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Cycling DA with MPAS-JEDI and overview on graphics package

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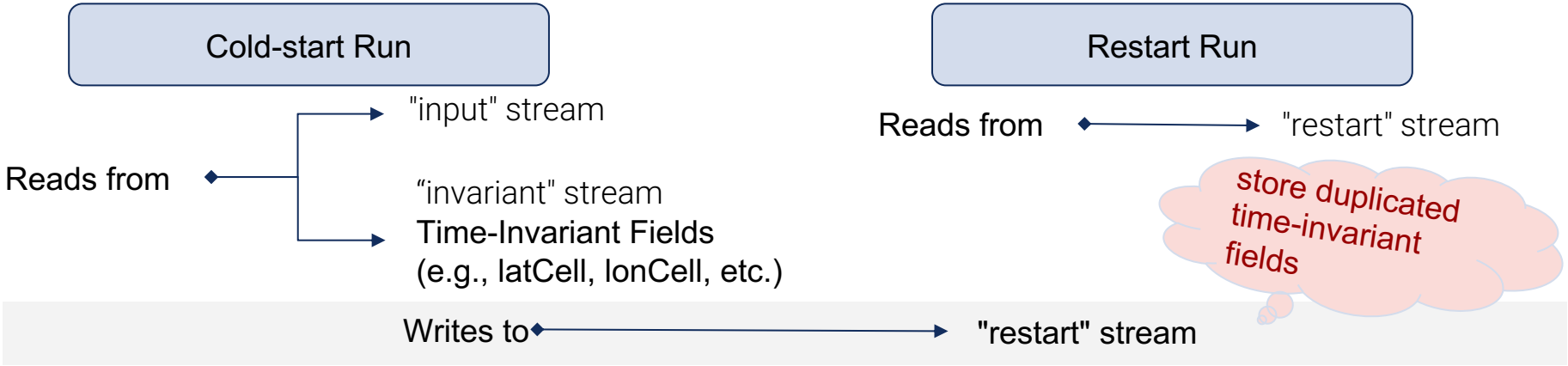
Outline

- Overview on the two-stream I/O (input/output) approach
  - 2-stream I/O in MPAS-JEDI
- Cycling DA with MPAS-JEDI
- Graphics package
  - Functionalities
  - Examples

From MPAS-A User's guide

2-stream I/O approach



In Large Ensembles:

- Each member writes its own restart file
- Time-invariant fields are **replicated**
- This leads to **redundant storage** !

Optimization approach:

- Store time-invariant fields **once**
- Reference shared fields across ensemble members

Running cycling DA more efficiently!!!

From MPAS-A tutorial

2-stream I/O approach

Real-data initial conditions

1. Processing static fields

In namelist.init_atmosphere:

```
&preproc_stages
    config_static_interp = true
    config_native_gwd_static = true
    config_vertical_grid = false
    config_met_interp = false
    config_input_sst = false
    config_frac_seaice = false
```

In streams.init_atmosphere:

```
<immutable_stream name="input"
                  type="input"
                  filename_template="x1.40962.grid.nc"
                  input_interval="initial_only" />

<immutable_stream name="output"
                  type="output"
                  filename_template="x1.40962.static.nc"
                  packages="initial_conds"
                  output_interval="initial_only" />
```

2. Interpolating meteorological fields

In namelist.init_atmosphere:

```
&preproc_stages
    config_static_interp = false
    config_native_gwd_static = false
    config_vertical_grid = true
    config_met_interp = true
    config_input_sst = false
    config_frac_seaice = true
```

