Update on University of Utah HIWC Research

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Thank you to Rod Potts, Walter Strapp, Alain Protat, Julien Delanoe, Alfons Schwarzenboeck, Delphine Leroy, Steve Harrah, Pat Minnis, and everyone else involved in processing data sets that we are using or plan to use

HAIC-HIWC Science Team Meeting
9-11 March 2015
NASA GISS, New York, New York

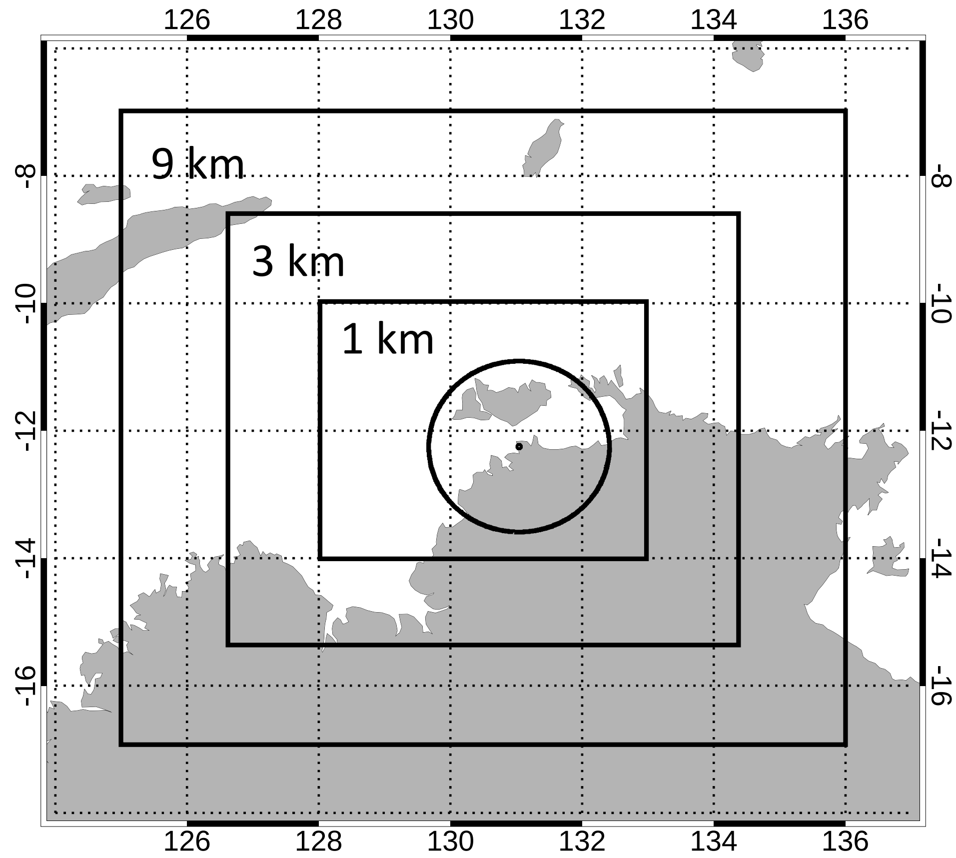
Flight 23 Simulation Setup

WRF V3.6.1

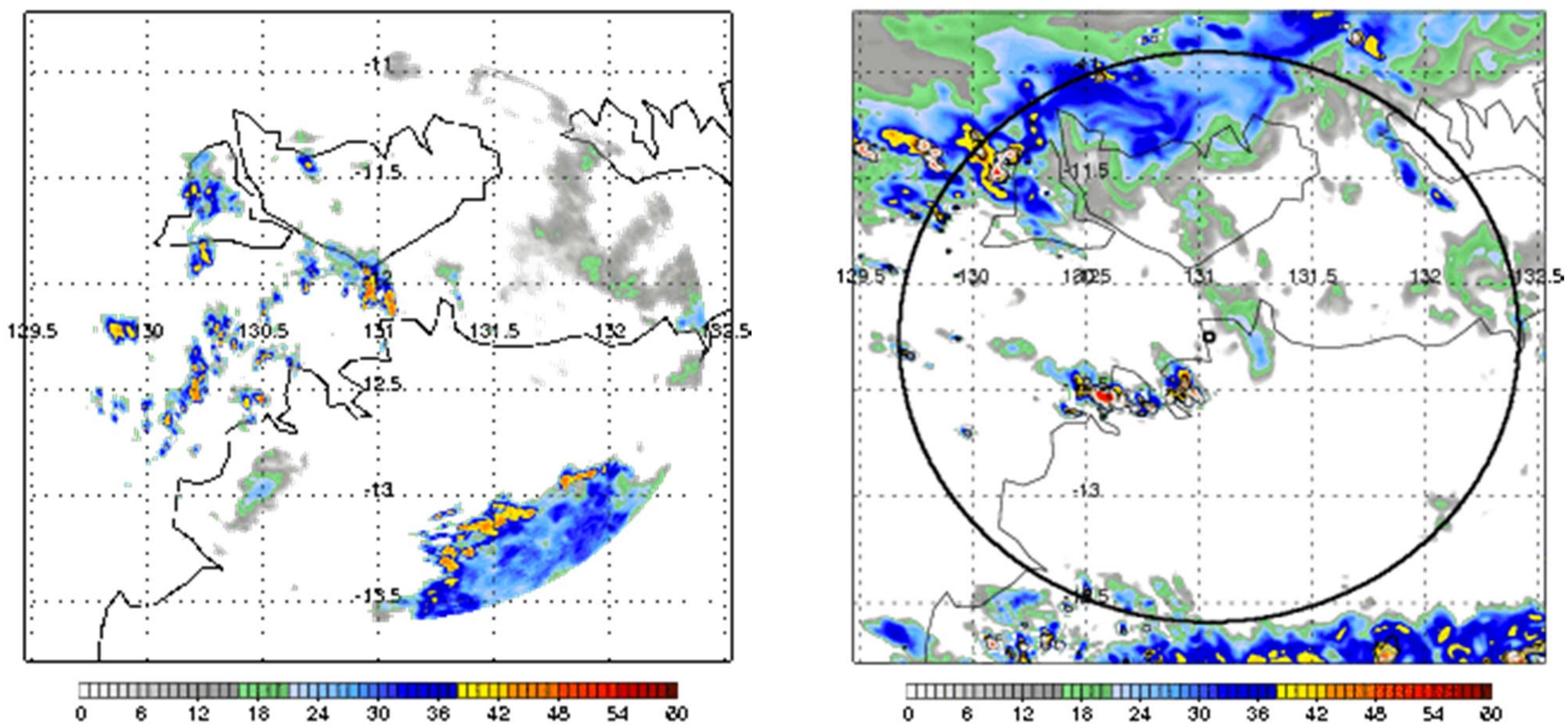
3 nested domains (9, 3, 1 km; 92 vertical levels) forced by ACCESS-R 12-km analyses

Thompson bulk microphysics, which has a sophisticated snow representation

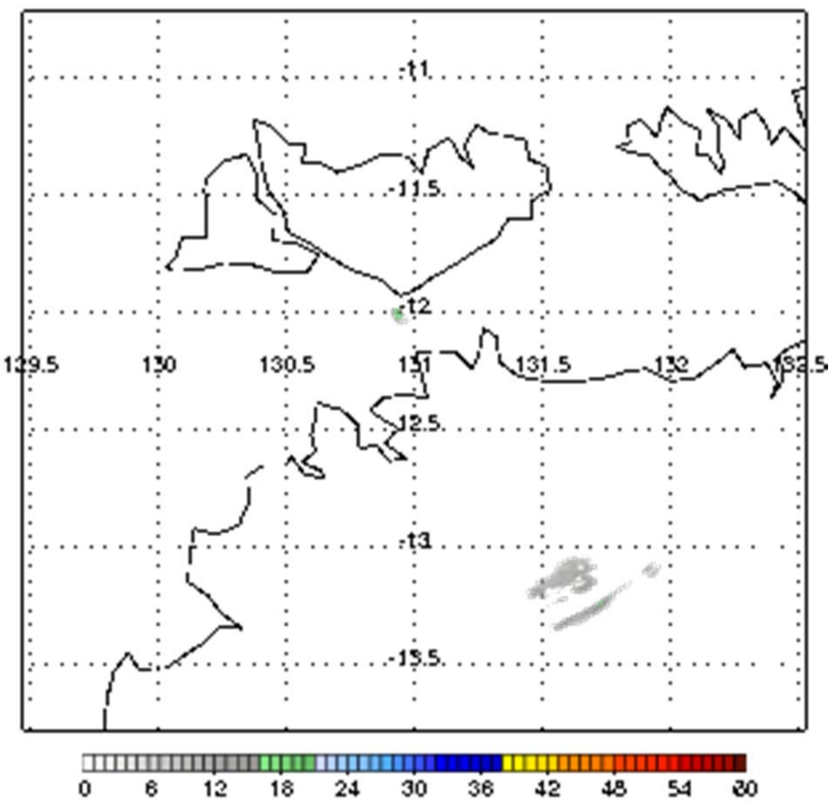
Initialized at 0Z 18 February and run through 6Z 19 February

