DTC Contributions to the UFS Physics Development and Advanced Testing and Evaluation towards UFS Physics Unification

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1. DTC 2. NCAR 3. NOAA/OAR/GSL 4. NOAA/OAR/PSL 5. CU/CIRES

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External Collaborators: *UFS Physics leads: Lisa Bengtsson (PSL), Fanglin Yang (EMC); PBL and SGScld: Joe Olson (GSL), Jongil Han (EMC); Microphysics: Ruiyu Sun (EMC); Gravity wave physics: Mike Toy (GSL); Convection: Lisa Bengtsson (PSL); Radiation: Qingfu Liu (EMC); HAFS physics: Andrew Hazelton (AOML); RRFS configuration: Eric Aligo (EMC), Jili Dong (EMC); L-A LoCo: Dave Turner (GSL), Julia Simonson (GSL).*

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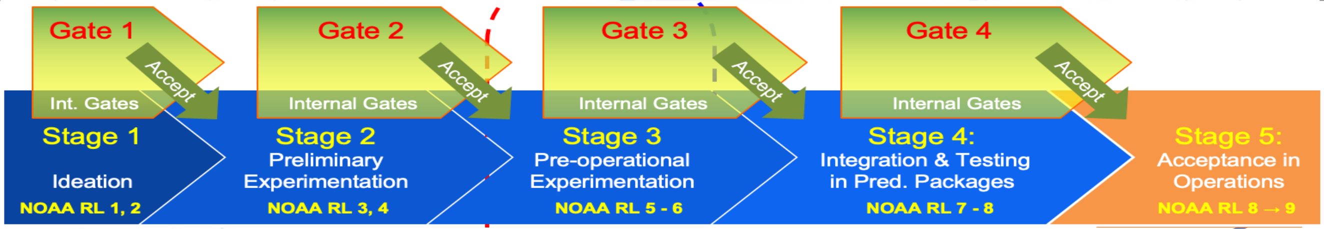
DTC UFS Physics Testing and Evaluation (T&E) activities & connection to UFS Stages and Gates

RL 1 ⟷ RL 9

Objective #1 (UFS R2O)	Facilitate transitions of near-term, pre-operational physics improvements to operations.
Objective #2 (NOAA Base)	Support one of the longer-term, high-priority UFS objectives of realizing the unification of physics parameterizations across applications and scales towards a unified Earth System Modeling (ESM) system.



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Real case studies - over both land and ocean

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- Capture processes of moist physics, atmospheric boundary layer, surface conditions, and their interplays.
- Represent phenomena under various cloud/weather/climate regimes:
  - ***ARM LASSO*** *non-precipitating shallow cumulus cases.*
  - ***Atlantic tropical cyclones*** *(TCs; Hurricanes Florence, Ian and Laura).*
  - ***CONUS cases****.*
  - ***DYNAMO*** *case with a transition from shallow to deep convection during the Madden-Julian Oscillation (MJO) initiation.*
  - *Marine ARM GPCI Investigation of Clouds (**MAGIC**) case featuring a transition from stratocumulus off the west coast to cumulus clouds in the trade wind regime.*
  - ***TWP-ICE****: Active and suppressed stages of Australian Monsoon case*
- **Simulated and evaluated against benchmarks (observations or analysis)**
  - CCPP single-column model (SCM) and/or UFS-SRW limited-area model (LAM)
  - 13 km and/vs 3 km for most cases

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DTC contributions to targeted physics for UFS

Worked more closely with physics developers to determine physics to work on:

- **Code base** - 3 suites (suite definitely file only; exact code base described below)
  - **GFS_v17_p8** (as in CCPP v6.0 or UFS-SRW v2.1; an experimental but not the final P8)
  - **RRFS v1beta & HRRR** (as in UFS-SRW v2.1)
  - **Or, using the latest code base (top branch) when evaluation conducted**
- **Several physics enhancements/innovations (*"PR watchers"*)**
  - Prognostic and scale-adaptive cumulus convection closure (dubbed *progsigma*) (*POC: Lisa Bengtsson@NOAA/PSL; **ufs/dev PR18***)
  - Updated Thompson microphysics (*POC: Ruiyu Sun@NOAA/EMC; **ufs/dev PR19***)
  - Refactored RRTMGP (*POC: Dustin Swale@NOAA/GSL; **ufs/dev PR34***)
  - Updated unified gravity wave physics (*POC: Mike Toy@NOAA/GSL; **ufs/dev PRs 22 & 40***)
  - Updated MYNN-EDMF PBL & shallow cumulus (*POC: Joe Olson@NOAA/PSL; **ufs/dev PR43***)
- **DTC visitor project by Andy Hazelton (NOAA/AOML/HRD)**

