Source Term Estimation for the 2011 Fukushima Nuclear Accident

2011 Fukushima Accident Special Session
Boulder CO, February 2012

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Problem

Accident

- Series of radioactive releases at the Fukushima Nuclear Power Plant
- Radioactive measurements are available at several ground locations
- The release rate is unknown

Objective

- Determination of release rate based on sensor measurements, Transport and Dispersion (T&D) modeling and machine learning
- Known data include: source location, meteorology and ground measurements of radiation

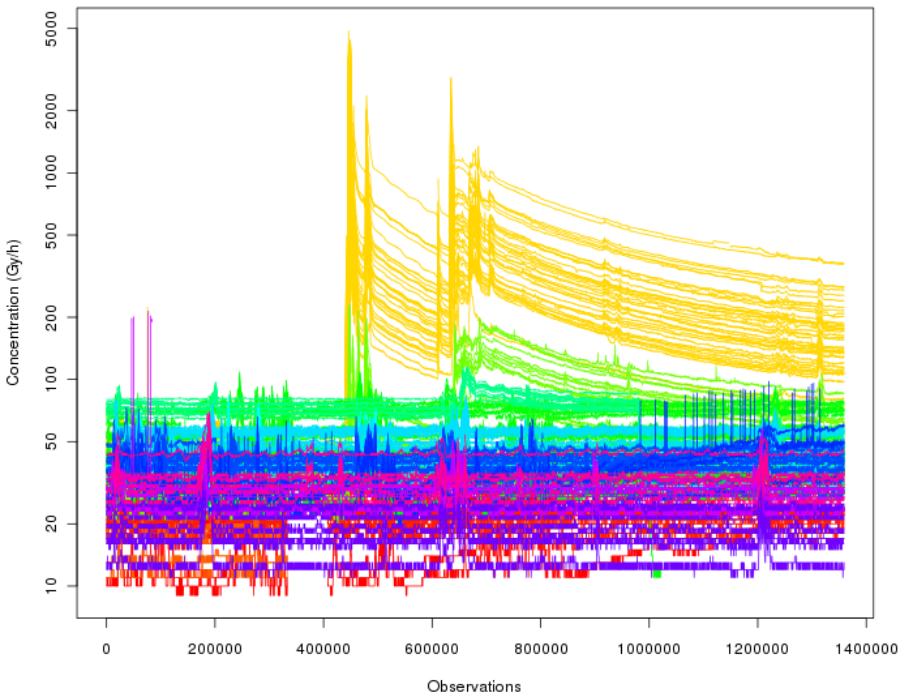
Realtime Radiation Data

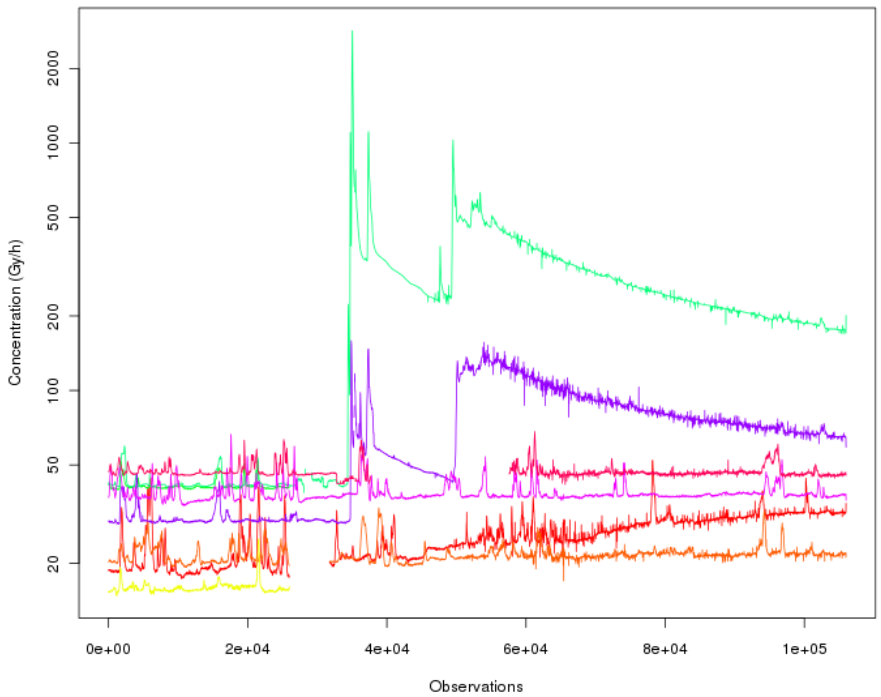
Data Characteristics

- Collected via the Disaster Prevention and Nuclear Safety Network for Nuclear Environment
- System for Prediction of Environment Emergency Dose Information (SPEEDI)
- http://www.bousai.ne.jp/eng/index.html
- 218 Stations grouped in 17 prefectures

