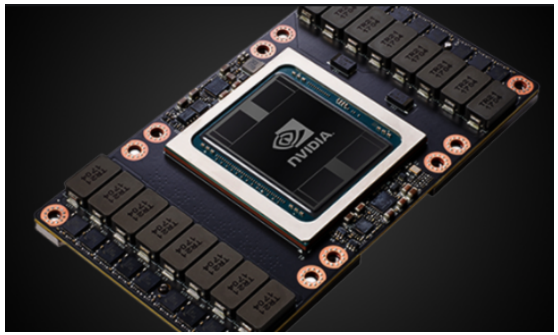
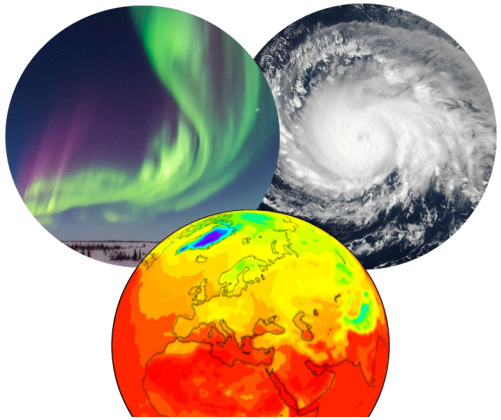
MPAS
Model for Prediction Across Scales

The Model for Prediction Across Scales Atmosphere

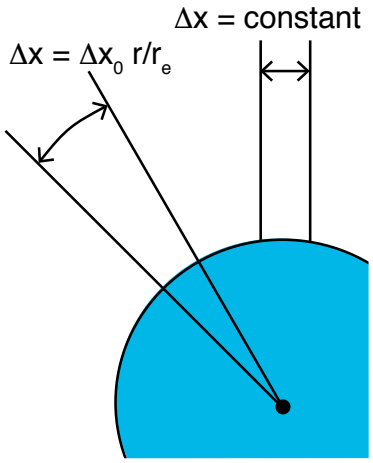
- GPU release for MPAS-Atmosphere
- Progress on the development of earth system model capabilities (MPAS-A in SIMA, CESM)
- Deep atmosphere extensions.



NVIDIA Tesla V100 GPU



System for Integrated Modeling of the Atmosphere



Bill Skamarock, NCAR/MMM, for the MMM-MPAS team and many outside collaborators

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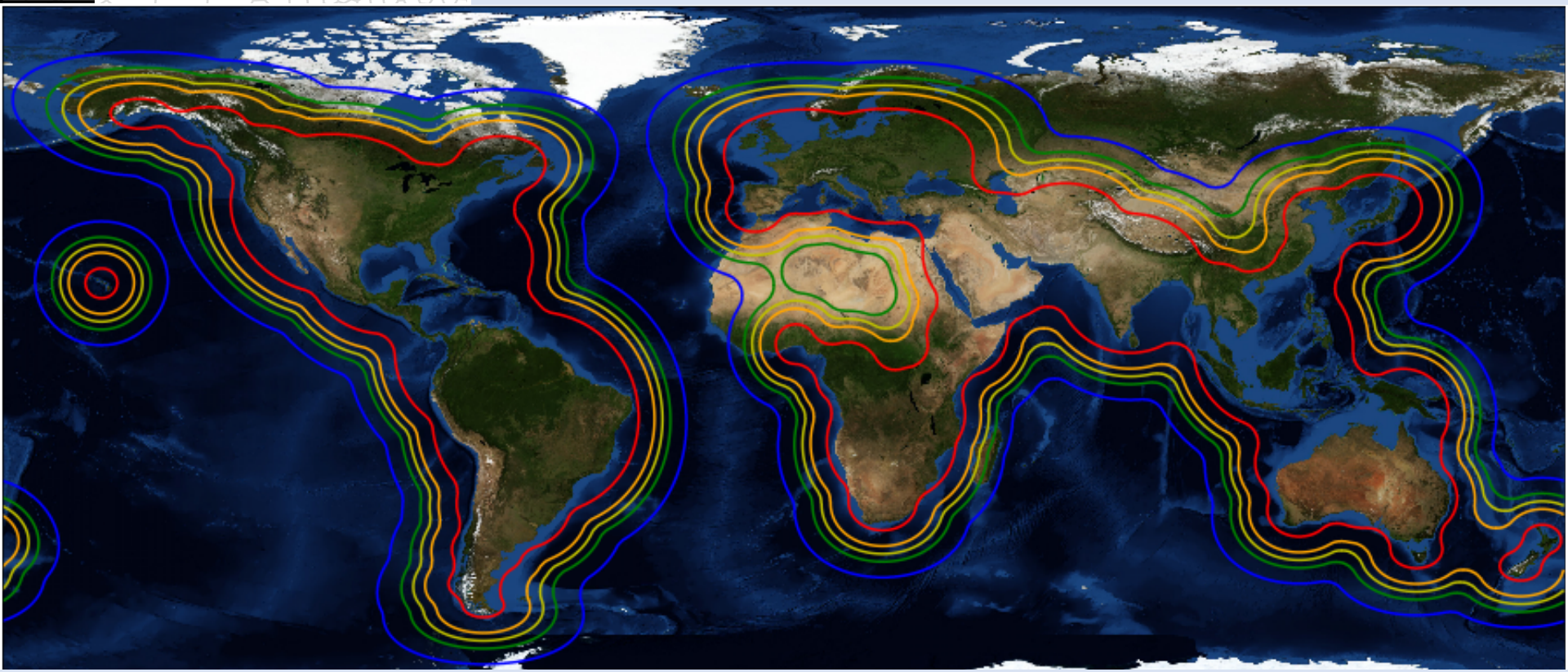
MPAS and GPUs



