

# Sea level variation in the Arctic Ocean and subarctic region

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## content

- What is sea level change?
  - The role of sea level change in the climate change
  - secular variation of the relative sea level & Numerical experiments in the 20th century
  - sea level variation and steric effects in the Bering Sea
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# Sea level change

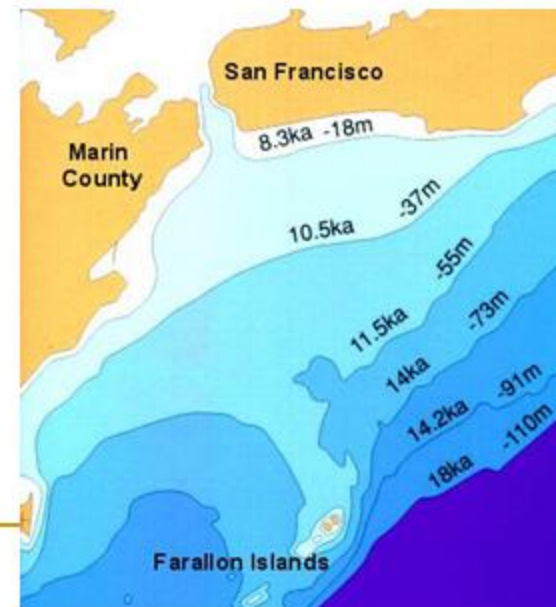
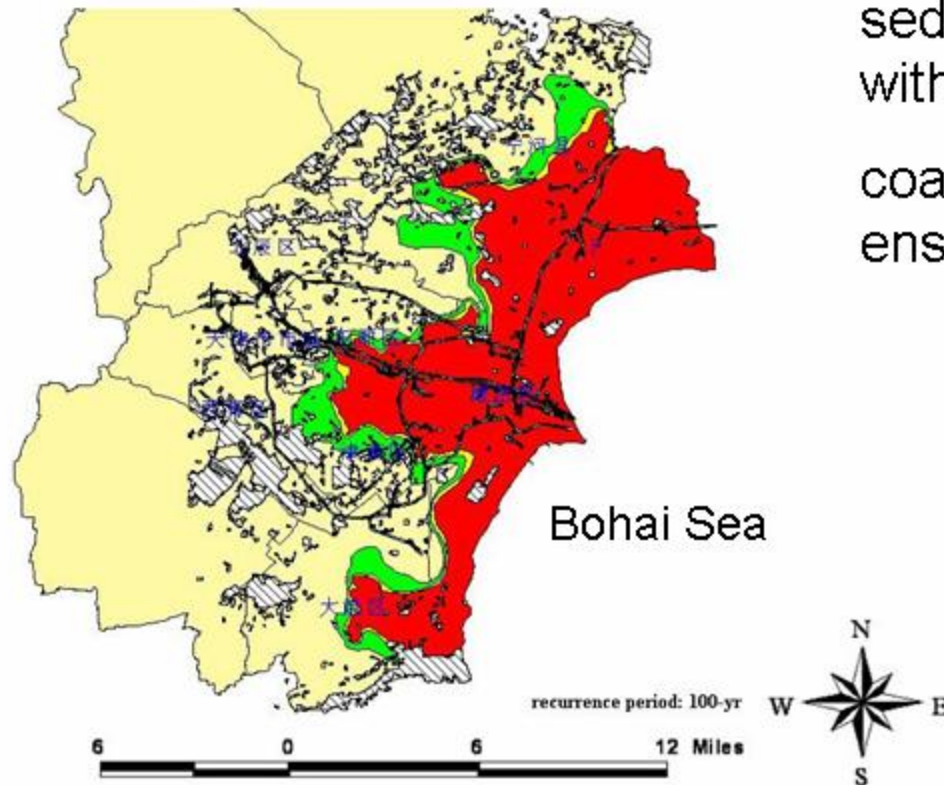
## vulnerable regions