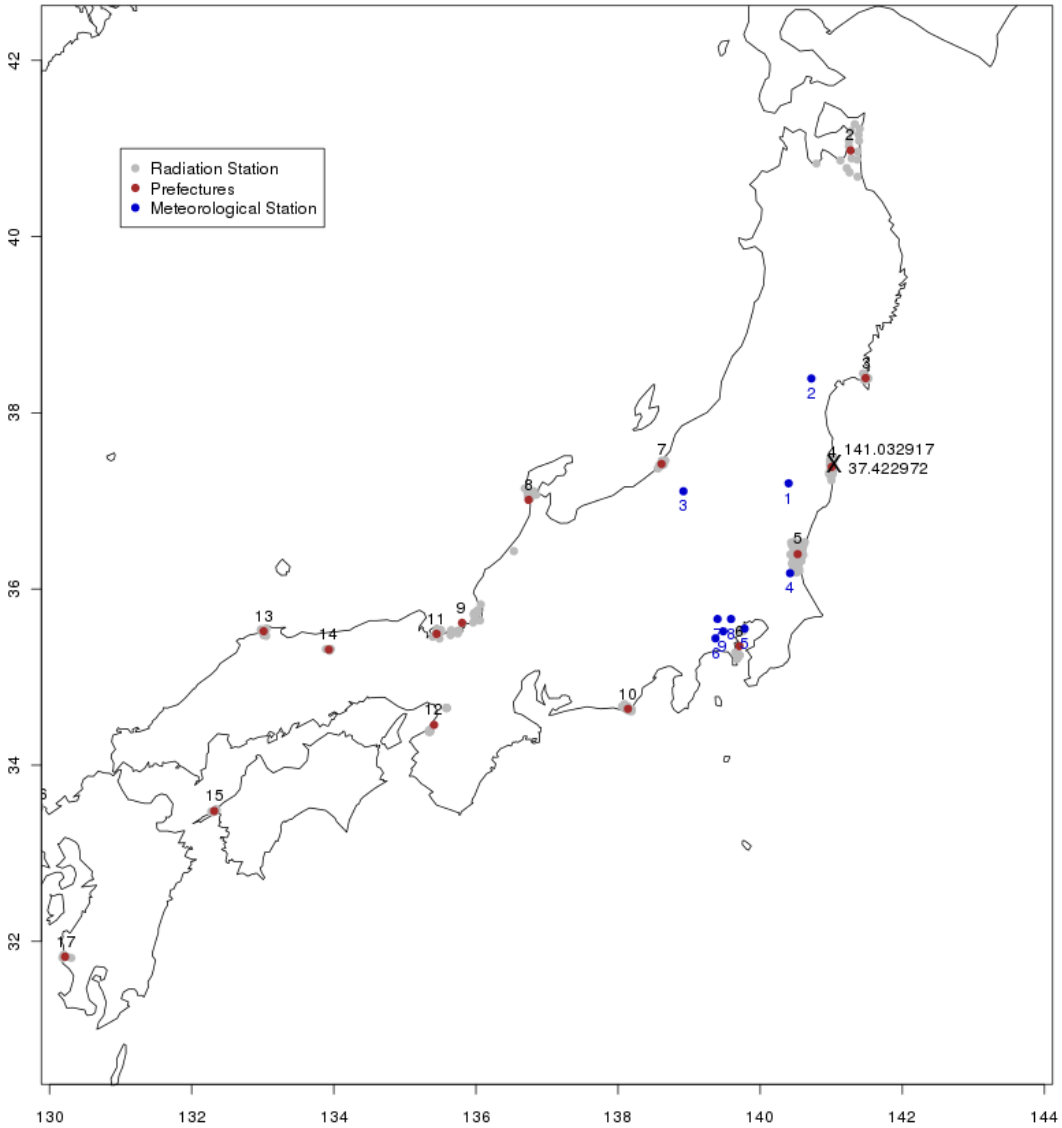
Radiation Time Series by Station and Prefecture