IBM GRAF (Global High Resolution Forecast) System - MPAS mesh (3-15 km cell spacing)
Physics: Scale aware nTiedtke CP, YSU PBL, NOAH LSM, WSM6 microphysics

- 47 minute runtime (including all I/O)
- runs on 55 Power 9 servers (220 GPUs, 2200 CPU cores)
- 15 hour forecasts, run every hour
- GSI drives the DA

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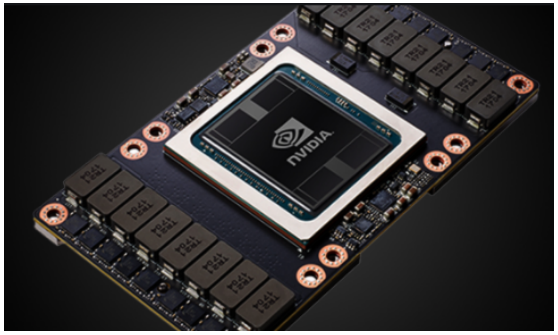
MPAS and GPUs

Project goals:

- Achieve performance portability across heterogeneous CPU/GPU architectures
- Use all the hardware (CPU and GPU) available
- Single source (CPU, CPU-GPU capability) using OpenACC.



NVIDIA Tesla V100 GPU

Status:

- GPU-CPU version of MPAS is now running operationally at IBM/TWC on IBM Power-9 architectures – IBM/TWC GRAF system
- Radiation and land-surface model (NOAH) on CPUs, all else (dynamics, other physics) on GPUs
- GPU-CPU version runs faster and uses less energy than a CPU-only configuration. We've met this important goal.

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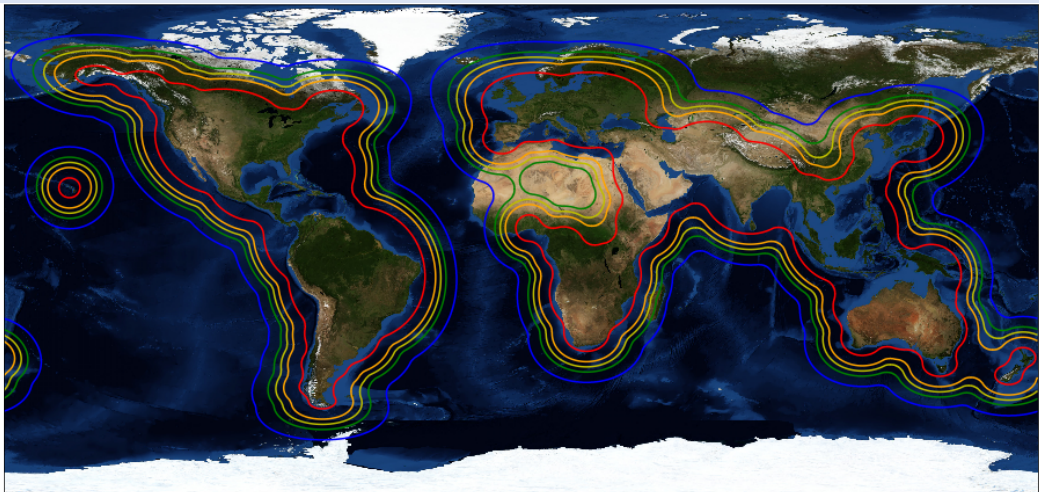
MPAS and GPUs

We are going to release the GPU-enabled MPAS-Atmosphere in September 2020 as a branch from MPAS Version 6.1, update to 7.X by mid-winter 2020-21



What will be in this special release?

- GPU-enabled MPAS dynamical core using OpenACC directives.
- Some GPU-enabled physics (e.g. YSU, WSM6, scale-aware nTiedtke)
- Asynchronous execution capability on heterogenous architectures - currently radiation (lagged) and NOAH land model on CPUs, all else on GPUs
- Configurations tested and validated on IBM POWER9 architectures

Our ability to support this release is limited. We expect early users to be *very friendly* and *very talented* (software engineering expertise is critical for success).