### Coastal area:

sedimentary coast is confronted with serious erosion

coastal people deal with the ensuing coastal management

prediction of sea level rise for 2030 along the Tianjin coast



**Sea level rise**

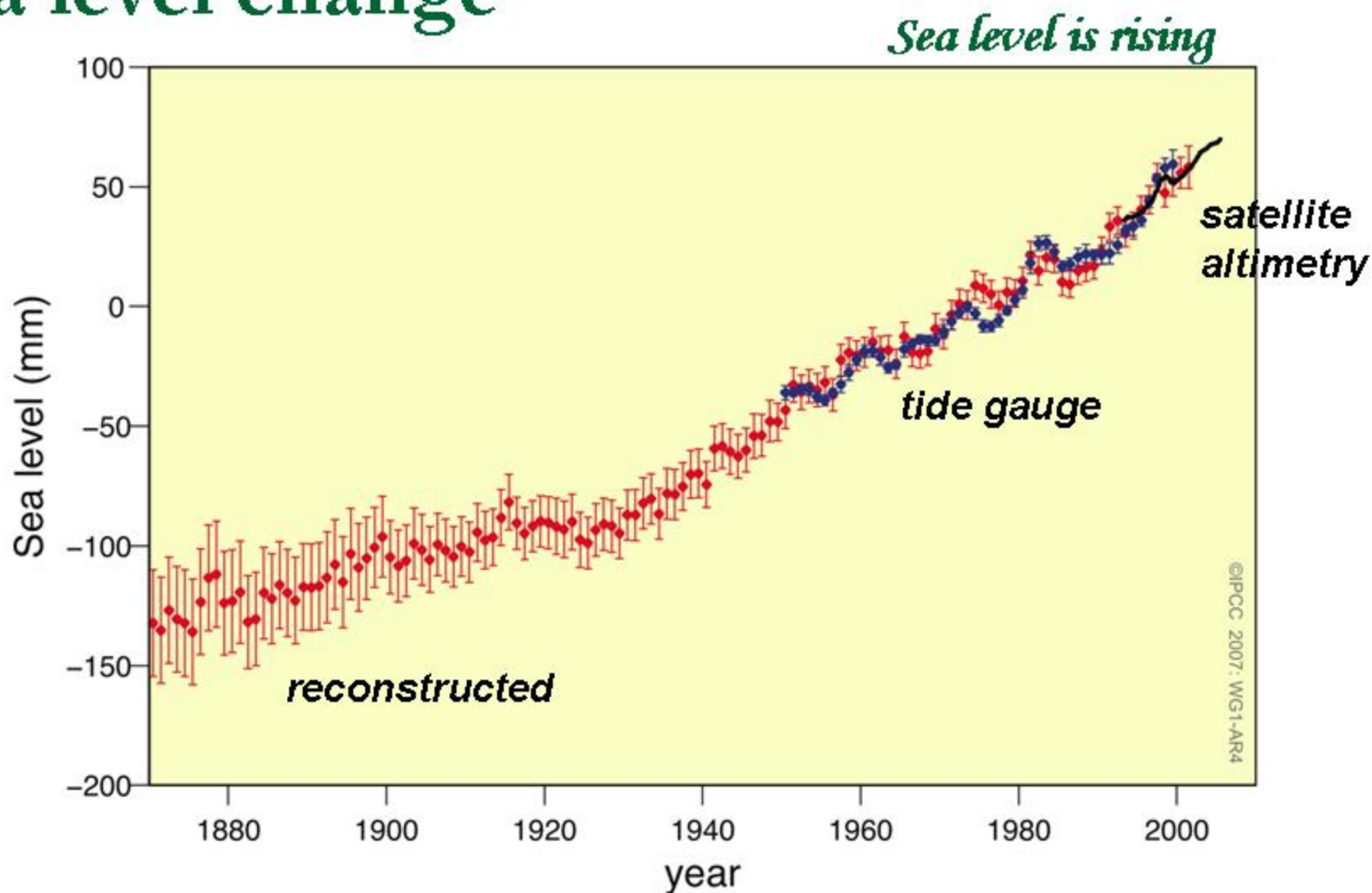


## Roberts Bank: 2100

Existing dike + normal high tide + sustained storm surge + breach

(Rong et al., 2008)

# Sea level change

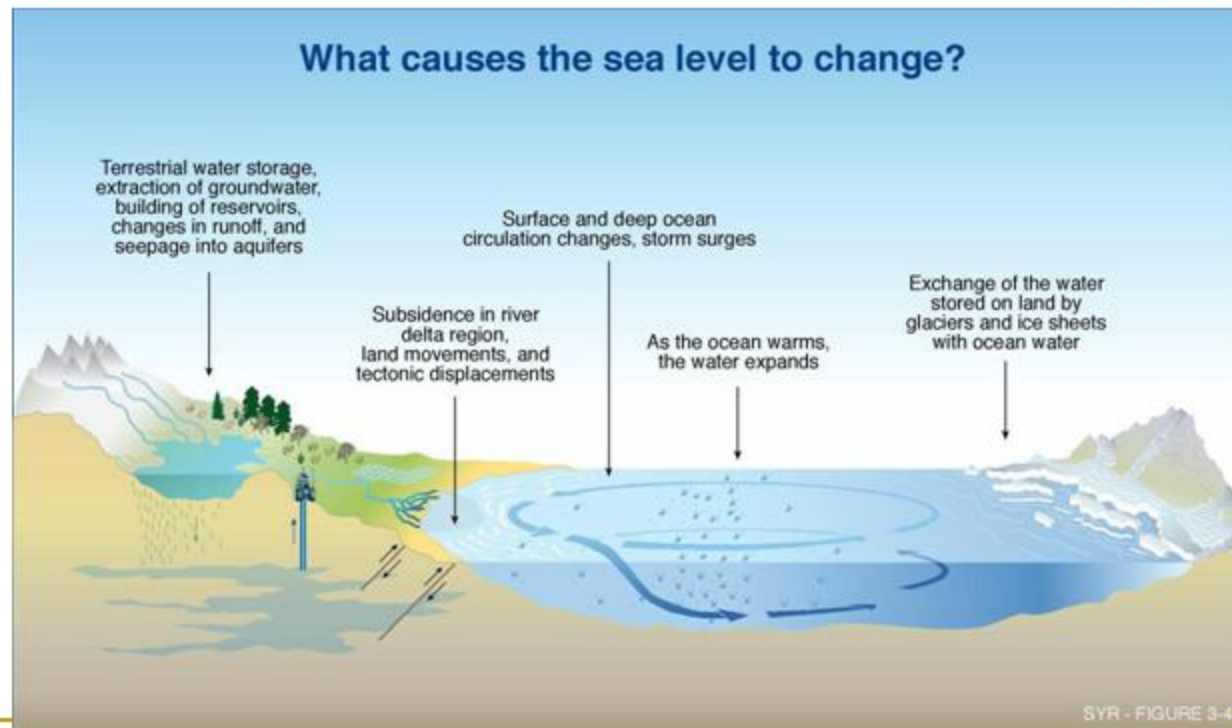
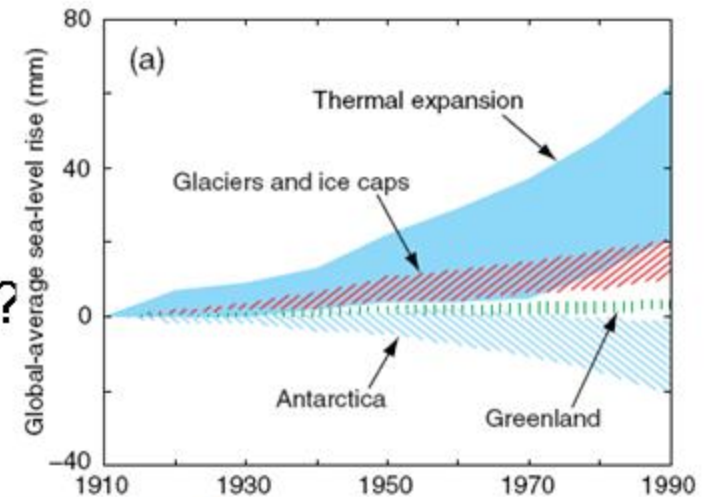


