High Ice Water Content Modelling Study

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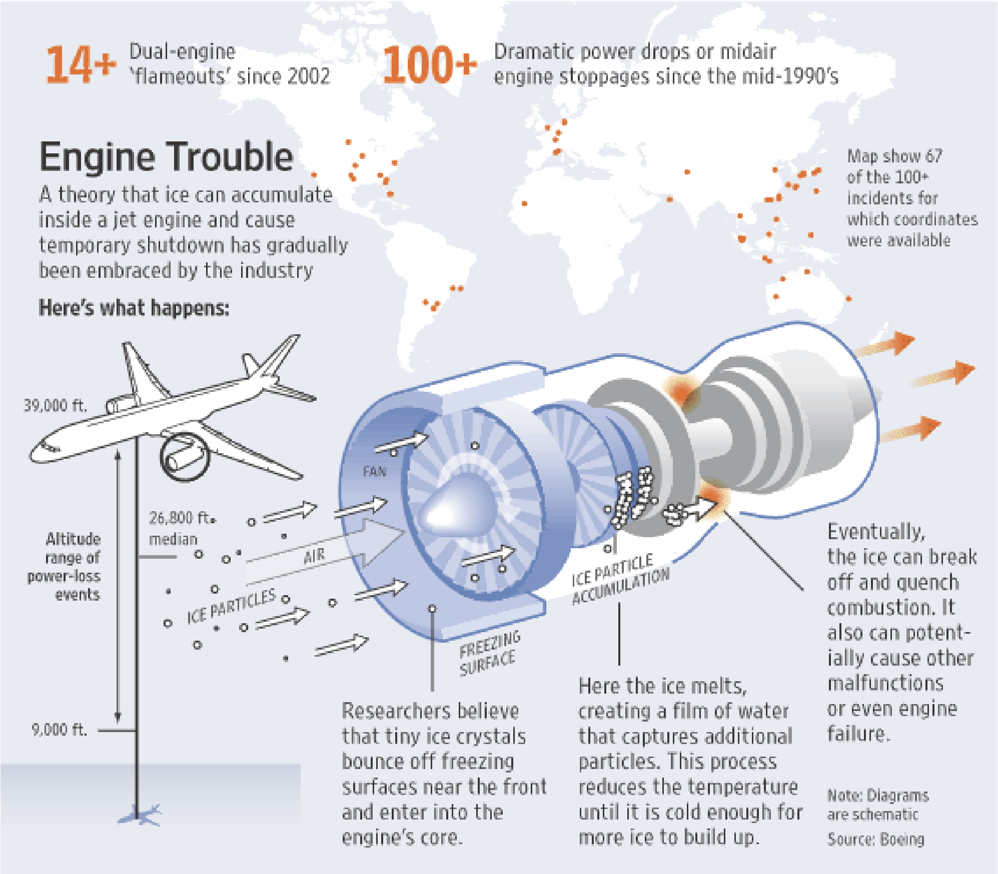
Motivation



Scientific motivations

- Observations of clouds with high ice water content but low radar reflectivity challenges our understanding of cloud processes
- Determine the small ice particle formation mechanism: nucleation or ice multiplication
- Determine the evolution of the mixed-phase in deep convective clouds - how does the liquid/ice water fraction change
- Improve the simulation of deep convective cloud systems

High Ice Water Content Modelling Study

- Evaluate ACCESS 1km (8.5 PS32) simulations of tropical convection
- Investigate the controls on phase composition in the model
- Examine the effects of dynamics, turbulence and microphysical parameterisations

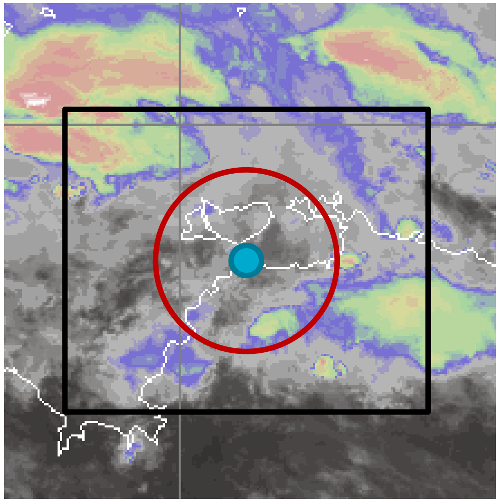
nd	= control, PS32 using new dynamics
eg	= ENDGame even newer dynamics
eg ndbcs	= ENDGAME using nd boundary conditions
3d	= 3d Smagorinsky rather than blended vertical diffusion
nopsd	= no generic ice size distribution parameterisation
qcf2	= nopsd but with additional ice prognostic
qcf2hm	= qcf2 but with Hallett-Mossop ice splintering parameterisation
qcf2ndrop500	= qcf2 but with cloud droplet number of 500 not 100
qcf2sr2graupel	= qcf2 but without snow-rain collisions producing graupel
qcf2noqgr	= qcf2 but without graupel
qcf2rainfreeze	= qcf2 but with freezing rain a source of graupel
qcf2raindsd	= qcf2 but with Marshall-Palmer rain drop size distribution

- Darwin mesoscale convective system case study February 18 2014
- Evaluation using CPOL radar, radiosonde, satellite and aircraft obs

