**Reply to Referee #1**

**General comment:**

*This article investigated implementation of semi-Lagrangian advection scheme in a specific type of numerical atmospheric model for limited-area, namely the Regional Spectral Model. It is mathematically known that usage of spectral dynamics can show up negative values when some features have spatially discontinuous distribution: known as Gibbs phenomenon. Since tracers and hydrometeors are definitely impossible to have negative value in the nature, the phenomenon causes serious errors especially when there is a single point emission of tracers.*
*The authors implemented semi-Lagrangian scheme to avoid the Gibbs phenomenon and evaluated behavior of simulated radioactive tracers with new advection scheme in their model, throughout a case of Japanese nuclear power plant explosion when it was hit by earthquake-induced tsunami. Effect of new advection scheme is very clear: noise-like signals formerly induced by Gibbs phenomenon are completely eliminated for tracers as well as hydrometeors.*
*The uniqueness of this study lies in their model framework and target of simulation; this advection scheme has rarely introduced in regional spectral model so far especially with considering emission of radioactive tracers. The objective of this study is very clear and it accomplished the authors' purpose appropriately. The paper is well-prepared and worth to be published. This reviewer raises few suggestions as below.*

: We appreciate the reviewer who gave very constructive comments which significantly improved the earlier version of manuscript. We address all issues raised from the reviewer and the manuscript has been revised accordingly.

Specific comments:

*[1] Besides elimination of Gibbs phenomenon for nonnegative variables, can the model bring additional improvements, such as enhanced performance and/or predictability? It is questionable at this stage; this reviewer recommends providing more and clarifying explanations in the manuscript.*

: We are grateful to this anonymous reviewer for a valuable comment. As the reviewer's comment, one may expect model performance improvement by eliminating the Gibbs phenomenon. In the manuscript, we presented that the NDSL scheme can remove negative errors in radioactive variable fields and humidity field (Figs. 6-8). To show improvement in precipitation field, we added the TMPA rainfall in Fig. 9. Spatial correlation between the ORG (SL) and the TMPA is 0.616 (0.622).

It shows that error correction in humidity field can lead improvement in precipitation even the enhancement is not that much large. Because the selected case in this study is not a heavy rainfall case, it is quite hard to find the simulated rainfall improvement due to the corrected humidity. We added more explanation on this issue in section 4.3 as follow:

"General rainfall patterns observed in the tropical rainfall measuring mission (TRMM) multi-satellite precipitation analysis (TMPA) are well captured in both experiments (Fig. 9c). The spatial correlation coefficient of precipitation between the ORG run and the TMPA is 0.616 whereas the correlation coefficient between the SL run and the TMPA is 0.622. It means that the corrected humidity field by the NDSL scheme can slightly improve precipitation or keep the simulation skill of the original IsoRSM in the rainfall simulation. When we consider that the ORG experimental set have been widely used for various downscaling researches, it is possible to understand that the regional NDSL can successfully calculate the transport and distribution of humidity in the RSM. One possible reason why the improvement of the rainfall simulation by the NDSL scheme is not much significant is that the selected case in this study is not a heavy rainfall case. For a heavy rainfall case, the large discontinuity of humidity field is expected, which means higher possibility of negative value occurrences in the original IsoRSM. Further study will be continued to examine how the NDSL can improve skills for the precipitation simulation in a heavy rainfall cases."

To give direct answer to the reviewer, we would like to introduce the ORG and the SL runs with 50-km resolution for a heavy rainfall case occurred in 14-16 July 2001 over the mid-part of the Korean peninsular. Figure A1 shows 48-hours accumulated precipitation from the ORG run, the SL run, and the TMPA. It is clearly showed that the semi-Lagrangian advection scheme can improve an intense rainfall band. Please note that these results are not included in this paper because these experiments also examine impacts of a mass-conserving NDSL scheme (Zhang and Juang, 2012) for real-cases.

