

NCAR Unified Community Atmosphere Modeling Roadmap

Andrew Gettelman, Bill Skamarock, Mary Barth,
Jean-François Lamarque
On behalf of the *Singletrack Steering Group*



Singletrack is currently an NCAR group (60+ total) developing/implementing this roadmap with an expanding list of community partners

Singletrack Purpose

Develop a strategic vision and roadmap to unify and improve community atmospheric modeling efforts across NCAR

- Intent: a Unified *Community* Atmosphere Model in the Earth System Model

Singletrack Goals

- Unify Weather (WRF, MPAS), Climate, Geospace (CAM-->WACCMX) applications
- Enable future ‘frontier’ science across scales: Weather-Climate Interface
- Engage the weather/climate/geospace community in this effort

Singletrack’s purpose and goals are aligned with recommendations from the Jan 2018 NCAR advisory panel and 2017 NSF Site Visit Team (SVT)

What is a unified atmosphere model?

A minimal set of interoperable components: dynamical cores, physical parameterizations, chemical models, etc, with compatible or identical infrastructure (e.g. coupling, I/O, testing). These components cover the primary applications for the climate, weather and geospace communities.

Over time, we expect to evolve towards fewer components covering more applications.

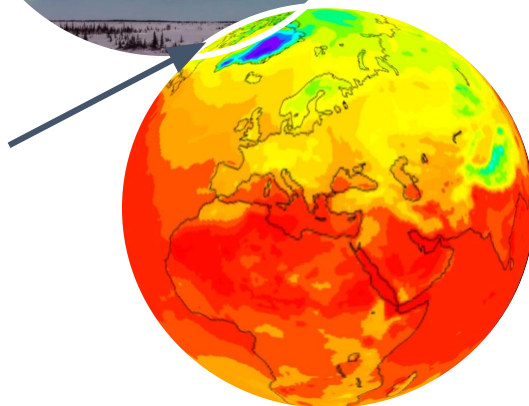
Current Community Atmosphere Models

Existing Applications

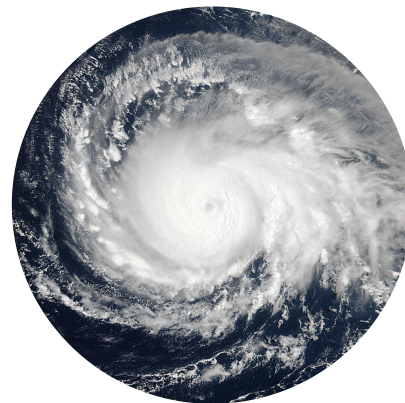
Geospace (TIE-GCM)



