Global Ocean Modelling for GOAPP and CONCEPTS

Outline:

- Team
- GOAPP and CONCEPTS
- Atmosphere and ocean components of the coupled system
- Global ocean configurations
- Initial results
- Plans
- Ocean model validation
- Interesting topics to study

Team of NEMO Modellers

- **Global and basins**

Dan Wright, Zeliang Wang, Fred Dupont, Jie Su,…

Youyu Lu, Jean-Marc Belanger, Francois Roy, …

Entcho Demirov, Yimin Liu, Youming Tang,…

Mike Stacey,Tsuyoshi Wakamatsu, …

- **Shelf/coastal**

Dave Brickman, Fraser Davidson, Andry Ratsimandresy, Paul Myers…

GOAPP and CONCEPTS

GOAPP – Global Ocean and Atmosphere Prediction and Predictability

- ✓ Canadian CFCAS research network
- ✓ Research on coupled atmosphere-ocean prediction at time scales from days to decades

CONCEPTS -- Canadian Operational network of Coupled Environmental PredicTion Systems

- ✓ Inter-agency plan: EC-DFO-DND +universities +Mercator-Ocean
- ✓ Core project: to improve forecasting using coupled global atmosphere (GEM)+ocean (OPA) + ice with data assimilation

Canadian Atmospheric Models

Numerical weather prediction – Environment Canada (CMC, RPN)

- ✓ Global Environmental Multigrids (GEM)
- ✓ Operational system, advanced data assimilation capacity
- ✓ Regional meso-scale model (GEM-LAM or MC2) for downscaling
- ✓ Global meso-scale model 35 km horizontal resolution
- ✓ Coupling to a global ocean-ice model underdevelopment

Climate model – Environment Canada (CCCma)

- ✓ Seasonal time scale and beyond; contributing to IPCC assessment
- ✓ Coupled to coarse-resolution global ocean-ice model

Regional climate models -- Canadian universities in partnership with EC

- ✓ Working on to combine the best components of NWP and climate models
- ✓ Require regional ocean models for coupling

Ocean and Sea-Ice Models

Goal

- ✓ To develop a modelling system with data assimilation capacity
- ✓ Ocean and ice models coupled to atmospheric models, for operational forecasting and climate studies
- ✓ Common code for global, basin and regional applications, hence development work can be shared among groups

Choice of models

- ✓ Ocean model based on OPA in NEMO
- ✓ NEMO has a strong development team, and a large user group in Europe, for operational (e.g., Mercator-Ocean) and climate (e.g., the DRAKKAR project) studies
- ✓ NEMO has a sea-ice model (LIM). Plan to replace LIM with CICE (from Los Alamos National Laboratory) for the Canadian system

Data Assimilation

Atmosphere

- ✓ Strong development team in EC
- ✓ 4Dvar in the operational forecasting system with GEM

Ocean

- ✓ Mercator-Ocean's DA system (OI and Kalman filter) to be imported in fall 2007
- ✓ New DA methods to be developed by GOAPP (Keith Thompson et al)

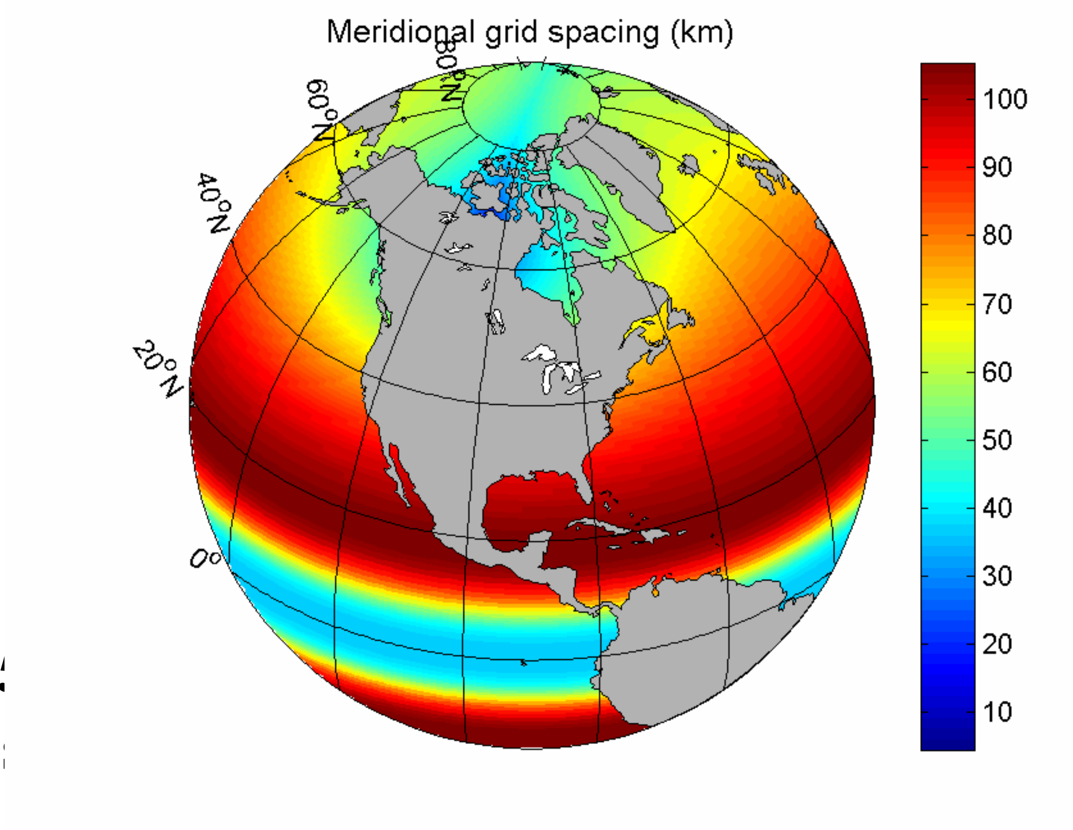
Sea-Ice

- ✓ New assimilation methods being developed in EC (Mark Buhner et al)
- ✓ Sea-ice forecasting is important for Canadians

Global Configurations

➢**Coarse resolution ORCA1:** tri-polar, nominal 1-deg grids, enhanced meridional resolution in tropics, consistent with UK SOC's setup, 46 (and 64) vertical levels

➢**High resolution ORCA025:** tri-polar, nominal ¼-deg grids, consistent with Mercator-Ocean's setup, 50 (or 46) vertical levels with 1m (or 6m) resolution near surface