(a) ORG (b) SL (c) TMPA

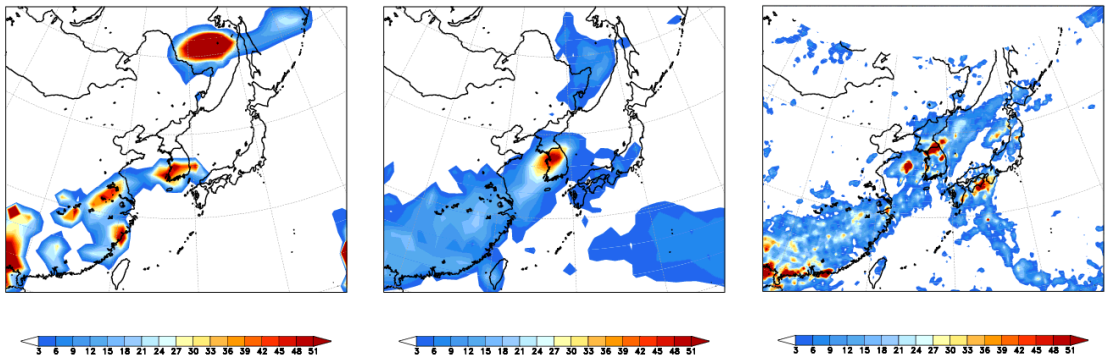


Fig. A1. 48-hours accumulated rainfall from (a) ORG run, (b) SL run, and (c) TMPA.

*[2] Page 4222, in the first paragraph of the introduction, the authors may need to emphasize what the specific advantage of "regional" spectral model is.*

: Responding to the reviewer's comment, we provide advantages of the regional spectral model in the introduction as follow:

"The RSM has advantages in accuracy for a regional high-resolution domain. In addition, the spectral representation of the RSM is two-dimensional perturbation method, which can eliminate the error due to reevaluation of the linear forcing from the base fields by the regional model (Juang et al., 1997). This is one of the reasons that the RSM can be easily used for long-range climate simulations."

*[3] This reviewer recommends strengthening information given by the introduction section. Study of Staniforth and Côté (1991) provides classical and comprehensive review, which may be referable in this paper. Recently, some studies have endeavored semi-Lagrangian advection scheme in regional model frameworks (e.g., Aranami et al. 2014); referring and comparison with those studies may helpful to address uniqueness of this study.*

: As the reviewer's recommendation, general review of the semi-Lagrangian and applying semi-Lagrangian method for a regional model are added in the introduction section.

"Staniforth and Côté (1991) reviewed semi-Lagrangian literatures for atmospheric models. They concluded that the semi-Lagrangian framework facilitates the incorporation of shape-preserving and monotonic schemes for moisture advection,

because of the relatively small dispersion errors in the presence of discontinuities or near discontinuities."

"For regional model system, the flux through the boundaries is needed to apply the mass restoration, whereas there are no boundaries for global domains. Aranami et al. (2015) applied a mass restoration scheme for limited-area models (LAMs) with semi-Lagrangian advection. As such, the boundary treatment is required to apply the NDSL advection scheme for the RSM."

*[4] Page 4223, line 3 to 4, it would be helpful if the authors provides brief descriptions about what kinds of topics have investigated with usage of regional spectral models. Besides NCEP RSM, there are series of regional spectral models that have been used (e.g., Lee and Hong 2014 and some references therein), which would be helpful to strengthen the importance of this study.*

: We added more descriptions about previous studies as follow:

"Kang and Hong (2008) assessed impact of the land surface parameters on the regional climate circulations. Kanamitsu et al. (2010) presented a refined spectral nudging technique for regional dynamical downscaling. Chang and Hong (2011) used the RSM to produce regional future scenarios by dynamical downscaling. Li et al. (2012) showed that the fully coupled RSM and regional ocean modeling system (ROMS) can produce detailed oceanic circulations over the California coast."

We also considered including studies from different regional spectral models, such as GRIMs RMP (Lee and Hong, 2014). However, we think presenting researches by the NCEP RSM only is more efficient to emphasize advantages of the NDSL in the RSM.

*[5] Page 4231, line 21, "However, ~ errors." Regarding to aforementioned description, it is hard to find materials underpinning this. Even though the simulated precipitation is far from the observation, as noted by the authors at the last paragraph of the last section, this reviewer thinks it is worth to show corresponding observation with respect to figure 9 and provide statistical index such as spatial correlation and/or root-mean- square error. This would be helpful to objectively explain even when model results are similar between ORG and SL experiments.*

: Thank you for the reviewer's comment. As we replied to the comment #1, we included rainfall observation (TMPA) in Fig. 9 and presented spatial correlation coefficients for the ORG and the SL runs.

We modified that paragraph as follow:

"However, the simulated surface depositions of radioactive tracers are still deviate from the observation and precipitation from the SL experiment does not show significant improvement, even though the NDSL removes severe errors."

**Technical corrections:**

*[1] Page 4224, line 1 to 2, GMP looks like different model to GRIMs while the GMP is a part of GRIMs. Please clarify the sentence.*

: Corrected accordingly.

"the Global/Regional Integrated Model System (GRIMs; Hong et al., 2013) Global Model Program (GMP)."