Observing System Simulation Experiments (OSSEs) with 3D Winds from space

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Team:

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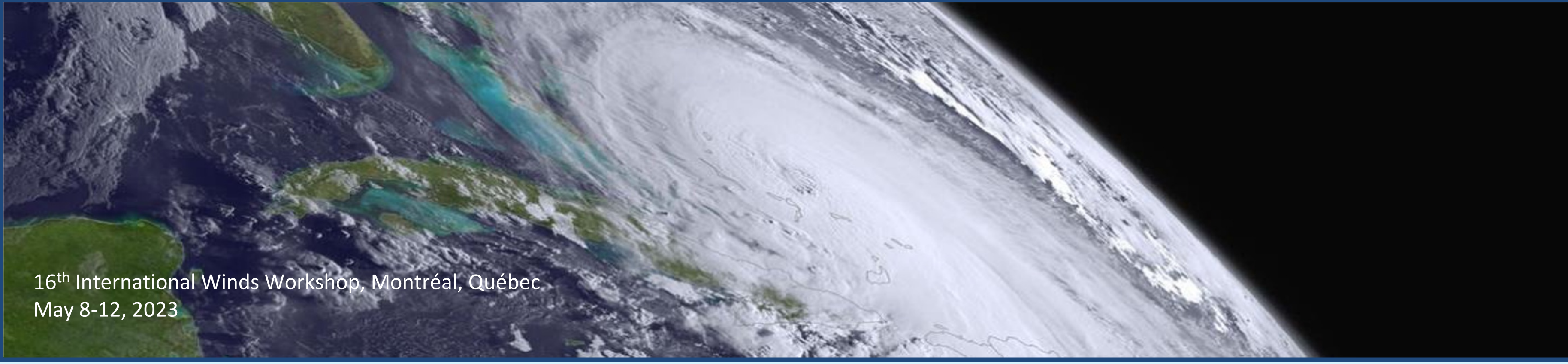

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May 8-12, 2023

Today's modeling and observing systems capabilities: Observing System Experiments (OSEs)

- Can we do better? - Optimize use of current observations in current modeling systems
    - Enhanced data assimilation strategies
    - More realistic characterization of observations
    - Management of large volume of data
    - Timeliness for model upgrades

- Can we leverage existing observations not currently utilized?
    - Driven by requirements and priorities
    - Investment in personnel and HPC resources

Looking ahead and simulating the future: Observing System Simulation Experiments (OSSEs)

- Costs of developing, deploying and maintaining new space-based architectures typically exceed $100-500 million/instrument.
- Need to provide quantitative information on the impact of proposed observing systems in the next planned generation of numerical weather prediction systems.
- Help inform major decisions by evaluating the impact of alternative mix of current and/or proposed instruments for better understanding and prediction of Earth Systems.
- OSSE studies provide an ideal platform for this
    - Analyze tradeoffs (coverage, resolution, accuracy and data redundancy)
    - Optimize data assimilation and modeling strategies

NOAA global OSSE system

- ECMWF (~ 9km) nature run
  - ECMWF operational configuration November 2016 – July 2017
  - 14 months: 00 UTC Sep 30, 2015 – Nov 30, 2016.
- QOSAP COSS package to generate error-added observations.
- Simulated conventional, RO profiles and MW/IR radiances under cloudy conditions.
- Incorporated 3D active and passive winds from space
  - Doppler Wind Lidar observations in collaboration with EUMETSAT/KNMI – completed.
  - 3D passive Atmospheric Motion Vector winds (tracking moisture features) – ongoing.
- Experiments were run at research resolution (lower than operations).
- OSSE system calibrated with the NOAA's global data assimilation and forecast system.
  - June-July with observing architecture operational in 2020
    - Two-week spin up period (2016060100-2016061418)
    - Forecasts verification (2016061500-2016073000)

