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INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

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Implementation of a new in-cloud wet deposition scheme into the ldX operational transport modelling

HARMO 18

12 October 2017

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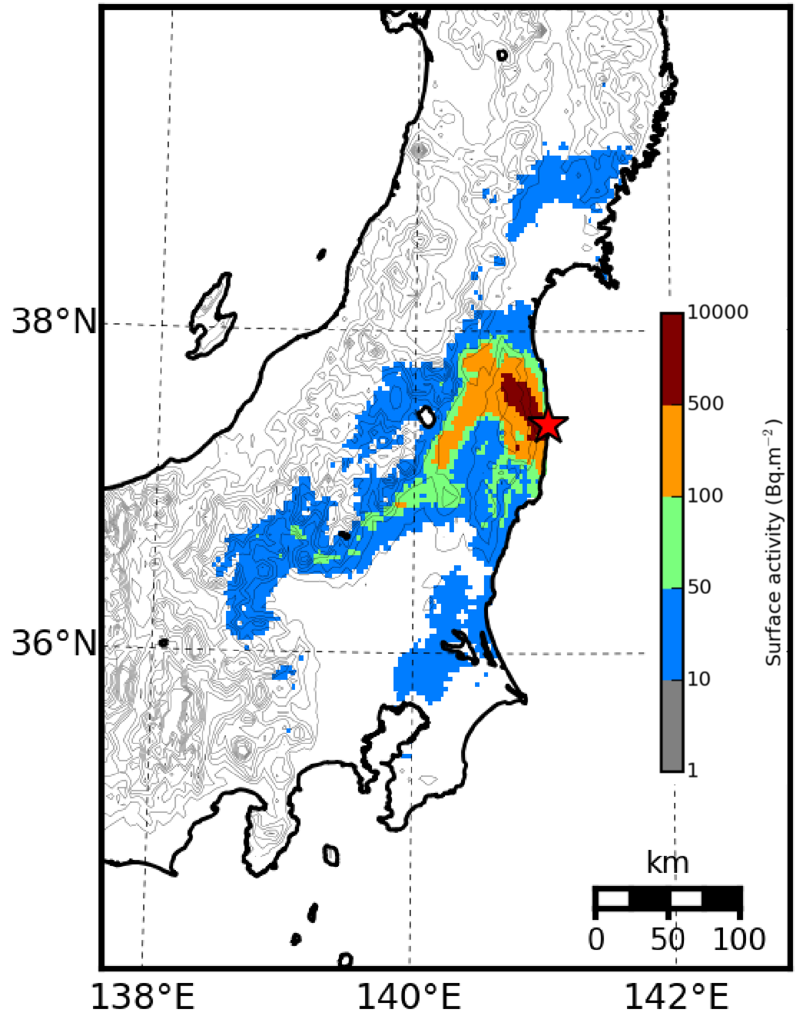
Introduction

- Observation map of cesium established several months after the accident.
- Several releases leading to a large scale deposit: contaminated areas further than 150 km.
- The main process of deposition was wet scavenging of the plume.
- Atmospheric transport modelling provide a quick response to urgent management questions.

➢ The Fukushima accident provided an opportunity to study the atmospheric dispersion modelling of radionuclides.

Cs-137 deposit map measured in April 2011



Introduction

- The wet deposition is composed of in-cloud scavenging, below-cloud scavenging and possibly fog deposition.

- In-cloud scavenging is mainly the combination of several mechanisms:

  - Nucleation: activation of the aerosol particle to droplet or ice crystal.

  - Coalescence: droplets and/or ice crystals grow and coalesce together, forming precipitation (snow or rain).

  - Collection: falling drops or snow flakes collect aerosol particles, droplet and cystals inside the cloud.

- To model properly the wet deposition (including the in-cloud scavenging), we have to get a fine description of the cloud and its precipitation.

