The Worldwide, Federated FV3 Community

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25 July 2023

FV3 and SHiELD development are principally funded by the NOAA Global-Nest Initiative
https://www.gfdl.noaa.gov/noaa-research-global-nest-initiative/
FV3 The GFDL Finite-Volume Cubed-Sphere Dynamical Core

FV3 is the fluid solver ("engine") for a community of atmosphere models
★ Accurate, physical numerics
★ Computationally efficient
★ Flexible solver and interface

➔ Timely forecasts
➔ Accelerated development
➔ Ultra high-resolution models
➔ Many applications
Weather, climate, DA, atmospheric chemistry, reanalysis, planetary atmospheres, and more

Carbon dioxide in FV3-based NASA GEOS
https://svs.gsfc.nasa.gov/11719
The Worldwide FV3 Community

Many missions, many models, one dynamical core

NOAA Minutes-to-Millennia
Unified Modeling

Unified Forecast System

GFDL Seamless Modeling Suite

GEOS-Chem
GEOS-Chem High Performance

CAM-FV
CAM-FV3

LASG FAMIL, F- GOALS

Taiwan Central Weather Bureau
CWBGFS

Chinese Academy of Sciences
FV3 Reference Information

FV3 Documentation and References

Disclaimer: We have made every effort to ensure that the information here is as accurate, complete, and as up-to-date as possible. However, due to the very rapid pace of FV3 dynamical core and FV3-powered model development, these documents may not always reflect the current state of FV3 capabilities. Often, the code itself is the best description of the current capabilities and the available options, which due to limited space cannot all be described in full detail here. We strongly recommend anyone who wishes to understand FV3 in more detail to read and study the articles linked below. Contact GFDL FV3 Dycore support or GFDL SHIELD/IAFS model support for assistance and more information.

FV3 Scientific Documentation:
- GFDL Technical Note GFDL202101 (July 2021):
  - Official Release on the NOAA Institutional Repository
  - Source, updates, and examples on GitHub

Tutorial Presentations:

Key Journal Articles (many now open access):
- Lin, Chao, Sud, and Walker, 1994: Van Leer transport scheme
- Lin and Rodd 1996: FV advection scheme
- Lin and Rodd 1997: FV lat-lon shallow-water model
- Lin 1997: FV pressure-gradient force formulation
- Lin 2004: The latitude-longitude PV core
- Putman and Lin 2007: FV3 cubed-sphere advection

Documentation on FV3 Portal:
www.gfdl.noaa.gov/fv3/fv3-documentation-and-references/
FV3 Community GitHub

Official site for FV3 releases, examples, issue tracking, code submissions, documentation, and more

Examples directory: Jupyter notebooks demonstrating FV3 capabilities. Updates released regularly.
R2O: Improving Hurricane Forecasts

2017 TC Track Error (lower is better)

- Euro
- Legacy US GFS
- GFDL SHIELD
- SHIELD + Euro data

Better Model
Better Data

Chen et al. (2019 GRL)

2021-2022 Mean Atlantic TC Track Error

Operational Transition + Improved DA

See also J-H Chen et al (2023, Earth Space Sci) for DIMOSIC intercomparison

Courtesy Kun Gao and Jan-Huey Chen
Advances in continental convection prediction

Revised advection (hord=5) and new GFDL MP v3 greatly reduce heavy precipitation biases and improve storm structure

Courtesy Kai Cheng and Linjiong Zhou, Princeton CIMES

CAPS Radar DA in UFS SRW significantly improves convective-scale hazard prediction

OU CAPS w/ EMC & GSL—courtesy Chengsi Liu and Ming Xue
See Jun Park’s poster on Thursday
Improved MJO Forecasts with FV3’s Grid Nesting

GFDL SPEAR and SHiELD get 25+ days of MJO at 100-50-25 km resolution. Higher resolution gives better forecasts.

AOML & GFDL Collaboration: 40-day runs during DYNAMO

Maritime Continent nest gives a full **39 days** of useful predictability!

Enhanced resolution improves precipitation and diurnal cycle over Maritime Continent
Global Storm-Resolving Modeling

3.25-km GFDL X-SHiELD and NASA GEOS latest FV3-based GSRMs—big wins with FV3 accuracy and efficiency.

Unprecedented years-long simulations in current & warmed climates for effect on convection, water resources, clouds, etc.

Allen Institute for AI trains ML with X-SHiELD output to correct 200-km FV3GFS ⇒ Much improved precipitation, land diurnal cycle, and Tsfc—at 10000x less cost.

Shift in intense convection under warming in year-long X-SHiELD simulations (O(10^8) updrafts)

Cheng et al. 2022, GRL

ML-Corrected 200-km FV3GFS Baseline

Courtesy Chris Bretherton (AI2 & UWashington) Bretherton et al. (2022, JAMES) and Kwa et al. (2023, JAMES)
“There’s plenty of room at the bottom”: towards sub-k-scale Tornado-like vortices in super-stretched 1-km domain.

Convection is fully resolved at ∆x = 250 m as per G. Bryan, NCAR

Weakly-forced convection in Radiative-Convective Equilibrium
100s of updrafts: Jeevanjee (2017, JAMES); Jeevanjee and Zhou (2022, JAMES)

1.4 km Tele-SHiELD for hyper-local impacts
Courtesy Jan-Huey Chen

LES experiments: 35-m forced shallow convection
FV3 Ongoing Development

- Advanced telescoping, moving, and vertical nesting (GFDL, AOML & EMC)
  - See Bill Ramstrom’s talk this session
- New numerics: Duo-Grid & LMARS (GFDL) and numerics upgrades (GFDL & EMC)
  - See Joseph Mouallem’s talk this session
  - Saw Kun Gao’s talk in HAFS session
- Super-regular regional domain (EMC)
  - See Jim Purser’s talk this session
- OpenACC (UWyoming) and GT4Py for performance portability (GFDL, GMAO, et al.)
  - See Oliver Elbert’s talk in System Architecture session
- Whole & Deep Atmospheres (EMC & SWPC)
- FV3 Integrated Physics (GFDL, AOML, EMC)
- Subgrid turbulence (GFDL, Clemson, FIU, AOML)
  - See Ping Zhu’s talk this session
- GitHub CI/CD (GFDL)
- FV3 Adjoint (GMAO & JSCDA)
- FV3net ML + Python Wrapper (AI2)
- ...
On Community and Cooperation

- The worldwide FV3 community has been a great opportunity to bring together some of the best model developers in the world.
- FV3’s flexibility, accuracy, and efficiency enable many different applications.
  - Portable nature of FV3 enable development of models tailored for each mission.
- FV3 crosses all scales, allowing exchange of innovations and accelerating development.
- There is a lot to learn from cooperation with other modeling efforts
  - ECMWF, UKMO, SCREAM (see Paul Ullrich’s talk next)
- Community is a two-way street

“A key element that makes collaborations successful is having individuals who enjoy working together and are able to do so.”—Morris Bender, BAMS 2019
There are no shortcuts around quality, and quality starts with people” — Steve Jobs

THE WEATHER MASTER

How Shian-Jiann Lin's atmospheric grids could unify weather forecasts and climate models

By Paul Vosen

Thanks to GFDL Modeling Systems and collaborators at EMC, AOML, Princeton CIMES, OU CAPS, and the Allen Institute for AI