# NARAC and the International Exchange Program: consequence assessment tool for radiological emergency support

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Lawrence Livermore National Laboratory

National Atmospheric Release Advisory Center

NARAC

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# NARAC is the Department of Energy's *National Atmospheric Release Advisory Center*

NARAC has maintained 24/7 readiness for over 35 years.

NARAC uses advanced computer models to:

- Predict meteorological conditions
- Predict atmospheric dispersion and deposition of radioactive material
- Predict dose, affected population, injuries, casualties, and protective actions
- Estimate radiological & nuclear source characteristics

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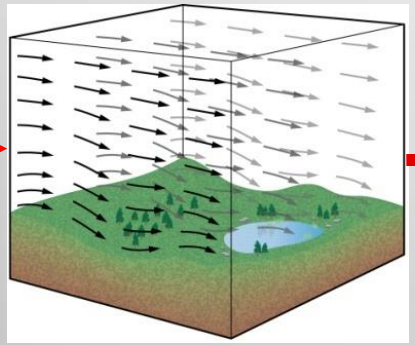
National Atmospheric Release Advisory Center
NARAC

# Center's Modeling System: Real-time Automated 3-D Worldwide Plume Model Predictions in minutes

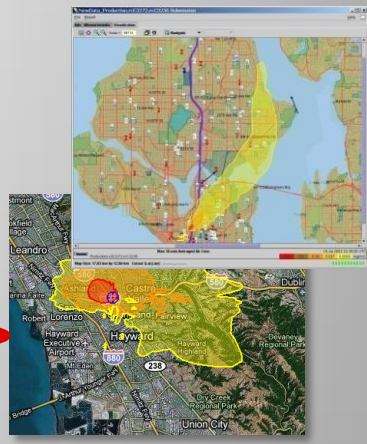
Hazardous material source characteristics

Global met, geographical, terrain, population databases



3-D met and geographical data assimilation and forecast models


Atmospheric dispersion and ground deposition models




- Air/ground contam., dose,
- Protective Action Guides, health effects
- Blast effects
- Population & casualty/fatality estimates

**Center's response level is based on the scale and potential consequence of release.**

# Center Has Over 30-Year Record of Timely and Accurate Multi-Hazard Atmospheric Release Assessments

1973 DOE R&D Program

1979 ARAC Operational Center established

Generation-2 system (nuclear/radiological)

Naval Nuclear Propulsion Program

DOE site support for toxic industrial chemicals

DOE CBNP program

1996 DOE NARAC facility dedicated

Generation-3 system (CBRN)

