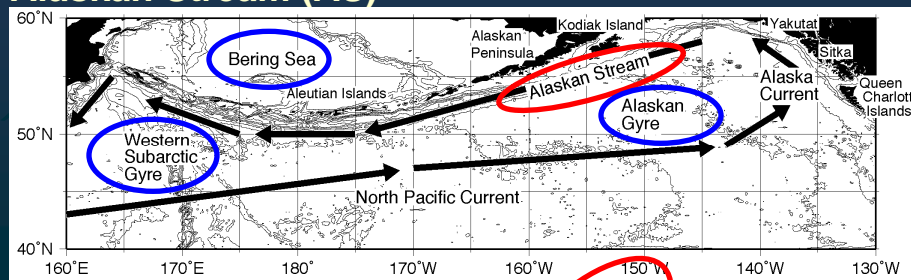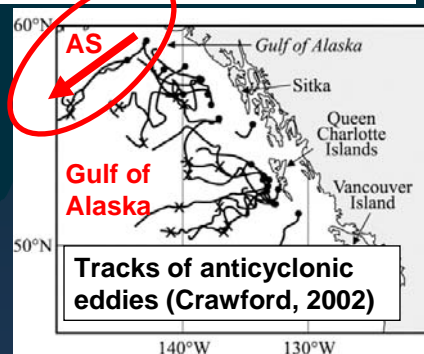## Alaskan Stream (AS)
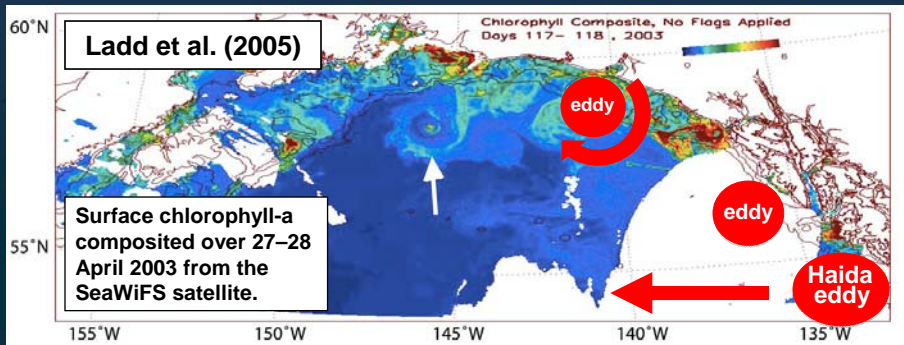

Alaskan Stream (AS)

- a connection btwn AG, WSAG & BSG
- volume, heat & freshwater transports (Onishi & Ohtani 1999)
- **Anticyclonic eddies**

Tracks of anticyclonic eddies (Crawford, 2002)

Water exchange by eddies in the GoA

Ladd et al. (2005)

Surface chlorophyll-a composited over 27–28 April 2003 from the SeaWiFS satellite.

Eddies in GoA: **heat, freshwater, nutrient & biota exchange** between shelf & off-shore regions by
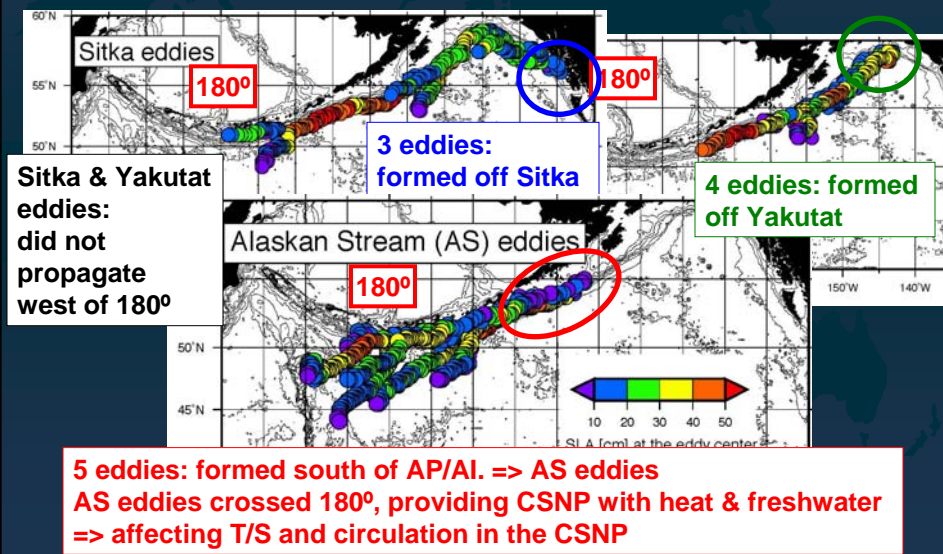- Containing shelf water at the eddy center & propargating offshore
- Advection in the outer ring of the eddy.
   (Crawford et al., 2005; Okkonen et al., 2003, Ladd et al., 2005; …)

