Synergistic and Collaborative Development Strategies for FV3 Powered Next Generation Unified Global Modeling System

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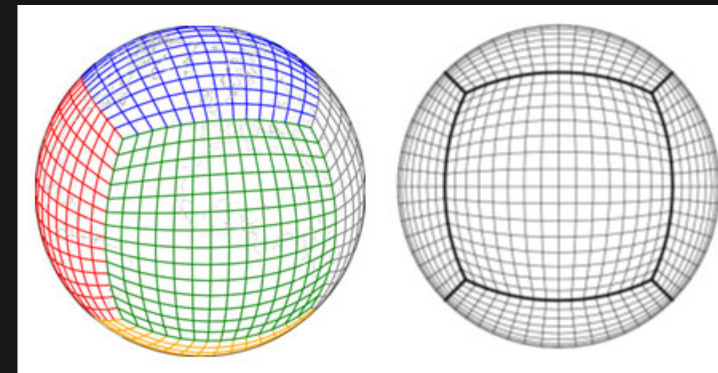
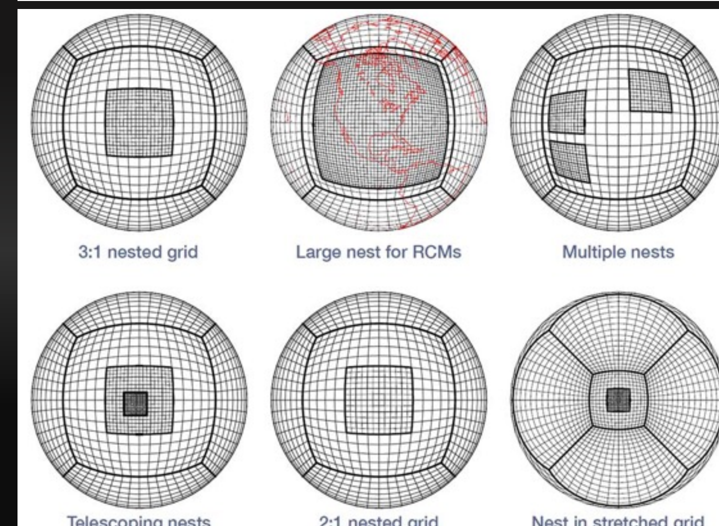
Finite-Volume Cubed-Sphere Dynamical Core





Finite-Volume transport on a Lat-Lon grid for chemistry transport

Multidimensional Flux-Form Semi-Lagrangian Transport Schemes

Lin and Rood, 1996

Shallow water model development

An Explicit Flux-Form Semi-Lagrangian Shallow Water Model on the Sphere

Lin and Rood, 1997

Full 3-dimensional hydrostatic dynamical core

A finite-volume integration method for computing pressure gradient force in general vertical coordinates

Lin, 1997

Vertically Lagrangian discretization

A "Vertically Lagrangian" Finite-Volume Dynamical Core for Global Models

Lin, 2004

Cubed-Sphere implementation

Finite-volume transport on various cubed-sphere grids

Putman and Lin, 2007

A non-hydrostatic finite-volume algorithm

A control volume model of the compressible Euler equations with a vertical Lagrangian Coordinate

Chen, Lin, and coauthors, 2013

Global to regional nesting

A two-way nested global-regional dynamical core on the cubed-sphere grid

Harris and Lin, 2014

Primary Stakeholders in FV3

GMAO	GFDL	EMC
GEOS	**AM3 CM3 HiRAM**	**GFS GEFS SFS**

GMAO — GEOS

- Data Assimilation
- Weather Prediction
- S2S Prediction
- Reanalysis
- Global Mesoscale

GFDL — AM3 CM3 HiRAM

- Climate (IPCC)
- S2S Prediction
- Weather
- High-Resolution

EMC — GFS GEFS SFS

- Operational DA
- Operational NWP
- S2S Prediction
- Reanalysis
- *Future CAM and CAM Ensembles*
- *Hurricanes, Space Weather, WoF …*

Other Stakeholders in FV3

GISS

modelE

- Climate (IPCC)
- Exo-planets

Harvard

GEOS-Chem

- Chemical Transport
- Composition

ESRL

NGGPS

- Real-time FV3-GFS
- Advanced Physics

NCAR

CESM

- Climate (IPCC)
- Data Assimilation

JEDI

- Data Assimilation

NOAA FV3 Virtual Lab (VLab)

https://vlab.ncep.noaa.gov/web/fv3gfs

VIRTUAL LAB
FV3GFS

Everything

FV3GFS / Home

FV3GFS Version 0 Release

Announcing the Version 0 Release of the FV3GFS!

