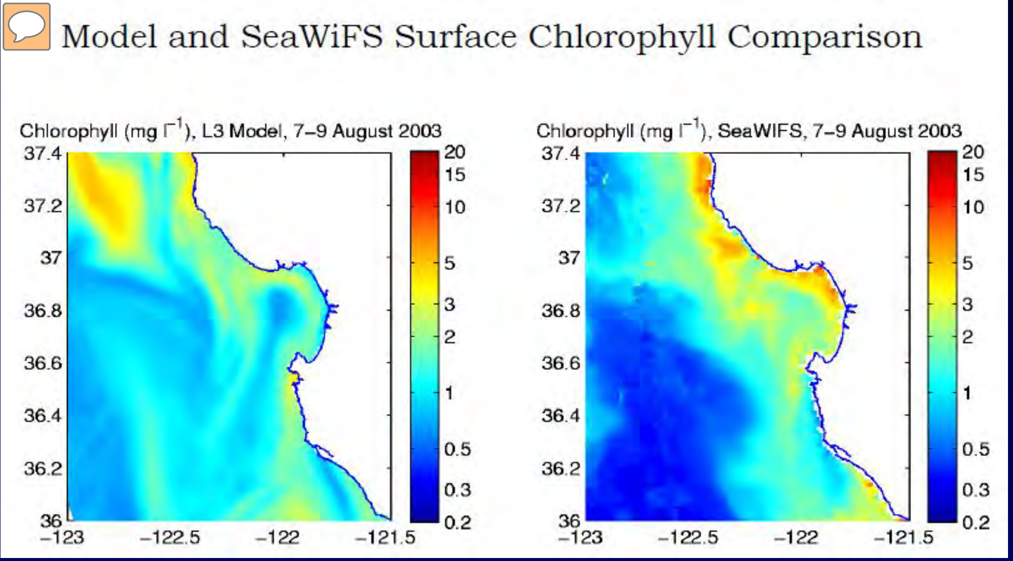
2. Similar hardware in USA & other PICES countries

3. Software improvements e.g. parallelization

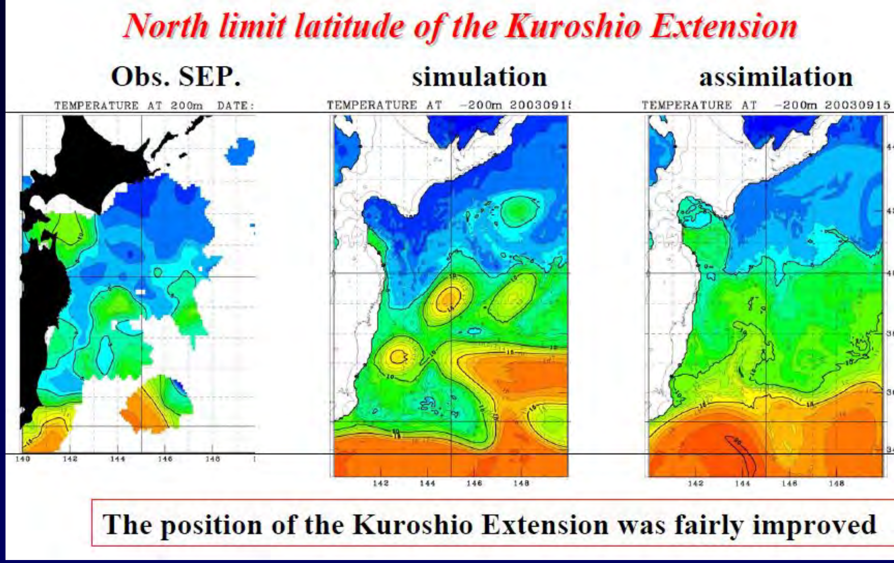
4. Allow models with
   - Higher resolution
   - Data assimilation
   - More complexity
   - Longer simulations (e.g., climate) & more ensembles



