Moving Nest Implementation in the Hurricane Analysis and Forecast System (HAFS)

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Additional Collaborators

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- Bin Liu, IMSG/NOAA EMC
- Chunxi Zhang, IMSG/NOAA EMC
- Weiguo Wang, IMSG/NOAA EMC
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- Lucas Harris, NOAA GFDL
- Rusty Benson, NOAA GFDL
- Joseph Mouallem, Princeton University

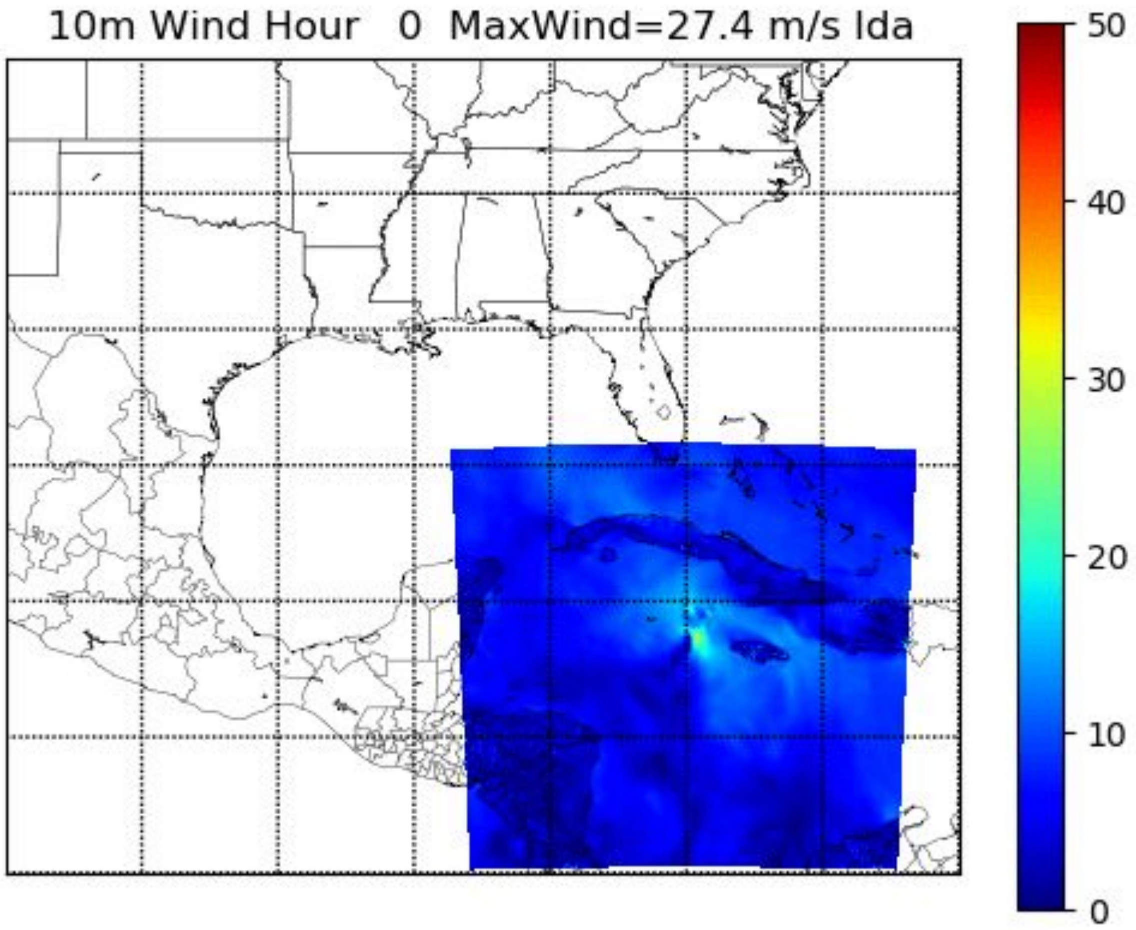
Moving Nest for Hurricanes

Moving Nest Overview

- Initial implementation of moving nest in HAFS using the FV3 dycore has been completed
- Similar functionality as moving nest in HWRF
- Global and regional configurations
- First moving nest in a global model

Hurricane Modeling

- Current global FV3 resolution is 13km over the globe
- To accurately model hurricanes, we need high resolution for areas with sharp gradients such as the eye and eyewall
- 1-4km for the hurricane core.
- Not feasible on operational timeframes over the globe with current computational facilities.



