Carbon Hot Spot

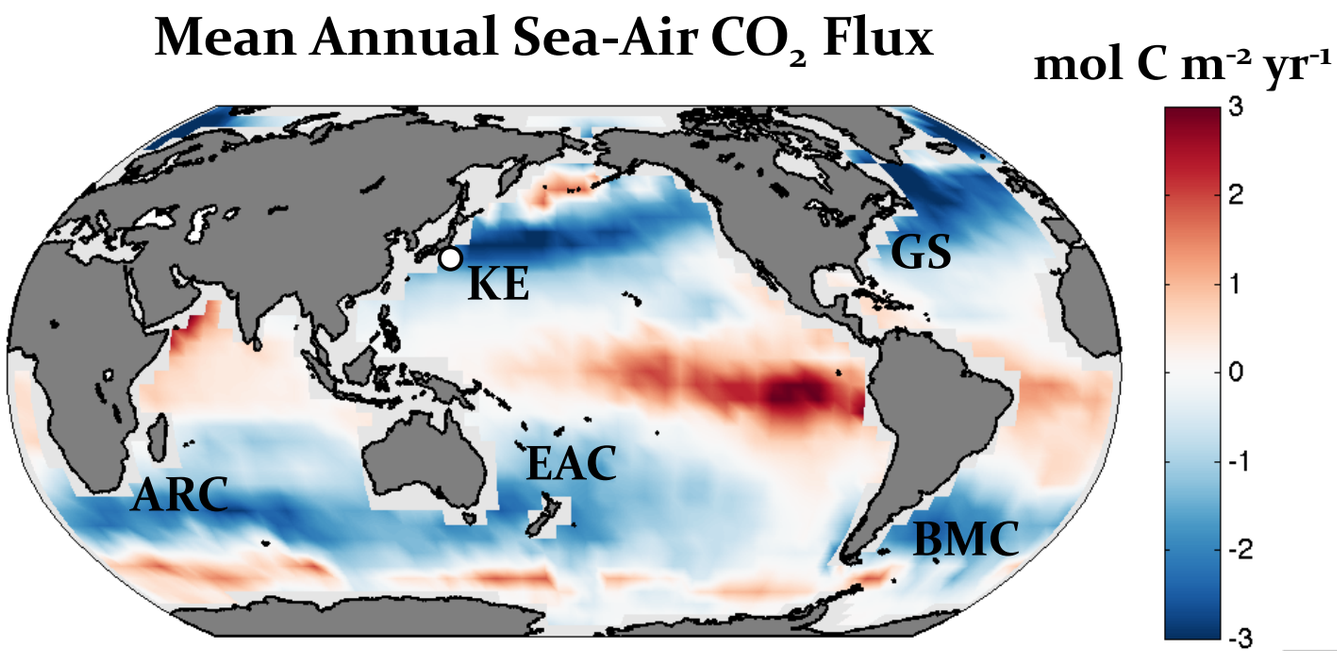
Andrea Fassbender (MBARI) & Stuart Bishop (NCSU)

PSMI Webinar

February 22, 2017

Image: PMEL OCS

Motivation: Global Patterns of Ocean Carbon Uptake and Physics



after Takahashi et al., 2002, 2009

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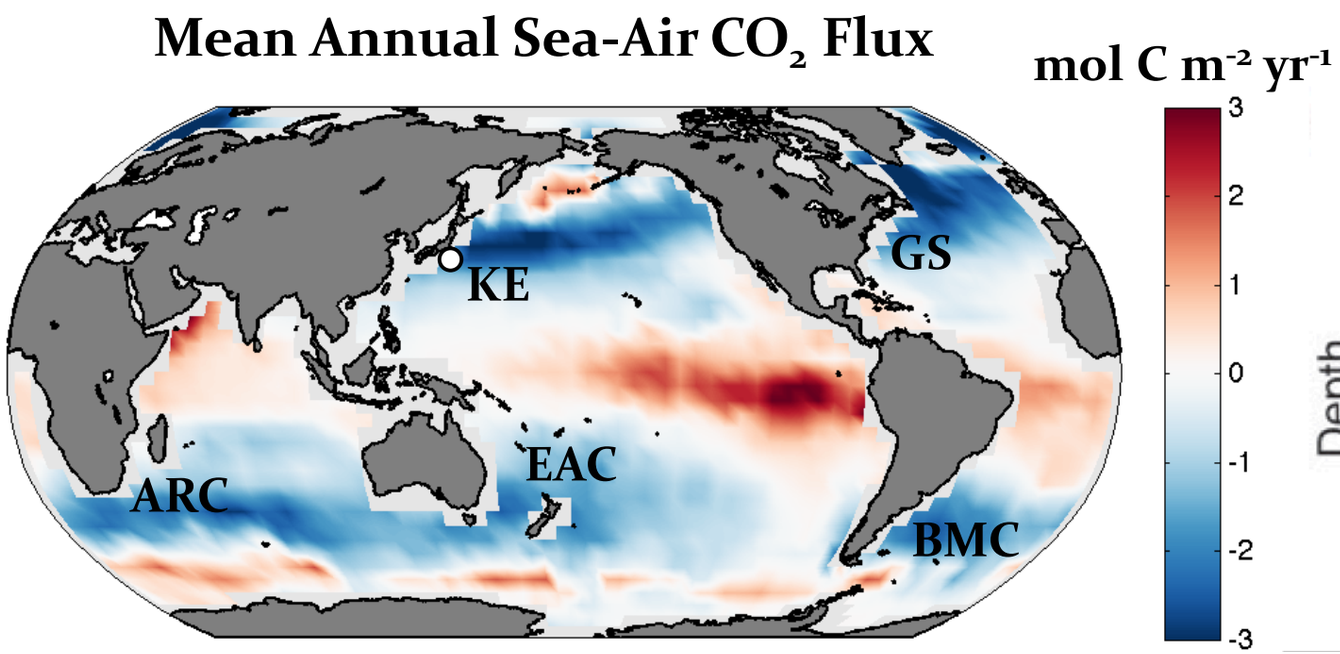

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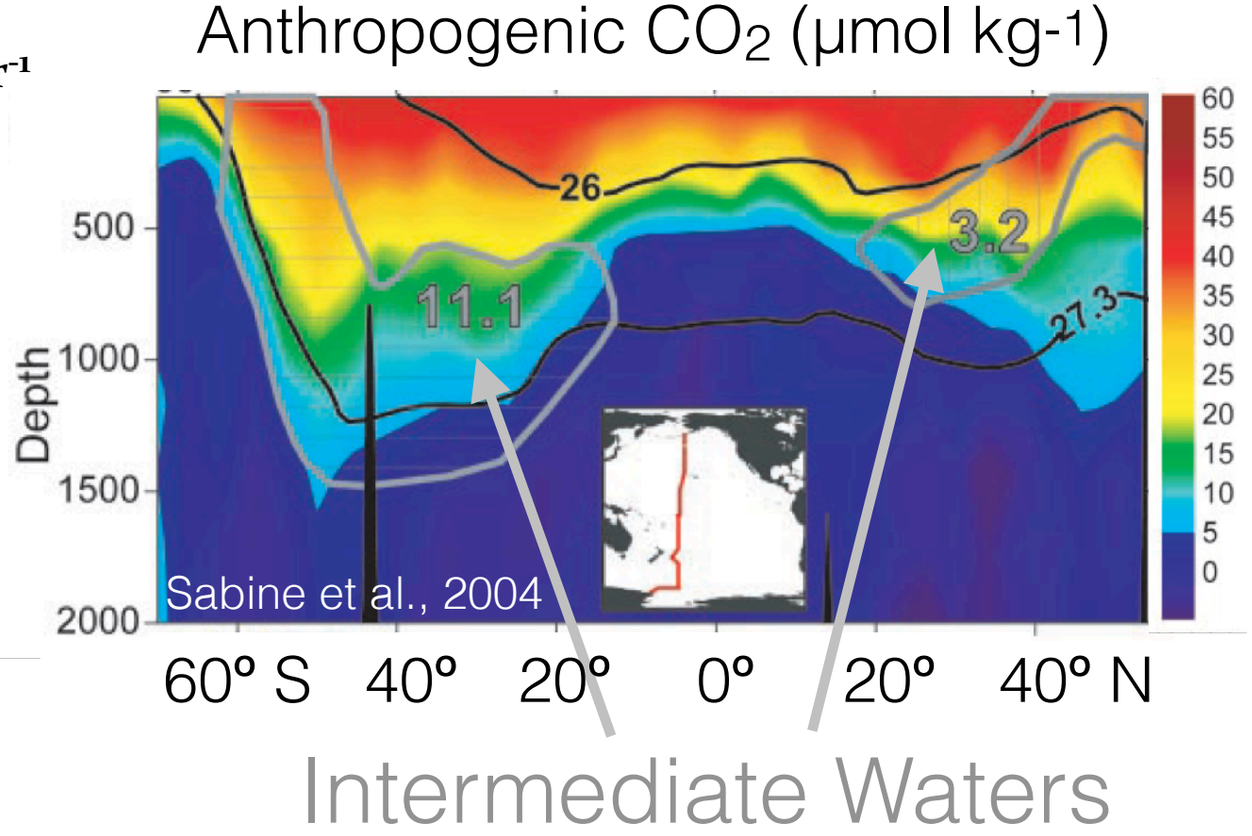

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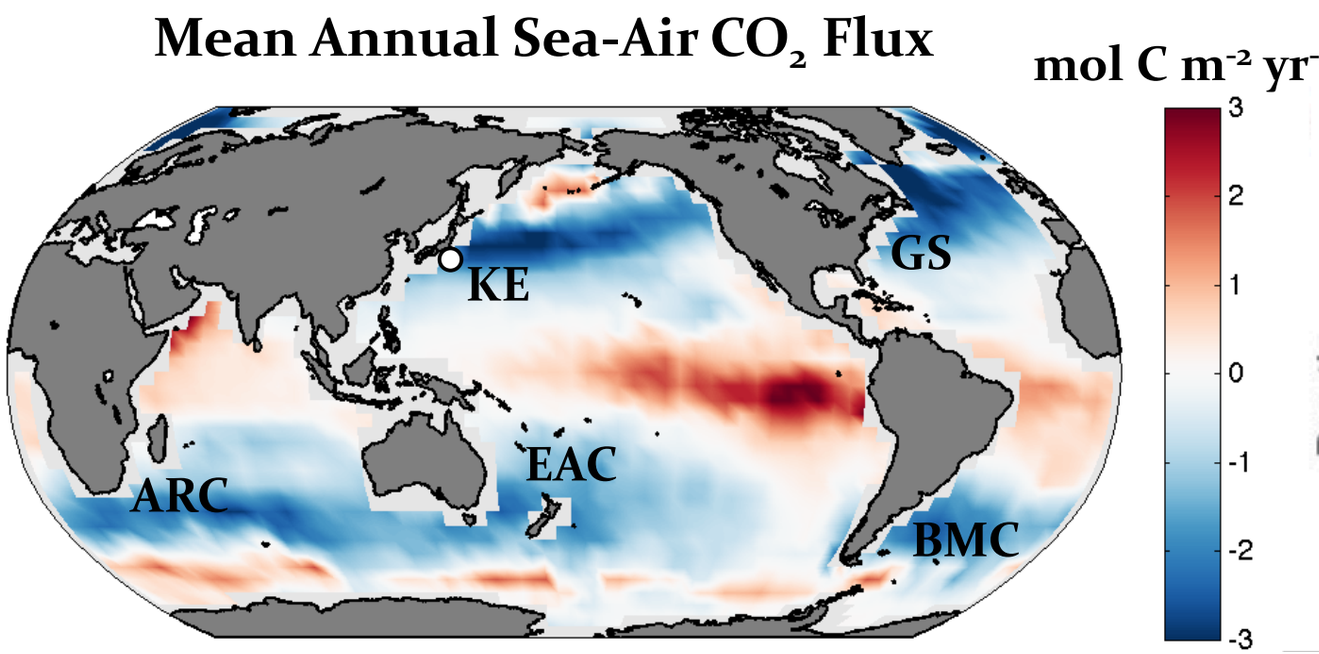

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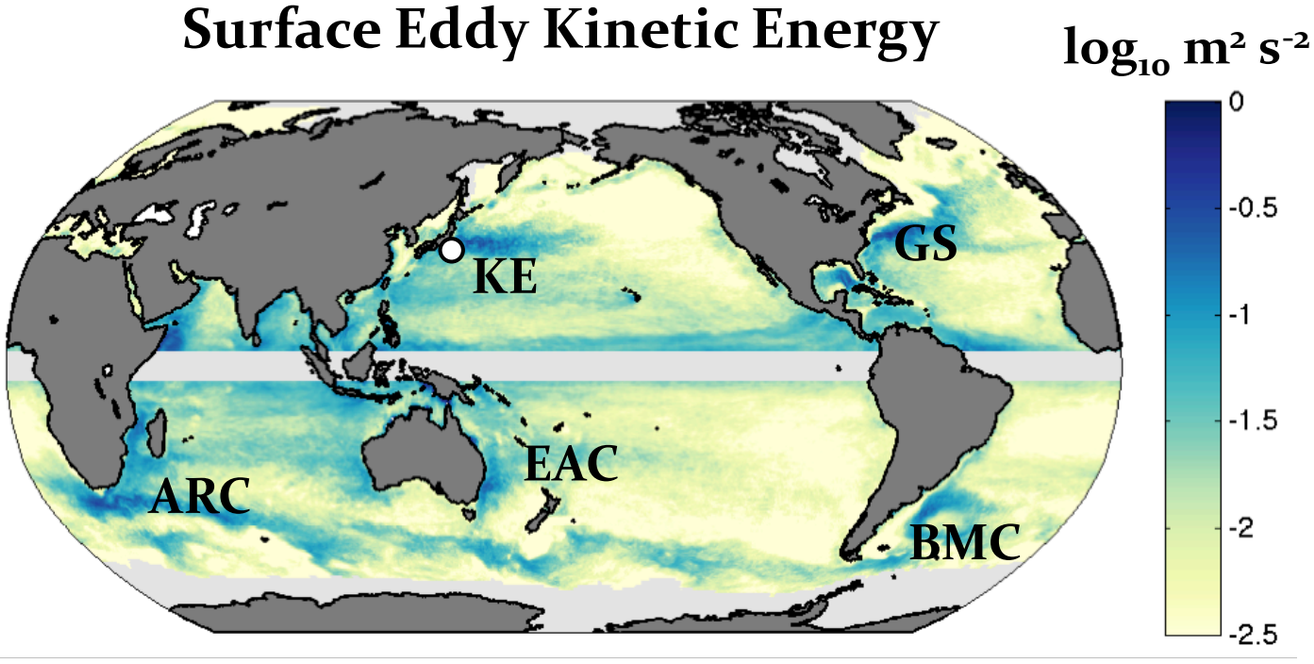
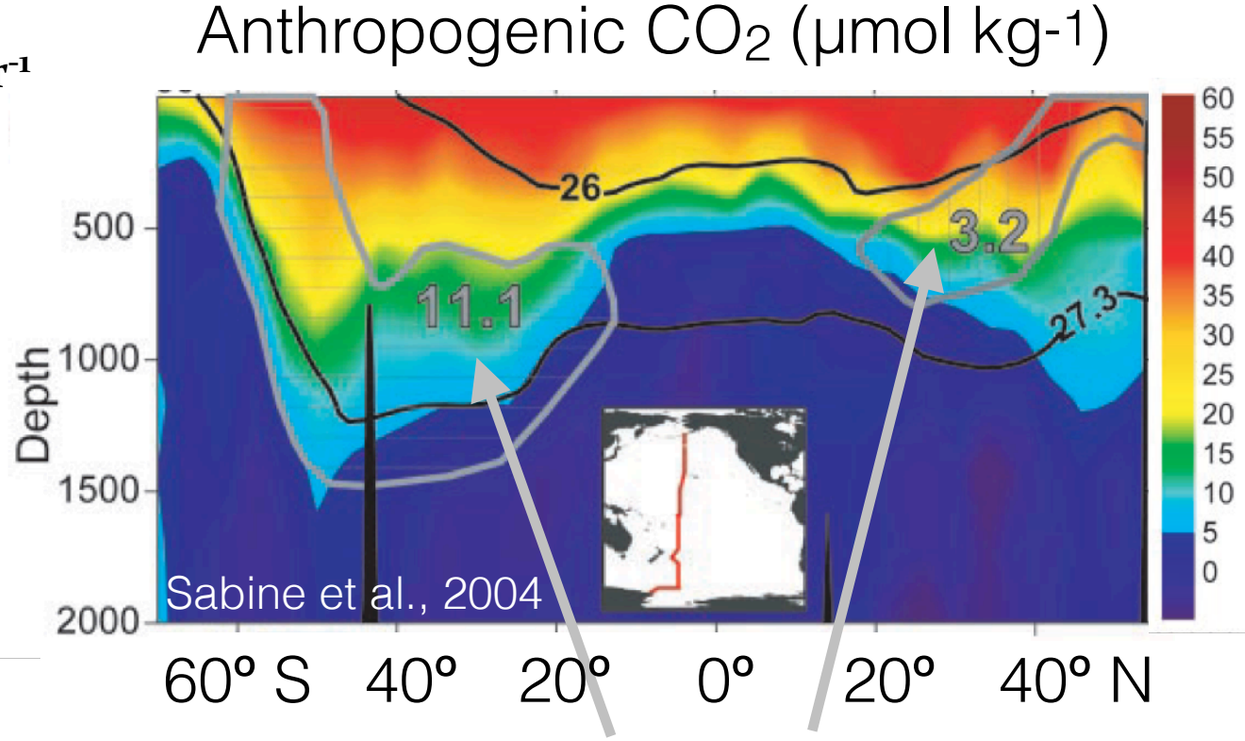


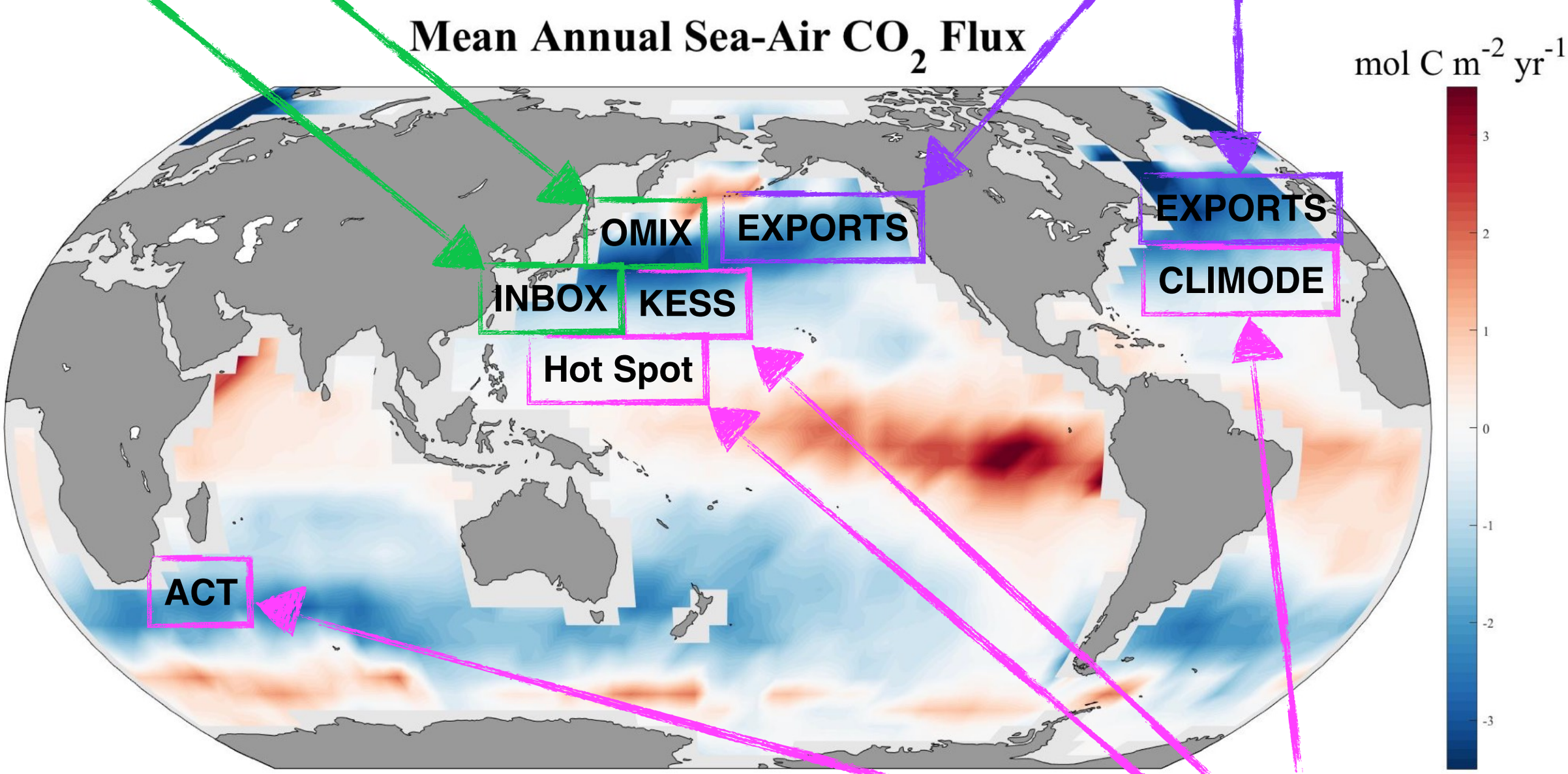


High eddy activity in all mode and intermediate water formation regions.

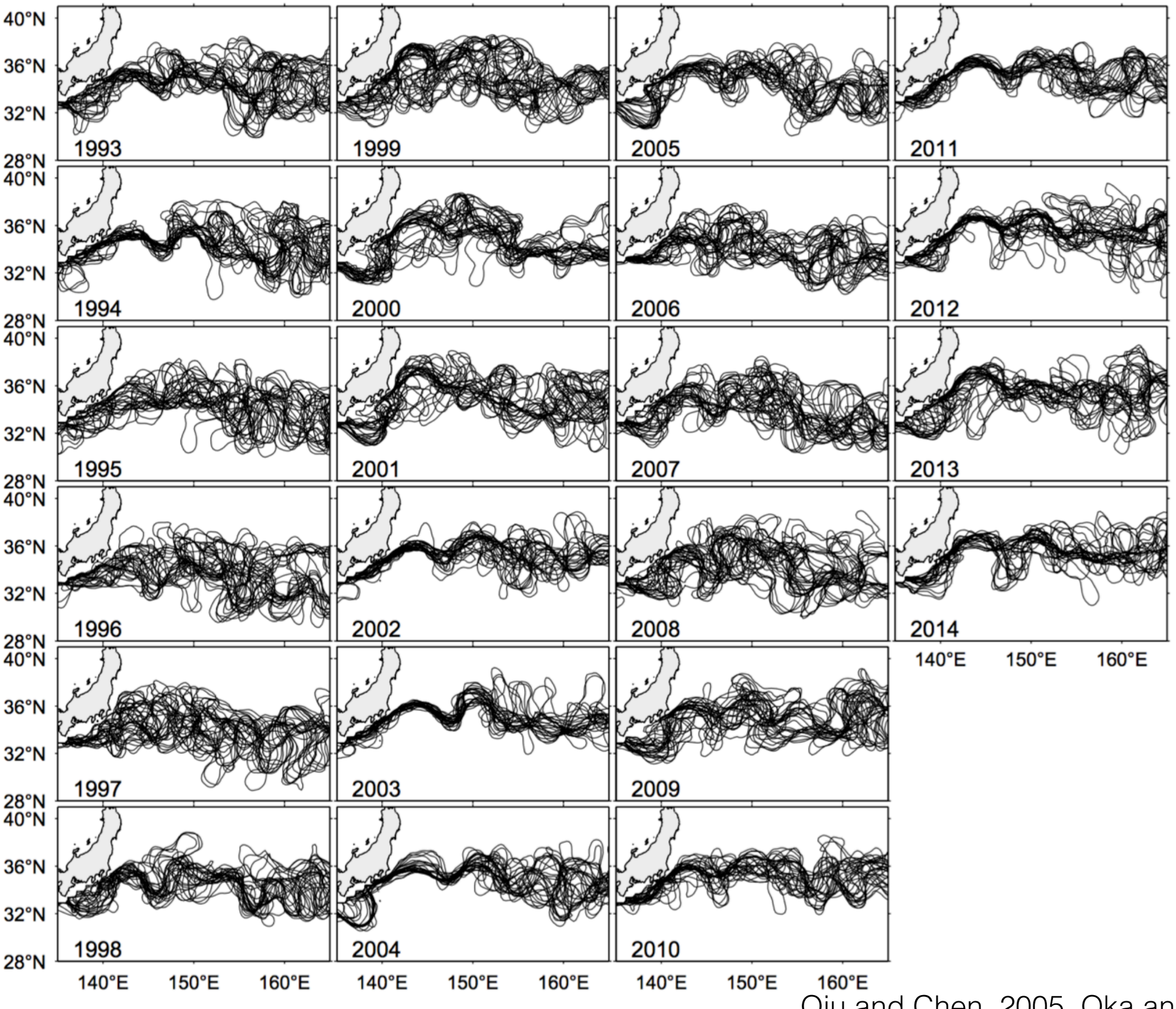
Motivation: Prior WBC Work has Not Targeted Carbon Uptake

Biogeochemistry, Ecosystems, and Mixing

Satellite-Based Carbon Export

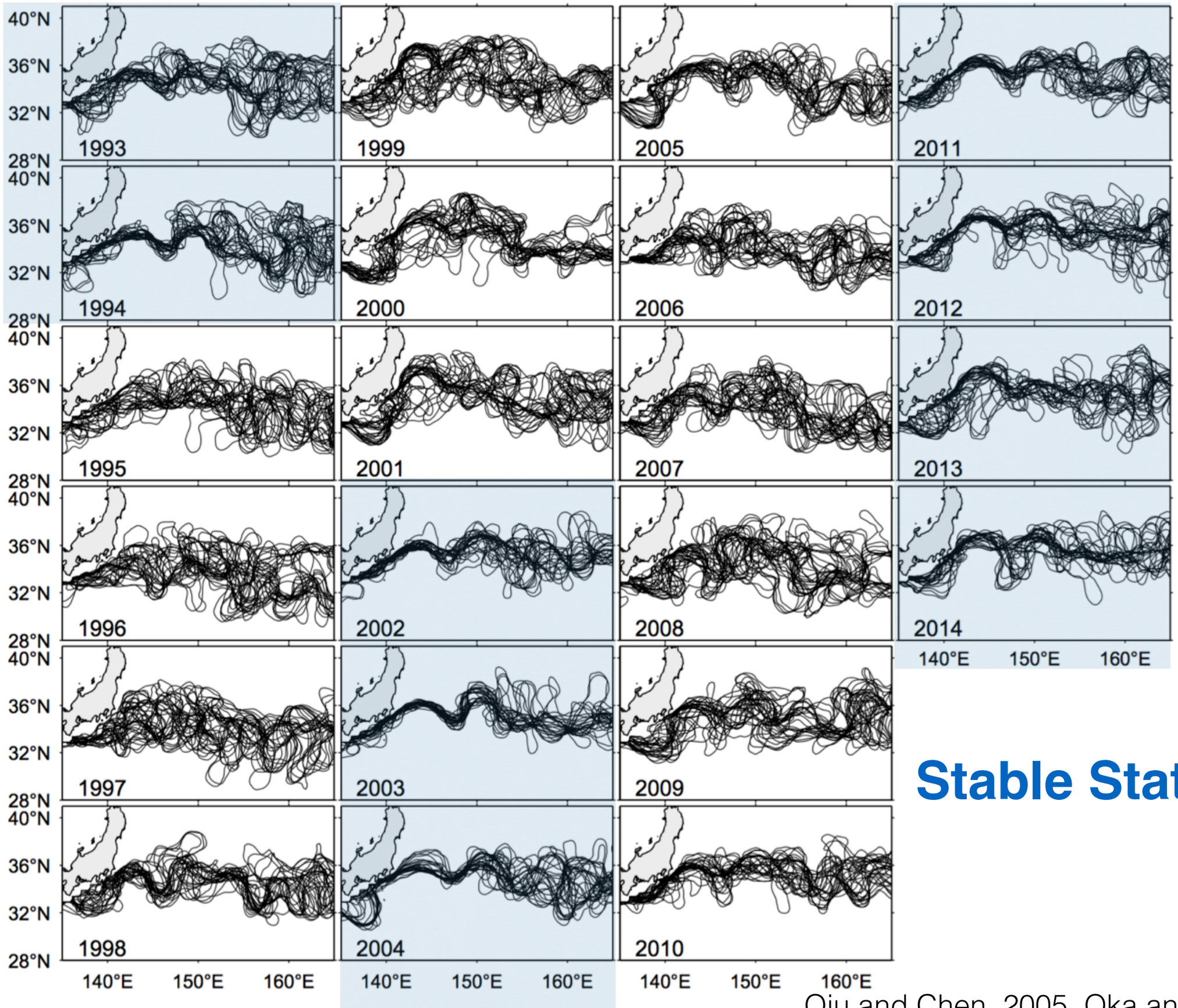


Dynamic States of the Kuroshio Extension



Qiu and Chen, 2005, Oka and Qiu 2015

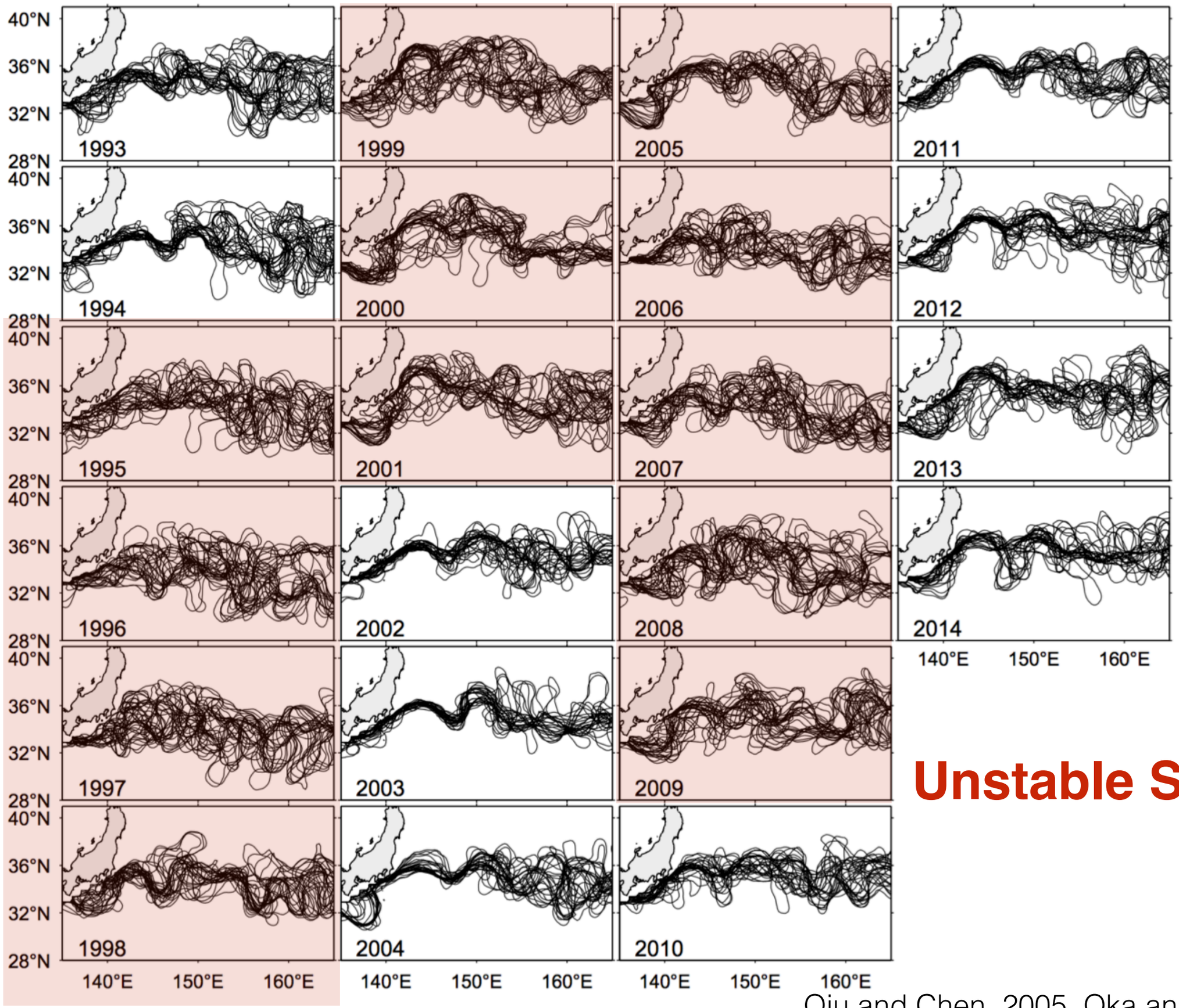
Dynamic States of the Kuroshio Extension



