Developing next-generation physics for UFS applications: The microphysics parameterization challenges

The 1st Annual UFS Physics Workshop (16-18 May 2023) Organization Committee

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With Support from

NOAA OSTI Modeling Program, NOAA Unified Forecast System Steering Committee

NOAA OAR and NWS, Office of Naval Research

NOAA/OAR Physical Sciences Laboratory, NOAA/NWS/NCEP Environmental Modeling Center

NCAR/Research Applications Laboratory (Paul Kucera and Jenny Bolton, in particular)

Historical Background

HFIP Physics Workshop 2011

Aug 9, 2011, 2:00am - Aug 12, 2011, 1:59am ET

Colony South Hotel & Conference Center
7401 Surratts Road, Clinton, MD 20735

→ The microphysics scheme in the HWRF was suitable for tropical cyclone prediction.

The ECMWF Workshop on Parametrization of clouds and precipitation across model resolutions was held from Monday 5 to Thursday 8 November 2012.
(As well as the Annual Seminar 2015)

→ The IFS scheme worked well for medium-range weather prediction.

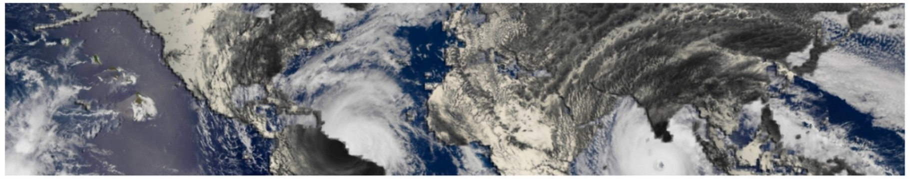
DTC Developmental Testbed Center   ABOUT   TESTING + EVALUATION   COMMUNITY CODE   VISITOR PROGRAM   NEWS   EVENTS

WORKSHOP ON NEXT-GENERATION PARAMETERIZATIONS OF MOIST PROCESSES

JAN 27 - 29 2015

→ It resulted in a white paper on future *directions* of moist process parameterization development for multi-scale prediction applications.

