Make American NWP Second to None

——from cloud physics perspective

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Outline

- Microphysics schemes in the current global systems in the major centers
- Current available MP options for Zhao and Carr (1997)
- NGGPS cloud physics priorities and recommendations from the previous moist physics workshop
- Current status of individual MPs and testing plans in the FV3 NGGPS
- Interactions between the cloud microphysics and other physical schemes

Current MPs at major centers —for global systems

- Environment Canada: The cloud and LS precipitation scheme is based on Sundqvist (1988) and was modified to predict rain. Cloud cover is diagnosed.
- NCEP GSM: The cloud and LS precipitation scheme is based on Zhao and Carr (1997) and Sundqvist et al (1989). Cloud cover is diagnosed (Xu/Randall, 1996).
- ECMWF IFS: The cloud and LS precipitation is based on Tiedtke (1993), but was significantly modified. The prognostic variables include cloud liquid water, cloud ice, rain, snow, and cloud cover. No assumption on PSD.
- UK MetUM: The LS precipitation is based on Wilson and Ballard (1999) (which was based on Rutledge and Hobbs, 1983). The prognostic variables include cloud liquid water, rain, and frozen water. Cloud cover and LS condensate are predicted by using PC2 (Wilson et al 2009). Assumed PSD for rain and frozen water.

Available MP options

~currently being worked on

	Ferrier &Aligo	GFDL MP	WSM6	MG (double)	Thompson (double)
prognositic variables	qv, qc, qr, qi+qs+qg, RF1/2	qv, ql, qi, qs, qr, qg	qv, ql, qi, qs, qr, qg	qv, ql,nl, qi, ni (testing qr and qs)	qv, ql, qi, qs, qr, qg, ni, nr
condensation and evaporation	Asai (1965)	Lord et al (1984) and Tao (1989)	Yau and Austin (1997)	MG2008, MG2015, Barahona et al 2014 SHOC 2013	Yau and Austin (1997), Thompson and Eidhammer(2014)
mixed-phase clouds	yes	yes	yes	yes	yes
precipitation sedimentation	qi, qr, qs, qg sediment vertically	qi,qr,qs,gq sediment verically	qi, qr, qs,qg sediment vertically	qc and qi sediment vertically (testing qr and qs)	qi, qr, qs, qg sediment vertically

The NGGPS priorities in cloud MPs

- Advance the sophistication of the microphysics parameterization, which should include a double moment capability for some species and an option for coupling with aerosols.

— NGGPS physics Overview (August 4, 2016)

by James Doyle(NRL), Bill Kuo (NCAR), Shrinivas Moorthi (EMC)

Moist workshop recommendations (01/2015)

- The most promising treatment of moist physics at or near the current state-of-the-art that roughly 100 US and international scientists agreed on:
  - "Two moment microphysics with multiple categories of ice habits. This implies that all particles are predicted (not diagnosed) and fall with finite velocity".
  - "Utilizing these approaches, especially the two-moment microphysics, places demands on other components of the model including dynamics (especially advection schemes) and aerosol representation"

Current status

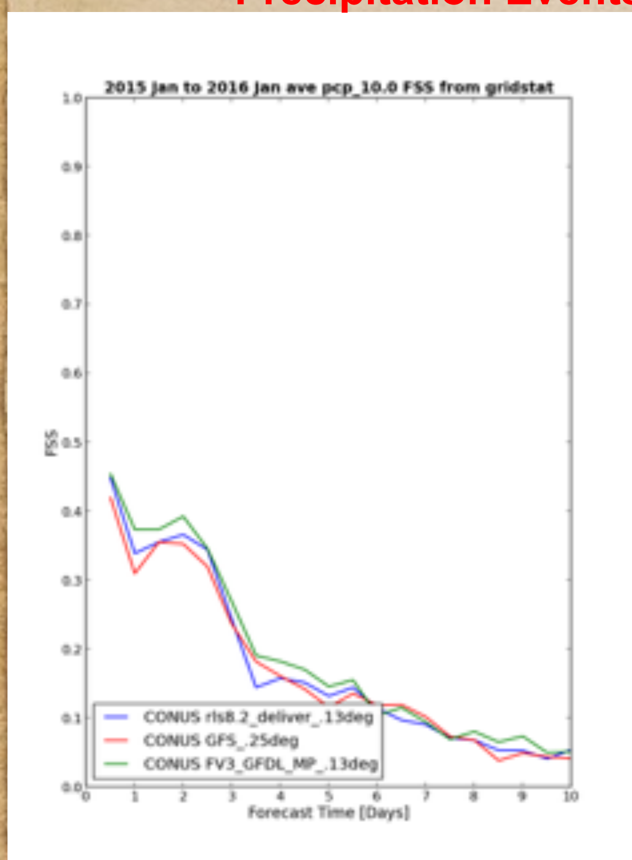
—GFDL MP

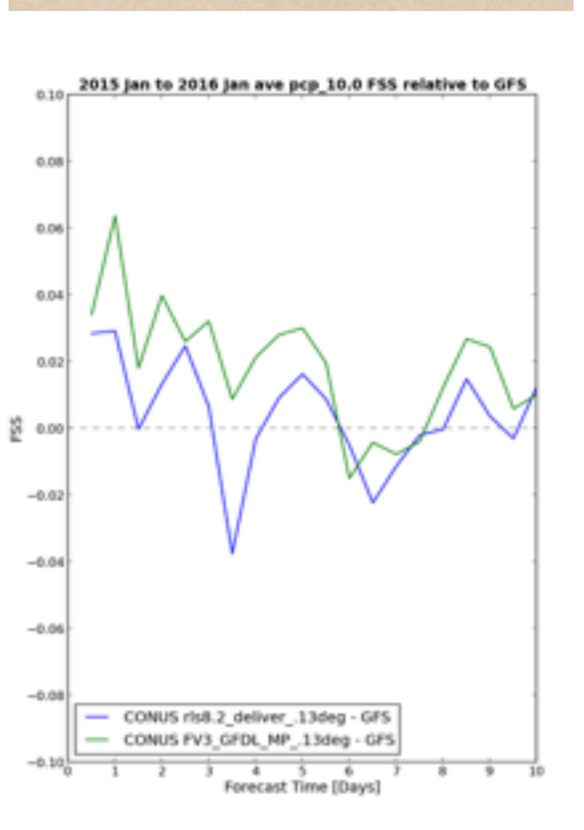
Fractions Skill Score over CONUS

(based on NGGPS 74 cases)

