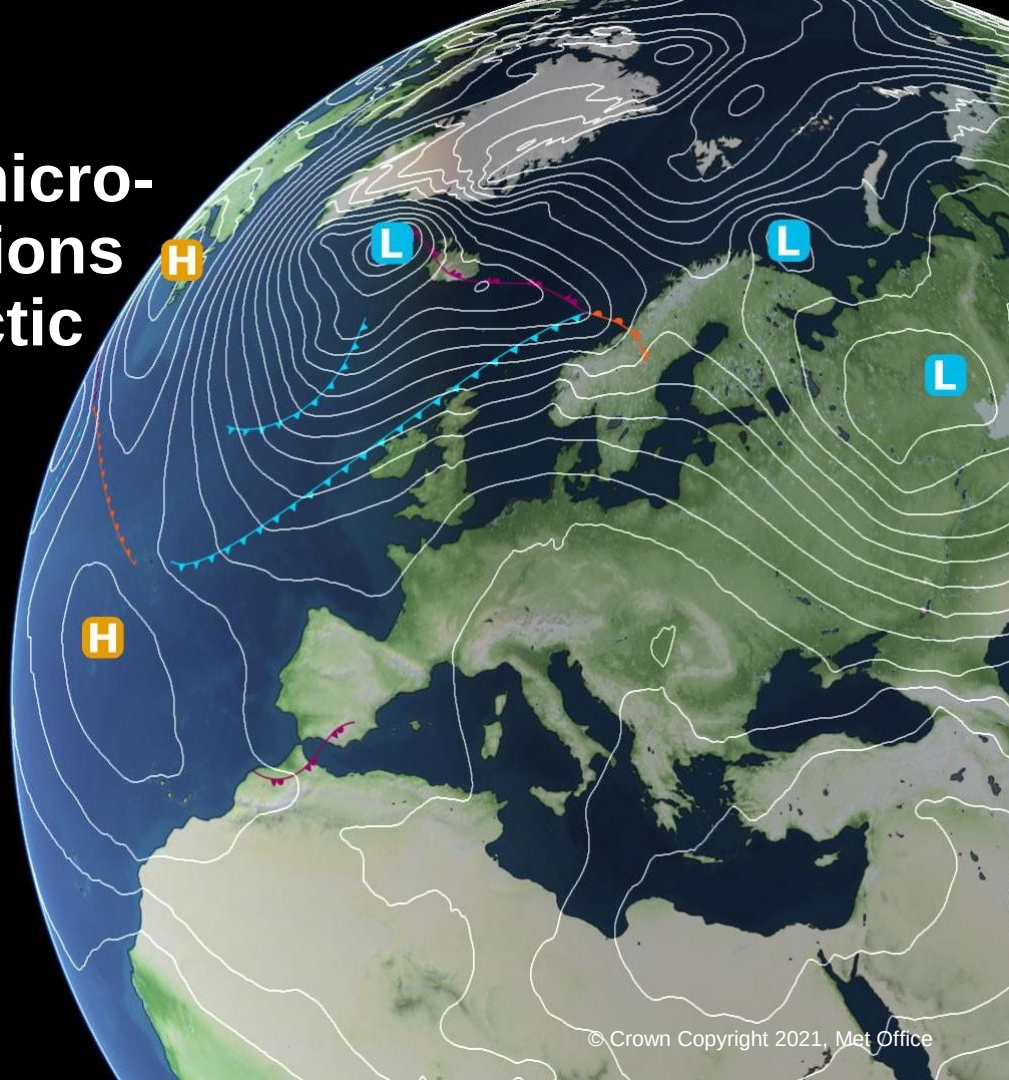
Role of cloud macro- and micro-physics in regional simulations over the tropics and the arctic



6th WGNE workshop on systematic errors in weather and climate models

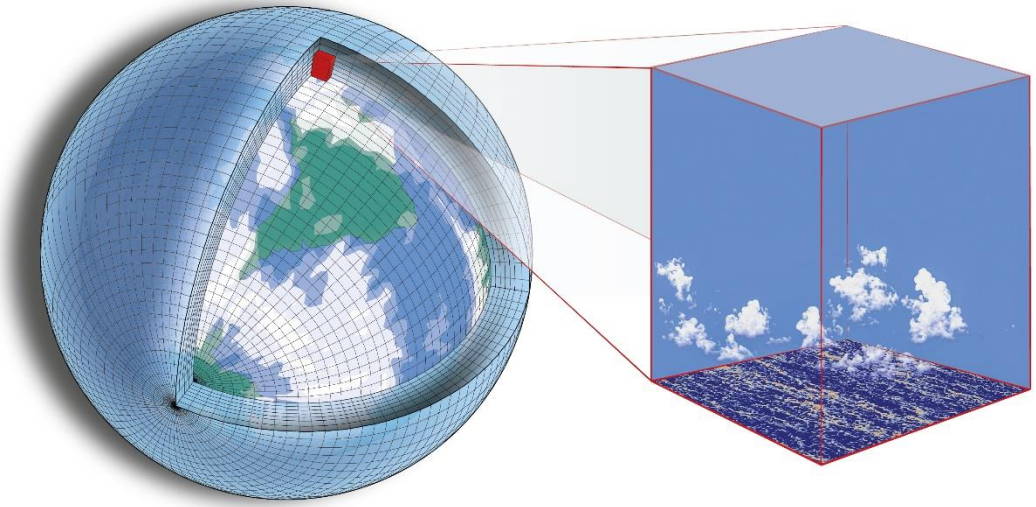
Kwinten Van Weverberg

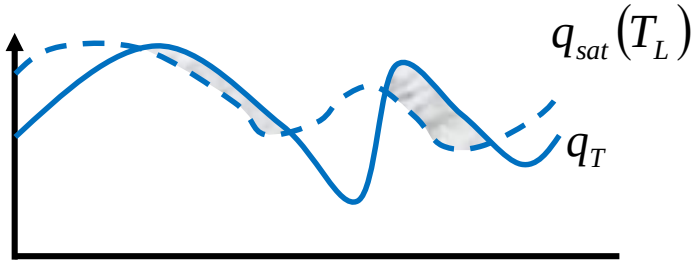
UK Met Office/University of Ghent/ Royal Meteorological Institute of Belgium

(Kwinten.vanweverberg@metoffice.gov.uk)

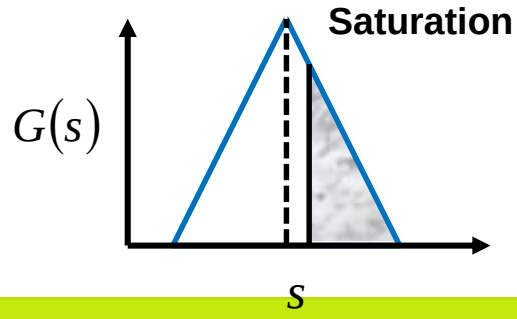
Cloud Macrophysics Schemes in the UM

Role of cloud fraction parameterization: represent fraction of grid box that is cloudy, based on assumed subgrid distribution of saturation departure f(T,q)