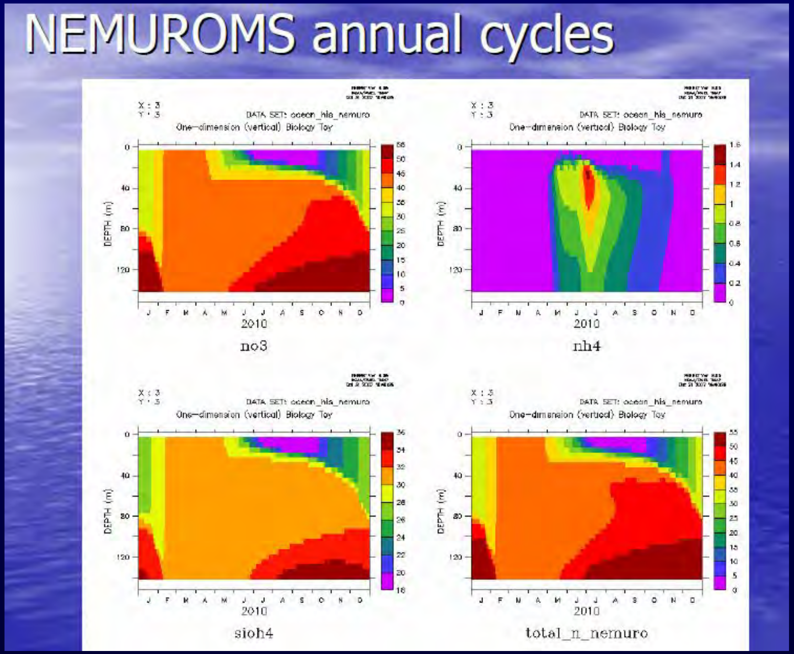
Davis & Di Lorenzo, Hiroshima 2012



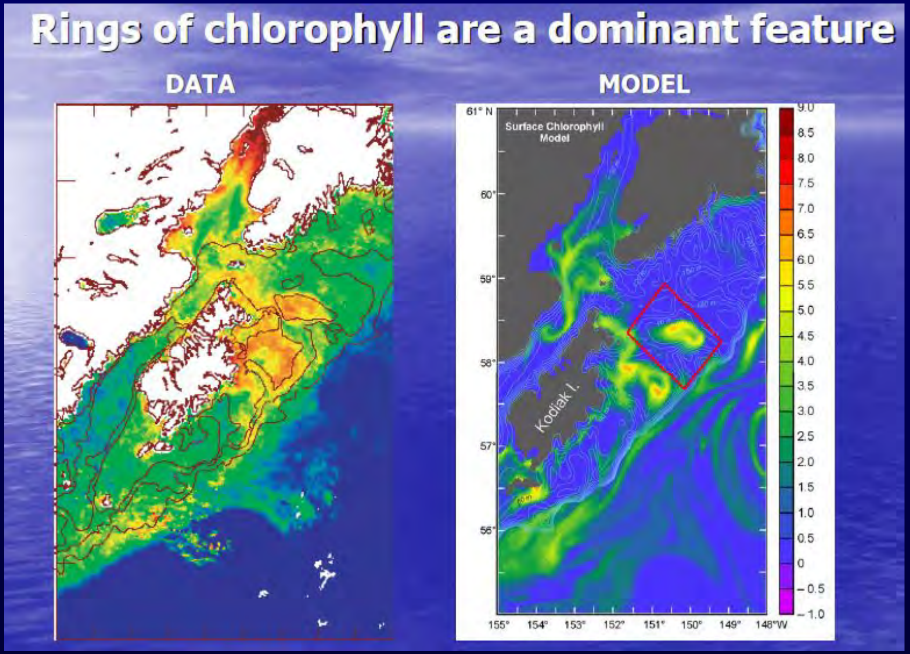
Chai, Honolulu 2004



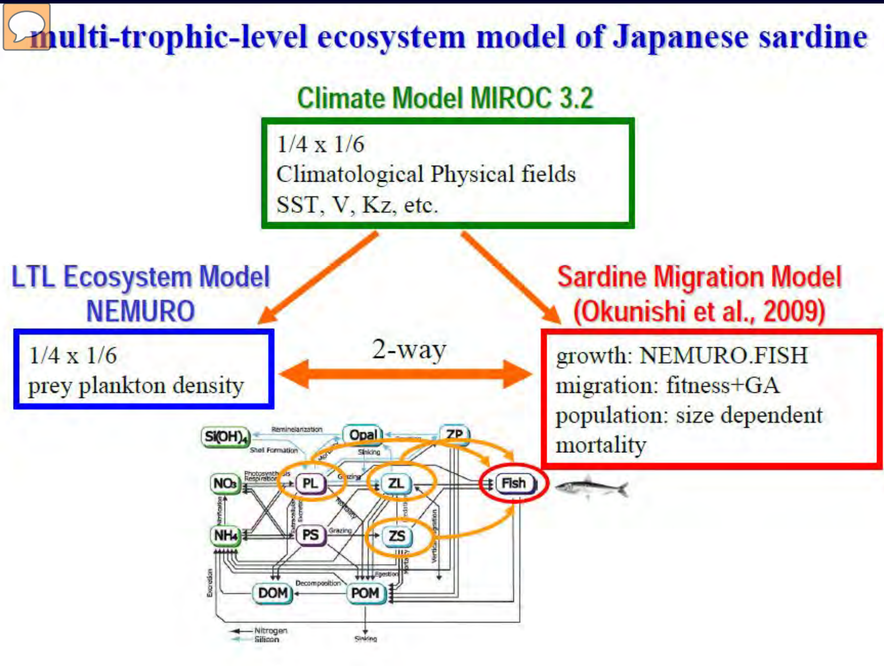
Ito et al., Vladivostok 2005



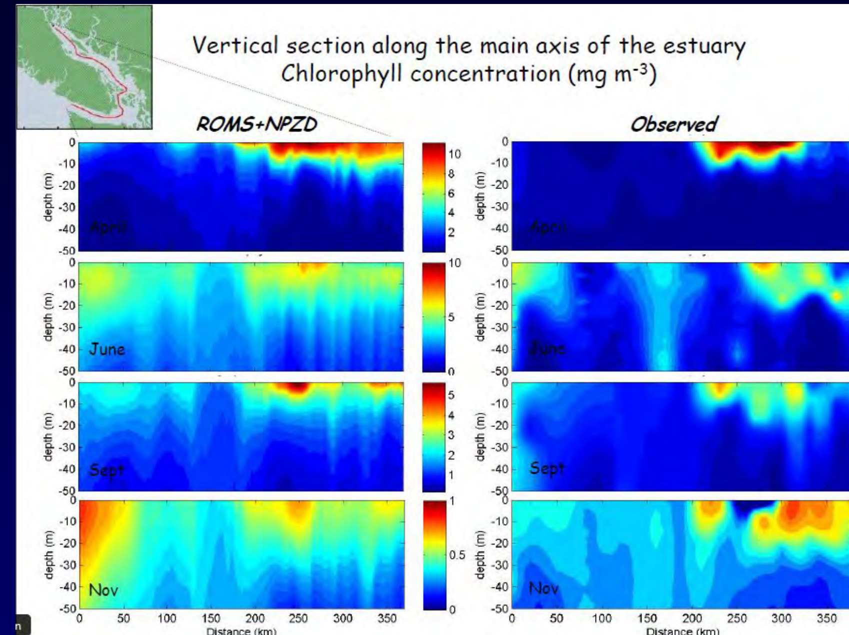
Hermann et al., Victoria 2007



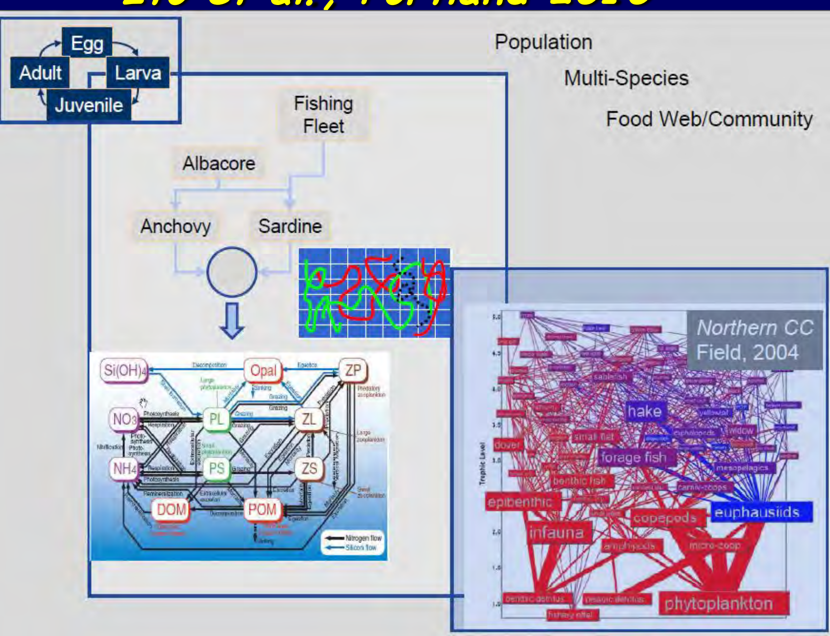
Hermann et al., Dalian 2008



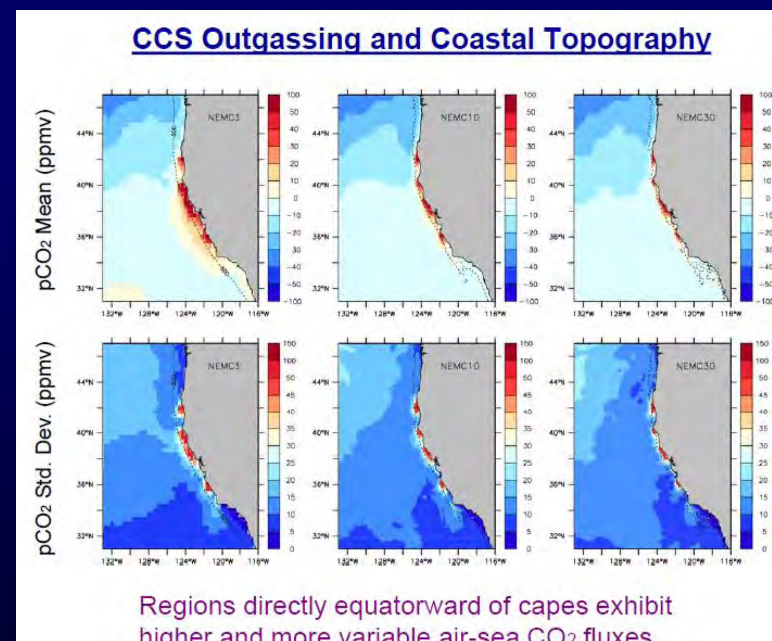
Ito et al., Portland 2010



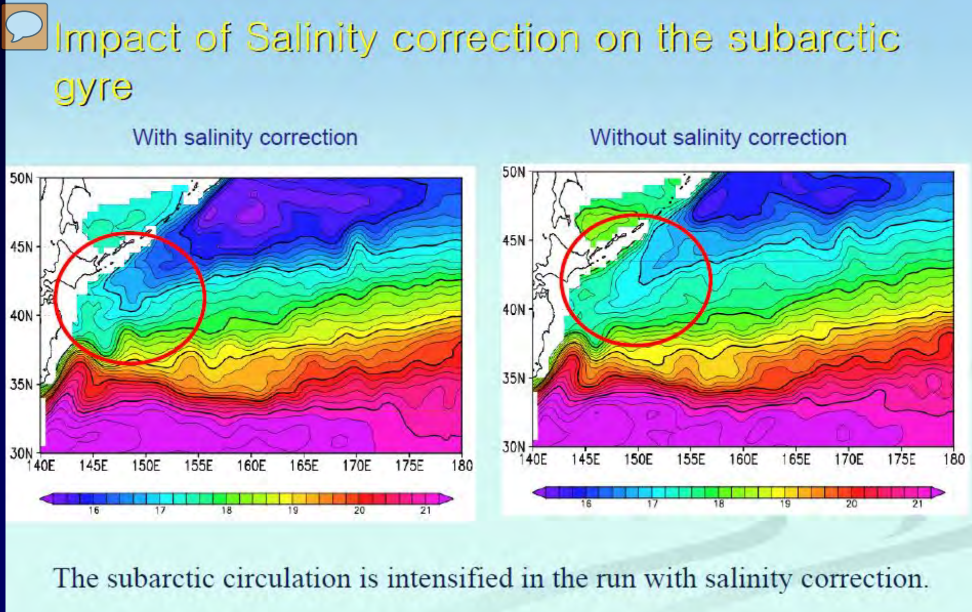
Peña & Masson, Khabarovsk 2011



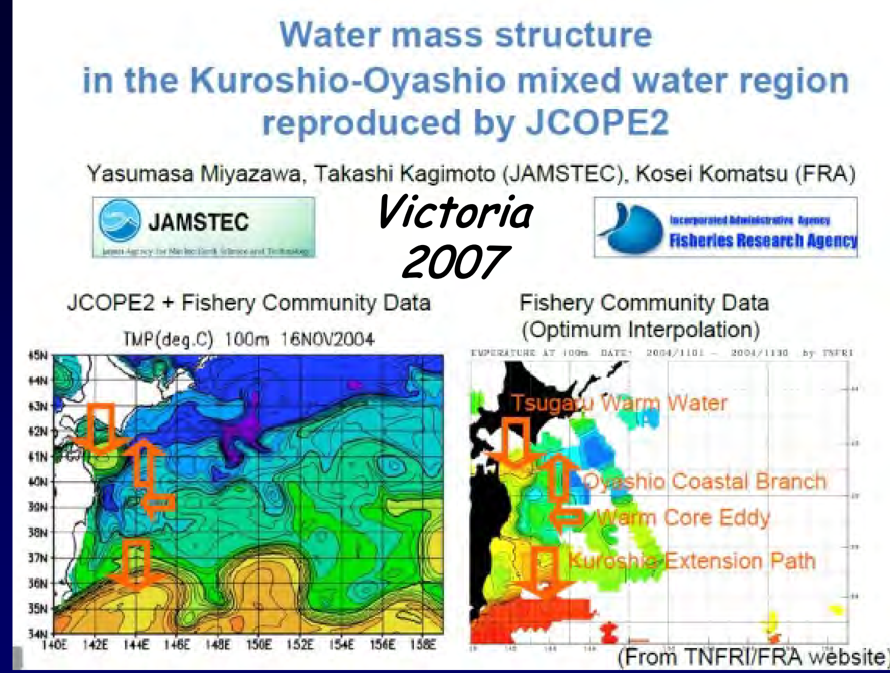
Rose et al., Khabarovsk 2011

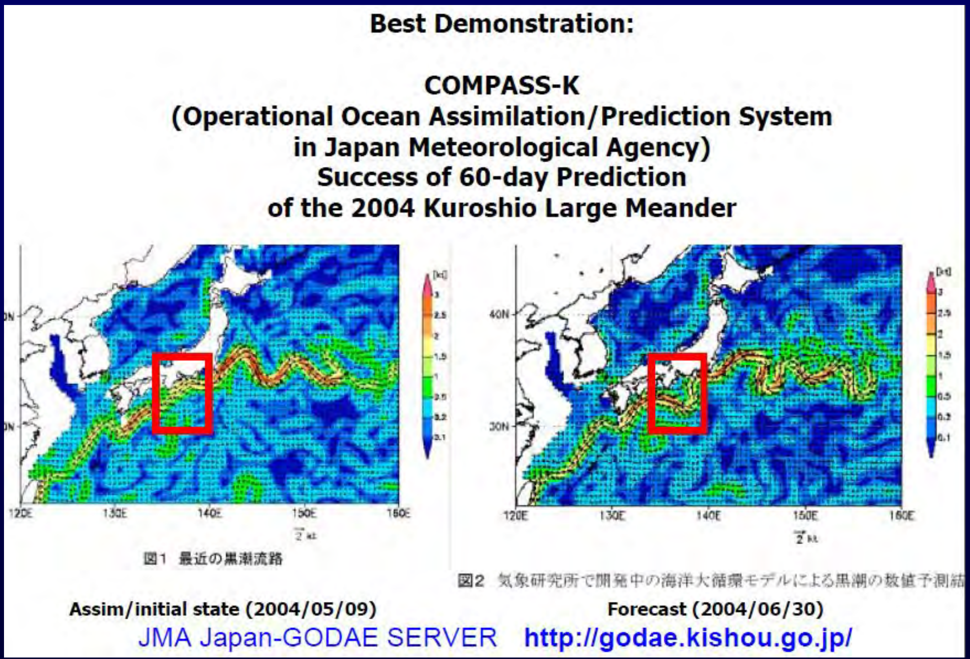


Fiechter et al., Nanaimo 2013

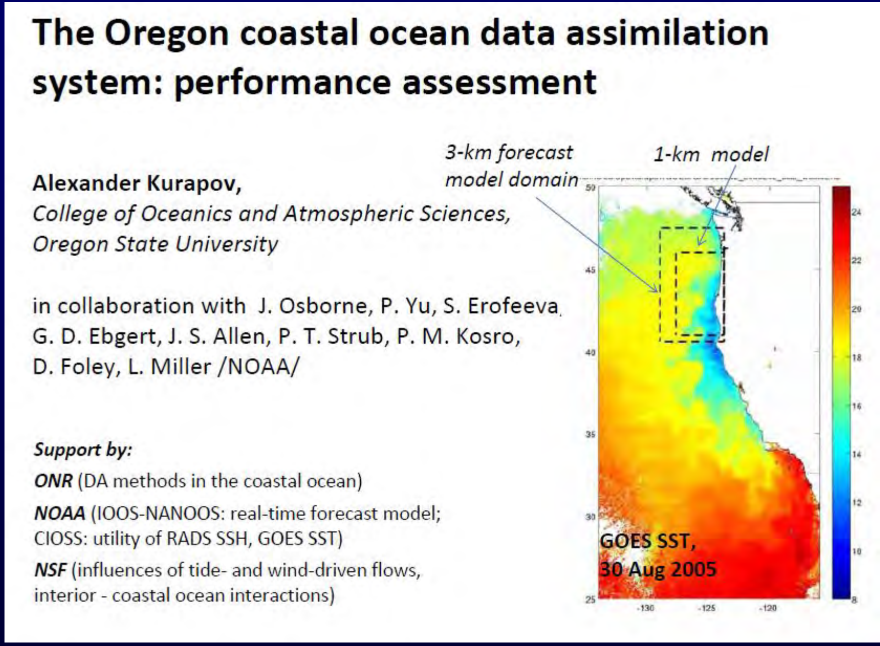


Kamachi et al., Honolulu 2004

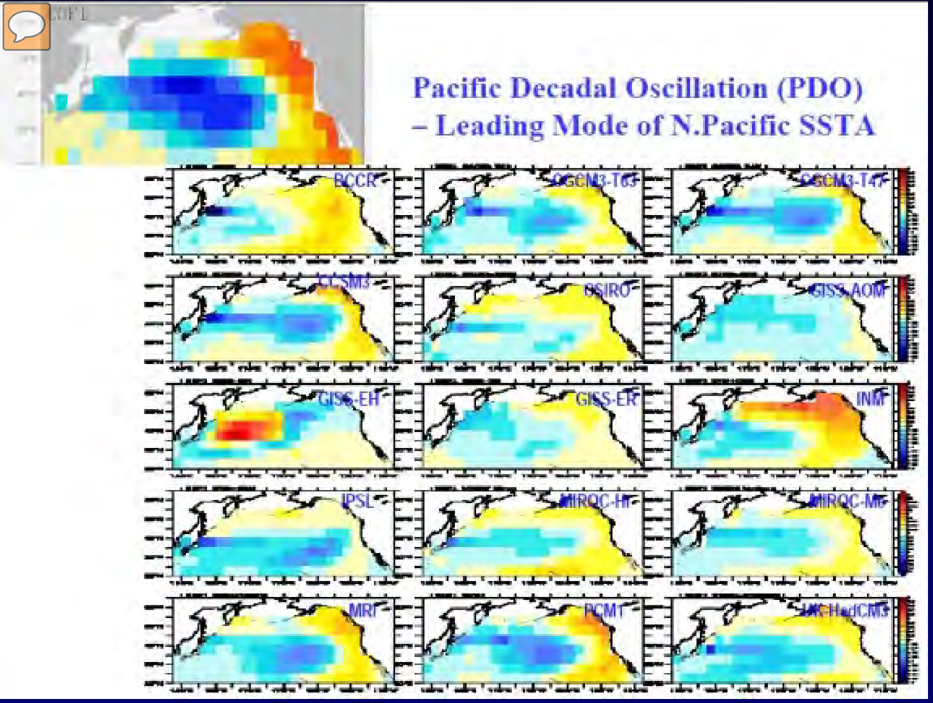




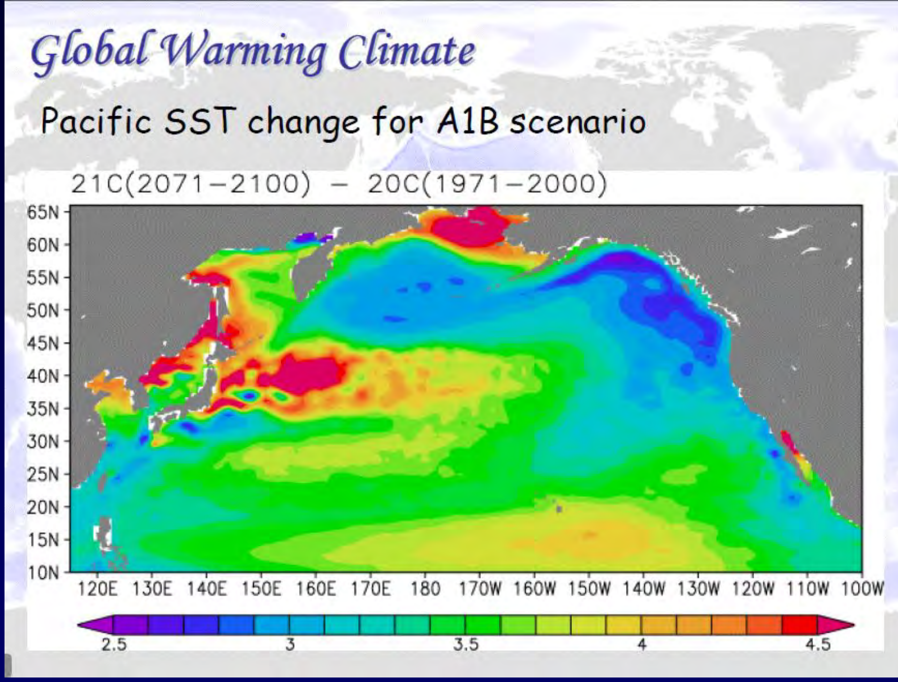
Kamachi et al., Victoria 2007



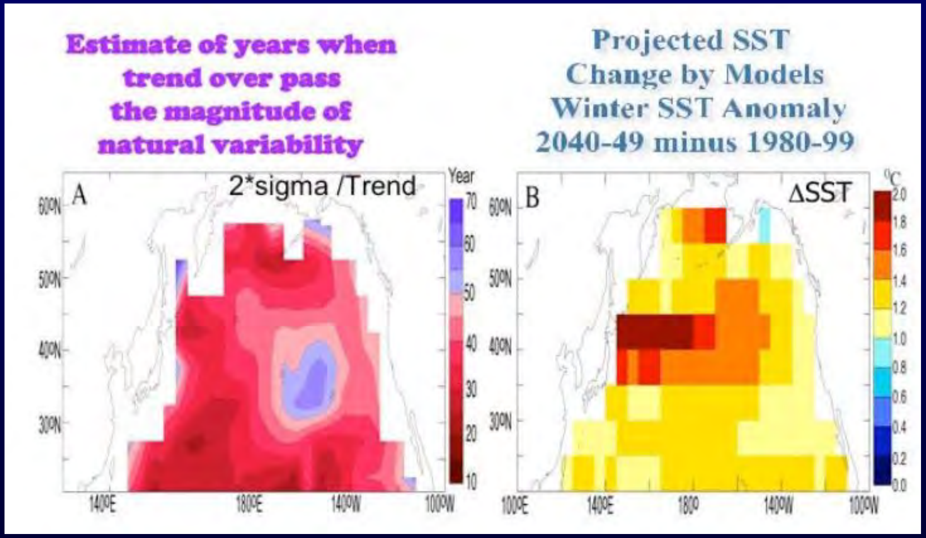
Kurapov et al., Khabarovsk 2011



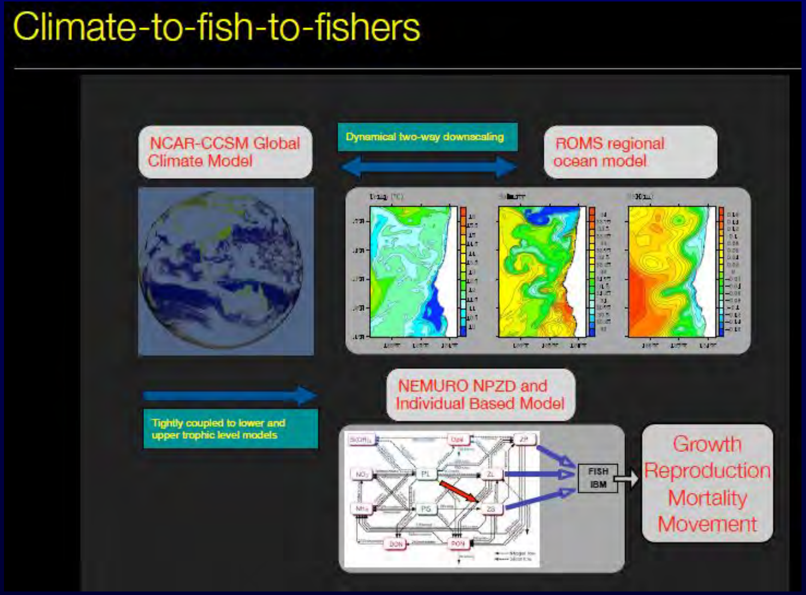
Wang & Overland, Vladivostok 2005



