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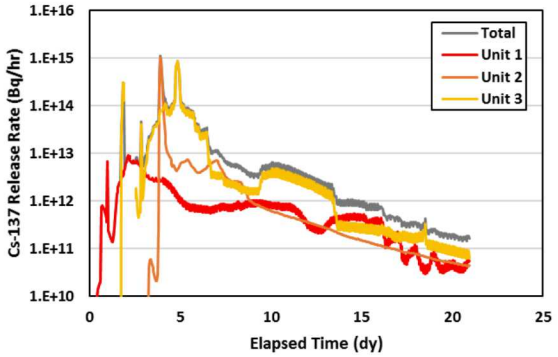


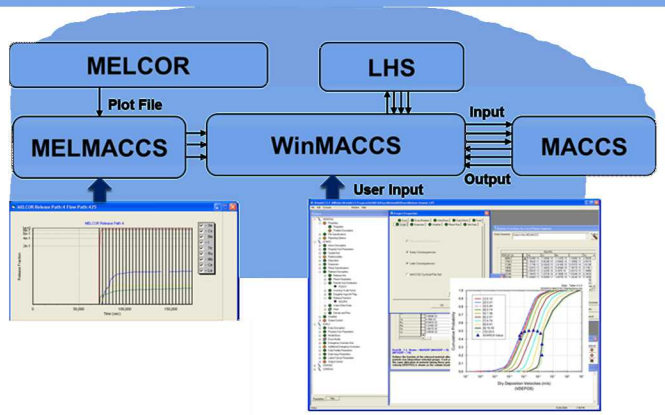


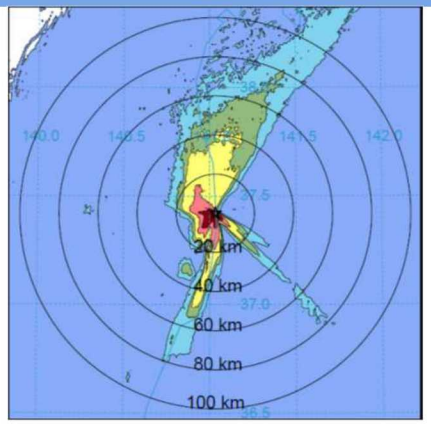


# Atmospheric Transport Results for Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Station (BSAF) Phase II

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**Sandia National Laboratories**

**Presented at the 31st Annual Regulatory Information Conference**

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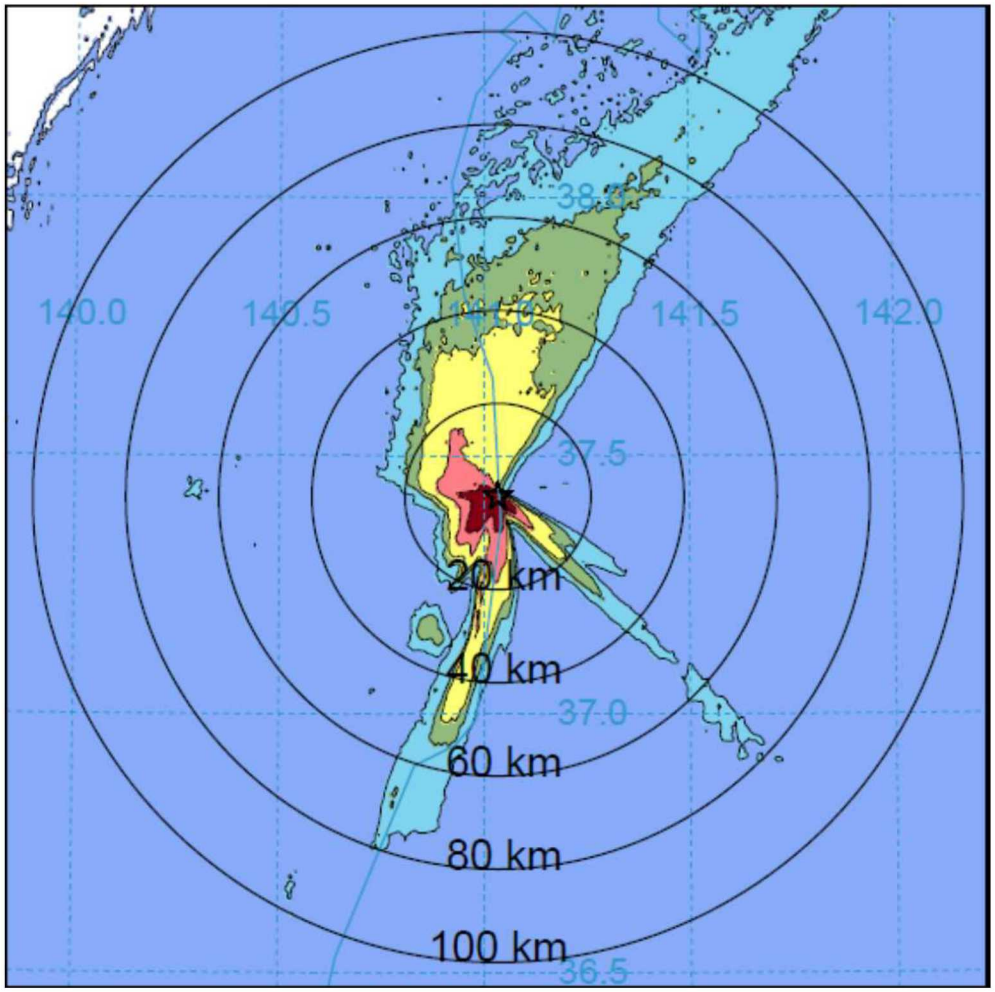
# Overview

