The microphysical properties of convective precipitation over the Tibetan Plateau by a sub-kilometer cloud-resolving simulation

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Motivation

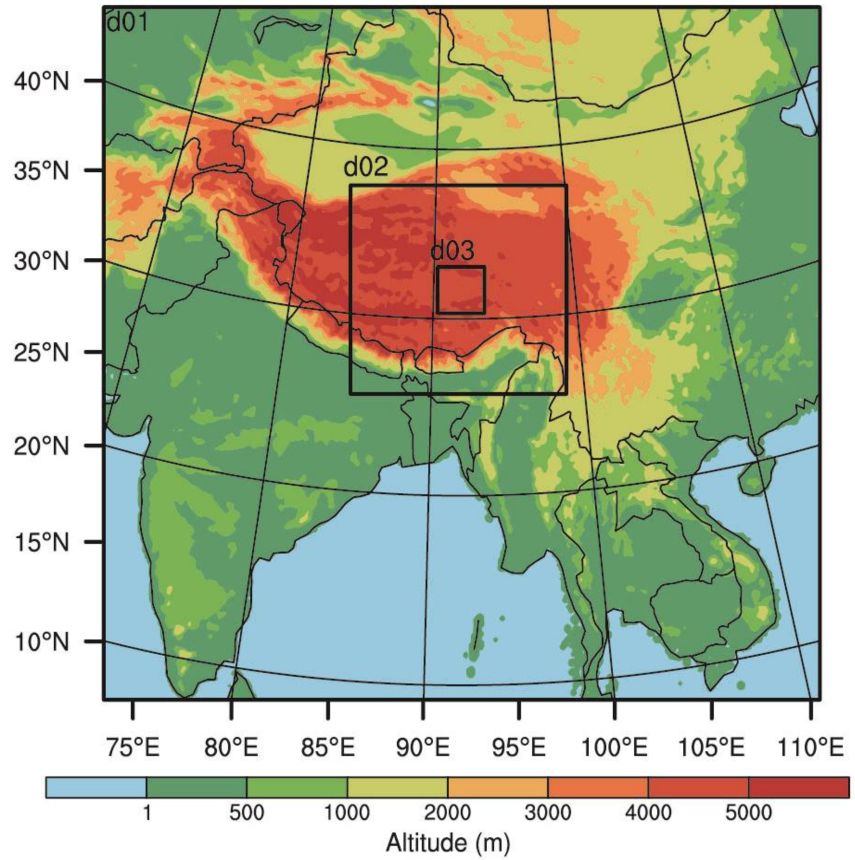
- Cloud microphysical properties and precipitation over the Tibetan Plateau (TP) are unique due to the high topography and special atmospheric conditions. Meanwhile, the studies about TP clouds and precipitation remain quite scarce because of the lack of observations and the poor representation of plateau cloud physical processes in numerical models.
- With the in-situ observations in the Third TP Atmospheric Scientific Experiment, this study investigates the characteristics of cloud microphysics processes in a convective event on 24 July 2014, and attempts to understand how the rainfall is influenced by the cloud microphysics and water vapor.

Experimental design

Model: WRFV3.8.1

Cumulus	G-F ensemble
Microphysics	Lin, WSM6, WDM6, Morrison, CAMS
Radiation	rrtmg
Land surface	Noah
PBL	MYJ
FDDA	Grid nudging
I.C, B.C	NCEP FNL

Study case: 0000 UTC 24 to 0000 UTC 25 July 2014



Geographic locations of the 3 nested domains, 15, 3 and 0.6 km horizontal grid spacings

CAMS two-moment microphysics

Microphysical Processes :
Accretion of cloud droplet: Ccr, Ccs, Ccg
Accretion of rain: Crr, Cri, Crs, Crg
Accretion of ice: Cii, Cir, Cis, Cig
Accretion of snow: Css, Csr, Csg
Nucleation and Multiplication of ice : Pvi, Pci
Condensation and Deposition: Svc, Svr, Svi, Svs, Svg
Freezing/Melting: Mrg, Mic, Msc, Msr, Mgr
Autoconversion: Acr, Aci, Acg, Ais, Asg

Both the mass mixing ratios and the number concentrations of five hydrometeors (cloud droplet, rain, cloud ice, snow, graupel) are predicted in the CAMS microphysics scheme.

