The Worldwide, Federated FV3 Community

Lucas Harris
For the GFDL FV3 Team

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/

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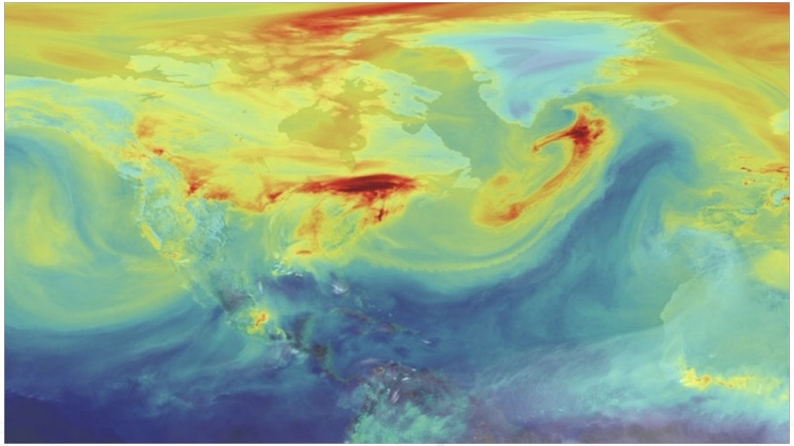
FV3 The GFDL Finite-Volume Cubed-Sphere Dynamical Core

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

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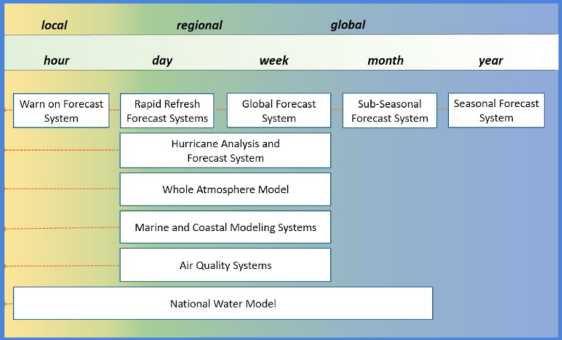
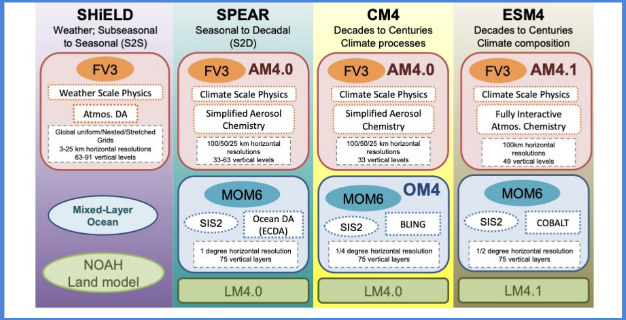
The Worldwide FV3 Community

