# Calculation of the far-range atmospheric transport of radionuclides after the Fukushima accident with the ADM MATCH of the JRODOS system using the freely available NWP data

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# Outline

1. JRODOS System overview
2. Usage of the JRODOS System during the Fukushima accident and how this motivated present work
3. MATCH model overview and details of NWP data preparation
4. Model setup (source terms, meteo-fields) for the calculation of atmospheric dispersion following the Fukushima accident
5. Presentation and discussion of the results
6. Conclusions

# JRODOS System Overview

- JRODOS is newly developed (redesigned) version of the EU Nuclear Emergency Response System RODOS developed since 1992

- It includes mathematical models and data bases for forecasting:
  - Radionuclides atmospheric dispersion and deposition
  - Hydrological transport of radionuclides
  - Food-chain transport of radioactivity
  - Dose estimations
  - Planning of short-term and long-term countermeasures

- Redesigned version allowed for:
  - running JRODOS on both Windows and Linux-based platforms (JRODOS means Java-RODOS)
  - Distributed system setup
  - Improvement of GUI and state-of-art GIS functionalities
  - Flexible and easy integration of new computational models
  - Easy customization to new sites

# JRODOS usage during Fukushima accident

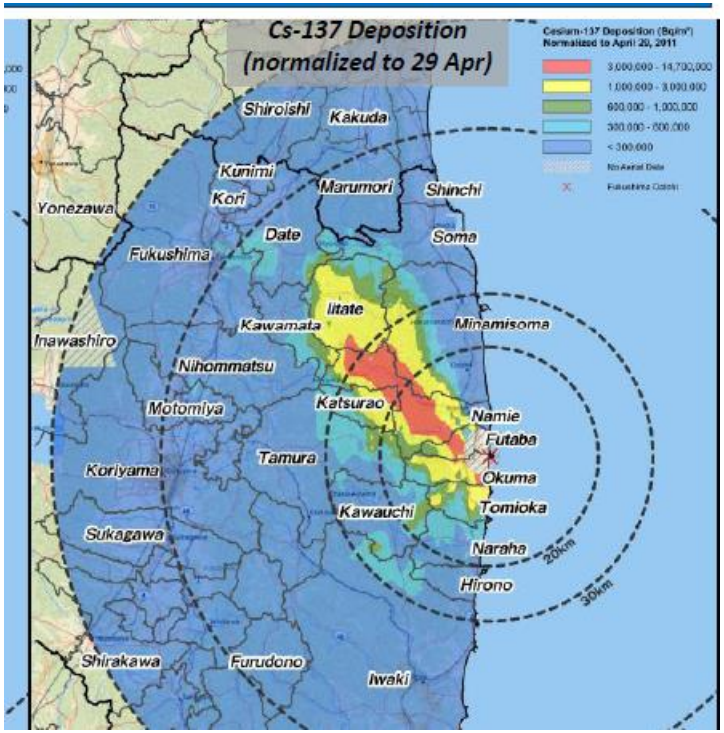
Following numerous requests from JRODOS Users the System which was not previously installed in Japan was adapted for calculations following Fukushima accident in 2-3 days

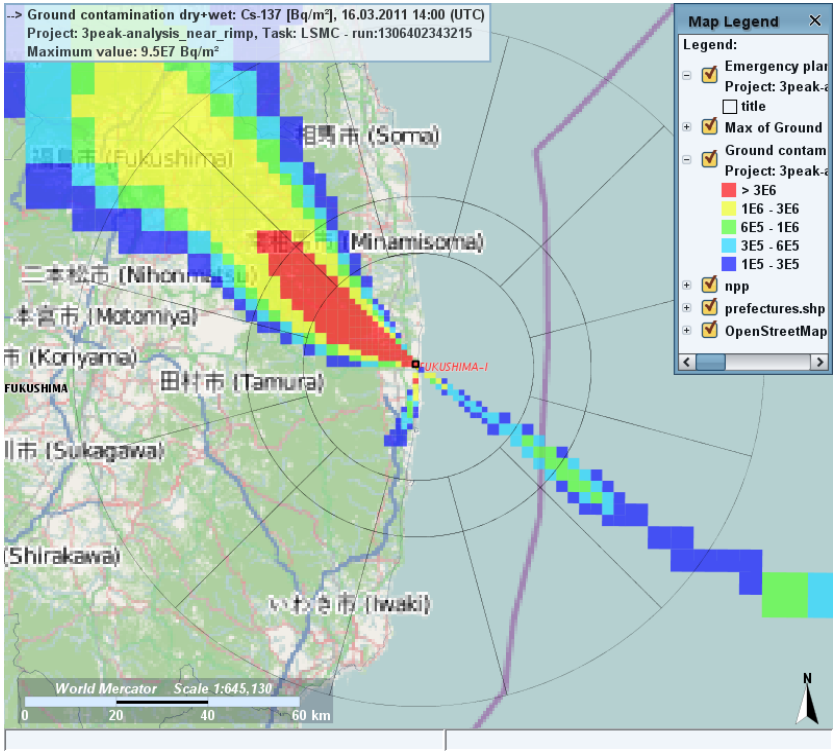
## What have we done?

- Basic information about NPP and GIS data describing terrain around NPP were introduced into the System
- WRF meteorological model was installed to provide operational weather forecasts on 0.1 deg. Grid covering Japan on the basis of GFS data
- The Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) has provided potential source terms for calculations JRODOS in KIT. Estimations published in Internet by various agencies had been used for conservative source estimations for JRODOS calculations by UCEWP
- Daily forecasts of radioactivity dispersion following conservative estimates of possible emission had been produced in real-time both by KIT and UCEWP as well as by other JRODOS users from 15 March to 30 April

# Results of diagnostic JRODOS calculations at a local scale

~1E16 Bq of Cs-137 released following NISA aposteriori estimates distributed in 3 peaks during 14-16 April 2011




29 April 2011

RIMPUFF-based Local Scale Model Chain was used

Deposition of 137Cs
Left: measured (image courtesy of the US Department of Energy and of the Japan Nuclear and Industrial Safety Agency, www.energy.gov/japan2011).
Right: results of JRODOS calculations. Both figures have the same color code

# Journal publications on local-scale JRODOS applications for Fukushima accident

Ievdin I. et al. (2012) Application of Decision Support System JRODOS for Assessments of Atmospheric Dispersion and Deposition from Fukushima Daiichi Nuclear Power Plant Accident // ***Int. J. of Energy for a Clean Environment*** 13 (No. 1-4)

describes work of JRODOS developers (UCEWP and KIT)

Dvorzhak A. et al. (2012) Spanish Experience on Modeling of Environmental Radioactive Contamination Due to Fukushima Daiichi NPP Accident Using JRODOS // ***Environmental Science and Technology*** 46, 11887−11895

describes work of JRODOS users from CIEMAT, Spain

# Motivation of present work

- MATCH atmospheric dispersion model is included in RODOS for calculation of far-range transport of radionuclides since 1997
- However in phase of accident it could was not used for assessments of long-range dispersion since it requires NWP data from HIRLAM or ECMWF which are not freely available to many of JRODOS users
- Development of the converting tools will allow MATCH running using freely available data of Global Forecasting System (GFS) operated by NCEP or data calculated by WRF
- This will allow calculation of long-range transport for every JRODOS user

# MATCH

MATCH is Eulerian model of long-range transport of radionuclides for a long time developed by Swedish Meteorological and Hydrological Institute (SMHI)

It's prototype was one of the first models applied to study atmospheric dispersion following Chernobyl accident:

Persson C. et al. (1987) The Chernobyl accident - A meteorological analysis of how radionuclides reached Sweden // *AMBIO* Vol. 16, No. 1

The model is fully described in

Robertson, L., and Langner, J., 1999, An Eulerian limited area atmospheric transport model*. J. Applied Meteorology* 38:190-210.