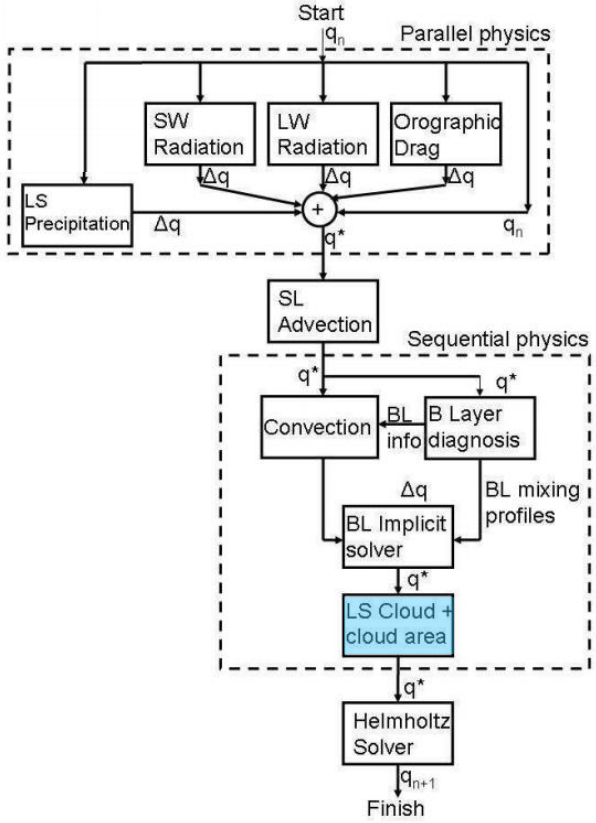
Mean conditions



Cloud Macrophysics Schemes in the UM

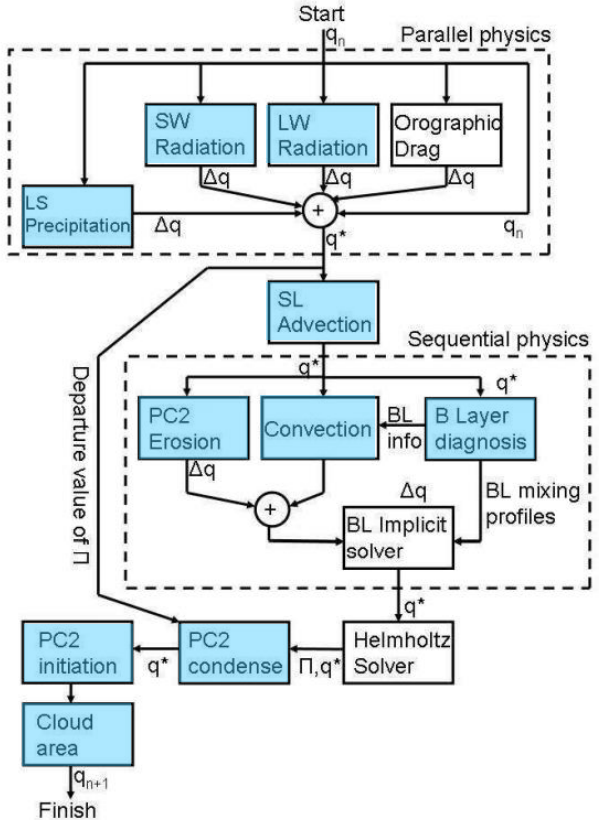
Smith/Bimodal cloud scheme

Diagnostic



PC2 cloud scheme

Prognostic



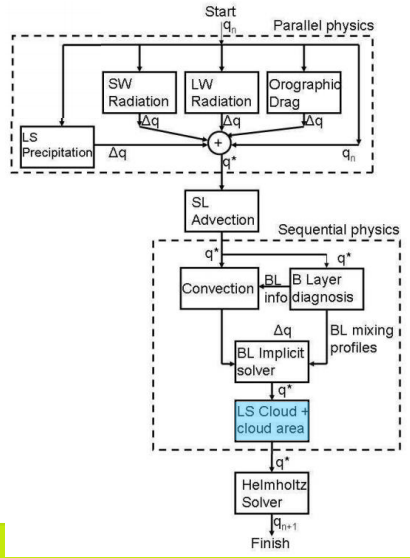
Hybrid Macrophysics Scheme

Combining the advantage of using entrainment zones to diagnose liquid clouds as in **bimodal** with prognostic ice clouds in **PC2**?

Hybrid cloud scheme

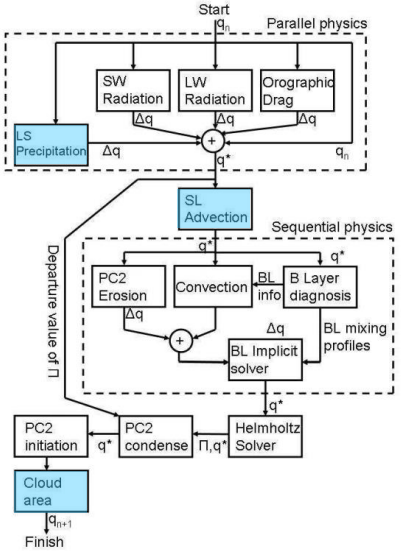
Liquid cloud fraction

Diagnostic



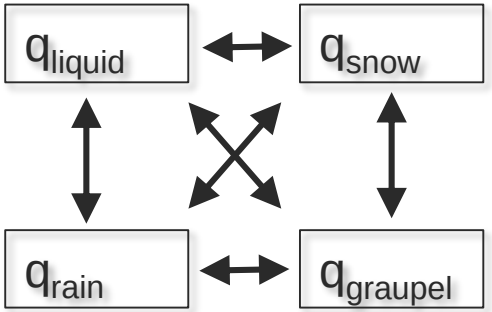
Ice cloud fraction

Prognostic

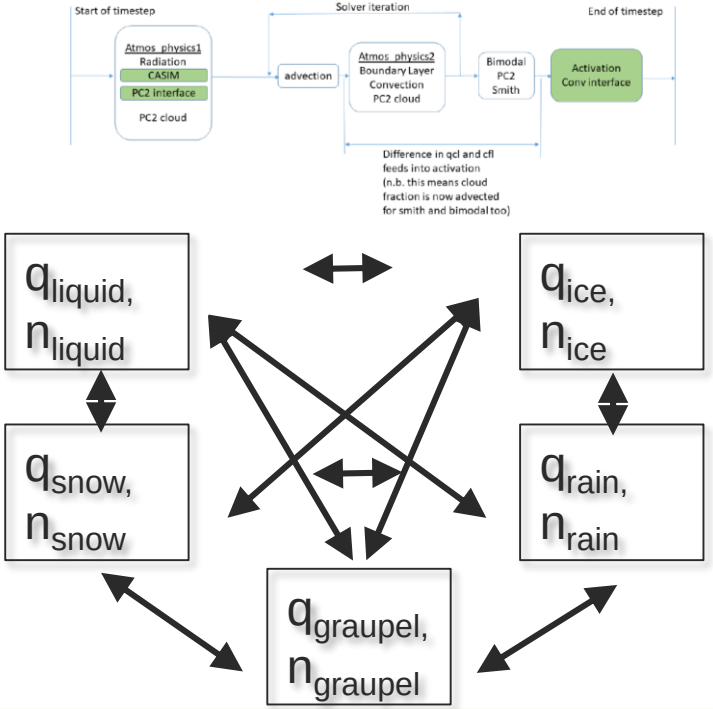


Cloud Microphysics Schemes in the UM

1-moment (Wilson and Ballard 1990)



2-moment (Field et al. 2022)



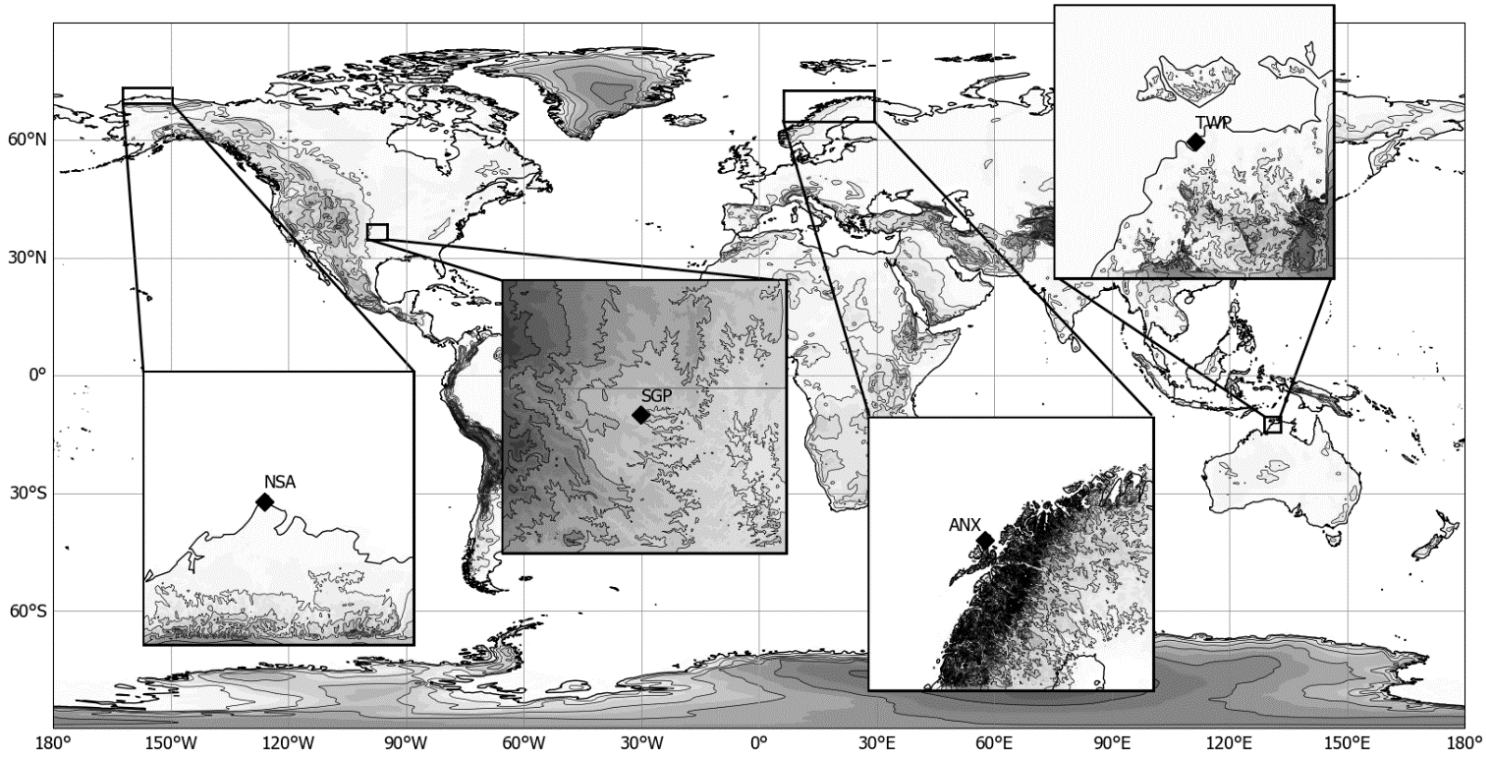
Cloud Micro- and Macrophysics in Regional Simulations

- Can more advanced micro- and macrophysics help unify regional configurations for different climate regimes in terms of cloud-radiative properties and precipitation?
- What processes play a role in outstanding biases (phase overlap, ice growth mechanisms)?