*Intergovernmental panel on climate change, 2007*



# Sea level change

## ■ What causes the sea level to change?

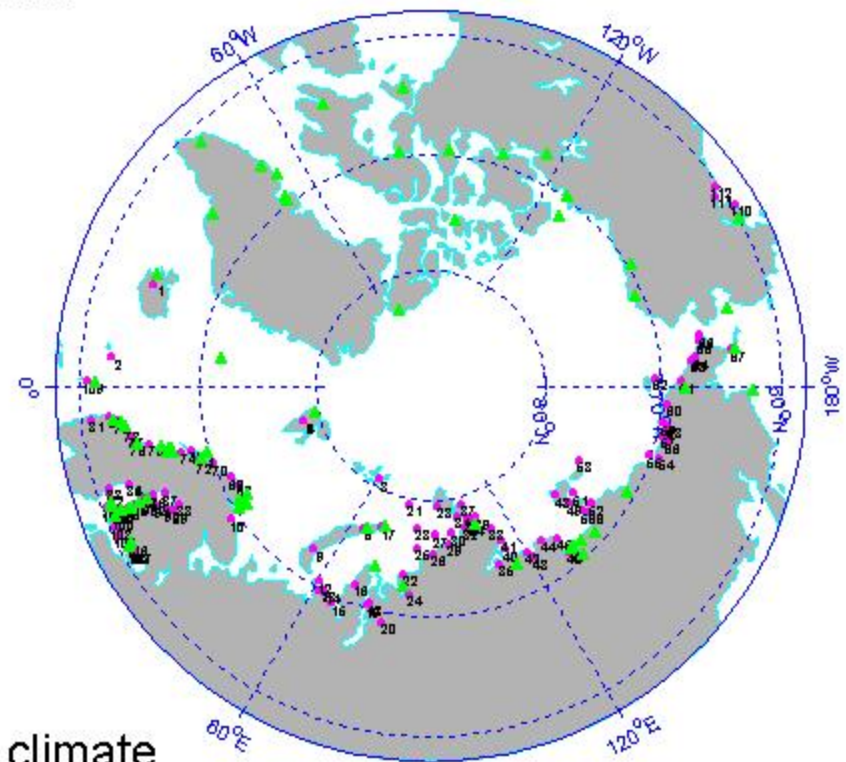


steric  
eustatic

- Different timescale: from seasonal to interdecadal, and secular change
- Global and regional change

# Data sources & method

- Permanent Service for Mean Sea Level (PSMSL) relative sea level data
- TOPEX/Poseidon altimetry data
- Ishii temperature/salinity field
- ◆ CCSR/NIES/FRCGC model
- ◆ Statistic method:
  - stochastic dynamic method
  - Maximum Entropy Spectra
  - EOF ...



model for interdisciplinary research on climate

# Steric Sea Level

## ■ Steric effect --SSL

steric effects (including thermal expansion and halosteric variation)

- $\alpha$  is specific volume (UNESCO, 1987)
- $z_1$  and  $z_2$  are the lower and upper limits of depth of integration.
- $\Delta$  signifies the departure of the given variable from its mean value

$$SSL \approx TSL + HSL$$

$$TSL = \int_{z_1}^{z_2} \frac{1}{\alpha} \frac{\partial \alpha}{\partial T} \Delta T dz$$

Thermosteric Sea Level

$$HSL = \int_{z_1}^{z_2} \frac{1}{\alpha} \frac{\partial \alpha}{\partial S} \Delta S dz$$

Halosteric Sea Level

- About 10% of sea level rise is due to a decrease of the volume mean salinity.
- Thermosteric anomaly is nearly compensated by the halosteric anomaly in some regions, for instance, the subpolar North Atlantic.

