Evaluation of Cloud Resolving Simulations by WRF driven by ARM Continuous Forcing

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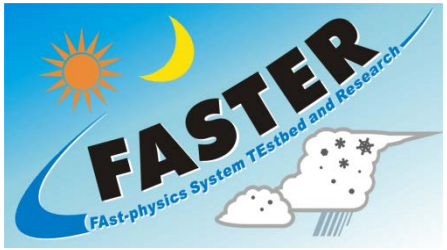
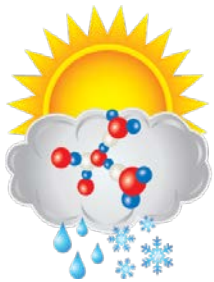


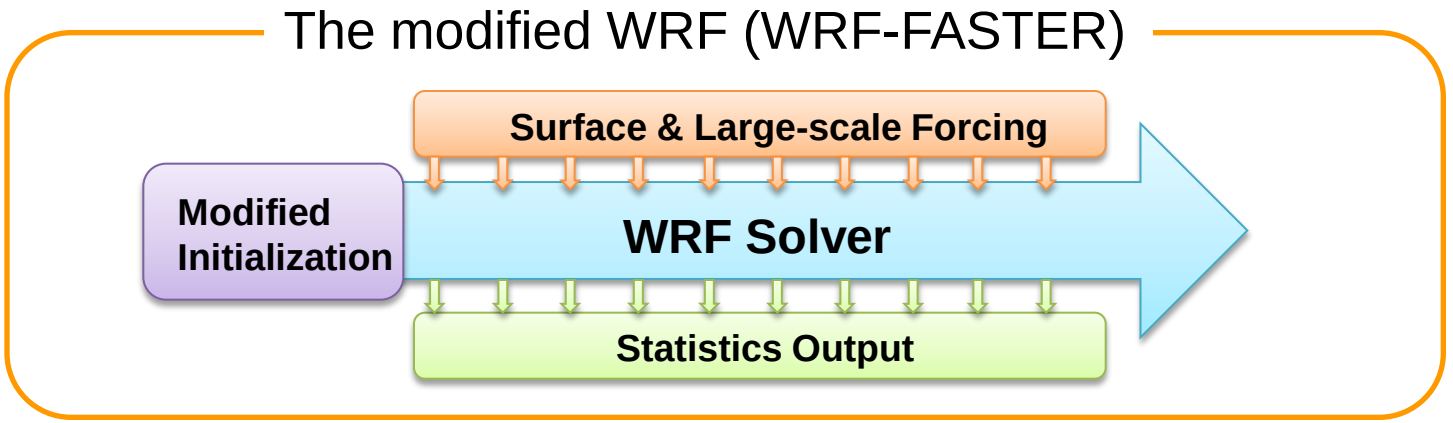


ASR
Atmospheric System Research

Motivation

● Large-eddy simulation (LES) and cloud-resolving models (CRM) have been widely used to study a variety of atmospheric phenomena and its parameterizations.

● Since the default functions of WRF's function was not suited for this purpose, we extended the capability of WRF for the CRM simulations.



● The framework have been validated for weakly-forced idealized simulations (GCSS cases).

We test the simulation under strong large-scale forcing in March 2000 IOP at SGP (FASTER warm-up case).

Large-Scale Forcing

- Large-scale forcing is represented as an additional source/sink term.

- There are three approaches commonly taken to implement the large-scale forcing:
  1. Advective forcing,
  2. Relaxation, and
  3. Combination of 1 and 2.