Moving Nest for Hurricanes

Moving Nest Overview

- High resolution nest to better capture small-scale processes in hurricanes
- Similar to nesting in HWRF
- Global and regional configurations
- First moving nest in a global model

Hurricane Modeling

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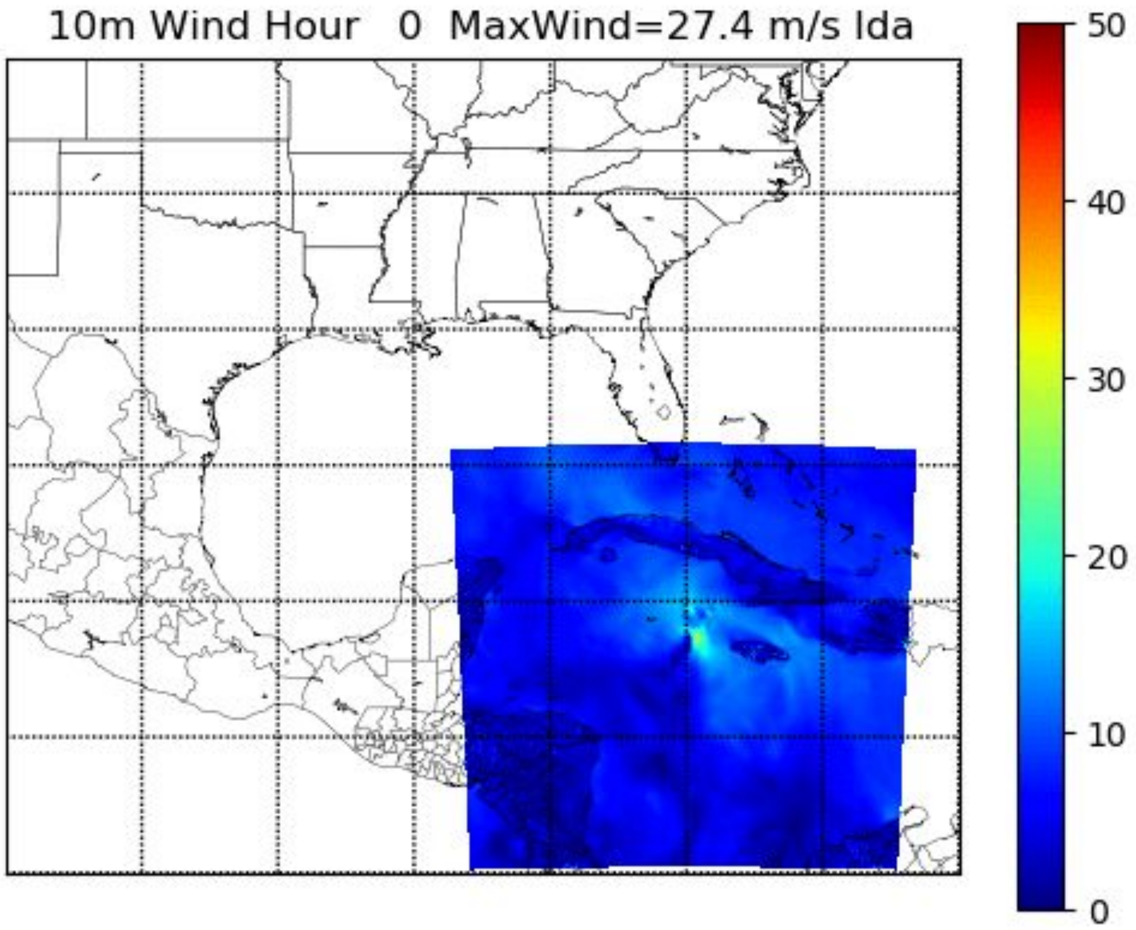
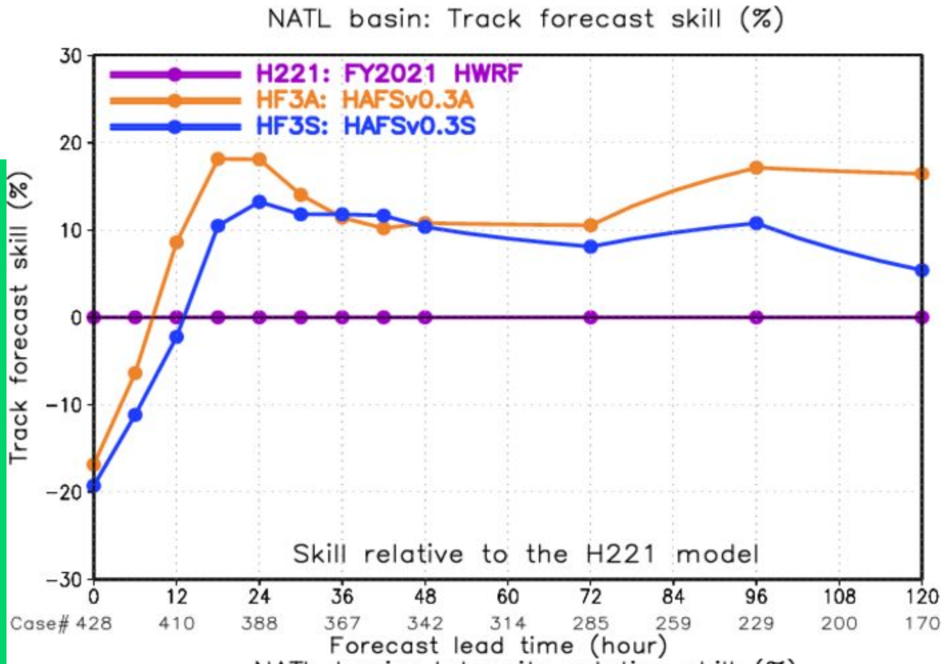
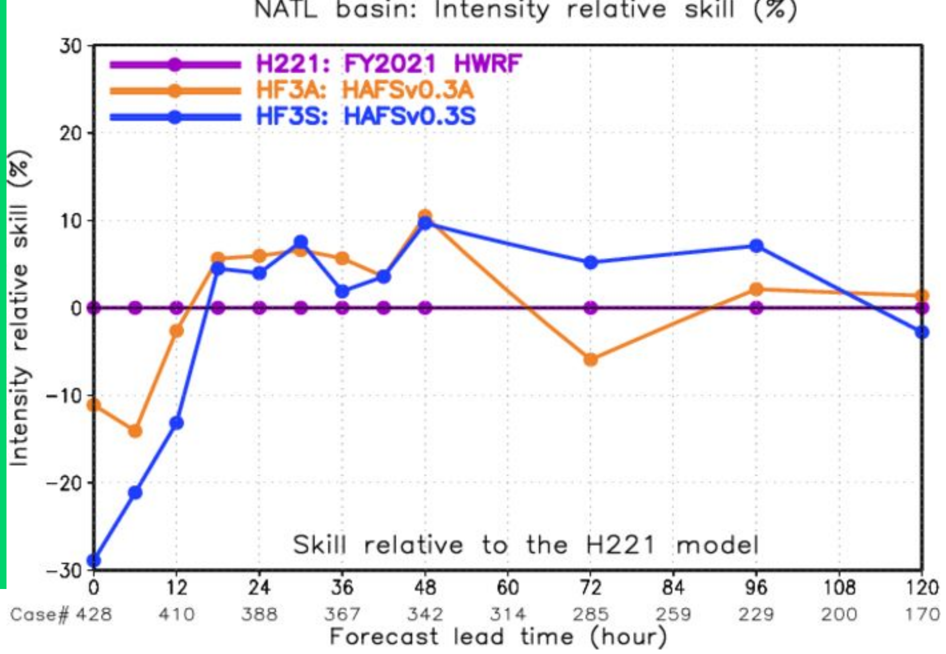