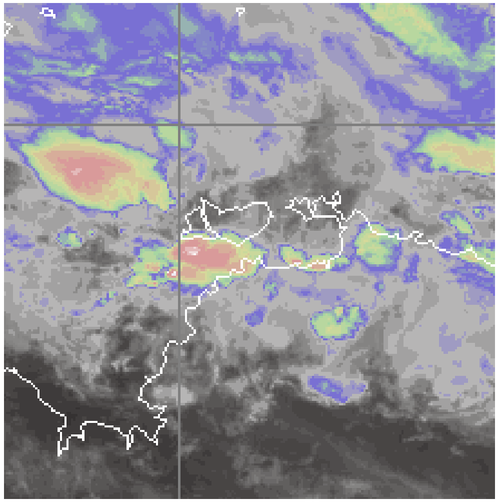
MCS lifecycle

BT (K)

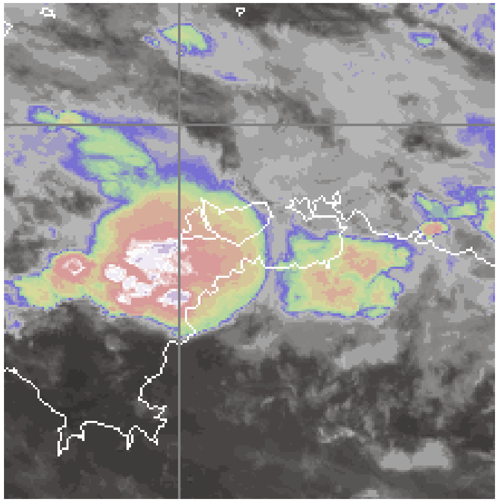
12 UTC = 21:30 local



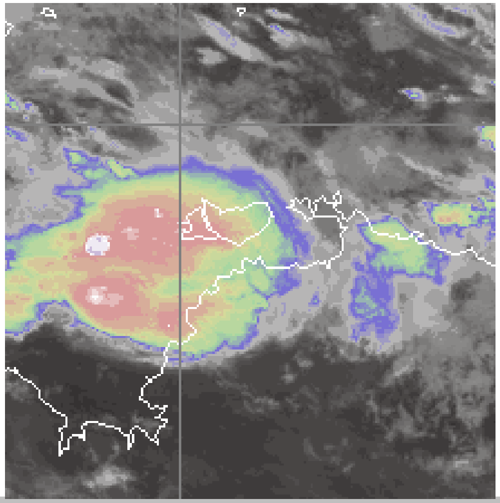
15 UTC



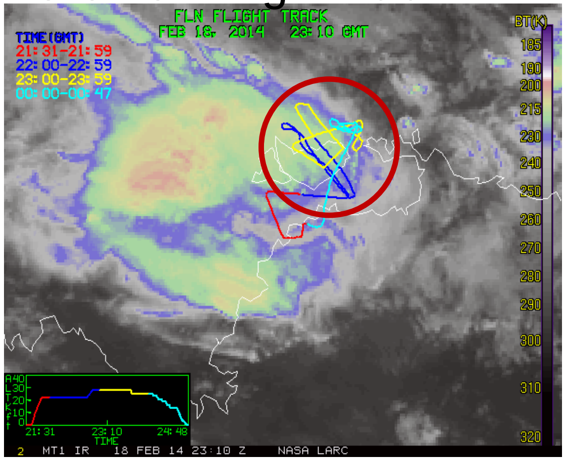
18 UTC



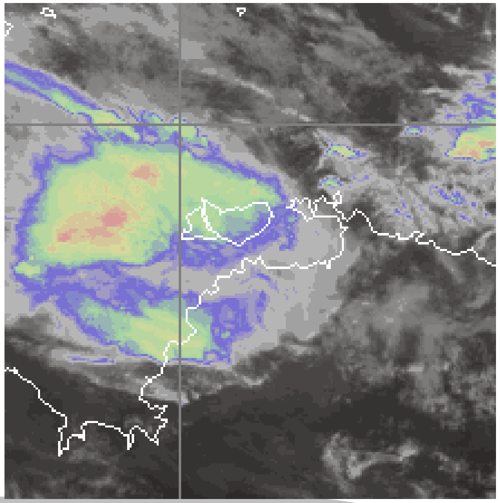