Data from 2011-02-28 to 2011-04-12





Spatial Location of Measurements



Implementation

Dispersion Model

- SCIPUFF Model
- 9 Meteo Stations
- Vertical Profiles from NCEP Reanalysis II
- Terrain Data from NOAA NGDC GLOBE (1km)

Methodology

Simulation

- Simulate consecutive releases (e.g. 1 every hour) using a constant rate
- Calculate the concentration C at each sampler i at time t from all the releases:

$$C_t^i = R_{1t}^i + R_{2t}^i + \cdots + R_{nt}^i$$

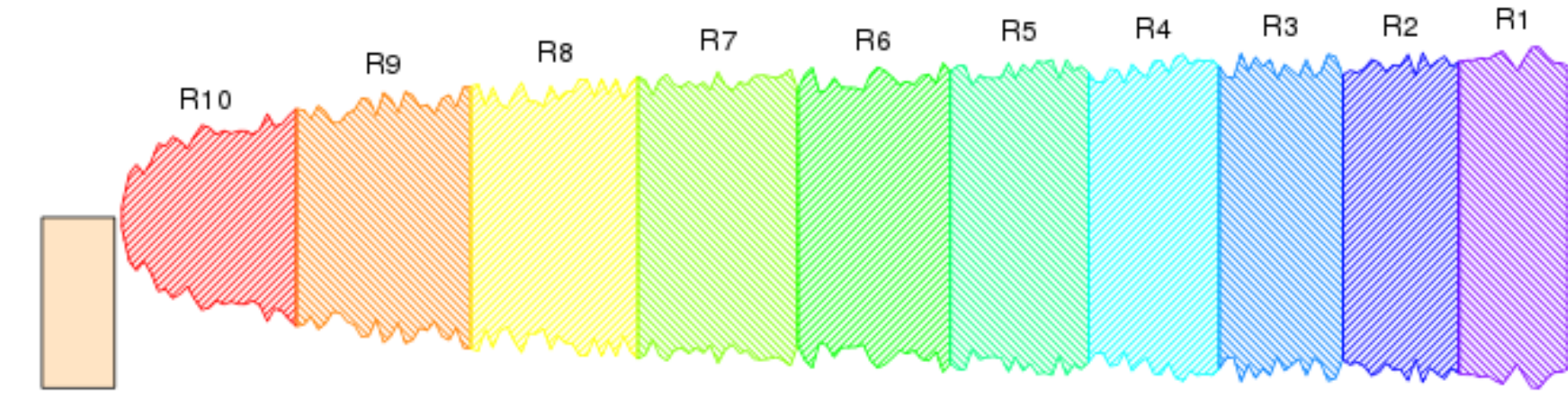
where R_{xt}^i is the concentration for release x measured at time t at location i

Optimization

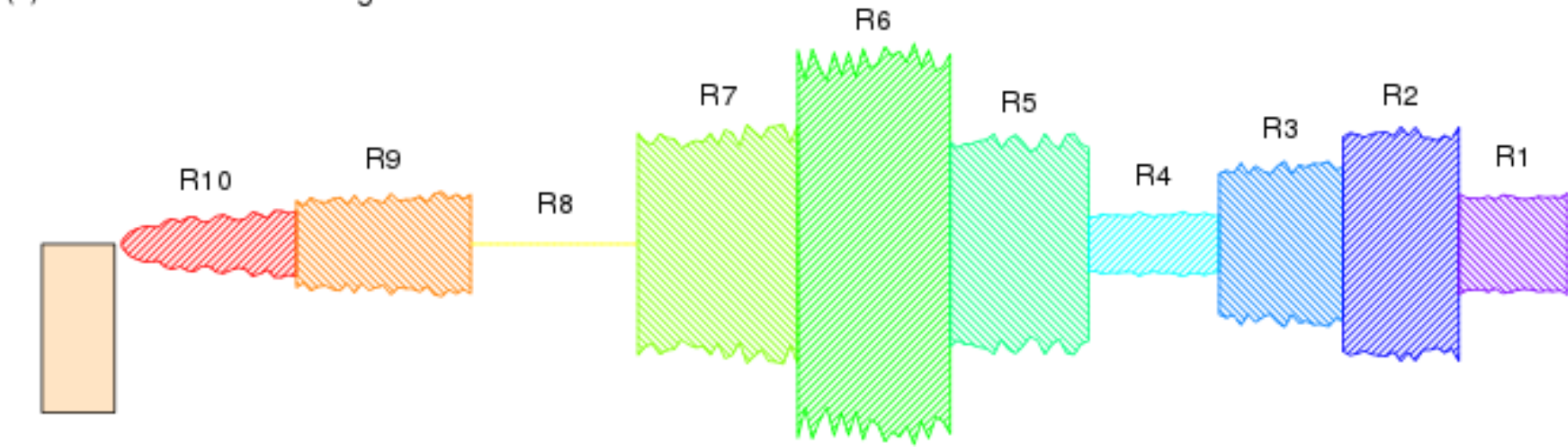
- Find the vector w that minimizes the error between the simulated and observed values at all locations and all time steps
- $E = \sum_{i,t}(w_1 \cdot R_{1t}^i + w_2 \cdot R_{2t}^i + \cdots + w_n \cdot R_{nt}^i - C_{ot}^i)$

