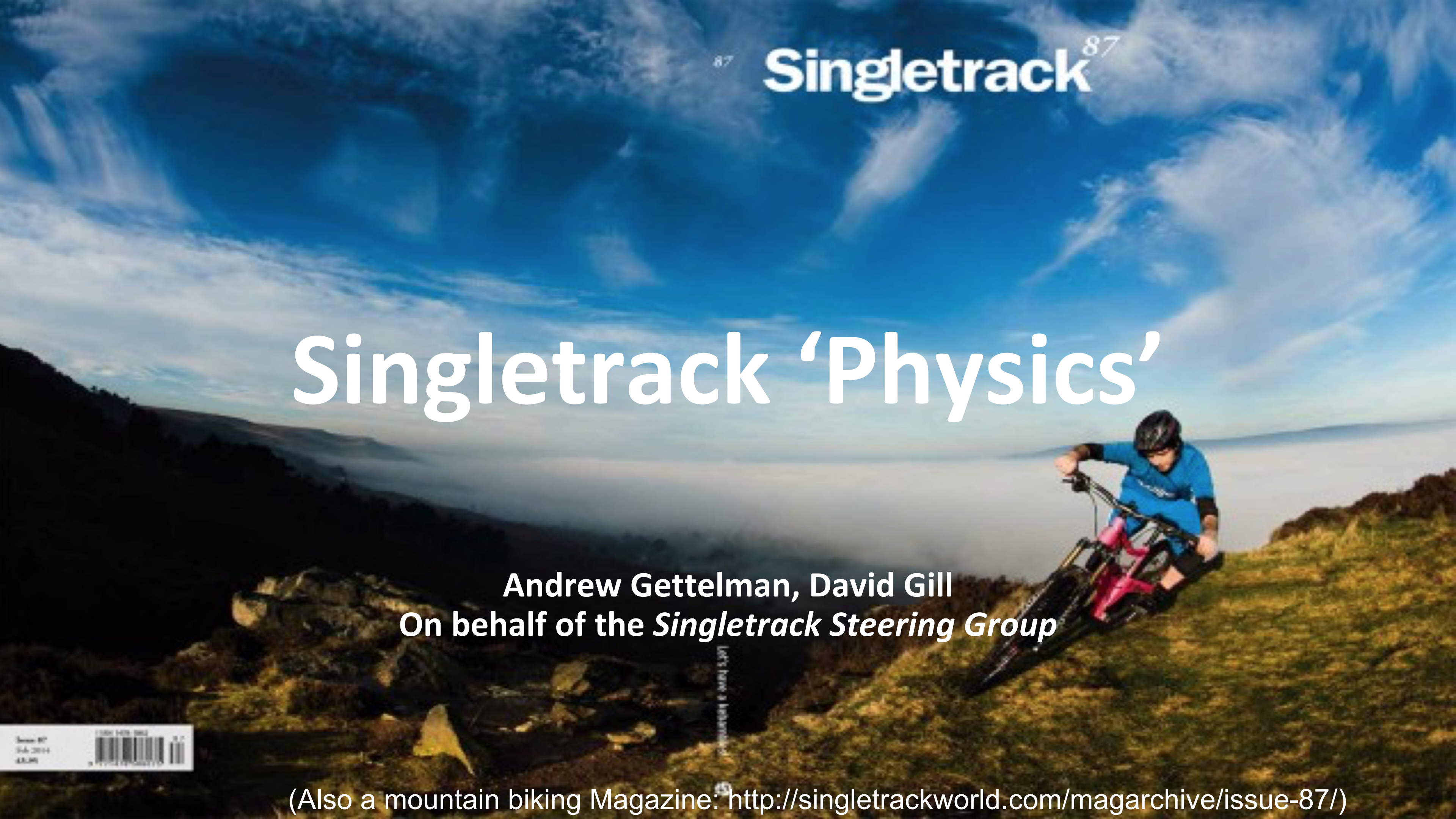



# Singletrack ‘Physics’

**Andrew Gettelman, David Gill**
**On behalf of the *Singletrack Steering Group***

(Also a mountain biking Magazine: http://singletrackworld.com/magarchive/issue-87/)

