CCPP Single Column Model Overview

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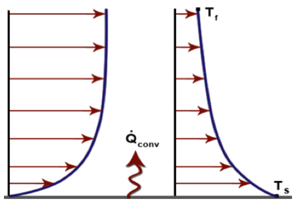
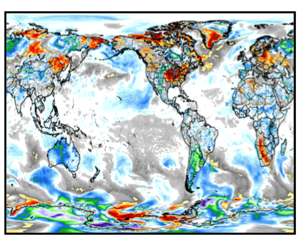
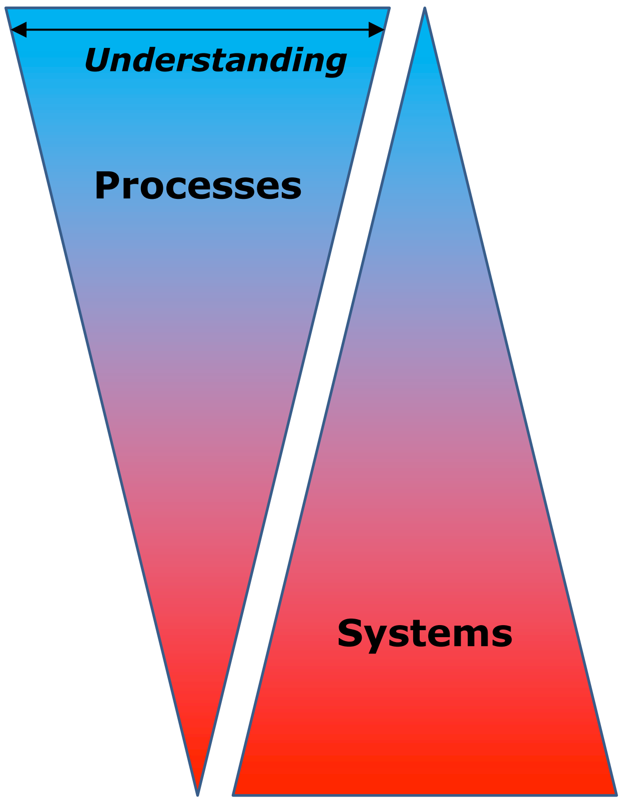
Motivation



"Simple"
Processes

Complex
Systems





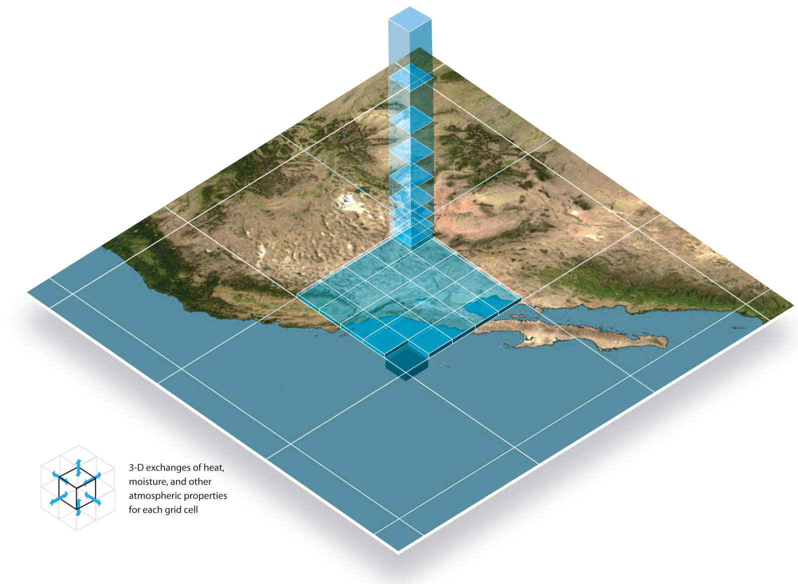
HSD Testing "Harness"

- Parameterization Simulator
- Single Column Model ◆
- 2-D Model
- Limited-Area Domain
- Regional Model
- Global Model
- Fully-Coupled Model

- Simplest framework for intra-suite physics interaction
- Necessary-but-not-sufficient for physics development