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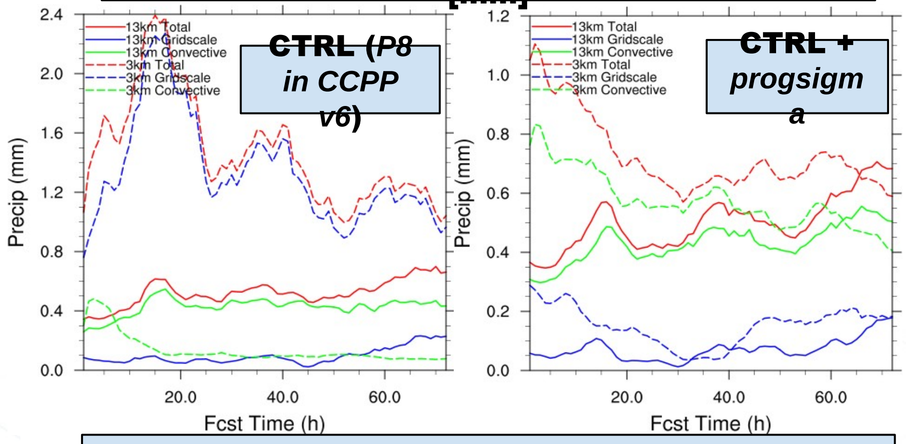
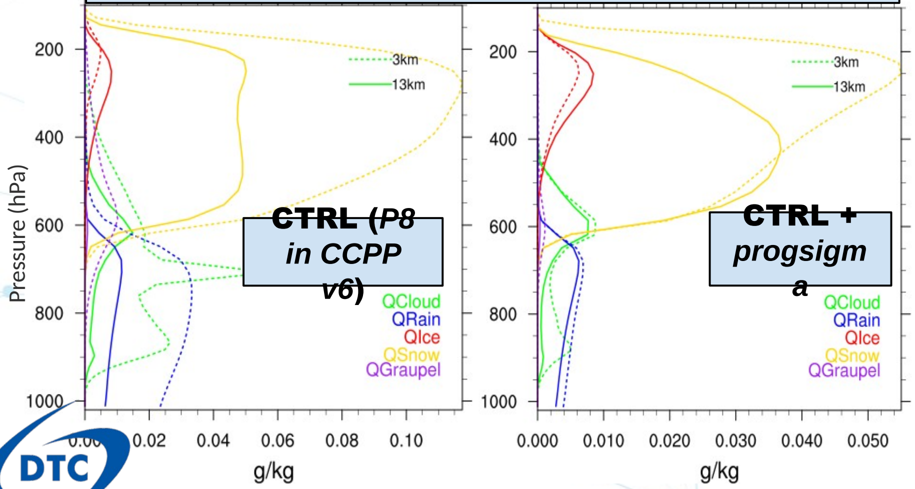
1. Prognostic & scale-adaptive cumulus convection closure (dubbed *progsigma*, FR18)

Example – UFS LAM simulations of Hurricane Florence (2018)

Total vs Grid-scale vs Parameterized precip [mm]



Hydrometeor Mixing Ratios [g kg⁻¹]



Total
Grid-scale
Parameterized

13 km (solid)
3 km (dashed)

- CTRL@3 km produces more grid-scale precipitation, low clouds, and microphysics resolved hydrometeors.
- *Progsigma* (Bengtsson et al. 2022*):* less scale sensitivity & tends to prevent microphysics from dominating rainfall production as grid spacing decreases.
- Importance of interplays between moist physics components when considering scale awareness.

