Strategic Implementation Plan (SIP) for a
Community-based Unified Forecast System (UFS)
College Park, MD, May 15, 2019

Common Community Physics Package (CCPP) Update

Ligia Bernardet

Developmental Testbed Center (DTC) Global Model Test Bed

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GSD: Dom Heinzeller, Man Zhang, and Linlin Pan

DTC Developmental Testbed Center

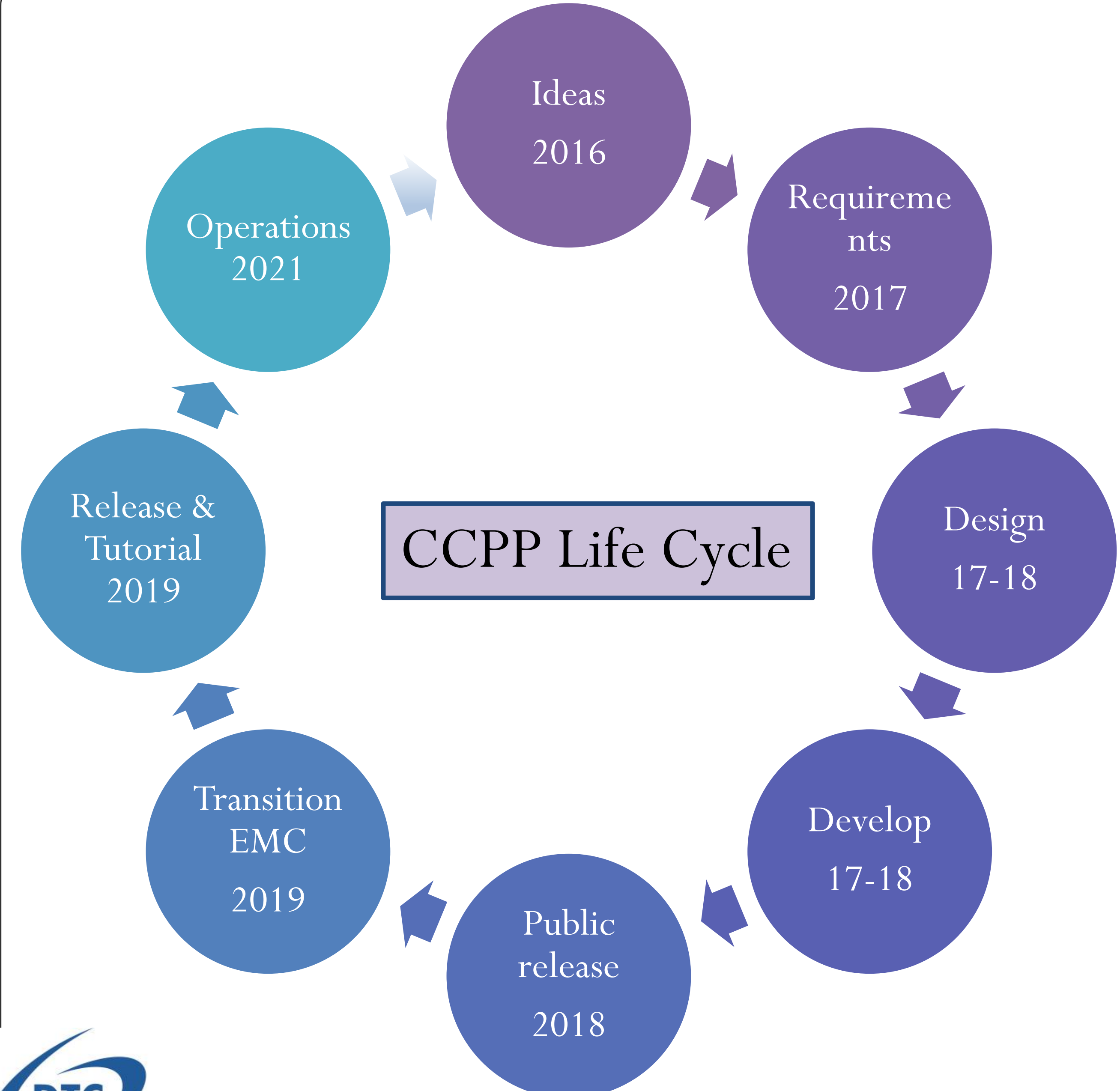
Acknowledgments

- NOAA Environmental Modeling Center
- Physics developers and contributors
- NCAR Climate and Global Dynamics Laboratory
- NCAR Mesoscale and Microscale Meteorology Laboratory
- Navy Research Laboratory
- Earth System Prediction Capability Physics Interoperability group