Exist both Hemispheric and Limited-Area versions of MATCH

RODOS version of MATCH is Limited-Area version with reduced functionalities: only 4 releases intervals with 1 release height/interval are allowed

# Adaptation of MATCH for JRODOS

Required 3 steps:

1. Recompiling model as dynamically linked library (.DLL or .SO), enabling it running on different platforms (previously MATCH run only on Linux platforms)

   This step is the same as for all models integrated in JRODOS

2. Converting meteorological data from WRF or GFS to HIRLAM-GRIB format
   a. Recalculations between HIRLAM – GFS/WRF variables
   b. Interpolation of variables on vertical levels of HIRLAM
   c. Writing results in GRIB format

3. Verification

   (done by comparing results of JRODOS Local-Scale Model Chain and MATCH using the same WRF data set)

# Model setup

3 Variants of calculations will be shown:

1. JRODOS-MATCH results with the *adapted* source term of Stohl et al (2012) and using GFS meteorological data

2. JRODOS-MATCH results with the conservative source term used in operational JRODOS applications for Fukushima + GFS data

3. SMHI-MATCH (standalone) results with the *full* source term of Stohl et al (2012) and using ECMWF meteorological data

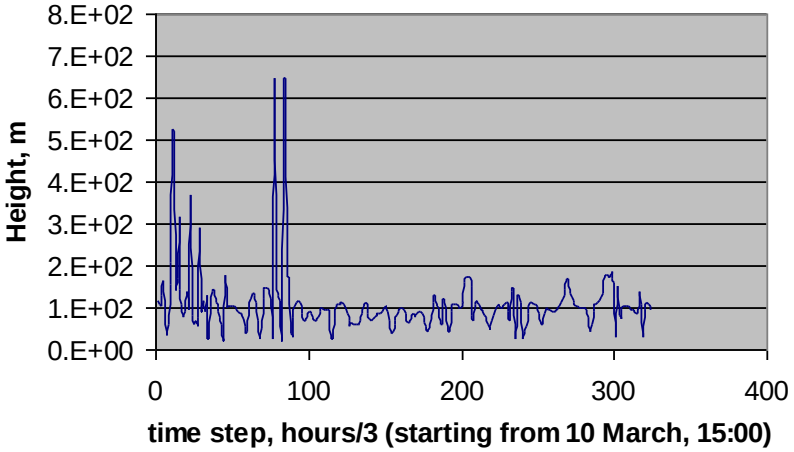
# Model setup – source terms (ST)

1. (ST1) ST of Stohl et al (2012)
   - distributed in 3 layers: [0-50], [50-300], [300-1000] (m)
   - 3-h time intervals from 10 March to 20 April, 2011

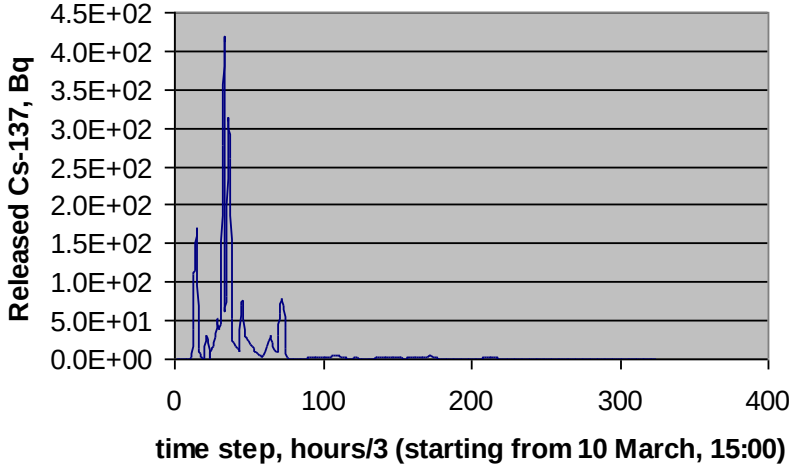
2. (ST1-modified) ST of Stohl et al (2012) adapted for JRODOS-MATCH
   - 4 point releases described as:

| No. | Start | End | Q [Bq] | H [m] |
|---|---|---|---|---|
| 1 | 11.03, 18h | 13.03, 0h | 4.1E15 | 300 |
| 2 | 13.03, 0h | 14.03, 3h | 2.4E15 | 132 |
| 3 | 14.03, 3h | 15.04, 12h | 1.7E16 | 108 |
| 4 | 15.03, 12h | 20.03, 12h | 9.3E15 | 120 |

**Center mass height of release**




**Time dependance ot total release of Cs-137 (Stohl et al, 2012)**



# Model setup – source terms (ST)

(continuation)

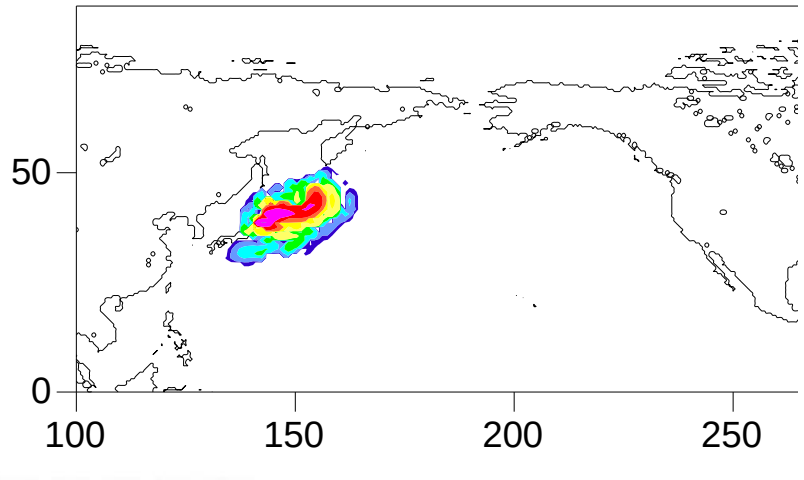
(ST2) ST used in operational JRODOS runs during Fukushima Accident :

2.6E16 Bq released at 50 m height during 14-15 March 2011

Total inventory close to that given by Stohl et al (2011) and well in between of of minimum-maximum estimates given by different estimations