2002-2005 LINC

2004 IMAAC established

2007 IXP Web

2008 CMweb

1980

1985

1990

1995

2000

2005

2010

*1979 Three Mile Island reactor leak*

*1980 Titan Missile explosion AK*

*1980 China atmospheric nuclear tests*

*1983 Russian Cosmos satellite re-entry*

*1986 Chernobyl reactor accident*

*1988 Henderson NV rocket fuel plant explosion*

*1991 Mt. Pinatubo eruption, Philippines*

*1991 Kuwaiti oil field fires*

*1993 TOMSK-7 waste-tank explosion, USSR*

*1993 Richmond, CA oleum tank car release*

*1997 Cassini satellite launch*

*1998 Tracy tire dump fire*

*1999 Tokaimura criticality accident*

*2001 Post-September 11 threat scenarios*

*2003 Staten Island oil barge fire*

*2003-2004 New Years Orange Alert*

*2004 Conyers, GA chemical fire*

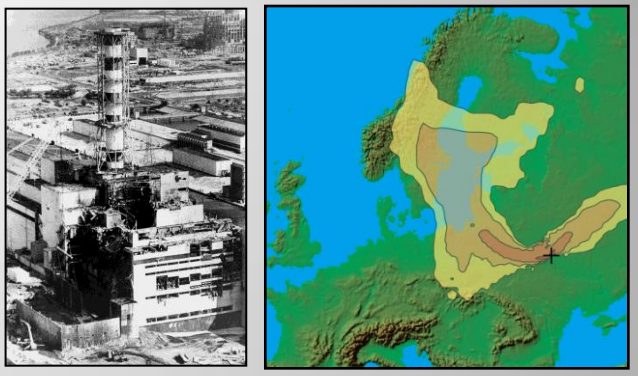
*2006 NASA Pluto New Horizons launch*

*2007 TOPOFF4*

*2009 Inaugural events*

***2011 Fukushima nuclear emergency***

***2014 Waste Isolation Pilot Plant (WIPP)***

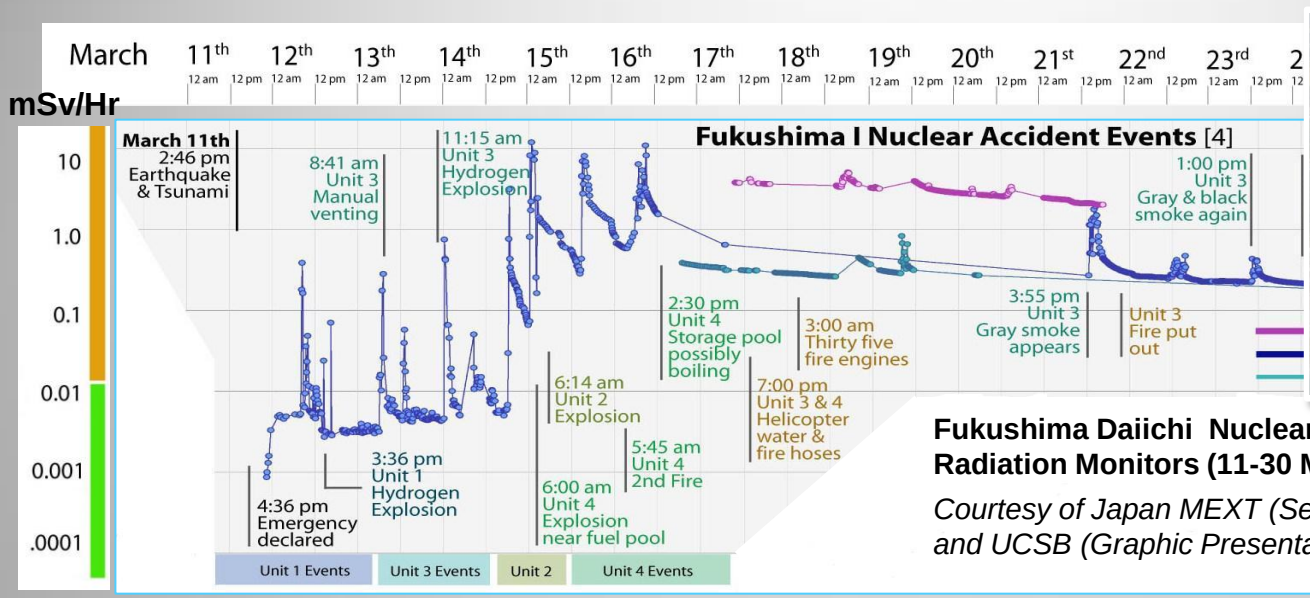


Chernobyl reactor building after explosion (Ukraine, 1986) and LLNL plume prediction


Photo of smoke from tire dump fire (Tracy, California,1998) with plume prediction in red

NARAC prediction of possible protective action areas around Fukushima Nuclear Power Station (2011)

# US-DOE Response (including NARAC Center) to Fukushima lasted months in 2011




**Fukushima Daiichi Nuclear Power Plant Radiation Monitors (11-30 March 2011)**

*Courtesy of Japan MEXT (Sensor Data) and UCSB (Graphic Presentation)*

**March / April / May / June / July**

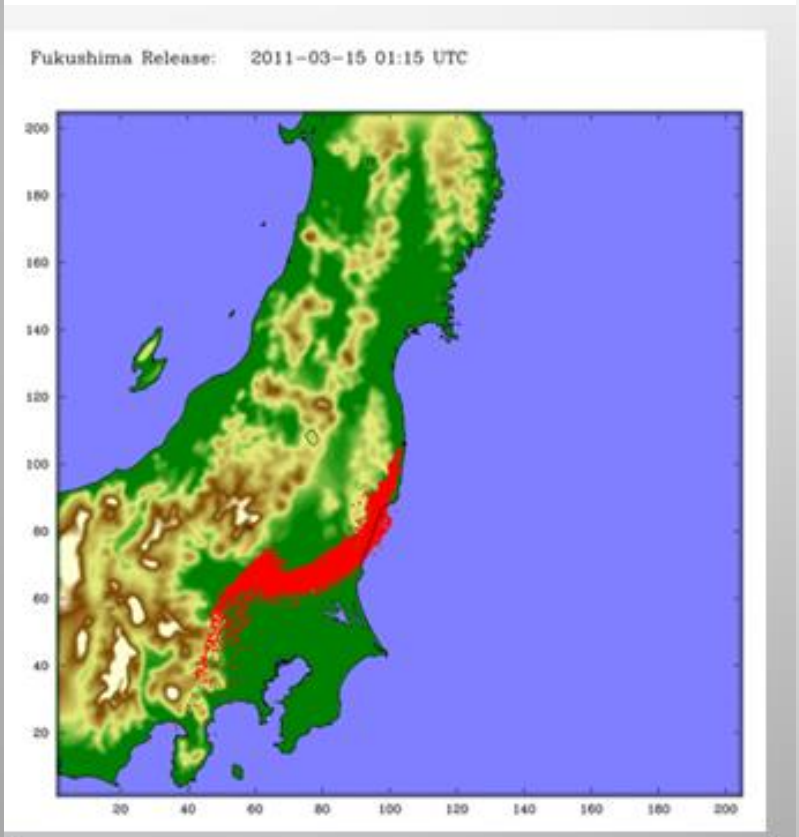
**Reactor release, transport, deposition, resuspension (ongoing)**