	Microphysics	macrophysics
NOCFP-1M	1-moment	None
SMITH-1M	1-moment	Smith
BM-1M	1-moment	Bimodal
BM-2M	2-moment	Bimodal
BM-MIN-2M	2-moment	Bimodal (consistent)
BM-MAX-2M	2-moment	Bimodal (maximum overlap)
HYB-MIN-2M	2-moment	Hybrid
PC2-MIN-2M	2-moment	PC2

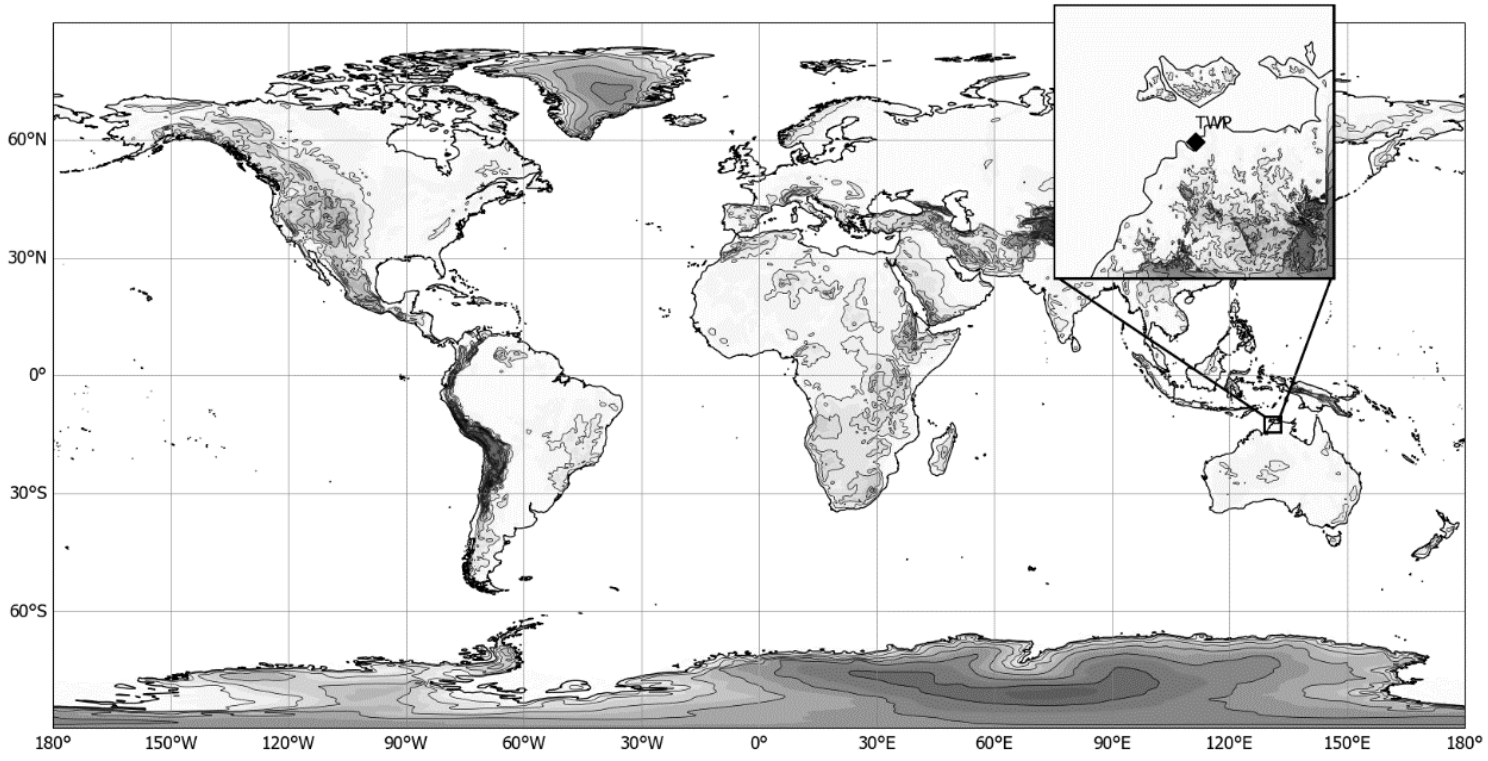
Cloud Micro- and Macrophysics in Regional Simulations

6-month simulations over ARM sites in Oklahoma, Alaska and Darwin and for the COMBLE-campaign in Norway (400 x 400 gp, Δx1 km).



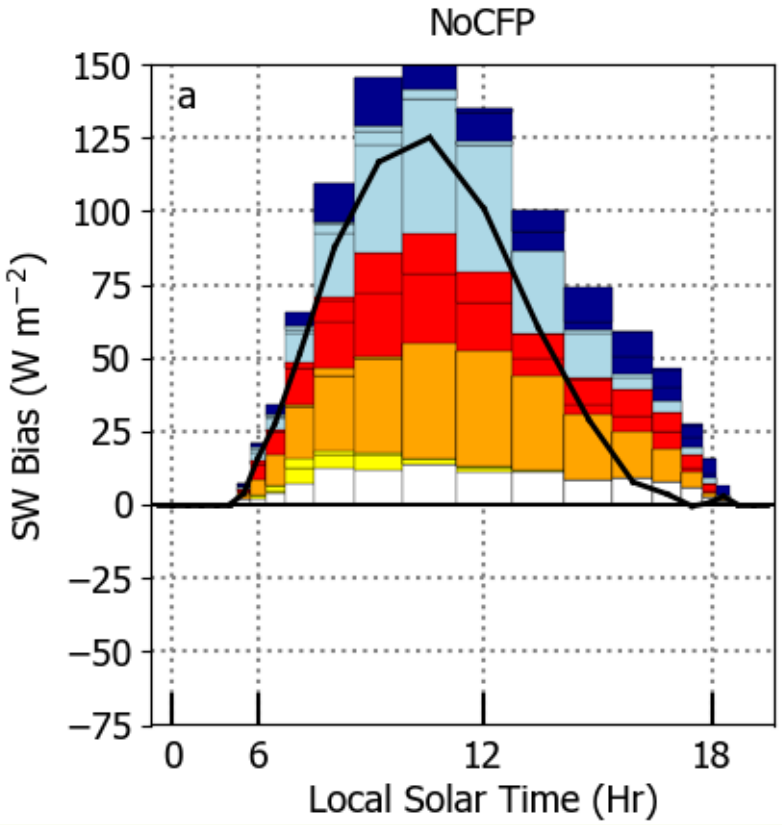
DARWIN (Tropical Western Pacific)

Wet Season DJF



Cloud-radiative effects: regime analysis

Which cloud regimes are responsible for the radiation biases?

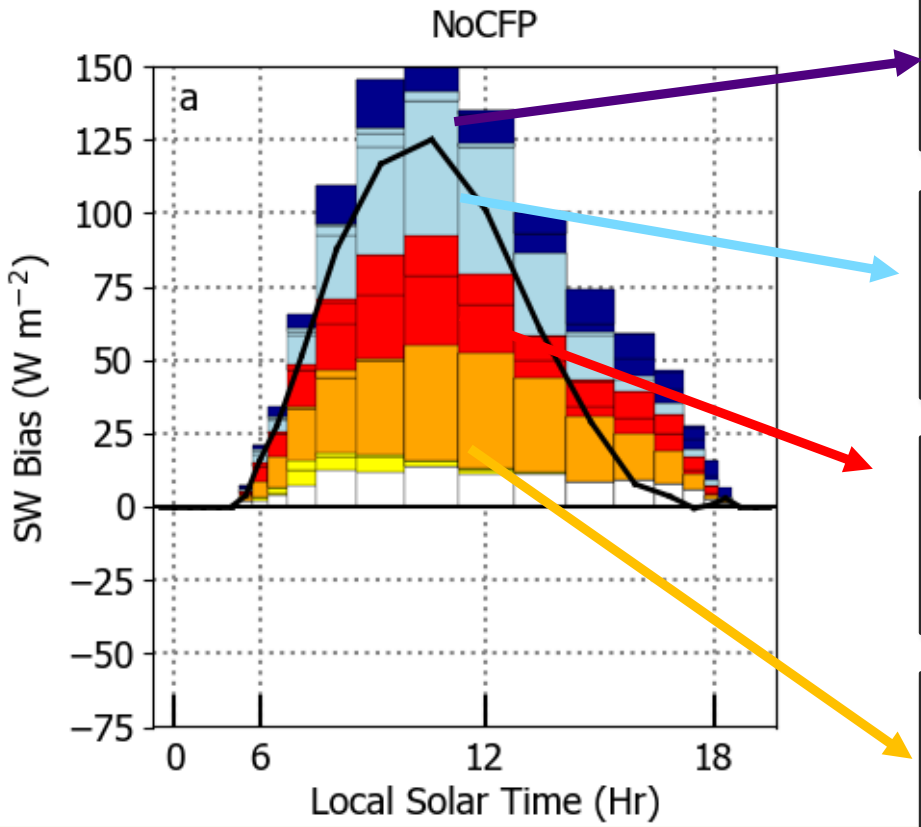


ObsMod
- clear
- high cloud
- broken thin low/mid cloud
- overcast thin low/mid cloud
- broken thick low/mid cloud
- overcast thick low/mid cloud

Decompose the bias in observed regimes

Cloud-radiative effects: regime analysis

Which cloud regimes are responsible for the radiation biases?

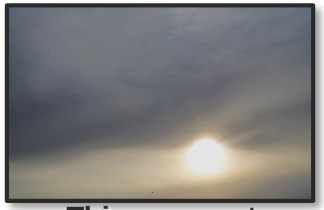


ObsMod

- clear
- high cloud
- broken thin low/mid cloud
- overcast thin low/mid cloud
- broken thick low/mid cloud
- overcast thick low/mid cloud