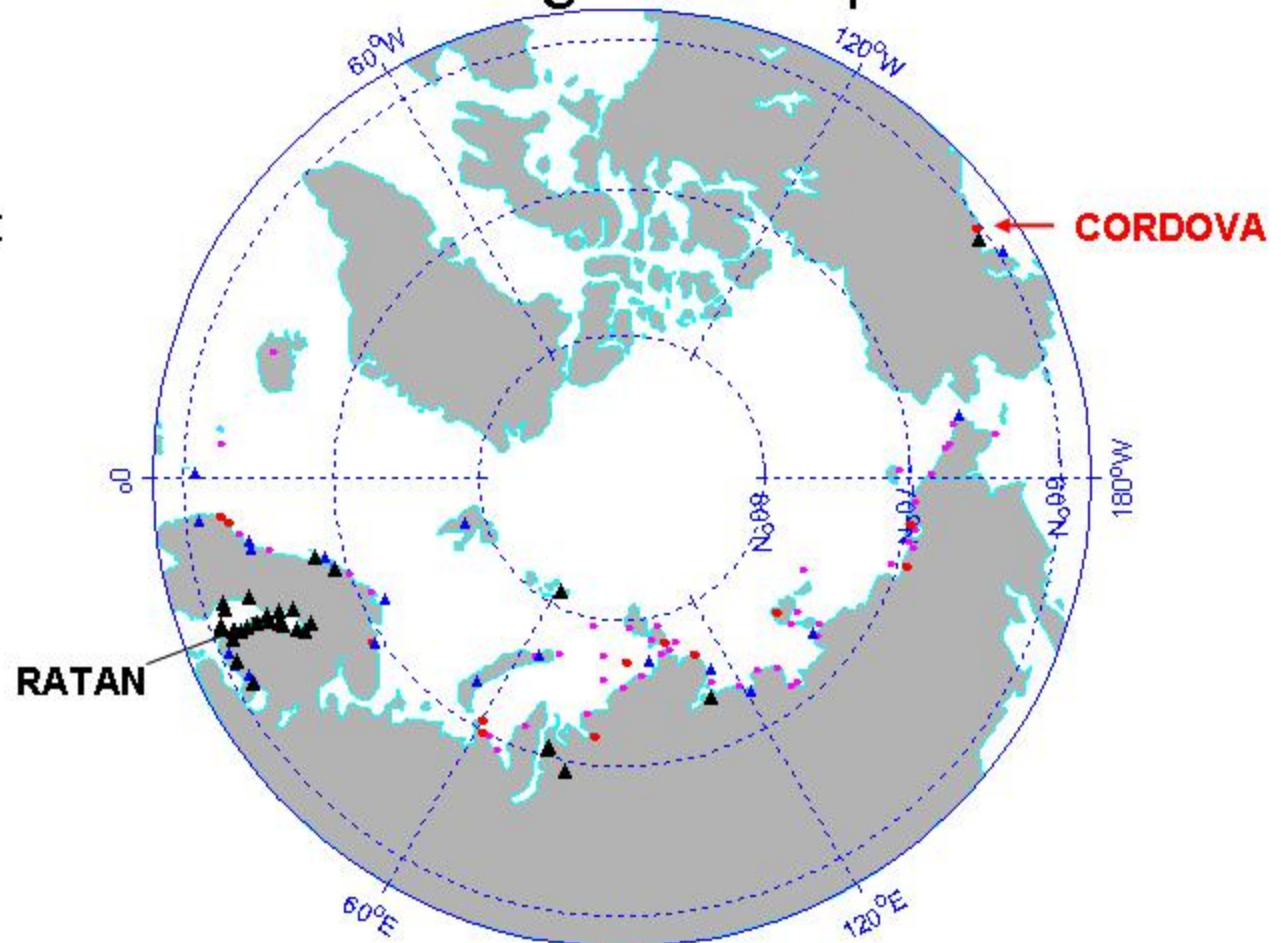


# Secular variation (RSL)

- secular trend in the coastal region / deep water

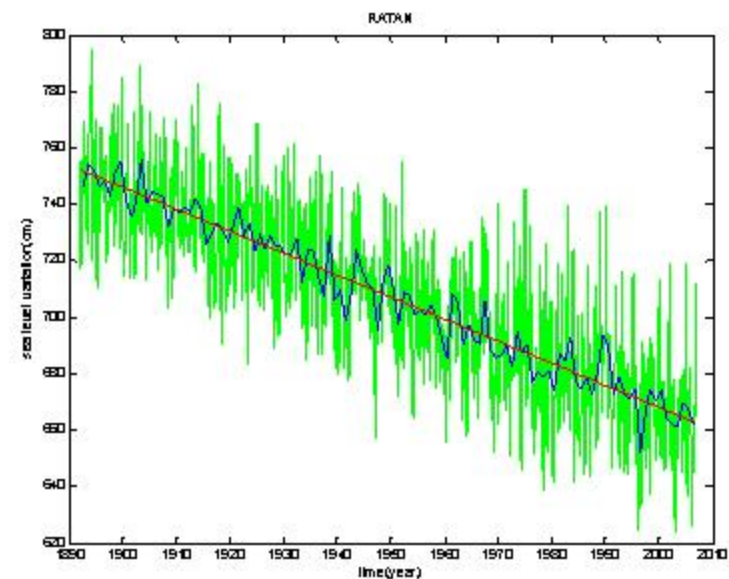
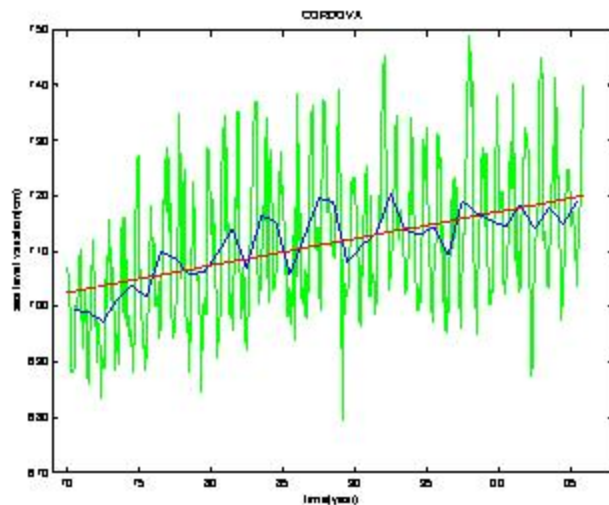
112 tide gauge:

- descent, 52
- ascent, 60
- 60% small



# Secular variation (RSL)

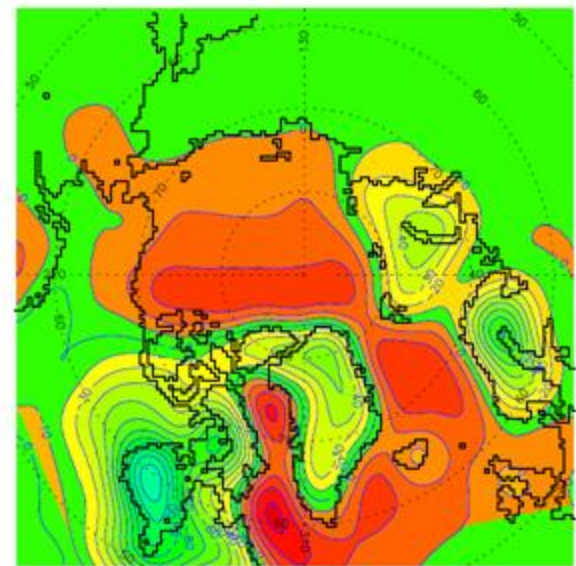
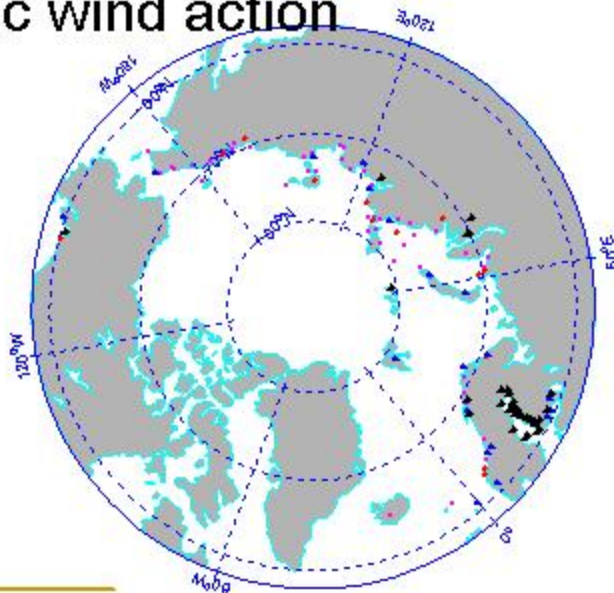
- secular trend in the coastal region / deep water