Moving Nest Features

- **Accurate**
  - Track more accurate than 2021 HWRF & HAFS
  - Max Wind Speed improvements most lead times
- **Fast**
  - Runtime Overhead 3%-7% compared to static nest
  - Scales with forward motion of storm
  - HWRF overhead is ~15-20%
- **Flexible**
  - Global and Regional
- **Robust**
  - 2020-2021 retrospective testing, stress tests
- **Configurable**
  - Enabled via namelist options

Verification diagrams courtesy of Bin Liu/EMC

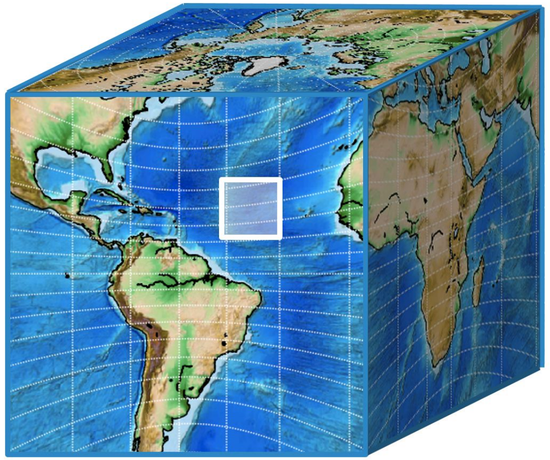


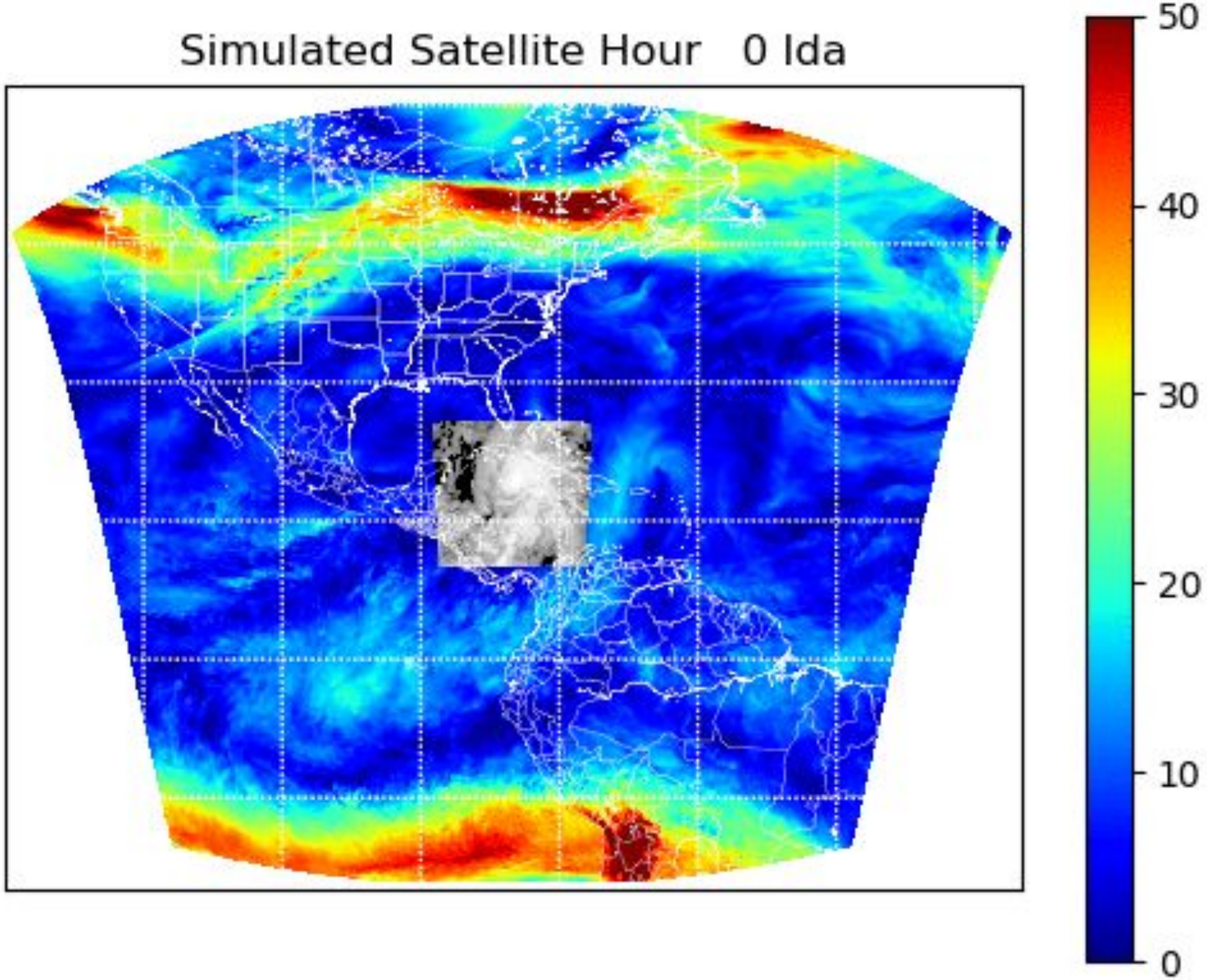


Regional and Global Configurations

Flexible Configurations

- Global cubed sphere
- Regional
  - Storm-centered
  - Basin scale
- Ocean Coupling
- Internal tracker