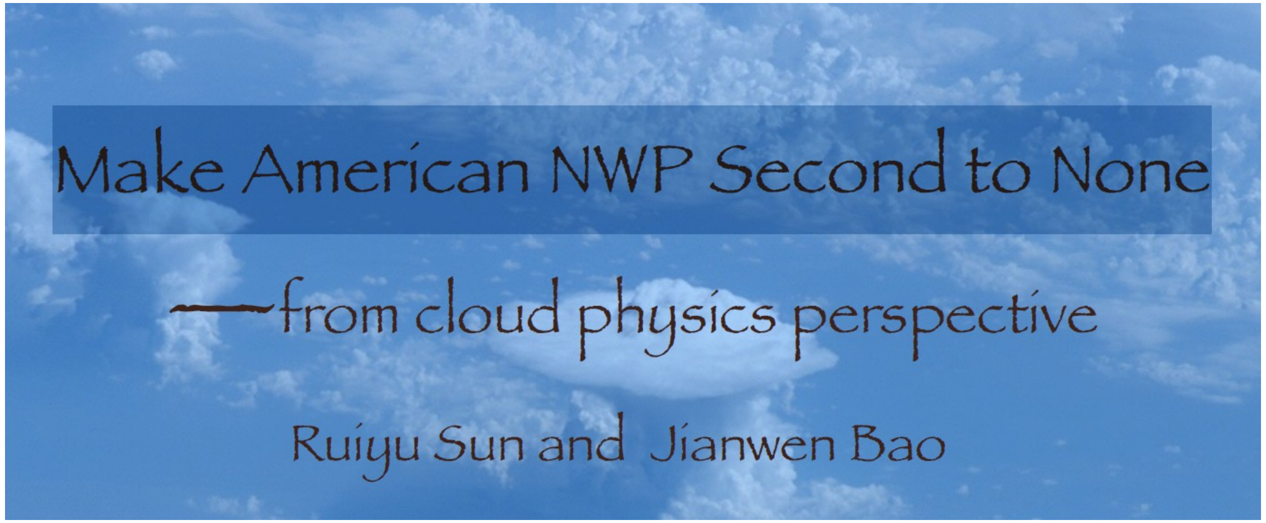
NGGPS ATMOSPHERIC PHYSICS WORKSHOP

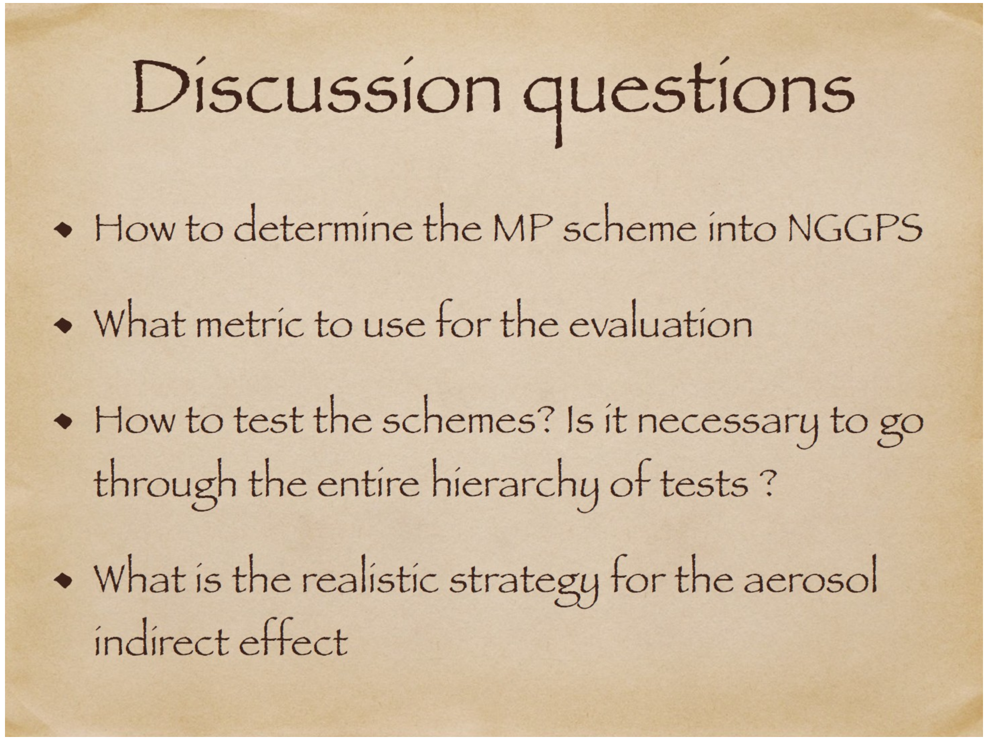


NOV 8 - 9 2016 | NOAA CENTER FOR WEATHER AND CLIMATE PREDICTION BUILDING 5830 UNIVERSITY RESEARCH CT, COLLEGE PARK, MD 20740

→ It was the prelude to the development of the UFS Physics Working Group and UFS-R2O Physics Physics Project, as well as the "SIP for Evolution of NGGPS to a National Unified Modeling System".

