Off-line tracer applications based on Global HYCOM simulations

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Also:

Present status of Global Real-Time Ocean Forecast System (with U.S. Navy HYCOM) at NOAA/EMC

Outline:

1. Studies of the Southern Ocean ventilation with idealized tracers (I.Kamenkovich)

2. Fukushima online (NCEP/EMC) and off-line (H.Kawamura) tracer simulations.

3. Biogeochemical modeling efforts (NCEP/EMC)

4. Global 0.08 HYCOM (NCEP/EMC) based on U.S. Navy GOFS.

Off-line tracer modeling is a powerful practical method to simulate tracer evolution using previously calculated velocity and density fields.

The main advantage of this approach is in its computational efficiency, which permits extended simulations and multiple sensitivity runs.

The off-line tracer model used for this work is based on the code originally developed for HYCOM by Rainer Bleck. It calculates the 3D tracer transport from daily averaged velocities, as well as daily-mean and instantaneous layer thicknesses.

On-going projects include studies of:
a) **Southern Ocean ventilation with idealized tracers by I. Kamenkovich et al, U. Miami. They are based on Southern Ocean and Global climatological runs.**
b) **radionuclides in the Pacific Ocean**

For these applications, one year of the climatological HYCOM+CICE GLBb0.08 model (from NRL, expt 23.0) was run saving daily mean archives, daily instantaneous dp, and daily mean salinity diffusion coefficients

Off-line tracer model by R. Bleck for dynamically passive tracers.
Bleck, R., M. Maltrud, S. Peacock, Global dispersion of anthropogenic CO2, unpublished manuscript, 2006.

In use by I. Kamenkovich et al. for **age-related tracers in the Southern Ocean**.

Advance the tracer:

Use **time-mean horizontal mass fluxes for each layer**, **instantaneous layer thickness at the beginning and end of time interval**, and **time-mean layer thickness** . **Accepting some temporal truncation errors**, the tracer can be advanced using $dp, \overline{dp}, \overline{u}, \overline{v}$

$$(Q\Delta p)_{new} - (Q\Delta p)_{old} + \nabla_s.\left(Q\overline{\boldsymbol{v}\Delta p}\right) + \left(Q\dot{s}\,\overline{\frac{\partial p}{\partial s}}\right)_2 - \left(Q\dot{s}\,\overline{\frac{\partial p}{\partial s}}\right)_1 = 0$$

Where over-bars indicate time integrals.

The last two terms on the vertical mass flux are computed by vertically adding the continuity equation (same equation with Q=1).

Southern Ocean Offline Tracer Model (SOOTM)

OFFLINE CONFIGURATION:

- uses previously computed fields (velocity, density, mixing) to simulate ***dynamically passive tracers***
- high spatial resolution of 1/12^{o}

ADVANTAGES:

- computational efficiency: 10 years takes 5-7 days on 16 CPUs (OMP)
- convenience for studies on the importance of specific processes

CONFIGURATION

- online model configured and run at NRL. (Re-run as regional model to save instantaneous layer thickness in addition to mean archives)
- based on the Hybrid Coordinate Ocean Model (HYCOM)
- global domain, 32 vertical layers (GLBb0.08)
- forced with monthly ECMWF (ERA40) forcing fields plus 6-hourly anomalies obtained from NOGAPS winds

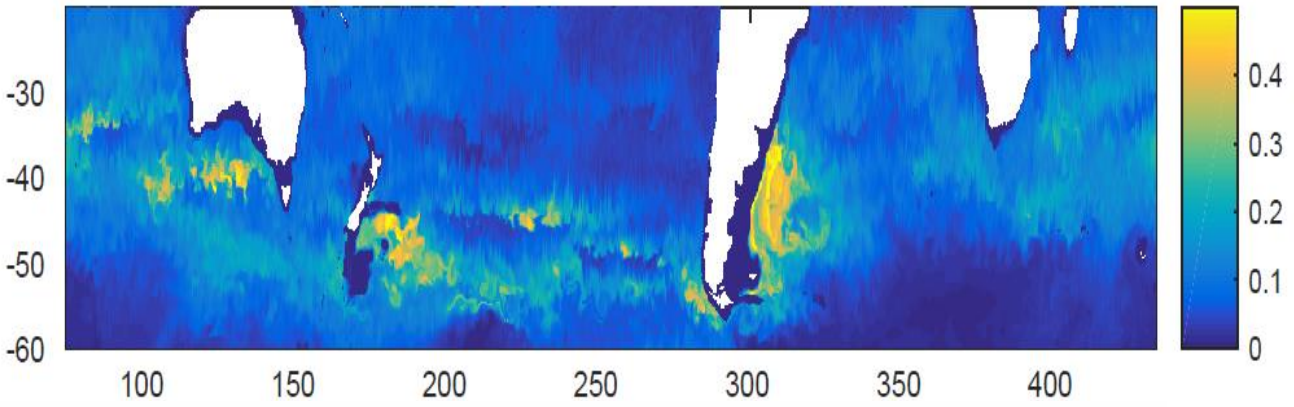
I. Kamenkovich. U. Miami

1) Offline tracer

SOOTM: Results

- "Boundary Impulse Response" (BIR) tracer:
  - surface concentrations are set to 1 for one year, then kept at 0
  - related to the Transient Time Distribution (TTD)

- Tracers enter in the south-western parts of the Atlantic and Pacific basins
- Eddies help to spread the tracer within the basins



BIR tracer after 2 years in the control simulation. The values are integrated in the vertical and normalized.

Simulation of Fukushima tracer in the North West Pacific, with HYCOM RTOFS-ET (episodic tracer)

Objectives

- **quick guidance on environmental contamination**. Provide information with the purpose of identifying ocean areas safe for human activity and areas that are potentially threatened.
- Serve as a practical **example for future implementation of ecobiological ocean modeling and forecast** with realistic ocean currents.