**DOE Home Team Operations (Plume Modeling, Assays, Dose)**

**DOE Field Operations (Air, Ground)**

**DOE After Action Review**

# Fukushima: rapidly changing meteorology presented a significant modeling challenge

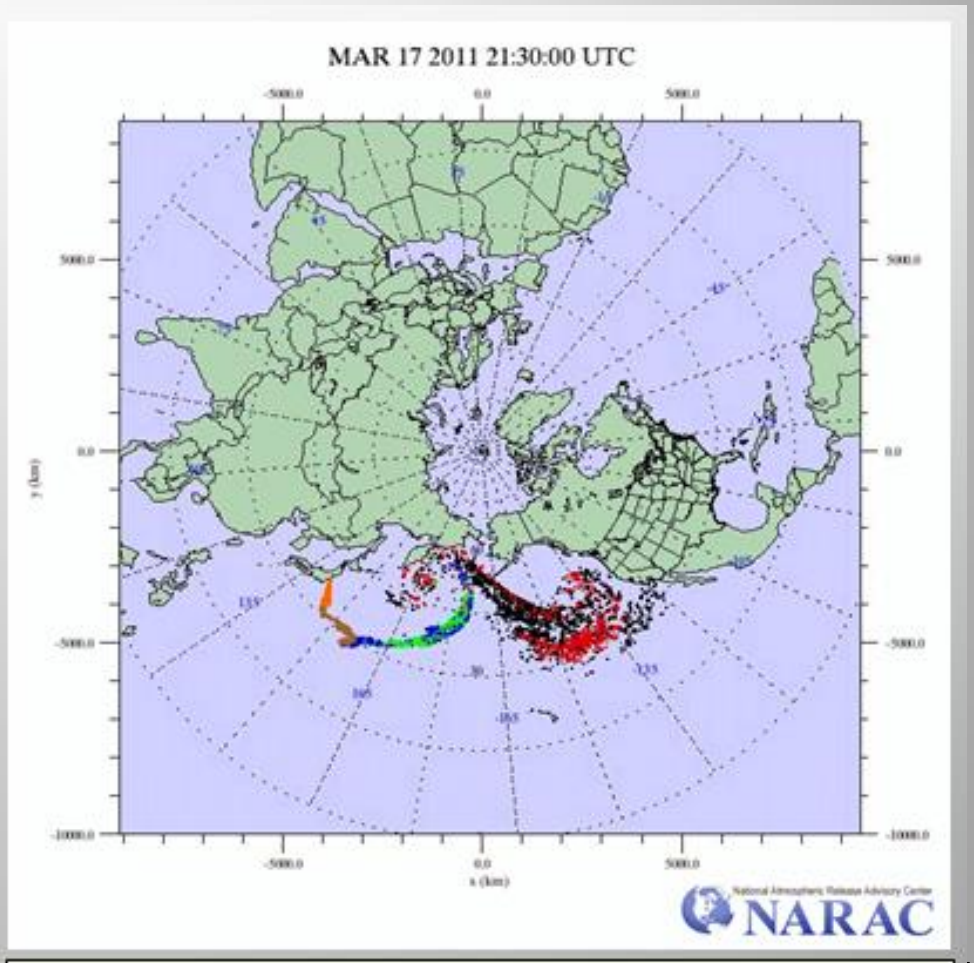



Particle animation for hypothetical constant release rate from March 14 00 UTC - March 16 00 UTC


Hypothetical scenario:
Contours show the areas where the TED over March 12-26 exceeds 0.05 Sv / 5 rem (orange) and 0.01 Sv / 1 rem (yellow)

# Fukushima: DOE/NARAC predicted possible arrival times and dose in US Territories

- NARAC estimated US arrival times and radiation dose using:
  - NOAA GFS met forecasts and analyses
  - NRC source term analyses
- 12- or 24-hour unit release rates, scaled by NRC source quantities and DOE dose conversion values
- Predictions consistent with detected plume arrival times and low levels of radiation

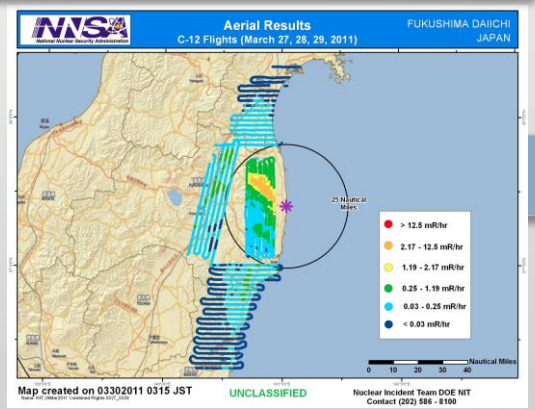



Particle animation of hypothetical unit release illustrates complexity of trans-Pacific dispersion

# Fukushima: NARAC conducted initial model refinement as part of its emergency response activities

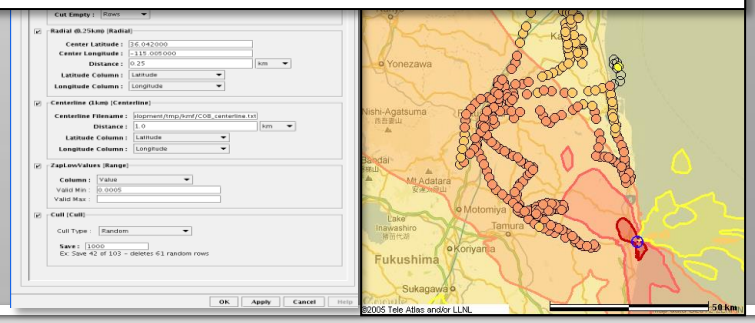
Initial Predictions Guide Measurement Surveys


Measurement surveys and sensor data collected

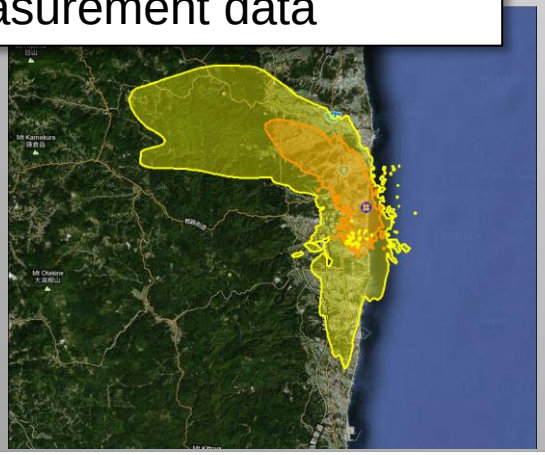



Measurement data transferred electronically to LLNL/NARAC


Software helps select, filter & statistically compare measurements and predictions