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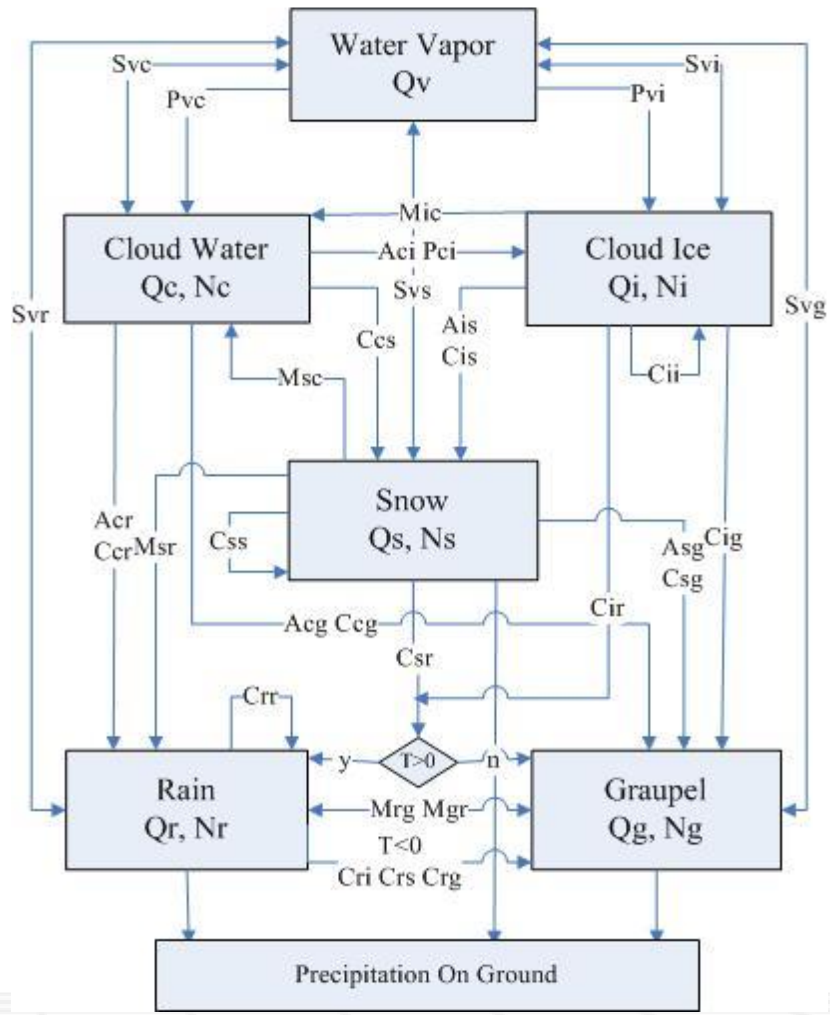