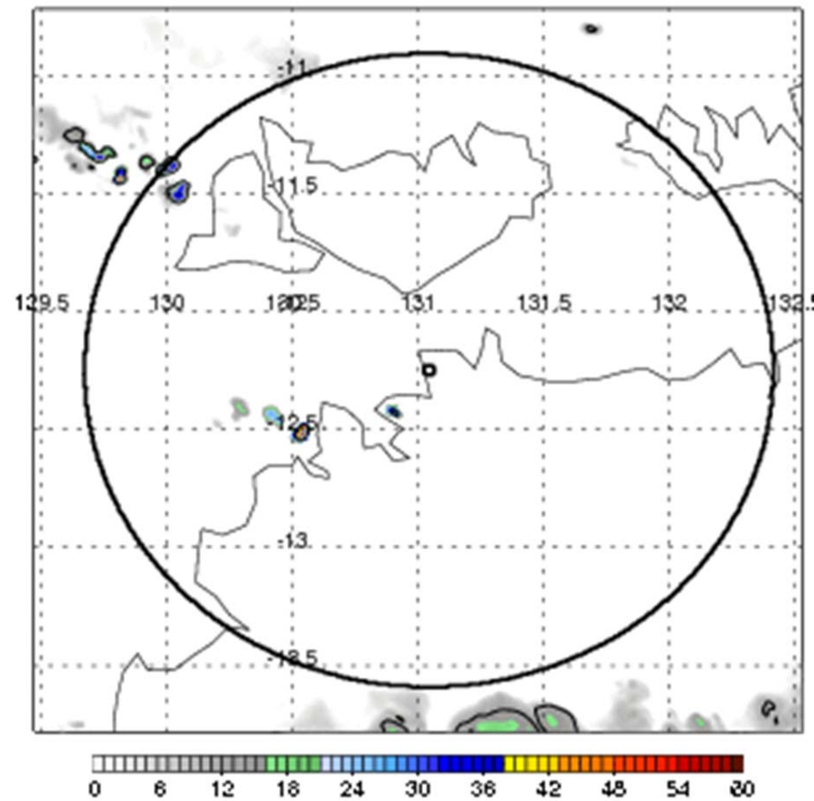


Simulated vs. Observed 2.5-km Reflectivity

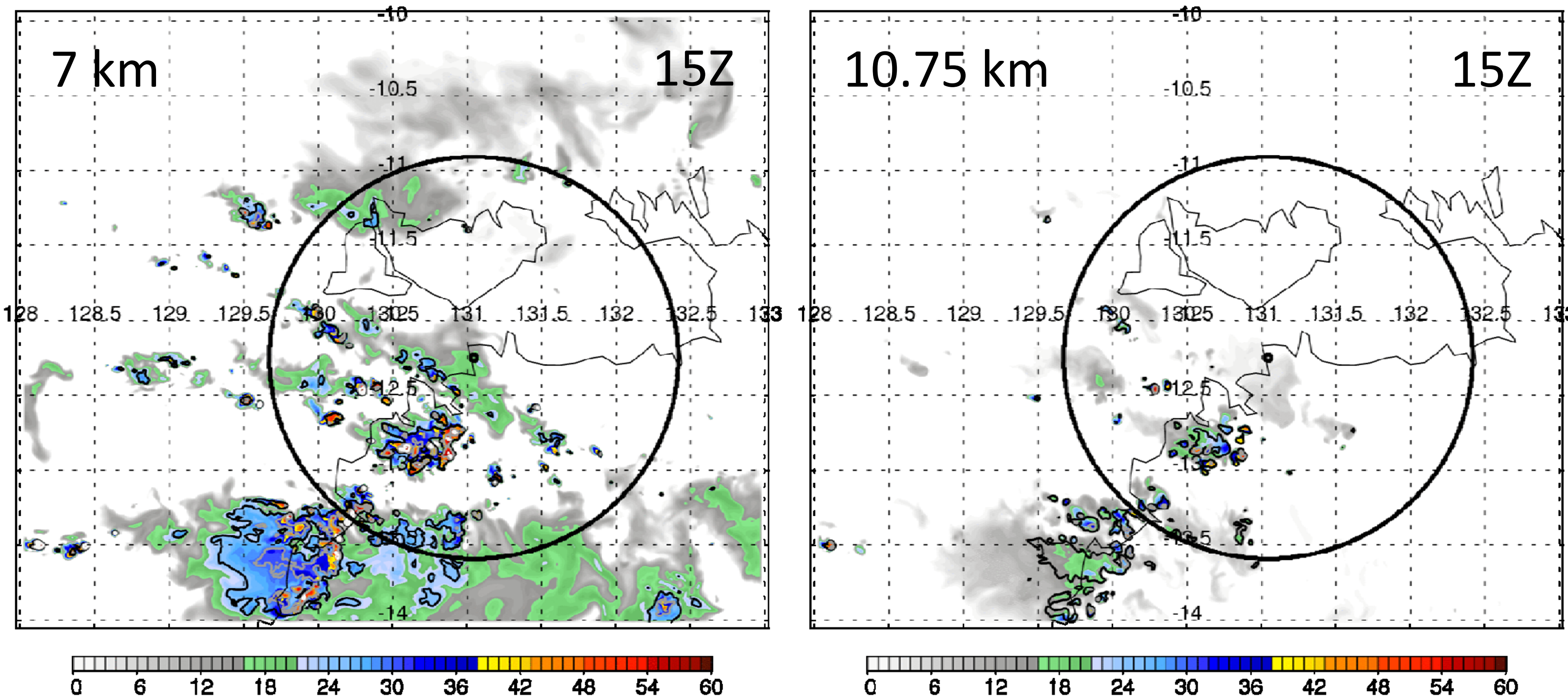


Simulated vs. Observed 10.75-km Reflectivity





Production of High IWC and low dBZ



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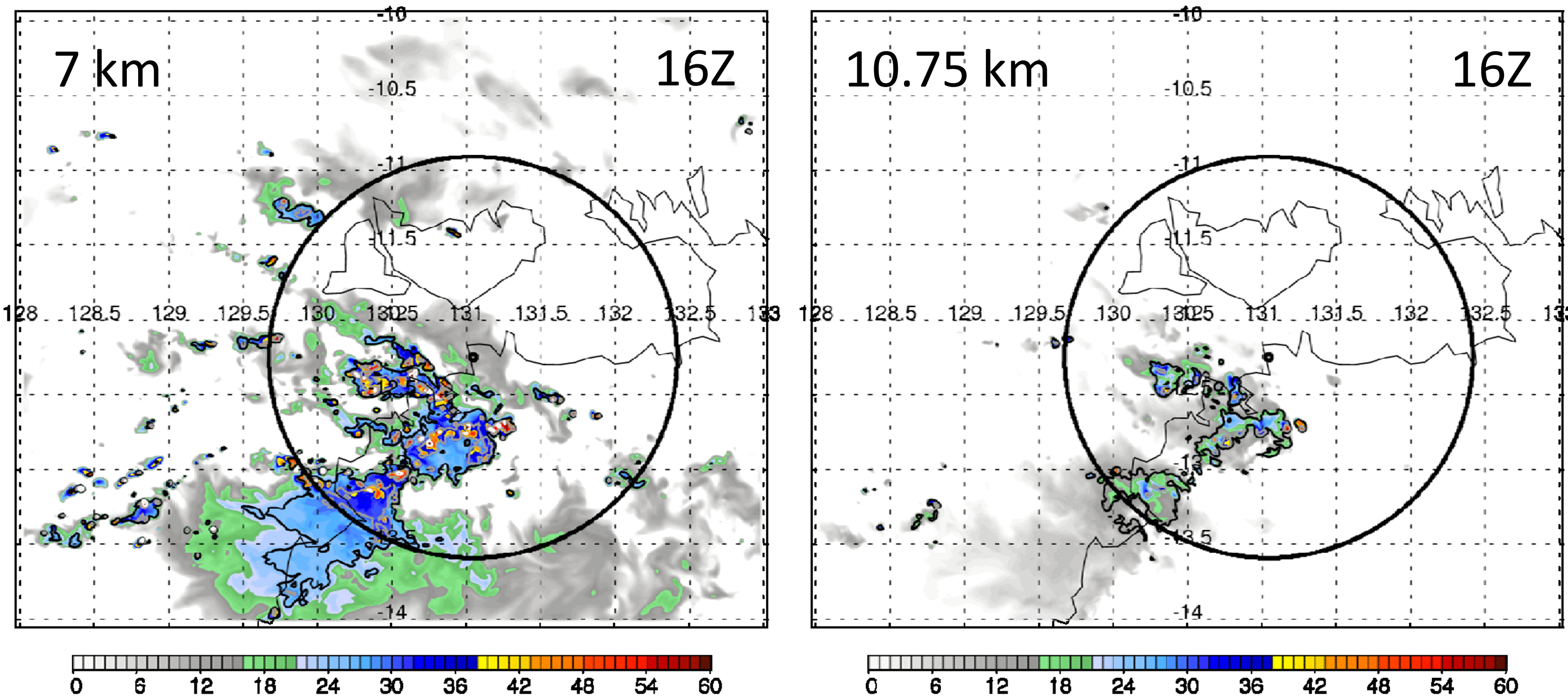

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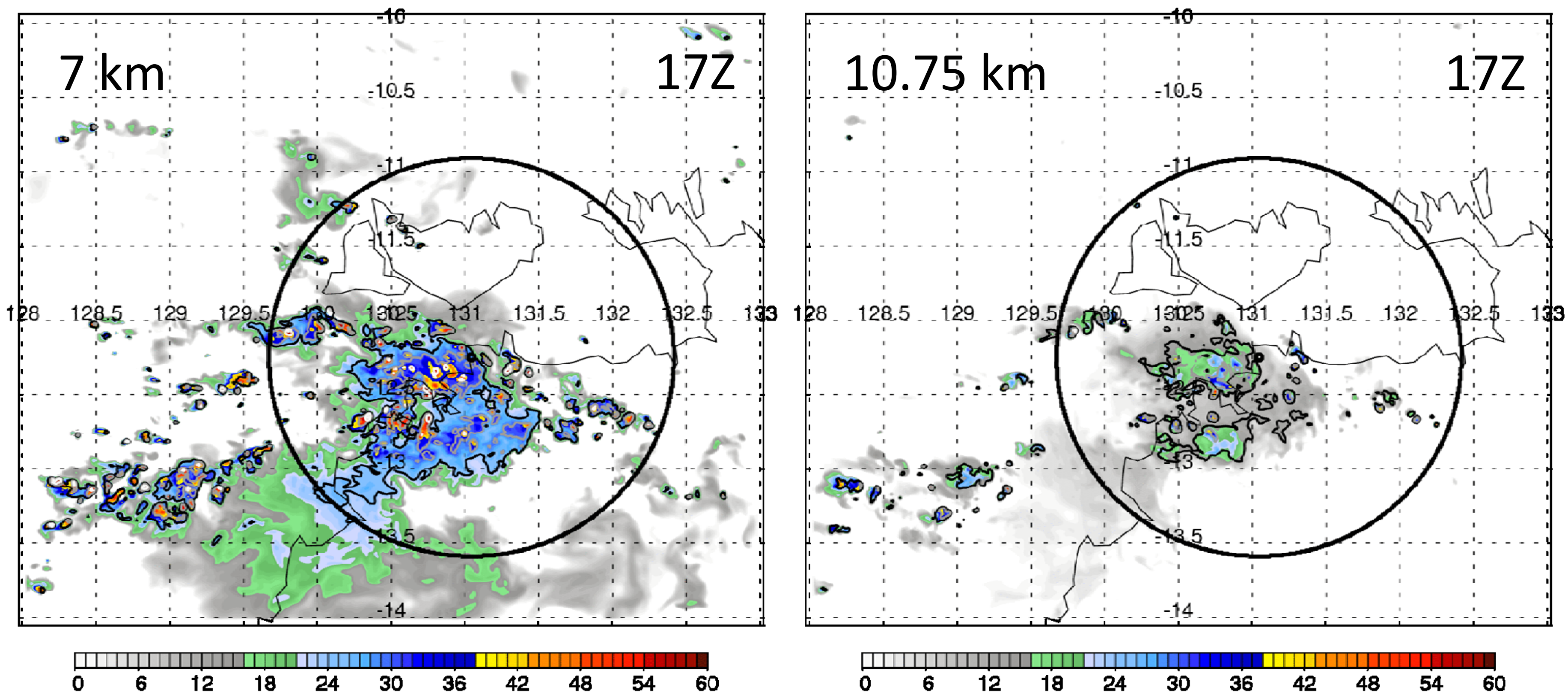

