VAAC Montréal

Modelling Volcanic Ash Transport and Dispersion

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Transport and dispersion modelling

- Tracer is transported by the air
- The tracer does not affect the motion of the air !
  - Where it does this is amalgamated in the « source » model
- Mixing occurs mostly in the atmospheric boundary layer
- Little mixing in the stratosphere
- Not much turbulent mixing in the troposphere
  - Vertical mixing is mostly caused by large scale vertical motion
  - Or in association with cloud systems

Description of MLDP0

(Modèle Lagrangien de Dispersion de Particules d'ordre 0)

- 3D Lagrangian particle model – trajectories of fluid elements
- Random Displacement in the vertical

$$dz = \left[\frac{\partial(\sigma_w^2 T_L)}{\partial z} + w_{sy} + w_{gs}\right] dt + \sqrt{(\sigma_w^2 T_L)}d\xi\,;\; d\xi \in N(0,\sqrt{dt})\,;\; \sigma_w^2 T_L = K_z$$

Horizontal diffusion: $u_m = -\frac{u_m}{T_m}dt + \sqrt{\frac{2\sigma_{u_m}^2}{T_m}}\,d\xi$

- –Wet deposition
- –Dry deposition
- –Can take into account particle and aerosol size distribution (volcanic ash)
  density of particles is constant for all sizes
- –Forward or adjoint (inverse) modes

- Meteorology: Full 3D fields (diag. and progs)
  - –Off-line model (resolution depends on the driving met model)

The Source Term

Parameters that could be reported in real time:

- Time when the eruption starts
- Height of eruption column
- Duration

Relating Column Height to Eruption Rate

- The height of a *maintained* buoyant plume is related to the energy release rate *Q*:

$$H \propto Q^{\frac{1}{4}}$$ (Morton et al. 1955)

  - Energy release rate can be related to magma release rate:

$$H = 2.00\,\dot{V}^{0.241} \qquad (\text{Mastin et al., 2009})$$
$$H = 1.67\,\dot{V}^{0.259} \qquad (\text{Sparks et al.1997})$$

  - Or power (in kilotons of TNT) for nuclear devices

$$H = 3210\,P^{0.268} \qquad (\text{D}'\text{Amours 2006})$$

- Assume that 10% of magma released will be transported larges distances
(i.e. no settling)

Hekla 2000 Benchmark Simulations

Release characteristics

- Start time: 26 February 2000 at 18:20 UTC
- Duration: 70 min (4200 s)
- Total released mass: 2×10^{19} micrograms
- Number of particles: 2×10^{6}
- Initial dispersion
  - Gaussian (σ= 1 km) in the horizontal
  - Uniform Surface-12km in the vertical

Simulation duration: 71 H 40 min (258000 s)

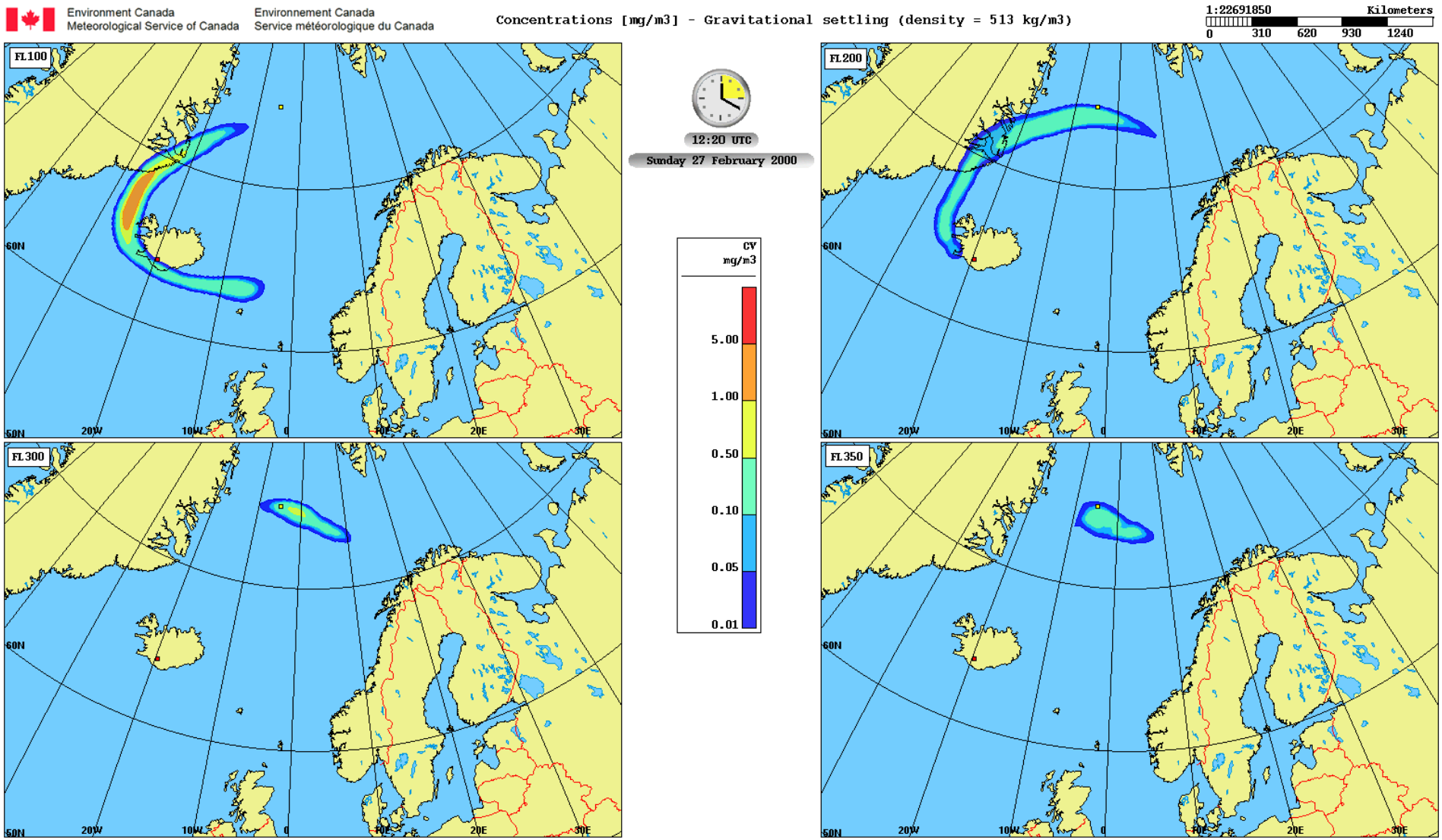
Meteorologica data:

ECMWF reanalysis at 0.25° horizontal resolution in pressure coordinates, transformed to a PS horizontal grid and to σ coordinates in the vertical

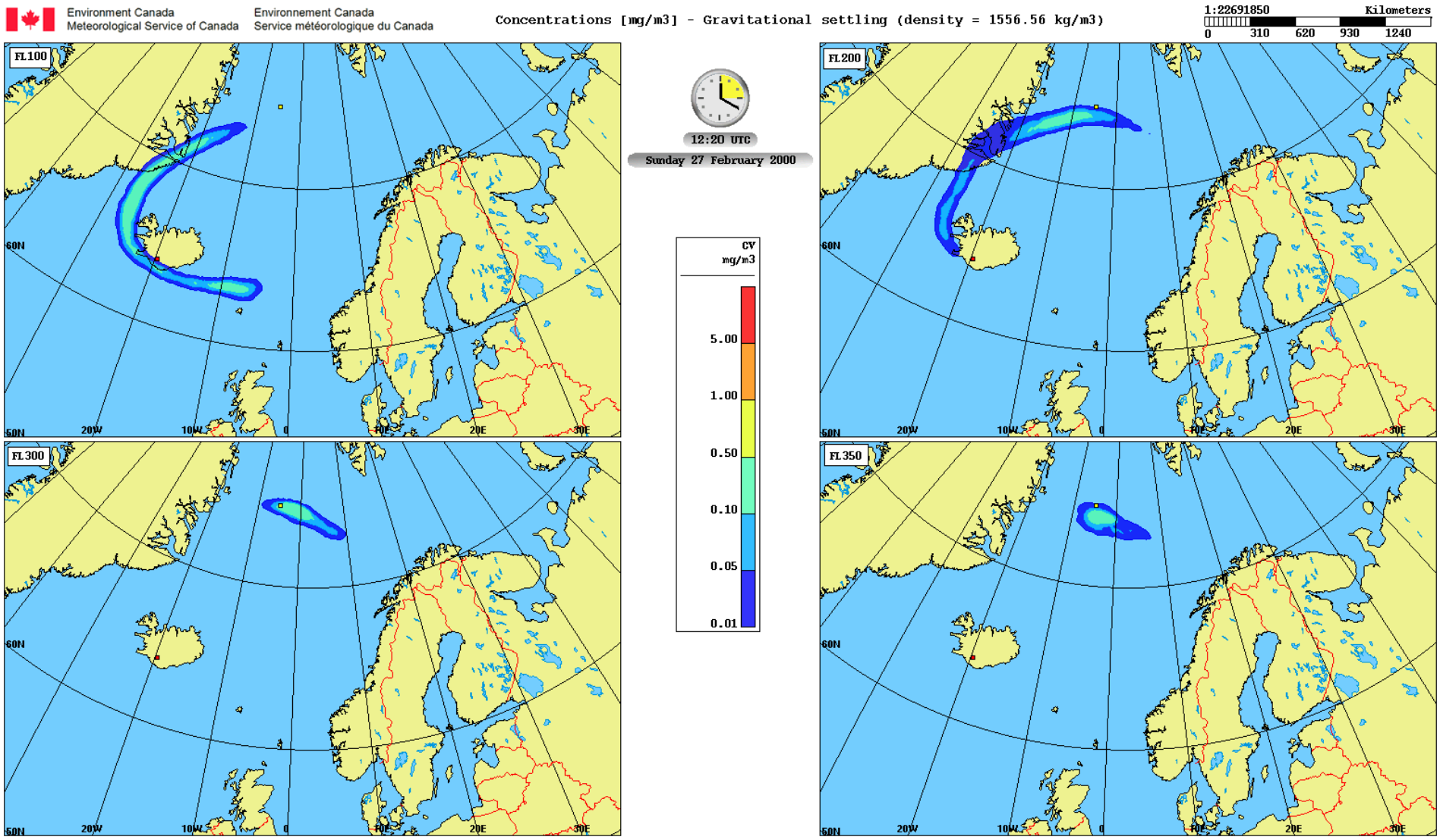
4 simulations :