- BSAF Project
- NRC/SNL MELCOR source term
- Sensitivity of deposition to meteorological data
- Sensitivity of deposition to source term
- Summary



# OECD/NEA BSAF Phase I

- BSAF was initiated by the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD)
- BSAF is a multi-phase study with participants from multiple countries
- Phase I was completed in 2015
  - Focus was to better understand accident progression at each of the three units over the first 6 days
  - New knowledge was to guide decommissioning
  - NRC/SNL (Sandia National Labs) contributed by performing MELCOR analyses of each unit

# OECD/NEA BSAF Phase II

- Phase II was completed in 2018
  - Focus was to extend investigation of accident progression, to evaluate source term, and to estimate atmospheric transport over the entire accident (3 weeks)
  - Research was to improved understanding of reactor end states for decommissioning
  - NRC/SNL contributed by performing MELCOR, HYSPLIT, and MACCS calculations for each unit

# Objectives of Atmospheric Transport Analysis to Support BSAF

- Provide guidance to source-term modelers by estimating ground deposition patterns
  - Focus on Cs-137 (best quantified of the released isotopes)
  - Deposition pattern depends critically on chronological alignment of release with weather pattern
- Benchmark atmospheric transport models against real data
  - HYSPLIT particle tracking model
    - As a stand-alone model
    - Integrated with MACCS
  - Results in this presentation use HYSPLIT in stand-alone mode

# Two Major Sources of Uncertainty

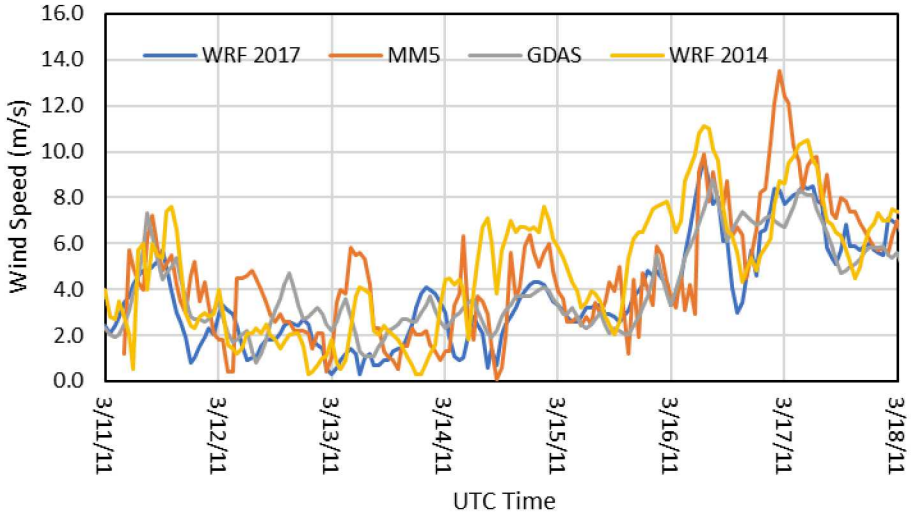
- Uncertainty in weather was investigated using three sources of weather data, all from NOAA
  - WRF (Weather Research and Forecasting) model, generated in 2014
    - 4-km spatial, 20 min temporal discretization
    - No nudging
  - GDAS (Global Data Assimilation System)
    - 0.5 degrees spatial, 3 hour temporal discretization
    - No nudging
  - WRF model, generated in 2017
    - 4-km spatial, 5 min temporal discretization
    - Nudged with observations
- Uncertainty in source term was assessed using source terms from BSAF contributors