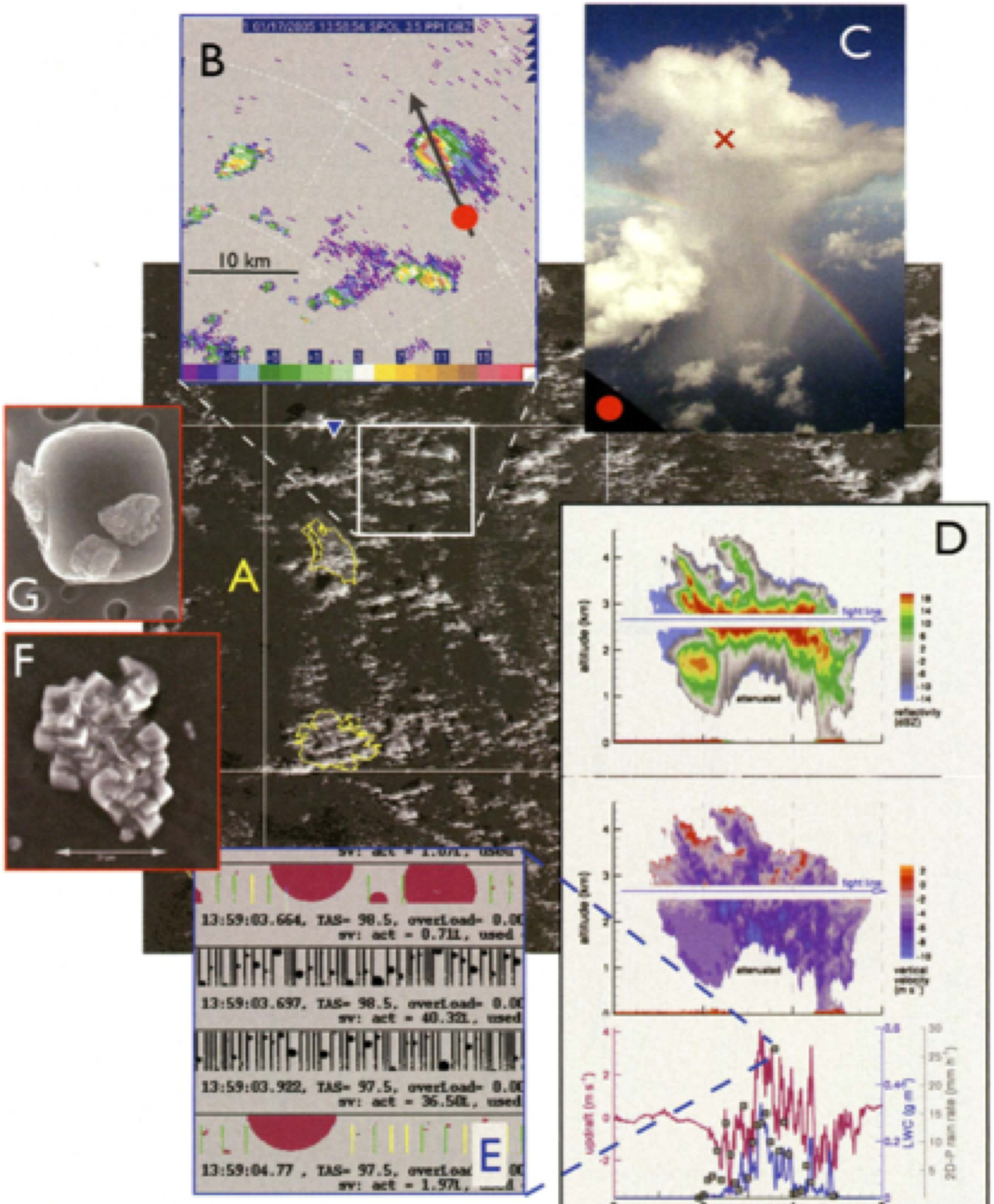
Single Column Model Overview

- Initial state (T, q, u, v) from observations, idealization, or model
- Forcing applied to mimic changes in column state from surrounding environment (replaces dycore)
  - 3 typical methods
    1. "total" advective forcing
    2. horizontal advection + prescribed vertical velocity
    3. 2 + nudging to observed profiles
- Physics responds to these changes and further modifies the column state
- End state is combination of forcing + physics



Pros
- Simple and cheap
- Interpretability
- Approachable

Cons
- Necessary, but not sufficient
- Forcing sensitivity



Output

Powered By unidata netCDF

Instantaneous Values
Every Timestep

https://github.com/NCAR/gmtb-scm

CCPP SCM Version 4.0

- Continuously up-to-date with NOAA operational UFS physics through the CCPP (and also works with developmental suites)
- Available to public on GitHub (soon)
- Bundled with CCPP v4 (soon)
  - Simple host model for calling physics through CCPP
    - Contains CCPP software framework and physics as Git submodules
    - Contains example of using CCPP framework to:
      - Reconcile model-provided data with that needed by all schemes in physics suite
      - Fill CCPP data structure through automatically generated code (based on metadata included within code comments)
      - Initialize a CCPP-compliant physics suite
      - Call physics suite (one-liner!)
  - Run script to run permutations of supported physics suites and cases

Ties to the UFS Atmosphere Model

- Same vertical coordinate
  - σ-p hybrid
  - Today: Eulerian
  - Soon: Lagrangian (allows for changing p_s)
- Physics namelist
- Physics data structure
  - GFS_typedefs.F90 with minor differences
- Soon: ICs/Forcing from configurable, selected columns
  - AKA “Column Replay”