Satellite architecture trade-offs

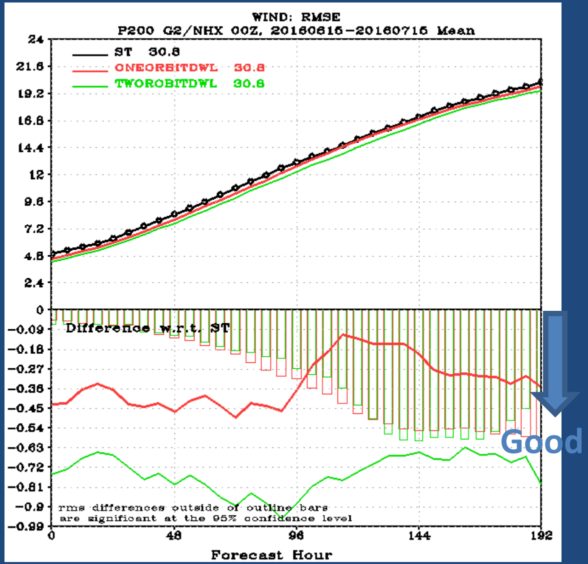
- NOAA conducted a study to plan for the next generation of weather satellites – NOAA Satellite Observing System Architecture (NSOSA).
- Outlined new capabilities and architectures which NOAA should invest in.
- Generated architectural questions that could be addressed by observing system simulation experiments (OSSEs).
- Benefits from existing observing systems to be combined with potential enhancements from non-yet-existing capabilities.
- Key questions to address:
  - Relative value of sounding quality and quantity for global NWP – to support decision making on sounder performance versus satellite numbers.
  - **Value of global wind observations and their value relative to enhanced sounding, relative value of different approaches to global wind observations (active versus passive).**

OSSE with active winds: one orbit versus two orbits

ST = Study Threshold (MW/IR @ 12-hr update rate, 5K RO prof/day)
ONEORBITDWL = ST + DWL in one orbit
TWOORBITDWL = ST + DWL in two orbits

200 hPa RMS Wind error

Northern Hemisphere extra-tropics



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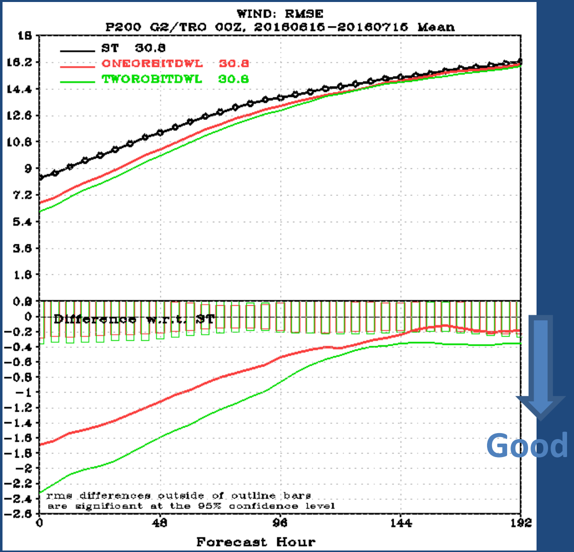
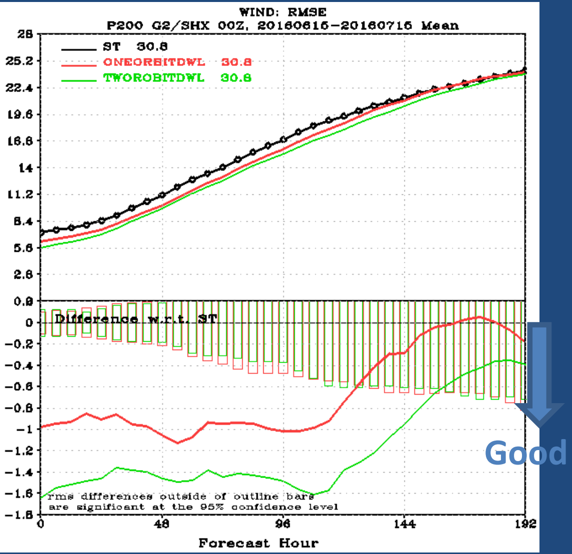