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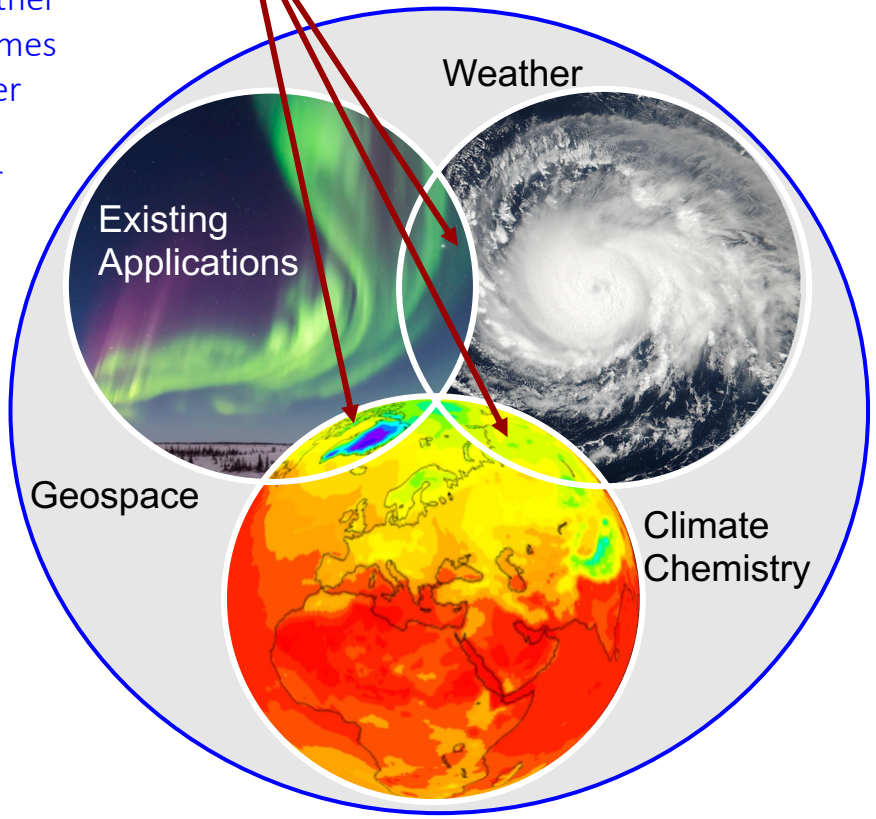
System for Integrated Modeling of the Atmosphere (SIMA)

SIMA is composed of common atmospheric model components & infrastructure embedded in an earth-system model

SIMA Frontier Applications

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

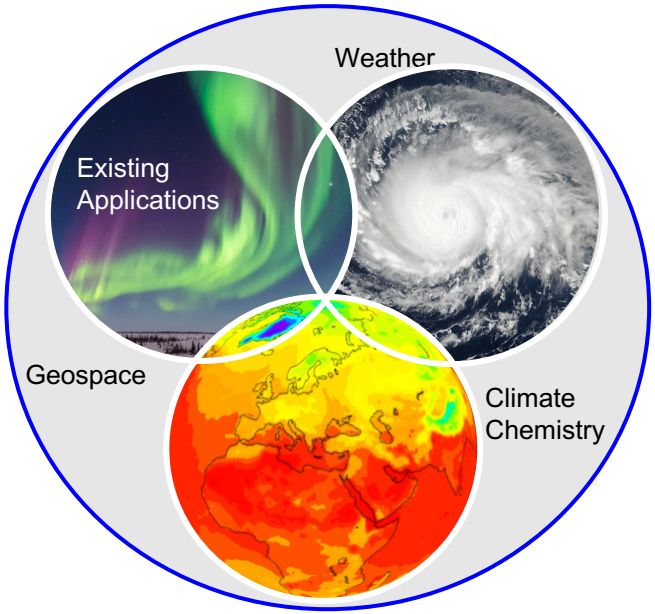


SIMA Vision

- Encompass Climate, Weather, Chemistry & Geospace
- Prediction (Initialized and Forecast) capabilities
- Complement & extend existing applications (CESM/WRF/MPAS)
- Shared infrastructure for efficiency
- Minimal set of components
- 'Center Wide' project including education, observations, computation