Plan

1) Short review of the wet deposition scheme

2) Vertical aspects of the possibilities provided by the meteorological modelling

3) Temporal aspects

Short review of some ATM in-cloud scavenging schemes

- The evolution of the air concentration (c) due to the wet deposition is calculated as follow:

$$c(t+dt) = c(t) \times e^{-\Lambda dt}$$

- The most common in-cloud deposition scheme types:

$$\Lambda = a \times I^b$$

(use by ldX, NAME, HYSPLIT,…)

Main hypothesis:
- All the precipitation is formed at the cloud top.

Needs:
- Rainfall intensity
- Cloud base and top

$$\Lambda = \frac{f}{3600} \frac{I}{LWC \times H}$$

(inspired by Hertel (1995), here RATM 2015 version)

Main hypothesis:
- In-cloud is only driven by the non-precip to precip water conversion.

Needs:
- Rainfall intensity
- Cloud base and top
- Liquid water content ($Kg.m^{-3}$)

$$\Lambda = c \times \frac{RH - RH_{th}}{100 - RH_{th}}$$

(Pudykievicz (1988), eg used by MLDP0)

Main hypothesis:
- In-cloud is driven by the relative humidity.

Needs:
- Relative humidity

Short review of some ATM in-cloud scavenging schemes

- All these schemes are strong simplifications of the cloud physics.
  - Hertel/RATM proposes a scheme that seems more physical.

- But, these schemes have the advantage of using available input data.

- Meteorological models are constantly improving. New output data are progressively available.

Question:

- Can the in-cloud scavenging modeling be improved to take into account this finer description of the atmosphere?

Possibilities provided by the meteorological modelling

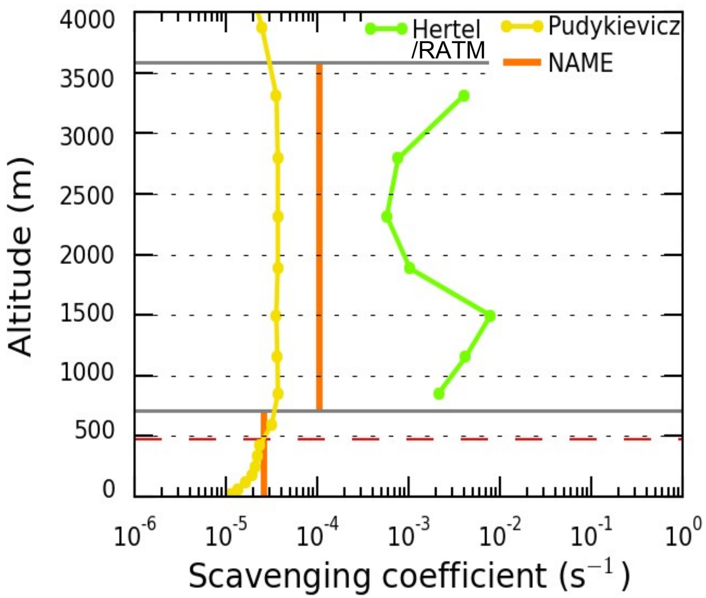
- Case of study : the Fukushima accident.