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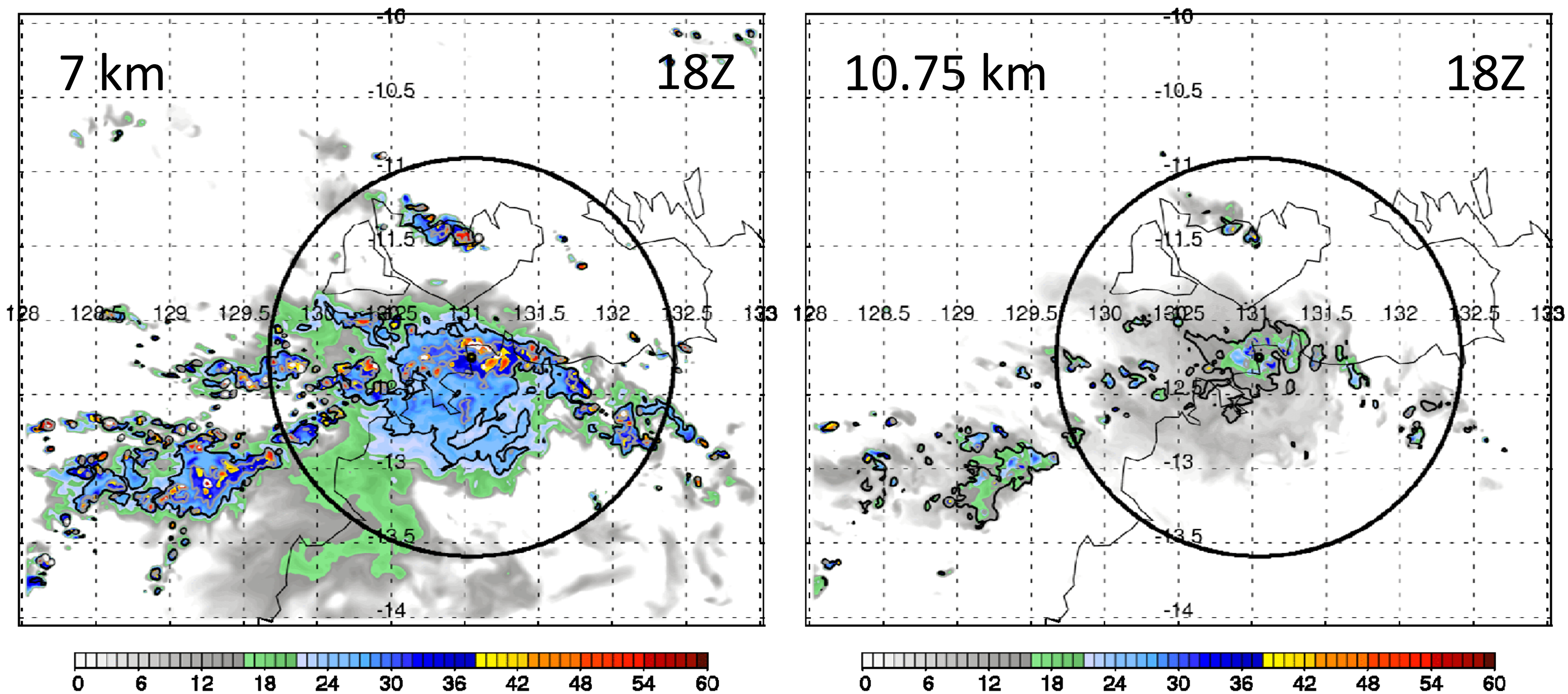
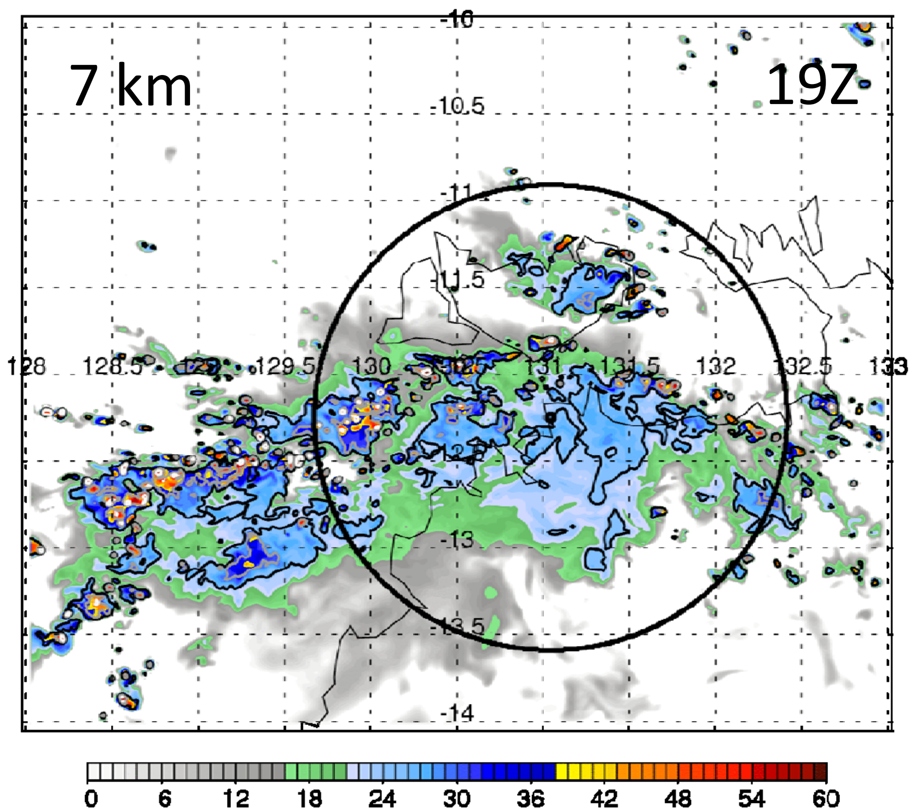
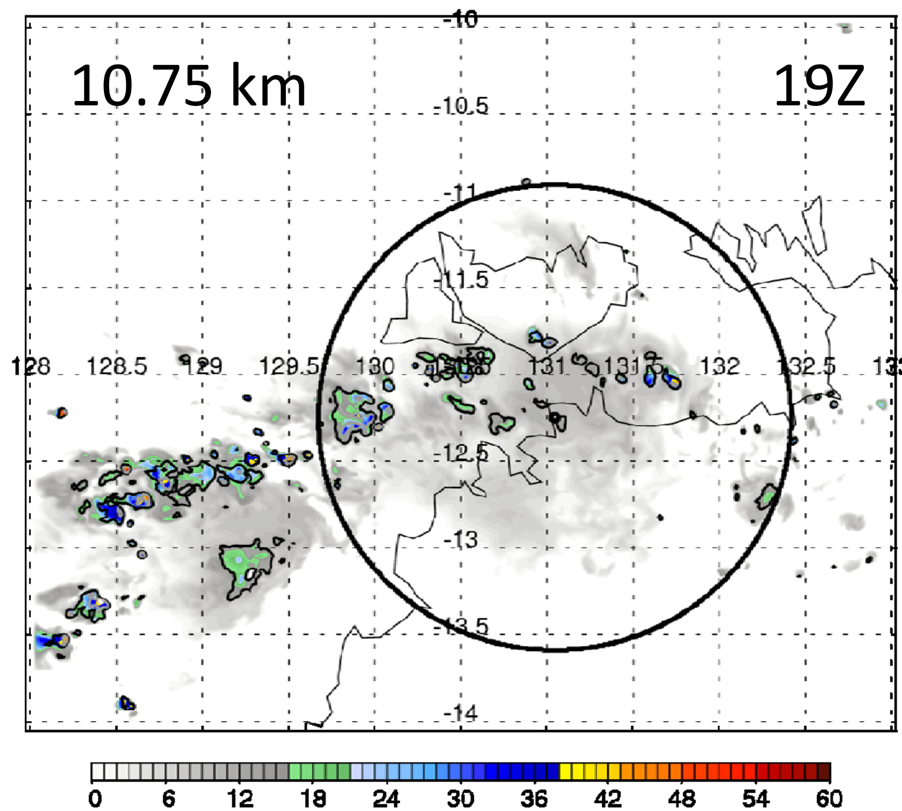
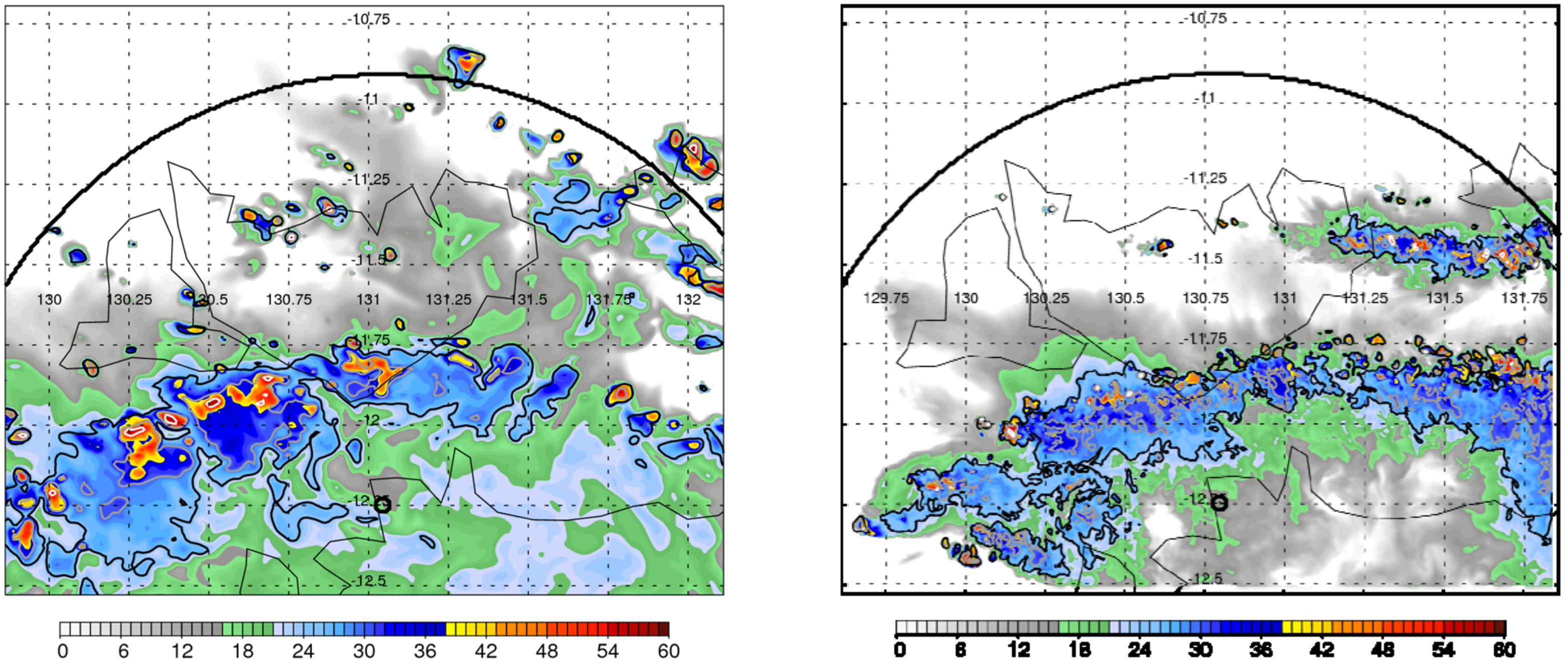