21 UTC



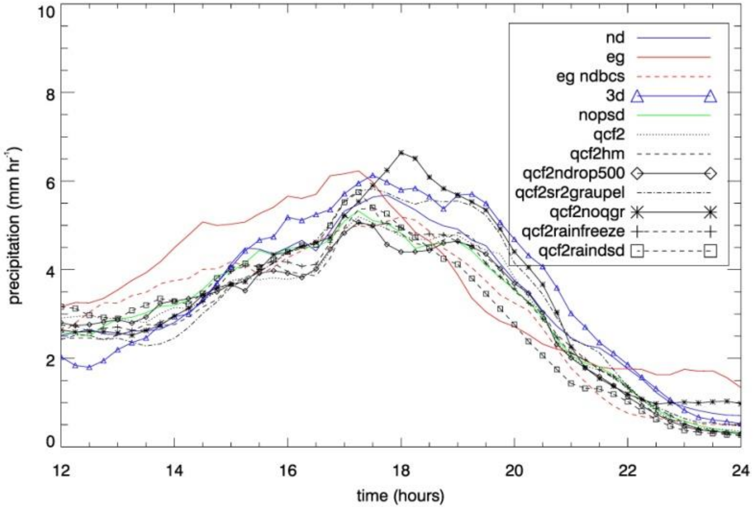
23 UTC – flight track

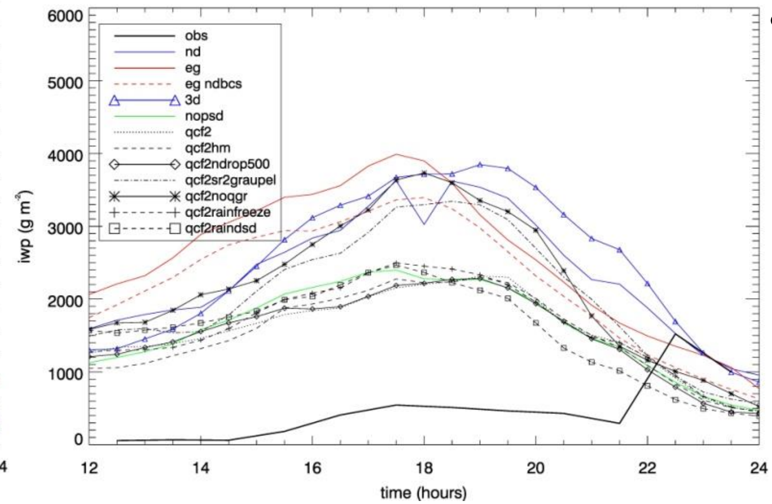


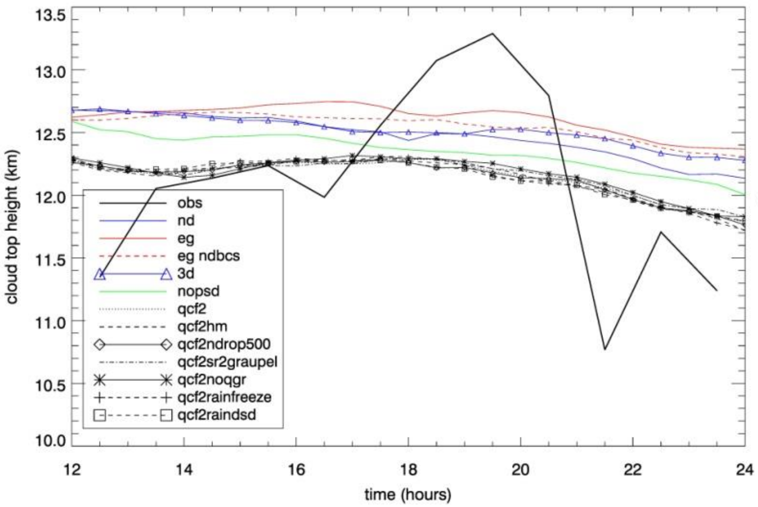
24 UTC = 9:30 local

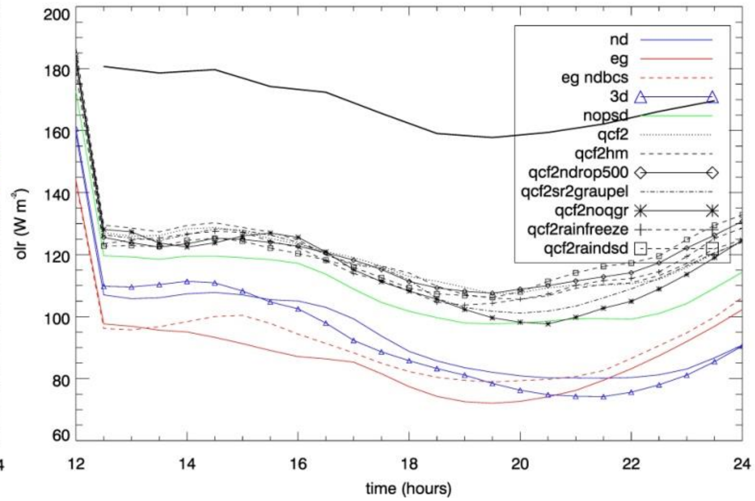