  where C_{ot}^i is the observed concentration at time t for location i

Optimization Problem



(a) Releases of Same Strength



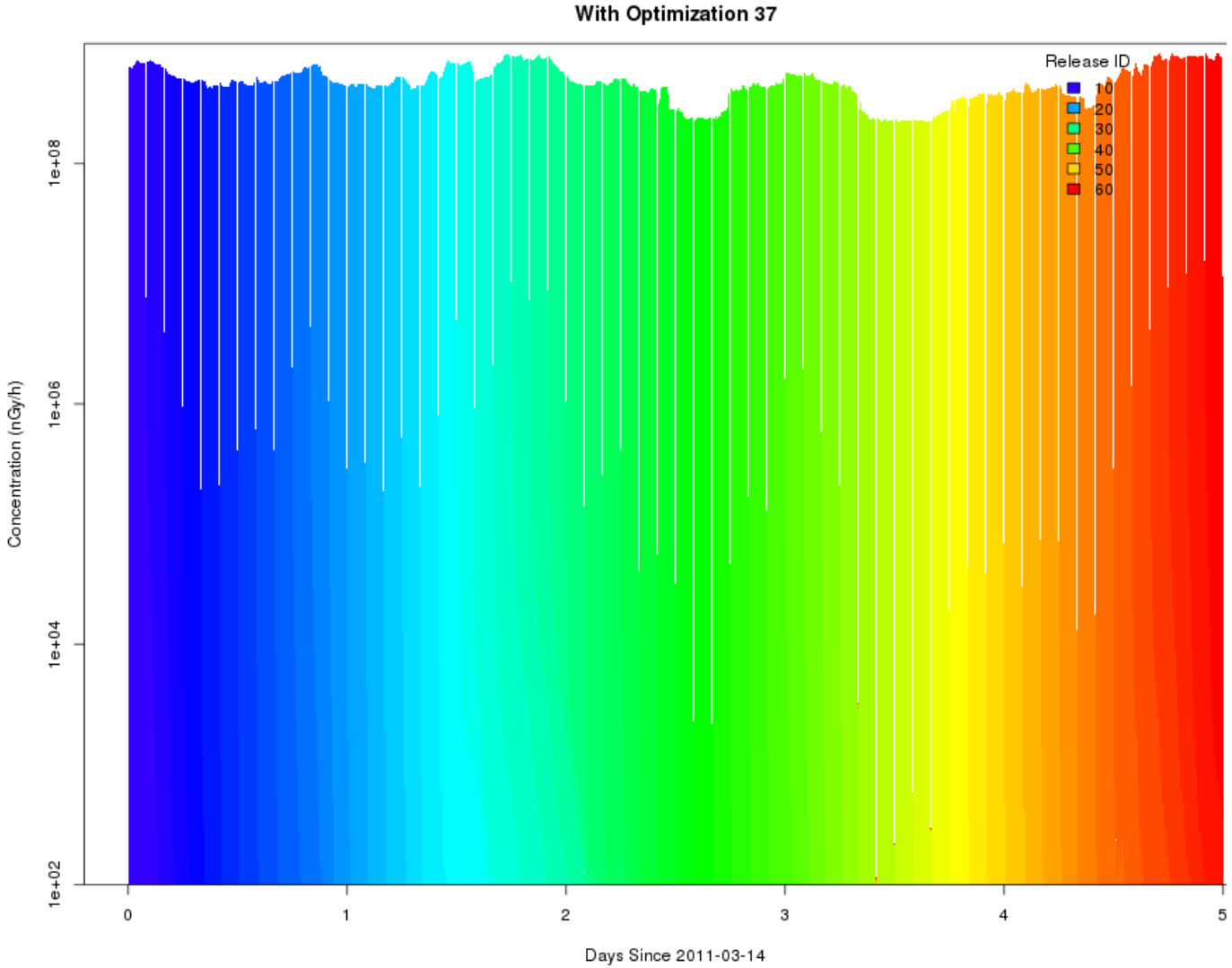
(b) Releases of Different Strength