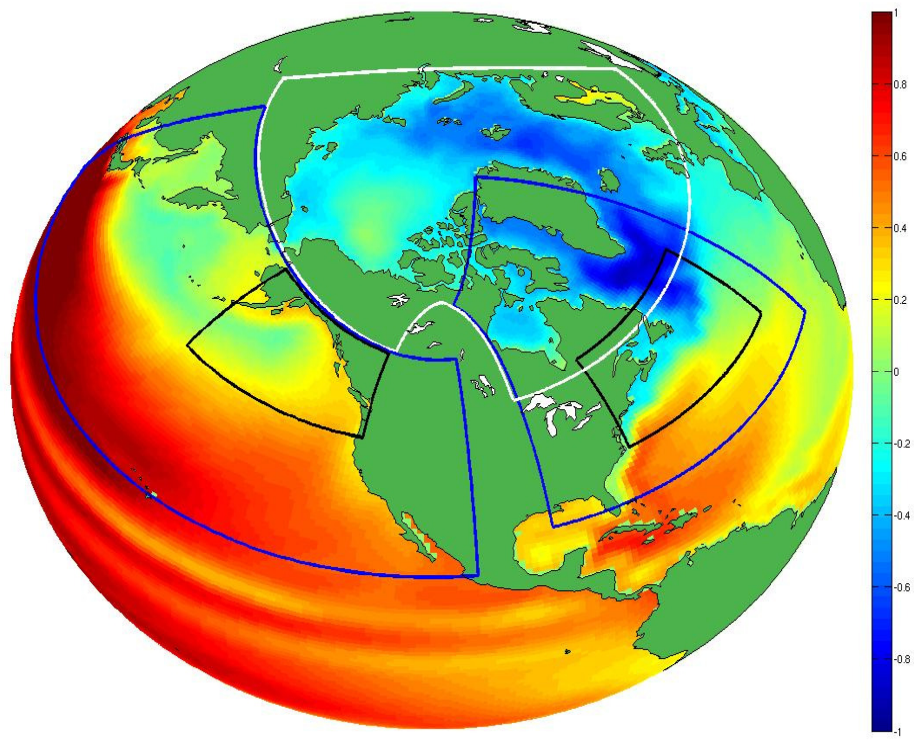
Common Domains

All grids consistent with Mercator/DRAKKAR ORCA025 model

- Global (1°,1/4°)
- North Atlantic (1/4°)
- NW Atlantic (1/4°)
- EAST (1/12°)

- North Pacific (1°,1/4°)
- NE Pacific (1/4°, 1/12°)

- Arctic (1°, 1/4°)



ORCA1 Initial Results

- **Surface forcing:** daily climatology derived from ECMWF reanalysis and used by OMIP (F Roske, 2005):

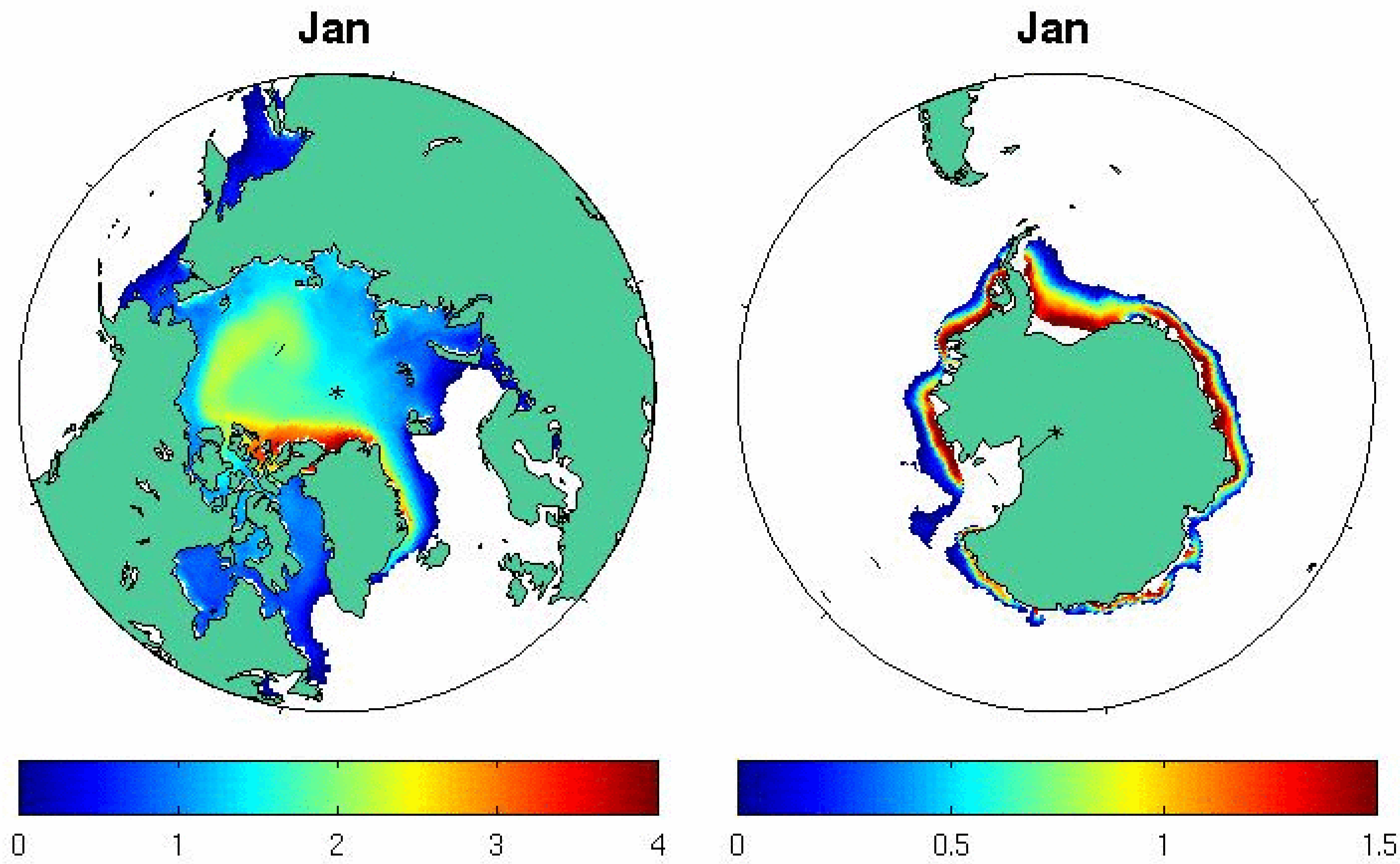
wind speed; surface air temperature; relative humidity; cloud cover; precipitation, zonal and meridional wind stress

- **River runoff:** monthly climatology of river runoff
- **Correction to surface fluxes:** no resorting for SST;

restoring SSS to monthly climatology on15-day time scale

- **Tides:** equilibrium tidal potential

Global Model (Ice Thickness)



ORCA025 Initial Results

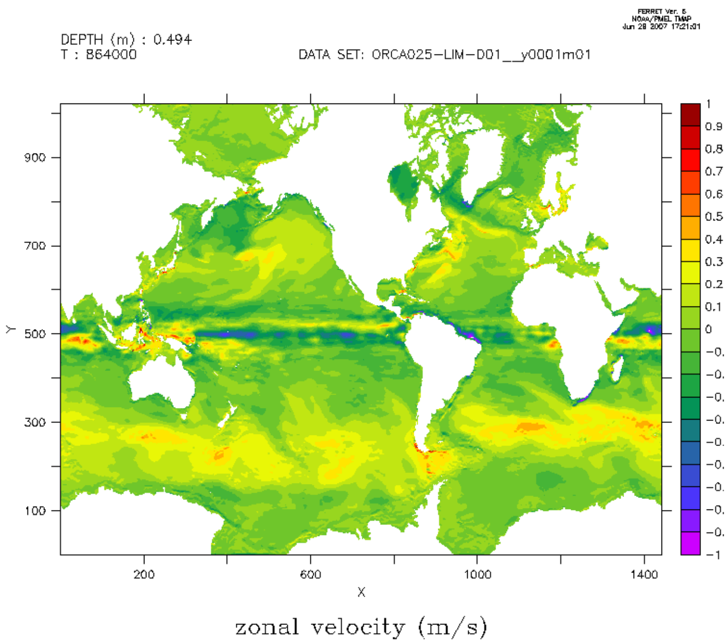
- Status:

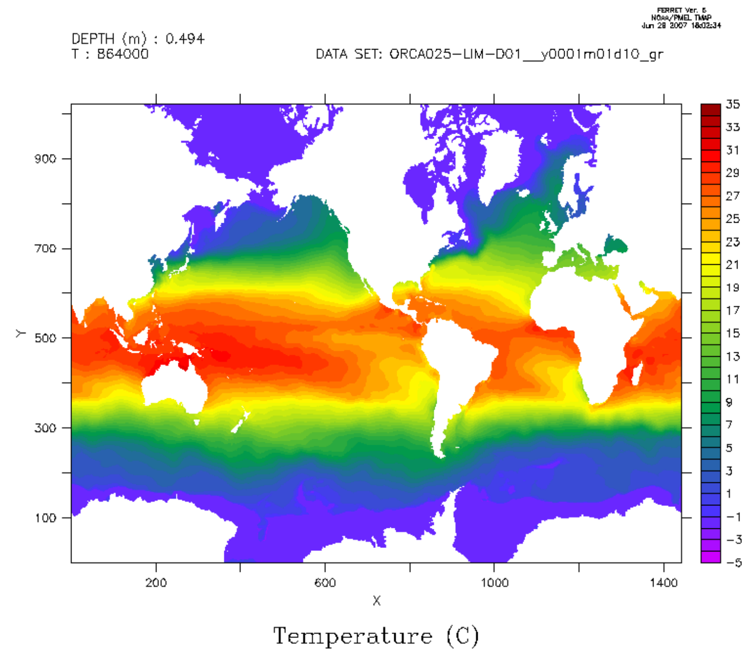
  Two versions of code ("older" from Mercator and "newer" debugged by BIO) have been compiled and run tests on CMC's IBM ("maia"); running parameters identical/close to Mercator's.

- Statistics:

  Time step 1080s (18 min); using 4 nodes (64 processors) 10-day run finished in 1.5 hour (i.e..1 month in 4.5 hour); memory ~ 50 Gb (ref 64 Gb per node on "maia").

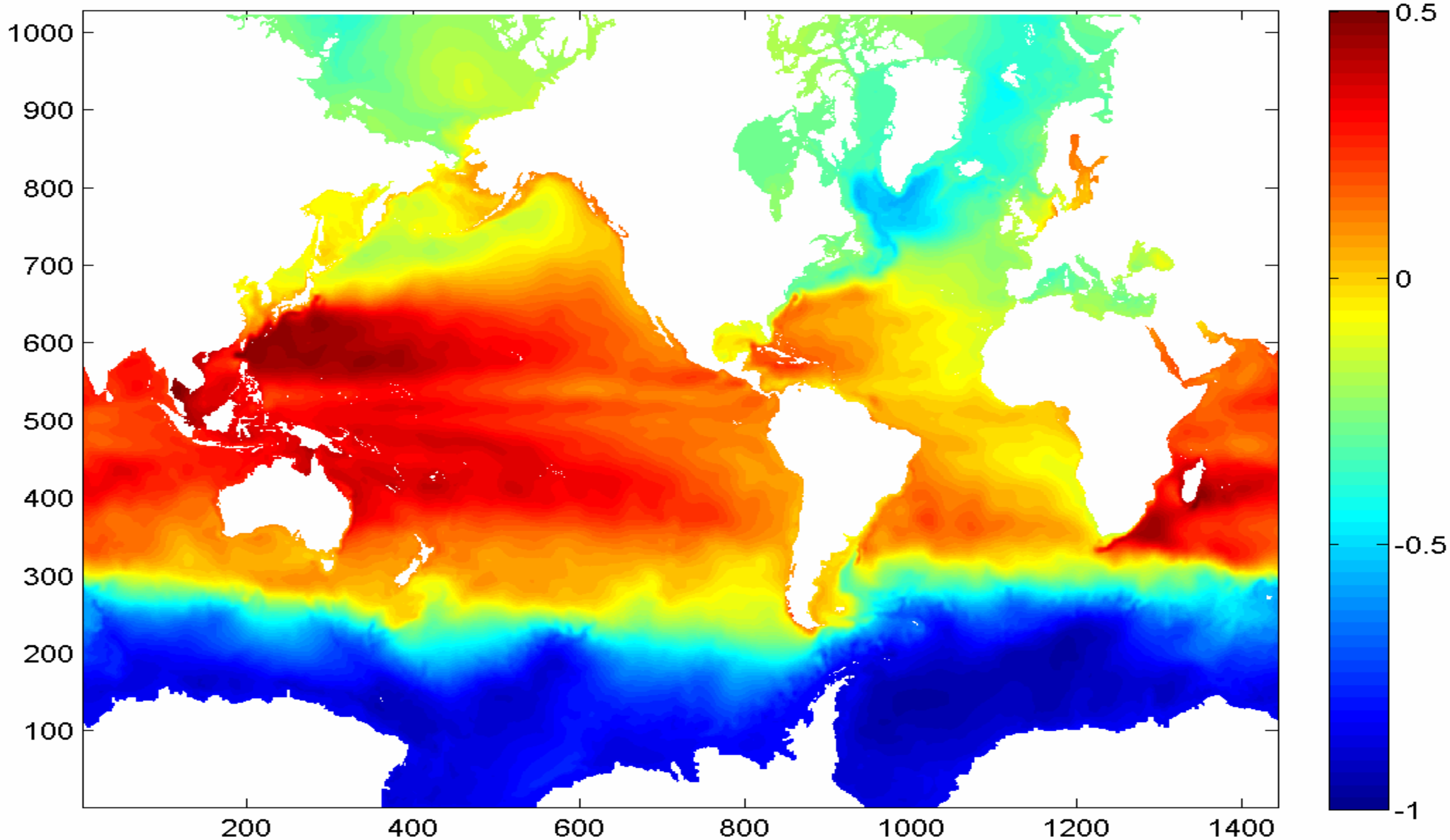
Day 10: Surface Velocity & Temperature





Spin-up stage, no eddies developed yet

Day 30: Sea Surface Height



ORCA1 Work in Progress

- ✓“Spectral nudging” implemented and tested;
- ✓ “Neptune” paramterization for meso-scale eddies;
- ✓Validation, e.g., with global climatology of currents;
- ✓Reanalysis, of past 60 years;
- ✓Examine low-frequency (inter-annual to decadal) variations; …

ORCA025 Work in Progress

- ✓ Reproducing Mercator's 14-day operational forecast run initialized on April 18 2007;
- ✓ Bring Mercator forcing subroutines into BIO version;
- ✓ Assess difference between two versions;
- ✓ Assess differences between using 50 (operational) and 46 (GOAPP R&D) vertical levels;
- ✓ Introduce GEM forcing into NEMO;
- ✓ Preparing for NEMO-GEM coupling (target December 2007)

Ocean Observational Data
– for model validation and constraining (parameter tuning and data assimilation)

