Investigating the Scale Dependence of SCM Simulations by Using 3D Forcing

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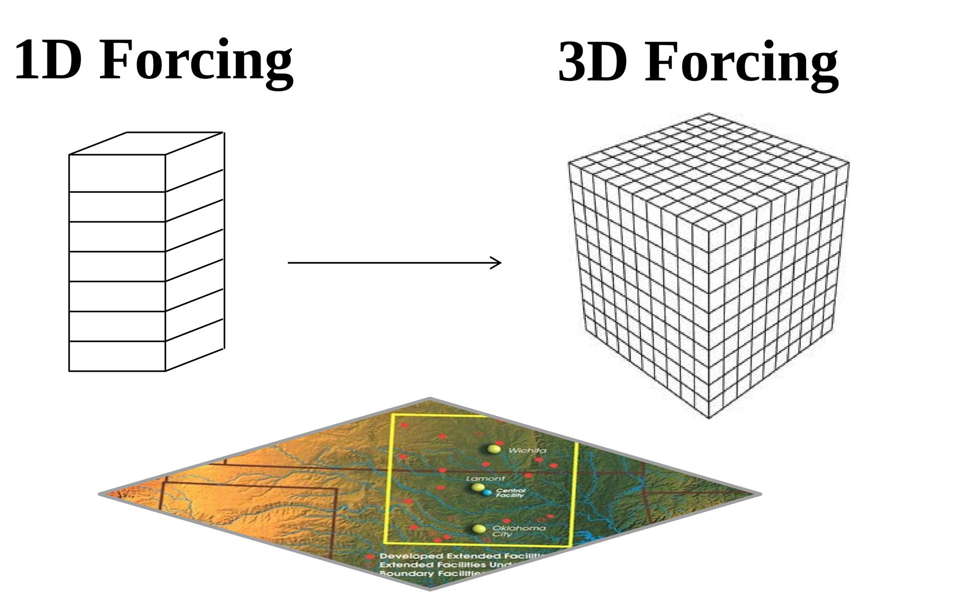
Introduction

- Previous studies (e.g., Xie et al., 2005) have indicated that SCM/CRM simulation errors might be partially attributed to the **lack of spatial variability** in the domain-mean large-scale forcing fields.
- The spatial variability of the large-scale forcing can be described in the gridded forcing data from a 3D constrained variational analysis (3DCVA) method (Tang and Zhang 2015).
- This study will use this gridded large-scale forcing data to investigate the benefits of including spatial variability and to explore its impacts on SCAM5 simulations of clouds and precipitation.

Gridded Large-Scale Forcing



$$\left\langle \nabla\cdot\vec{V}\right\rangle = -\frac{1}{g}\frac{dP_s}{dt}$$

$$\frac{\partial\langle q\rangle}{\partial t}+\left\langle \nabla\cdot\vec{V}q\right\rangle = E_s - P_{rec} - \frac{\partial\langle q_l\rangle}{\partial t}$$

$$\frac{\partial\langle s\rangle}{\partial t}+\left\langle \nabla\cdot\vec{V}s\right\rangle = R_{TOA} - R_{SRF} + LP_{rec} + SH + L\frac{\partial\langle q_l\rangle}{\partial t}$$

$$s \equiv C_pT + gz$$

Methodology

March 2000 IOP at SGP:

- Analysis domain: 5º × 4.5º
- Sub columns: 0.5º × 0.5º

SCAM5 settings:

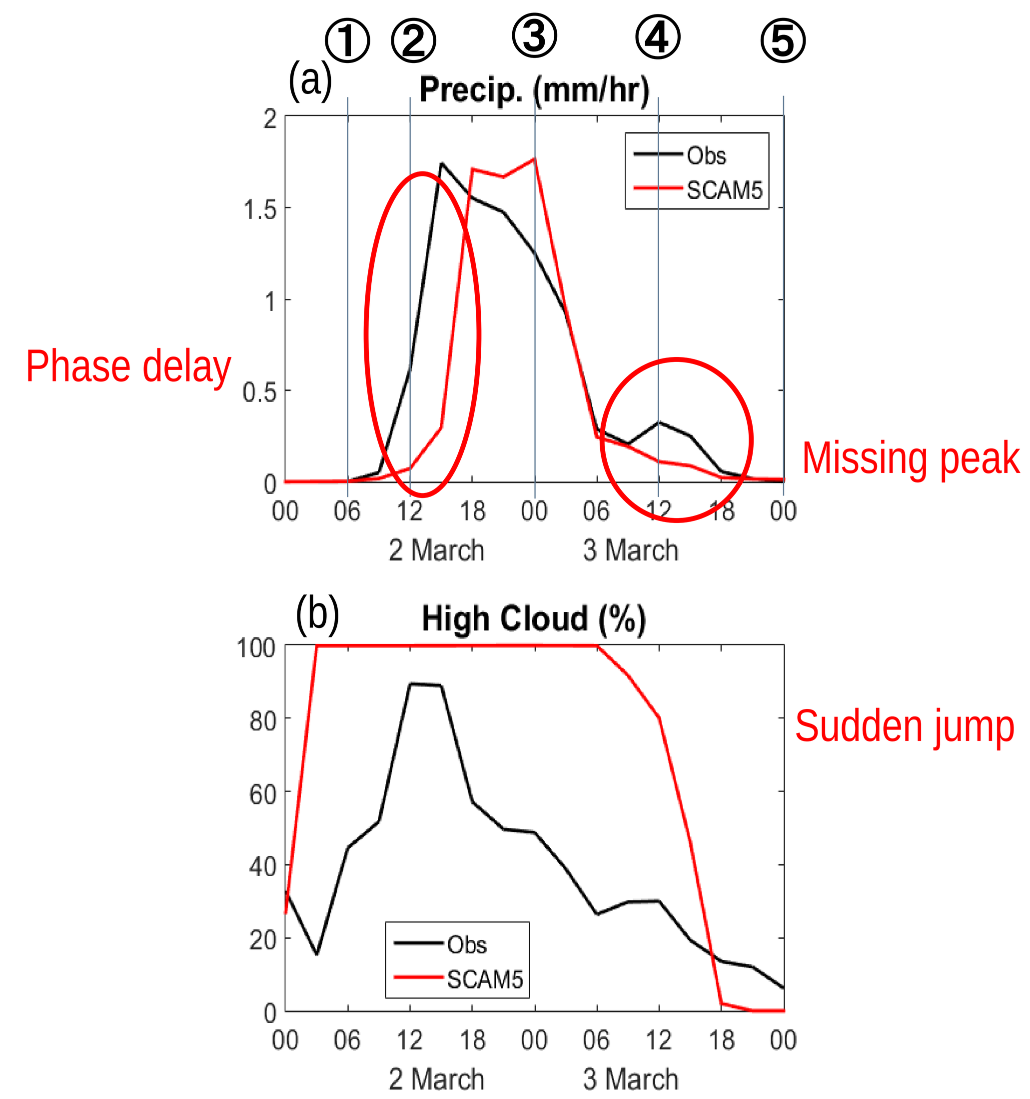
- Model started every 3 hr and simulations from 6 – 9 hr are used
- Prescribed surface turbulence fluxes
- No nudging

Experiment design:

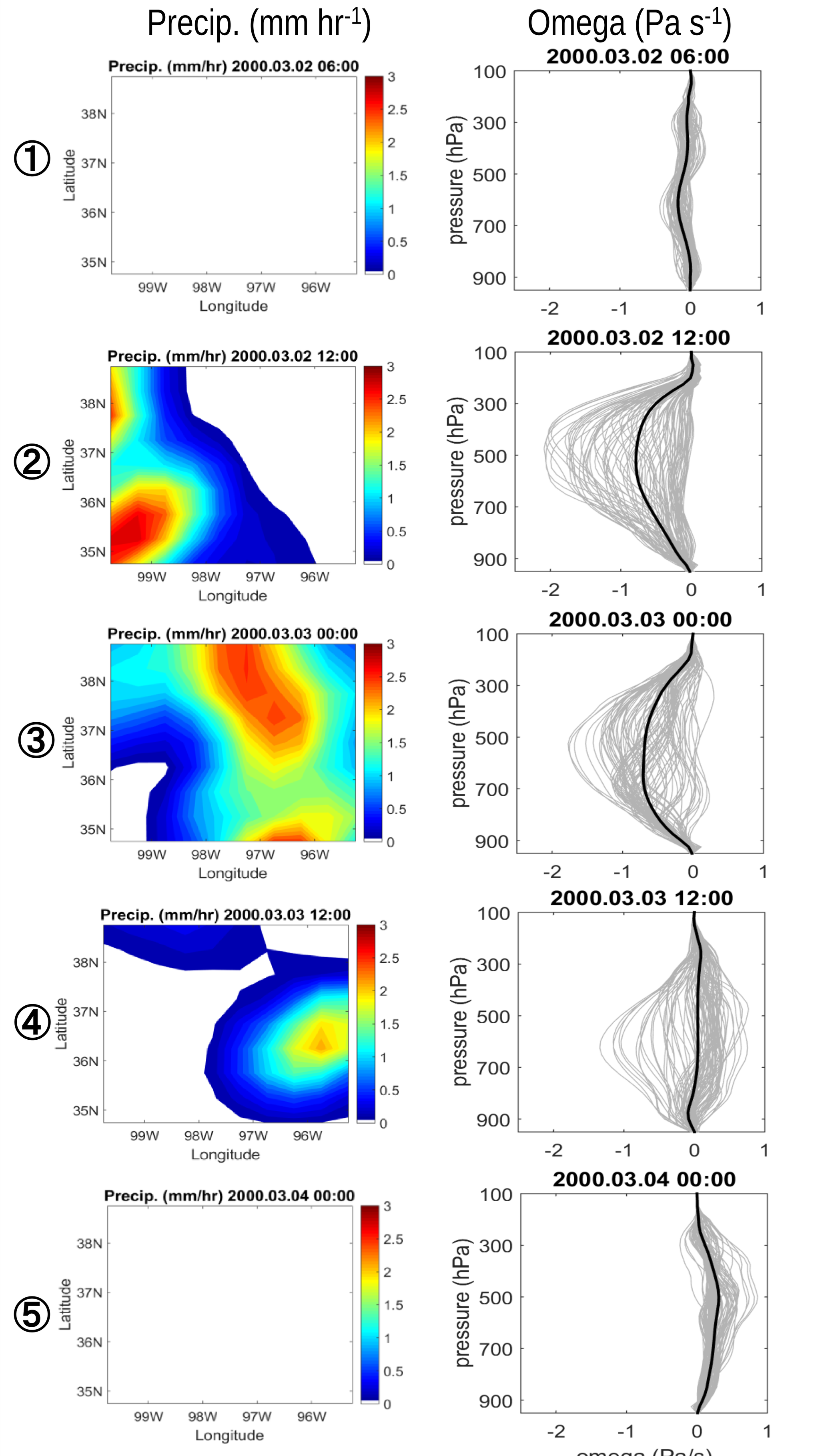
1. SCAM5 with domain-mean forcing (1D Forcing)
2. SCAM5 with each sub-column of the 3D Forcing, and the results are averaged over the domain for comparison

SCAM5 with 1D Forcing

Time series of surface precipitation (a) and high cloud (b)