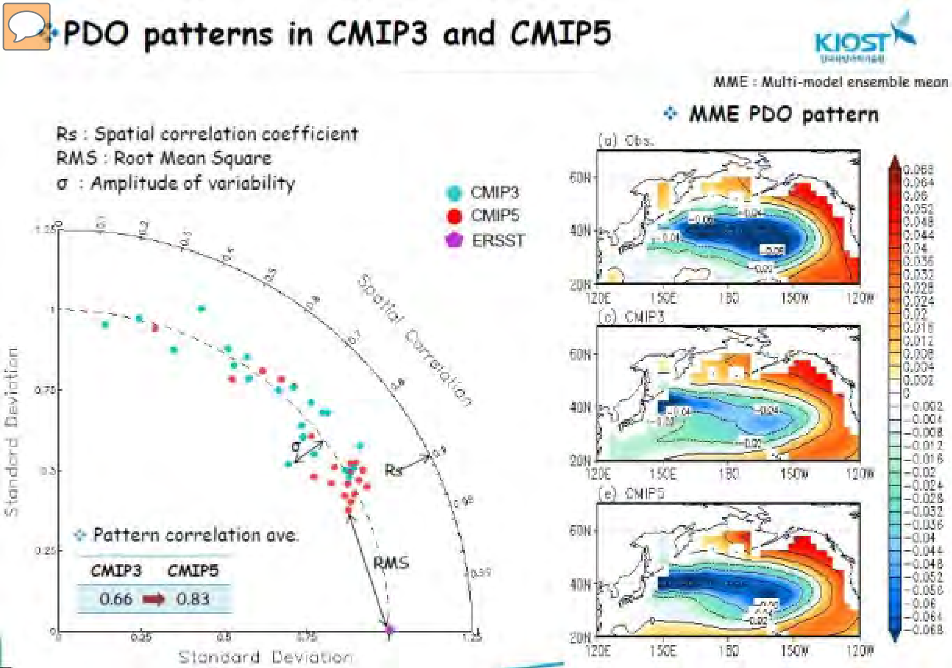
Hasumi et al., Vladivostok 2005



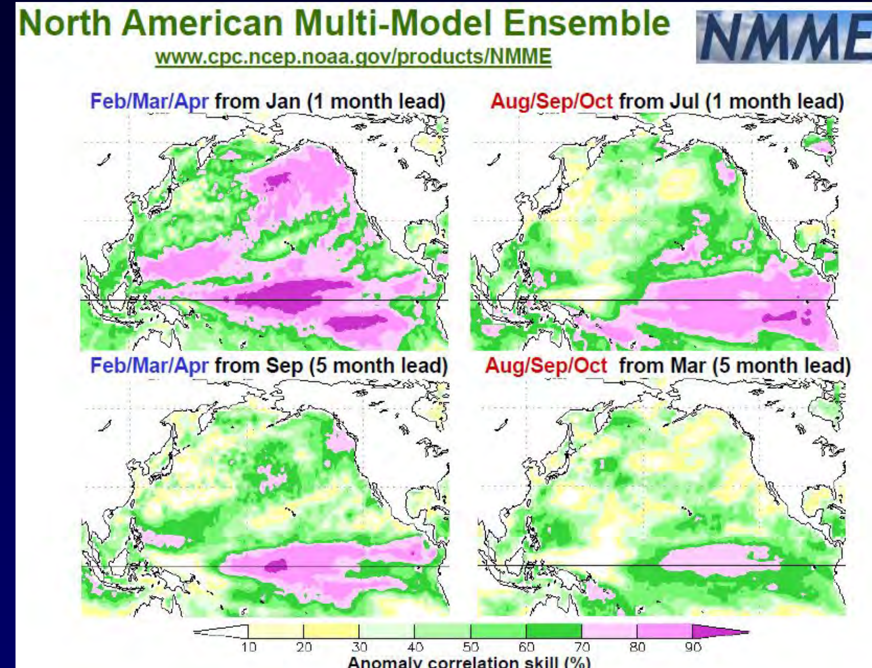
Wang & Overland, Victoria 2007



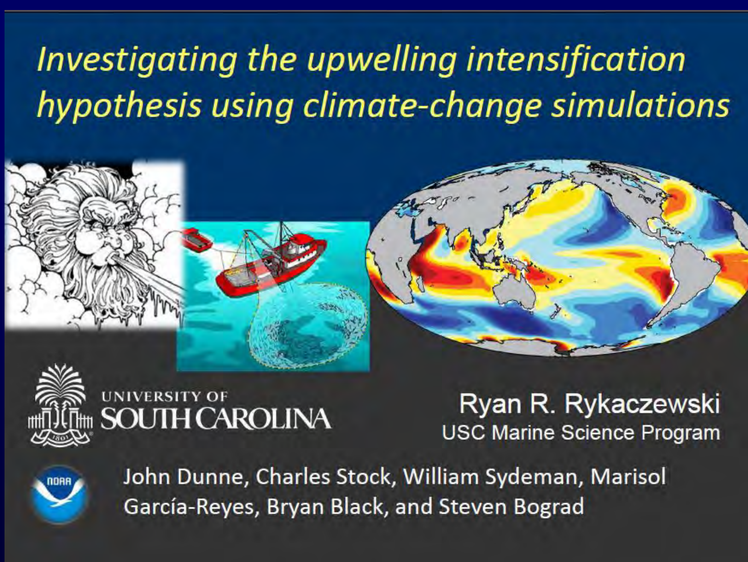
Curchitser et al., Portland 2010



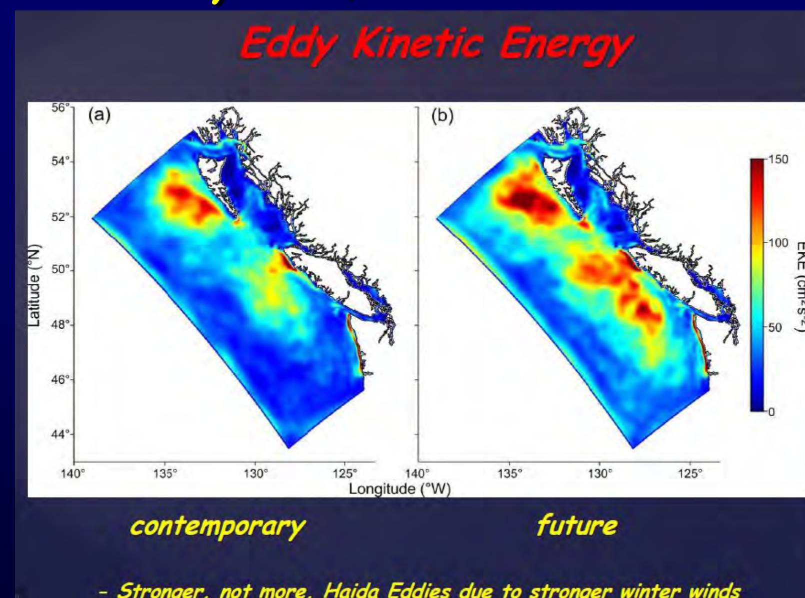
Joh et al., Nanaimo 2013



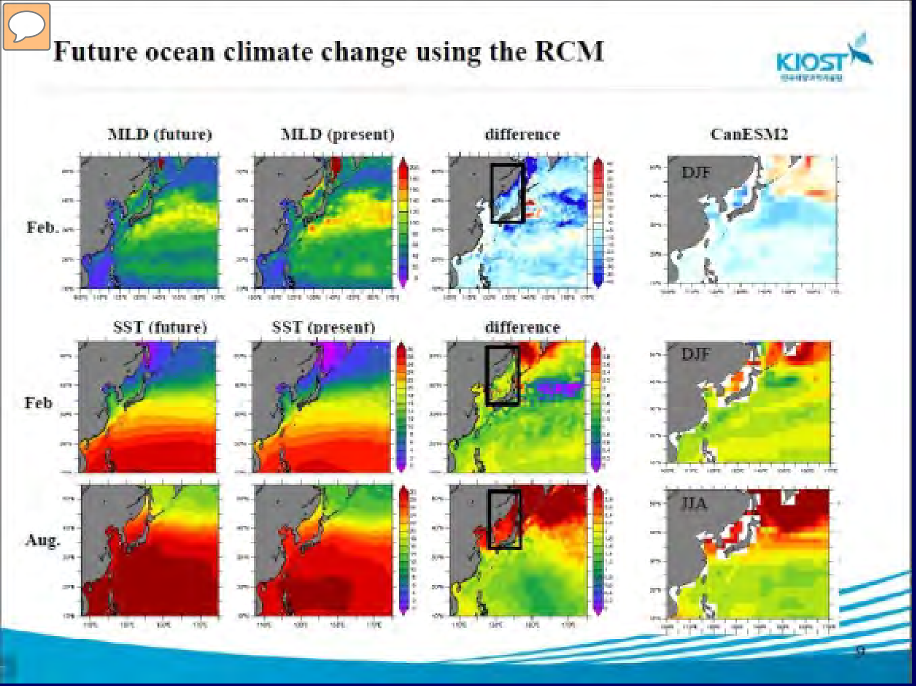
Merryfield, Nanaimo 2013

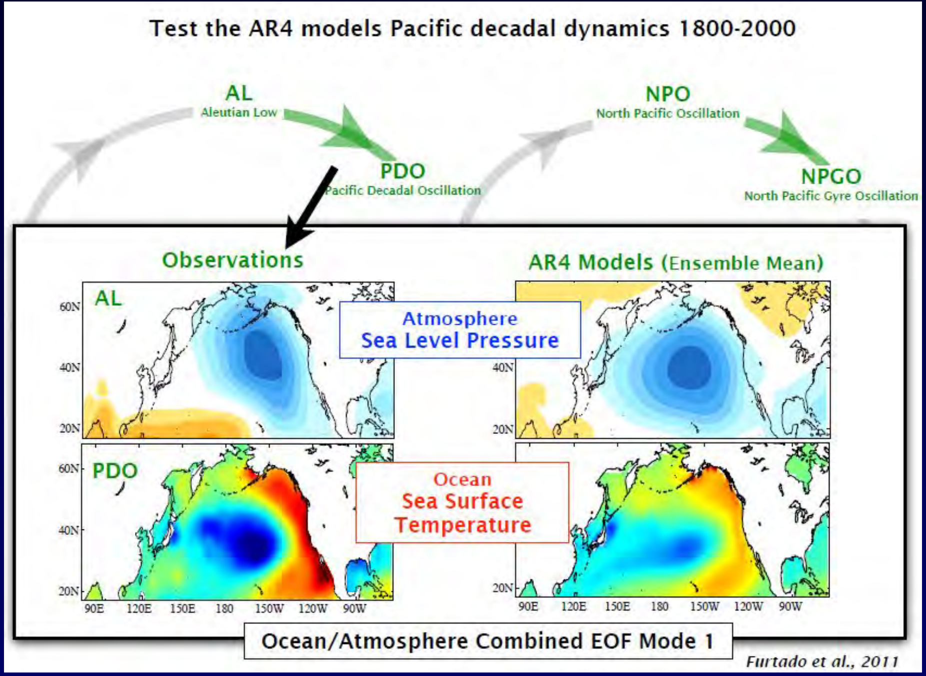


Rykaczewski et al., Nanaimo 2013



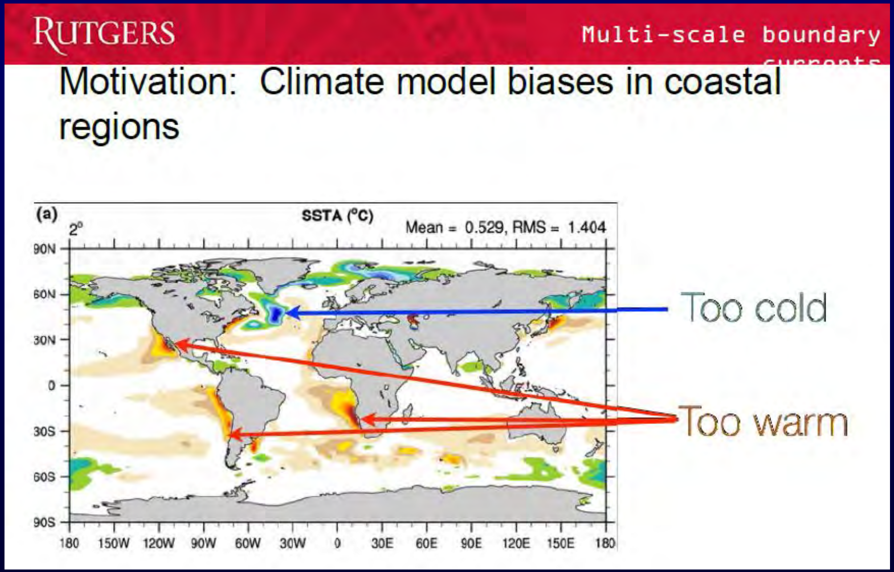
Foreman et al., Nanaimo 2013



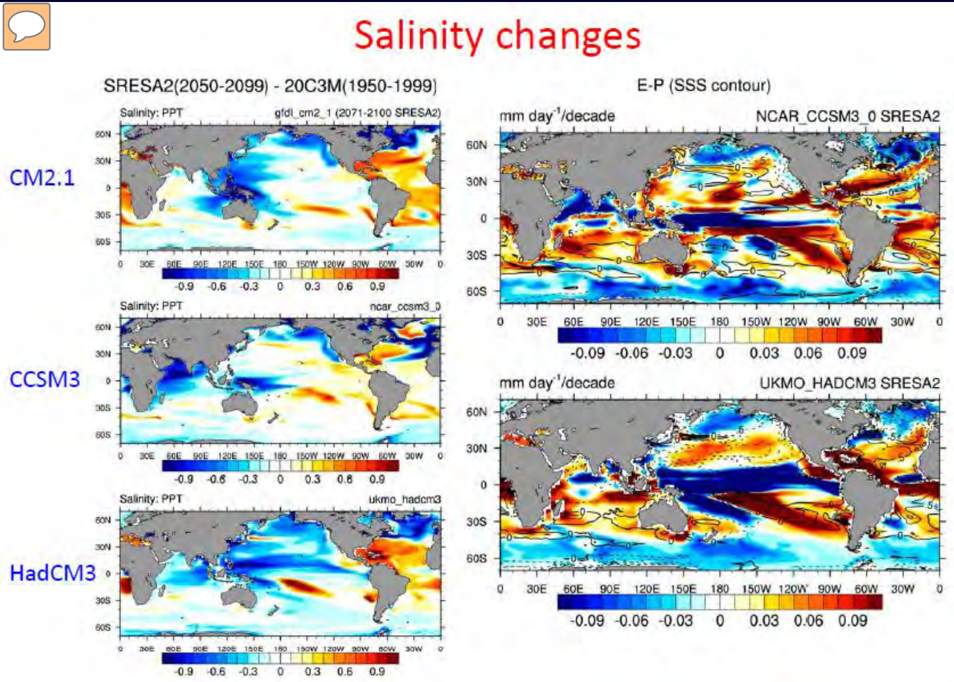


Ko, Jang et al., Nanaimo 2013

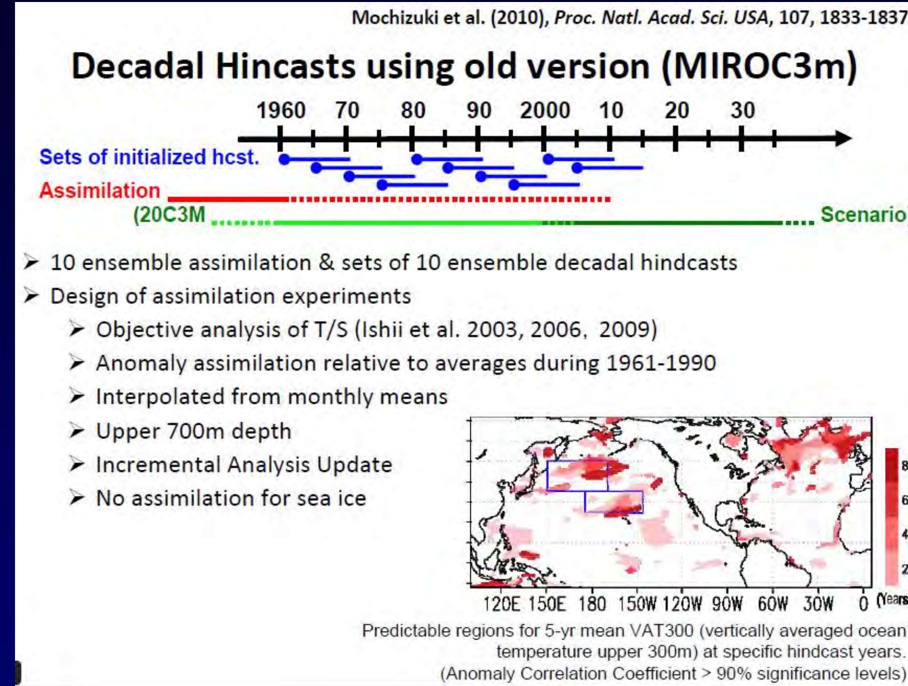
Di Lorenzo et al., Nanaimo 2013



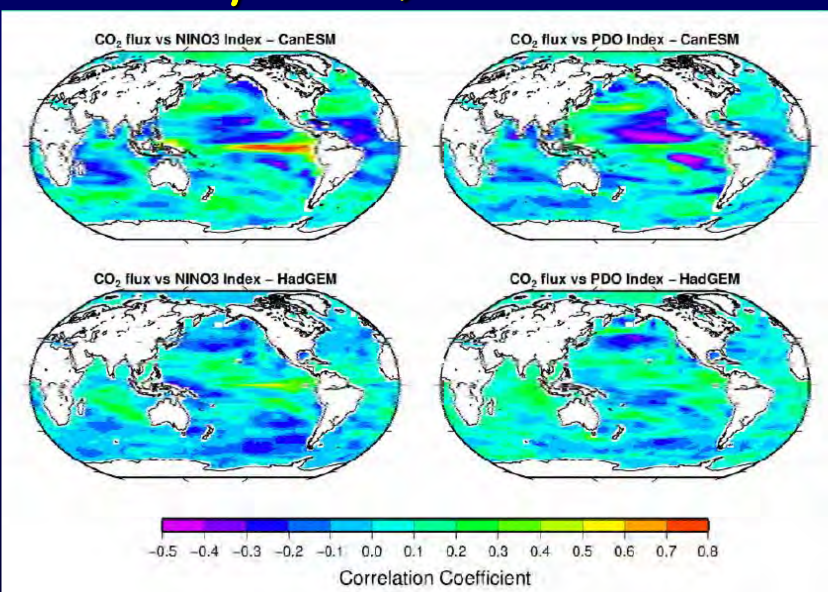
Curchitser et al., Yeosu 2014



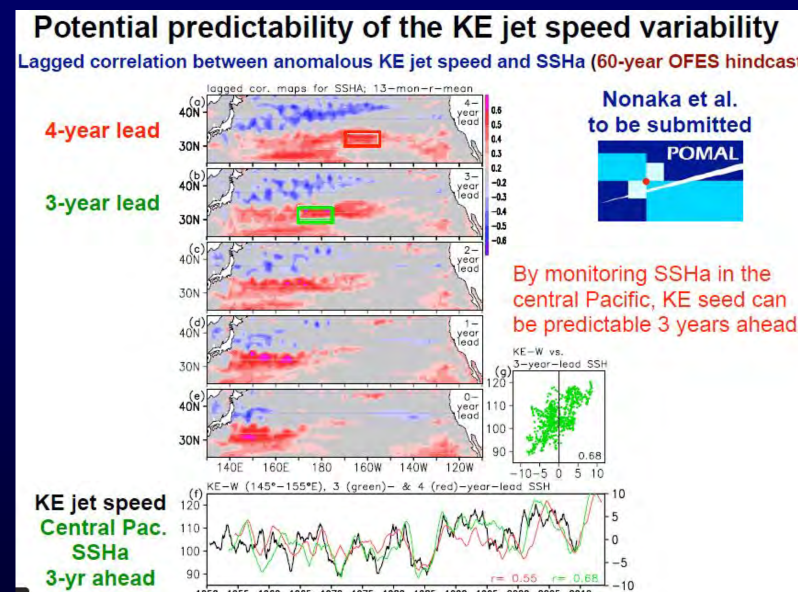
Capotondi, Portland 2010



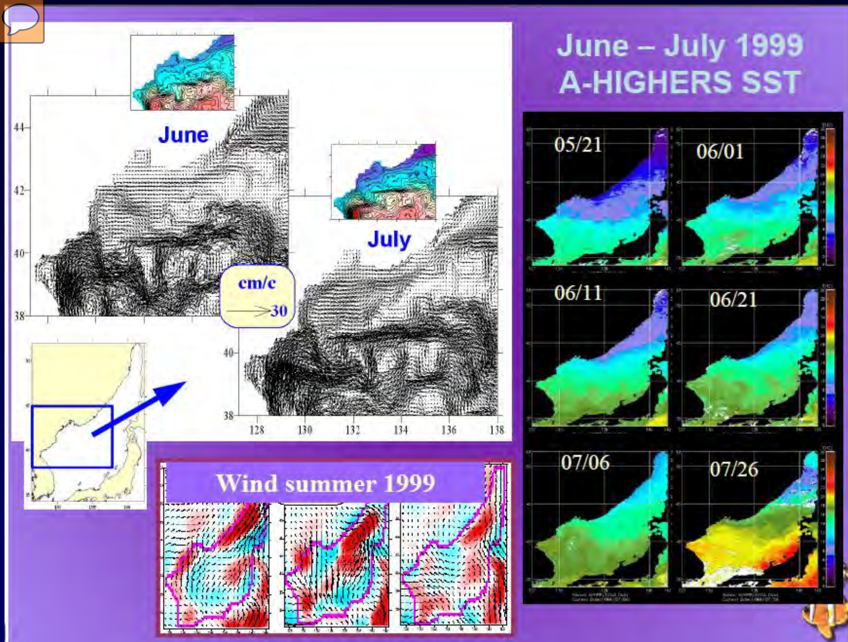
Mochizuki et al., Khabarovsk 2011



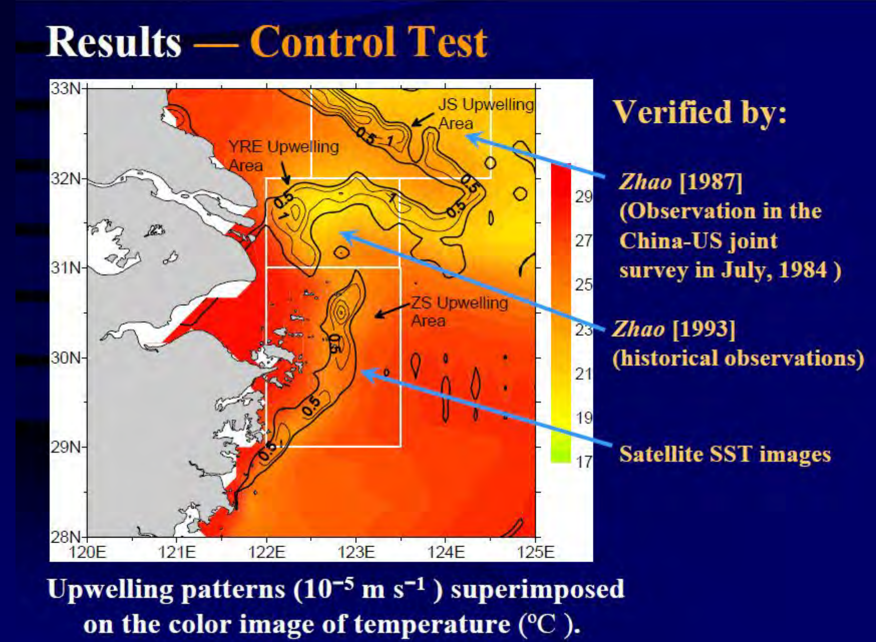
Christian, Khabarovsk 2011