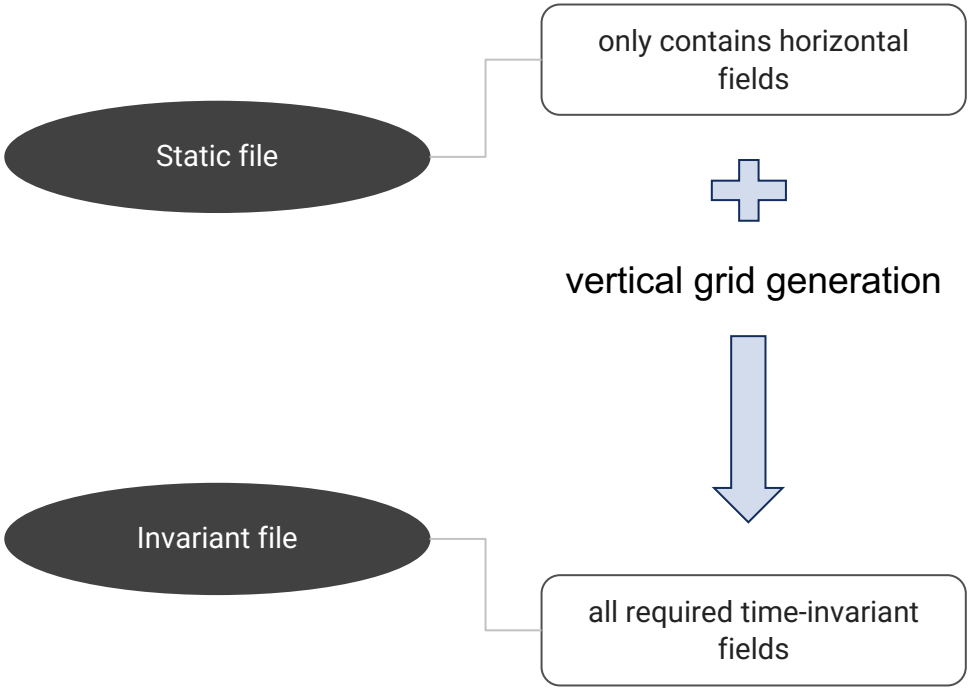
In streams.init_atmosphere:

```
<immutable_stream name="input"
                  type="input"
                  filename_template="x1.40962.static.nc"
                  input_interval="initial_only" />

<immutable_stream name="output"
                  type="output"
                  filename_template="x1.40962.init.nc"
                  packages="initial_conds"
                  output_interval="initial_only" />
```

From MPAS-A User's guide

2-stream I/O approach



namelist.atmosphere:

```
&preproc_stages
    config_static_interp = false
    config_native_gwd_static = false
    config_vertical_grid = true
    config_met_interp = false
    config_input_sst = false
    config_frac_seaice = false
/
```

streams.init_atmosphere:

```
<immutable_stream name="input"
                  type="input"
                  filename_template="x20.835586.static.nc"
                  input_interval="initial_only" />

<immutable_stream name="output"
                  type="output"
                  filename_template="x20.835586.invariant.nc"
                  packages="initial_conds"
                  output_interval="initial_only" />
```

2-stream I/O in MPAS-JEDI

➔ We use “mpasout” file instead of “restart” file for background and analysis files

New stream

```
<immutable_stream name="da_state"
        type="output"
        precision="single"
        clobber_mode="truncate"
        filename_template="mpasout.$Y-$M-$D_$h.$m.$s.nc"
        packages="jedi_da"
        io_type="pnetcdf,cdf5"
        output_interval="6:00:00" />
```

*time invariant fields in a separate file

*mpasout file excludes time invariant fields in the invariant file and also physical tendency fields

Dual role in DA cycling—input and output—updated through the analysis process

Ha et al. (2024): https://doi.org/10.5194/gmd-17-4199-2024

2-stream I/O in MPAS-JEDI

MPAS-JEDI reads in two streams (two files):

- ❏ "**invariant**" stream: mesh info, sfc input variables (landmask, soilcomp, ivgtyp, albedo12m, etc) and parameters for gravity wave drag over orography, vertical coordinate etc.
- ❏ "**da_state**" stream (i.e., 'mpasout' file): fields needed for DA purposes (either analysis variables or fixed input needed for CRTM or other obs operators).

2-stream I/O in MPAS-JEDI

Cold start (1st bkg generation)

```
<immutable_stream name="invariant"
                  type="input"
                  precision="single"
                  filename_template="x1.655362.invariant.nc"
                  io_type="pnetcdf,cdf5"
                  input_interval="initial_only" />

<immutable_stream name="input"
                  type="input"
                  precision="single"
                  filename_template="x1.655362.init.nc"
                  io_type="pnetcdf,cdf5"
                  input_interval="initial_only" />

<immutable_stream name="da_state"
                  type="output"
                  precision="single"
                  clobber_mode="truncate"
                  filename_template="mpasout.$Y-$M-$D_$h.$m.$s.nc"
                  packages="jedi_da"
                  io_type="pnetcdf,cdf5"
                  output_interval="06:00:00" />
```

vs.

Cycling DA

```
<immutable_stream name="invariant"
                  type="input"
                  precision="single"
                  filename_template="invariant.655362.nc"
                  io_type="pnetcdf,cdf5"
                  input_interval="initial_only" />

<immutable_stream name="input"
                  type="input"
                  precision="single"
                  filename_template="mpasin.$Y-$M-$D_$h.$m.$s.nc"
                  io_type="pnetcdf,cdf5"
                  input_interval="initial_only" />

<immutable_stream name="da_state"
                  type="output"
                  precision="single"
                  clobber_mode="truncate"
                  filename_template="mpasout.$Y-$M-$D_$h.$m.$s.nc"
                  packages="jedi_da"
                  io_type="pnetcdf,cdf5"
                  output_interval="6:00:00" />
```