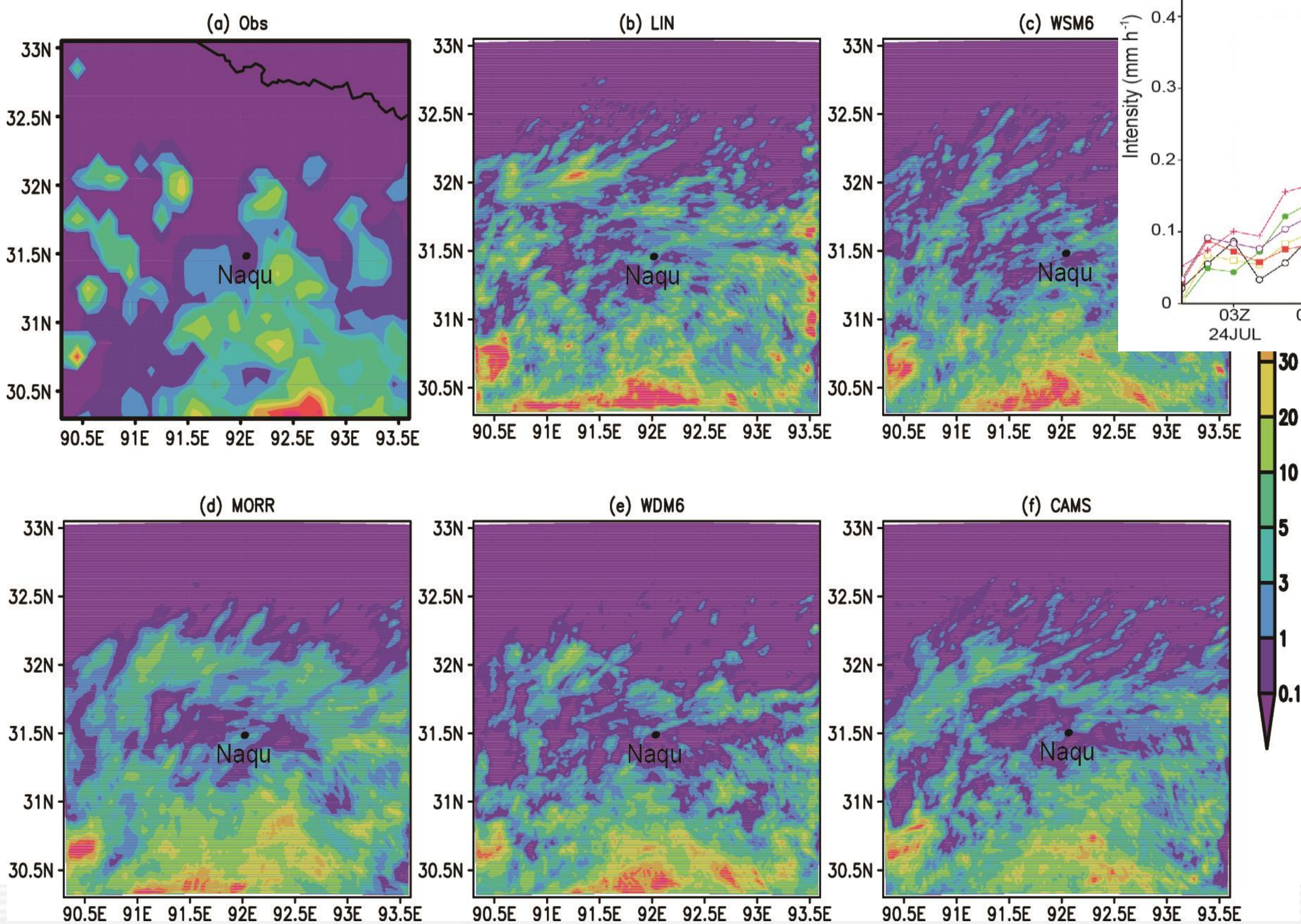
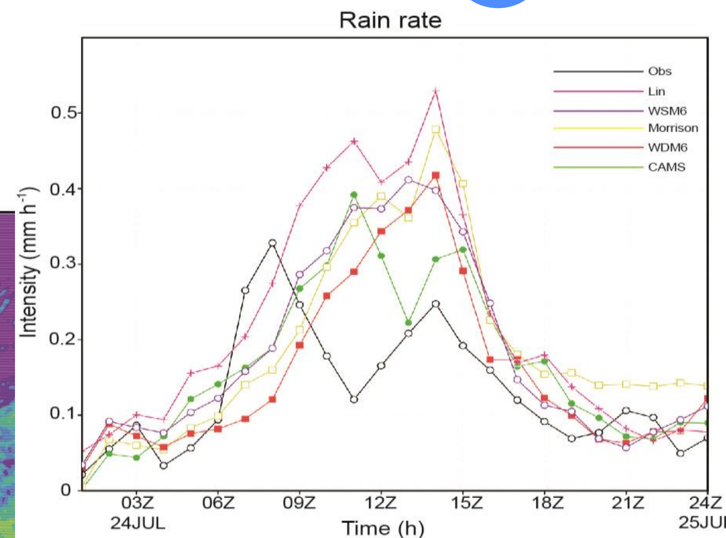
CAMS microphysical scheme