Timeseries and comparison with satellite obs



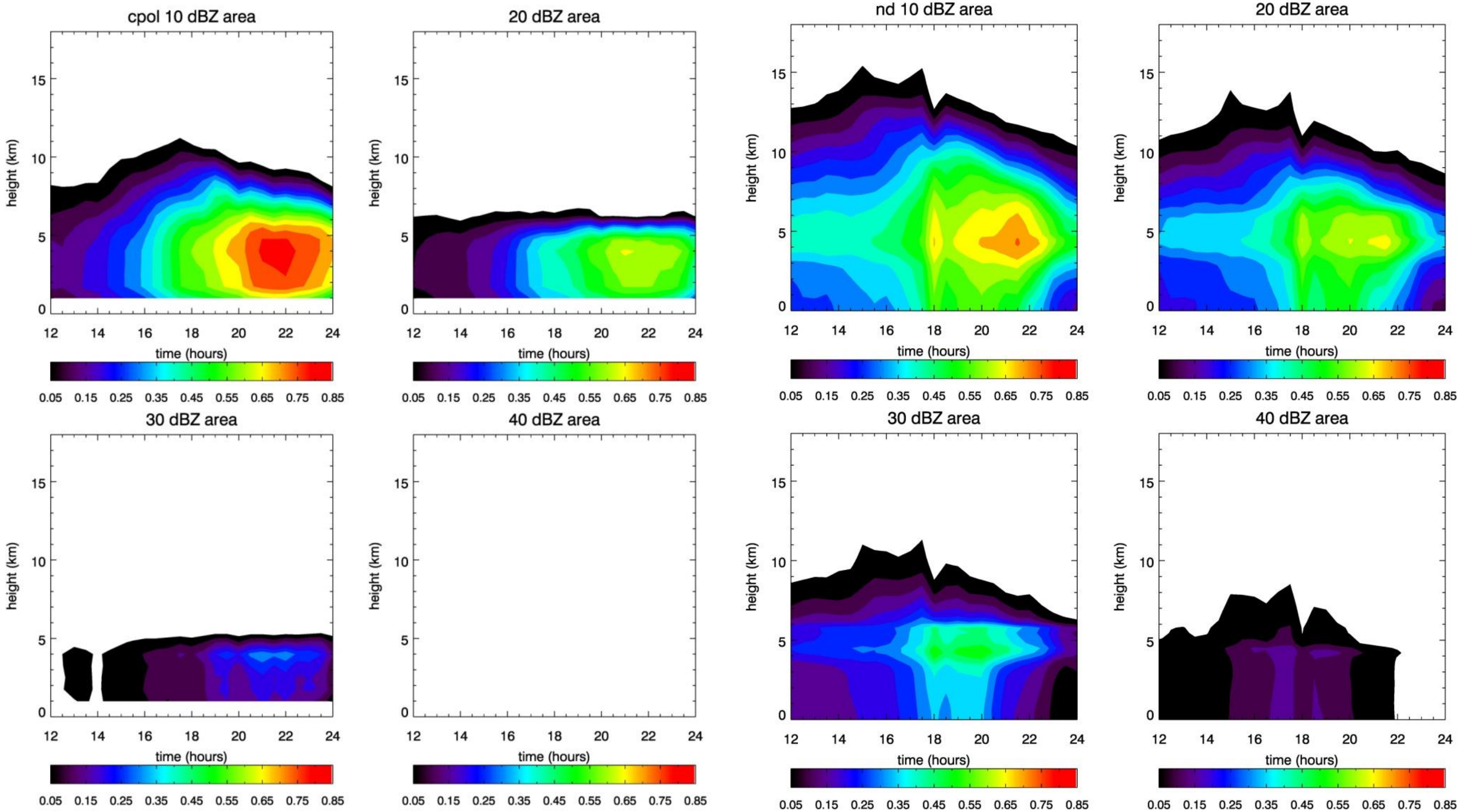






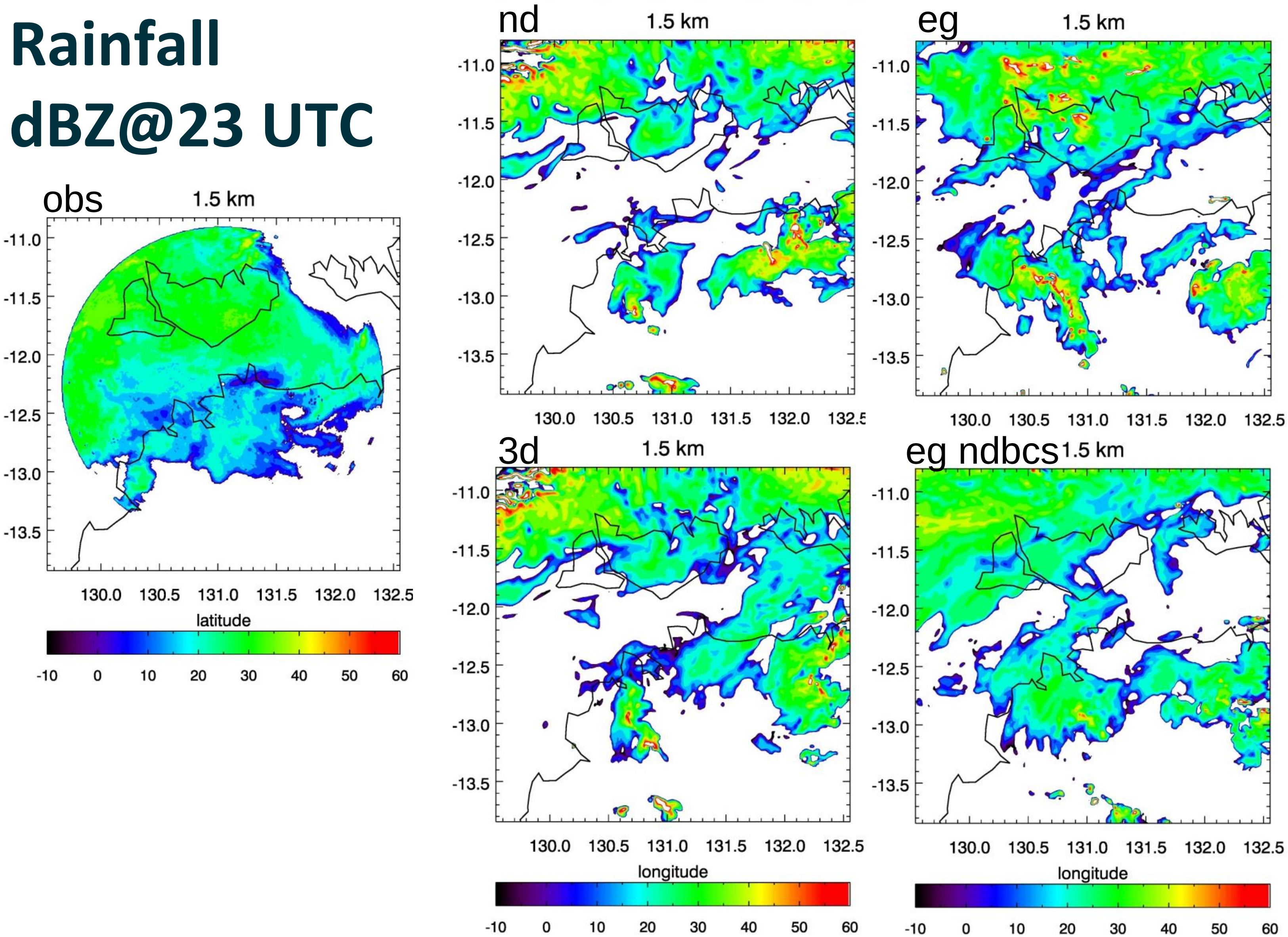
- Generic PSD has larger IWP, due to larger RH and greater vertical extent
- Avg cloud top heights reasonable, but temps too cold