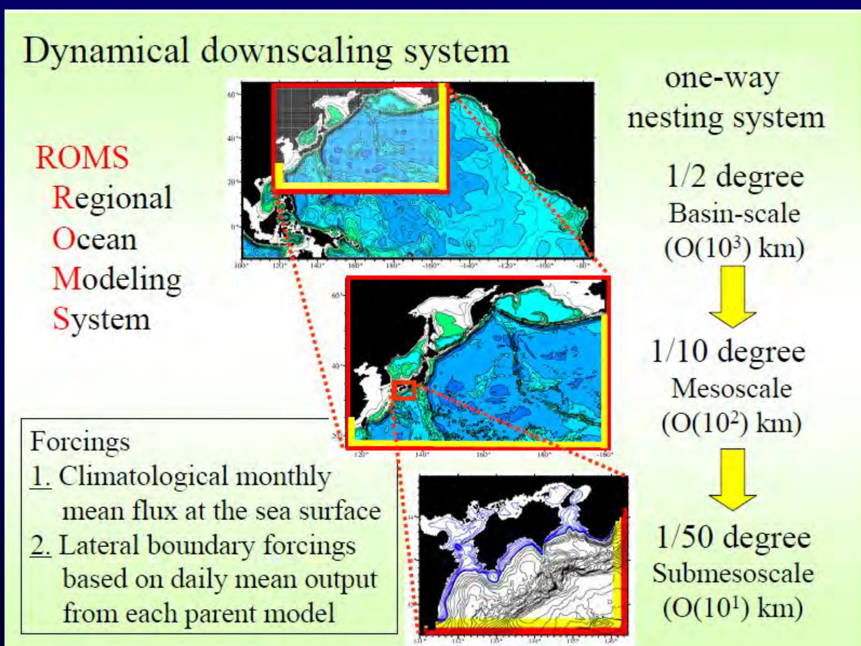
Taguchi et al., Khabarovsk 2011



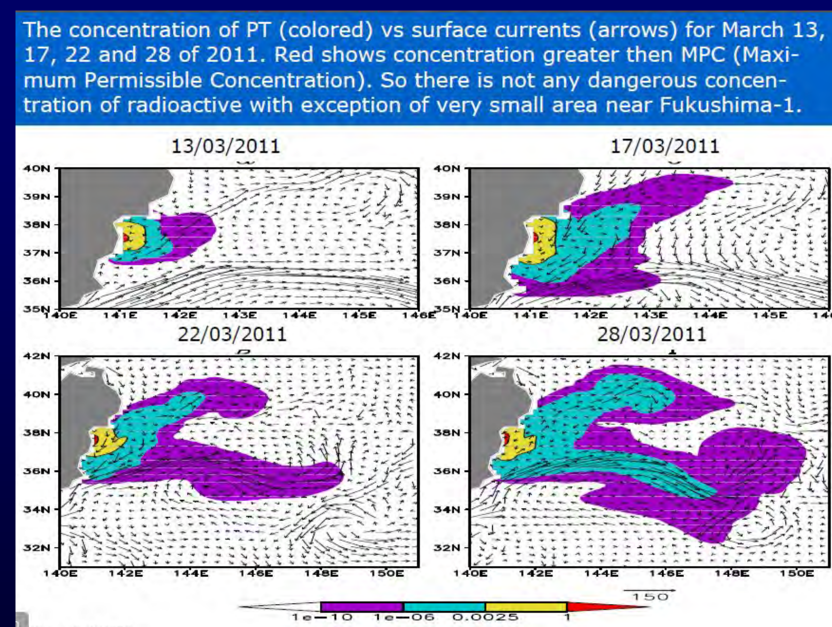
Trusenkova et al., Vladivostok 2005



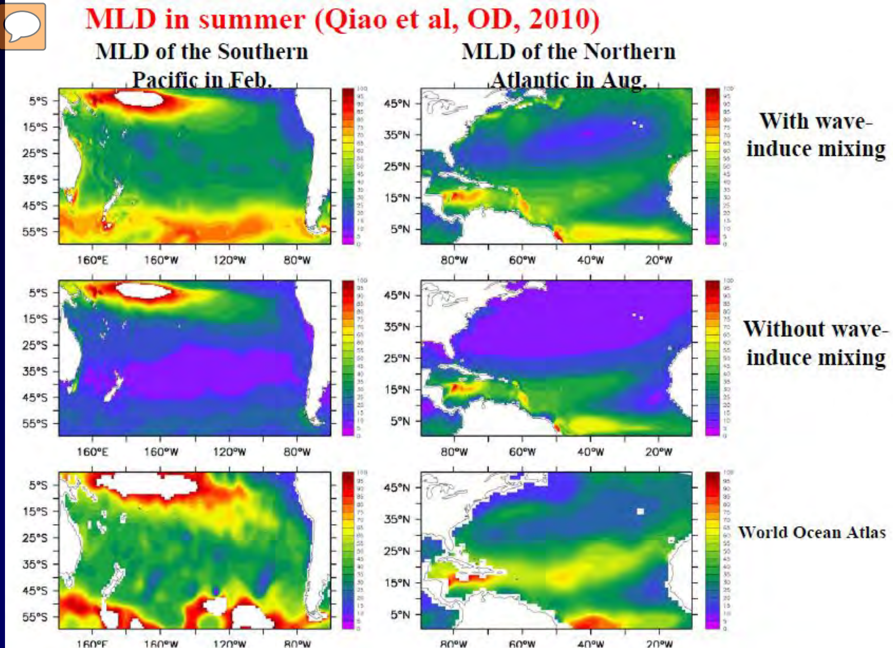
Qiao & Lv, Yokohama 2006



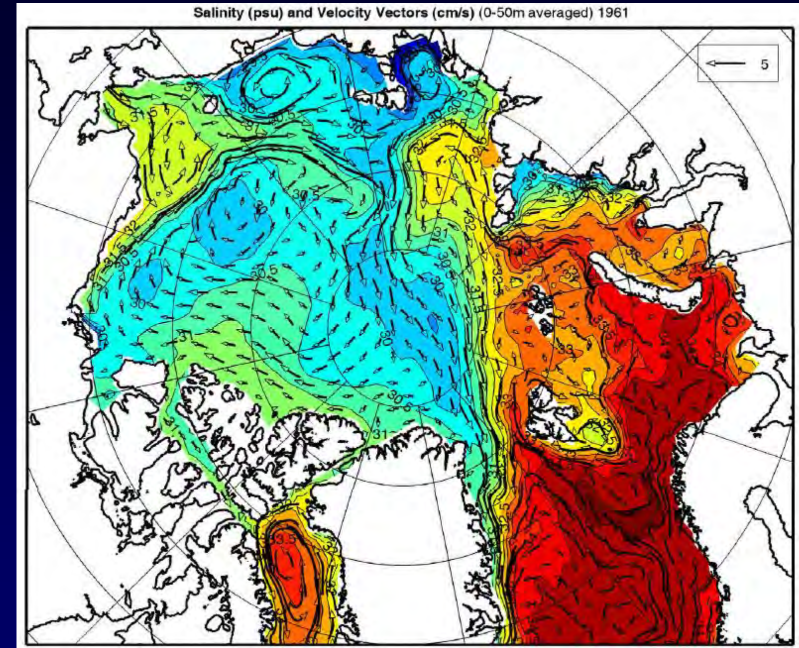
Kuroda et al., Portland 2010



Diansky & Zalesny, Khabarovsk 2011

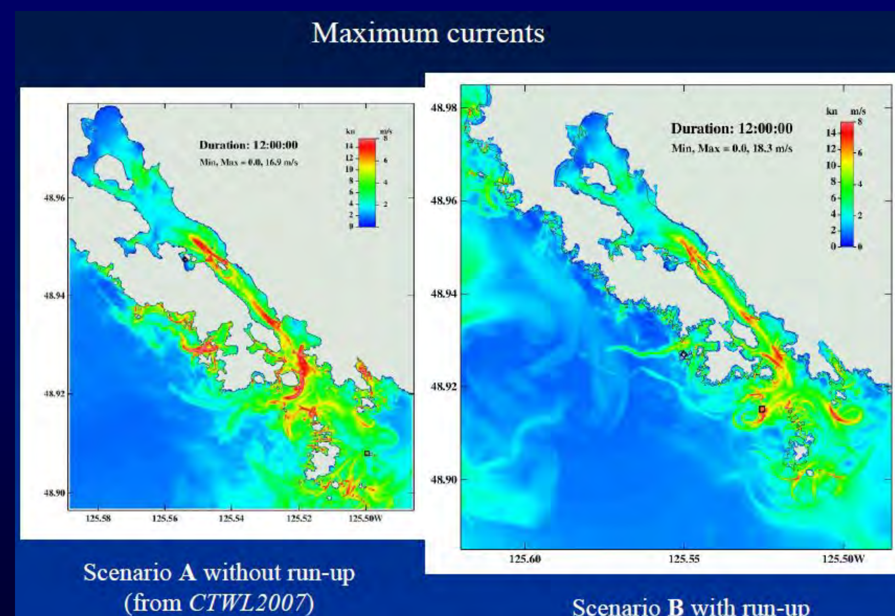


Qiao & Huang, Hiroshima 2012

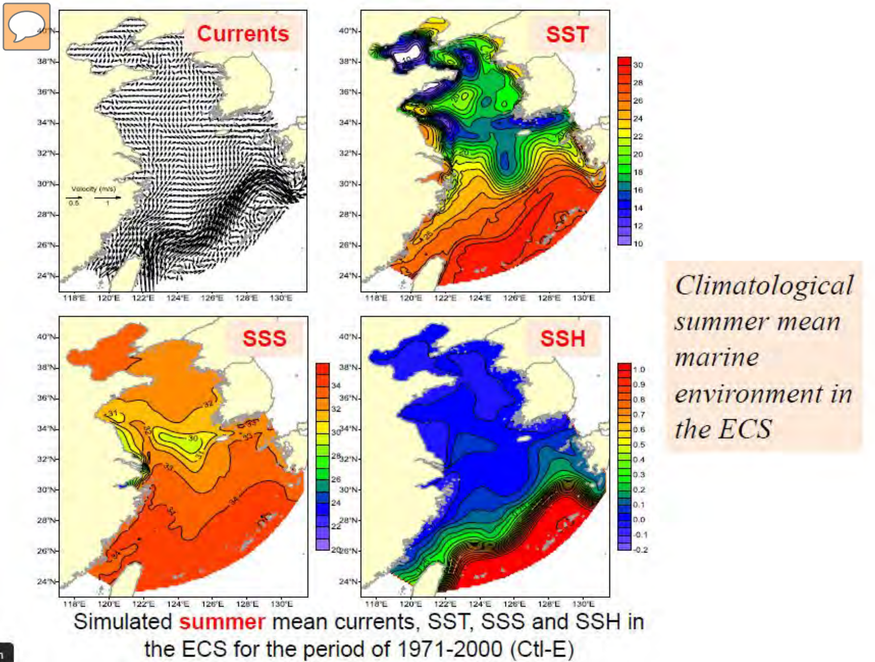


Kuzin, Hiroshima 2012

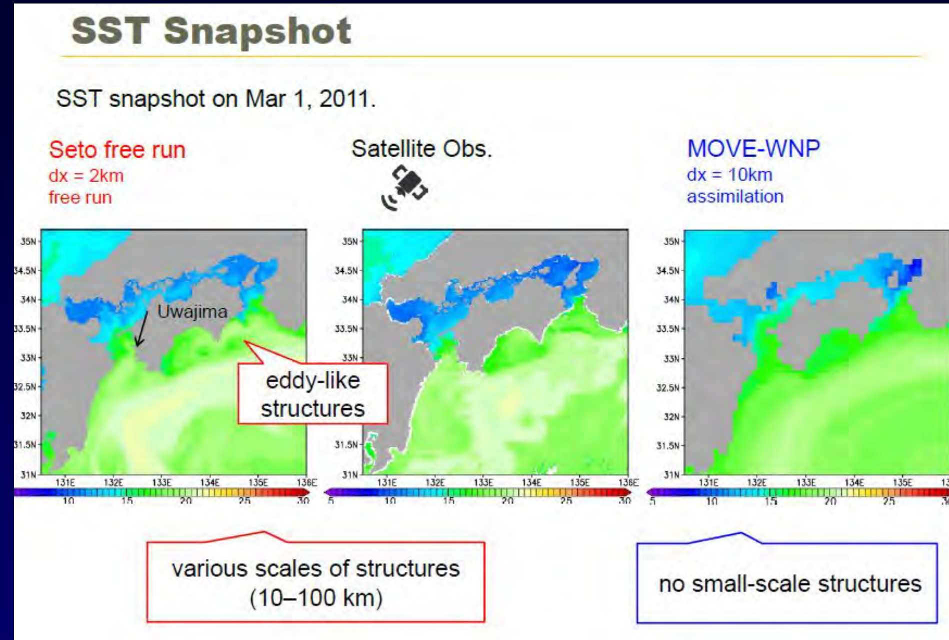
Li et al., Hiroshima 2012



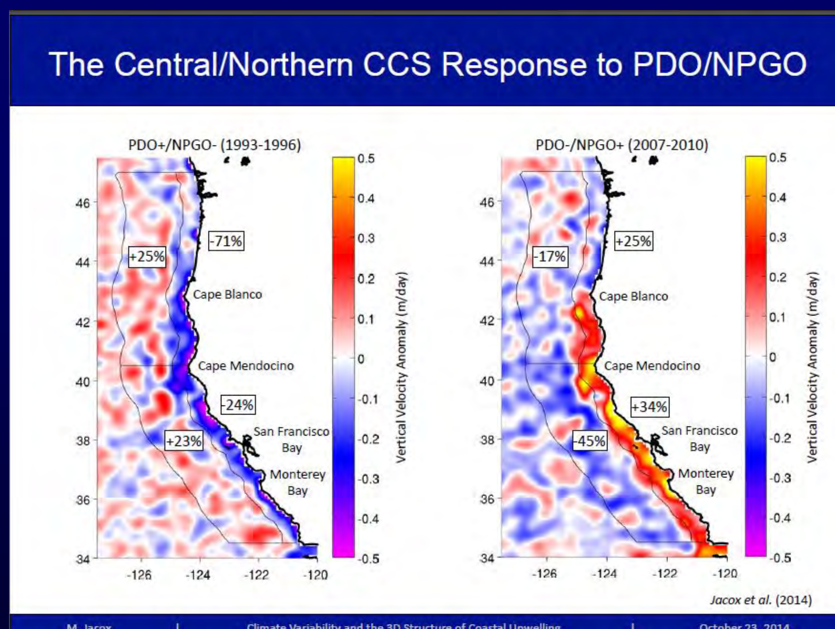
Cherniawsky et al., Hiroshima 2012



Cai & Zhang, Nanaimo 2013



Sakamoto et al., Yeosu 2014

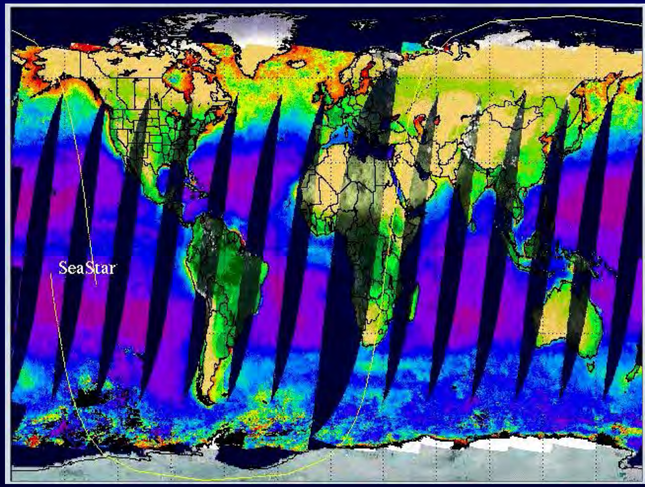


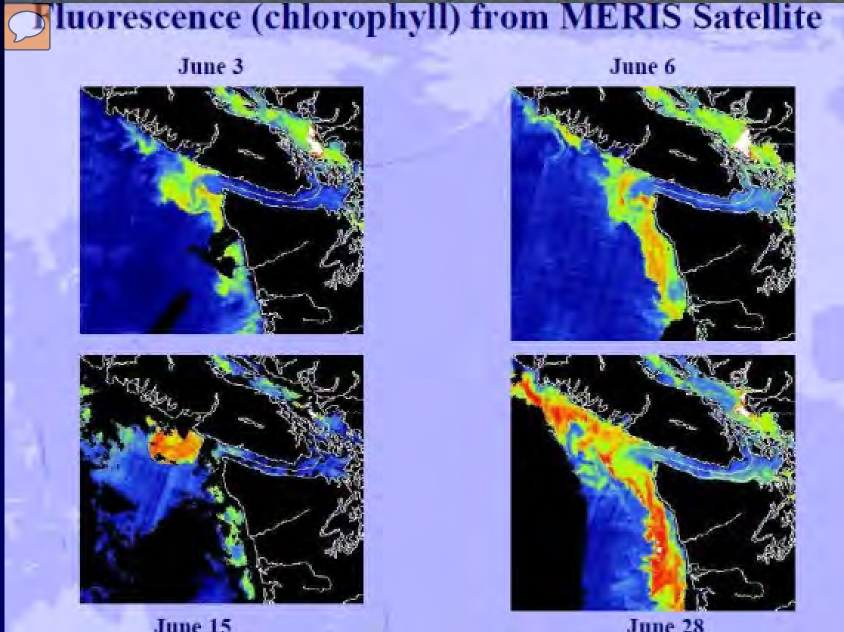
Jacox et al., Yeosu 2014

Satellite Observations

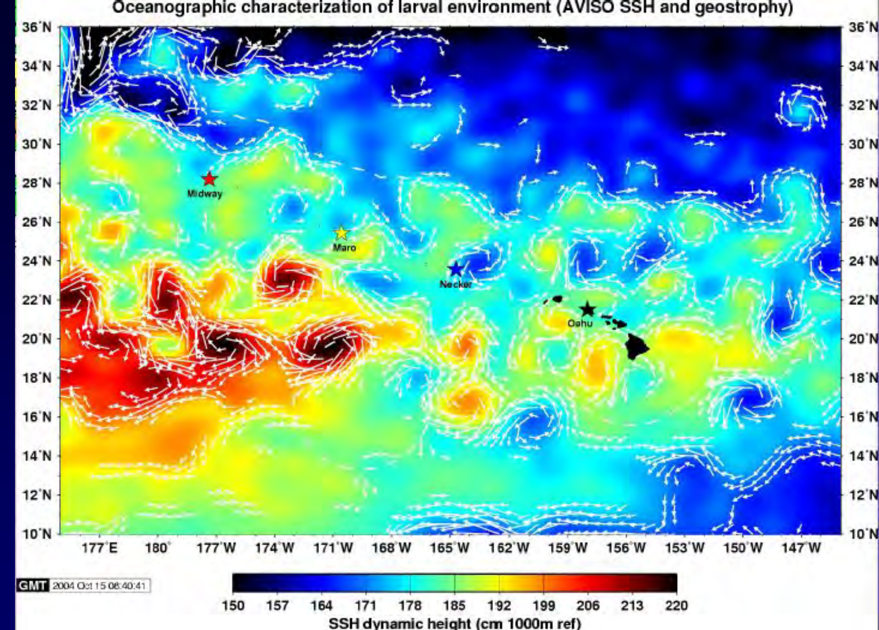
1. Topex/Poseidon/Jason altimetry
   - Lifetimes:
     - TP1: 1992-2006
     - Jason 1: 2001- 2013
     - Jason2: 2008 –
     - Jason3: 2016 -
