清華大學核能技术设计研究院

Sensitivity analysis on the wet deposition parameterization for ^{137}Cs transport modeling following the Fukushima Daiichi Nuclear Power Plant accident

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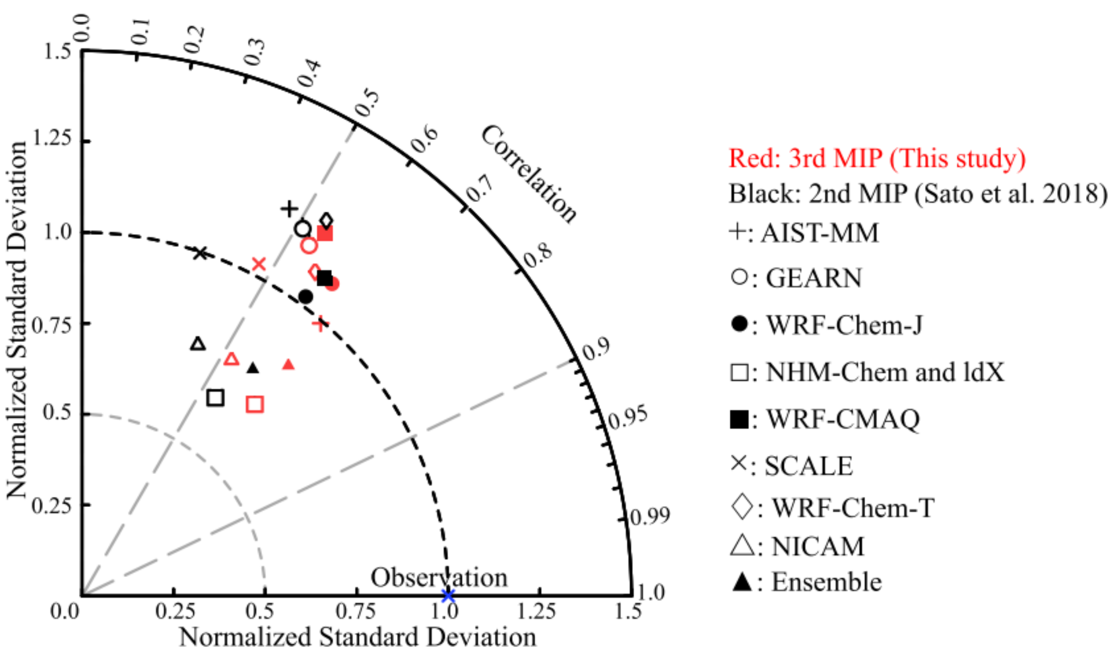
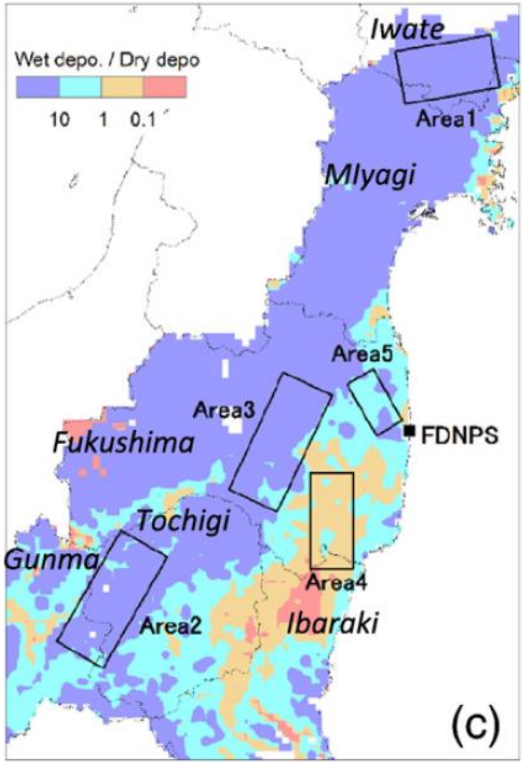
Background

