Remote Sensing in the Bering Sea and the Effects of Processes in the Bering Sea Basin

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Oshoro-Maru at Pier 66 Seattle in summer 2001
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• Two Topics
  - Coccolithophore Bloom dynamics during 1997-2002
  - Seasonal and interannual variability of Bering Sea Eddies along the green belt
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Background

OCEAN DEPTHS OF THE ARCTIC OCEAN AND ADJACENT SEAS

Max Depth
5450 m

Ecosystem

Studies of Sub-Arctic Seas Program
Study Area

West-East Comparison

North-South Linkage

Arctic Ocean

Okhotsk Sea

Bering Sea
The Green Belt (Springer et al., 1996)

Bering Sea Eddies

Coccolithophore Blooming


Sediment Trap (1990-2002)
Two Topics
Bering Sea Ecosystem from Space


2. Seasonal and interannual variability of Bering Sea Eddies along the green belt
Two Topics

Bering Sea Ecosystem from Space

2. Seasonal and interannual variability of Bering Sea Eddies along the green belt
May 1997 OCTS Coccolithophore mask Image

→ OCTS found 1997 bloom!!

OCTS Coccolithophore mask image in 1997 spring

SeaWiFS coccolithophore bloom Image from Sep.19 to Oct.3

Iida et al. (2002)
Variability of coccolithophore bloom and Sea Ice

Composite Monthly Sea ice and Coccolithophore Mask Image
Variability of coccolithophore bloom and Sea Ice

Composite Monthly Sea ice and Coccolithophore Mask Image

Coccolithophore bloom area

Feb. 1999
5 years Variability of coccolithophore bloom area

- 1998
  → massive summer bloom
- 1999
  → weak spring and fall bloom
- 2000
  → massive bloom (Apr-Jun-Sep.)
- 2001
  → low sea ice concentration weak bloom
- 2002
  → weak bloom
1998 Summer

Positive SST Anomaly!!

SST anomaly and coccolithophore blooms

Histogram of SST anomaly in cocco bloom area
SST anomaly and coccolithophore blooms

1999 Summer

Negative SST Anomaly!!
We found coccolithophore bloom using OCTS image in spring, before observation by SeaWiFS image in autumn 1997.

Coccolithophore bloom of *Emiliania huxleyi* began spring and distributed at the surface layer from 20m to 100m in depth in the southeastern Bering Sea Shelf.

Large bloom in 1998 and 2000, weak bloom in 1999 2001 and 2002. Positive sea surface temperature (SST) anomaly was corresponding to occurrence of massive coccolithophore blooms.
Two Topics
Bering Sea Ecosystem from Space


2. Seasonal and interannual variability of Bering Sea Eddies along the green belt
1. Shelf-Slope exchange
   Stabeno et al., 1999

2. Nutrient supply & high chl-a concentration
   Sapozhnikov, V.V., 1993
   Mizobata et al., 2002

3. Positive correlation of Walleye pollock larvae & Bering Sea eddies
   Schumacher and Stabeno, 1994
   Napp et al., 2000

4. High Iron & Low Nutrient of Shelf water
   Low Iron & High Nutrient of Basin water
   McRoy et al., 2001
Questions

Little are known about the horizontal distribution of mesoscale eddies along the shelf edge....

How many eddies are there along the shelf edge?

How much impacts does it affect on phytoplankton distribution and primary production along the “Green Belt”?
Data and Method

1. **TOPEX/ERS-2 daily Sea Surface Height Anomaly (SSHA) image 1998 Jan.1. ~ 2001 Dec.30**
   (http://www-ccar.colorado.edu/research/topex/html/topex.html)

2. **TOPEX/Poseidon 10days cycle SSHA**
   1997 Jan. ~ 2001 Dec (cycle 158 ~ 342)

3. **Orbview2/SeaWiFS L3 chl-a concentration**
   1997 October. ~ 2001 May

4. **Primary production**
   calculated from SeaWiFS chl-a, PAR and NOAA/AVHRR sea surface temperature using Kameda and Ishizaka model [advanced VGPM model]
   1997 October. ~ 2001 May
Results - 1: Lifetime of eddies