Example: Labrador Sea hydrographic survey

✓Observations since 1930s

✓Annual occupation of WOCE AR7W line since 1990

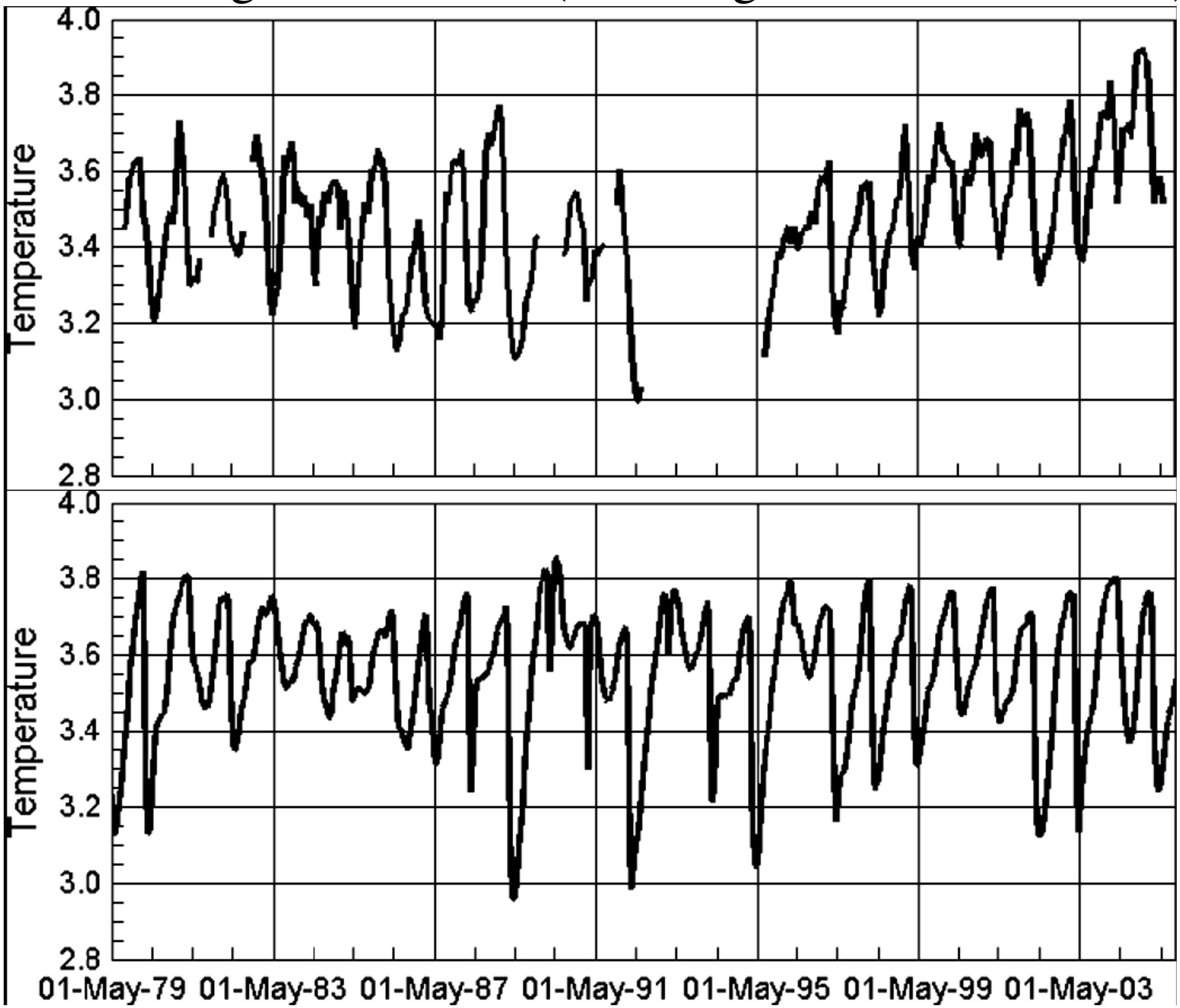
✓A deep mooring deployed on shelf slope at 1000 m isobath

-- resolving interannual and decadal variations

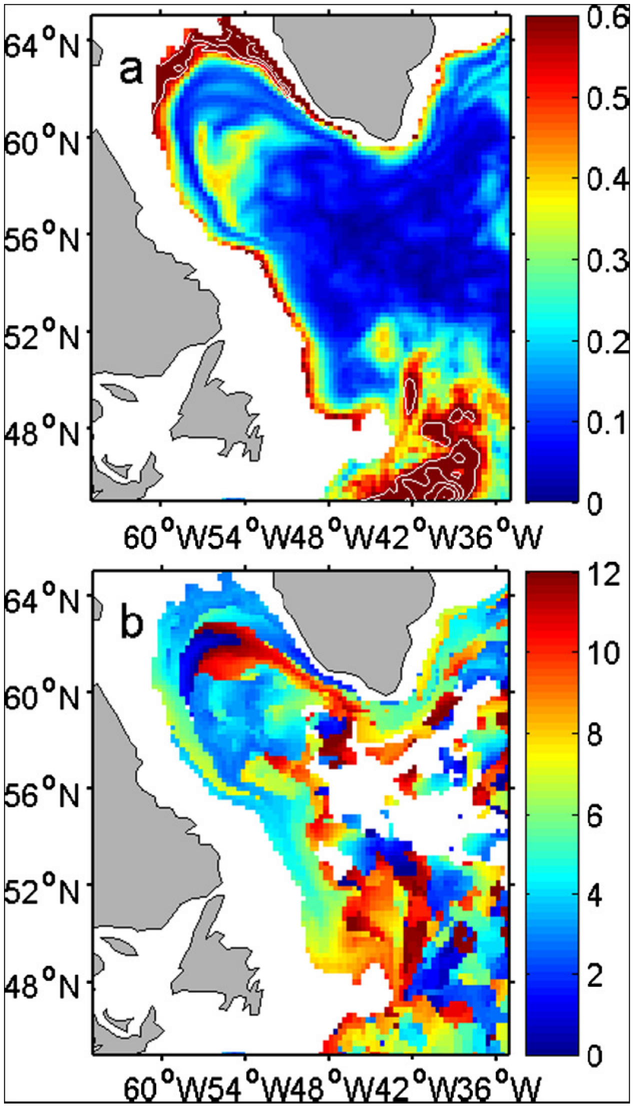
Labrador Slope deep temperature seasonal cycle: Able to reproduce with 1/3 deg ocean model (Lu, Wright and Clarke, 2006)

Observed

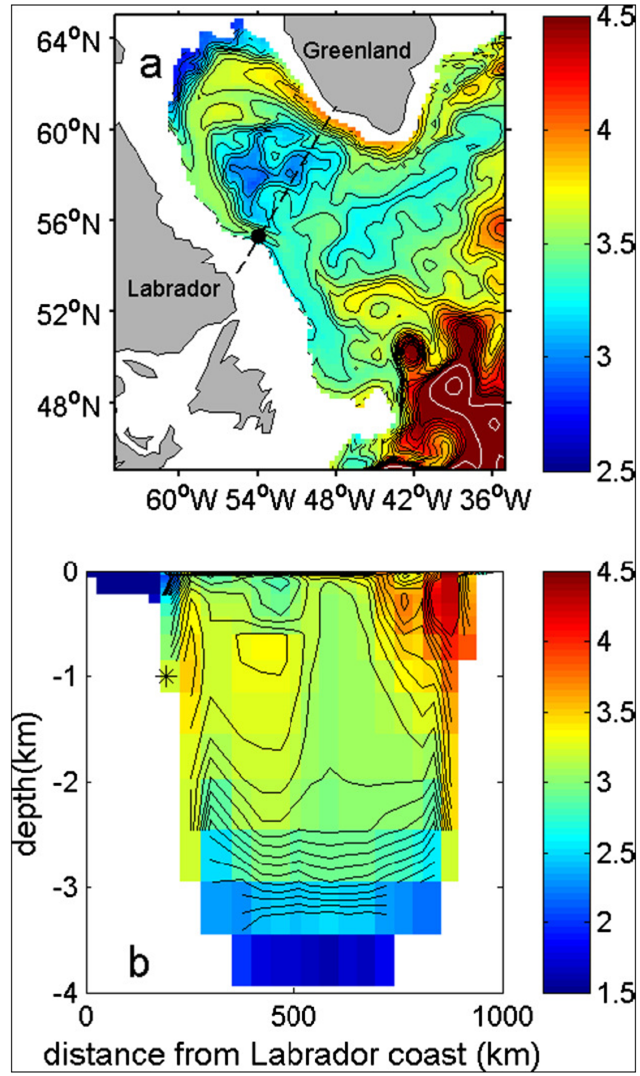
Modelled



Modelled spatial distribution of seasonal cycle: High resolution is needed to obtain detailed structure of boundary currents