At the NGGPS Atmospheric Physics Workshop in Nov 2016



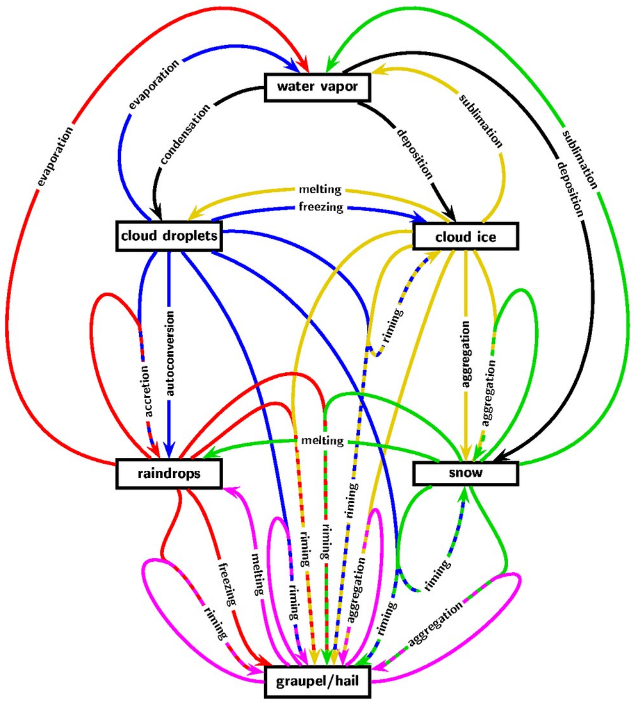


Decision to use and further develop and test the Thompson scheme in the GFSv17 prototype

After much work…
Thompson mp now in
HAFS v1 (op)
GFS v17 (pre-op)
GEFS v14 (pre-op)
RRFS v1 (pre-op)

Topics of the 1st UFS Physics Workshop (16-18 May 2023)

- **Complexity**
  - Minimal complexity for operations
  - Research needs
- Possibility of **unification** for operational applications
- **Aerosol/chemistry**-cloud interactions
- **Consistency** between resolved and subgrid moist physics
- **Mixed-phase clouds**, especially in the mid- and high-latitudes
- **Observations and LES** for evaluation and constraining
- Collaboration and **community** involvement



From A. Seifert via A. Gettelman of Pacific Northwest National Lab

Workshop Objectives

- Identify the current **challenges and opportunities** related to the microphysics parameterization development in the UFS
- Foster **collaboration** and knowledge sharing among the participants
- Develop **actionable strategies** and recommendations to address the identified challenges in both operation and research using the UFS
- Explore **innovative ideas** and potential solutions for long-term cloud microphysics development in the UFS

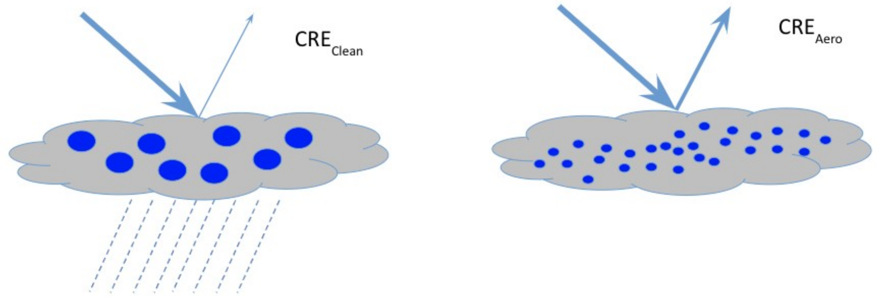
Recommendations for Res, Dev, & Ops - 1

- Operational UFS microphysics schemes should predict
    - Cloud water, rainwater, cloud ice, snow, and rimed ice (graupel and/or hail)
    - **Double-moment** for some species
- Consistent grid- and subgrid-scale clouds: **prognostic cloud scheme**

Photo of Polarstern and some fractional clouds at high latitude. From Amy Solomon, NOAA ESRL PSL, and CIRES

Recommendations for Res, Dev, & Ops - 2

- Development of **aerosol-microphysics interactions**
- Use **consistent aerosols** between
  - Convection and microphysics
  - Grid- and subgrid scales



From A. Gettelman (PNNL)

- Inclusion of g**as phase and aerosol chemistry processes** of different complexity
  - Wet scavenging process of all chemical species
  - Aqueous-phase chemistry processes
- Include a **configurable and flexible microphysics** scheme with optional components for processes and species and closer interactions with chemistry