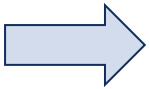
2-stream I/O in MPAS-JEDI

Changes in the **namelist.atmosphere:**

Cold start forecast:

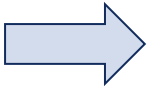
➔ invariant stream file should be set to the **invariant.nc** file, generated by MPAS *init_atmosphere* executable

```
&restart
    config_do_restart = false
    config_do_DAcycling = false
```



used for cycling DA experiments that analyze uncoupled fields in restart files

```
&assimilation
    config_jedi_da = true
```



run within the JEDI data assimilation framework

MPAS-Atmosphere Model User's Guide Version 8.2.0

2-stream I/O in MPAS-JEDI

Changes in the **namelist.atmosphere:**

Forecast in cycling DA:

➔ input stream should point the file generated from da_state stream in streams.atmosphere

```
&restart
    config_do_restart = false
    config_do_DAcycling = true
```

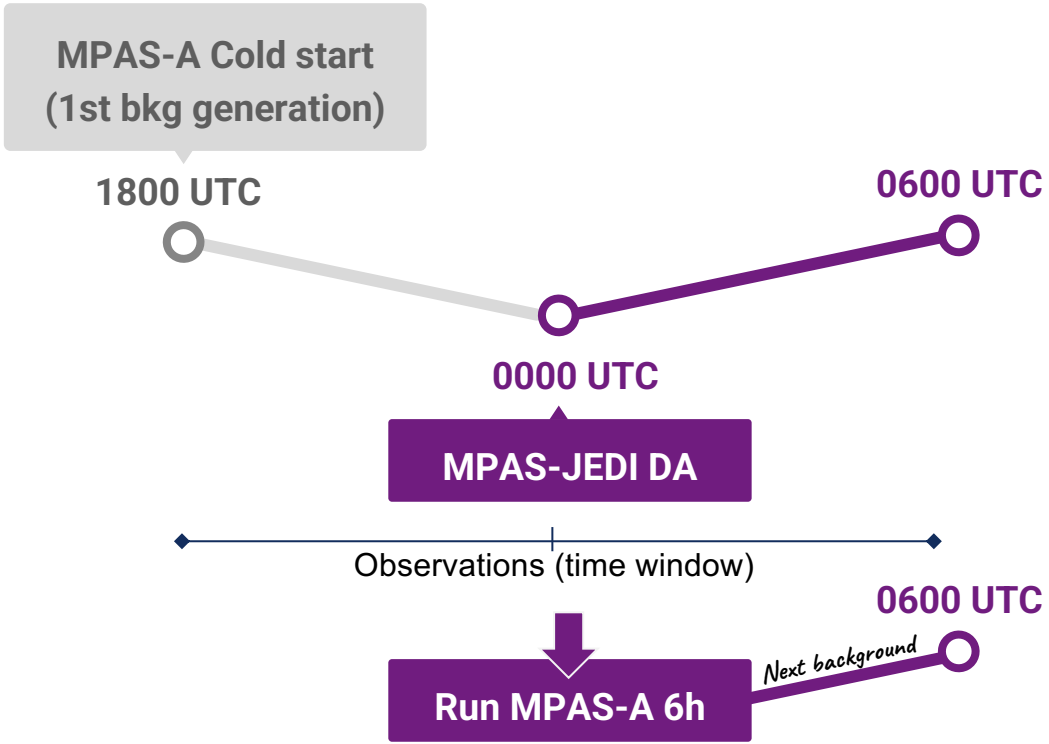
→ used for cycling DA experiments that analyze uncoupled fields in restart files

```
&assimilation
    config_jedi_da = true
```