- RATAN :41month,~1/6
- CORDOVA:33month~1/5

# Secular variation

- Contribution factors to secular sea level variation
  - Steric effect (thermal expansion and halosteric variation)
  - Dynamic sea surface height (oceanic and atmospheric processes)
    - sea level pressure--inverse barometer Effect
    - cyclonic wind action



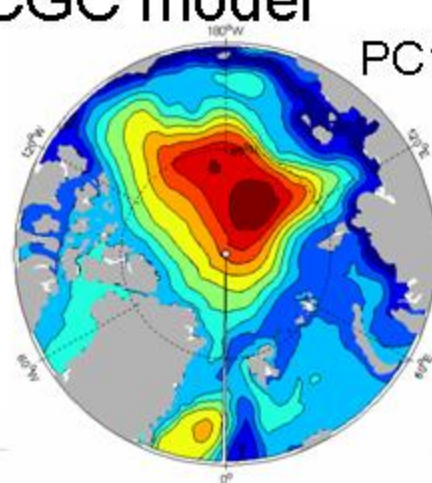
Glacial Isostatic Adjustment (Peltier 1996)



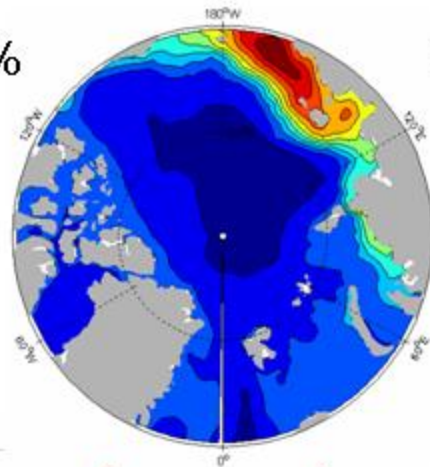
# AOSR sea level change in 20<sup>th</sup> century