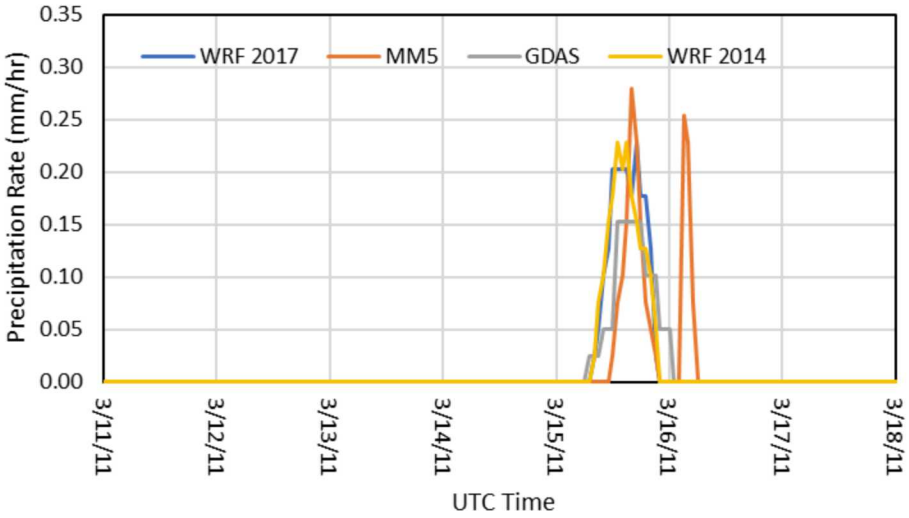
# Meteorological Data for First 7 Days

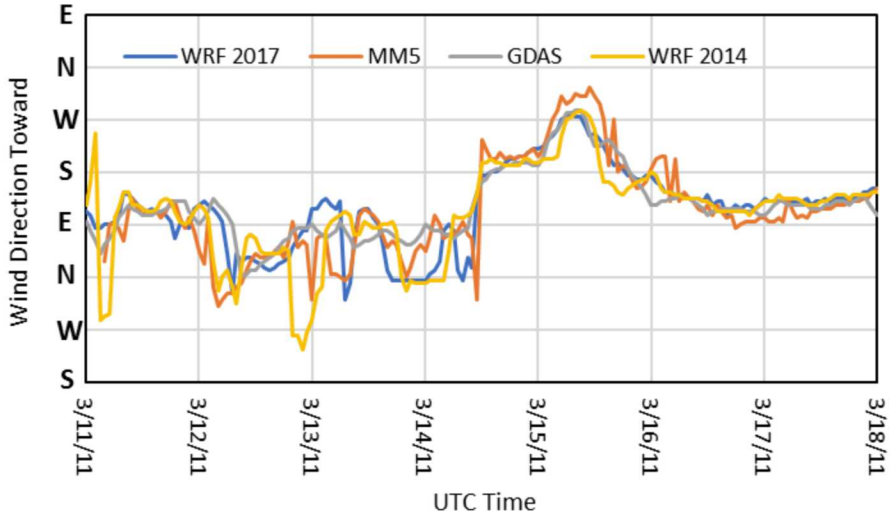
- Weather data have similar trends

but

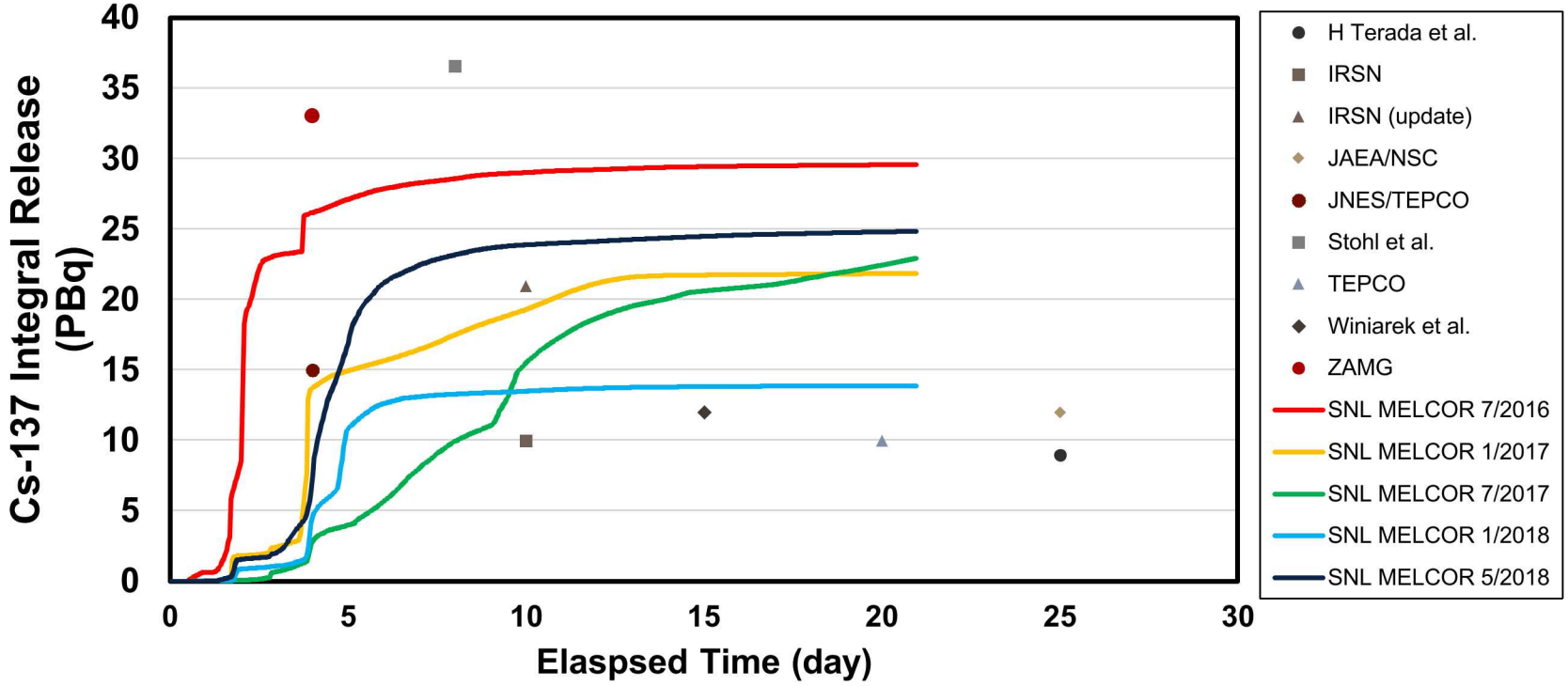
- Significant variations in detail



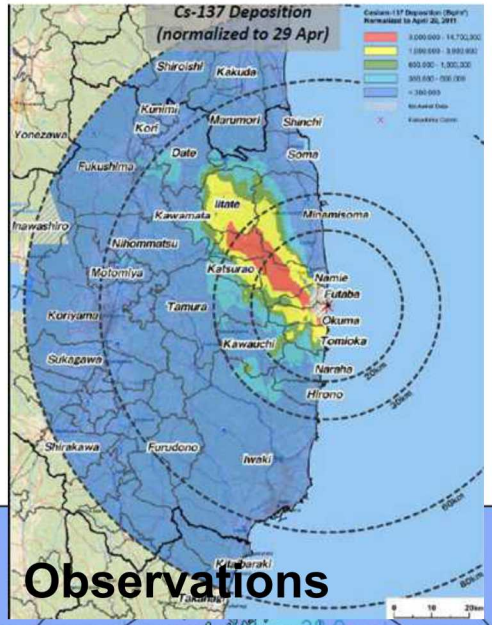
# Evolution of Integral Release Estimated by NRC/SNL

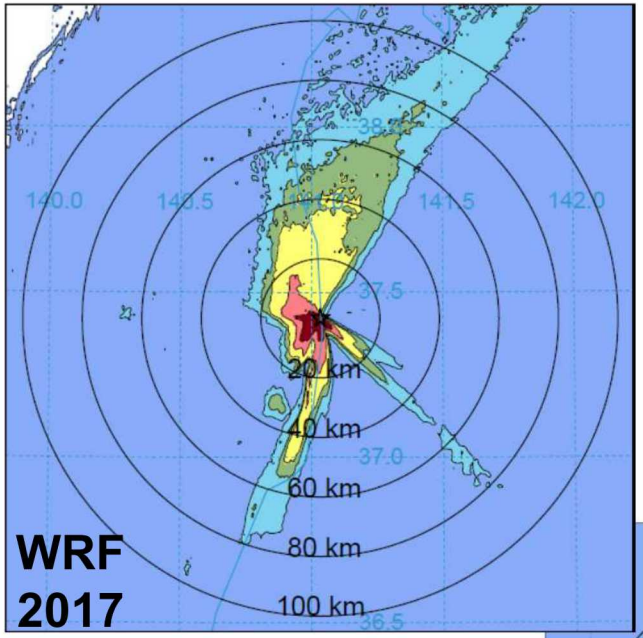


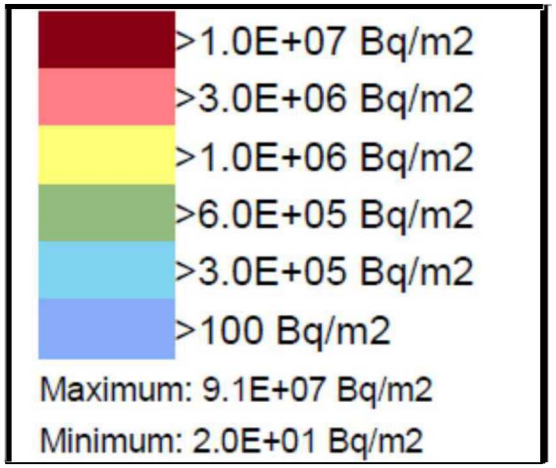

- Curves indicate evolution of integral release for three units as estimated by NRC/SNL over the course of BSAF Phase II
- Many of the initial and boundary conditions needed to estimate accident progression were poorly understood
  - Initial damage state was unknown
  - Water injection may have failed, succeeded, or partially succeeded