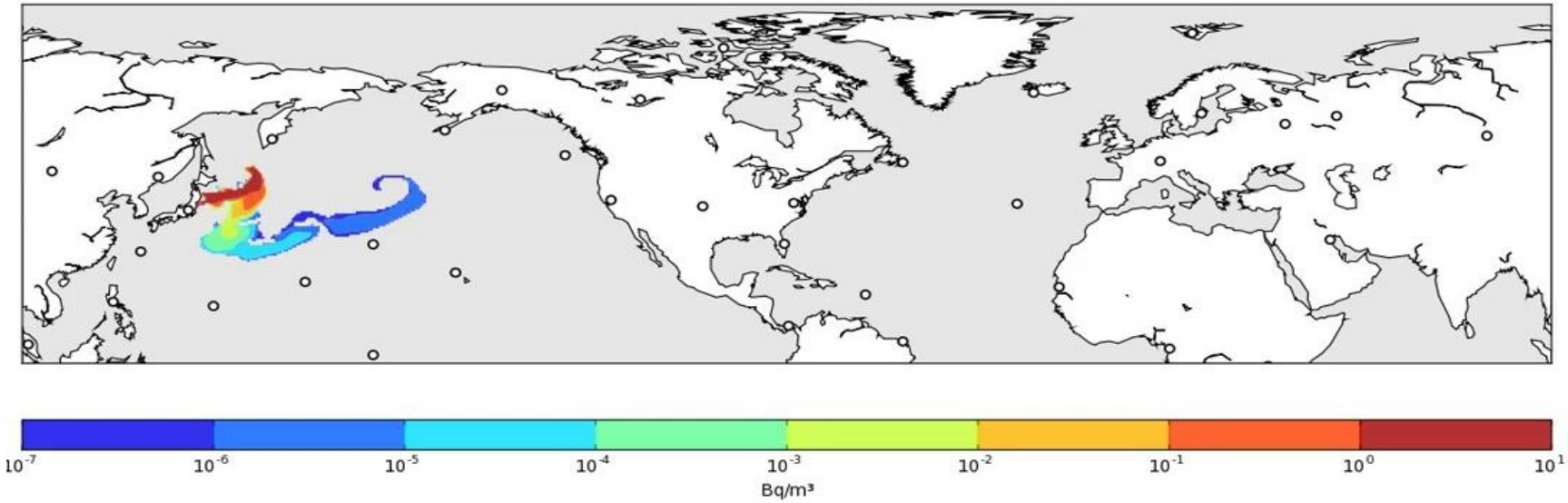
# Results, Instantaneous concentrations of Cs-137, 13.03, 12:00 h