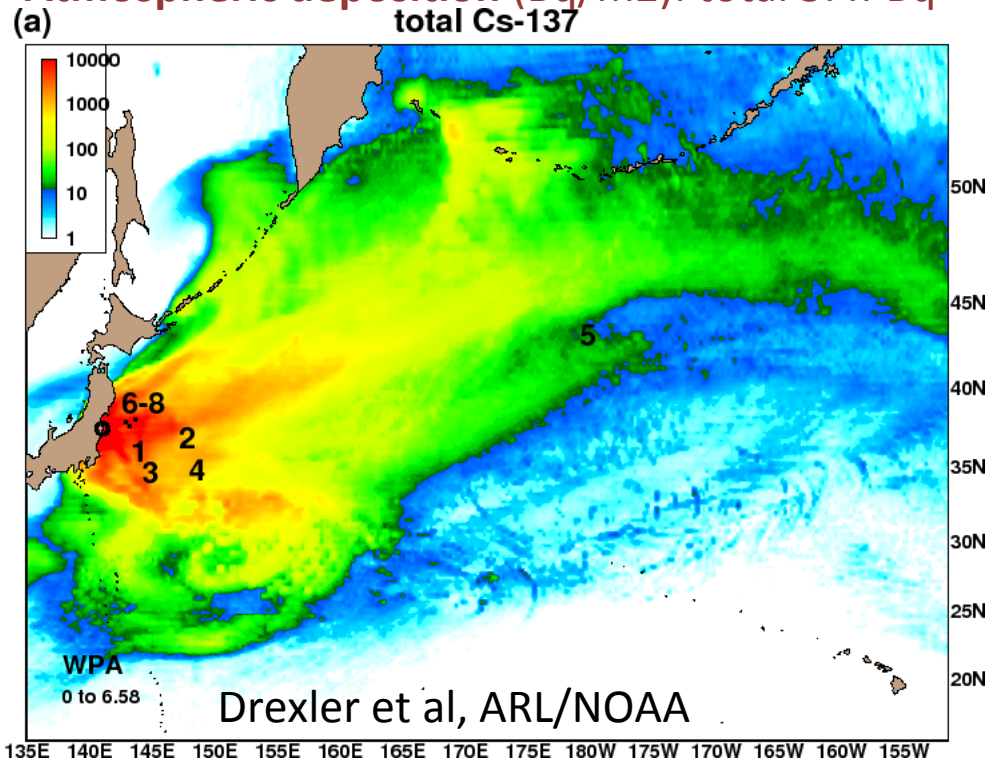
On-line tracer simulation:

- Domain: **Western North Pacific**, sub-region of Global HYCOM, 32 layers
- **Initialization and daily lateral boundary conditions from then pre-operational RTOFS-Global which received daily nowcasts from NRL-NAVO**.
- Regional model was run **each day for one day, in forecast mode, using NCEP GDAS atmospheric forcing (hindcasts with data assimilation).** In addition one ocean forecast day was produced each day (using NCEP GFS forecast atmospheric forcing)
- One tracer (^{137}Cs, with no decay, since ^{137}Cs has a half life of 30.17 years).
- **Tracer sources: atmospheric deposition and direct ocean discharge**.

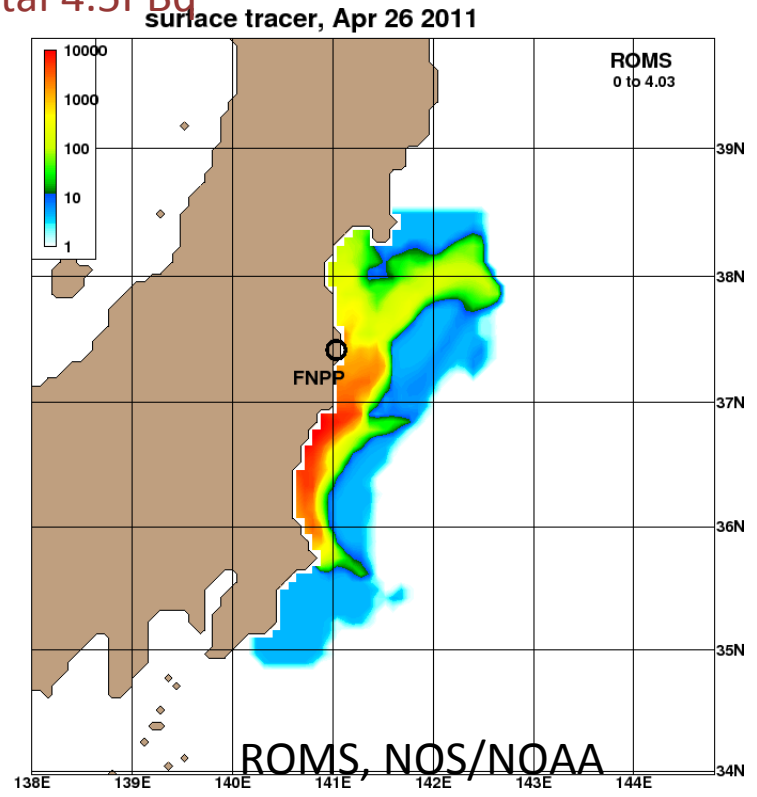
Garraffo, Z.D., H-C Kim, A. Mehra, T. Spindler, I. Rivin, H. Tolman, Weather and Forecasting, in press.

1Bq=1 disintegration/s

Atmospheric deposition (Bq/m2): total 5.4PBq



Direct ocean discharge (surface, Bq/m3): total 4.5PBq



Atmospheric deposition, after the accident:

From atmospheric dispersion model, HYSPLIT-NSC, Draxler et al, J. Environm. Radiact, Jan 2015. Deposition: 5.4PBq over ocean, 10PBq over land and ocean.

Direct ocean discharge: 3D from ROMS simulation (Lanerolle, NOS/NOAA, in Masumoto et al, 2012). Discharge: 4.5PBq

Total all times atmosphere + ocean : 10PBq over the ocean.

A high-end estimate of atmospheric emissions by Stohl (2012) was presented as 37PBq (20-53PBq).

