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Evaluation of Ice Nucleation Parameterizations in a Thunderstorm case of DC3

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Acknowledgement:

- My postdoc Kyo-Sun Lim
- My collaborators: Vaughan Phillips, Xiaohong Liu, Paul DeMott, Ruby Leung, Qing Yang

Objectives

- **Evaluate model performances of WRF-CAM5 at high resolutions.**
- **Intercompare recent heterogeneous ice nucleation parameterizations with field campaign observations.**
- **Examine dust effects on cloud and precipitation through ice nucleation.**

Ice nucleation parameterizations

- **Meyers parameterizations (Meyers et al. 1992): temperature-dependent**
- **DeMott2013 (DeMott et al., 2013, ACPD): connects with dust number concentrations with size >0.5 microns.**
- **Phillips2013 (Phillips et al., 2013, JAS): number and surface area of dust and soluble organics.**
- **Niemand2012 (Niemand et al. 2012, JAS): number and surface area of dust**
- **DW2004 (Diehl and Wurzler 2004): connect with dust particles and SO_4.**

Methods

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- **WRF-CHEM model (Version 3.4.1) with the physics package from CAM5**

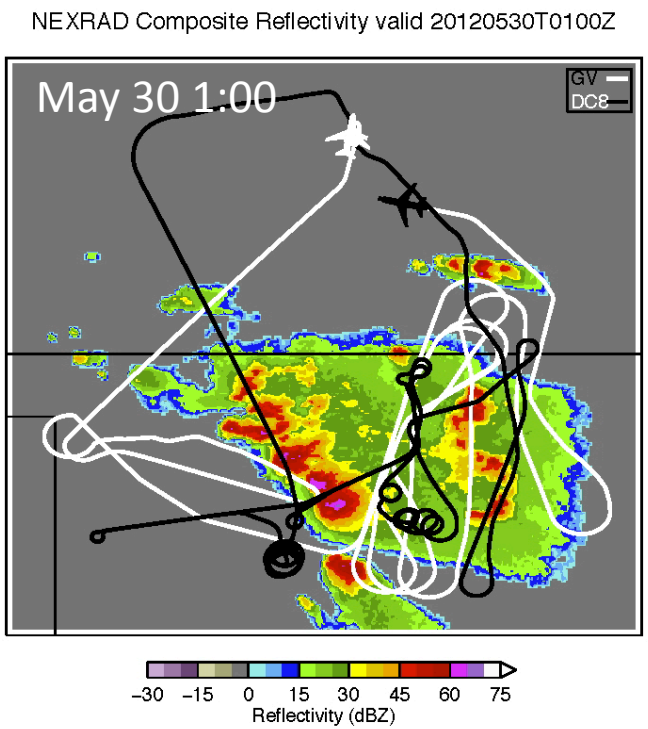
- Physics packages: CAM5 physics package
- 4 km resolution without Cumulus parameterization
- Microphysics: Morrison and Gettelman 2008
- PBL scheme: CAM5 UW
- Shallow cumulus: CAM5 US
- SW and LW radiation schemes: RRTMG

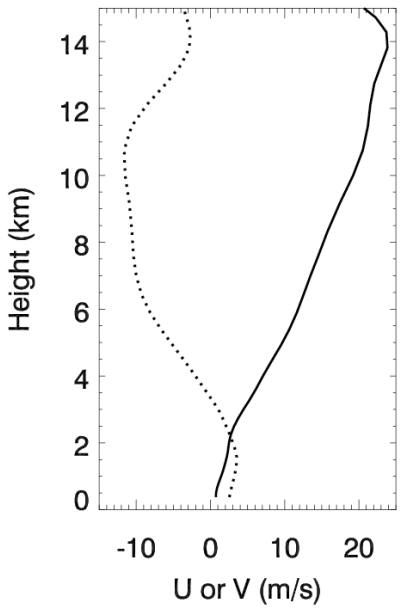
- **Initial and boundary meteorology data: NARR**

- **Chemistry and Aerosols model and data**

- Model chemistry and aerosol: CBMZ and MAM3
- Emission data: NEI05

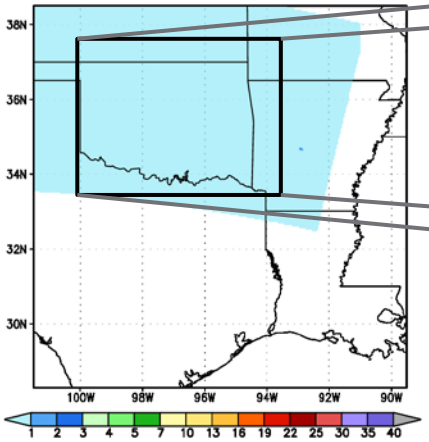
DC3 Case – May29-30



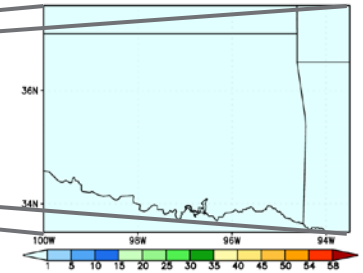


- Cloud base temperature: 18.3 C
- Cloud base height: 1.8 km
- U increases from 0.7 to 10 m/s from the surface to 5.3 km

