

Figure 5B.20. Same as Fig. 5B.11 except for a period between June 20 and June 29.

### Appendix 5C. Satellite Observations of the Anticyclonic Eddy off of the Ibaraki Coast

Evidence of the anticyclonic meso-scale eddy off of the coast of Ibaraki from late April to May can be obtained from several satellite images. Here, we show two examples of the sea-surface temperature and chlorophyll concentration observed by the Terra/MODIS satellite. A warm meso-scale eddy structure (Fig. 5C.1) with low chlorophyll-a concentration at the center of the eddy surrounded by high chlorophyll-a streamers (Fig. 5C.2) can be observed in a region off of the Ibaraki coast. Most of the models can capture this anticyclonic eddy in their simulations, although the detailed structure and location of the eddy differs among the models (see Fig. 5.7).

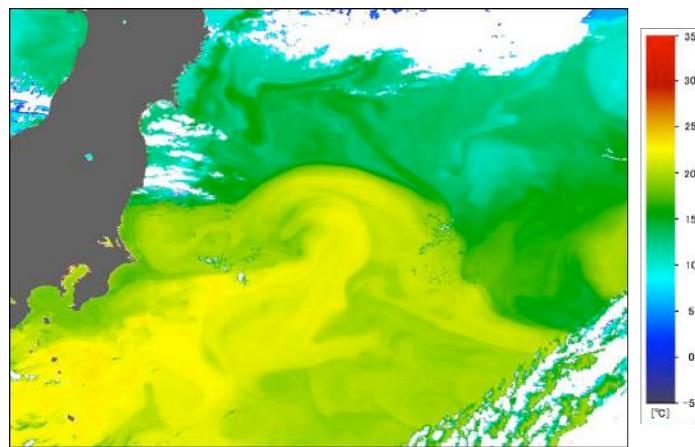


Figure 5C.1. Horizontal distribution of sea-surface temperature on May 15, 2011 observed by the Terra/MODIS satellite.

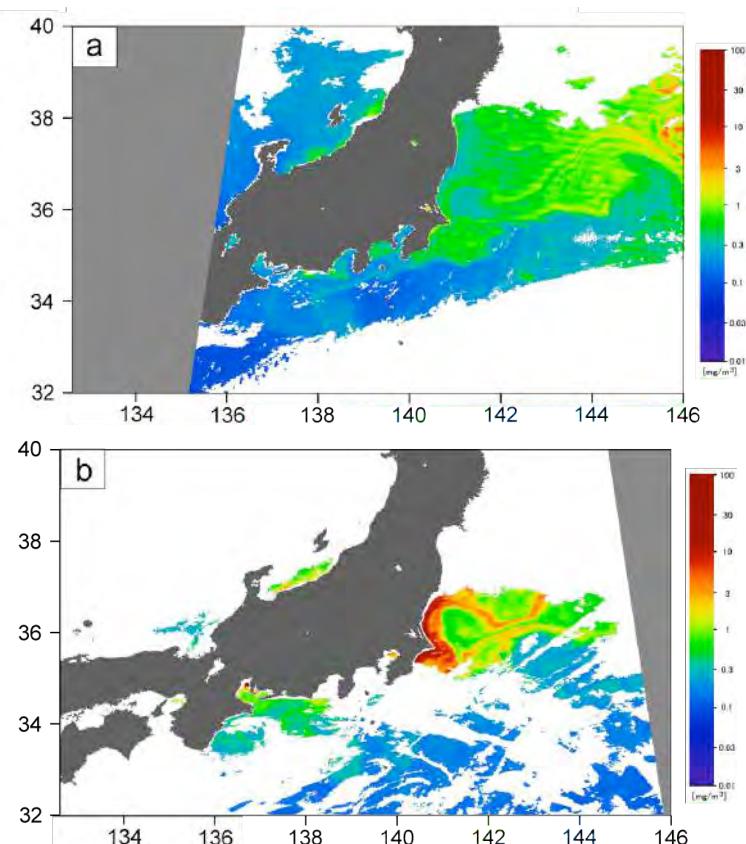


Figure 5C.2. Horizontal distribution of chlorophyll-a concentrations on (a) May 19, 2011 and (b) May 21, 2011 observed by the Terra/MODIS satellite.

## Appendix 5D. Aerial measurements of radioactivity

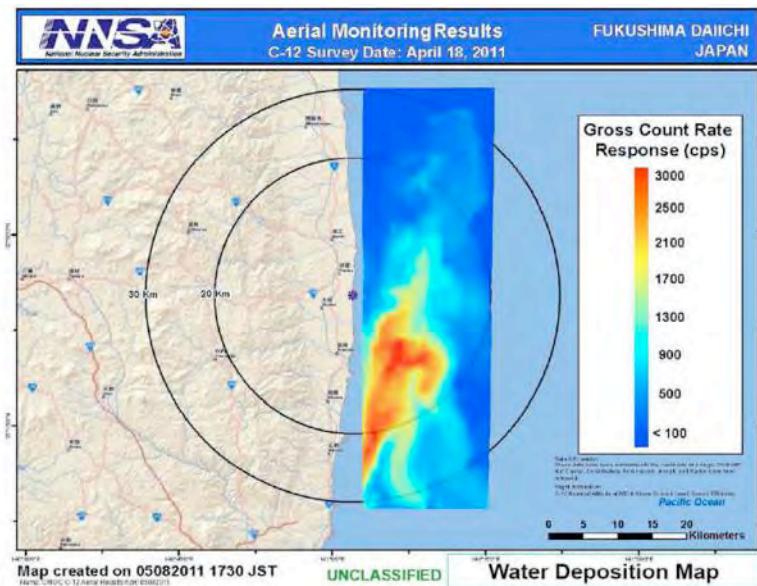


Figure 5D.1. An aerial measurement of the radioactivity (gross count rate response in cps) at the sea surface around the FDNPP on April 18, 2011. These data have been normalized to the count rate of a single  $2 \times 4 \times 10$  Nal crystal, and radon has been removed (Guss, 2011). Their flight altitudes were from 150 to 700 m above the ground (MEXT, 2011).