Current Capabilities

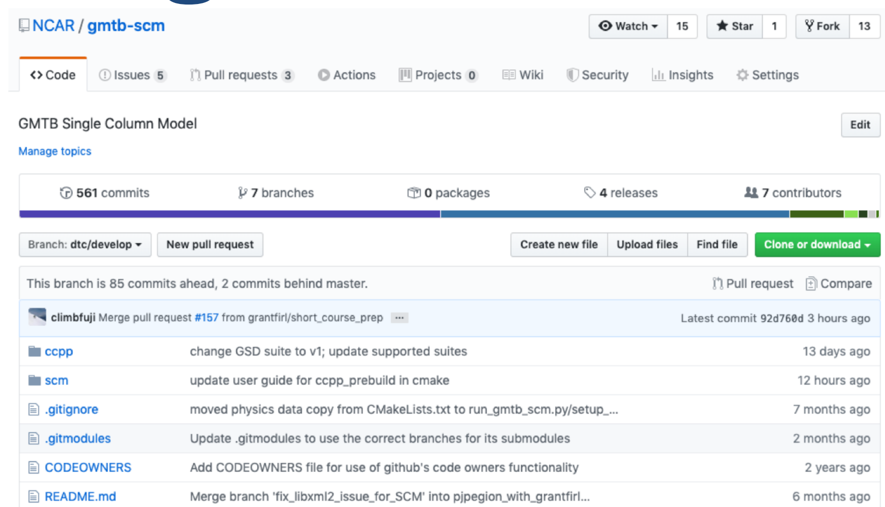
- Run several field campaign-based cases included in the repository
  - A run script exists to automate running through any combination of cases and physics suites you want (serially)
- Four supported CCPP physics suites work and it is possible to create new ones fairly easily
  - Can also run the same suite with different physics namelists for sensitivity tests or tuning
- Simple Python plotting scripts are included for analysis with appropriate system setup
- Create SCM initial conditions (only) for any location on the globe from FV3 initial conditions and run without forcing

Quick Start – Prerequisites and Supported Machines

- System Setup
  - FORTRAN 90+ compiler
    - ifort (18.0.1.163 and 19.0.2)
    - gfortran (6.2, 8.1, and 9.1)
  - C compiler
    - icc (18.0.1.163 and 19.0.2)
    - gcc (6.2 and 8.1)
    - Apple Clang (10.0.0.10001145)
  - cmake (2.8.12.1, 2.8.12.2, and 3.6.2)
  - netCDF (4.3.0, 4.4.0, 4.4.1.1, 4.5.0, 4.6.1 and 4.6.3)
    - not 3.x
    - with HDF5, ZLIB and SZIP
    - must be compiled with same compiler used for model
  - Python (2.7.5, 2.7.9, and 2.7.13) (not 3.x)
  - Libxml2 (2.2, 2.9.7, 2.9.9)
  - NCEPlibs
- Supported Machines
  - Hera (NOAA HPC), Cheyenne (NCAR HPC), generic Mac OSX, Ubuntu, CentOS
  - Soon: Docker container, Amazon Machine Image

Quick Start – Obtaining Code

- The code is maintained in a public repository on GitHub under the NCAR organization.
- It contains 2 submodule repositories: ccpp-physics and ccpp-framework
- Which branch to check out depends on your goals:
  - User: release branch
  - Developer: dtc/develop




```
git clone --recursive -b v4.0
https://github.com/NCAR/gmtb-scm
```

OR

```
git clone --recursive -b dtc/develop
https://github.com/NCAR/gmtb-scm
```

Quick Start – Building and Compiling

- CMAKE step
  - Creates a properly configured makefile for the SCM/CCPP system
  - Calls the code generation script automatically
    - Matches host-provided variables with physics-requested variables, generates software caps for schemes or suites

```
cmake ../src
```
Default (dynamic, release build)

```
cmake -DCMAKE_BUILD_TYPE=Debug ../src
```
Debug (dynamic, debug build)

```
cmake -DSTATIC=ON ../src
```
Static (static, release build)

- Compilation step
  - make [VERBOSE=1]

Quick Start – Running Individually

- Python run script
  - Functions
    - Sets up the run directory (bin)
      - Creates output directory, chooses the correct CCPP SDF for cases that require prescribed surface fluxes and links the SDF, links physics namelist, links all data in physics_input_data directory, links correct ozone data depending on the chosen ozone scheme, links plotting scripts and configuration files
    - Launches the executable! (can optionally launch within gdb)
  - Arguments
    - -c CASE_NAME (required; NO FILE EXTENSION!)
    - -s SUITE_NAME (optional, uses operational GFS physics as default)
    - -n PHYSICS_NAMELIST_WITH_PATH (optional, uses operational namelist by default)
    - -g (optional, execute in gdb)

```
./run_gmtb_scm.py -c CASE_NAME [-s SUITE_NAME] [-n PHYSICS_NAMELIST_WITH_PATH] [-g]
```

Quick Start – Multiple Runs

- Another python script
  - Serially calls individual run script depending on arguments
  - Arguments
    - Optionally specify one of the following
      - -c CASE_NAME
        - Runs all supported suites for the given case
      - -s SUITE_NAME
        - Runs all supported cases for the given suite
      - -f PATH_TO_FILE
        - Runs whichever cases and suites are specified in the file
    - -v or –vv
      - Optional to write SCM output to console or log
    - -t
      - Optional to time the individual runs (or run several times to get an average)