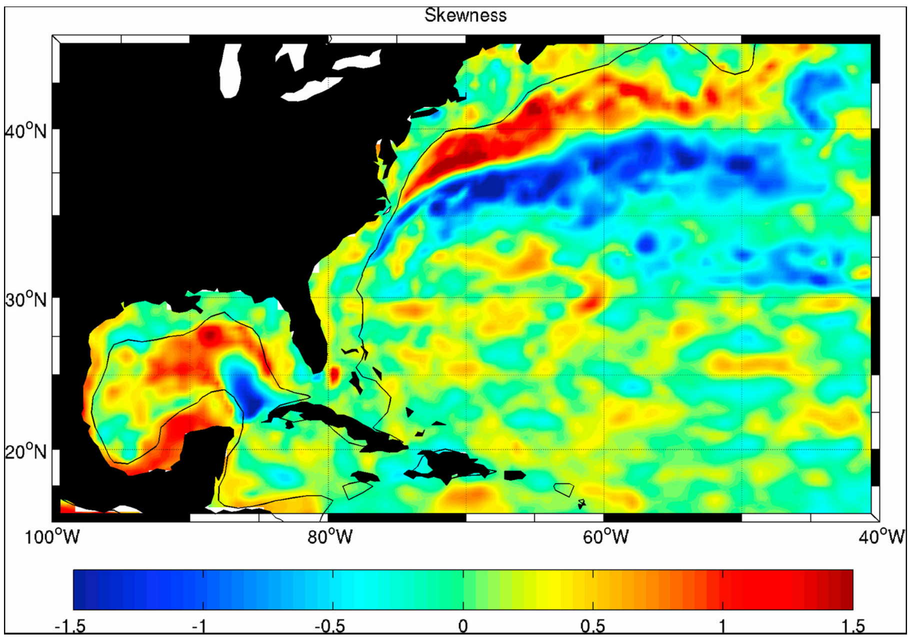
Model sensitivity study: reveals that deep layer communicates to surface layer by mixing along steeply sloped isopycnal surfaces

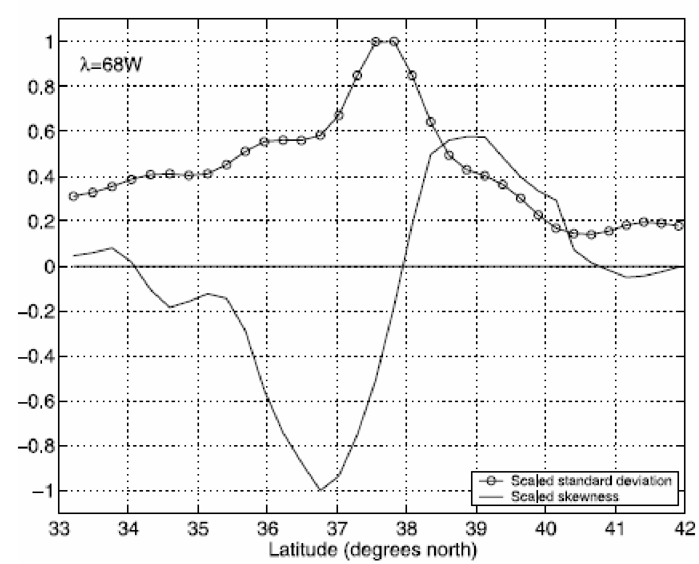


Global Satellite Remote Sensing

–- Sea surface height, temperature, sea-ice, ocean color ,…

➢**Example:** Variance and skewness of SSH (Thompson and Demirov, 2006)



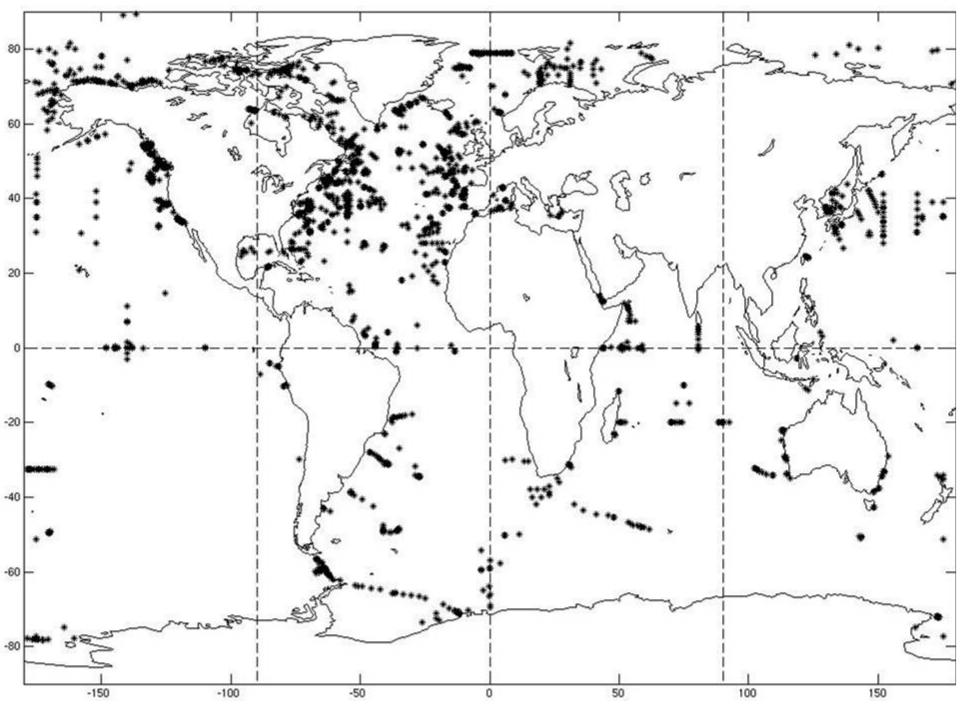


➢Similar analysis has been applied to SST (Lu and Thompson)

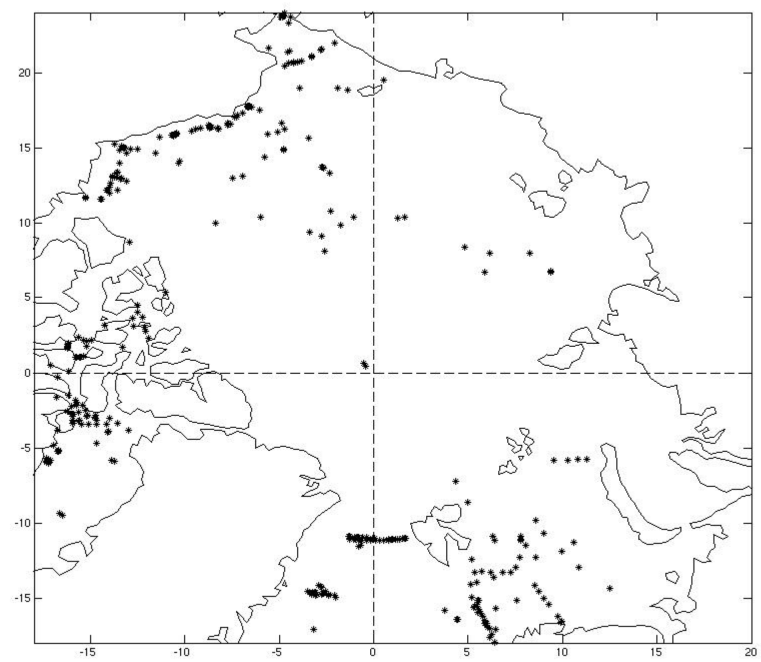
Global in situ Observations

- **Hydrography:** ARGO program
- **Current:** e.g., current-meter data (compiled by G Holloway)