## References

- Adachi, K., M. Kajino, Y. Zaizen, and Y. Igarashi, 2013: Emission of spherical cesium-bearing particles from an early stage of the Fukushima nuclear accident. *Nature Scientific Reports*, **3**, 2554, doi:10.1038/srep02554.
- Adachi, Y., S. Yukimoto, M. Deushi, A. Obata, H. Nakano, T.Y. Tanaka, M. Hosaka, T. Sakami, H. Yoshimura, M. Hirabara, E. Shindo, H. Tsujino, R. Mizuta, S. Yabu, T. Koshiro, T. Ose, and A. Kitoh, 2013: Basic performance of a new earth system model of the Meteorological Research Institute (MRI-ESM1). *Papers in Meteorology and Geophysics*, **64**, 1 -19, doi: 10.2467/mripapers.64.1
- Amante, C. and B. W. Eakins, 2009: ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. *NOAA Technical Memorandum NESDIS NGDC-24*, 19 pp.
- Antonov, J. I., R. A. Locarnini, T. P. Boyer, A. V. Mishonov, H. E. Garcia, and S. Levitus, 2006: World Ocean Atlas 2005, Volume 2 : Salinity. NOAA Atlas NESDIS 62, U.S. Government Printing Office, Washington, DC, 182 pp.
- Aoyama, M., D. Tsumune and Y. Hamajima, 2012: Distribution of  $^{137}\text{Cs}$  and  $^{134}\text{Cs}$  in the North Pacific Ocean: Impacts of the TEPCO Fukushima-daiichi NPP accident. *J. Radioanal. Nucl. Chem.*, doi: 10.1007/s10967-012-2033-2.
- Appel, K.W., K.M. Foley, J.O. Bash, R.W. Pinder, R.L. Dennis, D.J. Allen, and K. Pickering, 2011: A multi-resolution assessment of the Community Multiscale Air Quality (CMAQ) model v4.7 wet deposition estimates for 2002-2006. *Geosci. Model Dev.*, **4**, 357-371, doi:10.5194/gmd-4-357-2011.
- Bailly du Bois, P., F. Dumas, L. Solier, and C. Voiseux, 2012a: In-situ database toolbox for short-term dispersion model validation in macro-tidal seas, application for 2D-model. *Continental Shelf Res.*, **26**, 63-82. doi:10.1016/j.csr.2012.01.011.
- Bailly du Bois, P., P. Laguionie, D. Boust, I. Korsakissok, D. Didier, and B. Fiévet, 2012b: Estimation of marine source-term following Fukushima Dai-ichi accident. *J. Environ. Radioactivity*, **114**, 2-9. doi:10.1016/j.jenvrad.2011.11.015.
- Barron, C. N., A. B. Kara, H. E. Hurlburt, C. Rowley, and L. F. Smedstad, 2004: Sea surface height predictions from the Global Navy Coastal Ocean Model (NCOM) during 1998-2001. *J. Atmos. Oceanic Technol.*, **21**, 1876-1894.
- Barron, C. N., A. B. Kara, P. J. Martin, R. C. Rhodes, and L. F. Smedstad, 2006: Formulation, implementation and examination of vertical coordinate choices in the global Navy Coastal

- Ocean Model (NCOM). *Ocean Modeling*, **11**, 347-375.
- Batifoulier, F., P. Lazure, and P. Bonneton, 2012: Poleward coastal jets induced by westerlies in the Bay of Biscay. *J. Geophys. Res.*, **117**, doi:10.1029/2011JC007658.
- Brandt, J., J.H. Christensen, and L.M. Frohn, 2002: Modeling transport and deposition of cesium and iodine from the Chernobyl accident using the DREAM model. *Atmos. Chem. Phys.*, **2**, 397-417.
- Brenk, H.D., and Vogt, K.J., 1981: The calculation of wet deposition from radioactive plumes. *Nuclear Safety*, **22**, 362-371.
- Buesseler, K. O., S. R. Jayne, N. S. Fisher, I. I. Rypina, H. Baumann, Z. Baumann, C. F. Breier, E. M. Douglass, J. George, A. M. Macdonald, H. Miyamoto, J. Nishikawa, S. M. Pike, and S. Yoshida, 2012: Fukushima-derived radionuclides in the ocean and biota off Japan. *P. Natl. Acad. Sci.*, **109**, 5984-5988.
- Buijsman, M., Y. Uchiyama, J.C. McWilliams, and C.R. Hill-Lindsay, 2012: Modeling semidiurnal internal tides in the Sourthern California Bight. *J. Phys. Oceanogr.*, **42**, 62-77.
- Byun, D., J.K.S. Ching, and Eds., 1999: Science algorithms of the EPA Models-3 Community Multiscale Air Quality (CMAQ) Modeling System. EPA-600/R-99/030, Office of Research and Development, U.S. Environmental Protection Agency, Washington D.C.
- Byun, D., and K. Schere, 2006: Review of the governing equations, computational algorithms, and other components of the models-3 Community Multiscale Air Quality (CMAQ) modeling system. *Appl. Mech. Rev.*, **59**( 1 - 6 ), 51-77.
- Chang, J.S., R.A. Brost, I.S.A. Isaksen, S. Madronich, P. Middleton, W.R. Stockwell, and C.J. Walcek, 1987: A three-dimensional Eulerian acid deposition model: Physical concepts and formulation. *J. Geophys. Res.*, **92**, 14,681-14,700.
- Chino, M., H. Nakayama, H. Nagai, H. Terada, G. Katata, and H. Yamazawa, 2011: Preliminary estimation of release amounts of  $^{131}\text{I}$  and  $^{137}\text{Cs}$  accidentally discharged from the Fukushima Daiichi Nuclear Power Plant into the atmosphere. *J. Nucl. Sci. Tech.*, **48**, 1129-1134.
- Choi, Y., S. Kida, and K. Takahashi, 2013: The impact of oceanic circulation and phase transfer on the dispersion of radionuclides released from the Fukushima Dai-ichi Nuclear Power Plant. *Biogeosciences*, **10**, 4911-4925, doi:10.5194/bg-10-4911-2013.
- Christoudias, T., and J. Lelieveld, 2013: Modelling the global atmospheric transport and deposition of radionuclides from the Fukushima Dai-ichi nuclear accident. *Atmos. Chem. Phys.*, **13**, 1425-1438, doi:10.5194/acp-13-1425-2013.
- Comprehensive Nuclear-Test-Ban Treaty Organization Preparatory Commission, 2011a: Fukushima-related measurements by the CTBTO.