Thick overcast

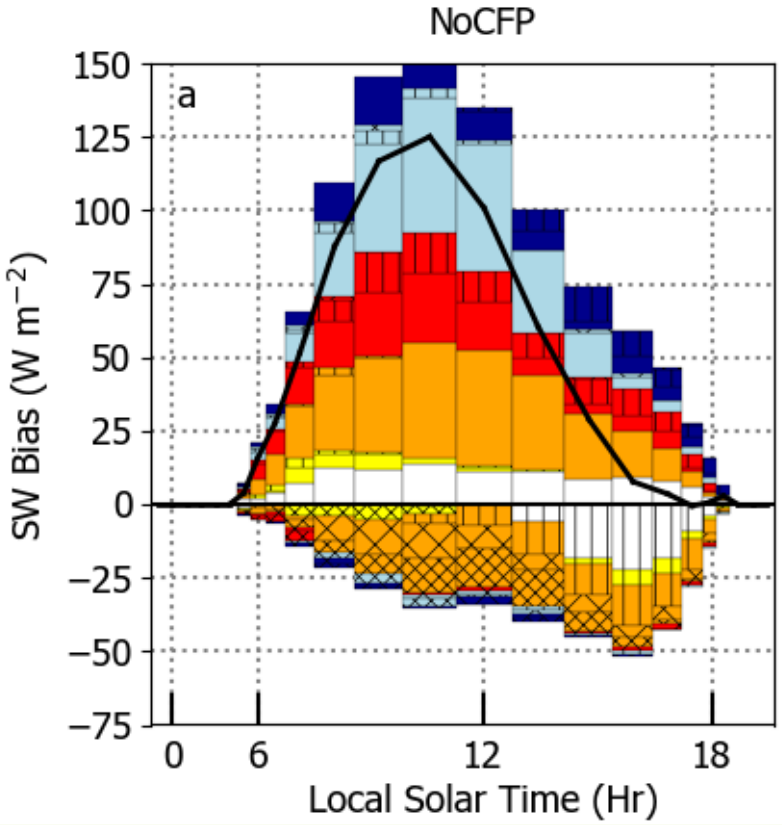

Thick broken


Thin overcast


Thin broken

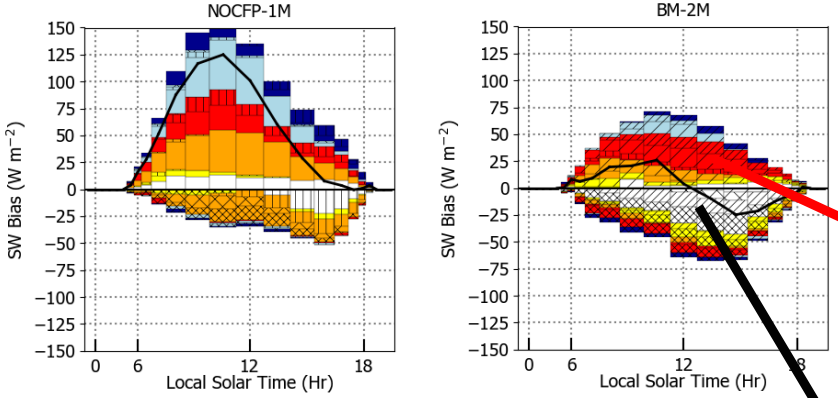
Cloud-radiative effects: regime analysis

Which cloud regimes are responsible for the radiation biases?



Decompose the bias in observed-simulated regime pairs

Cloud-radiative effects: regime analysis



ObsMod
clear
high cloud
broken thin low/mid cloud
overcast thin low/mid cloud
broken thick low/mid cloud
overcast thick low/mid cloud

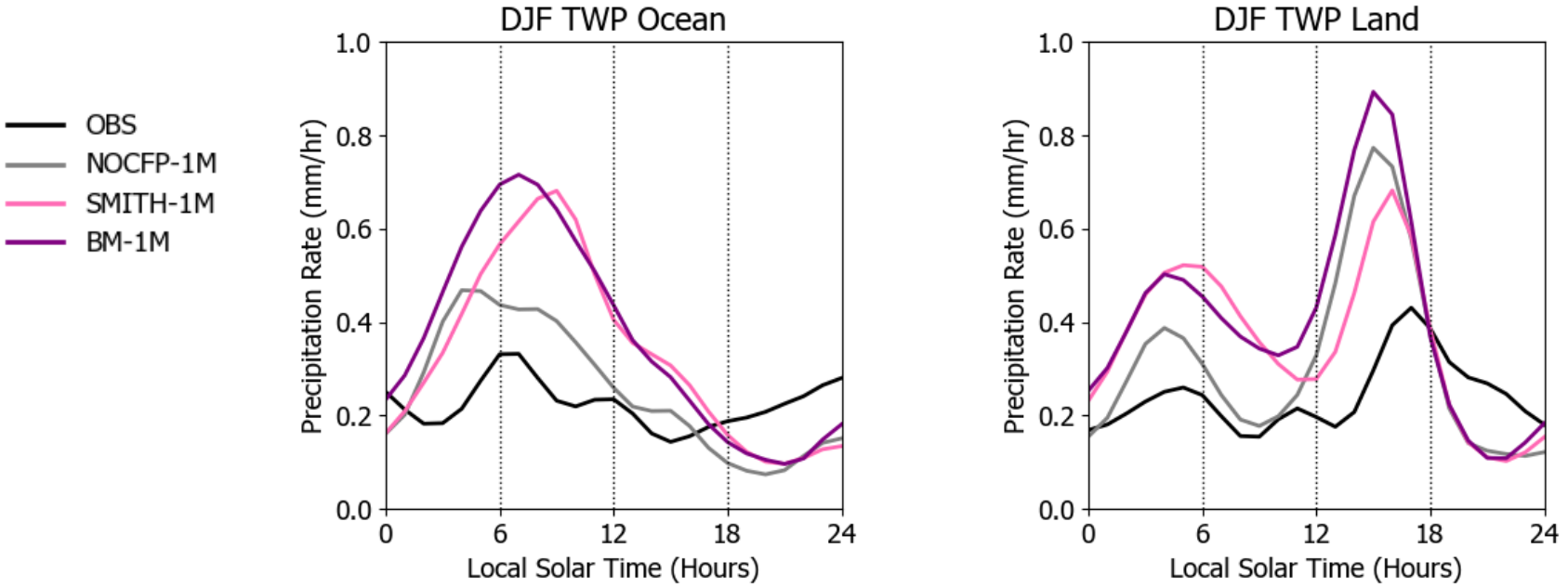
Error compensation

Thin broken **instead of**  **Thin overcast**

Thick broken/overcast **instead of**  **Clear sky**

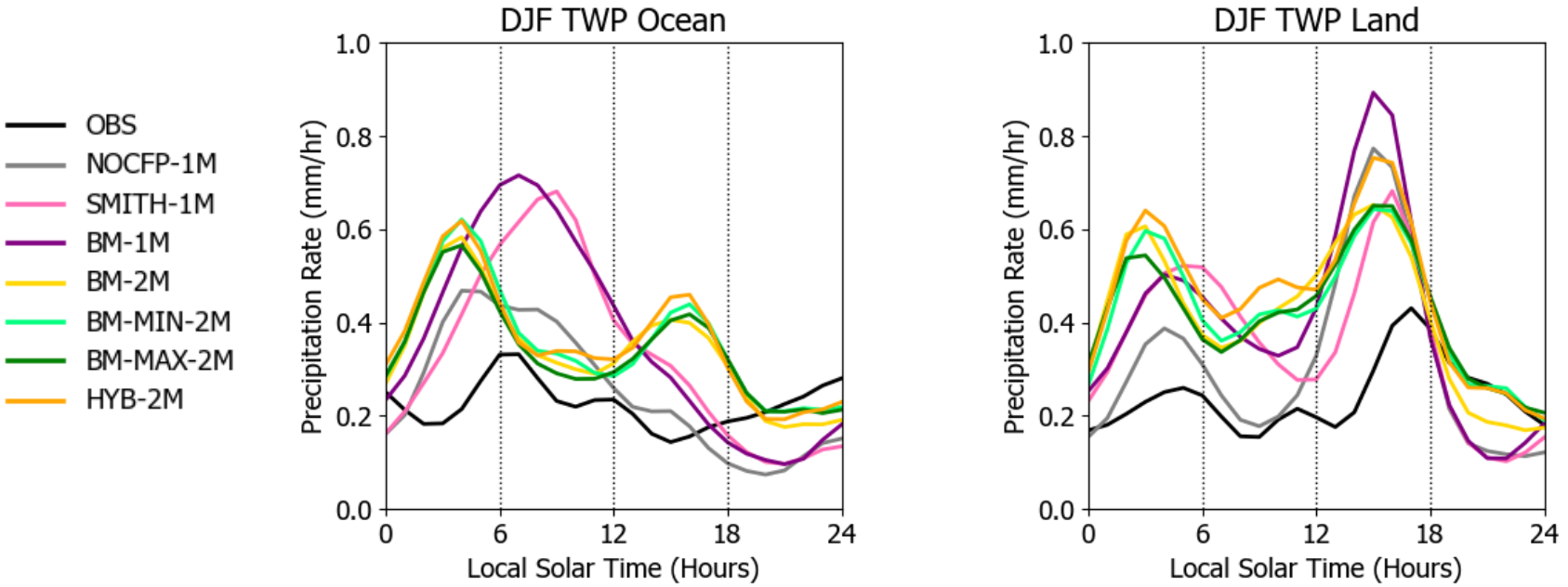
Surface Precipitation: diurnal cycle

Precipitation (against Darwin radar)