MCS radar evolution

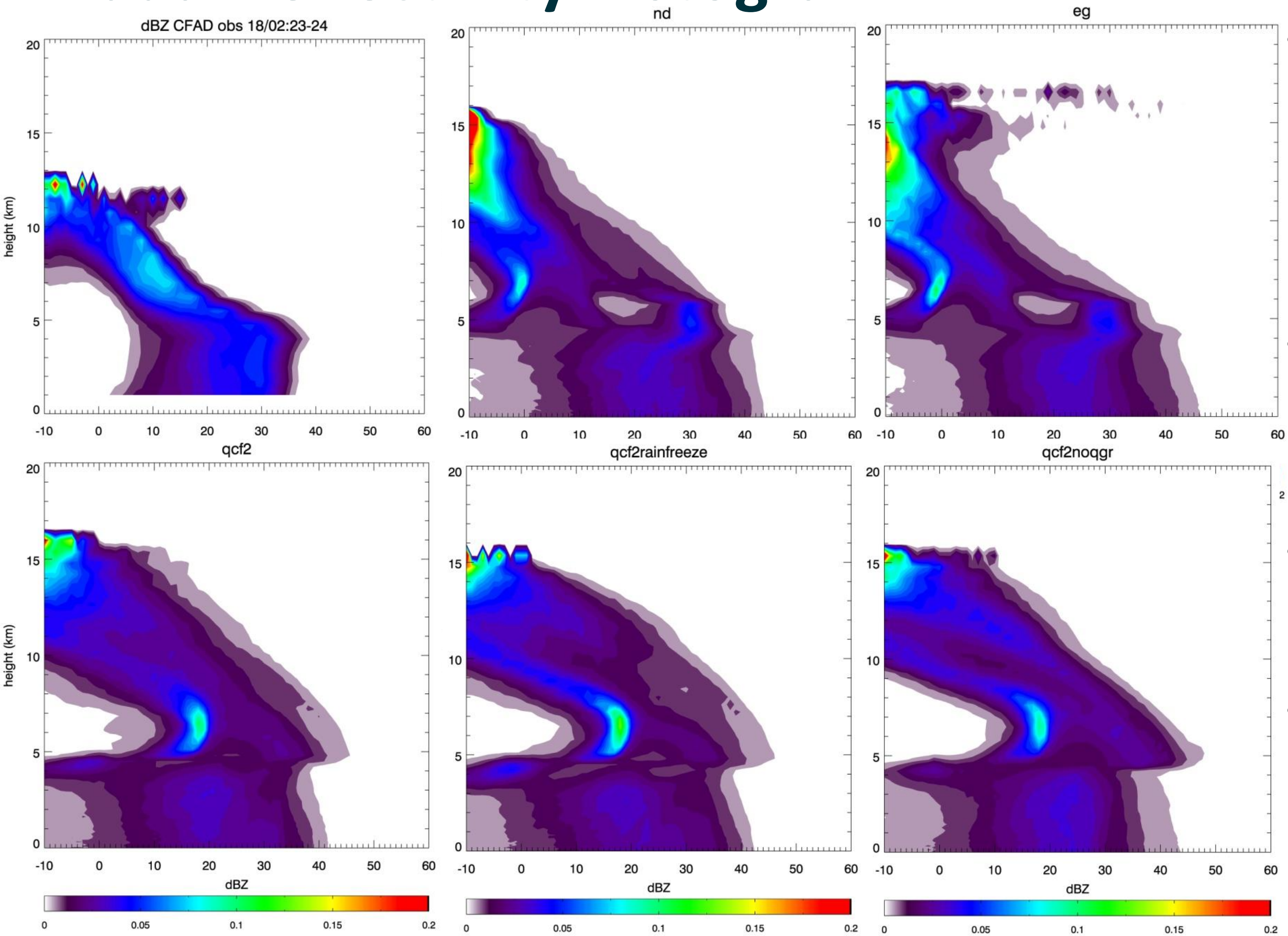


- Intensification and decay of convective strength well simulated
- Radar detected cloud top heights and areas > 30 dBZ overestimated