Stable States

Qiu and Chen, 2005, Oka and Qiu 2015

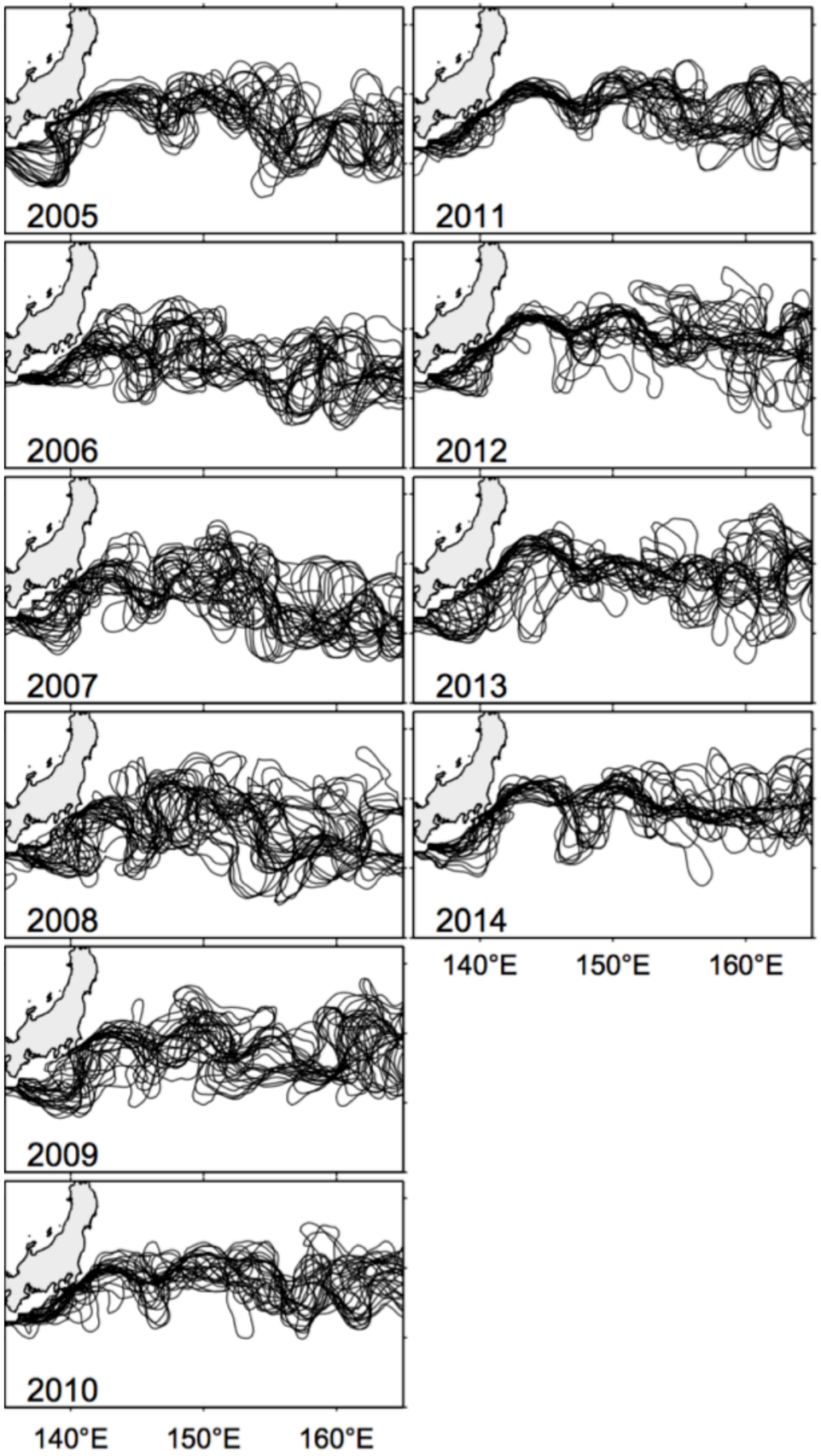
Dynamic States of the Kuroshio Extension

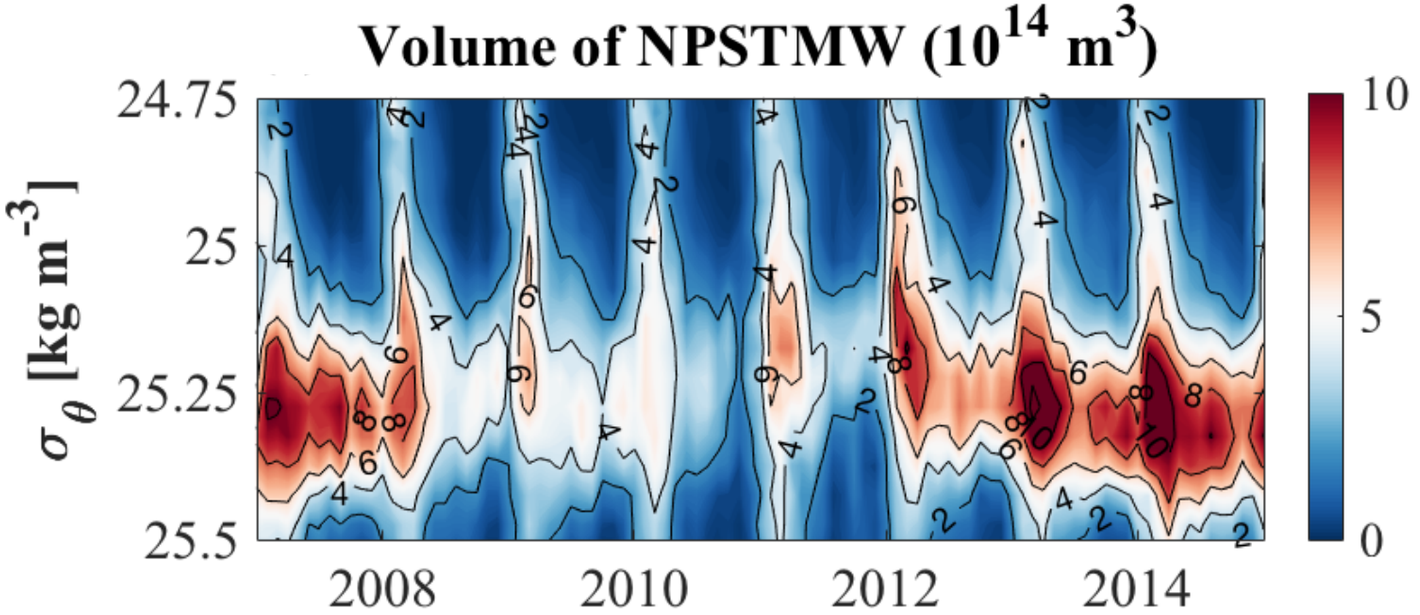


Unstable States

Qiu and Chen, 2005, Oka and Qiu 2015

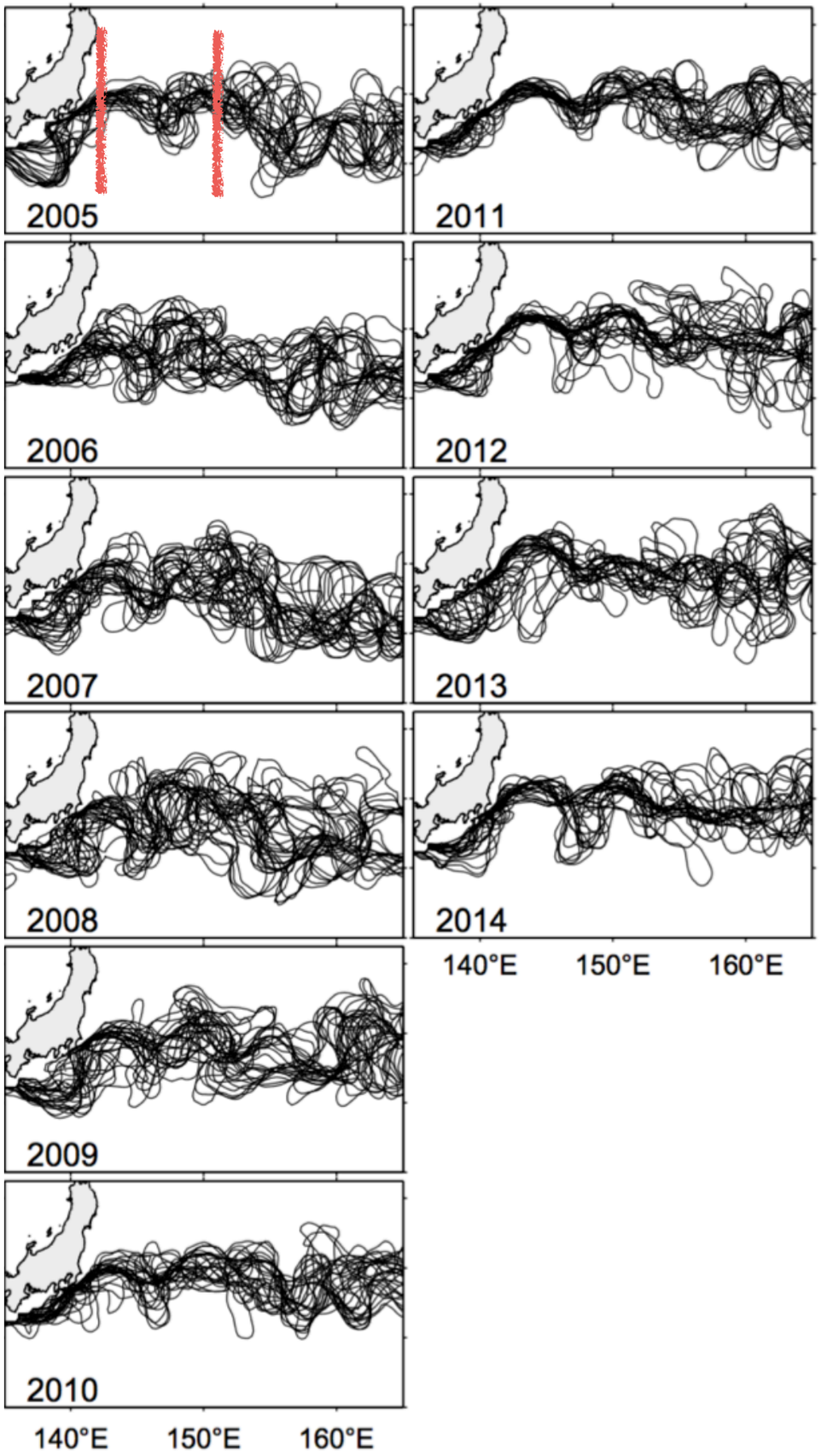
Meandering States and Volume of STMW

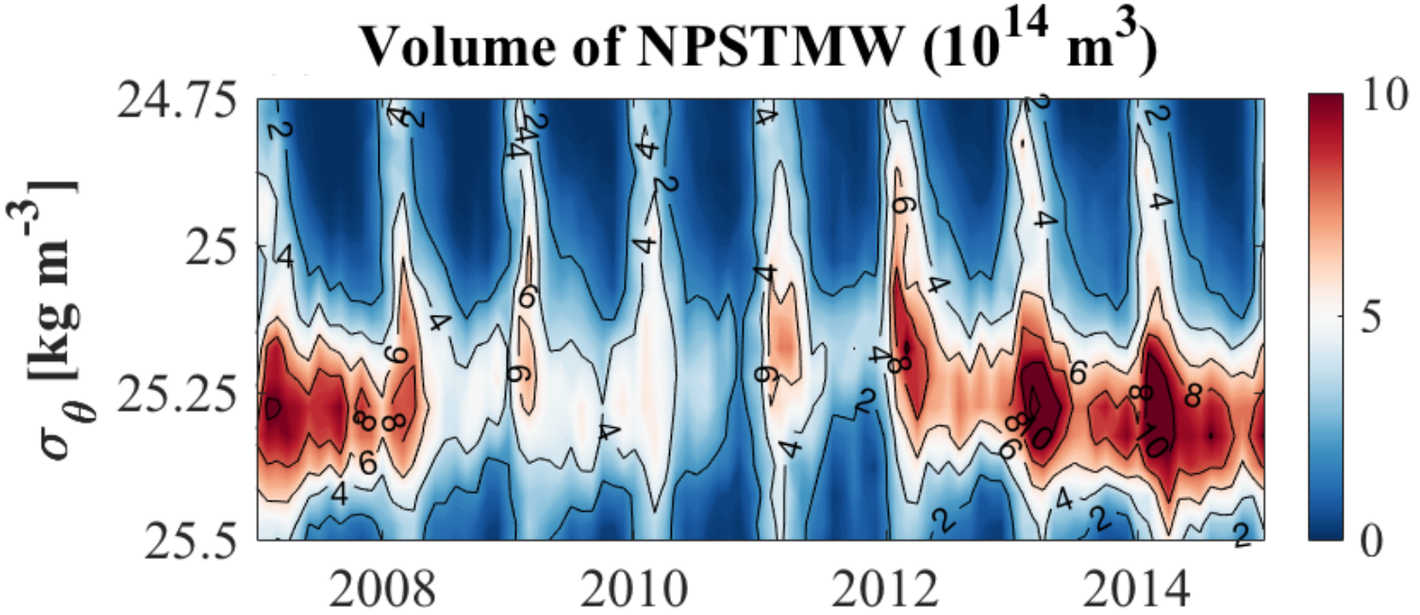




after Cerovečki & Giglio, 2016

Meandering States and Volume of STMW





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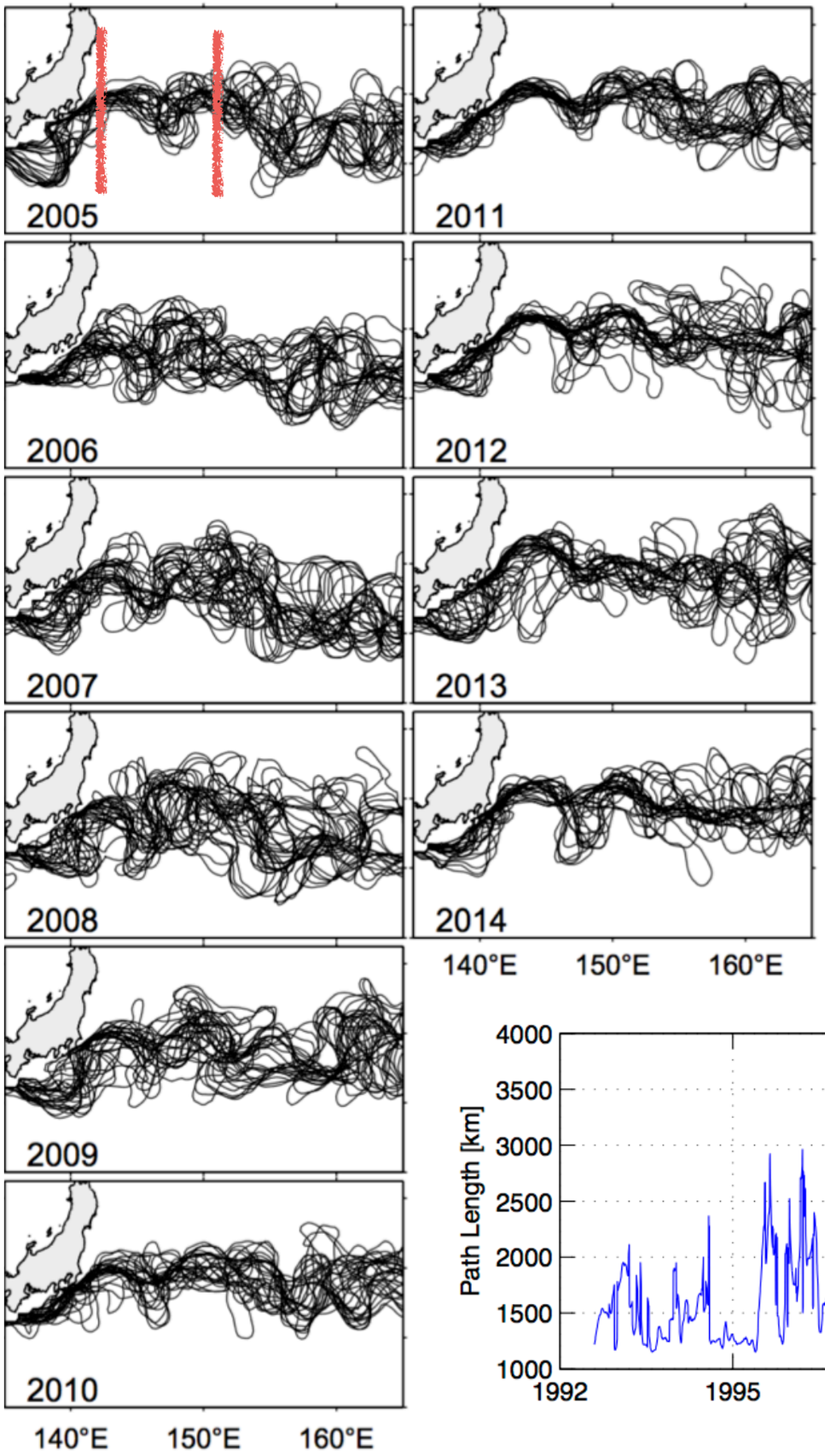
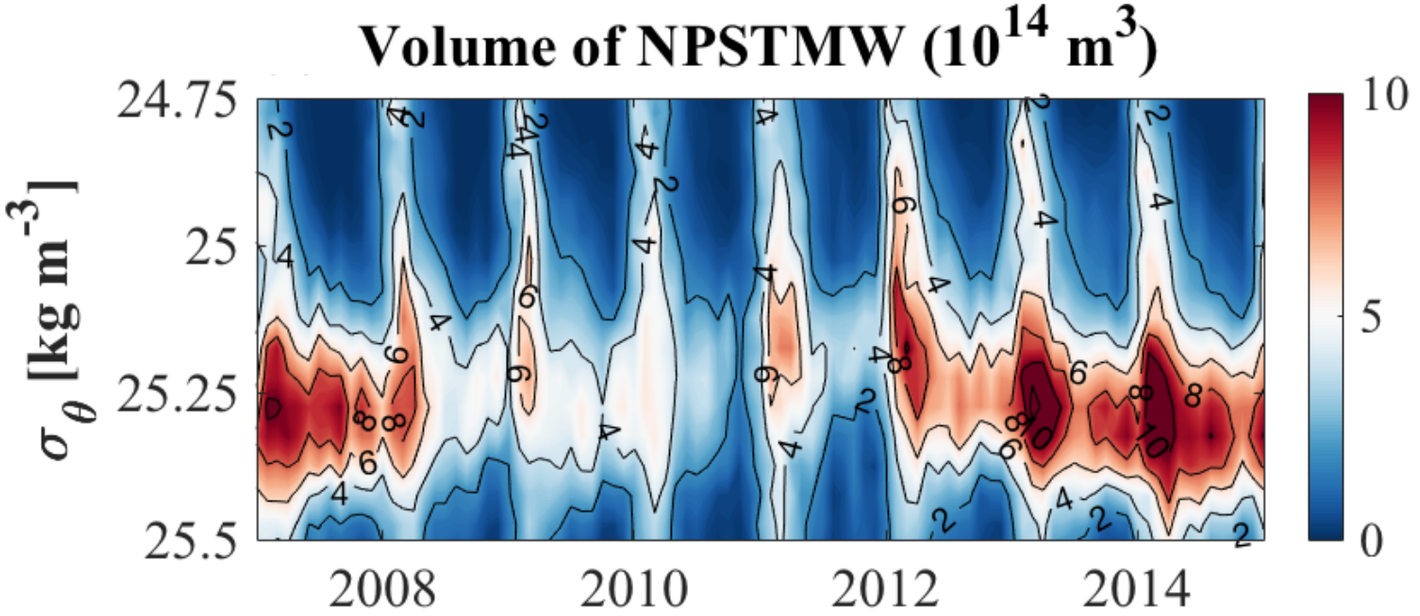
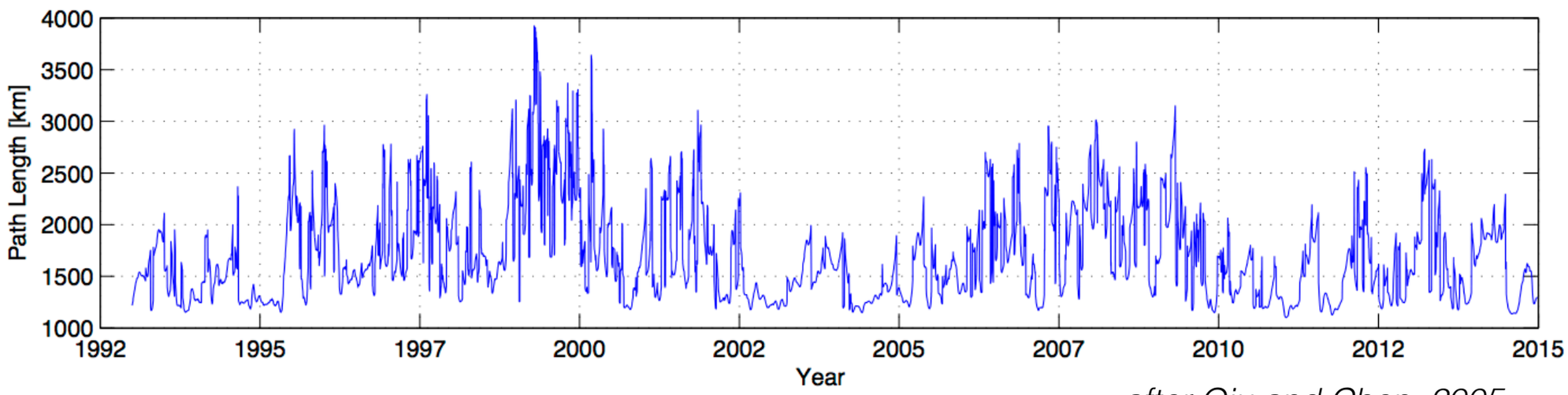




after Cerovečki & Giglio, 2016

Longer path = more eddies
Shorter path = less eddies



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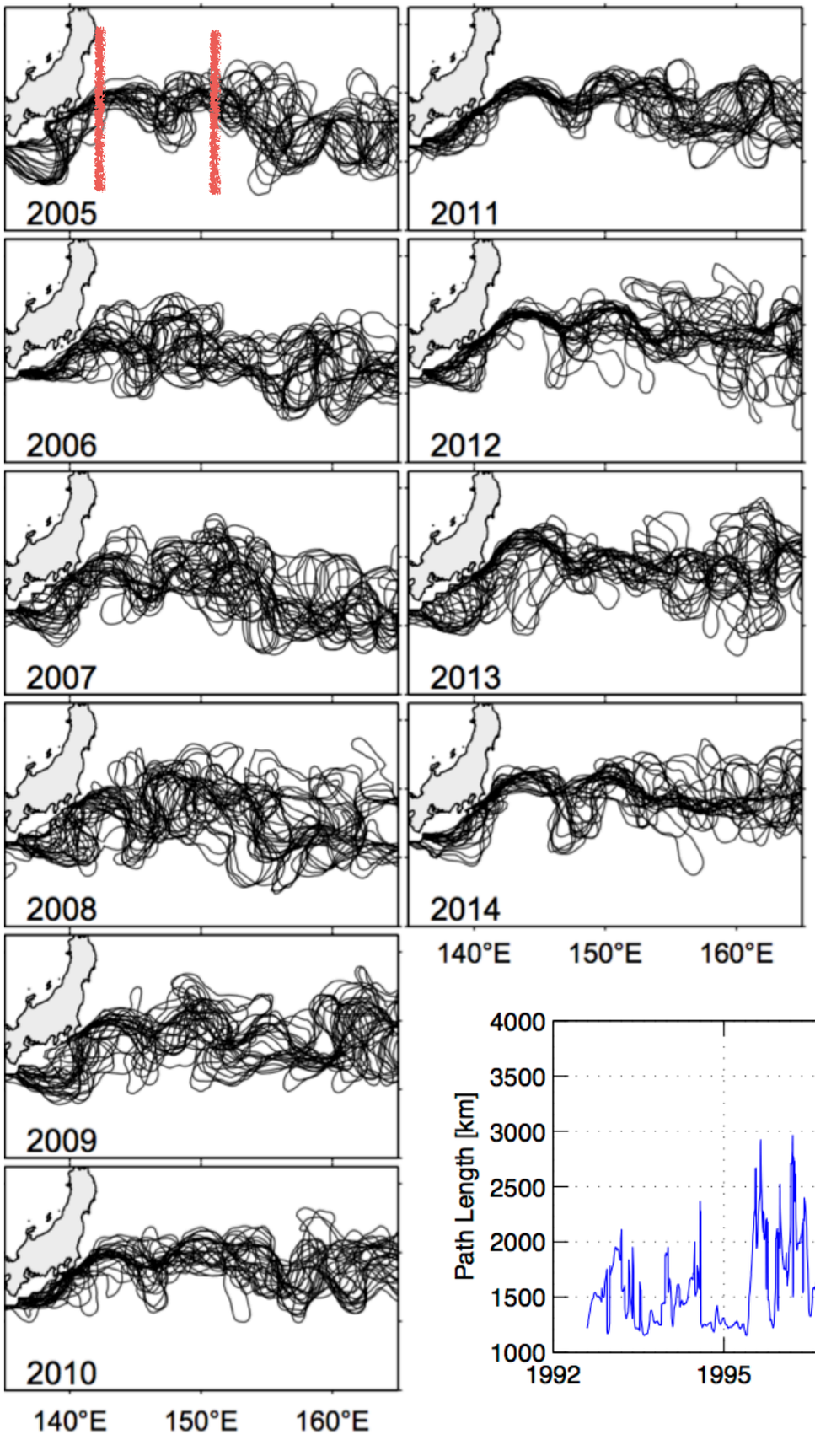
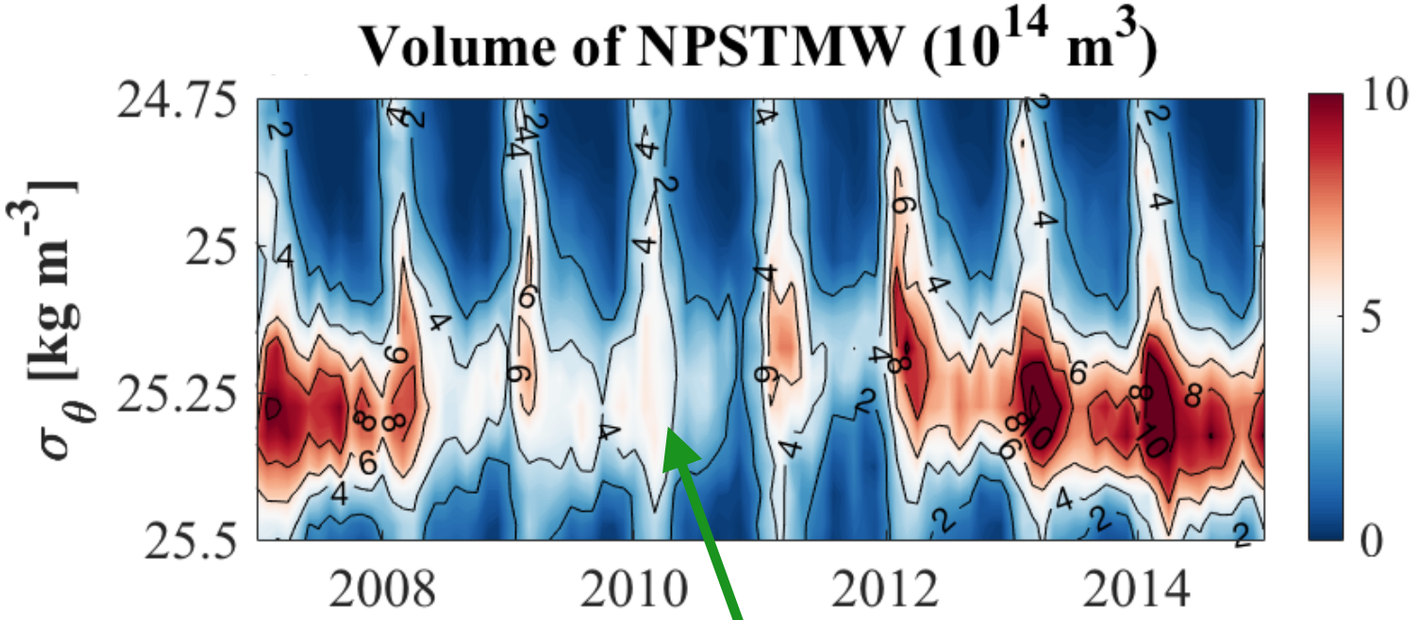
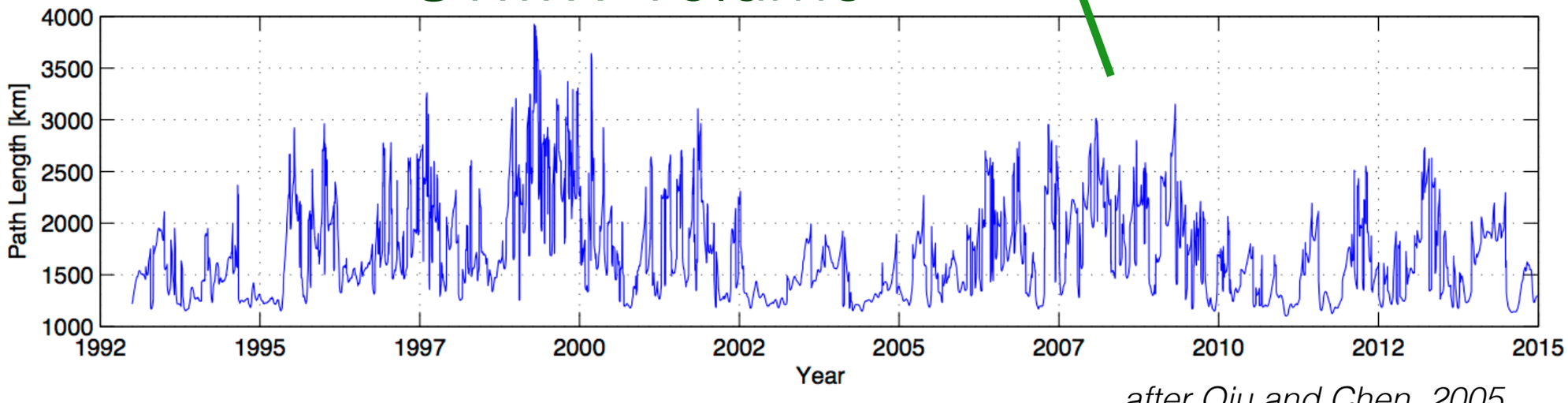