[http://www.ctbto.org/press-centre/highlights/2011/fukushima-related-measurements-by-the-ctbt  
o.](http://www.ctbto.org/press-centre/highlights/2011/fukushima-related-measurements-by-the-ctbt-o)

- Comprehensive Nuclear-Test-Ban Treaty Organization Preparatory Commission, 2011b: The 11 March Japan Disaster. <http://www.ctbto.org/verification-regime/the-11-march-japan-disaster/>.
- de Meij, A., Krol, M., Dentener, F., Vignati, E., Cuvelier, C., and Thunis, P., 2006: The sensitivity of aerosol in Europe to two different emission inventories and temporal distribution of emissions. *Atmos. Chem. Phys.*, **6**, 4287-4309, doi:10.5194/acp-6-4287-2006.
- Dietze, H., and I. Kriest, 2012: Cs-137 off Fukushima Dai-ichi, Japan – model based estimates of dilution and fate. *Ocean Sci.*, **8**, 319-332, doi:10.5194/os-8-319-2012.
- Draxler, R., D. Arnold, S. Galmarini, M. Hort, A. Jones, S. Leadbetter, A. Malo, C. Maurer, G. Rolph, K. Saito, R. Servranckx, T. Shimbori, E. Solazzo, and G. Wotawa, 2013: Evaluation of meteorological analyses for the radionuclide dispersion and deposition from the Fukushima Daiichi Nuclear Power Plant accident. *WMO Technical Publication*, **1120**, 64pp, [https://www.wmo.int/e-catalog/detail\\_en.php?PUB\\_ID=669](https://www.wmo.int/e-catalog/detail_en.php?PUB_ID=669).
- Egbert, G. D., and S. Y. Erofeeva, 2002: Efficient inverse modeling of barotropic ocean tides. *J. Atmos. Ocean. Tech.*, **19**, 183-204.
- ENVIRON International Corporation, 2009: CAMx USER'S GUIDE. pp.280.
- ENVIRON, 2011: CAMx 5.40 User's Guide.  
[http://www.camx.com/files/camxusersguide\\_v5-40.aspx](http://www.camx.com/files/camxusersguide_v5-40.aspx).
- Estournel, C., E. Bosc, M. Bocquet, C. Ulses, P. Marsaleix, V. Winiarek, I. Osvath, C. Nguyen, T. Duhaut, F. Lyard, H. Michaud, and F. Auclair, 2012: Assessment of the amount of Cesium-137 released into the Pacific Ocean after the Fukushima accident and analysis of its dispersion in Japanese coastal waters. *J. Geophys. Res.*, **117**, C11014, doi:10.1029/2012JC007933.
- Ferry N., E. Rémy, P. Brasseur, and C. Maes, 2007: The Mercator global ocean operational analysis system: Assessment and validation of an 11-year reanalysis. *J. Marine Systems*, **65**, 540-560.
- Flemming, J., Inness, A., Flentje, H., Huijnen, V., Moinat, P., Schultz, M. G., and O. Stein, 2009: Coupling global chemistry transport models to ECMWF's integrated forecast system. *Geosci. Model Dev.*, **2**, 253-265, doi:10.5194/gmd-2-253-2009.
- Furuno, A., H. Terada, M. Chino, and H. Yamazawa, 2004: Experimental verification for real-time environmental emergency response system: WSPEEDI by European tracer experiment. *Atmos. Environ.*, **38**, 6989-6998.
- Garreau, P., V. Garnier, and A. Schaeffer, 2011: Eddy resolving modelling of the Gulf of Lions and Catalan Sea. *Ocean Dynamics*, **61**, 991-1003, doi:10.1007/s10236-011-0399-2.
- Grell, G.A., J. Dudhia, and D.R. Stauffer, 1994: A Description of the Fifth-Generation Penn

- State/NCAR Mesoscale Model (MM5). *NCAR Tech*, Note NCAR/TN-3921STR, 122pp.
- Grell, G.A., S.E. Peckham, R. Schmitz, S.A. McKeen, G. Frost, W.C. Skamarock, and B. Eder, 2005: Fully coupled “online” chemistry within the WRF model. *Atmospheric Environment*, **39**, 6957-6975.
- Griffies, S. M., A. Gnanadesikan, K. W. Dixon, J. P. Dunne, R. Gerdes, M. J. Harrison, A. Rosati, J. L. Russell, B. L. Samuels, M. J. Spelman, M. Winton, and R. Zhang, 2005: Formulation of an ocean model for global climate simulations. *Ocean Sci.*, **1**, 45-79, doi:10.5194/os-1-45-2005.
- Guo, X., S. M. Varlamov, and Y. Miyazawa, 2010: Coastal ocean modeling by nesting method. *Bull. Coast. Oceanogr.*, **47**, 113-123 (in Japanese with English abstract and figure captions).
- Guss, P., 2011: DOE response to the radiological release from the Fukushima Dai-ichi Nuclear Power Plant, DOE/NV/25946-1236, *Proc. the NEI RETS/REMP Workshop*, Oak Brook, IL, 30 June 2011.
- Hashimoto, A., H. Hirakuchi, Y. Toyoda, and K. Nakaya, 2010: Prediction of regional climate change over Japan due to global warming (Part 1) - Evaluation of Numerical Weather Forecasting and Analysis System (NuWFAS) applied to a long-term climate simulation. *CRIEPI report*, N10044 (in Japanese).
- Hayami, H., A. Sato, M. Tsuzaki, and H. Shimadera, 2012: Atmospheric transport and deposition modeling of radioactive materials released from the Fukushima Daiichi nuclear power plant. *CRIEPI report*, V11054 (in Japanese).
- Higashi, H., Y. Hanamachi, H. Koshikawa, S. Murakami, and K. Kohata, 2012: A numerical study on relationships between climate change and short-necked clam (*Ruditapes philippinarum*) biomass in 1990s in Ise Bay, Japan, *Proc. 9th International Symposium on Ecohydraulics 2012*, 13389.
- Hirt, C.W., and B. D. Nichols, 1981: Volume of fluid method for the dynamics of free boundaries. *J. Comput. Phys.*, **39**, 201-225.
- Hoffmann, W., R. Kebeasy, and P. Firbas, 2000: Introduction to the verification regime of the Comprehensive 5 Nuclear-Test-Ban Treaty. *Phys. Earth and Planetary Interiors*, **113**, 5 - 9 .
- Honda, M., T. Aono, M. Aoyama, Y. Hamajima, H. Kawakami, M. Kitamura, Y. Masumoto, Y. Miyazawa, M. Takigawa, and T. Saino, 2012: Dispersion of artificial caesium-134 and -137 in the western North Pacific one month after the Fukushima accident. *Geochemical J.*, **46**, e1–e9.
- Hsu, S.-C., C.-A. Huh, C.-Y. Chan, S.-H. Lin, F.-J. Lin, and S. C. Liu, 2012: Hemispheric dispersion of radioactive plume laced with fission nuclides from the Fukushima nuclear event. *Geophys. Res. Lett.*, **39**, L00G22, doi:10.1029/2011GL049986.
- Huh, C.-A., Hsu, S.-C., and C.-Y. Lin, 2012: Fukushima-derived fission nuclides monitored around

Taiwan: Free tropospheric versus boundary layer transport. *Earth and Planetary Science Letters*, 319-320, 9-14. doi: 10.1016/j.epsl.2011.12.004

Huijnen, V., J. Williams, M. van Weele, T. van Noije, M. Krol, F. Dentener, A. Segers, S. Houweling, W. Peters, J. de Laat, F. Boersma, P. Bergamaschi, P. van Velthoven, P. Le Sager, H. Eskes, F. Alkemade, R. Scheele, P. Nédélec and H.-W. Pätz, 2010: The global chemistry transport model TM5: description and evaluation of the tropospheric chemistry version 3.0. *Geosci. Model Dev.*, 3, 445-473, doi:10.5194/gmd-3-445-2010.