Rainfall dBZ@23 UTC

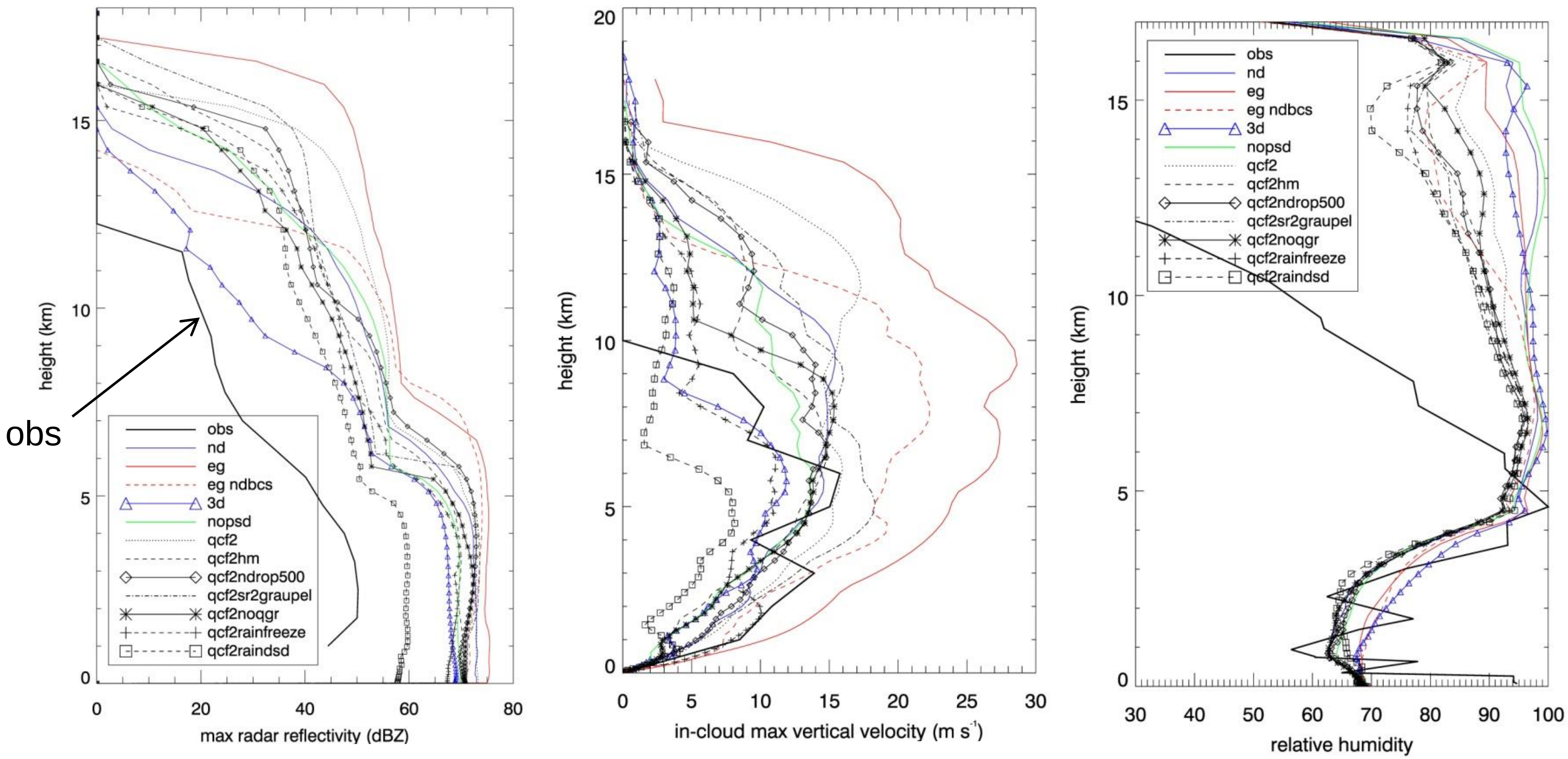


Radar reflectivity histogram



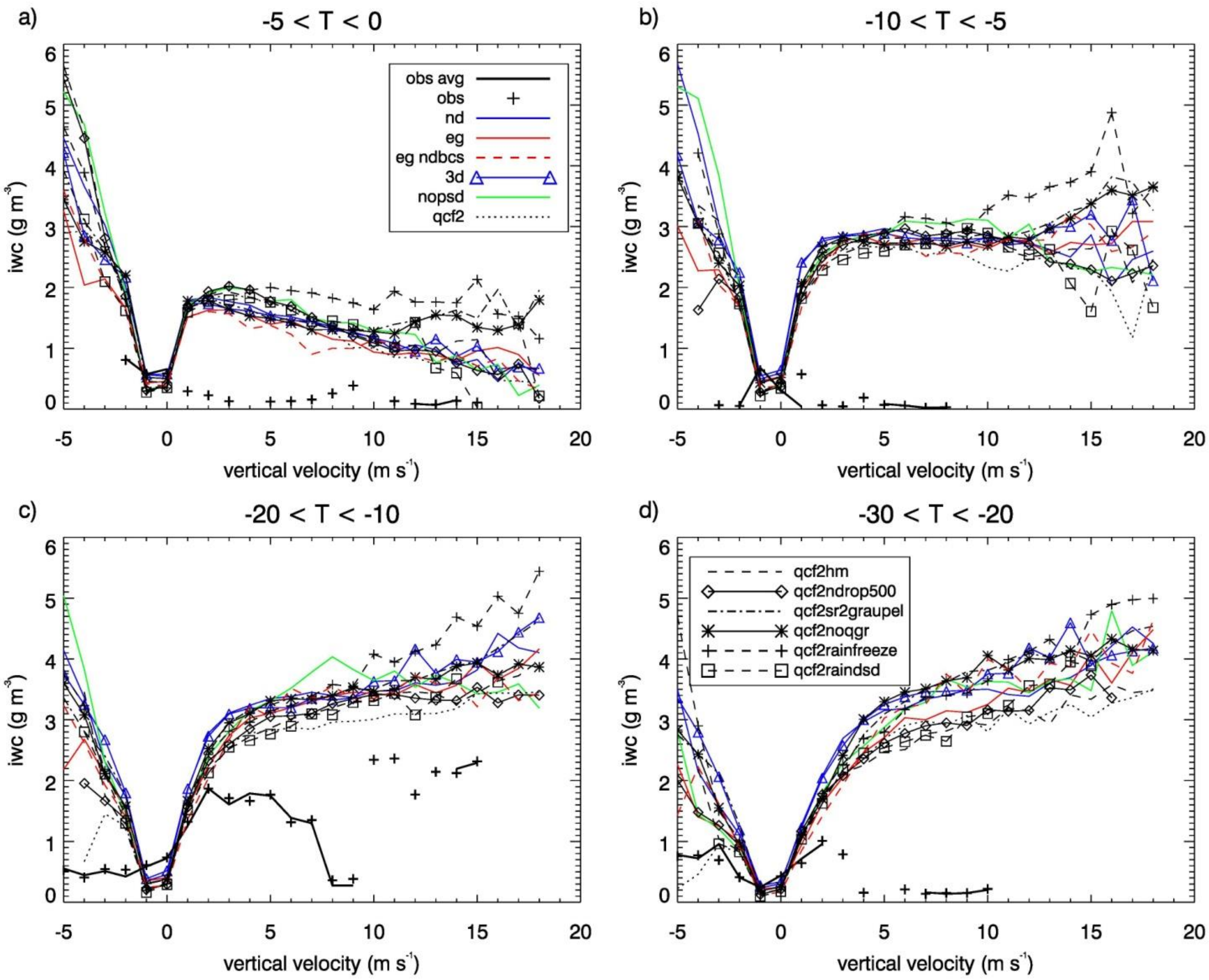
- Models show broader, more convective profile with many high dBZ outliers
- 5-7 km generic PSD dBZ too low and explicit PSD too high
- Evidence of large particles being lofted
- Rain dBZ suggests rain rate too low