Johnson et al. (2005): Haida eddies supply the central GoA (HNLC area) with **iron-rich** coastal water.

Some eddies in GoA went out of GoA. (e.g. crawford et al.,2000; Ladd et al., 2007)

Ueno et al. (2009) studied anticyclonic eddies propagating westward along the AS from GoA. => **12 long-lived eddies**

Sitka eddies

3 eddies: formed off Sitka

4 eddies: formed off Yakutat

Sitka & Yakutat eddies: did not propagate west of 180°

Alaskan Stream (AS) eddies

5 eddies: formed south of AP/AI. => AS eddies
AS eddies crossed 180°, providing CSNP with heat & freshwater
=> affecting T/S and circulation in the CSNP

北海道大学
HOKKAIDO UNIVERSITY

October 28, 2010, 17:20-17:40
PICES 2010 Annual Meeting
OCC, Portland, Oregon, USA

Observations of a Kenai eddy along the Alaskan Stream south of the Aleutian Islands
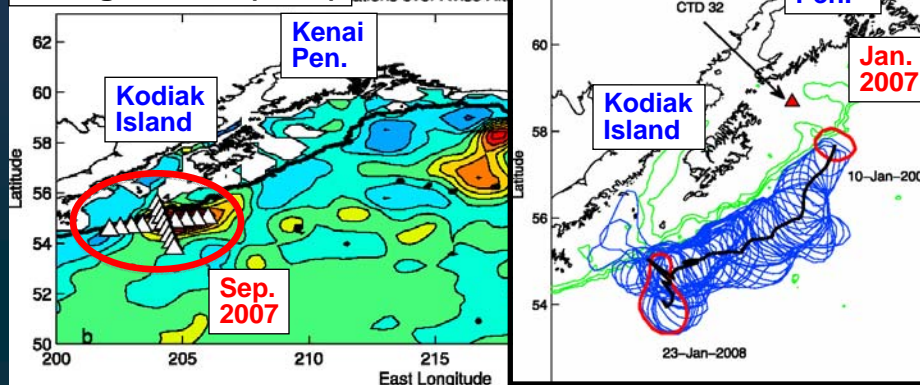
Hiromichi Ueno[1],

Hiroji Onishi[1], Sachihiko Itoh[2], Ichiro Yasuda[2],
Yutaka Hiroe[2,3], Toshio Suga[4,5] and Eitarou Oka[2,5]
1:Hokkaido Univ. 2:Univ of Tokyo 3:FRA
4: Tohoku Univ. 5:JAMSTEC

Rovegno et al. (2009)

...ations over Aviso Alt...

Kenai Pen.

Kenai Pen.

