Toward a Cloud Analysis and Forecasting System Leveraging JEDI

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Present on behalf of PANDA-C project team

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PANDA-C: Prediction **AND D**ata **A**ssimilation for **C**loud

- USAF funded (Phase 1: May 2018 – April 2021)
- Joint NCAR-JCSDA project
- Partnership with Met Office NextGen DA (formerly ExaDA)

PIs: Jake Liu, Chris Snyder, Thomas Auligné

Team: BJ Jung, JJ Guerrette, Junmei Ban, Steve Vahl, Yali Wu
Craig Schwartz, Jordan Powers, Jamie Wolff
Dave Gill, Maryam ABDI (Joint JCSDA-NCAR)

total 6~7 FTEs

Cloud Analysis and Forecasting (CAF)

- CAF is top weather priority for US Air Force
  - Affects multiple facets of USAF operations
  - At present, handled separately from NWP system

- CAF via NWP
  - Long-held, long-term goal for USAF weather
  - CAF is not a priority application for existing operational global NWP/DA systems
  - Research questions remain for key elements (e.g., all-sky DA for IR sensors)

DA Challenges for CAF

- Multivariate: Can't analyze cloud in isolation from other fields
- Multiscale: Fast time scales, small space scales with sensitive dependence on slower, larger scales
- No direct/in-situ cloud observations, reliance on remotely sensed observations with strongly nonlinear forward operators
- Substantial errors in both forecast models and observation operators

PANDA-C Phase I (May 2018-April 2021)

Goals:

- Prepare AF Weather for shift to **next-generation** forecast models and (model-agnostic) DA system
- Build foundation for improved USAF cloud analysis and forecasting, via NWP. Basis for potential Phase 2 development

Deliverables:

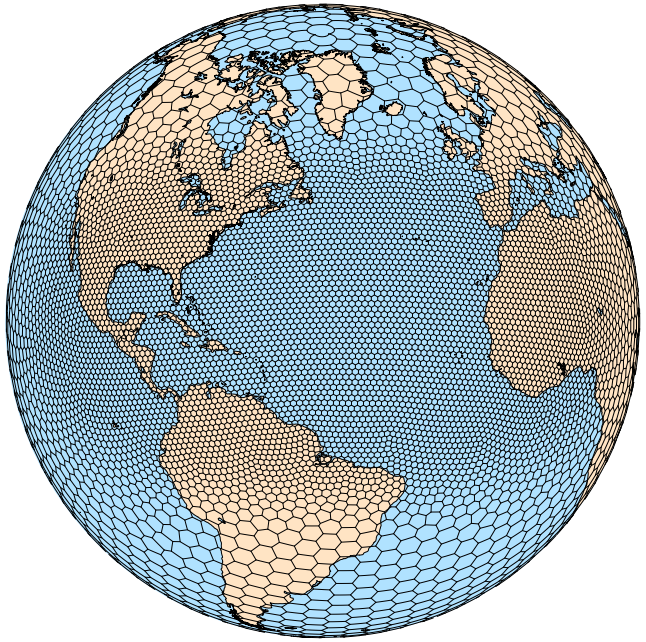
- Prototype DA system, usable with **LFRic** and **MPAS**
- Assimilate most of operational suite of observations with computational performance reasonably close to operational

PANDA-C collaboration with other teams

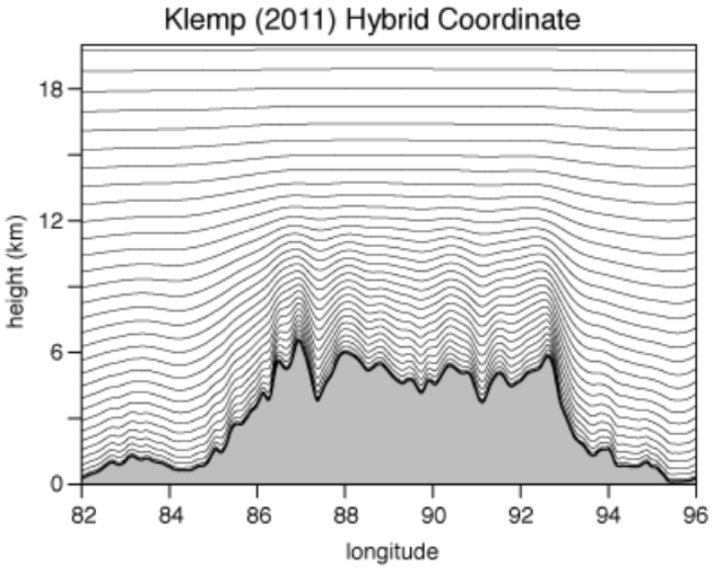
- JCSDA: JEDI core team
  - Mode-agnostic DA components: OOPS, UFO, IODA
  - PANDA-C contributes to and leverages OOPS/UFO/IODA
- UKMO: NextGen DA
  - Exploring JEDI as basis for their next-generation DA
- Also B. Ménétrier (France), BUMP
  - Background error covariance model for general meshes