Precipitation

Spatial distributions of 24-h accumulated rainfall.



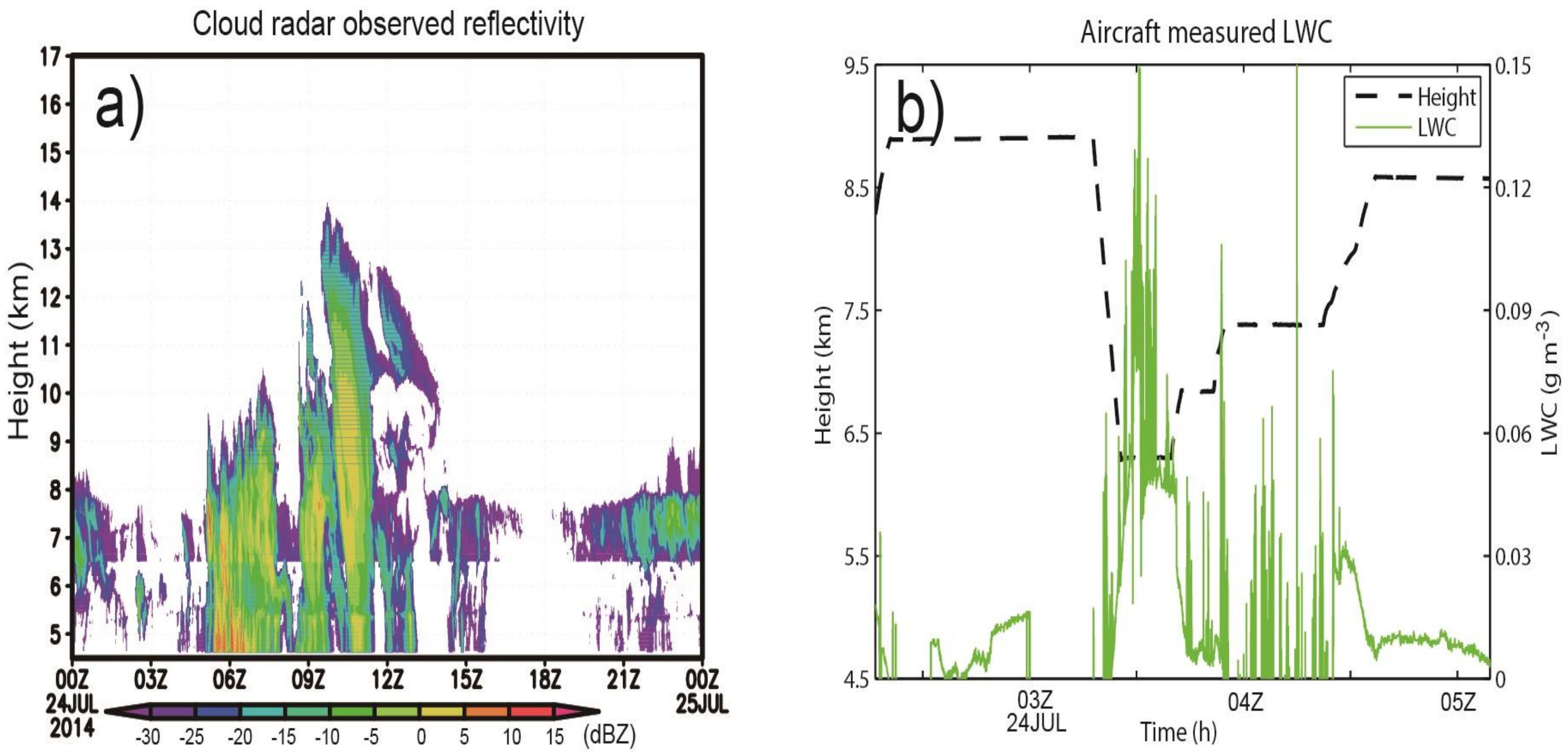


Area-averaged rain rates over Domain 3.

WRF with all five microphysical schemes generally reproduced the overall precipitation pattern but overestimated the rain rates. The evolution of rainfall was better captured by the CAMS scheme.