Kodiak Island
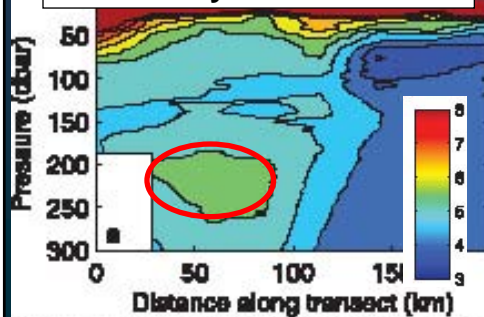
Jan. 2007

Kodiak Island

Sep. 2007

CTD 32

10-Jan-2007

23-Jan-2008

Rovegno et al., 2009 (R2009) observed an eddy near Kodiak Isl. in Sep. 2007 and found
  - This eddy formed in Jan. 2007 near Kenai Peninsula,
         an area not previously studied as a formation region.
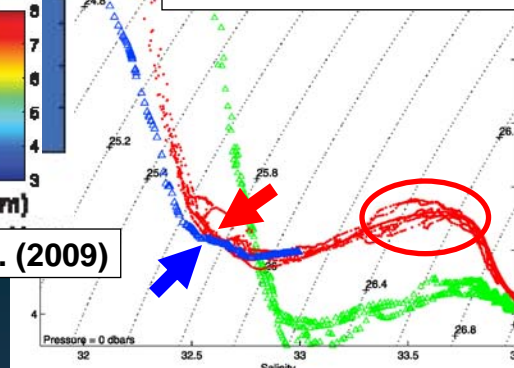 -> They called the eddy a Kenai eddy

Kenai Eddy N-S Transect θ

T/S relations
➡ **Kenai eddy center**
➡ **Shelf near Kenai Pen.**
-Basin

Pressure (dbar)

Distance along transect (km)

Rovegno et al. (2009)

Pressure = 0 dbars

Salinity

R2009 indicated
- Kenai eddy has **warm core** at the eddy center.
- T/S of Kenai center agrees with shelf water near Kenai Pen.
=> Kenai eddy contains **warn shelf water** at the eddy center.

Eddy trajectories
by Rovegno et al. (2009)
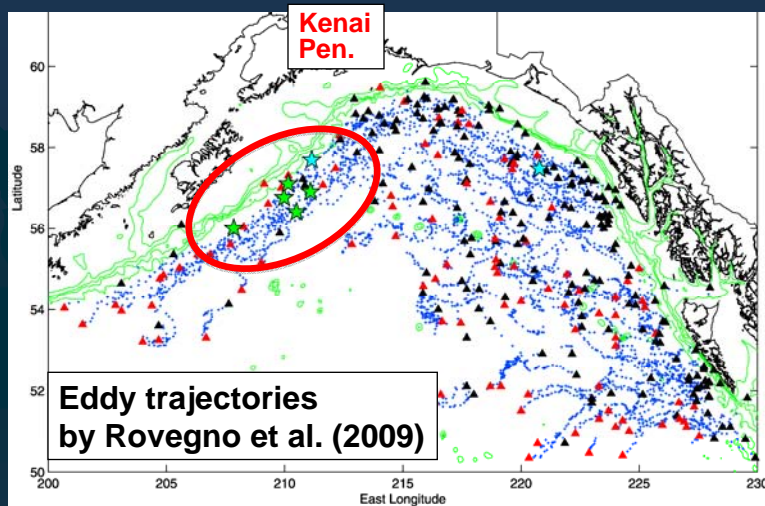
R2009 further found
- **6 eddies** formed south of Kenai Pen. during 1992-2008
=> The eddy observed in Sep 2007 was **not a singular event**.
=> **driving biological productivity** in the western Gulf of Alaska.

The Kenai eddy observed by R2009 further propagated westward along the Alaskan Stream.
=> ¶ How about trajectory, water properties etc. after R2009?

Last year, we observed the same eddy along the Alaskan Stream south of the Aleutian Islands by

Oshoro-maru

Hakuho-maru

In this presentation, we'd like to introduce
- Kenai eddy **trajectory** after obs. by R2009
- **water properties** in and around the Kenai eddy core

Data

- AVISO **Sea Level Anomaly (SLA)** data
- **T/S and Oxygen** data across the Kenai eddy core observed by T/S Oshoro-maru and R/V Hakuho-maru in summer 2009
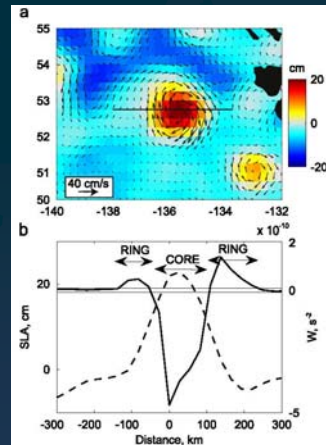- T/S data by Argo floats (preliminary analysis)

