

Relation between the physical processes and spectral nudging in simulating regional climate

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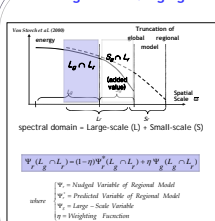
Introduction

- Regional climate models (RCMs) are one-way nested limited-area models that are used to downscale low-resolution atmospheric information, usually reanalyses or data simulated by general circulation model.
- Technically one-way nesting is performed by imposing the GCM coupling fields at the lateral boundaries of the limited area domain, which leads to an ill-posed problem for the partial differential equations of the RCM.
- This could possibly lead to **artificial data propagating into the regional model**. Such waves reflect and interfere with shorter waves, distorting the circulation on regional scale.
- As a solution, it has been proposed to **relax large-scales inside the regional model** towards driving fields. The so-called **spectral nudging** method has been developed by Waltron et al. (1996), Kida et al. (1991) and later by von Storch et al. (2000) and Biner et al. (2000).
- Nudging only the long waves allows the model to freely develop small-scale variability, and this maintains the utility of the nested model technique as a climate downscaling tool.
- As a drawback, the effect of small scales on the large-scale flow is greatly diminished, as the large scales are constantly relaxed toward the external fields.

- Would provide unrealistic large-scale feedback influencing the distortion of regional solution?**
- Precipitation improved by the nudging?
 - How the precipitation processes modulated by the nudging?
 - How physics sensitivity within the nudging?

Experimental Design

Large-scale Nudging Technique



In $L_s \ll L_L$, the results of the regional model should not deviate for the large-scale forcing because the results of L_s are considered skillful. Therefore, large-scale nudging technique is applied to these scales by using large values of α . In $S_s \ll L_L$, significant modifications are allowed in the regional model.

Spectral nudging is stipulated not only at the lateral boundaries but also in the model interior.

Scale Selective Bias Correction (Kanamaru and Kanamitsu 2007; Kanamitsu et al. 2009)

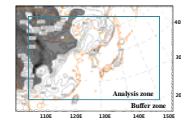
SSBC scheme is similar in function to the spectral nudging technique

- The nudging is applied to rotational part of wind perturbation (UV damping).

$$F_{m,n}^{rot} = \frac{1}{1 + \alpha} F_{m,n}^{rot}(m,n)$$
 For m, n, c, m_1, n_1 ; F : perturbation ($F = A_{rot} A_{uv}$); α : damping coefficient ($0 < \alpha < 1$)
 - The damping coefficient has a value of 0.9 which does not vary with height, which differs from other spectral nudging method.
 - The critical scale is set to the physical scale 1000 km, and consequently the critical wavenumber m_1 and n_1 vary with domain size and model resolution.
- A area averaged-perturbation is corrected for T (T correction).
 - The surface pressure perturbation correction is calculated from the hydrostatic equation with the surface elevation difference between the reanalysis and the regional model topography and area mean temperature. (sfc P correction).

Experimental Design

- Model : NCEP RSM (Jiang et al. 1997)
- Grid : 129 × 86 (horizontal resolution : 50km)
- BDY : NCEP/DOE Reanalysis II data (R2)
- LSM : OSULSM2 (Mahrt and Pan 1984)
- PBL : YSU_PBL (Hong et al. 2006)
- Convection : SAS (Hong and Pan 1996)
- Spectral nudging : NoSSBC / SSBC (Kanamitsu et al. 2009)



Impact of large-scale nudging on precipitation

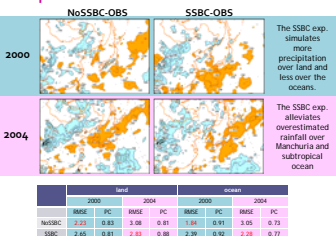
Precipitation (1979-2004)



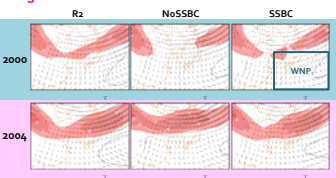
In 2000, error is increased and correlation is decreased by using nudging

In 2004, error is decreased and correlation is increased by using nudging

Precipitation



Large-scale circulation

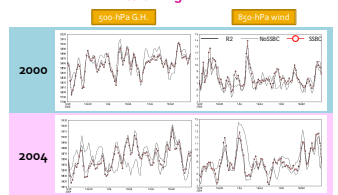


Summary & Conclusion

- Is precipitation improved by the nudging?
- How the precipitation processes modulated by the nudging?

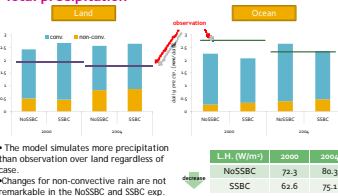
- In single case, precipitation is improved or not by the nudging. Although large-scale nudging works negatively to simulation of precipitation in single case, the large scale correction certainly helps to improve the simulation of precipitation in terms of interannual variability as shown in previous study (Kanamitsu et al. 2009).
- One possible reason for negative effect is that it is dependent on rainfall mechanism (e.g. baroclinic instability or local instability).
- While a complete understanding of doxious effect of spectral nudging has not yet been achieved, one of the comforting results of this investigation seems to be a clue to identify potential undesirable side effects brought by the use of large-scale nudging.