## ■ CCSR/NIES/FRCGC model

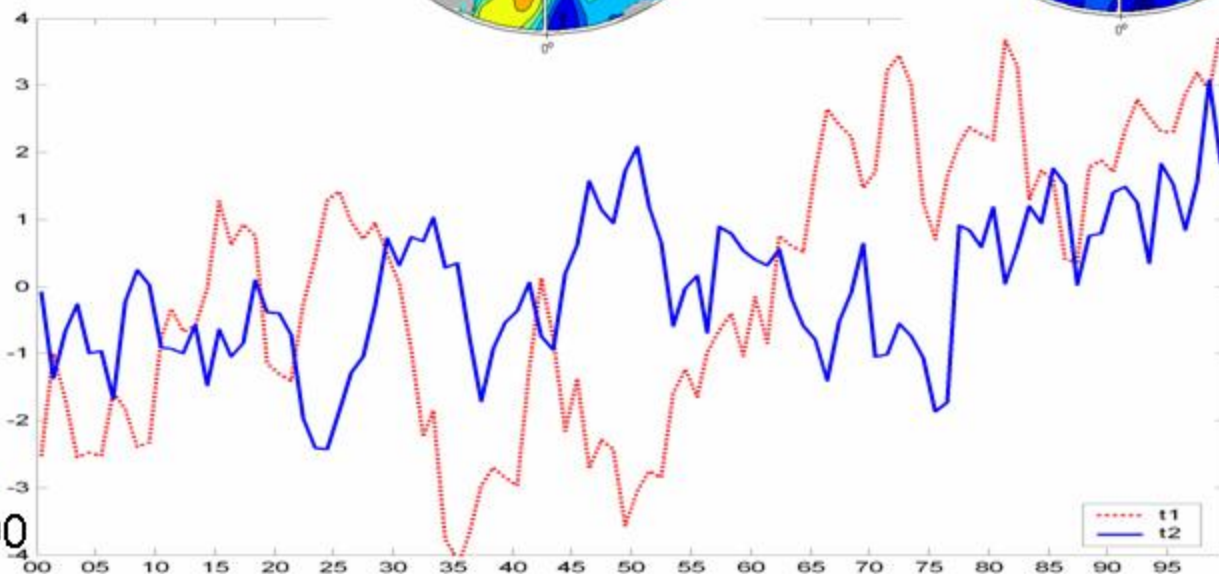
- coastal region
- deep water basins



PC1 30.4%



PC2 19.2%

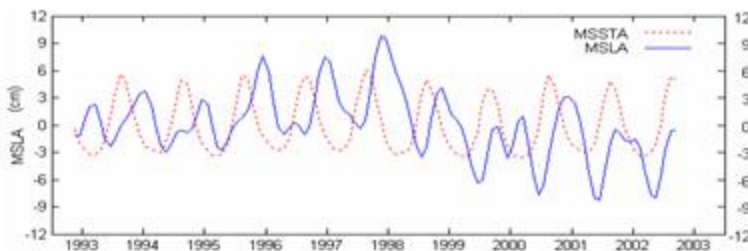


Trend  
Decadal

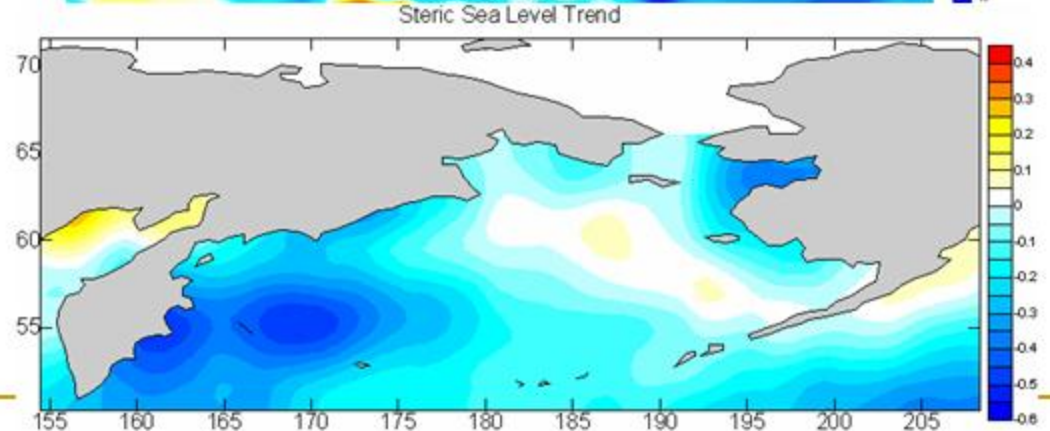
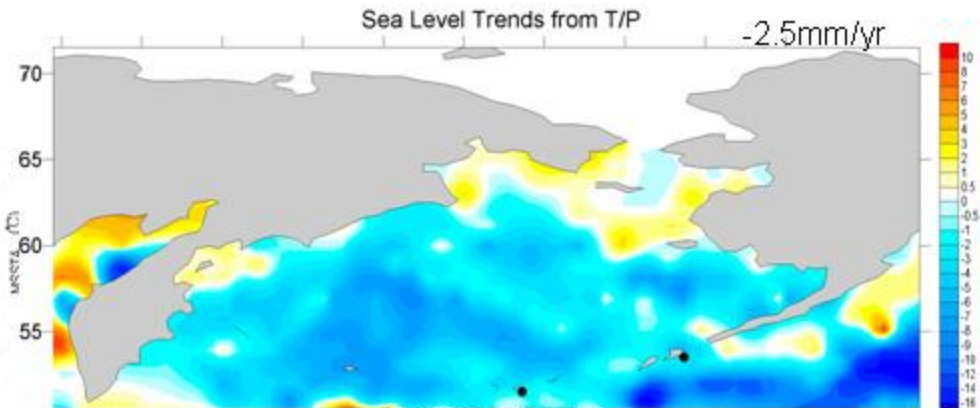
Hasumi, 2000

# Sea level change and steric effects in BS

## ■ Secular



- 0.7 (delay 3 months)
- drastic change from 1998 to 1999



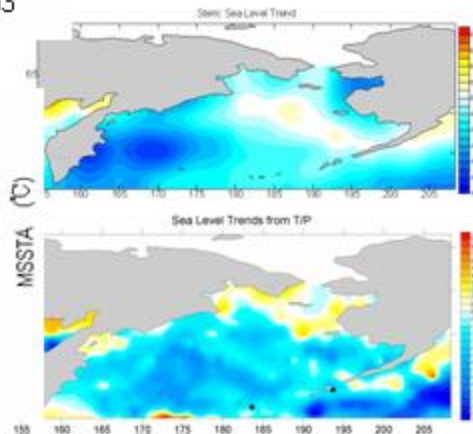
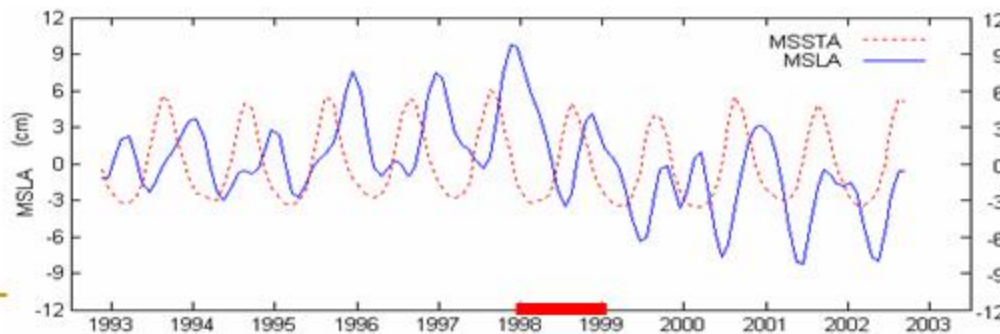
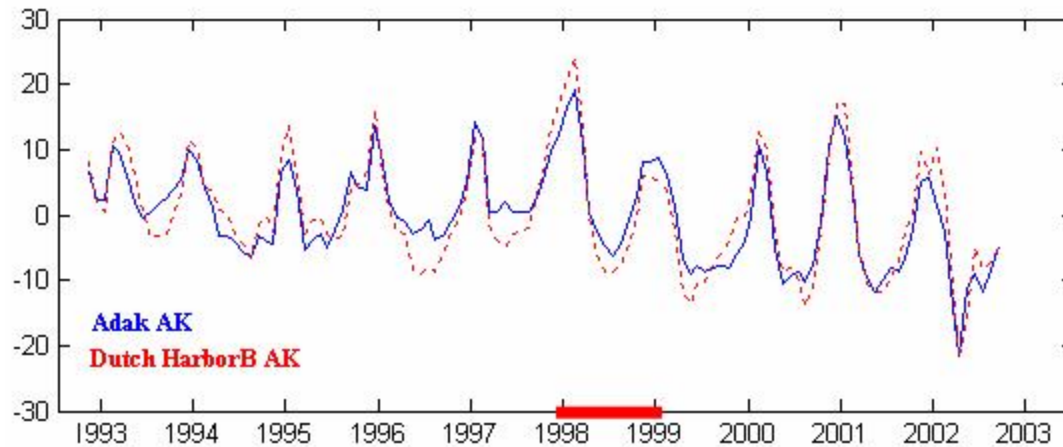
mean SLA exhibited a strong fall, accompanying with the SST cooling