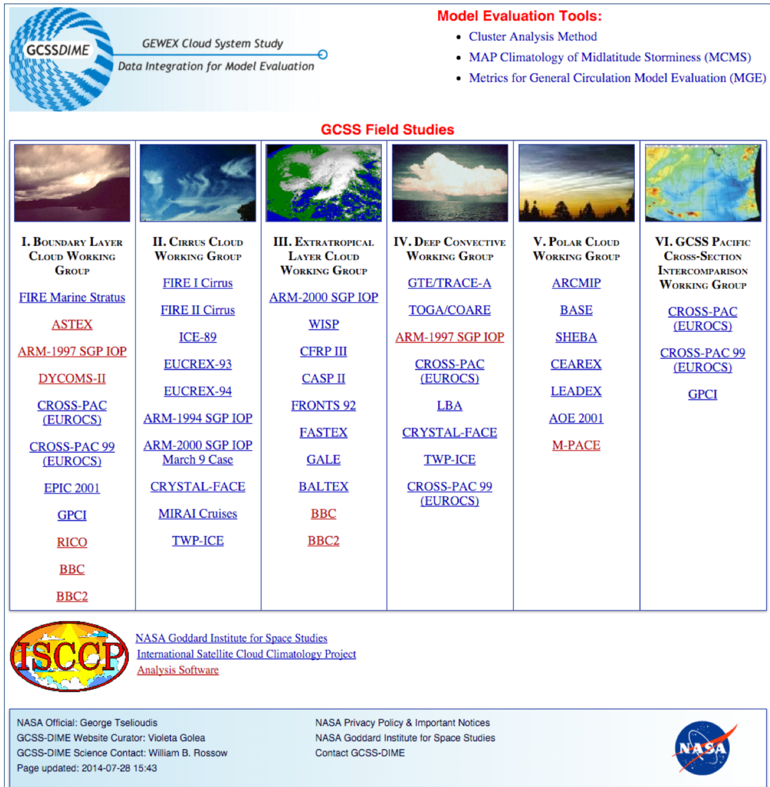
```
./multi_run_gmtb_scm.py {[-c CASE_NAME] [-s SUITE_NAME] [-f PATH_TO_FILE]} [-v{v}] [-t]
```

Quick Start – Analysis

- Yet another python script
  - Uses an external configuration file (its only argument) to tell it what to plot
    - Which output datasets to plot and how to label their data
    - Where to save the output
    - Whether observations are available to plot alongside SCM output
    - Whether plots are generated for individual datasets in addition to comparisons among all datasets
    - Definitions of which time period to average over for profile plots
  - Currently plots the following
    - Mean profiles (against obs if available)
    - Multiple profiles on one plot
    - Time series
    - Multiple time series on one plot
    - Time-pressure contours

```
./gmtb_scm_analysis.py filename_to_configuration_file_with_extension
```

Using Observations to Drive SCM



Available Today

- GASS/TWP-ICE (maritime convection; near Australia, Jan-Feb 2006)
- ARM Great Plains (continental convective, Jun-Jul 1997)
- EUCLIPSE/ASTEX field campaign (stratocumulus, June 1992)
- LASSO (continental shallow cu, May 18, 2016)
- BOMEX (maritime shallow cu, June 1969)

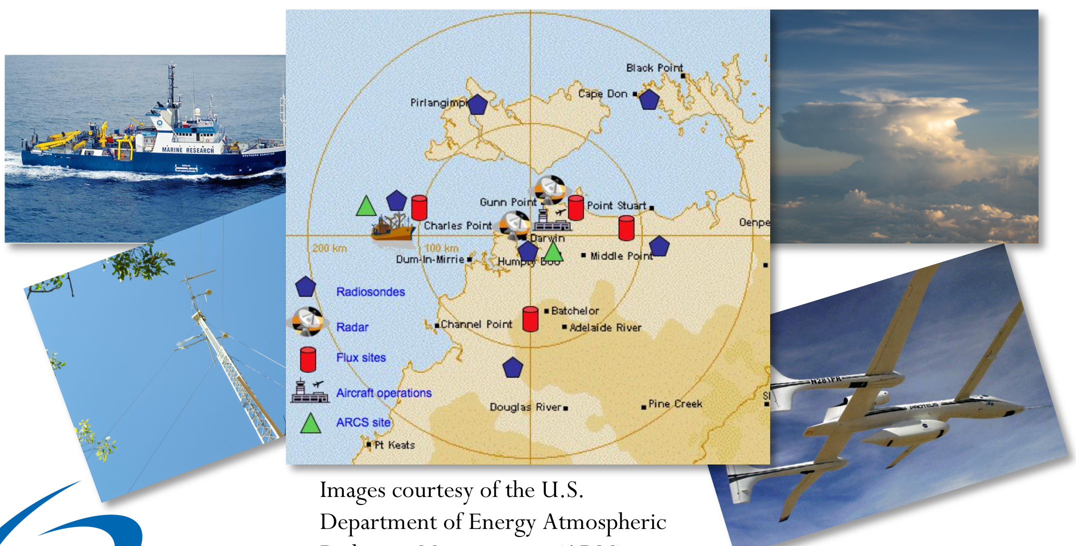
Planned

- Expand the variety of meteorological regimes

Note: A detailed SCM User's Guide explains how community users can add their own cases/data and we will be participating in an effort to standardize SCM input.