2) Fukushima on-line tracer

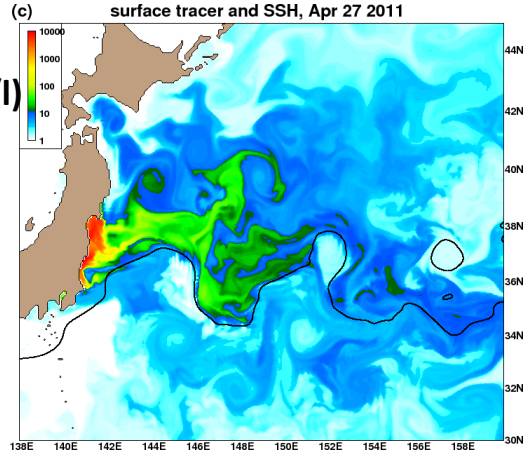
Hideyuki Kawamura. Japan Atomic Energy Agency.

Dr. Kawamura (JAEA) produced off-line tracer simulations for the N. Pacific. The ocean states are nowcasts by HYCOM (NAVO) and MOVE (Japan Meteorological Agency):

- Oceanographic model:
- HYCOM: HYCOM+NCODA Global Analysis (GLBa0.08)
  - Horizontal resolution: 1/12º
  - Vertical level: interpolated 33 z-levels
- MOVE: 3DVAR data assimilation system (JMA)
  - Horizontal resolution: 1/10º, 1/2º
  - Vertical level: 54 levels
- Tracer model (SEA-GEARN)
- Advection, diffusion, radiological decay
- Interaction among dissolved, suspended and sediment phases
- Source term
- Atmosphere: Kobayashi *et al.* (2013)
- Ocean: Kawamura *et al.* (2011)

H. Kawamura
2) Fukushima off-line tracer

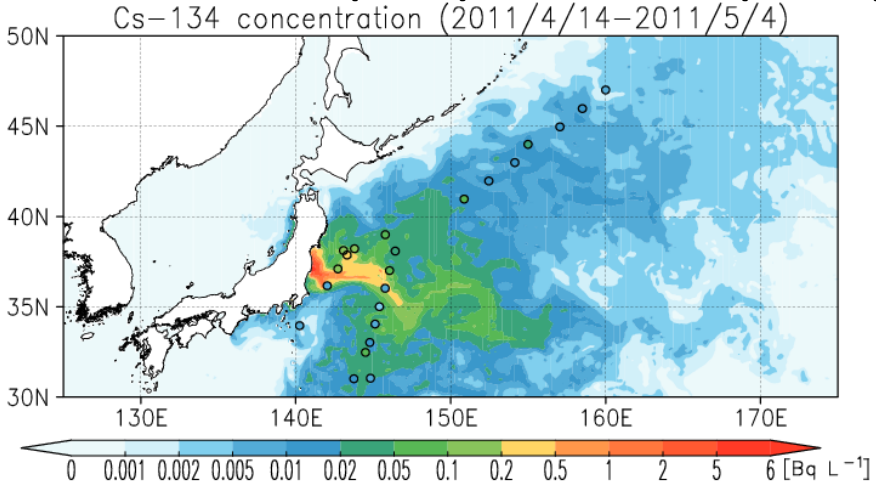
(Bq/m3=10^{-3}Bq/l)



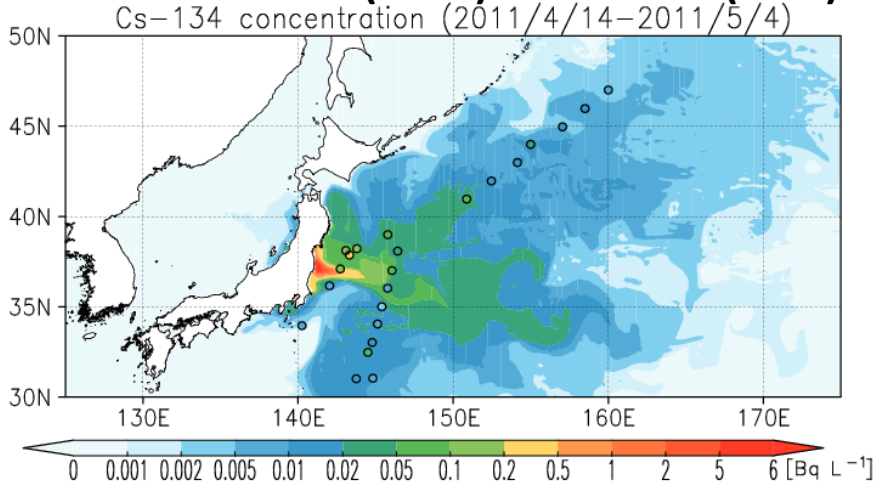
EMC/NOAA: On-line HYCOM

H. Kawamura (JAEA), Models and observations:

SEA-GEARN (JAEA) and HYCOM (NAVO)



SEA-GEARN (JAEA) and MOVE (JMA)



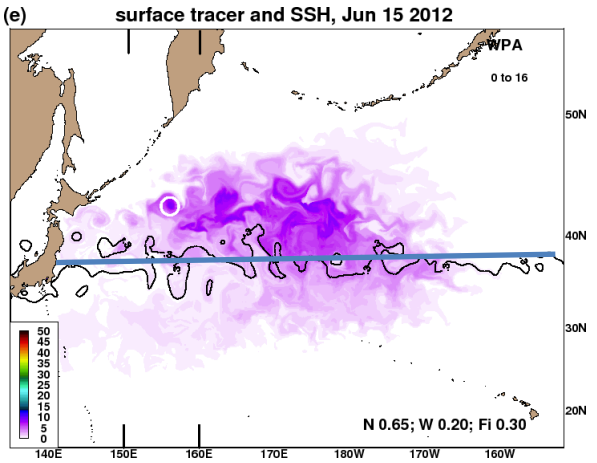
Data: MRI http://www.mri-jma.go.jp/Topics/hotyouhi/houtyouhi_sea.html