Spatial Variability of Forcing Fields

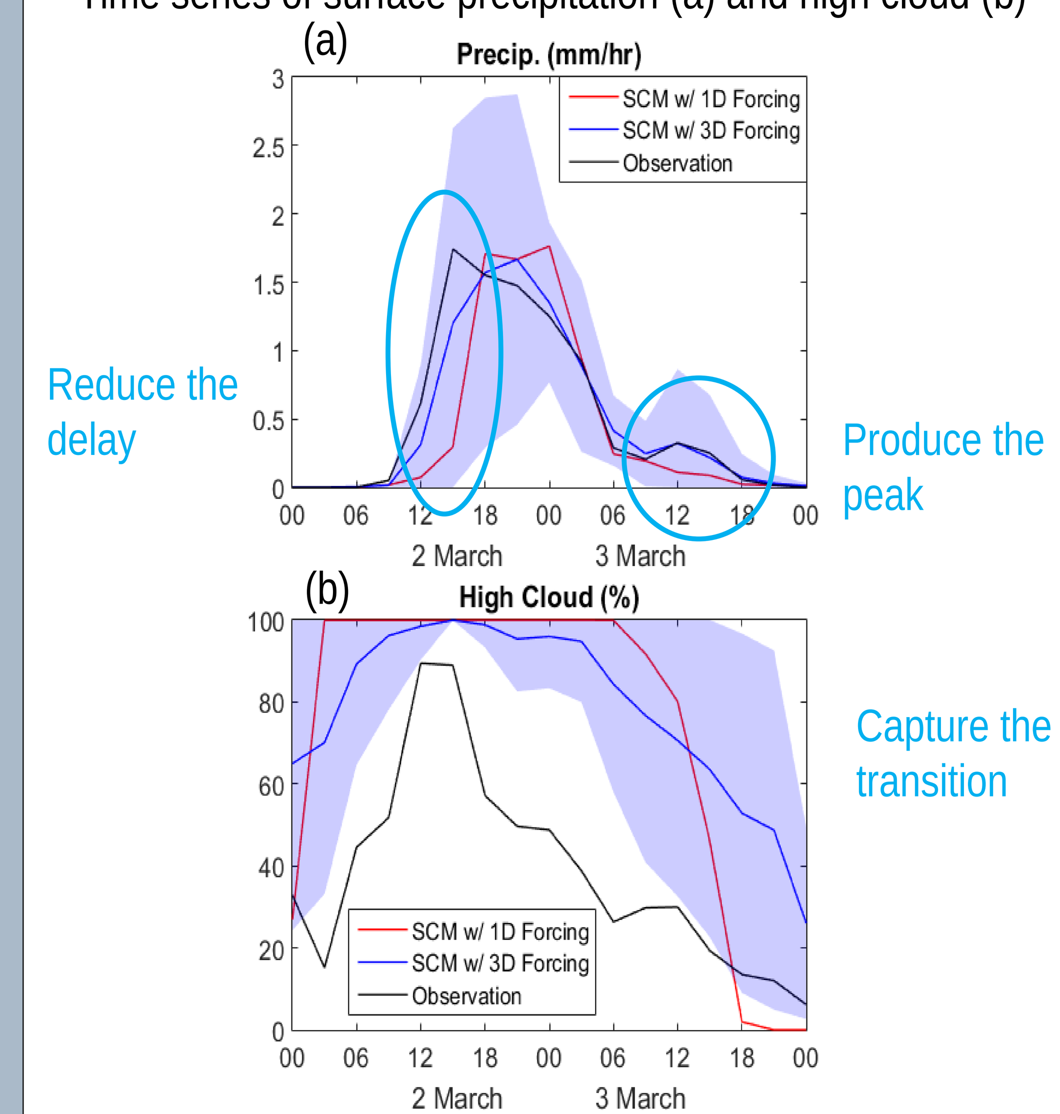


Spatial pattern of surface Precipitation

Domain-mean (black) and sub-column (gray) omega

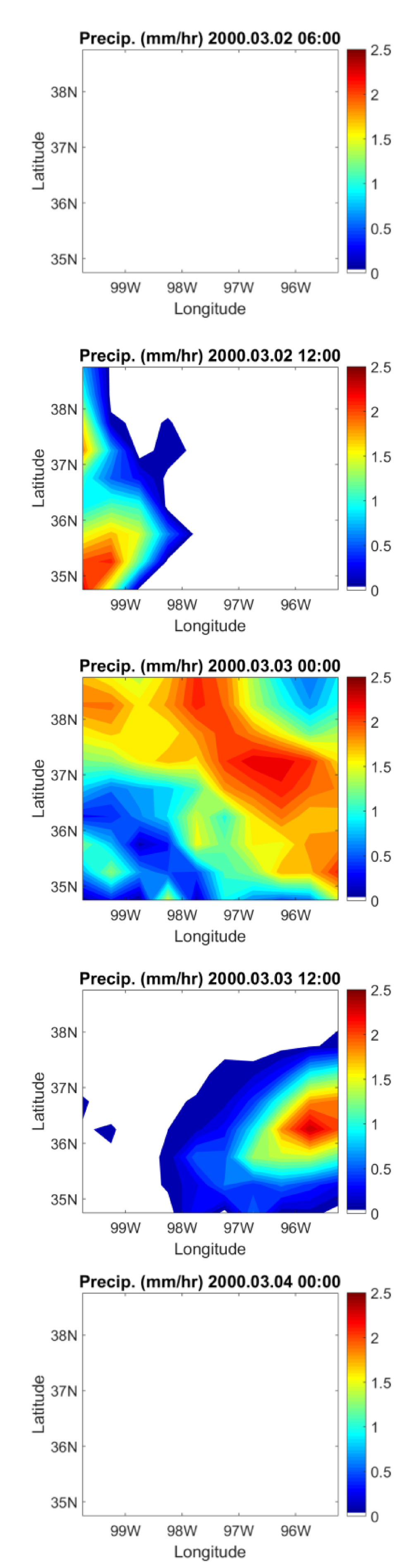
SCAM5 with 3D Forcing

Time series of surface precipitation (a) and high cloud (b)



SCAM5

Precip. (mm hr-1)



Domain-mean Precip.

Obs.	With 1D Forcing	With 3D Forcing
0.01	0.00	0.01
0.69	0.07	0.31
1.24	1.76	1.35
0.30	0.11	0.32
0.00	0.01	0.01

Statistics

RMSE of domain-mean fields for the whole March 2000 IOP (2-20 March).

	PREC	LWP	LWT	SWT	LWS	SWS
SCM w/ 1D Forcing	0.174	0.107	20.6	23.1	26.3	27.7
SCM w/ 3D Forcing	0.085	0.094	16.8	19.3	25.4	28.8

	CLDT	CLDH	CLDM	CLDL
SCM w/ 1D Forcing	38.4	40.7	37.1	52.4
SCM w/ 3D Forcing	32.3	33.0	29.1	44.6

- For most of variables SCAM5 with sub-column forcing has smaller RMSE than SCAM5 with domain-mean forcing.
- This RMSE difference is larger during frontal systems with larger spatial heterogeneity, but smaller in more homogeneous conditions.

Summary

- With the spatial variability of the large-scale forcing, SCAM5 better capture the characteristics of the frontal system with large spatial heterogeneity.

Potential Application

- Obtain a probability distribution function (PDF) of the large-scale forcing based on its spatial variability, and implement it in SCMs to allow the investigation of its nonlinear response of model physics on the large-scale dynamics.
- Average (interpolate) the gridded large-scale forcing data into different grid sizes to evaluate scale-aware parameterizations.
- Apply in CRM/LES to study the impact of spatially heterogeneous large-scale forcing.

Acknowledgement

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References

Xie, S., et al. (2005), JGR: A, 110(D15),
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