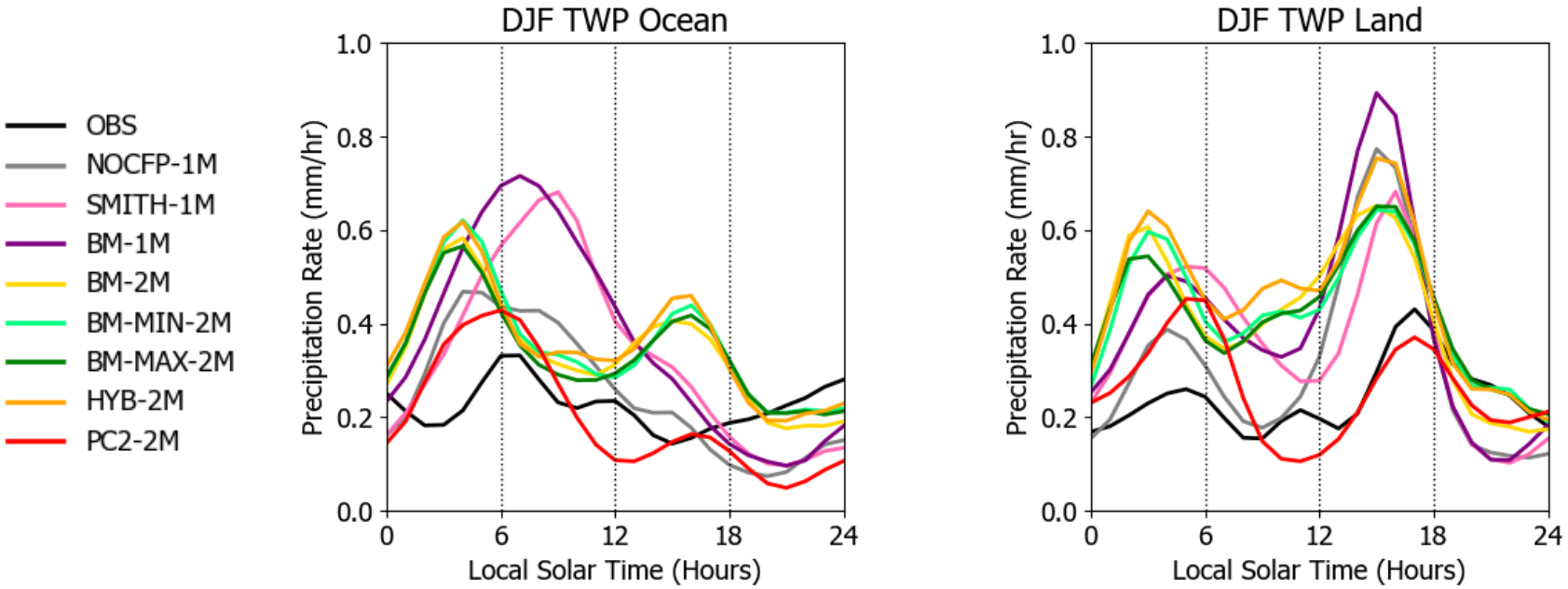
Surface Precipitation: diurnal cycle

Precipitation (against Darwin radar)



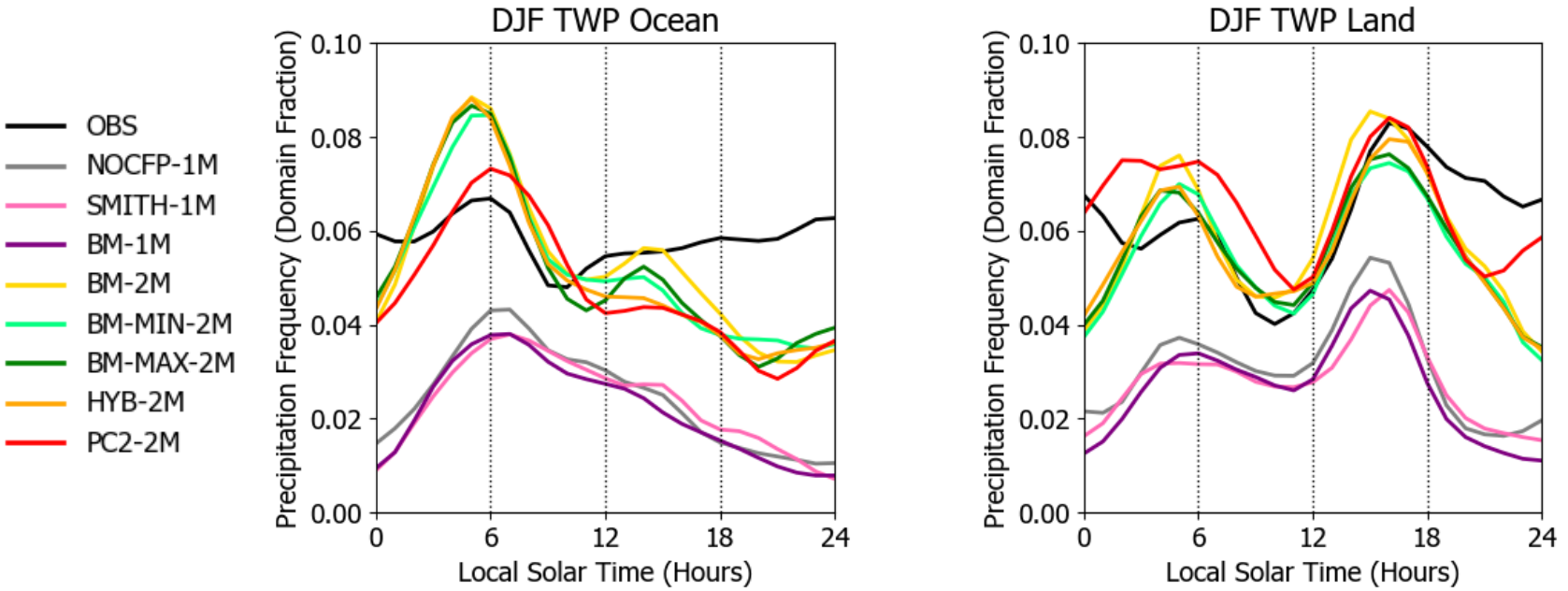
Surface Precipitation: diurnal cycle

Precipitation (against Darwin radar)



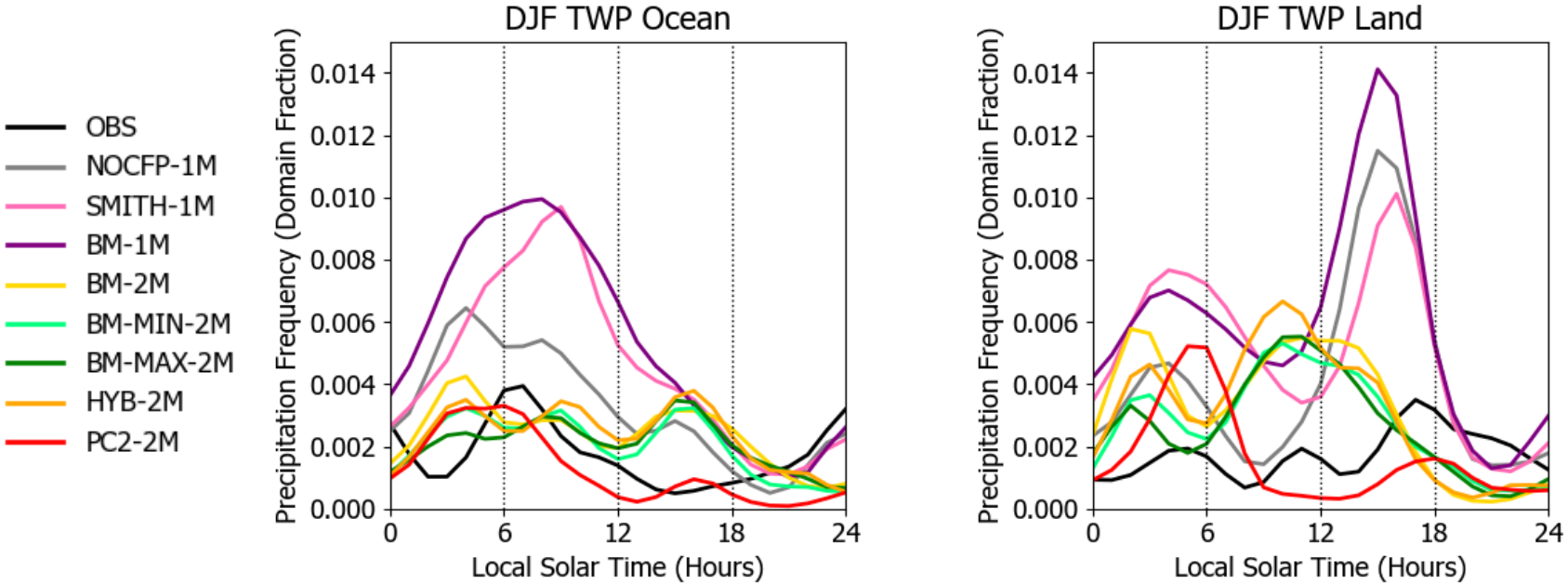
Surface Precipitation: light rain rates (< 2.5 mm/hr)

Precipitation (against Darwin radar)



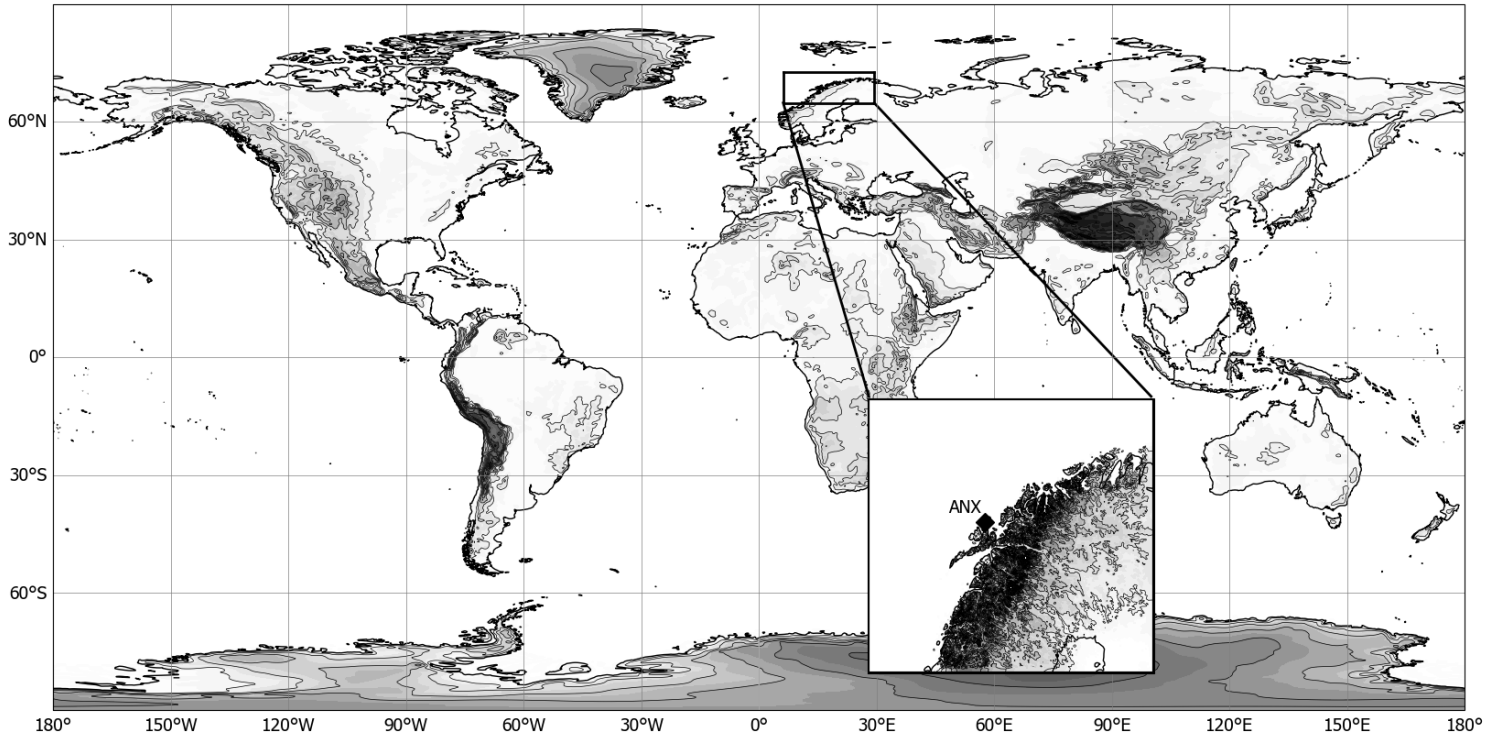
Surface Precipitation: heavy rain rates (> 20 mm/hr)