MPAS-JEDI Interfaces

- Capitalize on native MPAS model capabilities:
  - data structures for model fields (and copies and subsets)
  - domain decomposition and parallelization
  - subroutines for time stepping and I/O



- Analysis variables on height coordinate
  - 3D **U, V, T, Q, P** at cell centers



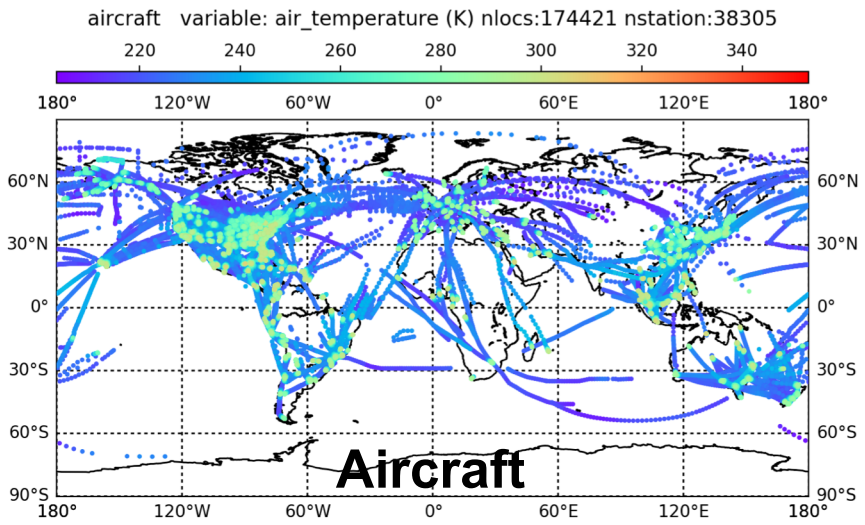
- Horizontal interpolation operator and its TL/AD adopted from BUMP

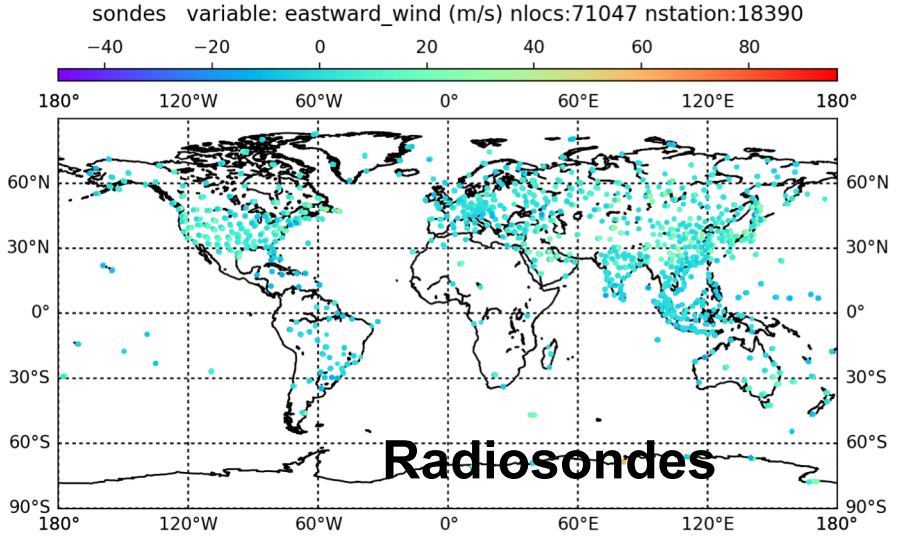
- Now can run **3DVar** (univariate analysis), pure **3D/4DEnVar**, and **hybrid-3DEnVar**. hybrid-4DEnVar to be done.