Method

- To track the Kenai eddy, we used **Okubo-weiss param. (W)**
  Eddy core: area of $W < -0.2\,\sigma_w$
  σ_w=SD of W over the SNP

$$W = s_{\mathrm{n}}^2 + s_{\mathrm{s}}^2 - \omega^2,$$

$$\omega = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}, \quad s_{\mathrm{n}} = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}, \quad s_{\mathrm{s}} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}.$$
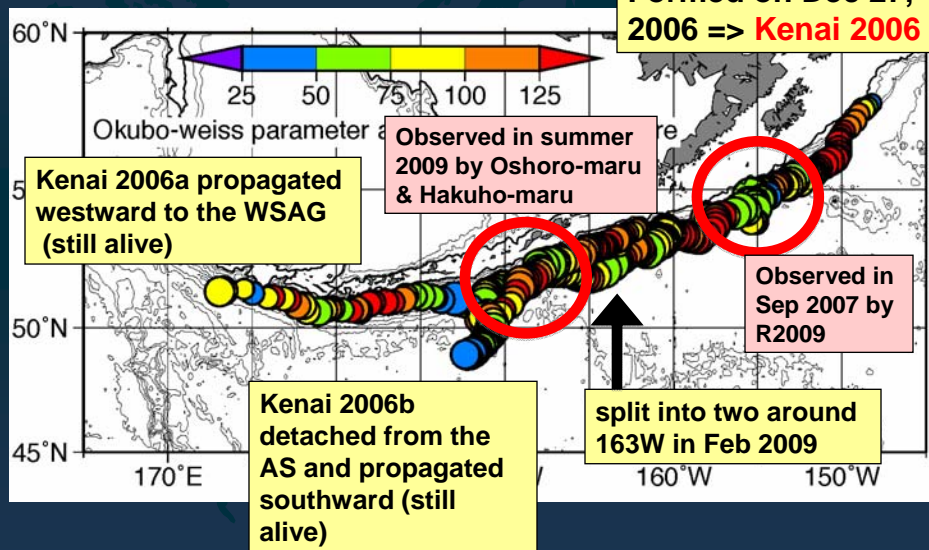
Vorticity   **normal & shear components of strain**

Henson & Thomas (2008)

Results

Kenai eddy trajectories from Dec 27, 2006 to Aug 10, 2010 (color: intensity)

Formed on Dec 27, 2006 => Kenai 2006

Kenai 2006a propagated westward to the WSAG (still alive)

Observed in summer 2009 by Oshoro-maru & Hakuho-maru

Observed in Sep 2007 by R2009

Kenai 2006b detached from the AS and propagated southward (still alive)

split into two around 163W in Feb 2009

Lon-time diagram of SLA along the AS

WSAG

Averaged within 2° south of 1000m depth contour

Kenai 2006b

Oshoro-maru Hakuho-maru

Kenai 2006a

Kenai 2006

Rovegno et al. (2009)

Kenai 2006 intensified several times btwn 2 obs.

=> May trigger modification of Kenai 2006 core water

GOA

SLA map around Kenai 2006a&b in June 2009 with obs stn. by Oshoro-maru

Hereafter, 2006a <= Hakuho

Although we missed the eddy center, strong T-max was observed near the eddy center.

55°N
CTD
XCTD
Kenai 2006b
52°N
50°N
49°N
174°W 172°W 170°W 168°W 166°W

Contour: 17Jun2009 A
Kenai 2006a

θ cross-section

Potential temperature [°C]
3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0

pressure (dbar)
0 100 200 300 400 500 600 700 800 900 1000

169W 168W 167W 166W

T/S relations (Oshoro2009)

Kenai 2006a

2009 Warm eddy core (T-max) 5-5.4 °C at 26.3-26.8 σ θ

T/S relations Rovegno et al. (2009)

Cooled by 0.4°C

2007 Warm eddy core (T-max) 5-5.8 °C at 26.3-26.8 σ θ

T-min around 26.8 σ θ at the periphery of the eddy core => cold water intrusion => Modification of eddy core

Salinity (psu)
32.0 32.5 33.0 33.5 34.0

Longitude
-170.0 -169.5 -168.5 -168.0 -167.0 -165.0

Kenai Core Casts Compared to CTD Casts 32 & 49
Kenai Core Casts
CTD Cast 32
CTD Cast 49

Hakuho KH-09-4 Sep 2009
CTD
Argo
MVP
Kenai 2006b
Kenai 2006a
Contour: 09Sep2009 AVISO SLA [

Obs stn by Hakuho are closer to the eddy center than those by Oshoro.