Precipitation (against Darwin radar)

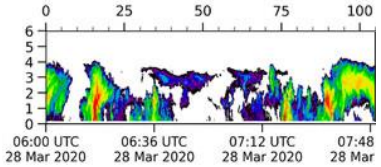


NORWAY (COMBLE)

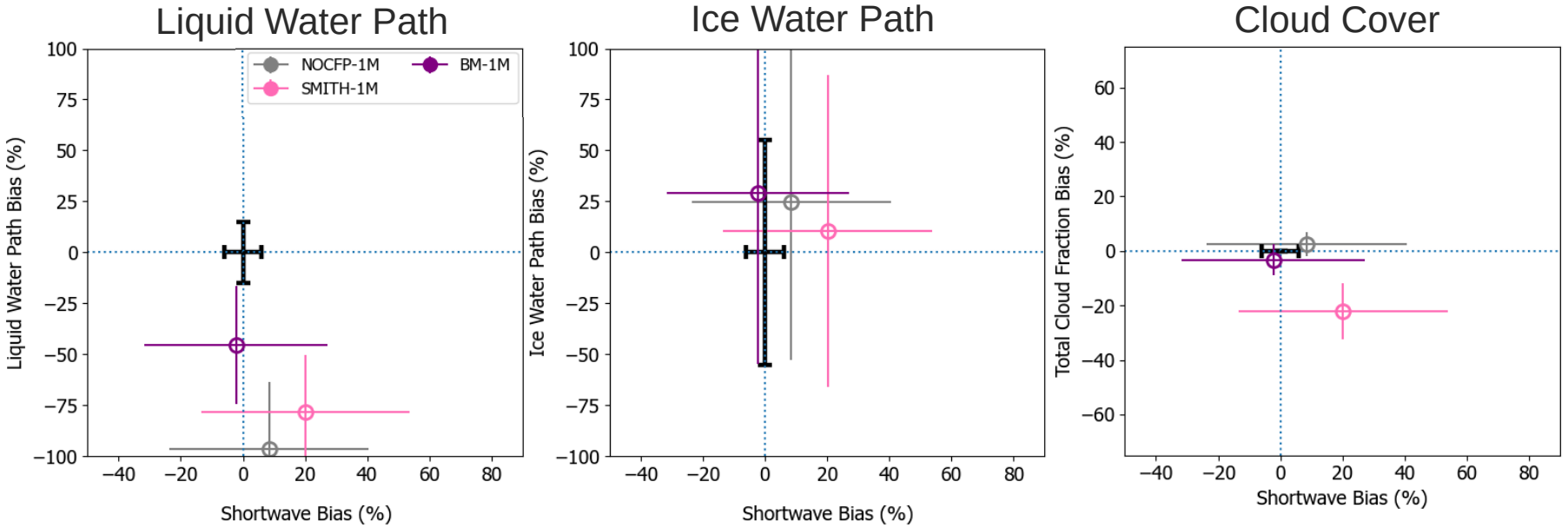
Cold-Air Outbreaks



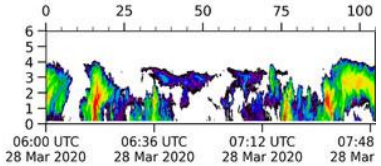
Cloud property biases: 1-moment

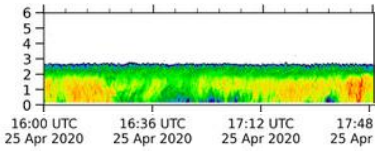


Joint biases cloud properties and downweling shortwave deep and shallow cold air outbreak regimes

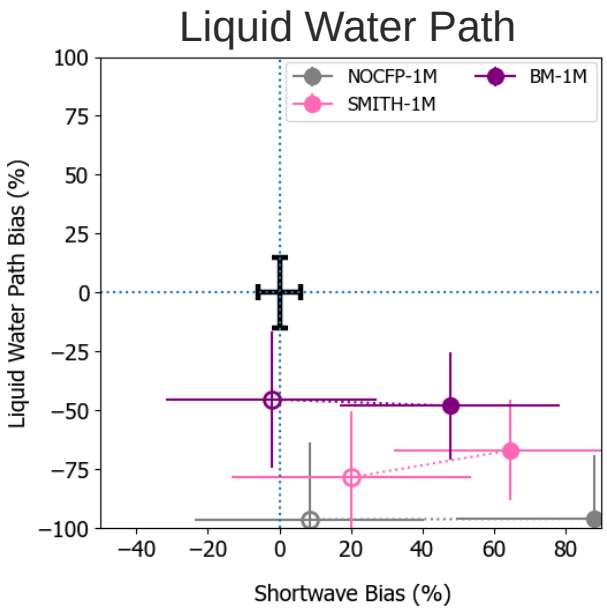


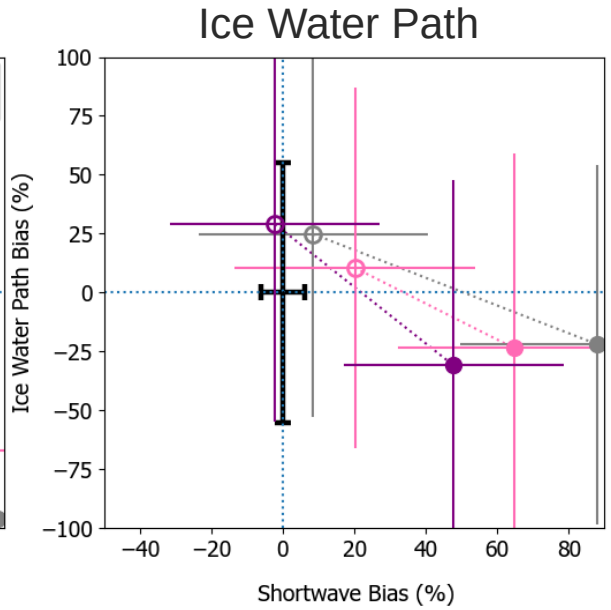
Cloud property biases: 1-moment

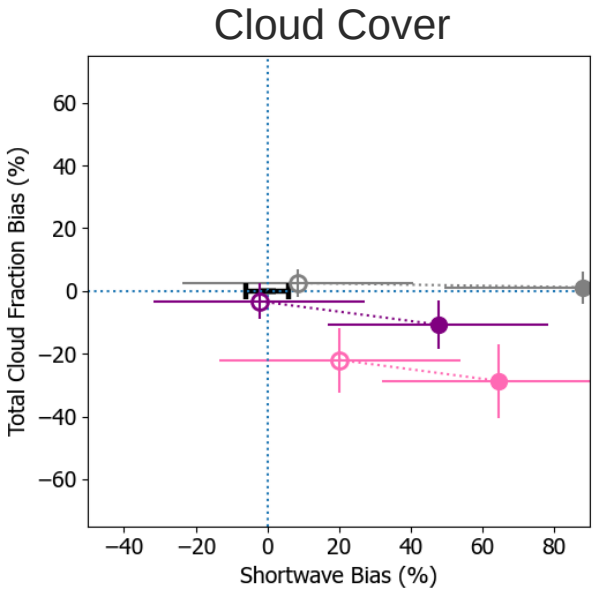




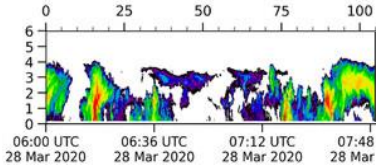
Joint biases cloud properties and downweling shortwave deep and shallow cold air outbreak regimes