Advective forcing

$$\left(\frac{\partial \theta}{\partial t}\right)_{\mathrm{LS}} = -\mathbf{V}\cdot\nabla\Theta - W\frac{\partial \theta}{\partial z}$$

$$\left(\frac{\partial q_v}{\partial t}\right)_{\mathrm{LS}} = -\mathbf{V}\cdot\nabla Q_v - W\frac{\partial q_v}{\partial z}$$

Relaxation

$$\left(\frac{\partial \theta}{\partial t}\right)_{\mathrm{R}} = \frac{\Theta - \overline{\theta}}{\tau}$$

$$\left(\frac{\partial \mathrm{q_v}}{\partial \mathrm{t}}\right)_{\mathrm{R}} = \frac{\mathrm{Q_v} - \overline{\mathrm{q_v}}}{\tau}$$

Which approach fits our purpose? How the relaxation works...?

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Three 2D experiments

ADV

ADV+RLX (τ = 3 h)

RLX (τ = 3 h)

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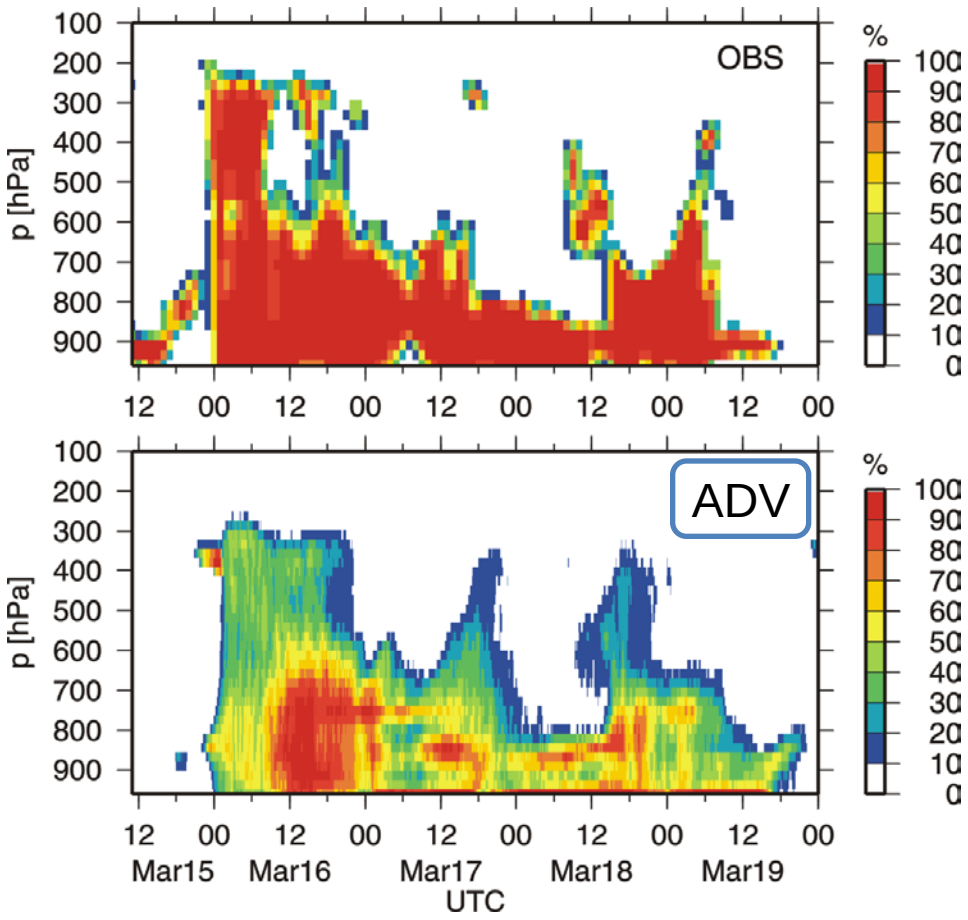
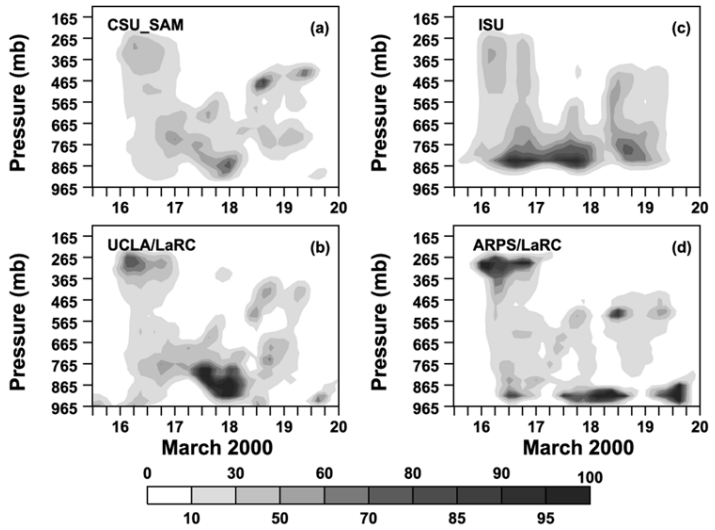
Cloud Fraction in ADV