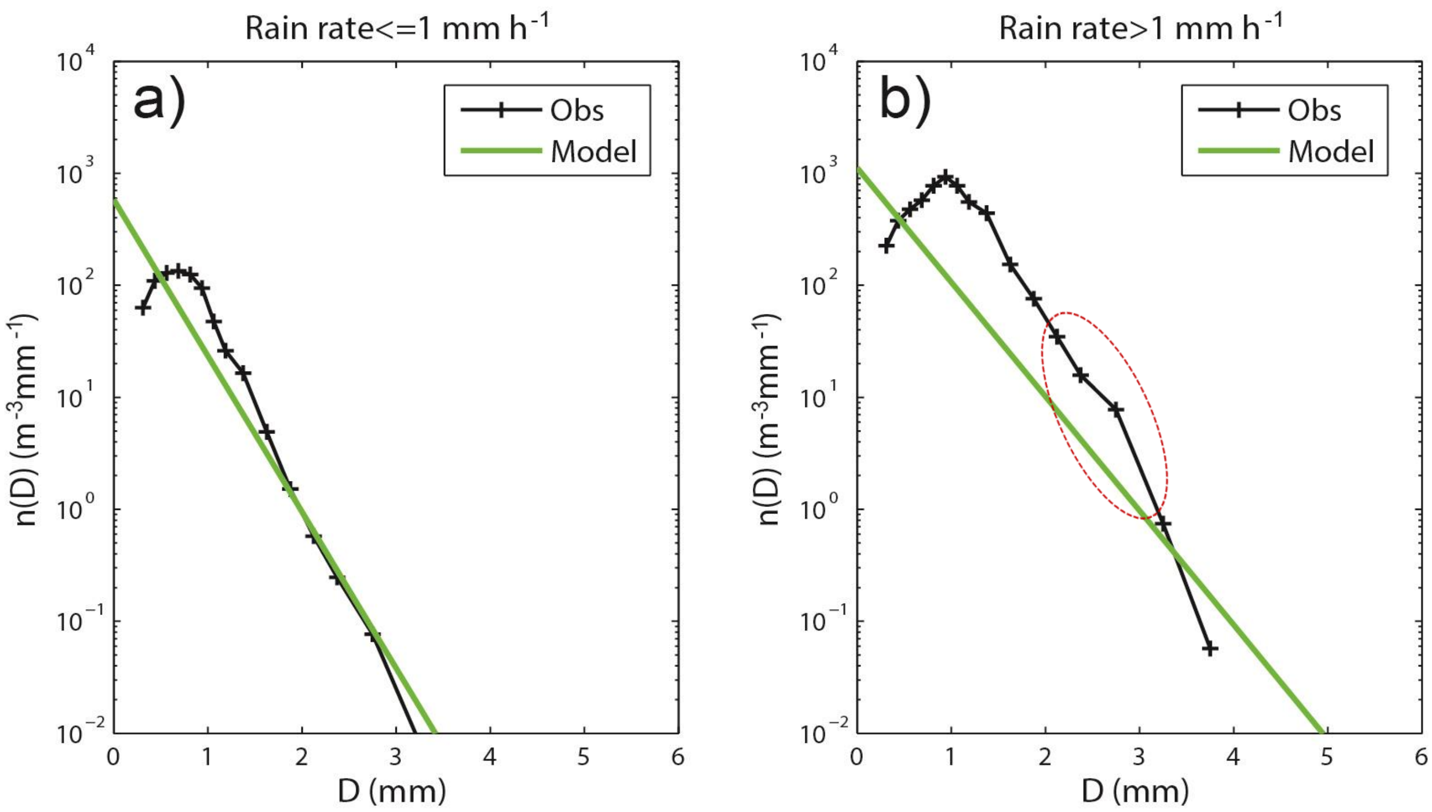
Cloud radar and aircraft measurements

The strongest convection occurred at about 1100 UTC. The LWC range between 0.005 and 0.06 g m-3, indicating that abundant supercooled water existed above the freezing level.



MMCR (millimeter cloud radar) observed reflectivity over the Naqu station,
Aircraft measured liquid water content (LWC) over the Naqu and its surrounding areas.

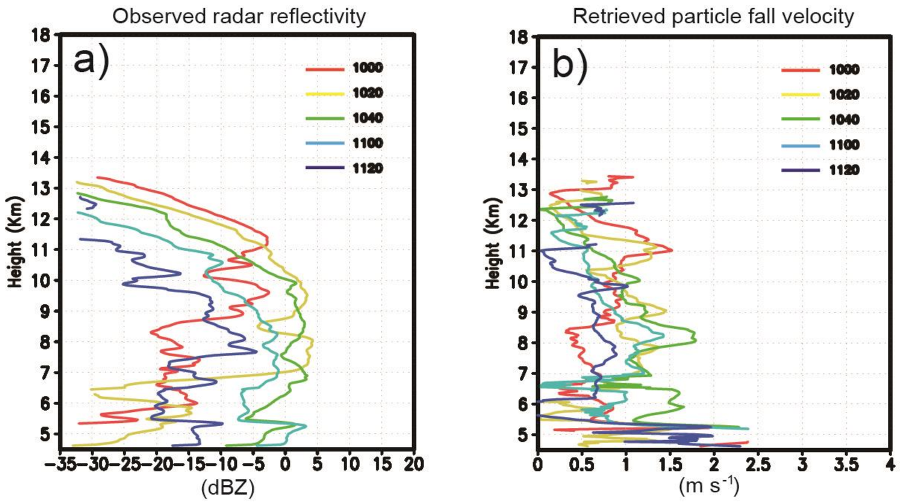
Raindrop size distribution (RSD)