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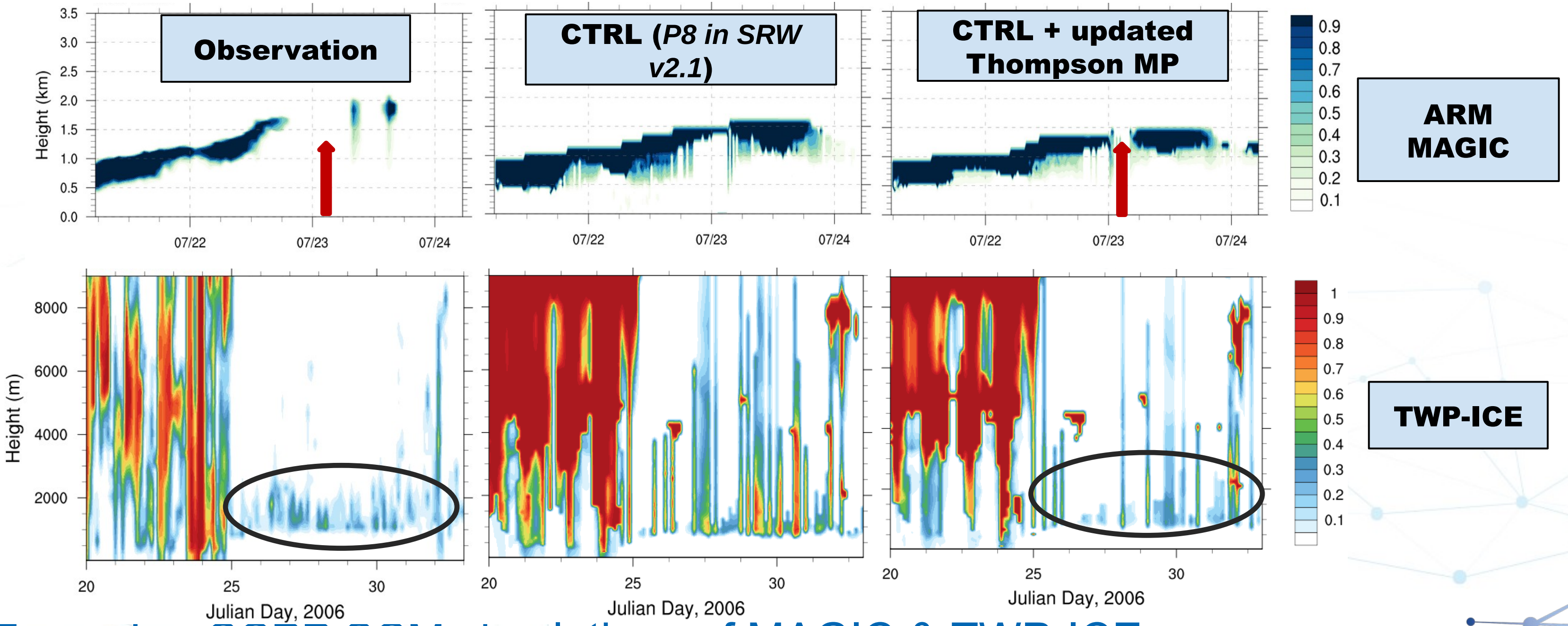
2. Updated Thompson microphysics (PR 19)