→ run within the JEDI data assimilation framework

MPAS-Atmosphere Model User's Guide Version 8.2.0

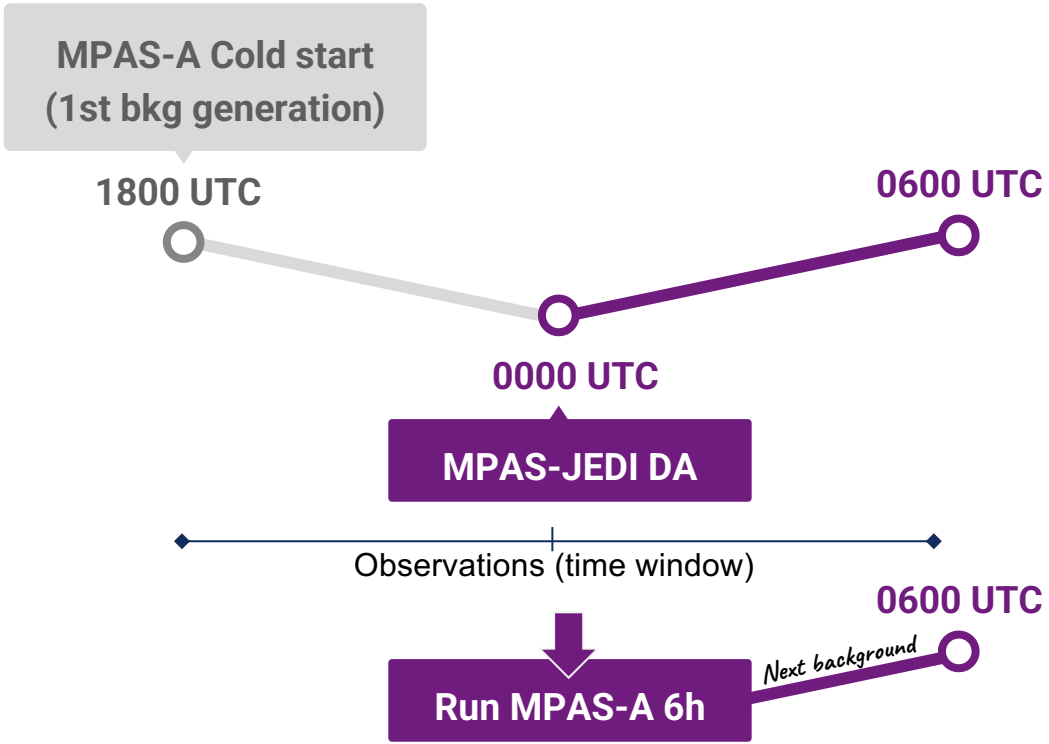
Cycling DA with MPAS-JEDI



Model-specific:

- Invariant file
- MPAS-A lookup tables
- Mesh partition file
- stream_list. files
- streams.atmosphere
- namelist.atmosphere

Cycling DA with MPAS-JEDI



MPAS-JEDI-specific:

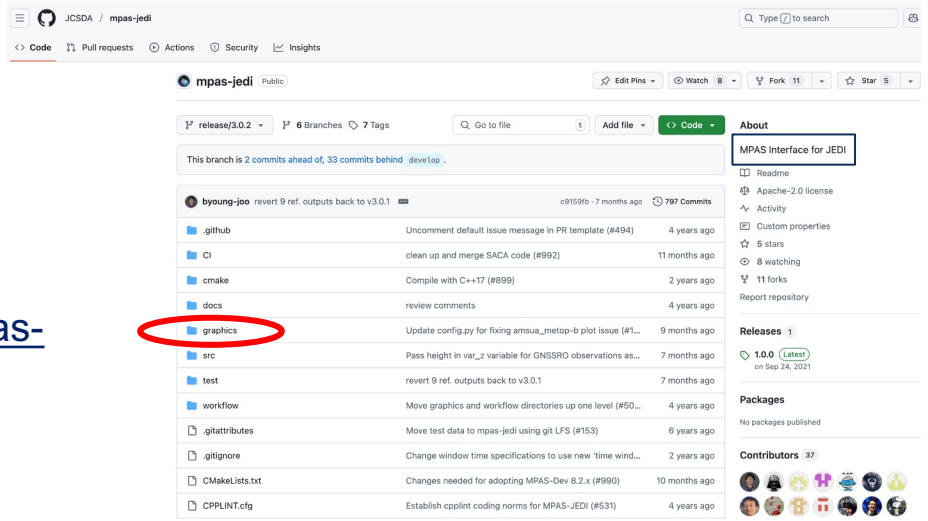
- YAML configuration file
- geovars.yaml
- keptvars.yaml
- obsop_name_map.yaml
- templateFields. file (link to background file)
- Copy of mpasout into **mpasin (analysis or IC for MPAS-A) → updated after DA**
- Observations
- mpasjedi executable

Cycling DA with MPAS-JEDI

geovars.yaml		Model variables on the MPAS mesh to `Geophysical Variables at Locations (GeoVals)` for UFO
keptvars.yaml		MPAS-A variables that we want to keep in memory
obsop_name_map.yaml		Mapping between observation variable names and MPAS-JEDI specific variable names
templateFields. file		Copy of background files with modified "XTIME" variable (converted date strings into NetCDF-compatible character arrays) to get geometry information from MPAS-A

Graphics package

- Developed at NSF NCAR/MMM to aid in diagnosing results with MPAS and MPAS-JEDI
  - Observation space verification can be used for any JEDI model interface
- Python scripts
- Currently, only operates on NSF NCAR's Derecho HPC