(b) Potential temperature

θ **cross-section**

pressure (dbar)

Potential temperature [ºC]
3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0

Latitude

Warm water was not confined to the eddy center.
=> Checking T/S relations

St40
St39
Kenai 2006a

T/S relations (Hakuho2009)

Potential temperature (
Salinity (psu)
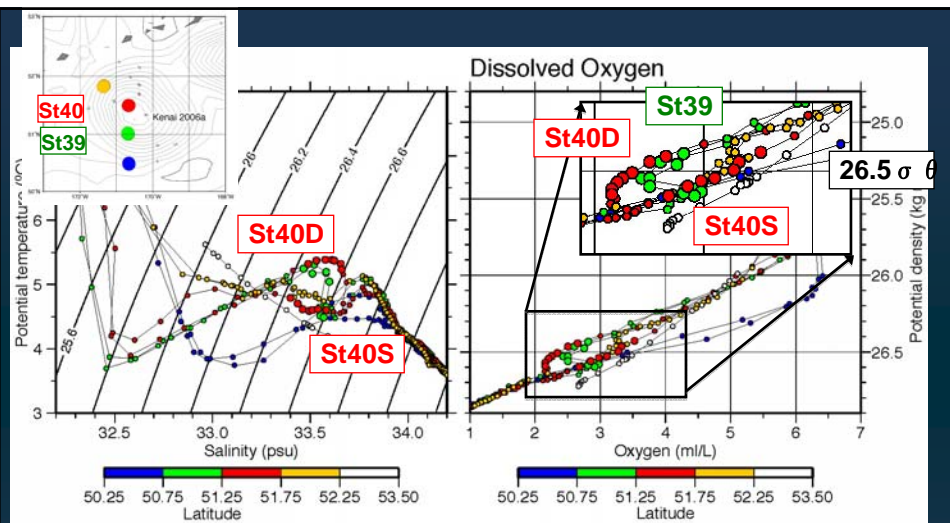
50.25 50.75 51.25 51.75 52.25 53.50
Latitude
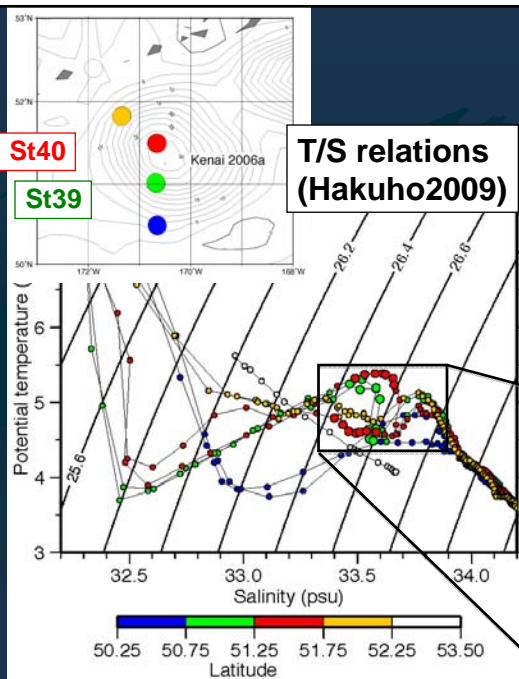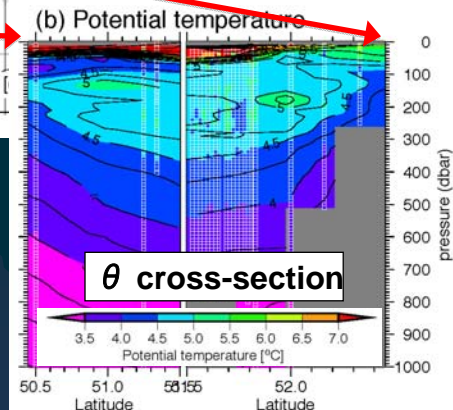
T/S relations =>
Strong spatial variation
e.g.
T/S of St40S&D (1.5km apart)
differ btwn 26.4 & 26.6 $\sigma\ \theta$
St40S: warm core
St40D: colder than periphery

Strong T-min observed
around 26.6 $\sigma\ \theta$ at St40S &
ST39.