Time-height profiles of cloud fraction



Example - CCPP SCM simulations of MAGIC & TWP-ICE

Updated Thompson microphysics → improved low cloud fraction, esp. stratocumulus

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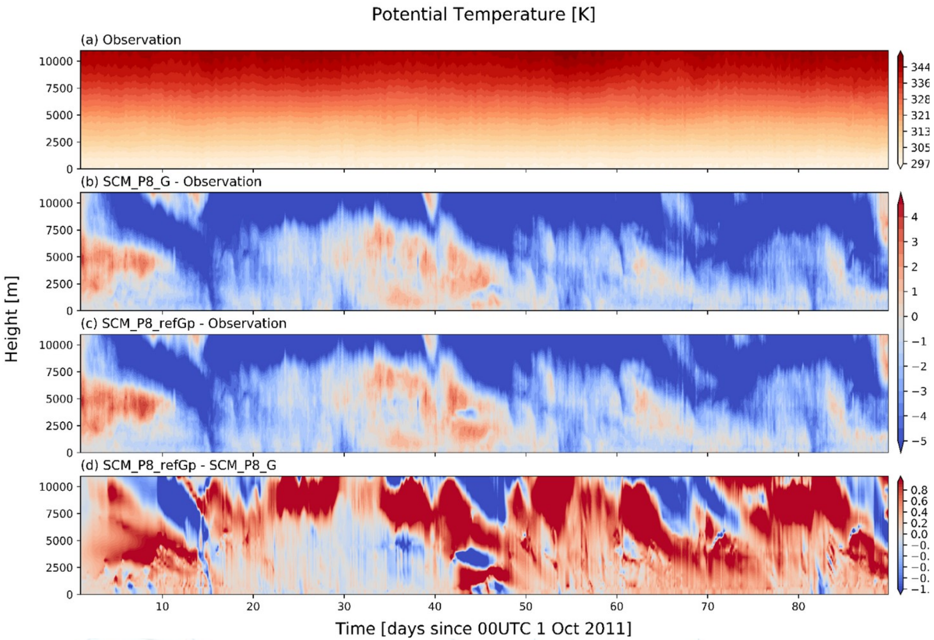
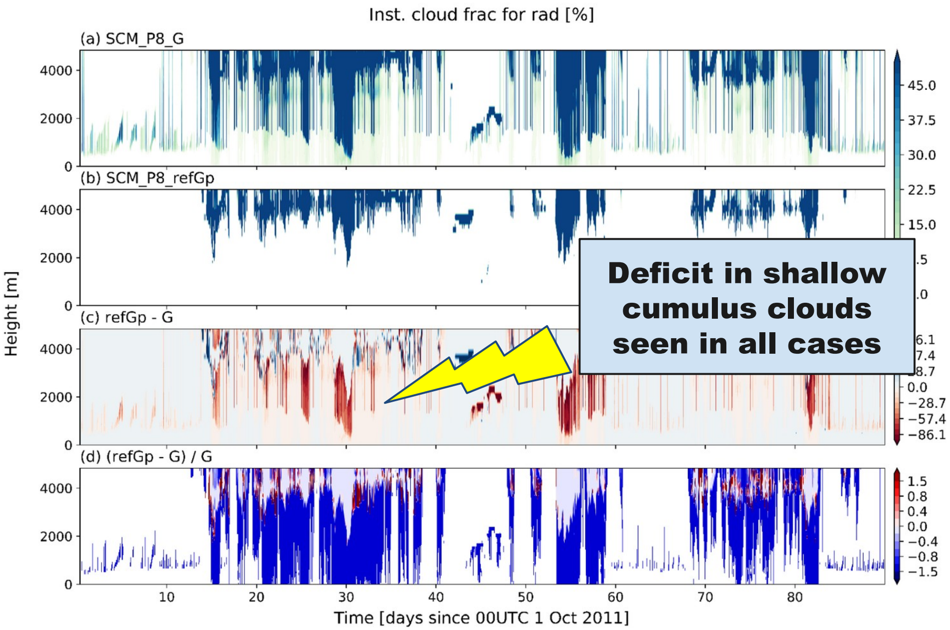
3. Refactored RRTMGP (PR 34)





Example - CCPP SCM simulations of DYNAMO

- RRTMGp *vs.* RRTMG (top branch) - better *wrt.* upper tropo cold condition but still colder than obs (perhaps due to radiative cooling by high clouds)
- Dearth of shallow cumulus clouds - an issue.