Production of High IWC and low dBZ





High Resolution Inner Domain

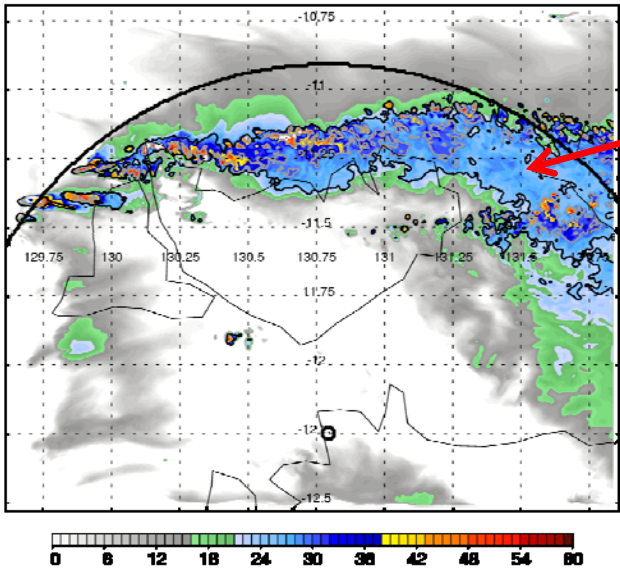


240 km by 200 km size with 333 m horizontal grid spacing and 183 vertical levels

Forced with 1-km grid spaced WRF output between 12Z 18 and 0Z 19 February

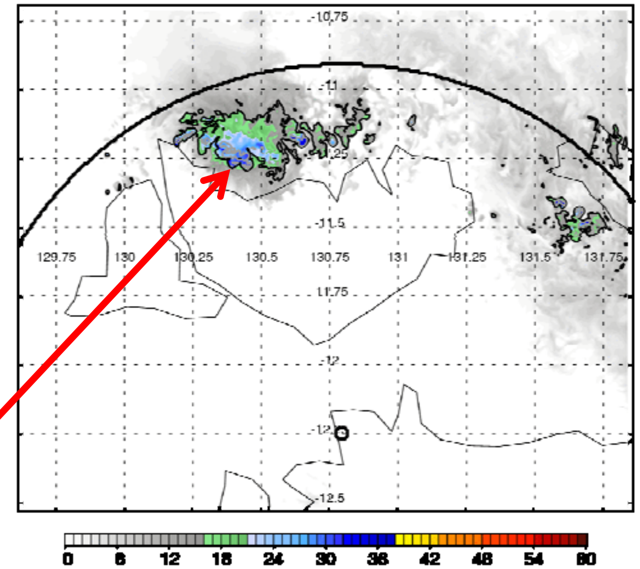
Better resolves updraft dynamics and mixing

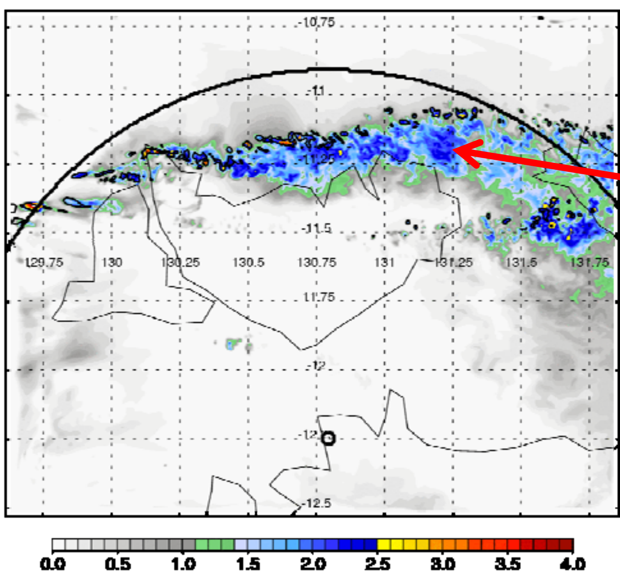
Simulated IWC, Reflectivity, and Vertical Velocity



Expansive region at 7 km of IWC > 1 g m^{-3} with up to 10 km diameter regions of > 2 g m^{-3} and dBZ < 30

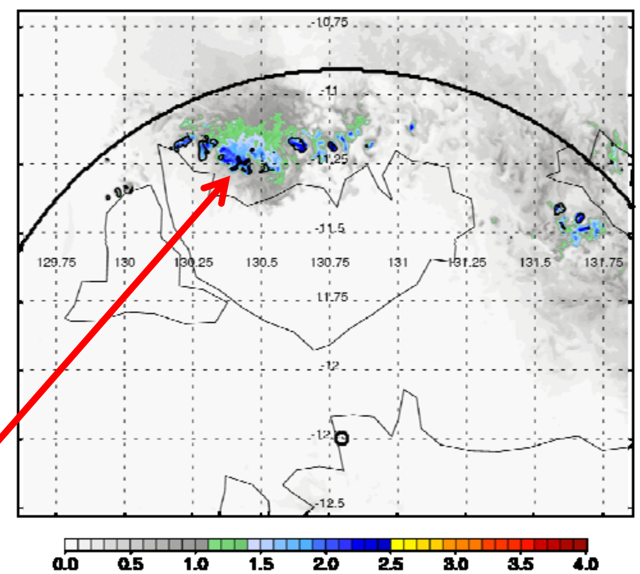
Much smaller region at 10.75 km but generally low dBZ and IWC > 1 g m^{-3} for stretches of up to 50 km



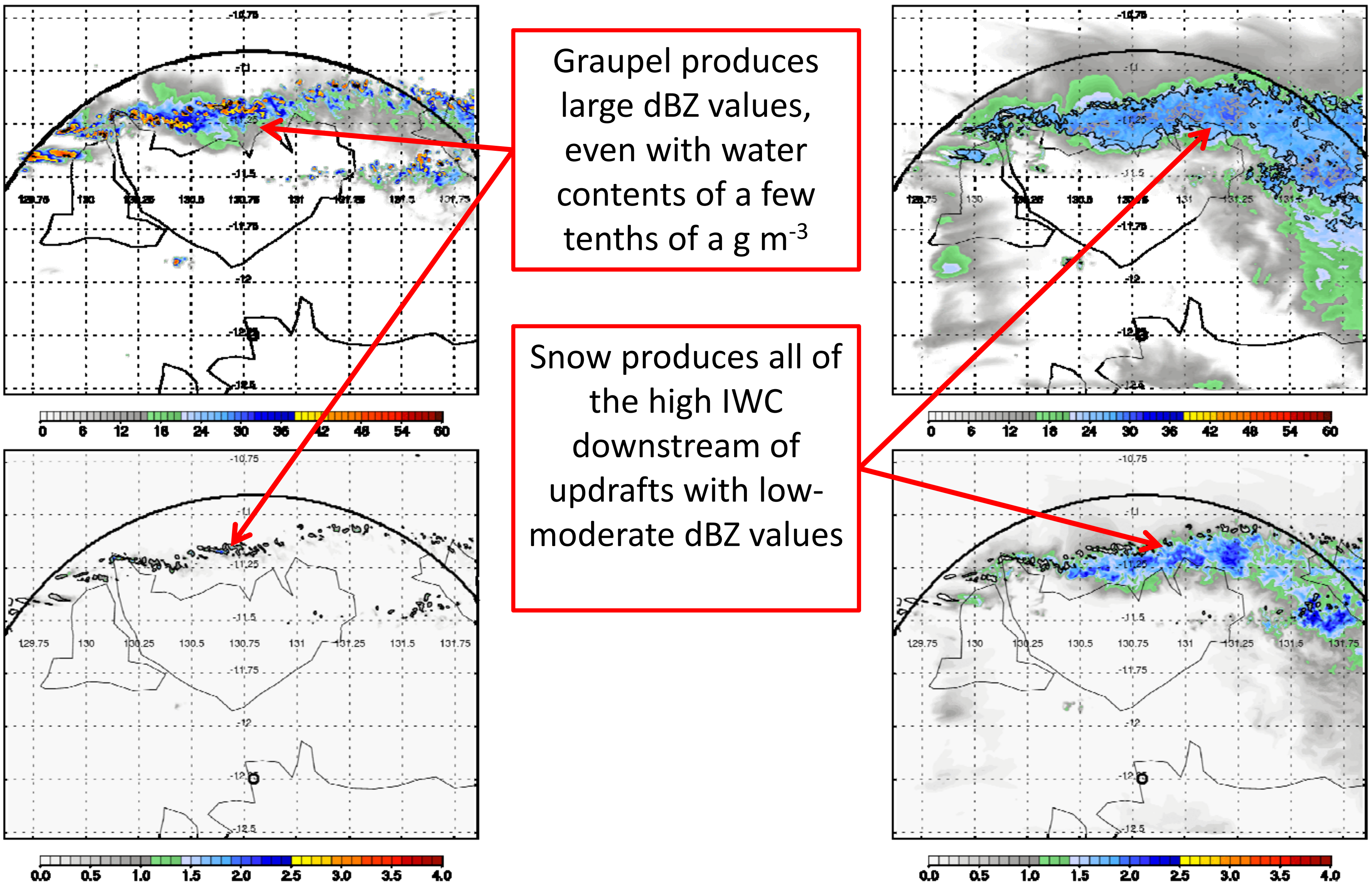


Updraft cores contain very high IWC, but also high dBZ; High IWC is also found downstream of updraft cores