26.4 St40S 26.6
St39
St40D
1ºC
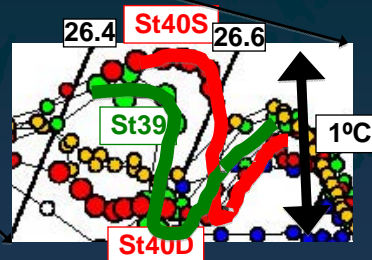
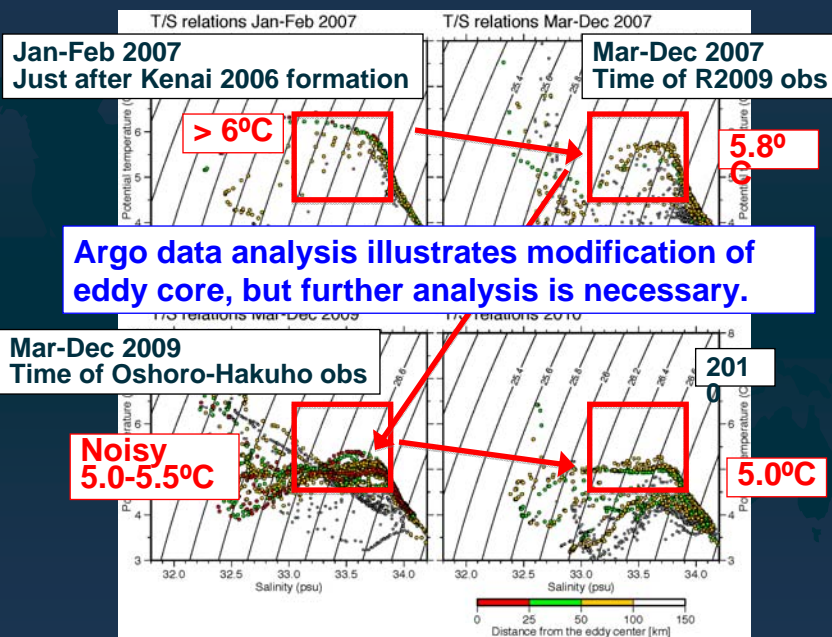**DO: relatively low around 26.5 $\sigma\ \theta$ at St40D & 39**
=> Corresponding to warm core
DO of Coastal water: Low (Whitney et al., 2007)
=> warm core water originates from coastal area
=> Cold & high-DO water intrusion modified the warm core water

Preliminary result: Argo float data analysis

Jan-Feb 2007
Just after Kenai 2006 formation

Mar-Dec 2007
Time of R2009 obs

> 6⁰C

5.8⁰C

Argo data analysis illustrates modification of eddy core, but further analysis is necessary.

Mar-Dec 2009
Time of Oshoro-Hakuho obs

2010

Noisy 5.0-5.5⁰C

5.0⁰C

Summary

We investigated a Kenai eddy (Kenai 2006) through analysis of satellite, ship-obs & Argo data and found

- Strong modification of Kenai eddy core

Characterized by cold intermediate water intrusions at the eddy core.
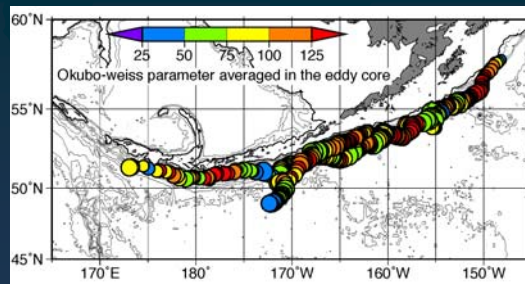
Data analyses are continuing…
with Tsuda-san Nishioka-san, Detobata-san …
- Argo data analysis
- Analysis of nutrient and iron data (Hakuho-maru)
- Analysis of phyto & zooplankton data (Hakuho-maru)
=> Clarify the properties and impact of Kenai eddy

MODIS Chl-a concentration

Kenai 2006a

Kenai 2006b