NOAA users and external partners with NWS Virtual Lab access can view the release information, as well as other developmental details, in the FV3GFS Community.

How to access the FV3GFS Version ...

NON-NOAA USERS

Users outside of NOAA will need to obtain a VLab External Partner Account. To get an external partner account please fill out the FV3GFS External Partner Request Form.

NOAA USERS AND EXTERNAL PARTNERS

FV3GFS VLab community:

VLab **Version 0** Release of FV3 is currently being evaluated for production implementation in GEOS

VLab **Version 1** Release of FV3 Planned for March 2018 (includes GDAS and Post)

Multi-Institutional FV3 Code Management with Git

Shared FV3 component lives in separate Git repos

FV3 exists as a normal subdirectory in GCM

- Most users unaware
- Gatekeepers need extra training
- May require some minor refactoring

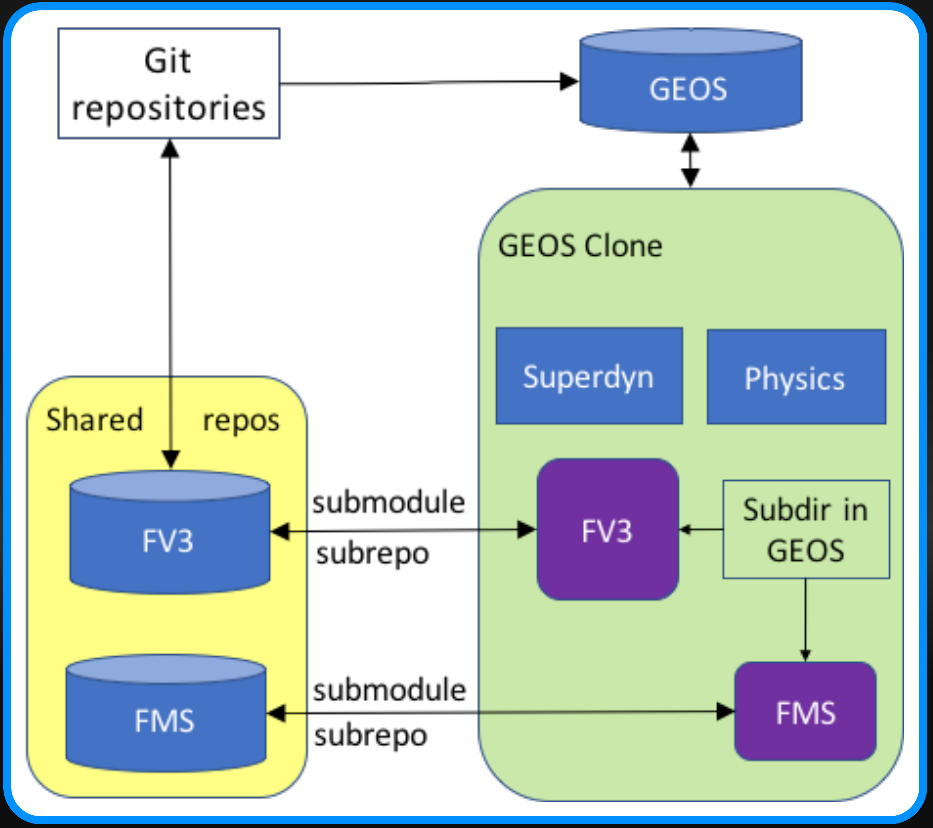
Two variant Git approaches

- Git **submodule**
  - Lightweight – just links are stored
  - Most users should treat subdir as static
- Git **subrepo**
  - Files stored in both repos
  - Unaware users can modify subdir contents