- Model-measurement discrepancies still exist in both the deposition pattern and spatiotemporal concentration distributions for Fukushima accident.
- One crucial source of the above uncertainties is the modeling of wet scavenging.[1]

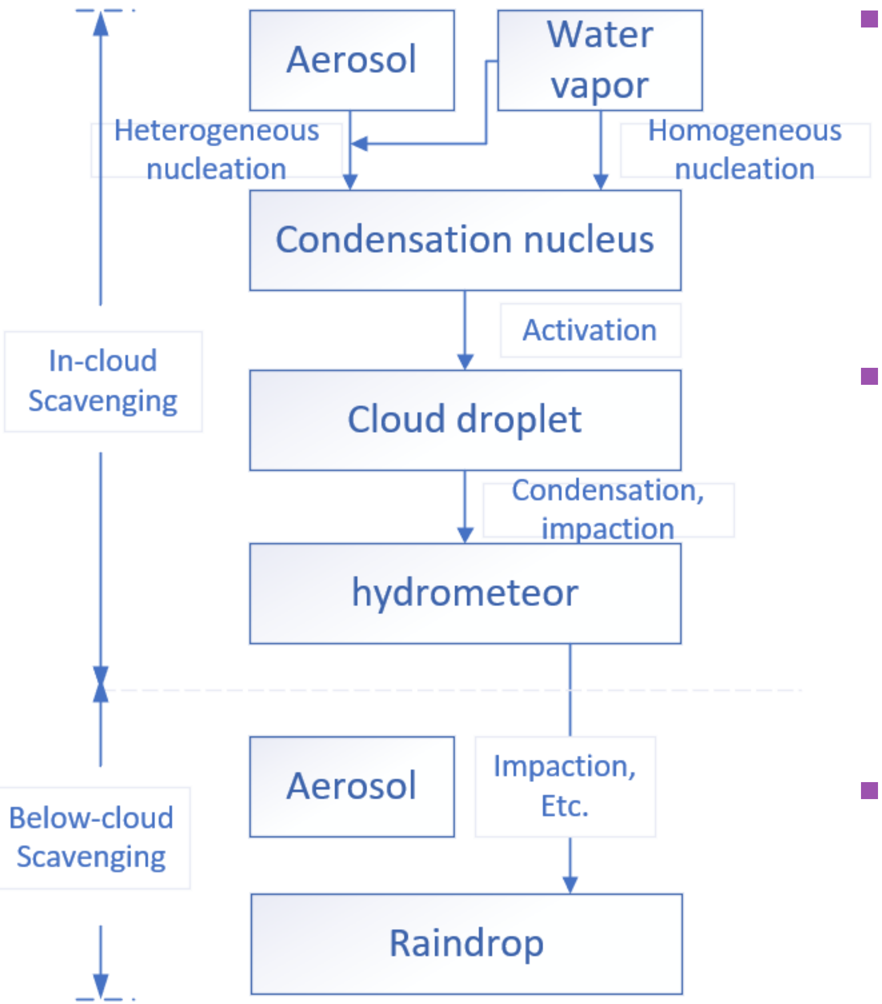


Taylor diagram results of 2nd and 3rd MIP [2, 3]



Ratio of wet/dry deposition simulated by Katata [4]