WACCM-X



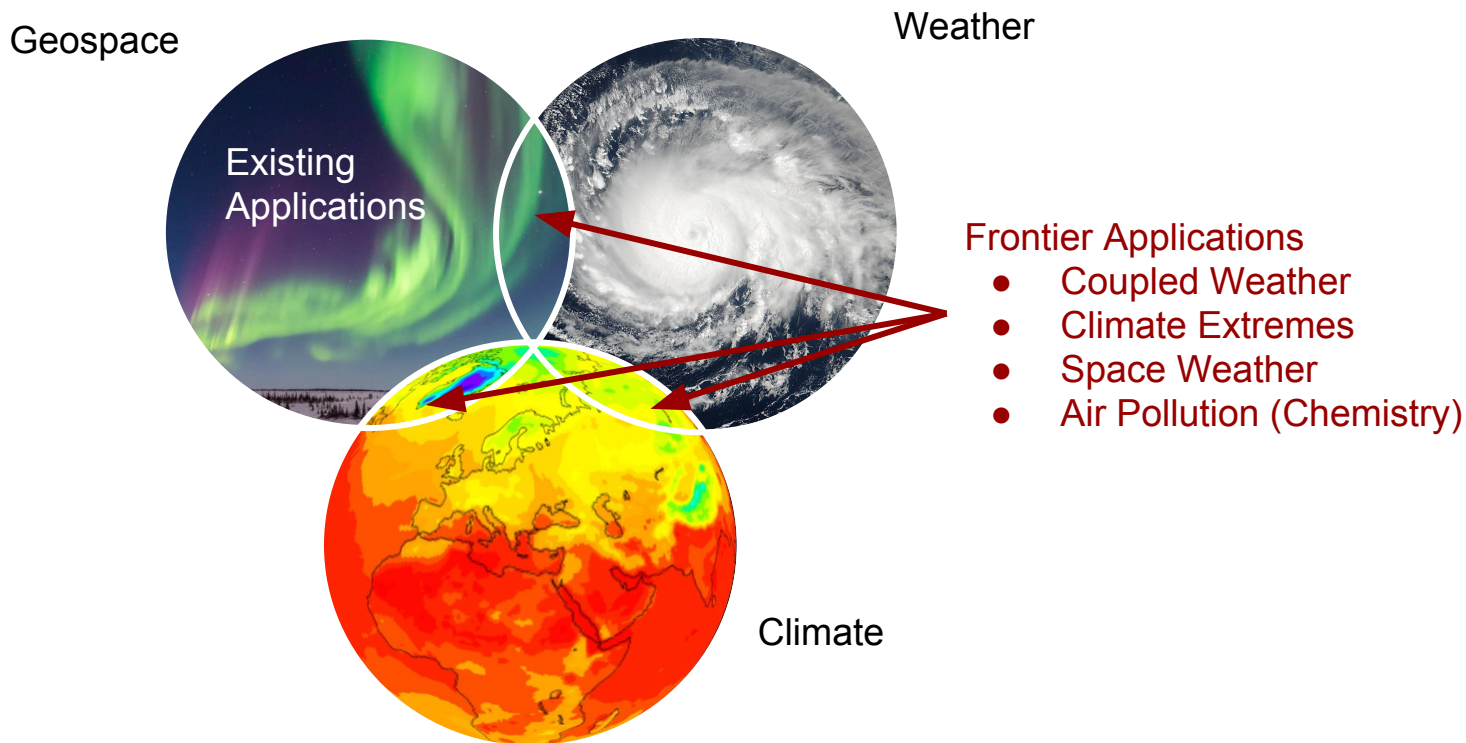
Weather (WRF & MPAS)
Chemistry (WRF-Chem)



Climate (CAM)
Chemistry (CAM-Chem, WACCM)