Recommendations for Res, Dev, & Ops - 3

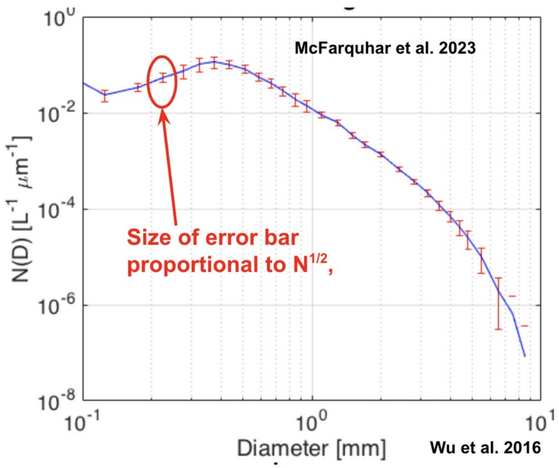
- Improve representation of **supercooled water** production, e.g., in Arctic clouds
- Use of **LES** to fill gaps associated with sparse observations for refining/calibrating bulk microphysics schemes
- Careful consideration of **dynamics-microphysics process coupling**
- **Collaborations**
  - Should be fostered with subject experts at universities
  - Requires open-minded developers and avoiding single-point failure

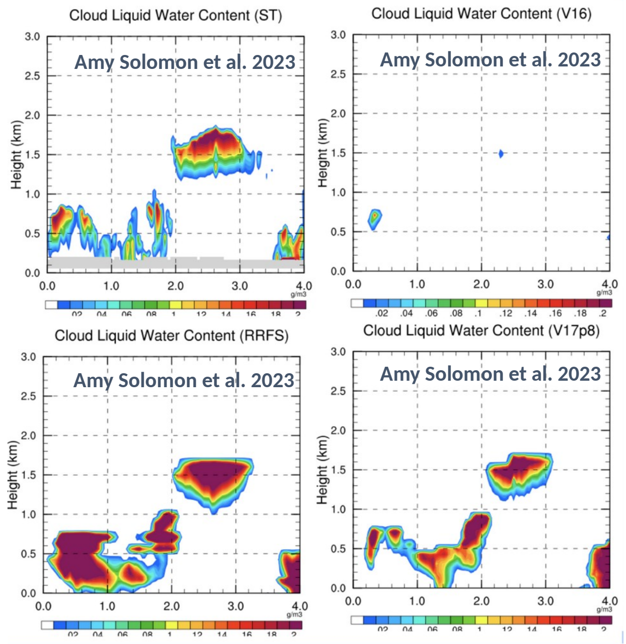
Recommendations for Res, Dev, & Ops - 4

- Evaluate cloud properties, radiative fluxes and precipitation
- Compare **statistical relationships** between mp and obs
- Reduce **compensating errors** - evaluate **subprocesses**
- Use satellite, radar, lidar and passive remote sensing
- **Explore observations fully**

  for in-depth scheme evaluations

- **Add more cases with comprehensive obs data for to the Common Community Physics Package Single Column Model**





Wrap Up

- A productive workshop that created a vision for future
- A white paper will be produced to inform community and funding agencies

Additional Slides

Workshop Structure

- Welcome and remarks on the workshop objectives
- Invited/contributed presentations and breakout sessions on
  - Research and development
  - Operational needs and ongoing UFS-R2O development (GFS, RRFS, HAFS)
  - Community development
  - Using observations to improve microphysics parameterization
- Presentation and discussion of findings from breakout sessions
- Summary and conclusion

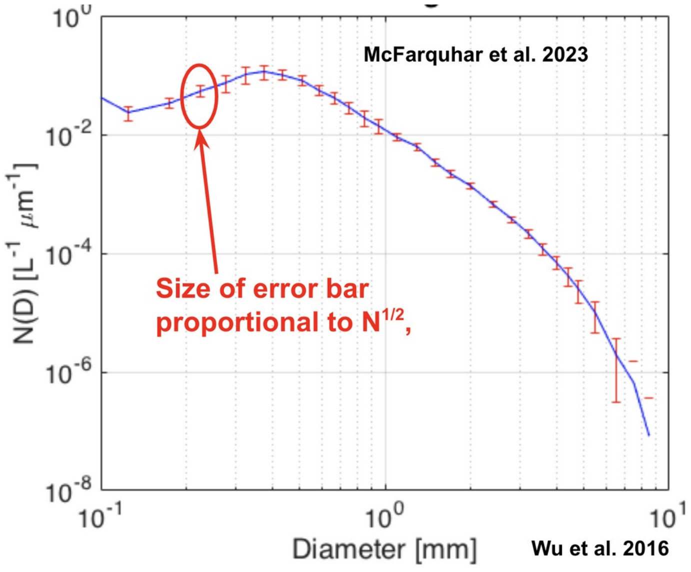
Recommendations for Obs - 1

- Evaluate cloud properties, radiative fluxes and precipitation
- Compare **statistical relationships** between mp and obs
- Reduce **compensating errors** - evaluate **subprocesses**
- Use satellite, radar, lidar and passive remote sensing
- **Explore observations fully**