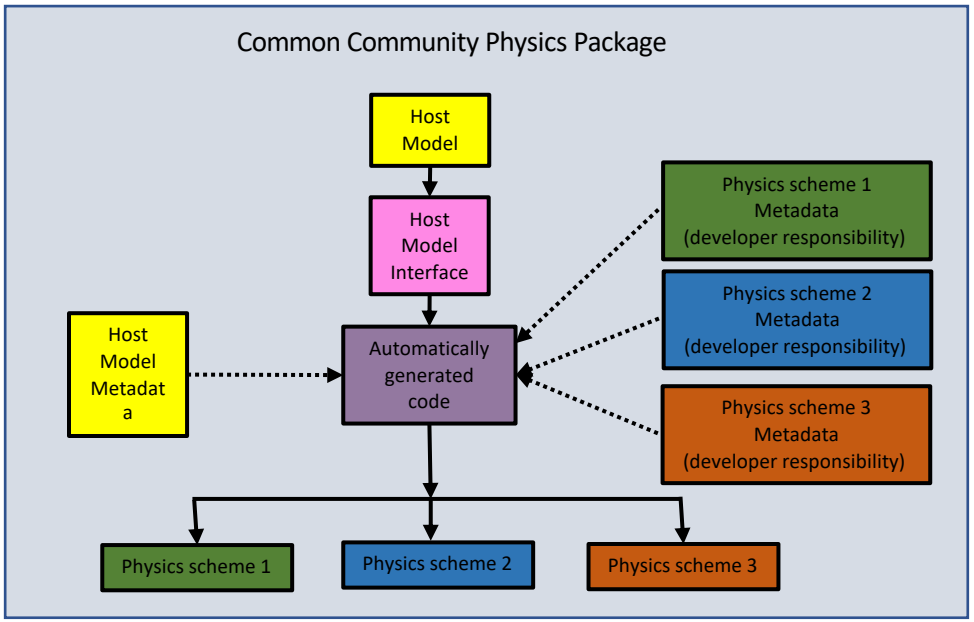
System for Integrated Modeling of the Atmosphere (SIMA)

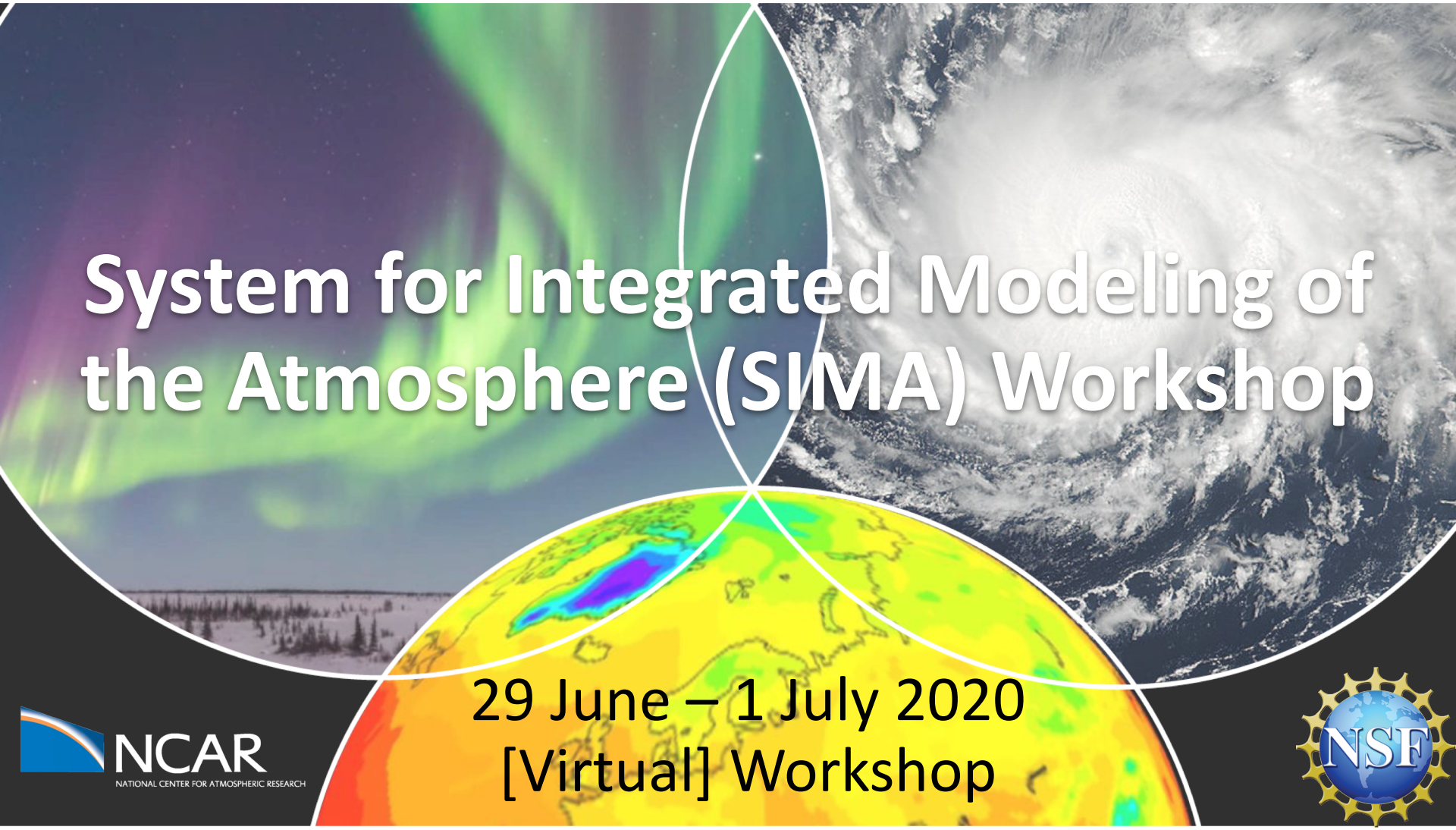
(1) MPAS-Atmosphere in an ESM, using CESM components.