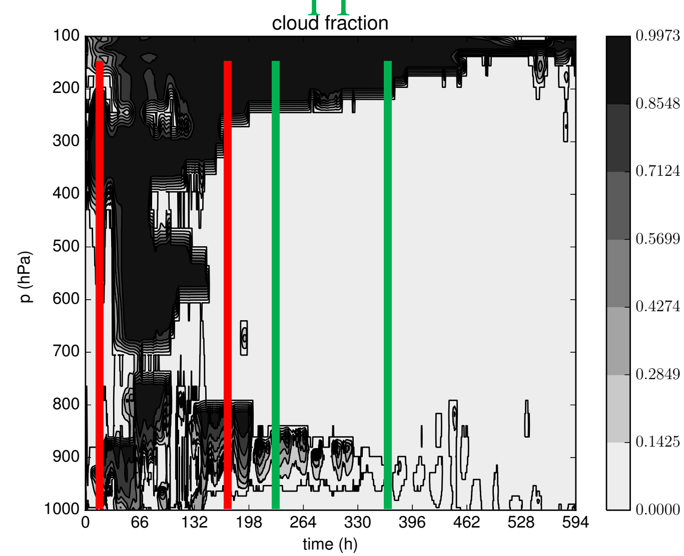
TWP-ICE case

- Tropical Warm Pool – International Cloud Experiment
  - DOE ARM field campaign near Darwin, Australia in Jan-Feb 2006
  - Features active and suppressed convective states related to monsoon
  - Model intercomparison studies using this case:
    - For CRMs: Fridland et al. (2012, JGR)
    - For SCMs: Davies et al. (2013, JGR)



Images courtesy of the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility.

Active Suppressed

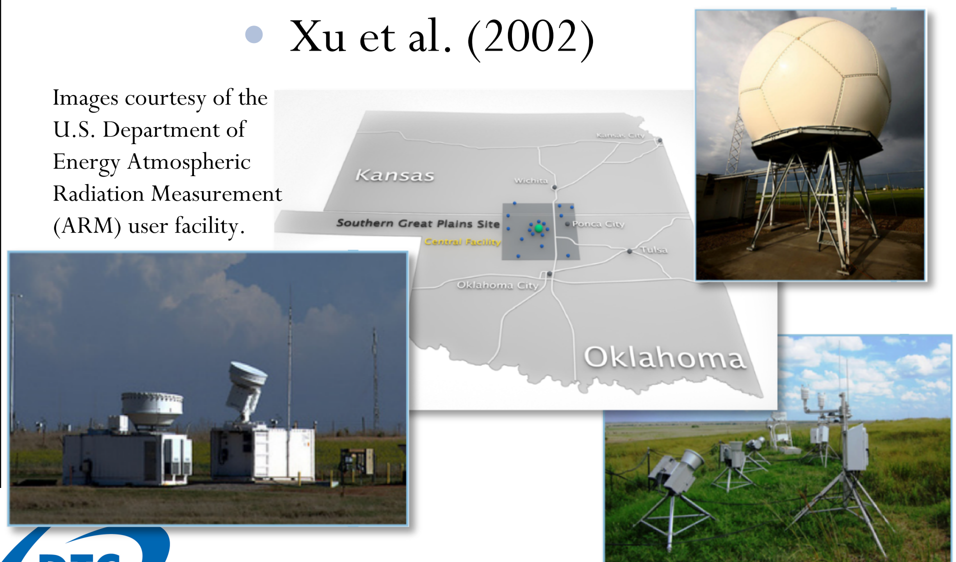


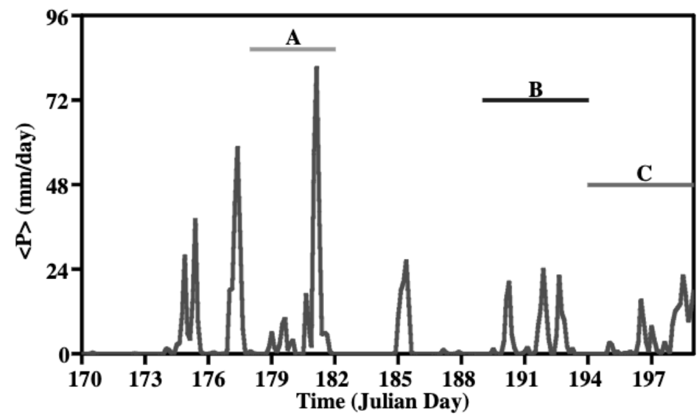
Developmental Testbed Center

ARM SGP Summer 1997 case

- Atmosphere Radiation Measurement Southern Great Plains site
  - DOE ARM "Laboratory Without Walls"
  - Features 3 different summertime weather regimes over 30 days
    - Disorganized convection, clear/hot, passing MCS
    - Case is divided into time periods by phenomenon
  - Model intercomparison studies using this case:
    - Xu et al. (2002)

Images courtesy of the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility.