Goals for the UFS Physics

- **Consolidated**: Single library of operational and developmental parameterizations and suites for all UFS applications
- **Supported:** Well-supported community code
- **Open:** Have accessible development practices (GitHub)
- **Clear interfaces:** Well-documented and defined interfaces to facilitate using/enhancing existing parameterizations and adding new parameterizations
- **Interoperable:** usable with other dycores/hosts to increase scientific exchange
  - Single-Column Model
  - Etc.

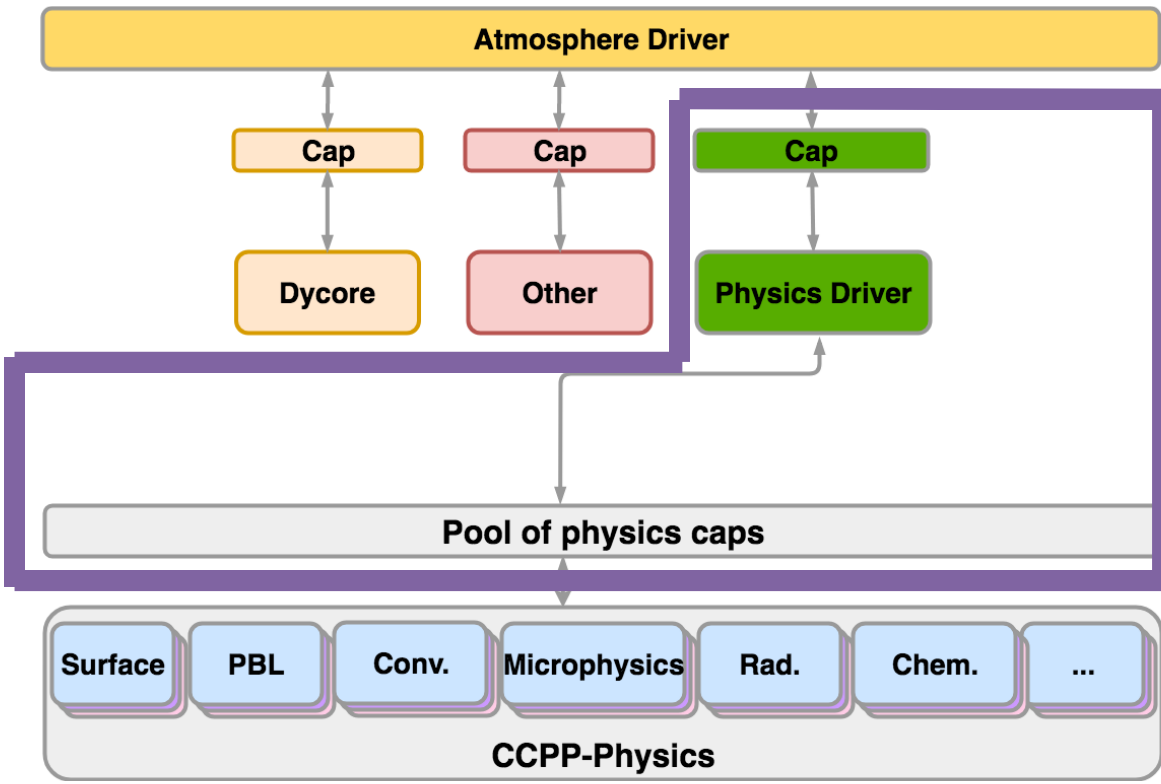
Common Community Physics Package (CCPP)



- CCPP has been mostly developed by GMTB with NGGPS funding
- Critical partnership with EMC in planning/adoption process
- Planned transition to operations with GFS v16 in 2021
- Continuously revise and iterate