Hosting shared components

- Ideally via a public site (e.g., GitHub)
- But can use read-only clones at each end

Released versions to NOAA VLab



Multi-Institutional Data Assimilation Development

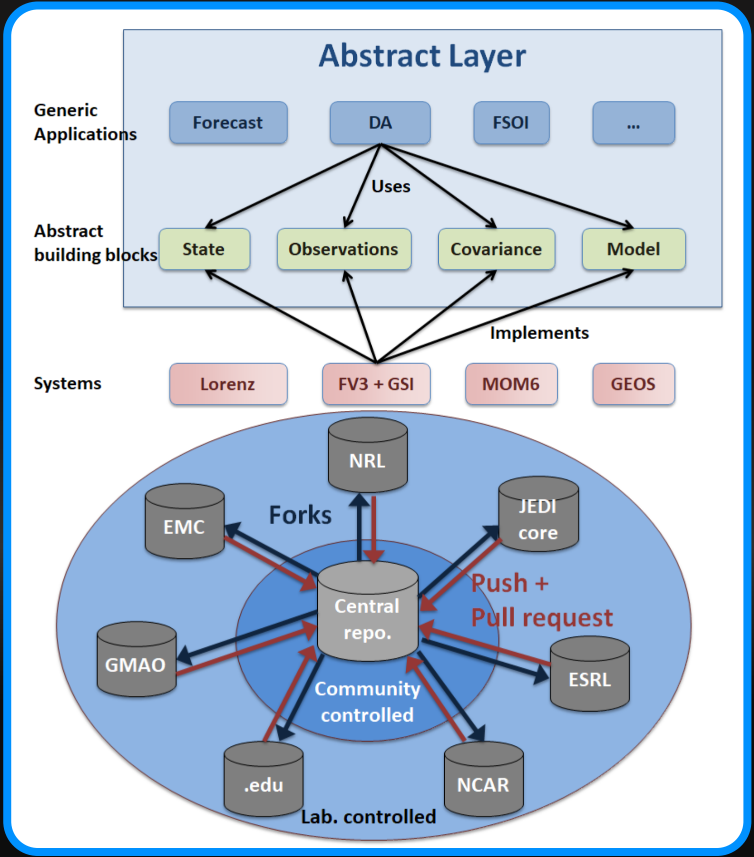
Joint Effort for Data Assimilation Integration (JEDI) Led by JCSDA

JEDI Abstract Design

- Generic applications
- Abstract building blocks
- Unified forward operator (UFO)
- Interface to Observations (IODA)
- 3D and 4D solvers
- Multi-Scale DA
- Coupled DA

Collaborations using Git-Flow Model

- Automated testing framework
- Documentation, training, support



Recent Collaborative Development

FV3 namelist configuration

	NASA (GEOS)		NCEP (GFS)	
Horizontal Resolution	c720 (13 km)	c360 (25 km)	c769 (13 km)	c384 (25 km)
Vertical Resolution	72 (0.01 mb)	72 (0.01 mb)	64 (0.28 mb)	64 (0.28 mb)
DT (s)	225	300	225	300
hydrostatic	T	T	F	F
k_split (vertical remapping steps)	2	1	2	1
n_split (acoustic time steps)	6	12	6	12
CORES (computer)	5400	1944	1536	576
n_sponge (sponge layer & dz-filter)	25	25	10	10
fv_sg_adj (remove 2-dz instability)	450	450	450	450
kord_mt/wz/tr (vertical remap)	9/9/9	9/9/9	9/9/9	9/9/9
hord_mt/vt/t/p/tr (horiz advection)	5/6/6/-6/8	5/6/6/-6/8	6/6/6/-6/8	6/6/6/-6/8
do_vort_damp (vorticity damping)	T	T	T	T

Recent Collaborative Development

32-bit (R4) FV3 Dry Mass Conservation

Original code for pressure update in d_sw:

```
delp(i,j) = delp(i,j) +                                   &
            (fx(i,j)-fx(i+1,j)+fy(i,j)-fy(i,j+1))*rarea(i,j)
```