# Sea level change and steric effects in BS

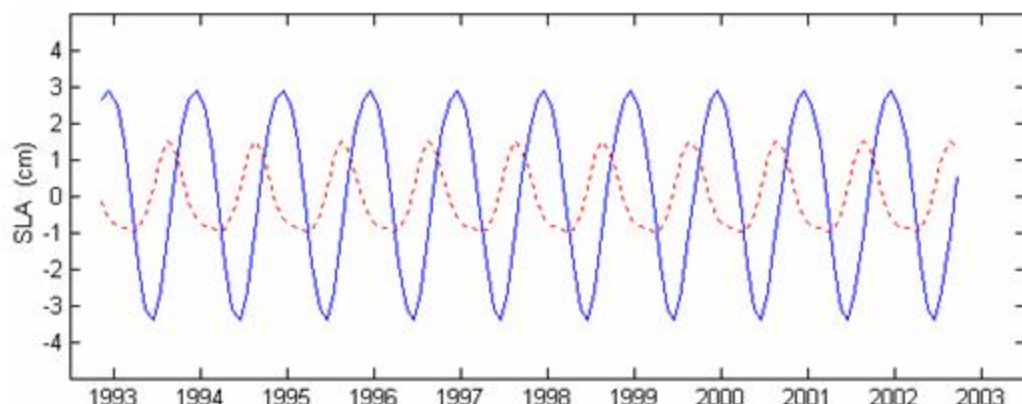
In the 1998/99 change over the North Pacific, SSTs increased abruptly in the Kuroshio/Oyashio Extension region and the central North Pacific, accompanied by cooling in the eastern North Pacific. (Minobe, 2002)

## ■ Secular



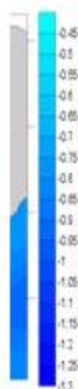
# Sea level change and steric effects in BS

## ■ Seasonal



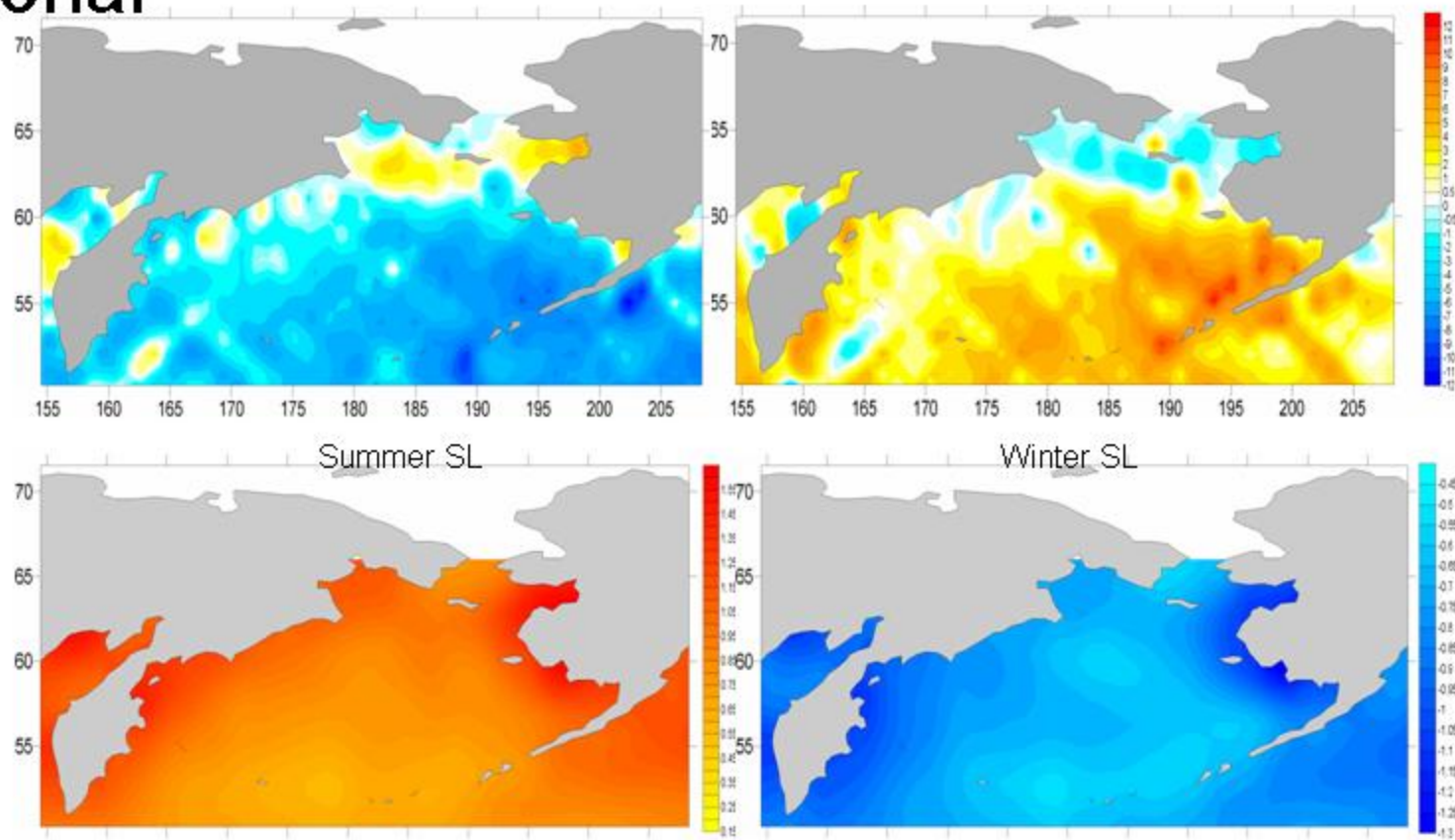
Strong seasonal variations in the Bering Sea