H. Kawamura
2) Fukushima off- and on-line tracer

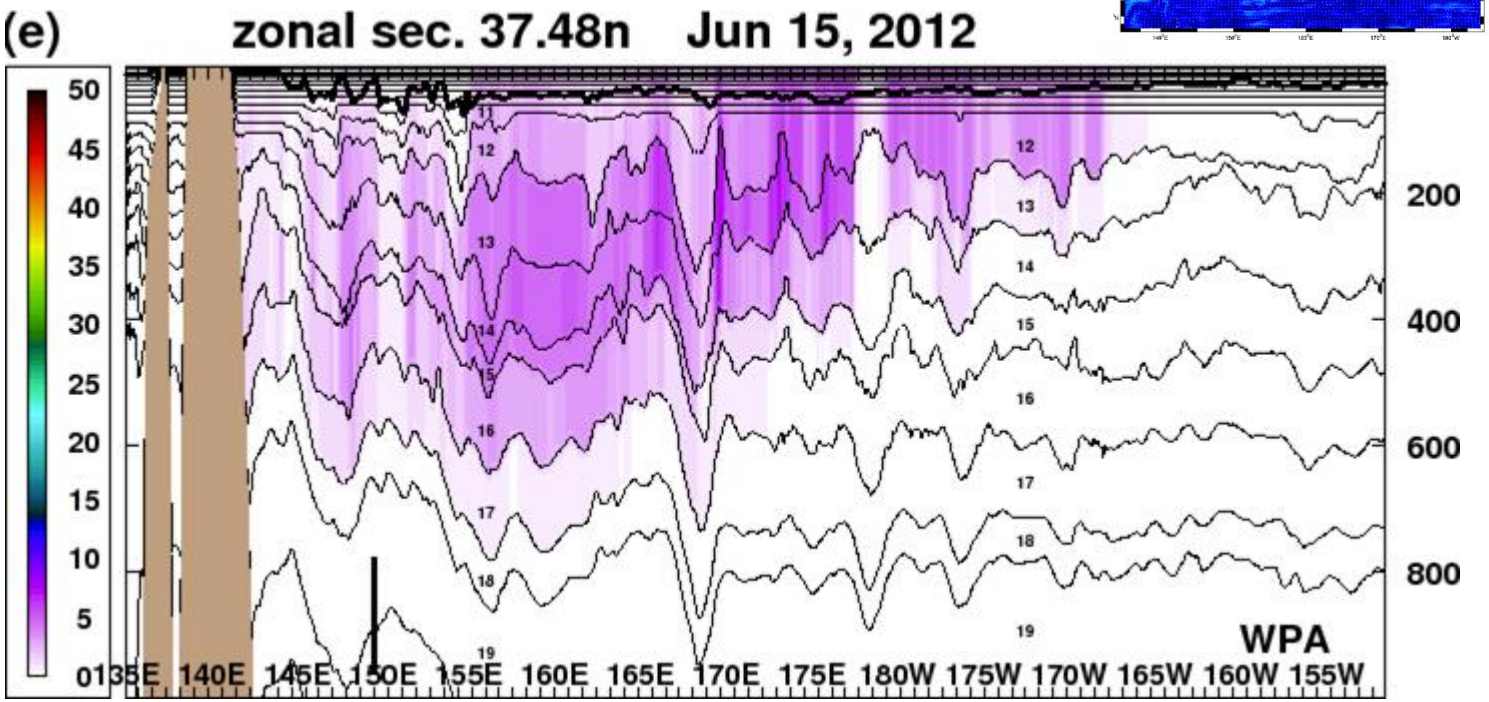
Zonal section 37.5°N, 15 months after accident, June 2012

Surface: Leakage south of the front, east of 160-170°E

Subsurface maximum, 160E, compatible with light central mode water (LCMW)

