Ferrier Microphysics in NCEP Operational Hurricane Models

Eric Aligo, Brad Ferrier, Young Kwon[1,2] and Vijay Tallapragada[1]

[1] Environment Modeling Center (EMC)/NCEP/NWS

[2] I.M. Systems Group, Inc.

HFIP Physics Workshop

09 Aug- 11 Aug 2011

HWRF/GFDL Microphysics

- Ferrier Scheme
  - Single moment scheme
  - Predicts water vapor and total condensate (cloud water, cloud ice, snow/graupel/sleet)
  - Assumes exponential size distribution for all precipitation particles
  - Advects total condensate and water vapor
    - This unique aspect makes it computationally efficient
    - Most other schemes advect each species separately

Hurricane Flavor of Ferrier Microphysics

- Tailored for Tropics
  - N_{cw} = 60 cm^{-3} in HWRF vs 100 cm^{-3} in NAM
    - Maritime versus continental environment
  - Max temperature at which ice nucleation occurs: -5°C in HWRF vs -15°C in NAM
- Onset of condensation:
  - Parent domain (27 km)= 97.5% in the middle-upper troposphere
  - Nest (9 km) = 100%

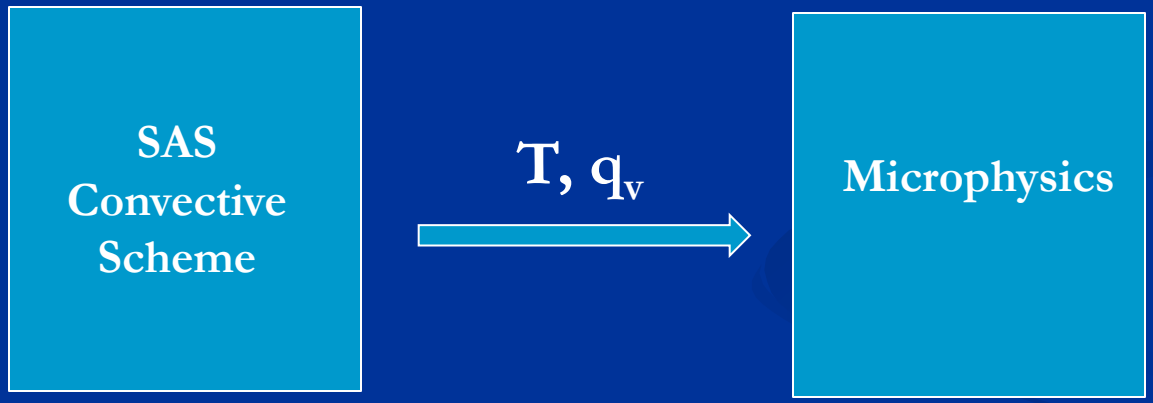
Microphysics and Hurricanes

- Several studies have shown that the intensity of tropical systems is sensitive to the ice phase (Willoughby et al. 1984; Wei-Kuo Tao et al. 2010, among others)
- Melting and evaporation help strengthen downdrafts and reduce intensity/ intensification rate (Wang 2002)
- Ice processes also play a role in the horizontal distribution of rain bands (McCumber et al. 1991; Wang 2002)
- Are we finding the same results from operational hurricane models?

