Zulema D. Garraffo (IMSG at NOAA-EMC)

Fukushima nuclear disaster after the 11 March 2011 earthquake and tsunami.
Discussion of work by Godae OceanView groups

I) Simulations by Japan Atomic Energy Agency (JAEA) using nuclear dispersion models on the global ocean analysis systems, Multivariate Ocean Variational Estimation (MOVE) for the North Pacific and North West Pacific, by Meteorological Research Institute (MRI) at Japan Meteorological Agency;

II) Simulations by NCEP/NOAA: a)using numerical drifters on the NOAA Global Real-Time Ocean Forecast System (RTOFS-Global); b) using a 3D tracer simulation, through a regional ocean model for episodic tracer, RTOFS-ET;

III) Work by Mercator Ocean and University of Toulouse, on dispersion of pollution at basin scale, a) using simulated Lagrangian particles on the Mercator Ocean analysis and forecasting system, and b)using the SIROCCO ocean model for dispersion of particles.

I) Simulations by Japan Atomic Energy Agency (JAEA) using nuclear dispersion models on the global ocean analysis systems, Multivariate Ocean Variational Estimation (MOVE) for the North Pacific and North West Pacific, by Meteorological Research Institute (MRI) at Japan Meteorological Agency;

- **Kamachi (MRI) et al;**
- **Kawamura (JAEA) et al; poster.**

H. Kawamura[1], T.Kobayashi[1], Y. Furuno[1], N. Usui[2], & M. Kamachi[2]
[1]JAEA (Japan Atomic Energy Agency; [2]JMA/MRI

Oceanic dispersion simulations for ^{134}Cs and ^{137}Cs after the Fukushima disaster, utilizing:

Oceanic currents from reanalysis, from Multivariate Ocean Variational Estimation (MOVE) MOVE-NP and MOVE-WNP(0.1°) of JMA/MRI.

Source terms from atmospheric deposition: from atmospheric model WSPEEDI-II, by JAEA, with nuclear dispersion model (GEARN), estimate wet-dry deposition into sea surface. Released amount to atmosphere: Terada el al. 2012.

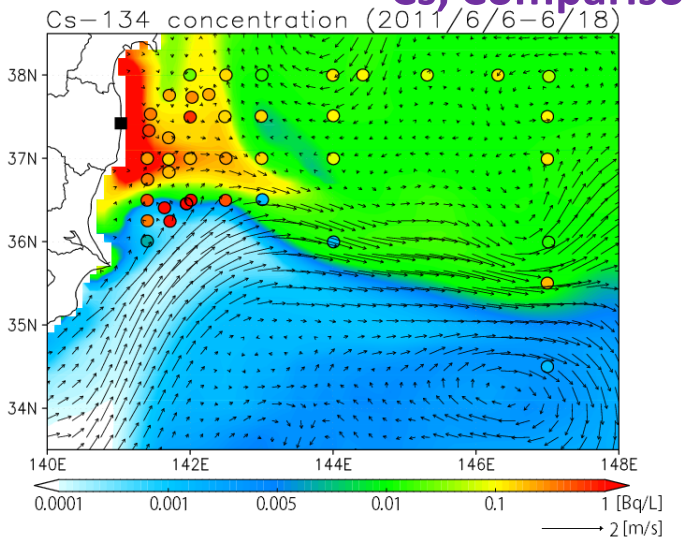
Direct ocean discharge: as Masumoto et al, 2012 (Tepco data, Kawamura et al, 2011, Tsumune et al, 2012).

Nuclear dispersion model: Sea-GEARN by JAEA
Lagrangian particles, horizontal resolution 0.1°. In different simulations, Cs was either treated as fully dissolved material or with interaction between dissolved-suspension-sediment phases. Alternative to Lagrangian particles: finite difference model.

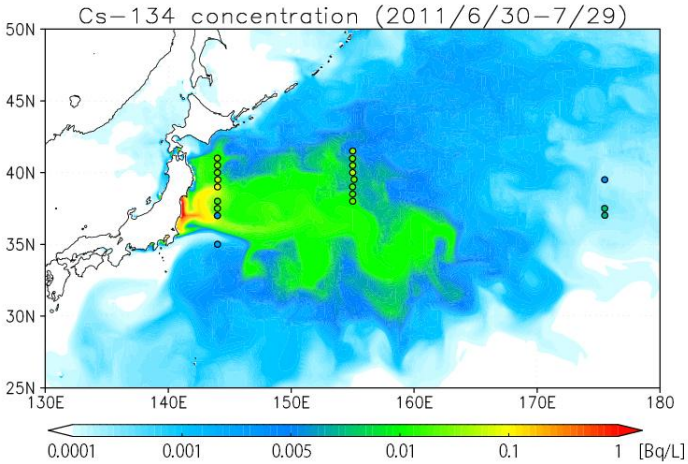
JAEA-MRI

Kawamura et al., this session, poster: Numerical experiments on dispersion of radionuclides in the ocean….