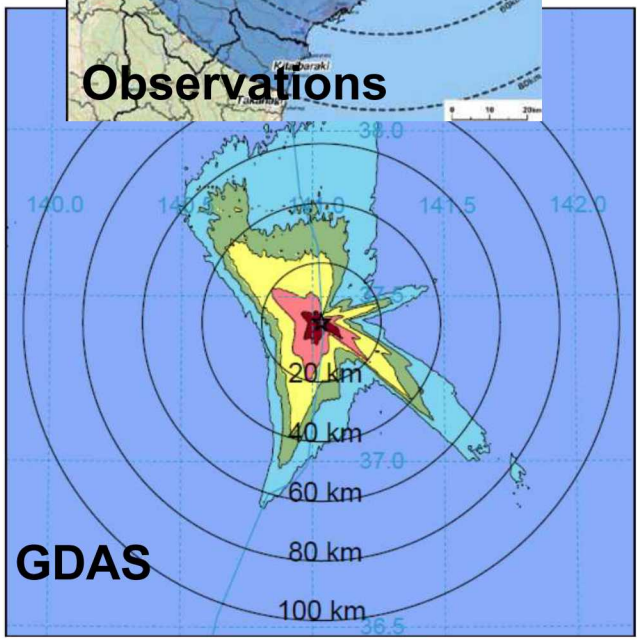
# Weather Data Comparison

**SNL MELCOR 5/2018**



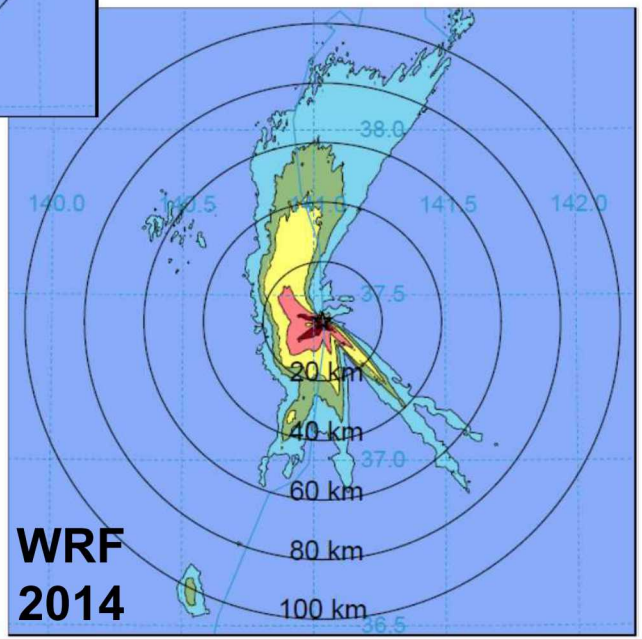



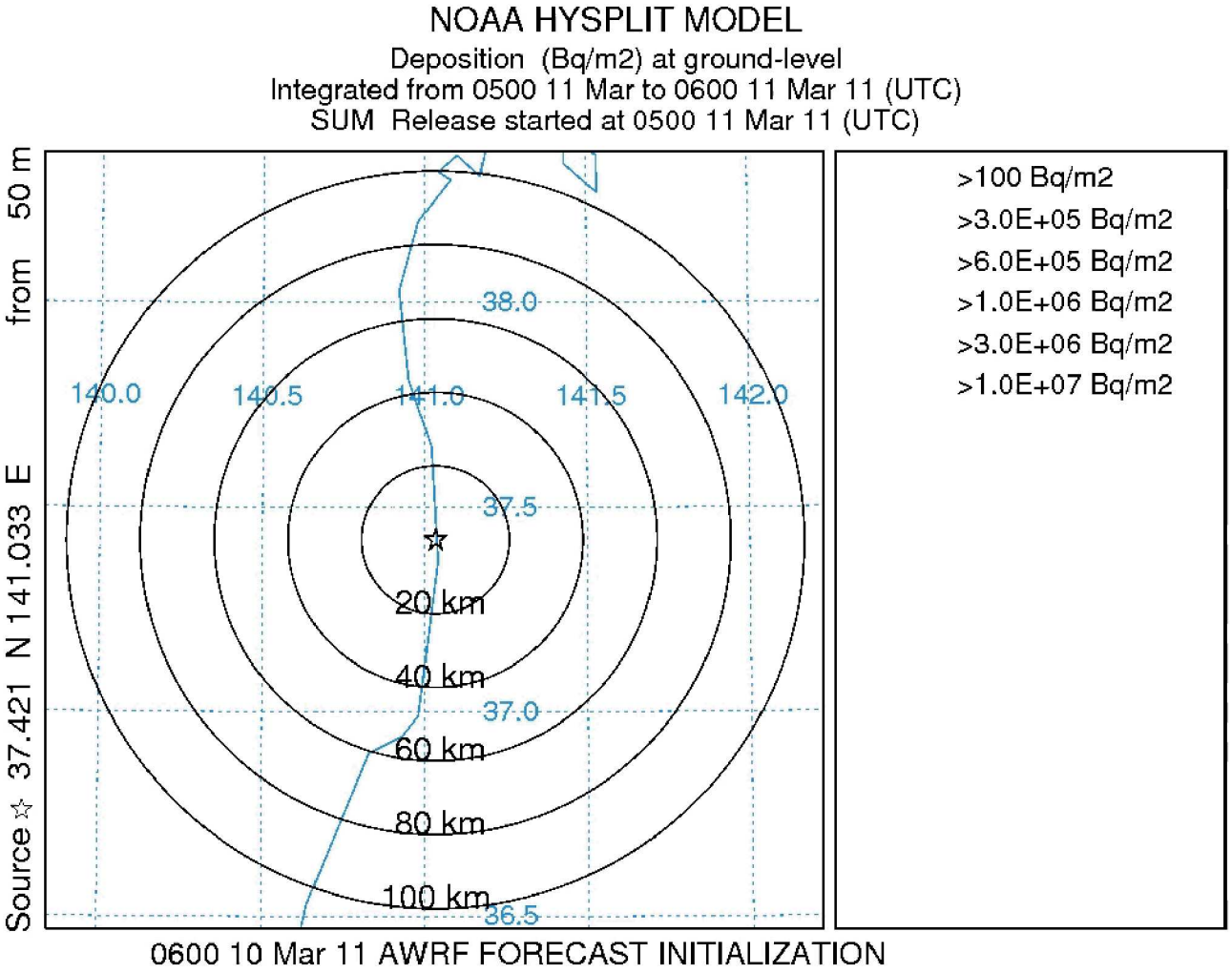

**Plots use**

- **Consistent scale**
- **Consistent isopleth shading (1 additional level in SNL plots)**



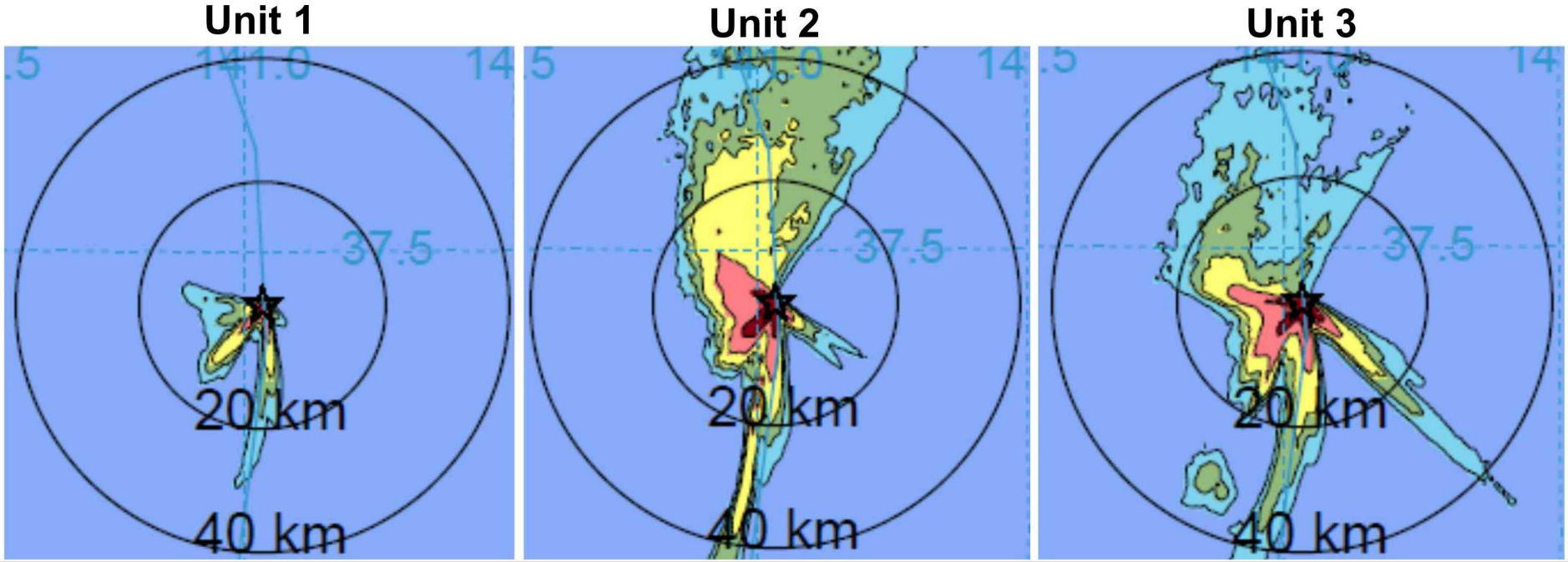
# Predicted Ground Deposition

## WRF 2017 SNL MELCOR 5/2018 Source Term



# Contributions to Deposition Pattern from Individual Units

- Figures show final deposition patterns created by each unit based on final NRC/SNL source term using WRF 2017 weather data
- Unit 1 contributes very little to the overall pattern
- Unit 2 and, to a lesser extent, Unit 3 create much of the NW deposition pattern, mostly on 3/15