Update predictions using measurement data

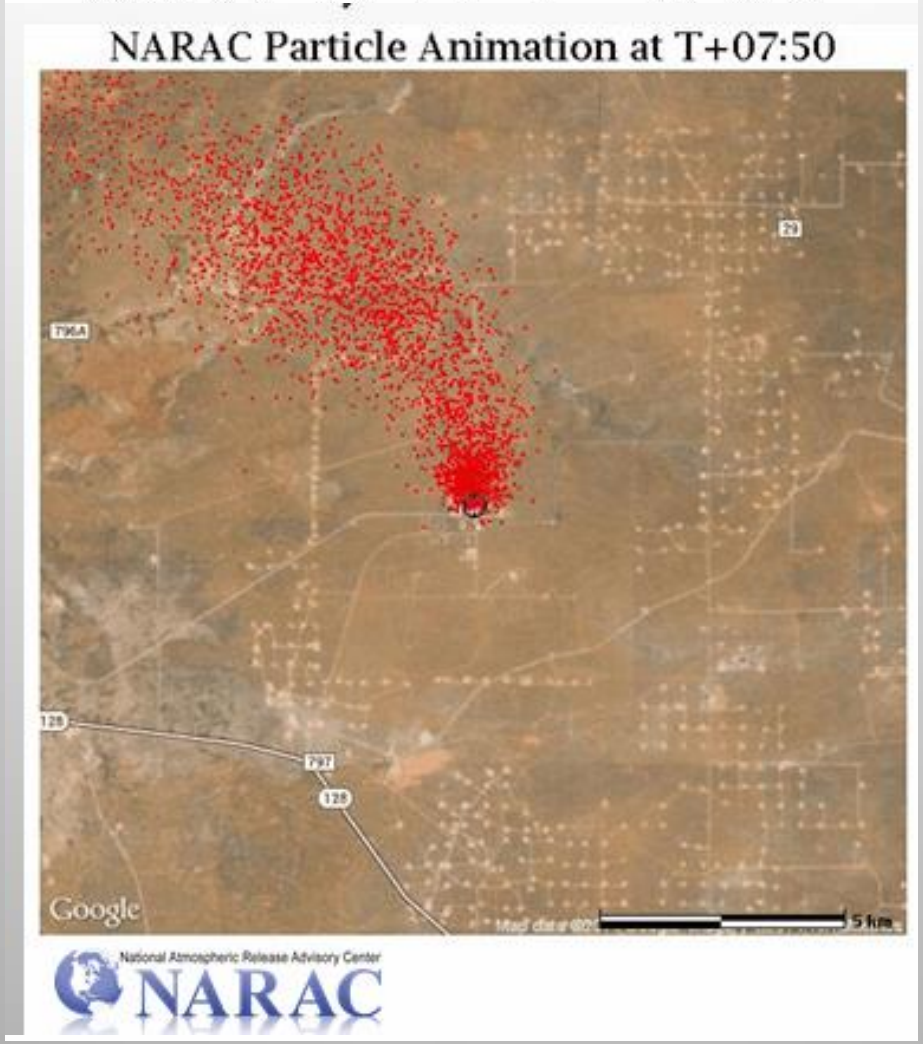


Waste Isolation Pilot Plant (WIPP)