Many missions, many models, one dynamical core

NOAA Minutes-to-Millennia Unified Modeling



Unified Forecast System



GFDL Seamless Modeling Suite

GEOS, MERRA
Ames Mars GCM

GEOS-Chem
GEOS-Chem High Performance

CAM-FV
CAM-FV3

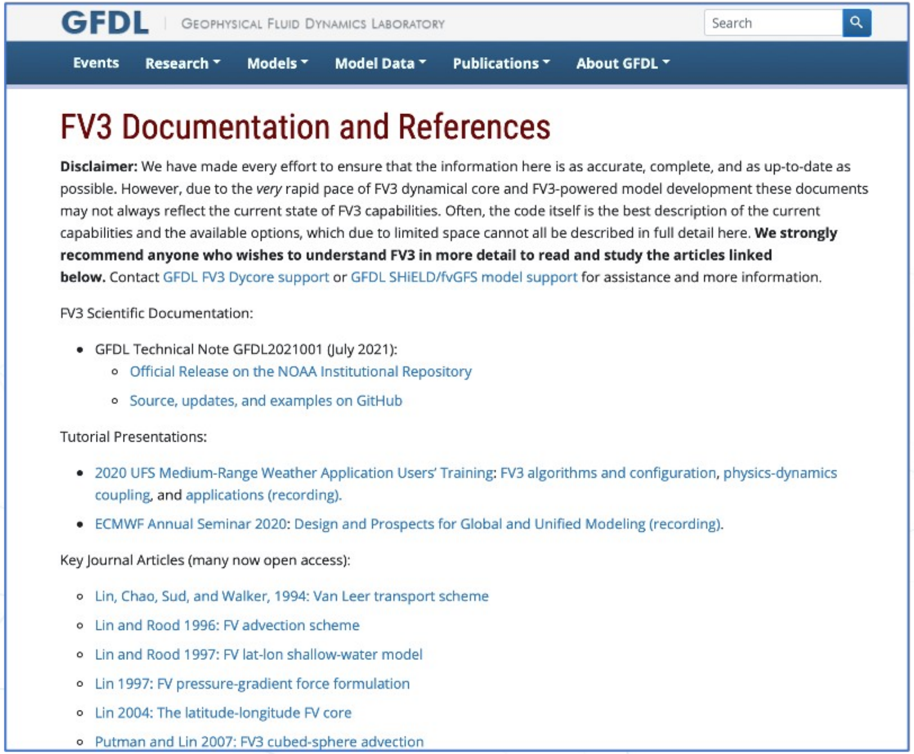
Taiwan Central Weather Bureau

CWBGFS

Chinese Academy of Sciences

LASG FAMIL, F-GOALS

FV3 Reference Information



GFDL | Geophysical Fluid Dynamics Laboratory

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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/fvGFS model support for assistance and more information.

FV3 Scientific Documentation:

- GFDL Technical Note GFDL2021001 (July 2021):
  - Official Release on the NOAA Institutional Repository
  - Source, updates, and examples on GitHub

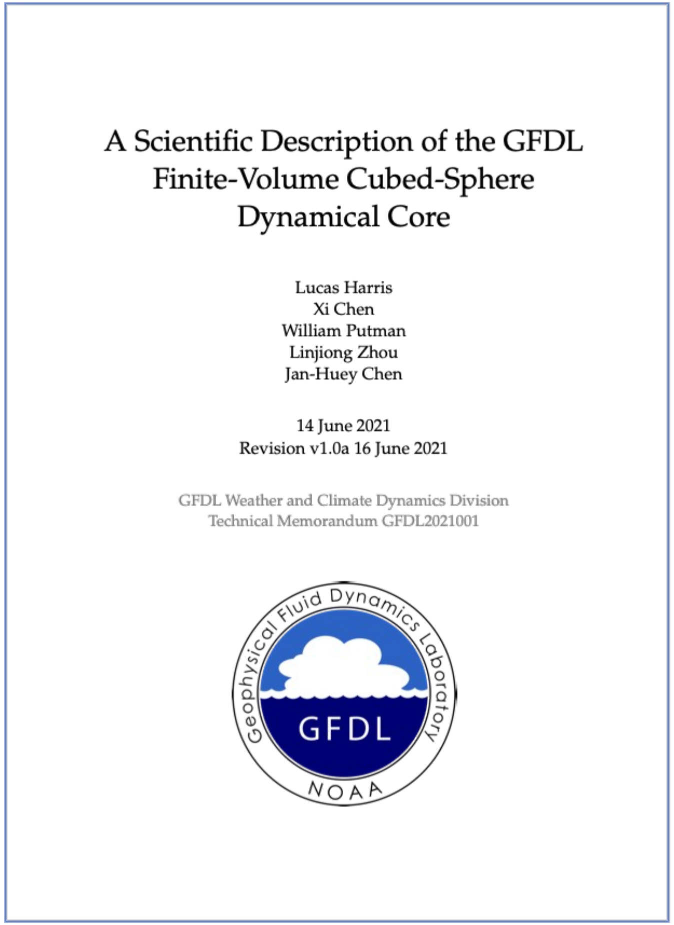
Tutorial Presentations:

- 2020 UFS Medium-Range Weather Application Users' Training: FV3 algorithms and configuration, physics-dynamics coupling, and applications (recording).
- ECMWF Annual Seminar 2020: Design and Prospects for Global and Unified Modeling (recording).