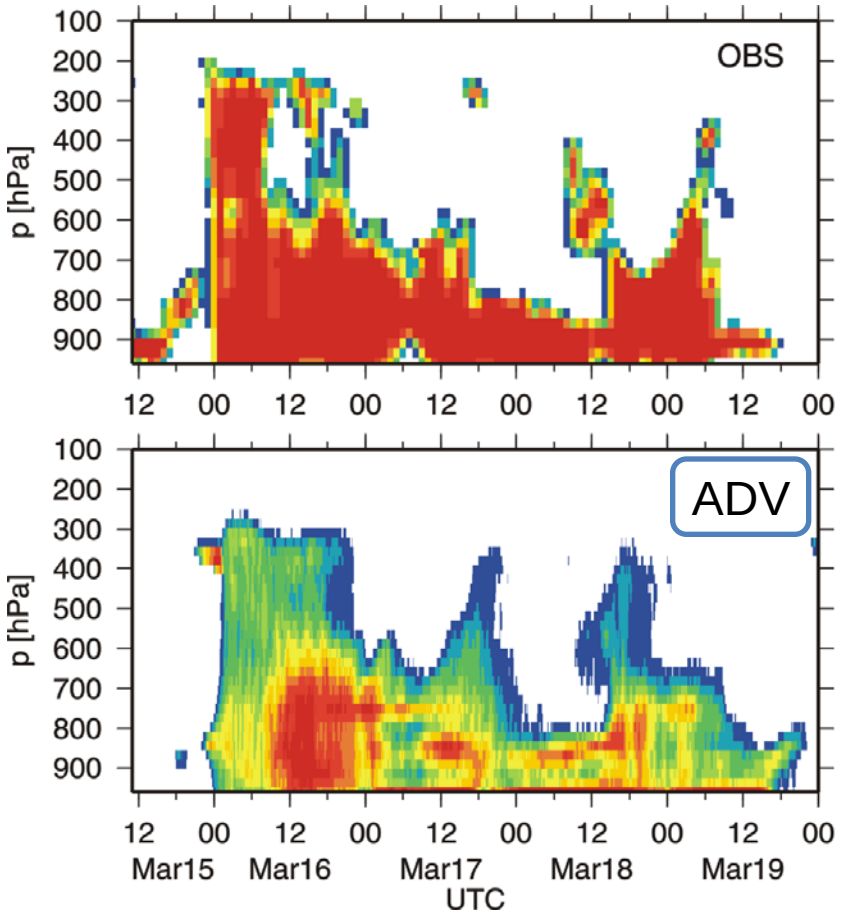
Cloud fraction in other CRMs

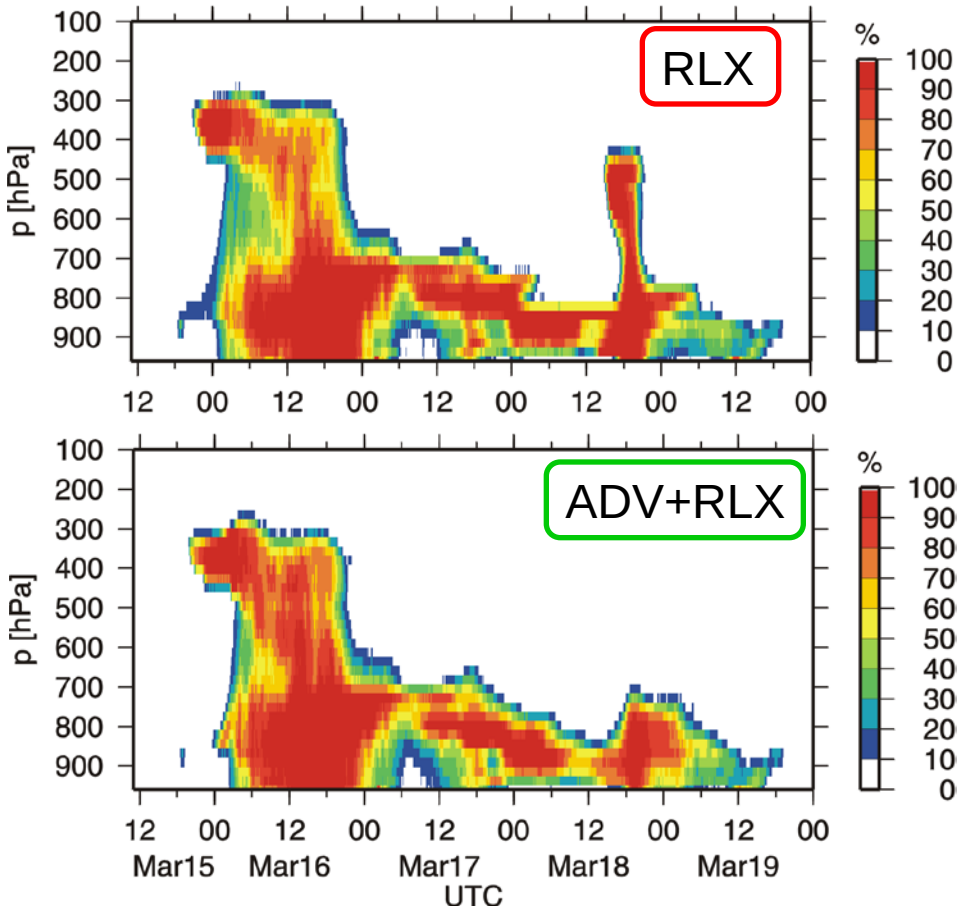


Xu et al. 2005

The ADV simulation produced smaller cloud fraction than of the observed.