^{134}Cs, Comparison with observations, June 2011



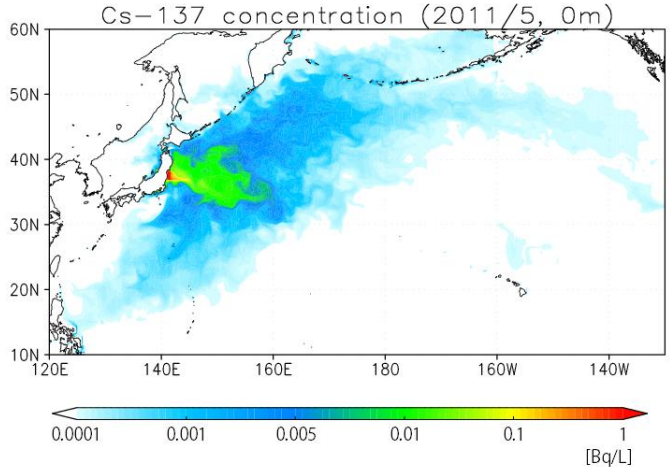
obs. by Buesseler et al, 2012



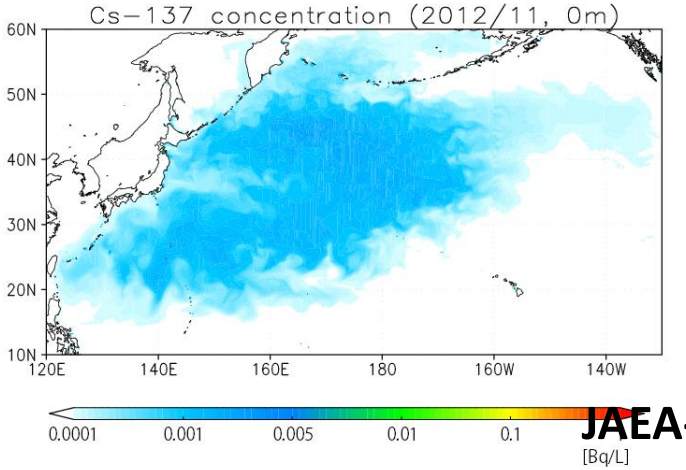
obs. by Kaeriyama et al, 2013

^{137}Cs

May 2011

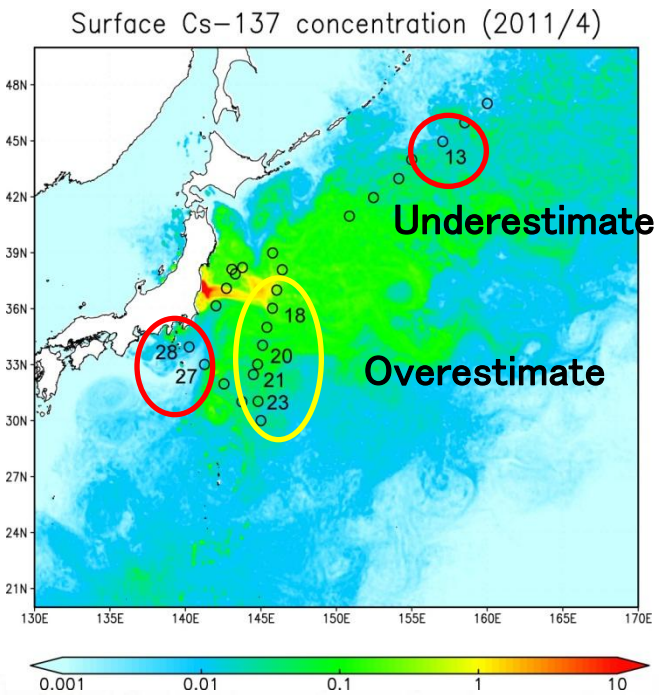


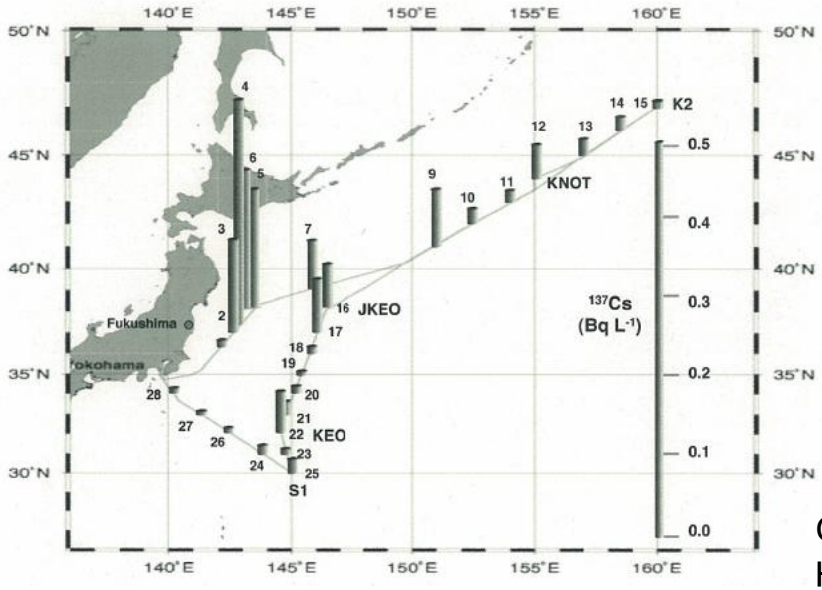
Nov 2012



JAEA-MRI

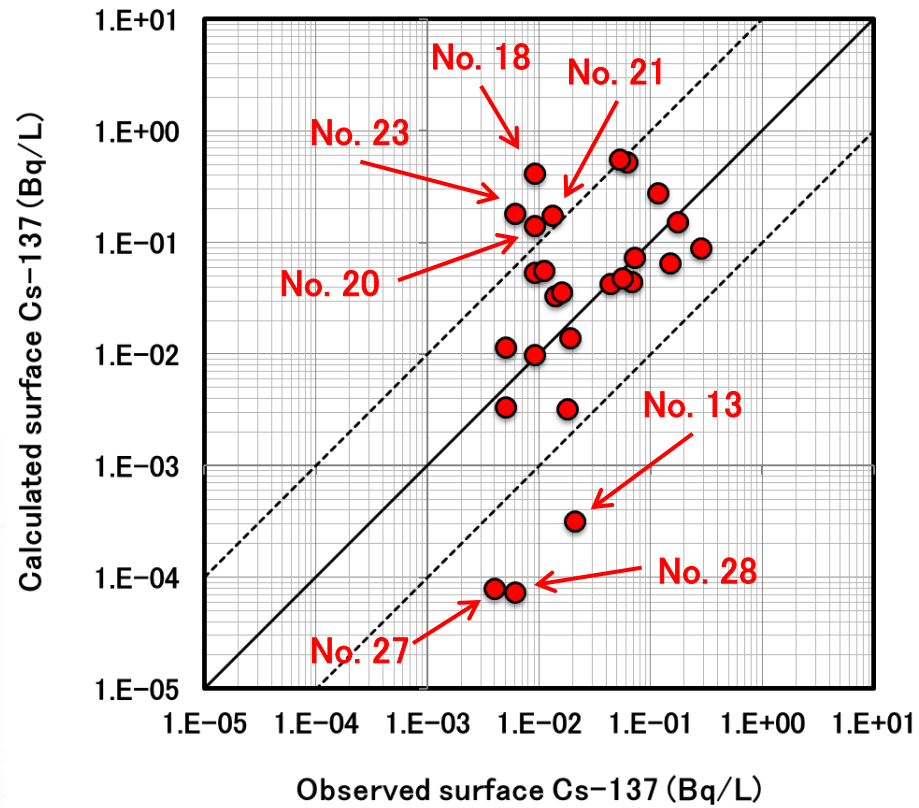
Validation of Distribution of ^{137}Cs Concentration (2011/4-5)