- 3 with the prescribed size distribution and 3 ash density settings
- 1 with no settling where the total released mass is assigned to « light» particles

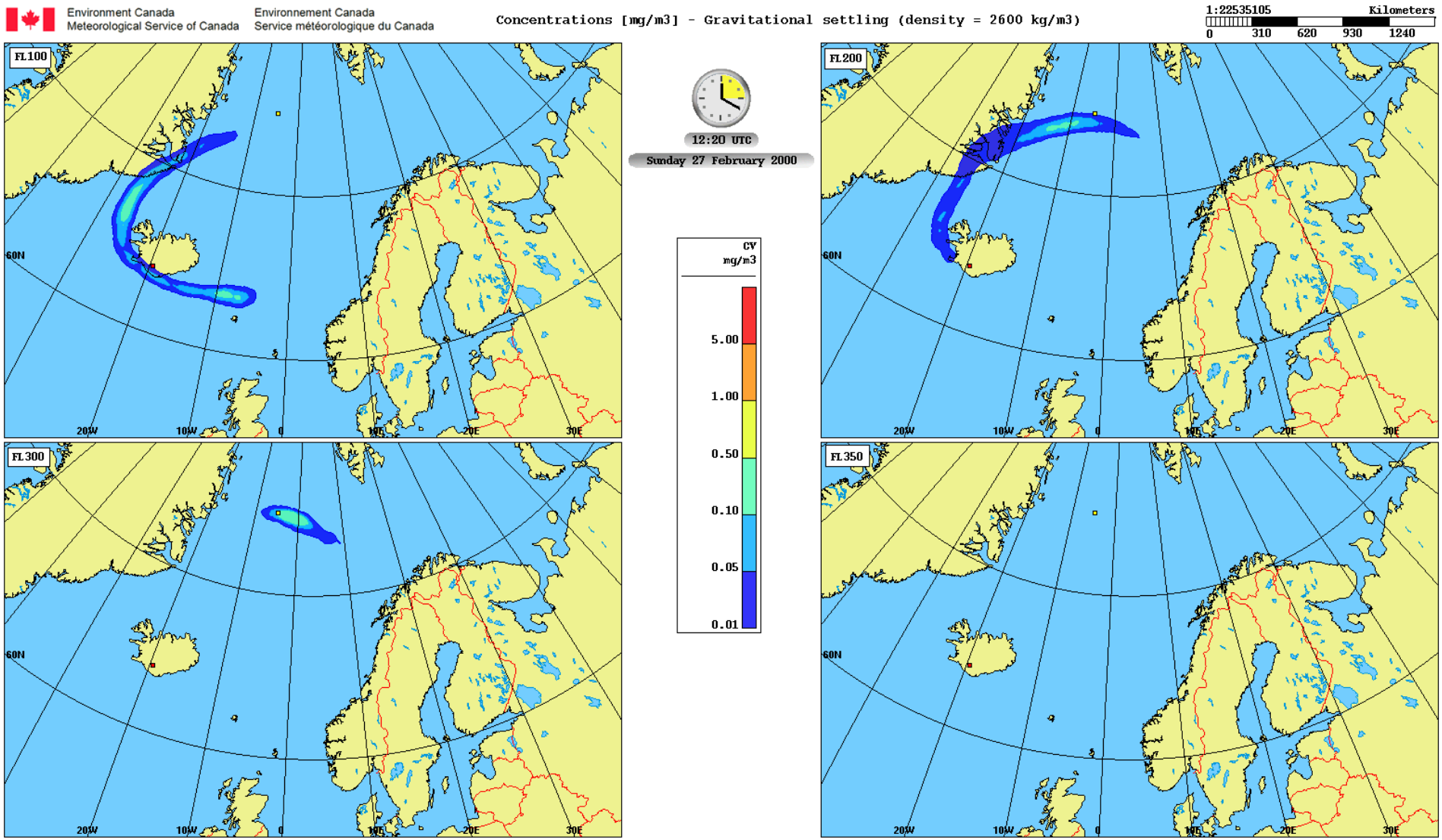
Gravitational settling ρ =513 kg m^{-3}



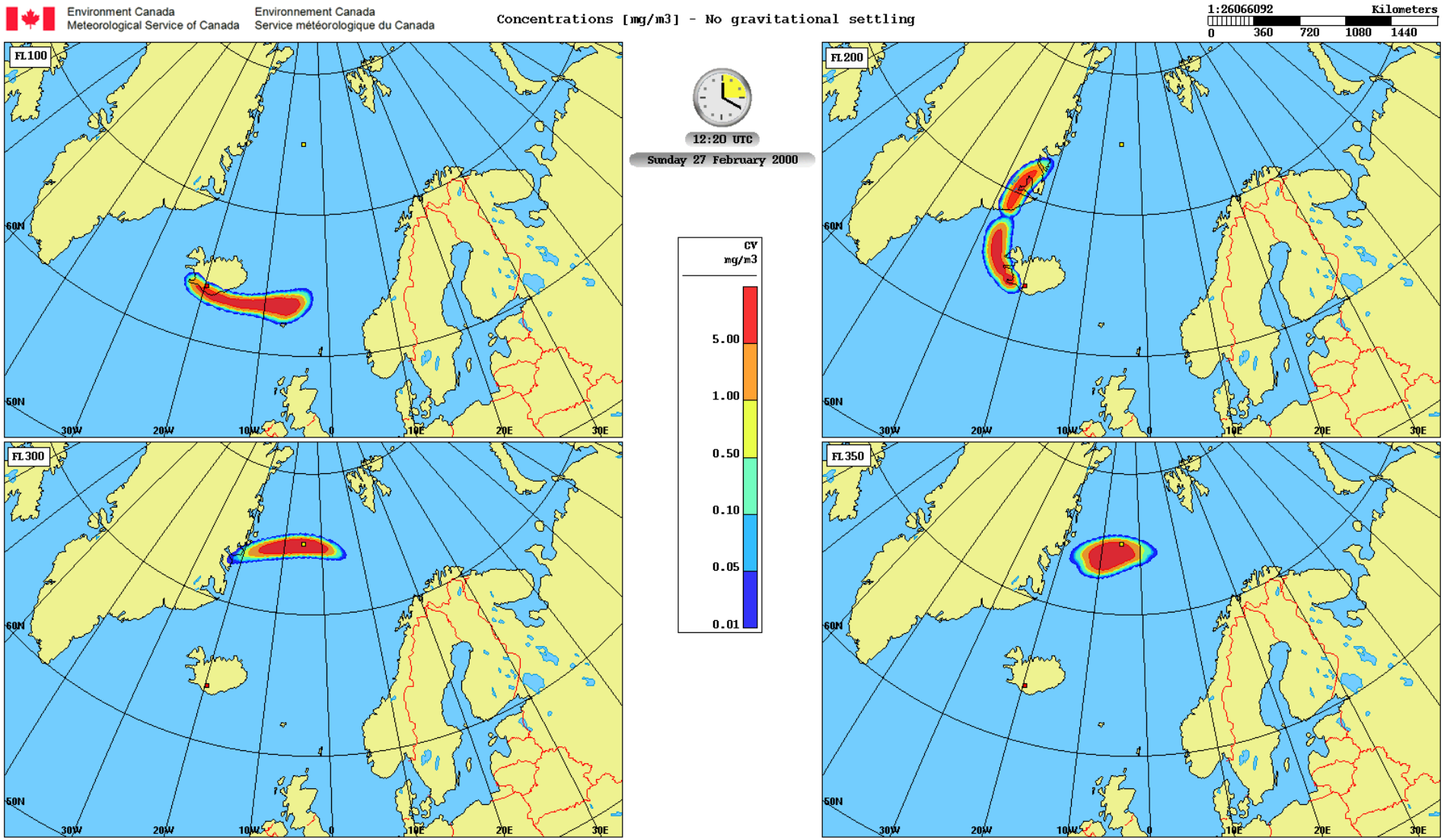
Gravitational settling ρ =1556 kg m^{-3}