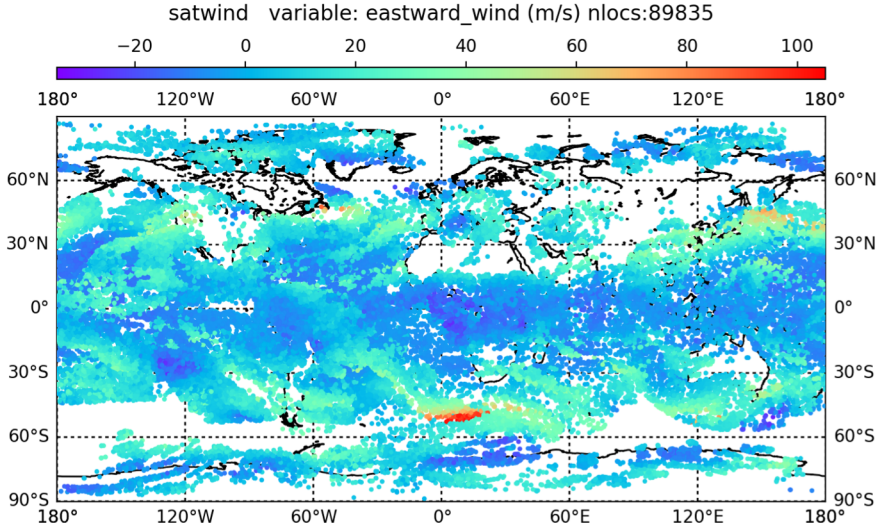
‘Successfully’ ran month-long cycling experiments!

- 15 April-15 May, 2018, 6-hourly cycling at 120-km MPAS mesh
  - Initial capability to run cycling with workflow manager “**Cylc**”
- 3 experiments
  - **3DVAR** with BUMP static univariate B
  - Pure **3DEnVar** (20-member ensemble from GEFS 6-h forecasts), BUMP localization (2000 km, 5 vertical levels)
  - **Hybrid-3DEnVar** (50% on static B, 50% on ensemble B)
  - Ran with 36 cores on NCAR HPC Cheyenne
- Assimilated four types of observations provided by JCSDA in GSI ‘ncdiag’ format and converted to IODA-NC format
  - u, v, T, q from radiosondes and aircraft
  - Atmospheric Motion Vectors retrieval from satellites
  - Refractivity from GNSSRO
  - Observation operators and QC filter from UFO
- 10-day forecasts at 00 UTC.

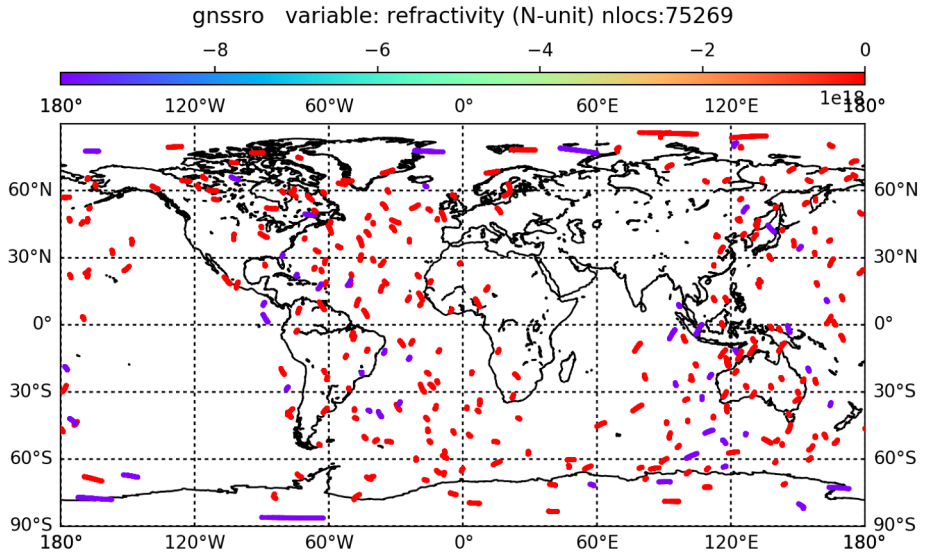
Observation Coverage (2018041500)