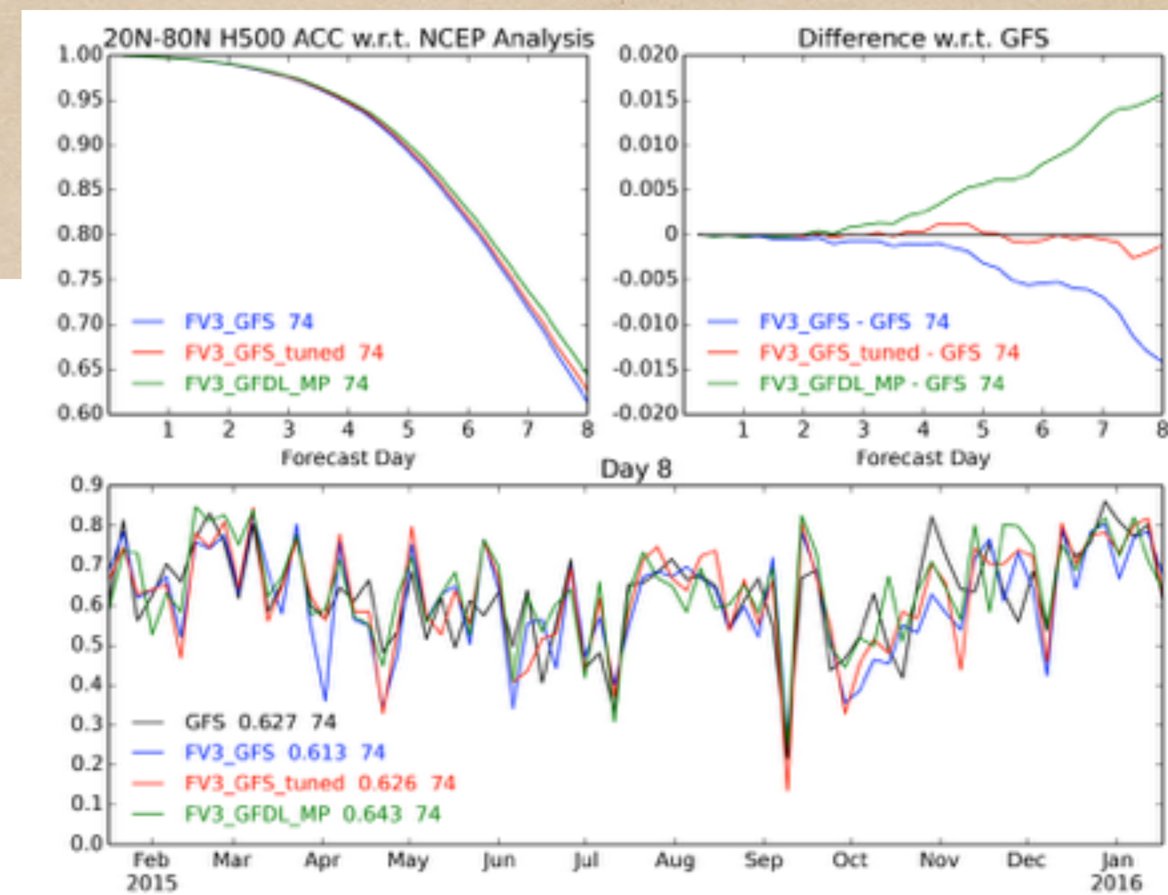
GFDL_MP made a significant improvement

Precipitation Events >= 10.0mm/6hr





Relative Skill to Operational GFS



13-km fvGFS with GFDL_MP

13-km fvGFS with tuned GFS

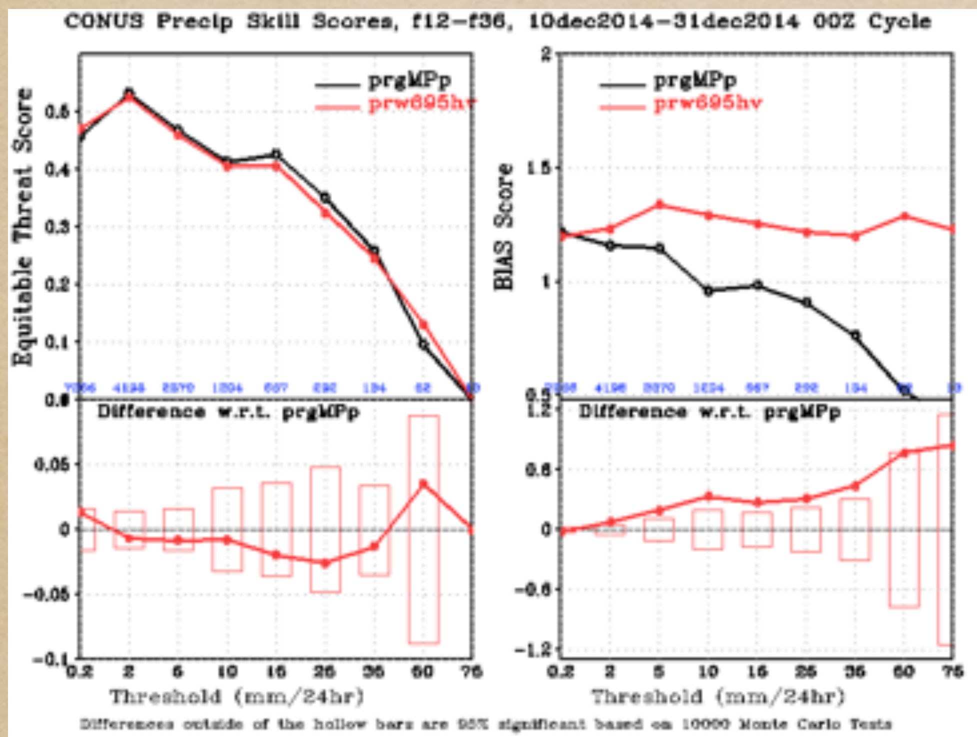
13-km fvGFS (no tuning)