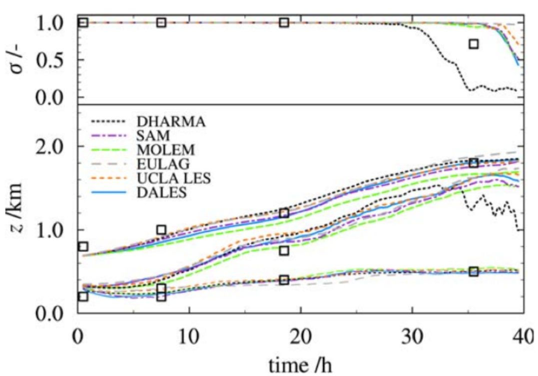




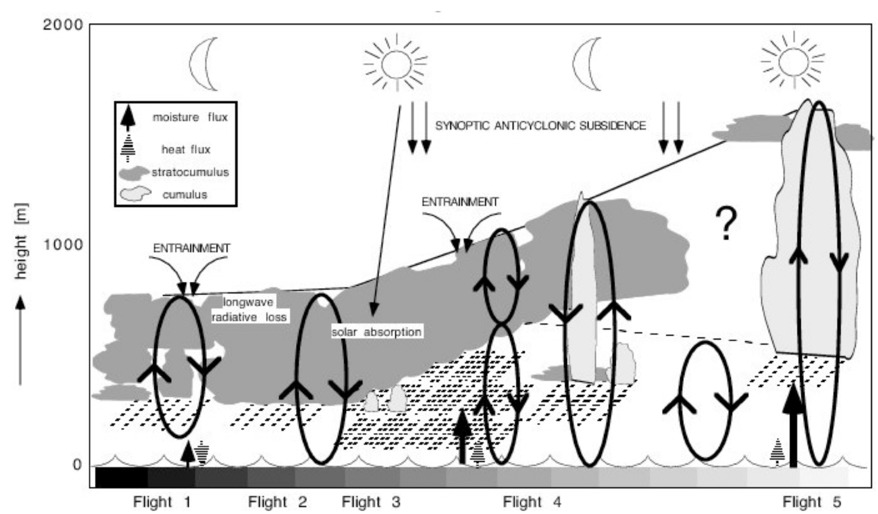
From Xu et al. (2002)

ASTEX (Lagrangian) case

- Atlantic Stratocumulus to Cumulus Transition Experiment
  - EUCLIPSE
  - Features stratocumulus-to-cumulus transition over 2 day period in June 1992 near the Azores via following a column in a Lagrangian sense
  - Model intercomparison studies using this case:
    - Bretherton et al. (1999)
    - van der Dussen et al. (2013)



Cloud base/top from van der Dussen et al. (2013)



Obtained from http://www.euclipse.nl/wp3/ASTEX_Lagrangian/Introduction.shtml

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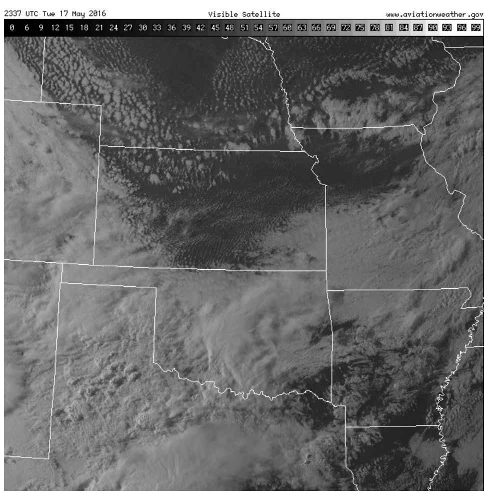
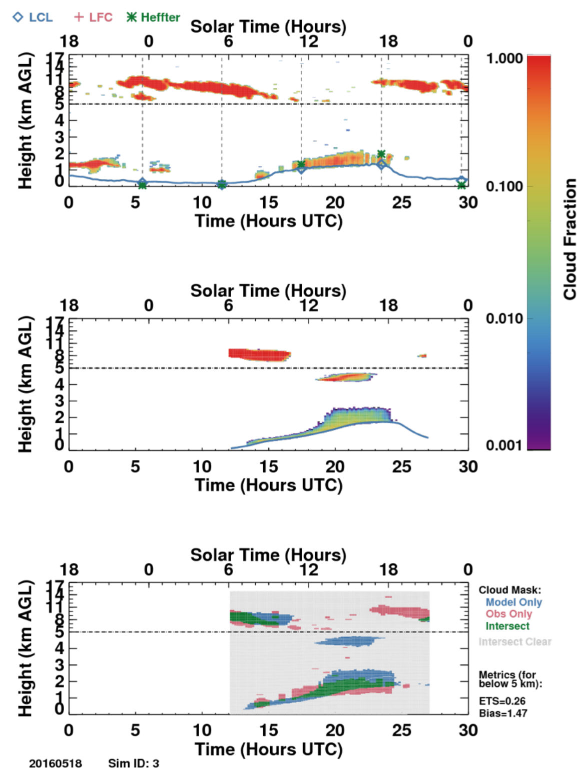
LASSO case(s)