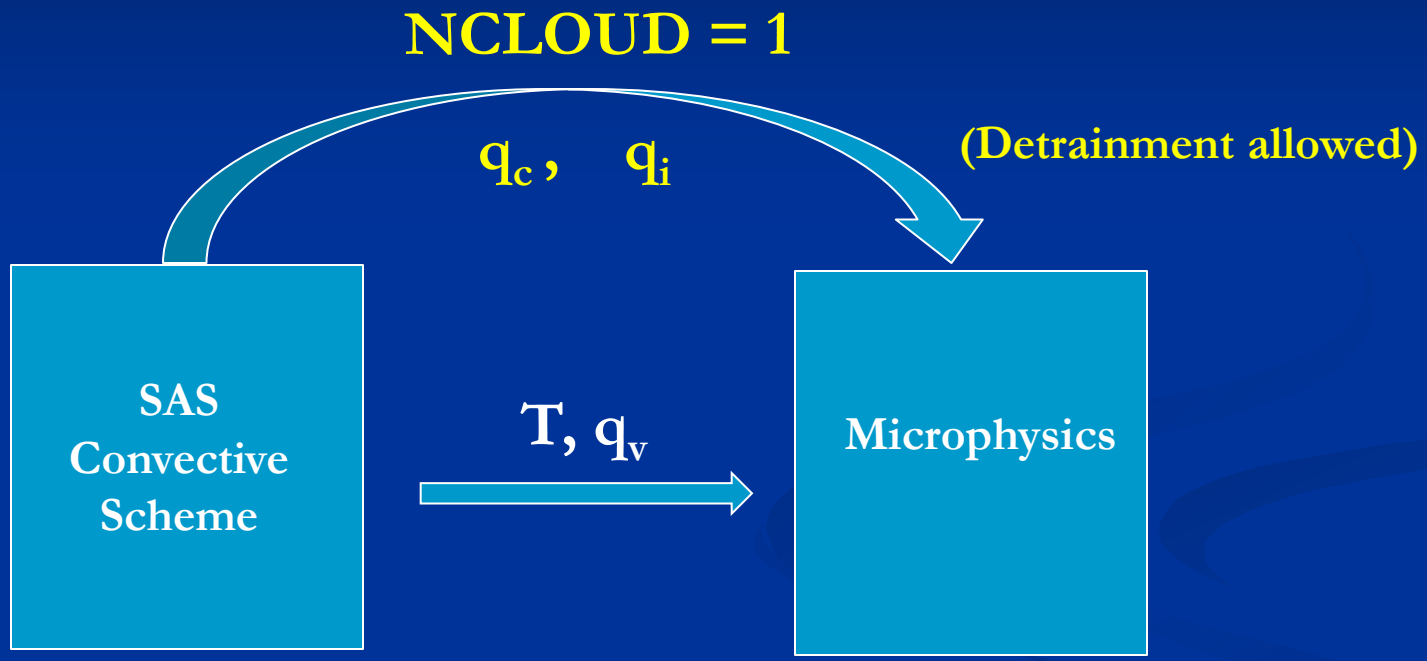
Evaluation of microphysical and convective processes for hurricane forecasts

- Need a tool to evaluate the impact of microphysical and convective scheme processes
  - Perform sanity checks
  - Better understand the role of specific processes
- Methodology
  - Microphysical and convective scheme tendencies and accumulations from the HWRF model are computed and tracked at every physics time step
    - BUCKETS subroutine used to set accumulation periods (3hrs, 6hrs, etc.)
  - Modify subroutines: /phys (2), /dyn_nmm (3), Registry (1) and UPP (9)
- Apply the diagnostics for a wide variety of cases

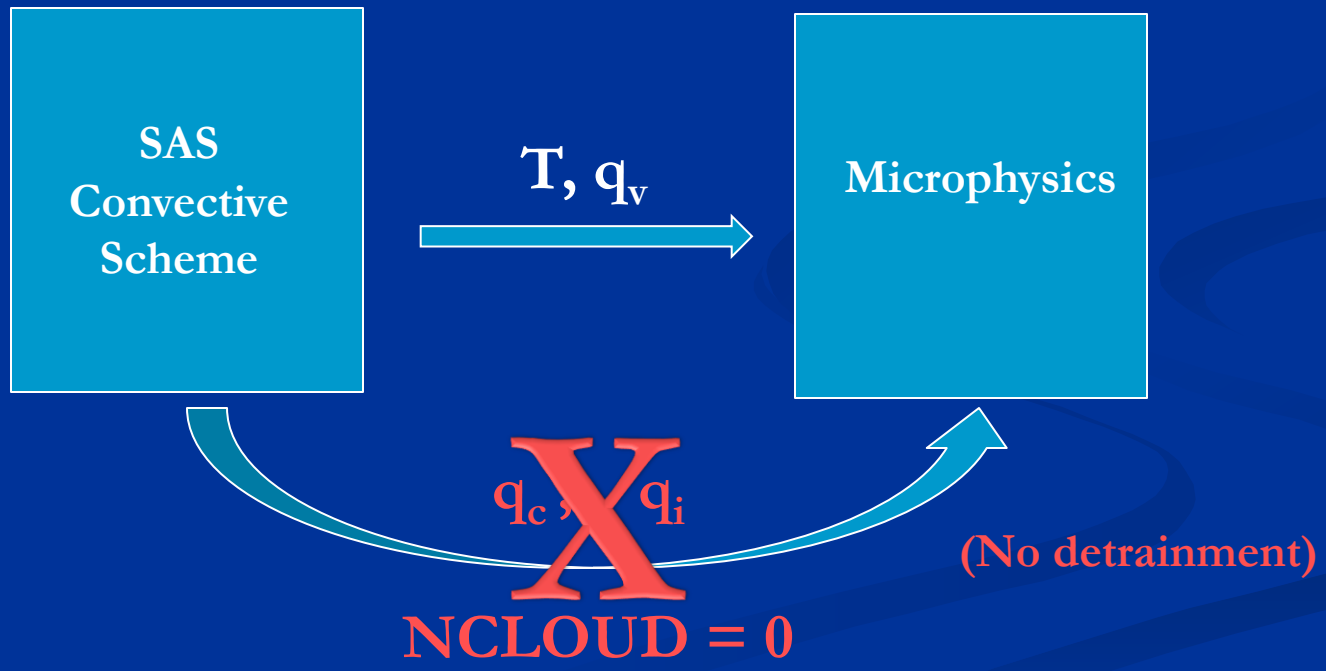
The Convective and Microphysical Scheme Communication