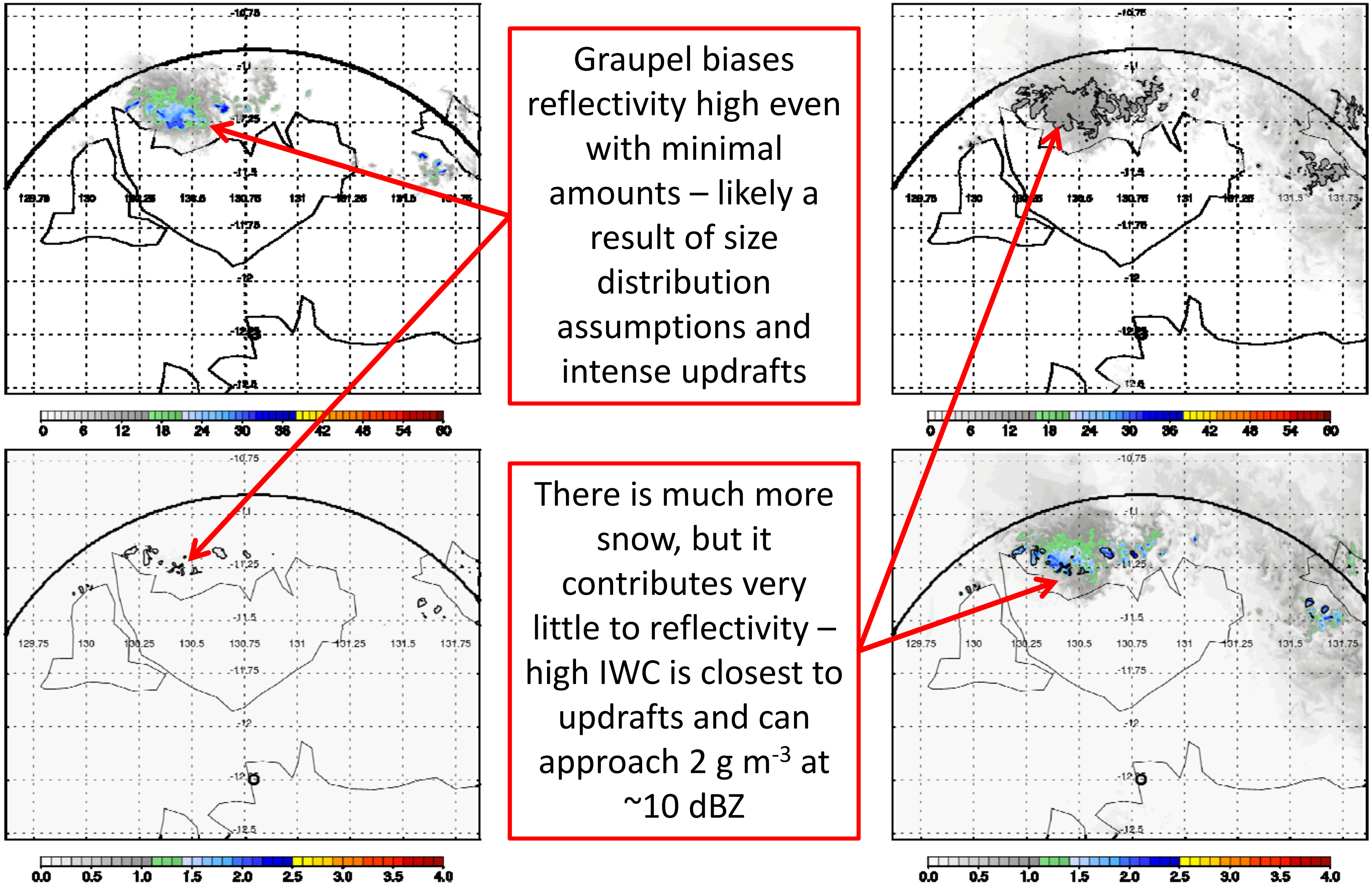
High IWC can be on different sides of updrafts at different altitudes



Graupel (left) vs. Snow (right) at 7-km Altitude



Graupel (left) vs. Snow (right) at 10.75-km Altitude



Convective Biases in the Simulation

Updrafts are likely too strong and certainly have too much graupel, particularly large graupel that biases reflectivity high

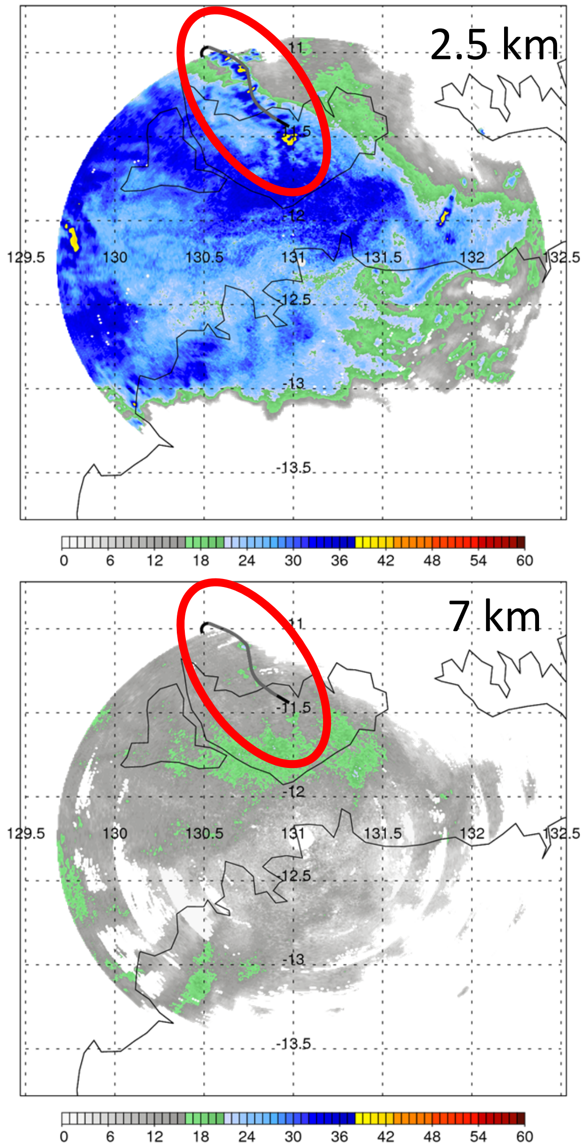
This is expected and can be somewhat accounted for while searching for processes impacting high snow water contents with low reflectivity

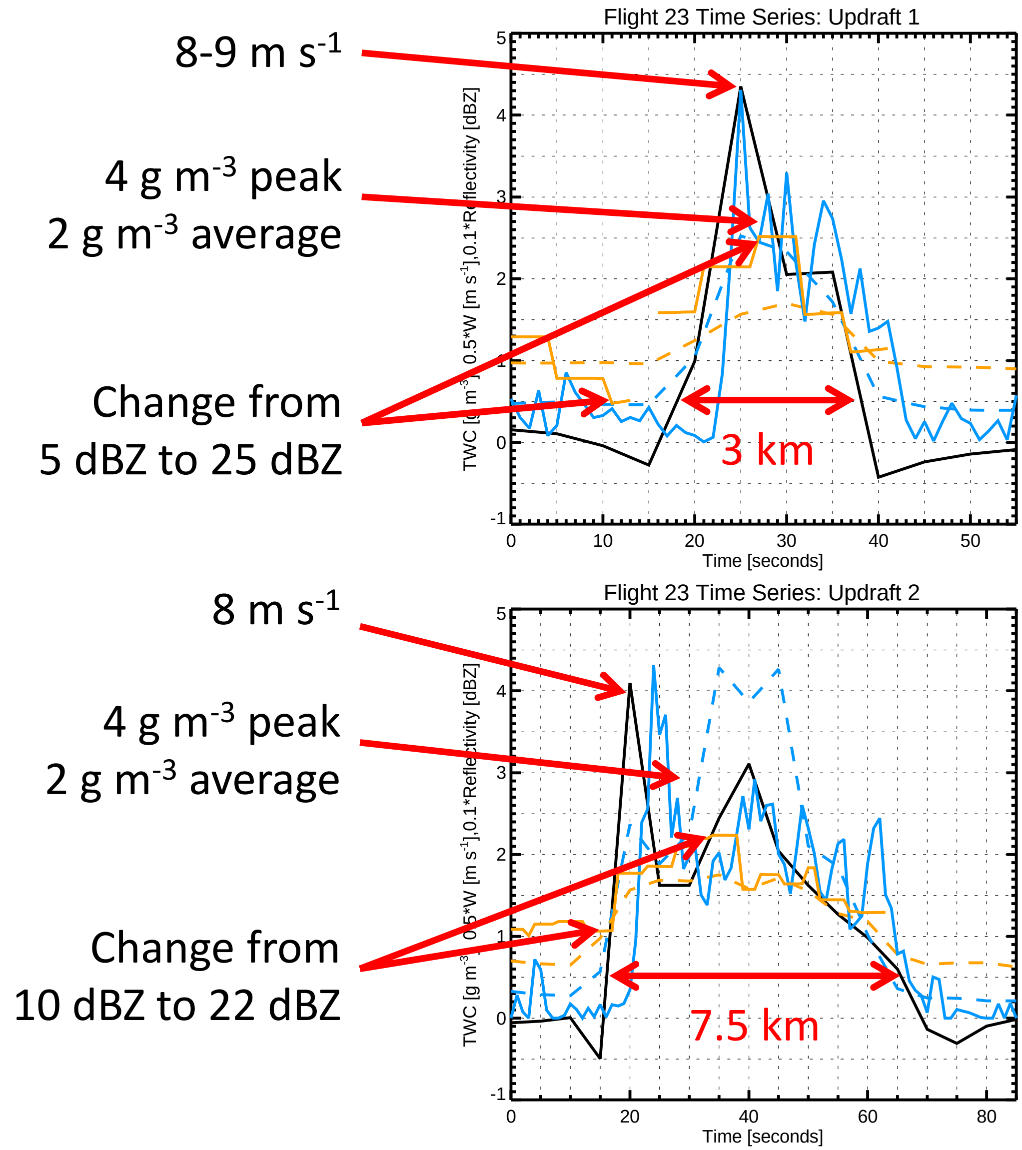
Snow reflectivity is strongly tied to assumptions of ice properties

Snow is typically smaller at colder temperatures and larger at warmer temperatures, as assumed in the Thompson scheme, but this can be reversed in some real-world updrafts