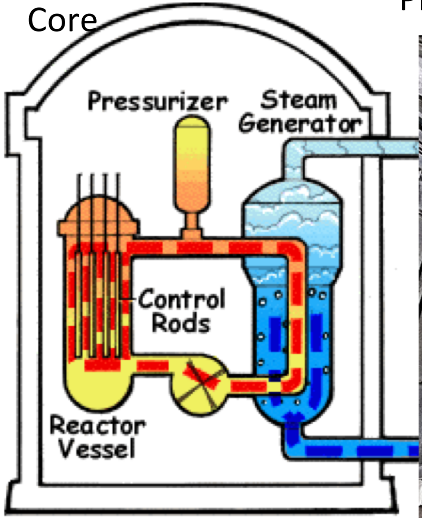
# Outline

- What is ‘Physics’?
- Physics Science Goals
- Physics Requirements
- Common Physics Framework (i.e. infrastructure)
- Which/Whose Physics?
- Physics development at NCAR (scale-insensitive/aware)
- Plans, Ideas, Next Steps

# What is ‘Physical Parameterization’?

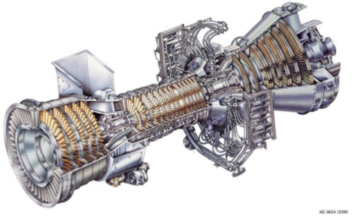
Core

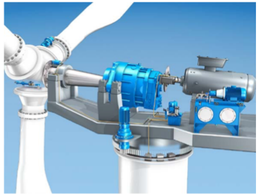
Dynamical



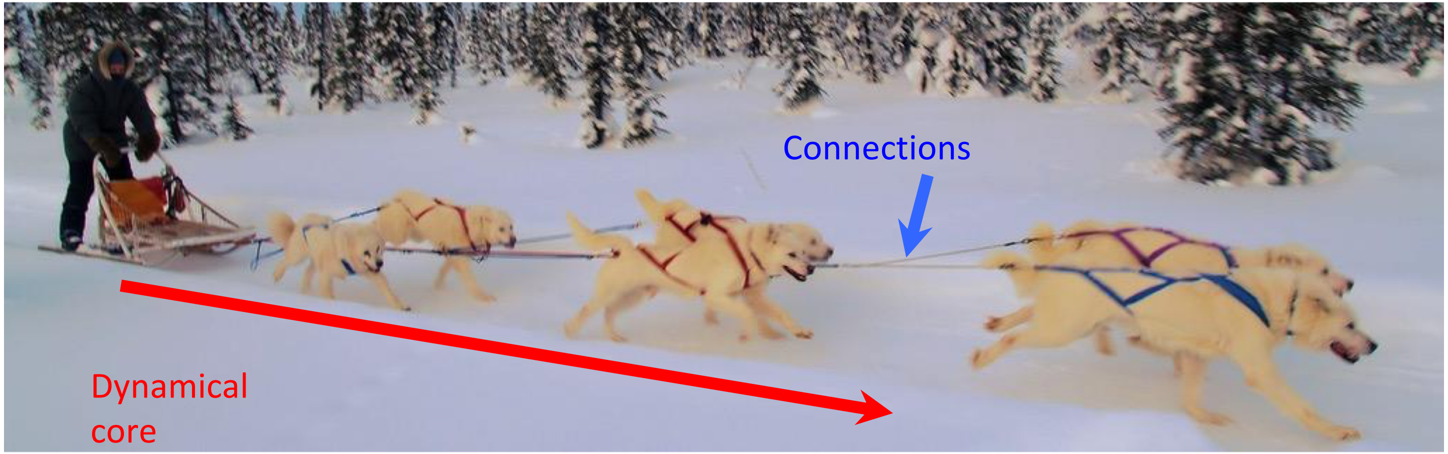

Plumbing that Connects Them

Parameterizations (Tendency Generators)

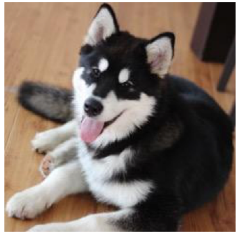





# The ‘Organic’ View




Parameterizations
(Tendency Generators)