(2) WRF/MPAS physics in an ESM using the Common Community Physics Package (CCPP).

CCPP - See Dave Gill's talk later this afternoon





System for Integrated Modeling of the Atmosphere (SIMA) Workshop

29 June – 1 July 2020
[Virtual] Workshop

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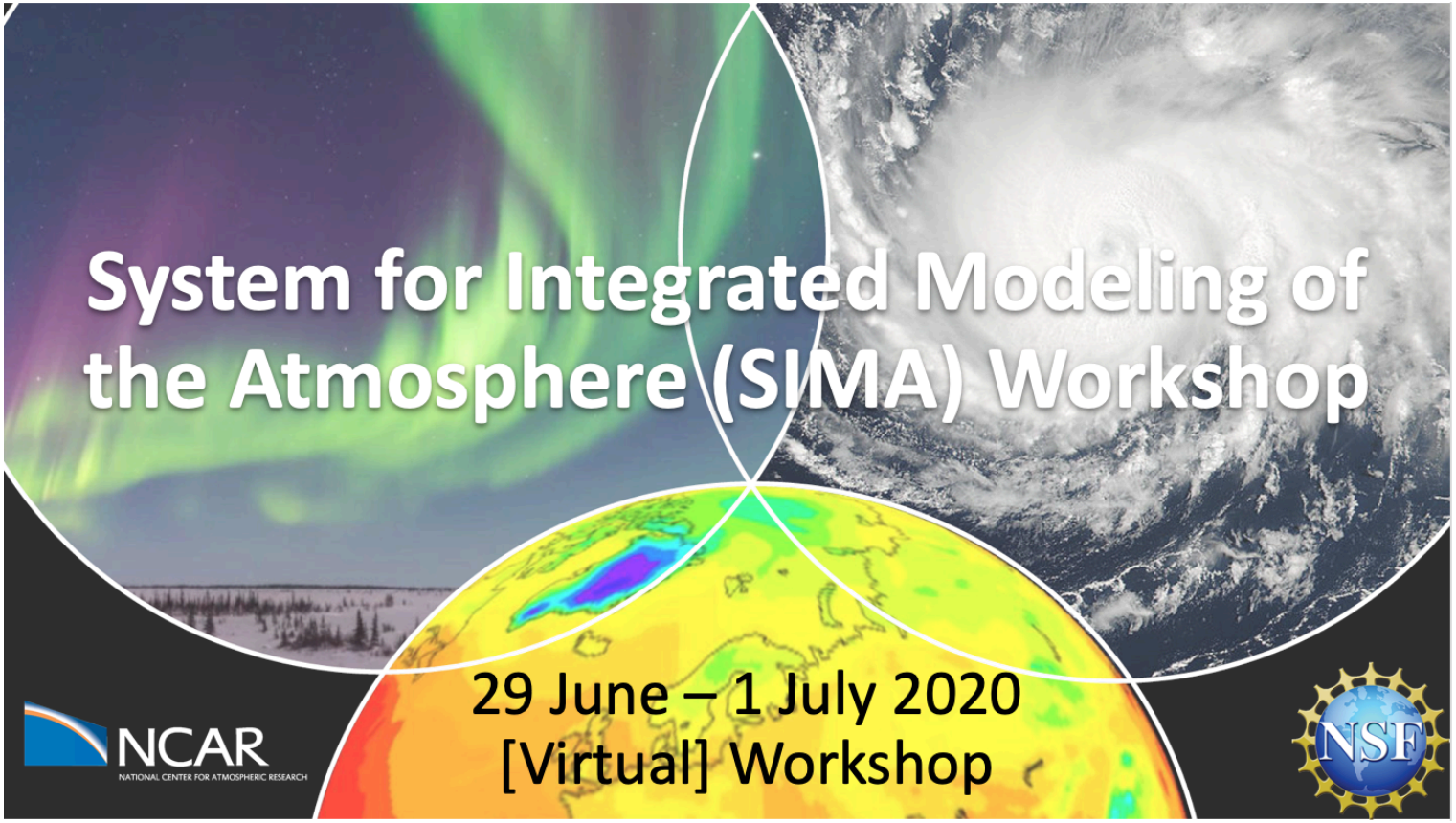
NSF

SIMA wiki → https://wiki.ucar.edu/display/SIMA

SIMA workshop webpage → https://cpaess.ucar.edu/meetings/sima-2020

Registration deadline: Wednesday 10 June 2020 – Tomorrow!