after Cerovečki & Giglio, 2016

Strongly meandering state preceded near collapse of STMW volume



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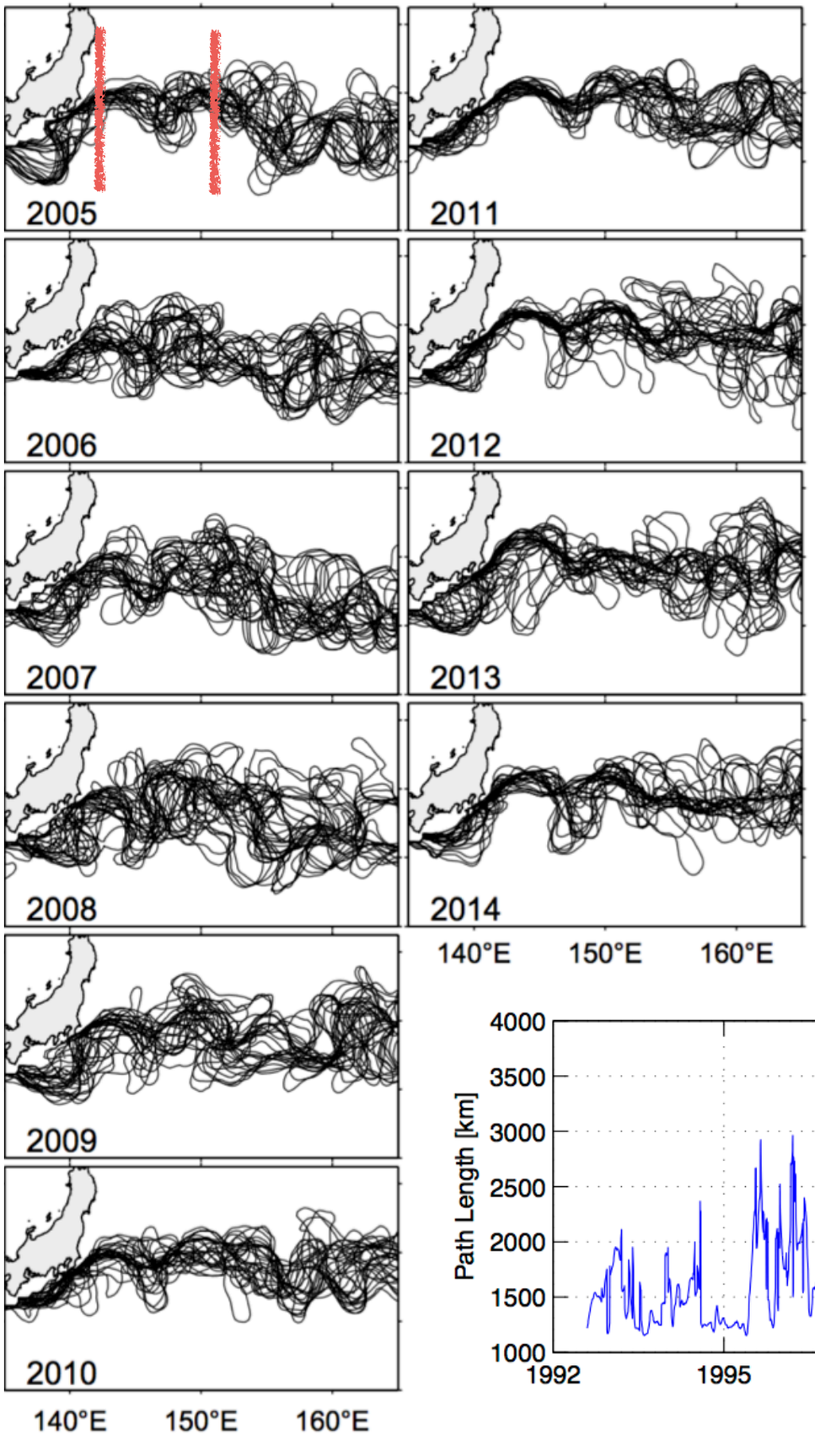
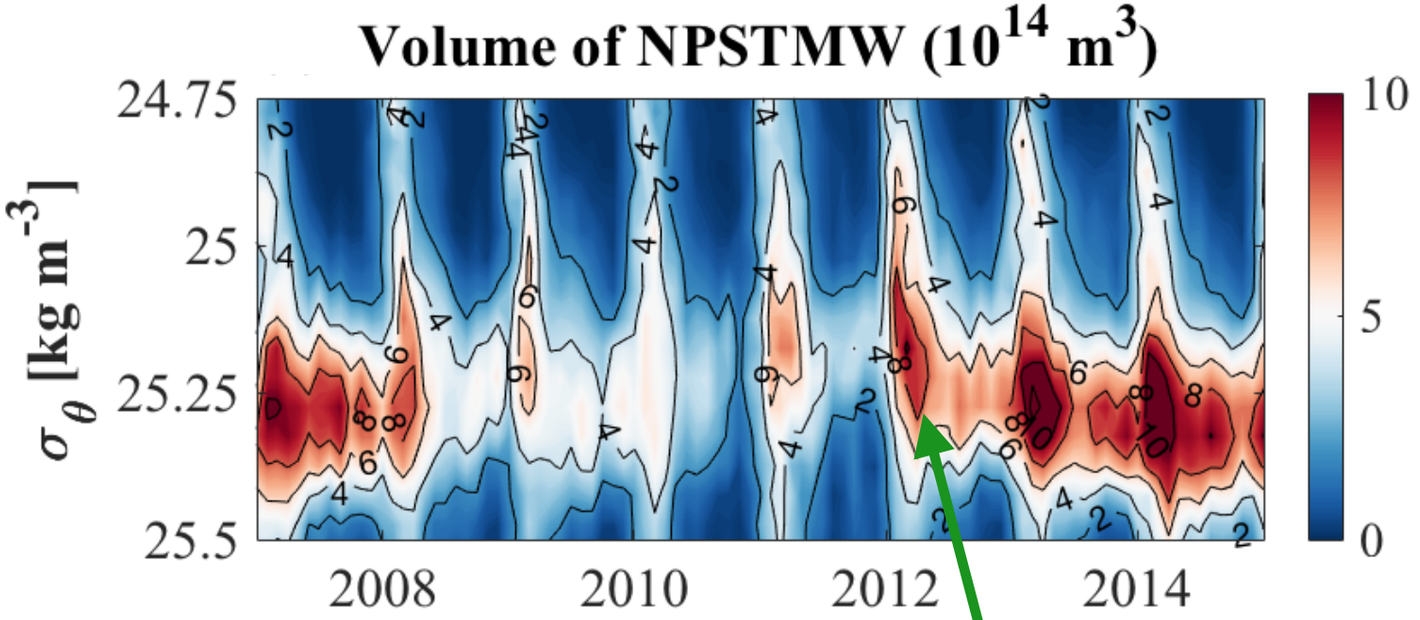
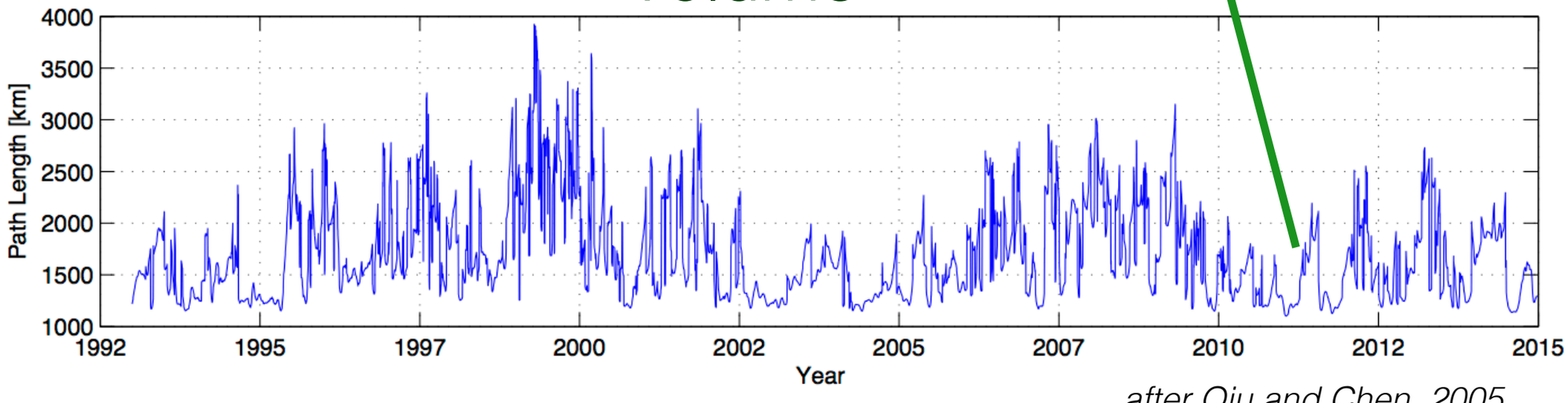




after Cerovečki & Giglio, 2016

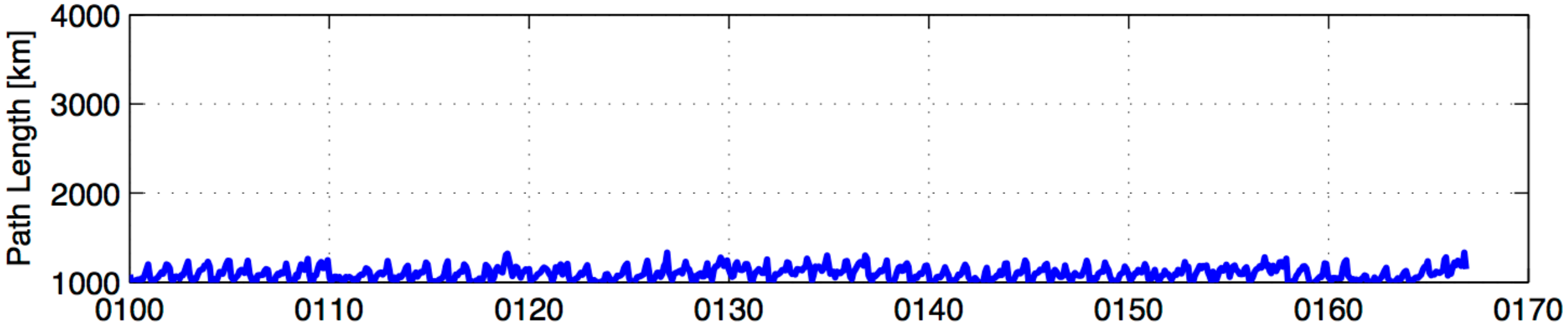
Weakly meandering state followed by a rebuild up STMW volume



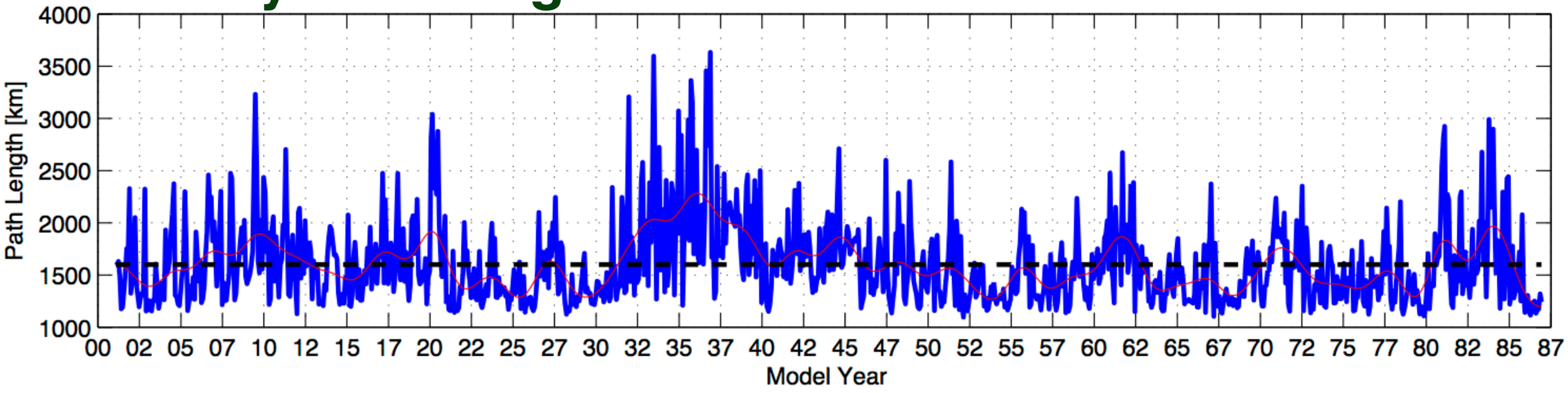
after Qiu and Chen, 2005

High vs. Low Resolution Modeling

Standard low-resolution climate model

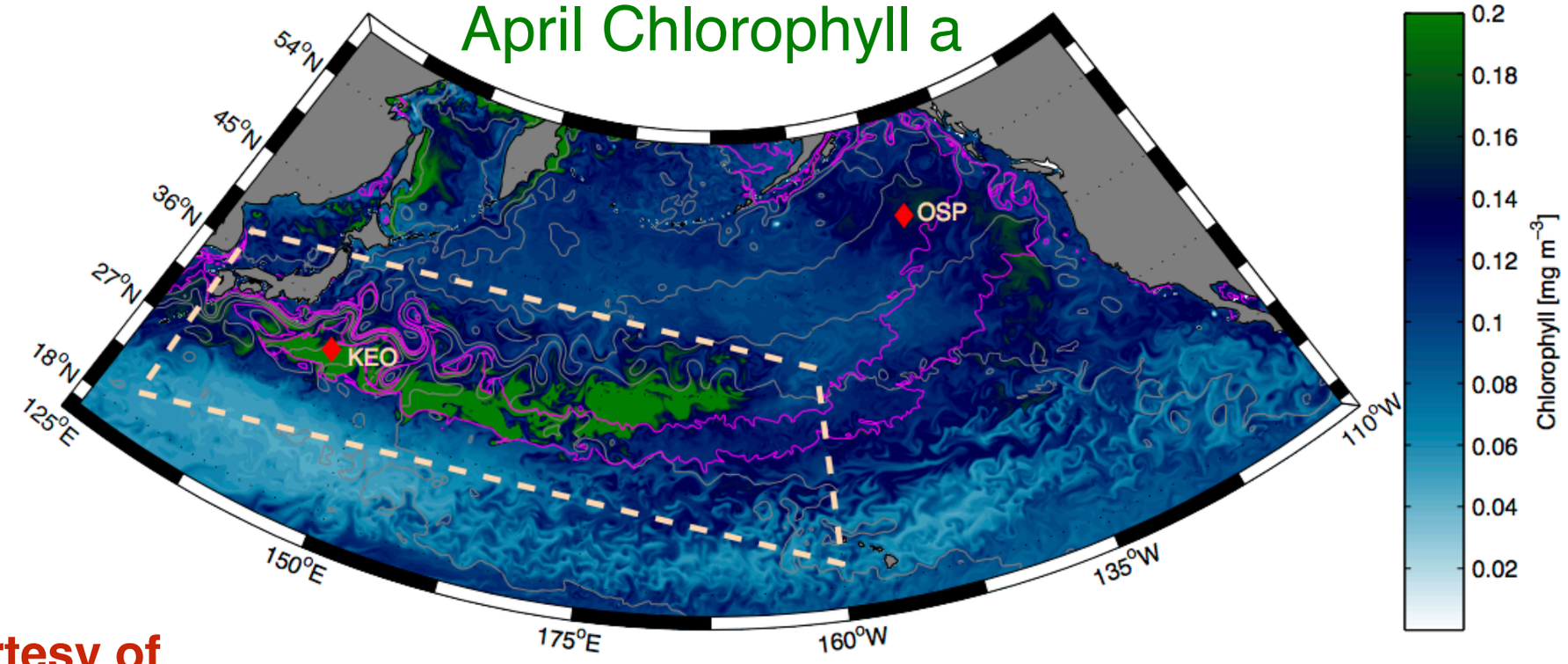


Eddy-resolving climate model

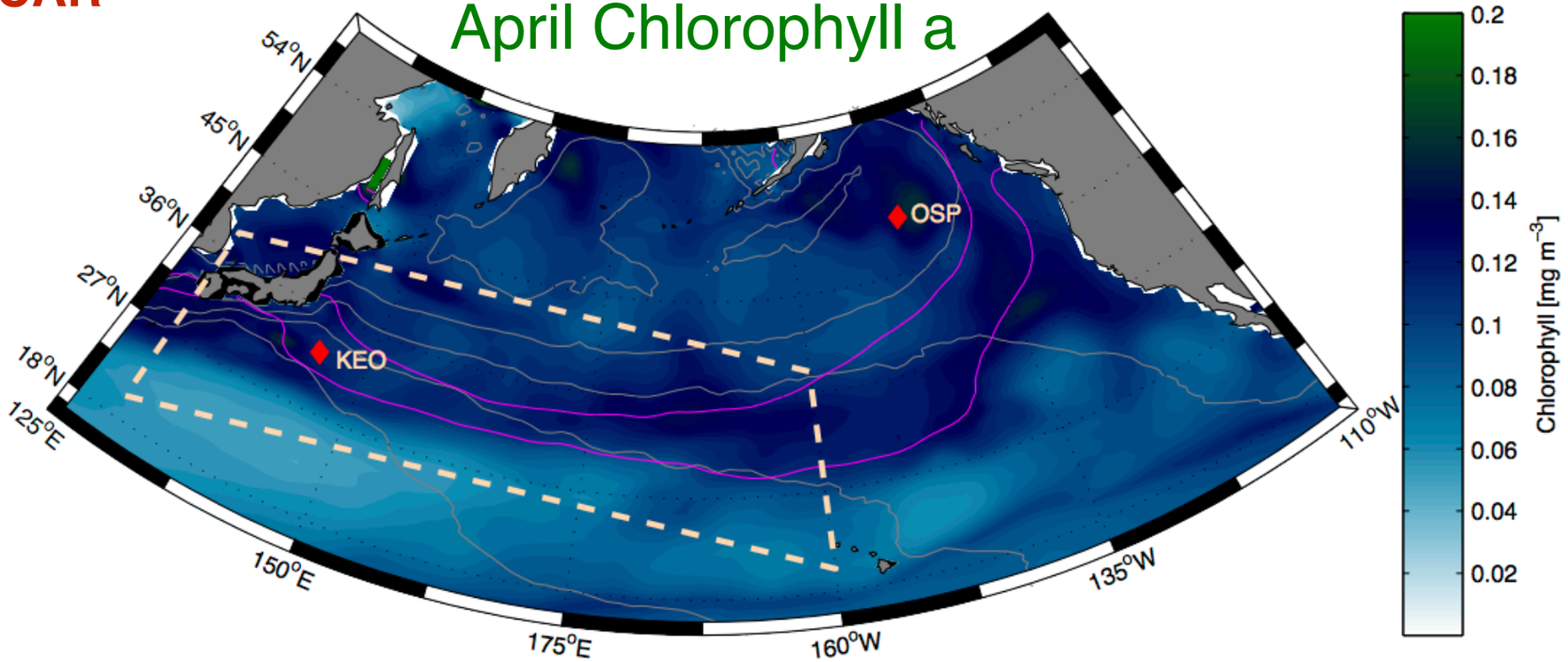


Bishop et al., 2015

Evidence of Bio-Physical Coupling at the Mesoscale

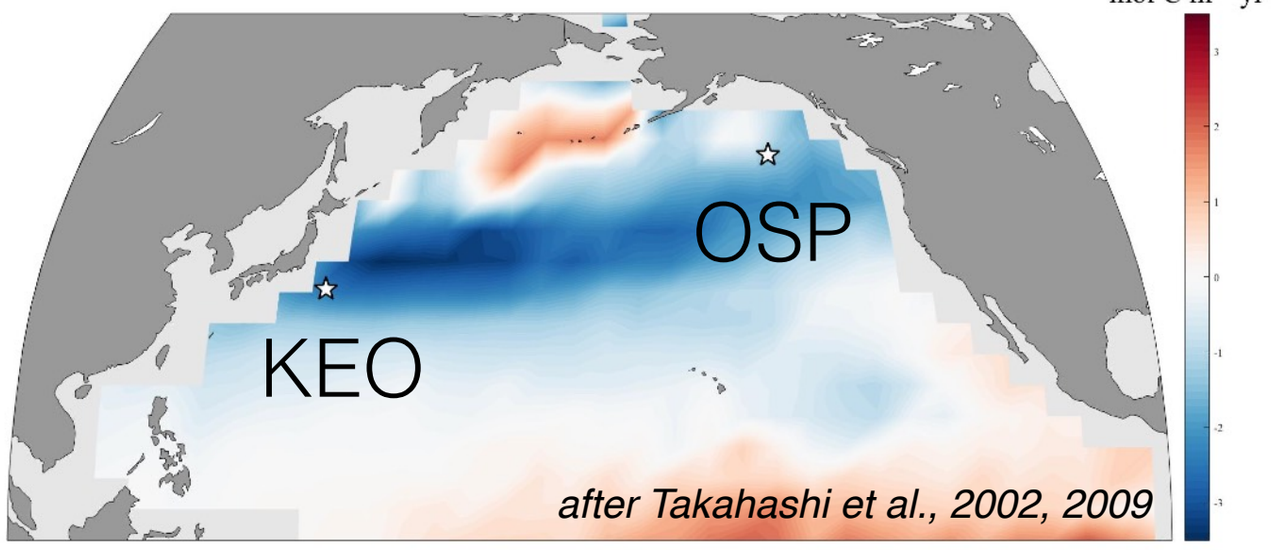


Model data courtesy of Matt Long at NCAR



High-resolution version of Community Earth System Model (CESM) with Parallel Ocean Program version 2

North Pacific Carbon Cycling



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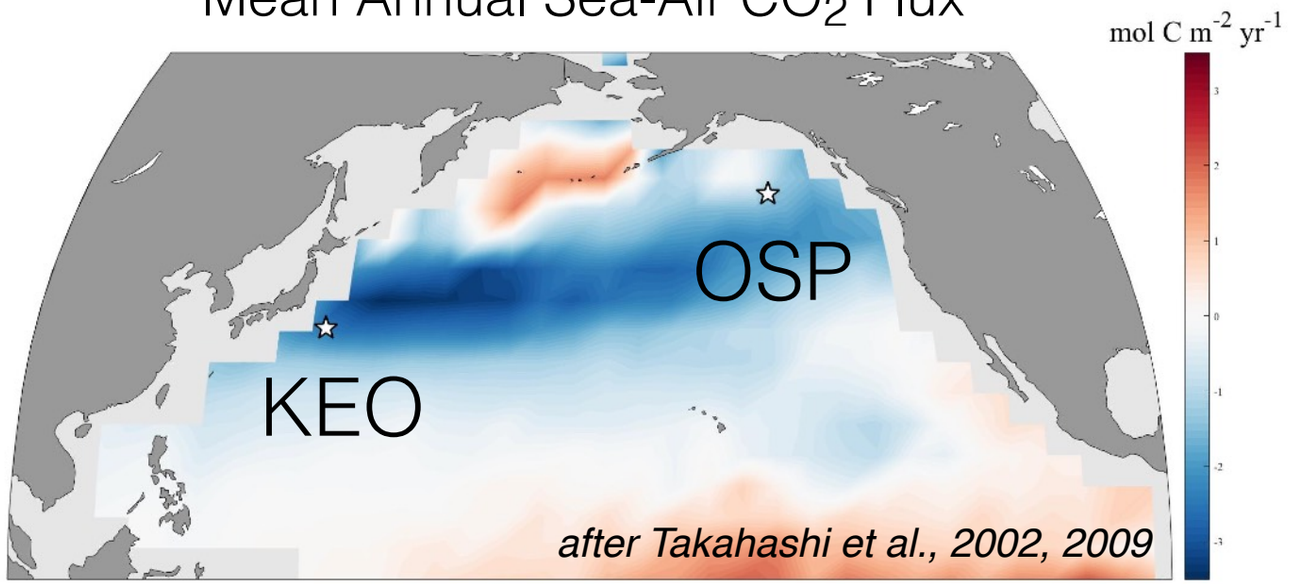
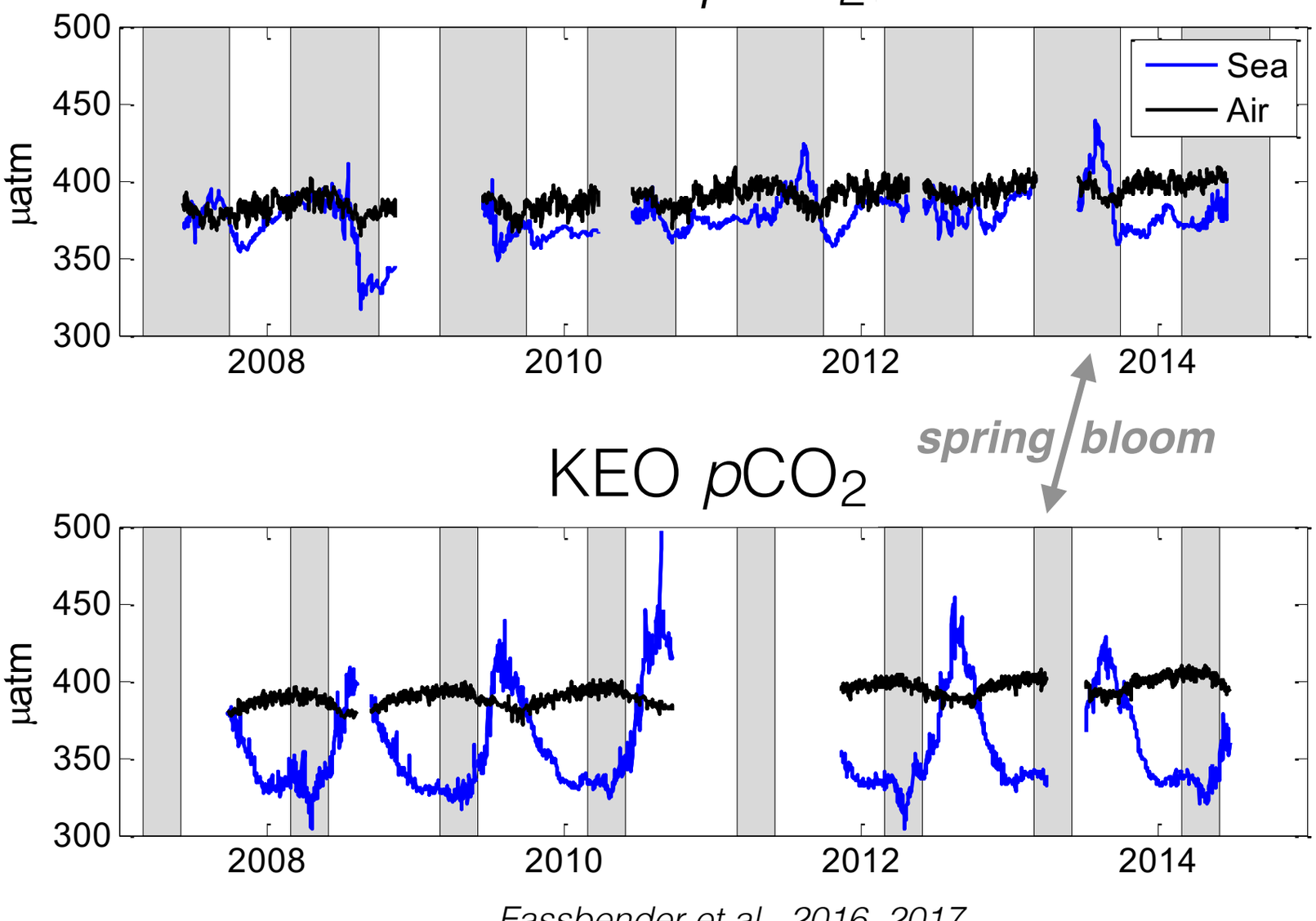