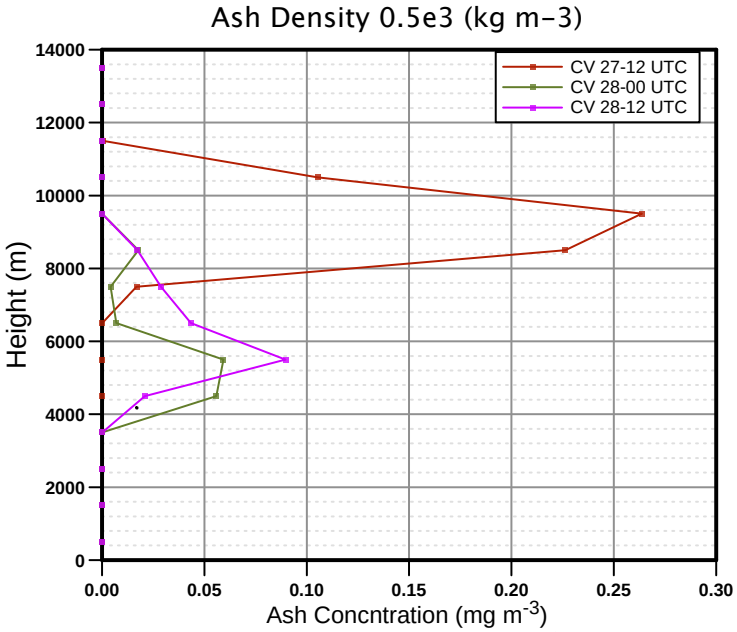
Gravitational settling ρ =2600 kg m^{-3}