JRODOS-MATCH, ST1-modified



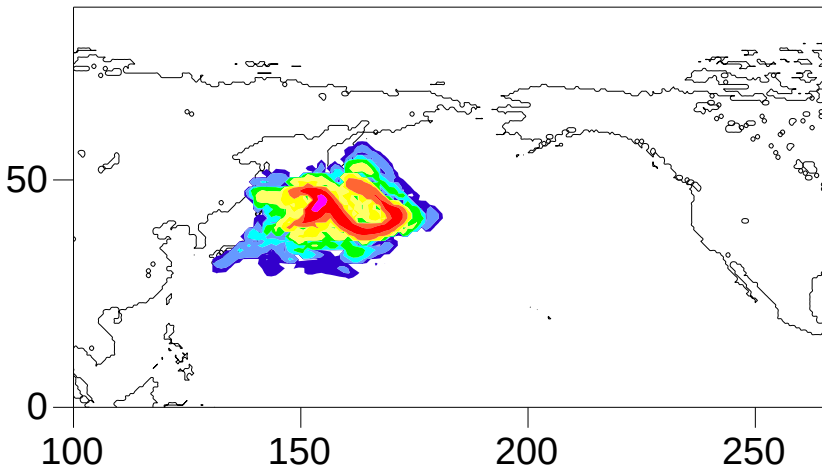

SMHI-MATCH, ST1

SMHI

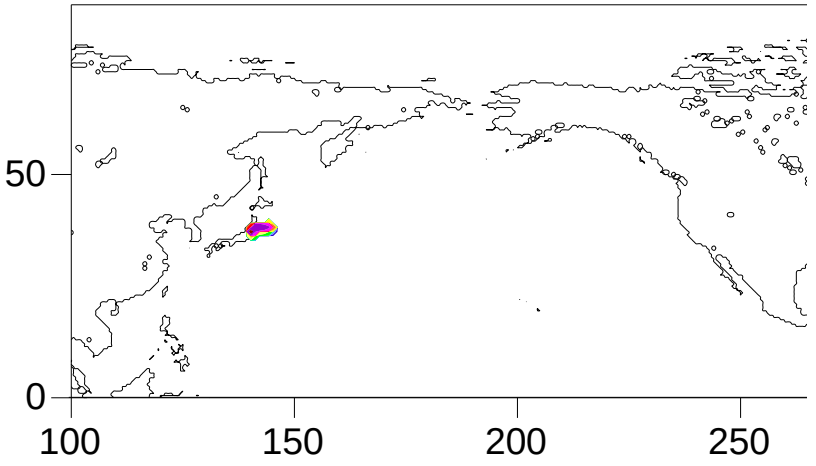


# Results, Instantaneous concentrations of Cs-137, 14.03, 12:00 h

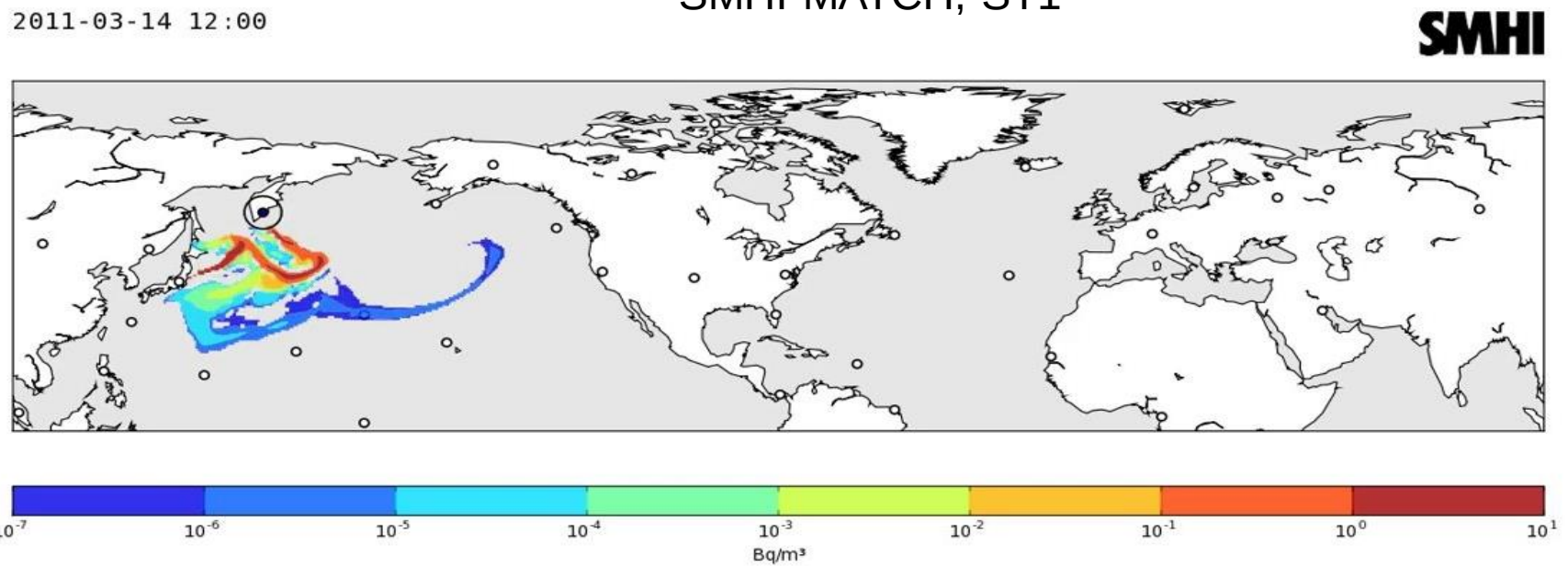
JRODOS-MATCH, ST1-modified




JRODOS-MATCH, ST2

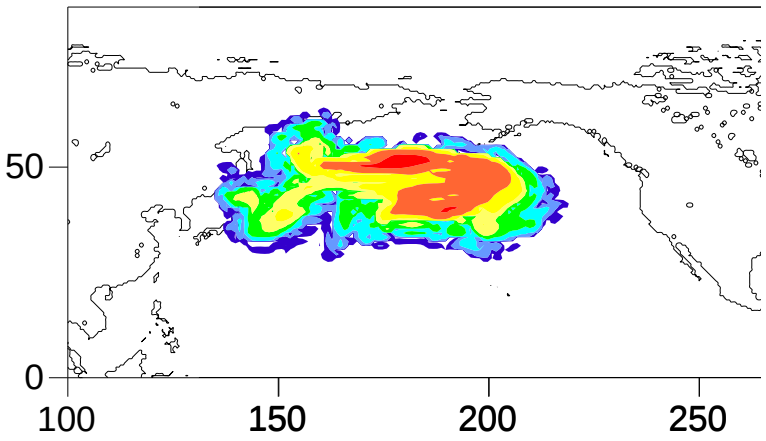



SMHI-MATCH, ST1

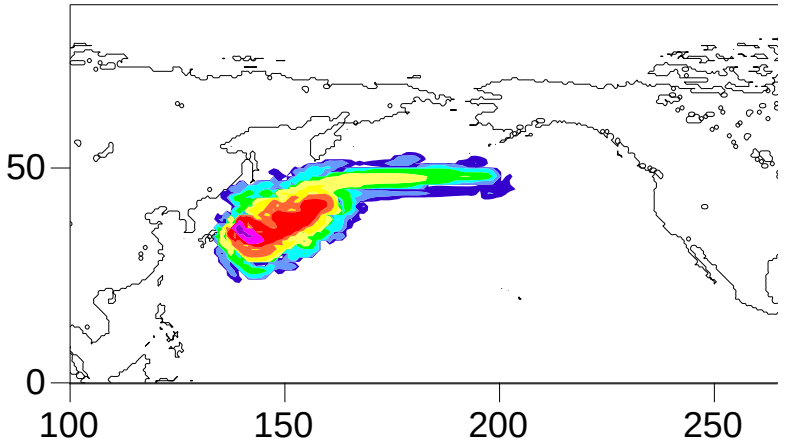


# Results, Instantaneous concentrations of Cs-137, 16.03, 12:00 h

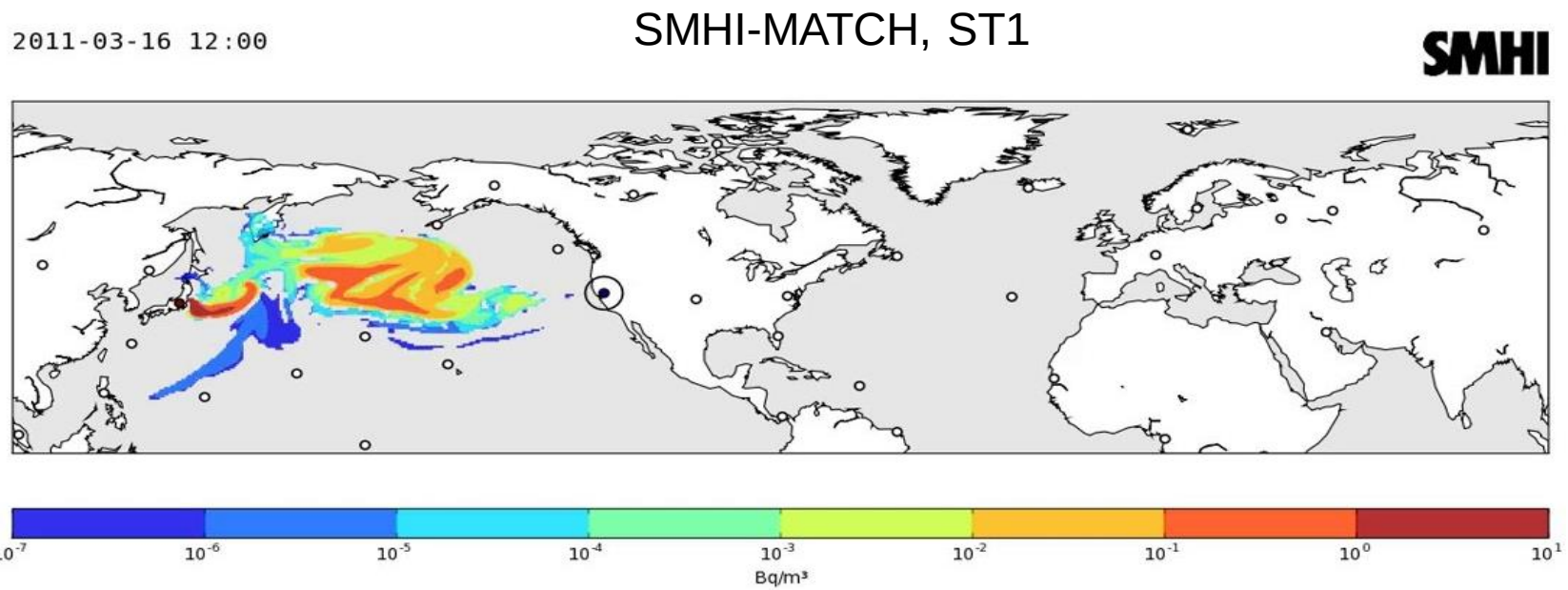
JRODOS-MATCH, ST1-modified




JRODOS-MATCH, ST2

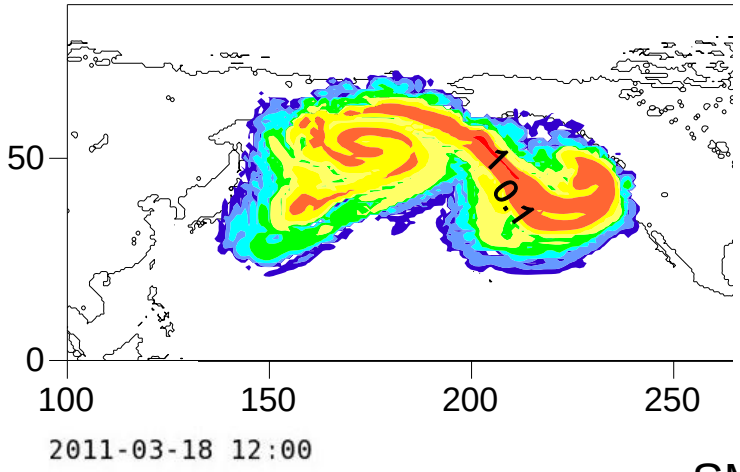



SMHI-MATCH, ST1

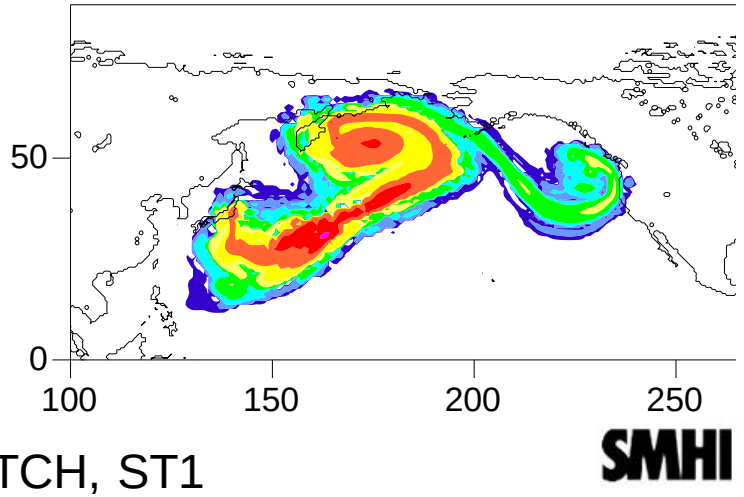