Igarashi, Y., Y. Inomata, M. Aoyama, K. Hirose, H. Takahashi, Y. Shinoda, N. Sugimoto, A. Shimizu, and M. Chiba, 2009: Plausible change in Asian dust source suggested by atmospheric anthropogenic radionuclides-observation of single wet deposition events during spring of 2007. *Atmospheric Environment*, 43, 2971-2980.

International Commission on Radiological Protection (ICRP), 1995: ICRP Publication 71: Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 4 Inhalation Dose Coefficients. *Ann. ICRP*, vol. 25/3-4, Pergamon, Oxford, U. K.

Ishikawa, Y., T. Awaji, T. Toyoda, T. In, K. Nishina, T. Nakayama, S. Shima, and S. Masuda, 2009: High-resolution synthetic monitoring by a 4-dimensional variational data assimilation system in the northwestern North Pacific. *J. Mar. Syst.*, 78, 237-248.

Iwasaki, T., T. Maki, and K. Katayama, 1998: Tracer transport model at Japan Meteorological Agency and its application to the ETEX data. *Atmos. Env.*, 32, 4285-4295.

JAEA workshop, 2012: JAEA Open Workshop 'Reconstruction of the Emission and diffusion processes of materials released by the Fukushima Daiichi Atomic Power Plant accident', March 6, 2012, Tokyo,

<http://nsed.jaea.go.jp/ers/environment/envs/FukushimaWS/index.htm>.

JODC, 2011: JODC-Expert Grid data for Geography (J-EGG500), 500m gridded bathymetric data set of Japan. [http://www.jodc.go.jp/data\\_set/jodc/jegg\\_intro.html](http://www.jodc.go.jp/data_set/jodc/jegg_intro.html).

Kajino, M., 2011: MADMS: Modal Aerosol Dynamics model for multiple Modes and fractal Shapes in the free-molecular and near-continuum regimes. *J. Aerosol Sci.*, 42, 224-248.

Kajino, M., and Y. Kondo, 2011: EMTACS: Development and regional-scale simulation of a size, chemical, mixing type, and soot shape resolved atmospheric particle model. *J. Geophys. Res.*, 116, D02303, doi:10.1029/2010JD015030.

Kajino, M. Y. Inomata, K. Sato, H. Ueda, Z. Han, J. An, G. Katata, M. Deushi, T. Maki, N. Oshima, J. Kurokawa, T. Ohara, A. Takami, and S. Hatakeyama, 2012: Development of the RAQM2 aerosol chemical transport model and predictions of the Northeast Asian aerosol mass, size, chemistry, and mixing type. *Atmos. Chem. Phys.*, 12, 11833-11856,

doi:10.5194/acp-12-11833-2012.

- Katata, G., M. Ota, H. Terada, M. Chino, and H. Nagai, 2012: Atmospheric discharge and dispersion of radionuclides during the Fukushima Dai-ichi Nuclear Power Plant accident. Part I: Source term estimation and local-scale atmospheric dispersion in early phase of the accident. *J. Environ. Radioactivity*, **109**, 103-113, doi:10.1016/j.jenvrad.2012.02.006.
- Kawamura, H., T. Kobayashi, A. Furuno, T. In, Y. Ishikawa, T. Nakayama, S. Shima, and T. Awaji, 2011: Preliminary numerical experiments on oceanic dispersion of  $^{131}\text{I}$  and  $^{137}\text{Cs}$  discharged into the ocean because of the Fukushima daiichi nuclear power plant disaster. *J. Nucl. Sci. Tech.*, **48**, 1349-1356.
- Kinoshita, N., K. Sueki, K. Sasa, J-I. Kitagawa, S. Ikarashi, T. Nishimura, Y-S. Wong, Y. Satou, K. Handa, T. Takahashi, M. Sato, and T. Yamagata, 2011: Assessment of individual radionuclide distributions from the Fukushima nuclear accident covering central-east Japan. *Proceedings of the National Academy of Sciences of the United States of America*, 4pp, doi:10.1073/pnas.1111724108.
- Kitada, T., 1994: Modelling of transport, reaction and deposition of acid rain. *Kishou Kenkyu Note*, **182**, 95–117 (in Japanese).
- Klug, W., G. Graziani, G. Gripa, D. Pierce, and C. Tassone, 1992: Evaluation of long range atmospheric transport models using environmental radioactivity data from the Chernobyl accident. *the ATMES report*, Technical report, Elsevier Applied Science.
- Kobayashi, T., S. Otosaka, O. Togawa, and K. Hayashi, 2007: Development of a non-conservative radionuclides dispersion model in the ocean and its application to surface cesium-137 dispersion in the Irish Sea. *J. Nucl. Sci. Technol.*, **44**, 238-247.
- Kobayashi T., H. Nagai, M. Chino, and H. Kawamura, 2013: Source term estimation of atmospheric release due to the Fukushima Dai-ichi Nuclear Power Plant accident by atmospheric and oceanic dispersion simulations. *J. Nucl. Sci. Technol.*, **50**, 255-264, doi:10.1080/00223131.2013.772449.
- Kondo, J., 1975: Air-sea bulk transfer coefficients in diabatic conditions. *Bound.-Layer Meteor.*, **9**, 91-112.
- Korsakissok, I., D. Didier, A. Mathieu, D. Quelot, J. Groell, E. Quentrec, M. Tombette, J.P. Benoit, and O. Saunier, 2011: Evaluation of the atmospheric releases of the Fukushima accident and their consequences. *Institute de Radioprotection et de Sécurité Nucléaire (IRSN)*, PRP-CRI/SESC n 2011-00299, 38p.
- Korsakissok, I., A. Mathieu, and D. Didier, 2013: Atmospheric dispersion and ground deposition induced by the Fukushima Nuclear power plant accident: a local-scale simulation and sensitivity