Singletrack Vision

Support Existing and Frontier Applications

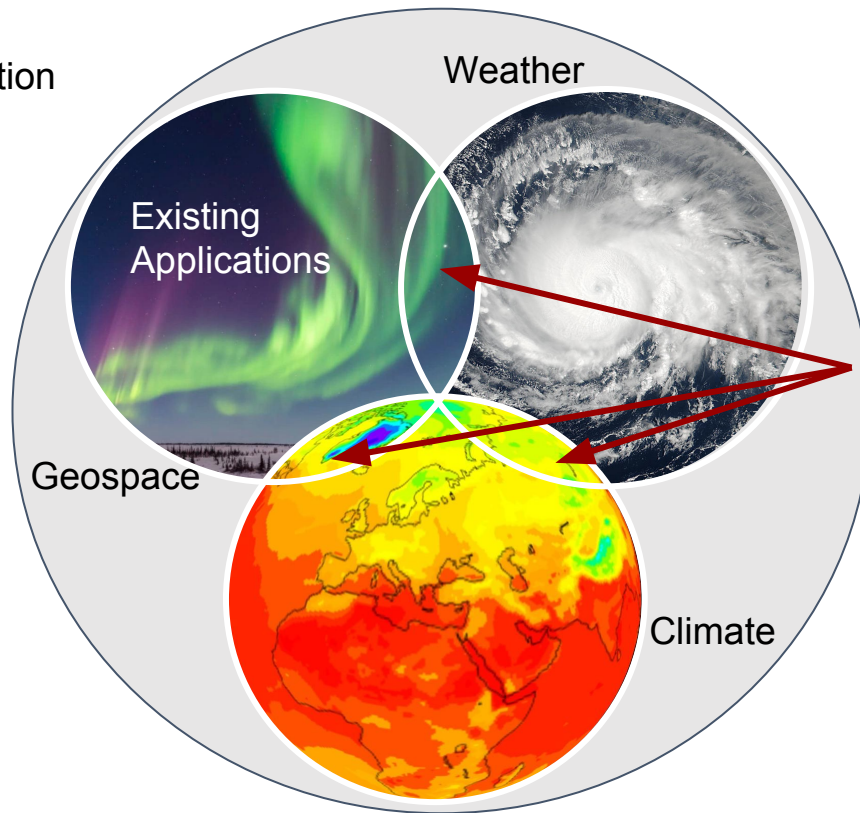


Singletrack Vision

Support Existing and Frontier Applications

Unified Infrastructure

- Initialization/Prediction
- Diagnostics
- Coupling in ESMs
- Small to Exascale
- Usability



Frontier Applications

- Coupled Weather
- Climate Extremes
- Space Weather
- Air Pollution

Unified modeling and existing applications

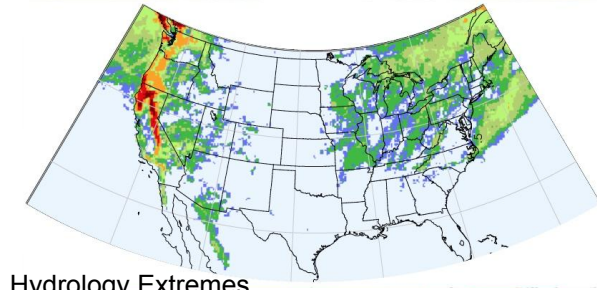
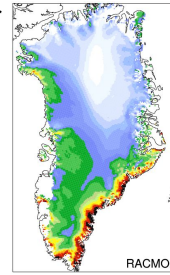
- Existing *Science Goals and Applications* will be supported
 - Includes CAM-Chem and WRF-Chem applications
- Singletrack developments meet atmospheric modeling needs in NCAR frontier science goals
- WRF/MPAS: support forecast and weather science
 - WRF and MPAS are NOT going away unless all applications can be met
 - Singletrack will enable better testing/portability of physics
- CESM: singletrack can be the atmosphere model for CESM3
 - Existing climate applications continued to be supported
 - Singletrack will enable better testing/portability of physics

Frontier Science Goals

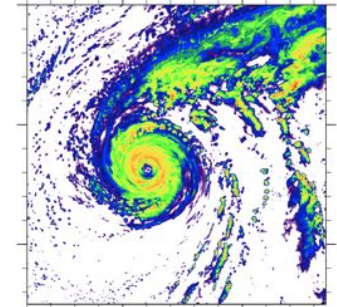
Map to specific applications

- Coupled Simulations at the Weather Scale
 - Tropical cyclones, Extreme convection, Urban pollution
- Extreme weather under climate conditions
 - Extreme heat and precipitation, extreme weather under climate change, air quality
 - Polar Prediction
- Integrated Geospace modeling
- Subseasonal to Seasonal (S2S) to Decadal Prediction
 - Intra-seasonal (MJO), And interannual (ENSO)
- An Atmospheric Model in the coupled system
 - Land - Atmosphere Interactions
 - Unified chemistry

