Common Community Physics Package (CCPP) update: enabling atmospheric physics development for research and operations

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acknowledging the Developmental Testbed Center (DTC) CCPP developer team

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 ³Developmental Testbed Center
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 ⁵Colorado State University Cooperative Institute for Research in the Atmosphere
 ⁶Now at UCAR/UCP/JCSDA

The beginning (2017): UFS infrastructure for atmospheric physics

... facilitate the improvement of physical parameterizations and their transition from research to operations by enabling the community to participate in the development and testing ...



Common Community Physics Package (CCPP)

Developmental Testbed Center-

https://github.com/NCAR/ccpp-framework https://github.com/NCAR/ccpp-physics https://github.com/NCAR/ccpp-doc



CCPP relies on documented interfaces (metadata)

DTC



Metadata is also used to generate scientific documentation

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RRTMG Clouds Module									
BRTMG Gases Module	This is cloud micr	rophysics package for GFDL global cloud resolving model.	The algorithms are originally derived from Lin et al. (1983)	[107], most of the key elements have	e been sim	plified/improved. This code at this	stage bears little to	no simi	larity to
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RRTMG dcvc2t3 Module		······,	, (,						
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https://dtcenter.ucar.edu/GMTB/v5.0.0/sci_doc

CCPP uses XML suite definition files at build time

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<?xml version="1.0" encoding="UTF-8"?>
```

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<suite name="FV3 GFS v16" version="1">
 <group name="fast physics">
   <subcycle loop="1">
     <scheme>fv sat adj</scheme>
   </subcycle>
 </group>
 <group name="time vary">
   <subcycle loop="1">
     <scheme>GFS time vary pre</scheme>
      <scheme>GFS rrtmg setup</scheme>
      <scheme>GFS rad time vary</scheme>
      <scheme>GFS phys time vary</scheme>
   </subcycle>
 </group>
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    <subcvcle loop="1">
      <scheme>GFS suite interstitial rad reset</scheme>
      <scheme>GFS rrtmg pre</scheme>
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<group name="physics"> <subcycle loop="1"> <scheme>GFS suite interstitial phys reset</scheme> <scheme>GFS suite stateout reset</scheme> <scheme>get prs fv3</scheme> <scheme>GFS suite interstitial 1</scheme> <scheme>GFS surface generic pre</scheme> <scheme>GFS surface composites pre</scheme> <scheme>dcyc2t3</scheme> <scheme>GFS surface composites inter</scheme> <scheme>GFS suite interstitial 2</scheme> </subcvcle> <!-- Surface iteration loop --> <subcycle loop="2"> <scheme>sfc diff</scheme> <scheme>GFS surface loop control part1</scheme> <scheme>sfc nst pre</scheme> <scheme>sfc nst</scheme> <scheme>sfc nst post</scheme> <scheme>lsm noah</scheme> <scheme>sfc sice</scheme> <scheme>GFS surface loop control part2</scheme> </subcvcle> <!-- End of surface iteration loop --> <subcycle loop="1"> <scheme>GFS surface composites post</scheme> <scheme>sfc_diag</scheme> <scheme>sfc diag post</scheme> <scheme>GFS surface generic post</scheme> <scheme>GFS PBL generic pre</scheme> <scheme>satmedmfvdifg</scheme> . . .

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<scheme>GFS PBL generic post</scheme> <scheme>GFS GWD generic pre</scheme> <scheme>cires ugwp</scheme> <scheme>cires ugwp post</scheme> <scheme>GFS GWD generic post</scheme> <scheme>GFS suite stateout update</scheme> <scheme>ozphys 2015</scheme> <scheme>h2ophys</scheme> <scheme>get phi fv3</scheme> <scheme>GFS suite interstitial 3</scheme> <scheme>GFS DCNV generic pre</scheme> <scheme>samfdeepcnv</scheme> <scheme>GFS DCNV generic post</scheme> <scheme>GFS SCNV generic pre</scheme> <scheme>samfshalcnv</scheme> <scheme>GFS SCNV generic post</scheme> <scheme>GFS suite interstitial 4</scheme> <scheme>cnvc90</scheme> <scheme>GFS MP generic pre</scheme> <scheme>gfdl cloud microphys</scheme> <scheme>GFS MP generic post</scheme> <scheme>maximum hourly diagnostics</scheme> </subcvcle> </group> <group name="stochastics"> <subcycle loop="1"> <scheme>GFS stochastics</scheme> <scheme>phys tend</scheme> </subcycle> </group> </suite>

CCPP provides options for performance and flexibility

- CCPP uses a multi-suite build to maintain the required performance for operations
 - Compile options for the UFS (and the CCPP Single Column Model (SCM))