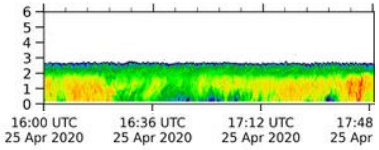




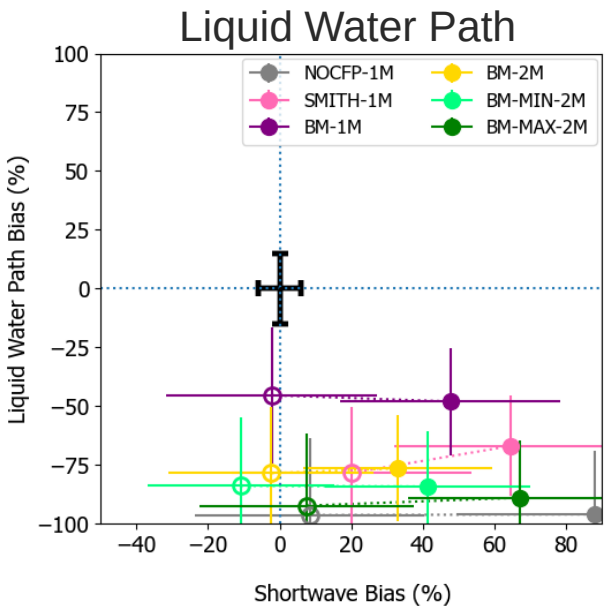


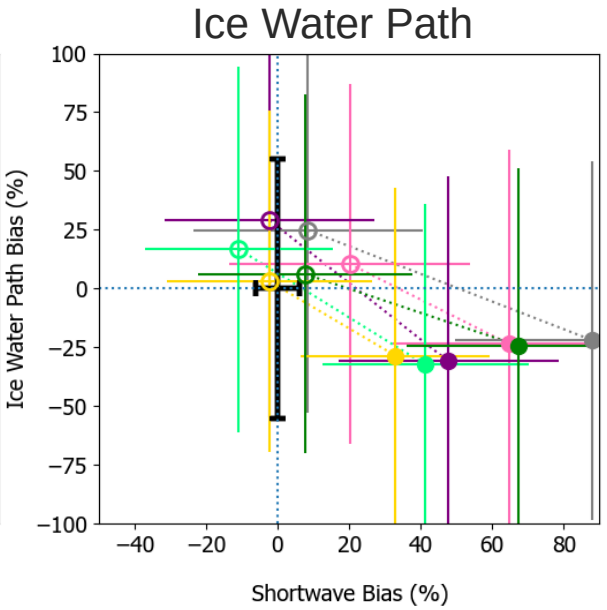
Cloud property biases: diagnostic schemes

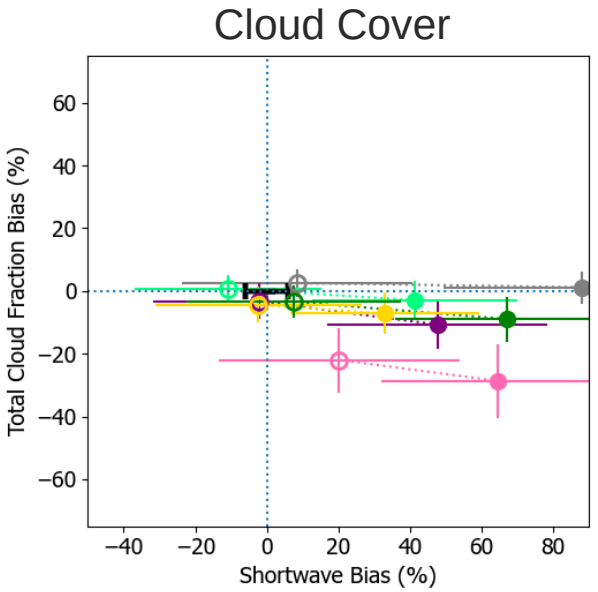




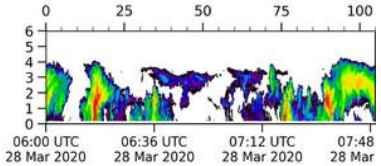
Joint biases cloud properties and downweling shortwave deep and shallow cold air outbreak regimes

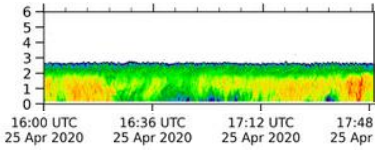






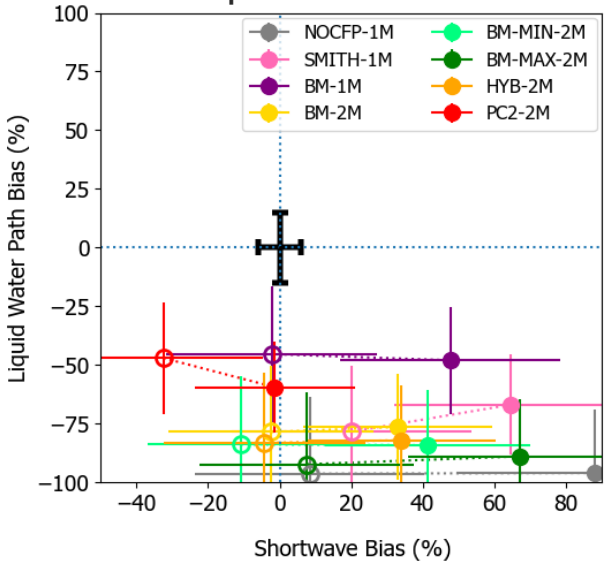
Cloud property biases: hybrid and prognostic



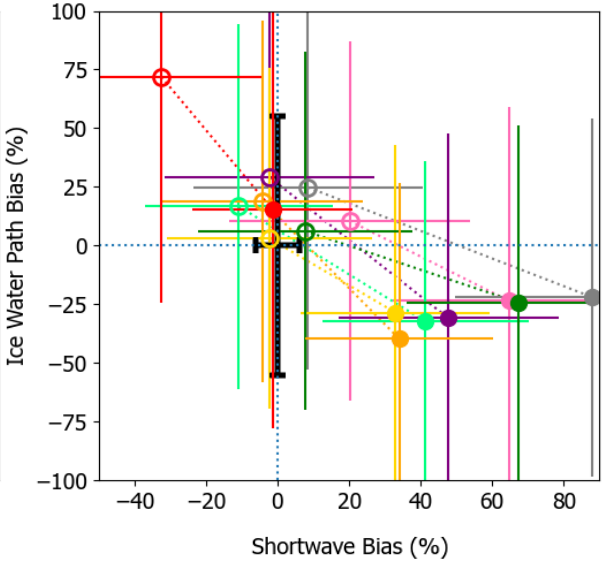


Joint biases cloud properties and downweling shortwave deep and shallow cold air outbreak regimes

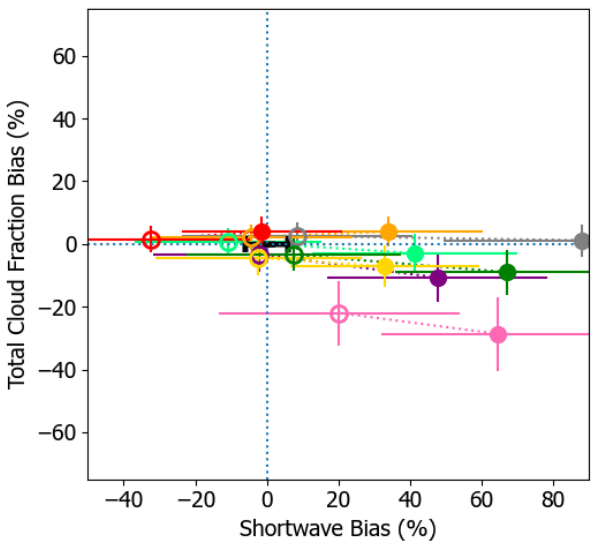
Liquid Water Path



Ice Water Path



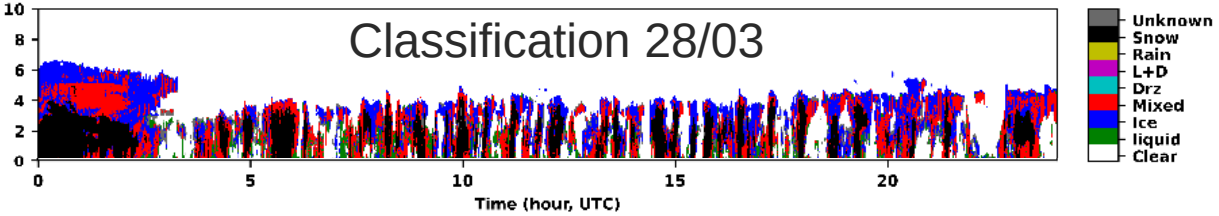
Cloud Cover

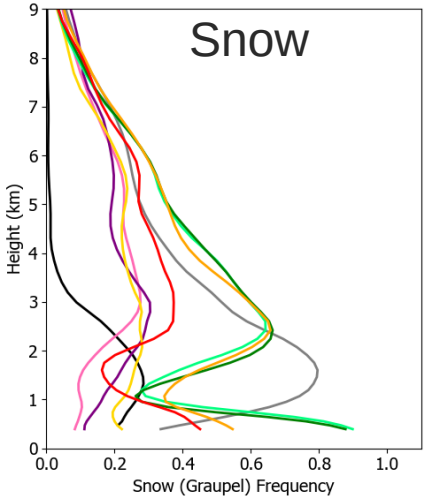


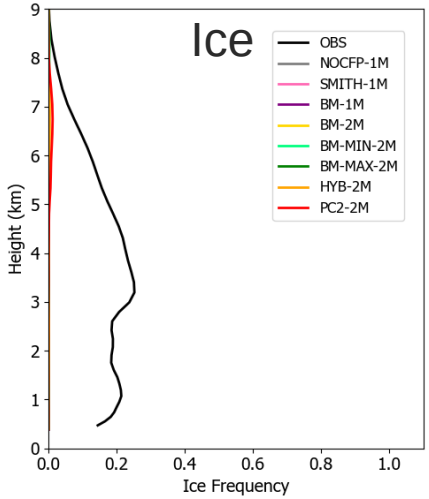
Role of ice microphyiscs

(in-)direct evidence of too strong glaciation and too large precipitation particles