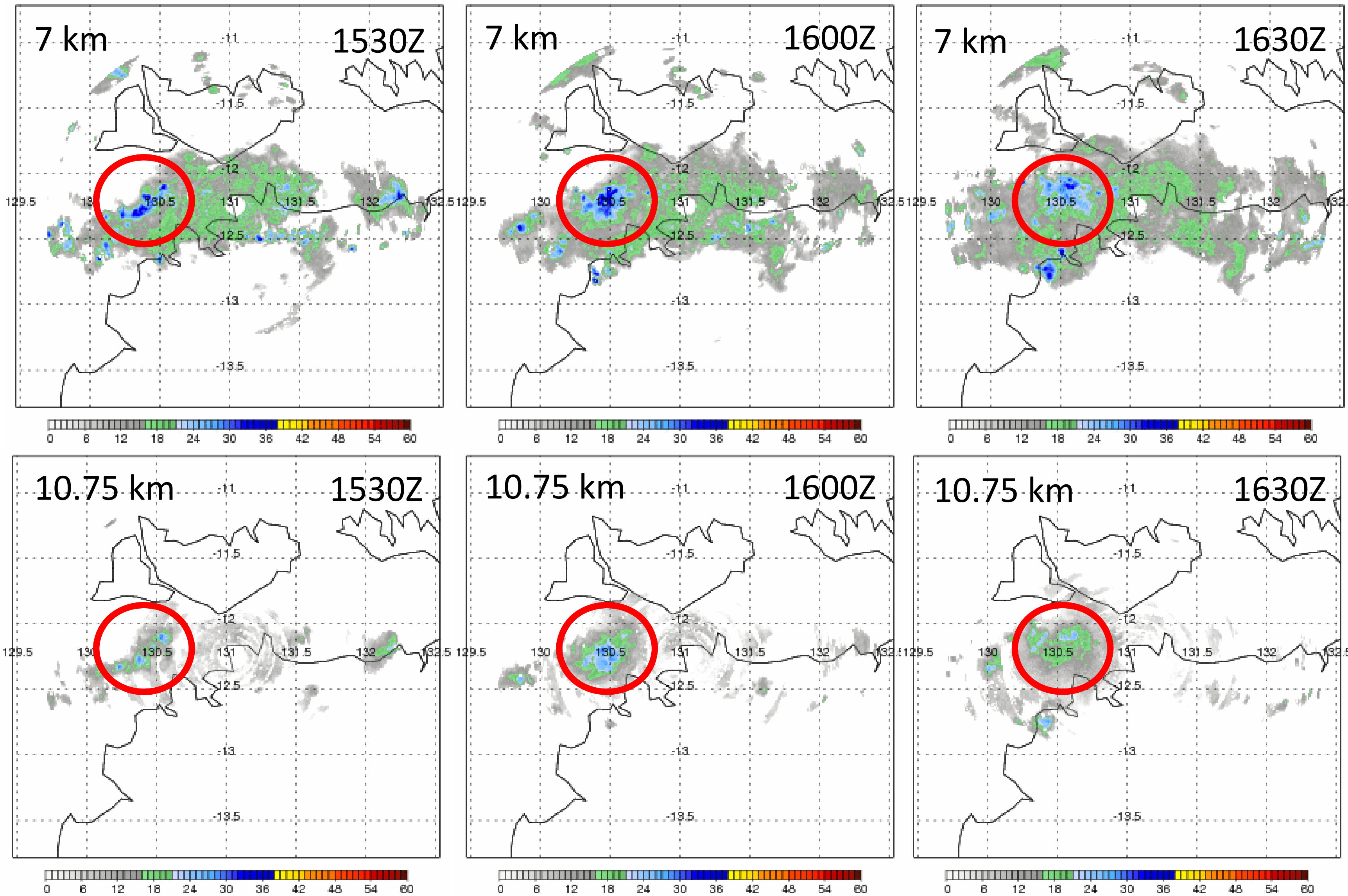
Predicting number concentration in addition to mass can fix this, but then another prognostic or diagnostic variable is needed for determining the size distribution dispersion

Connecting High IWC, Reflectivity, and Updrafts

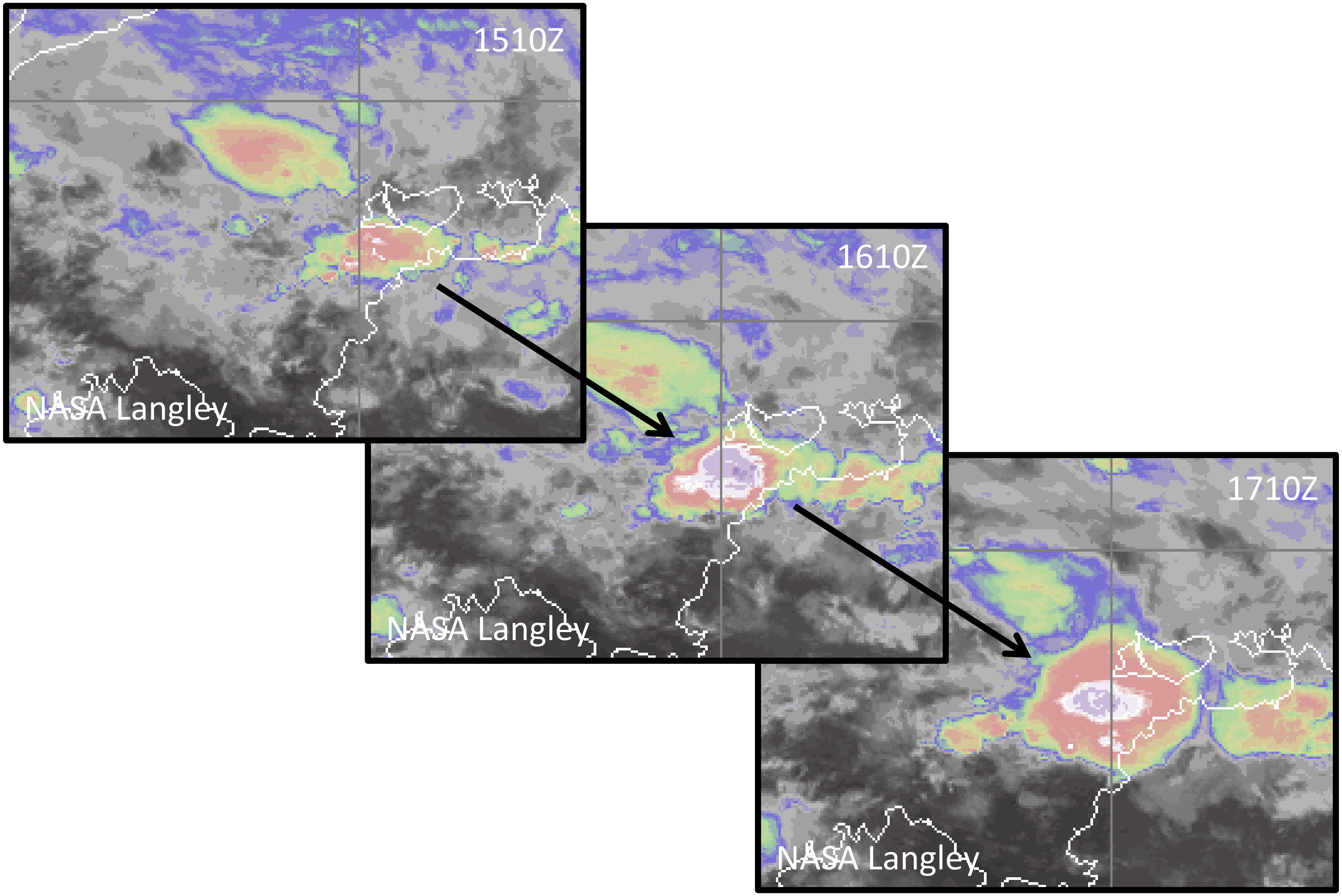




Contrast with a "Convective Burst"



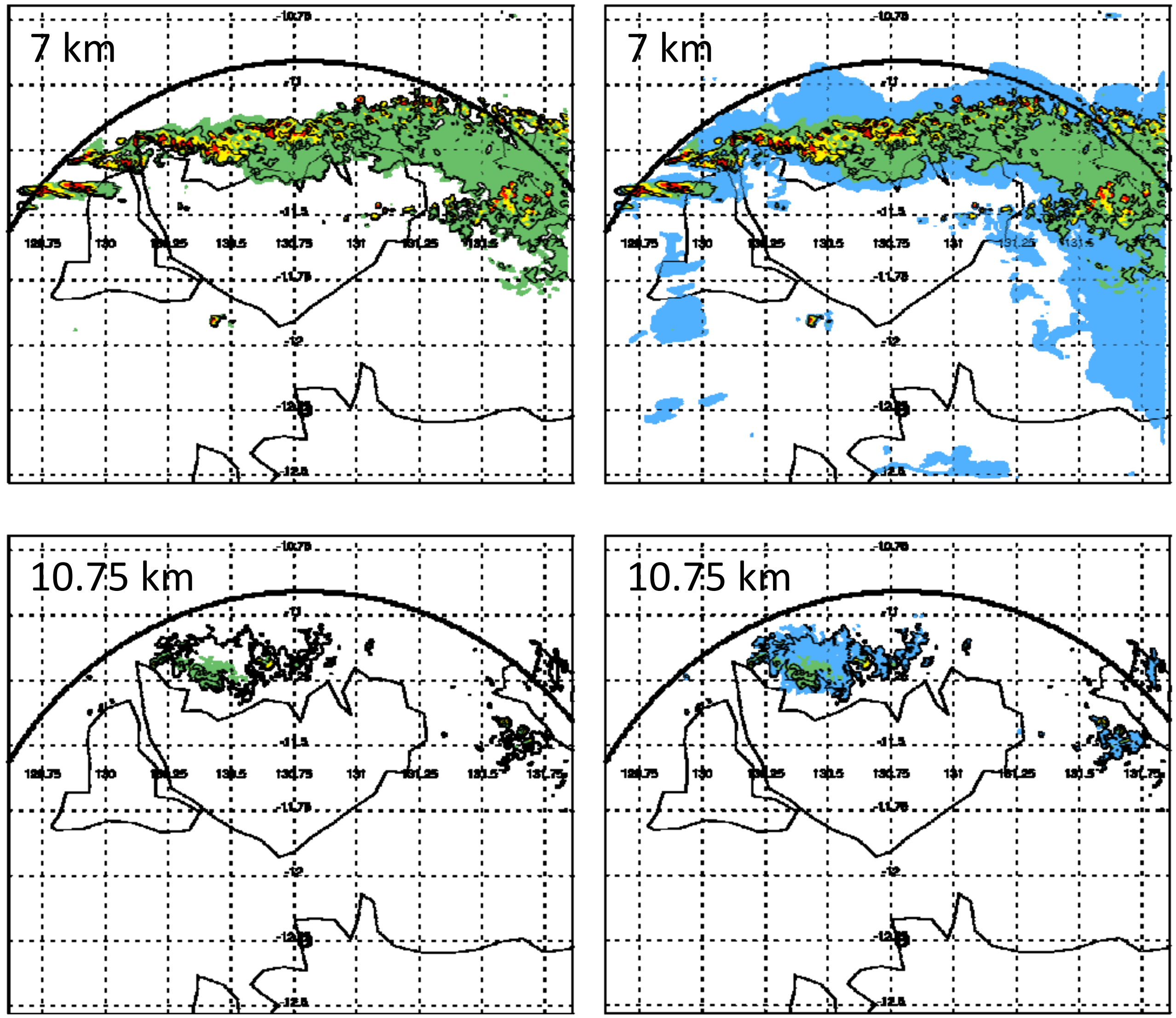
“Convective Burst” Satellite Perspective



Connecting High IWC and Pilot's Reflectivity

Green category (23-33 dBZ) captures all regions greater than 1 g m^{-3} at 7-km altitude