Polar



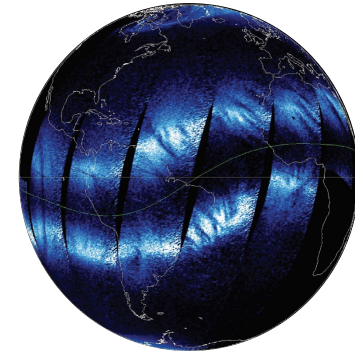
Hydrology Extremes



Tropical Cyclones



Air Quality



Space Weather

Singletrack Applications

Application Examples and Configurations

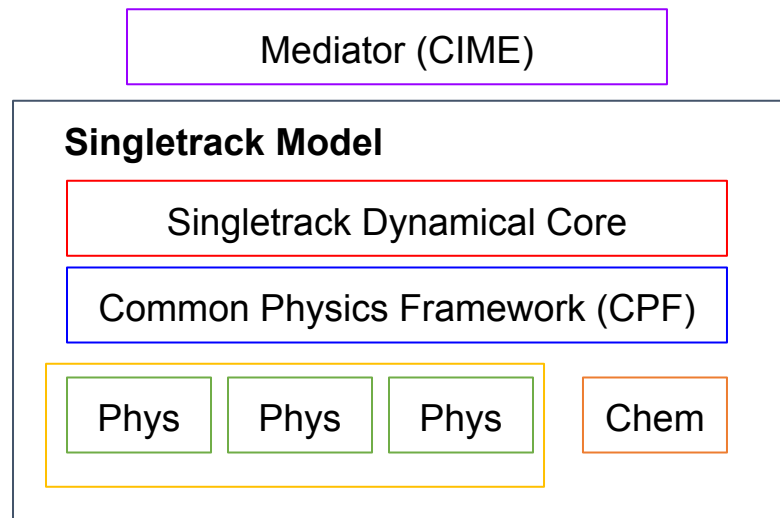
Topic	Example Application	Configuration
Weather	Tropical Cyclones	3km refined mesh, coupled ocean, forecasts
Climate	Hydrologic Extremes	3km refined mesh, forecast and climate simulations
Polar	Arctic Prediction	5km refined mesh, coupled ocean, land, sea ice, land ice. Forecast and climate simulations
Geospace	Space Weather Prediction	10km global atmosphere to the ionosphere, forecast.
Chemistry	Urban/Regional Air Quality Prediction	Urban: <1km regional forecast. Regional: 4km refined global mesh, climate and forecast

Singletrack: Modular Structure

Configure for different applications

Singletrack will use a **Common Physics Framework (CPF)** to link **physical parameterizations** (clouds, gravity waves, etc) to **dynamics** & a **coupling architecture** (land, ocean etc).

- Geospace will have it's own 'suite'
- **Chemistry** = set of physical parameterizations
- **Chemistry** can be any CPF compliant chemistry scheme
- Code will work across scales
 - Global
 - Global Refined Mesh
 - Regional



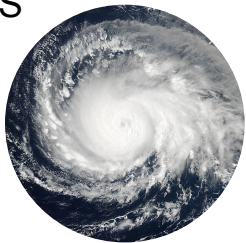
Physics 'Suites'
(CAM6, WRF/MPAS, Geospace)

Chemistry Modules
(MUSICA/MICM)

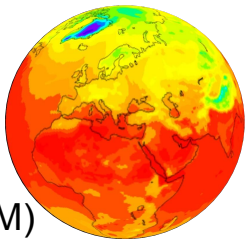
Singletrack Implementation

NCAR Community model evolution

WRF/MPAS



Singletrack



CESM (CAM)