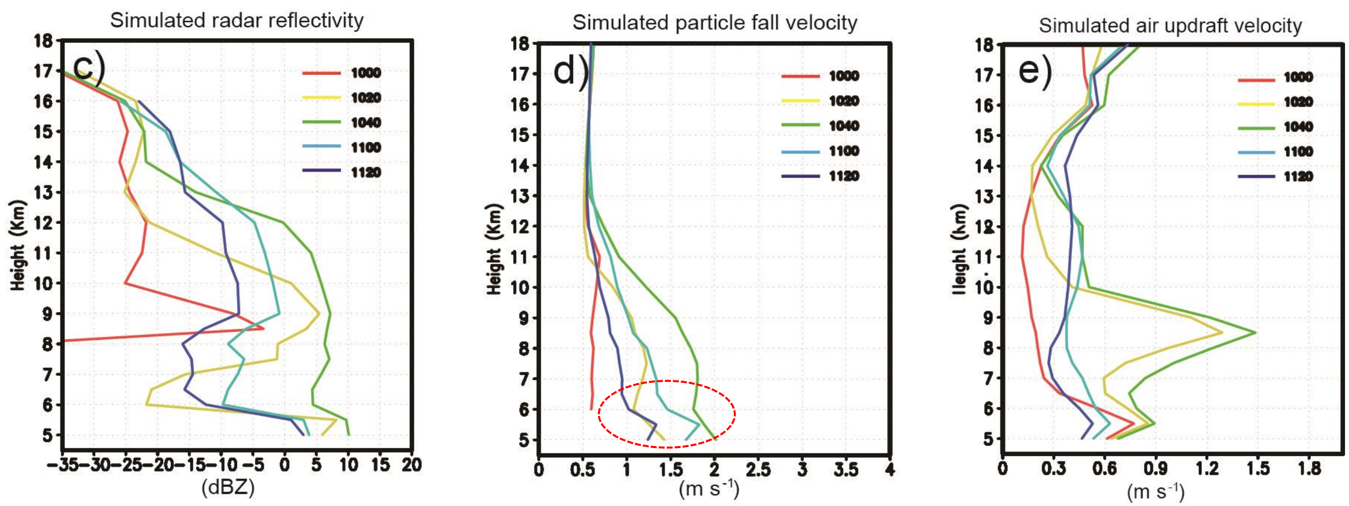
As the reduced air density over the TP, the maximum raindrop size is smaller than that in lower altitude. There is a distinct downward concavity, implying the happening of raindrop breakup, while this process occurs only with higher rain rates in lower altitude.

Disdrometer observed and WRF-CAMS simulated mean RSD (over Naqu from 1000 to 1130 UTC 24 July 2014).