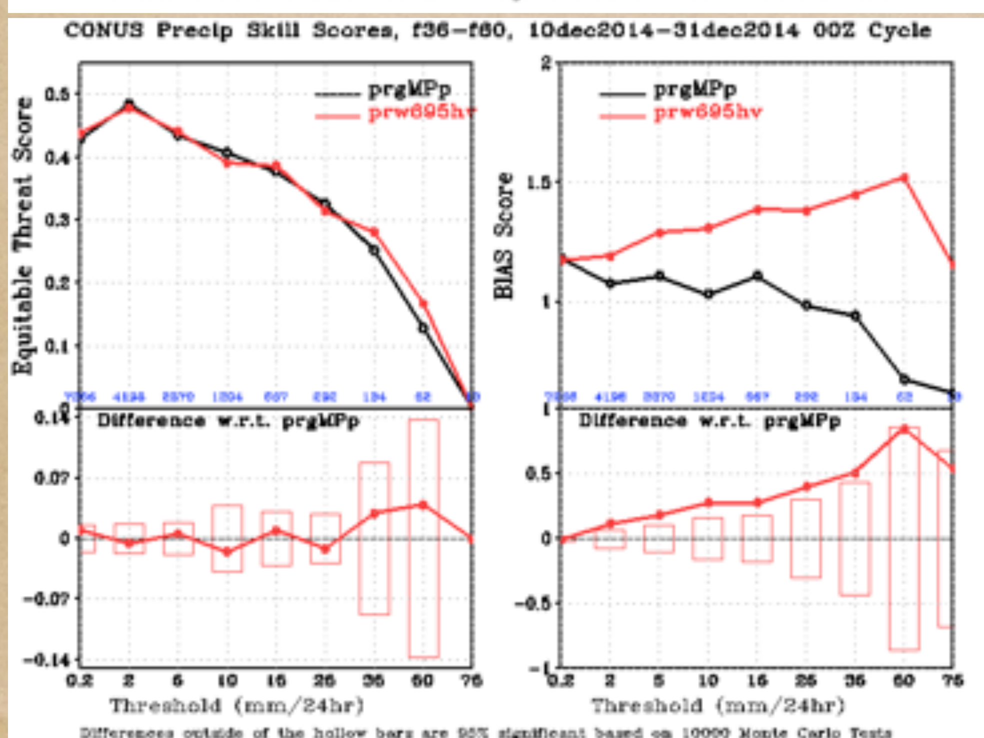
FSS by MET tool, using Stage IV data

The scheme is being tested with FV3 in NGGPS

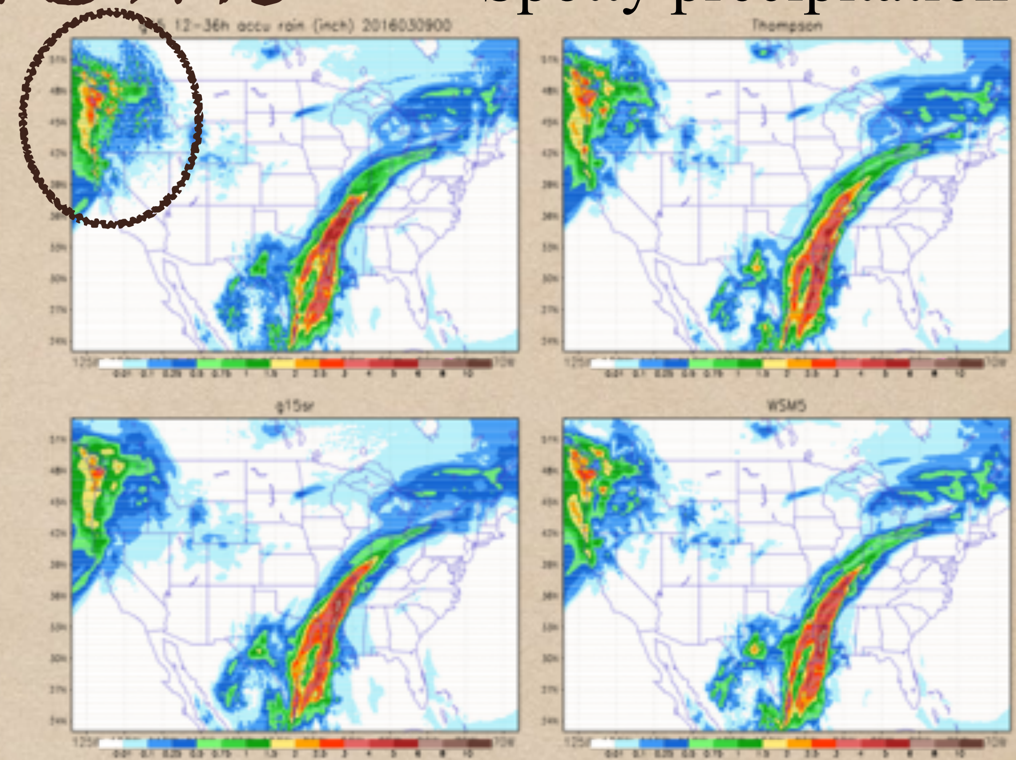
Courtesy of Dr S.J. Lin from FV3 workshop