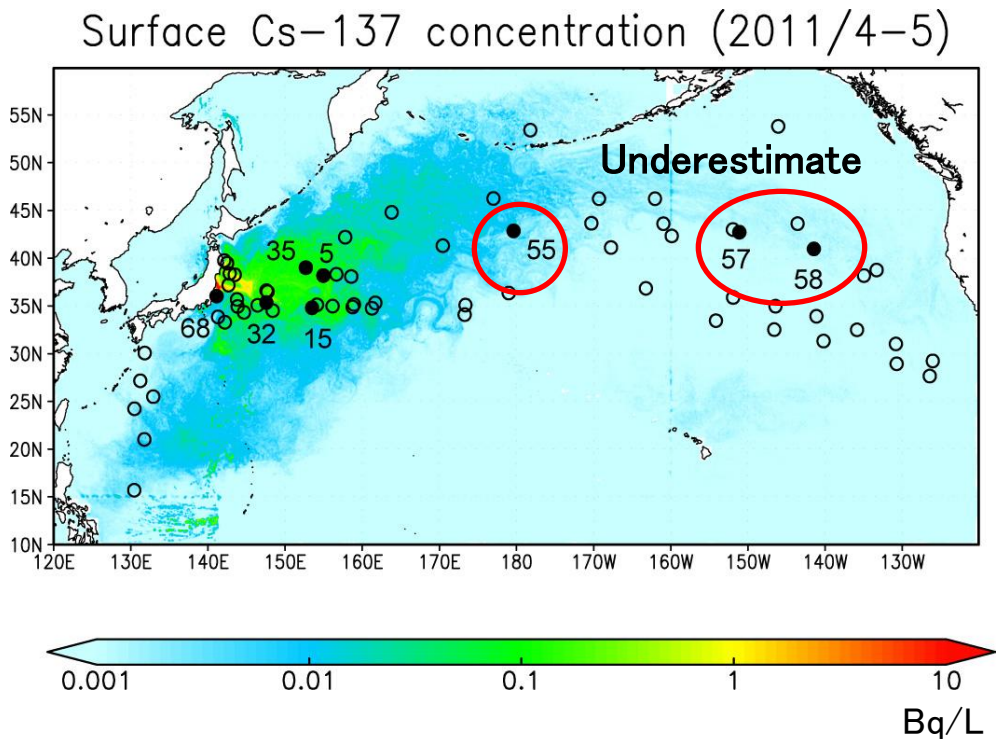
Observation
Honda *et al.*(2012)

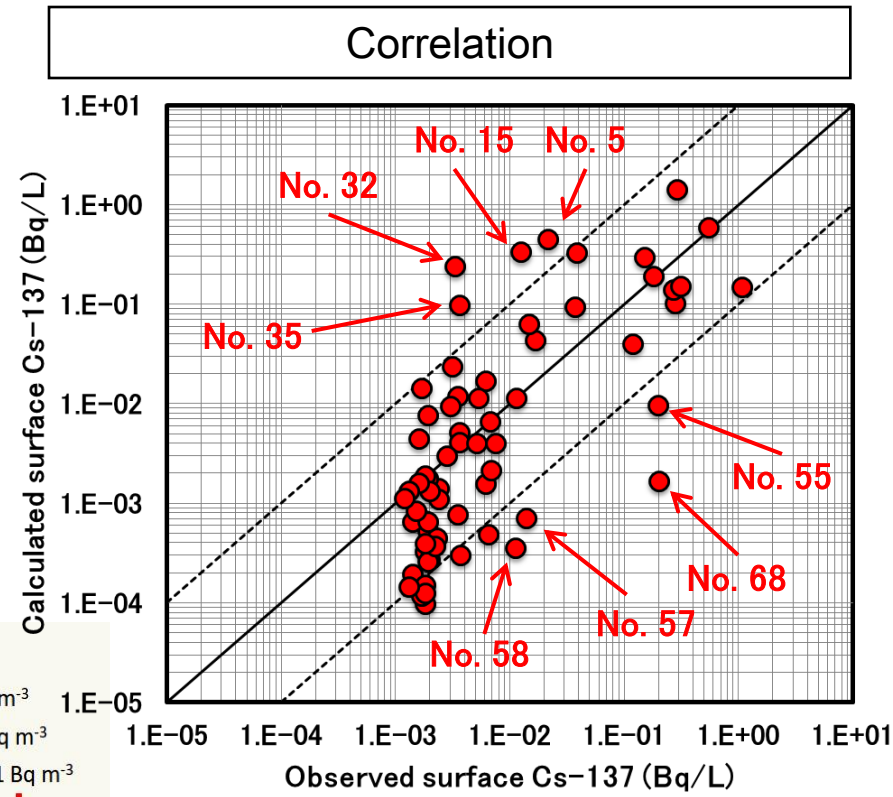
Correlation of ^{137}Cs concentration at the surface between observation by Honda *et al.* (2012) and simulation

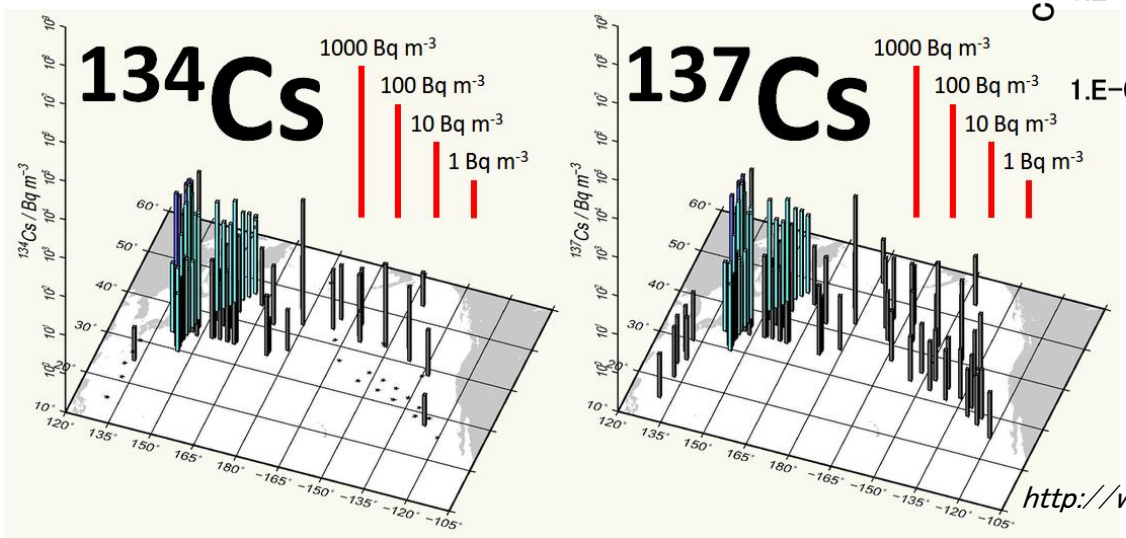


JAEA-MRI

Validation of Distribution of ^{137}Cs Concentration (2011/4-5)







JAEA-MRI

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

Summary

(Kamachi; Kawamura et al)
[Summary]