Background

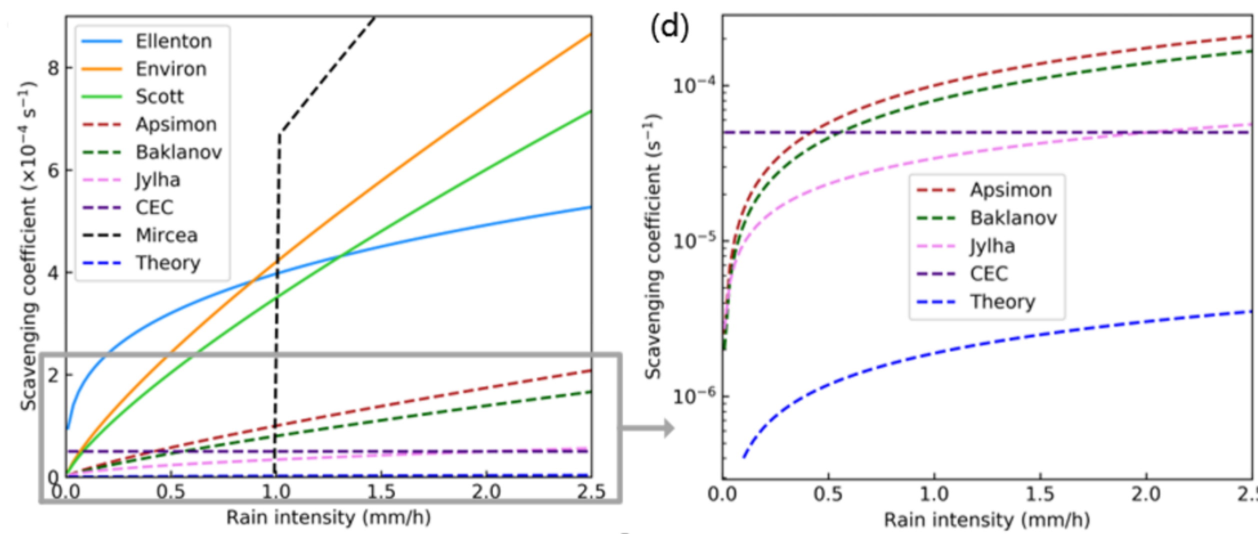


- The in-cloud scavenging happens inside the cloud where particles serve as cloud nuclei and evolve with cloud formation. However, since its measurement is quite limited, the in-cloud scavenging is usually more difficult to model mechanically.
- The below-cloud scavenging takes place below the cloud base where the particles are absorbed by the precipitation. However, the specific parameters of below-cloud scavenging schemes still vary over a broad range. The variation would be amplified by the uncertainty in meteorological input.[5]