Deep
Convection

Microphysics

Condensation/
Fraction

# Science Goals: Physics

- Weather:
  - Tropical Cyclones, Severe Convection, Winter storms
  - Weather Prediction (verification, global and regional)
- Climate
  - Global climatology (cloud radiative forcing, energy balance)
  - Low frequency climate variability
- Impacts of Aerosols & Chemistry on Climate and Weather (and vice versa)
- Complex terrain effects (precipitation, valley flows, mountain waves)
- Accurate and Efficient Radiative transfer
  - consistent with gas phase chemistry and cloud scheme

# Frontiers

- Effects of Organized Convection on weather and climate
  - Momentum transport, Diurnal cycle, interaction/generation of waves
- Interannual to decadal prediction
- Seasonal to Sub-Seasonal (S2S) phenomena: Kelvin waves, MJO, Monsoons
- Surface-Atmosphere interactions (boundary layer & ocean, ice, land)
- Medium-range global forecasting (anomaly correlations, etc.)
- Virtual global field campaigns (high-res 10-km grid global NWP analysis)
- Upper atmosphere: Space Weather and impacts on weather and climate
  - ionosphere, physics on MHD grid

# Physics Requirements (Basic)

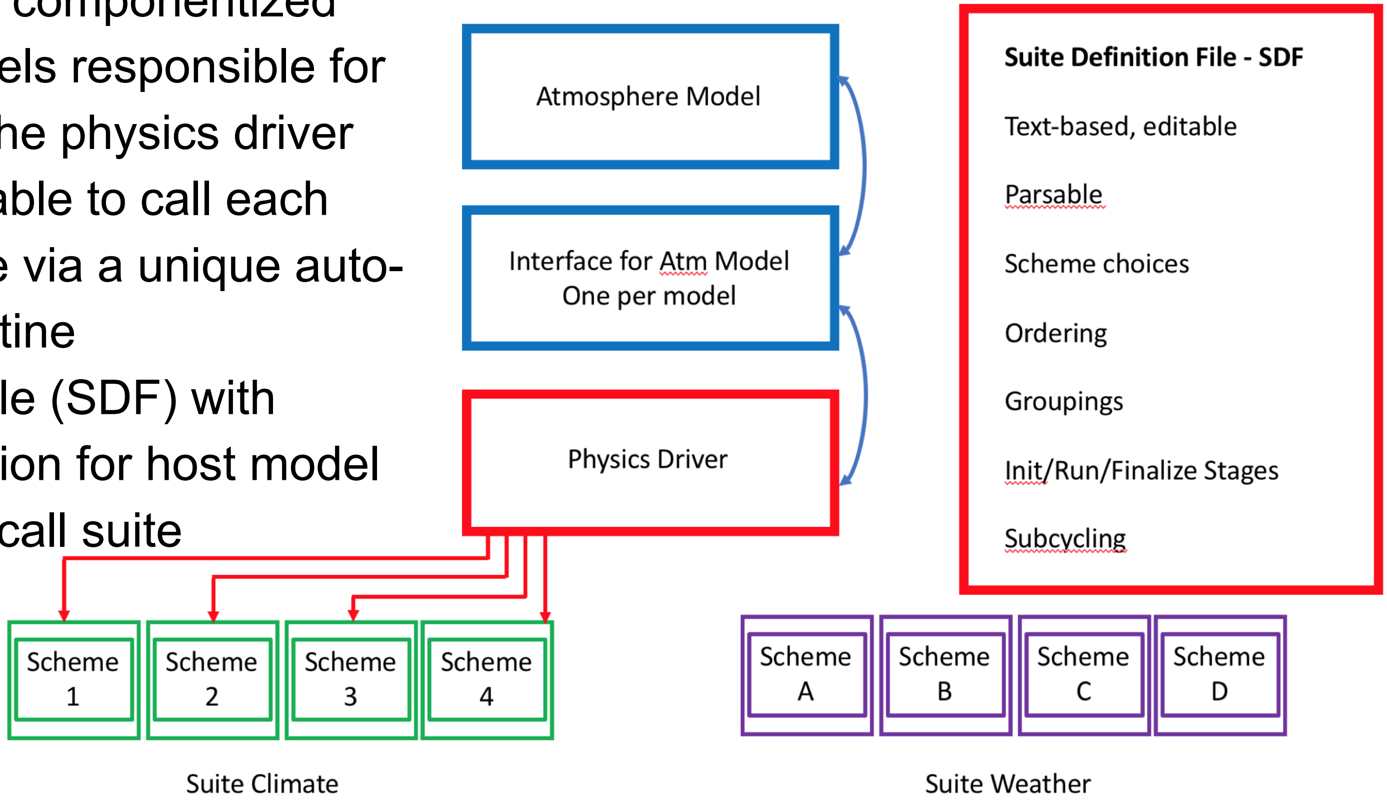
- Numerical stability of schemes (seconds/km → 15 min, 100km)
- Conserve energy, mass and (desired) momentum
- Able to handle cloud scale updraft velocities (several m/s).
- *Efficient* and *Conservative* tracer transport
- Scientifically consistent suite of parameterizations
- Compatibility with current NCAR models (runs in CESM/MPAS/WRF)
- Agnostic to dynamical core
- Simplified workflows: hierarchy of models (1-D to 3-D)
- Supports community development for adding schemes
- Meets coding standards and interface standards