```
cmake ... -DCCPP_SUITES="abc,xyz,..."
```

- Filters unused schemes and variables, auto-generates Fortran caps for each suite
- No branching (if-then-else, ...) inside the suite caps for improved performance
- CCPP supports automatic unit conversions to expedite development and transition



Active development: single precision physics, Xgrid

A single-precision build of all physics used in the UFS was recently contributed by the Naval Research Lab in collaboration with DTC and NOAA-EMC.

• Further research is needed into which processes need to be double precision in these and other physics. Talking to experts at ECMWF to learn more!

The ESMF team recently contributed the exchange grid capability to the UFS in collaboration with DTC and NOAA-ENC.

 CMEPS was modified to act as a CCPP host model to perform atmosphereocean flux computation





Five CCPP releases so far – v6 coming soon!

V	Date	Physics	Host
v1	2018 Apr	GFS v14 operational	SCM
v2	2018 Aug	GFS v14 operational updated GFDL microphysics	SCM UFS WM for developers
v3	2019 Jul	GFS v15 operational Developmental schemes/suites	SCM UFS WM for developers
v4	2020 Mar	GFS v15 operational Developmental schemes/suites	SCM UFS WM / UFS MRW 1.0
v5	2020 Nov	GFS v15 operational Developmental schemes/suites	SCM UFS WM / UFS SRW 1.0 / MRW 1.1
V6	2022 Jun	GFS v16 operational Developmental schemes/suites	SCM UFS WM / UFS SRW 2.0

- Scientific/Tech Docs, Users Guide, FAQ: <u>https://dtcenter.org/ccpp</u>
- CCPP Support Forum: <u>https://dtcenter.org/forum/ccpp-user-support</u>
- UFS Users' Support Forums: https://forums.ufscommunity.org
- GitHub discussions: https://github.com/NCAR/ccpp-framework/discussions (same for physics)

Developmental Testbed Centerter-

SCM – CCPP Single Column Model UFS WM – UFS Weather Model MRW/SRW – Medium/Short-Range Weather

Parameterizations in CCPP authoritative main branch

Microphysics	Zhao-Carr, GFDL, MG2-3, Thompson, Ferrier-Aligo, NSSL	Impleme	ntation
PBL	K-EDMF, TKE-EDMF, moist TKE-EDMF, YSU, saYSU, MYJ	DTC	>
Surface Layer	GFS, MYNN, MYJ	NO/	AA GSL
Deep Convection	oldSAS, saSAS, RAS, Chikira-Sugiyama, GF, Tiedtke	NOA	A PSL
Shallow Convection	oldSAS, saSAS, RAS, GF, Tiedtke	NOA	A NSSL
PBL and Shal Convection	SHOC, MYNN		
Radiation	RRTMG, RRTMGP		
Gravity Wave Drag	GFS orographic, GFS convective, uGWD, RAP/HRRR drag suite		
Land Surface	Noah, Noah-MP, RUC		
Ocean / Lake	Simple GFS ocean, Flake		
Sea Ice	Simple GFS sea ice, RUC		
Ozone	2006 NRL, 2015 NRL		
H ₂ O	NRL		

CCPP v6 Supported Suites - release June 2022

Туре	Operational	Developmental				
Suites	Suites GFS_v16		RAP	RRFS_v1beta	WoFS	HRRR
UFS regional SRW						
SCM						
Microp	GFDL	Thomp	Thomp	Thomp	NSSL	Thomp
PBL	TKE EDMF	TKE EDMF	MYNN	MYNN	MYNN	MYNN
Sfc lay	GFS	GFS	GFS	MYNN	MYNN	MYNN
Deep cu	saSAS	saSAS + CA	Grell-Freitas	N/A	N/A	N/A
Shal cu	saMF	saMF	Grell-Freitas	N/A	N/A	N/A
Radiation	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
GWP	cires_ugwp	unified_ugwp	drag_suite	cires_ugwp	cires_ugwp	drag_suite
LSM	Noah	NoahMP	RUC	NoahMP	Noah	RUC

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CCPP Standard Names: Rules and Dictionary

- Standard names are a key aspect of the CCPP since they are used to communicate variables between the host model and the physics
- Whenever possible, use CF convention
- If standard name not available in CF convention, invent new name



CCPP Standard Names

This document contains information about the rules used to create Standard Names for use with the Common Community Physics Package (CCPP). It describes the

- CCPP Standard Name rules
- Standard Name qualifiers
- Other common standard name components
- Acronyms, abbreviations, and aliases
- Units

CCPP Standard Name Rules

1. Standard names should be identical to those from the latest version of the Climate and Forecast (CF) metadata conventions unless an appropriate name does not exist in that standard.

2. When a standard name doesn't exist in the CF conventions,

https://github.com/ESCOMP/CCPPStandardNames

Code management for shared physics and chemistry