The Convective and Microphysical Scheme Communication

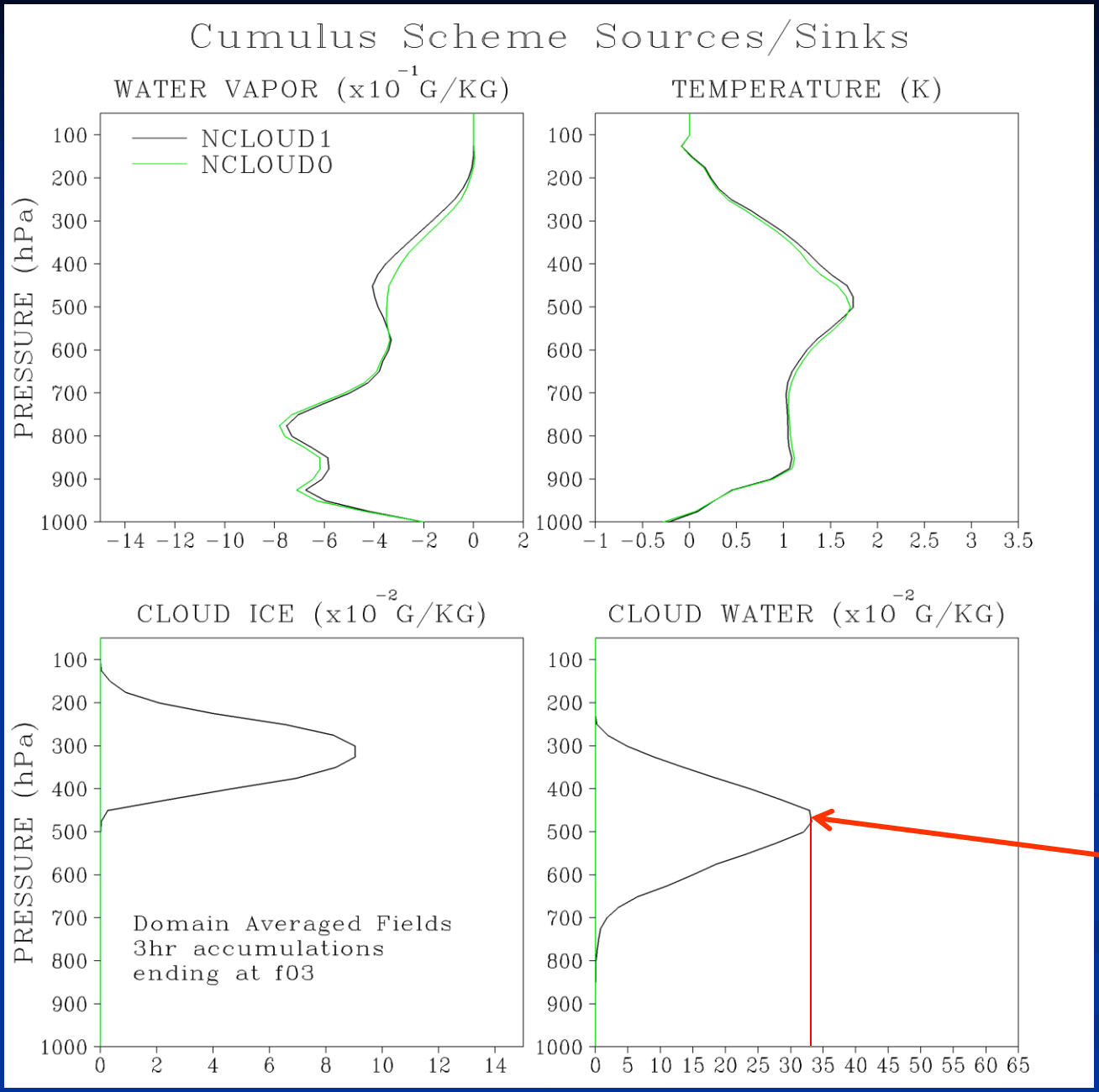


The Convective and Microphysical Scheme Communication



Model Diagnostics: Convective Detrainment Example

- NCLOUD = 1 (current setting in HWRF)
  - Detrainment of q_c and q_i is *allowed*
- NCLOUD = 0
  - Detrainment is *not allowed*
- Question: How do these settings impact hurricane track and intensity, and through which microphysical and convective scheme processes?