   - http://sealevel.jpl.nasa.gov/missions/topex/
   - Measure sea level to within few cm
     - Sea level rise
     - Tides, eddies, El Niño, PDO, …
     - Assimilation into models

2. MERIS, Modis, AVHRR, SeaWIFS, Landsat
   - SST, chlorophyll, winds

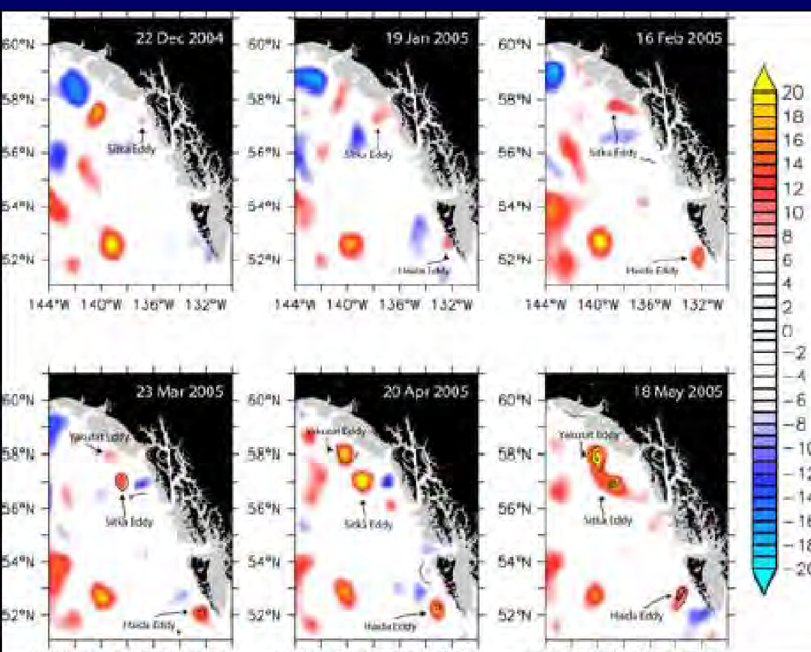




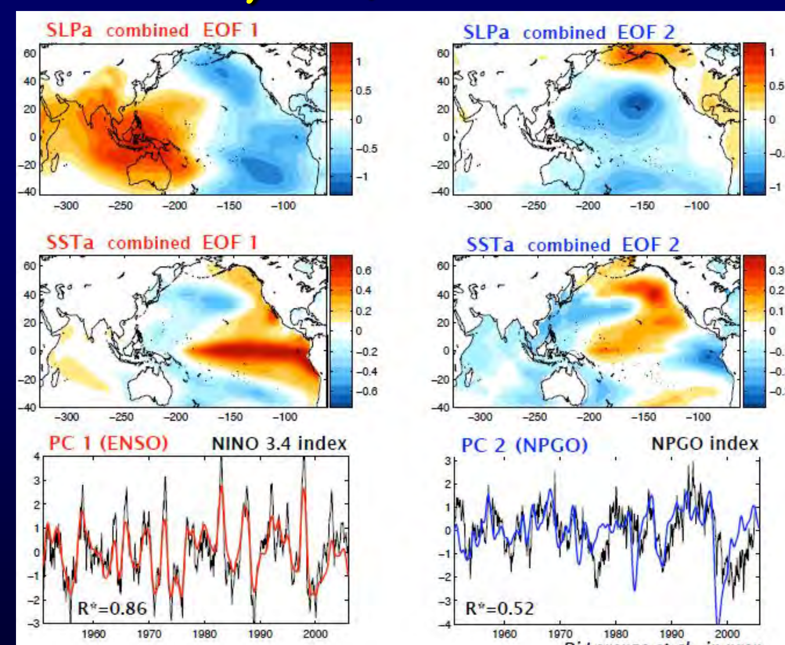
Foreman et al., Seoul 2003



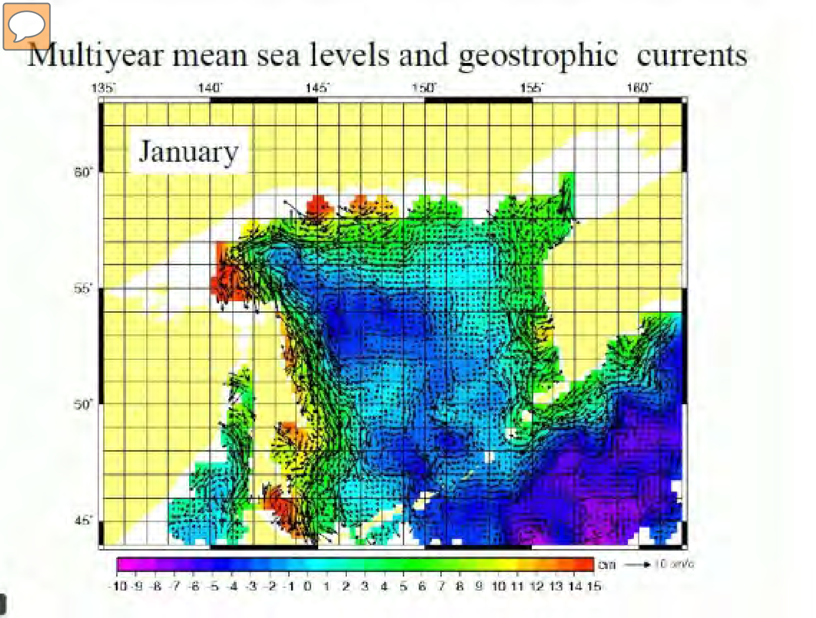
Kobayashi, Honolulu 2004



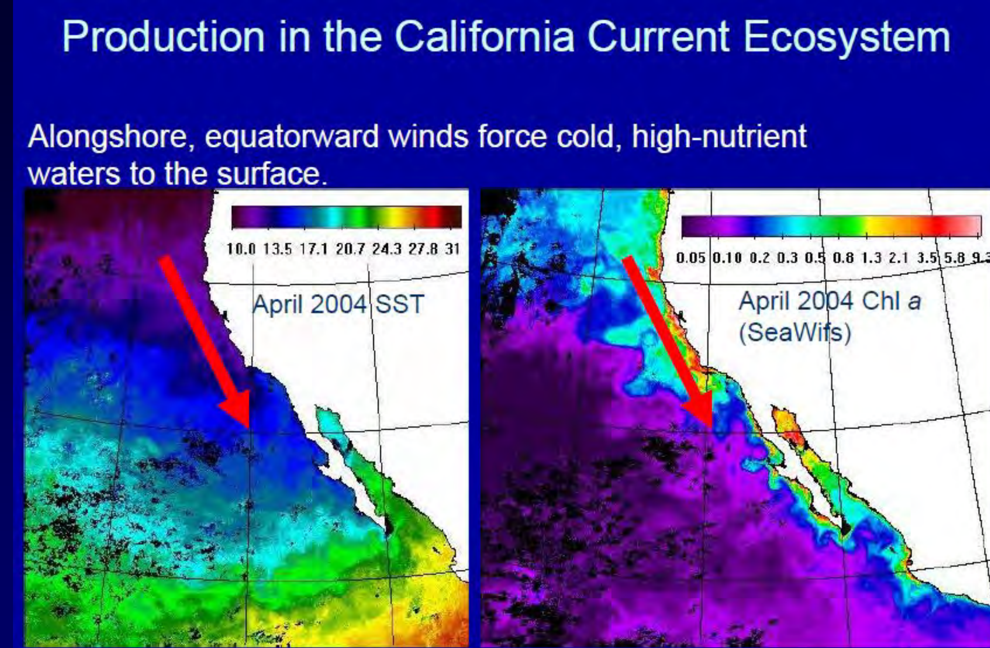
Ladd et al., Victoria 2007



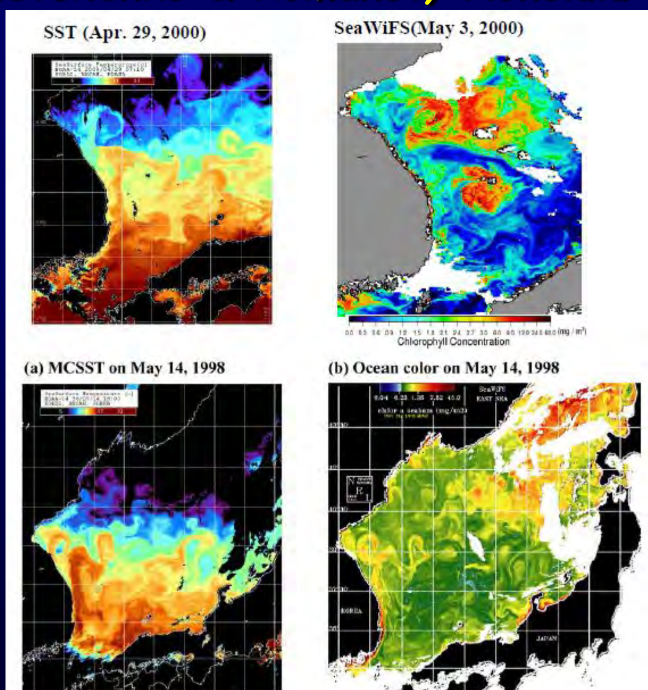
Di Lorenzo et al. Dalian 2008



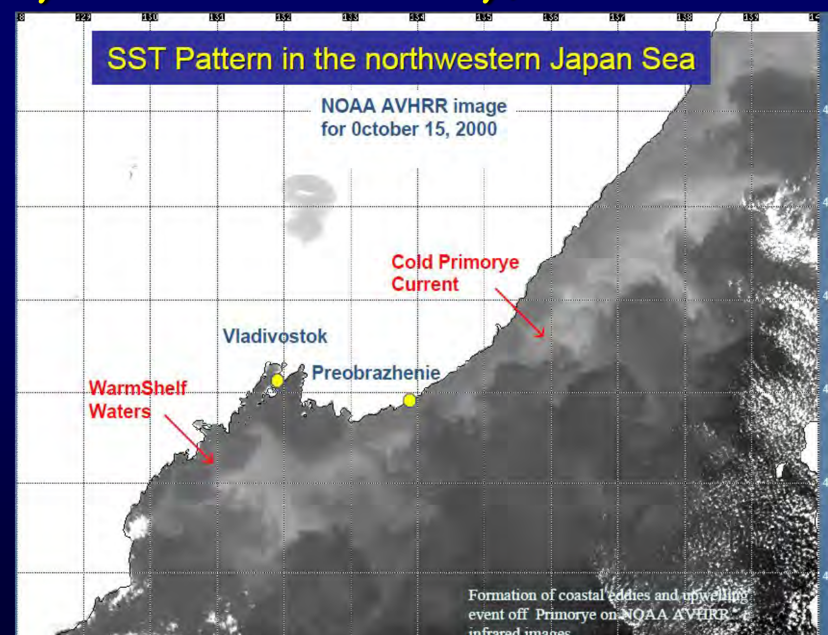
Shevchenko & Romanov, Honolulu 2004



Rykaczewski & Checkley, Yokohama 2006

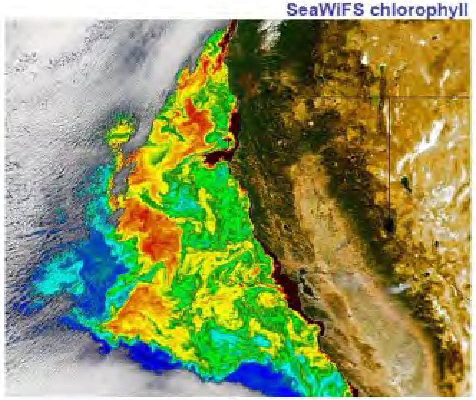


Kim et al., Dalian 2008



Lobanov et al., Dalian 2008

California Current Large Marine Ecosystem



- Seasonal (coastal upwelling) & interannual (ENSO) forcing
- Highly productive marine ecosystem
- Eastern Boundary Upwelling System