- Multi-institutional team: DTC, NRL, NOAA, and NCAR
- What do we want this collaborative effort to look like?
- Various common interests, such as
 - Parameterizations for some processes
 - Collaborations with broader community
- Topics addressed so far
 - Code repository structure
 - Standardization of scheme names
 - Responsibilities for PR reviews
 - Best practices for interoperability
 - Dictionary of standard names
- Currently: an authoritative CCPP Physics repo for SCM/ UFS/NEPTUNE (DTC),



and a NCAR repository for of CCPP-compliant physics being shared among WRF, MPAS, and CM1 (see <u>Fowler, L., 2022</u>, starts at 1h38 min into video).

NOAA-NCAR Memorandum of Agreement (2019)

In 2019, NOAA and NCAR agreed to jointly develop the CCPP framework as a single system to communicate between models and physics.

NCAR contributions to the CCPP framework (within SIMA*):

- Augmented metadata standard (already adopted in the UFS)
- Automatic variable allocation for variables used by physics only
- Compare metadata to actual Fortran code
- Improved build system and code generator
- Advancements for chemistry (constituents, ...)



Original timeline: Transition to next-generation framework in 2021 – then delayed to 2022 – then came the SIMA review.

*SIMA: System for Integrated Modeling-Atmosphere

13

Framework development and code management

- Developing a process for joint code management and testing of CCPP framework
- Currently limited to participants of CCPP framework developer meetings (NOAA, NCAR)
- In the future, all organizations using CCPP in their models must be involved
- These efforts have been put on hold as we await the outcome of the SIMA review



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Transition to Operations

- CCPP selected as the framework for atmospheric physics (and possibly chemistry) in the UFS
- Included in UFS Medium-/Short-Range Weather, Subseasonal-to-Seasonal, Hurricane Apps
- Scheduled for operational implementation in the GFS/GEFS in 2024
- On track for operational use with the Rapid Refresh Forecast System (RRFS) and the Hurricane Analysis and Forecast System (HAFS) starting 2023

Without CC	PP UFS	Operational	Implementa	With CCPP	
2019	2020	2021	2022	2023	2024
GFS v15		GFS v16	L		GFS v17
	GEFS v12) SSS oriun		GEFS v13
			WC0 norat	HAFS v1	HAFS v2
				RRFS v1	RRFS v2

adapted from Tallapragada (2021)

Take home messages



- The Common Community Physics Package lowers the bar for adding new physics or transferring them between models, and facilitates development and testing of innovations
- The CCPP metadata and code generator provide ample opportunities for development
- Prototypes exist for running aerosol chemistry in CCPP, inline with the physics
- The future of CCPP at NCAR depends on the outcomes of the SIMA review.

Additional material



DTC

Opportunities for future development

- Automatic array transformations: (i,k,j) to (i,k) to (k,i) to ... also vertical flipping
- Calculation of derived variables: pot. temp. from temp. & geopotential, ...
- Visualization of how variables travel through a physics suite



- Error handling including traceback information to replace existing error message/flag
- Specification of time-split vs process-split processes in suite definition file
- Logic to handle schemes that update the state in place or that return tendencies
- Extended diagnostic output capabilities from schemes (beyond tendencies)
- Improved handling of constituent arrays and properties (especially for chemistry)
- Automated saving of physics scheme state for restarts

Opportunities for future development (cont'd)

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- Creation of CCPP or NUOPC cap for physics, run inline or as a separate component (required for UFS)
- Generation of optimized caps to dispatch physics on CPUs, GPUs, ... (required for next-generation HPCs)
- Capability to decompose and recombine grid columns into different surface types for selected physics

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