SIMA Workshop Objectives/Outcomes

- An updated vision statement
- Input to the scientific objectives of SIMA and its future applications
- Use-cases and workflow needs for applications
- Identification of critical near-term tasks for moving SIMA forward
- An assessment of community support for SIMA

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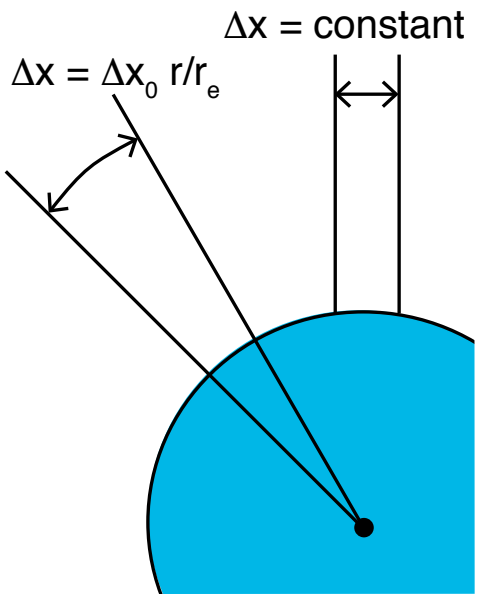
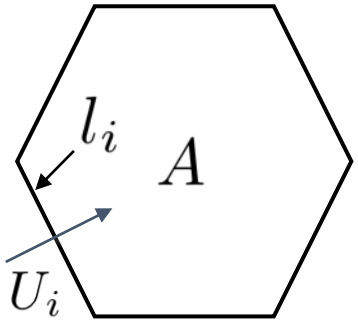
Deep Atmosphere: Geometry



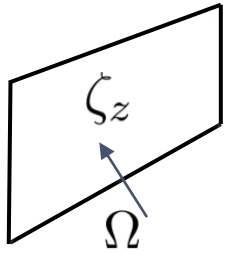
$$\frac{\partial \tilde{\rho}}{\partial t} = \nabla_\zeta \cdot \mathbf{V_H} + \frac{\partial \Omega}{\partial \zeta}$$

$$\tilde{\rho} = \frac{\rho}{\zeta_z}, \quad \mathbf{V_H} = (U, V) = (\tilde{\rho}u, \tilde{\rho}v), \quad \Omega = \tilde{\rho}\dot{\zeta}$$ (shallow atmosphere)

Hexagonal grid cell:



horizontal



vertical

$$\frac{\partial \tilde{\rho}}{\partial t} = \frac{1}{A_0} \sum_{i=1}^{n} U_i l_{0_i} + \frac{\Delta \Omega}{\Delta \zeta}$$

$A_0, l_{0_i} =$ Cell area and edge lengths at surface

Deep Atmosphere: $\tilde{\rho} = \frac{A}{A_0}\frac{\rho}{\zeta_z}, \quad U_i = \frac{A_0}{A}\frac{l_i}{l_{0_i}}\tilde{\rho}u_i, \quad \Omega = \tilde{\rho}\dot{\zeta}$

Shallow Atmosphere: $\tilde{\rho} = \frac{\rho}{\zeta_z}, \quad U_i = \tilde{\rho}u_i, \quad \Omega = \tilde{\rho}\dot{\zeta} \quad (A = A_0, \quad l_i = l_{0_i})$

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Deep Atmosphere: Gravity and Ω

Shallow atmosphere

$$\frac{\partial U}{\partial t} = -\frac{\rho_d}{\rho_m}\left[\nabla_\zeta\left(\frac{p}{\zeta_z}\right) + \rho_m g\,\nabla_\zeta z\right] - \eta\,\mathbf{k}\times\mathbf{V}_H - \mathbf{v}_H\nabla_\zeta\cdot\mathbf{V} - \frac{\partial\Omega\mathbf{v}_H}{\partial\zeta} - \tilde{\rho}_d\nabla_\zeta K + \mathbf{F}_{V_H}$$

$$\frac{\partial W}{\partial t} = -\frac{\rho_d}{\rho_m}\left[\frac{\partial p}{\partial\zeta} + g\tilde{\rho}_m\right] - \left(\nabla\cdot\mathbf{v}\,W\right)_\zeta + F_W$$