  for in-depth scheme evaluations

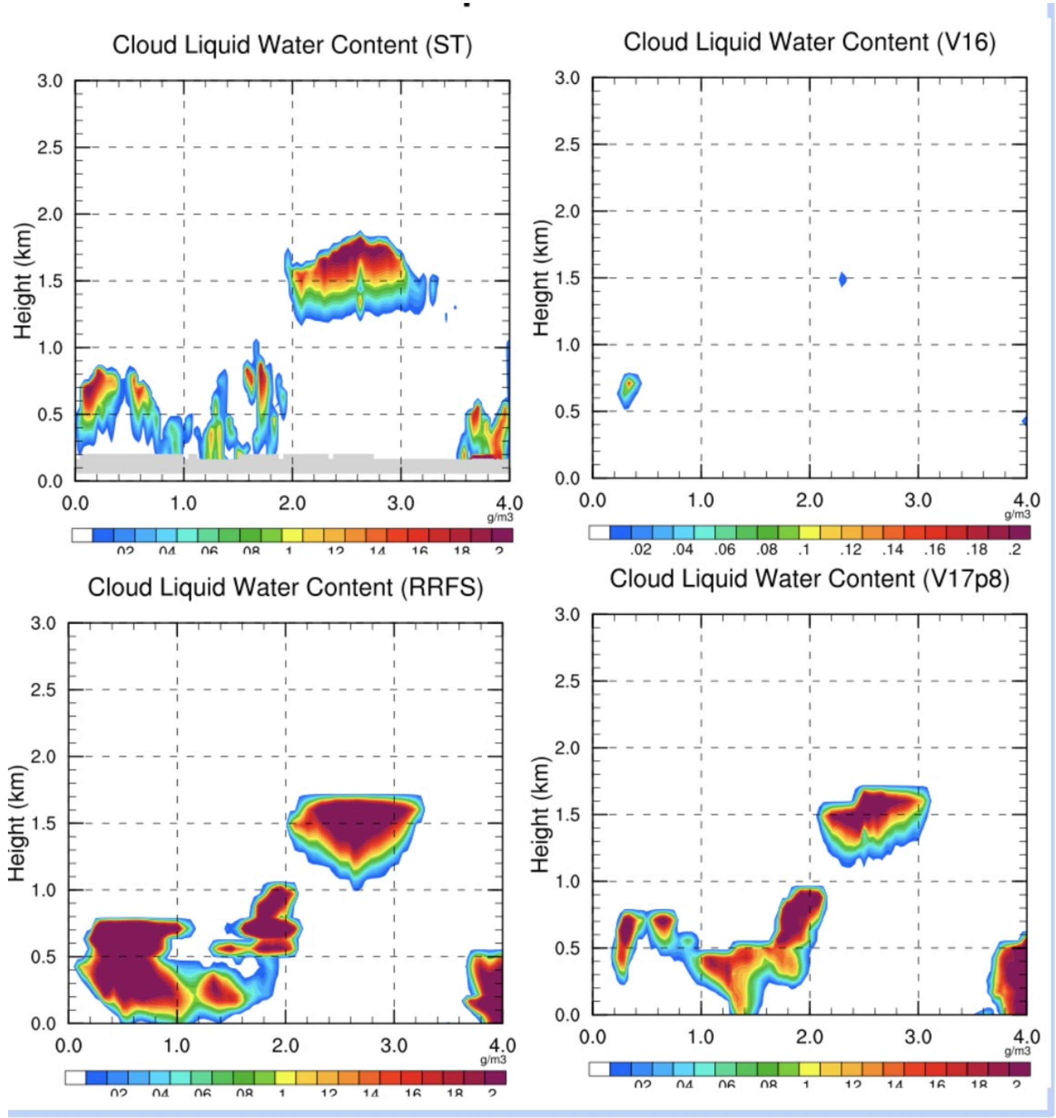
Observations have uncertainty too!