- The dual uncertainties in wet scavenging modeling and the meteorological input indicate the importance of improving them at the same time.
- Online coupled model: WRF-Chem

Methods

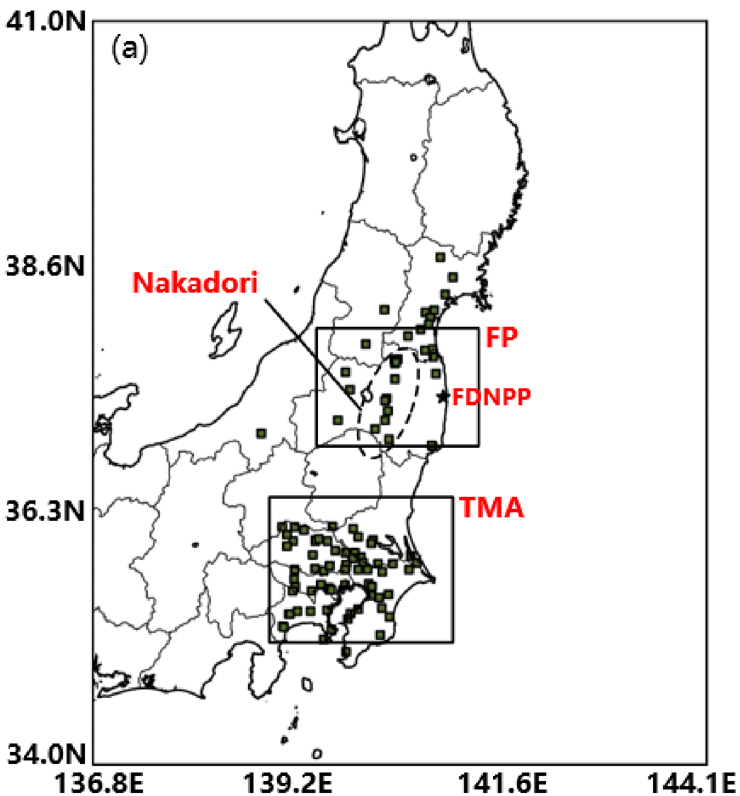
- In-cloud schemes;
  - **Roselle**;
  - **Hertel**;
  - Ellenton/Environ/**Scott**;
- Below-cloud schemes;
  - Apsimon/**Baklanov**/Jylha;
  - **CEC**;
  - **Mircea**.[6]
- Ensemble mean: 9 model sets;
- Microphysics scheme
  - the six-category single moment cloud microphysics scheme (6)
  - the Morrison's double moment cloud microphysics scheme (10)