- Deposition of ^{137}Cs, from 2011/3 Fukushima Daiichi Nuclear Power Plant, is mainly in the north-east and south-east directions from Fukushima, onto the sea-surface, and dispersed in the Pacific. Its concentration is, in 2011/10 (half year after the earthquake), diluted into the order of 0.01 Bq/L. (The concentration is now under background level in 2013)
- Directly released ^{137}Cs into the ocean is advected eastward along the Kuroshio Extension. It shall be mixed and diluted by mesoscale eddies, and arrive at 170ºW after one year (2012/3)
- **Issues are unknown source information, unknown coastal process, and related modeling-assimilation**
- **International coordination will be established in the framework of JCOMM/TT-MEER under WMO-IOC; the Task Team collaborates IAEA; Japanese system is developed by JAEA and JMA/MRI**

II) Simulations by NCEP/NOAA, using:

a)numerical drifters on the NOAA Global Real-Time Ocean Forecast System (RTOFS-Global);

b) 3D tracer simulation, through a regional ocean model for episodic tracer, RTOFS-ET;

NCEP/NWS/NOAA simulations

II a)Ocean plume simulations:

- Tolman, H., Z. Garraffo, A. Mehra, I. Rivin, and T. Spindler, Sept 2013. Ocean plume modeling for the Fukushima Dai'ichi Event: Particle tracing. NOAA/NWS/NCEP technical note, please email Hendrik.Tolman@noaa.gov for a copy

First particle tracking products delivered to the governmental Inter-agency Working Group, 4 weeks after the first significant release of radionuclides. First quantitative offshore contamination estimates delivered in approximately 6 weeks.

- **Ocean model: analysis and prediction, RTOFS-Global, using initial conditions from the analysis of 2 days before the model run by the U.S. Navy (NAVO, Stennis, MS). RTOFS-Global is run with NCEP forcing for 2 days before the present, and then for 6 forecast days.**
- **Numerical drifters on the RTOFS-Global velocities.**

M. Kamachi (MRI)' s presentation
Dispersion Simulation of Released ^{137}Cs from Fukushima Daiichi Nuclear Power Plant after 2011/3/11

H. Kawamura[1], T.Kobayashi[1], Y. Furuno[1], N. Usui[2], & M. Kamachi[2]

[1]JAEA (Japan Atomic Energy Agency)

[2]JMA/MRI

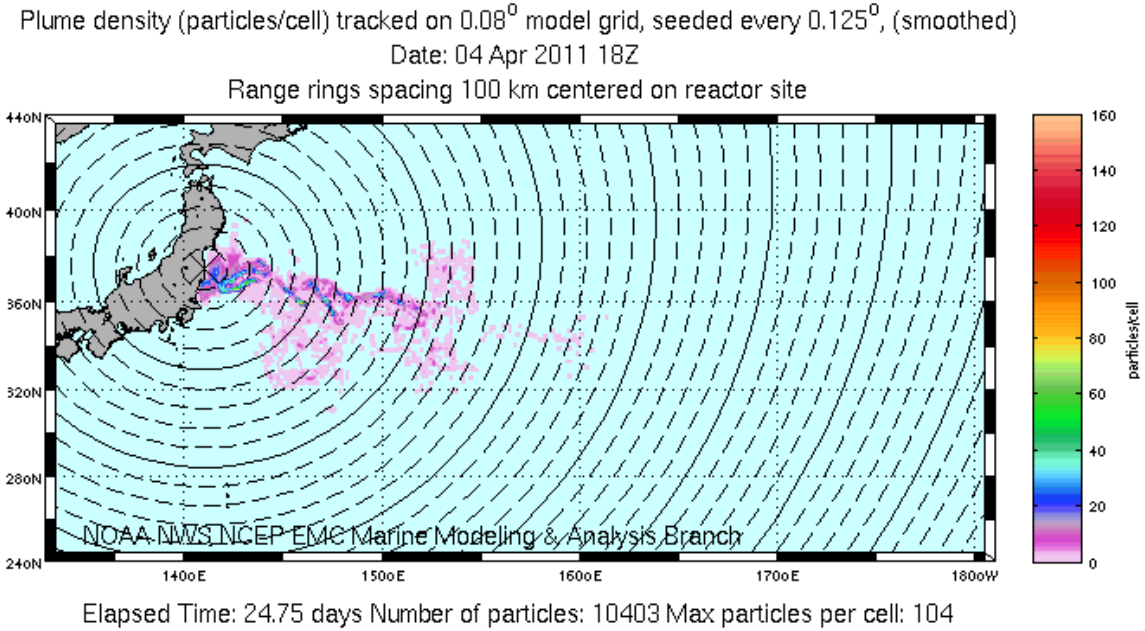
Methods of Numerical Simulation

◆ Nuclear Dispersion Model (SEA-GEARN)

- Lagrangian particle model developed by JAEA
- Include interaction among dissolved-, suspension-, bottom sedimentary-phases
- Include radioactive decay (^{137}Cs=30yr)
- Horizontal resolution 0.1°
- Ocean current: realistic assimilation (MOVE/MRI.COM-WNP of JMA/MRI)

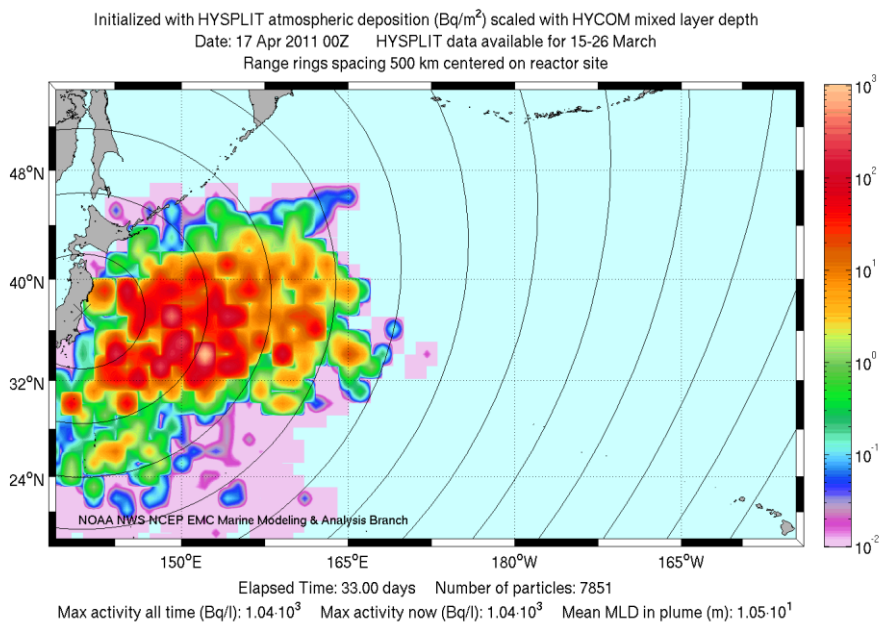
II a) Plume simulations ; Tolman et al, Sept 2013

Plume density, particles seeded in a grid near Fukushima; day 22 after first seeding.