Simulation domain

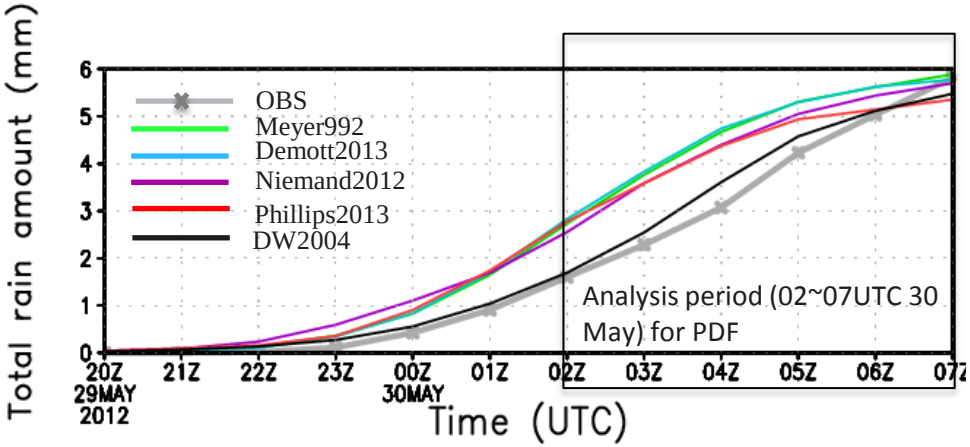


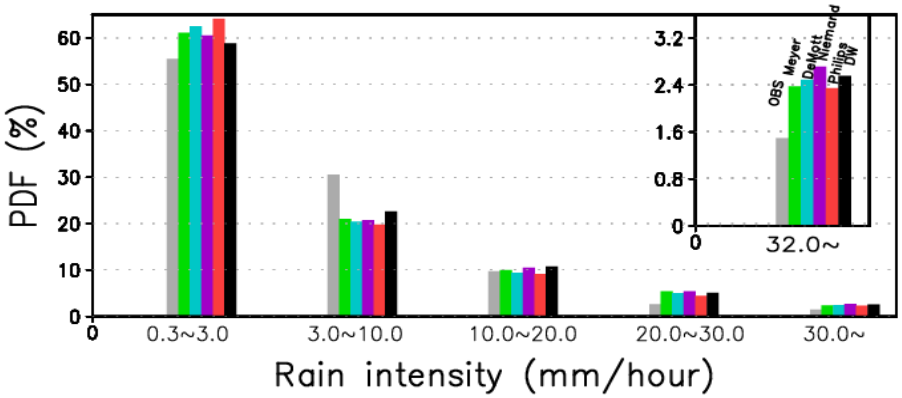
Analysis domain



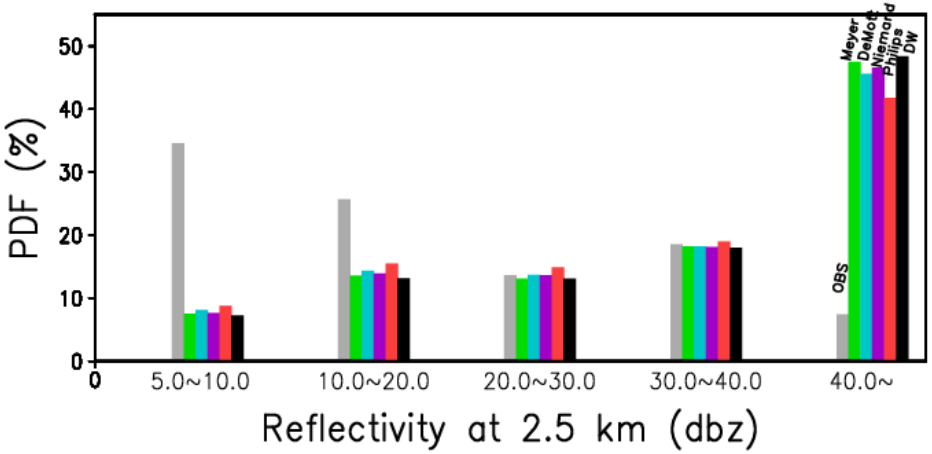