In-cloud schemes	Scavenging coefficient (s^{-1})
Roselle	$\Lambda = \frac{1}{3600}\left(1 - exp\left(-10^3 \Delta z \frac{LWC}{p_0}\right)\right)$
Hertel	$\Lambda_i = 1.25 \times {p_0}^{0.64} / H_i$
Ellenton	$\Lambda = 3.97 \times 10^{-4} {p_0}^{0.31}$
Environ	$\Lambda = 4.2 \times 10^{-4} {p_0}^{0.79}$
Scott	$\Lambda = 3.5 \times 10^{-4} {p_0}^{0.6}$



Validation

Simulation domain



- Comprehensive evaluation [2, 3]
- Deposition

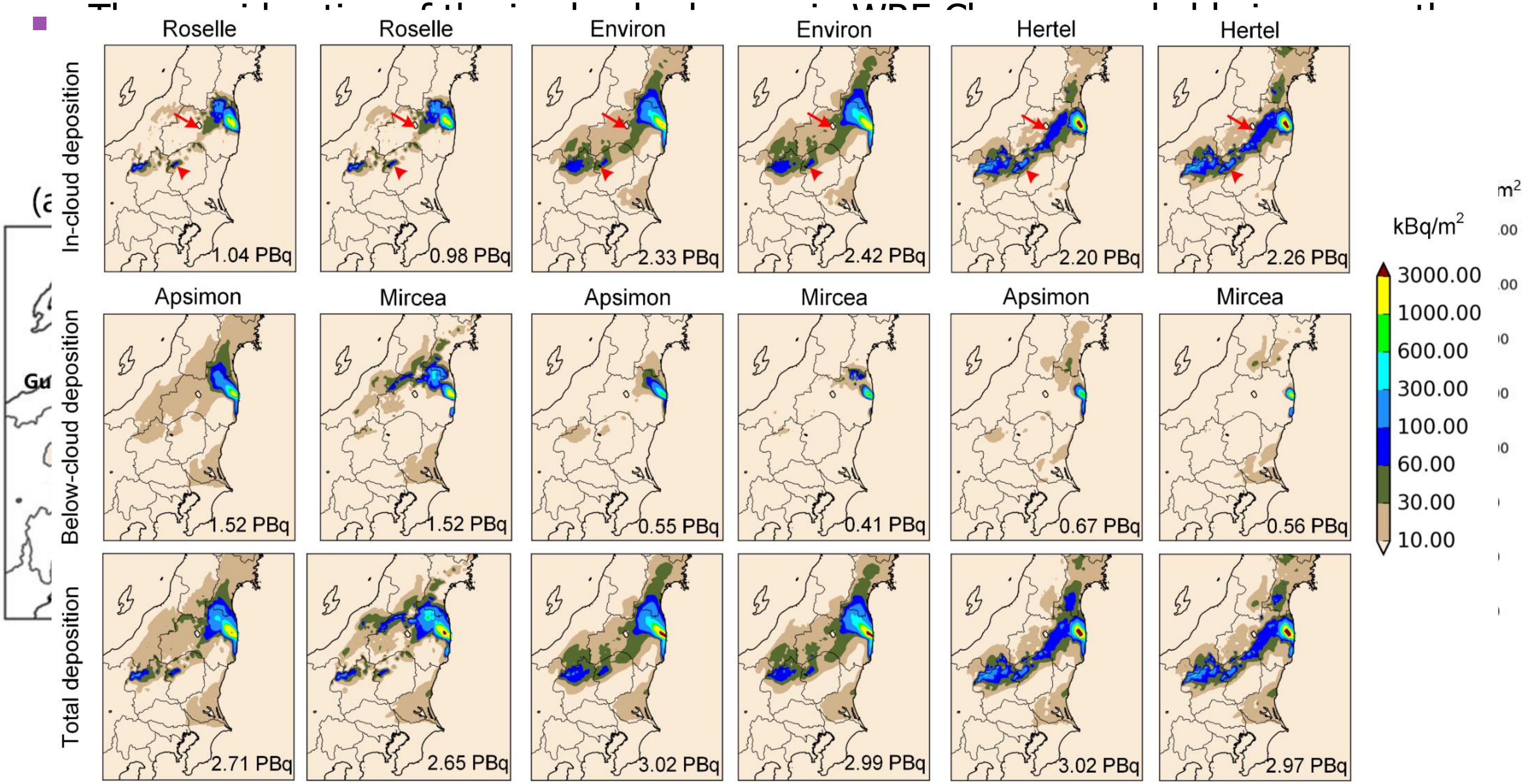
$$RANK = CC^2 + \left(1 - \left|\frac{FB}{2}\right|\right) + \frac{FMS}{100} + \left(1 - \frac{KSP}{100}\right)$$