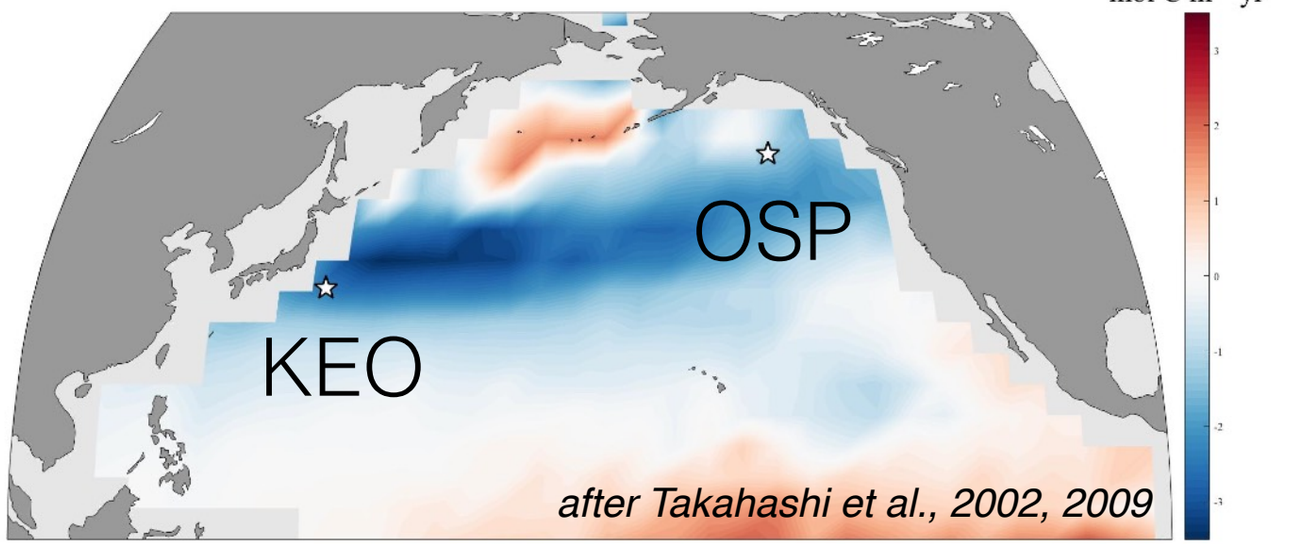


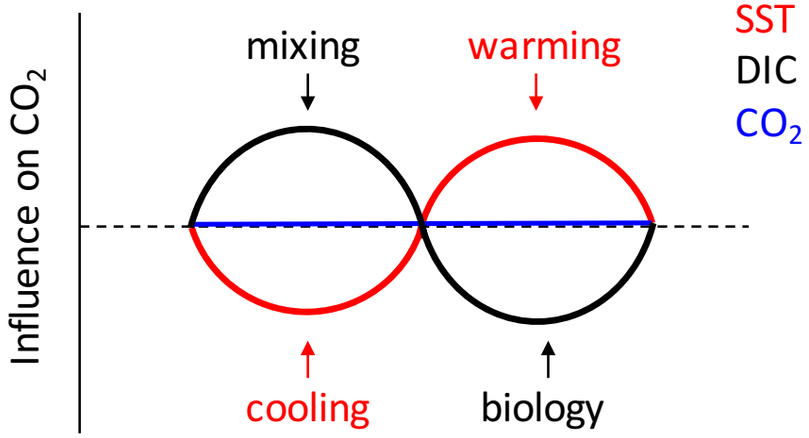
Fassbender et al., 2016, 2017

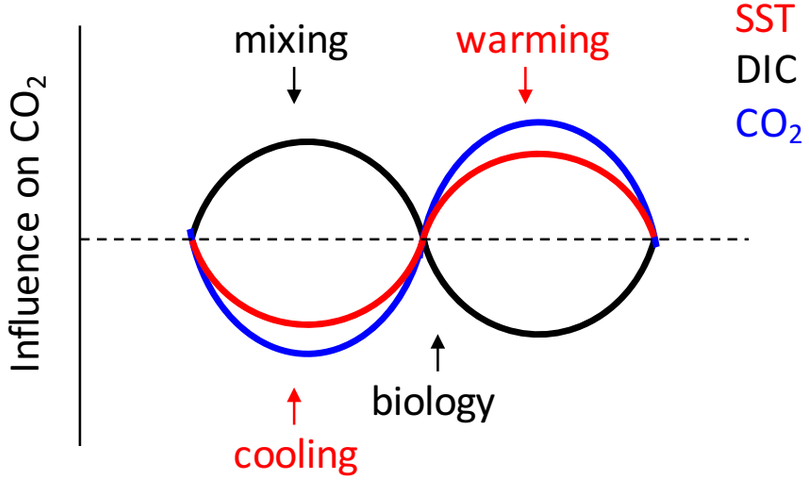
North Pacific Carbon Cycling

Different processes dominate seasonal pCO_2 changes at OSP and KEO.

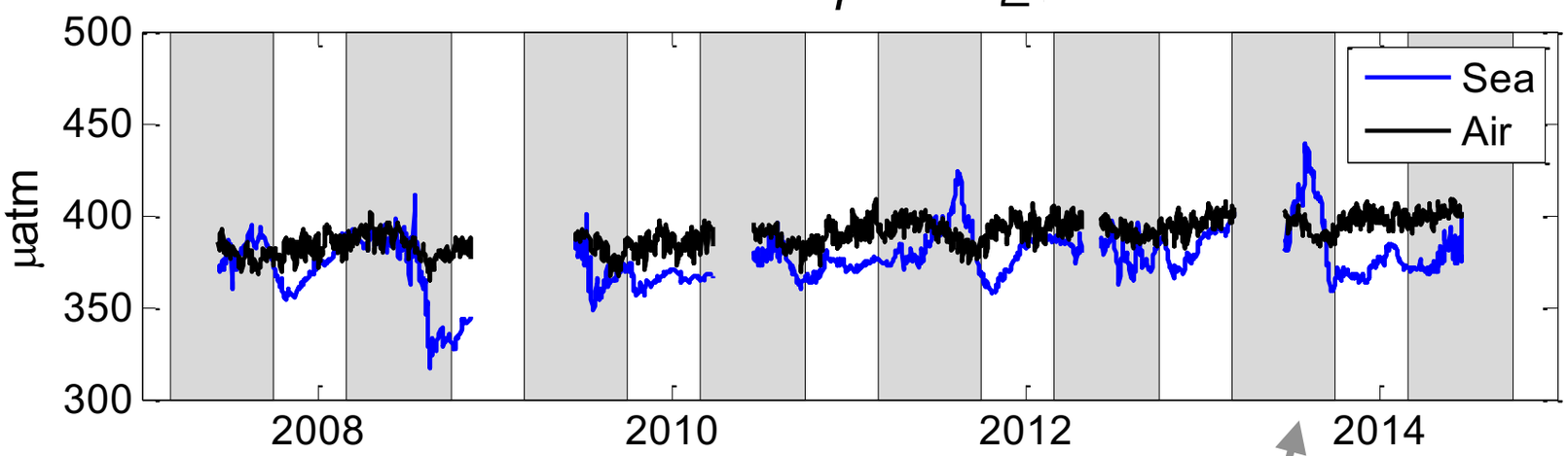
Mean Annual Sea-Air CO_2 Flux





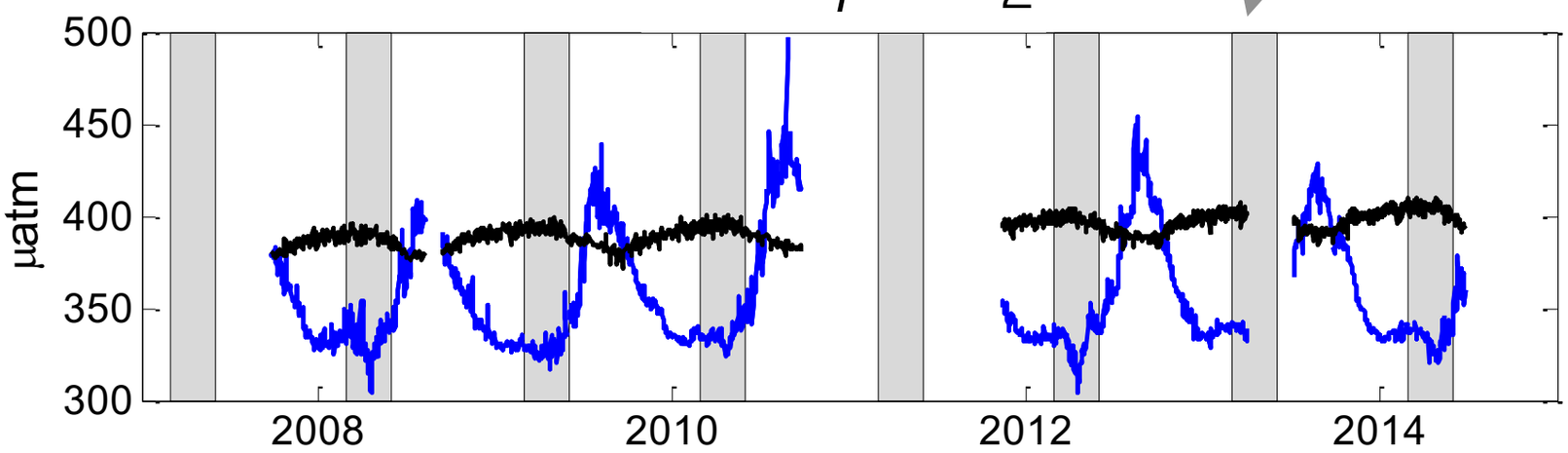


OSP pCO_2



spring bloom

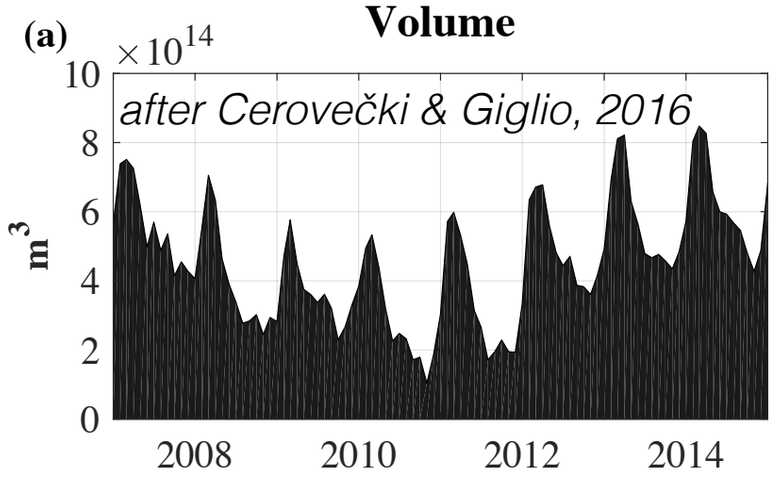
KEO pCO_2

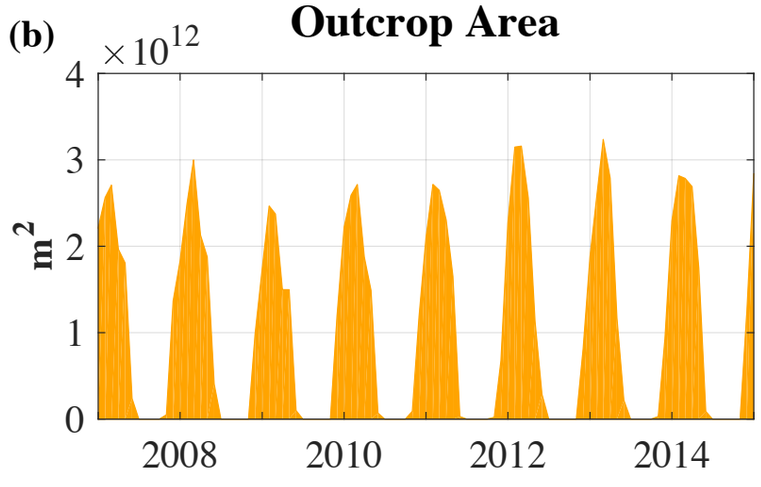


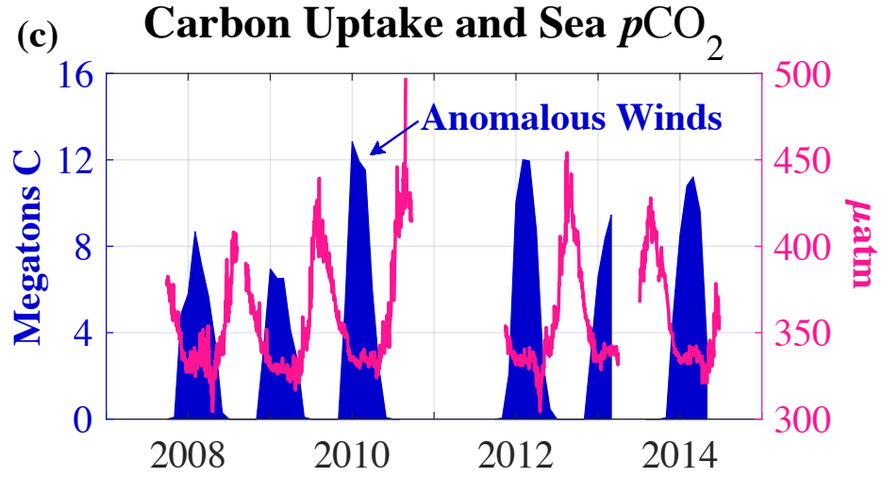
Fassbender et al., 2016, 2017

Carbon Uptake Processes Near the Kuroshio Extension

Air-Sea CO_2 Exchange and Mode Water Outcrop







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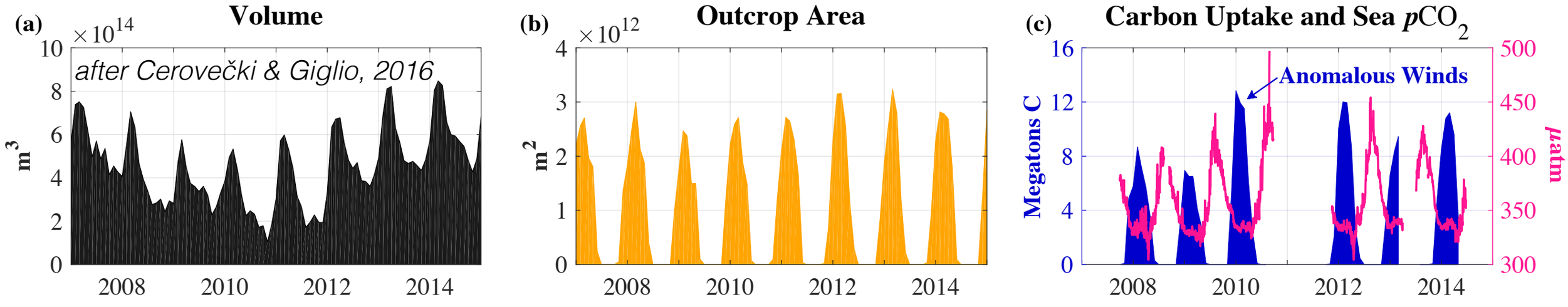
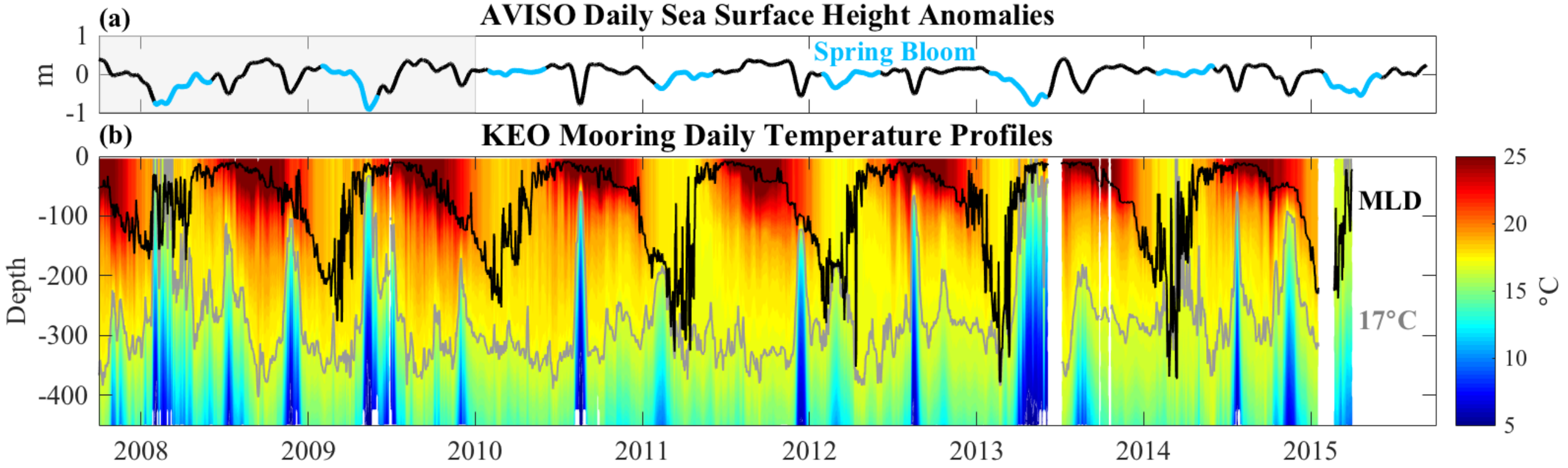
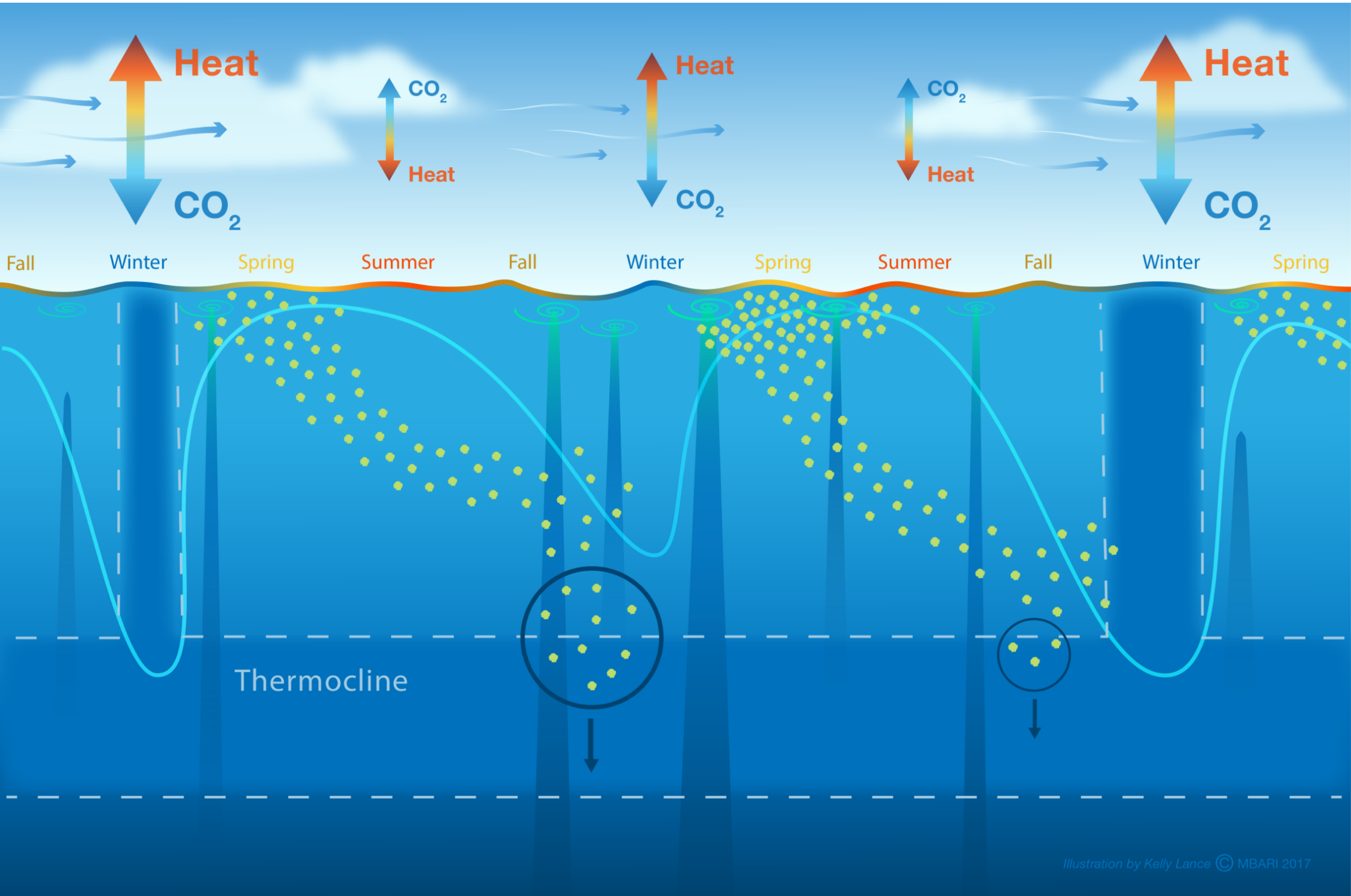


Eddy Activity and Biological Production and Export

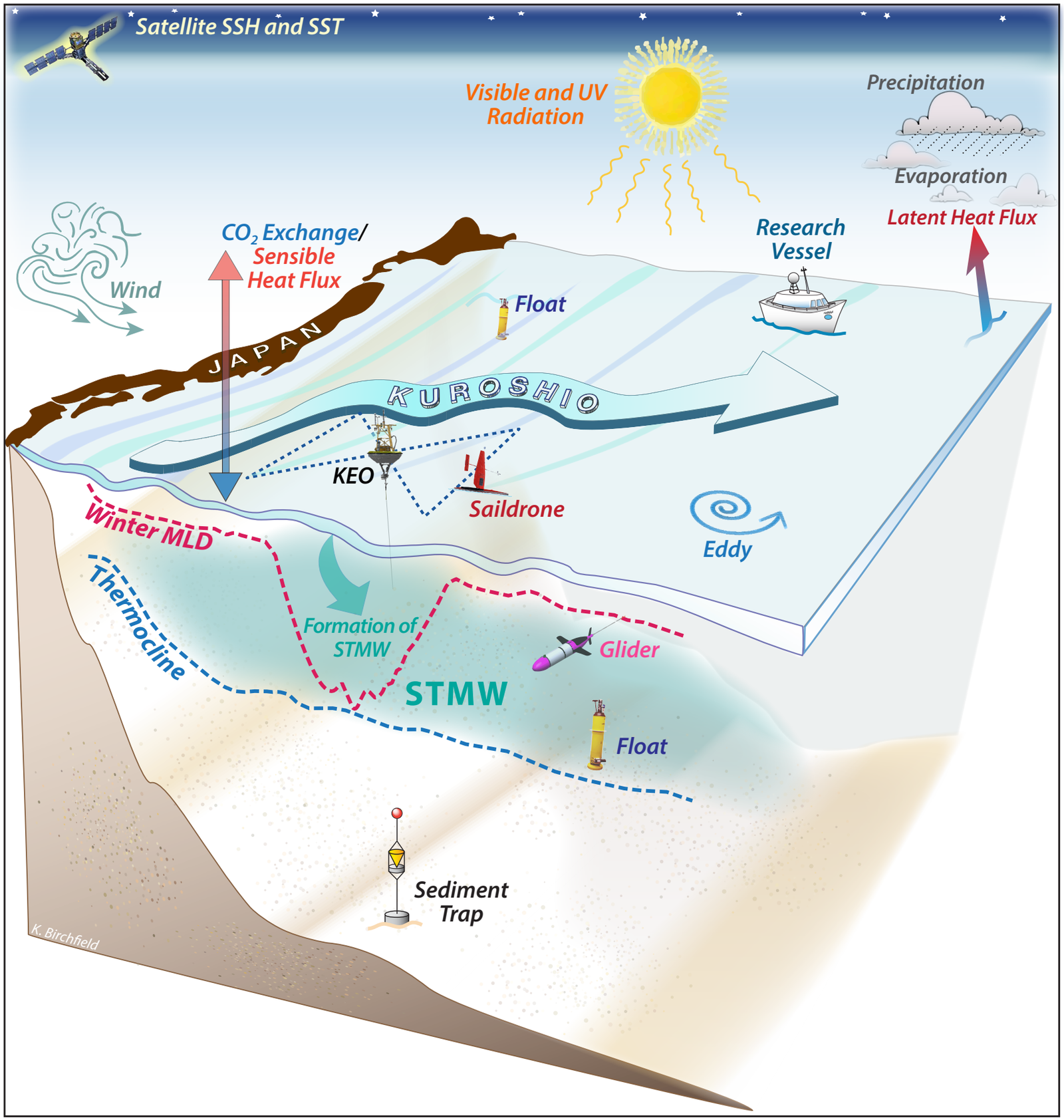


Fassbender et al., 2017

Carbon Uptake Processes Near the Kuroshio Extension



Carbon Hot Spot Workshop, October 2017



Workshop: "This workshop will convene scientists from the fields of the biogeochemistry, ecology, and ocean physics to explore the integration of observational and numerical modeling tools to link biophysical dynamics with carbon uptake processes and explore feedbacks in Western Boundary Current regions." - OCB

Goal: International process study near Kuroshio Current to evaluate processes that influence ocean carbon uptake and storage.

NSF: Proposals

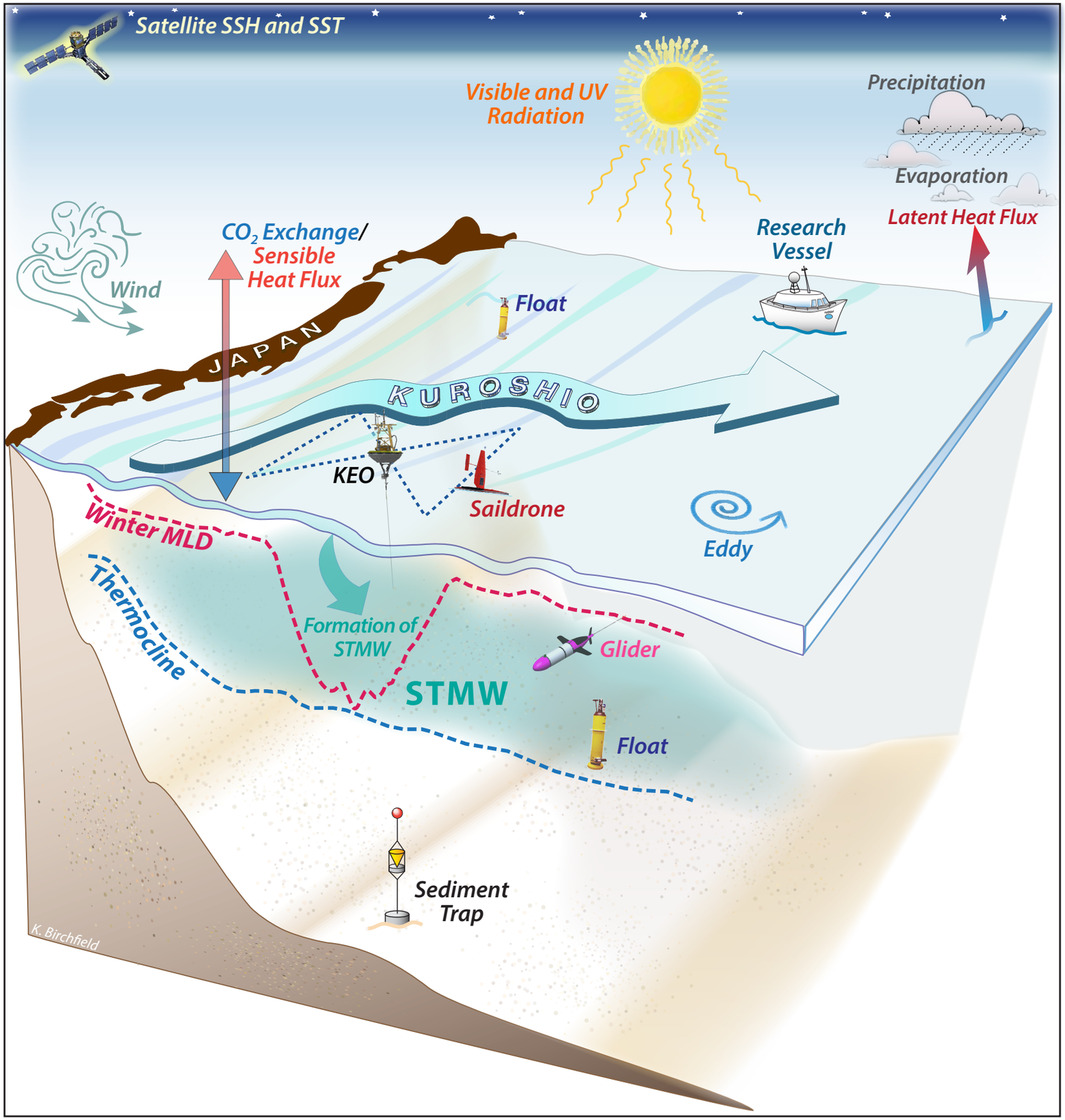
1. **Modeling proposal** focused on characterizing baselines and decadal variability for mesoscale eddy activity and STMW formation, and their influence on carbon export

Ivana Cerovečki (Scripps), Stuart Bishop (NCSU), and Andrea Fassbender (MBARI)

2. ***Carbon Hot Spot*** pilot study focused on submesoscale processes, including restratification of the mixed layer, and how they impact STMW formation and carbon export

Stuart Bishop (NCSU), Andrea Fassbender (MBARI), Dongxiao Zhang (JISAO), Meghan Cronin (PMEL), Chris Roman (GSO), Zhaohui Wang (WHOI), Eitarou Oka (U. Tokyo), Ryuichiro Inoue (JAMSTEC), and Takeyoshi Nagai (TUMST)

NSF: Carbon Hot Spot Proposal



Observational Assets:

- Ship surveys
- In situ sensors on rosette
  - DIC, pH, nitrate
- Towed WireFlyer
  - O_2
- Seagliders (O_2)
- Saildrone (CO_2)

Assets in Place:

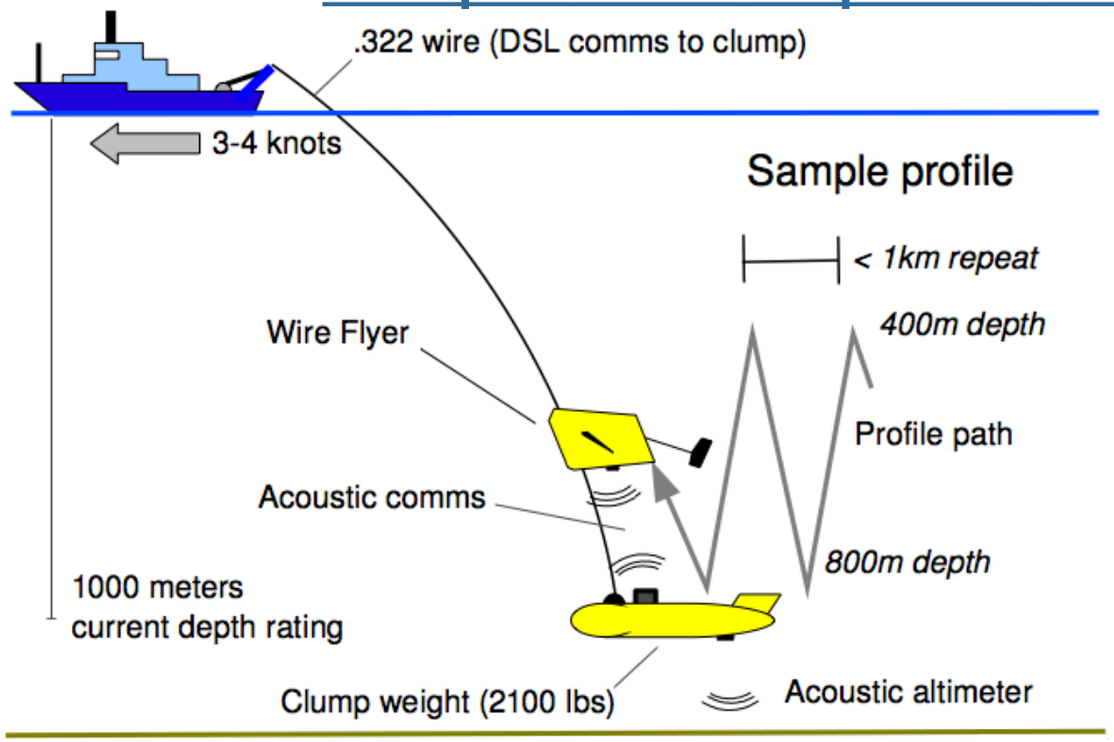
- KEO mooring (pH + CO_2)
- Floats (nitrate)
- Satellites

Assets for Process Study:

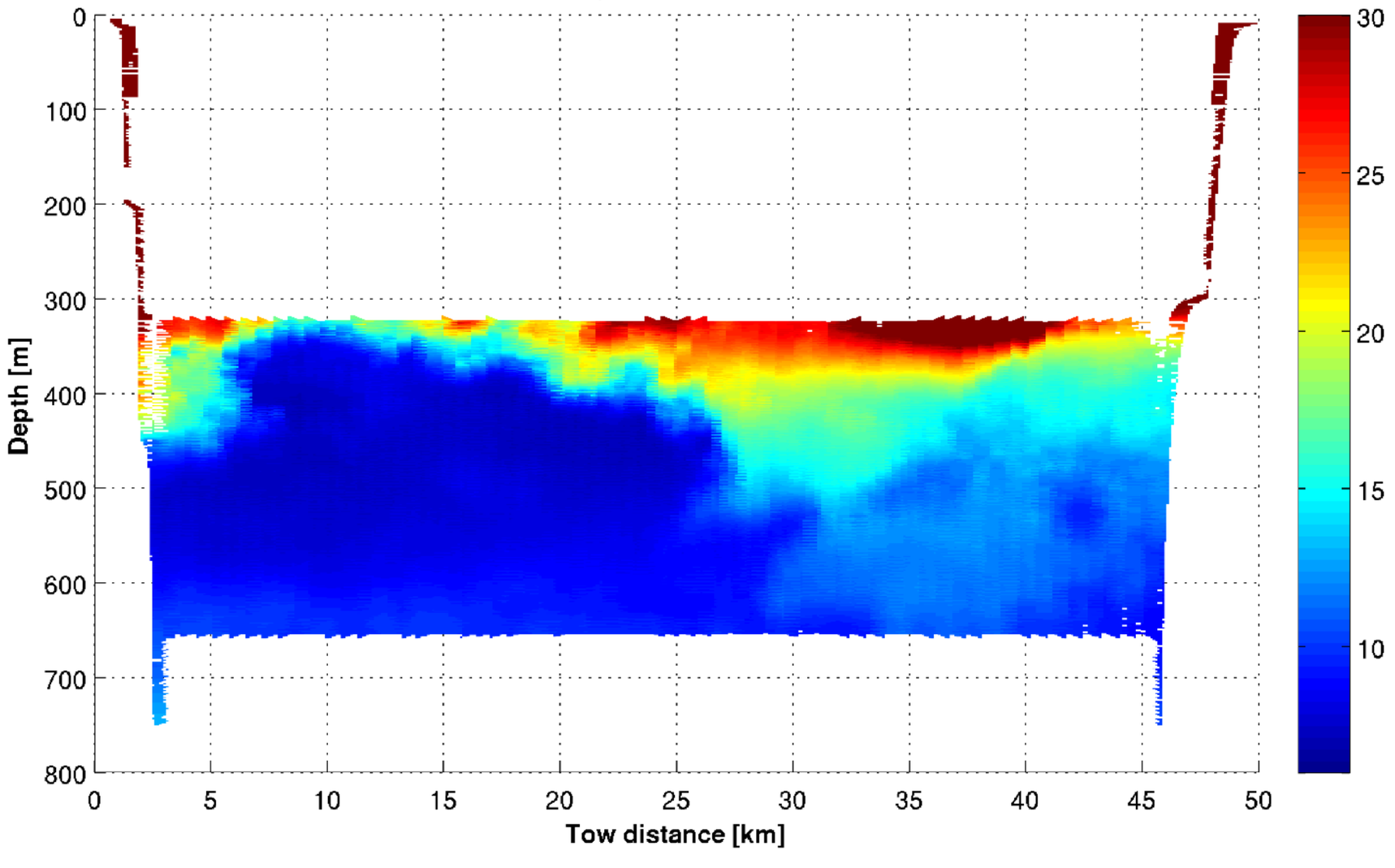
- Sediment trap
- Floats (pH + nitrate + O_2)
- Modeling component

Participants: NCSU, MBARI, WHOI, URI, PMEL, JAMSTEC, U. Tokyo, & UW

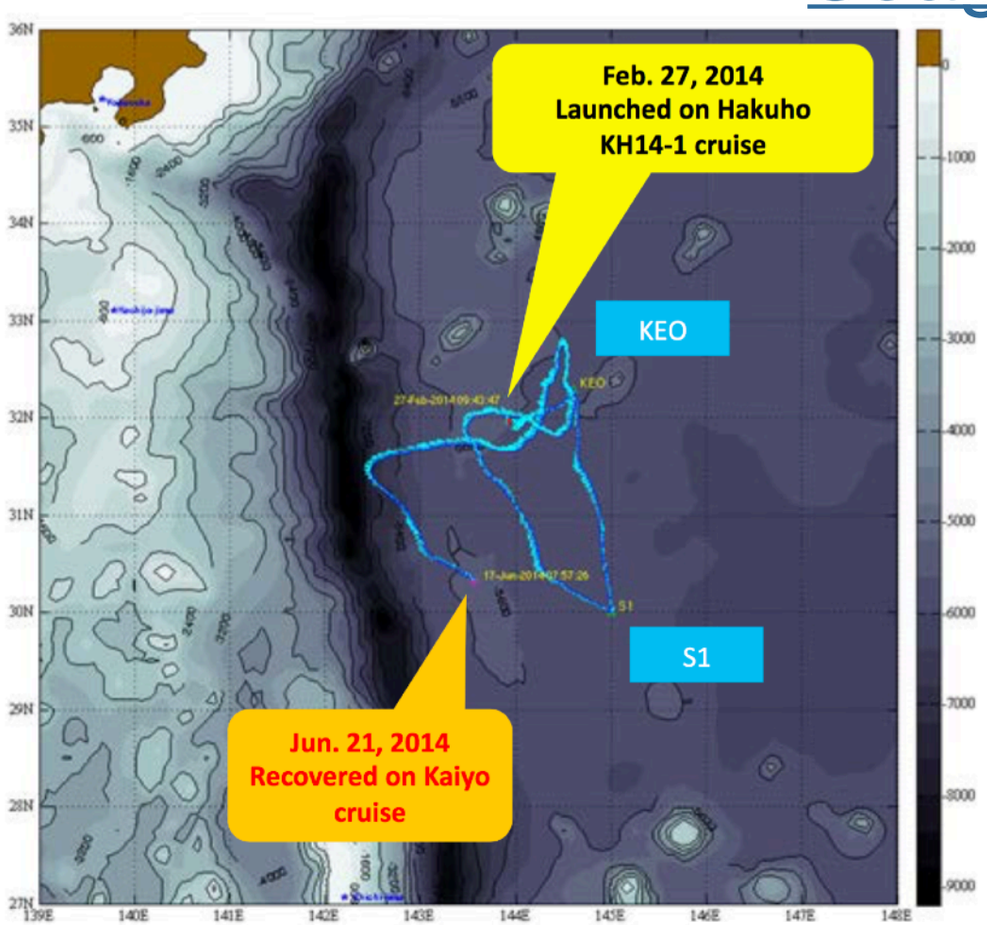
Proposed Ship-Based Wire Flyer Observations



Dissolved oxygen measurements made using the Wire Flyer towed instrument in the Eastern Tropical Pacific within the Oxygen Minimum Zone.

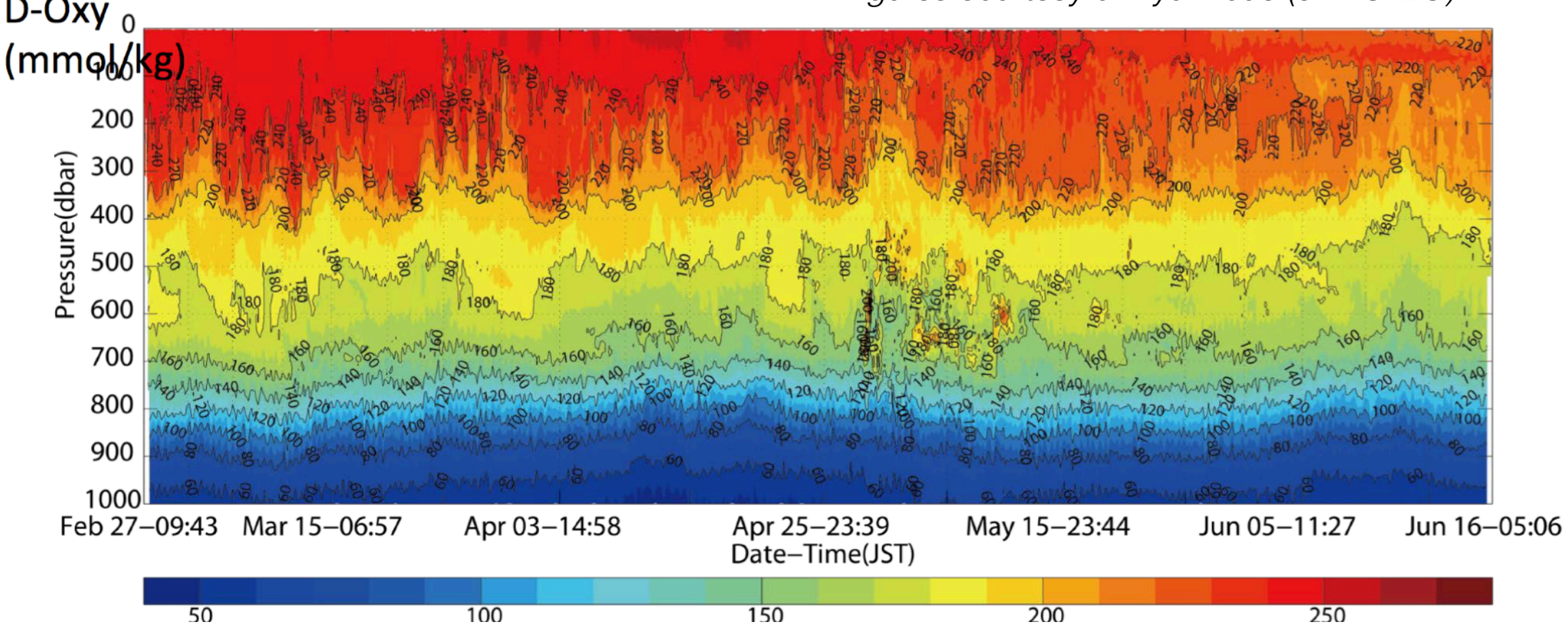


Seaglider Observations



JAMSTEC's Seaglider mission in February to June 2014. There is small-scale structure at the submesoscale observed in the dissolved oxygen record.

Figures courtesy of Ryu Inoue (JAMSTEC)



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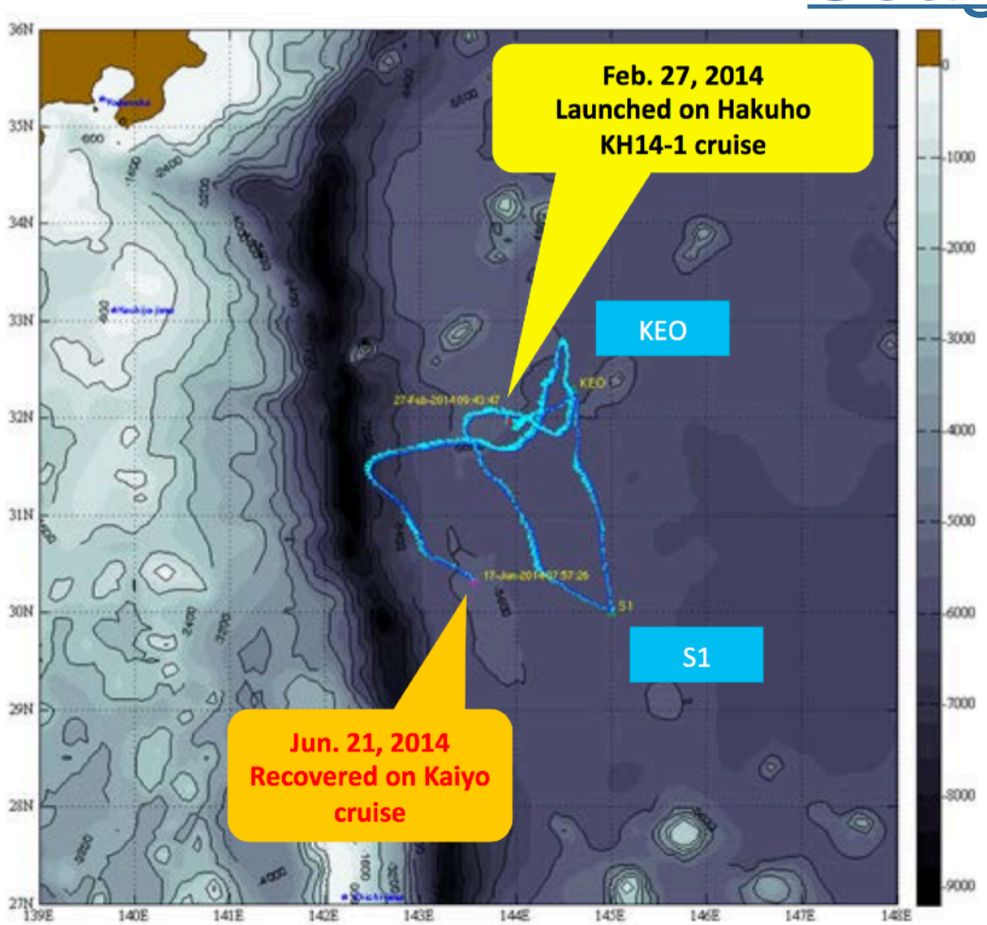
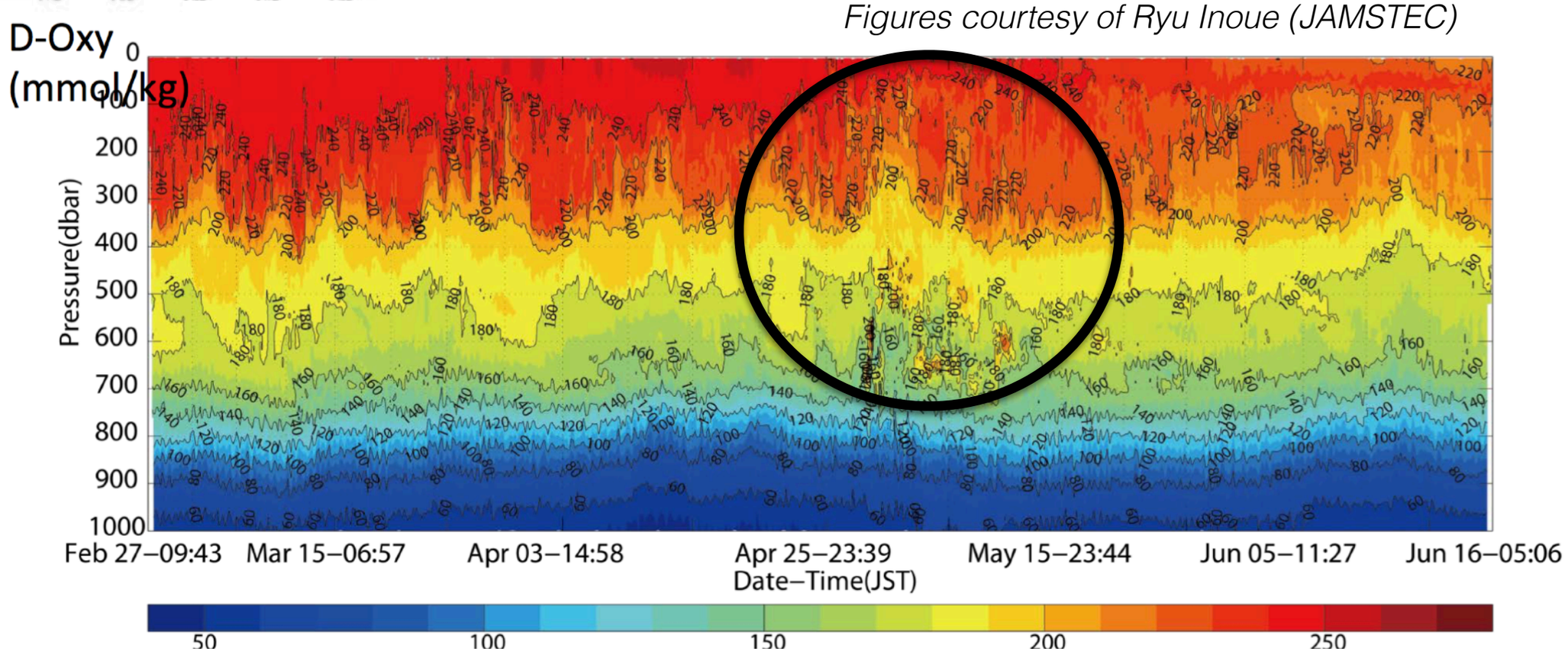


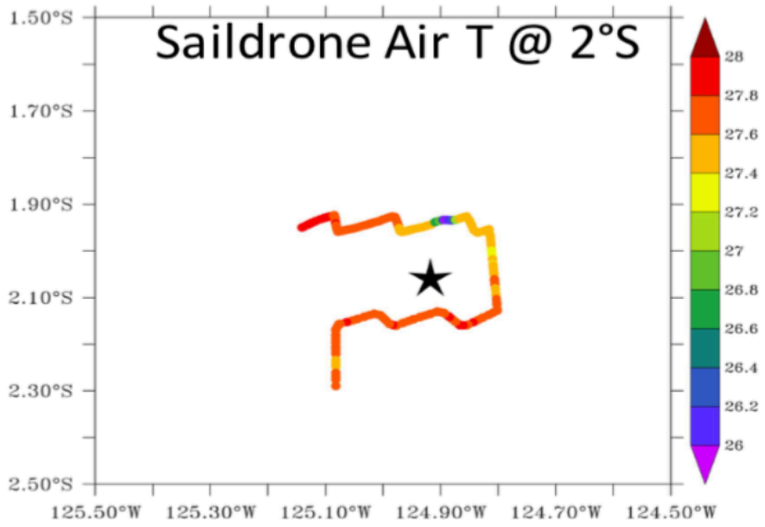
JAMSTEC's Seaglider mission in February to June 2014. There is small-scale structure at the submesoscale observed in the dissolved oxygen record.

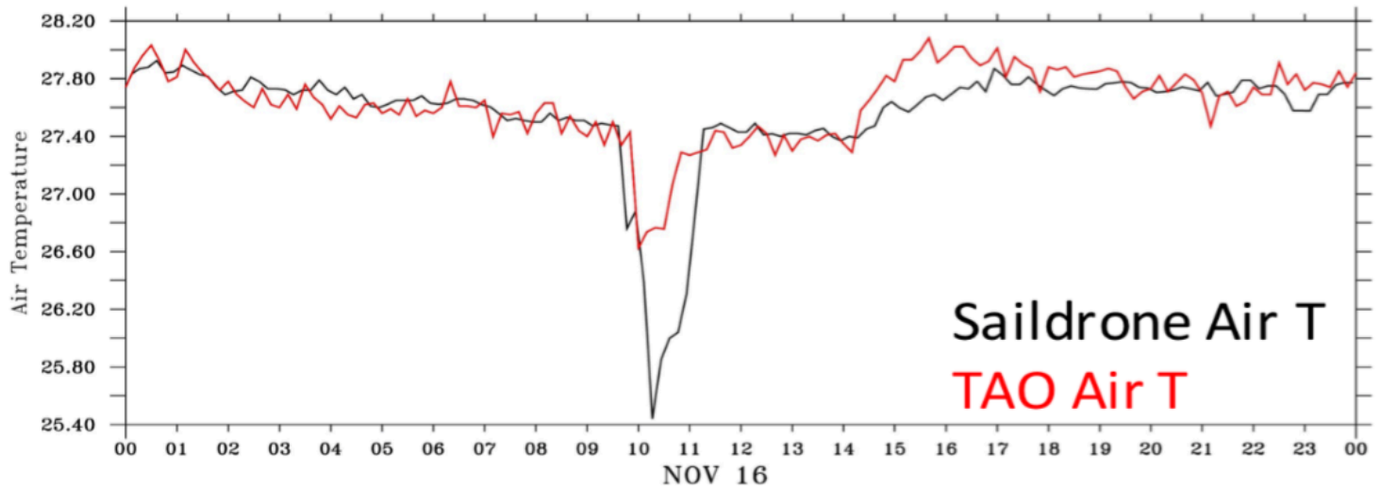
Submesoscale lens observed in Seaglider DO optode

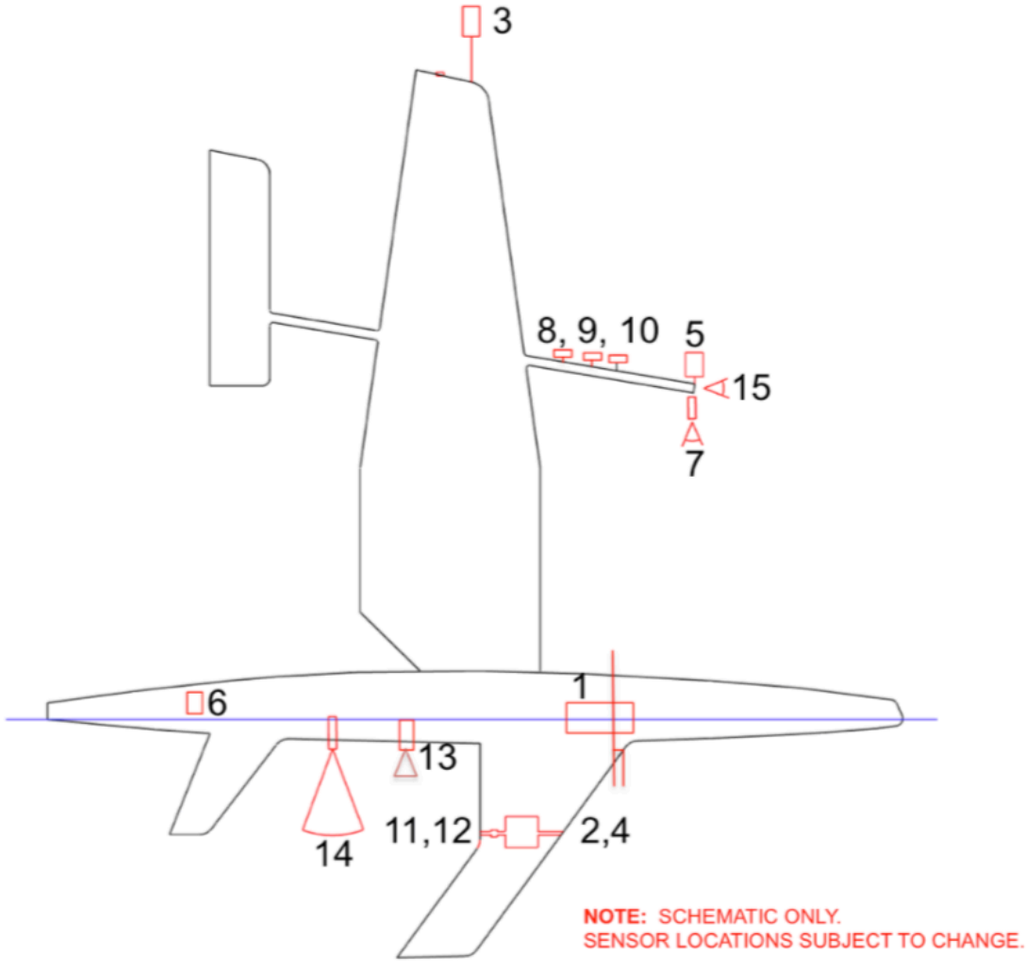
Figures courtesy of Ryu Inoue (JAMSTEC)



Saildrone Observations

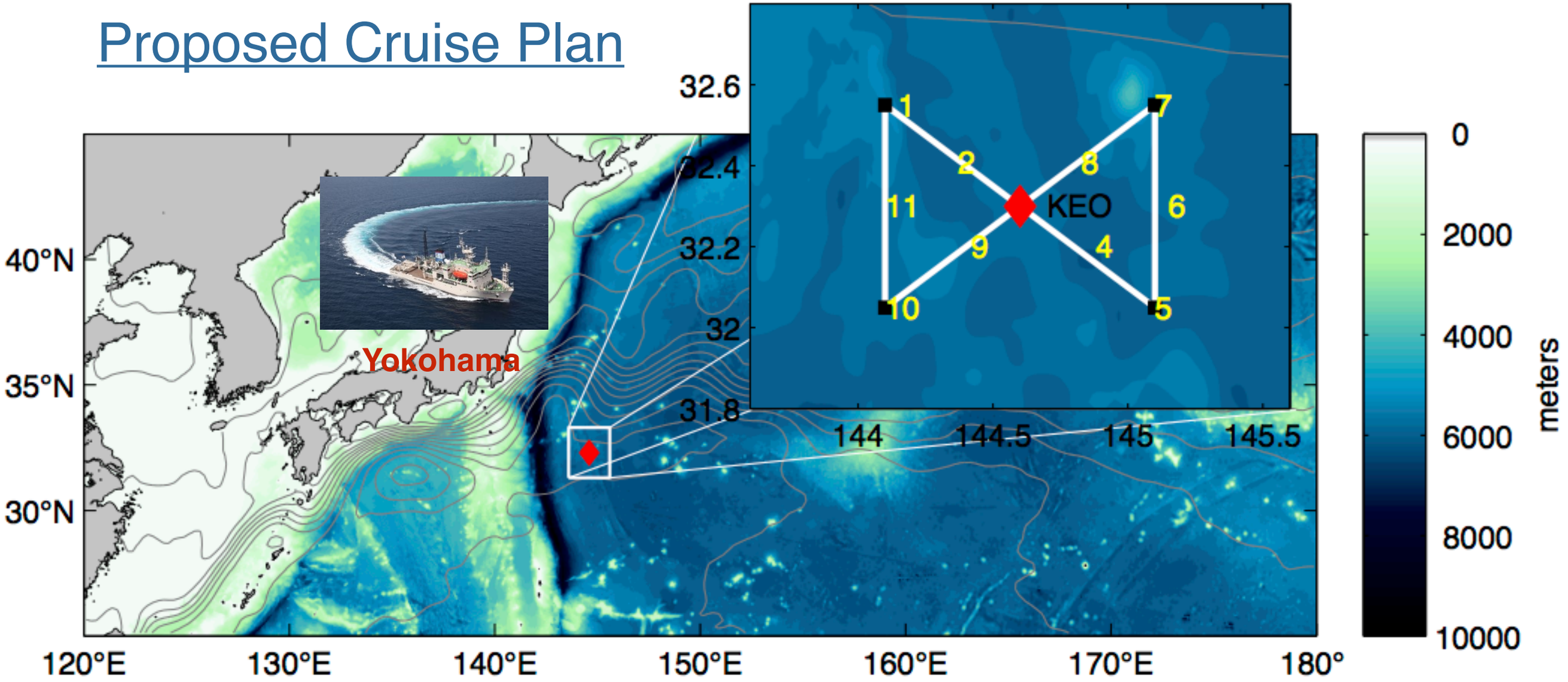






	Sensor	Meters from Waterline	Manufacturer & Model
1	pCO_2	0.5 m depth	PMEL ASVCO2 System
2	Sea Surface Temperature & Salinity	0.5 m depth	Seabird SBE-PRAWLER
3	3D Ultrasonic Anemometer (20Hz)	4.5 m height	Gill WindMaster
4	Thermosalinograph	0.5 m depth	Teledyne Citadel
5	AT/RH – S3 with Radiation Shield	2.2 m height	Rotronic HC2
6	Barometric Pressure	0.2 m height	Vaisala PTB 210
7	SST IR Pyrometer	2.2 m height	Heitronics KT15 II
8	Longwave Radiation	2.2 m height	Eppley PIR
9	Sunshine Pyranometer	2.2 m height	Delta-T Devices SPN1
10	Shortwave Radiation	2.2 m height	Unshaded SPN1
11	pH	0.5 m depth	Honeywell Durafet
12	Dissolved Oxygen	0.5 m depth	Aanderaa 4831
13	Fluorescence, Backscatter	0.2 m depth	Wetlabs Triplet
14	Acoustic Doppler Current Profiler	0.2 m depth	RDI Workhorse 300kHz
15	Cameras: Up/Down/Left/Right	2.2 m height	Saildrone Custom Design

Proposed Cruise Plan



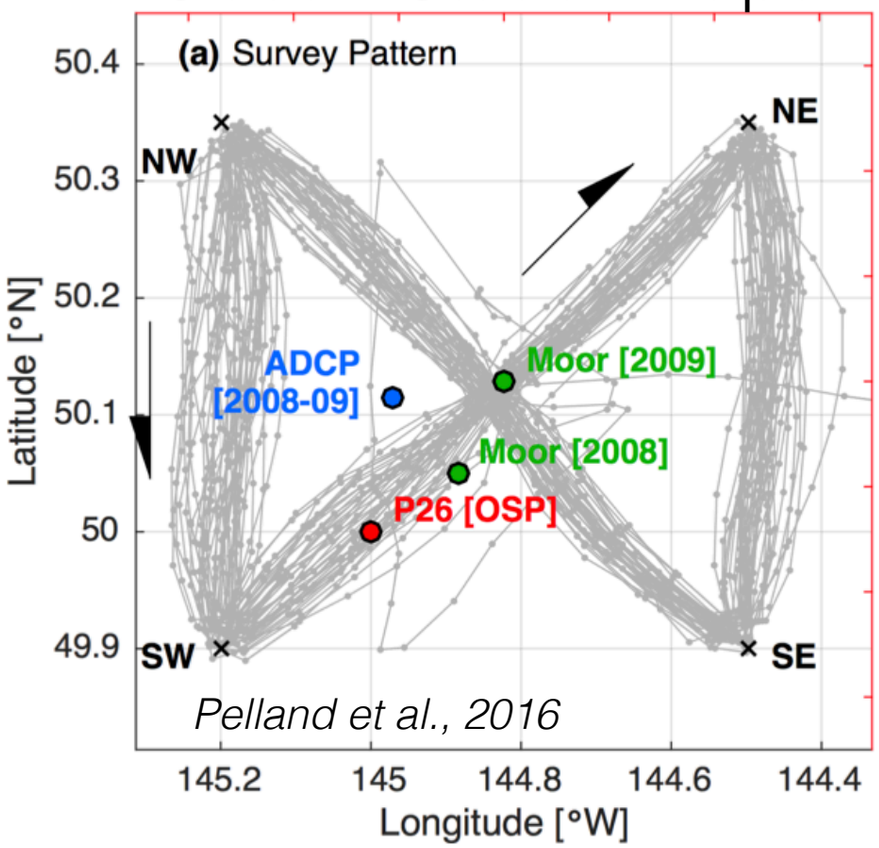
Two 14-day cruises: Yokohama to *Carbon Hot Spot* array aboard *R/V Shinsei Maru*

January & May 2018

- CTD/water sample stations including CHANOS II DIC, SeaFET pH, & ISUS nitrate.
- Transects between stations using Wire Flyer
- 2 Seagliders deployed in January and recovered in May.
- Saildrone deployed from Guam in January to meet Seagliders and to remain for the duration of Seaglider deployment.
- Ship measurements will be used to build empirical relationships that will be applied to subsurface Seaglider data to close upper ocean carbon budgets.

