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Outline (2 pages requested):

1. Scientific Need/motivation: Frontier Application

Air pollution is a serious threat to human health and food security: poor air quality causes one in eight deaths globally and air pollutants reduce crop yields that could otherwise feed millions of people. Air pollution hazards include high amounts of ozone and fine and ultrafine aerosols from anthropogenic and wildfire emissions. Extreme AQ events can be triggered by heat waves or stagnation events, as occurred in Paris during the summer of 2003. Hence, there is a pressing need to develop the next generation of air quality management and prediction systems, to enable extreme event risk assessment and to inform mitigation strategies.

Short-term climate pollutants (reactive species and aerosols) can also affect weather and climate by altering radiation and clouds, while clouds play a role in redistributing and removing trace gases and aerosols. These multiple links between air quality, weather and climate necessitate a flexible modeling system across many scales.

Critical applications are (1) the representation of air quality in urban regions and (2) interactions between atmospheric chemistry, and weather and climate. These applications will require comprehensive chemical modeling at fine horizontal (<5km) and vertical (multiple layers in the urban canopy) resolution within a global modeling system. This will allow the two-way coupling between phenomena that occur on the urban, regional and global scales. For example, it will allow examination of the effects of wildfires in remote regions on urban air-quality, or improvements in S2S AQ prediction from better representation of the teleconnections in global-scale phenomena such as ENSO, QBO, and MJO, all within a single modeling framework.

The new Model Independent Chemistry Module (MICM), implemented in the proposed unified atmospheric model, allows for chemistry to be represented consistently in simulations from the urban scale to global scale and across NCAR atmosphere models. MICM, currently under development, provides a single entry point for the specification of chemical schemes and parameterizations suitable for prediction of atmospheric composition. It will supersede the current chemistry modules in WRF-CHEM, CAM-CHEM, and WACCM, bringing those communities and their expertise under a unified framework.

Air quality forecasts will benefit immensely from an advanced chemical data assimilation capability that is developed in conjunction with NCAR's next-generation data assimilation system.

2. Current Capability

Currently, ACOM chemistry modules are supported in two modeling frameworks, CESM (CAM-Chem and WACCM) and WRF-Chem. The global-scale CESM simulations are routinely done at ca. 1˚ grid spacing, but can be conducted at finer resolution (> 0.1 degrees) and using regional refinement, although this later configuration is still in a very experimental stage. The regional-scale WRF-Chem simulations are typically done at grid spacings of 15 km or less, with many air quality (e.g. the Front Range Air Pollution and Photochemistry Experiment) and cloud chemistry studies computed at grid spacings of 4 km or less. Regional-scale chemistry-climate simulations using NRCM-Chem, which is driven by CESM, have been performed (at 12 km grid spacing), producing projections of future air quality in North America, South Asia, and Southeast Asia. When chemistry or photolysis rates are updated, effort is placed to make these updates in both CAM-Chem and WRF-Chem.

3. Target Capability
   a. Where we can be in 1 year; 3 years.

In one year, we should have a prototype MICM that works as a stand-alone model initially forced by specified environmental conditions. The MICM interface will be made compatible with the Community Physics Framework interface definitions. The prototype will demonstrate its capabilities with the 0-dimensional version and can be used for science investigations on chemical transformation pathways.

In three years, MICM will be expanded to include aerosol physics and chemistry as well as cloud chemistry. MICM will be hooked through the Community Physics Framework with a variety of atmosphere models, with demonstrations of capabilities in global and regional-scale studies.

In parallel, we expect the exploration (within CESM) of the performance of multiple dynamical cores (FV3, MPAS and SE, with or without CSLAM) in terms of tracer transport accuracy and computation performance. This is critical since most applications require tracer transport for many (50-200) tracers, and this can quickly become prohibitive. We expect that preliminary results will be available in 1 year.

Within the next 3 years, we are targeting regional refinement with SE or MPAS, with coarse resolution on the order of 1° down to a few kilometers (5km over CONUS or similar regions). This will combine the CESM, MPAS and WRF capabilities within the Singletrack framework.

   b. Different Scenarios if appropriate (ambitious, incremental)

The key uncertainty resides in the dynamical core ability to perform accurate high-count tracer transport and regional refinement. It is critical for the chemistry to have this information with the 3-year time frame in order to start developing this capability

4. Key requirements/tasks to get there
   a. Any decision points?

What is the dycore we should focus on to reach our 3-year target?

5. Tasks before/after decision points
   a. Estimate of resourced required

MICM development could be greatly accelerated if additional software engineering support was provided.

6. Key Deliverables

MICM