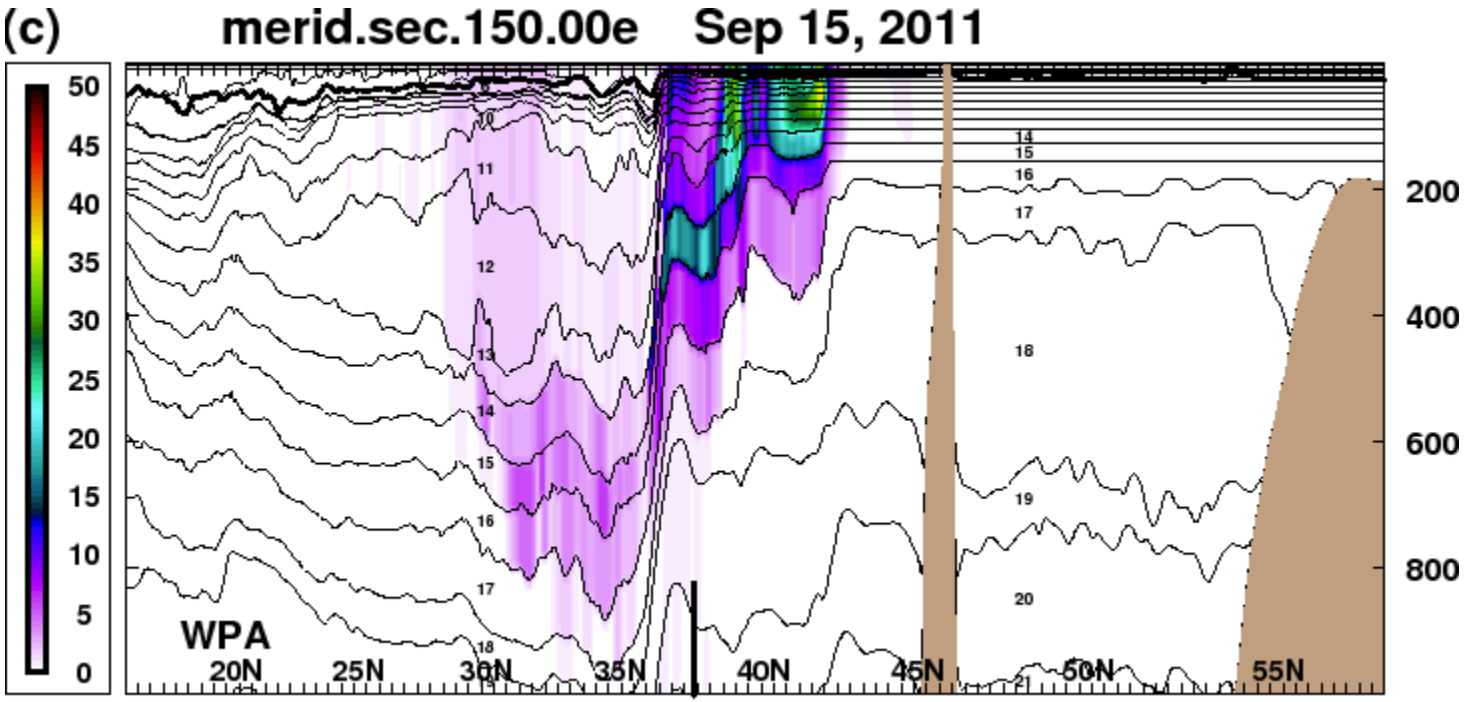


Modeled annual mean surface velocity



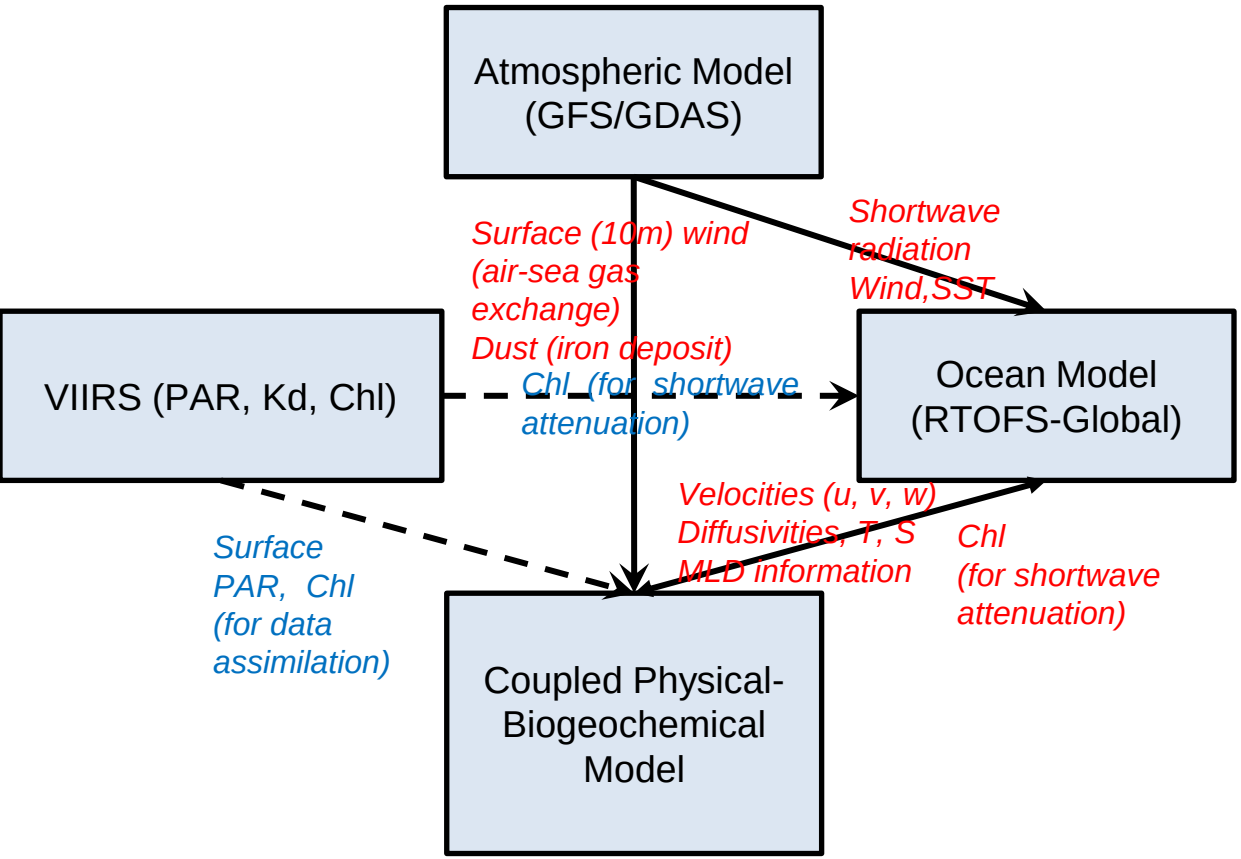
2) Fukushima on-line tracer

6 months after accident, 150°E section :
Some tracer migrates south below 500m across the well defined surface front, showing a possible pathway at the layer of the intermediate water.



2) Fukushima on-line tracer

Initial biogeochemical modeling efforts at NOAA/NCEP: Using VIIRS ocean color data for validation and data assimilation Funded project, A. Mehra et al, 2015.



Objectives:

- Employing coupled BGC-physical models to improve NWS forecasting skill (e.g., biological heating) with direct assimilation of Chl and Kd_{par} (Kd_{490}) fields from VIIRS or radiative transfer (RT) computations (Gregg, 2002)
- EMC's global model also serves as the outer nest for regional and coastal modeling for NOAA's ecological forecasting efforts (e.g., HAB, Hypoxia, Pathogens)
- Assessing effects of carbon dynamics between atmosphere and ocean and subsequent changes in acidity of the global ocean.