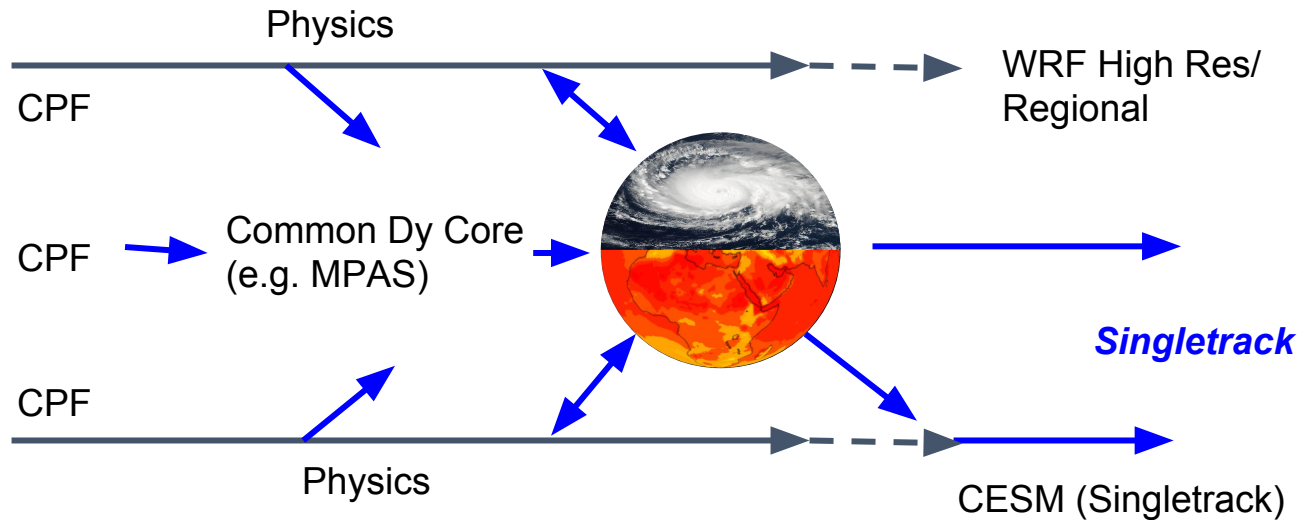
Proposed
Development Steps

Put CPF in
CAM & WRF

Physics from
CAM & WRF

Test
applications in
CAM & WRF

**Also: CPF Compliant
Chemistry (MICM/MUSICA)**



Singletrack: a *community* atmosphere model

- ❖ Community engagement in planning, definition, applications
- ❖ Education/Training/Tutorial components
 - New science areas for early career scientists
 - Facilitate broader community interactions with modeling scientists
 - Access and training on new model developments
- ❖ A model for research and education: Simplified configurations
- ❖ Improved usability for focused problems (regional weather, idealized)
- ❖ Common interfaces/infrastructure to aid community development
- ❖ Diagnostic tools to incorporate observations & facilitate analysis
- ❖ Community governance: Weather, climate & chemistry components

Singletrack: Timeline

Past, **Present**, Future

- Jan-February: Organized, developed science goals, requirements
- March: Development of specific application examples
- April: feedback from NCAR stakeholders
- May: develop vision/applications
- May: Develop roadmap ideas (Define Tasks/Resources)
- June: Discussions with NSF
- June: Solid vision/plan draft presented at WRF/CESM meetings
- **Solicit further feedback and incorporate into plans, develop roadmap**
- Late summer/fall: Release of an initial plan/roadmap

Singletrack and GEOS-CHEM

- Singletrack framework can take any chemistry which is CPF compliant
 - Chemistry includes any aerosol model
- Put next to physics so can interact with clouds
 - Flexible ordering, implementation
- Single port will work across scales
 - Configure singletrack system from regional to global
- Evolution: CPF put in CESM and WRF this year
 - Any CPF compliant scheme should run in WRF & CAM/CESM in 1-2 years