➢ Open-source: https://github.com/JCSDA/mpas-jedi/tree/release/3.0.2/graphics

but **NOT** supported

Graphics package: functionalities

- ❑ Produces statistics for selected diagnostics using the `DiagSpaces` selection.
- ❑ Distributed generation of information results in a database of processed statistics, stored in HDF5 files
- ❑ Distributed diagnostic files across multiple experiments, multiple cycle initial times, and multiple forecast lengths
- ❑ Enables portable reading of user-selected variables from multiples types of UFO feedback files (ObsSpace, GeoVaLs, ObsDiagnostics)
- ❑ Supports PBS script to submit verification jobs on Casper and Cheyenne
- ❑ IODA observation convention updates
- ❑ Updated QC flag numbers based on recent changes in UFO
- ❑ Users can select specific observation types, channels and variables to plot

Graphics package: functionalities

DiagSpaces:

Sondes, aircraft, AMV winds,

GNSSRO, surface pressure

AMSU-A (NOAA-15, NOAA-18,

NOAA-19, METOP-A, METOP-B)

MHS (NOAA-18, NOAA-19,

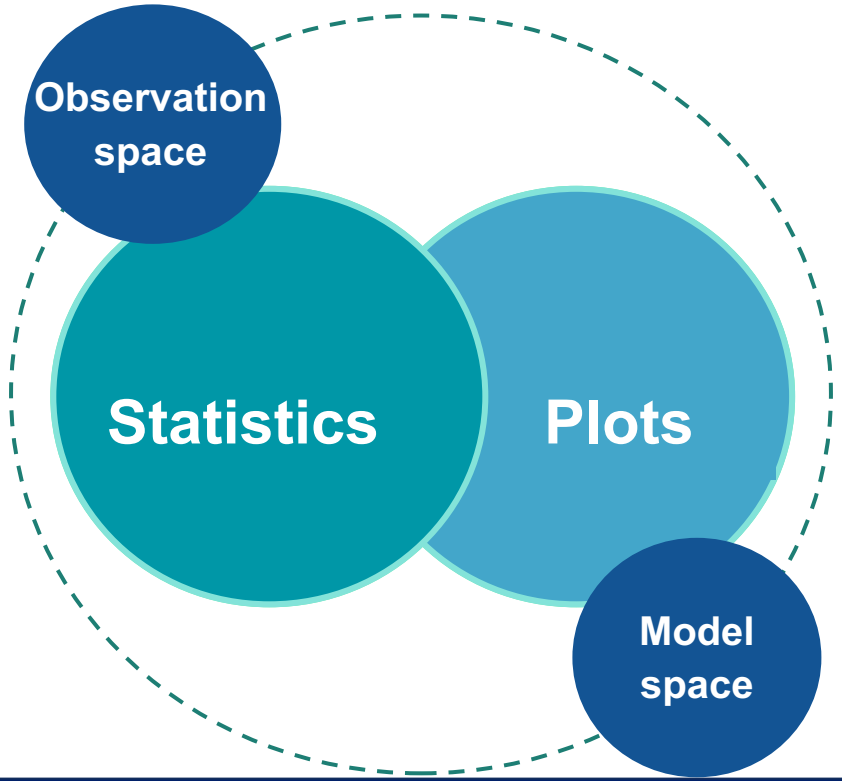
METOP-A, METOP-B)

IASI (METOP-A, METOP-B,

METOP-C)

ABI (GOES-16)

AHI (Himawari-8)



Analyzed variables:

2m T
2m Q
10m U and V
Ps
T
Theta
rho
W
Ps
U and V
Qv
Qv 1 to 10 model level
Qv 11 to 20 model level
Qv 21 to 30 model level
Qv 31 to 40 model level
QV 41 to 55 model level

Graphics package: functionalities

- **Binning methods:**
  - global
  - by latitude bands: Tro (-30.0, 30.0),
    NXTro (30.0, 90.0), SXTro (-90.0, -30.0), NMid (30.0, 60.0), SMid (-60.0, -30.0),
    NPol (60.0, 90.0), SPol (-90.0, -60.0)
  - by tropical latitude bands: ITZC (-5.0, 5.0), STro (-30.0, -5.0), NTro (5.0, 30.0))
  - by cloudiness: clear, mixed-pixels, cloudy, all-sky
  - Latitude vs Pressure 2D
  - Longitude vs Latitude 2D
  - Brightness temperature as a function of cloud fraction 2D

- **Types of plots:**
  - Time series plots with or without confidence intervals calculated using bootstrap resampling
  - profile plots of binned data (e.g., over pressure or latitude on the y-axis) with and without confidence intervals
  - maps of 2D-binned statistics
  - score-card
  - standalone: OmA/OmB diagnostics, observations locations, analysis increments, cost function

Count, Mean, STD, RMS, RMS relative difference

Statistics

Graphics package: functionalities

How to run it?