Global



Arctic



Interesting Topics to Study

- **Impacts of coupling, and improved air-sea interaction, on prediction (short-term and extended weather forecasting, seasonal and climate prediction)**

  -- Coupled system to provide useful tools

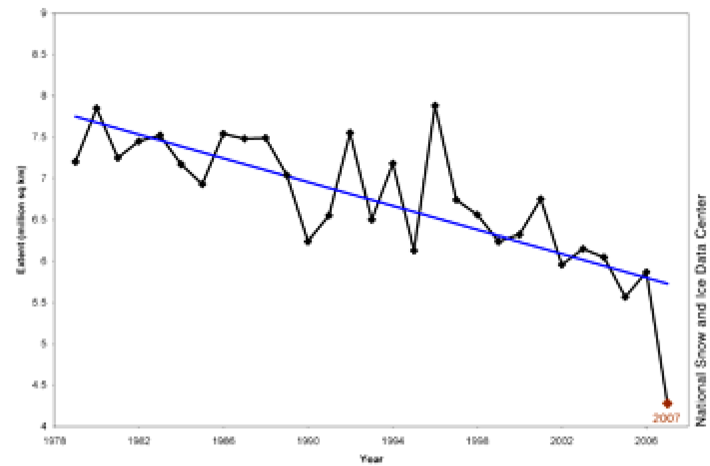
- **Impacts of ocean model improvements on SST and air-sea fluxes**

  -- Improved meso-scale eddy solution, parameterization; mixing due to tides, tidal and wind-driven internal-waves; sea-ice presentation, …

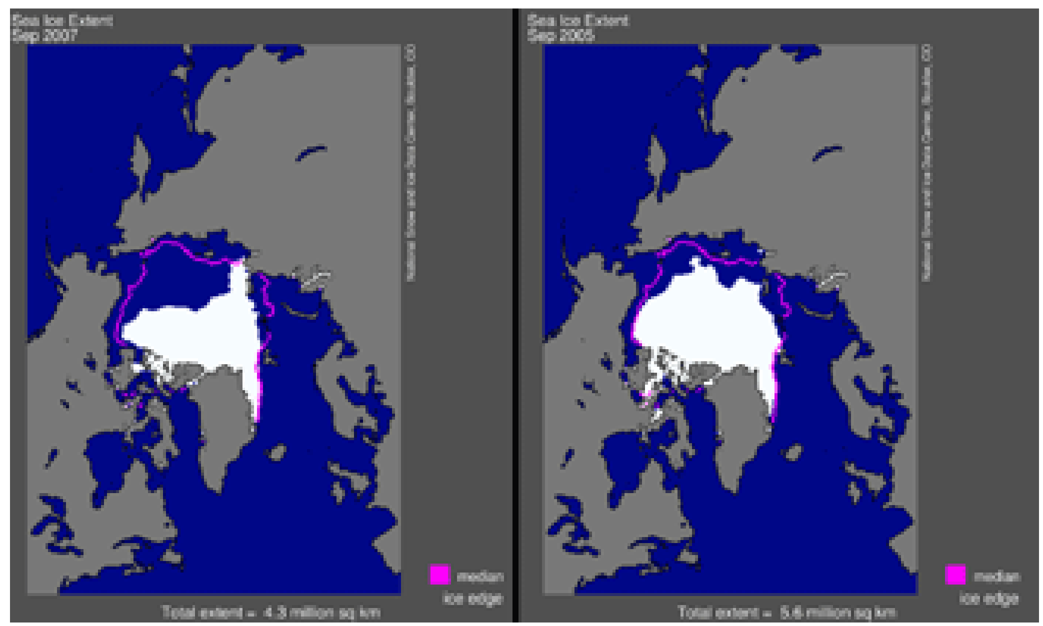
Impacts of Arctic Sea-Ice Changes?

Observed changes:

September ice extent from 1979 to 2007 shows a steep decline

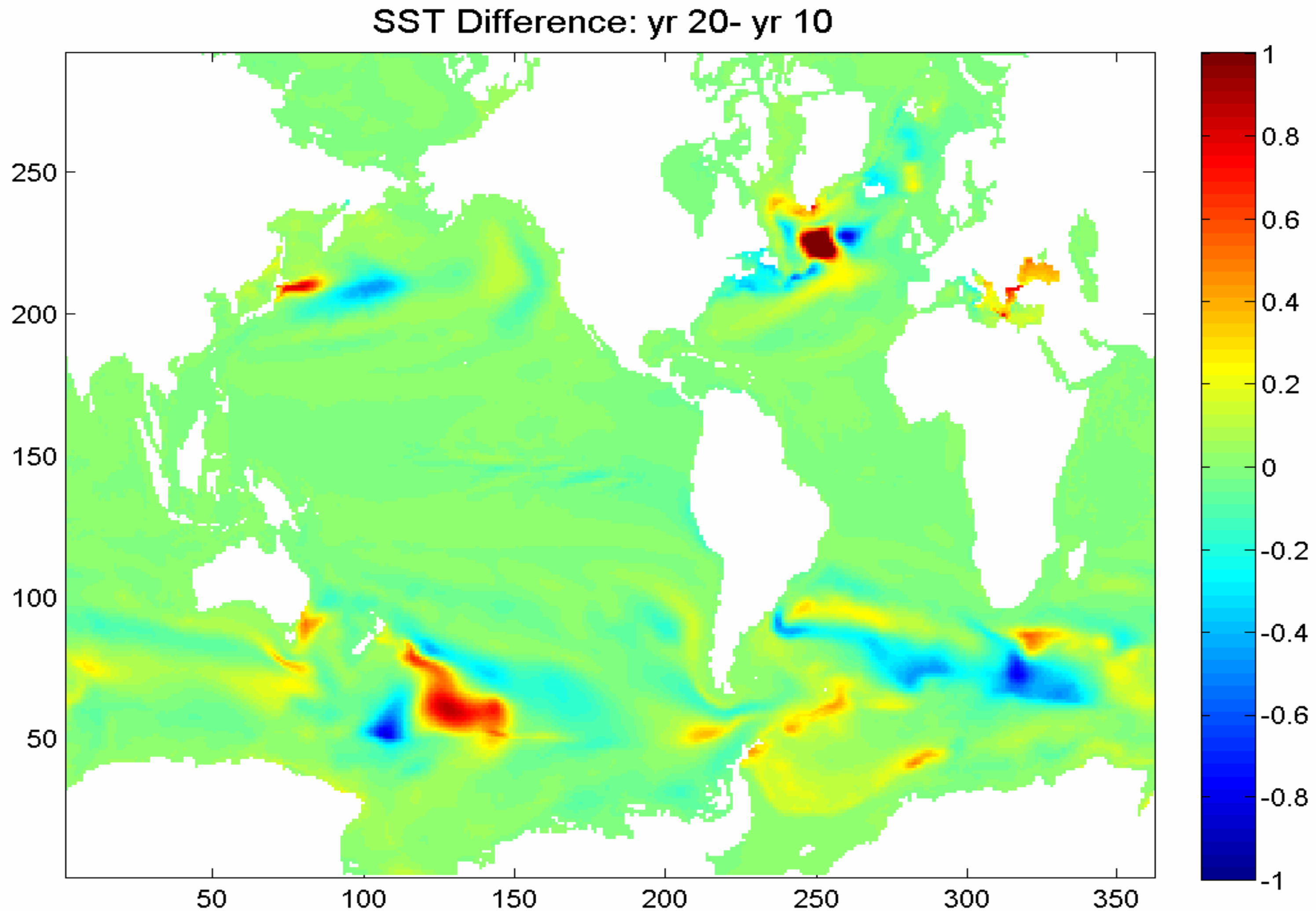


Shrinking Arctic Sea Ice Opens Northwest Passage !!