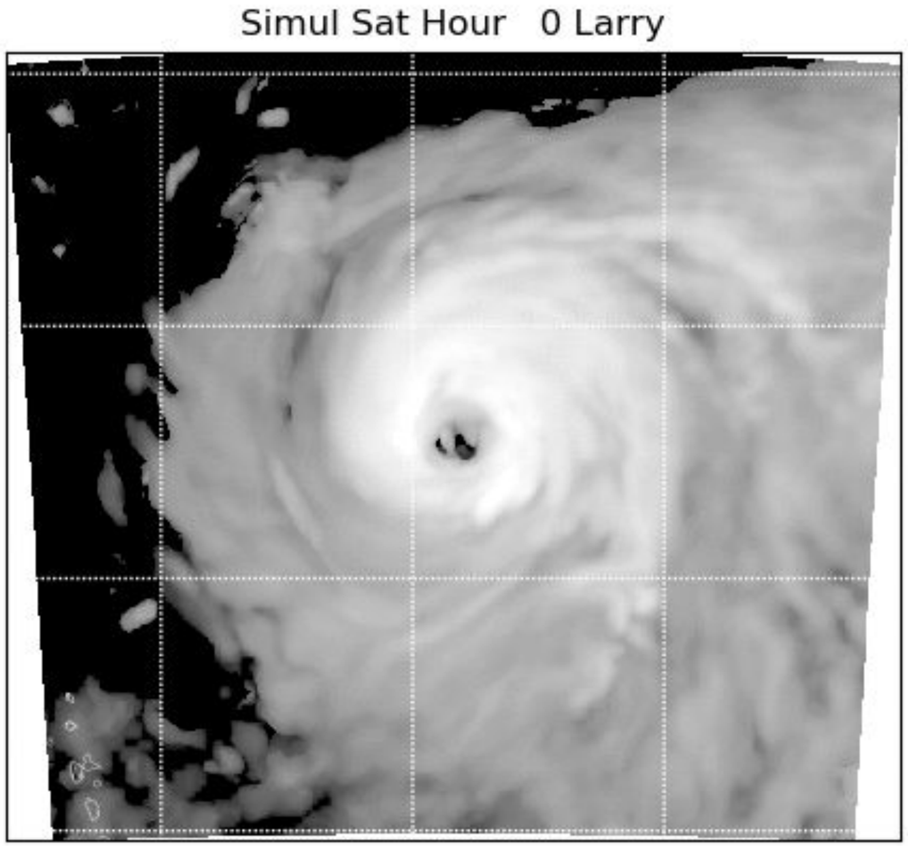




Shifting of Atmospheric and Surface Fields

Model Variable Motion

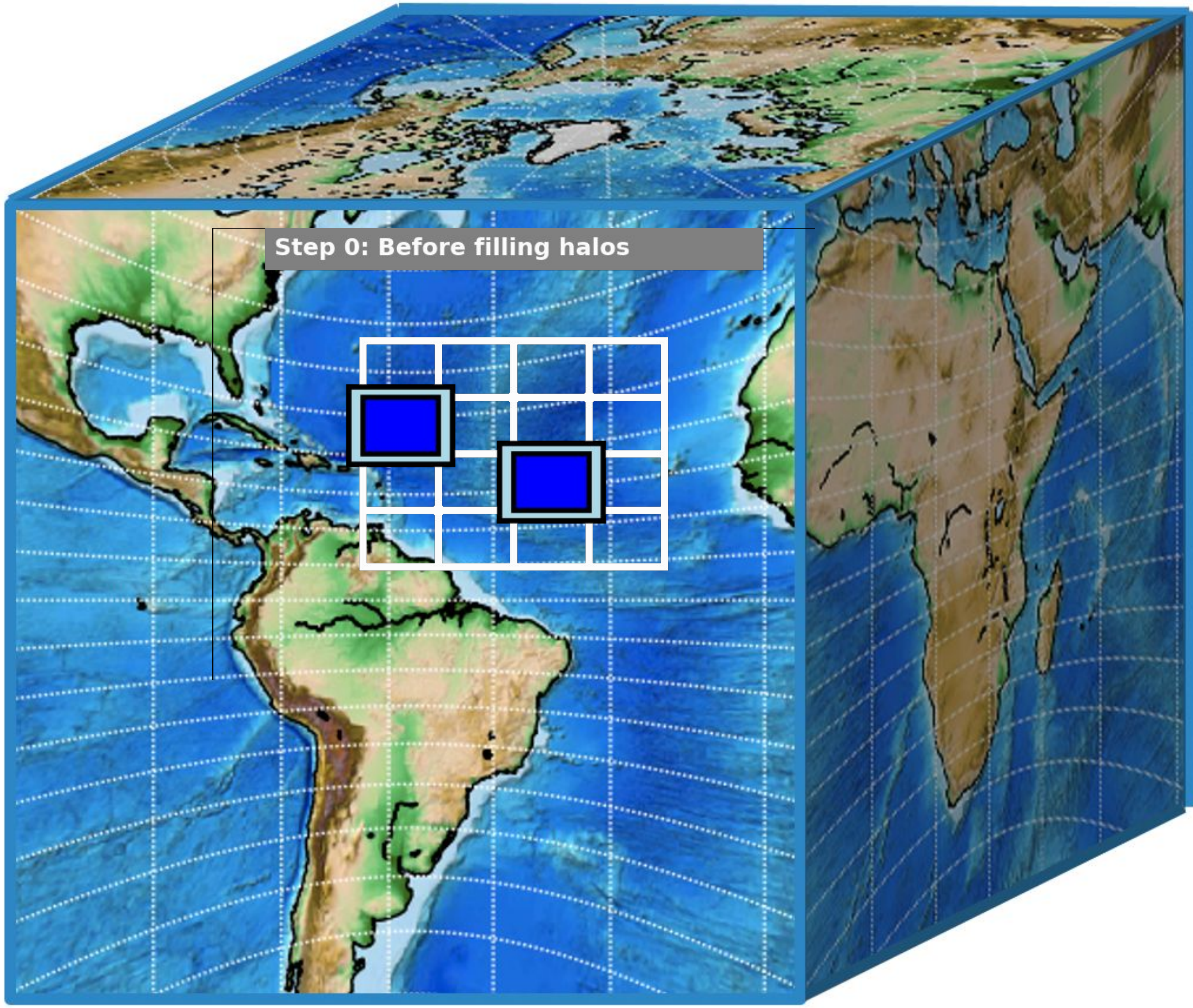
- Prognostic
  - T, delz, pressure, u & v wind, humidity, tracers
- Physics
  - 56 separate variables
  - 1D vectors
- Terrain and static surface fields
  - High resolution
  - Nest resolution from files
- Grid distances, areas, Coriolis, etc.
  - Calculated at 64 bit precision from lat/lons