# Results, Instantaneous concentrations of Cs-137, 18.03, 12:00 h

JRODOS-MATCH, ST1-modified

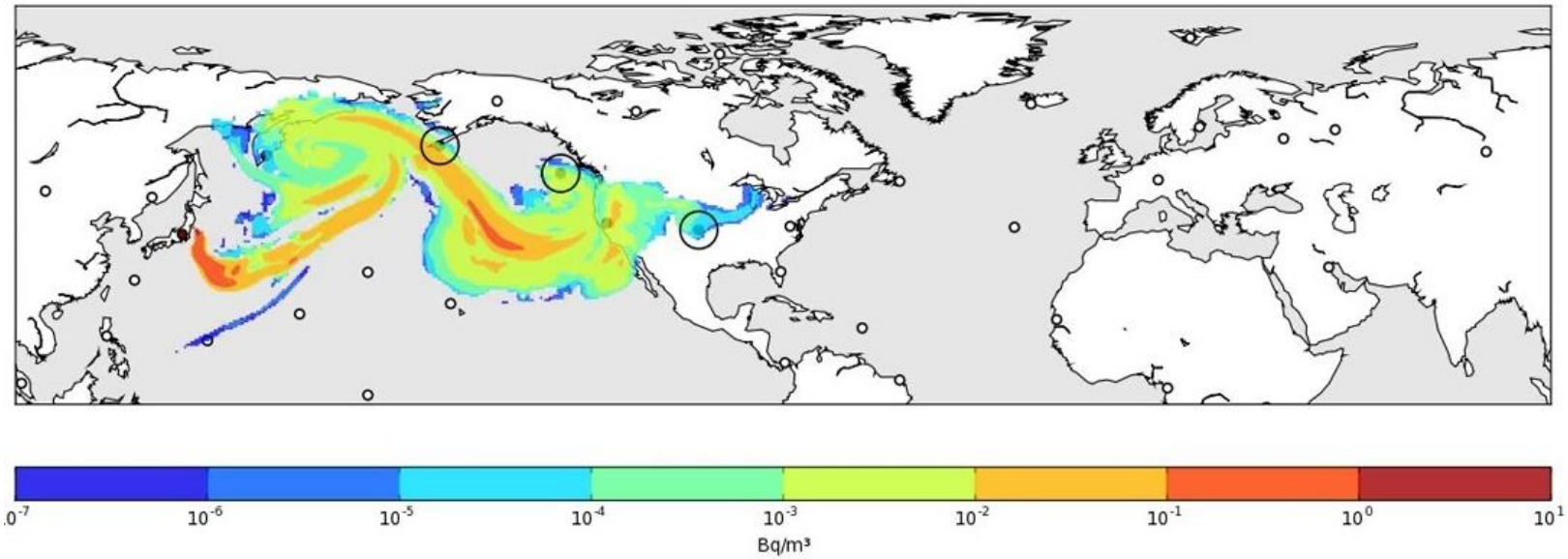



JRODOS-MATCH, ST2



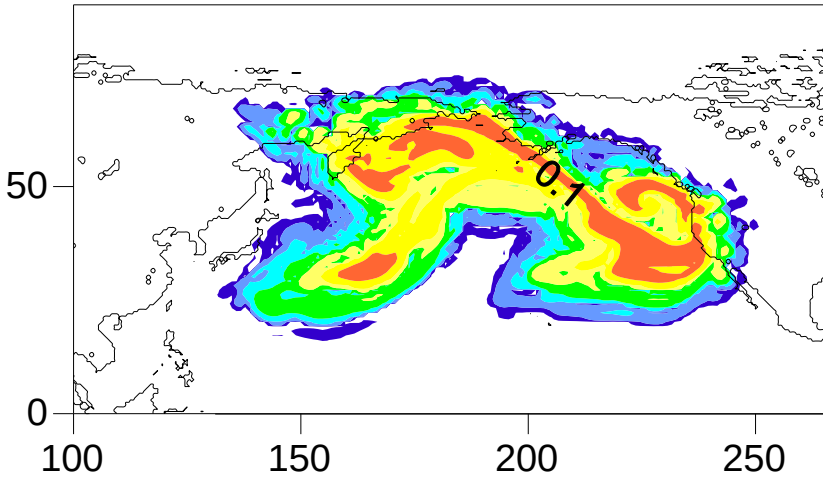

SMHI

SMHI-MATCH, ST1

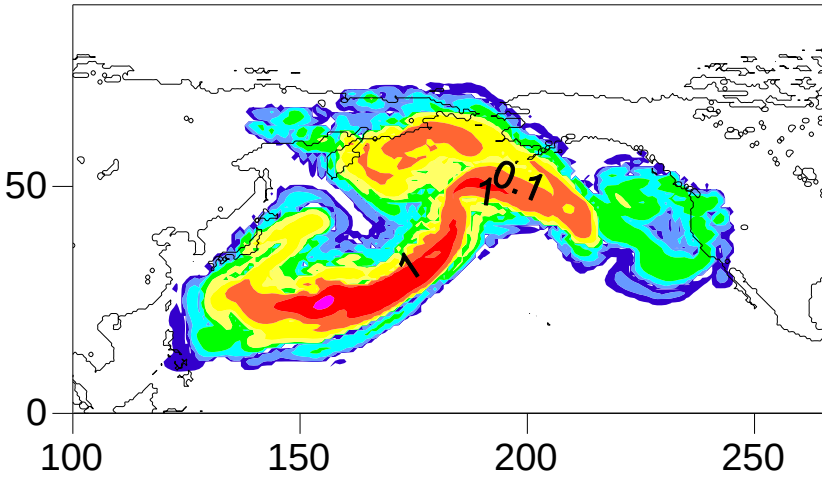


# Results, Instantaneous concentrations of Cs-137, 19.03, 12:00 h

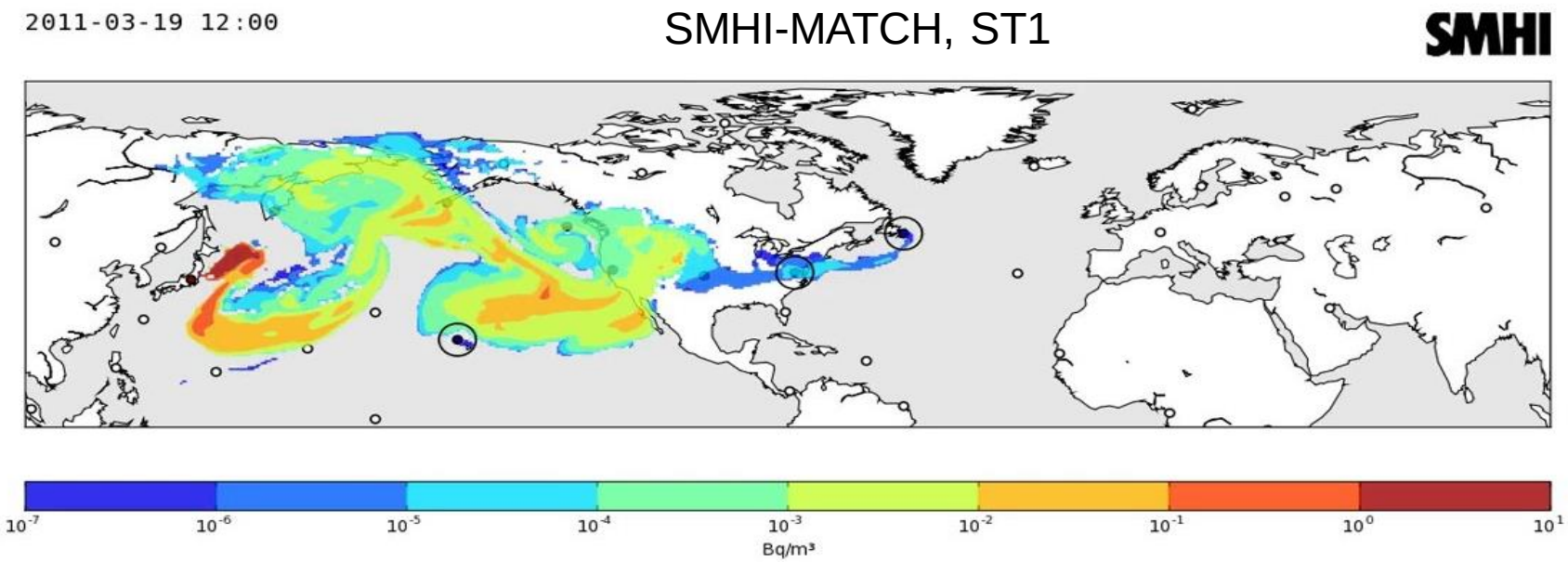
JRODOS-MATCH, ST1-modified




JRODOS-MATCH, ST2

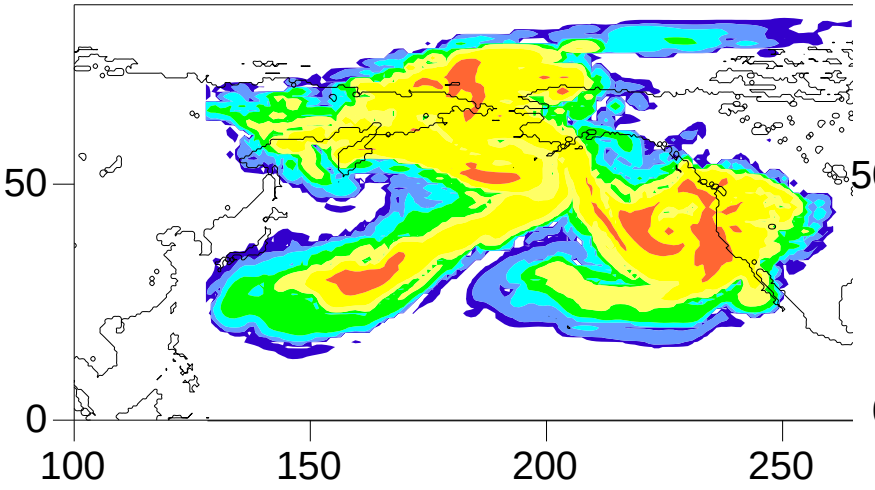



SMHI-MATCH, ST1

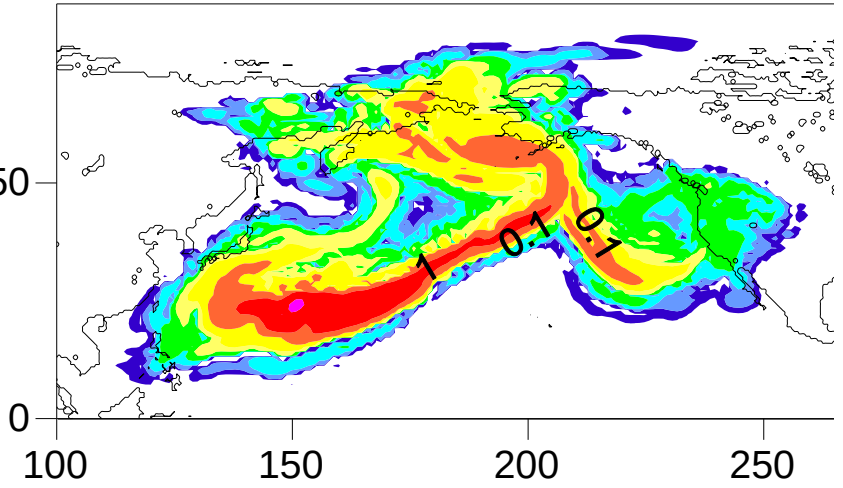


# Results, Instantaneous concentrations of Cs-137, 20.03, 12:00 h

JRODOS-MATCH, ST1-modified

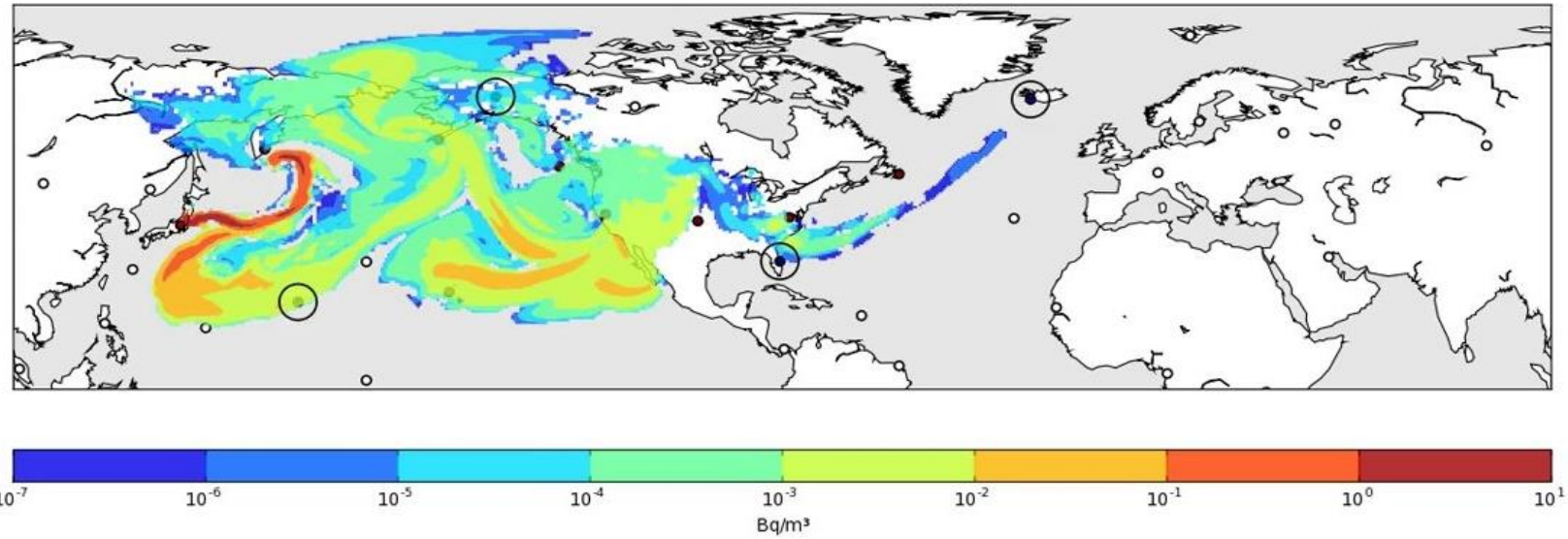



JRODOS-MATCH, ST2