- study. *Atmos. Environ.*, **70**, 267-279.
- Krol, M., S. Houweling, B. Bregman, M. van den Broek, A. Segers, P. van Velthoven, W. Peters, F. Dentener and P. Bergamaschi, 2005: The two-way nested global chemistry-transport zoom model TM5: algorithm and applications. *Atmos. Chem. Phys.*, **5**, 417-432, doi:10.5194/acp-5-417-2005.
- Kunii, M., 2013: Mesoscale data assimilation for a local severe rainfall event with the NHM-LETKF system. *Weather and Forecasting*, e-View, doi: <http://dx.doi.org/10.1175/WAF-D-13-00032.1>.
- Large, W.G., J. C. McWilliams, and S. C. Doney, 1994: Ocean vertical mixing: A review and a model with a nonlocal boundary layer parameterization. *Rev. Geophys.*, **32**, 363-403.
- Lazure, P., and F. Dumas, 2008: An external-internal mode coupling for a 3D hydrodynamical model for applications at regional scale (MARS). *Adv. Water Resources*, **31**, 233-250.
- Locarnini, R. A., A. V. Mishonov, J. I. Antonov, T. P. Boyer, H. E. Garcia, and S. Levitus, 2006: World Ocean Atlas 2005, Volume 1: Temperature, NOAA Atlas NESDIS 61, U.S. Government Printing Office, Washington, DC, 182 pp.
- Long, N.Q., Y. Truong, P.D. Hien, N.T. Binh, L.N. Sieu, T.V. Giap, and N.T. Phan, 2012: Atmospheric radionuclides from the Fukushima Dai-ichi nuclear reactor accident observed in Vietnam. *J. of Environmental Radioactivity*, **111**, pp.53-58, doi: 10.1016/j.jenvrad.2011.11.018.
- Lyard, F., F. Lefevre, T. Letellier, and O. Francis, 2006: Modelling the global ocean tides: modern insights from FES2004. *Ocean Dynamics*, **56**, 394-415. doi:10.1007/s10236-006-0086-x.
- Maki, T., T. Y. Tanaka, T. T. Sekiyama, and M. Mikami, 2011: The impact of ground-based observations on the inverse technique of Aeolian dust aerosol. *SOLA*, **7A**, 21-24.
- Margvelashvily, N., V. Maderich, and M. Zheleznyak, 1997: THREEOX - computer code to simulate three-dimensional dispersion of radionuclides in homogeneous and stratified water bodies. *Radiation Protection Dosimetry*, **73**, 177-180.
- Maryon, R.H., F.B. Smith, B.J. Conwy, and D.M. Goddard, 1992: The UK nuclear accident response model (NAME). *Progress in Nuclear Energy*, **26**, 85-104.
- Maryon, R.H., J. Saltbones, D.B. Ryall, J. Barnicki, H.A. Jakobsen, and E. Berge, 1996: An intercomparison of three long range dispersion models developed for the UK meteorological office, DNMI and EMEP. *UK Met Office Turbulence and Diffusion Note*, **234**, ISBN: 82-7144-026-08, pp. 44.
- Mason, E., J. Molemaker, A.F. Shchepetkin, F. Colas, J.C. McWilliams, and P. Sangra, 2010: Procedures for offline grid nesting in regional ocean models. *Ocean modelling*, **35**, 1 -15.
- Masson., O., et al., 2011: Tracking of Airborne Radionuclides from the Damaged Fukushima Dai-Ichi Nuclear Reactors by European Networks. *Environ. Sci. Technol.*, **45**, 7670-7677, doi:

10.1021/es2017158.

- Masumoto, Y., Y. Miyazawa, D. Tsumune, T. Kobayashi, C. Estournel, P. Marsaleix, L. Lanerolle, A. Mehra, and Z. D. Garraffo, 2012: Oceanic dispersion simulation of Cesium 137 from Fukushima Daiichi Nuclear Power Plant. *Elements*, **8**, 207-212.
- Mathieu, A., I. Korsakissok, D. Quélo, J. Groëll, M. Tombette, D. Didier, E. Quentric, O. Saunier, J.-P. Benoit, and O. Isnard, 2012: Atmospheric dispersion and deposition of radionuclides from the Fukushima Daiichi nuclear power plant accident. *Elements*, **8**, 195-200.
- Medici, F., 2001: The IMS radionuclide network of the CTBT. *Radiat. Phys. Chem.*, **61**, 689-690.
- Mellor, G. L., 2001: One-dimensional, ocean surface layer modeling: A problem and a solution. *J. Phys. Oceanogr.*, **31**, 790-809.
- Mellor, G. and A. F. Blumberg, 2004: Wave breaking and ocean surface layer thermal response. *J. Phys. Oceanogr.*, **34**, 693-698.
- MEXT, 2011: Results of airborne monitoring by the Ministry of Education, Culture, Sports. Science and Technology and the U.S. Department of Energy. Available at  
[http://radioactivity.nsr.go.jp/ja/contents/4000/3710/24/1305820\\_20110506.pdf](http://radioactivity.nsr.go.jp/ja/contents/4000/3710/24/1305820_20110506.pdf),  
[http://radioactivity.nsr.go.jp/ja/contents/5000/4858/24/1305819\\_0708.pdf](http://radioactivity.nsr.go.jp/ja/contents/5000/4858/24/1305819_0708.pdf),  
[http://radioactivity.nsr.go.jp/ja/contents/5000/4901/24/1910\\_1216.pdf](http://radioactivity.nsr.go.jp/ja/contents/5000/4901/24/1910_1216.pdf).
- Miyazawa, Y., R. Zhang, X. Guo, H. Tamura, D. Ambe, J.-S. Lee, A. Okuno, H. Yoshinari, T. Setou, and K. Komatsu, 2009: Water mass variability in the western North Pacific detected in a 15-year eddy resolving ocean reanalysis. *J. Oceanogr.*, **65**, 737-756, doi: 10.1007/s10872-009-0063-3.
- Miyazawa, Y., Y. Masumoto, S.M. Varlamov, T. Miyama, M. Takigawa, M. Honda and T. Saino, 2012a: Inverse estimation of source parameters of oceanic radioactivity dispersion models associated with the Fukushima accident. *Biogeosci. Discuss.*, **9**, 13783-13816, doi:10.5194/bgd-9-13783-2012.
- Miyazawa, Y., Y. Masumoto, S. M. Varlamov, and T. Miyama, 2012b: Transport simulation of the radionuclide from the shelf to open ocean around Fukushima. *Cont. Shelf Res.*, **50-51**, 16-29.
- Morino, Y., T. Ohara, and M. Nishizawa, 2011: Atmospheric behavior, deposition, and budget of radioactive materials from the Fukushima Daiichi nuclear power plant in march 2011. *Geophys. Res. Lett.*, **38**, doi:10.1029/2011GL048689.
- Morino, Y., T. Ohara, M. Watanabe, S. Hayashi, and M. Nishizawa, 2013: Episode analysis of deposition of radiocesium form the Fukushima Daiichi Nuclear Power Plant accident. *Environ. Sci. Technol.*, **47**, 2314-2322, dx.dox.org/10.1021/es304620x.
- Noh, Y., and H.J. Kim, 1999: Simulations of temperature and turbulence structure of the oceanic