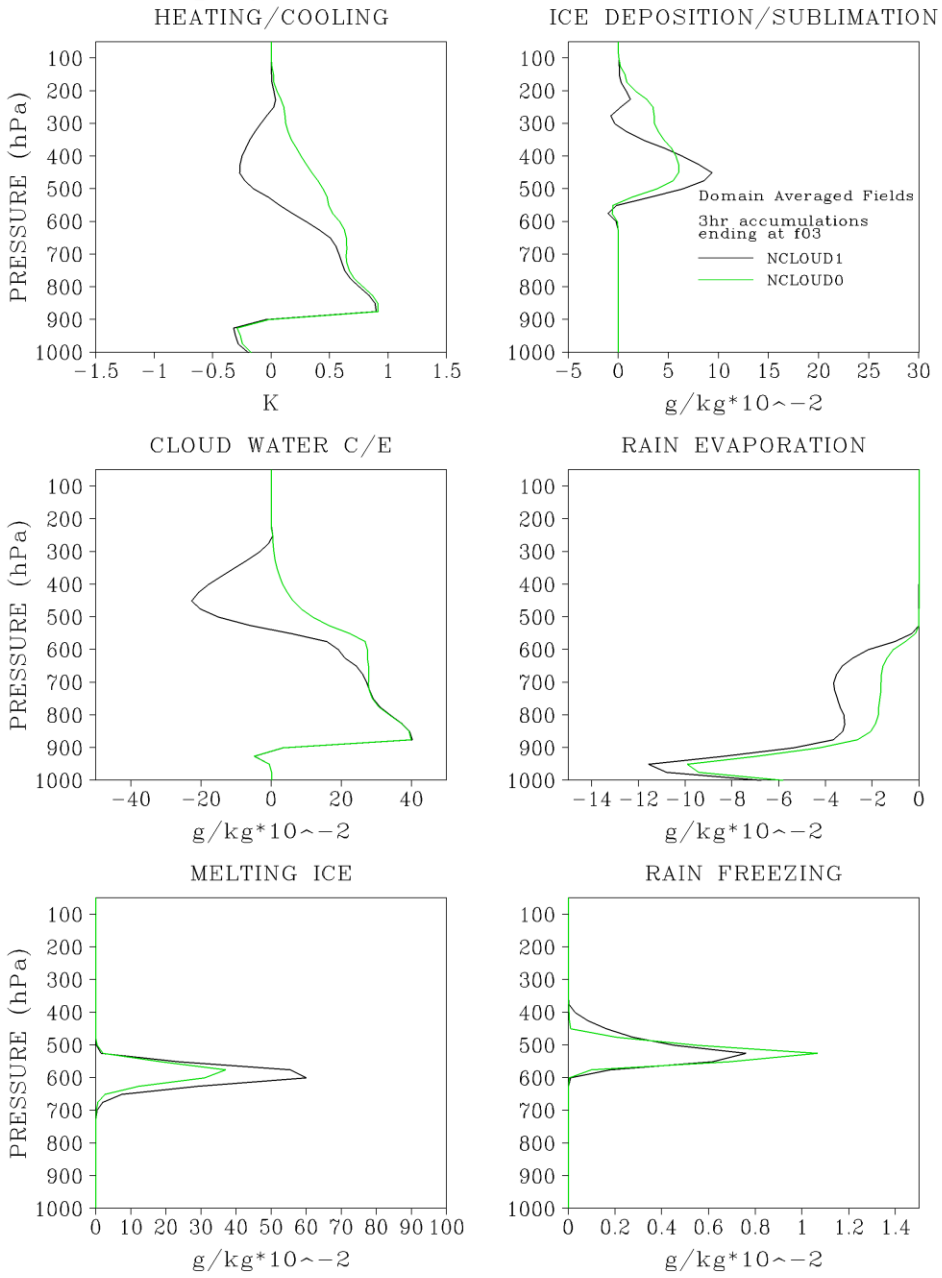


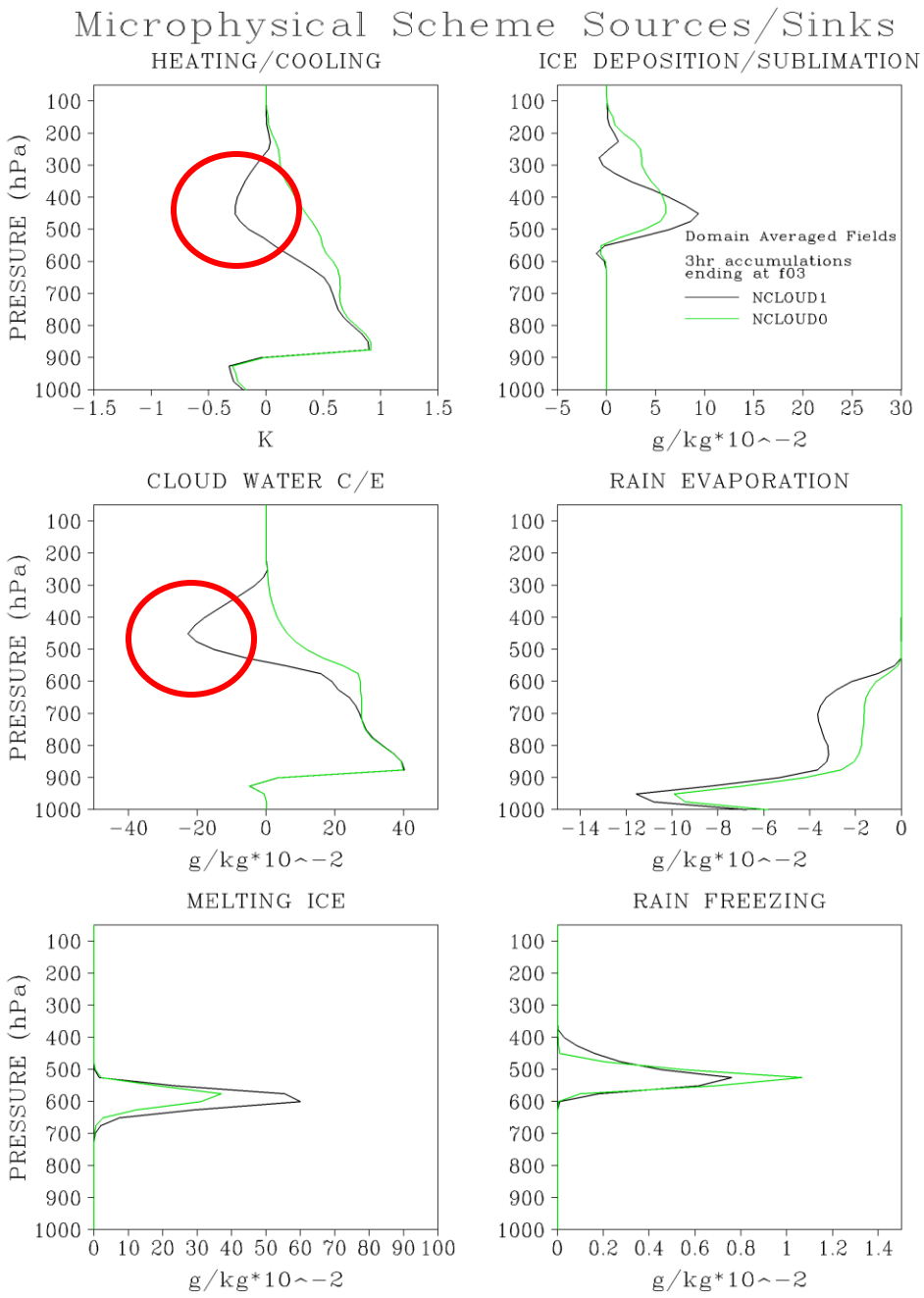
No q_i and q_c convective scheme tendencies for NCLOUD = 0. **Good!**

Sanity check!

~ 0.34 g kg $^{-1}$ of q_c produced by convective scheme at 475 hPa

Microphysical Scheme Sources/Sinks





At ~ 475 hPa:

- **NCLOUD = 0**
  - Slight microphysical scheme warming
  - No cloud water evaporation
- **NCLOUD = 1**
  - Slight microphysical scheme cooling
  - ~ 0.30 g kg^{-1} of cloud water evaporation
- **In this example, most of the q_c from convective detrainment is evaporated in the microphysics scheme resulting in mid-level cooling**

Ongoing Work

- Construct a universal diagnostic tool
  - Evaluate impact of different microphysical schemes (e.g. Thompson, WSM6) on tropical system track and intensity
- Advect individual species of water (q_s,q_g,q_r,q_i) instead of CWM in Ferrier scheme and evaluate the impact
- Future of Ferrier Scheme in HWRF/GFDL

Microphysical Processes in the Ferrier Scheme