Performance Optimization

Moving Nest Features

- NWP can always exploit more CPU resource for higher resolution in horizontal, vertical, timestep, forecast length, ensemble members
- Leveraged several existing fast procedures
    - Field shifts between processors
        - FMS halo infrastructure from GFDL for shifting prognostic and physics fields
    - Field shifts on same processor
        - Fortran intrinsic EOSHIFT for efficient shifting of fields– compiler developers ensure this is fast
- Profiling to meter subsections
- Optimize algorithms in slower subsections
- Overhead went from >30% to <7%



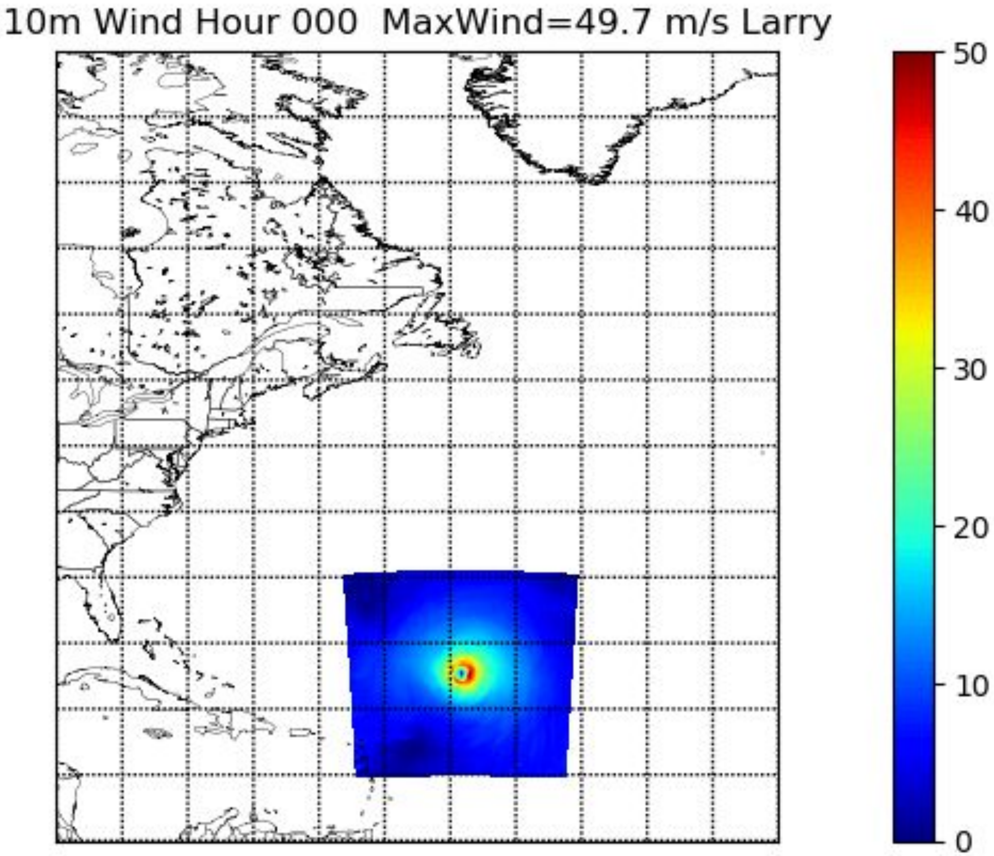
Real Time Runs

Real time Experiments

- Begin August 1, 2022
- 2 regional configurations
- Ocean coupling, VI, DA
- EMC real time
- HRD real time
    - Storm-centered
    - Thompson microphysics
    - Basin configuration possible
- Available on https://storm.aoml.noaa.gov