Key Journal Articles (many now open access):

- Lin, Chao, Sud, and Walker, 1994: Van Leer transport scheme
- Lin and Rood 1996: FV advection scheme
- Lin and Rood 1997: FV lat-lon shallow-water model
- Lin 1997: FV pressure-gradient force formulation
- Lin 2004: The latitude-longitude FV core
- Putman and Lin 2007: FV3 cubed-sphere advection

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



A Scientific Description of the GFDL Finite-Volume Cubed-Sphere Dynamical Core

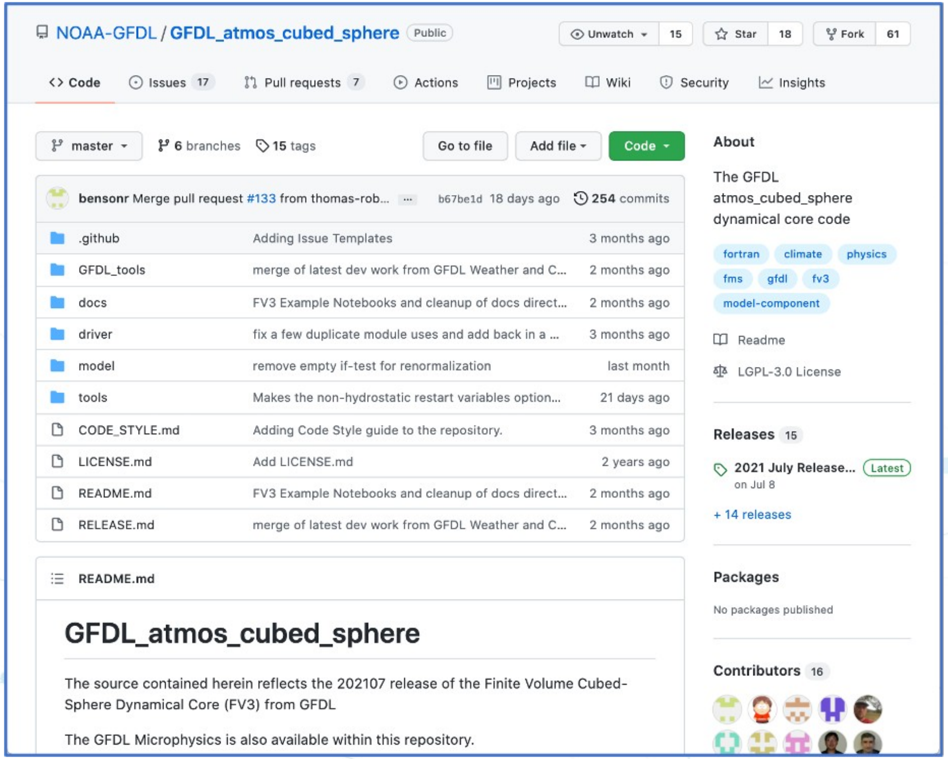
Lucas Harris
Xi Chen
William Putman
Linjiong Zhou
Jan-Huey Chen

14 June 2021
Revision v1.0a 16 June 2021

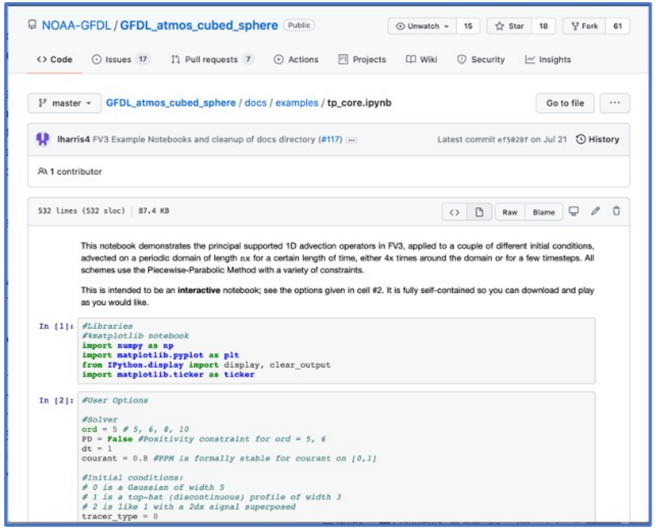
GFDL Weather and Climate Dynamics Division
Technical Memorandum GFDL2021001