Updated code for pressure update in d_sw:

```
delp(i,j) = delp(i,j) +                                   &
            ((fx(i,j)-fx(i+1,j))+(fy(i,j)-fy(i,j+1)))*rarea(i,j)
```

Save original surface pressure in fv_dynamics before k_split loop:

```
psx(i,j) = pe(i,npz+1,j)
```

Zero out 64-bit storage for mass update (dpx) in sw_core:

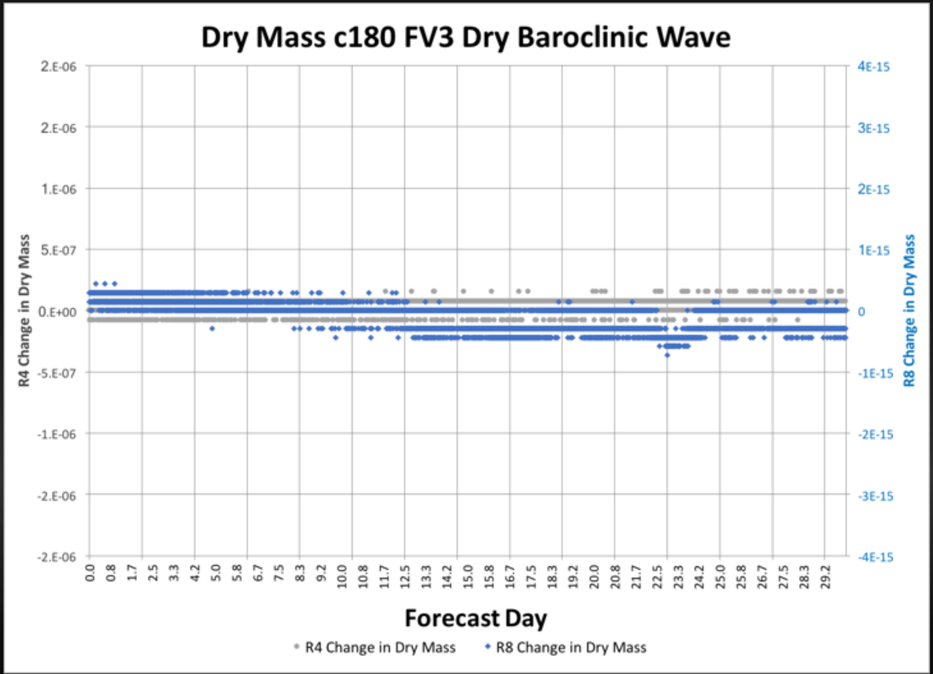
```
dpx(i,j) = 0.0
```

Accumulate mass update in 64-bit (dpx) inside d_sw:

```
dpx(i,j) = dpx(i,j) + ( (fx(i,j)-fx(i+1,j)) + (fy(i,j)-fy(i,j+1)) )*rarea(i,j)
```

Remove roundoff error by replacing PS with R8 accumulated mass update before going into remap:

```
if (last_step) then
   psx(i,j) = psx(i,j) + dpx(i,j)
   pe(i,npz+1,j) = psx(i,j)
endif
```



Recent Collaborative Development

Advanced Vectorization Optimizations in FV3 (GEOS)

Compiler Optimization	Floating Point Optimization	Prec	FV3 (s)	PHYS (s)	GCM (s)
Intel 15 -O3	-fpe0 -fp-model source -ftz -align all -fno-alias	64-Bit	1769	1041	2798
Intel 18 -O3	-fpe0 -fp-model source -ftz -align all -fno-alias	64-Bit	1574	966	2551
Intel 18 -O3 -xCORE-AVX2	-fpe3 -fp-model consistent -ftz -align all -fno-alias -fma	64-Bit	1214	884	2107
Intel 18 -O3 -xCORE-AVX2	-fpe3 -fp-model consistent -ftz -align all -fno-alias -fma	32-Bit	859	896	1771
Intel 18 -O3 -xCORE-AVX2	-fpe3 -fp-model fast=2 –no-prec-div -ftz -align all -fno-alias -fma	64-Bit	1184	793	1992
Intel 18 -O3 -xCORE-AVX2	-fpe3 -fp-model fast=2 –no-prec-div -ftz -align all -fno-alias -fma	32-Bit	800	792	1602