Current status —WSM6



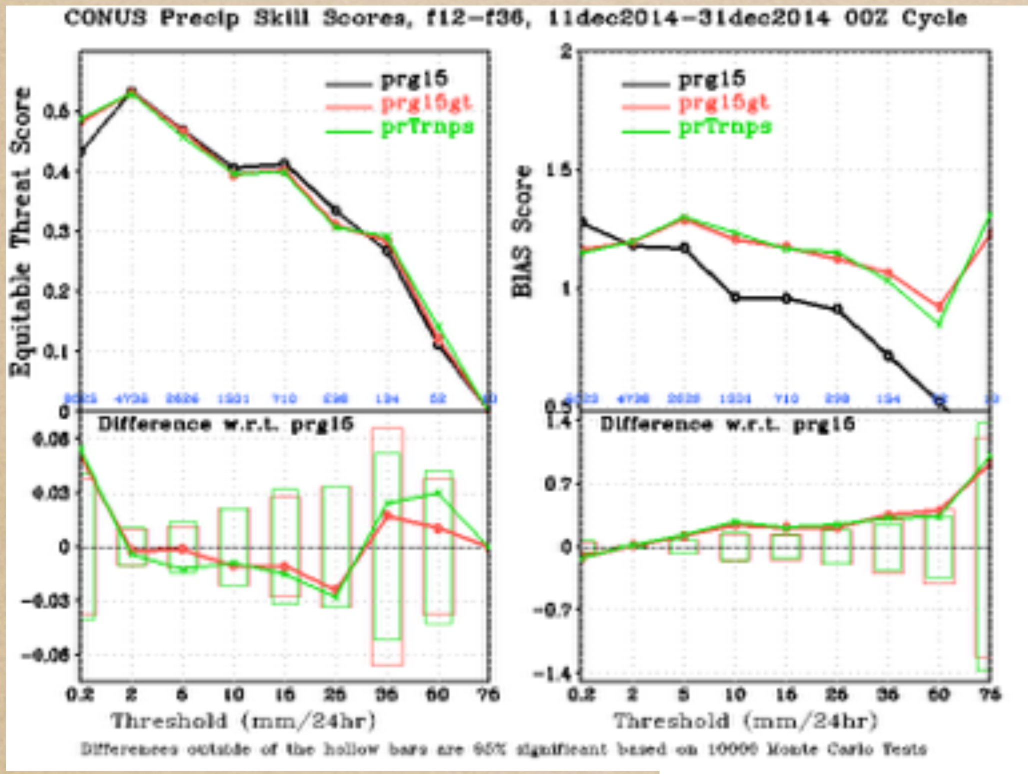


Spotty precipitation

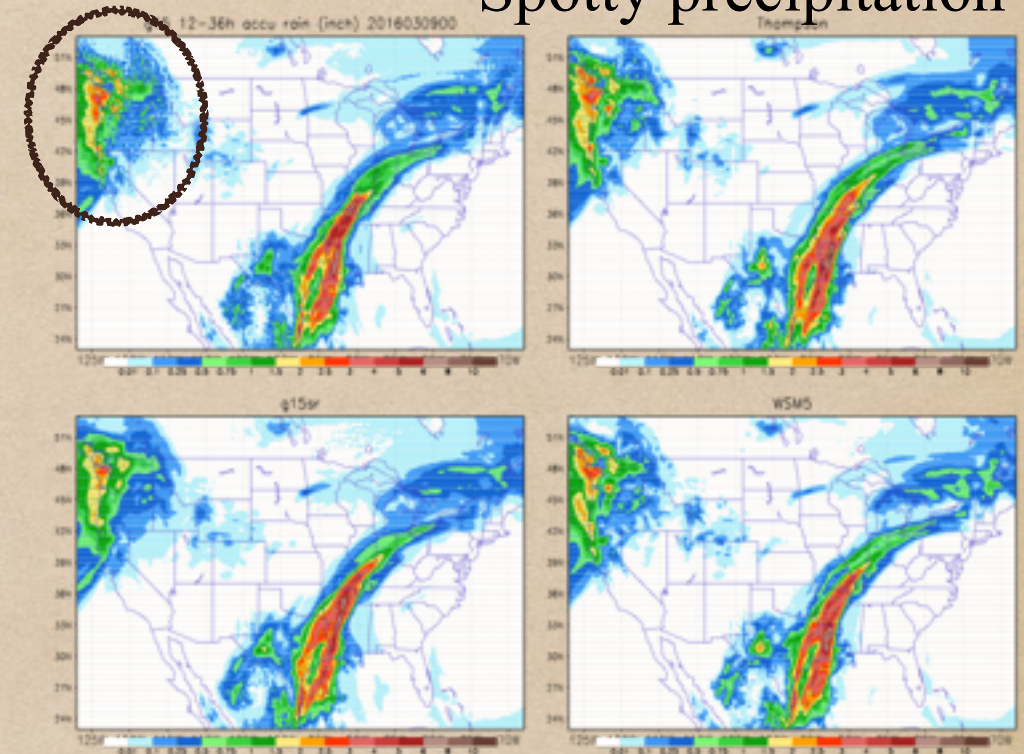


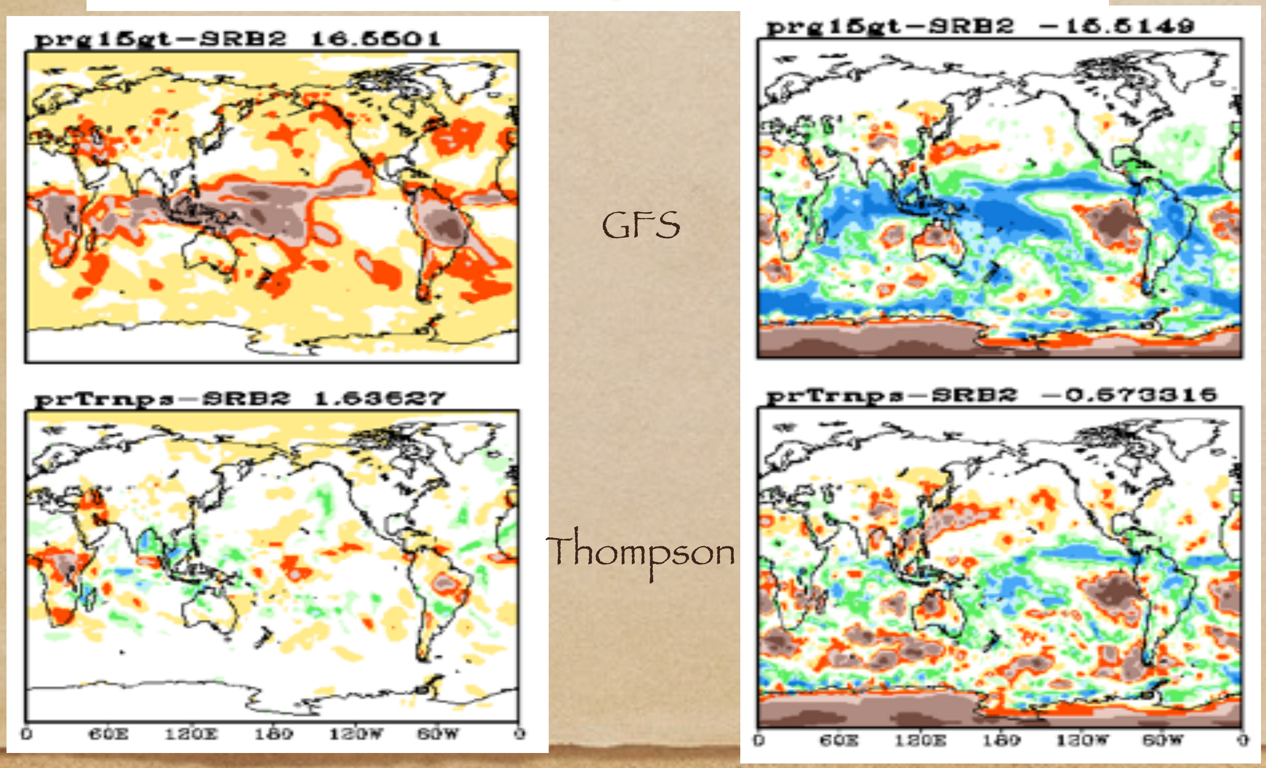
- Tested in the operational GFS
- Precipitation ETS score is close to GFS
- Cloud radiative effect is a little weaker than the GFS
- Eliminated spotty precipitation seen in the GFS with Zhao and Carr (1997)