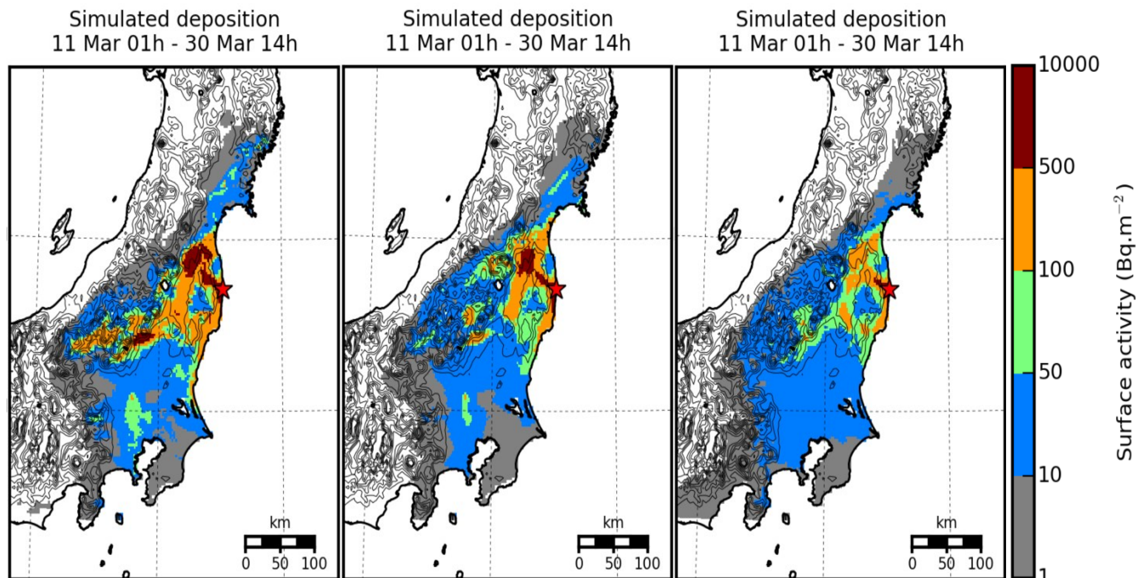
- The Sekiyama (2015) determinist meteorological simulation is used.
  - Based on the Japan Meteorological Agency's non hydrostatic model (JMA-NHM)
  - Concern Japan on March 2011
  - Horizontal resolution: 3 km
  - Output frequency: 10 min
  - Precipitating and non-precipitating water content are vertically described

- Two meteorological output data improvement are considered:
  - The data vertically resolved
  - The temporal resolution

Vertical

- Hertel/RATM is the only scheme with a vertical evolution among our three schemes.
- Today, differences between schemes are dominated by mean value of the scavenging coefficient?
- In a future, can we improve this vertical dependency? Make it more significant?





Hertel-inspired deposition scheme | NAME deposition scheme | Pudykiewicz deposition scheme

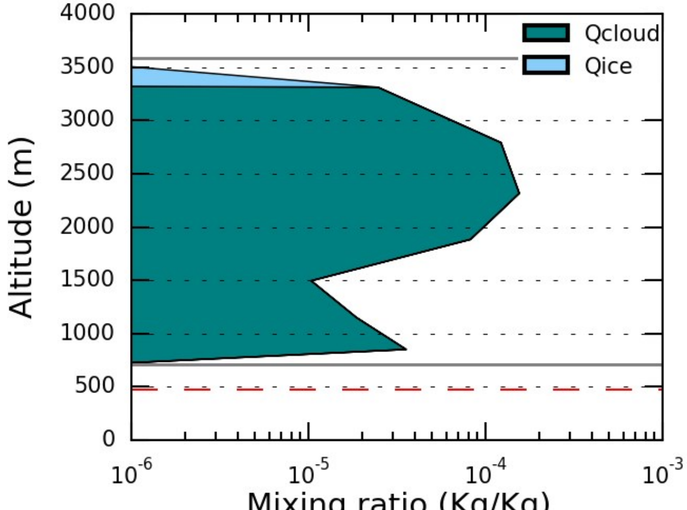
Vertical
Water mixing ratio

- Today, only the rainfall intensity, the relative humidity and the liquid water are commonly used for the operational models.

- But, a larger quantity of vertically resolved water data can be available:

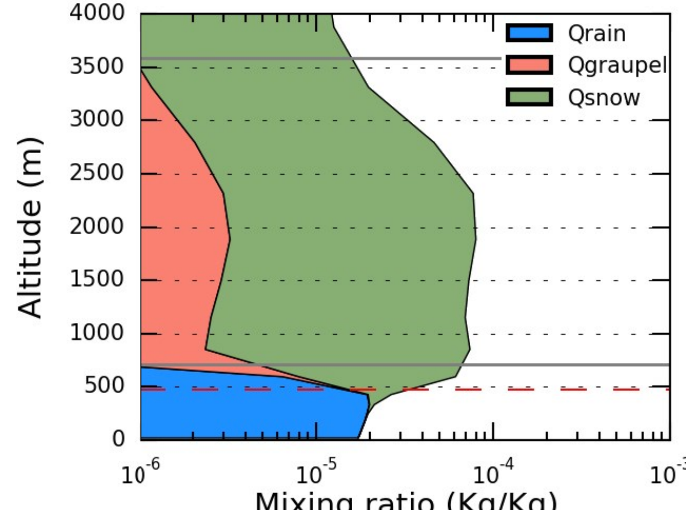
Cloud water:

- 3D field of cloud water mixing ratio (Q_{Cloud})
- 3D field of ice water mixing ratio (Q_{ice})



Precipitating water:

- 3D field of graupel mixing ratio ($Q_{Graupel}$)
- 3D field of snow mixing ratio (Q_{Snow})
- 3D field of rain mixing ratio (Q_{Rain})



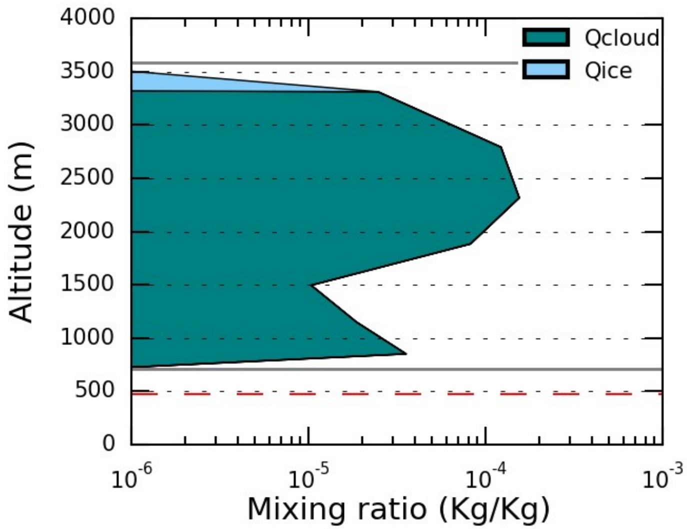
Vertical
Water mixing ratio

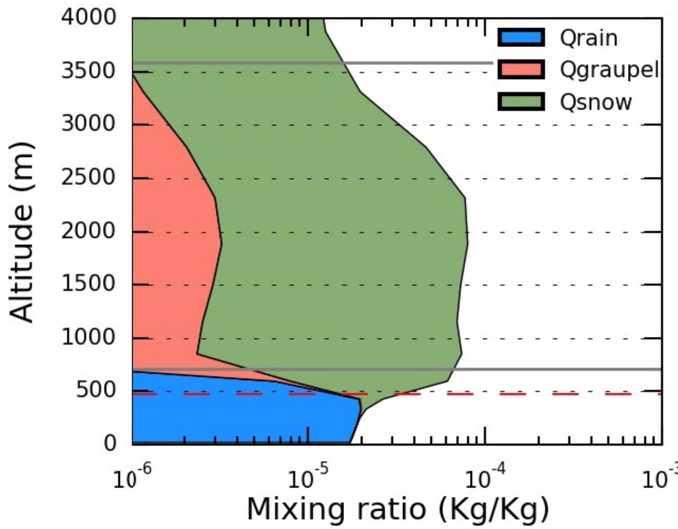
- Water mixing ratio are necessary to represent the vertical complexity.

- But, water mixing ratio are instant data.
  - Q_{Rain} is the sum of the local conversion of cloud to rain and of the rain falling from upper levels.

- Then is not possible to use the Hertel scheme* with local data like the water mixing ratio.