Observation space:

OmA/OmB

python **DiagnoseObsStatistics.py** -n 36 -p ./dbOut -o obsout -g geoval -d ydiags -app variational -nout 2

Forecast vs observations (HofX)

python **DiagnoseObsStatistics.py** -n 36-p ./dbOut -o obsout -g geoval -d ydiags -app hofx

Model space (vs GFS analysis):

Forecast vs model

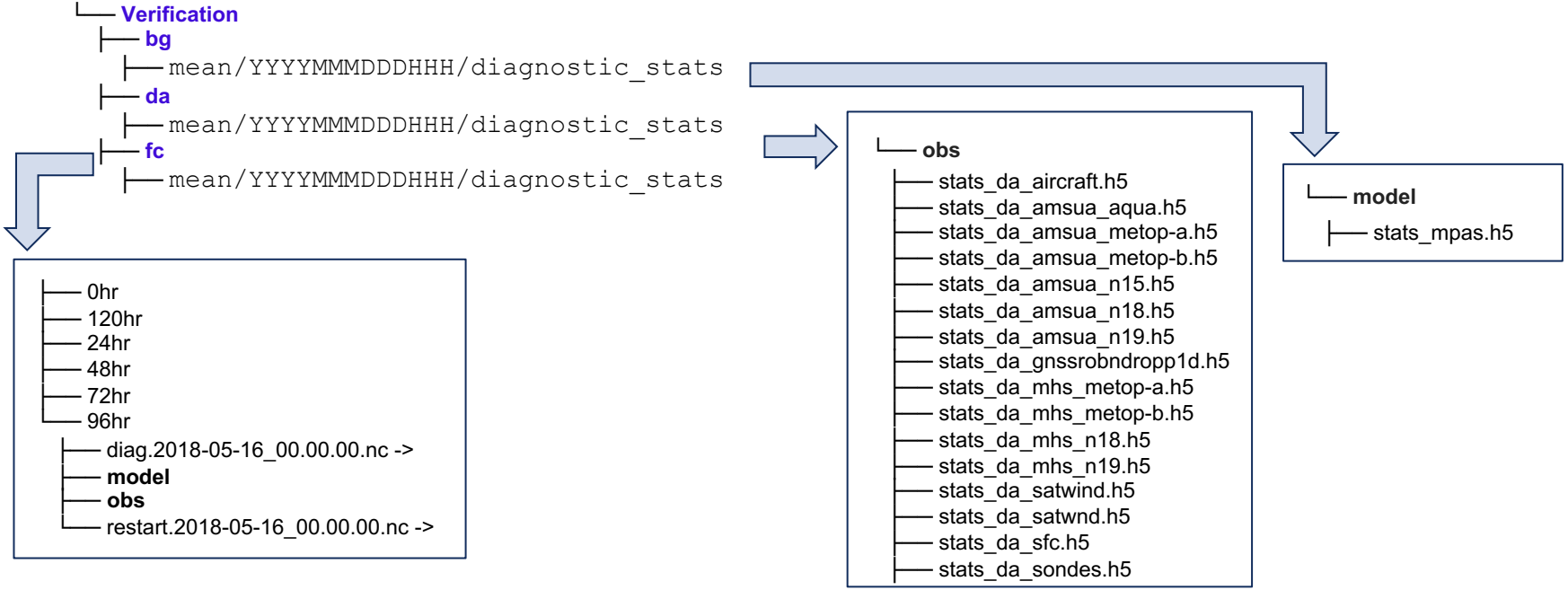
python **DiagnoseModelStatistics.py** YYYYMMMDDDHHH -n 36 -r ./x1.655362.init

30km

Graphics package: examples

Statistics

Experiment folders structure: ivette_3dvar_OIE120km_WarmStart



Plots

Graphics package: functionalities

How to run it?

analyze_config.py: top-level script that controls cycle times and forecast length, verification configuration, experiments and statistics to analyze, and analysis types to apply to the statistics

Observation space:

Carry out analyses for all DiagSpaces that contain "amsua"

python **AnalyzeStats.py** -d amsua

Job-submission examples:

./**SpawnAnalyzeStats.py** -nout 2 -d amsua_,sonde,airc,sfc,gnssro,satw

./**SpawnAnalyzeStats.py** -app hofx -d mhs,amsua,abi_,ahi_,sonde,airc,sfc,gnssro,satw

Model space (vs GFS analysis):

./**SpawnAnalyzeStats.py** -d mpas

Graphics package: functionalities

Plots

How to set it up?