Precipitation and radar reflectivity

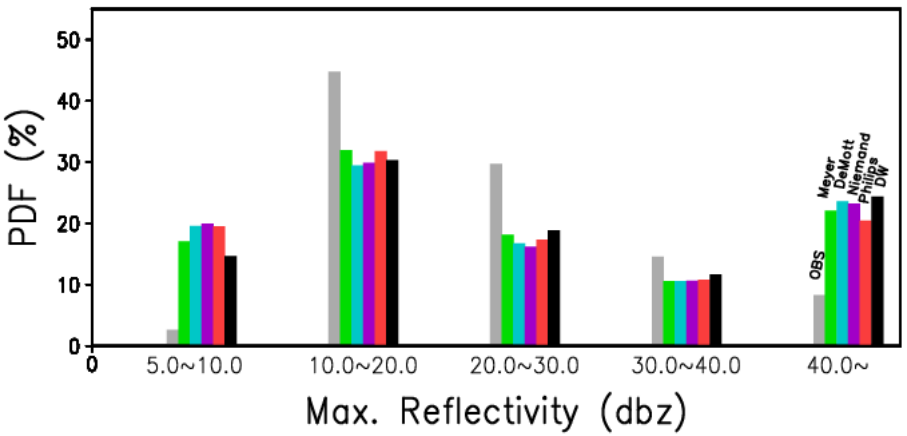
Rain amount and rain rate



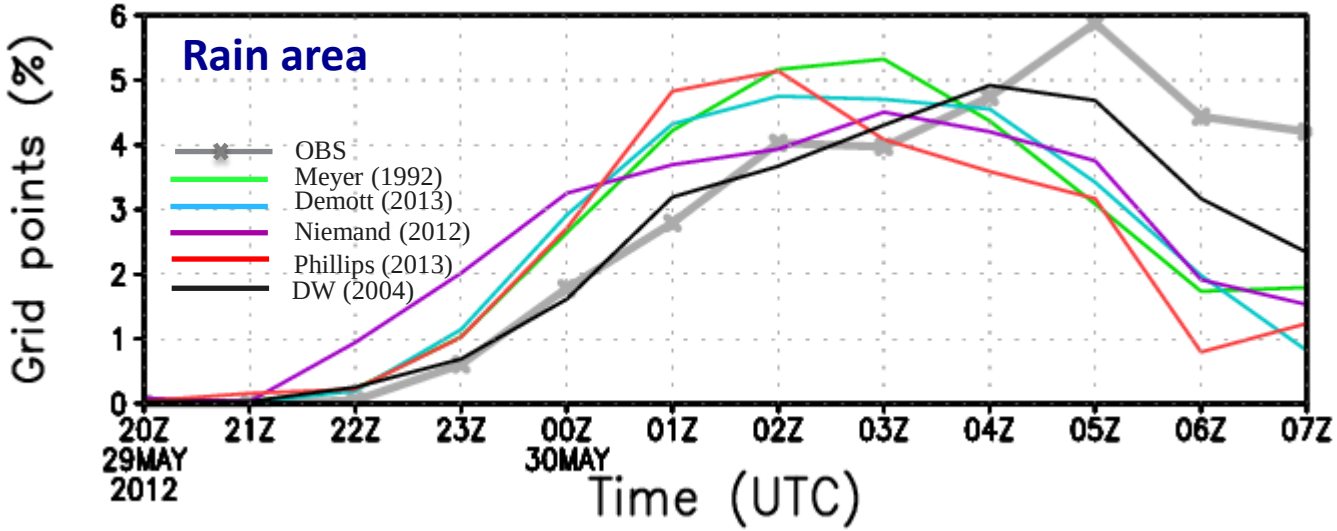