Plume density April 4 2011

Activity for ^{137}Cs, from Lagrangian particles and HYSPLIT version 1 deposition (DOE-HYSPLIT), particles initialized at deposition time/space locations.



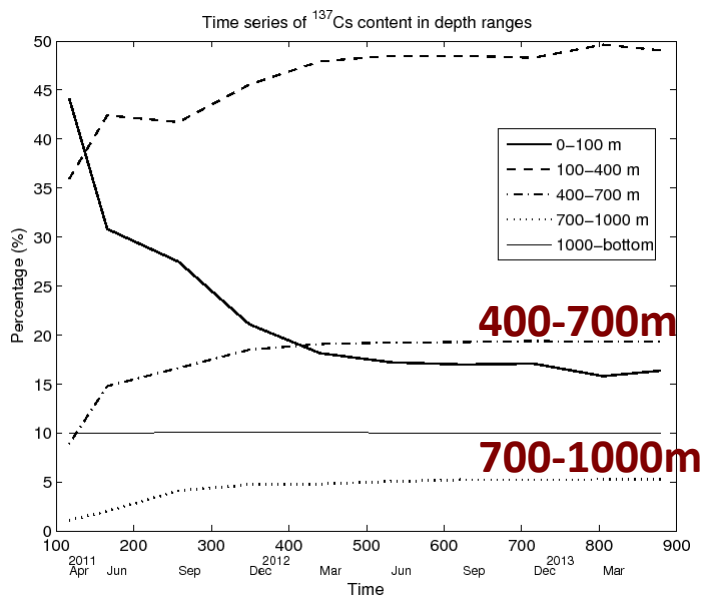
Activity ^{137}Cs, April 17 2011

NOAA

II b)3D tracer simulation , through a regional ocean model for episodic tracer, RTOFS-ET for the North West Pacific:

- **Garraffo, Z., H-C Kim, A. Mehra, T. Spindler, I. Rivin, H. Tolman. Modeling of 137Cs as a tracer in a regional model for the Western Pacific, after the Fukushima Daiichi Nuclear power plant accident of March 2111. Submitted to Weather and Forecasting, Sept 2013.**

- **HYCOM with one tracer for ^{137} Cs, with no decay (2-3 year simulation)**
- **Initialization and lateral boundary conditions from RTOFS-Global analysis; no other data constraint.**
- **Atmospheric deposition from HYSPLIT version 3, sources Nuclear Safety Commission (NSC, Japan)**
- **Direct ocean discharge from ROMS model at NOAA-NOS (by Lanerolle , Masumoto et al 2012).**