Cloud radar reflectivity and particle fall velocity

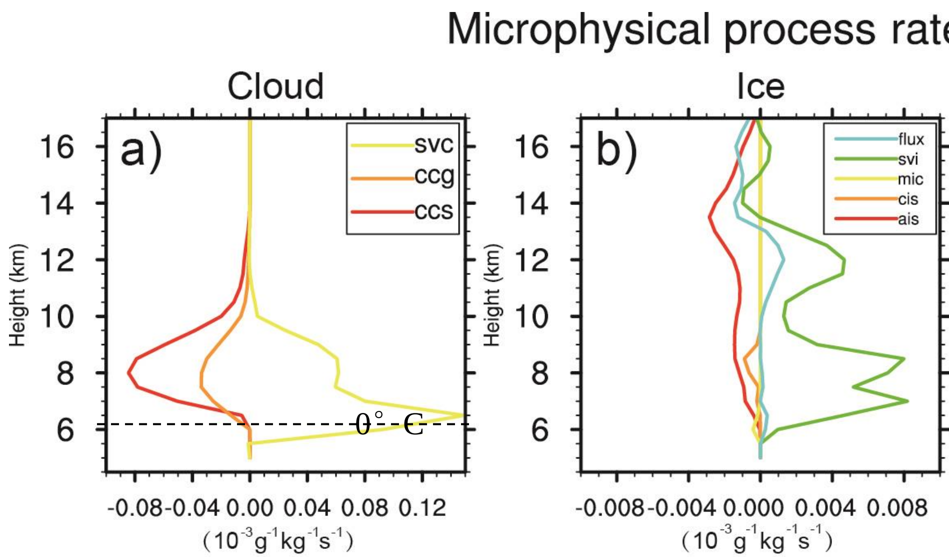


The simulated Vt shows an obvious increase below the melting level as in MMCR observation, indicating the melting process of raindrops (since the fall coefficient of raindrop is larger than that of snow/graupel). The Vt decreases again near the surface, implying the evaporation of raindrops.

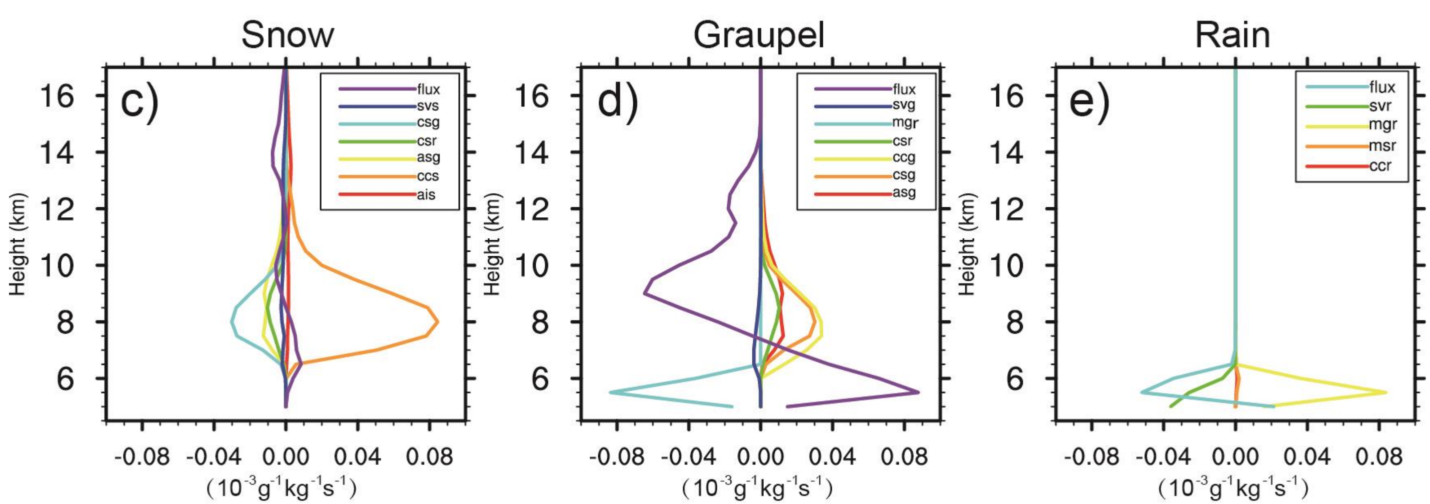


Time evolution of the profiles of radar reflectivity and particle fall velocity at a 20 min interval (from 1000 to 1130 UTC 24 July).

Microphysical process rates



As a result, the efficient formation of graupel, as well as its sedimentation and melting to raindrop are closely related to the precipitation over the TP. Msr rarely occurs because snow almost converts to graupel, which is quite different from that in low altitude.