# Preliminary NARAC modeling of the WIPP February 2014 airborne release

Source: DOE Waste Isolation Pilot Plant

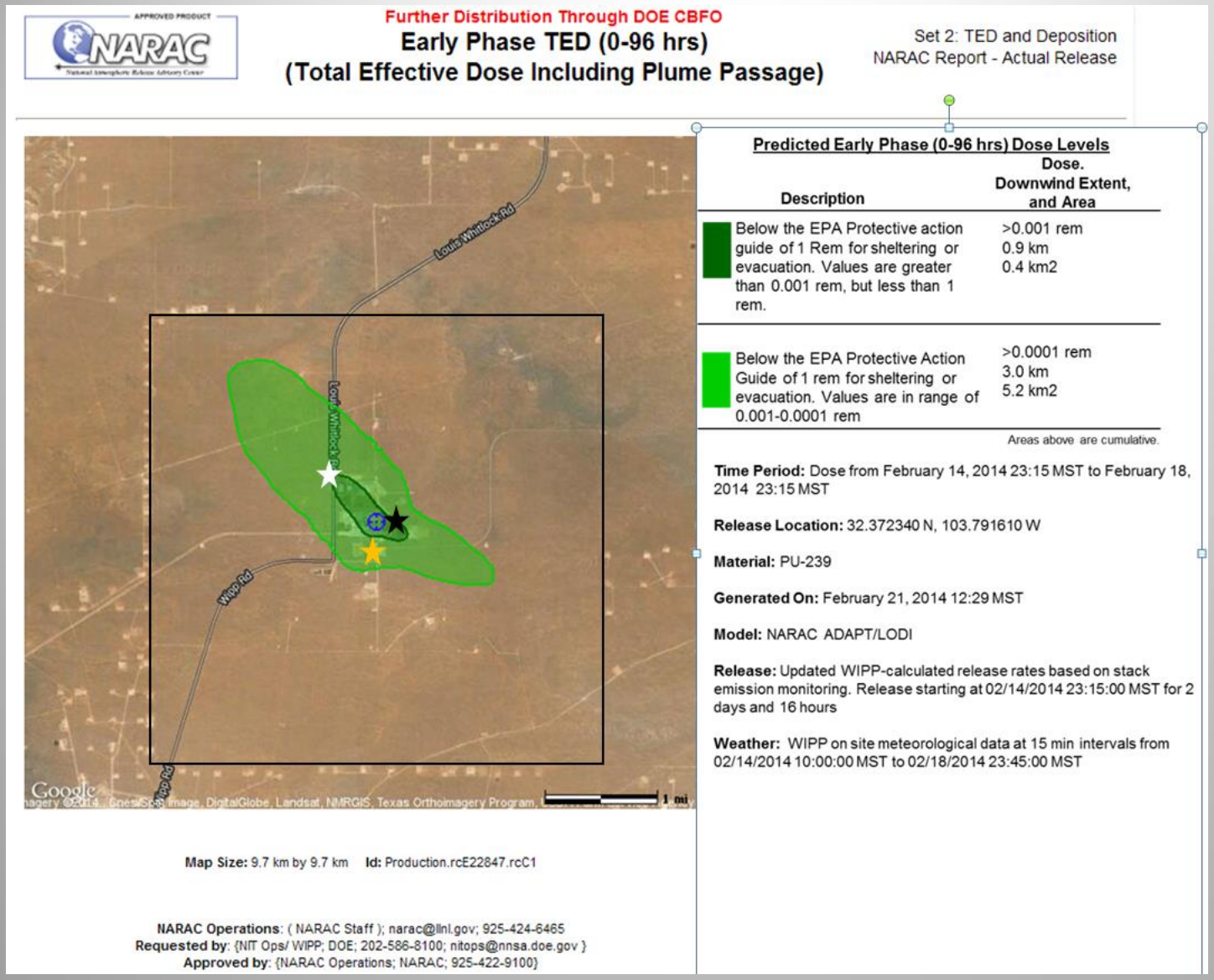
# DOE NA-42 NARAC Dispersion Prediction for First 12 hours of Feb. 14, 2014 Release from WIPP




Red dots show horizontal location of all NARAC-simulated airborne particles at all heights for every 10 minutes from beginning of the release

- Release Start Time: February 14, 2014 23:54 Mountain
- Emission rates from continuous air monitoring from Stack B
- On-site met data used to update wind fields every 15 minutes for over 2 days

# NARAC Predicted Total Effective Dose 0-96 hours



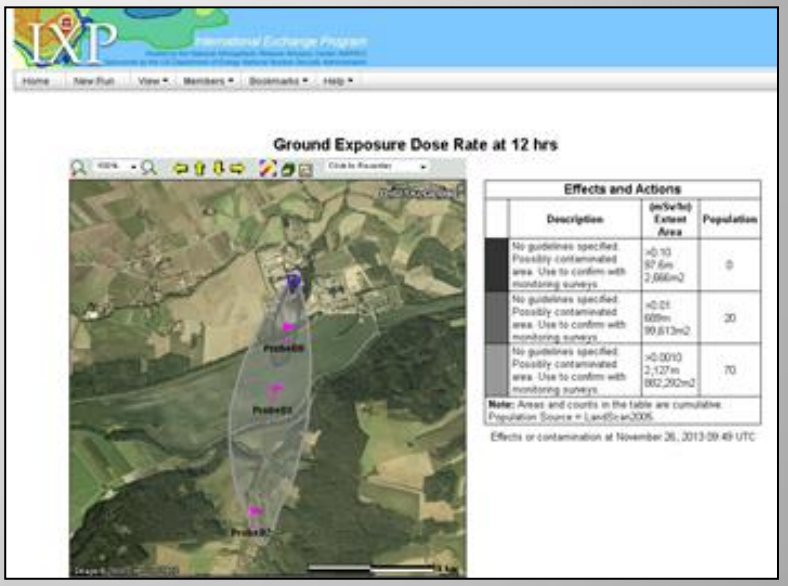

**NARAC model predicted dose contours using Station B emission estimate, and on-site meteorological observations updated very 15 minutes**

Local air monitoring stations are labeled with stars: Far Field Station is labeled with a white star, South Station is labeled with an orange star and East Station is labeled with a black star

Source: WIPP Report *February 14th, contamination release consequence assessment-Rev. 1*, Robert Hayes, http://www.wipp.energy.gov

# What is the *International eXchange Program* (IXP)?

- A Web-based system that allows users around the world to:
  - Quickly share information
  - Run atmospheric dispersion and dose calculations on the NARAC system
  - Receive dispersion and dose calculations from NARAC experts
  - No special software is required




- The secure IXP web is available to all member states, currently 243 users

https://ixp.llnl.gov

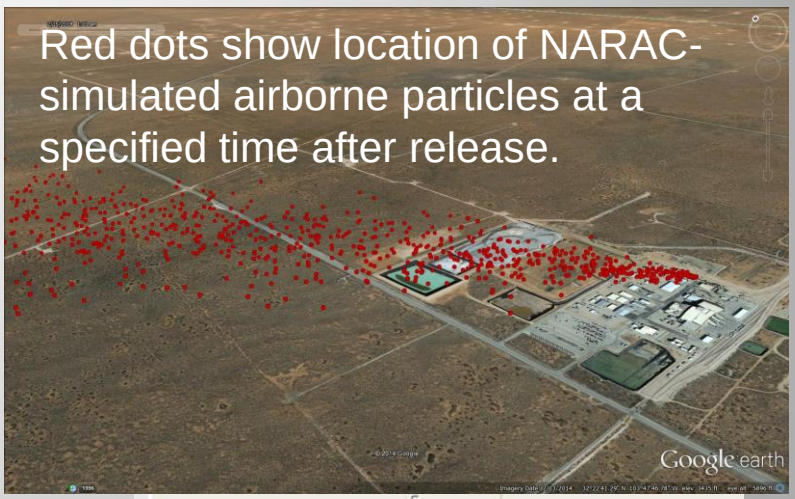
**IXP is constantly available to support all IAEA Member States in the event of radiological & nuclear emergencies.**