- The dominant seasonal variations with a range of about **6 cm** (7.4 cm )
- Annual extrema: **November ; June**
- much **smaller** than those of about 10 cm in the mid-latitudes region near  $30^{\circ} \sim 50^{\circ} \text{ N}$  .
- basin-averaged mean SSL shows dominant seasonal variation with a range of about **2.5 cm**.
- The seasonal amplitude of the steric height is about **35%** of the observed amplitude
- T/P observed total sea level delays the model-derived SSL about **three months** (eastern shallow area and the Aleutian Islands area)



# Sea level change and steric effects in BS

## ■ Seasonal

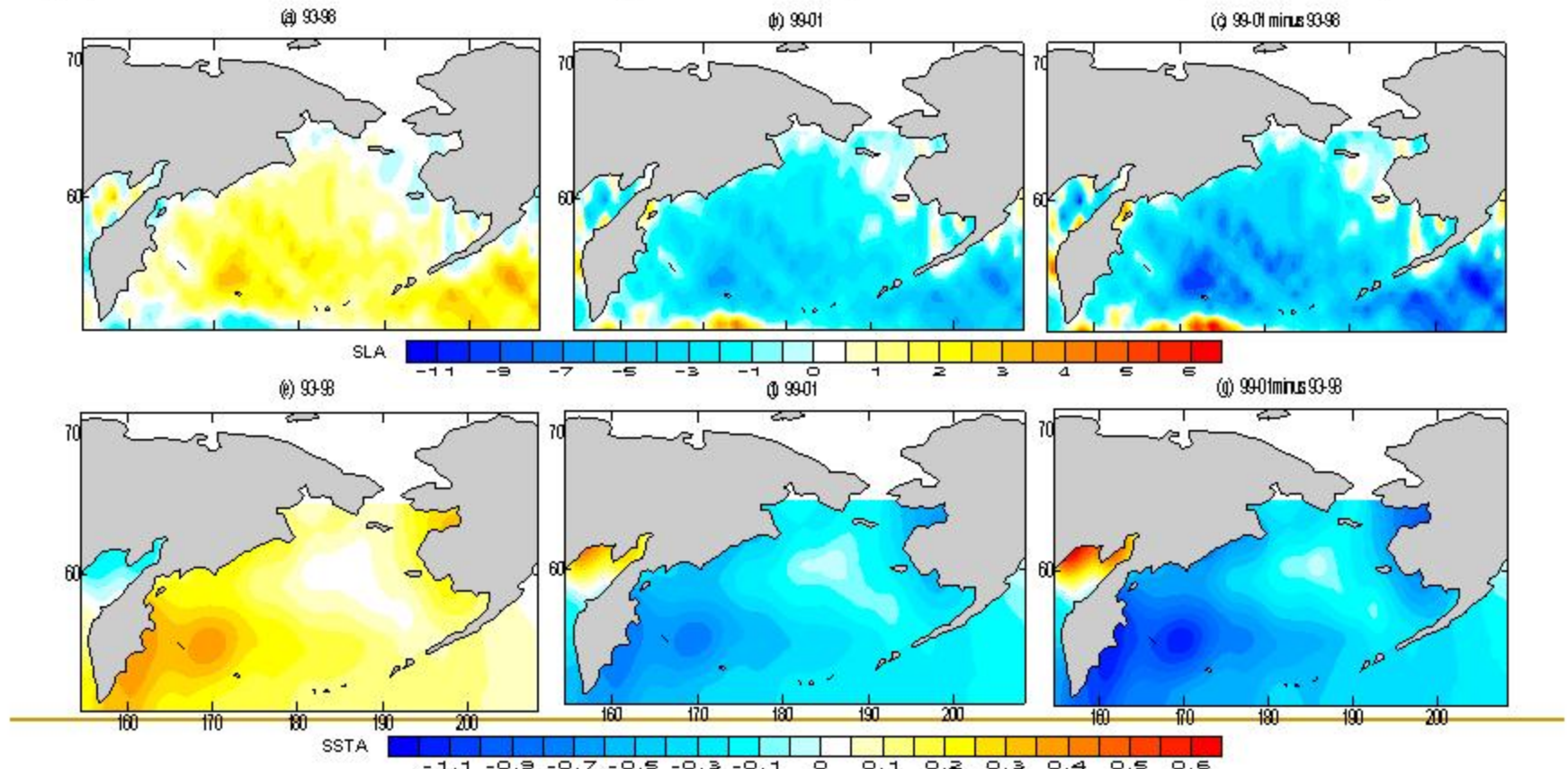


SSL is not very good in agreement with the seasonal variations of the T/P observed sea level. This indicates that the **geostrophic circulation** in the Bering Sea caused by steric height makes a greater contributions to the total circulation in **summer** than in autumn or winter



# Sea level change and steric effects in BS

During the **1998/99 change**, the mid-latitudes central North Pacific exhibited strong warming accompanied with cooling in the eastern and northern North Pacific, both for the SST and the sea level, especially in the **southern** part of the Bering Sea. The sea-level anomaly exhibits a significant fall in the deep basin of Bering Sea (about **10 cm** in the southwestern Bering Sea), roughly in the same location as the region where a prominent SST fall (about **2 °C** ) exists.



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# Summary

- Sea level is a natural integral indicator of climate variability
  - Regional sea level change's contribution factors: dynamic oceanic and atmospheric processes and steric effect
  - Sea level change in AOSR differs from that in the mid-latitudes
  - Steric effect contribute to seasonal sea level variation
  - During the 1998/99 change, a significant sea-level fall in Bering Sea
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*Thank you!*