Optimization Strategy

- Evolutionary Algorithm
- Parallel Stochastic Search
- Evolving solutions of vector W

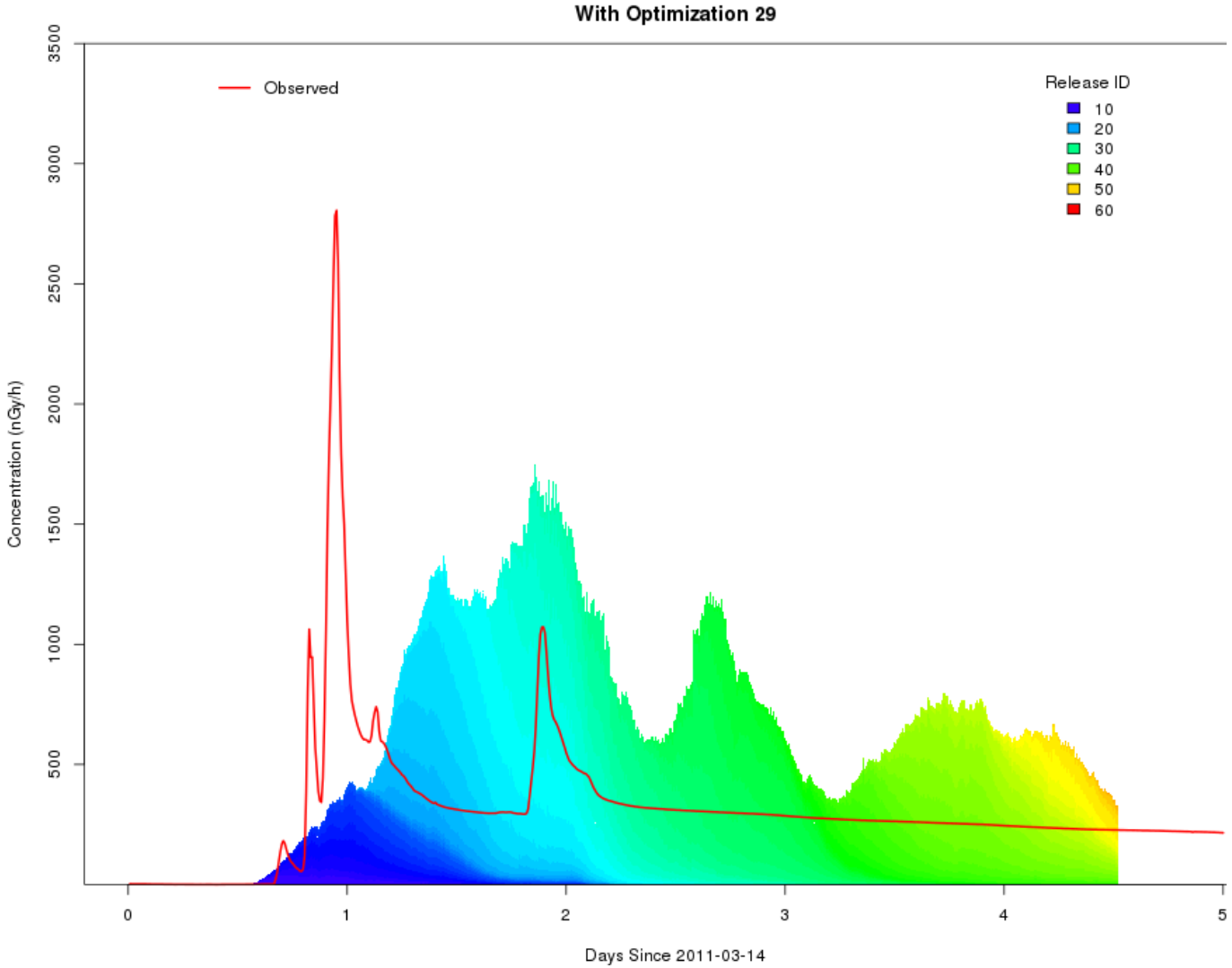
Original Release at Fukushima (Pref. 4)