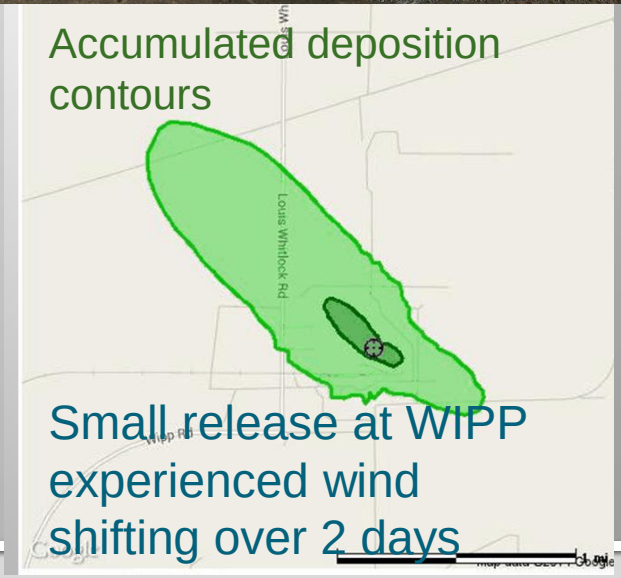
# The Global IXP Community
## (Status as of May 2015)

- 46 Members
  - Argentina, Armenia, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, Denmark, Finland, France, Germany, Hungary, Iceland, India, Ireland, Israel, Japan, Jordan, Latvia, Lithuania, Luxembourg, Malaysia, Mexico, Mongolia, Morocco, Netherlands, Norway, Pakistan, Portugal, Republic of Korea, Russia, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Taiwan, United Arab Emirates, United Kingdom, USA, Vietnam
- IAEA Incident and Emergency Centre (IEC)
- Comprehensive Test Ban Treaty Organization (CTBTO)
- European Commission Joint Research Center (ITU)
- Nuclear Energy Agency of the Organization for Economic Cooperation and Development

# IXP uses the advanced capabilities of the NARAC modeling system

- Nuclear power plant locations for all plants worldwide
- Buoyant & momentum plume rise from fires or stack
- Conventional explosive blast effects
- High resolution meteorology and atmospheric dispersion integrated with high resolution geographic databases (e.g., terrain, population, land use)
- Compatibility with geographical information systems, e.g., IRMA
- Consequence assessment: real time-evolution of, e.g., dose and deposition using international units

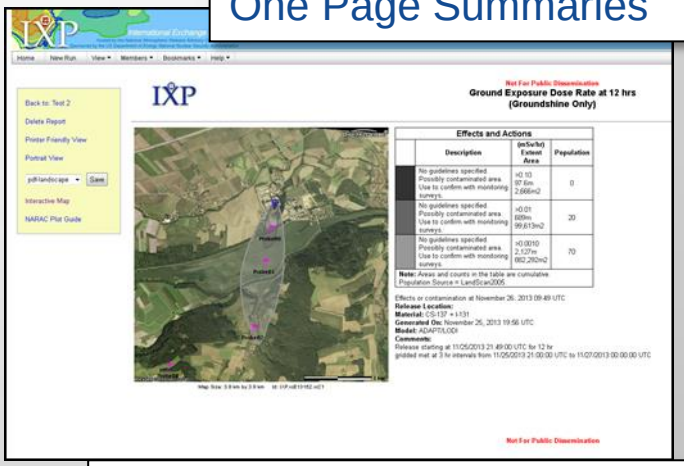


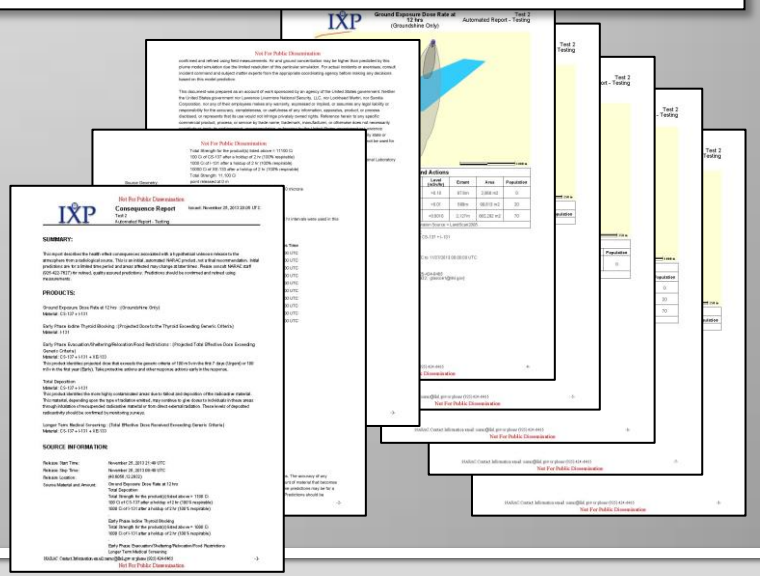
# IXP automatically produces dose maps, reports and interpretation guides for model products