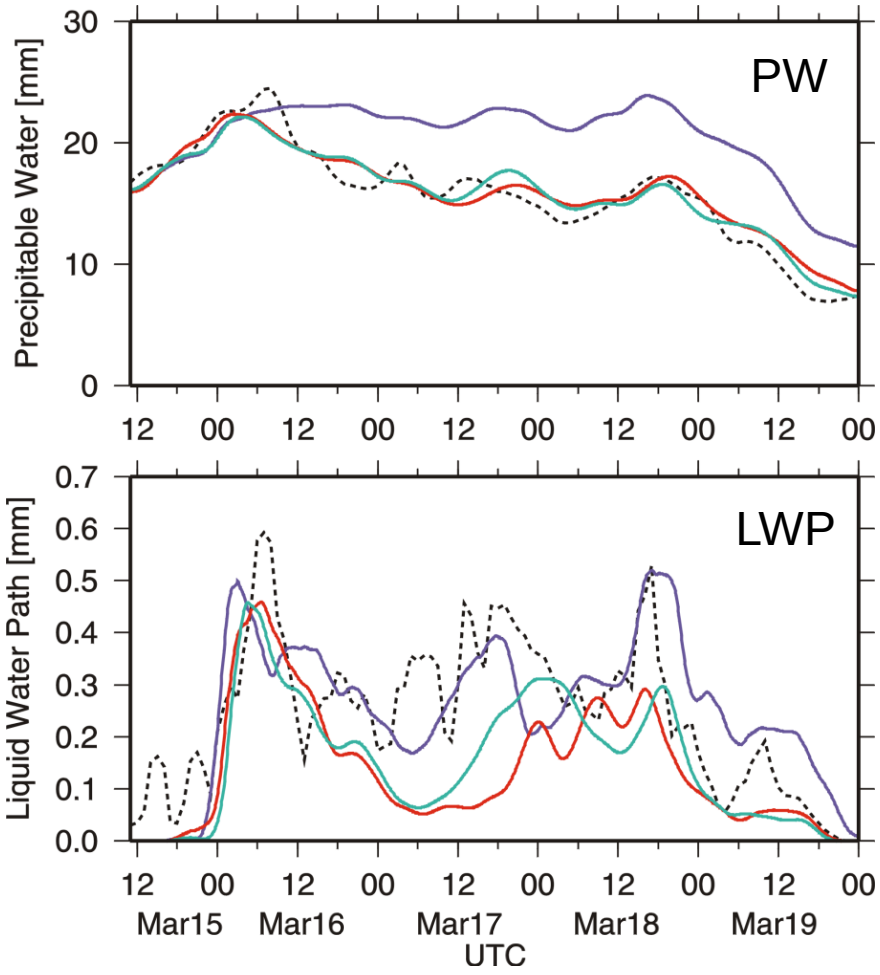
Cloud Fraction in ADV, RLX and ADV+RLX

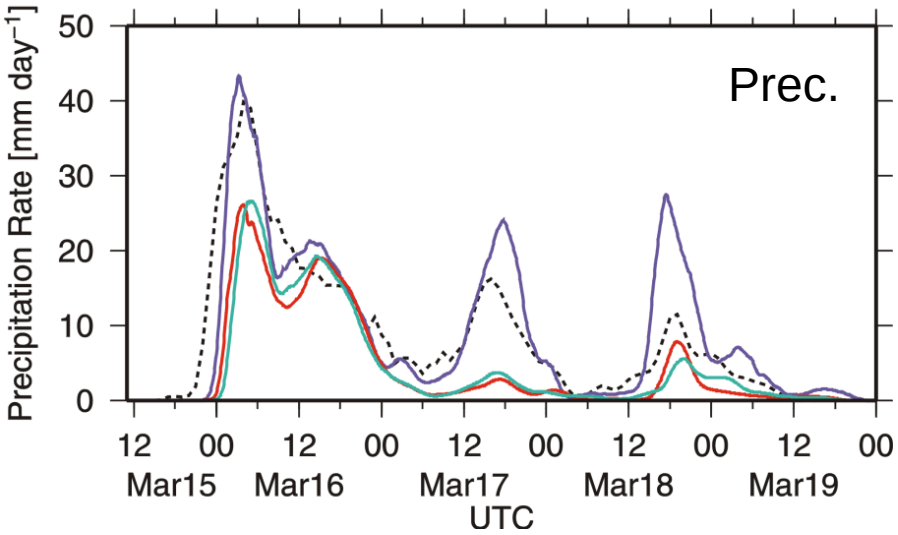




Relaxation increased cloud fraction.