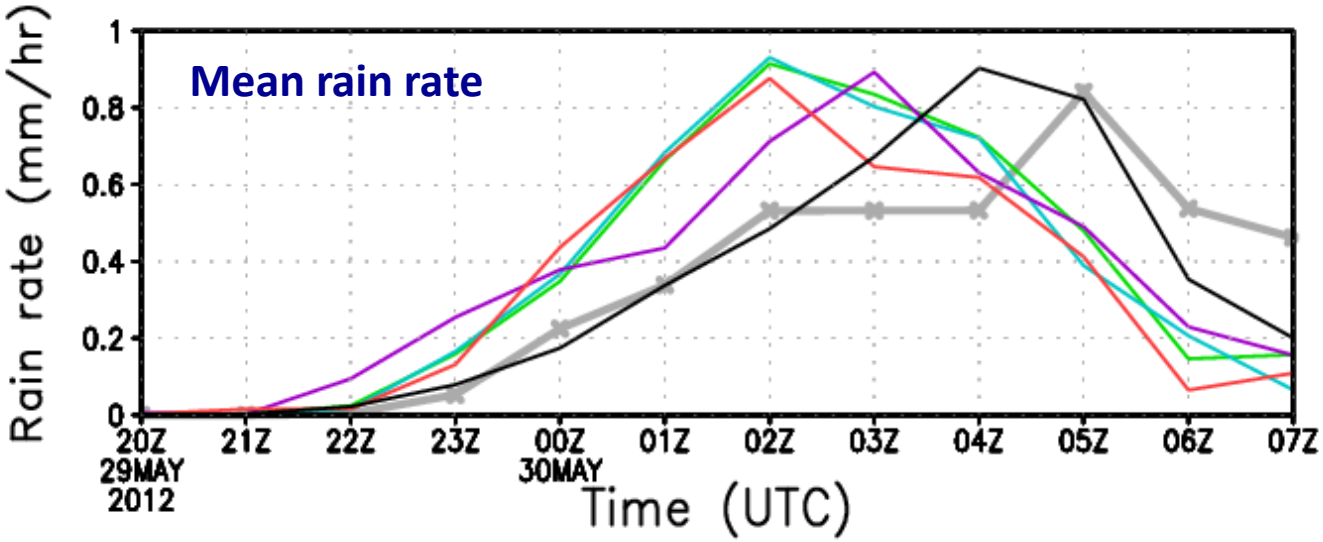
Radar Reflectivity



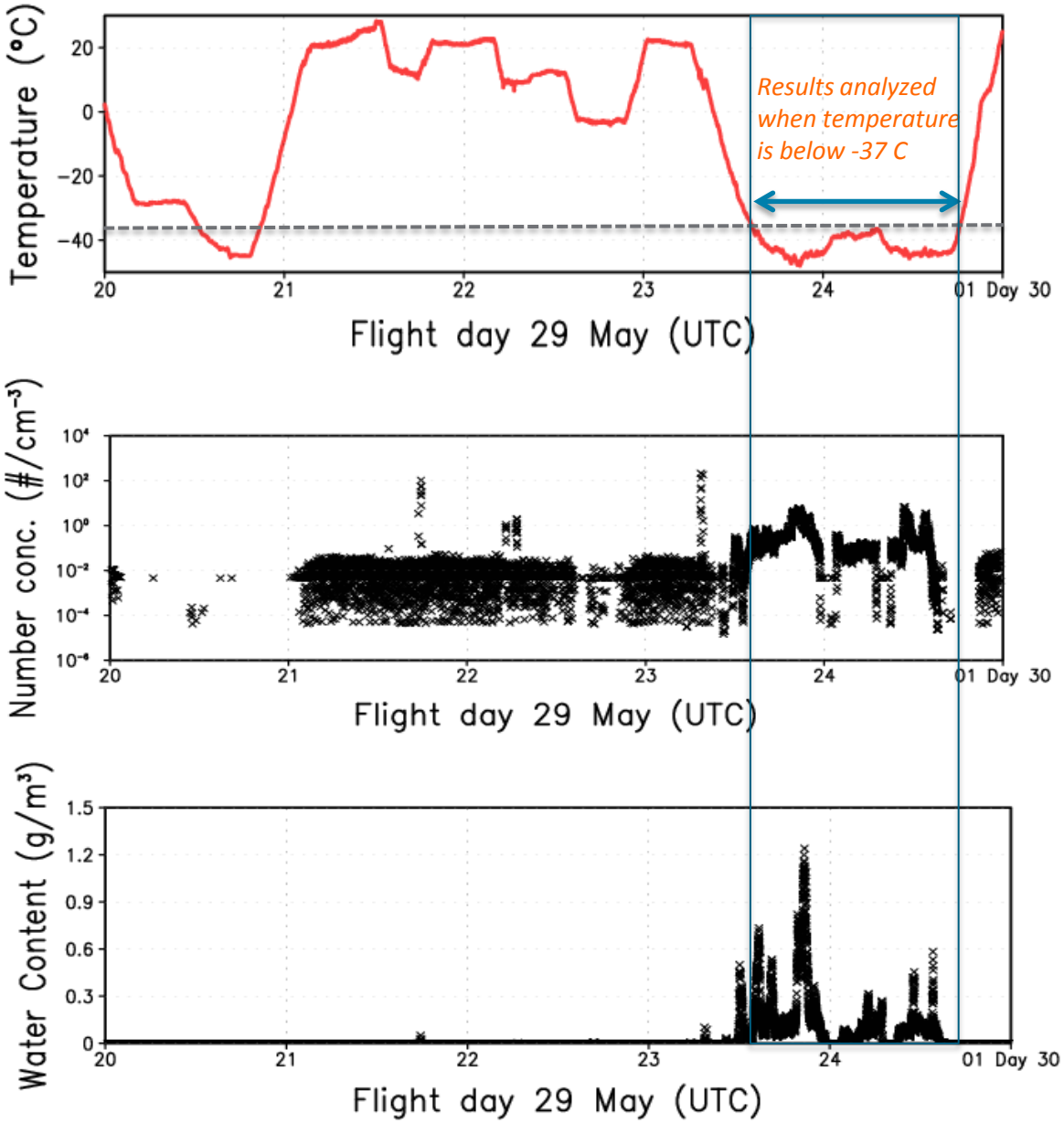


Rain area and mean rain rate with rain rate > 5 mm/h