Current status —Thompson's MP



Spotty precipitation

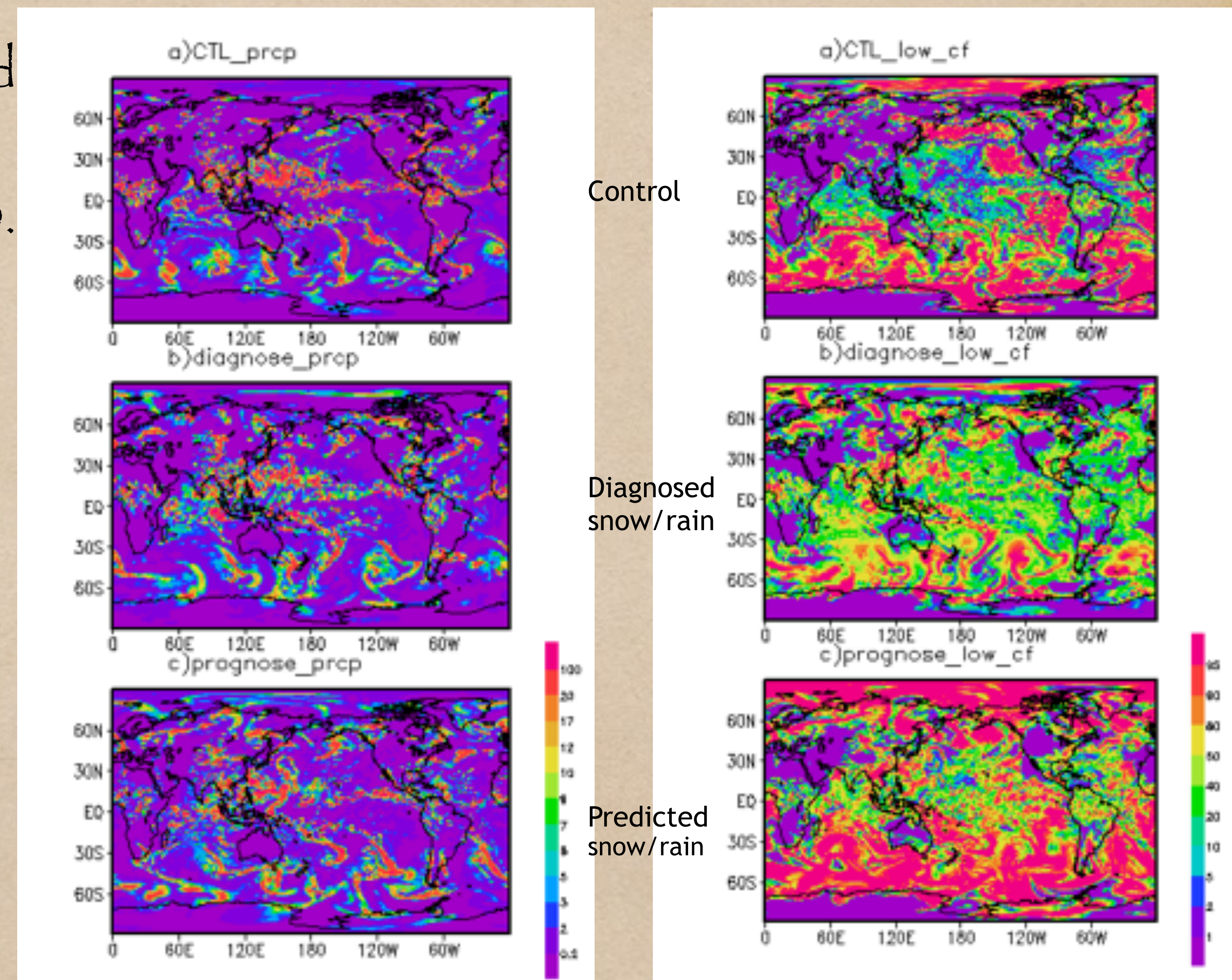




- Tested in the operational GFS
- Significantly improved the cloud radiative effects
- Significantly improved the precipitation skill score in the light rain, but degraded in the moderate range
- Eliminated spotty precipitation seen in the GFS with Zhao and Carr (1997)
- In a version of NEMS now.