- boundary layer with the improved near-surface process. *J. Geophys. Res.*, **104**, 15621-15634, doi:10.1029/1999JC900068.
- Onogi, K., J. Tsutsui, H. Koide, M. Sakamoto, S. Kobayashi, H. Hatsushika, T. Matsumoto, N. Yamazaki, H. Kamahori, K. Takahashi, S. Kadokura, K. Wada, K. Kato, R. Oyama, T. Ose, N. Mannoji, and R. Taira, 2007: The JRA-25 Reanalysis. *J. Meteor. Soc. Japan*, **85**, 369-432.
- Park, S.-U., 1998: Effects of dry deposition on near-surface concentrations of SO<sub>2</sub> during medium-range transport. *J. Applied Meteor.*, **37**, 486-496.
- Park, S.-U., A. Choe, M.-S. Park, and Y. Chun, 2010: Performance tests of the Asian Dust Aerosol Model 2 (ADAM2). *J. of Sustainable Energy and Environ.*, **1**, 77-83.
- Park, S.-U., A. Choe, and M.-S. Park, 2013: Atmospheric dispersion and deposition of radionuclides (<sup>137</sup>Cs and <sup>131</sup>I) released from the Fukushima Dai-ichi nuclear power plant. *Computational Water, Energy, and Environ. Engineering*, **2**, 61-68.
- Quélo, D., M. Krysta, M. Bocquet, O. Isnard, Y. Minier, and B. Sportisse, 2007: Validation of the Polyphemus platform on the ETEX, Chernobyl and Algeciras cases. *Atmos. Environ.*, **41**, 5300-5315.
- Ralph, E. A., and P. P. Niiler, 1999: Wind-driven currents in the tropical Pacific. *J. Phys. Oceanogr.*, **29**, 2121-2129.
- Roeckner, E., G. Bäuml, L. Bonaventura, R. Brokopf, M. Esch, M. Giorgetta, S. Hagemann, I. Kirchner, L. Kornblueh, E. Manzini, A. Rhodin, U. Schlese, U. Schulzweida and A. Tompkins, 2003: The atmospheric general circulation model ECHAM5.PART I: Model description. *Technical report, Max Planck Institute for Meteorology*.
- Roeckner, E., R. Brokopf, M. Esch, M. Giorgetta, S. Hagemann, L. Kornblueh, E. Manzini, U. Schlese., and U. Schulzweida, 2006: Sensitivity of simulated climate to horizontal and vertical resolution in the ECHAM5 atmosphere model. *J. Climate*, **19**, 3771-3791.
- Roland, A., Y. J. Zhang, H. V. Wang, Y. Meng, Y.-C. Teng, V. Maderich, I. Brovchenko, M. Dutour-Sikiric, and U. Zanke, 2012: A fully coupled 3D wave-current interaction model on unstructured grids. *J. Geophys Res.*, **117**, C00J33, p. 1 -18 doi:10.1029/2012JC007952.
- Romero, L., Y. Uchiyama, C. Ohlmann, J.C. McWilliams, and D.A. Siegel, 2013: Particle-pair dispersion in the Southern California coastal zone. *J. Phys. Oceanogr.*, **43**, 1862-1879.
- Saito, K., T. Shimbori, and R. Draxler, 2014: JMA's regional atmospheric transport model calculations for the WMO Technical Task Team on meteorological analyses for Fukushima Daiichi Nuclear Power Plant accident. *J. Environ. Radioact.*, doi: 10.1016/j.jenvrad.2014.02.007. (in press).
- Saunier, O., A. Mathieu, D. Didier, M. Tombette, D. Quélo, V. Winiarek, and M. Bocquet, 2013: An

- inverse modeling method to access the source term of the Fukushima nuclear power plant accident using gamma dose rate observations. *Atmos. Chem. Phys.*, **13**, 11403-11421.
- Sehmel, G.A., 1980: Particle and gas dry deposition: A review. *Atmos. Environ.* **14**, 983-1011.
- Seinfeld, J.H., and S.N. Pandis, 1998: Atmospheric Chemistry and Physics, From Air Pollution to Climate Change. John Wiley and Sons, Inc., NY.
- Seino, N., H. Sasaki, J. Sato, and M. Chiba, 2004: High-resolution simulation of volcanic sulfur dioxide dispersion over the Miyake Island. *Atmos. Env.*, **38**, 7073-7081.
- Shchepetkin, A. F., and J. C. McWilliams, 2005: The Regional Ocean Modeling System (ROMS): a split-explicit, free-surface, topography following coordinates oceanic model. *Ocean Modelling*, **9**, 347-404.
- Shimbori, T., Y. Aikawa, and N. Seino, 2009: Operational implementation of the tephra fall forecast with the JMA mesoscale tracer transport model. *CAS/JSC WGNE Res. Act. Atmos. Ocea. Model.*, **39**, 5.29-5.30.
- Shimbori, T. , Y. Aikawa, K. Fukui, A. Hashimoto, N. Seino, and H. Yamasato, 2010: Quantitative tephra fall prediction with the JMA mesoscale tracer transport model for volcanic ash: A case study of the eruption at Asama volcano in 2009. *Pap. Met. Geophys.*, **61**, 13-29 (in Japanese with English abstract and figure captions).
- Simmons, A., S. Uppala, D. Dee, and S. Kobayashi, 2007: ERA-Interim: New ECMWF reanalysis products from 1989 onwards. *ECMWF newsletter*, **110**, 25-35.
- Skamarock, W. C., J.B. Klemp, J. Dudhia, D.O. Gill, D.M. Barker, M.G. Duda, X.Y. Huang, W. Wang, and J.G. Powers, 2008: A description of the advanced research WRF version 3, NCAR Tech. Note NCAR/TN-475+STR, 113pp.
- Smagorinsky, J., 1963: General circulation experiments with the primitive equations, I. The basic experiment. *Mon. Weather Rev.*, **91**, 99-164.
- Smith, A. R., K. J. Thomas, E. B. Norman, D. L. Hurley, B. T. Lo, Y. D. Chan, P. V. Guillaumon, and B. G. Harvey, 2014: Measurements of Fission Products from the Fukushima Daiichi Incident in San Francisco Bay Area Air Filters, Automobile Filters, Rainwater, and Food. *Journal of Environmental Protection*, **5**, 207-221.
- Sportisse, B., 2007: A review of parameterizations for modeling dry deposition and scavenging of radionuclides. *Atmospheric Environment*, **41**, 2683-2698.
- Stohl, A., P. Seibert, G. Wotawa, D. Arnold, J. F. Burkhart, S. Eckhardt, C. Tapia, A. Vargas, and T. J. Yasunari, 2012: Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition. *Atmos. Chem. Phys.*, **12**, 2313-2343, doi:10.5194/acp-12-2313-2012.