c720 72 Level 1-Day GEOS Benchmark on 1536 Cores

Recent Collaborative Development

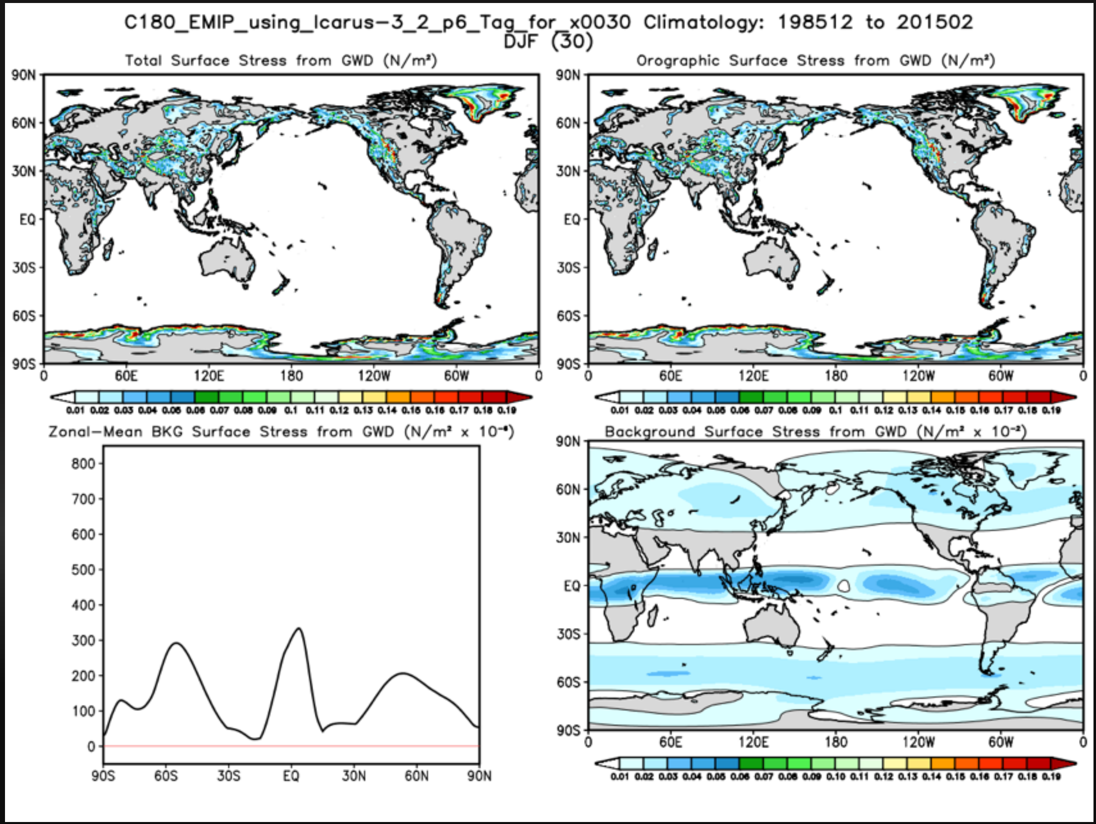
Gravity Wave Drag – GFS and GEOS Unification

GMTED topography/variances
GTOPO30 patch for Antarctica

GEOS Currently uses
Orographic: McFarlane, 1987
Non Orographic: Garcia & Boville, 1994
Form Drag: Beljaars et al, 2004

GFS Scheme
Orographic: Alpert et al. 1988
Mountain Blocking: Lott and Miller, 1997
Convective: Chun and Baik, 1998

Increasing Vertical Resolution
GFDL GWD Unification
QBO Impacts



Recent Collaborative Development

Advanced physics development around FV3

Implementation using Interoperable Physics Driver (IPDv4)