Part of the tracer is advected-diffused below the mixed layer

~25% increase in 2years, tracer 400-1000m

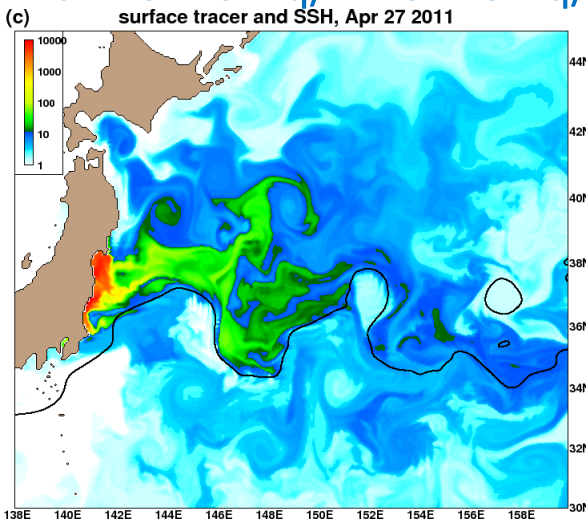
March 2011-May 2013

NOAA

^{137}Cs concentration

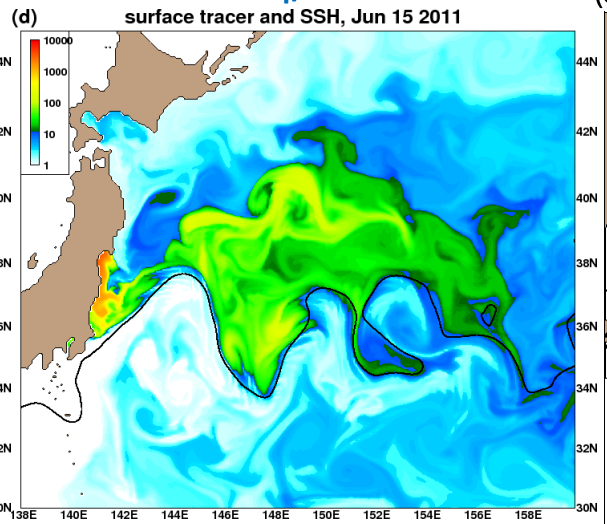
Apr 27, 2011, detail

Max $10*10^3 Bq/m^3$ or 10 Bq/l

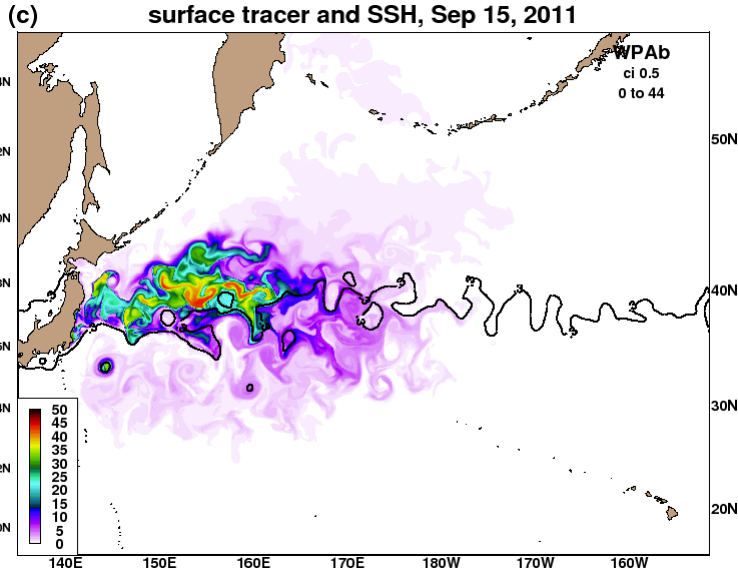


Jun 15, 2011, detail

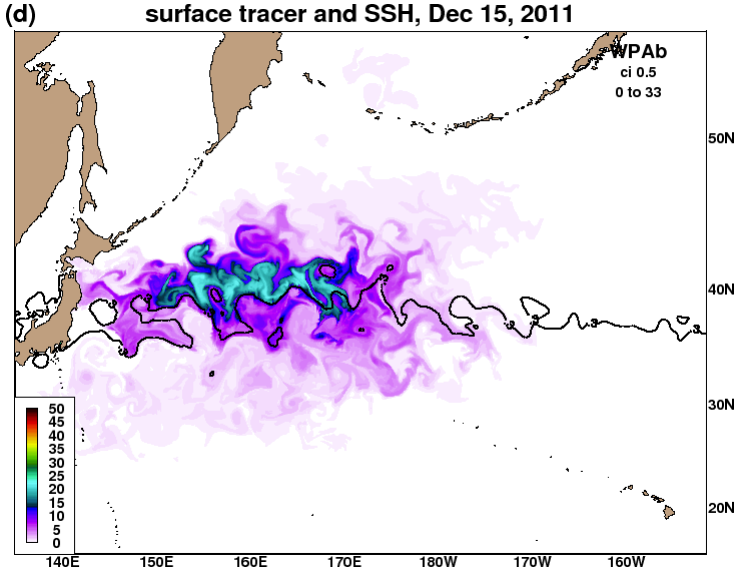
Max 3Bq/l



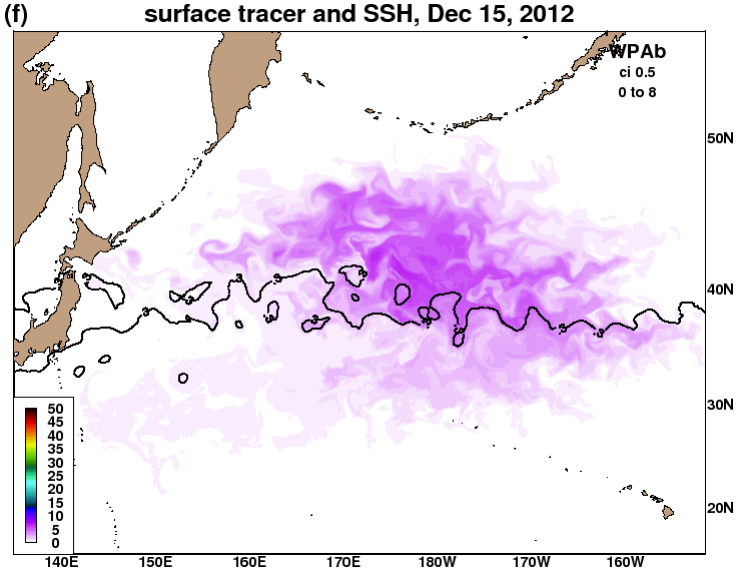
Sep 15, 2011, max 0.04Bq/l



Dec 15, 2011, max 0.03Bq/l



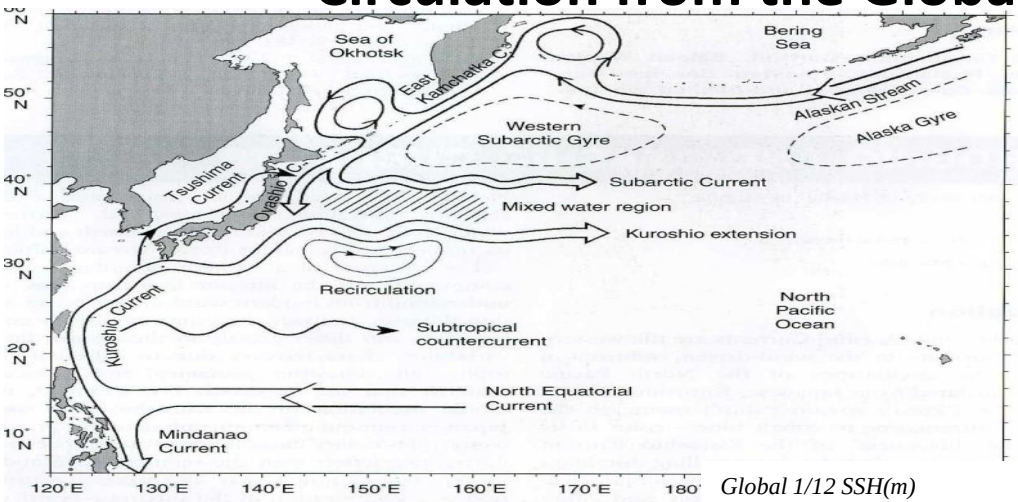
Dec 15, 2012, max 0.008Bq/l



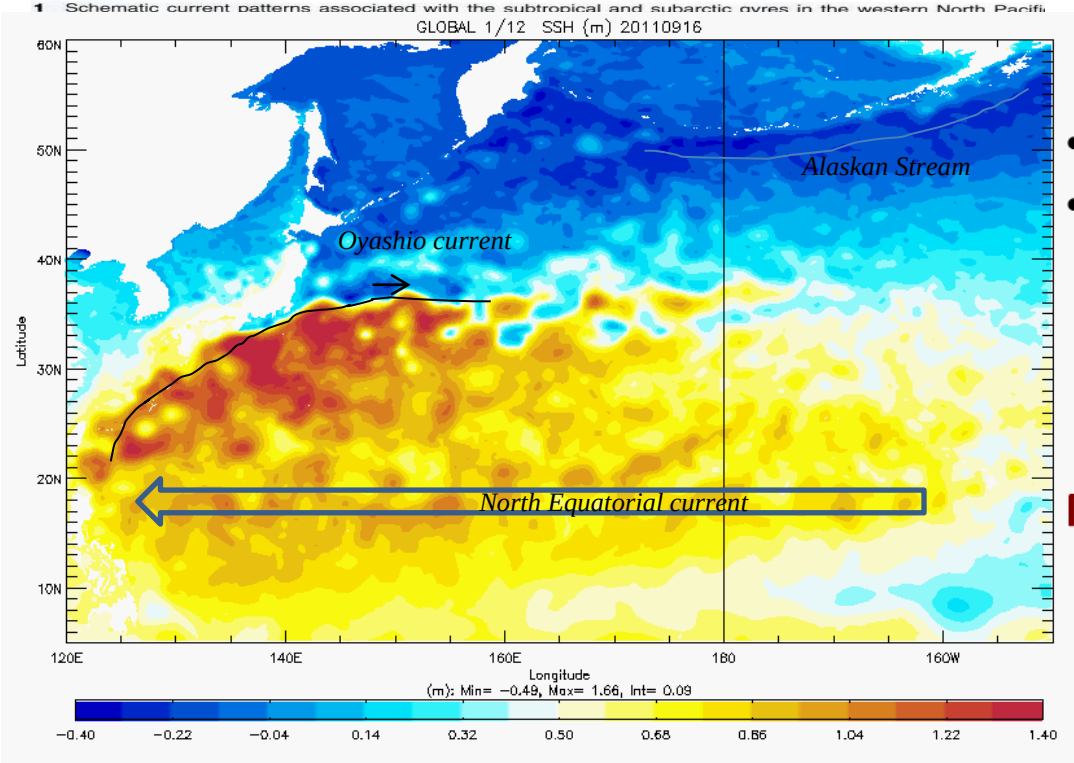
NOAA

III) Work by Mercator Ocean and University of Toulouse, on dispersion of pollution at basin scale, a) using simulated Lagrangian particles on the Mercator Ocean analysis and forecasting system, and b) using the SIROCCO ocean model for dispersion of particles.

a) MERCATOR PSY4: analysis and forecasting for North Pacific Circulation from the Global ocean system.