Bograd et al., Dalian 2008

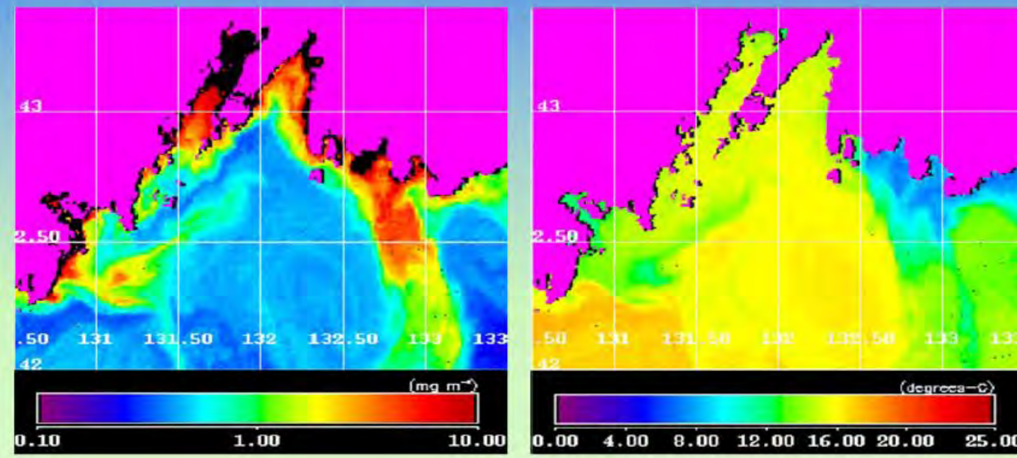
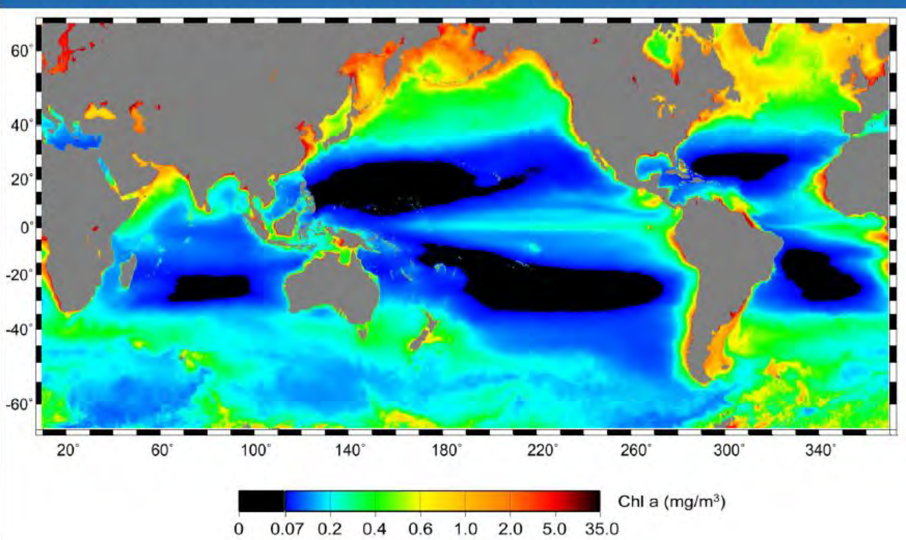


Figure 11. Chlorophyll-a and SST distribution in Peter the Great Bay at the wind upwelling on November 13, 2007.

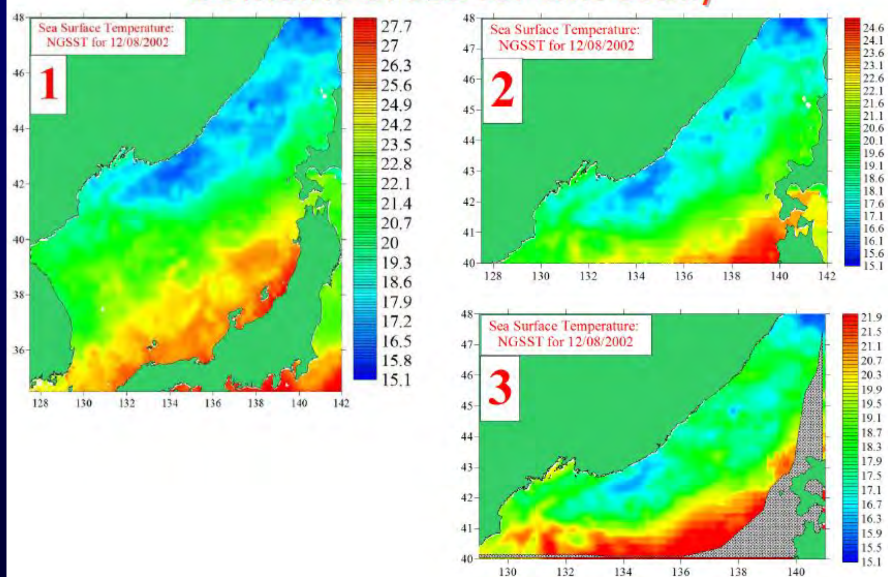
Schtraikhert et al.,Dalian 2008

SeawiFS surface chlorophyll climatology with oligotrophic gyres in black

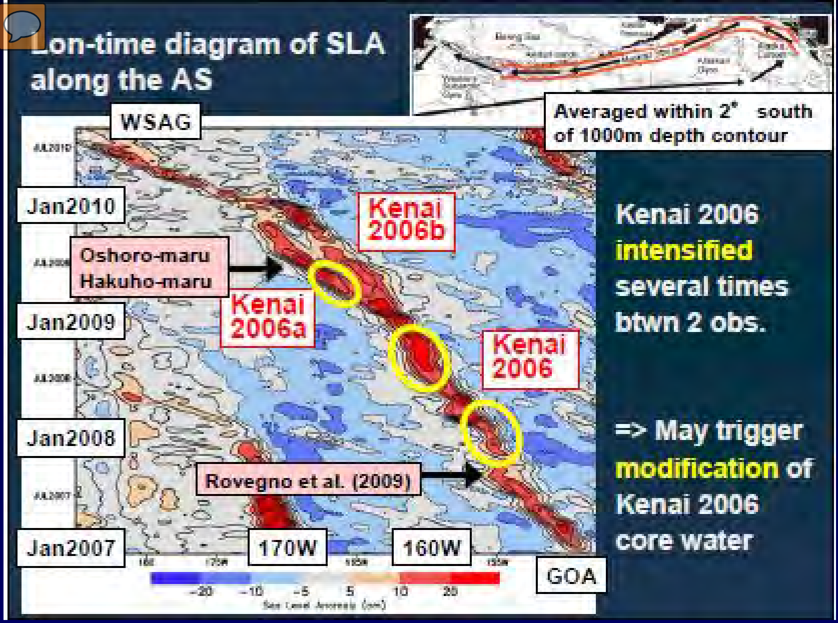


Polovina et al., Jeju 2009

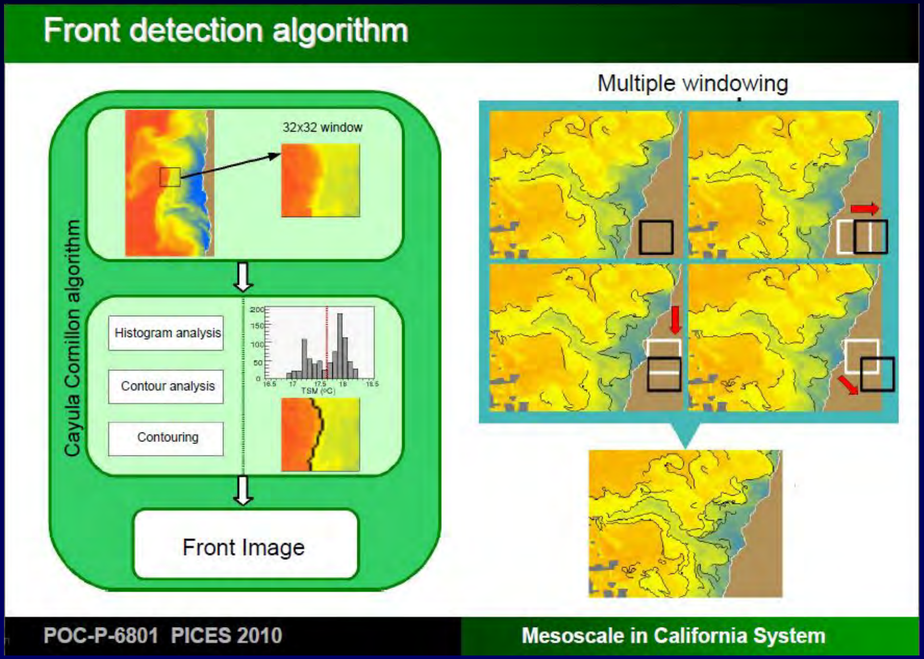
Domains of JES for this study



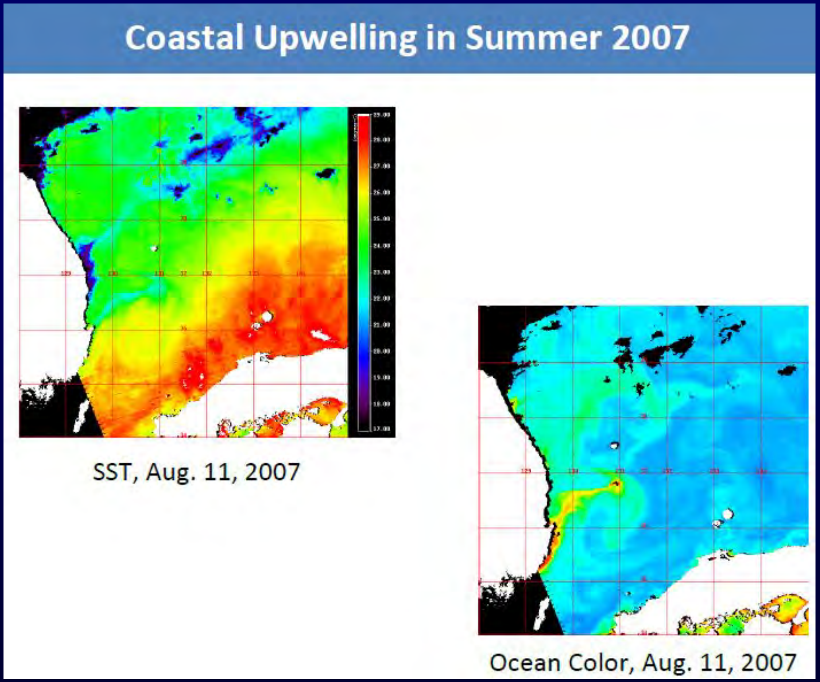
Kaplunenko et al., Jeju 2009



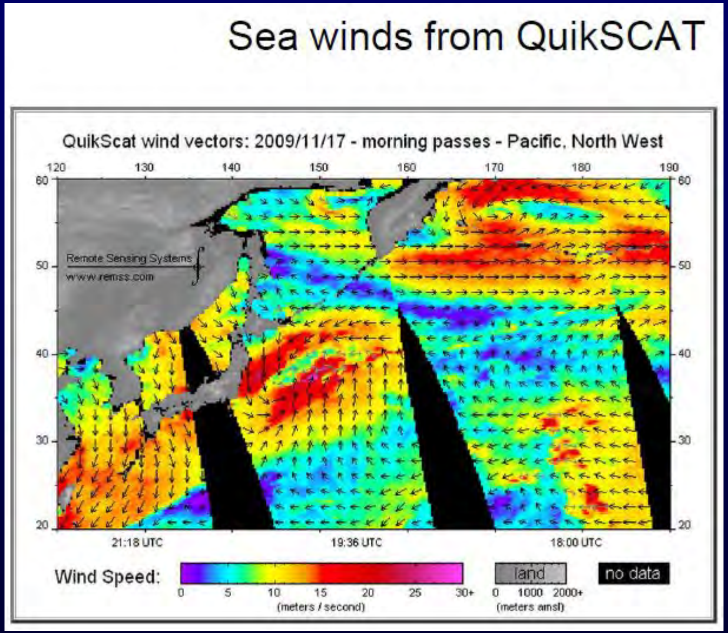
Ueno et al., Portland 2010



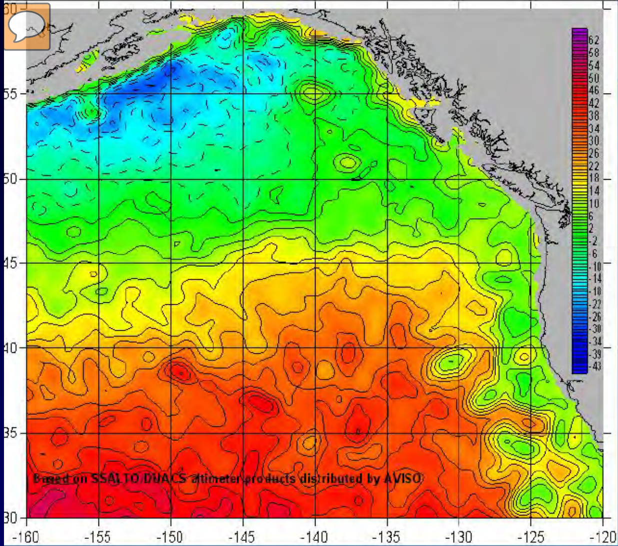
Nieto et al., Portland 2010



Park et al., Portland 2010



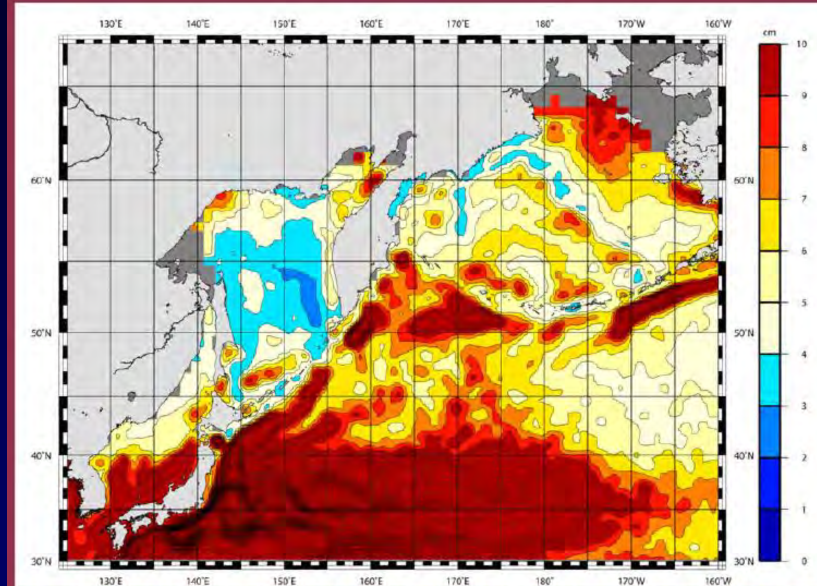
Trusenkova, Portland 2010



Observations from 1992 to present.