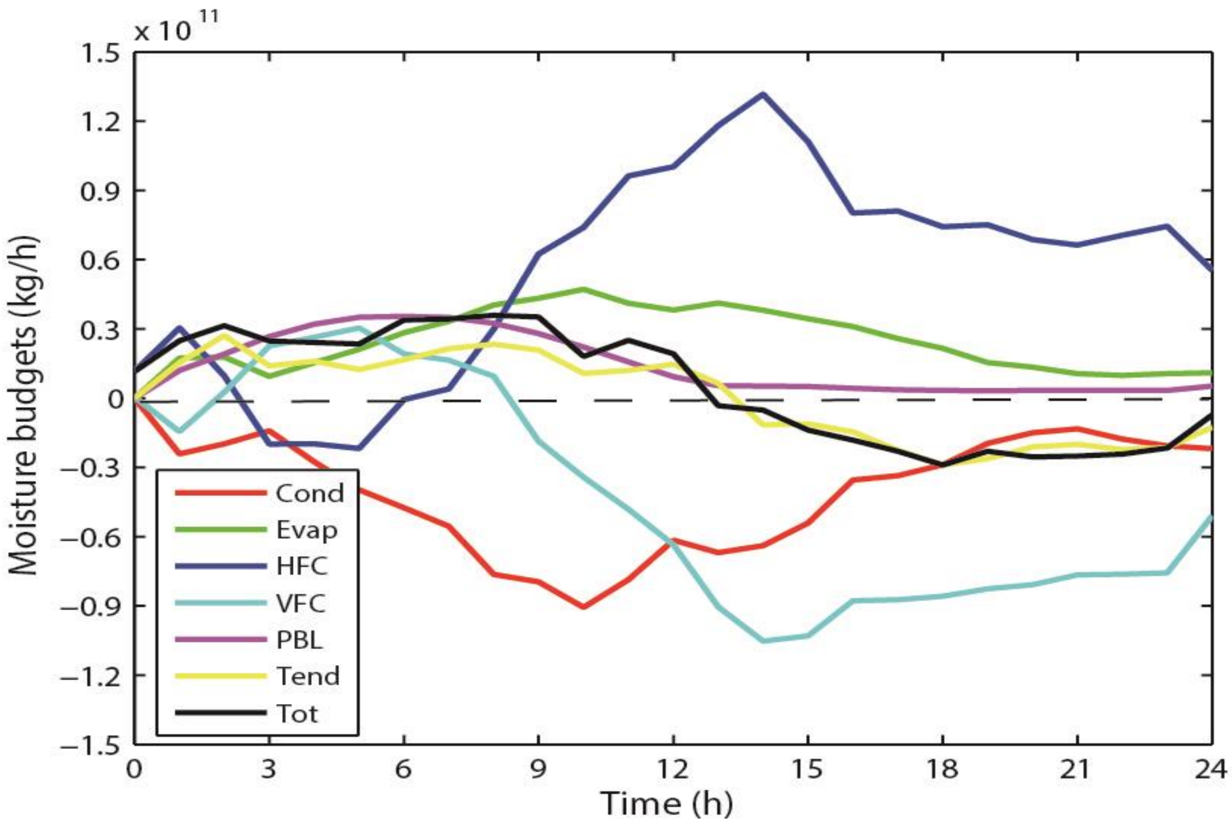


The profiles of microphysical process rates averaged over Naqu from 1000 to 1130 UTC 24 July 2014

Water vapor budgets

$$\frac{\partial q_v}{\partial t} = -\nabla\left(q_v \cdot \mathbf{V}\right) - \frac{\partial\left(q_v w\right)}{\partial z} + q_v\left(\nabla \cdot \mathbf{V} + \frac{\partial w}{\partial z}\right) - C + E + B_v + R_{esd}$$

Tend HFC VFC Div Cond Evap PBL Resd



An evident delay of HFC's peak than the Cond's peak, indicates the priority starting of local cloud microphysics processes. The PBL occurs mainly in daytime (before 1200 UTC), which is the dominant source of water vapor at the beginning of convection. The Evap is roughly equal to the HFC and VFC before 0800 UTC. i.e., self-circulation of moisture supply happens.

Temporal evolutions of the volumetrically integrated budget terms of water vapor over the domain 3.

Conclusions

- The ground-based cloud radar and disdrometer observations as well as the 600-m resolution of WRF-CAMS simulations are used to investigate the properties of cloud microphysics and precipitation in a convection event over the TP on 24 July 2014.
- Abundant supercooled water exists through the condensation of water vapor. The major ice crystal microphysical processes are deposition and autoconversion to snow. The dominant source of snow/graupel is riming of supercooled water. Sedimentation of graupel plays a vital role in the formation of precipitation, and melting of snow is rather small and quite different from that in lower altitudes.
- The water vapor budgets suggest that surface moisture flux be the principal source of water vapor and self-circulation of moisture happen at the beginning of convection, while total moisture flux convergence determine condensation and precipitation during the convective process over the TP.

Thank you for your attention!