Harris et al. (2021)
109-page FV3 Scientific Documentation
on GitHub and NOAA Institutional Repository

FV3 Community GitHub



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

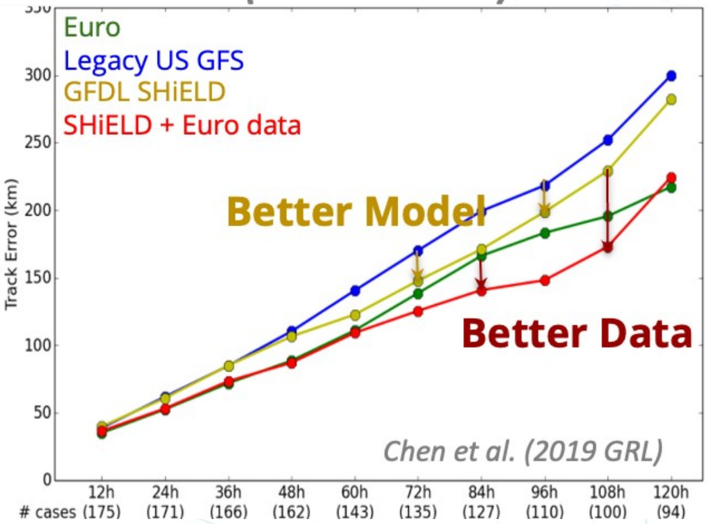


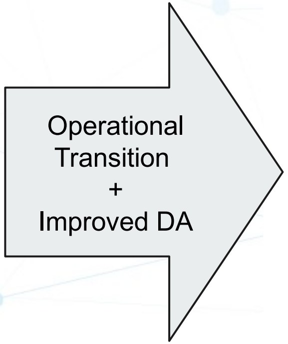
github.com/NOAA-GFDL/GFDL_atmos_cubed_sphere

Examples directory: Jupyter notebooks demonstrating FV3 capabilities.
Updates released regularly.