# Physics Requirements (Extended)

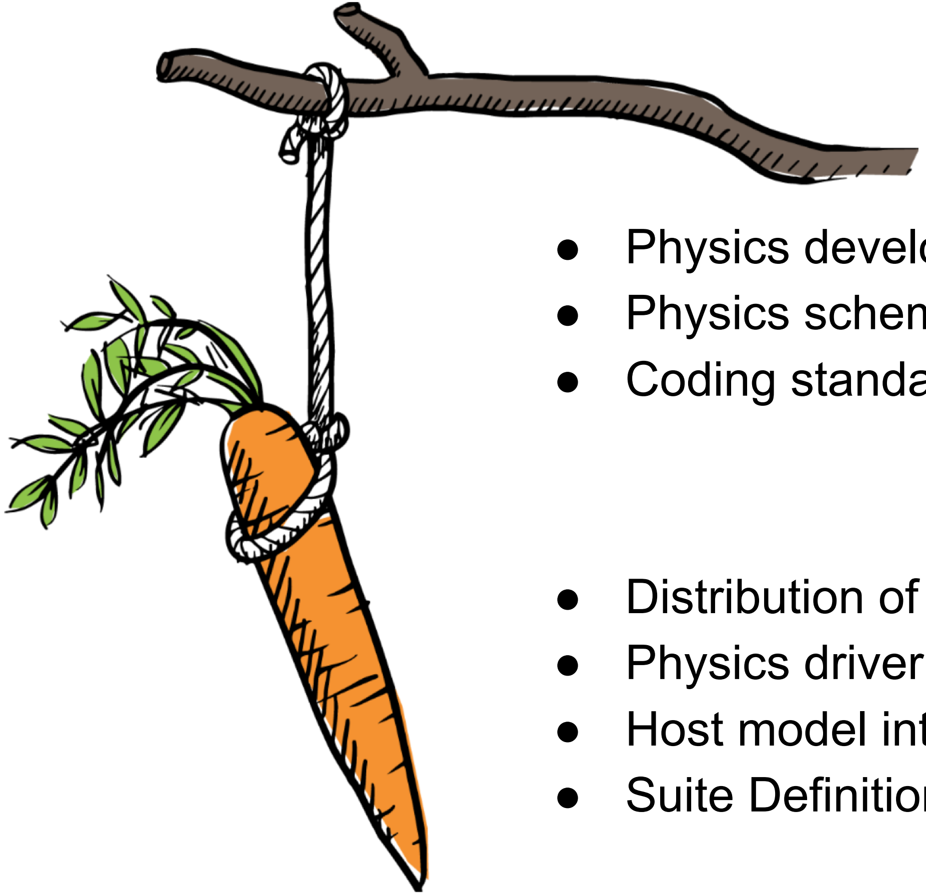
- Chemistry: physical processing of chem species in the atmosphere model.
  - Wet deposition (aqueous chemistry)
  - Vertical mixing (including dry deposition)
  - Convective transport
  - Emissions, especially natural emissions
- Aerosol physics: a range of options: simplified, fixed or interface to a full aerosol model (e.g.: WRF-Chem or CESM treatments)
- Schemes suitable for geospace modeling (or shut themselves off)
- Sub-column representation
- ‘Stencil’ of neighboring cells