3) Bio-Geochemical modeling efforts

RTOFS Global v1.1.0

Teams: EMC: Avichal Mehra, Ilya Rivin, Zulema Garaffo, Bhavani Balasubramaniam, and Todd Spindler

NCO: Rebecca Cosgrove, Carissa Klemmer, Steven Earle

NRL-NAVO: Joe Metzger, Ole Martin Smedstad, Alan Wallcraft, Chris Dehaan

4) Global 0.08° HYCOM at EMC

Present production, implemented Oct 2011: RTOFS-Global v1.0

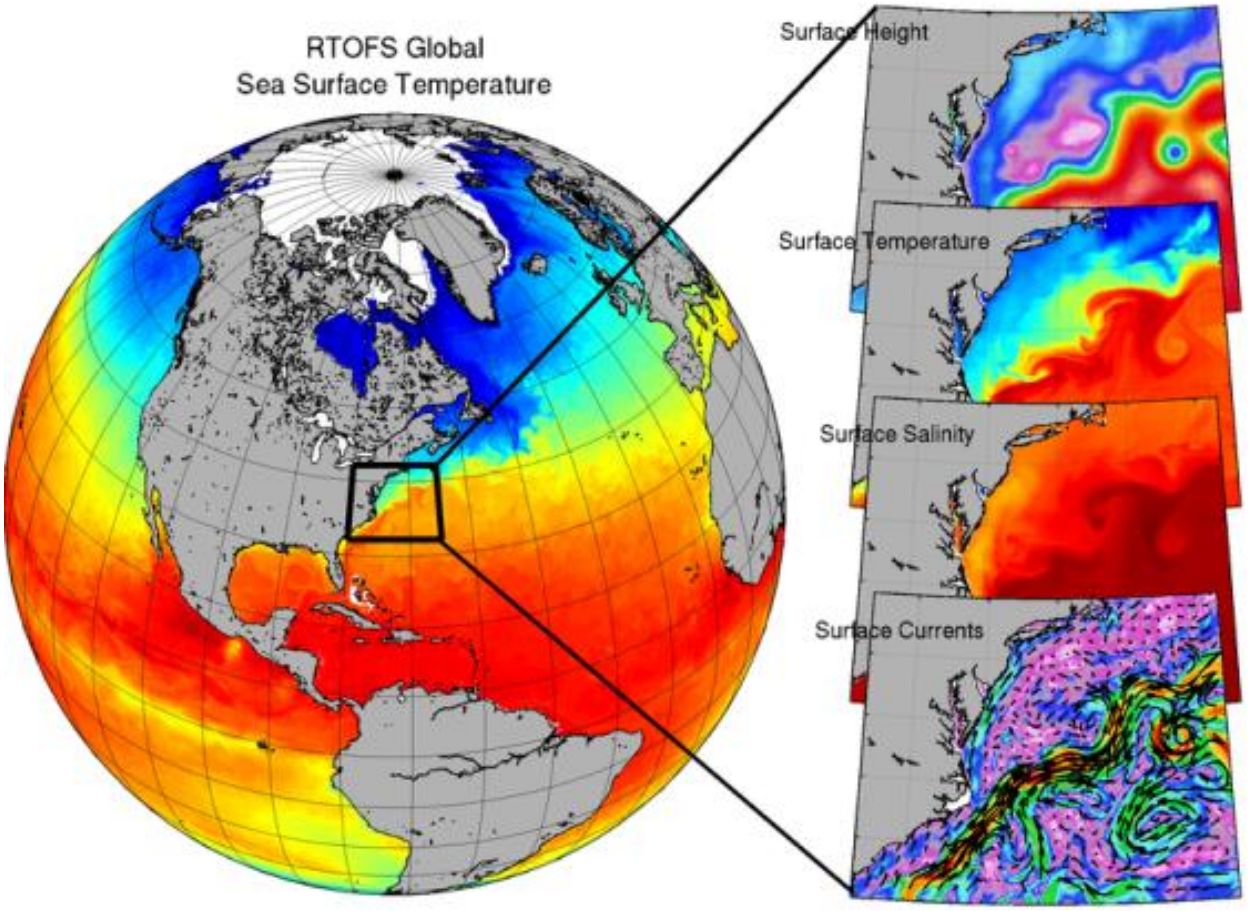
- **It is US Navy GOFS 3.0 except for forecast:**
- HYCOM 0.08°, 32 layers, NCODA at U.S. Navy,
- each day 10 days are run at NCEP/NOAA with NCEP forcing, 2 days in the past (GDAS forcing) , and 8 days in the future (GFS forcing).

To be upgraded to RTOFS-Global Version 1.1.0

Developed fully at US Navy (GOFS 3.1) with ongoing independent validation.

- **Will be US Navy GOFS 3.1 except for forecast:**
- HYCOM 0.08°, 41 layers, improved equation of state, topography, climatology, coupled with Los Alamos CICE, data-assimilation through NCODA at U.S. Navy.

1/12 Degree Global Domain



Primary Users:

NWS:
EMC,OPC,NHC,
WFO/NWPS

NOS:
CO-OPS, IOOS RA's

OAR:
OWAQ, AOML/HRD

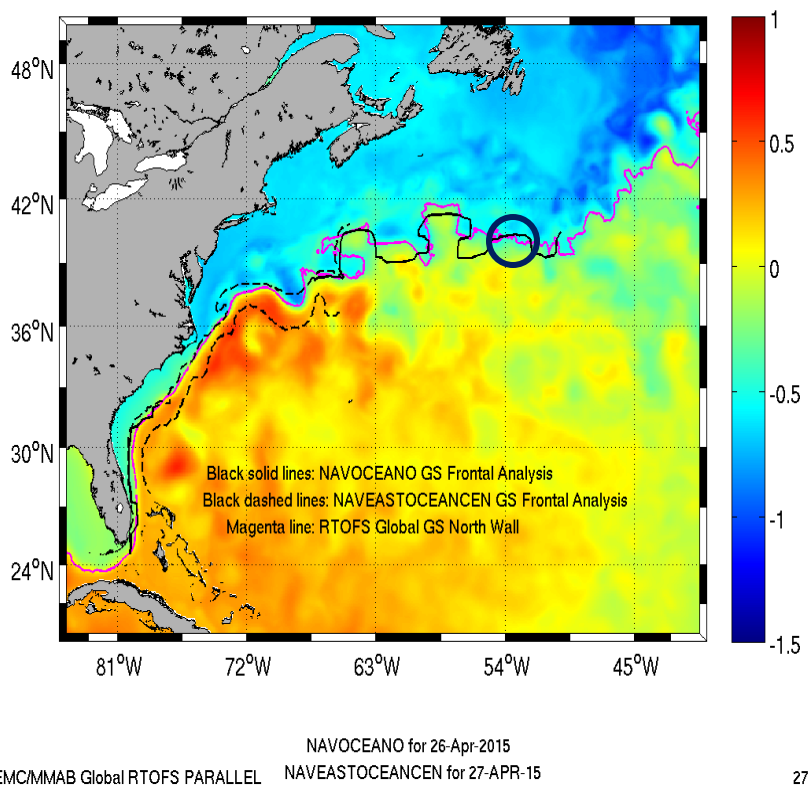
US Coast Guard

Primary research partners: NRL, ESRL, AOML, NESDIS, JCSDA, JAEA (Japan), UMD, FSU, MSU, INCOIS (India)