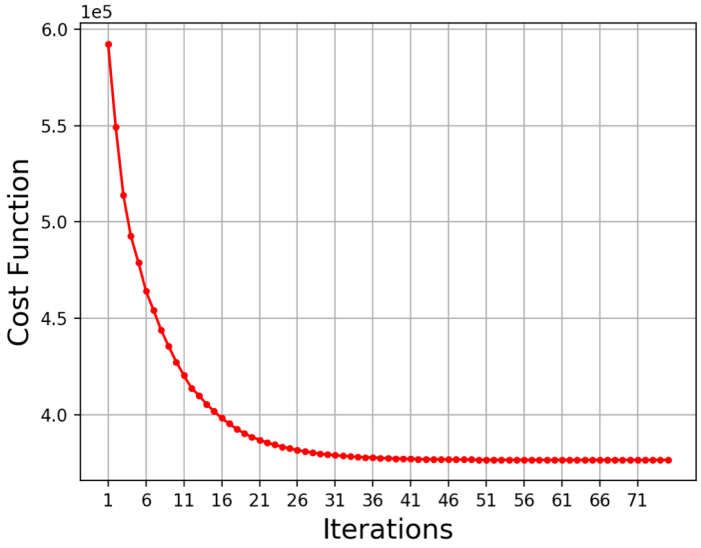


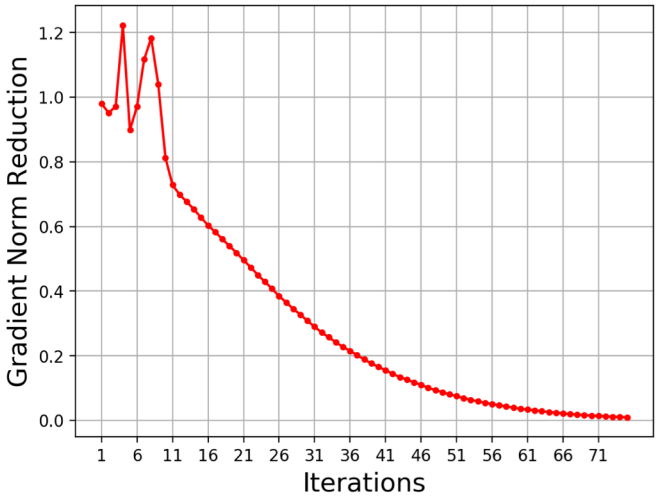
Satellite AMVs (applied thinning)



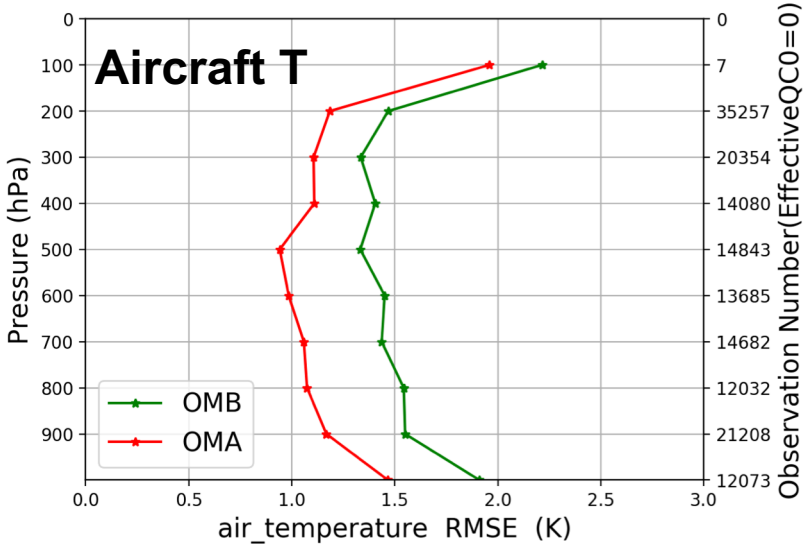
GNSSRO

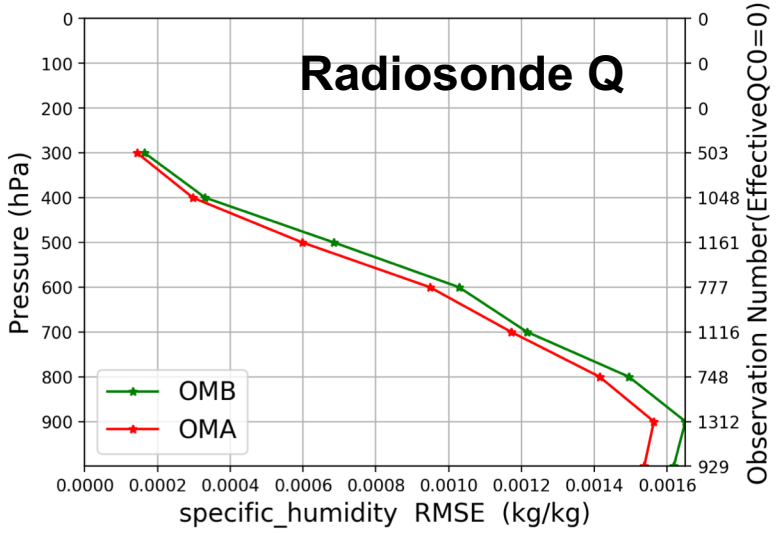
CostFunction/Gradient (3DVAR, 2015041700)