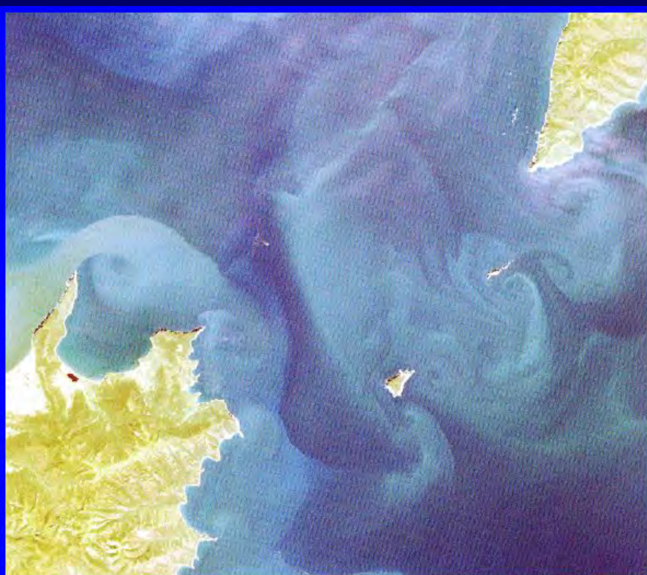
Sea level from AVISO, based on TOPEX/Poseidon, Jason-1, 2, ERS-1, 2, Envisat, GFO. Referenced to Foreman et al. (2008) average sea level.

Crawford, Portland 2010



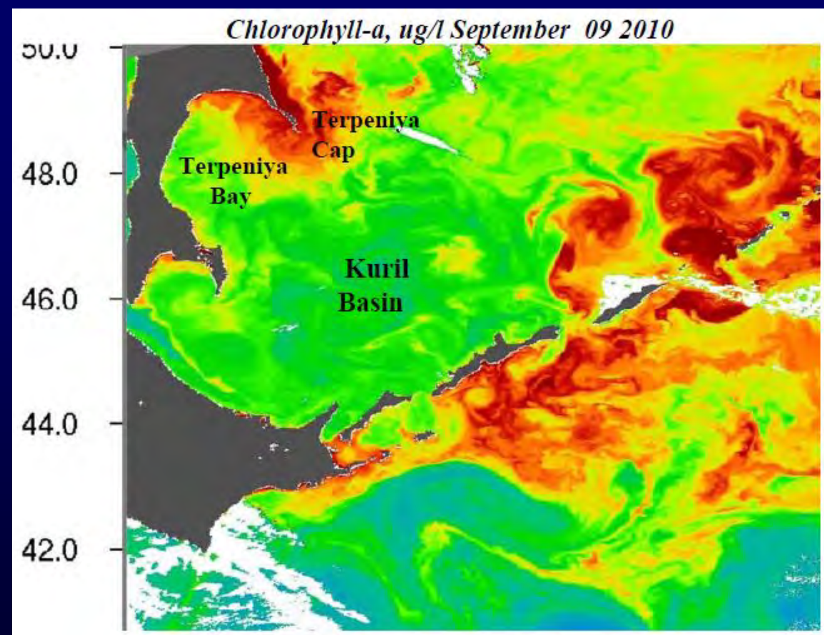
The root-mean-square deviation from the mean multiyear values of absolute dynamical sea-surface topography

Belonenko, Khabarovsk 2011

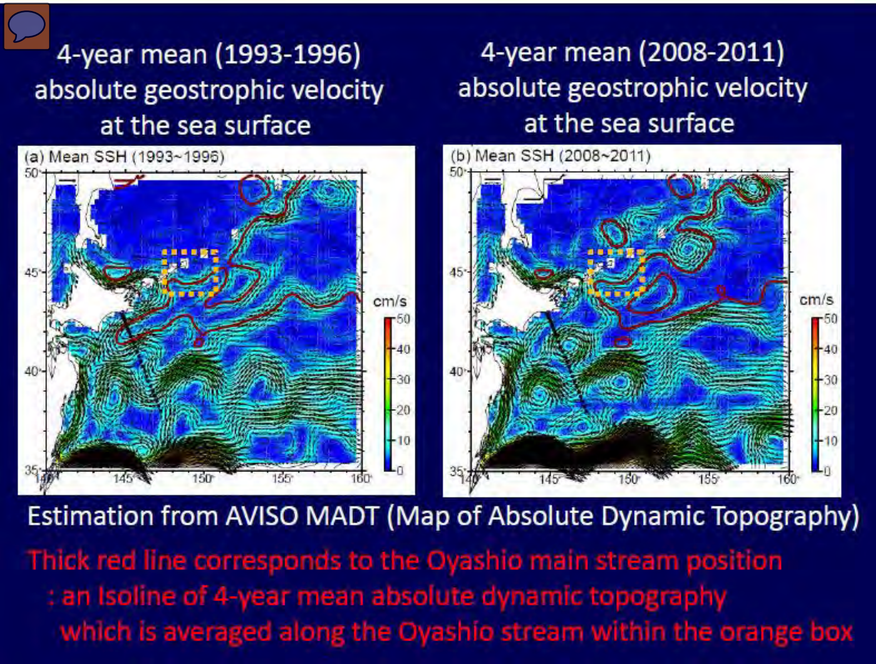


Landsat-5 TM RGB image acquired on 10 August 2010.
The headland eddy system is complicated by the presence of an islands offshore, which generates an additional island wake eddy system

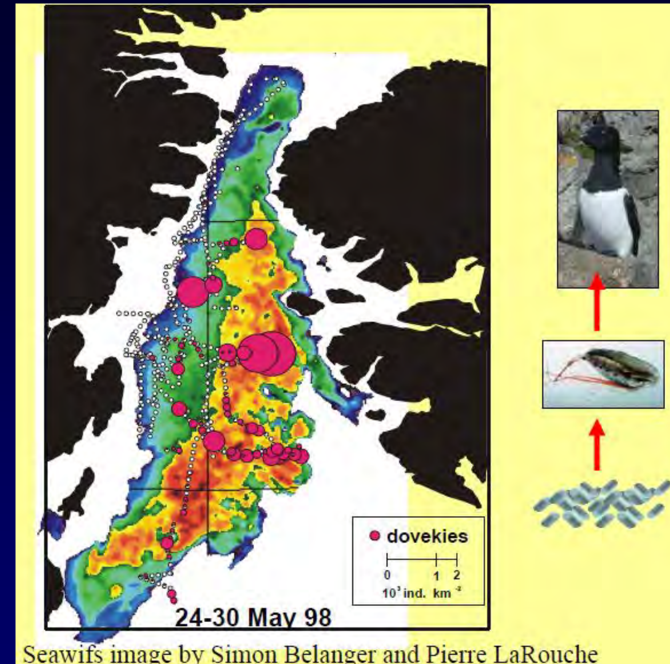
Zhabin, Khabarovsk 2011



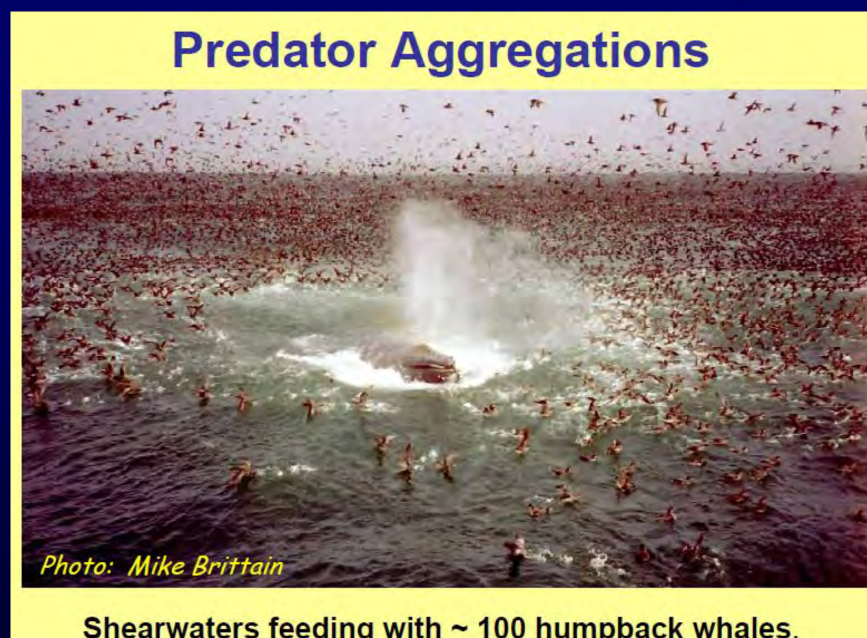
Andreev & Zhabin, Hiroshima 2012



Kuroda et al., Nanaimo 2013



Hunt, Khabarovsk 2011

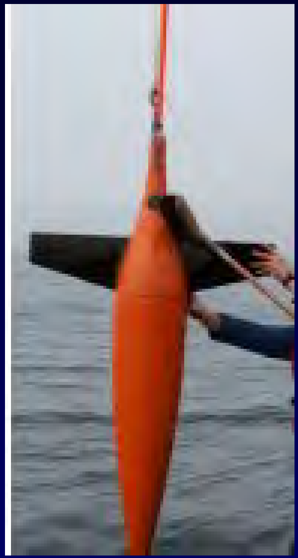


Hunt, Khabarovsk 2011

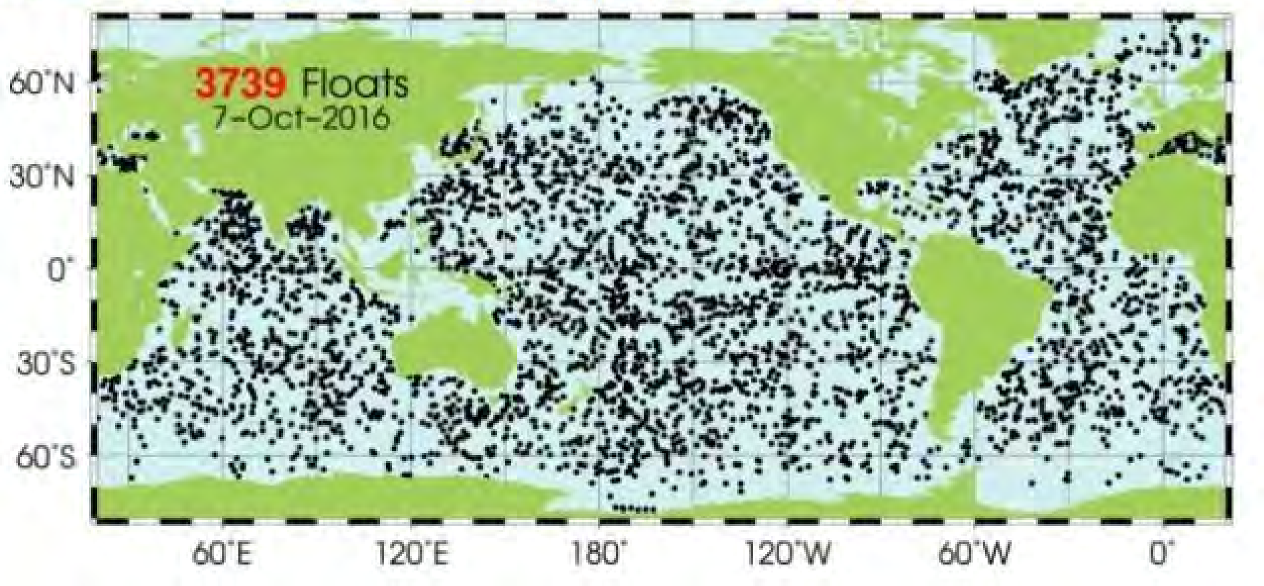
Autonomous Floats

1. *Gliders*

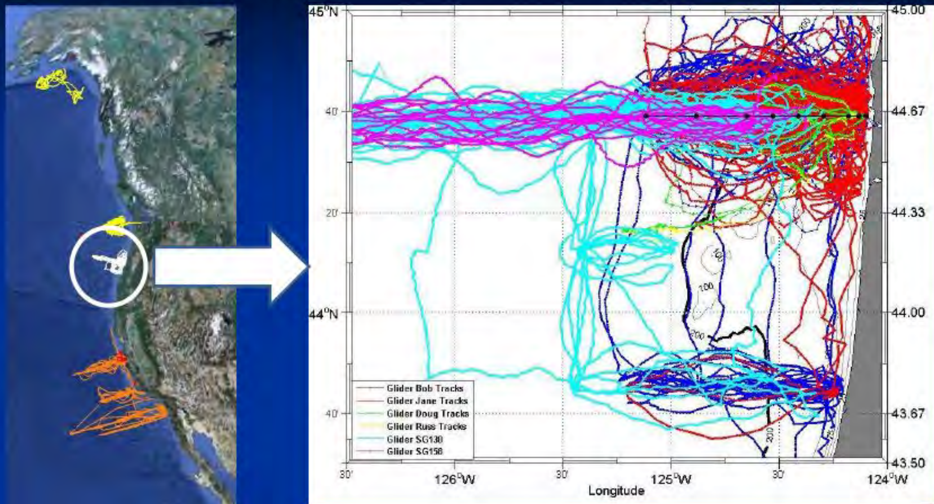
2. *Argo floats*
   - *First deployed in 2000*
   - *Millionth profile by Nov 2007*
   - *Now over 3700 floats*
   - *http://www.argo.ucsd.edu/*



University of Washington's Seaglider at the surface between dives



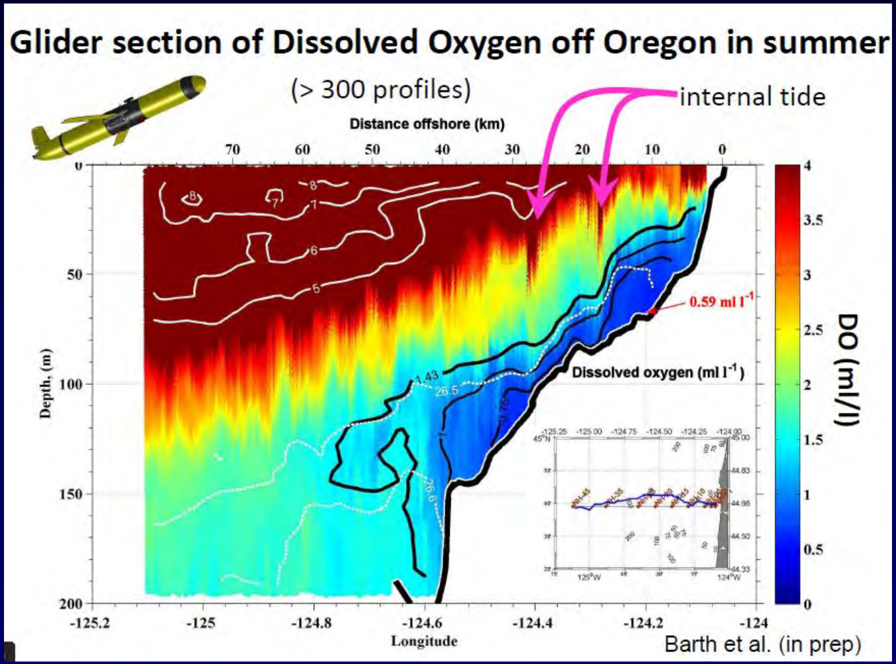
U.S. west coast glider measurements



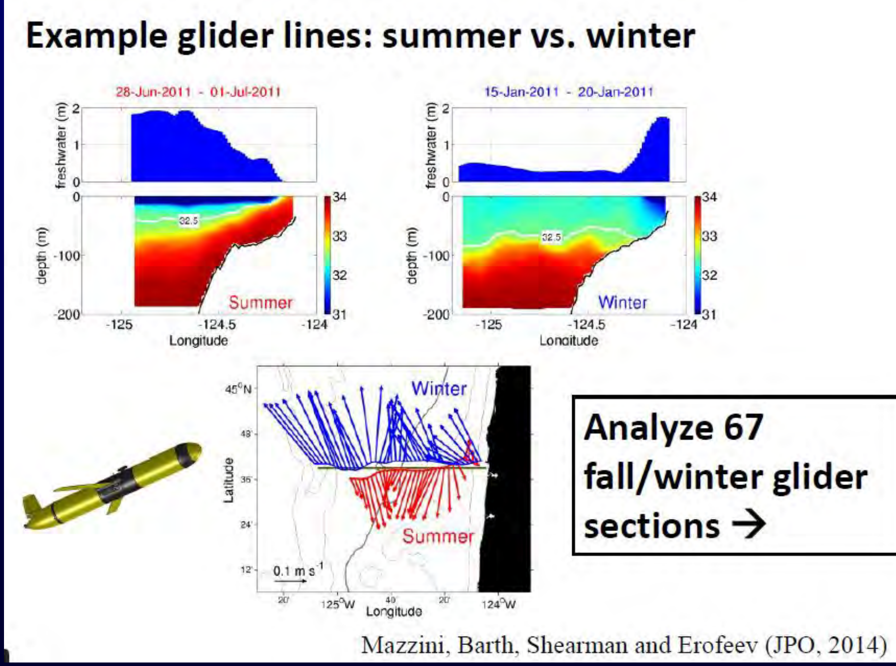
Oregon State University April 2006–Sep 2014