Time-series over WNP region



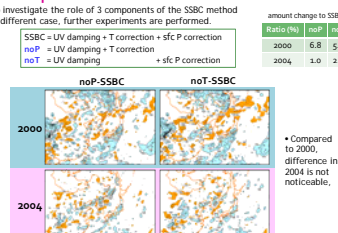
- In both 2000 and 2004, the simulated trends from the SSBC run follow that from reanalysis.
- Error in 2000 are not as large as in 2004, therefore, improvement is not dramatic.
- On the other hand, for summer 2004, the SSBC run improves temporal evolution of 850-hPa height, especially, weakened intensity during July represented in the NoSSBC.

Total precipitation



- Over the ocean, SSBC reduces amount of precipitation regardless of case, which has different meaning in each year.
- In 2000, less precipitation by applying the SSBC method indicates large bias, while, in 2004, the SSBC experiment improves positive bias in the NoSSBC experiment.
- The reduced precipitation is caused by decrease of convective rain in both years.

Precipitation difference

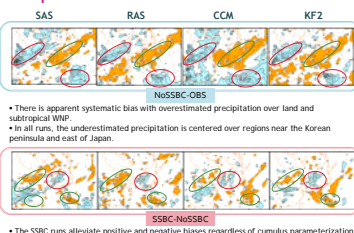


- In 2000, the impact of T correction and P correction is significant (mass dependent).
- In 2004, the impact of UV damping is more reliable (baroclinic dependent).

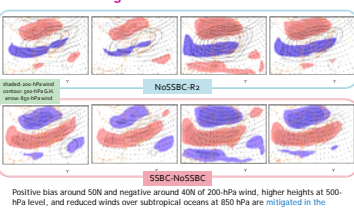
Impact of large-scale nudging on physics forcing

- Four convection schemes (JJA 2004)
 - SAS (Hong and Pan 1998)
 - RAS (Moorthi and Suarez, 1992)
 - CCM (Zhang and McFarlane, 1995)
 - KF2 (Kain 2004)

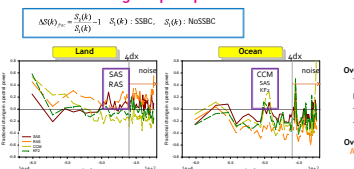
Precipitation difference



Difference of large-scale circulation



Fractional change of precipitation

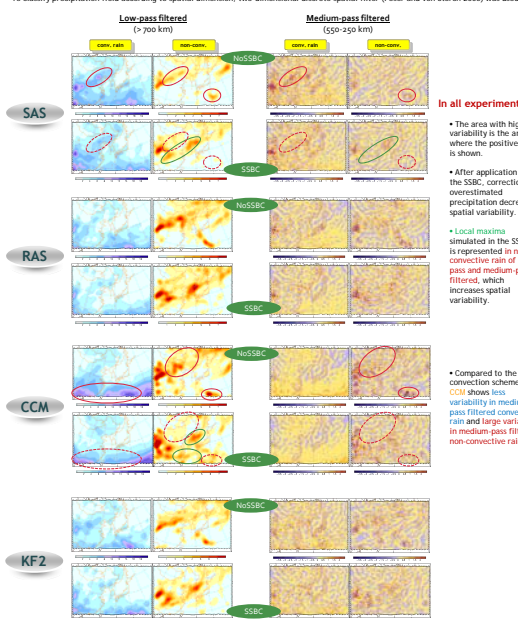


Summary & Conclusion

- This study assesses the sensitivity of regional climate model to the choice of cumulus parameterization scheme and the influence of adopting the SSBC method on the modeling of summer precipitation over East Asia.
- The internal spectral nudging is capable of providing the model with reliable states of these crucial large-scale systems, therefore enables the regional model with a more reasonable background for resolving precipitation.
- Compared to experiments without the SSBC, individual experiment with the SSBC shows different added information in four convection scheme over land, whereas the spatial variability is decreased by using the large-scale nudging over the ocean because of less precipitation over western north Pacific.
- Large-scale errors in the regional domain interact with the small-scale and distort variability in fields of precipitation, which is removed by large-scale error correction.

Precipitation difference

To classify precipitation field according to spatial dimension, two-dimensional discrete spatial filter (Eser and von Storch 2005) was used.



How physics sensitivity within the nudging?

- The spectral nudging technique may have the potential to diminish or eliminate regional climate model's sensitivity to convective parameterization schemes.
- Note that large-scale nudging decreases systematic error, which results in improvement in simulation of precipitation.
- As a result, eliminating model's sensitivity to convection scheme may not be a side effect induced by spectral nudging methodology.