- One page summaries
- Multipage reports with expanded descriptions of
  - products
  - input data and assumptions
  - approvals and interpretation guides
- Consistent and straightforward briefing products for decision makers
- Multiple formats accommodated:
  - PDF, PowerPoint, GIS Shape files, HTML/XML, JPG/PNG graphics
  - Compatible with Google and IRMA

One Page Summaries




Multi-page Consequence Reports



# Summary

- NARAC at LLNL has provided assessment for radiological emergencies for over 35 years
- Recent NARAC responses of note include last year's release at the WIPP site in New Mexico and the failure of the Fukushima reactors in 2011
- The International eXchange Program (IXP) is an easy to use web-based tool that provides a subset of NARAC's capabilities to approved users
  - IXP was launched in 2007 to support the IAEA's needs for assessing the consequences associated with radiological and nuclear releases
  - New features added to the IXP
  - IXP currently has 243 users over 46 states and several centers

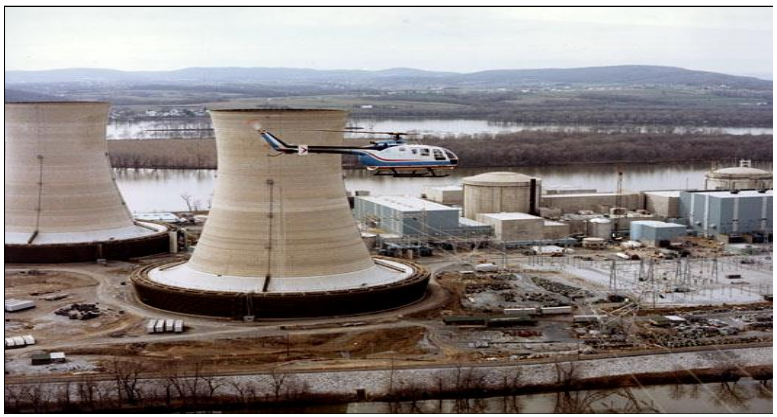
# Questions?


IXP
International Exchange Program
Hosted by the National Atmospheric Release Advisory Center (NARAC)
Sponsored by the US Department of Energy National Nuclear Security Administration

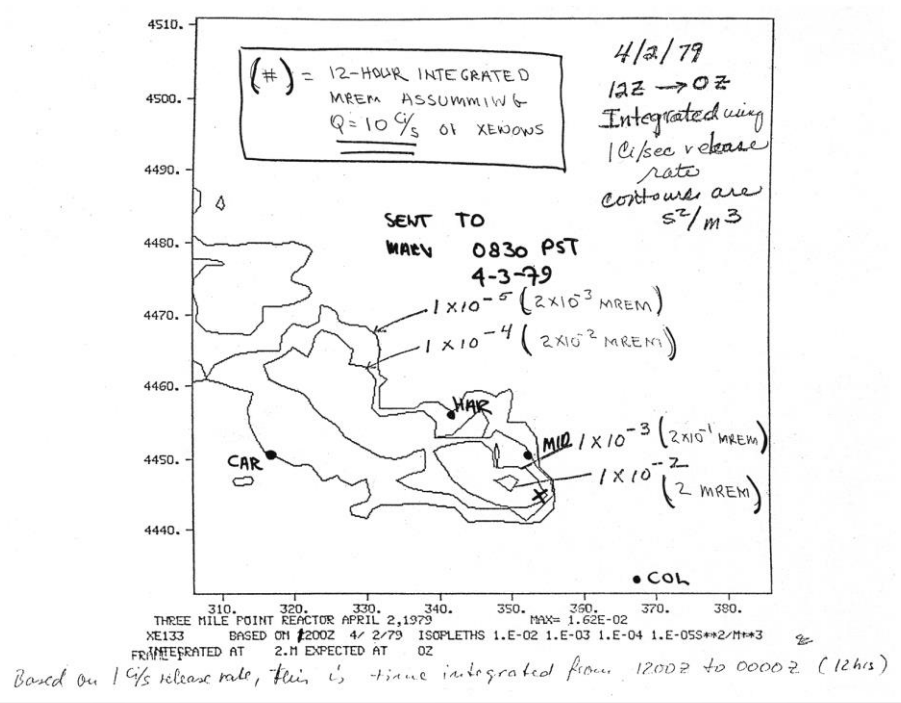
# The operational center was founded during Three Mile Island (Dept. of Energy / Nuclear Regulatory Commission)