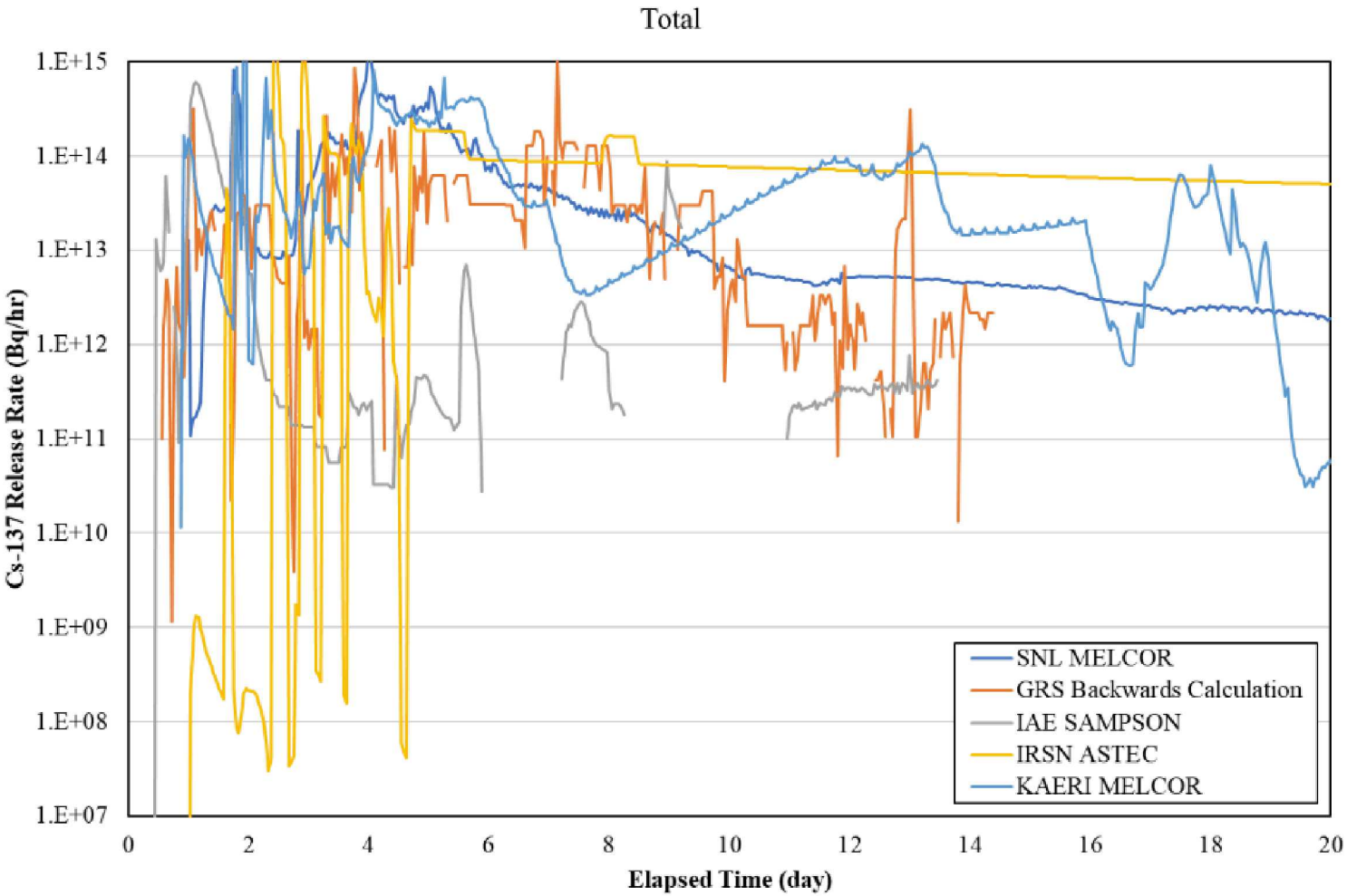
# BSAF Source Terms

- SNL received source terms from eight BSAF organizations

| Organization | Country | Code | Units |
|---|---|---|---|
| SNL | USA | MELCOR | 1, 2, & 3 |
| IAE | Japan | SAMPSON | 1, 2, & 3 |
| IRSN | France | ASTEC | 1, 2, & 3 |
| KAERI | Korea | MELCOR | 1, 2, & 3 |
| CIEMAT | Spain | MELCOR | 1 |
| CNL | Canada | MELCOR | 2 |
| CRIEPI | Japan | MAAP | 2 |
| PSI | Switzerland | MELCOR | 3 |

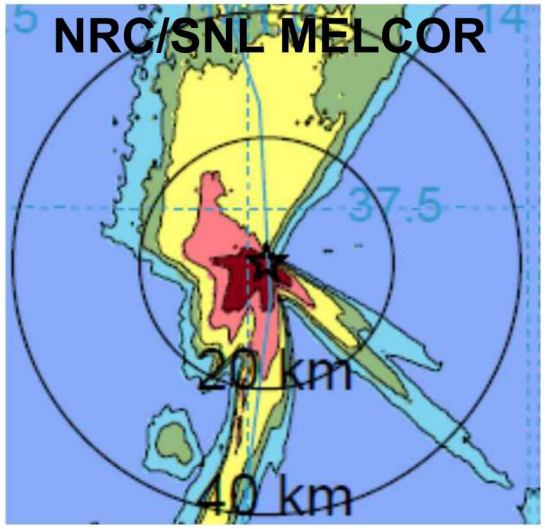
- Four provided a source term for all three units
- GRS (Germany) reconstructed a source term using data from radiation monitors in the area surrounding Fukushima (reverse method)

