ESRL Global Model Research & Development for Weather and Climate Predictions

Dr. Jin-Luen Lee
March 9-12, 2010
Weather Forecast
(Initial Boundary Value Problem)

0~2 weeks
Non-Hydrostatic
Limited Area Models

Climate Projection
(Forcing Problem)
decadal, millennia
Hydrostatic Global Models

- Lateral Boundary Limitation
- Inadequate GCM Cumulus Parameterizations
Weather Forecast (Initial Boundary Value Problem)

| 0~2 weeks |
| Non-Hydrostatic Limited Area Models |

Climate Projection (Forcing Problem)

decadal, millennial
Hydrostatic Global Models

Unified Approach: Global Cloud Resolving Model (GCRM)

- GCRM to “Explicitly Resolve” Tropical Convective Cloud Systems
- Lateral Boundary Limitation
- Inadequate GCM Cumulus Parameterizations
OLR Hovmoller Showing MJO Simulation

NICAM dx=3.5 km
(Non-hydrostatic ICosahedral Atmospheric Model)

DX7 average(10S–10N)

16DEC2006-
21DEC2006-
26DEC2006-
1JAN2007-
6JAN2007-
11JAN2007-

MTSAT TBB

250  270  290

Courtesy of Prof. Satoh (Science, Dec. 7, 2007)
• Near constant resolution over the globe
• Efficient high resolution simulations
ESRL Finite-volume Icosahedral Models

1. **FIM (Flow-following Finite-volume Icosahedral Model):**
   - a hydrostatic model for weather applications
   - close collaboration with NCEP for global model ensembles as an ensemble member

2. **NIM (Non-hydrostatic Icosahedral Model):**
   - a non-hydrostatic global cloud resolving model for weather and climate applications
   - collaboration with GFDL, CSU, NCAR, and others
Novel Features of FIM/NIM:

- **Finite-Volume Integrations on Local Coordinate**

Lee and MacDonald (*MWR, 2009*): A Finite-volume Icosahedral Shallow Water Model on Local Coordinate.
Novel Features of FIM/NIM:

- Finite-volume Integrations on *Local Coordinate*
- Conservative and Monotonic Adams-Bashforth 3\textsuperscript{rd}-order FCT Scheme
  - Lee, Bleck, and MacDonald (2010, JCP): A Multistep Flux-Corrected Transport Scheme (in review).
  - AB3-MFCT extends Zalesak’s (1979) two-time level to multiple time levels.
Novel Features of FIM/NIM:

- Finite-volume Integrations on *Local Coordinate*.
- Conservative and Monotonic Adams-Bashforth 3\textsuperscript{rd}-order FCT Scheme
- Efficient Indirect Addressing Scheme on Irregular Grid
  - MacDonald, Middlecoff, Henderson, and Lee (2010, IJHPC): A General Method
    for Modeling on Irregular Grids (in review).
Novel Features of FIM/NIM:

- Finite-volume Integrations on *Local Coordinate*.
- Conservative and Monotonic Adams-Bashforth 3\(^{rd}\)-order FCT Scheme
- Efficient Indirect Addressing Scheme on Irregular Grid
- Grid Optimization for Efficiency and Accuracy
    on Sphere (minor revision).
Novel Features of FIM/NIM:

- Finite-volume Integrations on *Local Coordinate*.
- Conservative and Monotonic Adams-Bashforth 3\(^{rd}\)-order FCT Scheme
- Efficient Indirect Addressing Scheme on Irregular Grid
- Grid Optimization for Efficiency and Accuracy
    on Sphere (minor revision).
Novel Features of FIM/NIM:

- Finite-volume Integrations on Local Coordinate
- Conservative and Monotonic Adams-Bashforth 3$^{rd}$-order FCT Scheme
- Efficient Indirect Addressing Scheme on Irregular Grid
- Grid Optimization for Efficiency and Accuracy
- FIM: Hybrid $\sigma$-$\theta$ Coordinate w/ GFS Physics
Novel Features of FIM/NIM:

- Finite-volume Integrations on *Local Coordinate*.
- Conservative and Monotonic Adams-Bashforth 3rd-order FCT Scheme
- Efficient Indirect Addressing Scheme on Irregular Grid
- Grid Optimization for Efficiency and Accuracy
- FIM: Hybrid $\sigma$-$\theta$ Coordinate w/ GFS Physics
- Novel Features of NIM:
  - Use of Three-dimensional Control Volume in Height Coordinate
  - 3-D Volume Integration w/o Terrain Transformation Terms to Improve PGF Accuracy
  - An Explicit Riemann Solver to Resolve Vertically Propagating Acoustic Wave
  - Dynamical Design to Utilize Fast Graphic Processing Unit (GPU) to Speed up Calculations
Novel Features of FIM/NIM:

- Finite-volume Integrations on Local Coordinate.
- Conservative and Monotonic Adams-Bashforth 3rd-order FCT Scheme
- Efficient ilrect Addressing Scheme on Irregular Grid
- Grid Optimization for Efficiency and Accuracy
- FIM: Hybrid σ-θ Coordinate w/ GFS Physics
- Novel Features of NIM:
  - Use of Three-dimensional Control Volume in Height Coordinate
  - 3-D Volume Integration w/o Terrain Transformation Terms to Improve PGF Accuracy
  - An Explicit Riemann Solver to Resolve Vertically Propagating Acoustic Wave
  - Dynamical Design to Utilize Fast Graphic Processing Unit (GPU) to Speed Up Calculations

Research leads to operational technology transfer

- FIM Achieves Comparable Weather Forecast Scores as GFS
- FIM Successfully Improves Hurricane Forecasts
72-h
250-hPa
Wind
RMS
vector
error (vs. analyses)
smaller is better

FIM – _________
GFS ___________
GSI init conds
EnKF init conds

FIM much better than GFS
EnKF IC adds further accuracy
Final Remarks and Future Outlook

• A hydrostatic Flow-following Icosahderal Finite-volume Model, FIM, has been developed, tested and prepared for operational NCEP global model ensemble systems.

• A Non-hydrostatic Icosahderal Finite-volume Model, NIM, has been developed and tested w/ meso-scale benchmarks.

• Future NIM applications for intra-seasonal predictions, and hurricane intensity forecasts.

*Relevant to NOAA climate predictions and projections mission: Improving intra-seasonal and inter-annual climate forecasts.