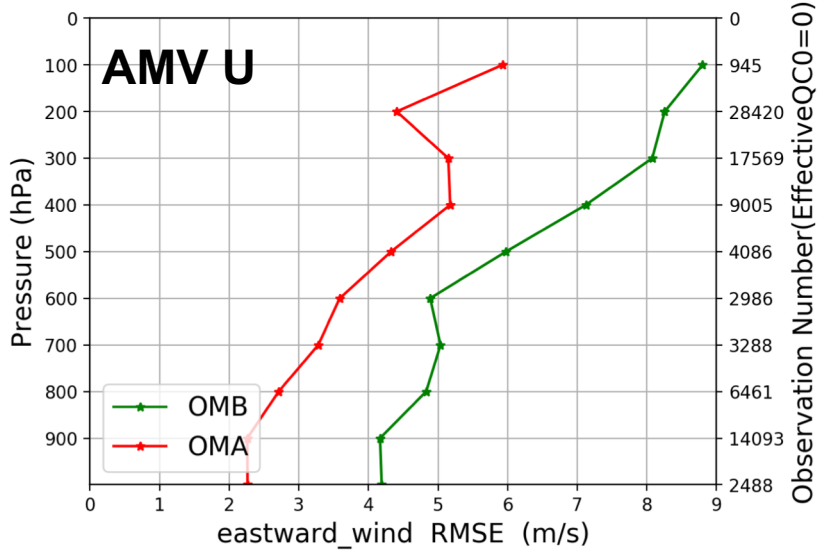


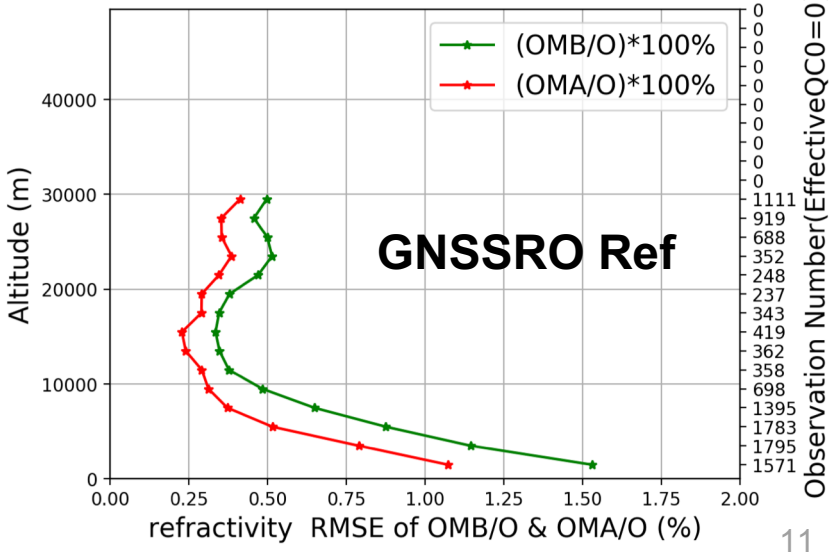


OMB/OMA (3DVAR, 2015041700)