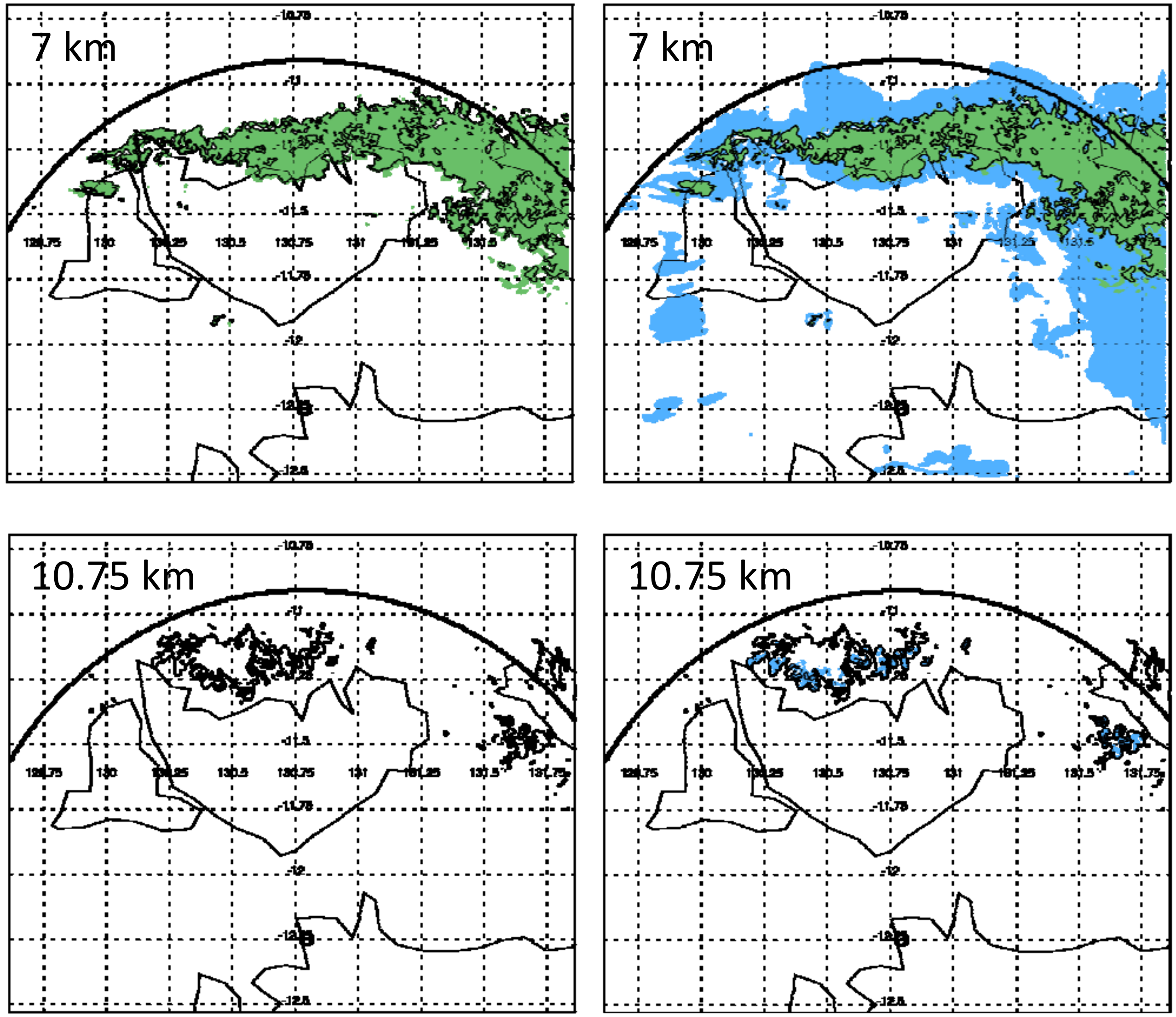
Adding a cyan category (13-23 dBZ) is necessary to capture IWCs between 1 and 2 g m^{-3} at 10.75 km



Connecting High SWC and Pilot's Reflectivity

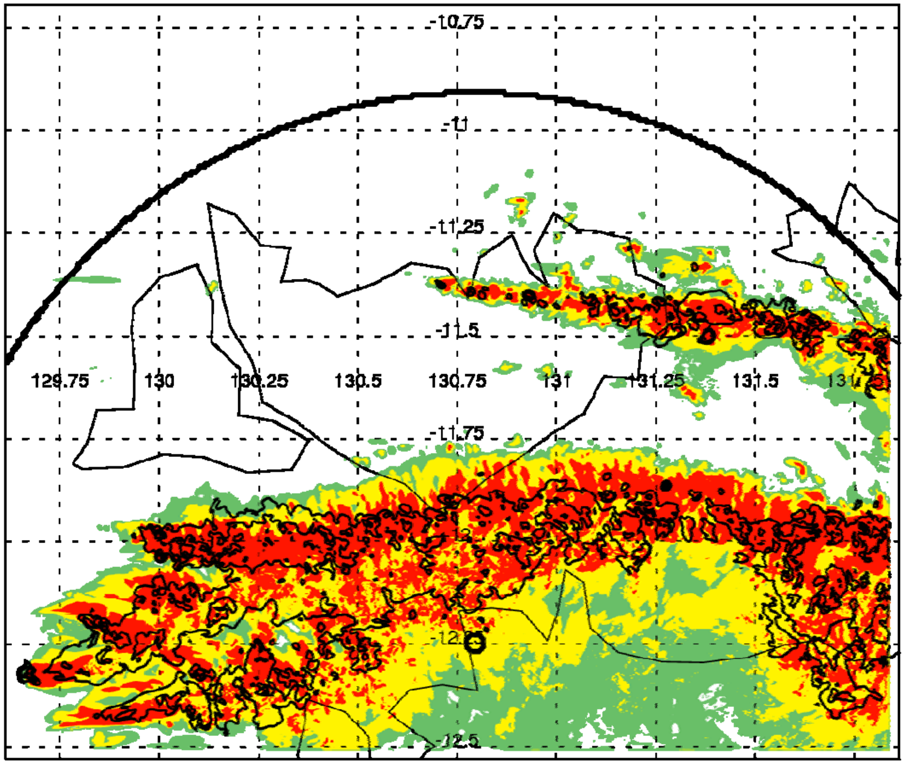
Green category (23-33 dBZ) still captures all regions greater than 1 g m^{-3} at 7-km altitude

Adding a cyan category (13-23 dBZ) now does not capture all IWC between 1 and 2 g m^{-3} at 10.75-km altitude

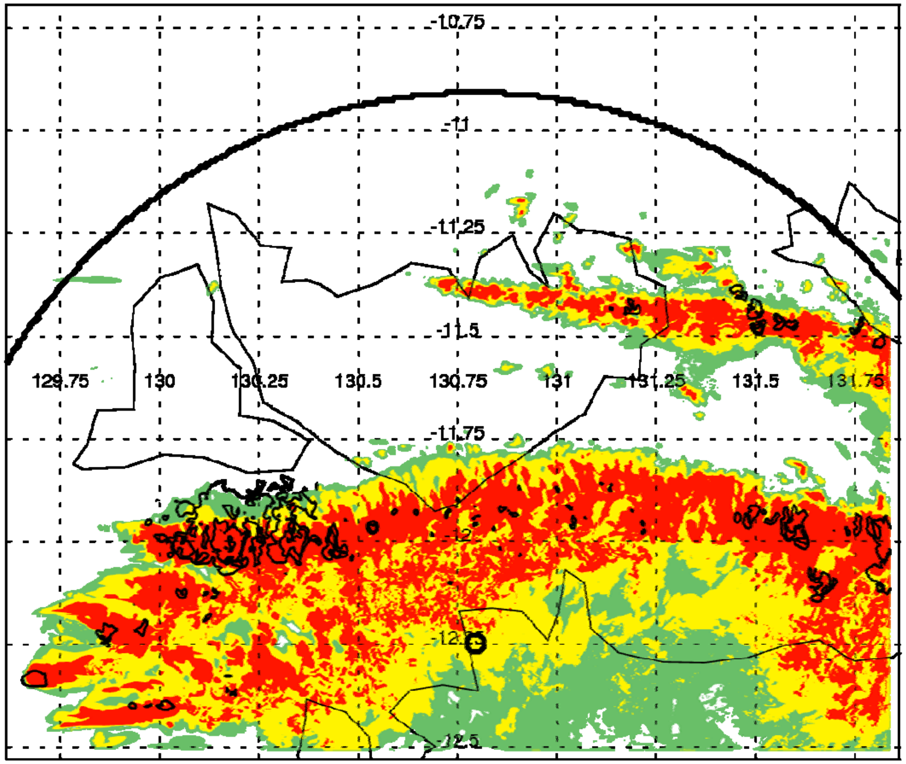


Connecting High IWC with Pilot's Maximum Column Reflectivity

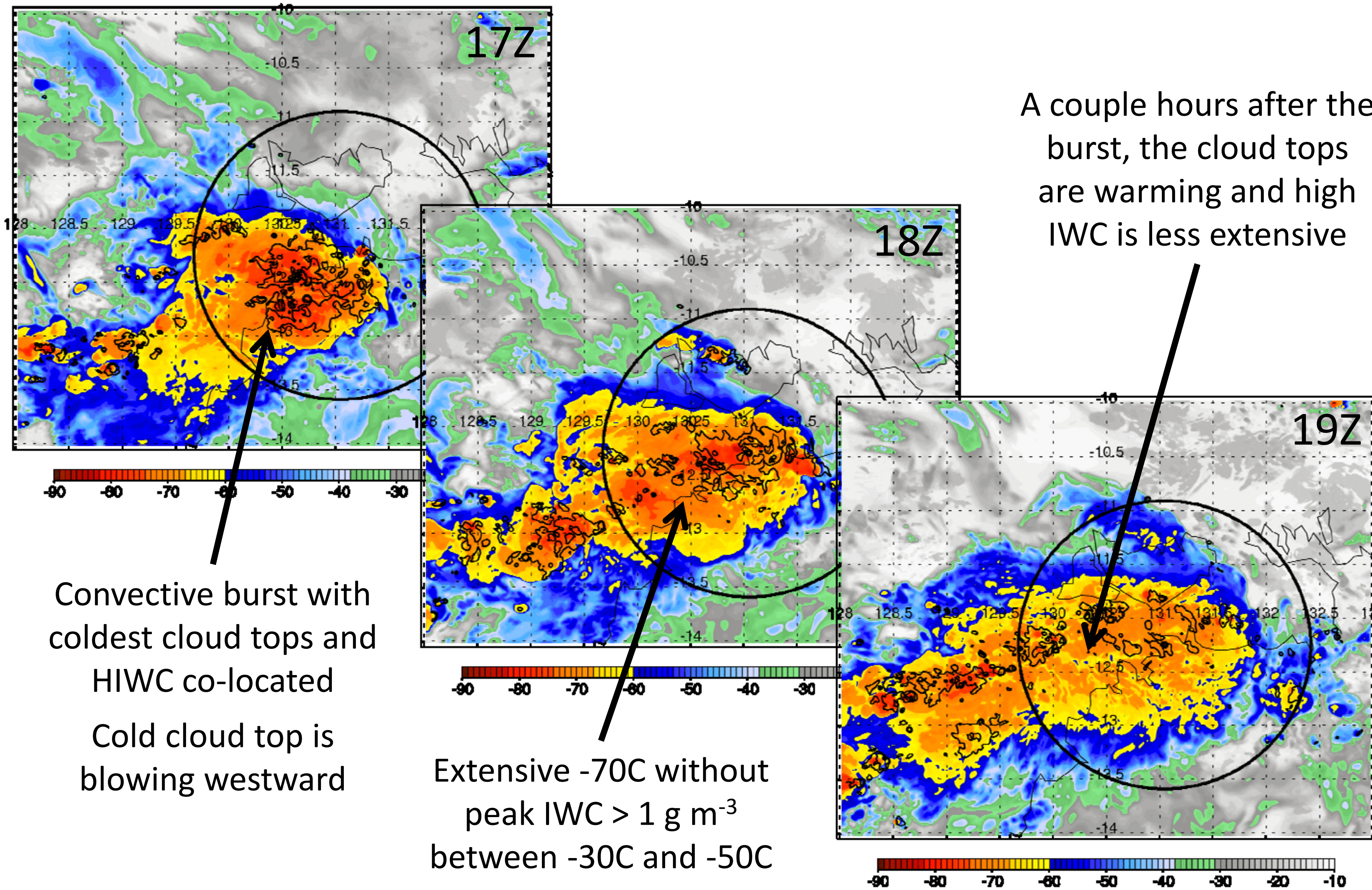
7-km IWC and Maximum Column dBZ



10.75-km IWC and Maximum Column dBZ



What About Cold Cloud Tops?