Southern Hemisphere extra-tropics



OSSE with active winds: one orbit versus two orbits

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850 hPa RMS Wind error

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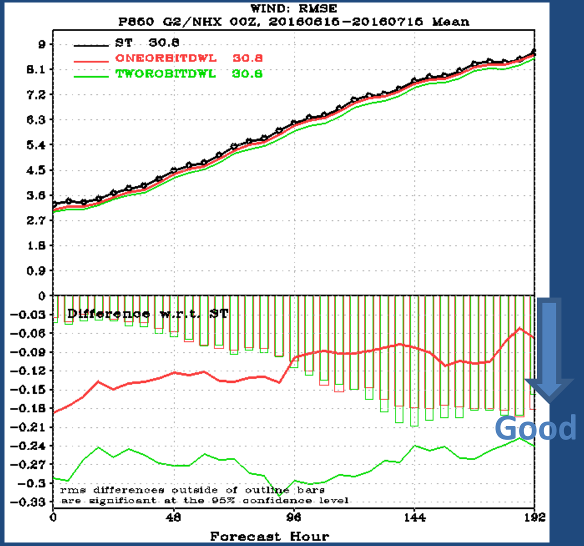

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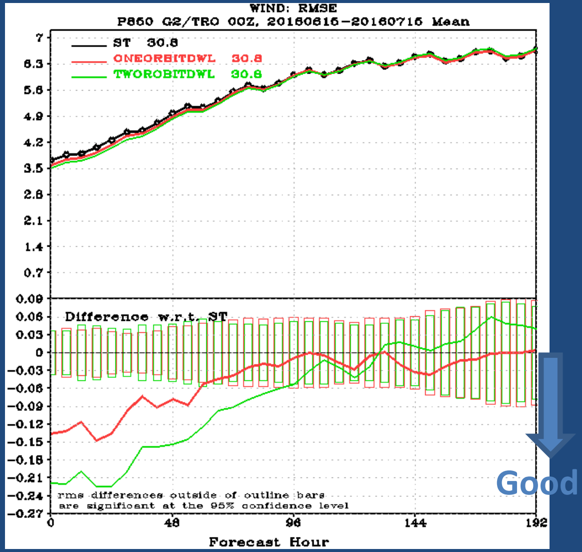

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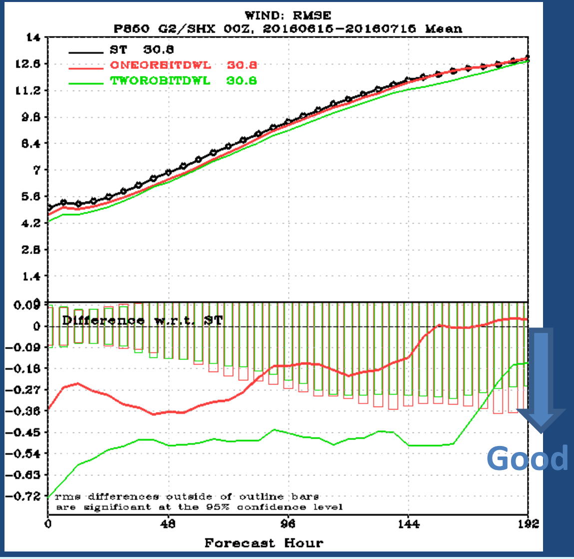
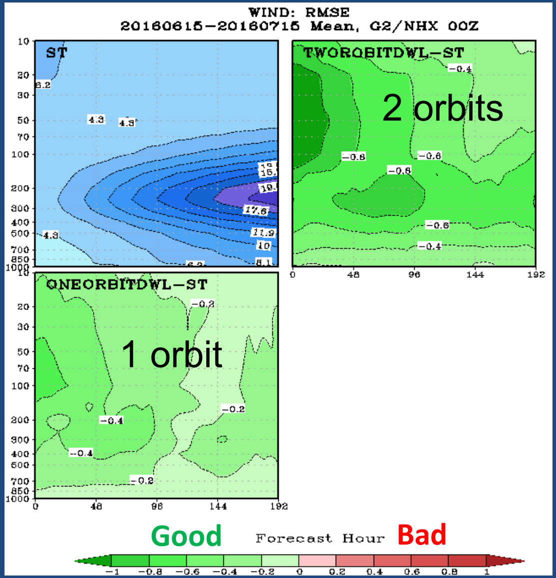