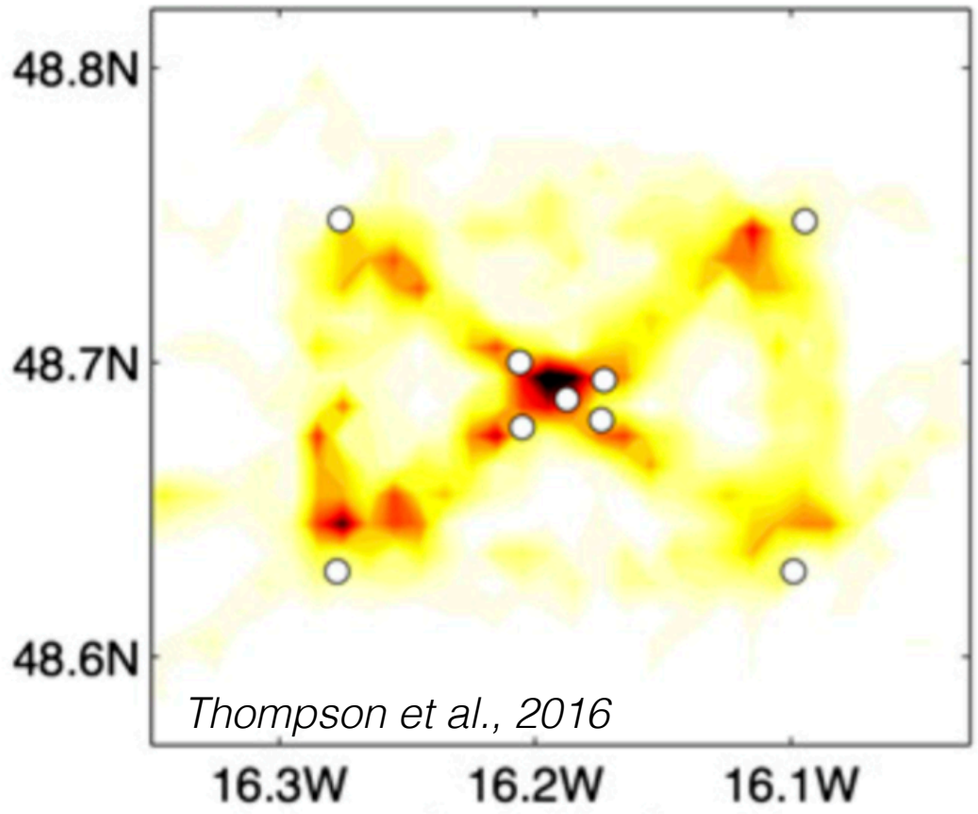
Proposed Autonomous Vehicle Tracks

Ocean Station Papa



Pelland et al., 2016

OSMOSIS



Thompson et al., 2016

Ocean Station Papa

- Mapped Seaglider data to monthly mesoscale.
- Gradients observed to be 10x larger than climatology and in some cases changed sign.

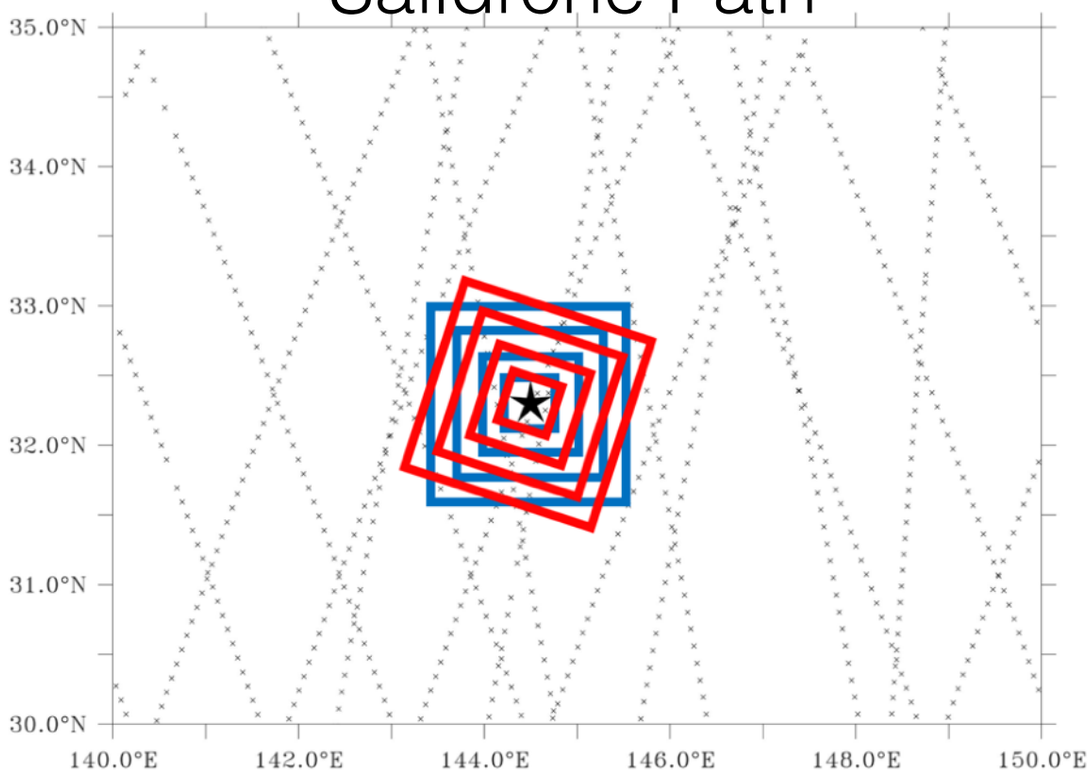
OSMOSIS

- Submesoscale mixed layer instabilities observed.

Carbon Hot Spot

- Seaglider and Saildrone tracks could follow satellite tracks.

Saildrone Path



Challenges We *Knowingly* Face

Planning:

- International collaboration with government agencies involved
- International shipping (hazmat)
- Coordination of international proposal cycles/timelines
- International asset and data sharing

Field work:

- Strong currents – how to keep vehicles on desired track?
- Calibrating gliders – how to do well in patchy environment?
- The KE is dynamic – we can't predict what state we will observe

Synthesis:

- Data management – multiple partners, lots of data
- Data analysis – when to involve modelers?

Questions We Have

- Is there a streamlined way to coordinate (international) funding agencies?
  - NOAA is already involved through KEO.

- How best can we engage modelers early on so that observations are optimized to assess/improve models?

- After the October 2017 workshop, what are the next steps forward in developing a process study? Writing a proposal, engaging with funding agencies, hosting a smaller PI meeting to hash out details?

- Is there an ideal number of lead PIs for a process study of this size?

Potential Deliverables:

- New insights on how to observe WBC regions globally (OceanObs 2019)
- Better understanding of mode water and eddy effects on carbon cycling
- Improved model parameterizations of bio-physical processes
- Enhanced collaboration between modelers and observationalists

- Are there additional opportunities for deliverables to consider at this stage?

Carbon Hot Spot

Andrea Fassbender (MBARI) & Stuart Bishop (NCSU)

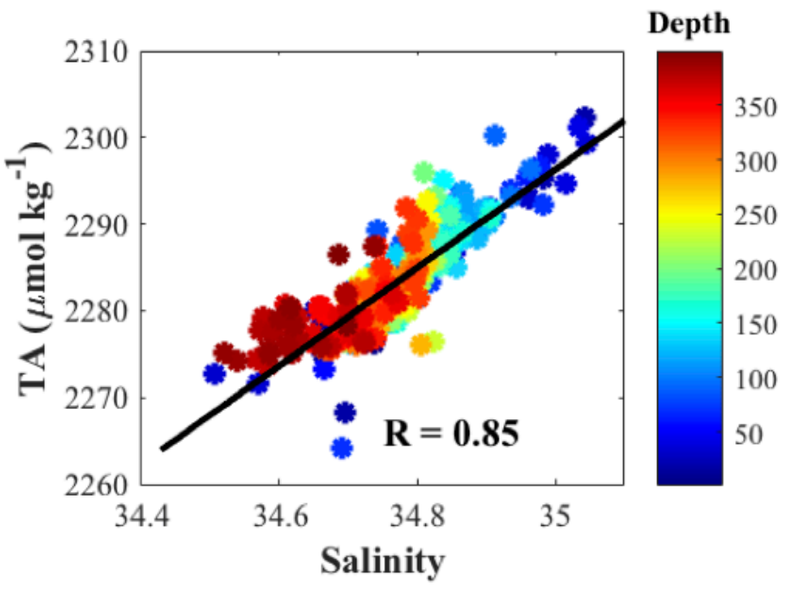
PSMI Webinar

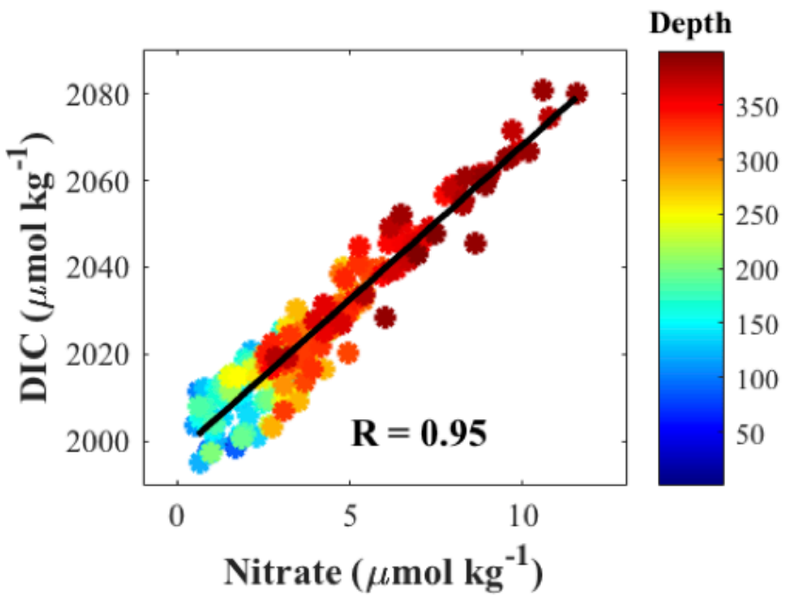
February 22, 2017

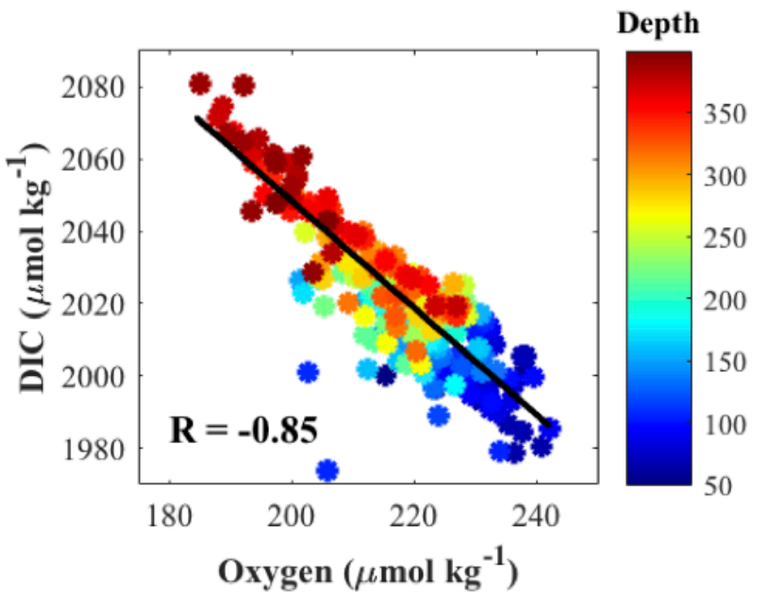
Image: PMEL OCS

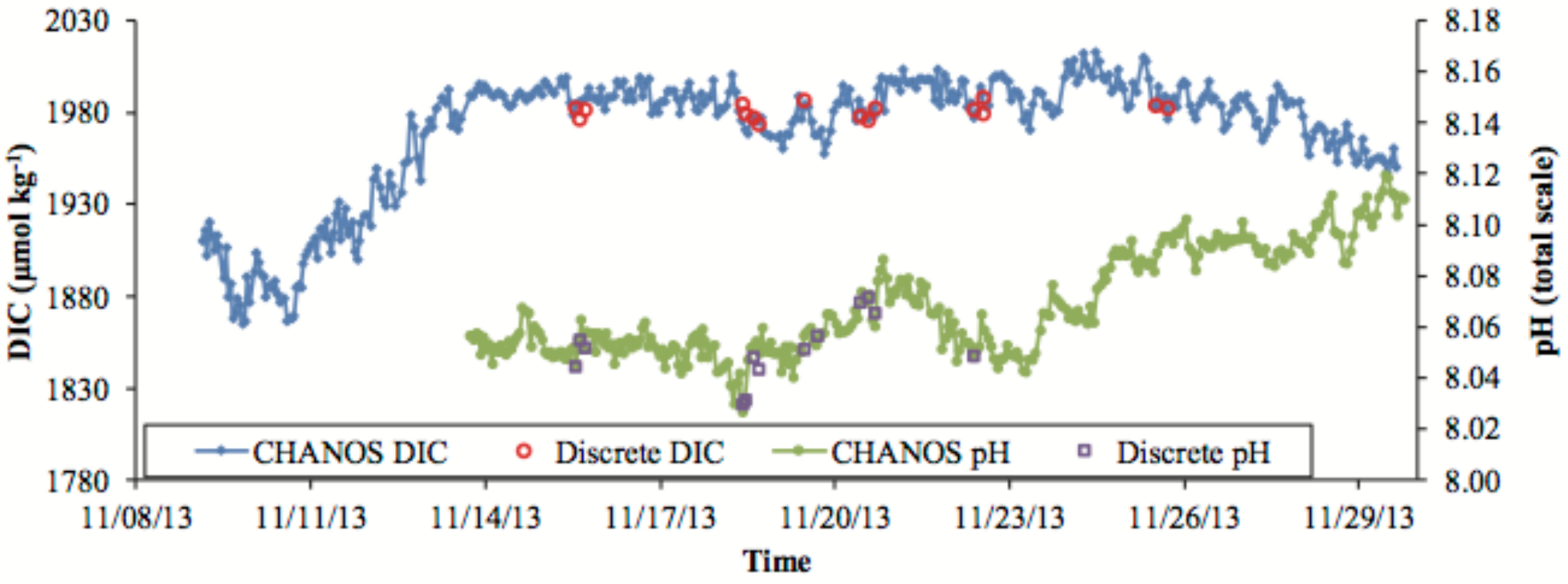
Extra Slides

Phys-BGC Empirical Relationships

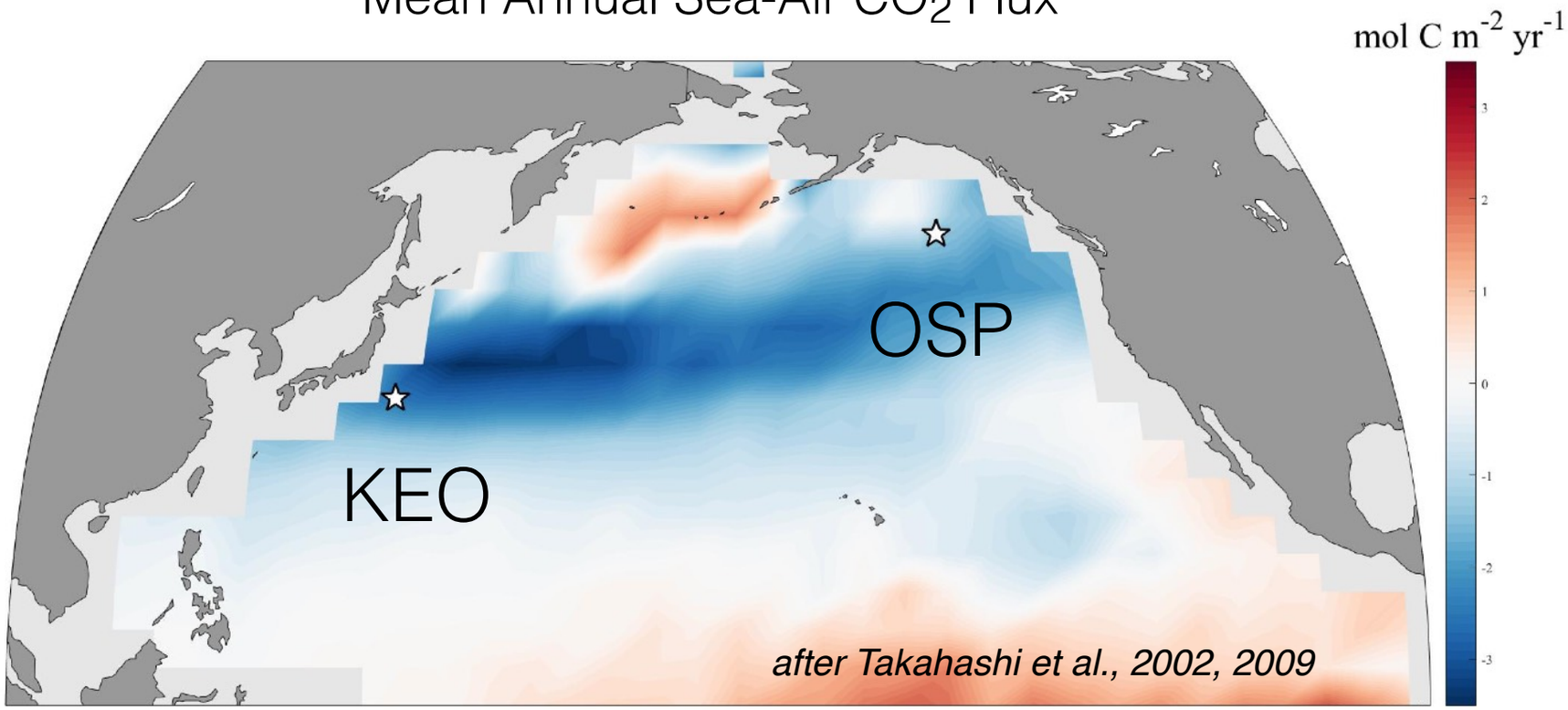


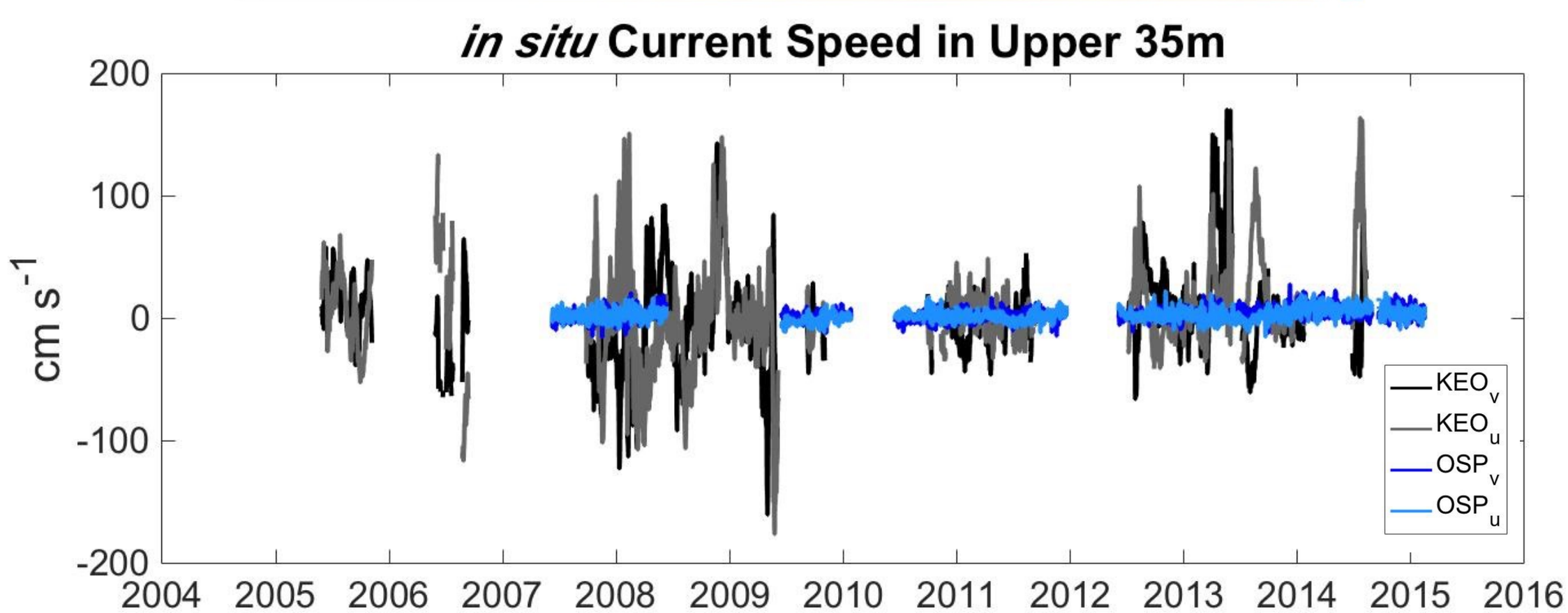




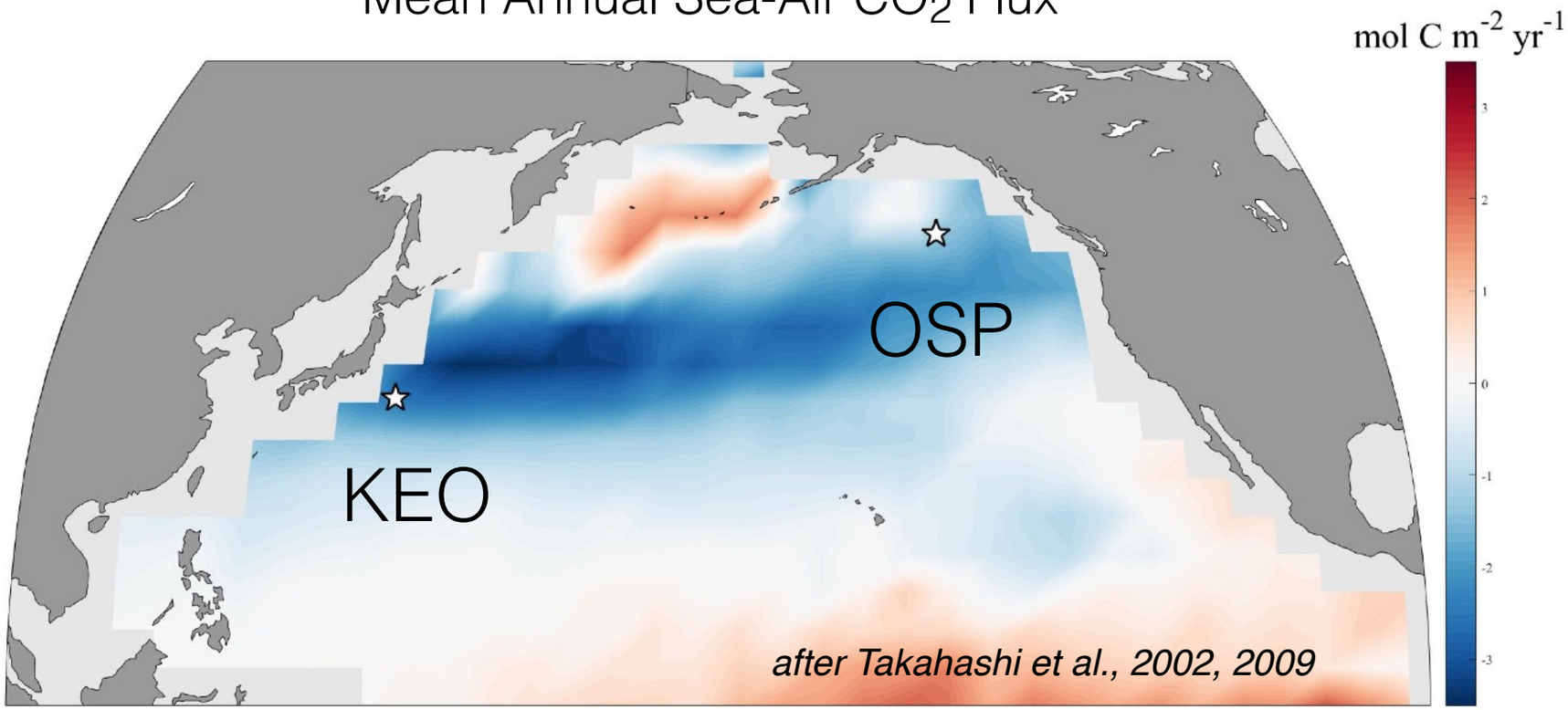


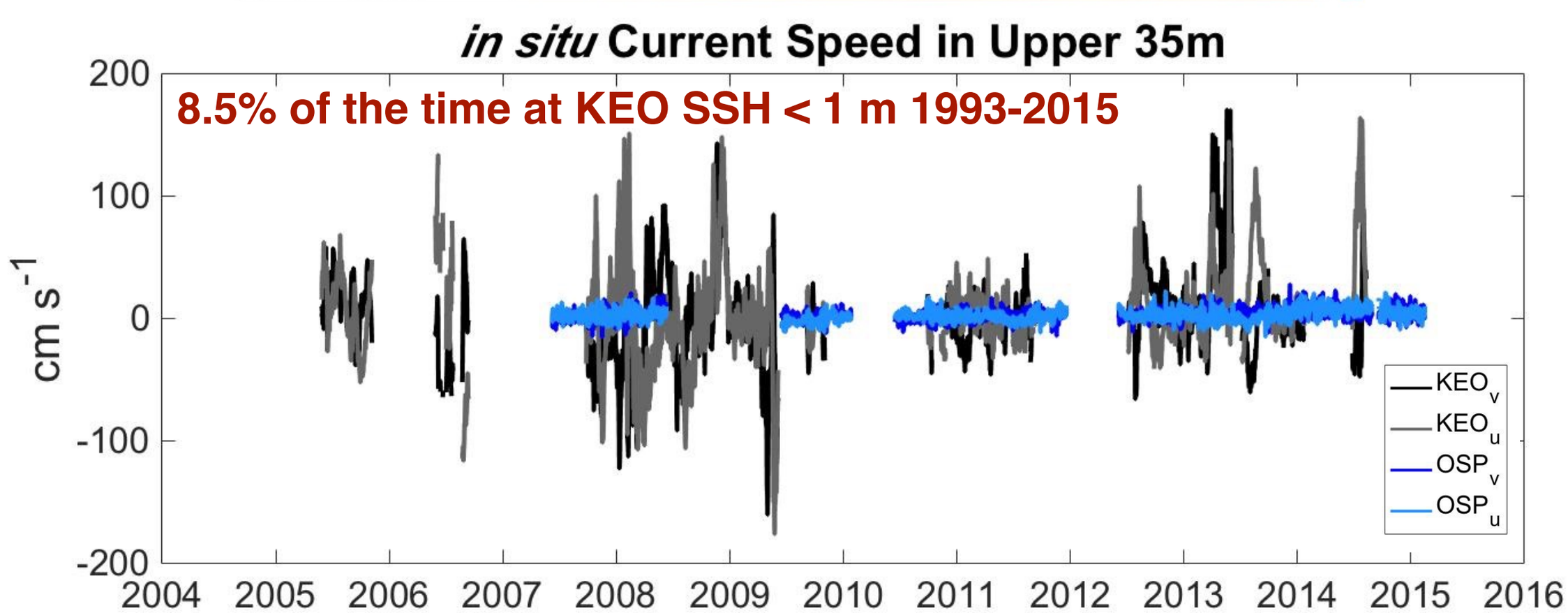
Potential Challenges Piloting Seagliders