CCPP Physics and Framework

The physics and the framework are distinct aspects of the CCPP



Host application cap with auto-generated code from host metadata

CCPP-Framework used before/at compile time and during run

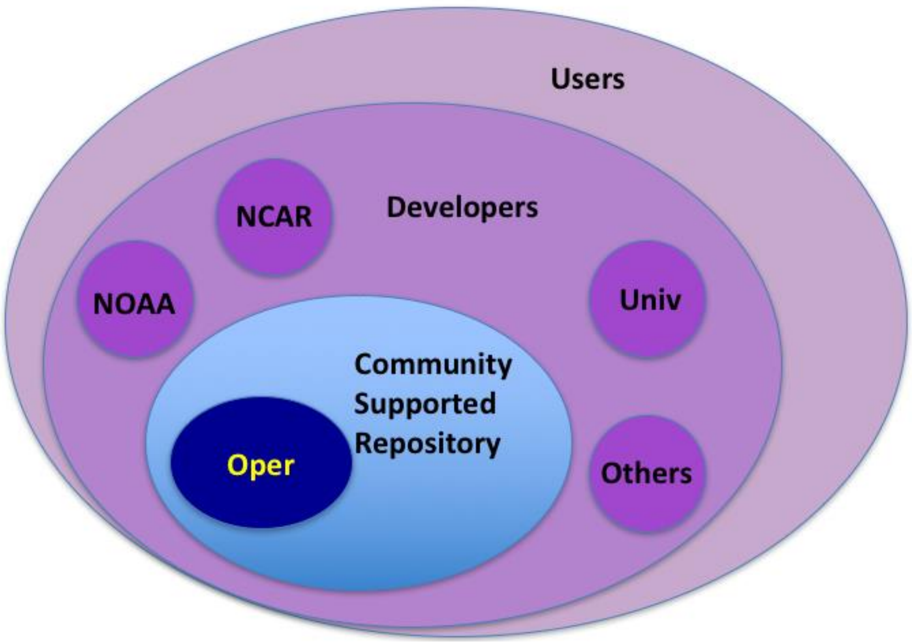
Physics caps (auto-generated)

Parameterizations

Key Features of the CCPP Framework

- **Configuration**
  - Compile time (for performance)
  - Run time (to be phased out in favor of multi-suite selected at compile time
- **Subcycling**
  - Schemes can be called at higher frequency than others or than dynamics
- **Grouping**
  - Schemes can be called in groups with other computations in between (e.g. dycore, coupling)
- **Ordering**
  - User-defined order of execution of scheme
  - But note that this must be done very carefully. Just because you can re-order, it does not mean it will make scientific sense and be computationally stable!

CCPP Physics Vision



- CCPP contains both operational suites and innovations for the next few years
- Subset is vetted and supported to the community
- Vibrant distributed development
- Usable by various models (hosts)
- Users, developers, operational implementers synergistically benefit
- Translates into benefits for NOAA operational models

Host Models Currently Using CCPP

- **Using the CCPP Physics and Framework**
  - **GMTB:** Single-Column Model
  - **UFS Atmosphere:** global and stand-alone regional
  - **NRL:** Neptune (successful implementation and ongoing testing)
- **Using the CCPP Framework**
  - **NCAR:** ongoing development for CESM, WRF, MPAS, chemistry model

Parameterizations in authoritative code

Category	Scheme
Microphysics	Zhao-Carr, GFDL, MG2-3, Thompson
Planetary Boundary Layer	K-EDMF, TKE-EDMF, MYNN, YSU, saYSU
Surface Layer	GFS, MYNN
Deep Convection	saSAS, GF, Chikira-Sugiyama, Tiedtke
Shallow Convection	EDMF, Tiedtke
PBL and Shallow Convection	SHOC, MYNN
Radiation	RRTMG
Gravity Wave Drag	GFS orographic, GFS convective
Land Surface	Noah, RUC
Ozone	2006 NRL, 2015 NRL
H_2O	NRL
Stochastic	SKEB, SHUM, SPPT, SPT

CCPP: Commonly Used Suites (13 km)