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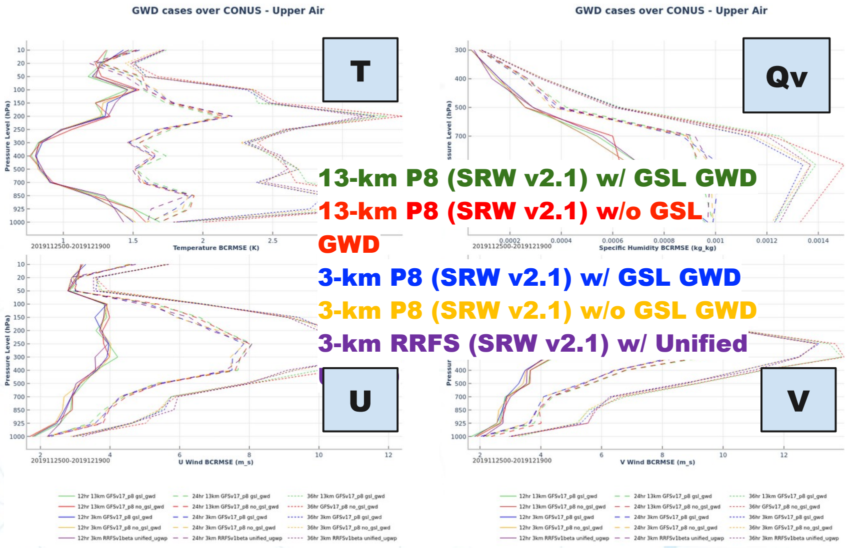
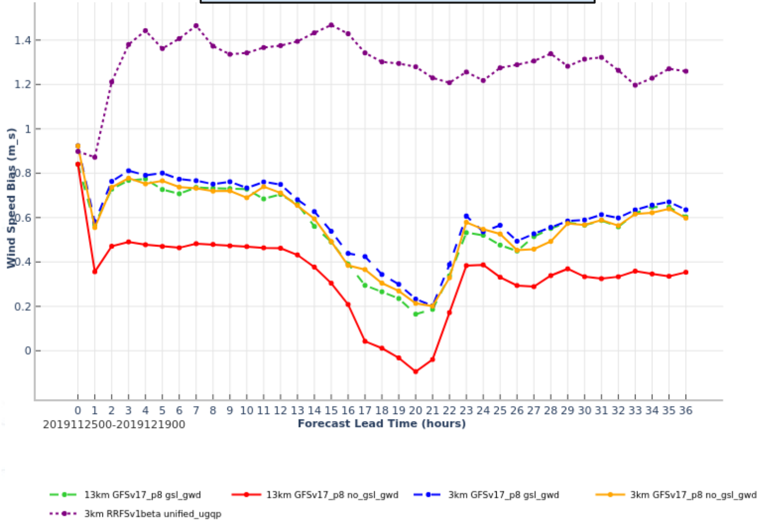
4. Updated unified gravity wave physics (PR 22 & 40)

Upper-air verification



Bias - surface wind speed



Example – UFS-SRW LAM simulations w/ METplus for 9 CONUS cases

Using GSL gravity wave drag (GWD):

- Overall higher skill in predicting upper-air variables
- But, lower skill of surface temperature and winds (*wrt* both bias and RMSE).

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5. Updated MYNN-EDMF PBL & shallow cumulus (PR 43)

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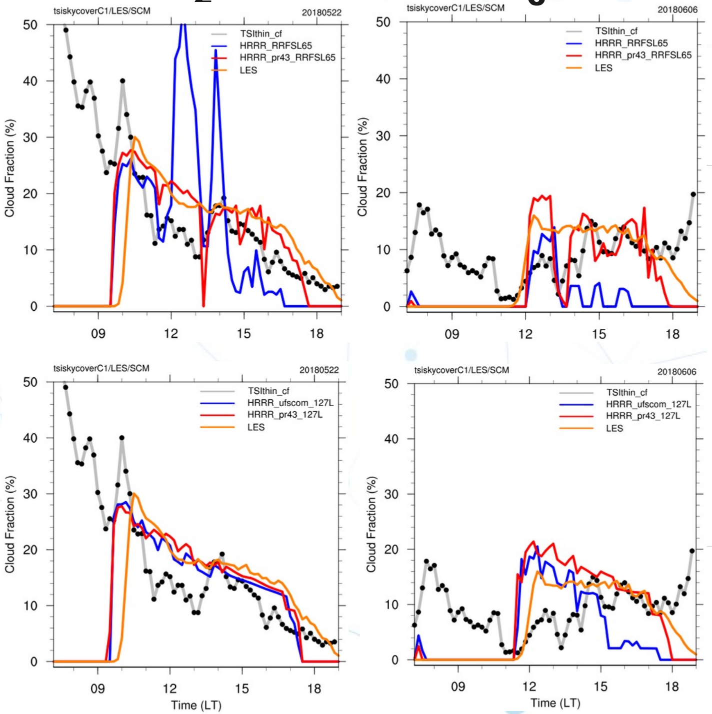
Time series of total cloud fraction [%] vs TSI & LES