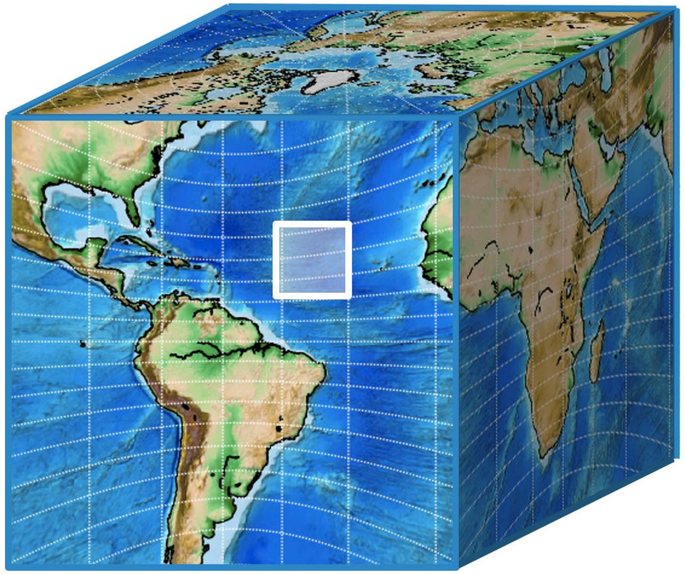
Initial Operational Configuration

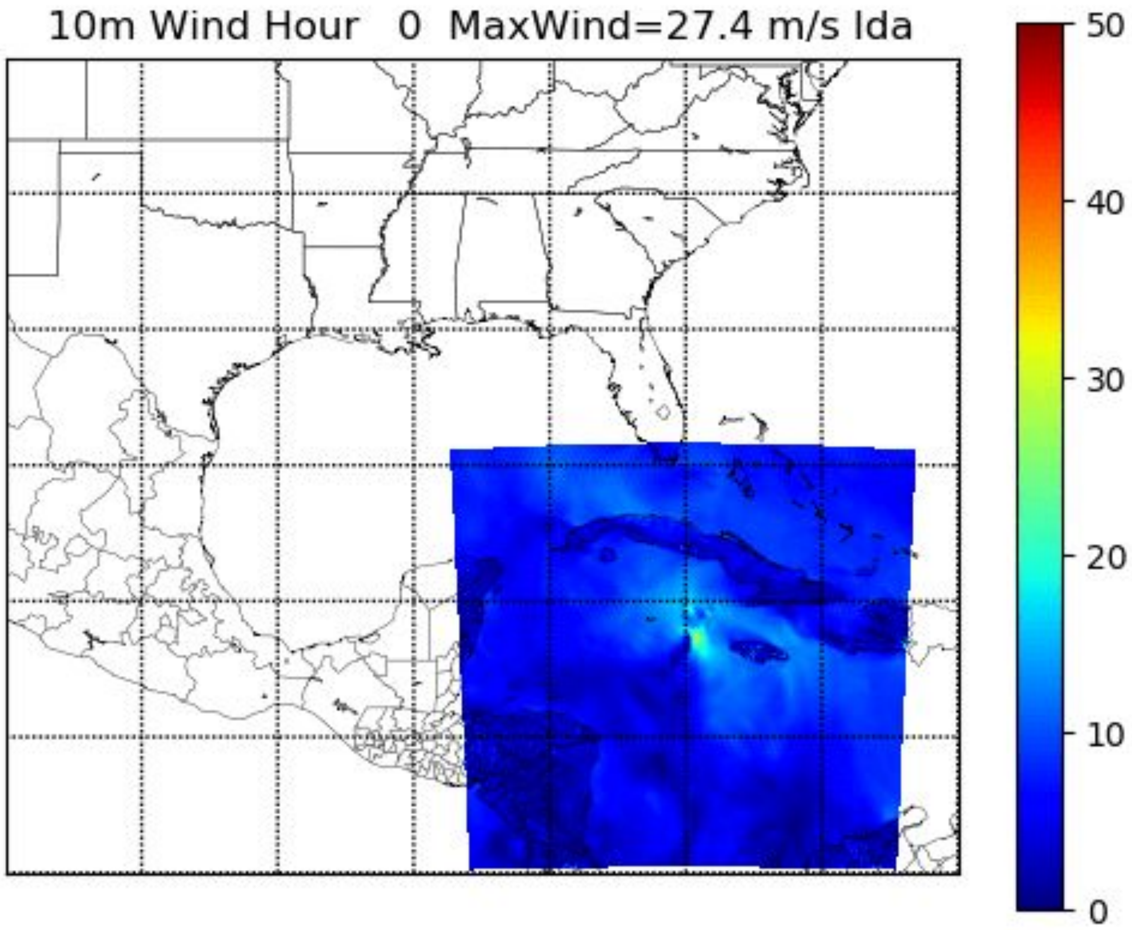
- Code freeze March, 2023
- Operations for summer, 2023