Schemes/Suites	GFS_v14	GFS_v15	GFS_v15+	CPT_v0	GSD_v0
Microphysics	Zhao-Carr	GFDL	GFDL	M-G3	Thompson
Boundary Layer	K-EDMF	K-EDMF	TKE EDMF	K-EDMF	saMYNN
Surface Layer	GFS	GFS	GFS	GFS	GFS
Deep convection	saSAS	saSAS	saSAS	Chikira-Sugiyama	Grell-Freitas
Shallow Convection	saSAS	saSAS	saSAS	saSAS	saMYNN and saSAS
Radiation	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
Gravity Wave Drag	GFS	GFS	GFS	GFS	GFS
Land Surface	Noah	Noah	Noah	Noah	RUC
Ozone	NRL 2006	NRL 2015	NRL 2015	NRL 2015	NRL 2015
H_2O	-	NRL	NRL	NRL	NRL

CCPP: Commonly Used Suites (3 km)

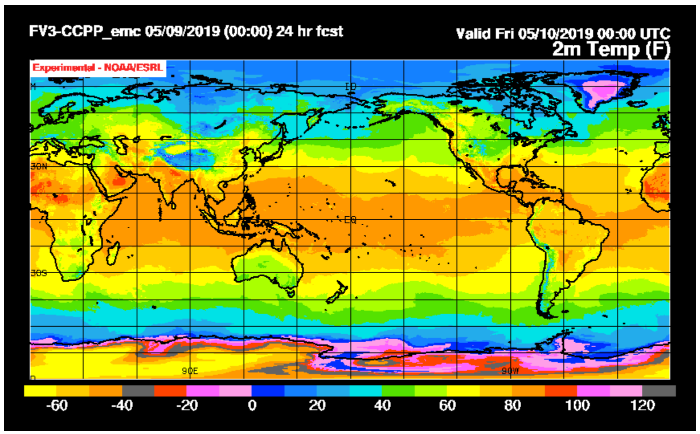
	Microphysics	PBL	SFC layer	LSM
OU-CAPS configurations for HWT Spring Experiment	Thompson	saMYNN	GFS	Noah
	Thompson	saYSU	GFS	Noah
	Thompson	EDMF	GFS	Noah
	NSSL	saMYNN	GFS	Noah
	Morrison-Gettelman	saMYNN	GFS	Noah
	Thompson	saMYNN	GFS	RUC
	Thompson	saMYNN	MYNN	RUC
	Thompson	saMYNN	GFS	Noah
GSD	Thompson	MYNN	GFS	RUC

OU-CAPS configurations: courtesy of Ming Xue
GSD configuration: courtesy of Jeff Beck and Gerard Ketefian