Schematic current patterns associated with the subtropical and subarctic gyres in the western North Pacifi



Global 1/12 SSH(m)

- Good simulation of North West Pacific circulation
- Global ocean model, 1/12 ° degree
- Data assimilation based on SEEK filter,
- assimilates satellite Sea Level Anomaly and SST, and in-situ T,S profiles
- Analysis and 7 day forecast
- Successful validation of sea surface velocities with drifting buoy velocities.

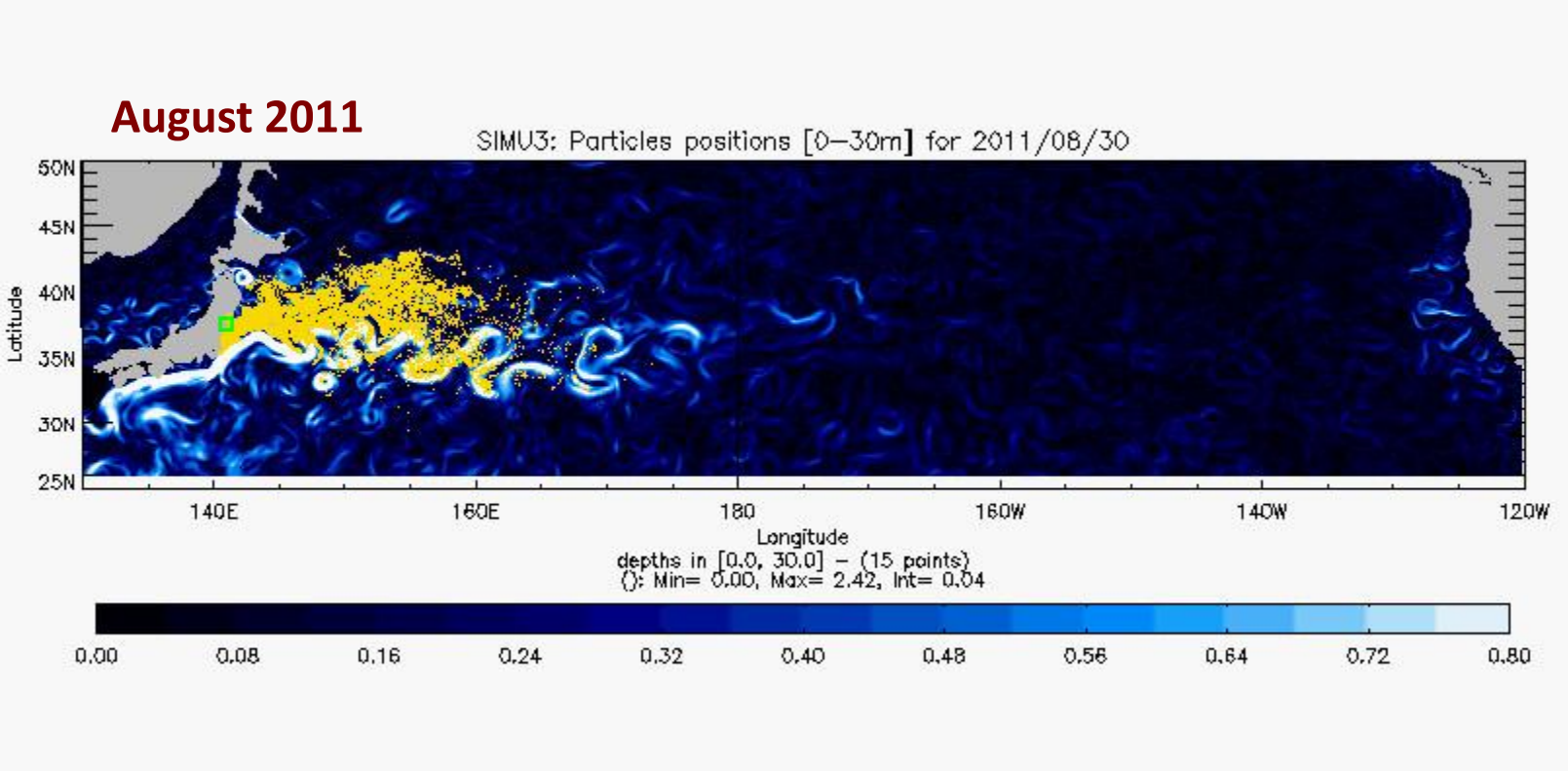
See poster by C. Derval on Mercator Ocean Service)

Mercator

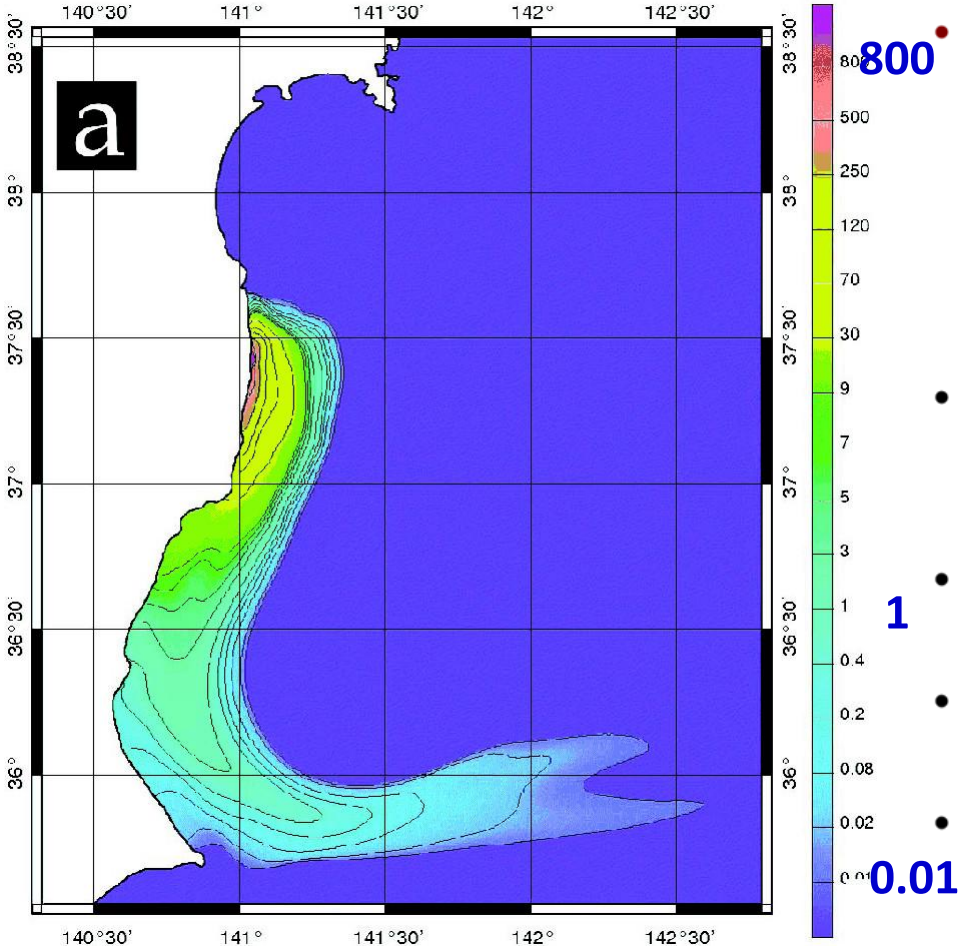
C. Derval (poster).