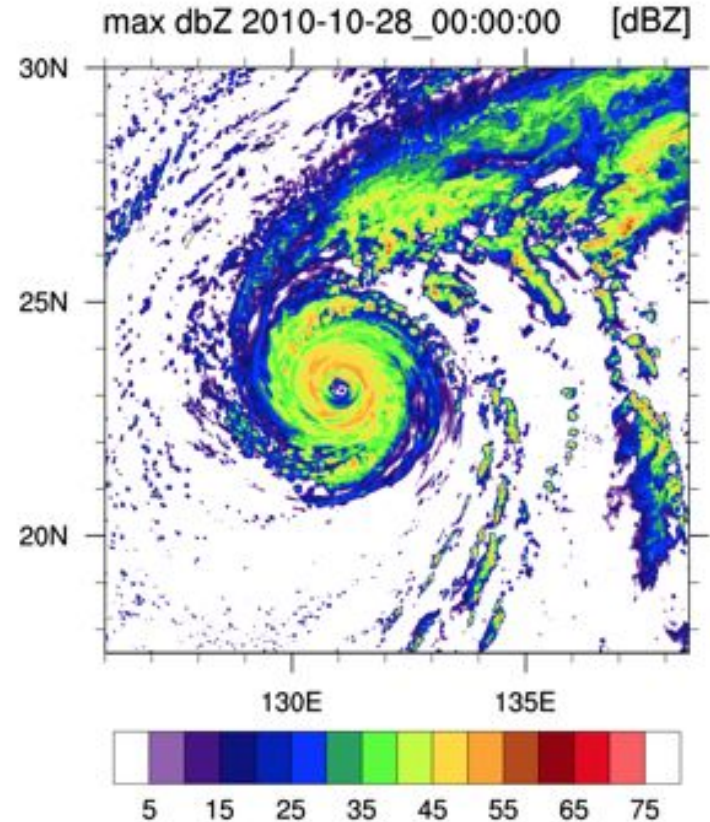
Extra: Applications Details

Applications: Weather

Tropical Cyclones

Simulate coupled weather phenomena in a coupled system at high (<5km) resolution. Example: tropical cyclones.

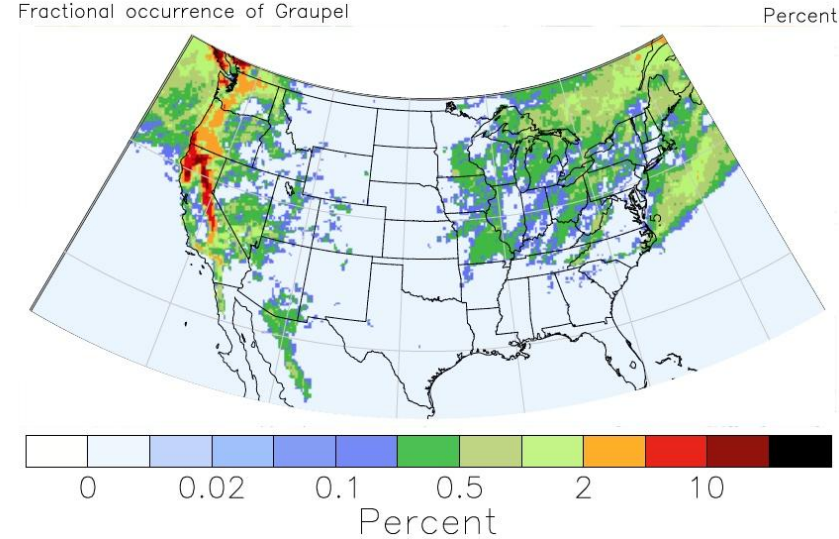
Also applies to MCS (convection) and S2S sub-seasonal prediction (MJO)



Applications: Climate Hydrological Extremes

Simulate high impact weather extremes in a coupled system at high (< 5km) resolution. Example: occurrence of graupel (extreme precipitation) in a 14km global model

Also applies to floods, hydrology, droughts (up to seasonal). Prediction as well as climatologies of extreme hydrological events