# Community Physics Framework (CPF)

- Interoperable and componentized
- Atmospheric models responsible for their interface to the physics driver
- Physics driver is able to call each compliant scheme via a unique auto-generated subroutine
- Suite Definition File (SDF) with sufficient information for host model Physics Driver to call suite



# Community Physics Framework (CPF)



- Physics developers: comply with requirements
- Physics scheme collection: 25
- Coding standards: 26

- Distribution of mandates:
- Physics driver: 35
- Host model interface: 14
- Suite Definition File: 5

# Community Physics Framework (CPF)

- UPSIDE 1: More easily get new physics into a compliant community model

- Physics developers already have to adhere to rules with each model
- Now they are spelled out and documented
- Most are “Mom and apple pie” - broadly viewed favorably
    - Modules
    - Specific names for subroutine entry points
    - Document each variable: description, units, indexing, type, intent
    - Everything through the argument list: variables, flags, constants
    - Strive towards portability, try to usually avoid: external, parallelism
    - Independent columns, no assumptions on horizontal index locality

# Community Physics Framework (CPF)

- UPSIDE 2: Method to get the new scheme into ALL compliant models
- Small support routines (interstitial) may be interleaved between schemes
  - Add up total moisture for mass
  - Diagnose potential temperature from temperature and pressure
  - Water vapor saturation pressure
- If the model has the necessary variables (possibly via interstitial computation), the physics driver can call a compliant scheme
- Same physics driver will be used in all NCAR models

# Community Physics Framework

- Suite Definition File (SDF)

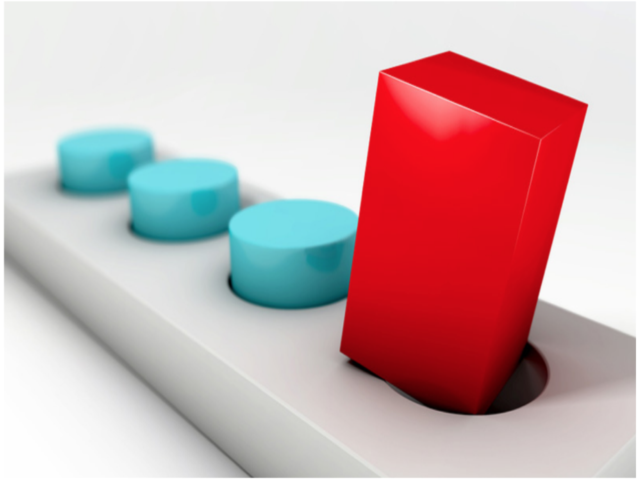
- XML - easy for people and computers
- Suite name is associated with scheme names, ordering, interstitial
- Contains init and finalize sections
- Easy to add new sections, for example stochastic
- Same suite could have different SDF for different model
- “Combo” schemes OK

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

<suite name="WRF_conus" ver="1">
  <init>CPF_initialize</init>
  <group name="LUT_gridded_data">
    <subcycle loop="1">
      <scheme>IPD_setup_step</scheme>
    </subcycle>
  </group>
  <group name="first_rk_step_part1">
    <subcycle loop="1">
      <scheme>rrtmg_sw_pre</scheme>
      <scheme>rrtmg_lw_pre</scheme>
      <scheme>rrtmg_sw</scheme>
      <scheme>rrtmg_lw</scheme>
      <scheme>myjsfc</scheme>
      <scheme>noah</scheme>
      <scheme>myjpbl</scheme>
      <scheme>g3cu</scheme>
    </subcycle>
  <group name="after_all_rk_steps">
    <subcycle loop="1">
      <scheme>thompson</scheme>
    </subcycle>
  </group>
  <finalize>CPF_finalize</finalize>
</suite>
```

# Community Physics Framework

- Automatically generated interfaces for physics schemes



Physics scheme cap interface:

```
function get_prs_wrf_run_cap(ptr_data)
```

Physics scheme:

```
subroutine get_prs_wrf_run(ix, levs, phii, prsi, tgrs,
qgrs1, del, del_gz, errmsg, errflg)
```

# Community Physics Framework

- Close coordination between NOAA and NCAR
  - NOAA close to operational implementation
- NCAR
  - Design for model interfaces by early summer (each NCAR model)
  - Single compliant internal physics suite running in each NCAR model by early 2019
  - Test ‘Singletrack’ ideas from these platforms
- NCAR and NOAA collaboration includes at least:
  - Requirements for various components
  - Metadata definitions and versioning
  - Script to read metadata and generate physics interface
- NCAR and NOAA anticipate an eventual single effort for:
  - Suite definition file
  - Shared physics
  - Physics driver

# Singletrack Physical Parameterization ‘Suites’

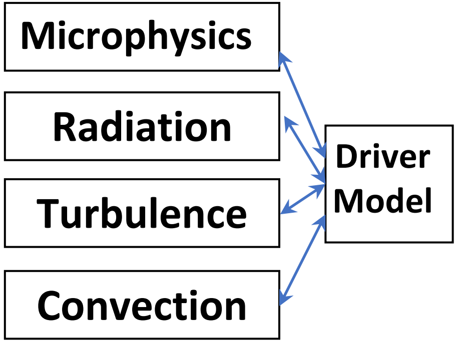
- WRF has a multitude of physical parameterizations
- Moving towards ‘suites’
  - Consistent set of physical parameterizations
  - Some notion of ‘curated’ suites: Someone is watching, testing, etc
- CESM: nine curated ‘suites’, most with further options
  - Only one is ‘operational’ for any given version
- CESM Options are typically:
  - Parameterization options (e.g., Aerosol model complexity: MAM 7 vs. MAM4)
  - Several chemistry options
- Singletrack expected to follow ‘suite’ concept
  - Initial demonstration of schemes running within Community Physics Framework
  - Expect to pull a limited set of schemes into a hybrid WRF/CESM ‘suite’
  - May bring along other WRF physics
- Goal is a minimal set: “One Suite to Rule them All”? (Most applications)