Lagrangian drift of water particles originated in Fukushima, March 12, 2011

- Computed from the analysis of the global system, using a computational tool (ARIANE) by Blanke, B, Raynaud, S, JPO 27, 1038-1053.



Mercator



^{137}Cs (Bq/l) near Japan, **March 20-April 19 2011**, from direct release, initialized with NCOM model.

(**See collaboration Mercator-Sirocco in poster by C. Derval**)

b)

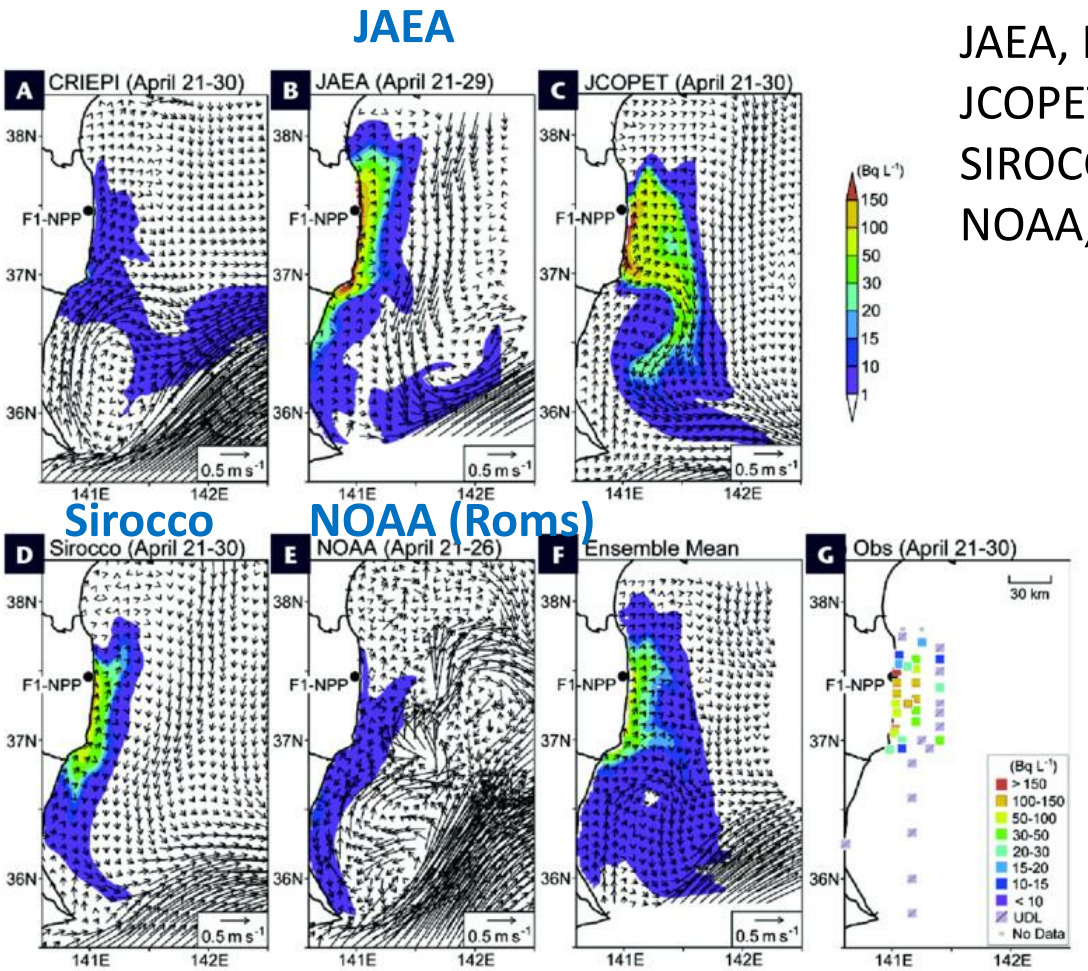
- **Estournel, Marsaleix, Laboratory of Aerology, Toulouse, SIROCCO team**: Used 3-D Sirocco ocean circulation model (Symphonie) for dispersion of radionuclides originated in the Fukushima nuclear accident.
- The SIROCCO group was the first to publish on the web results on marine dispersion of radionuclides
- Model resolution 600m near Fukushima to 5km offshore.
- Source term was estimated by an inverse method.
- The initial fields and lateral boundary conditions were provided by the MERCATOR global ocean 1/12° system.
- Later, the SIROCCO group used NCOM model fields instead of MERCATOR.
- They are now using new MERCATOR fields; PhD thesis in progress on Cesium transfer to zooplankton and fish.

U. Toulouse

Masumoto et al, Elements, vol8, 207-212, 2012.

Model tracer and observations, **April 21-30 2011**.

Models by:
CRIEPI, Japan, Tsumune
JAEA, Kawamura
JCOPET, Miyazawa
SIROCCO, Toulouse U, Estournel
NOAA, Lanerolle



Masumoto et al

(Kamachi; Kawamura et al)
[Summary]

- Issues are unknown source information, unknown coastal process, and related modeling-assimilation

The NCOM model is run by the Navy routinely for Japanese waters, and since March 6 was available at NCEP's Ocean Prediction Center (OPC).
The routine NCOM has 3.5 km grid spacing, and a 1km horizontal grid spacing model near Fukushima was nested by the Navy.