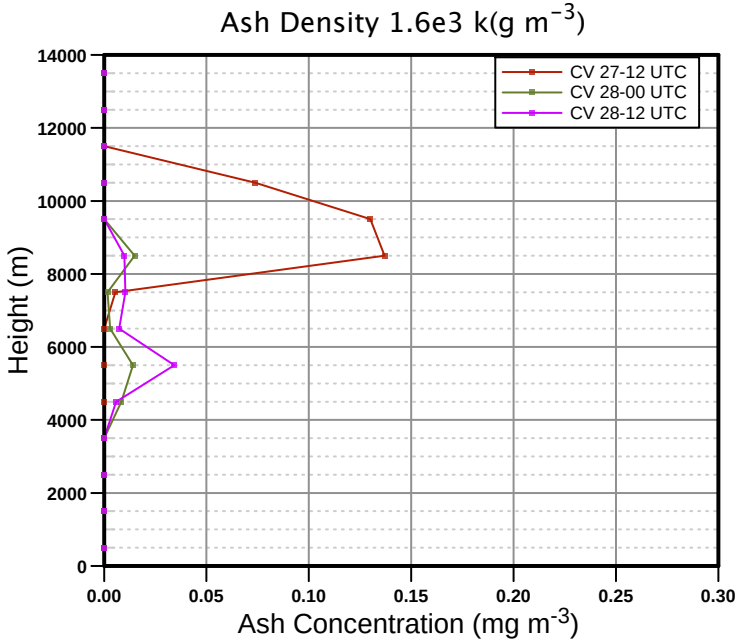


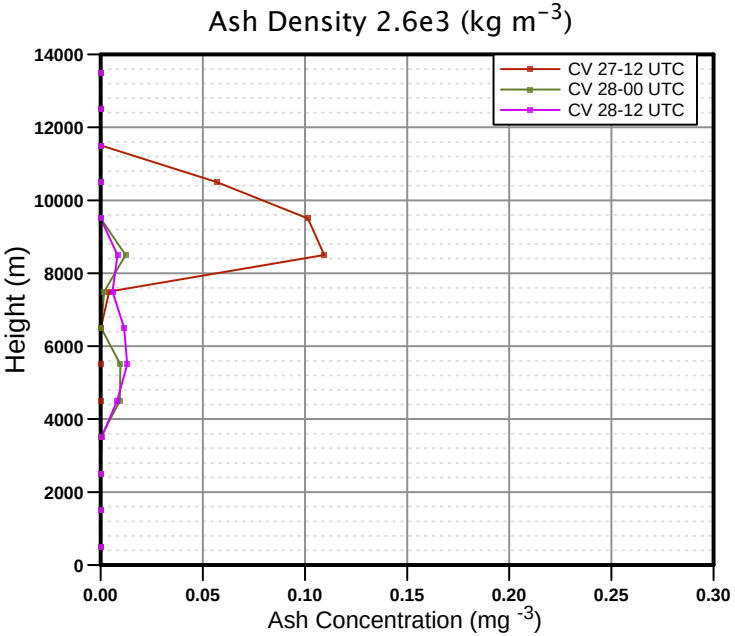
No Gravitational settling

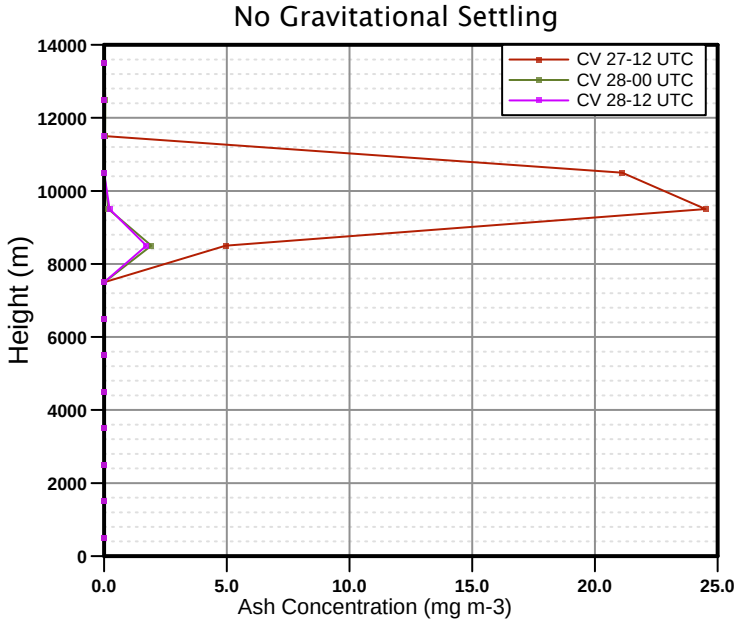


Ash concentration vertical profiles at 70N-05W









Kasatochi Eruption - Aleutians 2008

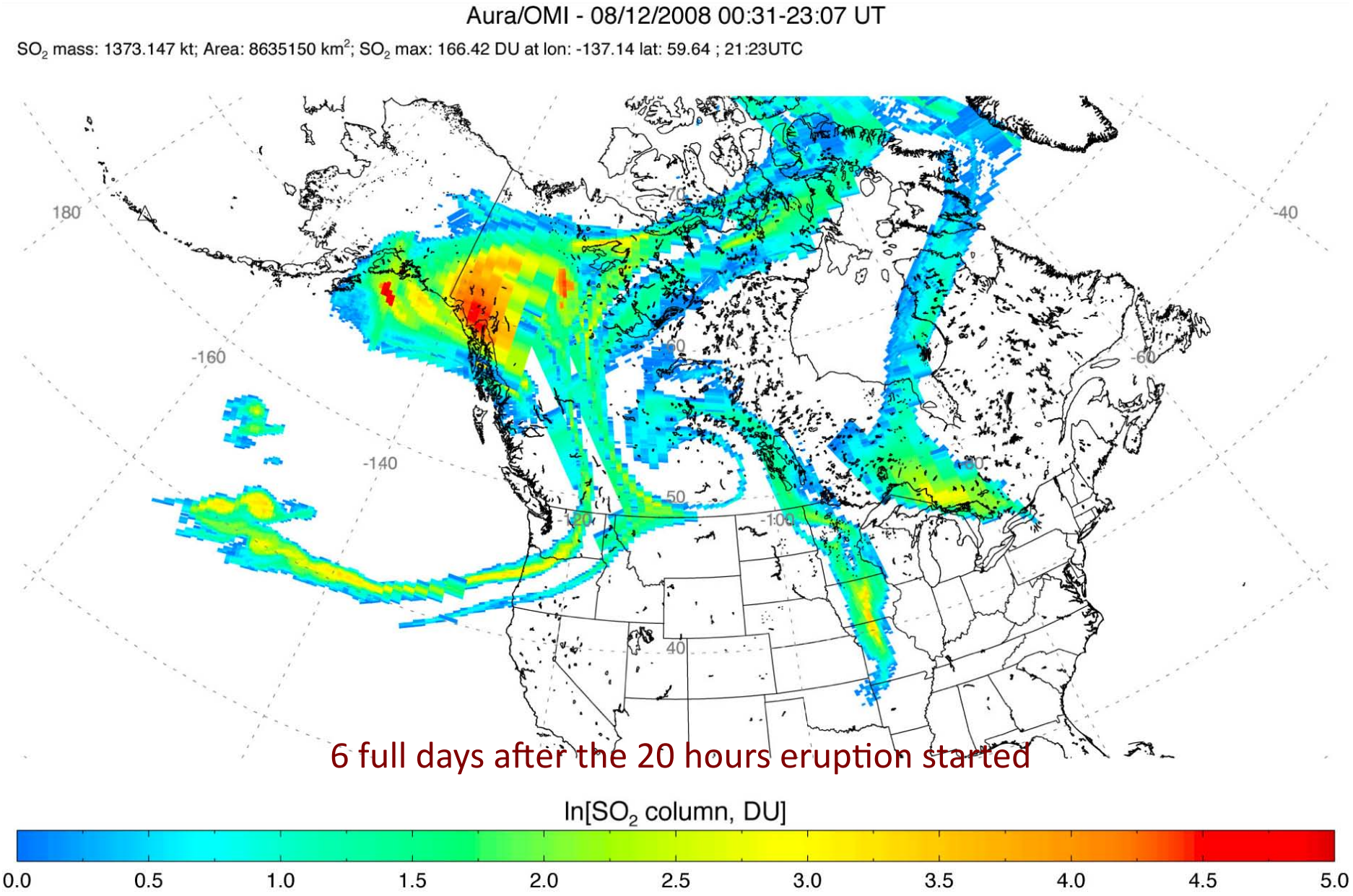
- A first explosion August 7 ~ 20:00 UTC
  - Ash and gas plume reaching as high as 14 km
- Two other explosions
  - 8 August 01:50 UTC and 8 August 04:35 UTC
- According to the AVO, 20 hours, with more or less continuous intense gas and ash discharges.