- Concentration

$$RANK2 = \frac{FAC2}{100} + \frac{CAPTURE}{100} + F \times \left(1 - \frac{OVERESTIMATE}{100}\right)$$

- Participating models
  - 25 combinations of the in- and below-cloud schemes;
  - Ensemble mean of the 9 models with equal weight;
  - The models with only the below-cloud scheme Baklanov (Baklanov-6 and Baklanov-10).

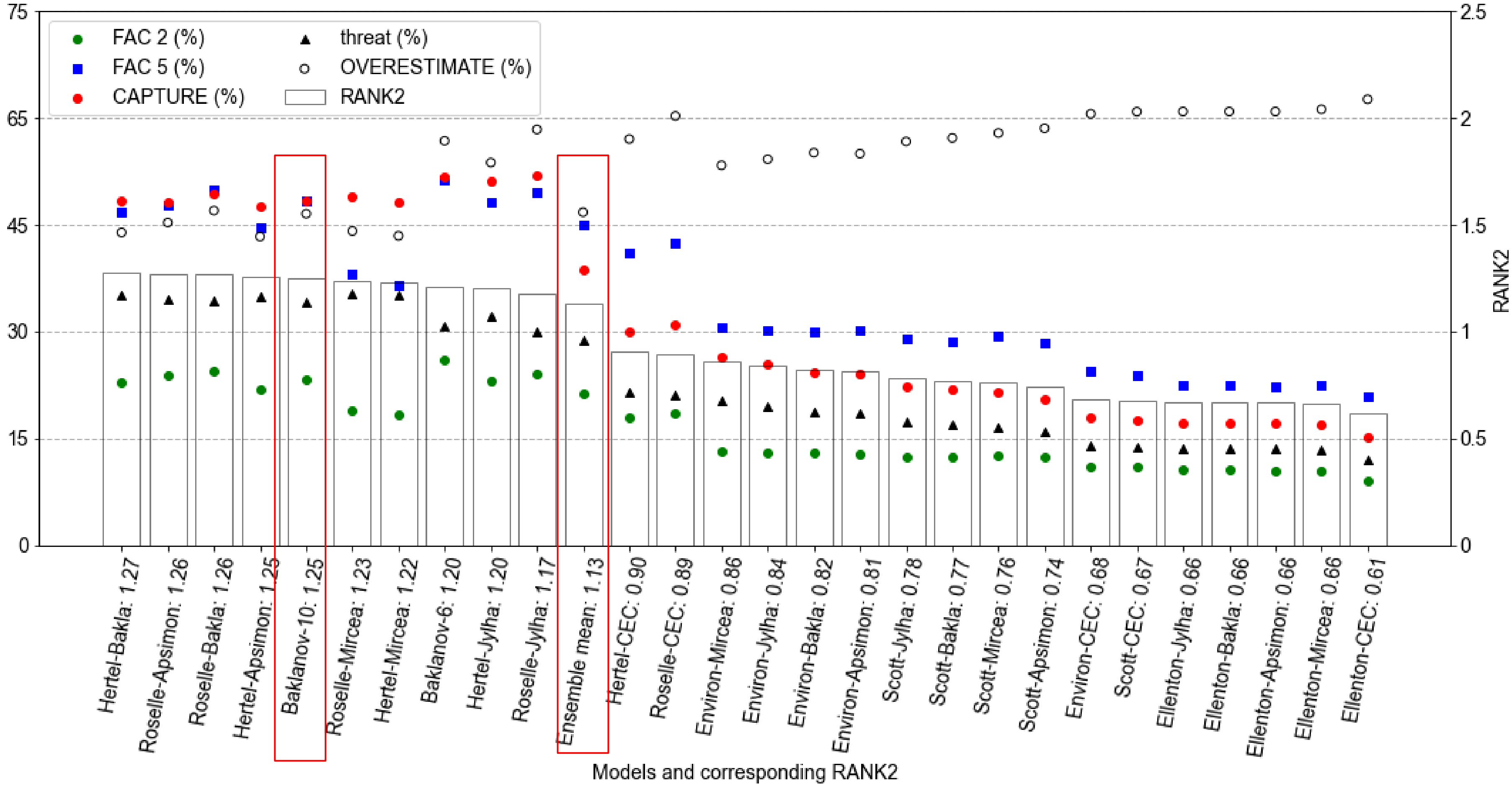
Results and discussions



- The in-cloud scheme plays a more dominant role in simulating ^{137}Cs transport following the FDNPP accident than the below-cloud scheme, with respect to the detailed deposition pattern.