Preliminary Impressions

(from participation at Darwin, analysis of Flight 23, and simulation output)

High IWC > 2 g m^{-3} is located in or just downstream of active/decaying updrafts and is associated with reflectivity peaks

To capture all of these reflectivity peaks likely requires sensitivity to at least 10 dBZ

Extensive regions (100 km or greater) of IWC > 1 g m^{-3} are related to many updrafts in close proximity (e.g., a convective burst) or mesoscale organization of convection (e.g., a squall)

These regions are typically visible by radar and satellite as anomalously large echoes/cold cloud tops followed by upper level outflow in all directions

Next Steps

1. Validate simulations with all possible observations (RASTA, PSDs, TWC, winds, geostationary satellite) – more flight data between -10C and -30C in and around convective bursts with reflectivity from scanning radar are extremely helpful
2. Explore ice property differences in simulated updrafts of different size and strength – perform pseudo-flight tracks in the model
3. Analyze the life cycle of simulated “mesoscale” regions of high IWC including their relation to updraft mass flux and ice sedimentation/divergence
4. Explore sensitivity to resolution (entrainment, detrainment, sedimentation), ice properties (size distribution, fall speeds), and ice processes (rime splintering, collection, etc.)
5. Relate high IWC to polar-orbiting satellite observables (e.g., multi-frequency microwave brightness temperatures and reflectivity profiles) using idealized and model outputted microphysics information?

Potential Papers

Nothing planned in the short term for conferences or publications

1. Production of co-located high ice water content and low reflectivity regions in simulated tropical deep convective systems (sensitivity to different processes in model and model resolution; comparison to observations including model biases)

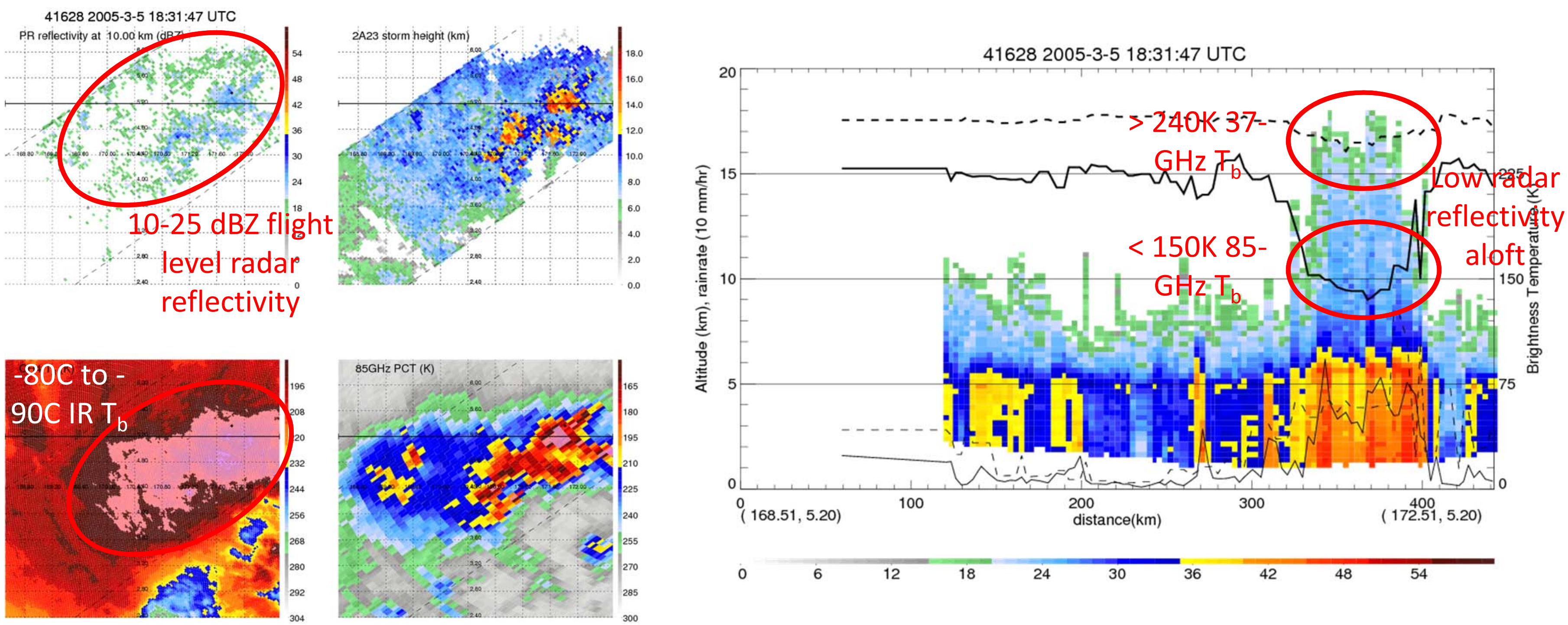
2. Impact of convective updraft properties and mesoscale convective organization on the distribution and evolution of high ice water content regions (using simulations validated with observations)

3. A TRMM/GPM climatology of high ice water content in deep convective systems?

Will happily collaborate with anyone providing observational datasets

Using Polar Orbiting Satellites to Identify Regions of High IWC and Low Reflectivity

Utilizing Satellite (TRMM) Radar and Microwave Sensing with Simulations

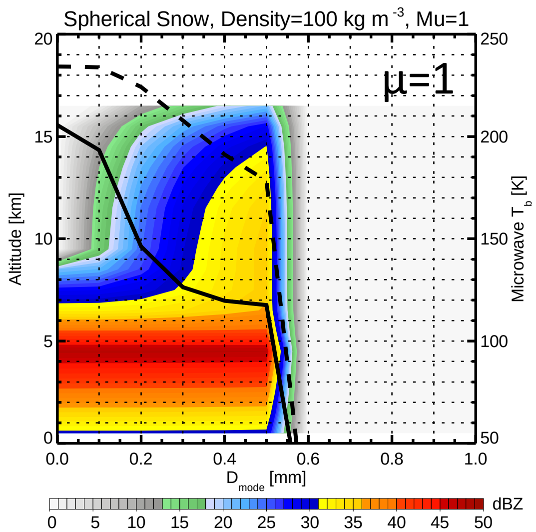


Here is a typical tropical oceanic MCC with low dBZ aloft, warm 37-GHz T_b, and cold 85-GHz T_b.

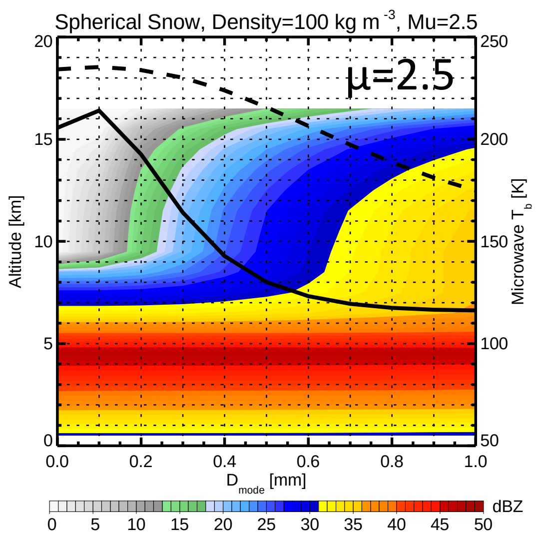
Are these potential high IWC regions?

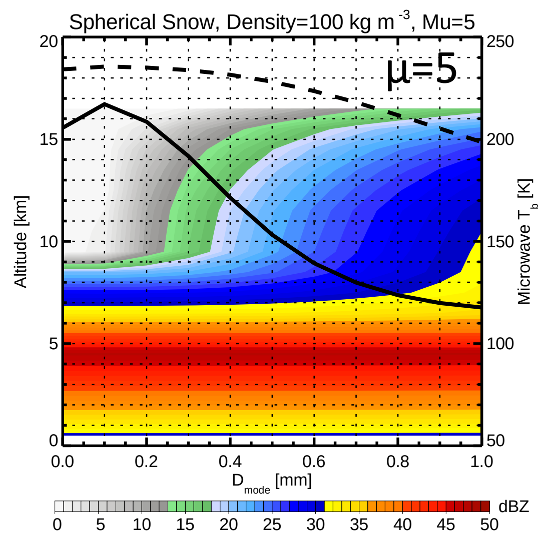
Can these be reproduced in simulations?

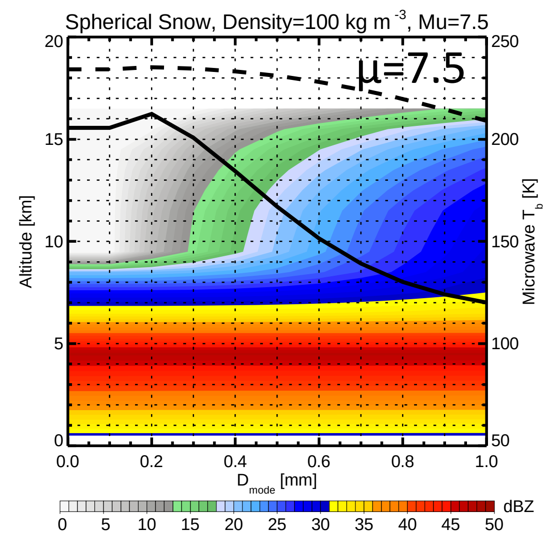
Utilizing Satellite Radar and Microwave Sensing with Simulations



For the idealized profile of condensate amount (only snow size distribution is varying; snow is assumed spherical with a density of 100 kg m^{-3}), these plots show TRMM PR reflectivity, 37-GHz T_b, and 85-GHz T_b as a function of gamma diameter mode and μ







Utilizing Satellite Radar and Microwave Sensing with Simulations

- Combined with a reflectivity profile where upper tropospheric reflectivity is low and 37-GHz T_b is warm, a warm 85-GHz T_b guarantees a substantial amount of ice that isn't large
- Co-located microwave and reflectivity observations can be generated for simulations using a satellite simulator so that simulations can be validated and used to understand high IWC regions.
- Higher frequency MW channels (e.g., 183 GHz) available on GPM will scatter more at smaller sizes than warmer frequencies and will yield more information on small ice in the upper troposphere.