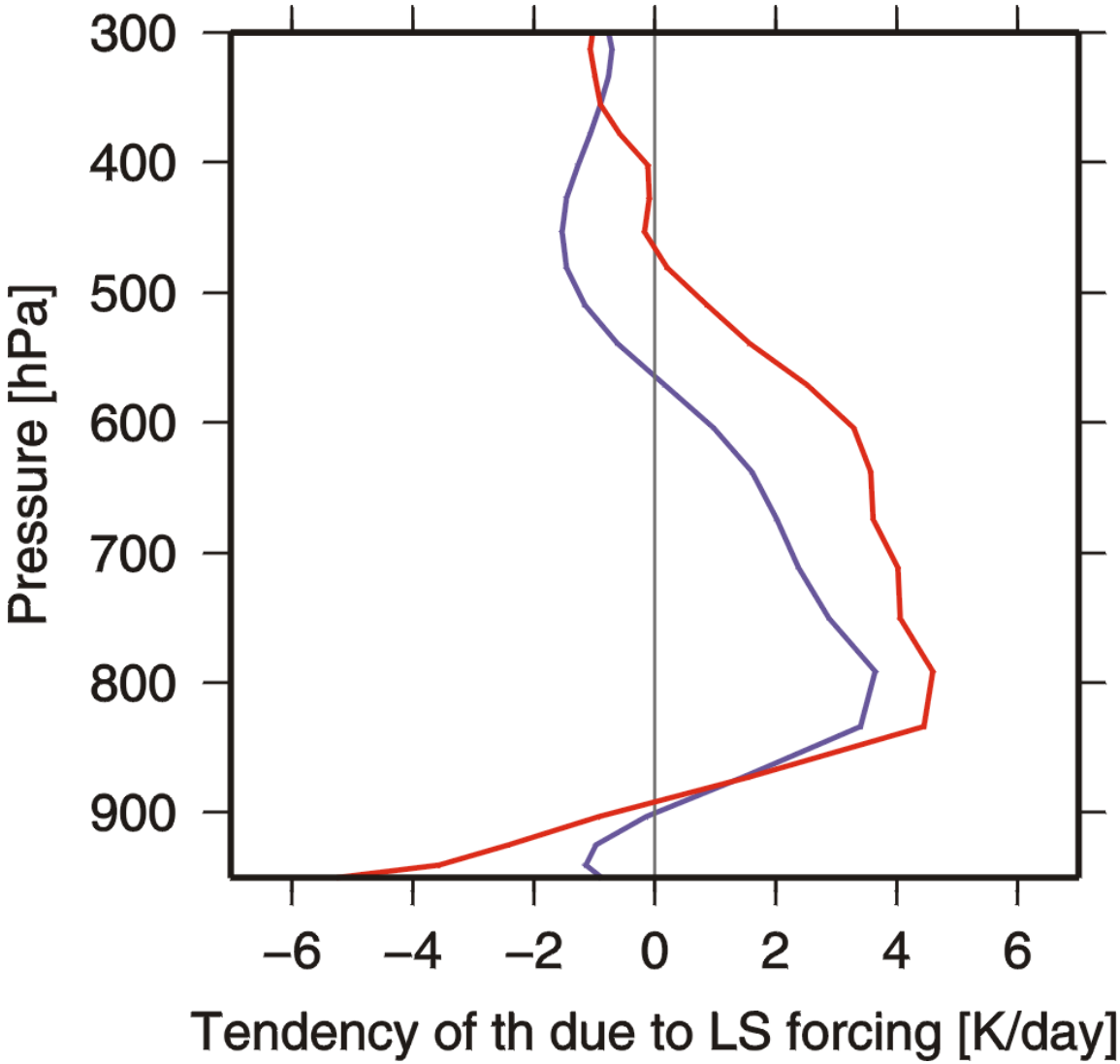
Time series of PW, LWP, and surface precipitation





ADV overestimated surface precipitation, while RLX and ADV+RLX underestimated it.

LS forcing averaged over the period



On average, relaxation stabilized the atmosphere in the low level.