Scale aware convection parameterization *(Grell Freitas)*

Shallow convection parameterization *(UW, Bretherton)*

2-Moment cloud microphysics *(Morrison, Gettelman, Barahona)*

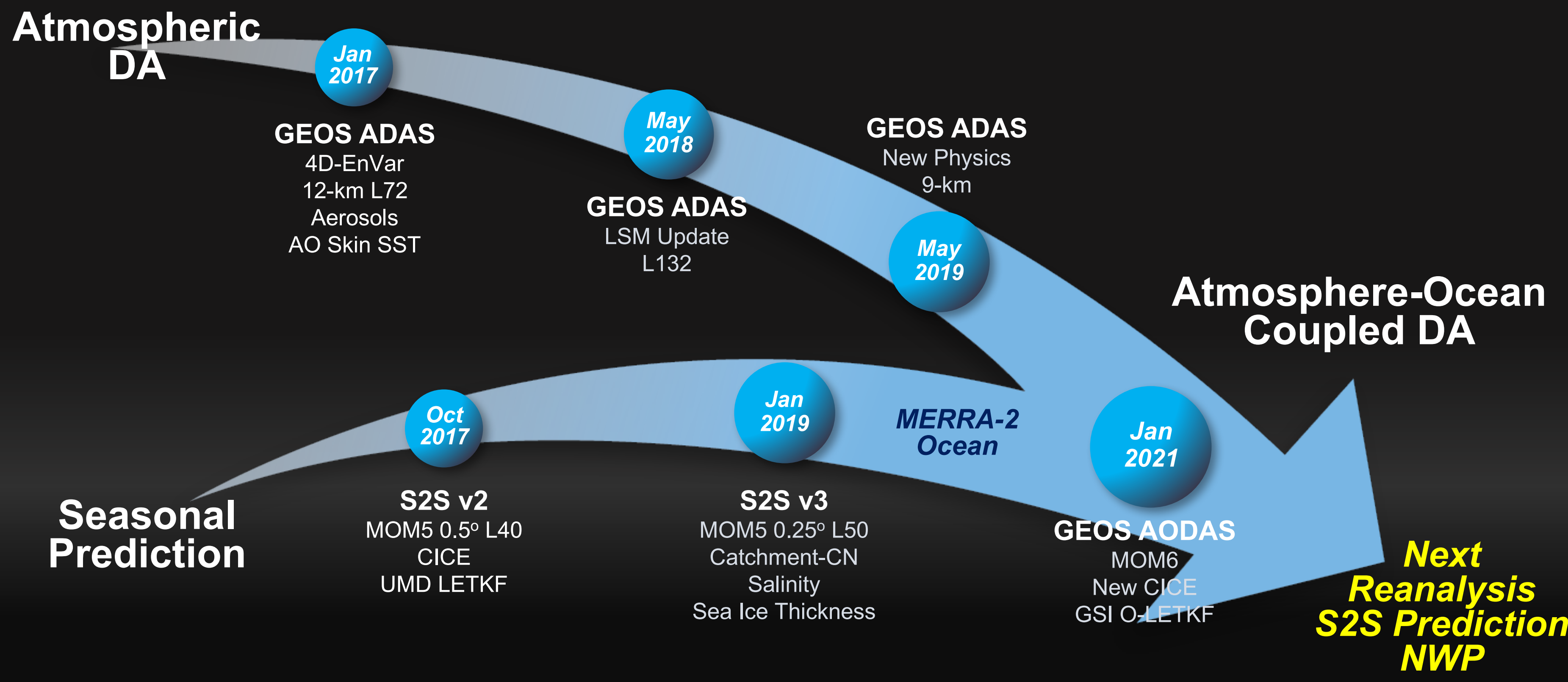
Warm cloud microphysics *(Thompson or Lin)*

Aerosol aware cloud microphysics *(MAM)*

Turbulence *(EMDF or SHOC)*

Common Community Physics Package (CCPP) to enable more streamlined physics development

GEOS Coupled DA Development Plans with FV3



Thank You.