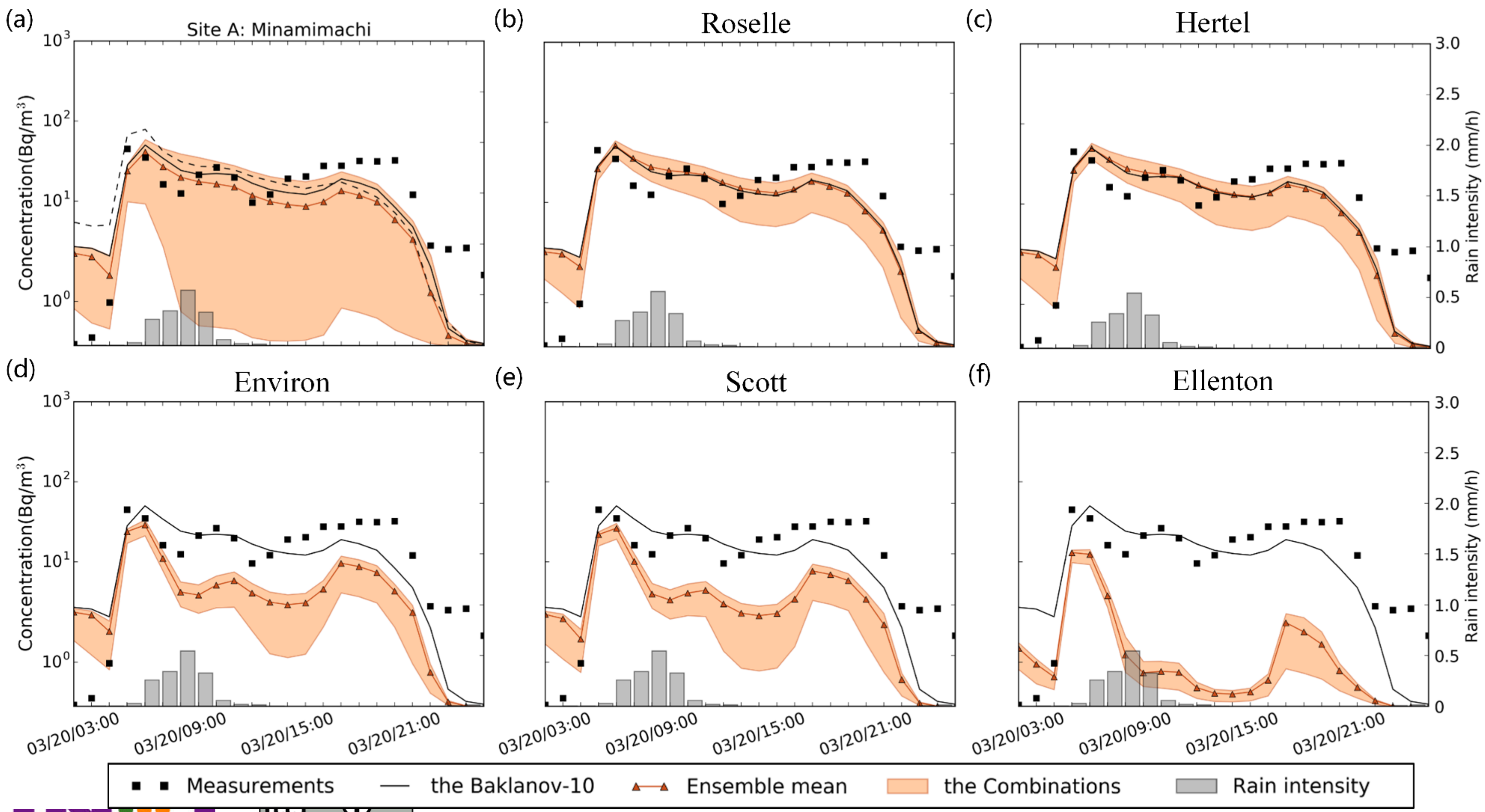
Results and discussions

- Those in-cloud schemes considering cloud parameters also improve the atmospheric concentration simulations.
  - The ensemble mean achieves satisfactory performance in general.