analyze_config.py: Most common parameters to set up for 6hr verification

General settings

```
dbConf['firstCycleDTime'] = dt.datetime(2018,4,15,0,0,0)
dbConf['lastCycleDTime'] = dt.datetime(2018,5,14,18,0,0)

# time increment (TimeInc) between valid Cycle (cy) date-times
dbConf['cyTimeInc'] = dt.timedelta(hours=6)
```

Experiment names (cntrlExpName has to match!!)

```
## cntrlExpName is the experiments key of the control experiment, which is used for DiffCI analyses
dbConf['cntrlExpName'] = 'clrama'

## experiments - dictionary with key, value pairs as follows
#  + the key is a short name for the experiment (see expNames below)
#  + the value is the directory where the verification statistics files are located
#  + if using MPAS-Workflow, users only need to add one new `experiments` entry per experiment and
#    select their desired VerificationType and VerificationSpace above

experiments = OrderedDict()

experiments['clrama'] = \
  'guerrett_3dhybrid-60-60-iter_gnssrorefncep_030kmI60km_ensB-SE80+RTPP70_VarBC_RefNCEP_2ndDoaDob' + \
  deterministicVerifyDir
```

Verification type and Verification space

```
## VerificationType
# OPTIONS: 'omb/oma', 'forecast'
# 'omb/oma' - calculated from a da application, only available when
#             VerificationSpace=='obs'
# 'forecast' - single- or multi-duration forecasts either in observation or model space
VerificationType = 'forecast'

## VerificationSpace
# OPTIONS: 'obs', 'model'
# 'obs' - observation space
# 'model' - compare to analyses in model space, only available when VerificationType=='forecast'
VerificationSpace = 'obs'
```

Graphics package: examples

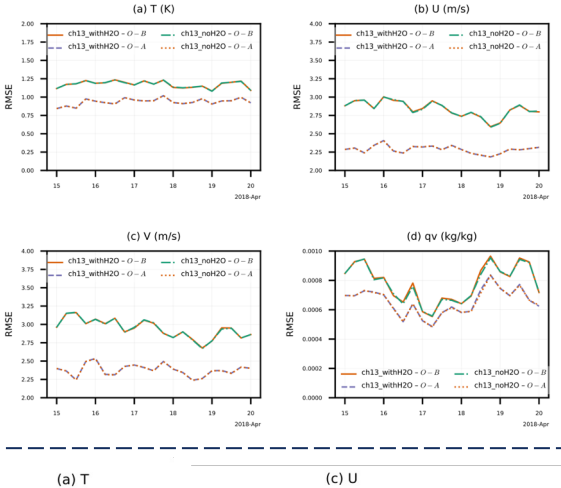
Plots

Observation space

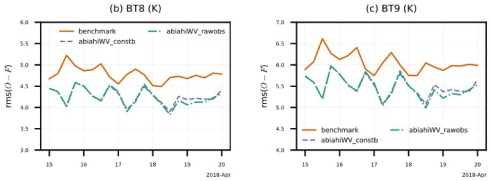
DiagSpace_analyses

- BinValAxes2D
- BinValAxisProfileDiffCI
- CYandBinValAxes2D
- CYAxisExpLines

aircraft: OmA/OmB



ABI: OmB (HofX)