4) Present Global 0.08° HYCOM at EMC

RTOFS v1.1 vs RTOFS v1.0

RTOFS 1.1

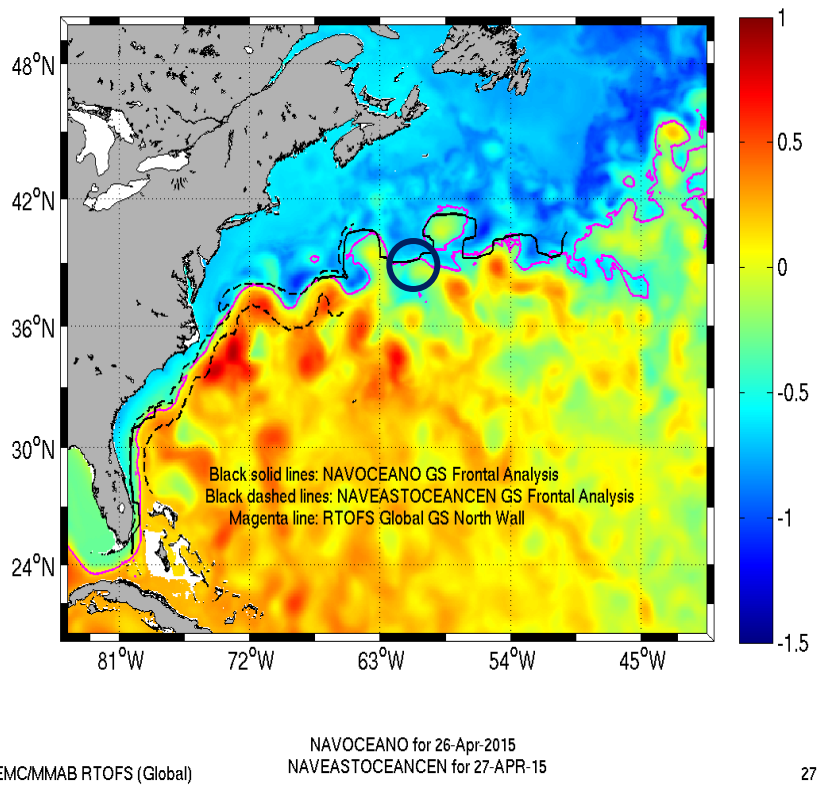


NCEP/EMC/MMAB Global RTOFS PARALLEL

NAVOCEANO for 26-Apr-2015
NAVEASTOCEANCEN for 27-APR-15

27 Apr 2015

RTOFS 1.0



NCEP/EMC/MMAB RTOFS (Global)