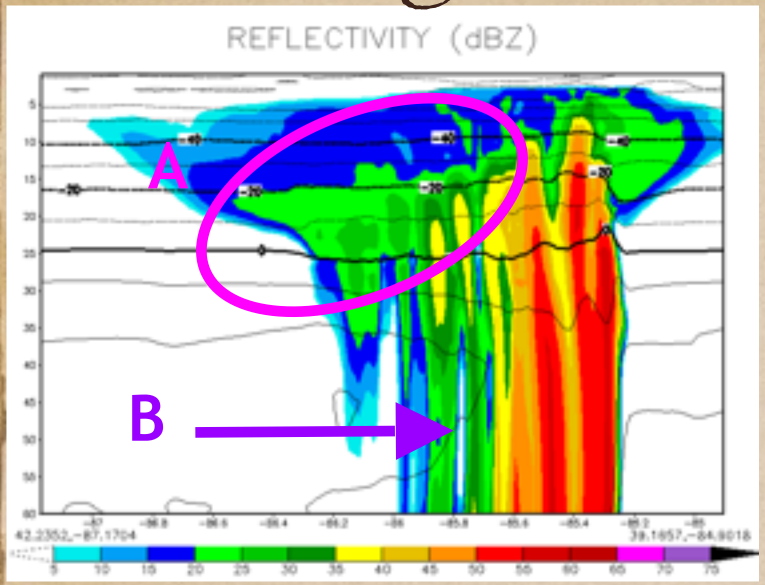
Current status —MG MP

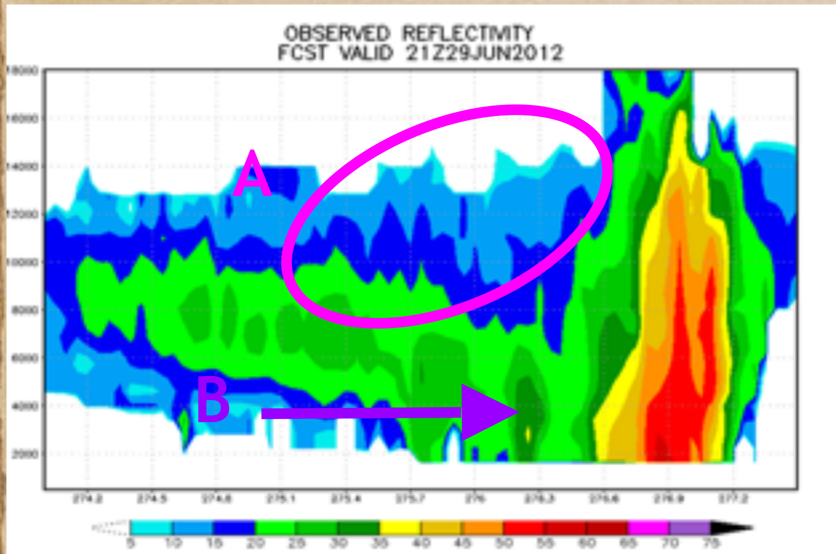
- Implemented and tested the prognostic rain and snow number and mass with T62 and T760. Diagnosed rain and snow was tested with T2460.
- Produced reasonable global precipitation and cloud pattern and nice Sandy track from T2046.
- Tuning-up and bugs-fixing for the global ice and water mixing ratio and low-, middle, and high-level cloud fraction with the parallel scripts.
- Future work: coupling with other physical processes such as SHOC and CS deep convective scheme.



Courtesy of Anning Cheng/Yutai Hou

Ferrier-Aligo MP (in NAM)