- Sugiyama, G., J. Nasstrom, B. Pobanz, K. Foster, M. Simpson, P. Vogt, F. Aluzzi, and S. Homann, 2012: Atmospheric dispersion modeling: challenges of the Fukushima Daiichi response. *Health Physics*, **102**, 493-508, doi:10.1097/HP.0b013e31824c7bc9.
- Takahashi, K., X. Peng, R. Onishi, M. Ohdaira, K. Goto, H. Fuchigami, and T. Sugimura, 2008: Impact of coupled nonhydrostatic atmosphere–ocean–land model with high resolution. *High Resolution Numerical Modelling of the Atmosphere and Ocean*, K. Hamilton and W. Ohfuchi, Eds, Springer-Verlag, 261-274.
- Takano, I., Y. Aikawa, and S. Gotoh, 2007: Improvement of photochemical oxidant information by applying transport model to oxidant forecast. *CAS/JSC WGNE Res. Act. Atmos. Ocea. Model.*, **37**, 5.35-5.36.
- Takemura, T., H. Okamoto, Y. Murayama, A. Numaguti, A. Higurashi, and T. Nakajima, 2000: Global three-dimensional simulation of aerosol optical thickness distribution of various origins. *J. Geophys. Res.* **105**, 17853-17873.
- Takemura, T., T. Nakajima, O. Dubovik, B.N. Holben, and S. Kinne, 2002: Single-scattering albedo and radiative forcing of various aerosol species with a global three-dimensional model. *J. Climate*, **15**, 333-352.
- Takemura, T., T. Nozawa, S. Emori, T.Y. Nakajima, and T. Nakajima, 2005: Simulation of climate response to aerosol direct and indirect effects with aerosol transport-radiation model. *J. Geophys. Res.*, **110**, D02202, doi:10.1029/2004JD005029.
- Takemura, T., H. Nakamura, M. Takigawa, H. Kondo, T. Satomura, T. Miyasaka, and T. Nakajima, 2011: A numerical simulation of global transport of atmospheric particles emitted from the Fukushima Daiichi Nuclear Power Plant. *SOLA*, **7**, 101-104, doi:10.2151/sola.2011-026.
- Tanaka, T. Y., and M. Chiba, 2005: Global simulation of dust aerosol with a chemical transport Model, MASINGAR. *J. Meteor. Soc. Japan*, **83A**, 255-278.
- Tanaka, T. Y., K. Orito, T.T. Sekiyama, K. Shibata, M. Chiba, and H. Tanaka, 2003: MASINGAR, a global tropospheric aerosol chemical transport model coupled with MRI/JMA98 GCM: Model description. *Pap. Meteor. Geophys.* **53**, 119-138.
- Tanaka, T. Y., T. Maki, T.T. Sekiyama, Y. Igarashi, M. Kajino, and M. Mikami, 2013: Numerical analysis of the global transport of radionuclides from Fukushima Dai-ichi nuclear power plant accident. *93rd American Meteorological Society Annual Meeting*.
- TEPCO, 2011: Press release 'Submission of a report to Ministry of Economy, Trade and Industry, Nuclear and Industrial Safety Agency, on the tsunami investigation at Fukushima Daiichi and Daini Atomic Power Plants. July 8, 2011 (in Japanese). Available at <http://www.tepcō.co.jp/cc/press/11070802-j.html>.

TEPCO, 2012: Estimation of the released amount of radioactive materials into the atmosphere as a result of the accident in the Fukushima Daiichi Nuclear Power Station (in Japanese).

Available at [http://www.tepco.co.jp/cc/press/betu12\\_j/images/120524j0105.pdf](http://www.tepco.co.jp/cc/press/betu12_j/images/120524j0105.pdf).

Terada, H., A. Furuno, and M. Chino, 2004: Improvement of worldwide version of system for prediction of environmental emergency dose information (WSPEEDI), (I) new combination of models, atmospheric dynamic model MM5 and particle random walk model GEARN-new. *J. Nucl. Sci. Technol.*, **41**, 632-640.

Terada, H., and M. Chino, 2005: Improvement of Worldwide Version of System for Prediction of Environmental Emergency Dose Information (WSPEEDI), (II) evaluation of numerical models by  $^{137}\text{Cs}$  deposition due to the Chernobyl nuclear accident. *J. Nucl. Sci. Technol.* **42**, 651-660.

Terada, H., and M. Chino, 2008: Development of an atmospheric dispersion model for accidental discharge of radionuclides with the function of simultaneous prediction for multiple domains and its evaluation by application to the Chernobyl nuclear accident. *J. Nucl. Sci. Technol.*, **45**, 920-931.

Terada, H., H. Nagai, A. Furuno, T. Kakefuda, T. Harayama, and M. Chino, 2008: Development of worldwide version of system for prediction of environmental emergency dose information: WSPEEDI 2nd version. *Trans. At. Energy Soc. Japan*, **7**, 257-267 (in Japanese with English abstract).

Terada, H., G. Katata, M. Chino, and H. Nagai, 2012: Atmospheric discharge and dispersion of radionuclides during the Fukushima Dai-ichi Nuclear Power Plant accident Part II: verification of the source term and analysis of regional-scale atmospheric dispersion. *J. Environ. Radioact.*, **112**, 141-154.

Torii, T., T. Sugita, C. E. Okada, M. S. Reed, and D. J. Blumenthal, 2013: Enhanced analysis methods to derive the spatial distributions of  $^{131}\text{I}$  deposition on the ground by airborne suveys at an early stage after the Fukushima Daiichi nuclear power plant accident. *Health Physics*, **105**, 192-200.

Tsumune, D., M. Aoyama, K. Hirose, F. O. Bryan, K. Lindsay, and G. Danabasoglu, 2011a: Transport of  $^{137}\text{Cs}$  to the Southern Hemisphere in an ocean general circulation model. *Progress In Oceanography*, **89**, 38-48, 10.1016/j.pocean.2010.12.006.

Tsumune, D., T. Tsubono, M. Aoyama, and K. Hirose, 2011b: Distribution of oceanic  $^{137}\text{Cs}$  from the Fukushima Daiichi Nuclear Power Plant simulated numerically by a regional ocean mode. *CRIEPI Environmental Science Research Laboratory Rep.*, No.V11002, (in Japanese, with English abstract and figure captions).