Convective updraft reflectivity and vertical velocity



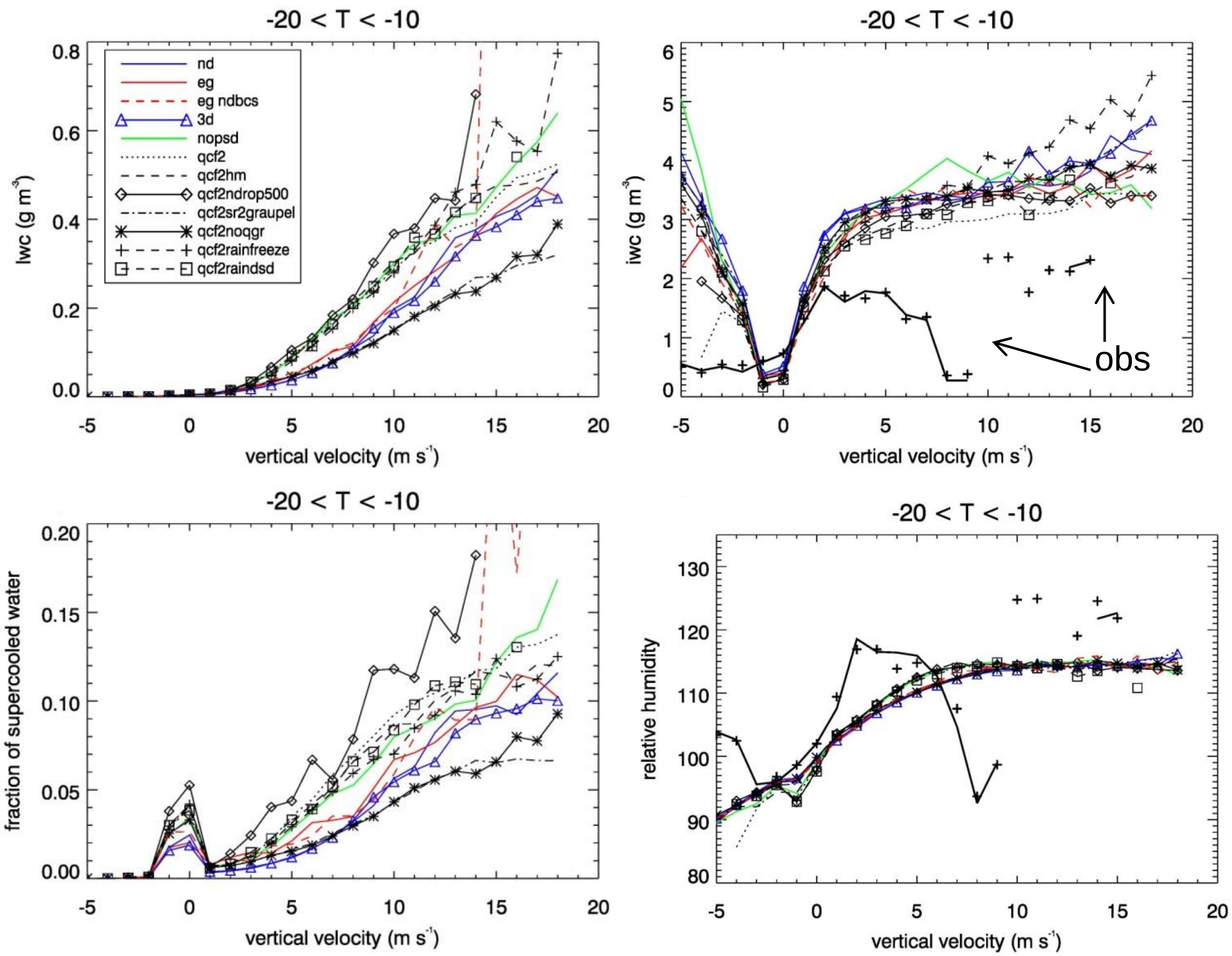
- Strong updrafts loft large particles producing profile of constant max dBZ
- Large sensitivity in max updraft from dynamics and turbulence formulations, as well as microphysics
- Strong updrafts have minimal entrainment and produce moisture bias