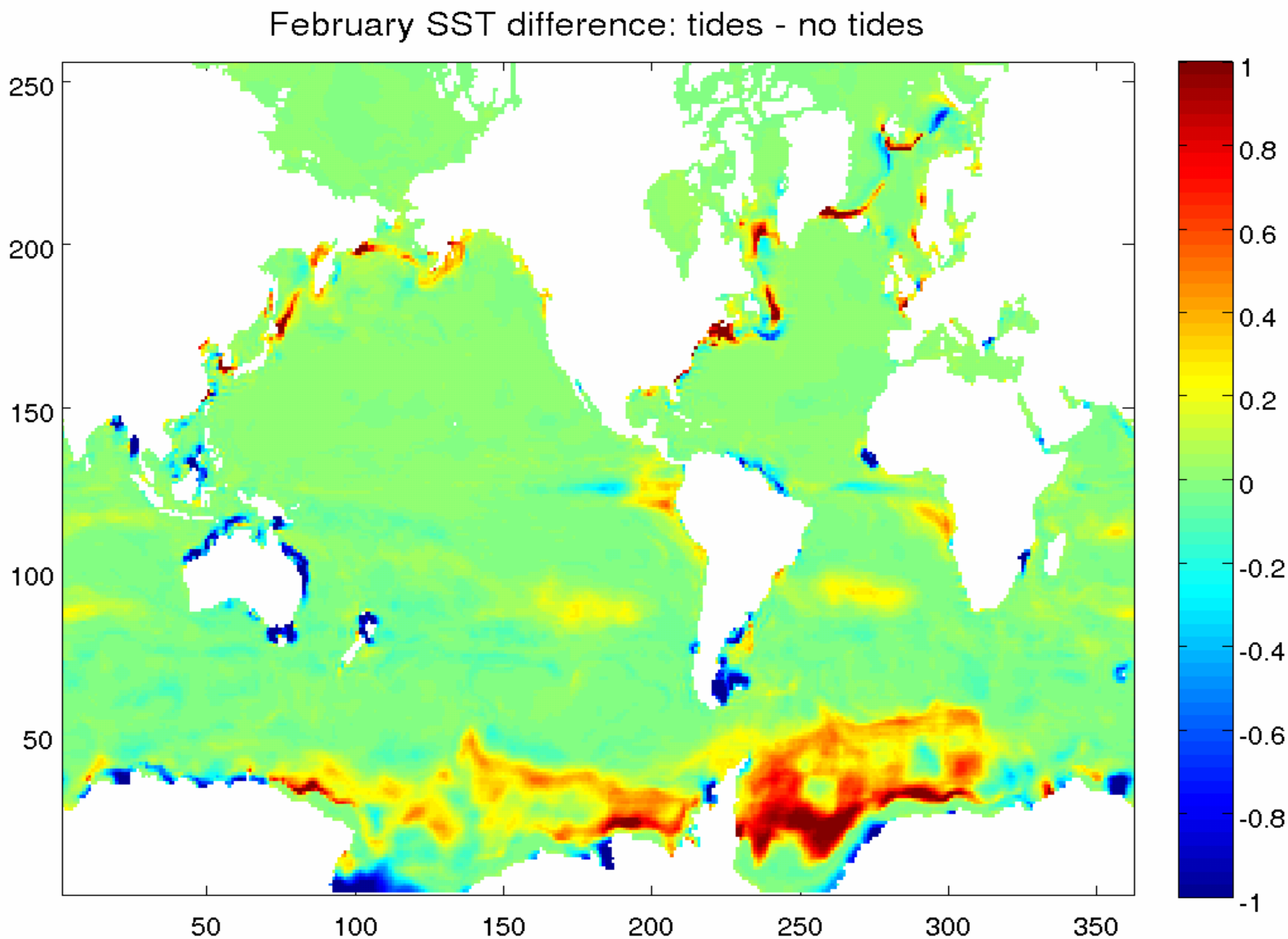


Average sea ice extent for September 2007 (left) and September 2005 (right). The magenta line indicates the long-term median from 1979 to 2000.