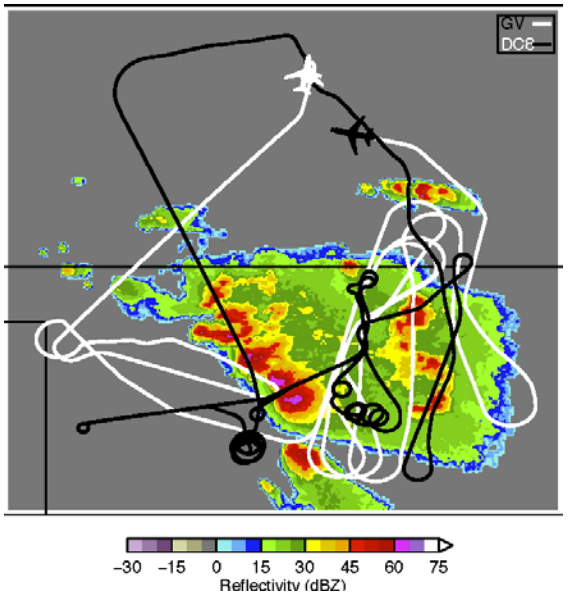




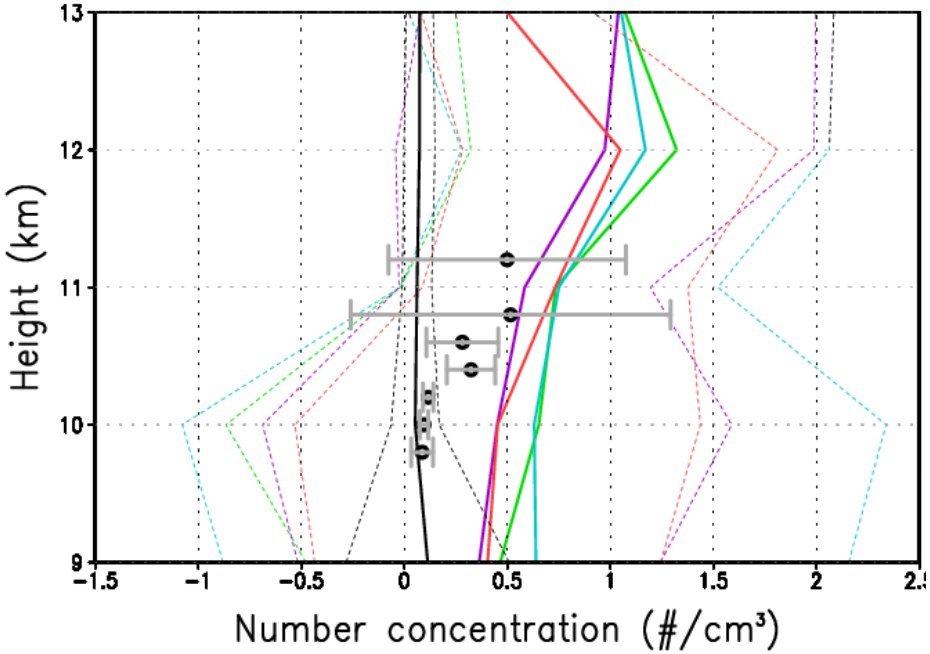
Aircraft measurements

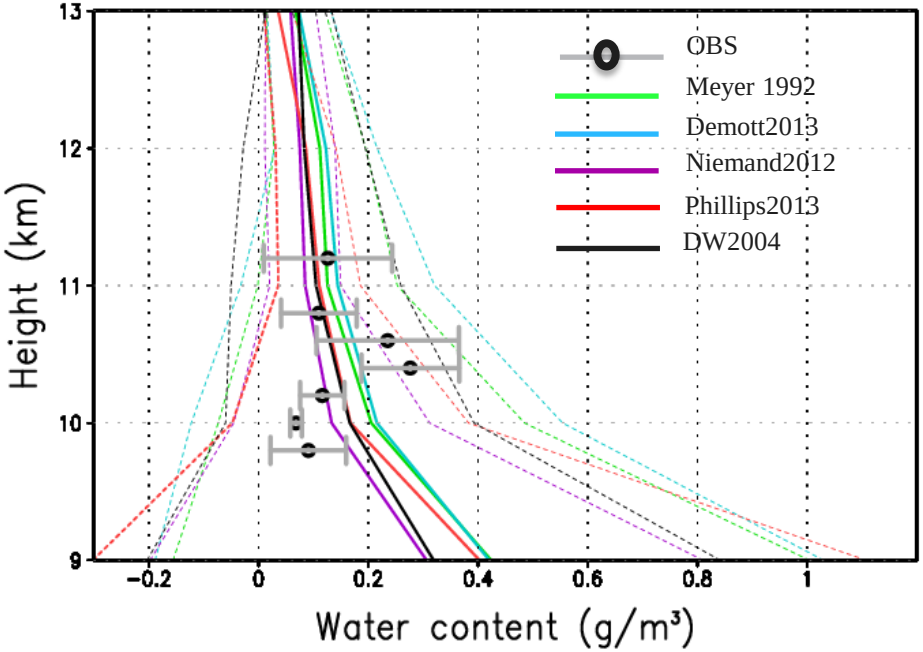


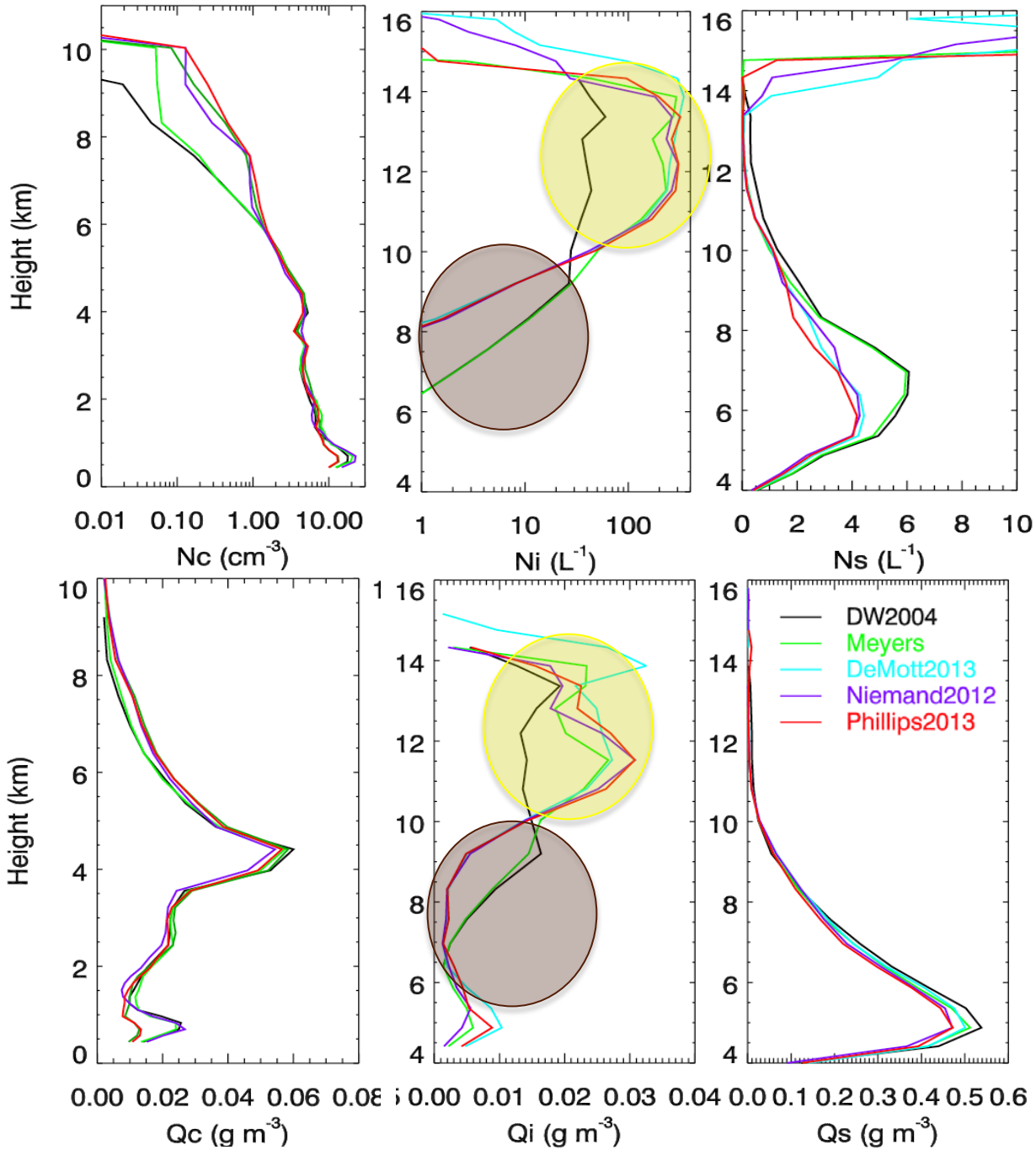