Ice water content



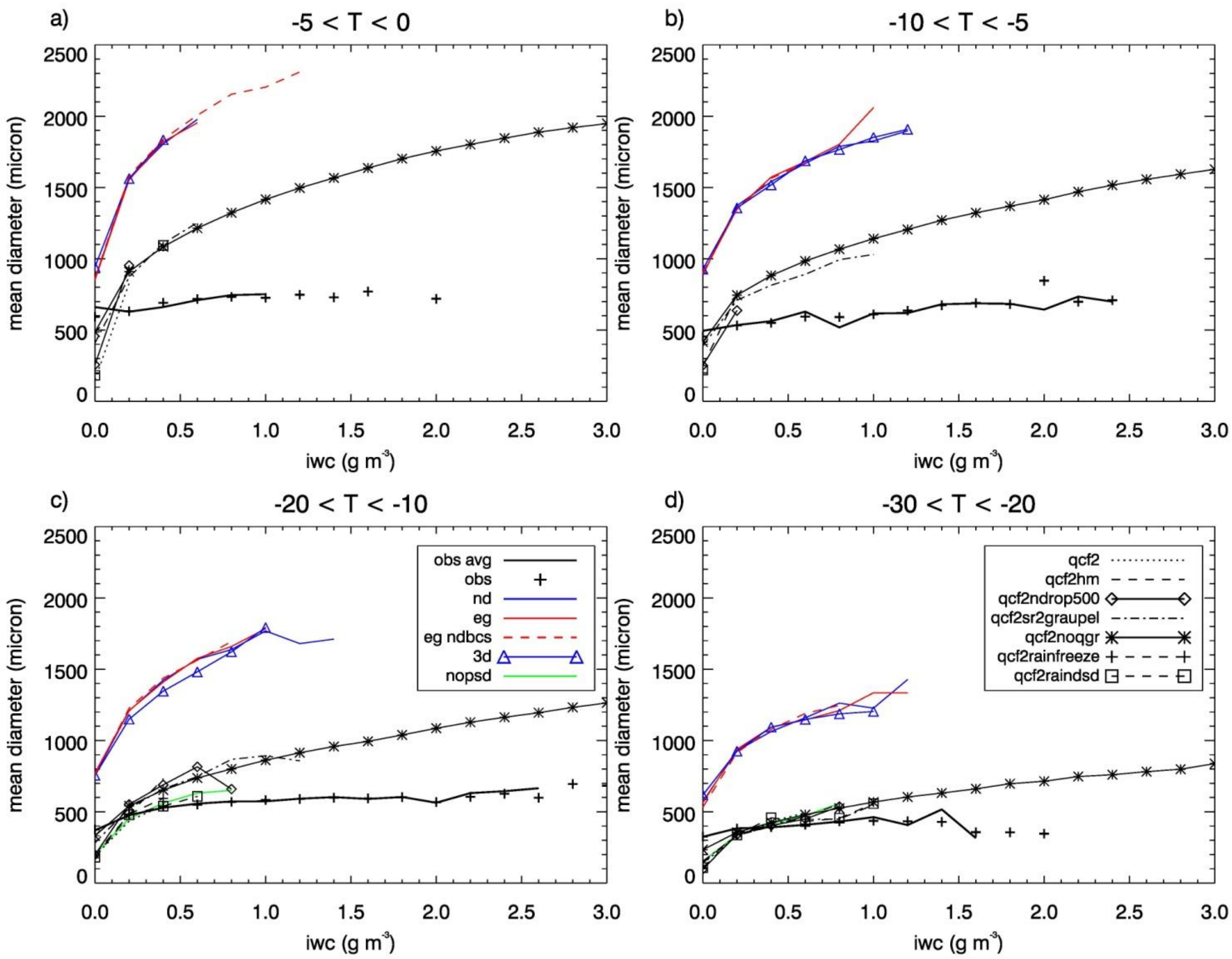
- IWC does not increase with w until the temp regimes cools to where ice nucleation occurs
- Inclusion of freezing rain produces more ice at high w
- IWC decreases at the colder temp regime due to lower supercooled water contents
- Large IWC in warm downdrafts, large fast particles help to initiate downdrafts

Phase composition



- Growth of ice less dependent on vertical velocity than liquid
- Control on LWC is updraft strength and ice size: stronger updrafts have minimal entrainment; larger ice remove more LWC via accretion
- Control on IWC is ice size and available LWC, larger sizes with less evaporation produce more occurrences of high IWC

Particle sizes



- Model snow sizes too sensitive to IWC
- Generic PSD mean sizes larger than explicit PSD and obs
- Explicit PSD mean sizes too large for warmer temps

Summary

- Intensification and decay of convective strength associated with the MCS life cycle is well simulated, but > 30 dBZ areas overestimated due to larger particle sizes and rain above the freezing level
- Reflectivity distributions and large scale environment better simulated when not using the generic ice size distribution parameterisation and with freezing rain
- Including freezing rain generates more ice in updrafts – balance between latent heating driving stronger updrafts and the increased water loading decreasing buoyancy
- Strong updrafts loft large particles producing profile of constant max dBZ, large sensitivity in max updraft from dynamics and turbulence
- ENDGame produces largest vertical velocities & dBZ regardless of BC
- Growth of ice less dependent on vertical velocity than liquid, high IWC determined in the model by ice size and available liquid

Thank you

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