# Scale insensitive physics for weather & climate

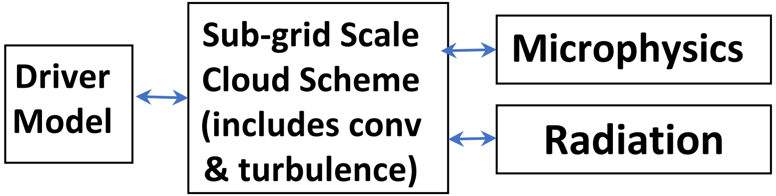
- The atmosphere only knows one physics
- Ultimate goal is a single set of physical parameterizations that work "across scales"
    - LES (100m) → Global (100km)
- "Good Luck with That"
- Actually: Getting there

# ’Unified’ Approach to Moist Physics

**Standard approach (WRF, MPAS, CAM6)**




**Proposed ‘unified’ approach**




- Goal: single *cloud parameterization package* that is portable across models.
- Allow “plug and play” for individual parameterization pieces (microphysics, radiation, etc.)
- Works across multiple scales (target: 100m → 1km → 100km)
- “Scale awareness” is at the level of the SGS cloud scheme (PDF based?)
- Further develop microphysics by building upon recent advances at NCAR and in the wider the community

# Where we are

- Thompson-Eidhammer ‘aerosol aware’ microphysics [HRRR]
- MG2 → MG3 [CESM] microphysics (global version of M2005)
  - Includes Graupel/Hail
  - Links to drop and liquid nucleation/aerosols
- Experiments with:
  - MG in deep convection
  - MG with unified ice
- P3: Multi-category unified ice [WRF]
- CLUBB Unified Turbulence Scheme [CESM, LES]
  - Sub-columns available in CESM

# Where we are going

- Bring all the microphysics together
  - Bring together MG efforts: Graupel, Unified Ice
  - Add in elements of Thompson (internal aerosols, some process rates)
  - Expand (and perhaps simplify) Unified Ice treatment
- Develop a common (git) repository
  - Put 'portable physics' in it
  - Unified Microphysics, Deep Convection (Grell-Frietas), Unified Turbulence (CLUBB)
  - Call same code from WRF/MPAS and CESM