Analysis domain

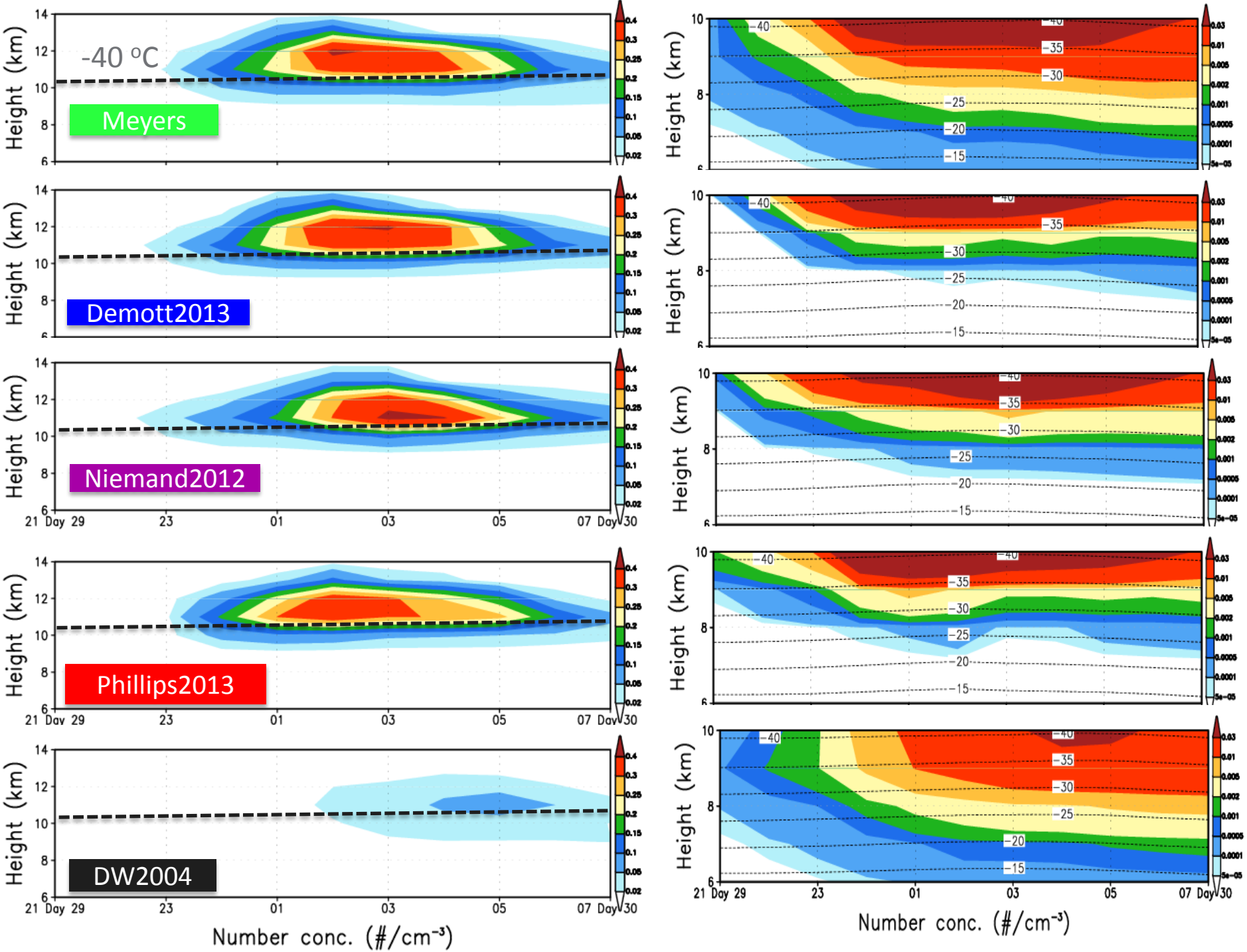


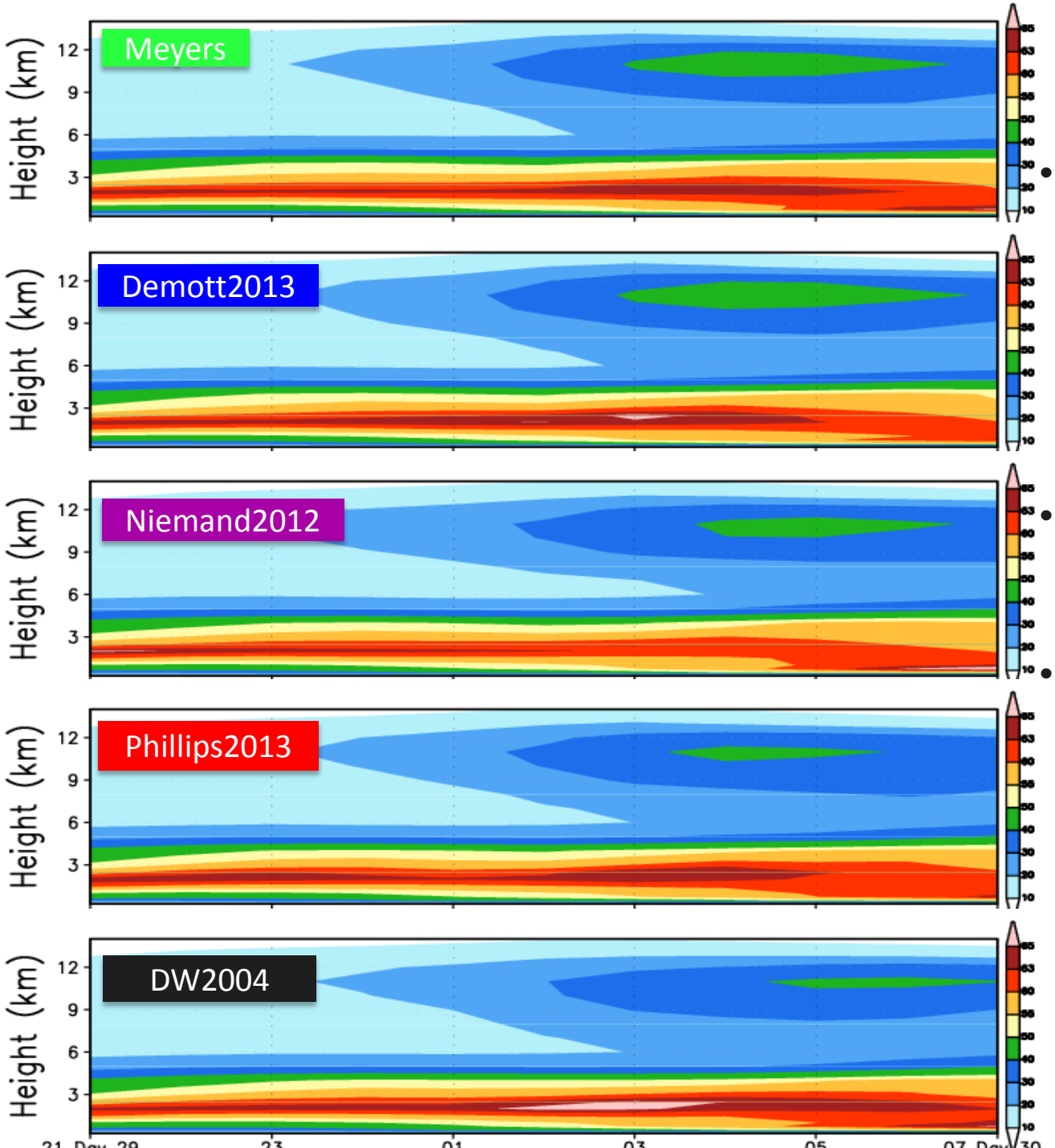
With the limit of water content > 10^{-2} g m^{-3}