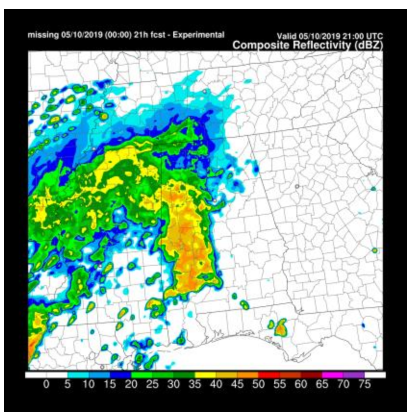
CCPP in realtime

GSD

Global



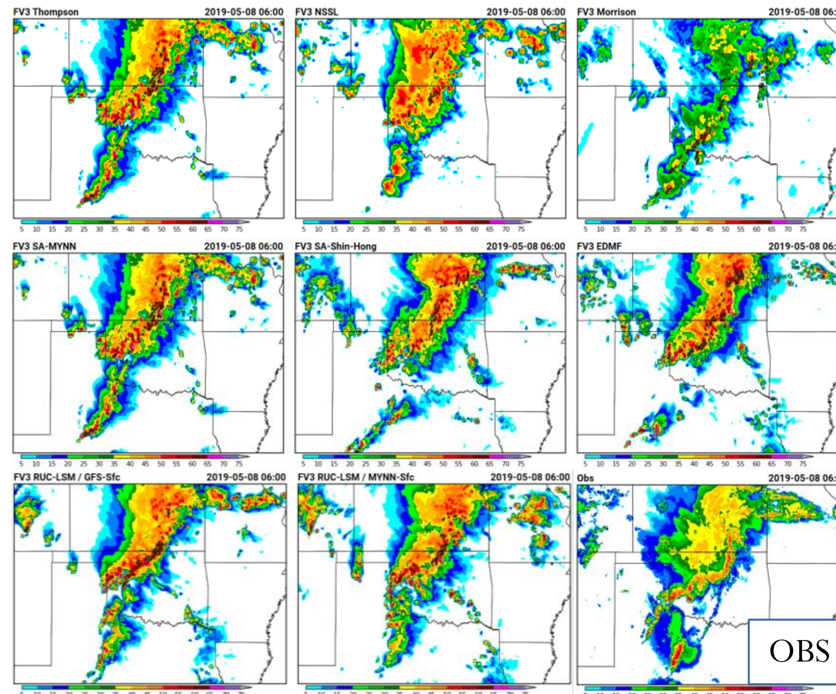
Regional



Global: https://fim.noaa.gov/FV3

Regional: Courtesy J. Beck and G. Ketefian

OU-CAPS



OU-CAPS HWT Spring Experiment

Courtesy: Ming Xue

CCPP Releases

V	Date	Physics	Host
v1	2018 April	GFS_v14	Single Column Model (SCM)
v2	2018 August	GFS_v14 and GFS_v15 Stochastic Physics	SCM FV3 for developers
v3	June 2019	GFS_v15 plus 3 experimental suites used in GFS v16 physics test	SCM FV3 for developers

CCPP v2: https://dtcenter.org/gmtb/users/ccpp/

- Physics and Framework
- Access: GitHub (release code and access to development)
- Portability: Theia, Cheyenne, Mac and beyond
- Docs: Scientific Doc, Users Guide, Developer's Guide, FAQ, Known Issues
- Technical overview, requirements, design
- Helpdesk: gmtb-help@ucar.edu

CCPP Scientific Documentation

- Inline documentation with Doxygen

GMTB Common Community Physics Package(CCPP) Documentation

Version 0

Search

- GMTB Common Community Physics Package(CCPP) Document
  - Introduction
  - GFS RRTMG Shortwave/Longwave Radiation Scheme
  - GFS Scale-Aware Mass-Flux Deep Convection Scheme
  - GFS Scale-Aware Mass-Flux Shallow Convection Scheme
  - GFS Hybrid Eddy-Diffusivity Mass-Flux PBL and Free Atmos
  - GFS Zhao-Carr Microphysics Scheme
  - GFS Surface Sublayer Scheme
  - GFS Sea Ice Scheme
  - GFS Noah Land Surface Scheme
  - GFS Near Sea Surface Temperature Scheme
  - GFS Orographic Gravity Wave Drag Scheme
  - GFS Convective Gravity Wave Drag Scheme
  - GFS Ozone Sources and Sinks Scheme
  - GFS Dominant Precipitation Scheme

Introduction

Welcome to the GMTB Common Community Physics Package (CCPP) documentation for **the 2017 Operational GFS physics suite**. In this website you will find documentation on various aspects of the 2017 operational GFS physics, including basic description, input/output augument list and general/detailed algorithm.

Author

Global Model Test Bed (GMTB) at DTC and NOAA/ESRL

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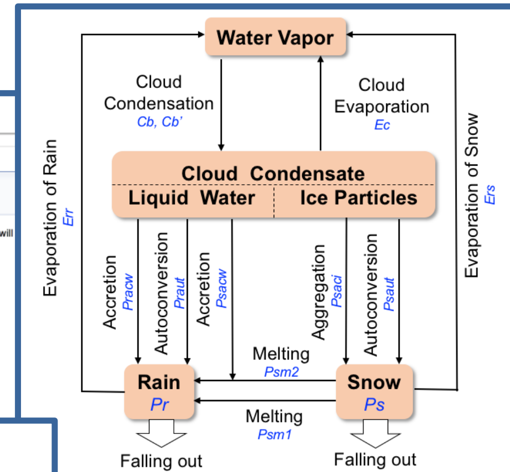
GMTB

Documentation for the individual physics scheme can of 2017 operational GFS physics suite be access through the following links:

- **GFS RRTMG Shortwave/Longwave Radiation Scheme**
- **GFS Scale-Aware Mass-Flux Deep Convection Scheme**



The following two equations can be used to calculate the precipitation rates of rain and snow at each model level:

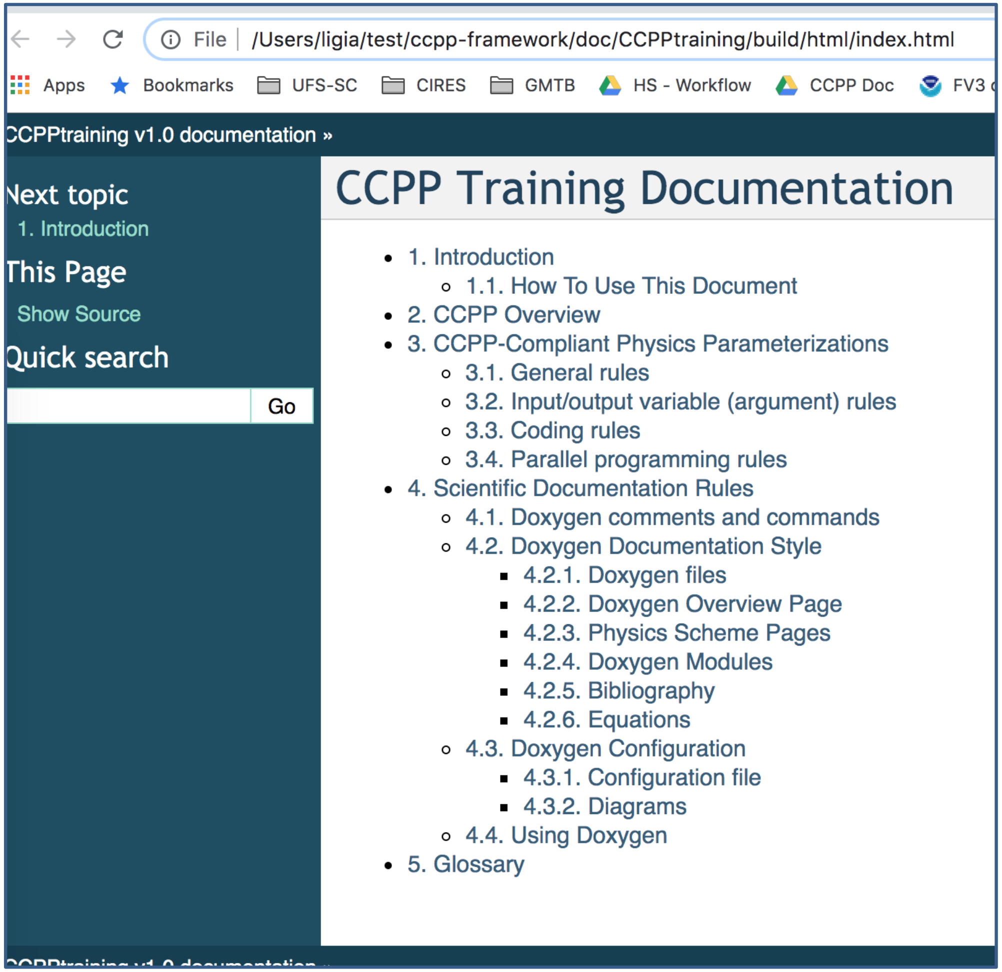
$$P_r(\eta) = \frac{p_s - p_t}{g\eta_s} \int_{\eta}^{\eta_t} (P_{raut} + P_{racw} + P_{sacw} + P_{sm1} + P_{sm2} - E_{rr})d\eta$$

[82] Q. Zhao and F.H. Carr. A prognostic cloud scheme for operational nwp models. *Monthly Weather Review*, 125:1931–1953, 1997.

Argument Table

local var name	longname	description	units	rank	type	kind	intent	optional
im	horizontal_loop_extent	horizontal loop extent	count	0	integer		in	F
ix	horizontal_dimension	horizontal dimension	count	0	integer		in	F
km	vertical_dimension	vertical layer dimension	count	0	integer		in	F
dt	time_step_for_physics	physics time step	s	0	real	kind_phys	in	F