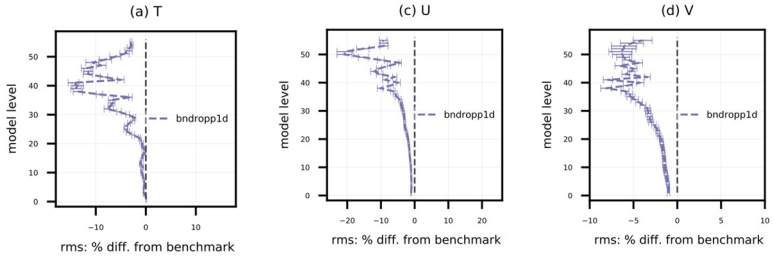


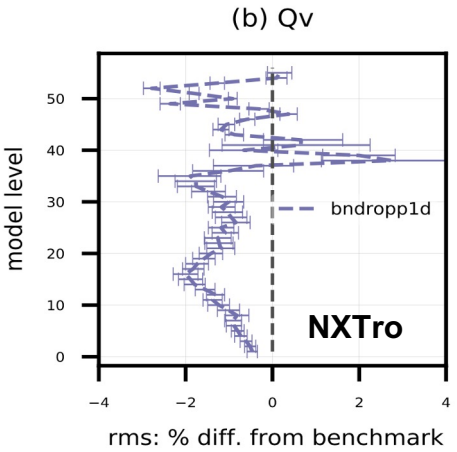
Model space

mpas_analyses

- BinValAxes2D
- BinValAxisProfileDiffCI
- CYandBinValAxes2D
- CYAxisExpLines

MPAS 6-h verification vs GFS analysis



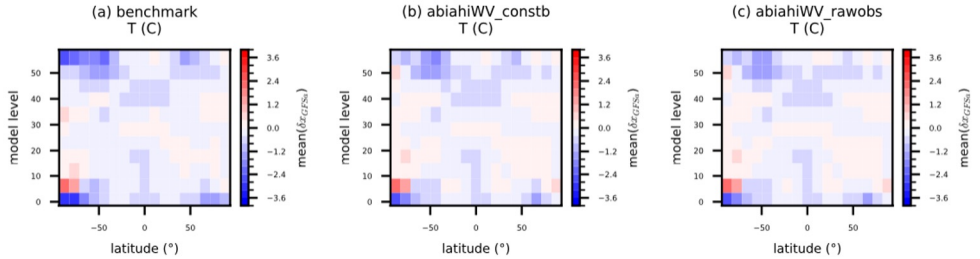


Graphics package: examples

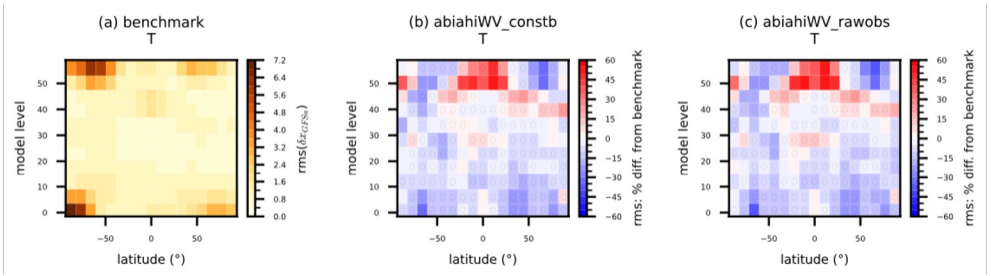
Plots

MPAS 6-h verification vs GFS analysis

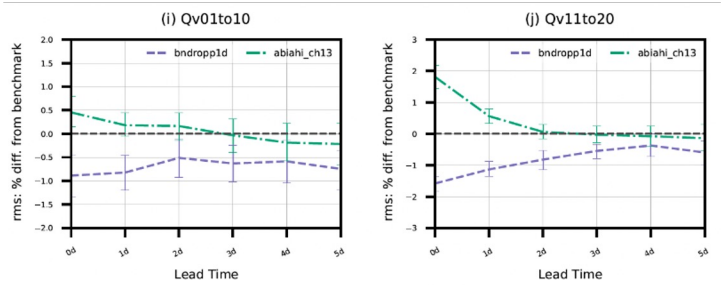
BIAS

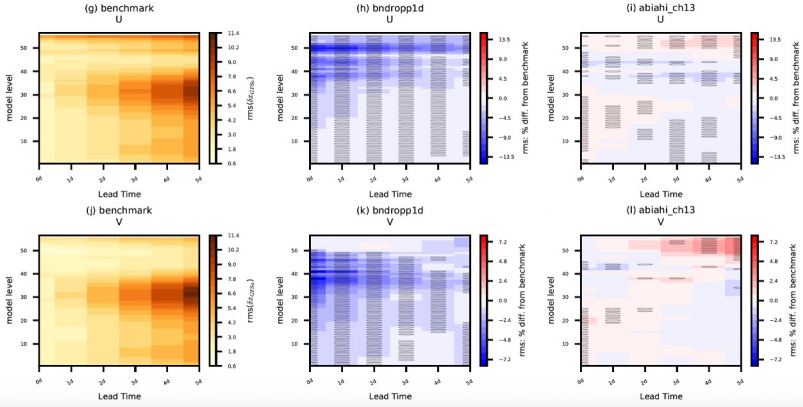


RMSE



MPAS 5-days verification vs GFS analysis





Contributions for new diagnostics/capabilities are welcome!!!

https://github.com/JCSDA/mpas-jedi/tree/develop/graphics

References

Duda, M., Fowler, L., Skamarock, B., Roesch, C., Jacobsen, D., & Ringler, T. (2024). *MPAS-Atmosphere Model User's Guide Version 8.2.0* (Last updated: June 27, 2024). UCAR. https://www2.mmm.ucar.edu/projects/mpas/mpas_atmosphere_users_guide_8.2.0.pdf

Ha, S., Guerrette, J. J., Hernández Baños, I., Skamarock, W. C., and Duda, M. G.: Incremental analysis update (IAU) in the Model for Prediction Across Scales coupled with the Joint Effort for Data assimilation Integration (MPAS–JEDI 2.0.0), Geosci. Model Dev., 17, 4199–4211, https://doi.org/10.5194/gmd-17-4199-2024, 2024.