Potential Challenges Piloting Seagliders





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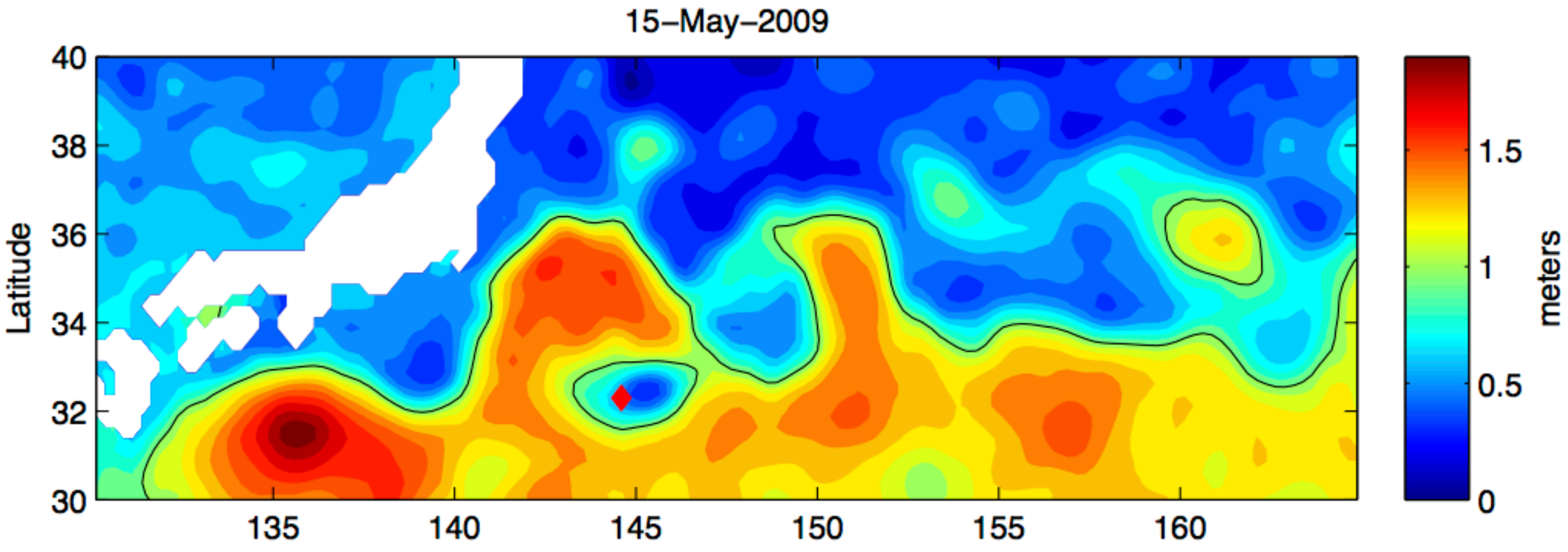

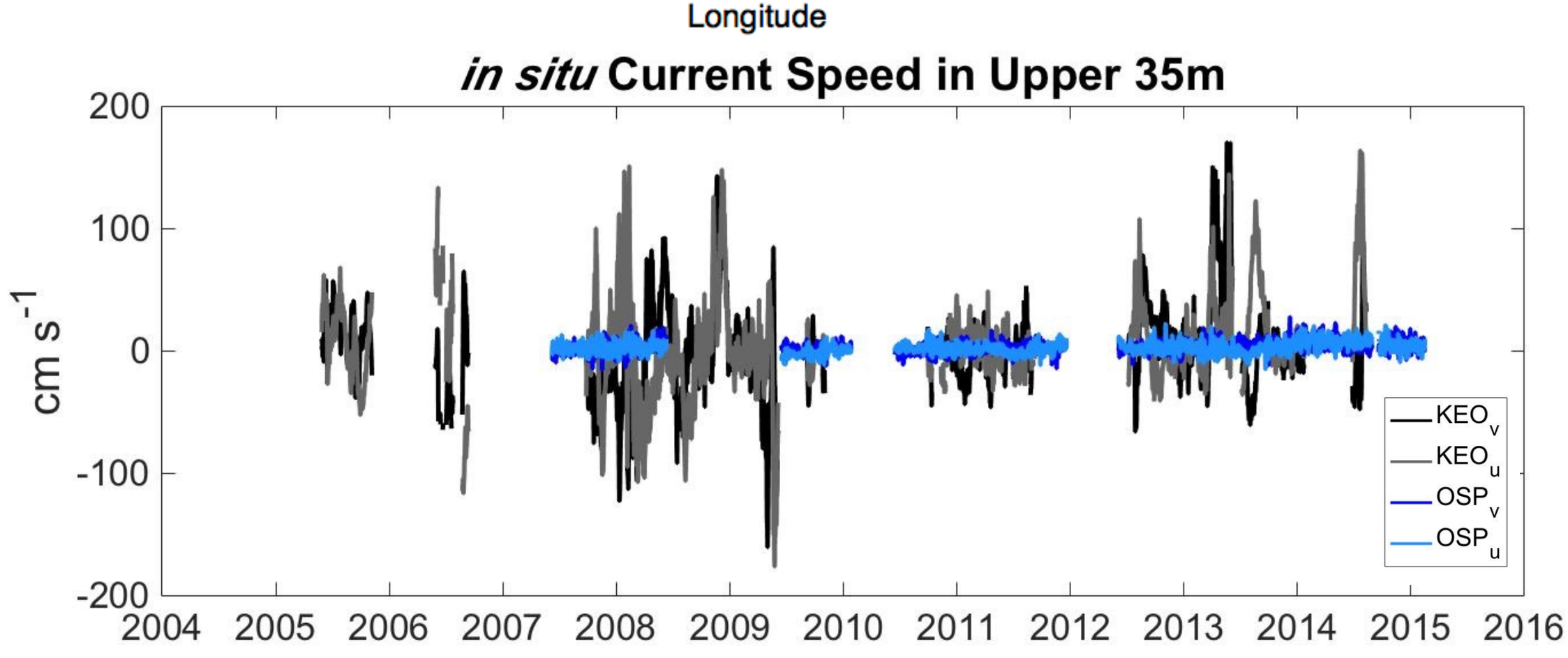

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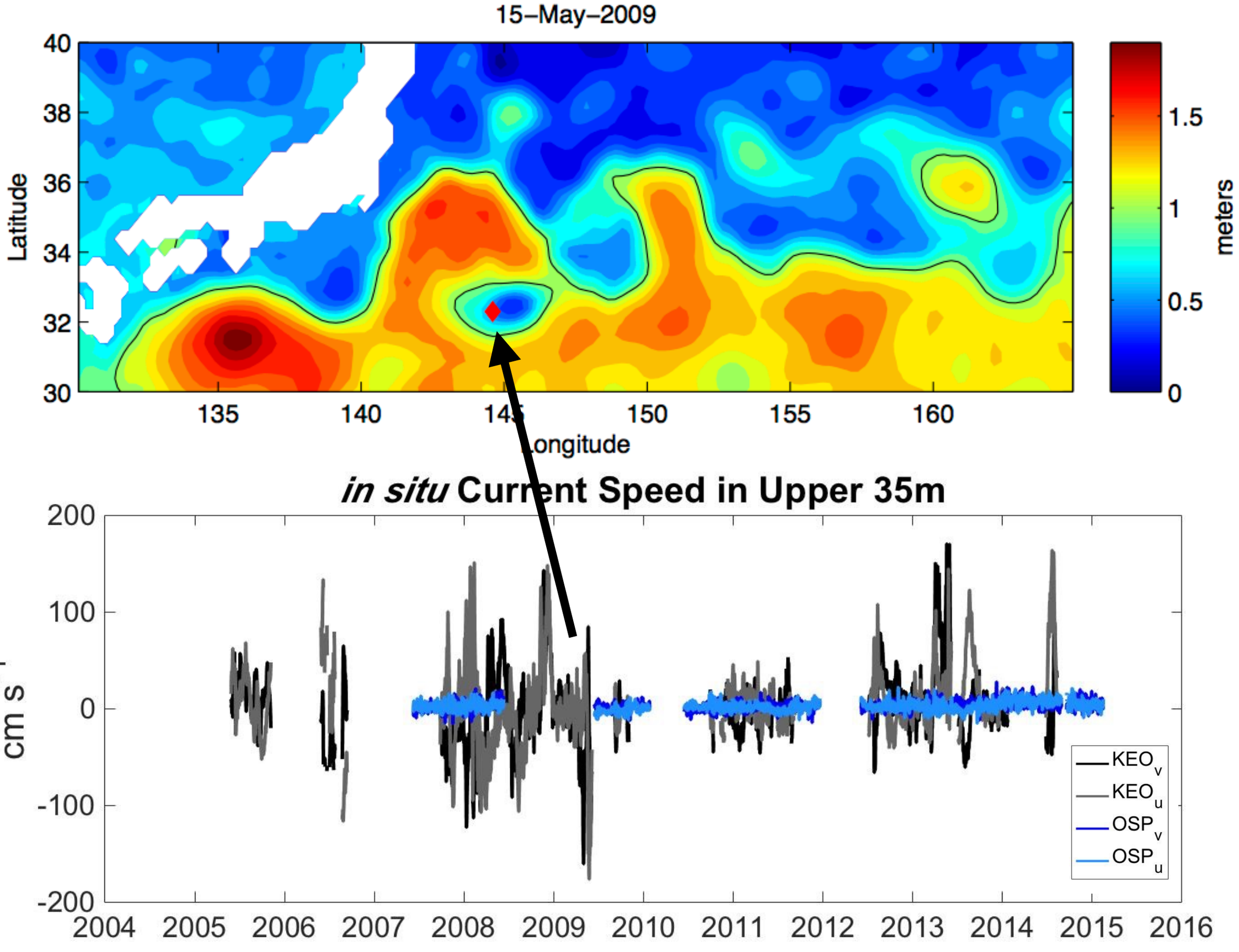

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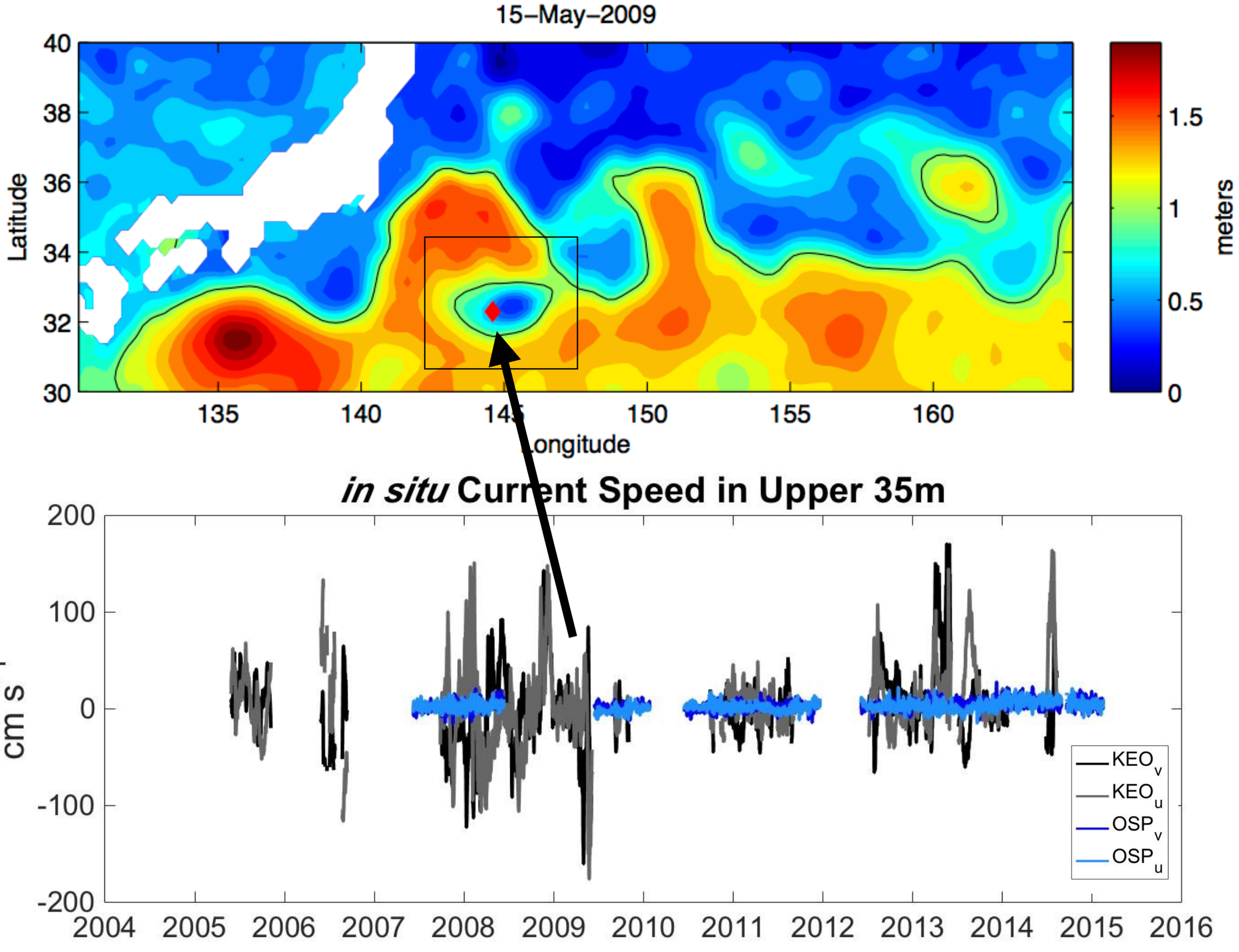

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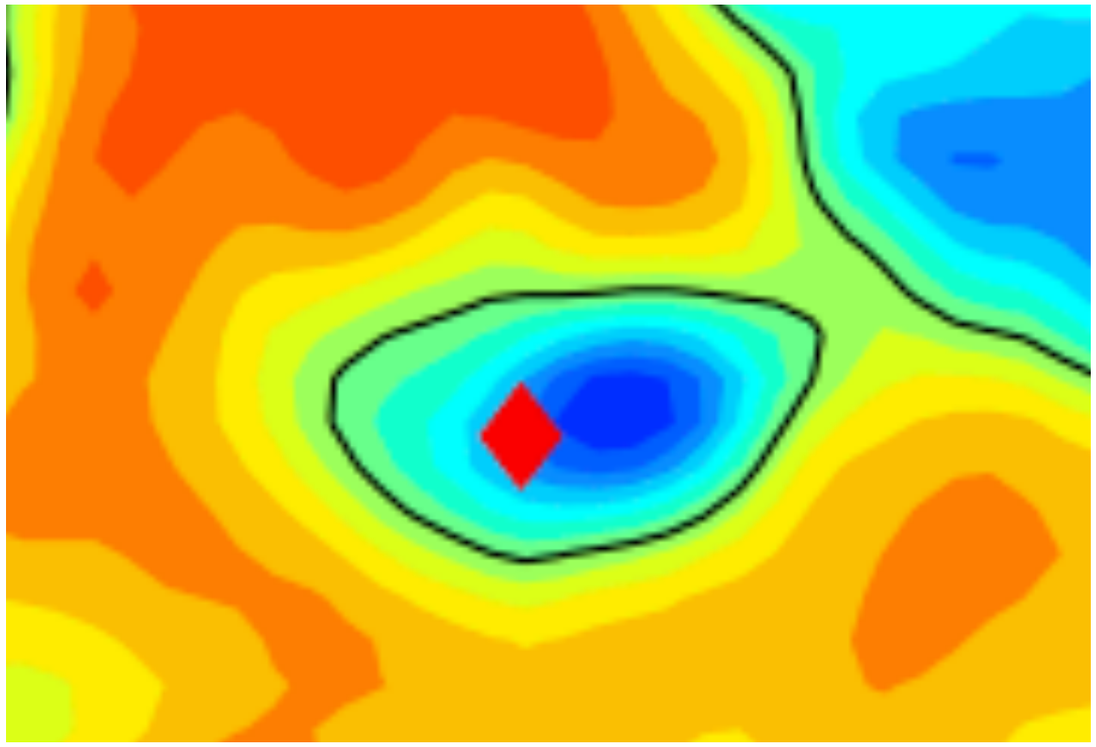

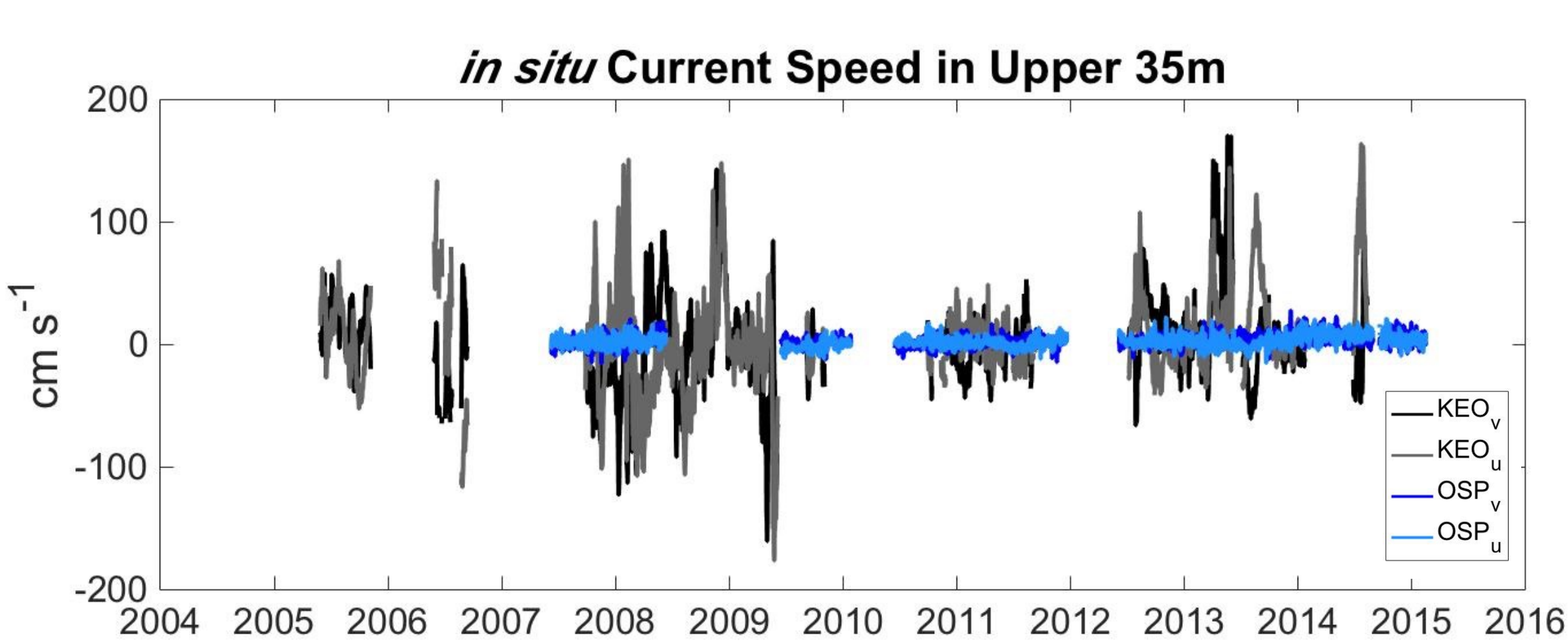

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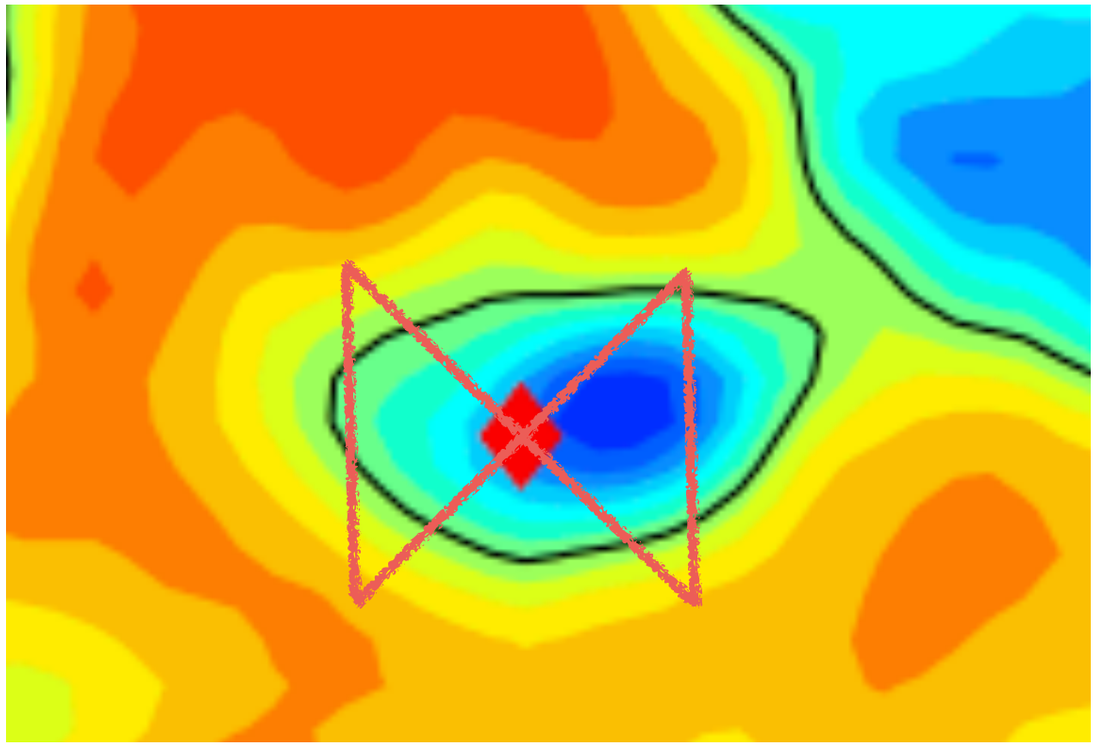

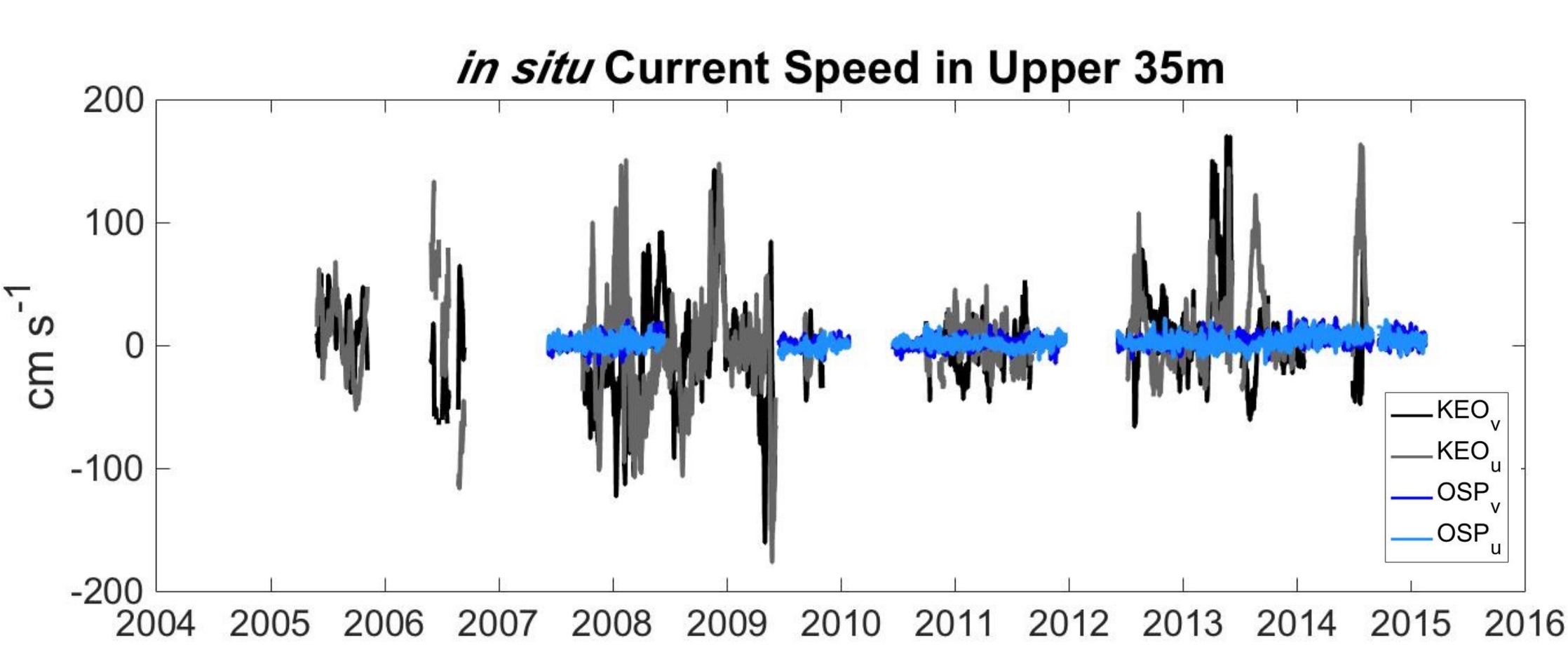

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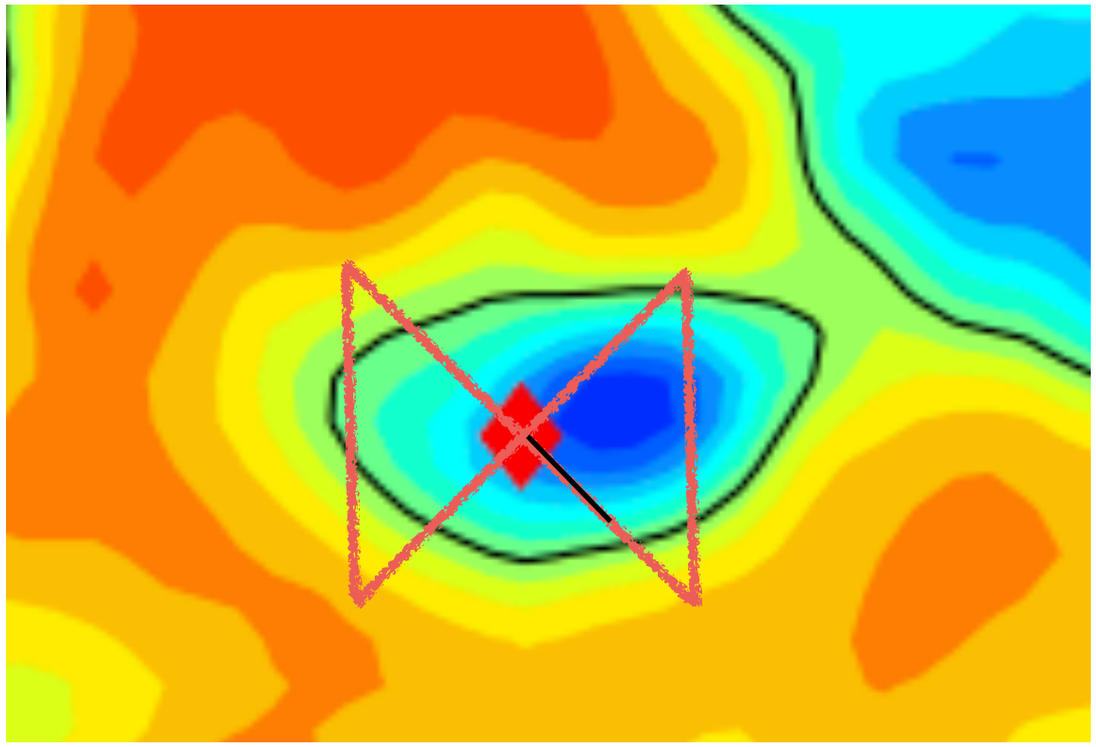