- LES ARM Symbiotic Simulation and Observation
  - DOE ARM Southern Great Plains site
  - Focuses on shallow cumulus; example case from May 18, 2016
  - Includes observations, SCM forcing data, and LES simulations for MANY days from 2015-2017



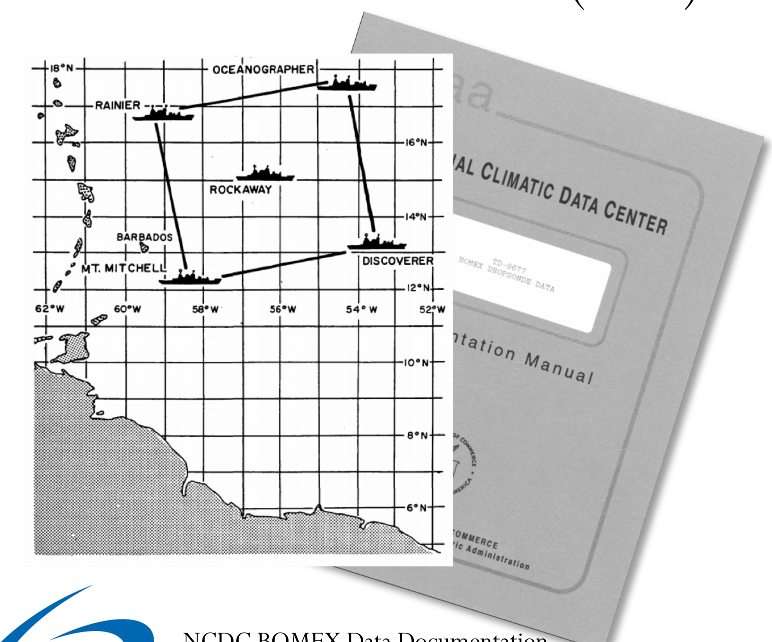
Images obtained from the LASSO Bundle Browser: https://adc.arm.gov/lassobrowser



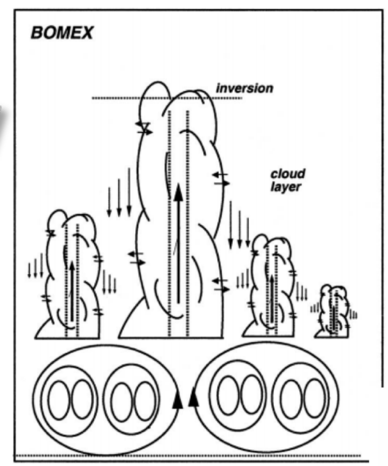
Developmental Testbed Center

BOMEX case

- Barbados Oceanographic and Meteorological EXperiment
  - Near Barbados; joint project among 7 US agencies
  - Focuses on maritime shallow cumulus from June 22, 1969(!)
  - Model intercomparison studies using this case:
    - Siebesma et al. (2003)



NCDC BOMEX Data Documentation



Plots from Siebesma et al. (2003)

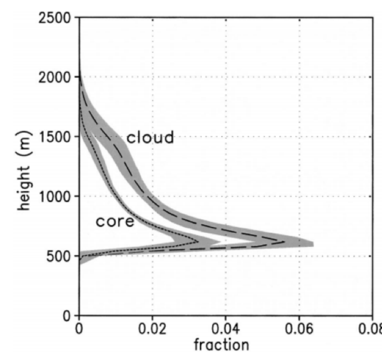
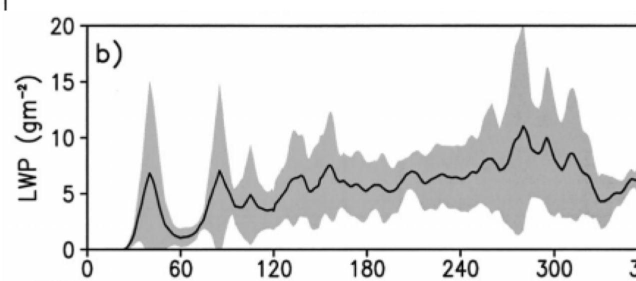
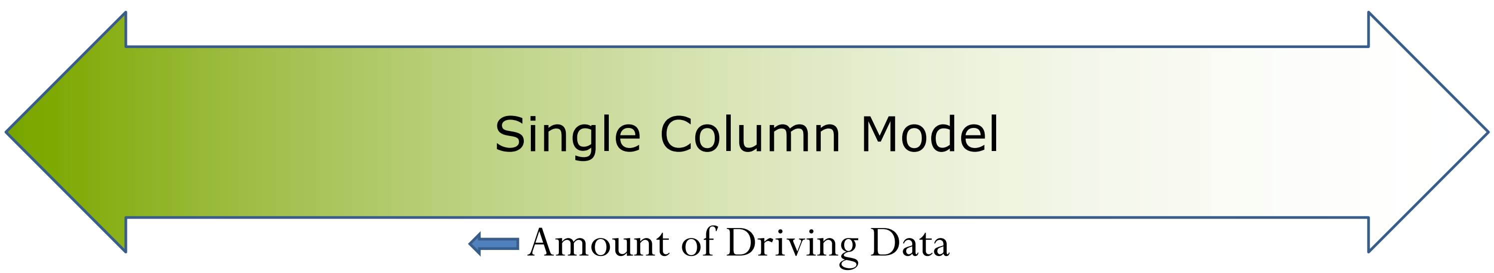