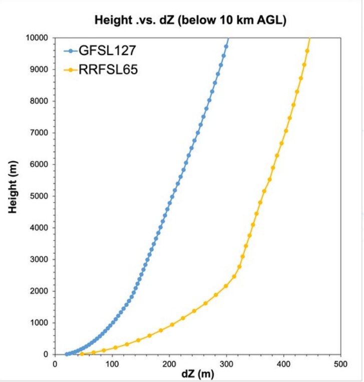
20180522 | **20180606**

RRFSL65

GFSL127



Total Sky Imager (TSI)
LES
HRRR_RRFS (top branch)
HRRR_RRFS + PR43



Example - CCPP SCM simulations of LASSO

- PR43 improves cloud fraction (*wrt.* amount and continuity) using both GFSL127 and RRFSL65, particularly in the afternoon.
- Clouds are better represented at higher/finer vertical resolution, i.e., GFSL127

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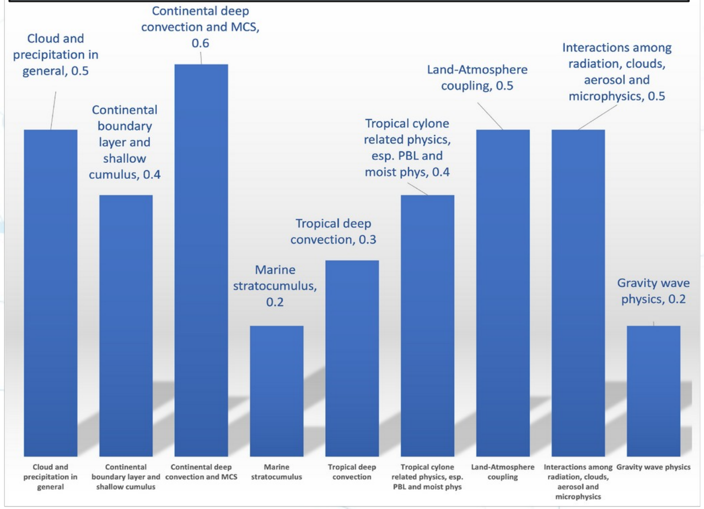
Summary

- DTC, working tightly with developers, tested and evaluated physics updates/innovations for the operations, across the spectrum of model physics.
- Results inform both improvements or areas of attention in these physics, and stress the importance of
    - Interplays between physics components when considering scale awareness.
    - Appropriate vertical coordinate to work with particular physics.
    - Physics applicable to cases across different cloud/weather/regimes.
- It is hopeful that our evaluations against relatively reliable benchmarks can help constrain parameterized processes and inform further physics development/improvement.

Activities for UFS-R2O Phase II

DTC Advanced Phys T&E Interest Survey Results - Feedback from Physics Developers (as of Dec, 2022)



Top processes/phenomena for UFS physics development were identified, in combination with scalability investigations:

- Interaction between land/ocean surface states, boundary layer, and shallow cumulus – **also coordinated with SFS development**
- Interactions among microphysics, clouds, precipitation, radiation and aerosols.
- *(Year 5 beyond) Deep convection (oceanic and continental) (MCS, CAPE, convective initiation and cold pools).*

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DTC Visitor Program

https://dtcenter.org/visitor-program

Propose a project to work on with us!

Two types of visitor projects:

PI - Up to 2 months salary, travel and per diem - can be split into multiple visits

Graduate Student - Up to 1 year of temporary living per diem and travel expenses for graduate student, plus support for advisor visits

See Announcement of Opportunity on DTC website for more information on how to apply and guidance on topics of interest