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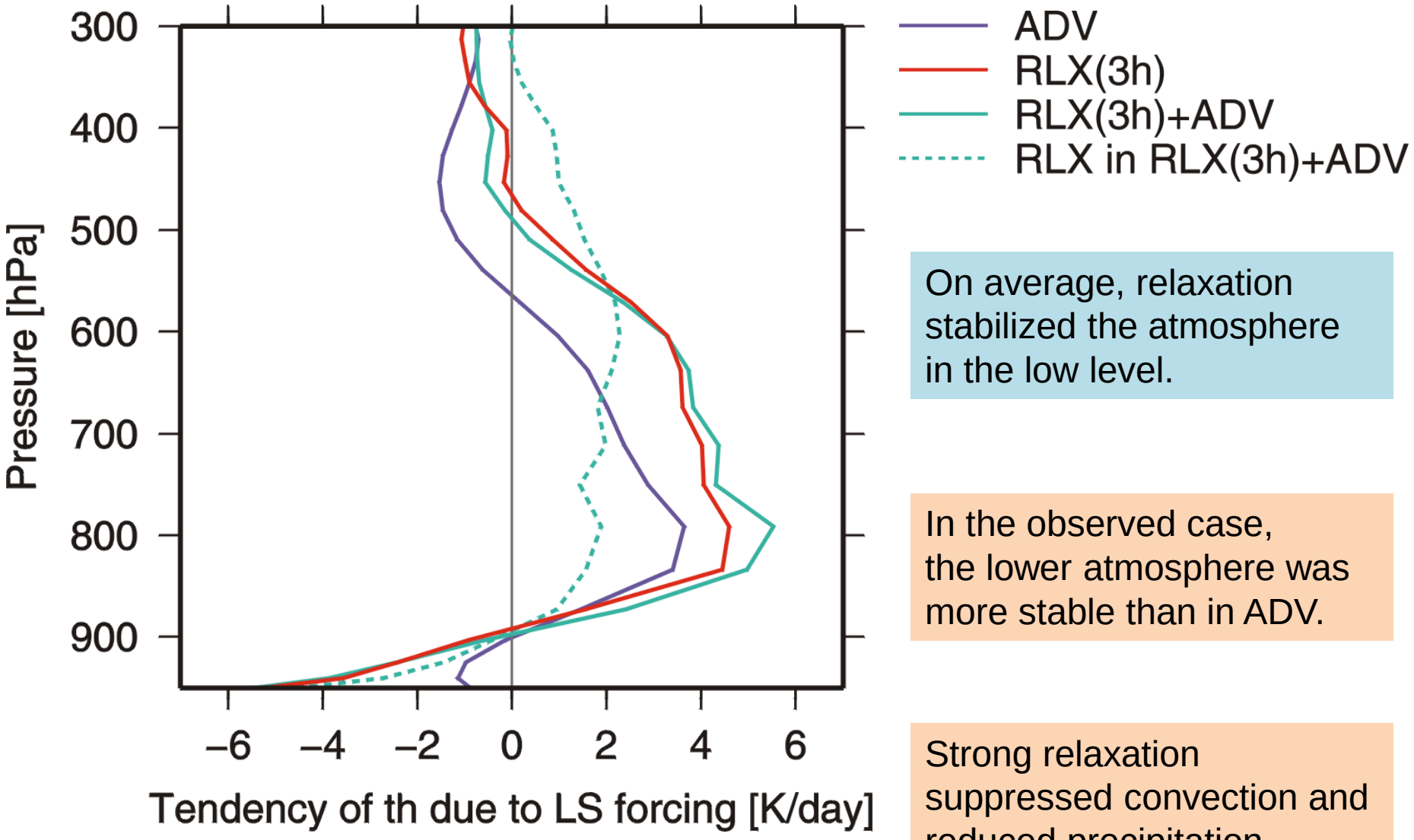
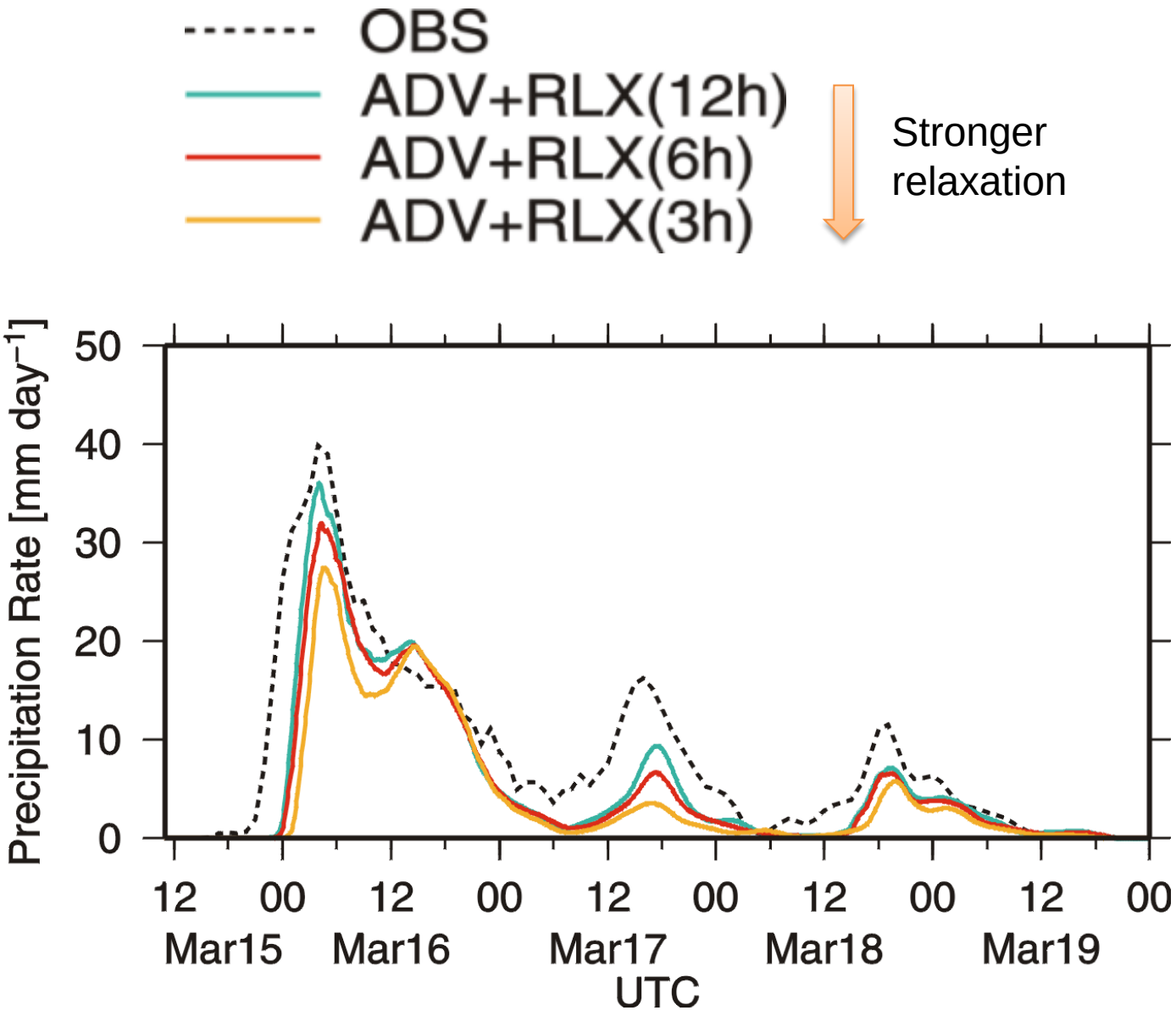


On average, relaxation stabilized the atmosphere in the low level.

In the observed case, the lower atmosphere was more stable than in ADV.

Strong relaxation suppressed convection and reduced precipitation.

ADV+RLX experiments with changing tau



Summary & Next Steps

Using the WRF-FASTER, we examined the LS forcing strategies.

- The frontal clouds in March 2000 IOP at SGP simulated with advective forcing produced more surface precipitation with less cloud fraction.

- The simulations with relaxation showed better agreement in cloud fraction. However, relaxation stabilized the lower atmosphere, and reduced precipitation.

- Relaxation would be able to produce better profile, but it may skip or change process of interest.

Next steps
- Summer time local convection
- Longterm simulation with adv + weak relaxation