Fig. 6. Cloud cover and core cover profiles.



Ongoing Development

- Continual updates to keep pace with CCPP-physics and CCPP-framework development
- Process isolation capability
    - Data from non-active parameterizations can be "saved" from previous run, or specified from observations or idealization
    - Possible due to flexibility afforded by CCPP



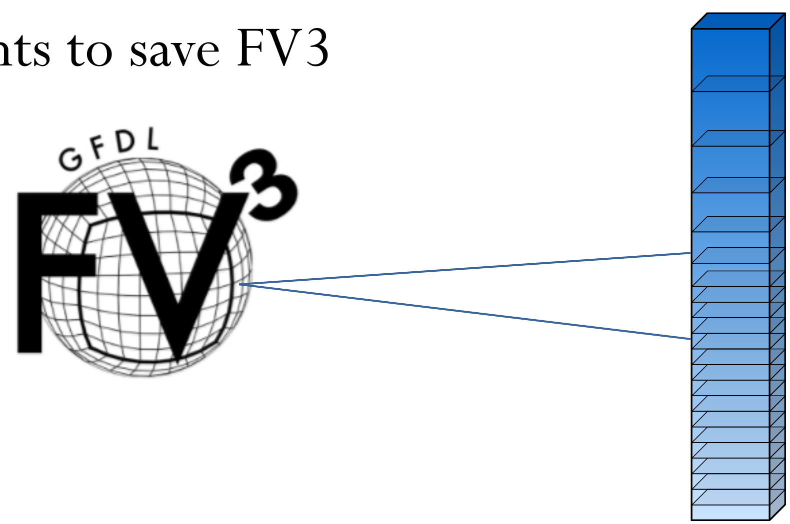
One parameterization active only

Arbitrary subset of parameterizations active

All parameterizations active

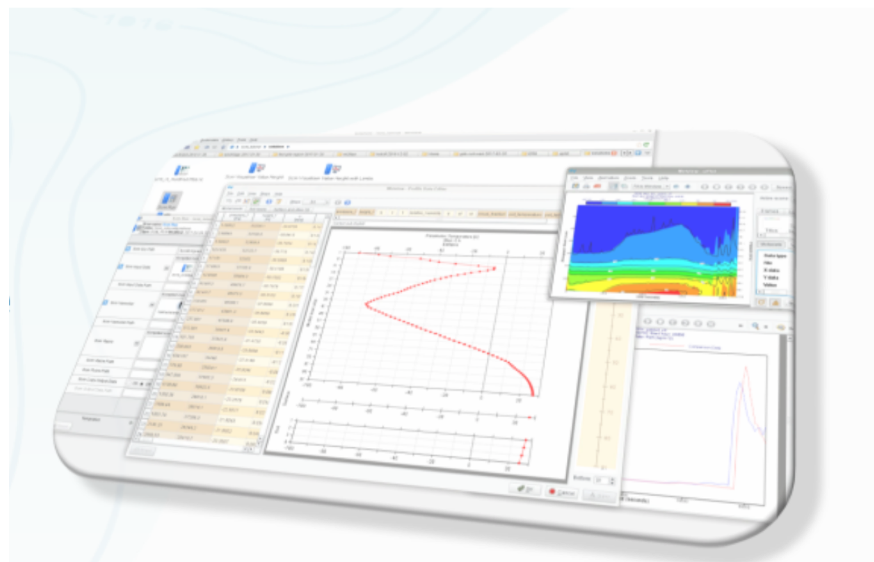
Ongoing Development

- More Cases
  - From GASS, EUCLIPSE, use data from long-term sites (like DOE ARM SGP, Cabauw, Lindenberg, etc.)
  - Participate in standard SCM case data format led by MeteoFrance
- UFS Column “Replay” Mode
  - Partially implemented (initial conditions only)
  - Namelist-controlled list of points to save FV3 dycore tendencies



Ongoing Development

- Better Visualization and Analysis
  - Visualize and edit ICs, forcing, physics choices and parameters
  - Set up ensemble runs varying the same
  - Choose output variables and frequency
  - Execute the model on a local machine
  - Analyze the output



Courtesy: ECMWF (link)

DTC Developmental Testbed Center