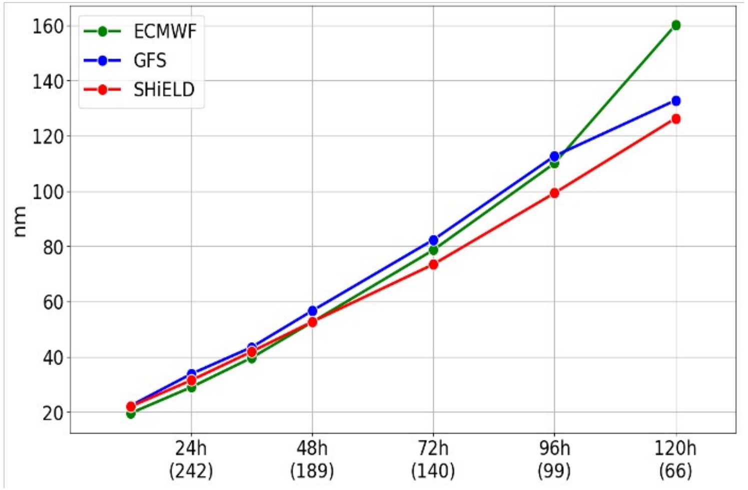
R2O: Improving Hurricane Forecasts

2017 TC Track Error
(lower is better)





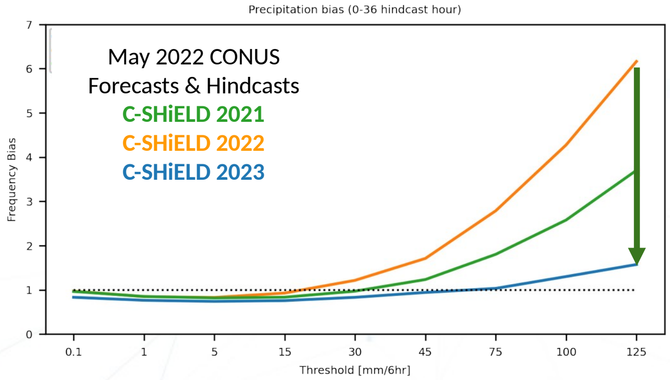
2021-2022
Mean Atlantic TC Track Error



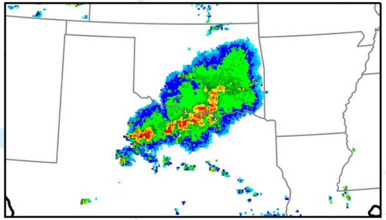
Courtesy Kun Gao and Jan-Huey Chen

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

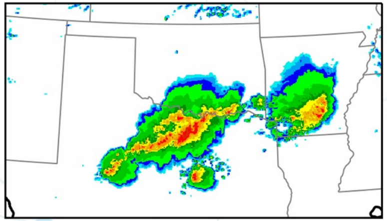
Advances in continental convection prediction



OBS Radar
23Z 1 May 2019

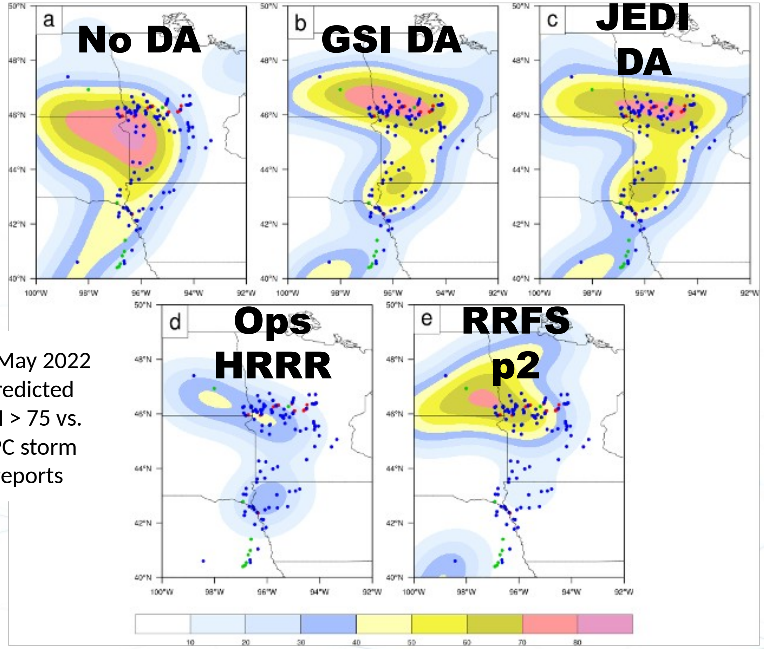


C-SHiELD 2023
00 1 May 2019 + 23h



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



13 May 2022 predicted UH > 75 vs. SPC storm reports

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

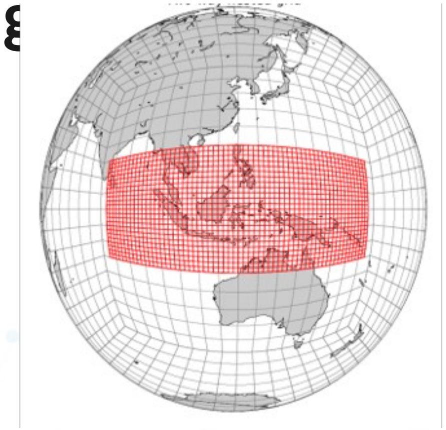
GFDL SPEAR and SHiELD get 25+ days of MJO at 100-50-25 km resolution. Higher resolution gives better forecasts.