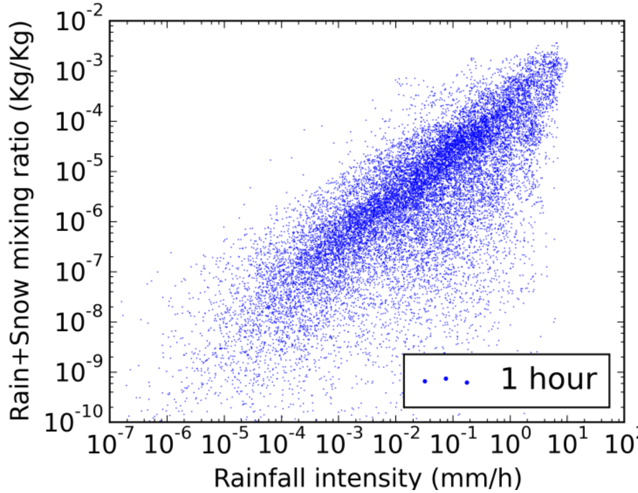
*which implied that the in-cloud scavenging is proportional to the conversion rate of cloud water to rain.

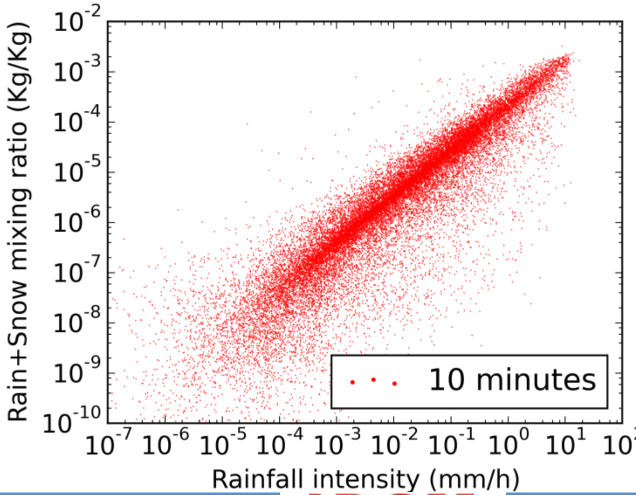




Temporal
Cumulated and instant data

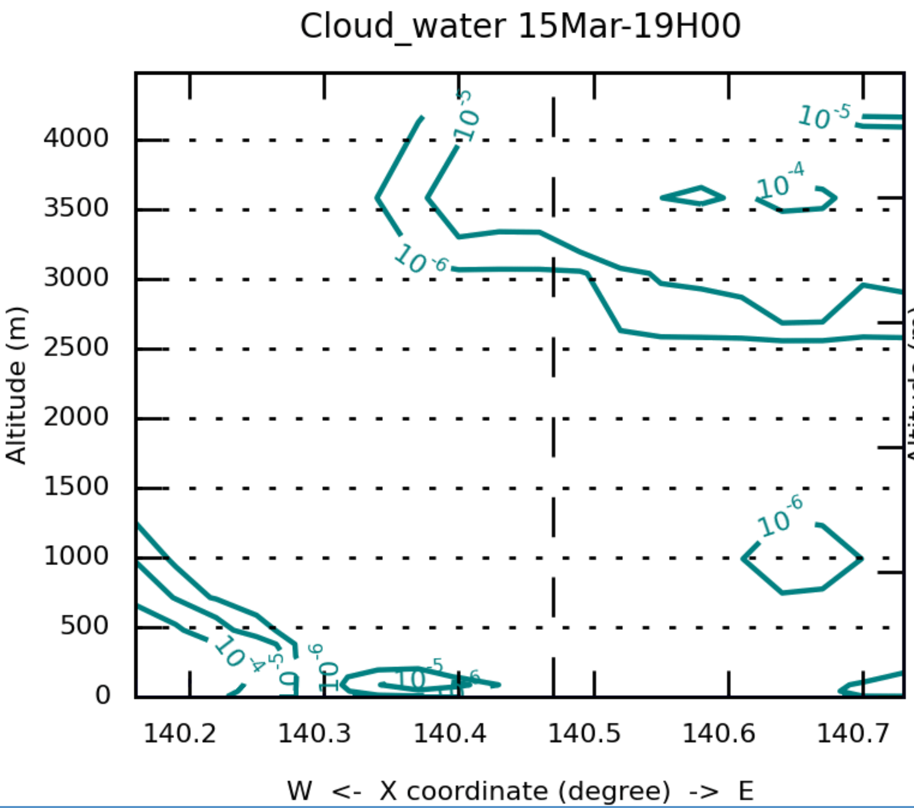
- Today, the in-cloud scavenging schemes use a the rainfall (I), a cumulated data.
- Rain and snow mixing ratio are instant data.
  - Potentially used for the next generation of wet deposition schemes of the operational ATM.
- What is the temporal consistency between instant data and cumulated data ? Can the instant data be representative of the deposit ?
- The instant data could be used, but not with an 1 hour time step.
  - With an hourly output, instant and cumulated rain data are not consistent (54% of Pearson correlation between Q_R and I).
  - 10 min output allows a much better consistency (83% of Pearson correlation between Q_R and I).