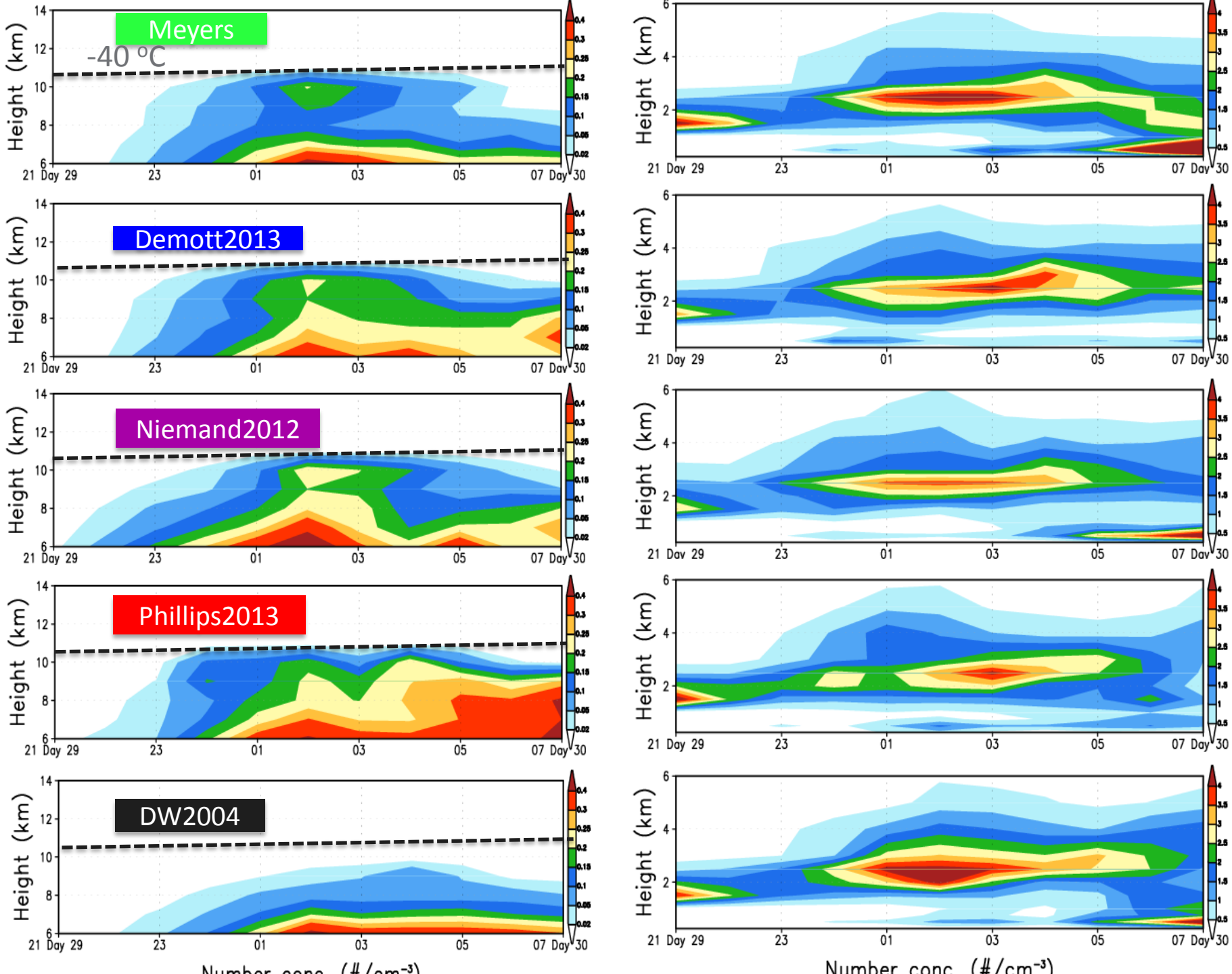


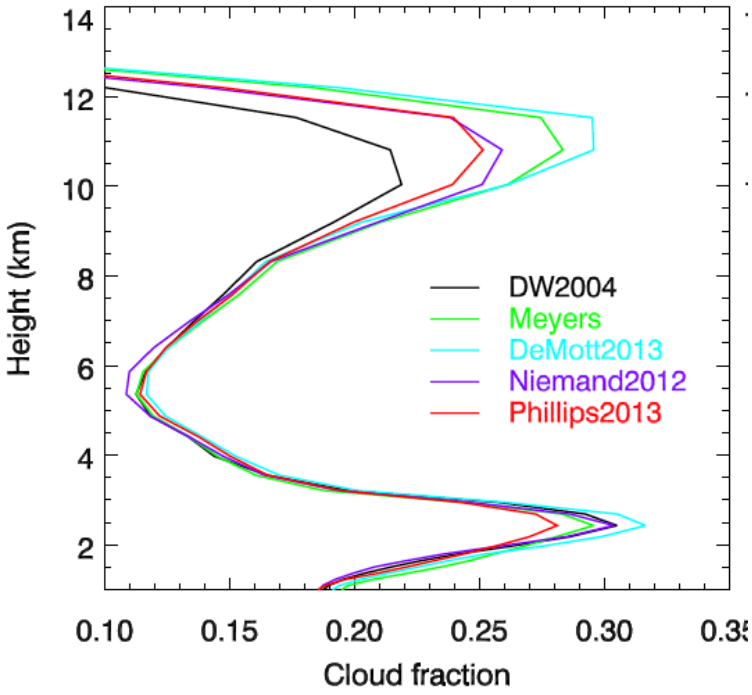

Height (km)
Nc (cm^{-3})
Ni (L^{-1})
Ns (L^{-1})
Qc (g m^{-3})
Qi (g m^{-3})
Qs (g m^{-3})
DW2004
Meyers
DeMott2013
Niemand2012
Phillips2013