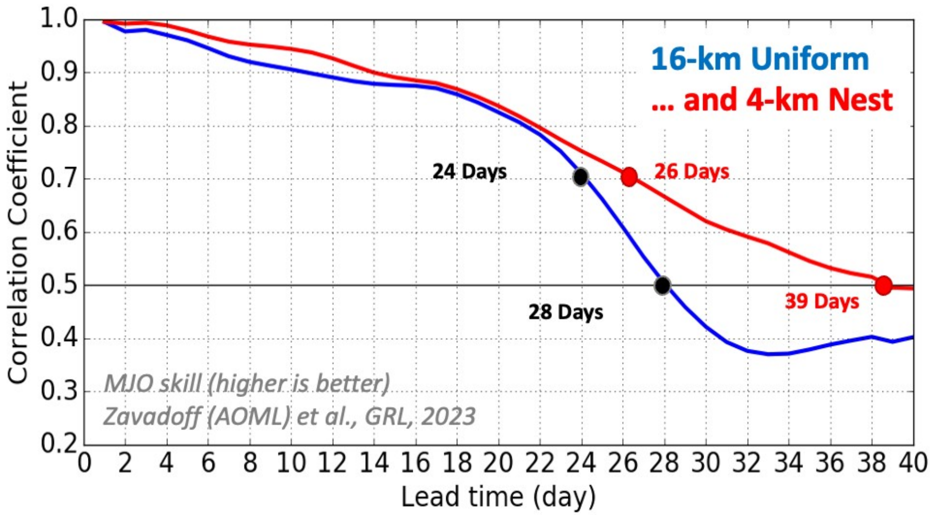
AOML & GFDL Collaboration:
40-day runs during DYNAMO

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

Enhanced resolution improves precipitation and diurnal cycle over Maritime Continent

SHiELD global 16-km grid
4-km Maritime Continent nest
40-days in 8 hours with 4K Gaea cores



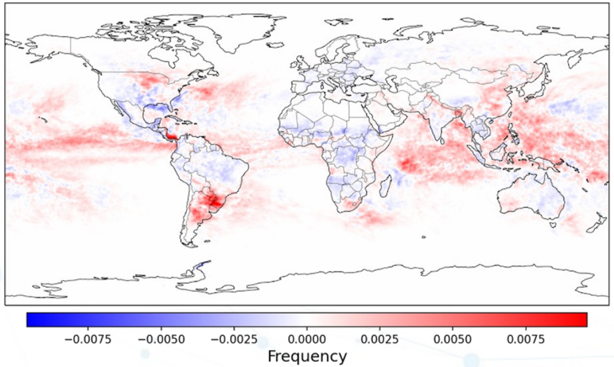


Global Storm-Resolving Modeling

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

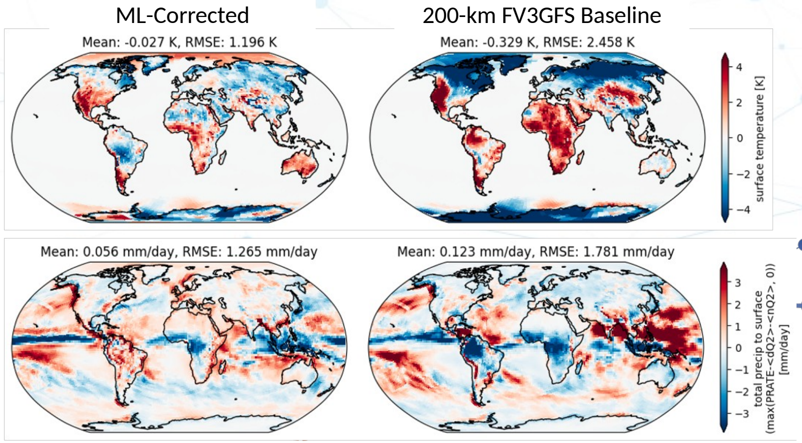
Unprecedented years-long simulations in current & warmed climates for effect on convection, water resources, clouds, etc.

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.



