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

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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 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
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