Deep atmosphere

$$\frac{\partial U}{\partial t} = -\frac{\rho_d}{\rho_m}\left[\nabla_\zeta\left(\frac{p}{\zeta_z}\right) + \rho_m g\left(\frac{r_e}{r}\right)^2\nabla_\zeta z\right] - \eta\,\mathbf{k}\times\mathbf{V}_H - \mathbf{v}_H\nabla_\zeta\cdot\mathbf{V} - \frac{\partial\Omega\mathbf{v}_H}{\partial\zeta} - \tilde{\rho}_d\nabla_\zeta K + \mathbf{F}_{V_H} - \left(eW\cos\alpha_r + \frac{uW}{r}\right)$$

$$\frac{\partial W}{\partial t} = -\frac{\rho_d}{\rho_m}\left[\frac{\partial p}{\partial\zeta} + g\left(\frac{r_e}{r}\right)^2\tilde{\rho}_m\right] - \left(\nabla\cdot\mathbf{v}\,W\right)_\zeta + F_W + \left[\frac{uU+vV}{r} + e\left(U\cos\alpha_r - V\sin\alpha_r\right)\right]$$

Additional terms

Gravity

Coriolis

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Reduced Radius Sphere Test

Work with Hing Ong, Paul Roundy, SUNY Albany

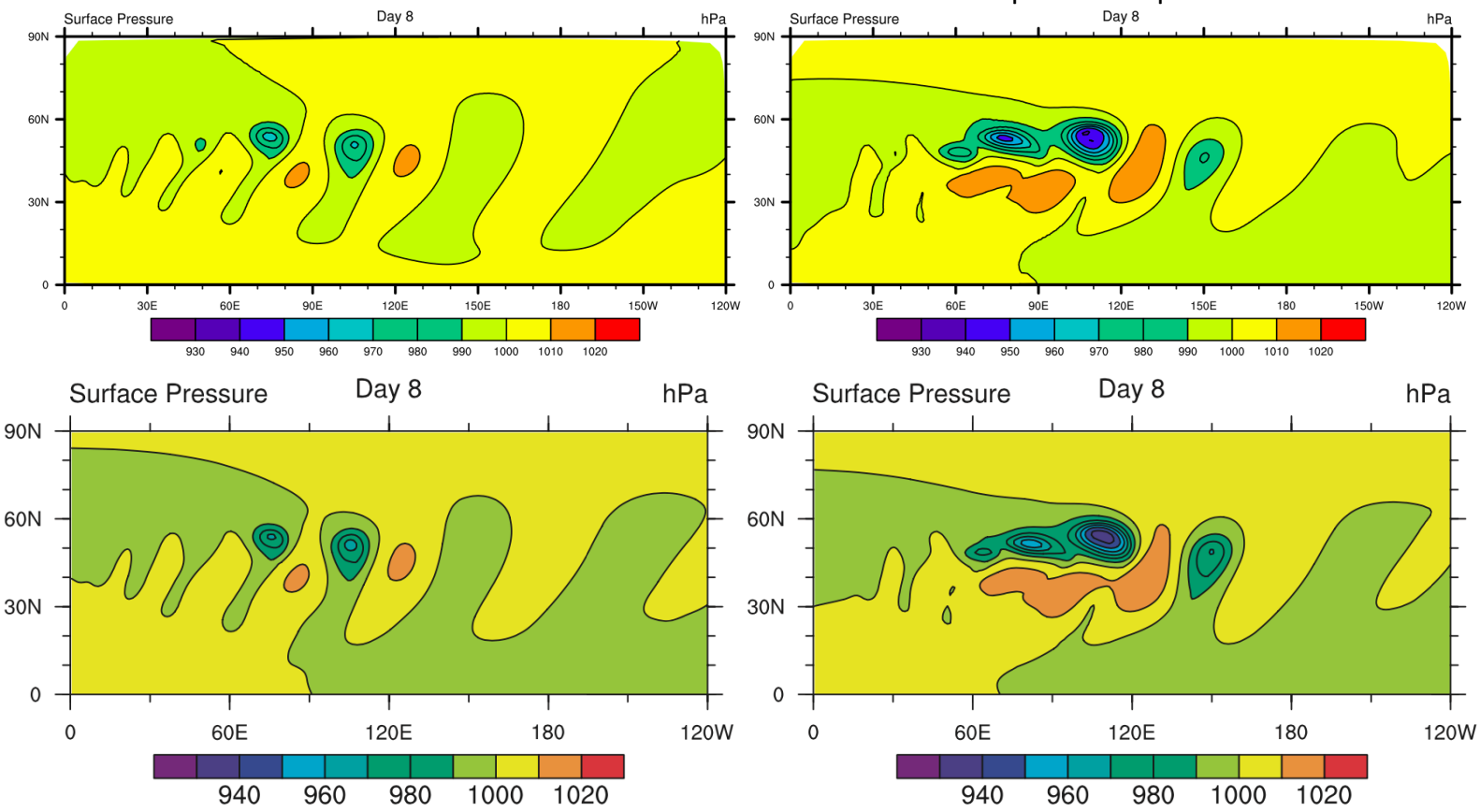
Baroclinic wave test, reduced radius sphere
(radius = $r_e/20$, $\Omega = 20\,\Omega_e$)