OSSE with active winds: one orbit versus two orbits

RMS Wind Cross Sections

Northern Hemisphere extra-tropics



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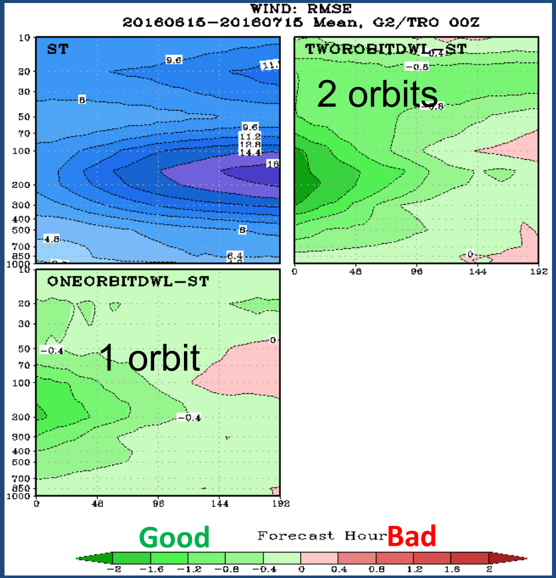
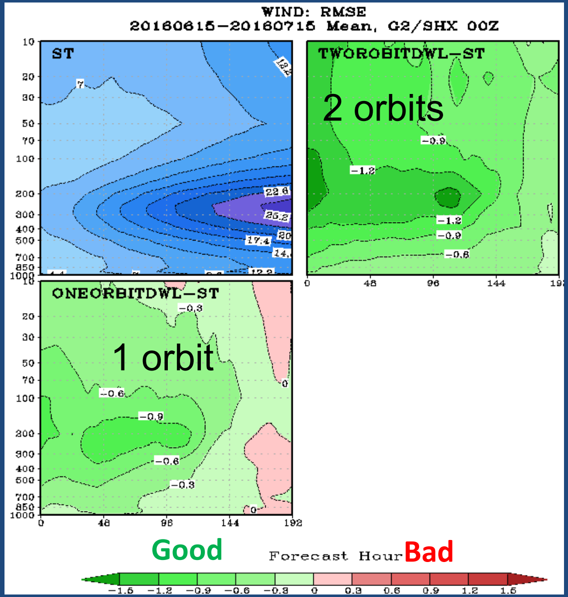


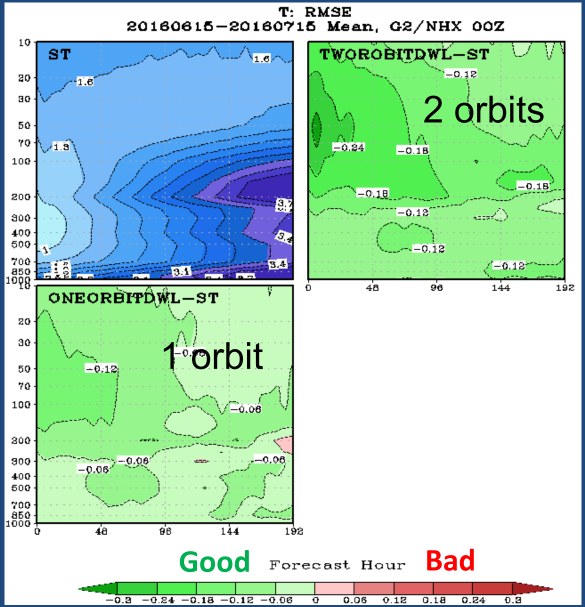
Southern Hemisphere extra-tropics



OSSE with active winds: one orbit versus two orbits

RMS Temperature Cross Sections

Northern Hemisphere extra-tropics



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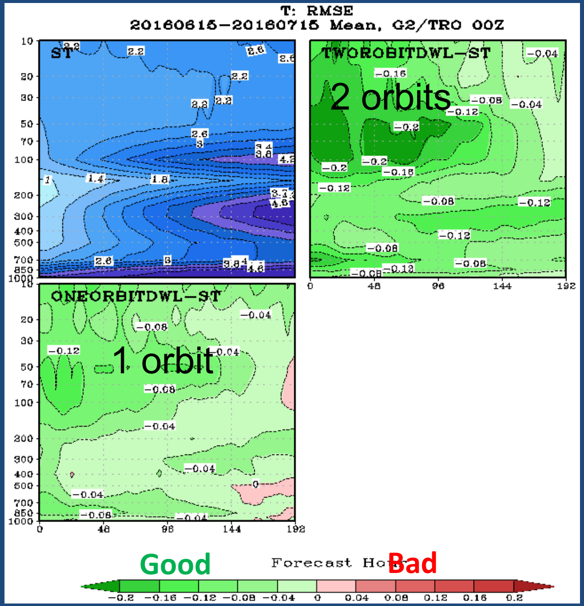