From Wu et al. (2016) via Greg McFarquhar, Cooperative Institute for Severe and High Impact Weather Research and Operations & School of Meteorology, University of Oklahoma



Recommendations for Obs - 2

Add more cases with comprehensive obs data for to the **Common Community Physics Package Single Column Model**



SCM cloud liquid water content with different physics configurations

From Amy Solomon, NOAA ESRL PSL and CIRES

Discussion Questions for This Workshop

- What is the minimal complexity in cloud and precipitation microphysics parameterizations required for all operational applications?
- Is a unification in the cloud and precipitation microphysics parameterizations possible for all operational applications?
- How do we efficiently and consistently represent the microphysical impacts of sub-grid heterogeneous clouds in the "gray zone"?
- How do we efficiently and consistently represent aerosol-cloud interactions in convection and microphysics parameterizations?
- How do we evaluate and improve the operational forecast of mixed-phase clouds, especially in the mid- and high-latitudes?
- How do we use observations and/or LES simulations to diagnose/evaluate and constrain parameterized cloud and precipitation processes?
- What should be included in a research grade version of the UFS microphysics scheme (and other physics and chemistry components)?
- How can we collaborate more effectively with the community at large on microphysics parameterization to address the UFS development needs?

Objectives of the workshop

- Identify the current challenges and opportunities related to the microphysics parameterization development in the UFS.
- Foster collaboration and knowledge sharing among the participants.
- Develop actionable strategies and recommendations to address the identified challenges in both operation and research using the UFS.
- Explore innovative ideas and potential solutions for long-term cloud microphysics development in the UFS

Structure of the workshop

- Welcome and remarks on the workshop objectives.

- Invited and contributing presentations on Research and Development, Operational Needs and Ongoing UFS-R2O Development, Community Development, and Using Observations to Improve Microphysics Parameterization.

- Breakout sessions for interactive discussions and recommendation generation.

- Presentation and discussion of findings from breakout sessions.

- Summary and conclusion.

Three breakout discussions of recommendations for future

1. Research and development in the UFS

2. Addressing UFS research-to-operation needs

   i. GFS applications

   ii. RRFS applications

   iii. HAFS applications

3. How to use Observations to evaluate and improve operational scheme(s)

Recommendations for addressing R2O needs

- Development of aerosol-microphysics interactions and microphysical connections between various grid- and subgrid-scale cloud production processes in the framework of a physically-consistent prognostic cloud scheme

- Careful consideration of dynamics-microphysics process coupling

- Inclusion of gas phase and aerosol chemistry processes of different complexity with represent wet scavenging process of all chemical species and aqueous-phase chemistry processes.

- Use of LES to fill gaps associated with sparse observations for refining/calibrating bulk microphysics schemes

- Collaboration of open-minded developers and avoiding single-point failure

Recommendations for research and development

- Operational UFS microphysics schemes should include liquid and clouds, rainwater, snow, graupel, and hail as predictive hydrometeor variables, with double-moment formulations for some.
- Convection schemes in the UFS should use aerosol information consistently with that used in the microphysics scheme.
- Aerosol information should be consistently used between grid- and subgrid-scale cloud microphysics parameterizations to allow an accurate representation of supercooled water production, e.g., in Arctic clouds.
- Future UFS physics suite have a configurable and flexible microphysics scheme with optional components for processes and species and closer interactions with chemistry.
- The UFS microphysics parameterization development should also include close collaborations with subject experts at universities.

Recommendations for incorporating observations

- Use different cloud observations from satellite, radar, lidar and passive remote sensing to evaluate cloud microphysics properties, radiative fluxes and precipitation simulated by the UFS physics to reduce compensating errors in the model

- Use observation-based metrics to provide a more sensitive measure of future microphysics parameterization improvements

- Comparing statistical relationships between different microphysical property observations and simulations to focus on evaluating individual process parametrizations

- More representative cases with comprehensive observational data for SCM studies using the CCPP to be made available to the UFS community