MPAS

MCore

Shallow atmosphere

Deep atmosphere



(Ullrich et al 2013, JAMES)

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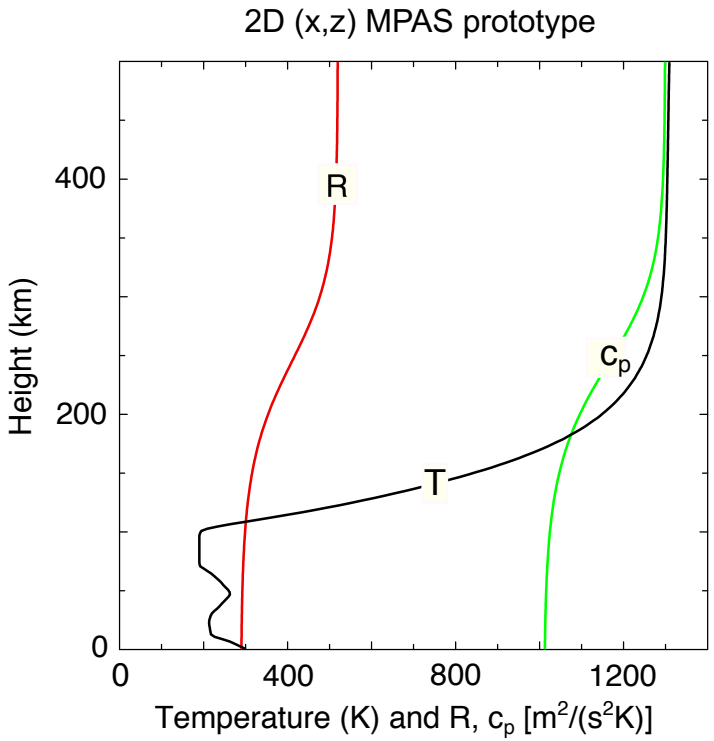
Deep Atmosphere: Future Tasks

In the next year:

- Continued testing of the geometry – enabled solver. Interest from friendly users?
- Release of the geometry – enabled solver (capabilities presented today)

Further out:

- Development and release of a geospace – capable solver (2D prototype design and testing are largely complete).
  - Variable (prognostic) constituents (O, O_2, N_2)
  - Numerics for large physical viscosities
  - Geospace physics



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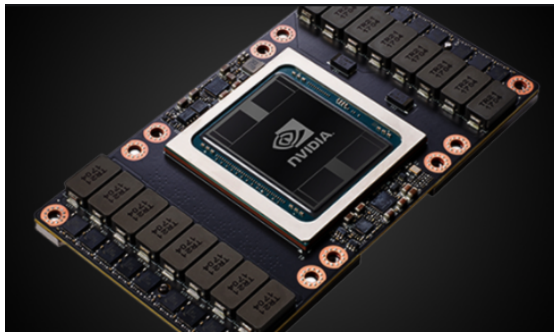
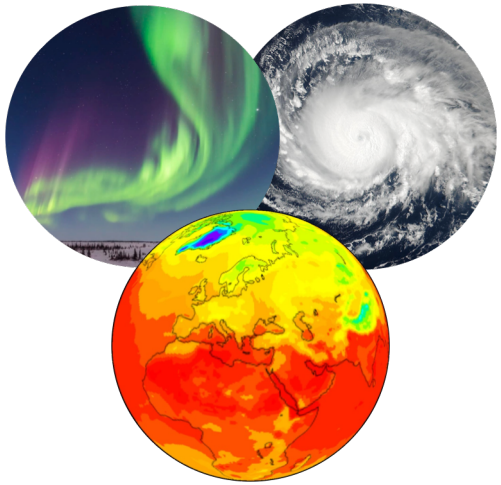
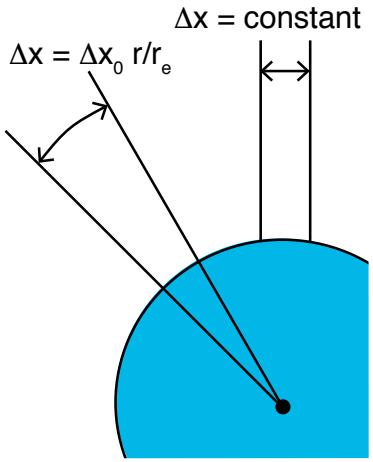
Summary

- GPU release for MPAS-Atmosphere is coming in September, update to MPAS V7.X in the winter.
- MPAS-A in SIMA (CESM/CAM) is progressing. SIMA virtual workshop will occur at the end of this month.
- Deep atmosphere extensions are coming soon.







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