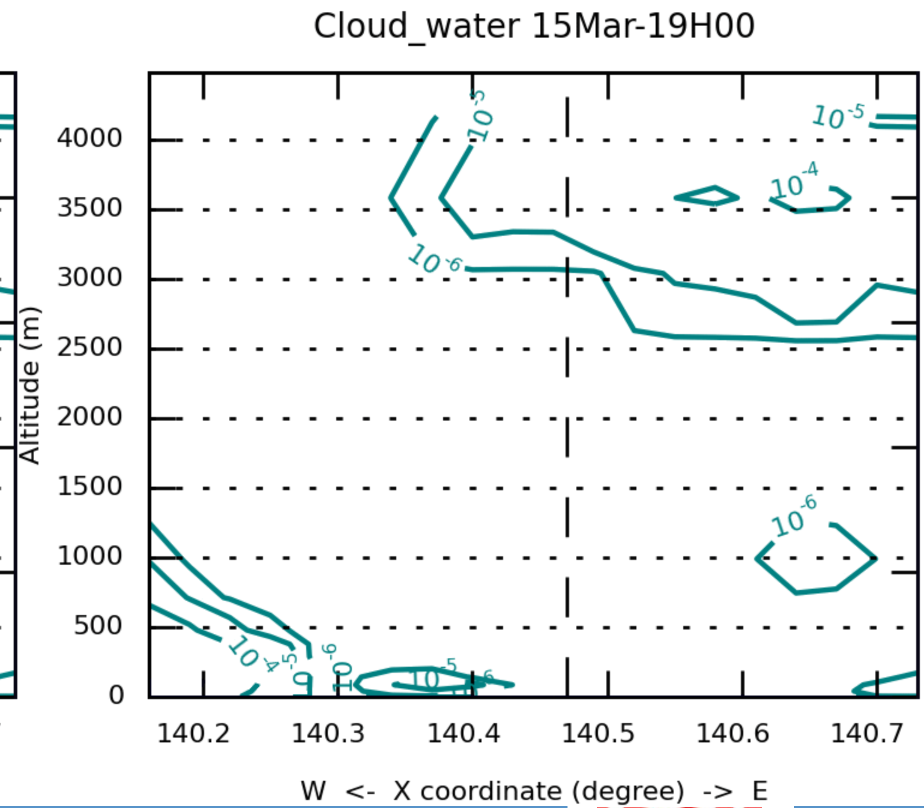




Temporal
Cloud diagnosis

- With a 3 km resolution, it is not always possible to follow a cloud evolution with an hourly resolution.
- Ten minutes allows a better tracking of the cloud evolution





Conclusion

- Ten minutes resolution allows a better tracking of the cloud and precipitation. Moreover, the cumulated precipitation has a better correlation with the instantaneous precipitating water at ground level data.
- Ten minutes meteorological output data and the access to additional vertical water content data offer new possibilities for the wet deposition modelling.
- It is confirmed that the rainfall intensity is poorly representative of the mechanism occurring in the cloud. Besides, the scavenging schemes can have an important influence over the final deposition maps.
- A consistent in-cloud scavenging scheme has to distinguish, at least, the precipitating water coming from a higher altitude and the precipitating water formed by the cloud water conversion.
- Then, a more detailed in-cloud scavenging scheme is expected to used favorably the possibility provided by a ten minutes resolution of the meteorological data and by the use of a larger number of water content fields.