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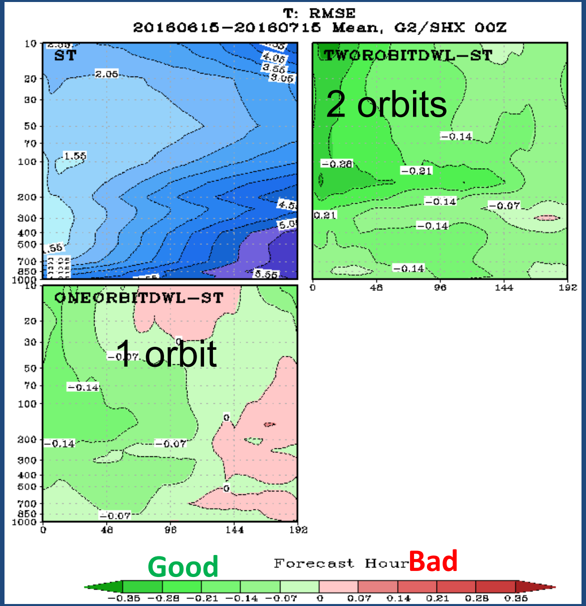


Passive approach (ongoing effort)

- Train formation versus staggered orbits
- Exp1: 3D AMVs from 9 satellites: A 3-satellite train in each orbit (orbits at 0530, 0930, 1330 local equator crossing time) and each satellite train (triplet) spaced no more than 15 minutes apart.
- Exp2: 3D AMVs from 9 evenly distributed sun-synchronous orbits with one orbit at 1330.

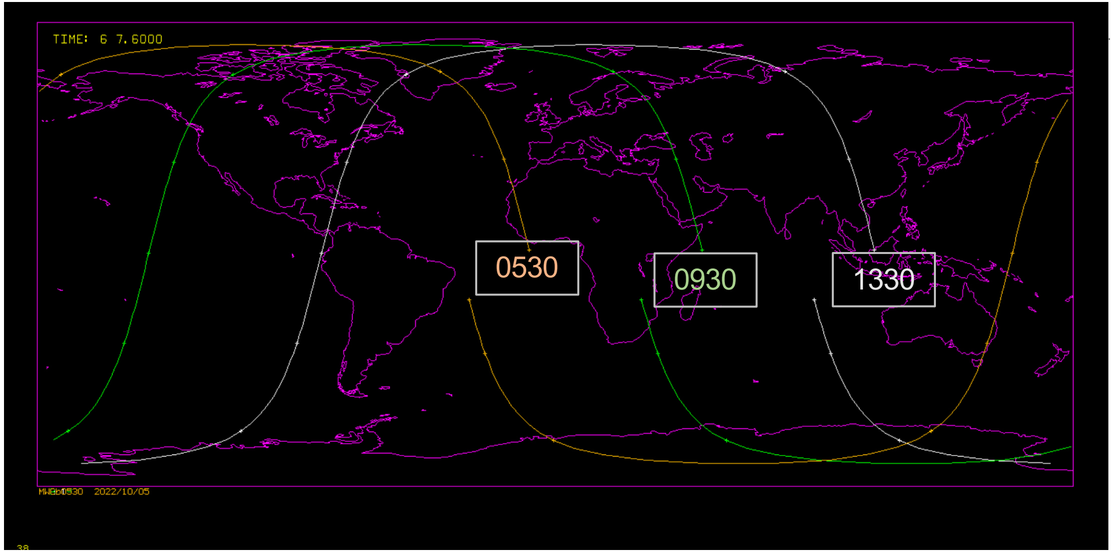
Simulation of 3D Passive Winds

- Track humidity features in the grid Nature Run (ECO1280)
- Winds produced on eight pressure levels (200, 250, 300, 400, 500, 600, 700, 850 hPa)
- Nature Run grids divided into 4 sectors to derive winds
  - NPole, NHemi, SHemi, SPole
- Nature Run cloud top grid used to flag those AMVs in clear sky and above cloud (IR sounder)
  - All AMVs are retained in dataset to simulate all-weather sounding instruments (e.g., microwave)
    - Would sample in vertical (e.g., 300, 500, 700 hPa) to simulate degraded vertical resolution of microwave
- Polar satellite orbit to sample observations
  - Orbit and instrument swath are configurable