Constant Release Rate from 14 March 2011



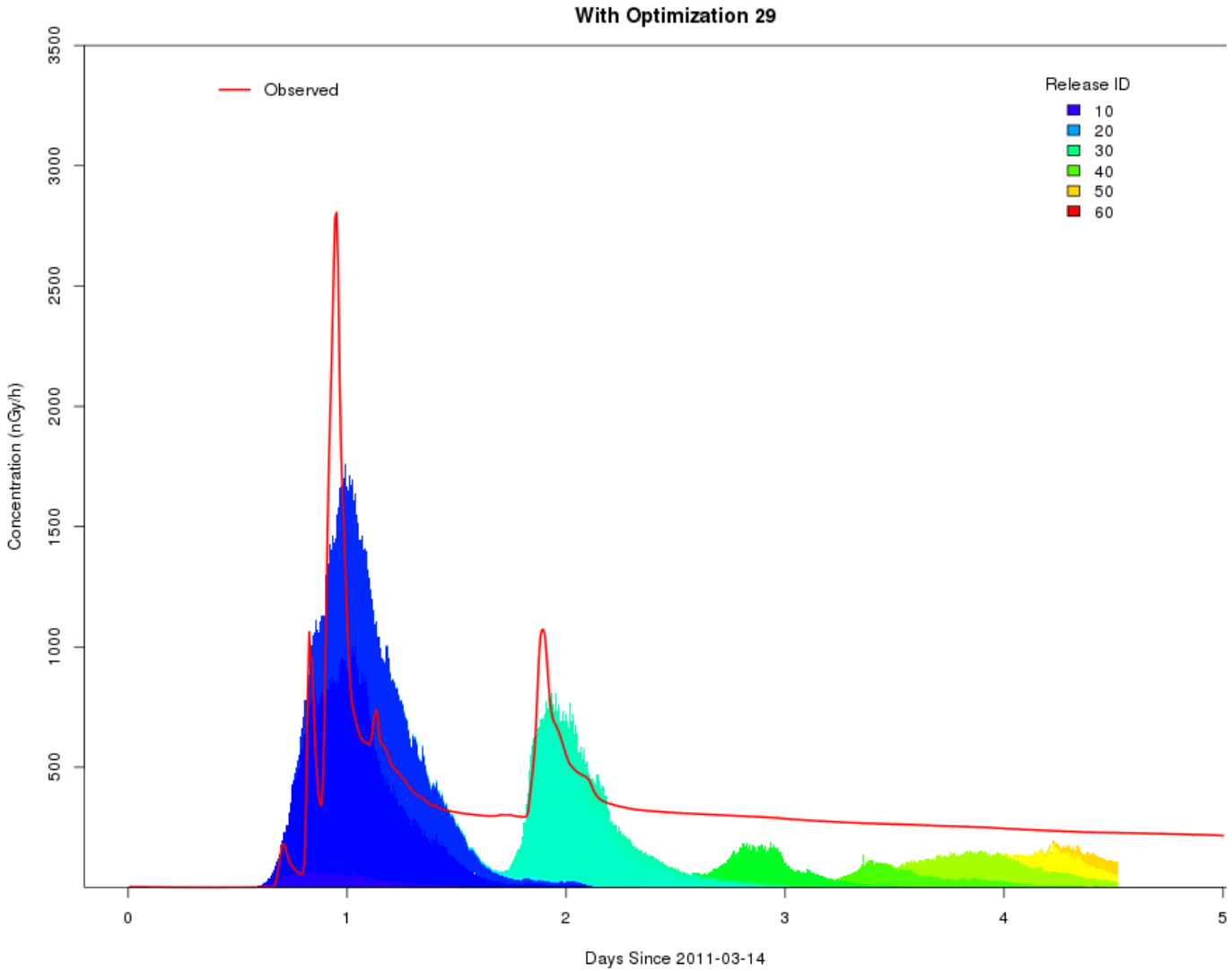
Simulated Release in Tokyo (Pref. 6)