D'Amours, R., A. Malo, R. Servranckx, D. Bensimon, S. Trudel, and J.-P. Gauthier-Bilodeau (2010), Application of the atmospheric Lagrangian particle dispersion model MLDP0 to the 2008 eruptions of Okmok and Kasatochi volcanoes, *J. Geophys. Res., 115, D00L11, doi:10.1029/2009JD013602.*

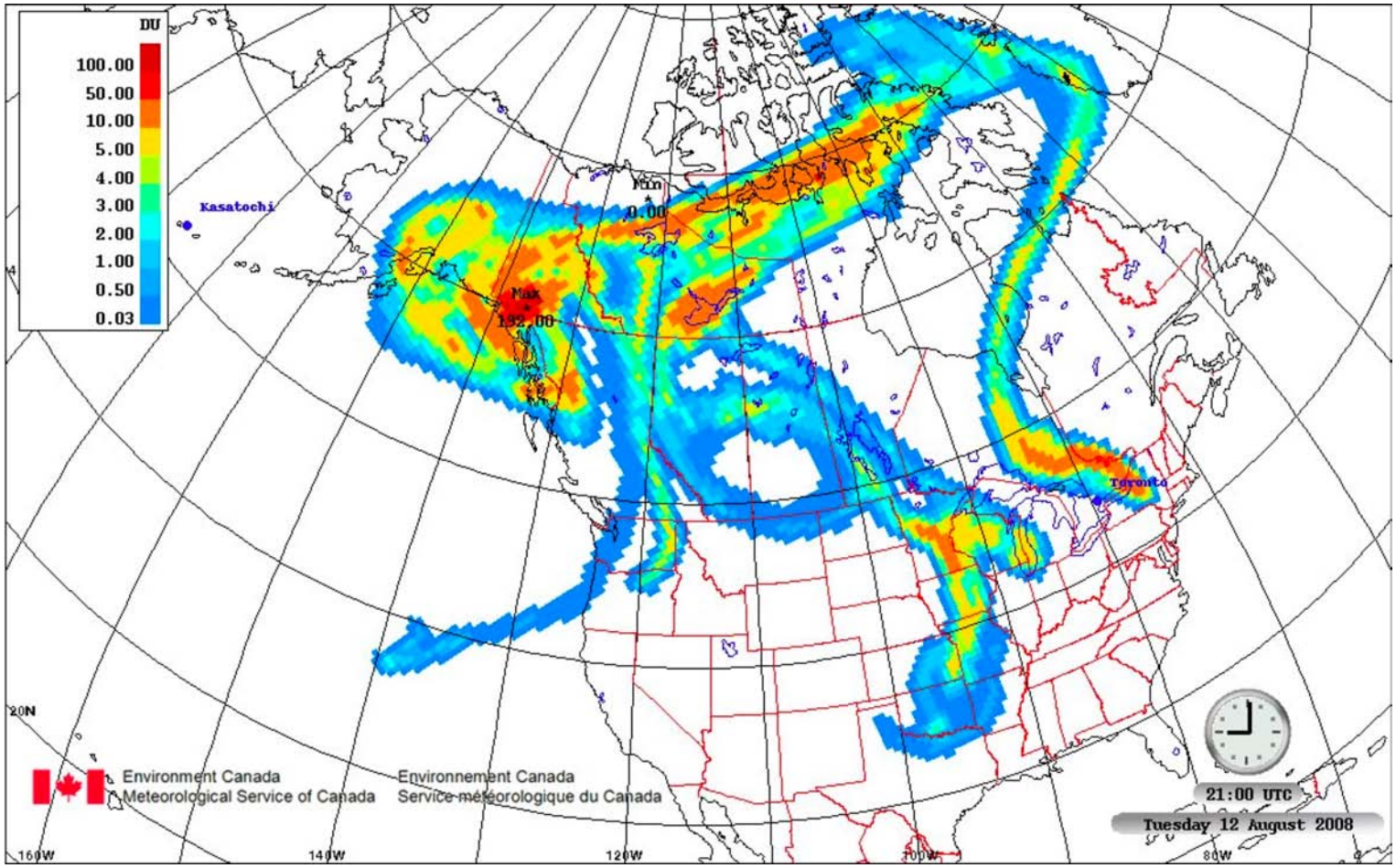
This and the next four slides were skipped during the oral presentation