New with CCPP v3: Sphinx doc



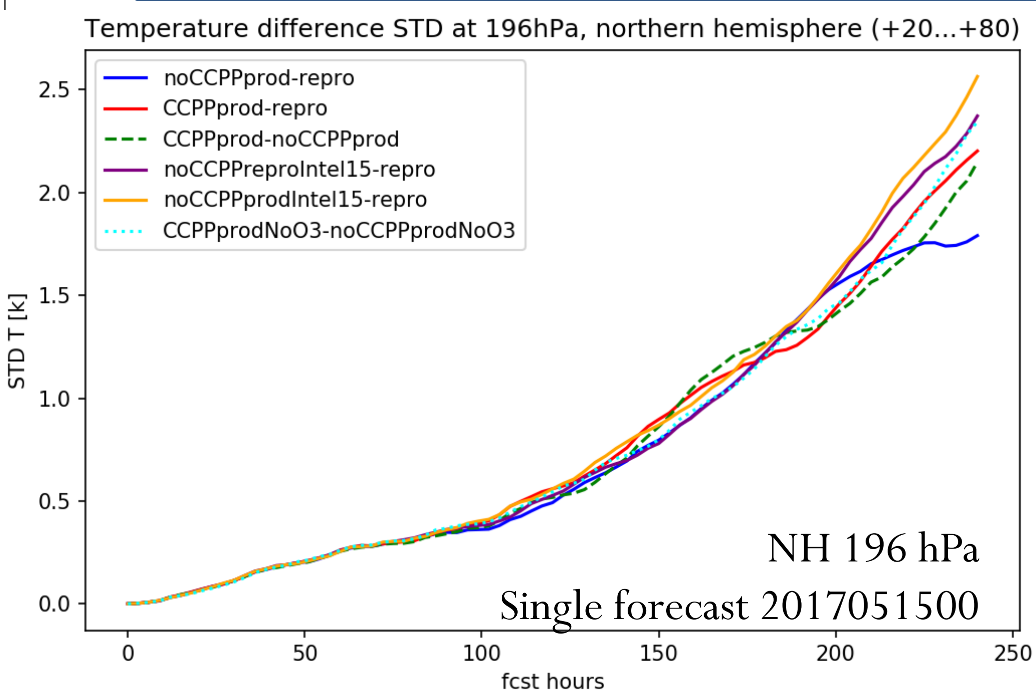
- Next release will have a CCPP overview created with Sphinx and displayed in html
- All documentation under version control and in CCPP GitHub repositories

Changes to NEMSfv3gfs, NEMS, and FV3 for CCPP-compliancy are under review for inclusion in EMC master

Transition of CCPP to EMC

Formal transition plan created with EMC and NGGPS PO

- Documentation of code changes and their impact on various platforms, compiler versions, and compiler options
- For suites that can be run with and without CCPP, result is b4b identical up to O2 optimization. Aggressive performance flags alter the answer. While expected due to code restructuring, impact needs to be quantified and accepted



Std dev T differences (K)

CCPP vs no-CCPP

No CCPP: with vs without aggres optim

No CCPP: Intel 15 vs Intel 18

Changes introduced by adding CCPP are similar to those introduced by varying compiler versions or options

CCPP Training at EMC (March 2019)

https://dtcenter.org/gmtb/users/ccpp/training/CCPPtraining.php

GLOBAL MODEL TEST BED

- CCPP Overview
- Terms of Use
- CCPP Release Notes
- CCPP Downloads
- FAQ
- Known Issues
- CCPP Documentation
- CCPP Training
- Developer's Corner ▶
- Contact GMTB Help
- Related Links

CCPP TRAINING MARCH 2019

CCPP Training Presentations

The following presentations were part of a 2.5 day training held at NCWCP for NCEP/EMC staff.

- Introduction
- Physics_Schemes and Intersititials
- Suite Definition_File
- GitHub_Instructional
- CCPP_Build
- CCPP_Run
- Day1_Wrap-Up

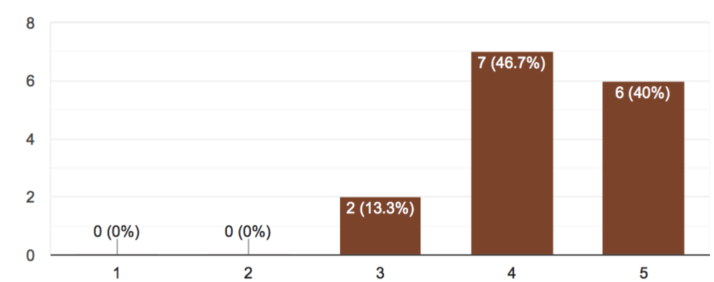
- CCPP_Compliant_Parameterizations
- CCPP_Scientific_Documentation
- CCPP_Prebuild
- Adding_New_Scheme
- Host-Side_Coding
- CCPP_Code_Mgmt
- Governance
- Day2_Wrap-Up