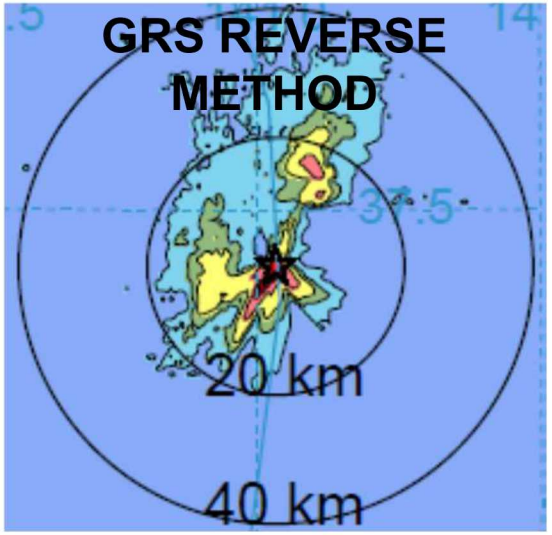
# Total Source Term Comparison

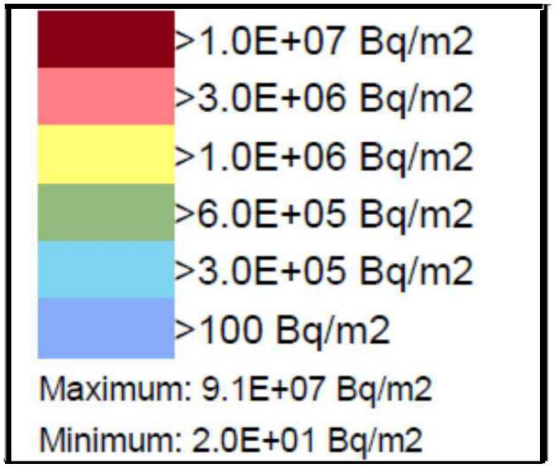


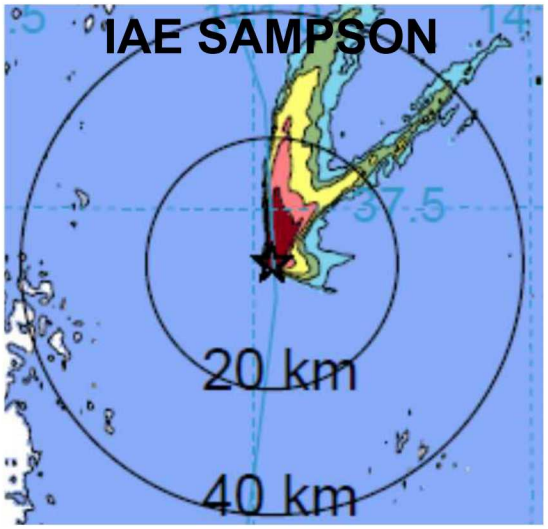
# Total Deposition Comparison

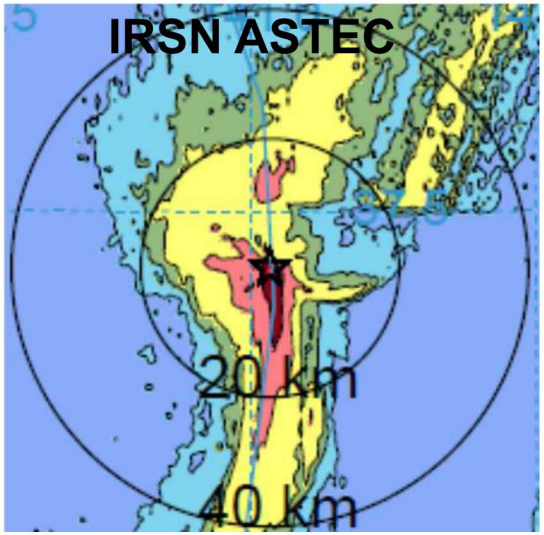
Using WRF 2017 Weather Data

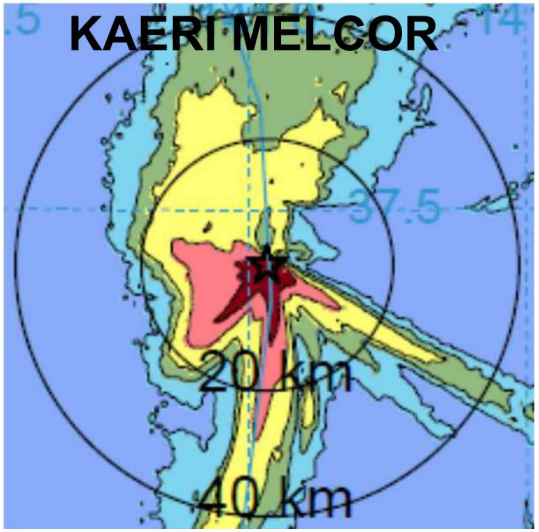


# Summary

- NRC/SNL evaluated atmospheric transport with HYSPLIT and MACCS
- Uncertainty in meteorology makes a significant difference in the deposition pattern
- Uncertainty in source term makes an even larger difference in the deposition pattern
- Insights from atmospheric transport modeling improved the fidelity of the source terms over the course of BSAF Phase II
- BSAF results have provided preliminary guidance for decommissioning the Fukushima Daiichi units