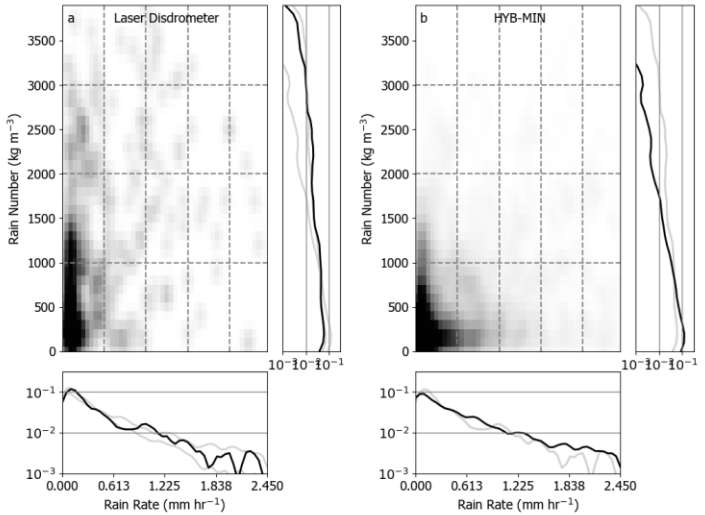
New hydrometeor classification product (Zhang and Levin 2022) based on radar, lidar and radiometer

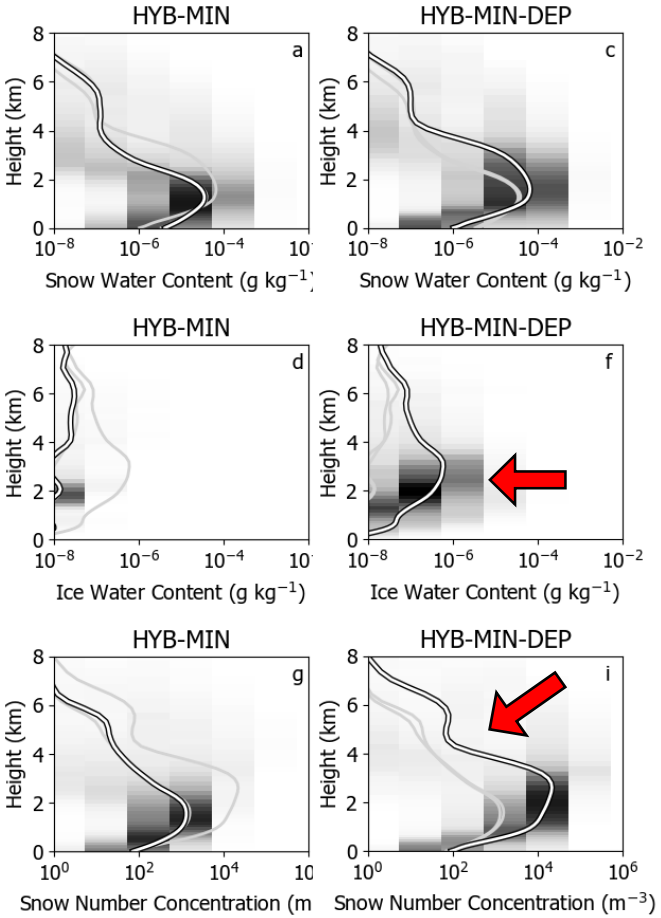






Disdrometer DSDs



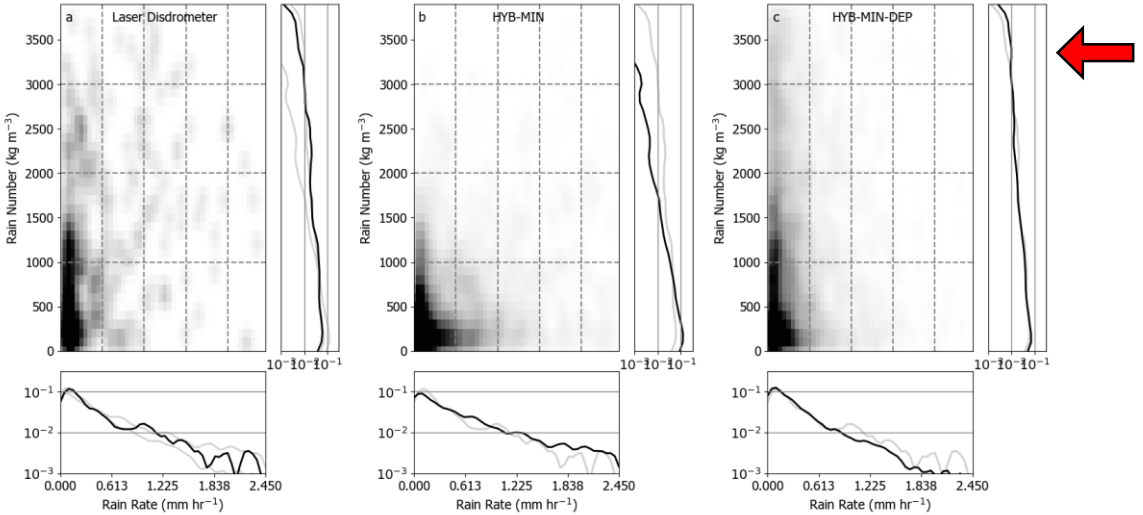


Role of ice microphysics

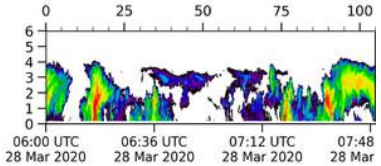
(in-)direct evidence of too strong glaciation and too large precipitation particles

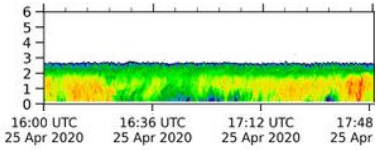
Additional experiments: reduce (1) riming, (2) **deposition**

Disdrometer DSDs



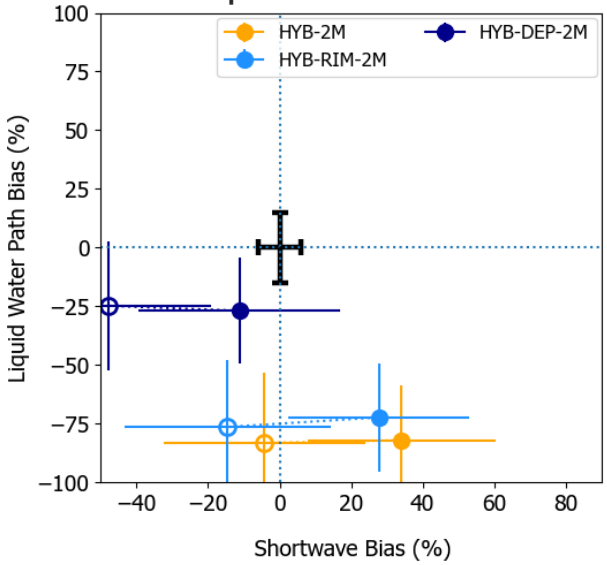
Role of ice microphysics



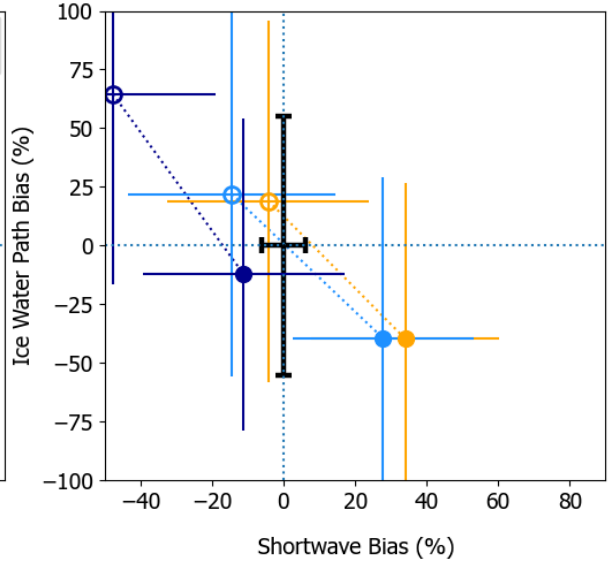


Improved water paths in reduced deposition experiment

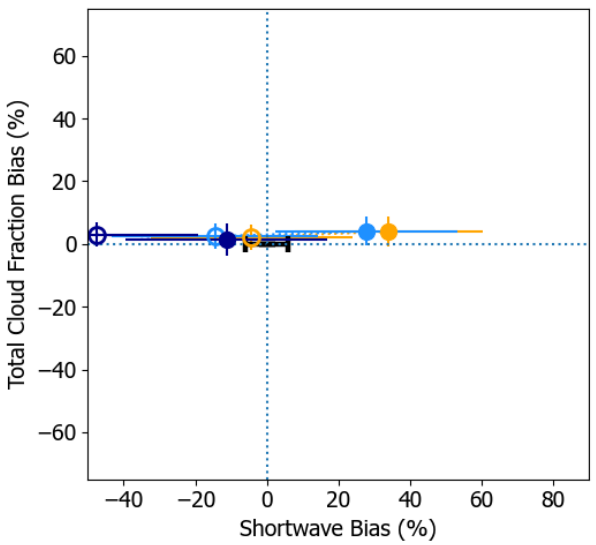
Liquid Water Path



Ice Water Path



Cloud Cover



Conclusions

- Role of cloud macro- and microphysics in kilometre-scale models.

Tropics:

- Cloud fraction scheme crucial for cloud-radiative effects
- Lack of thin overcast cloud compensated by spurious convective cloud
- Microphysics more important than macrophysics for precipitation
- Improved precipitation intensity distributions in 2-moment scheme

Arctic:

- Too small LWP in mixed-phase cloud, too large IWP in deep cloud regime
- Little impact of phase overlap due to persistent overcast conditions
- No improved LWP in 2-moment; Improved LWP with prognostic cloud fractions
- Too large precipitation particles and too small LWP alleviated by reduced deposition

→ Van Weverberg and Morcrette (QJRMS 2022), Van Weverberg et al. (JGR in review)