Tsumune, D., T. Tsubono, M. Aoyama, and K. Hirose, 2012: Distribution of oceanic  $^{137}\text{Cs}$  from the

Fukushima Dai-ichi Nuclear Power Plant simulated numerically by a regional ocean model. *J. Environm. Radioact.*, **111**, 100-108.

Tsumune, D., T. Tsubono, M. Aoyama, M. Uematsu, K. Misumi, Y. Maeda, Y. Yoshida, and H.

Hayami, 2013: One-year, regional-scale simulation of  $^{137}\text{Cs}$  radioactivity in the ocean following the Fukushima Dai-ichi Nuclear Power Plant accident. *Biogeosciences*, **10**, 5601-5617, doi:10.5194/bg-10-5601-2013.

Uchiyama, Y., T. Ishii, D. Tsumune, and Y. Miyazawa, 2012: Oceanic dispersion of radioactive cesium-137 from Fukushima Daiichi Nuclear Power Plant. *J. JSCE*, **68**, 931-935 (in Japanese with English abstract).

Uchiyama, Y., T. Yamanishi, D. Tsumune, Y. Miyazawa, and T. Ishii, 2013: Influences of coastal jet and mesoscale eddies on initial dispersion of the radionuclides released from Fukushima Daiichi Nuclear Power Plant. *J. JSCE*, **69**, 1051-1055 (in Japanese with English abstract).

Uchiyama, Y., E. Idica, J.C. McWilliams, and K.D. Stolzenbach, 2014: Wastewater effluent dispersal in Southern California bays. *Cont. Shelf Res.*, **76**, 36-52. doi: <http://dx.doi.org/10.1016/j.csr.2014.01.002>.

Uppala, S. M., et al., 2005: The ERA-40 re-analysis. *Q. J. Roy. Meteorol. Soc.*, **131**, 2961-3012, doi:10.1256/qj.04.176.

Vignati, E., M. Karl, M. Krol, J. Wilson, P. Stier, and F. Cavalli, 2010: Sources of uncertainties in modelling black carbon at the global scale. *Atmos. Chem. Phys.*, **10**, 2595-2611, doi:10.5194/acp-10-2595-2010

Watanabe, M., T. Suzuki, R. Oishi, Y. Komuro, S. Watanabe, S. Emori, T. Takemura, M. Chikira, T. Ogura, M. Sekiguchi, K. Takata, D. Yamazaki, T. Yokohata, T. Nozawa, H. Hasumi, H. Tatebe, and M. Kimoto, 2010: Improved climate simulation by MIROC5: Mean states, variability, and climate sensitivity. *J. Climate*, **23**, 6312-6335.

Wetherbee, G. A., D.A. Gay, T.M. Debey, C.M.B. Lehmann, and M.A. Nilles, 2012: Wet deposition of fission-product isotopes to north America from the Fukushima Dai-ichi incident. *Environ. Sci. Technol.*, **46**, 2574-2582, doi:10.1021/es203217u.

Winiarek, V., M. Bocquet, O. Saunier, and A. Mathieu, 2012: Estimation of errors in the inverse modeling of accidental release of atmospheric pollutant: Application to the reconstruction of the cesium-137 and iodine-131 source terms from the Fukushima Daiichi power plant. *J. Geophys. Res.*, **117**, D05122.

Winiarek, V., M. Bocquet, N. Duhanyan, Y. Roustan, O. Saunier, and A. Mathieu, 2014: Estimation of the caesium-137 source term from the Fukushima Daiichi nuclear power plant using a consistent joint assimilation of air concentration and deposition observations. *Atmos. Env.*, **82**,

WMO, 2011: Final report of the Meeting of the WMO Task Team on Meteorological Analyses for Fukushima Daiichi Nuclear Power Plant Accident. Geneva, Switzerland, 30 November- 2 December 2011, Available at

[http://www.wmo.int/pages/prog/www/CBS-Reports/documents/FinalRep\\_TT\\_FDnpp\\_v6.pdf](http://www.wmo.int/pages/prog/www/CBS-Reports/documents/FinalRep_TT_FDnpp_v6.pdf).

WMO, 2013: The World Meterological Organization's evaluation of meteorological analyses for the radionuclide dispersion and deposition from the Fukushima Daiichi Nuclear Power Plant accident. Annex III, ERA/TT-MA-NPP-accident 3<sup>rd</sup> Meeting 2012.

[http://www.wmo.int/pages/prog/www/CBS-Reports/documents/WMO\\_fnpp\\_final\\_AnnexIII\\_4\\_Feb2013\\_REVISED\\_17June2013.pdf](http://www.wmo.int/pages/prog/www/CBS-Reports/documents/WMO_fnpp_final_AnnexIII_4_Feb2013_REVISED_17June2013.pdf)

Yonezawa, C., and Y. Yamamoto, 2011: Measurements of the anthropogenic atmospheric radionuclides by the observational network of radionuclides for nuclear weapons test watch. *Bunseki*, **440**, 451-458 (in Japanese).

Yukimoto, S., H. Yoshimura, M. Hosaka, T. Sakami, H. Tsujino, M. Hirabara, T.Y. Tanaka, M. Deushi, A. Obata, H. Nakano, Y. Adachi, E. Shindo, S. Yabu, T. Ose, and A. Kitoh, 2011: Meteorological Research Institute-Earth System Model Version 1 (MRI-ESM1) - Model Description. *Technical Reports of the Meteorological Research Institute*, **64**, ISSN 0386-4049, Meteorological Research Institute, Japan, 88pp.

Yukimoto, S., Y. Adachi, M. Hosaka, T. Sakami, H. Yoshimura, M. Hirabara, T.Y. Tanaka, E. Shindo, H. Tsujino, M. Deushi, R. Mizuta, S. Yabu, A. Obata, H. Nakano, T. Koshiro, T. Ose, and A. Kitoh, 2012: A new global climate model of the Meteorological Research Institute: MRI-CGCM3 -Model description and basic performance. *J. Meteor. Soc. Japan*, **90**, pp.23-64.

Zhang, L., S. Gong, J. Padro, and L. Barrie, 2001: A size-segregated particle dry deposition scheme for an atmospheric aerosol module. *Atmos. Environ.*, **35**, 549-560.

Zhang, L., J. R. Brook, and R. Vet, 2003: A revised parameterization for gaseous dry deposition in air-quality models. *Atmos. Chem. Phys.*, **3**, 2067-2082.

Zhang, Y., and A. M. Baptista, 2008: SELFE: A semi-implicit Eulerian–Lagrangian finite-element model for cross-scale ocean circulation. *Ocean Modelling*, **21**, 71-96.