3485 glider-days 260,190 vertical profiles

82,000+ km



Barth et al., Yeosu 2014



S12, Nov 10, 15:00:
"The subsurface and inner-shelf structure of 25 years of variability in the Northern California Current"

The Argo Project

New observations of the physical state of the ocean and their potential application to climate
including fisheries and ecosystems impacts

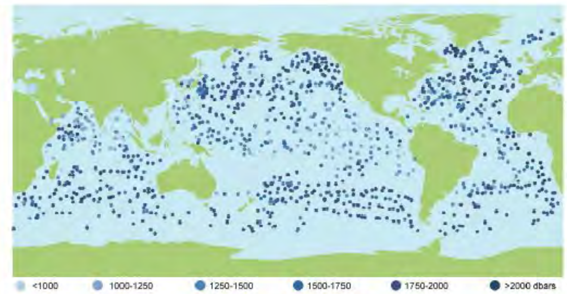
John Gould,
Argo Project Director

Dean Roemmich
Argo Steering Team Chair

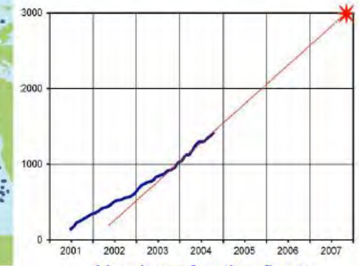
Scripps Institution of Oceanography
La Jolla , USA

The array

- Presently almost 1500 floats
- Sparse array in four oceans



Float profile depths

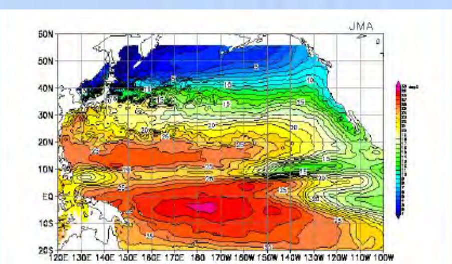


Number of active floats

- Array growth depends on
  - Number of floats deployed
  - Their survival rate
- Data are unique
  - Quasi random spatial
  - No seasonal bias
  - Deeper than XBTs + salinity

Argo data use

- Many operational centres now produce products and forecasts based on Argo data.
  - ENSO analysis and forecasts (Argo expands the area covered by the ENSO observing system)



JMA regional analysis 100m temp

Profiles 29 Sept - 8 Oct 2004 From :
• Argo • XBT • TAO array

Argo ecosystem applications

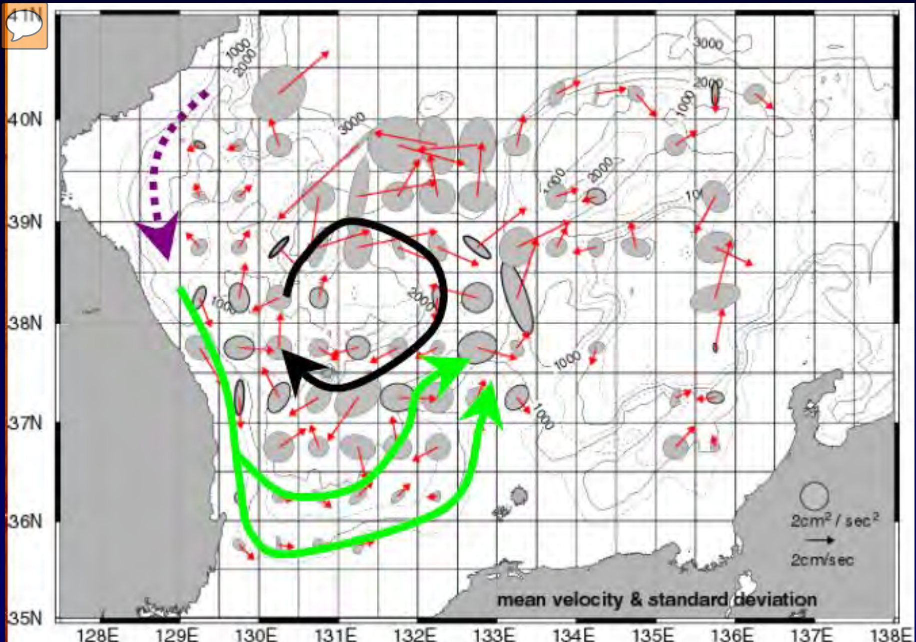
- Argo can help define the physical conditions of the open ocean (Temperature/salinity/velocity)
- The Argo array is sparse so it needs to be combined with other data to resolve frontal and mesoscale features) (e.g altimetry, infrared imagery, ocean color)
- Argo cannot provide data from continental shelves (Models are needed to link open ocean to shelf. Gliders may help with observations)

The future

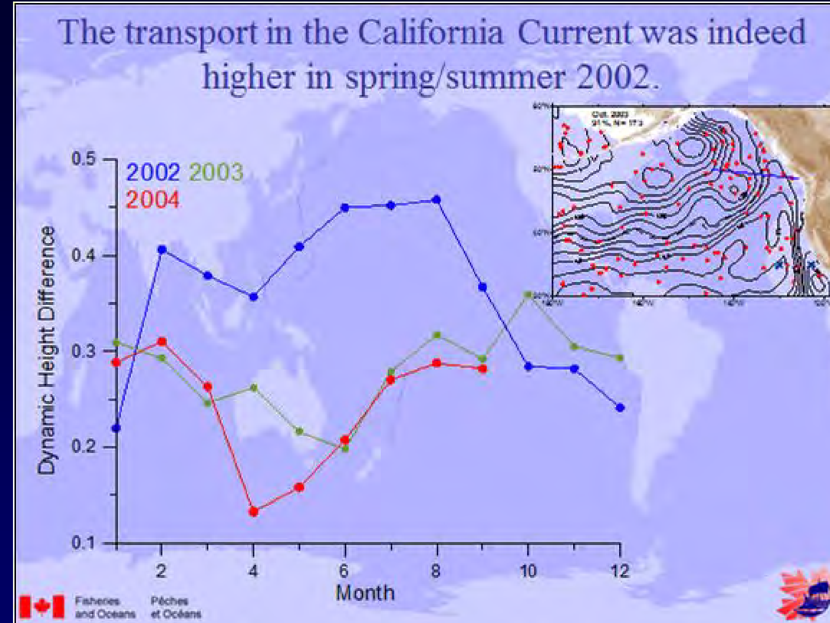
- Routine products based on Argo data
- Learn how to use these novel data
- New sensors - Now dissolved oxygen, shear, microstructure
  - In future nutrients, fluorometers, rain and wind, + +

  Develop new technologies in parallel with Argo
- Better communication (cleaner data, more points per profile)
- Argo still needs ship-based CTD data to update climatologies
- How to sustain Argo in the long term?
  Operational - but still needs strong research involvement - partnership.

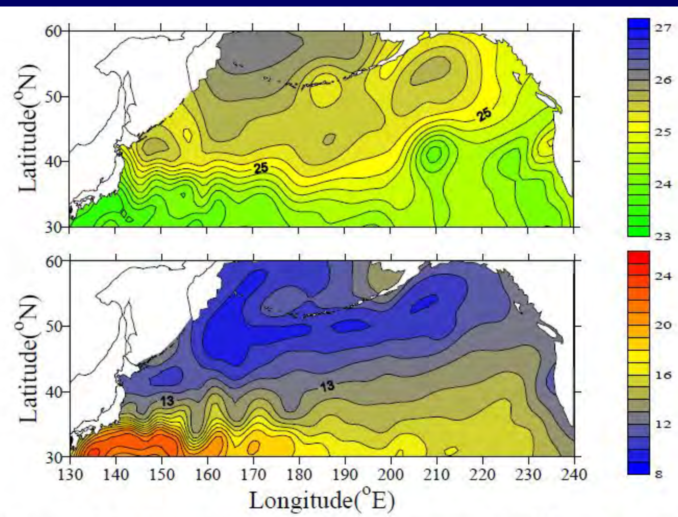
Honolulu 2004



Park et al., Seoul 2003



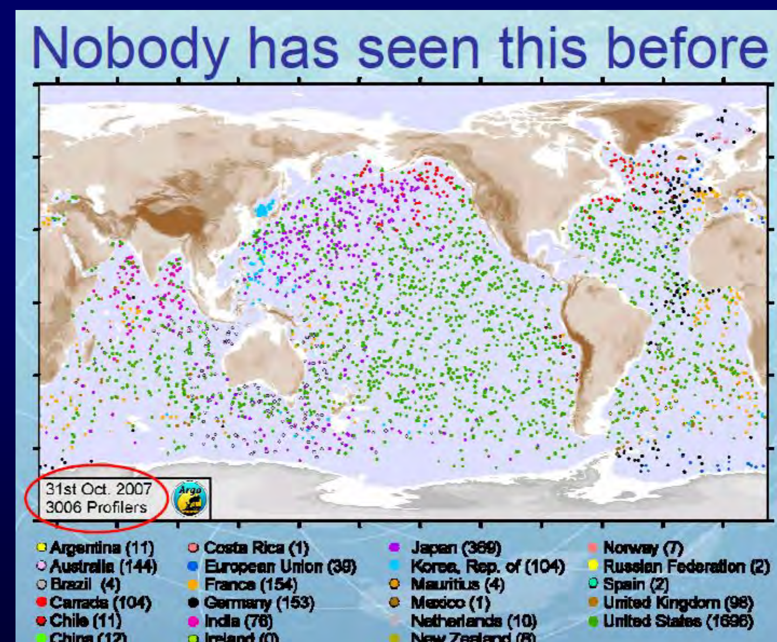
Freeland & Cummins, Honolulu 2004



e.g (top) potential density and (bottom)geopotential anomaly(m^2/s^2) on 20db in Nov-Dec 200

The data(1°×1°) of every 20db was made between 20db and 1000db.

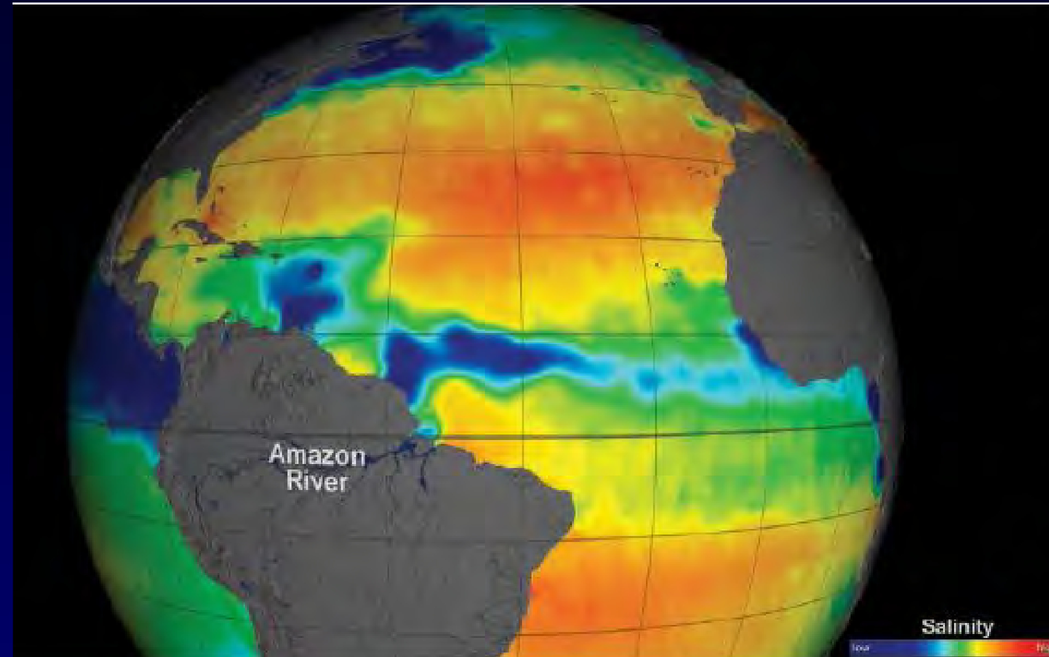
Sato & Kono, Yokohama 2006



Freeland et al., Victoria 2007

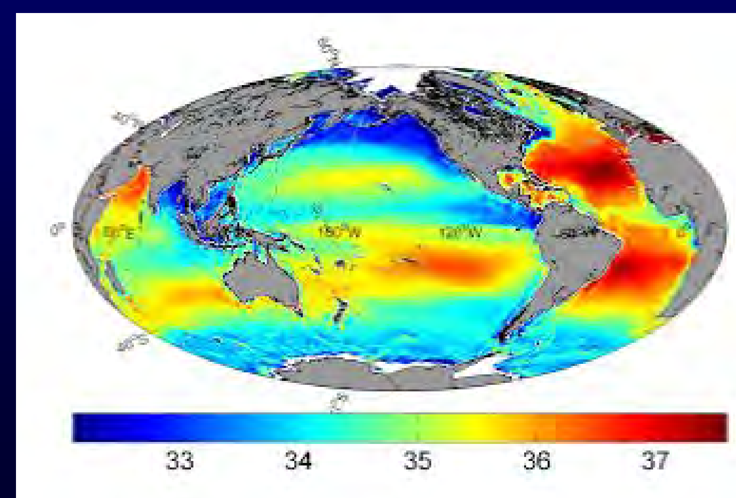
What Lies Ahead

1. Sea Surface Salinity Observations



Data from NASA's Aquarius instrument reveal seasonal changes in the Amazon River's plume. (This map shows conditions on 27 February 2013. Red indicates high salinity, and blue indicates low salinity.) Depending on the prevailing currents, the river's freshwater outflow heads east toward Africa or bends north toward the Caribbean. Salinity variations are one of the main drivers of ocean circulation.

- NASA Aquarius image, Stammer, EOS, June 15, 2016
  - ceased operation June 2015
  - http://aquarius.nasa.gov
- But European Space Agency's Soil Moisture and Ocean Salinity (SMOS) spacecraft continues
  - http://bit.ly/SMOS-spacecraft



2. SWOT Altimetry

- *Surface Water and Ocean Topography mission (NASA/CNES/CSA)*
- *Planned launch in 2020*
- *10 times resolution of present technology*
  - *120km swath*
  - *Resolve 100m rivers & 1km^2 lakes*
  - *Coverage twice every 21 days*
- *https://swot.jpl.nasa.gov/mission/ & http://ctoh.legos.obs-mip.fr/products/altimetry/future-missions/swot*

3. Continuing Bigger & Faster Computers

- New architectures for computing & storage
- Models will continue to
  i. refine their spatial resolution
  ii. simulate for longer time periods
  iii. Compute ensembles over larger sets
  iv. Increase their complexity in terms of
     i. incorporating more biogeochemistry + physics + human factors (e.g., end-to-end)
     ii. including more subgrid-scale processes

Summary

1. POC research has benefited from many technological advances over the past 25 years

2. Focused on those arising from
   a) Bigger & faster computers (better models)
   b) Satellites (SST, Chlorophyll, SSH)
   c) Autonomous platforms (Argo floats, gliders)

   But of course, there are others

3. Examples from past POC-Paper & POC co-sponsored presentations

4. Some thoughts on what lies ahead

The next 25 years will interesting!

Earth Simulator

Acknowledgements

1. PICES Secretariat (Julia) for archiving presentations from previous annual meetings

2. All presenters who allowed their talks to be posted for me to use
   - Hopefully I didn't misrepresent your work!

3. And to everyone who has contributed to POC over these 25 years.


Thanks for your attention!