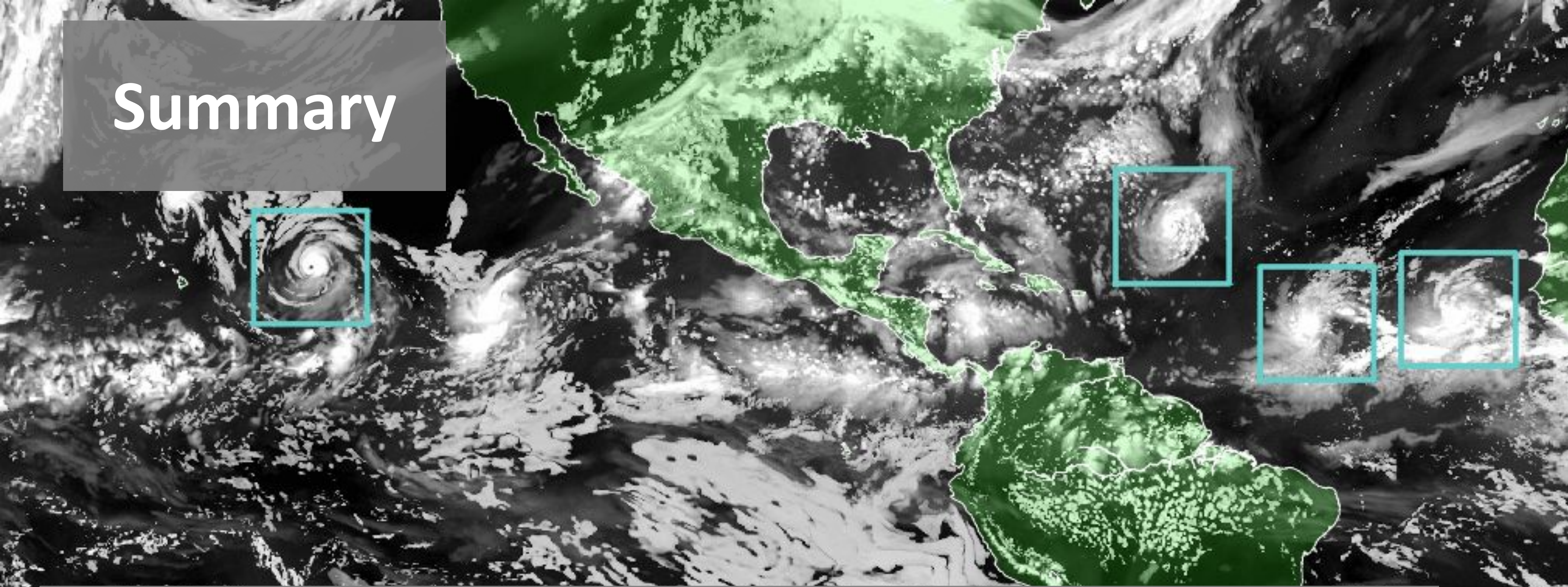
Future Work

- Multiple Moving Nests
  - Regional and Global
- Flexible Refinement Ratios
  - 4X and higher
  - FV3 dycore permits odd and even multiples
- Edge crossing for global cubed sphere





Summary



- Moving nest functionality for atmospheric, surface, and physics variables is now integrated into FV3 dynamic core
- Track accuracy statistics beating 2021 HWRF and HAFS
- Intensity accuracy statistics from cold-start competitive with warm-start 2021 HWRF and HAFS
- Very efficient – Runtime overhead 3%-7% compared with 15%-20% for HWRF
- Aiming to run 2 regional configurations in real time experiments this summer
- Planned to be operational in Summer, 2023

Acknowledgements

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- NOAA Hurricane Forecast Improvement Project.