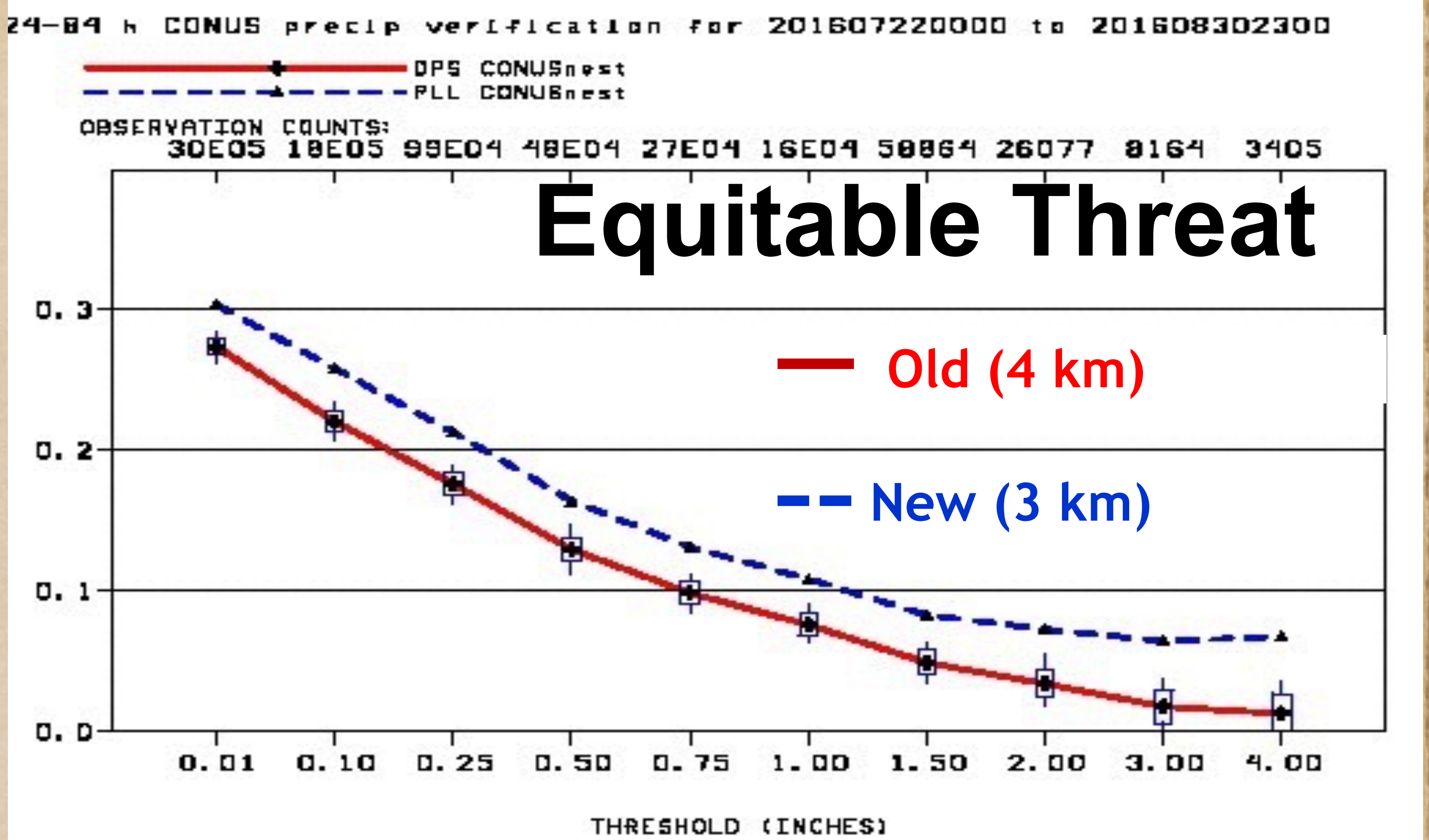


(Note different vertical coordinate)

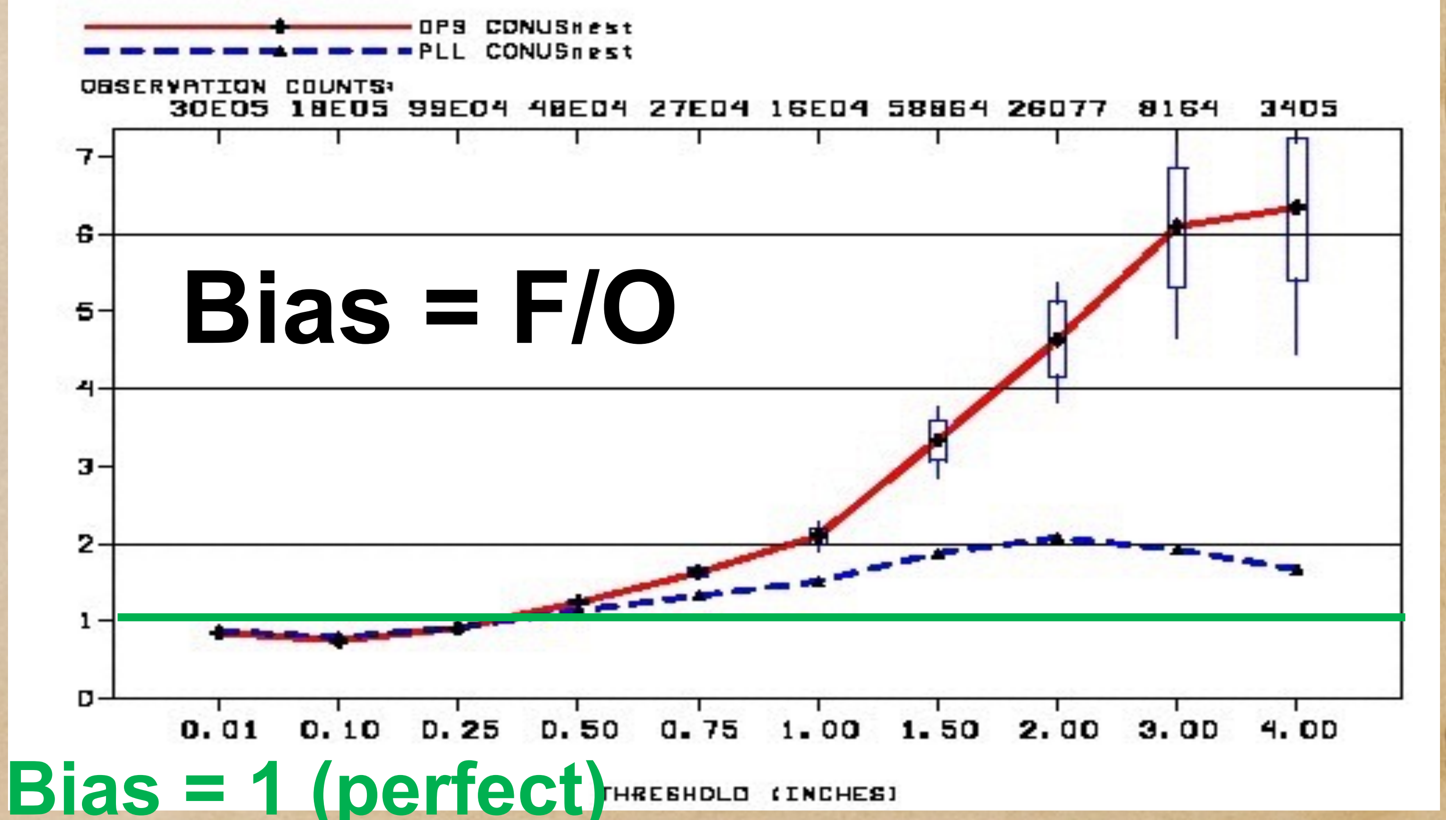
A - Reduced reflectivity in stratiform anvils
B - Increased reflectivity & rainfall below anvils
C - Improved dBZ (from objective verification)