NAVOCEANO for 26-Apr-2015
NAVEASTOCEANCEN for 27-APR-15

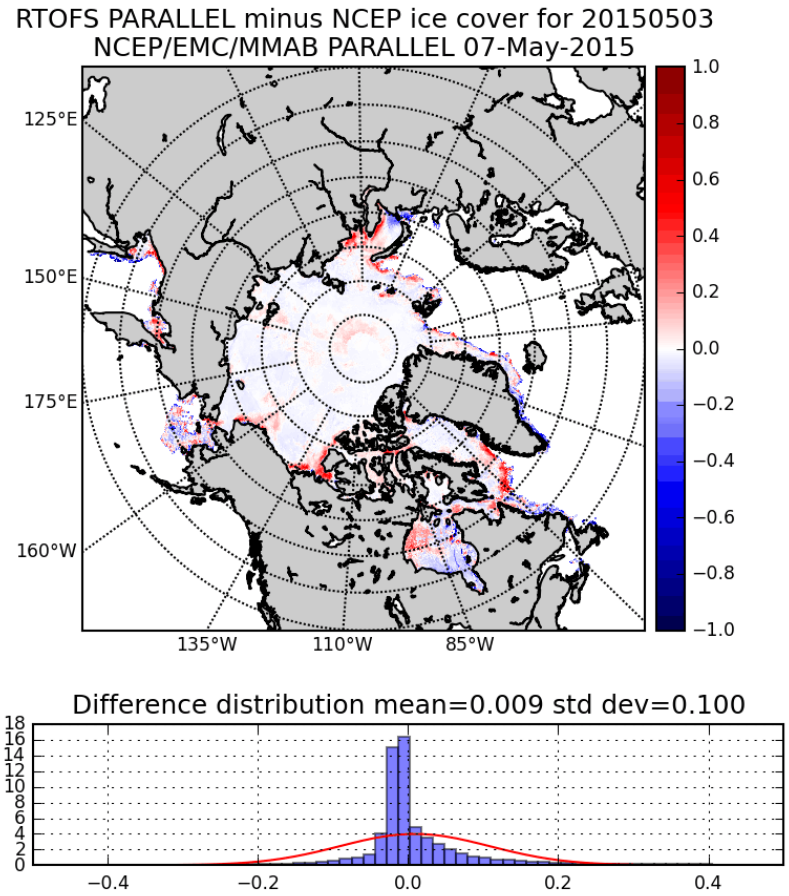
27 Apr 2015

GS North Wall location very similar with some differences in meanders

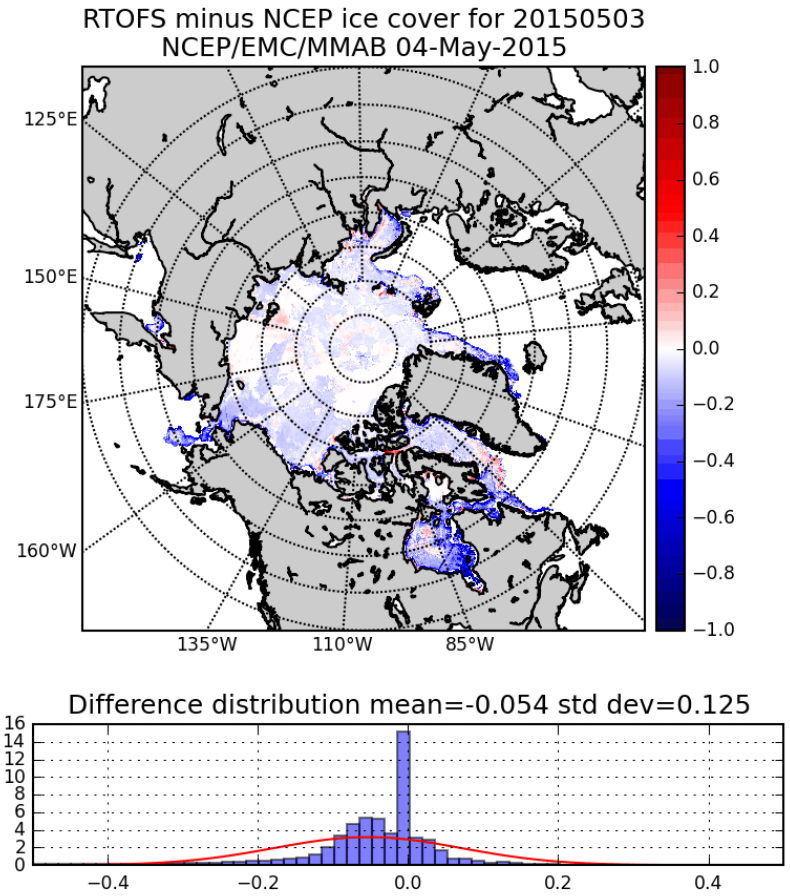
4) Future and present Global 0.08° HYCOM at EMC

Sea Ice Cover RTOFS v1.1. vs RTOFS v1.0 vs Analysis

RTOFS 1.1



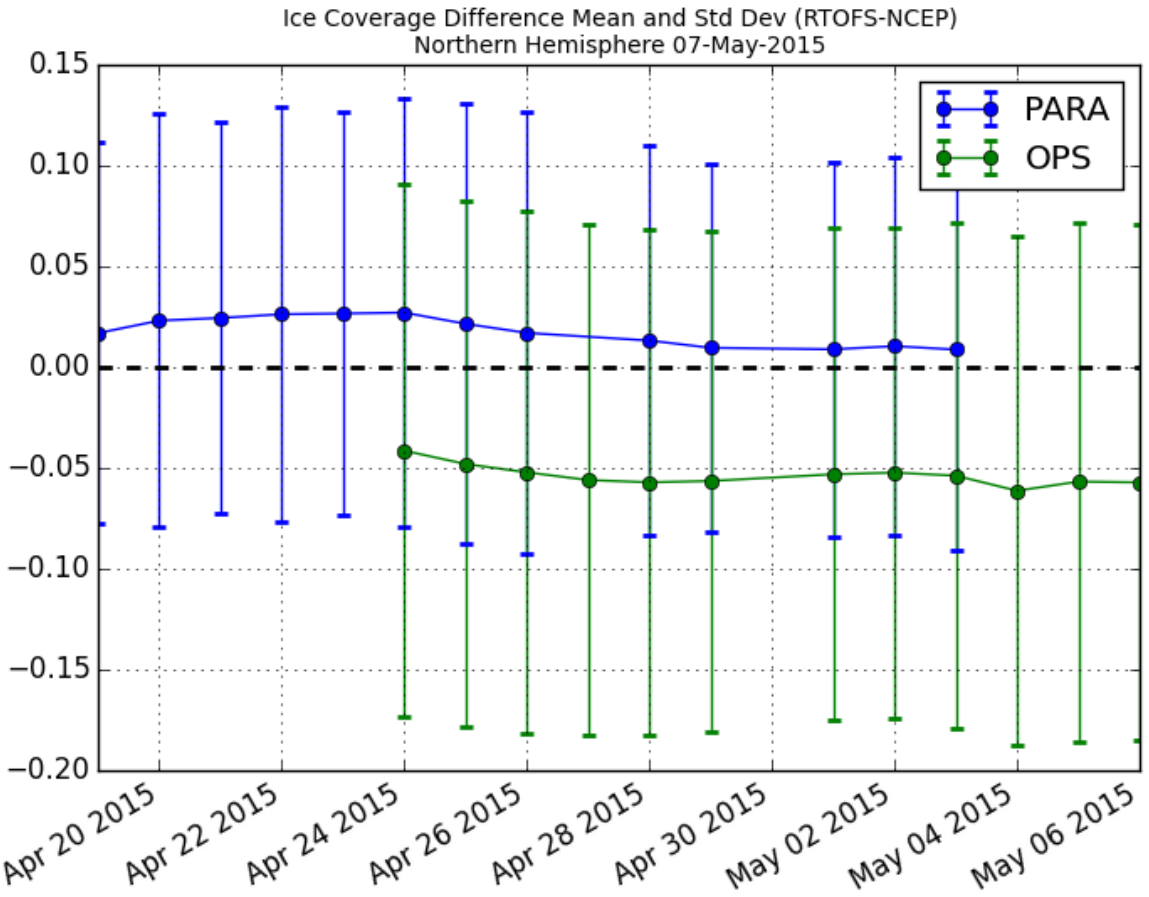
RTOFS 1.0



Differences in the Arctic region (May 2015)

4) Future and present Global 0.08° HYCOM at EMC

Sea Ice Cover RTOFS v1.1. vs RTOFS v1.0 vs Analysis



Mean differences in the Arctic region

Future work:

1. Studies of the Southern Ocean ventilation with idealized tracers (I.Kamenkovich). **Will be continued**

2. Off-line tracer simulations for radionucleides and for nutrients. **Will be continued**.

3. Biogeochemical modeling efforts (NCEP/EMC). **Will be started**

4. Global 0.08 HYCOM (NCEP/EMC) based on U.S. Navy GOFS. **Forecasts will be improved**.