Constant Release Rate from 14 March 2011

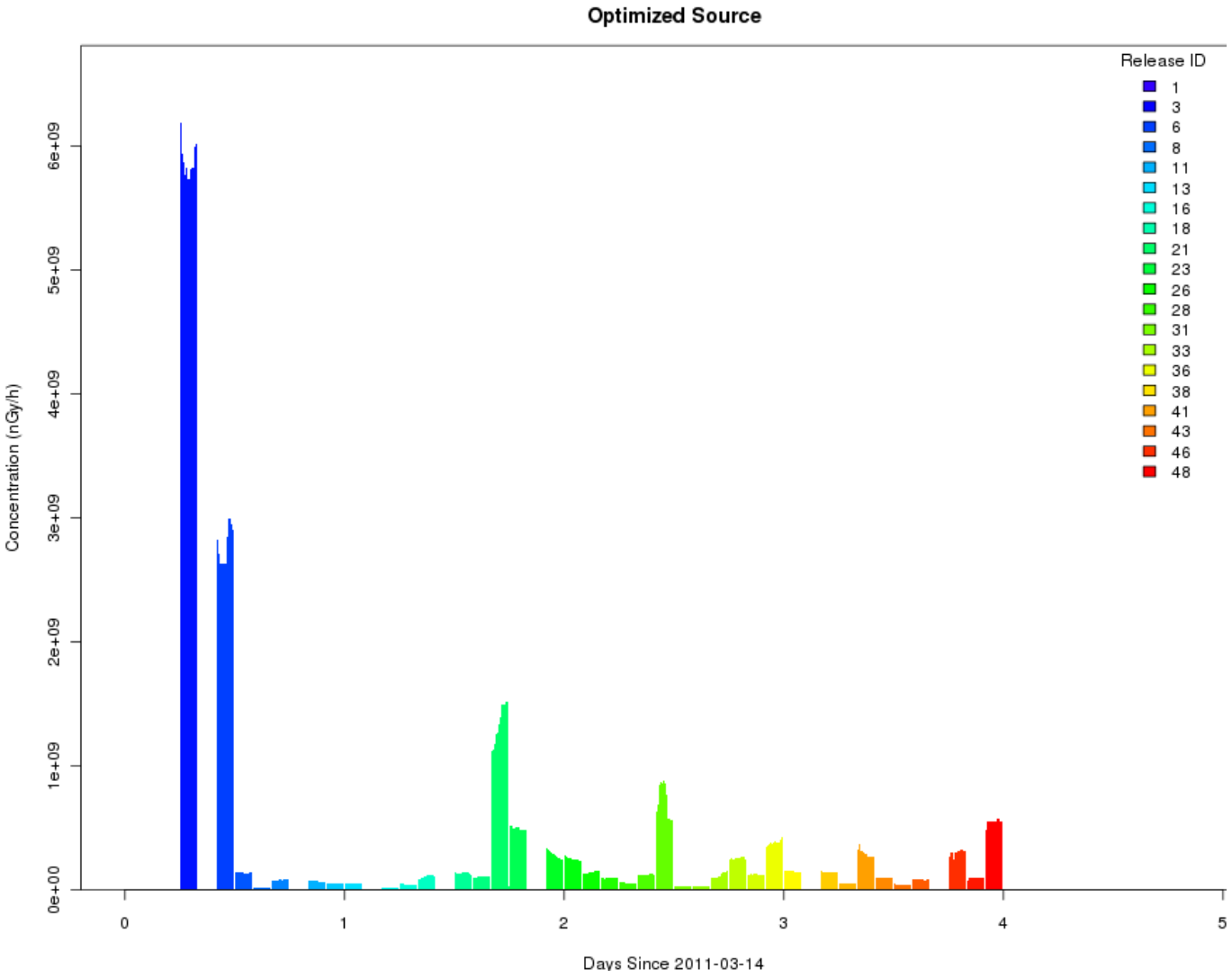


With Optimized Release Rate in Tokyo (Pref. 6)

Optimized Release Rate from 14 March 2011



With Optimized Release at Fukushima (Pref. 4)



Conclusions

Summary

- SCIPUFF model was used to simulate multiple gas releases
- An optimization process was employed to find coefficients that minimize the error between simulations and observations
- These coefficients indicate the release rate as a function of time