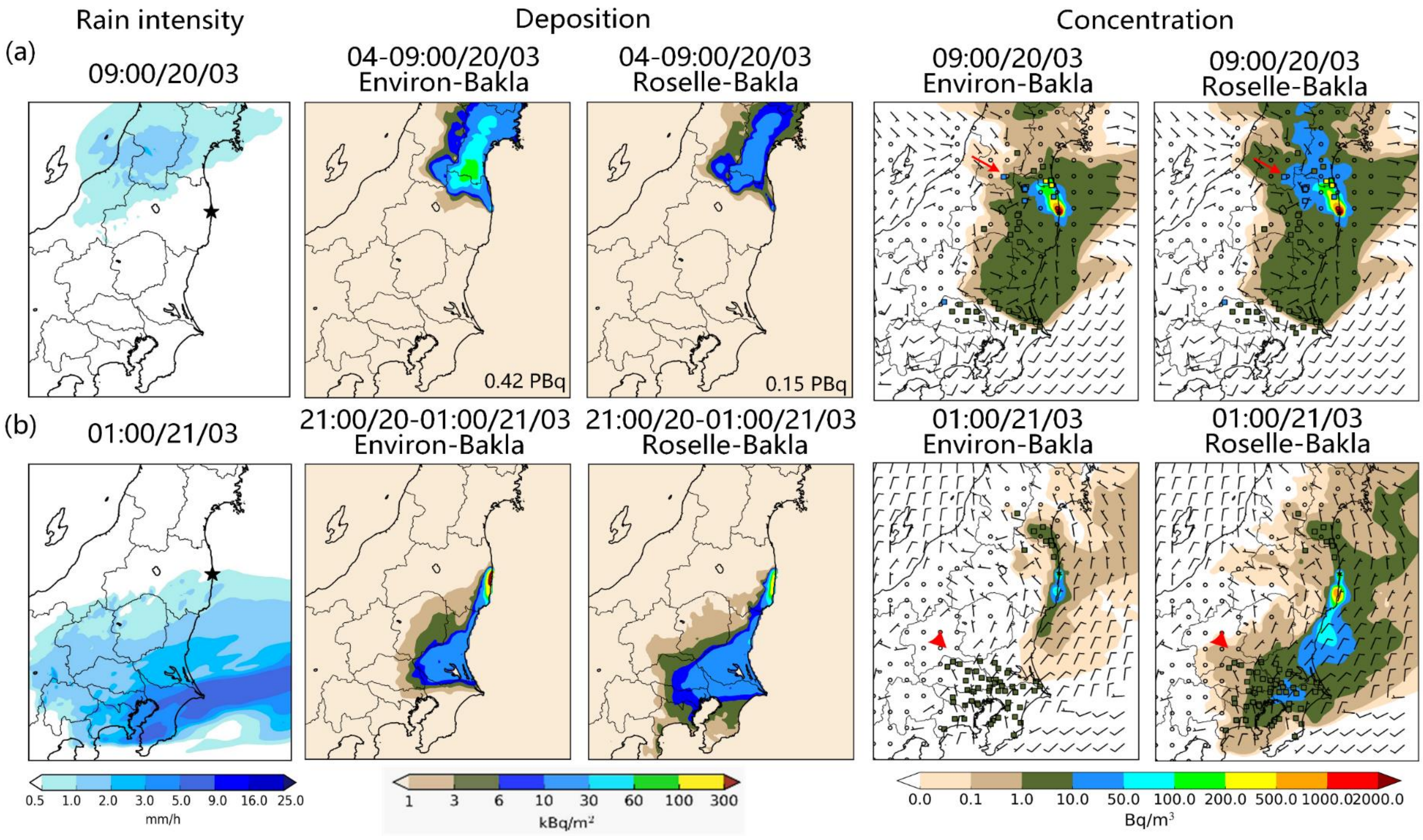
Results and discussions

- Evaluation of each plume
  - P8: The in-cloud schemes solely relying on rain intensity are quite sensitive to meteorology and show varied performances in the tested plume events.



Results and discussions

- Spatial patterns of the plumes



Conclusions

- The modification of microphysical scheme from WSM6 to MORR could improve the meteorological input and simulation at the same time but to a limited extent while the improvement of wet deposition scheme is more influential but model-dependent.
- The consideration of the in-cloud schemes in WRF-Chem remarkably improves the cumulative deposition simulation for most models, especially at Nakadori, while in concentration prediction, only in-cloud schemes considering cloud parameters shows better and stable performances.
  - The Roselle-Bakla, Hertel-Bakla and Roselle-Apsimon are the best among all the compared models, indicating a better allocation between deposition and concentration.
  - The in-cloud scheme plays a more dominant role in simulating ^{137}Cs transport following the FDNPP accident than the below-cloud scheme, with respect to both the detailed deposition pattern and atmospheric concentration distributions.
  - The in-cloud schemes solely relying on rain intensity are quite sensitive to meteorology and show varied performances in the tested plume events.
  - The model ensemble mean shows fair and stable results in various plume events.

Thank you for your attention!

References

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