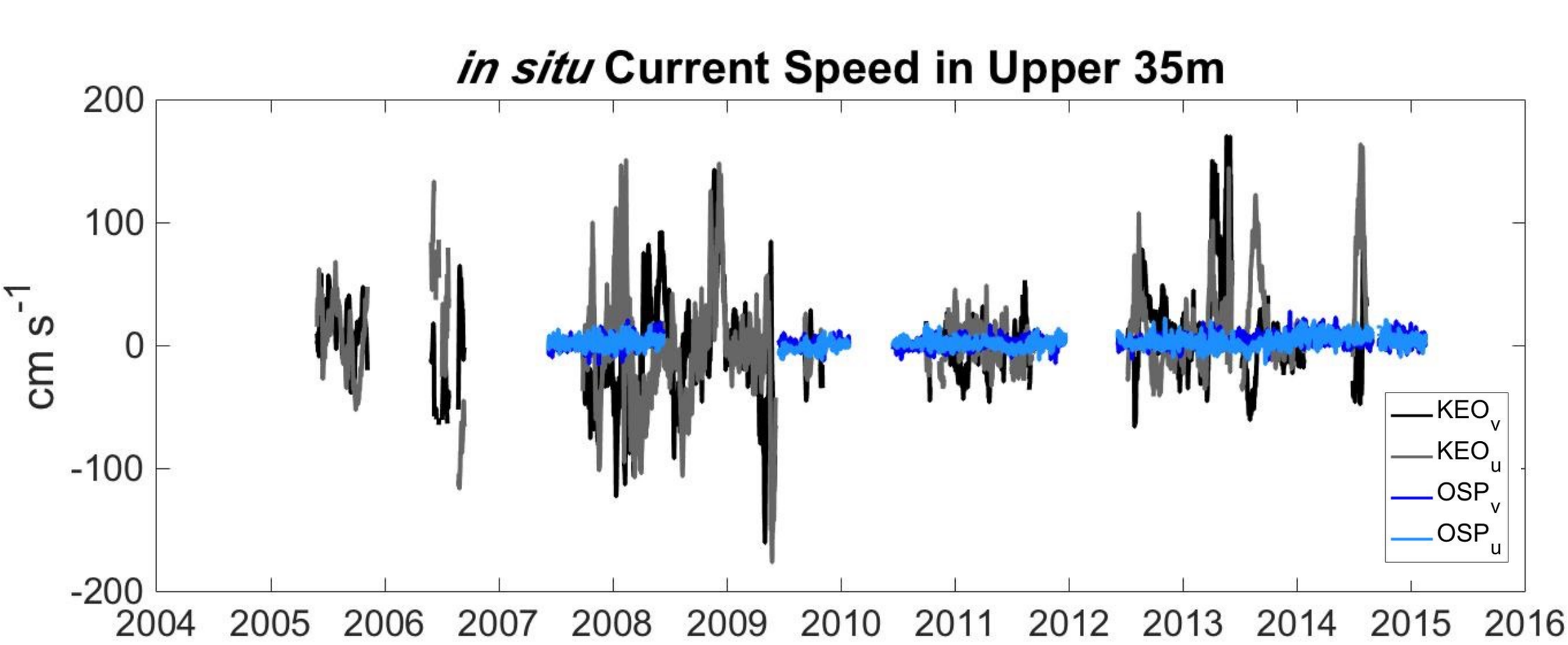

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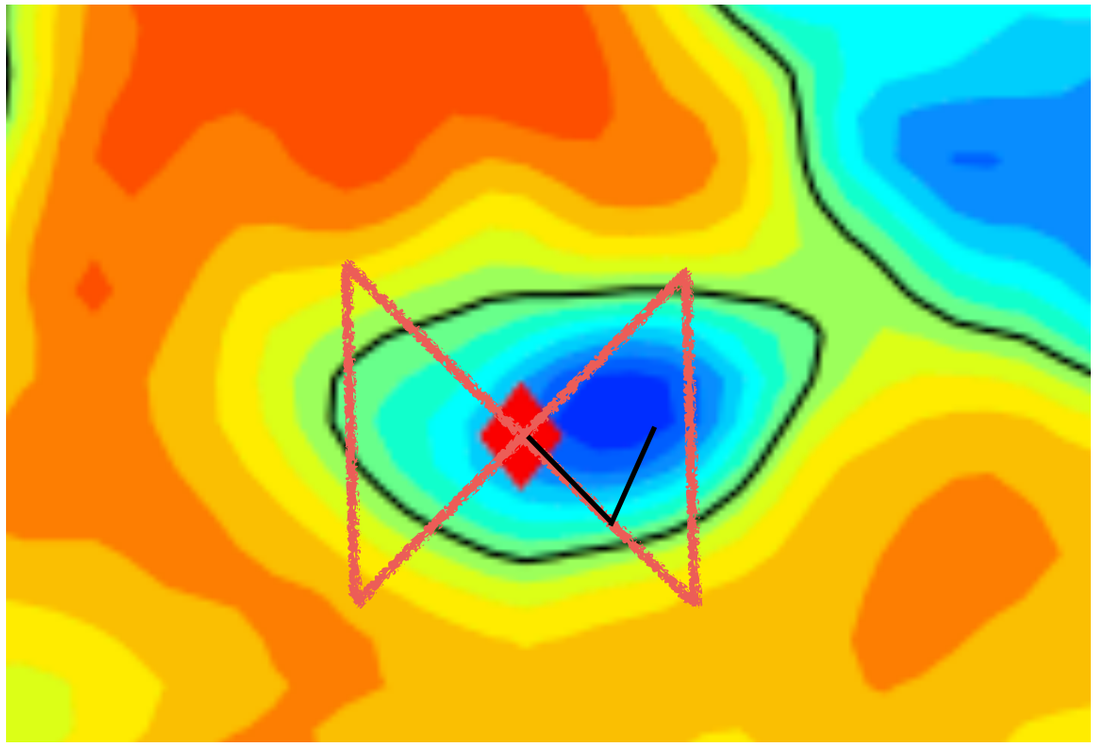

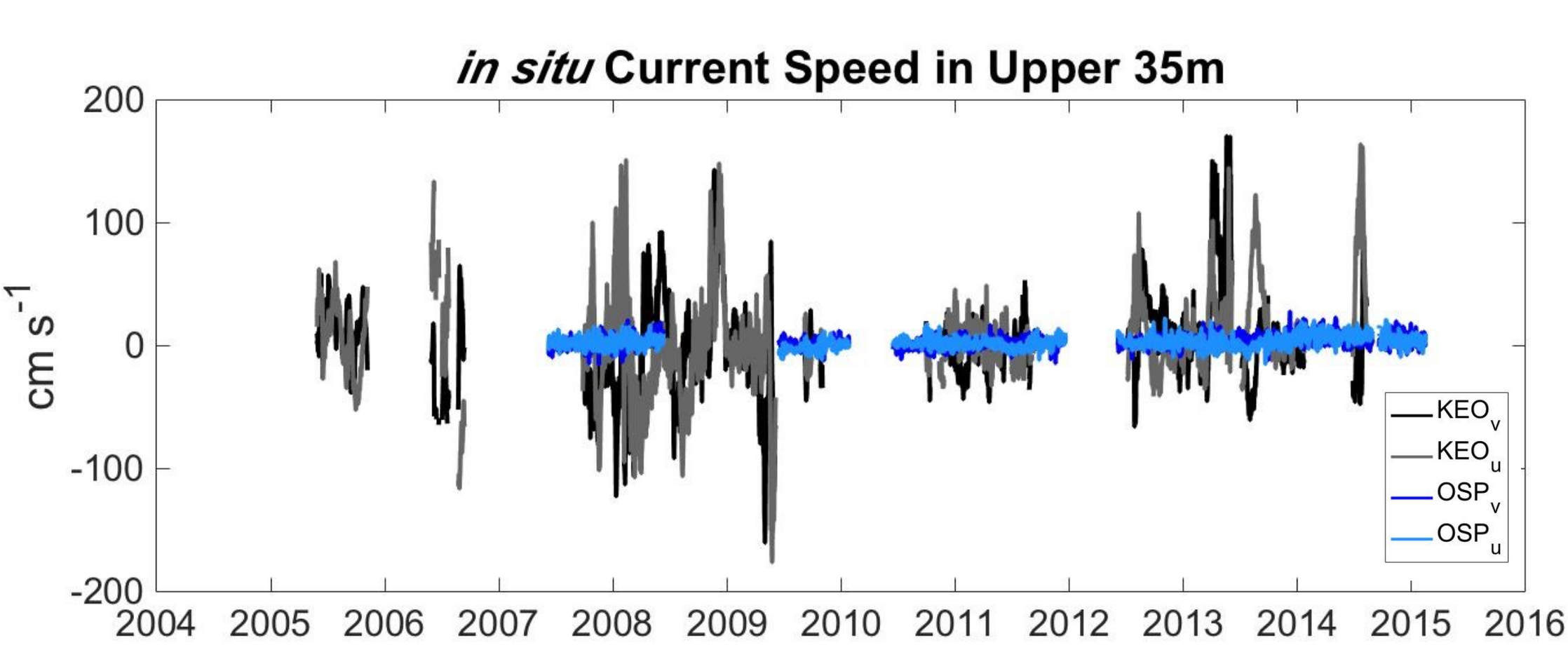

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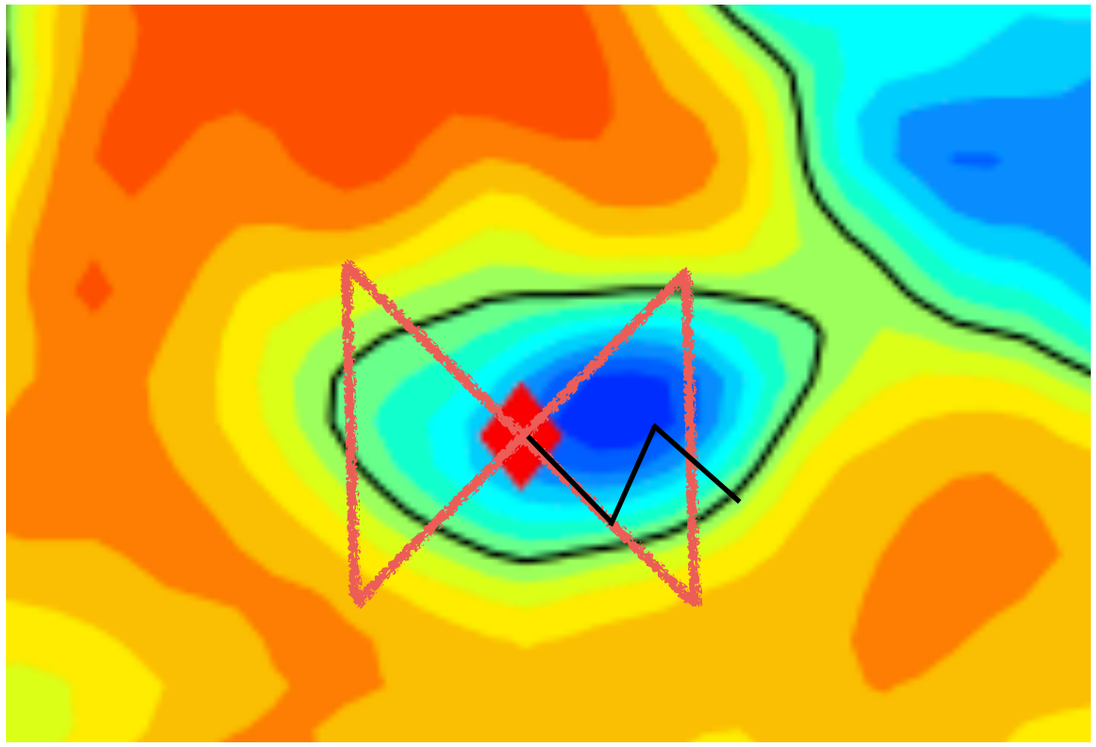

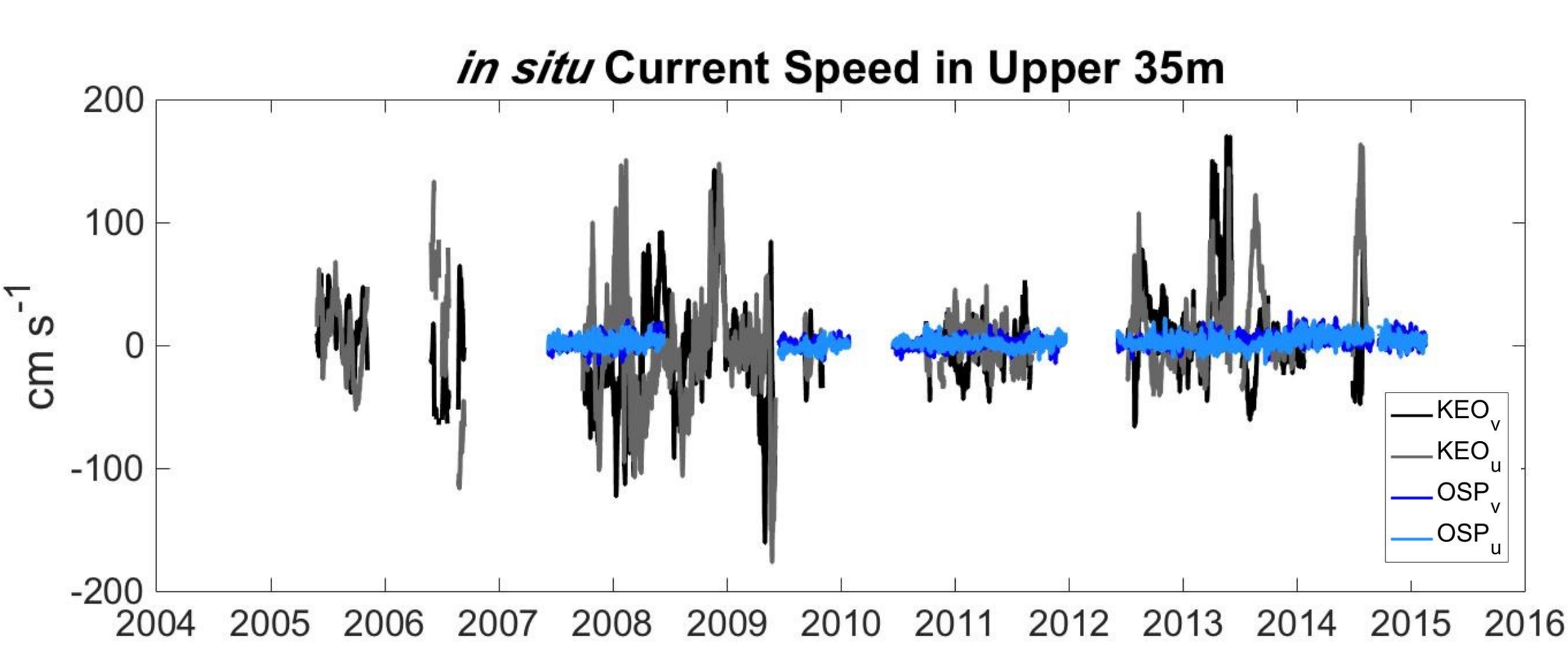

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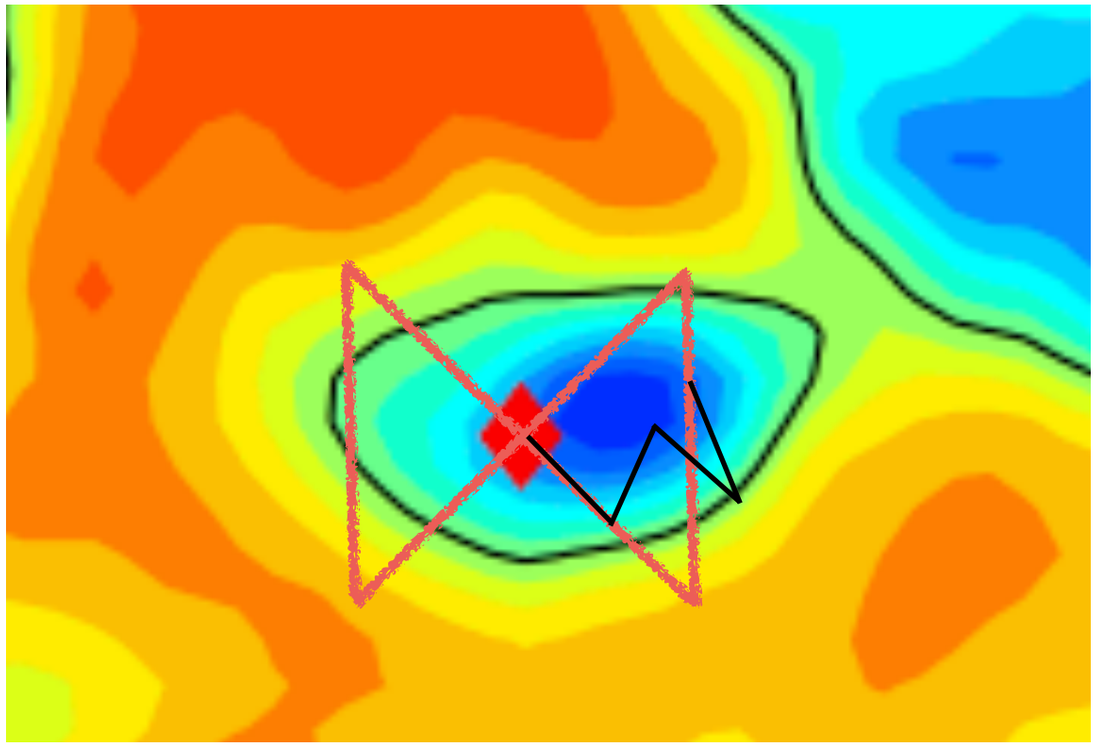

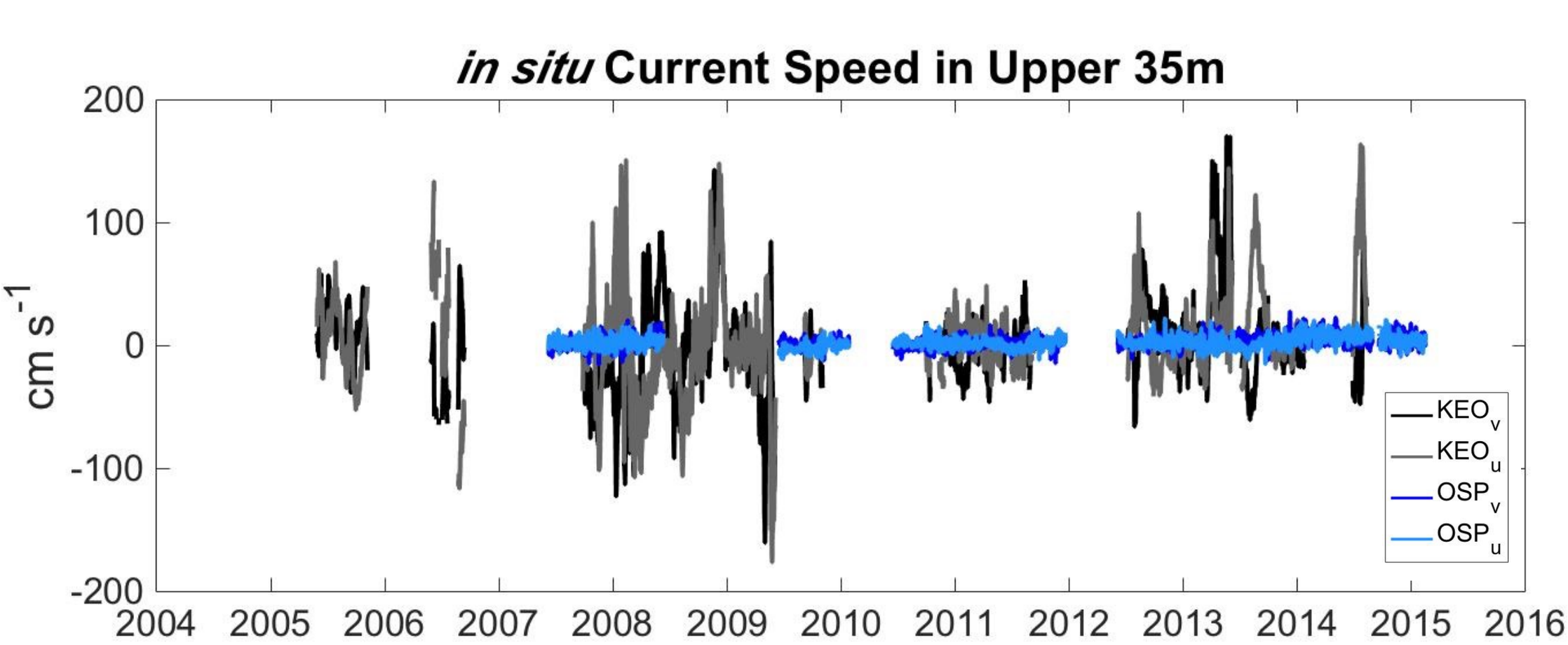

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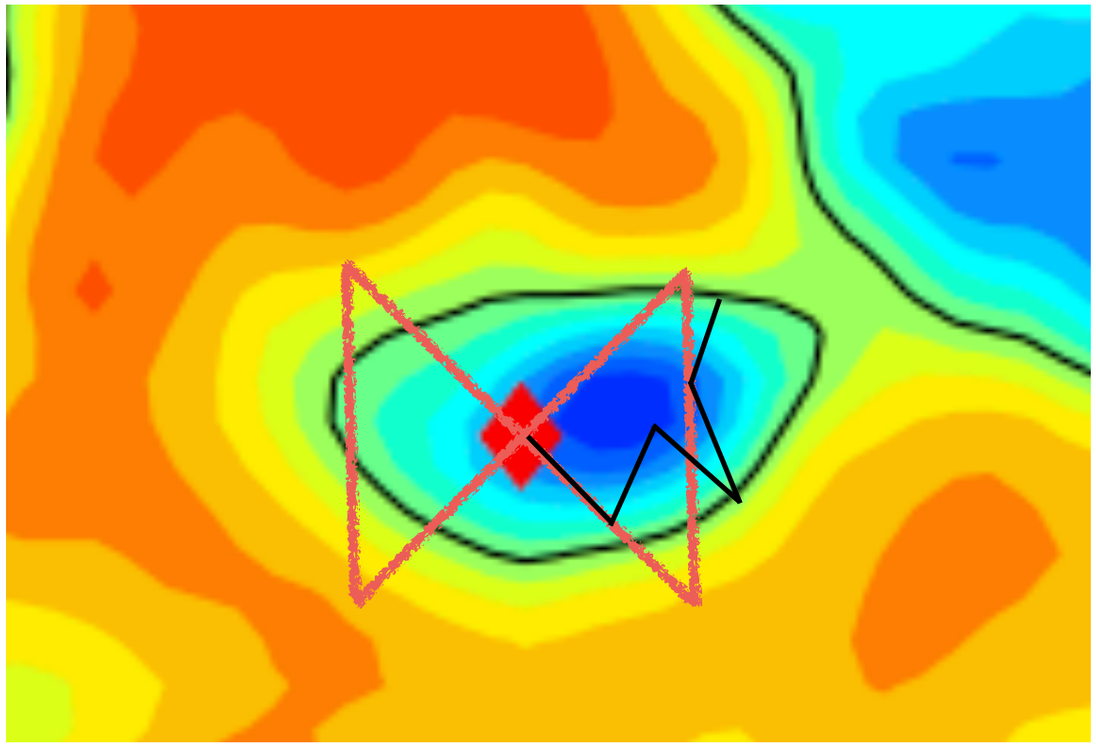

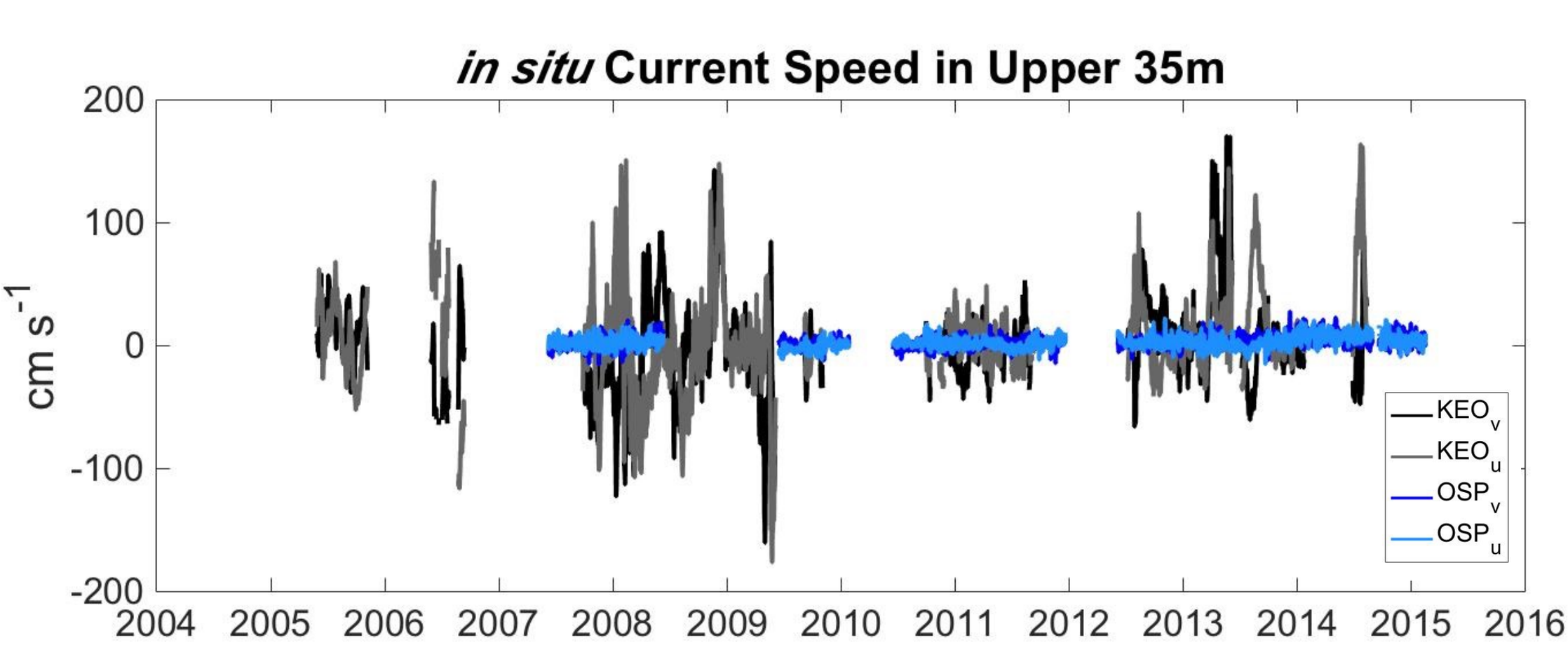

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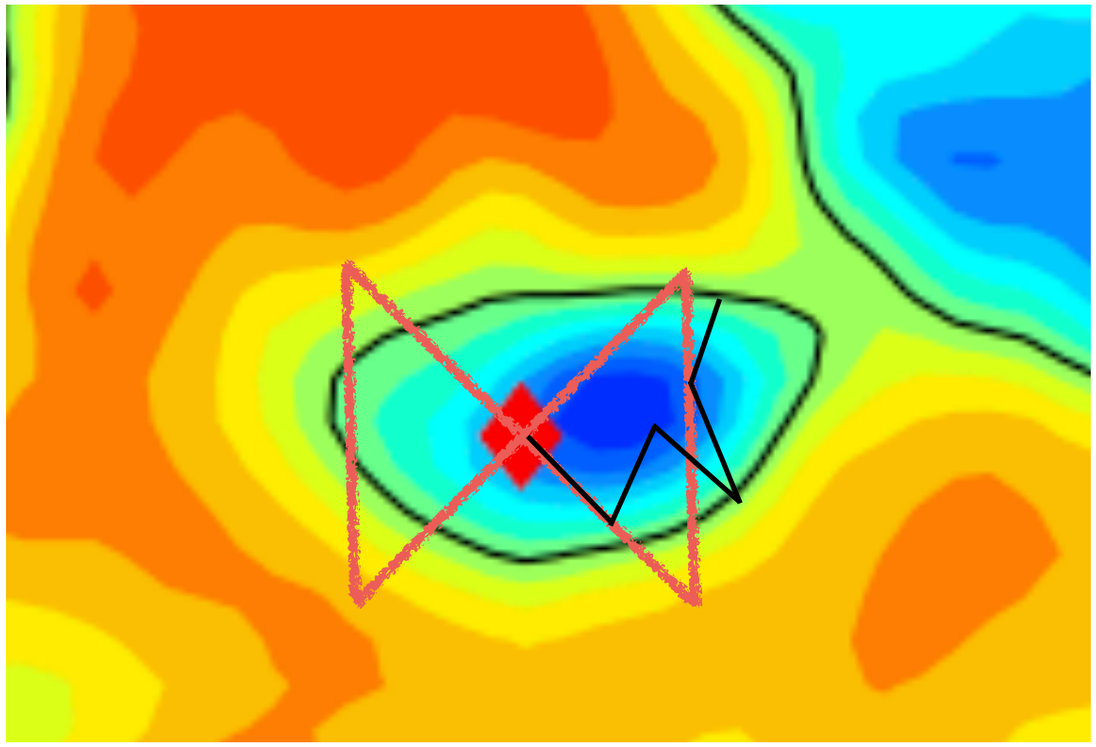

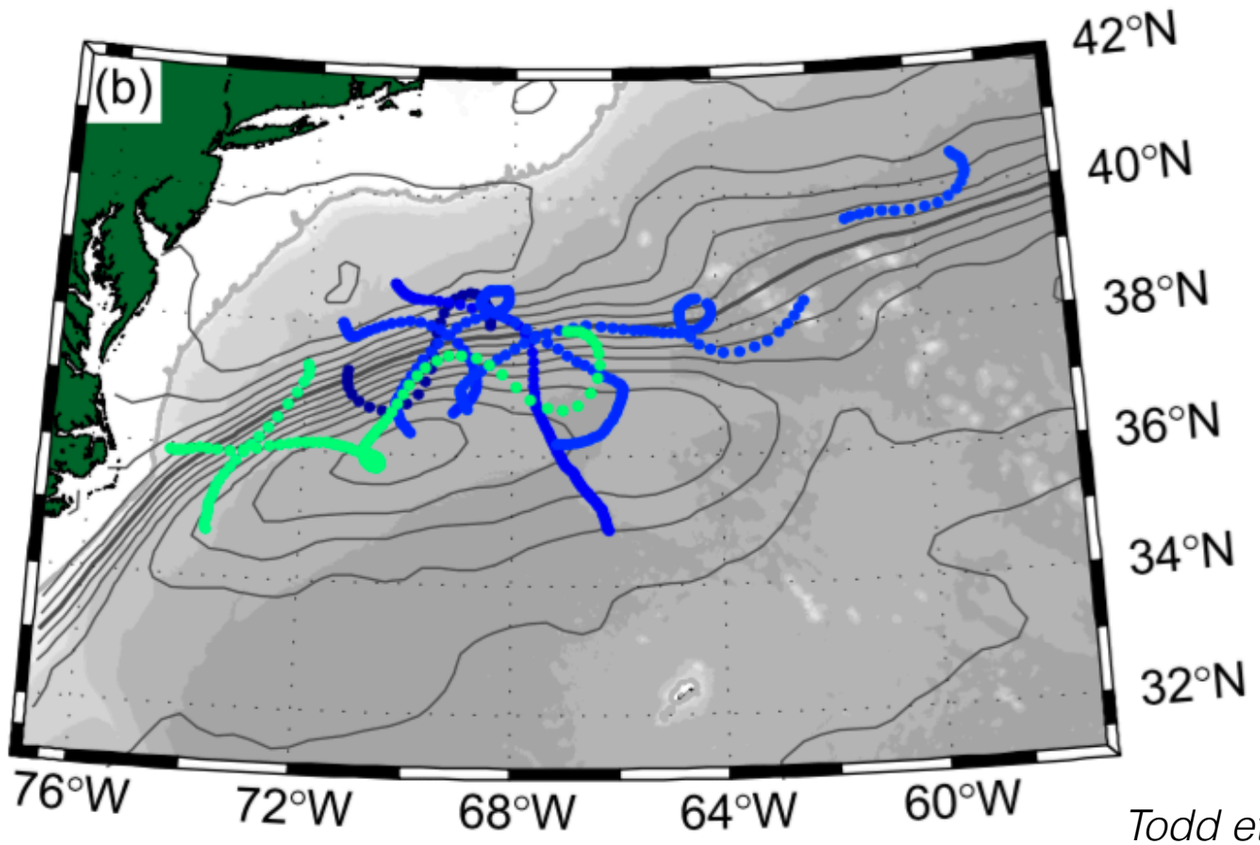

Todd et al., 2016