Courtesy of Brad Ferrier and Eric Aligo

19 July – 29 August 2016 (0-24 h + 12-36 h + 24-48 h + 36-60 h)



Precipitation Scores (CONUS Nests)



Interactions between the MPs and other physical schemes — Coordinated activities

- Microphysical consistency between sub-grid and grid-resolved cloud schemes
  - Allow the use of more complex microphysics in a mass-flux scheme
  - Evaluate the sensitivity of a consistent microphysics treatment between sub-grid and grid-resolved cloud schemes to assumed vertical distribution of detrained cloud condensate
- Physically consistent treatment of clouds in cloud-radiation interaction
  - Cloud properties diagnosis/input consistent with microphysics assumptions
- Physically-based treatment of clouds in stochastic physics parameterizations
  - Allow stochastic perturbations in all the parameterized microphysical processes

Testing plan

- The plan depends on when the FV3 is available in NEMS (assuming Q2/FY17).
- The tests will be conducted in the NEMS framework with FV3 (NGGPS).
- Forecast only experiments or full data assimilation experiments need to be conducted in both summer and winter. The experiment periods need to be long enough for solid performance evaluations.
- Timelines :
  - Finish developing/tuning/testing of the MP schemes in the GMTB SCM and the NEMS or the GFS before FV3 is available in the NGGPS.
  - Implement the MPs into NGGPS for further tuning with the FV3 and other physics (Q2/FY17)
- Deliverables : MPs for the NGGPS with FV3.

Gaps

- What is the best strategy to test individual MPs with FV3 in the NGGPS? What are the other physical parameterization schemes (for example, convection, etc) to choose, operational schemes ?
- Computer resources for the tests of the MP schemes
- What is the strategy to choose a MP scheme for the NGGPS
  - EMC global evaluation metrics
    - Global energy and mass conservation
    - Precipitation skill score (ETS), and bias score, cloud related fields, cloud radiative effects, 500mb AC scores, etc
  - Other metrics (climate, storm scale metrics, etc)
  - Interactions with other physical parameterization schemes
  - Scientific basis

Cloud macrophysics

- Cloud cover schemes available :
  - Diagnostic schemes: Xu/Randall (1996), Sundqvist (1988), simple uniform PDF, triangular PDF and Double Gaussian PDF schemes.
  - Prognostic schemes: Tiektdk(1993), Thompsins (2002), and PC2 (Wilson et al 2009)
- Cloud water condensation and evaporation :
  - Sundqvist et al (1989), simple uniform PDF, triangular PDF and Double Gaussian PDF schemes
  - Prognostic schemes: Tiektdk(1993), Thompson's (2002), and PC2 (Wilson et al 2009)

Discussion questions

- How to determine the MP scheme into NGGPS
- What metric to use for the evaluation
- How to test the schemes? Is it necessary to go through the entire hierarchy of tests ?
- What is the realistic strategy for the aerosol indirect effect

Backup

NGGPS Physics Team Plan

Cloud Microphysics SWG

GFS Upgrade Timeline

New Dycore Operational

GFS V15 | GFS V16 | GFS V17

Two-Stream Strategy

Operational Physics (Evolved) → Advanced Physics →

Cloud Microphysics SWG

Current capability (SAS, RAS, Hybrid EDMF) →

Double-Moment Cloud and Aerosol Aware Microphysics (Primary Thrust)

Dependencies for achieving? Subtask chart could include task leads, testing responsibilities, dates, decision points

Evaluate/Adapt Advanced Microphysics Schemes Using NOAA-HMT Obs (Bao/Cifelli)

(Compare bulk microphysics schemes; Develop budget analysis procedure to compare parameterized microphysical processes; Establish hierarchy of evaluation platforms (1-D to 2-/3-D idealized/real case studies)

- Deliver effective solution to alleviating physically inconsistent interaction between subgrid and grid-resolved cloud parameterizations at the resolution of the NGGPS

- Complete analysis of microphysics schemes (names?) and present findings to support selection of new scheme for NGGPS (timing?)

Thompson's MP (Ruiyu Sun, Greg Thompson, and others)

- Next step(s)? Testing thru EMC/TEG or GMTB? Implementation in GFS (timing)?

Need to adjust/add timelines/ responsibilities (use color bar) where applicable

- Other cloud microphysics activities needed to address high priority gaps?
What are primary candidate schemes and where do they fit in the evaluation/testing timeline?
- Development, testing, transition addressed for each SWG?

- Path(s)/timeline(s) for above to transition to ops?

1 Jan 2017 | 1 Jul 2017 | 1 Jan 2018 | 1 Jul 2018 | 1 Jan 2019 | 1 Jul 2019 | 1 Jan 2020 | 1 Jul 2020 | 1 Jan 2021

Legend: Red text = unfunded; (add colors to indicate funding source?) **Red = Phys Dev; Blue = DTC; Green = EMC**

Moist workshop recommendations (01/2015)

- Several themes emerged from the workshop time and time again:
    - NGGPS represents an opportunity for dramatic progress that will be available once a decade or even less frequently. There was a strong sense that EMC, NCEP, and NOAA should make the most of this opportunity. As one participant put it: "This is no time for small steps. Be bold."
    - The representation of moist processes is a suite of inter-connected pieces, and careful attention is required due to the way the various components interact. This problem is more conceptual than technical, i.e. addressing code interfaces is necessary but insufficient. In the words of one participant, "It's the package that's hard