Original NARAC Operations Center at LLNL

1979



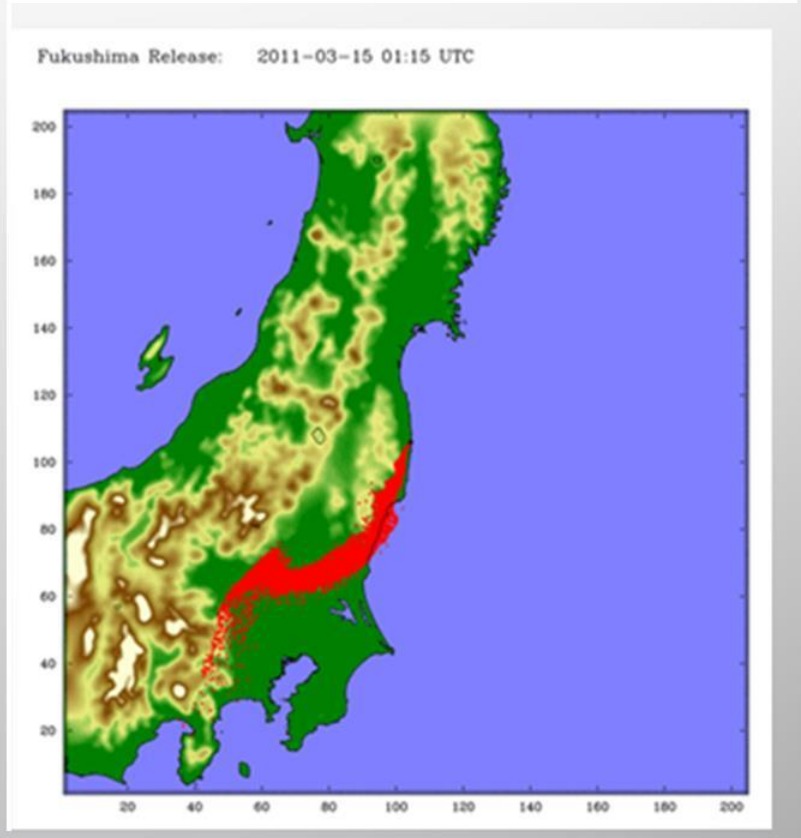
Three Mile Island Nuclear Power Plant and DOE Aerial Measuring System (AMS)




NARAC prediction of downwind dose from a potential release from the Three Mile Island nuclear power plant

# Fukushima: rapidly changing meteorology presented a significant modeling challenge

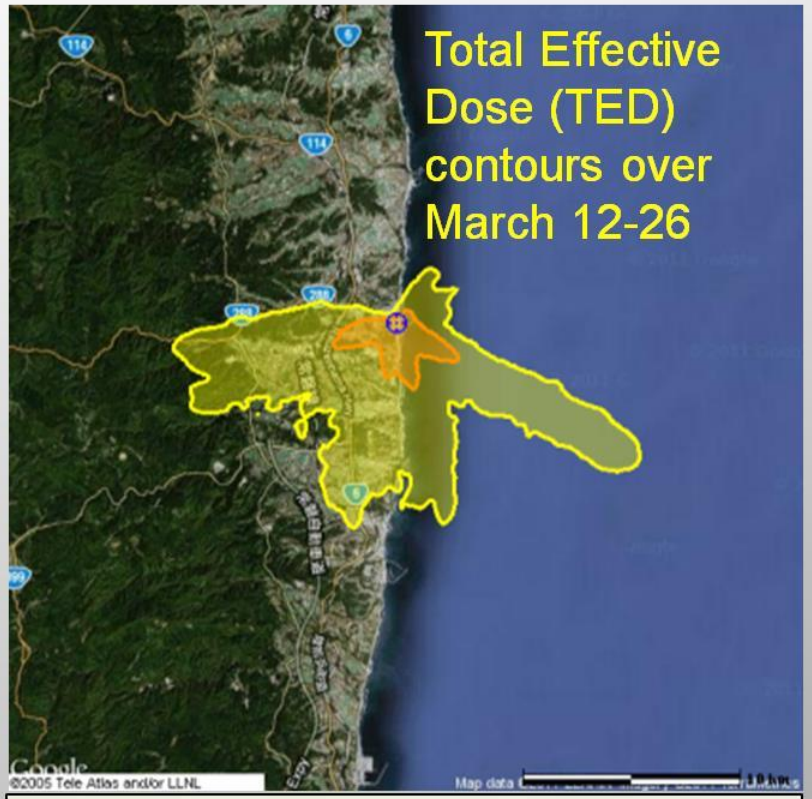
- Winds primarily off-shore until March 14 –16
  - wind direction then rotated clockwise
  - winds remained primarily off-shore until March 21
- Initial NARAC forecasts captured
  - overall wind pattern
  - precipitation
- Subsequent higher resolution (3-km) WRF simulations
  - increased resolution of prediction of wind shifts and precipitation patterns




Particle animation for hypothetical constant release rate from March 14 00 UTC - March 16 00 UTC

# Fukushima: DOE/NARAC worked with the US NRC to estimate possible release scenarios

- Predicted arrival times and protective action areas for
  - sheltering / evacuation,
  - relocation,
  - iodine administration, and
  - worker protection
- Analyses on a range of hypothetical scenario source terms provided by the US NRC
  - RASCAL and MELCOR reactor modeling
  - Separate and combined impacts for reactor cores and spent fuel
- Use of a variety of met conditions, including real-world weather and artificial hypothetical weather conditions
- Informed US recommendations regarding actions to protect US citizens in Japan




Hypothetical scenario:
Contours show the areas where the TED over March 12-26 exceeds 0.05 Sv / 5 rem (orange) and 0.01 Sv / 1 rem (yellow)

# Fukushima: Center provided regular forecasts to support mission planning and analysis

- Thrice-daily forecasts of hourly air concentrations informed
  - field ops, monitoring, and planning
- Met forecast summaries provided to U.S. agencies
- 5-km resolution WRF forecasts driven by NOAA GFS model
  - Were checked for consistency with NOAA forecasts
  - Compared well against available Japanese meteorological data


Hypothetical daily weather forecasting for mission planning to illustrate predicted wind directional shifting