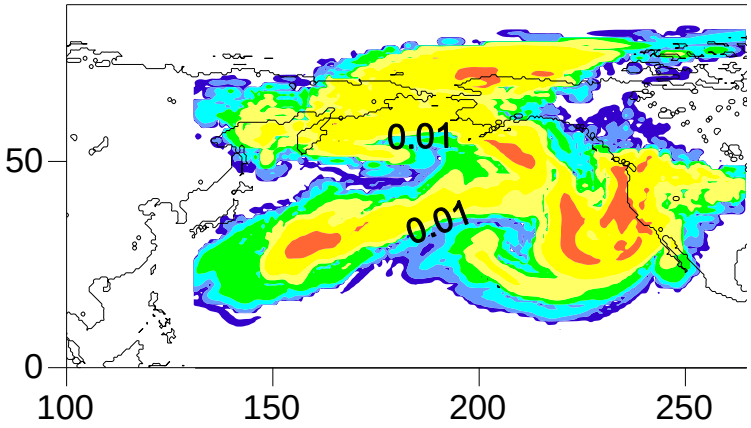

SMHI-MATCH, ST1

SMHI

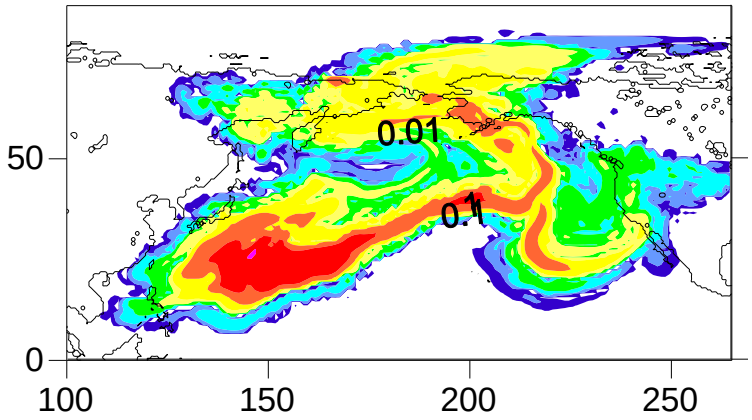


# Results, Instantaneous concentrations of Cs-137, 21.03, 12:00 h

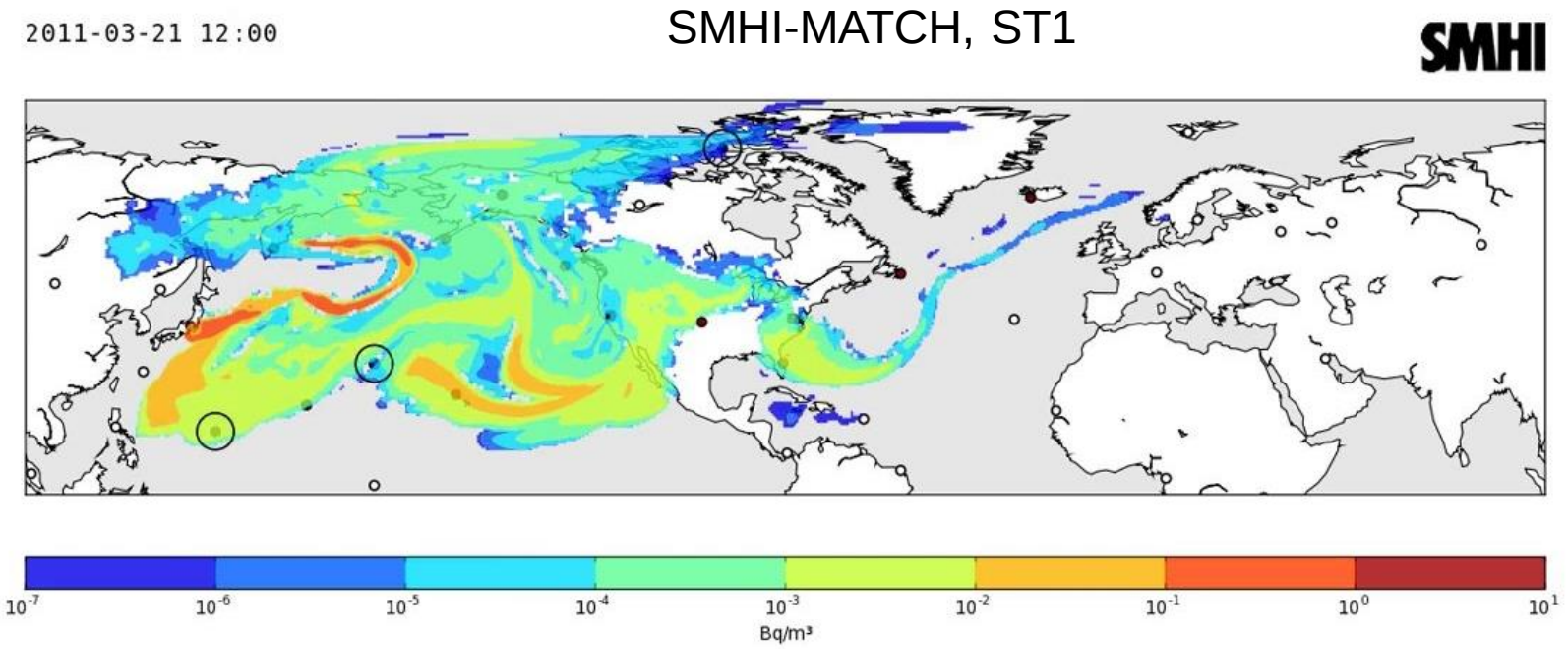
JRODOS-MATCH, ST1-modified




JRODOS-MATCH, ST2

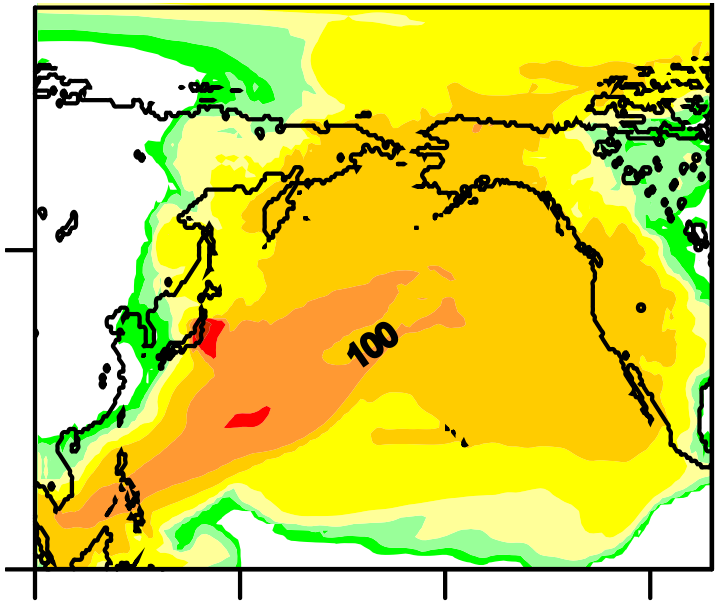



SMHI-MATCH, ST1

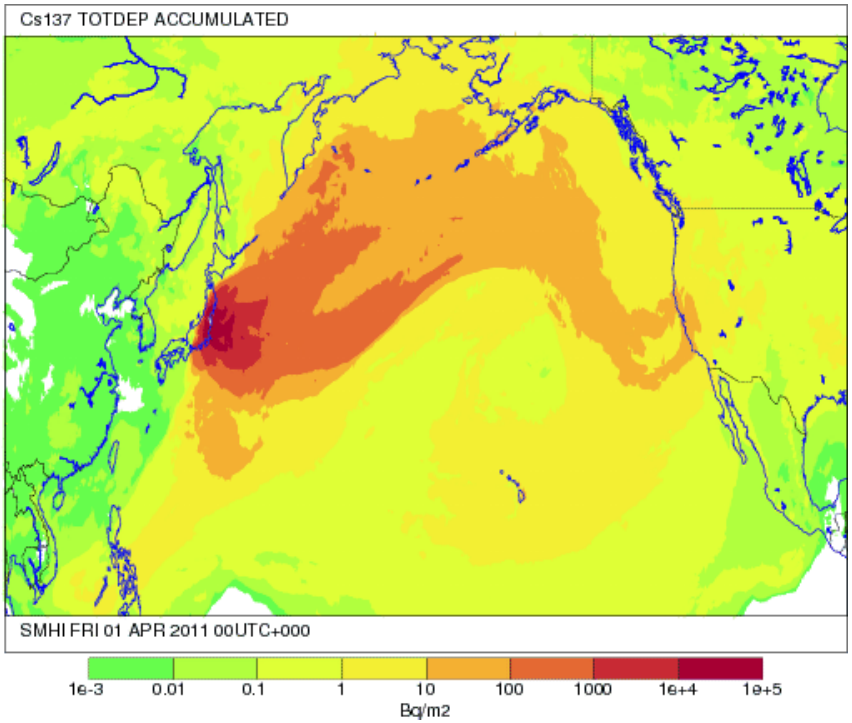


# Total deposition by 30 March 2011

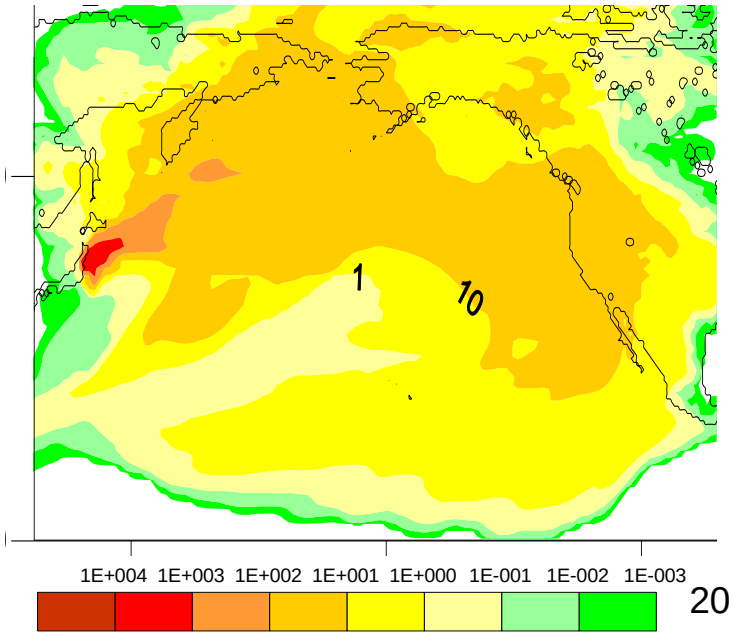
JRODOS-MATCH, ST2




SMHI-MATCH, ST1

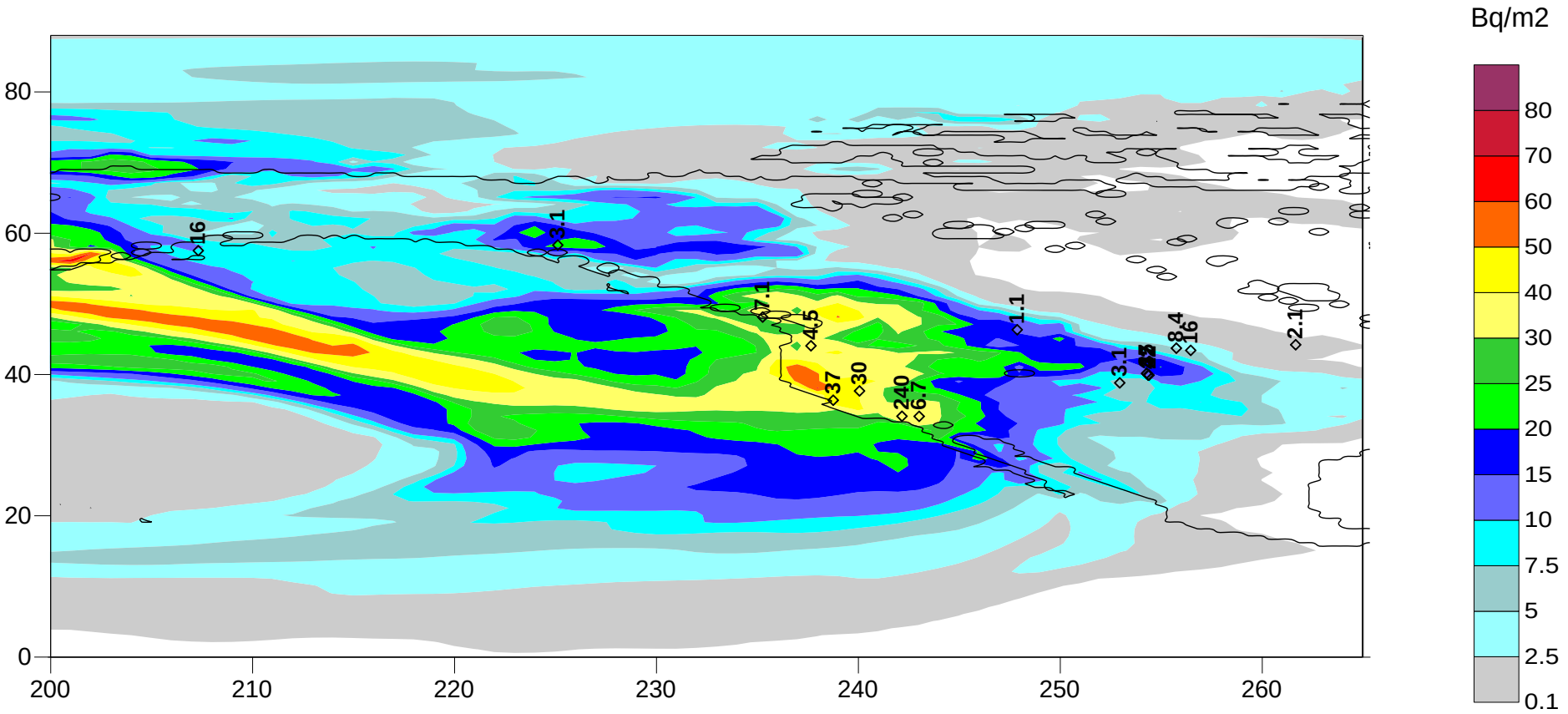



JRODOS-MATCH, ST1-modified



# Comparison of Cs-137 deposition with measurements

Colored fields – JRODOS-MATCH, values – measurements (USGS, Report 2011–1277 )



# Conclusions

All JRODOS users can now benefit from running long-range transport model MATCH by using freely available NWP data of GFS or calculated with WRF

MATCH driven by both ECMWF and GFS NWP data well predicts complex shape of the plume (as far as this can be judged by plume arrival times reported by CTBTO stations)

On average MATCH is also able to reproduce the deposition of Cs-137 at the West Coast of USA as compared to USGS measurements

Large simplifications in source term of Stohl et al (2012) (only 4 release intervals and 1 point release per each interval) don't preclude MATCH of producing useful results which are of comparable quality (in terms of plume shape) with the results obtained by using full source term of Stohl.

Even more simplifications in source term (just release of 48-h duration with constant rate and height) also allow producing useful results in the far field (beyond a few thousands km from Fukushima) even though some features of the plume's shape are not captured. Closer to the source plume is greatly affected by such oversimplification in source properties

# Further developments

It is desirable to integrate hemispheric version of MATCH in JRODOS and also to enable the more detailed source term description

# Acknowledgements

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Thank you for attention!