244(H:124, L:120) in 1998
256(H:137, L:119) in 1999
312(H:141, L:171) in 2000
324(H:150, L:174) in 2001
Results - 2: Bering Sea eddy field

SSHAs calculated from Merged Geophysical Data Record – B[JPL] (Benada, 1997)

10 days cycle data along the shelf break of the Bering Sea

D-79

Zhemchug canyon

Pribilof canyon
Results - 2: Bering Sea eddy field

Time-latitude isopleths of T/P SSHAs

- 0.43 cm/s (1998)
- 0.54 cm/s (1999)
- 1.0~1.8 cm/s (2000-2001)
Results - 3 : Biological conditions (PPeu)

About 6 months

Time-latitude isopleths of primary production estimated using Kameda and Ishizaka model (2002)
Results - 3: Biological conditions (PPeu)

Averaged primary production along the shelf break

PPeu (gC m\(^{-2}\) month\(^{-1}\))

- 1998
- 1999
- 2000

Averaged primary production along the shelf break
Conclusions

Bering Sea eddies and primary production

Satellite Remote sensing revealed,

1. The interannual variability of Bering Sea eddy field affected by the BSC transport. (From 2000, there was an increase in Bering Sea eddy field.)

2. Difference in Propagation and distribution characteristics between cyclonic and anticyclonic eddy

3. An importance of Bering Sea eddy field for maintaining the productivity.
Future Application
Bering Sea Ecosystem from Space

**New method of sea ice thickness estimation** using passive microwave radiometers
- amount of sea ice production interannual
- variability of sea ice thickness

**New ocean color data sets and Multi-sensor**
- SeaWiFS, two MODISs (from Aqua and Terra) and GLI (from ADEOS-II)
- The frequency of shutter chances is increasing and hyper-spectral data sets are available.
New method of sea ice thickness estimation

\[ H(cm) = -537.33 \cdot PR + 83.88 \cdot R_{37V/85V} - 6.91 \]

Tateyama et al. (2002)
Inter-seasonal out-of-phase response in the Okhotsk Sea and the Bering Sea

Tateyama et al. (2002)
New method of sea ice thickness estimation

Accumulated ice volume

Tateyama et al. (2003), unpublished
New ocean color data sets and Multi-sensor

Chlorophyll a

August 2002

MODIS

Suspended Matter

August 2002

MODIS
New ocean color data sets and Multi-sensor

MODIS False Color image

April 7, 2002
New ocean color data sets and Multi-sensor

ADEOS-II SeaWinds (Microwave)

Four days composite (Jan. 28- Jan. 31, 2003)
Some Suggestions

• **Bio-optical drifting buoy (TOGA-TAO type)** to study time-series primary production and biogeochemical process

• **ARGO-type bio-optical buoy system** (such as K-SOLO) to study vertical structure of biological processes in the basin region of the Bering Sea
Some suggestions: Instrumentation

**Bio-optical Drifting Buoy**

**Sensors**

1. Barometer (Ba)
2. Sea Surface Temperature (SST)
3. Air Temperature (AT)
4. Lu(683nm)
5. Lu(670nm)
6. Lu(555nm)
7. Lu(510nm)
8. Lu(490nm)
9. Lu(443nm)
10. Lu(412nm)
11. Ed(490nm)
Some suggestions: Instrumentation

**Bio-optical Drifting Buoy**

TSRB Obs. map

Mooring optical buoy

\[
\text{Chl} = 0.59807 \times \left( \frac{\text{Lu}_{443}}{\text{Lu}_{555}} \right)^{-1.04598}
\]
Comparison trajectory with TOPEX and SeaWiFS data

2001
Variability of SST and chl–a field in 2001

Anti-cyclonic
Cyclonic
Spin out
Some suggestions: Instrumentation

Bio-optical Drifting Buoy

Thank you

Photo by Sei-ichi Saitoh
Baby Island, Aleutian Islands
in Summer, 1975