- Code for Common Physics Framework (CPF)

# Summary

- Have strong motivation for unifying physical parameterizations
- New CPF infrastructure to enable this
  - Start with CPF implemented in WRF, CESM
- Have a science plan for moving to physics across scales

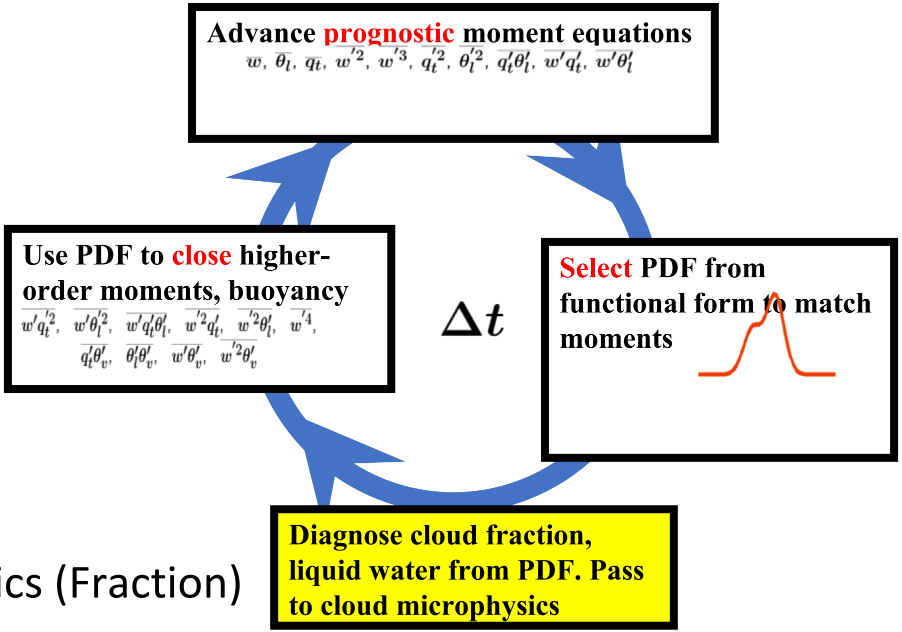
# Questions

- Can we get to one set of physics?
- Are multiple ‘suites’ necessary? (WRF-Forecast, CAM6, CAM4, etc)
- How to facilitate community testing, analysis and development?
  - E.g. Maybe our microphysics is not the best/right way
- Curation of physics? (Governance). How limited a set?
- Do we have the right key science drivers, critical areas?
- Are we missing applications?

# Extra: Physics Details

# Unified Higher Order Closure

## CLUBB: Cloud Layers Unified By Bi-normals

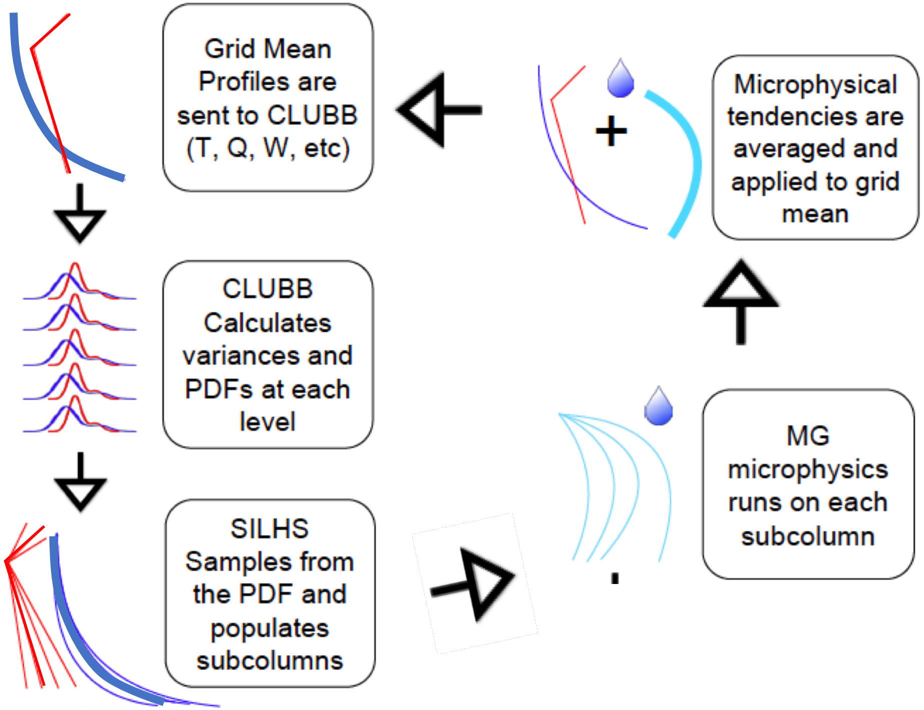


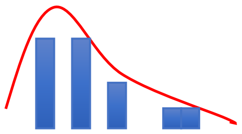

Integrated for CESM2
Unifies PBL, Macrophysics (Fraction) & Shallow Convection

Golaz-Larson, 2002

# Advancements: Sub-columns

Statistically Sample Sub-Grid Variability: non-linear process rates
Unified turbulence (PBL, even convection) and macrophysics (fraction)



Sub-column Sampling

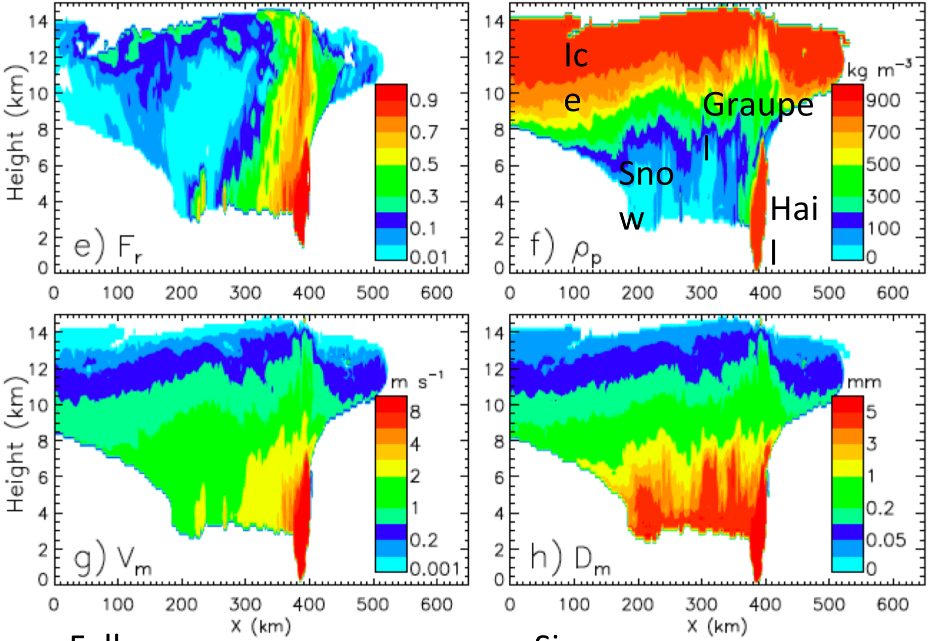
Thayer-Calder et al 2015, Larson et al 2005

# Advancements: Unified Ice

*Squall line simulations using the P3 microphysics scheme in WRF*

Rimed Fraction

Density




Fall
Speed

Size

Unify ‘Ice’, ‘Snow’, ‘Graupel’, ‘Hail’ into one hydrometeor class. Predict multiple properties: Mass, Number/Size, M-D (density), Rimed Fraction ($F_r$).

Evolves a range of properties with no artificial conversion terms.

Morrison & Milibrant 2015, Eidhammer et al 2016, Xi et al 2017