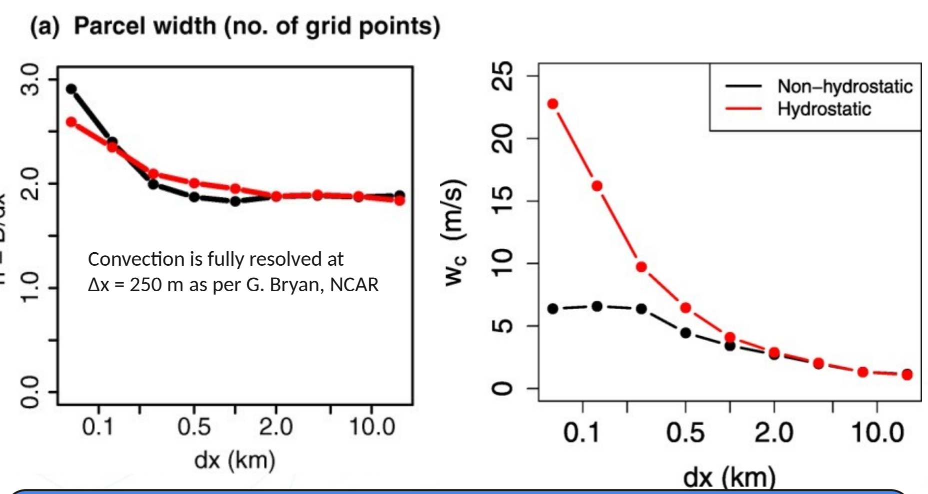
Shift in intense convection under warming in year-long X-SHiELD simulations ($O(10^8)$ updrafts)

Cheng et al. 2022, GRL

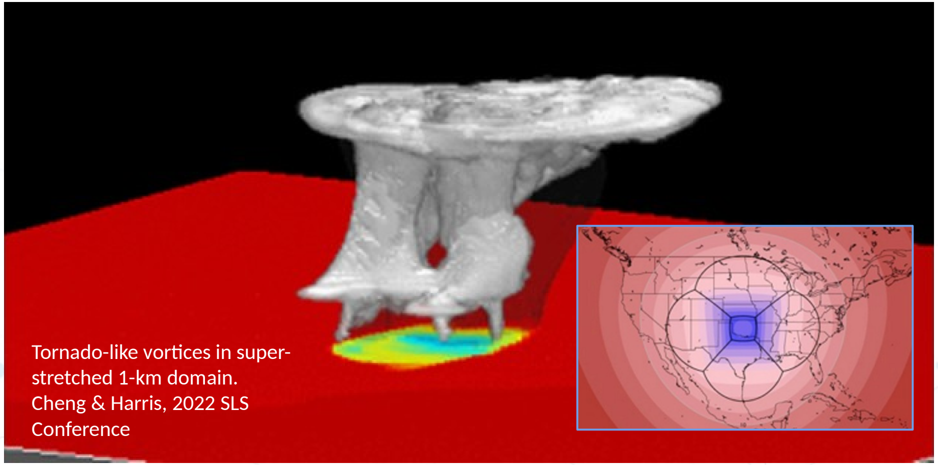


Courtesy Chris Bretherton (AI2 & UWashington)
Bretherton et al. (2022, JAMES) and Kwa et al. (2023, JAMES)

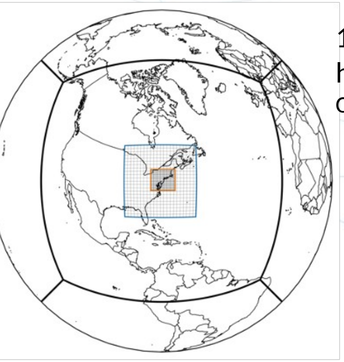
“There’s plenty of room at the bottom”: towards sub-k-scale



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

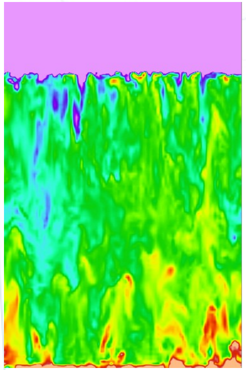


Tornado-like vortices in super-stretched 1-km domain. Cheng & Harris, 2022 SLS Conference



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

LES experiments:
35-m forced shallow convection



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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)
- …

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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

THE WEATHER MASTER

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

By **Paul Voosen**

Downloaded from http://science.sciencemag.org/ on October 4, 2019

"There are no shortcuts around quality, and quality starts with people" — Steve Jobs

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