SO_2 Modelling

- Forward simulation
- Release 1.3 megaton
  - based on AURA/OMI data (Aug. 10 scans)
- Constant rate for 20 hours.
- 50% between 10 km and 14 km

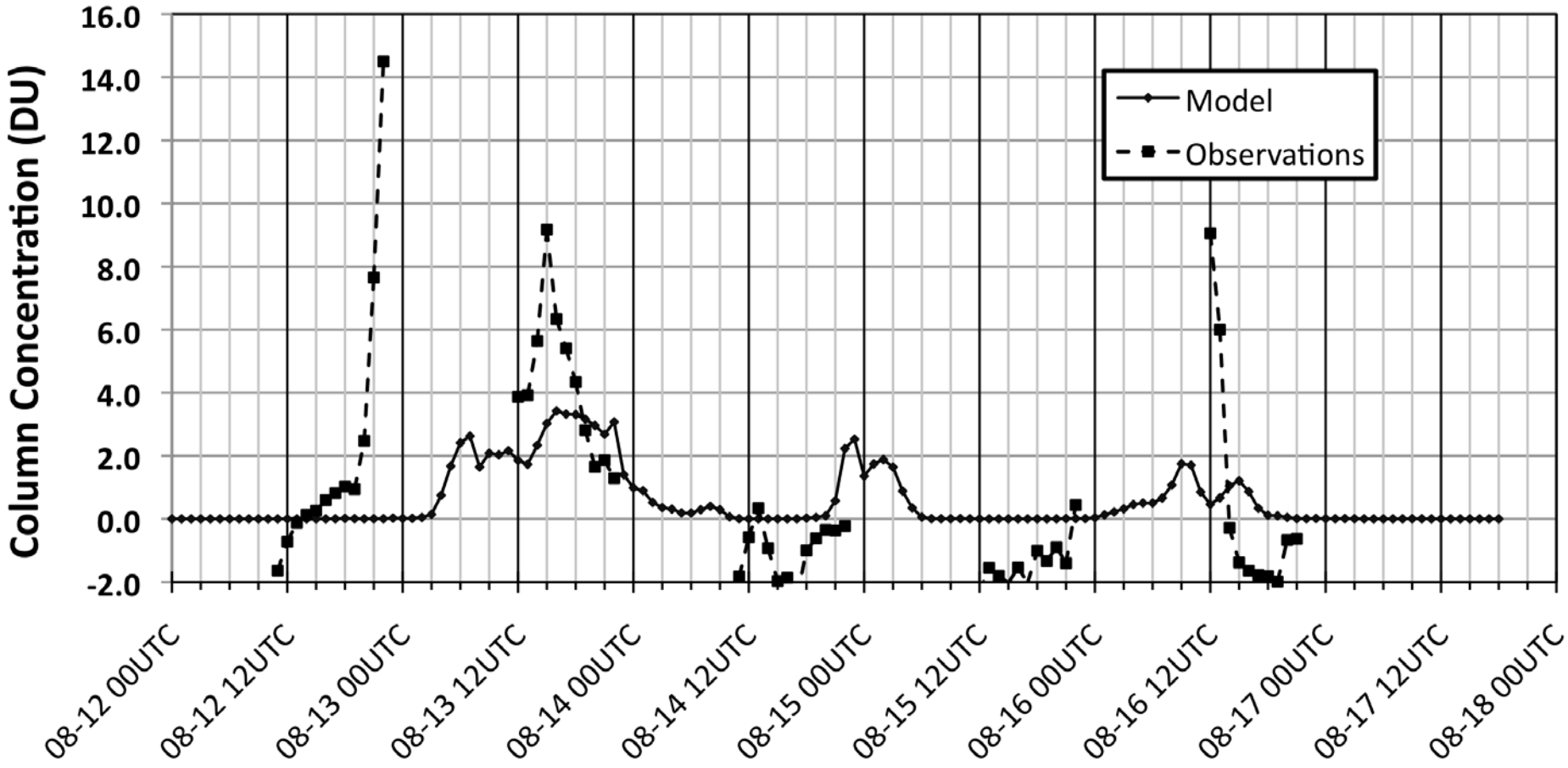

Aura/OMI - 08/12/2008 00:31-23:07 UT
SO_2 mass: 1373.147 kt; Area: 8635150 km^2; SO_2 max: 166.42 DU at lon: -137.14 lat: 59.64 ; 21:23UTC
180
-160
-140
-120
-100
-80
-60
-40
70
60
50
40
6 full days after the 20 hours eruption started
ln[SO_2 column, DU]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

MLDP0 Simulation



Environment Canada (EC) in Toronto

Multiple Brewer Spectrophotometer Instruments



Conclusions ?

- Dispersion models can provide very useful information
- Need to know much more about volcanic ash releases
- Need air concentration measurements
  - Real time and after the fact
  - Inverse modelling could help assessing source parameters
- Knowing about aircraft tolerances would be useful