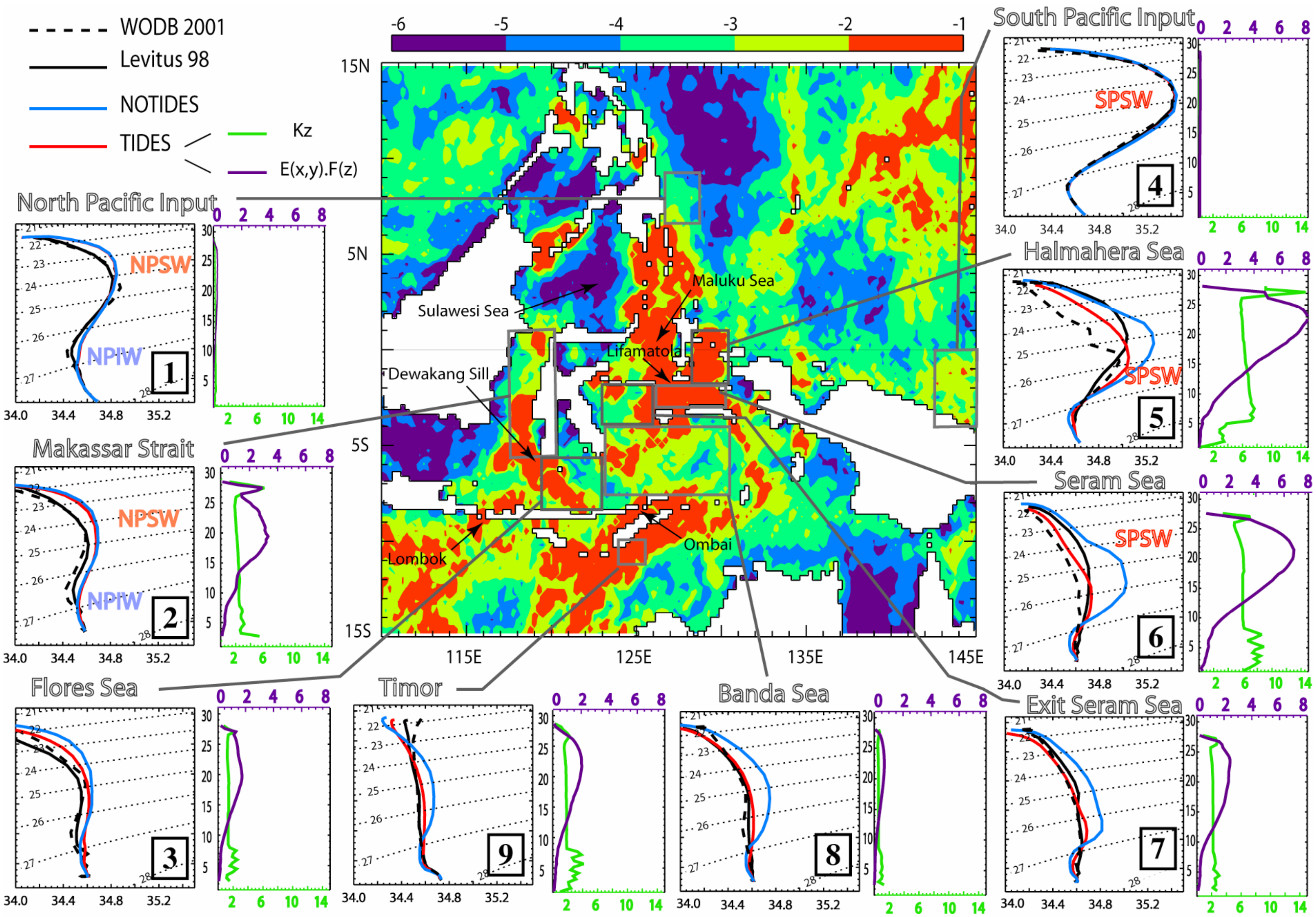
Model Drift in SST



Impacts of Tides on SST



Example: Water mass transformation in Indonesian Through Flow region modified by tidal mixing – through including parameterization of internal tide mixing (Koch-Larrouy et al., 2007)



Further Studies on Tidal Mixing

- **Example: K**och-Larrouy et al is examining the influences of tidal mixing on atmospheric convection in coupled models

- **Can tidal mixing be explicitly included (vs parameterized) in global ocean models?**

-- **N**eed high resolution to resolve internal tides -- ¼ deg? 1/12 deg?

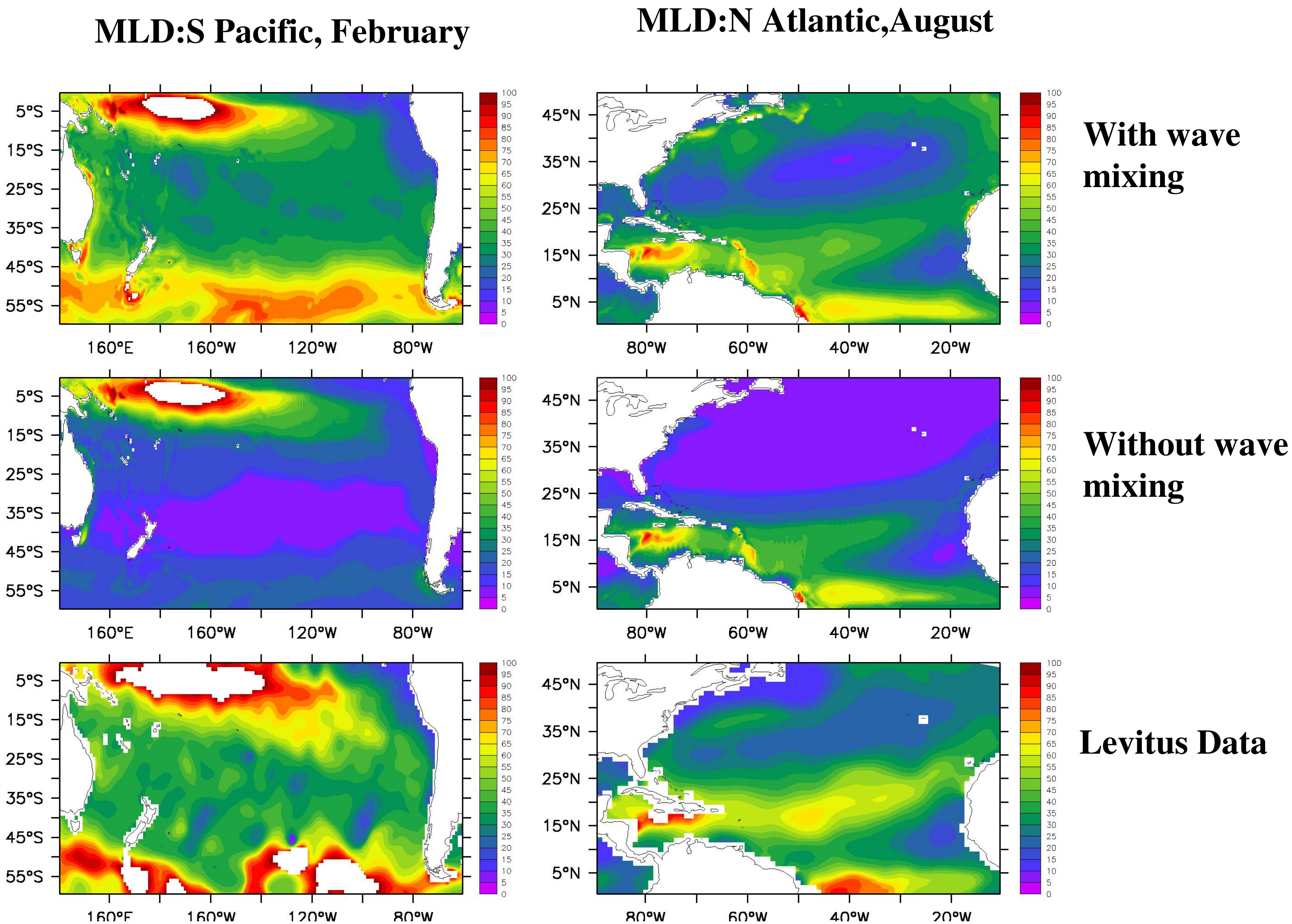
Mixing Due to Surface Waves

(Qiao et al, 2004)

Enhancement to vertical diffusivity/viscosity:

$$B_V = \alpha \iint_{\vec{k}} E\left(\vec{k}\right) \exp\left\{2kz\right\} d\vec{k} \, \frac{\partial}{\partial z}\left(\iint_{\vec{k}} \omega^2 E\left(\vec{k}\right) \exp\left\{2kz\right\} d\vec{k} \right)^{1/2}$$

The wave spectrum E(K) can be calculated from wave models. It changes with (x, y, t), so Bv is the function of (x, y, z, t).


MLD:S Pacific, February
MLD:N Atlantic,August
With wave mixing
Without wave mixing
Levitus Data
5°S
15°S
25°S
35°S
45°S
55°S
160°E
160°W
120°W
80°W
45°N
35°N
25°N
15°N
5°N
80°W
60°W
40°W
20°W
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

Summary

➢CONCEPTS and GOAPP support coupled atmosphere ocean model development

✓To develop coupled atmosphere-ocean modelling systems including data assimilation capacity
✓To study the prediction and predictability at time scales from days to decades

➢Coordinated ocean model development

✓To contribute to the coupled systems
✓To study the impacts of coupling on prediction
✓To satisfy global and regional interests

➢Issues of ocean modelling

✓Initial results from prognostic simulations; demonstrate reasonable quality
✓Further improvements including resolution, sea-ice, physics (mixing)
✓Observational data are used for model validation and constraining (parameter tuning and data assimilation)
✓Interesting topics to study: influences of sea-ice, meso-scale eddies, mixing etc on SST and air-sea fluxes