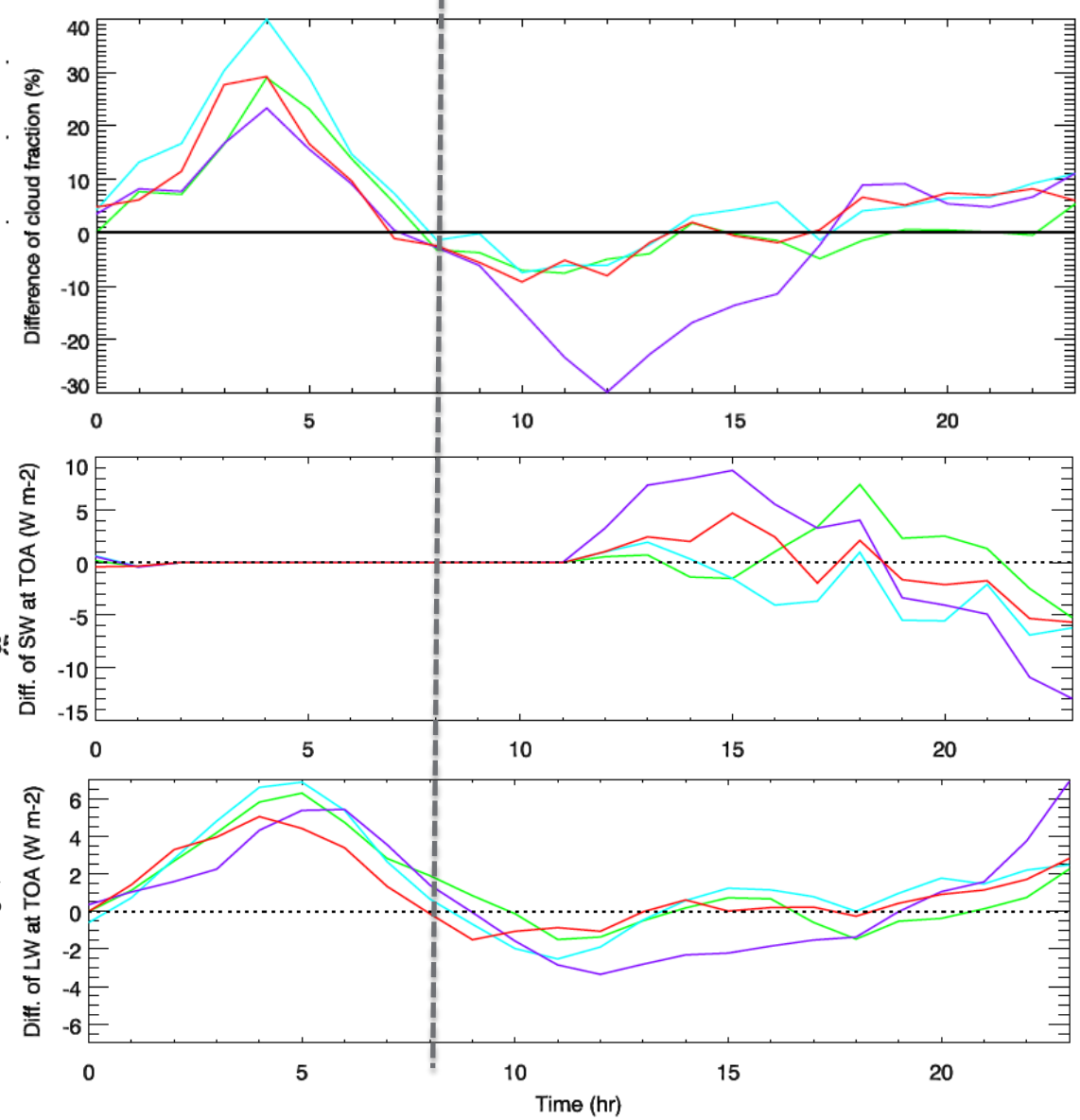

-40 °C
Meyers
Demott2013
Niemand2012
Phillips2013
DW2004
Height (km)
Day
Number conc. (#/cm⁻³)



- **Higher RH in the homogeneous regime in Meyers, DeMott, and Niemand schemes, leading to more efficient homogeneous aerosol freezing.**
- **More droplet homogeneous freezing boosts Ni in Phillips**
- **Less homogeneous droplet freezing and less aerosol freezing contribute to less Ni**


Meyers
-40 °C
Demott2013
Niemand2012
Phillips2013
DW2004
Height (km)
Day 29
23
01
03
05
07 Day 30
Number conc. (#/cm⁻³)





- **Cloud fraction at upper levels is significantly increased from DW2004 to DeMott2013, leading to more droplet nucleation due to the morphology changes >> more Ni >> larger fraction.**
- **Leading to up to 6 W/m^2 LW heating.**

Summary

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- WRF-CAM5 performs reasonable at high resolution in terms of precipitation and convection evolution.
- Meyers and DW schemes gives much higher Ni than recent new parameterizations in the mixed-phase regime, especially at the temperature > -25 ^{o}C.
- Homogeneous aerosol and droplet freezing is significantly impacted by ice nucleation in the mixed-phase regime, leading to very different anvil cloud micro- and macro-physical properties due to changes on humidity and dropelt nucleation. More Ni > larger cloudy area > more droplet nucleation > more Ni >…