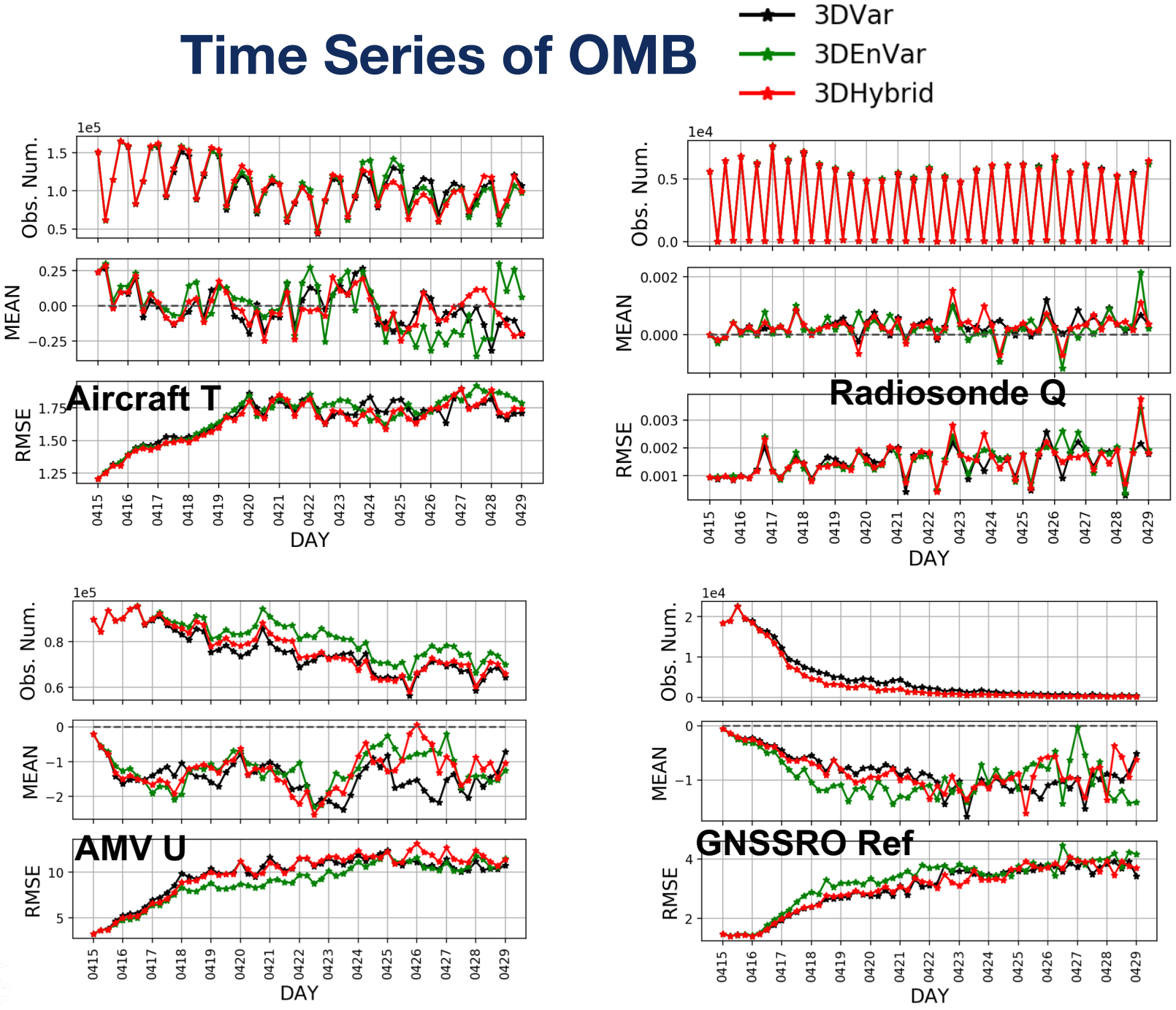


‘Successful’ with some crashes

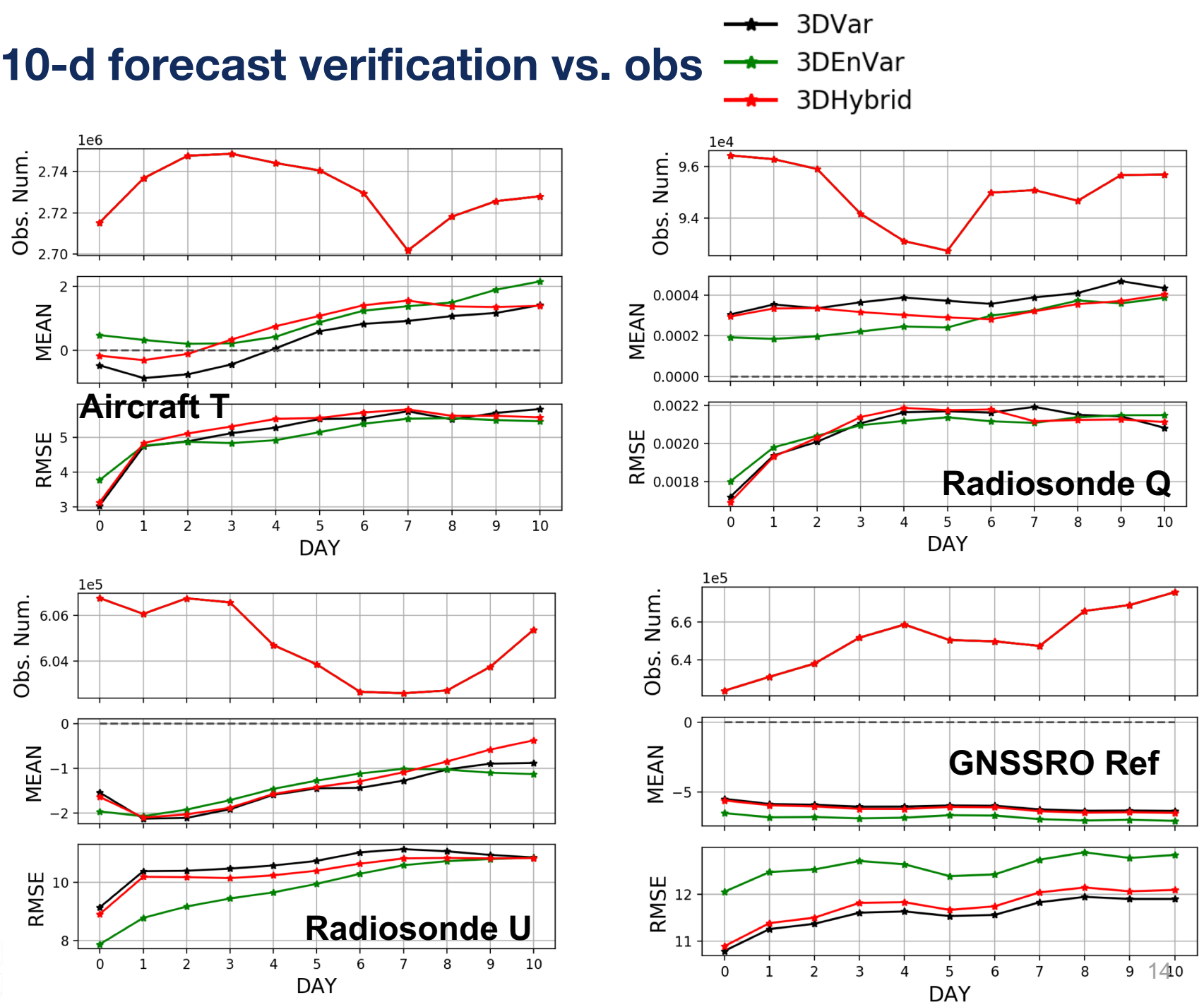
- **3DVAR**
  - DA cycling crashed @2018050718 (i.e., 6h fc crashed)
  - 10-d forecasts crashed from 2018050100 to 2018050700
- **3DEnVar**
  - DA cycling run through the whole month
  - 10-d forecasts crashed @2018050800, 2018050900, 2018051000, 2018051100
- **Hybrid-3DEnVar**
  - DA cycling crashed @2018050712 (i.e., 6h fc crashed)
  - 10-d forecasts crashed @2018043000

So next two slides only show results for the first two weeks cycles.

Time Series of OMB



10-d forecast verification vs. obs



Summary and Outlook

- MPAS-JEDI development proceeding well (ahead of schedule)
- JEDI framework greatly facilitates leveraging/sharing
- Important next steps
  - **Multivariate** static background error covariance
  - Add more observations
    - **AMSU-A radiances**, waiting for bias correction
    - **Surface pressure**, pretty much ready to go
  - Add **cloud analysis variables**, basis for all-sky DA
  - Tune background/obs errors for more stable cycling + hybrid-4DEnVar
  - Test global MPAS-JEDI with **variable mesh** (e.g., 60-15 km)
  - Develop/Test **regional MPAS-JEDI** at high-resolution (regional MPAS will be released in early June)
  - Interface to and assimilate **ODB/ODC** format observation input

Other two aspects of PANDA-C, see Posters:

Liu and Xu: Variational All-Sky AHI Radiance Data Assimilation at Convective-Scale

Schwartz et al.: Strategies for Verifying Cloud Forecasts Over the Globe