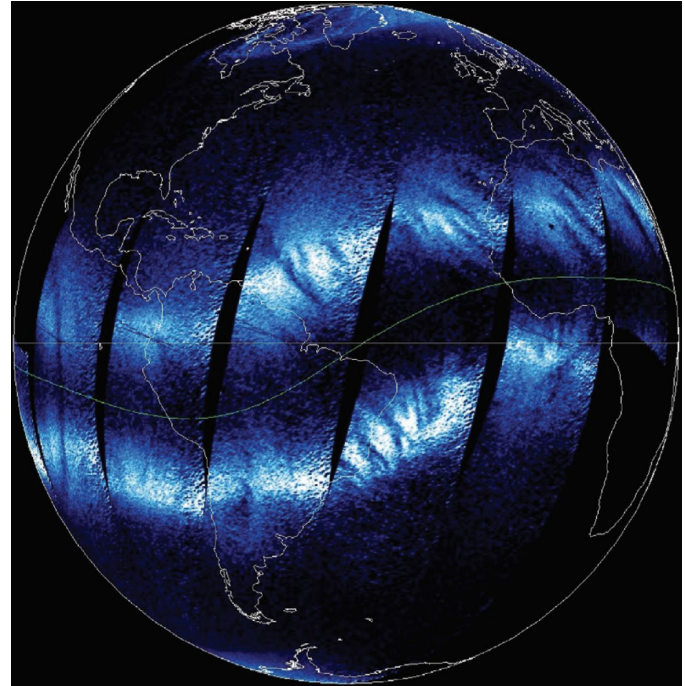


Applications: Geospace

Space Weather Prediction

Simulate forced events in the upper atmosphere that affect human systems and climate. Example: Ionospheric plasma bubbles that disrupt radio waves (Communication, navigation)

Couple specialized geospace models on different grids to a deep atmosphere model



Applications: Chemistry

- Represent air quality in urban regions
- Interactions between atmospheric chemistry, weather and climate

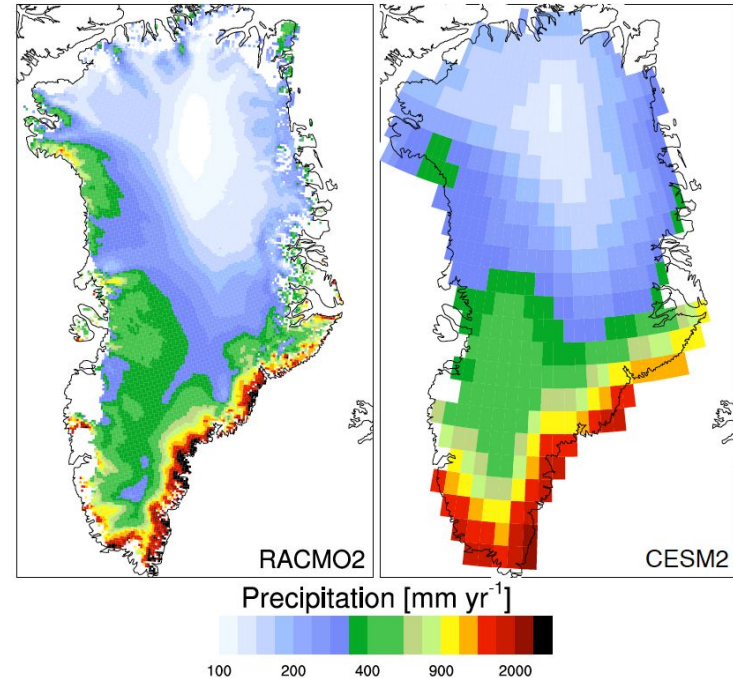
Requires chemical modeling at fine horizontal ($< 5\text{km}$) and vertical (multiple layers in the urban canopy) resolution within a global modeling system.



Delhi, March 2018

Applications: Polar

- Simulate evolution of the Arctic environment
- Requires high resolution, but also a coupled system (especially to the cryosphere and ocean)
- Seasonal to Sub-seasonal (S2S) scale, but also Decadal scale



Target applications: 5km refined mesh forecast, 10-25km climate simulations. Coupled ocean, land, sea ice, land ice.

Singletrack Topical Areas

Initial Topics

- Dynamical Core
- Physical Parameterizations
- Data Assimilation
- Infrastructure

Phase 2 Topics

- Diagnostics/Observations
- Governance
- Education/Training/Tutorials