On-line instructions for example exercises (NOAA/theia only!) can be found here

Survey: 88% above or much above expectations

15. Overall, how did the training compare to your expectations (1=much below expectations; 2=below expectations; 3=met expectations; 4=above expectations; 5=much above expectations)

15 responses



New Parameterizations

Soon in CCPP-Physics: NOAA funding

- **RAP/HRRR drag, sea salt, dust, and wildfire** (by GSD)
- **RRTMGP** (by PSD)
- **NSSL microphysics** (by OU-CAPS)
- **RAS** (by EMC)
- **Alternate SAS convection used in CFS**
- **Unified gravity wave drag**
- **Noah-MP**
- **Flake**
- **HWRF suite**: Ferrier-Aligo mp, saSAS convection, K-EDMF PBL, GFDL sfc layer, RRTMG, Noah LSM

Other initiatives

- **RAMS microphysics** (by NRL)
- **NCAR physics** (by NCAR)

Governance

- **CCPP-Framework:** well-established governance by contributors (NOAA and NCAR) https://github.com/NCAR/ccpp-framework/wiki
- **CCPP-Physics**
  - GMTB has been governing based on NOAA priorities
  - A formal governance is under discussion within NOAA (link)
  - Progress is needed to determine criteria for inclusion in master, for defining what is supported, for determining roles and responsibilities of GMTB, physics developers, and other groups

Next Steps

- **Complete transition to EMC**
  - Add all necessary parameterizations/suites to CCPP
  - Insert CCPP in build systems and workflows for all UFS apps
  - Testing with all necessary options
  - Phase out non-CCPP configurations
  - Continue path to transition to operations in 2021
- **Community Engagement**
  - Public release and tutorial with SCM and UFS Atmosphere (2019)
  - Short-course at AMS annual meeting (2020)
  - Formalize governance

Contributed by Steve Goldhaber, NCAR

Collaboration with NCAR on CCPP-Framework

NCAR funding type and purpose	2018/2019 (k)
Direct funding for CCPP Framework development	$660
Support for suite and host model development and testing (from MICM project)	$265
Total Support	$925

Contributed by Steve Goldhaber, NCAR

Collaboration with NCAR (under MOA)

- **2017:** NCAR Decided to use interoperable infrastructure so physics could be shared among its models
- **2018:** NCAR put forth new requirements and started working closely with GMTB on the CCPP Framework under a joint governance agreement
- **Since then, NCAR has**
  - Updated the CCPP-Framework
  - Made a Kessler microphysics scheme and a set of chemistry schemes (Model-Independent Chemistry Module) compatible with the CCPP Framework
  - Started using the updated CCPP-Framework in simpler models, chemistry, and WRF development

Upcoming features for CCPP Framework

By NCAR

- Ability to parse user-friendly and extensible metadata format
- Automated checking for compatibility between metadata and associated Fortran code
- Support to run more than one suite during a single model execution
- Support for automated field conversion capabilities (e.g., flipping vertical coordinate)
- Advanced memory management: allocation of variables needed for intra-physics communication, but not for host model, managed by CCPP-Framework*
- Advanced diagnostic support (e.g., time averaging) within suites*

By GMTB in consultation with NCAR (late 2019)

- Transition of upgraded CCPP-Framework for use with UFS

*Required for running CCPP suites as a separate NUOPC component (targeted for land surface models and radiation)

Collaboration with NRL

Contributed by Alex Reinecke, NRL

NRL Implementation of CCPP in NEPTUNE

- Initial work to implement CCPP in NEPTUNE during two-day visit of NRL to NOAA GSD/NCAR in February 2019
- Full first-cut working implementation of CCPP into NEPTUNE completed in April 2019
- Extensive use of existing IPDv4 infrastructure and data types eased the CCPP implementation
- Currently testing NEPTUNE with CCPP GFS-FV3 physics with plans to test a second suite
- Several software issues that could restrict the use of CCPP in NEPTUNE have been identified and communicated to back to the developers