Satellite configuration
Exp 1

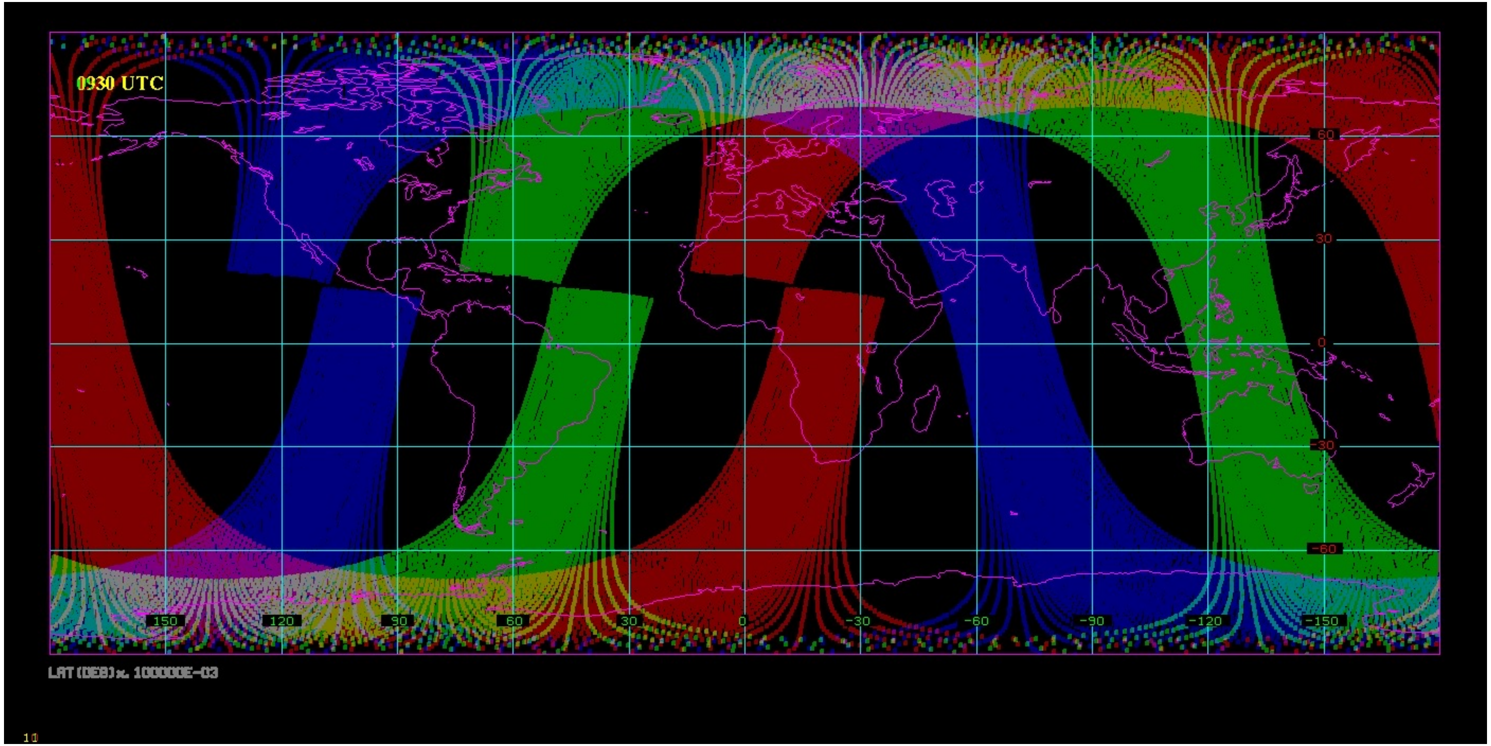
AMVs from 9 satellites: A 3-satellite train in each orbit (orbits at 0530, 0930, 1330 local equator crossing time) and each satellite train (triplet) spaced no more than 15 minutes apart.

Winds are derived from a time-separated triplet of images (3 satellites with the same ground track).



Paths of one orbit for each satellite train

Satellite configuration
Exp 1



Swath coverage of one orbit (100 minutes) for each satellite train
Note: Different time window than previous slides

Satellite configuration
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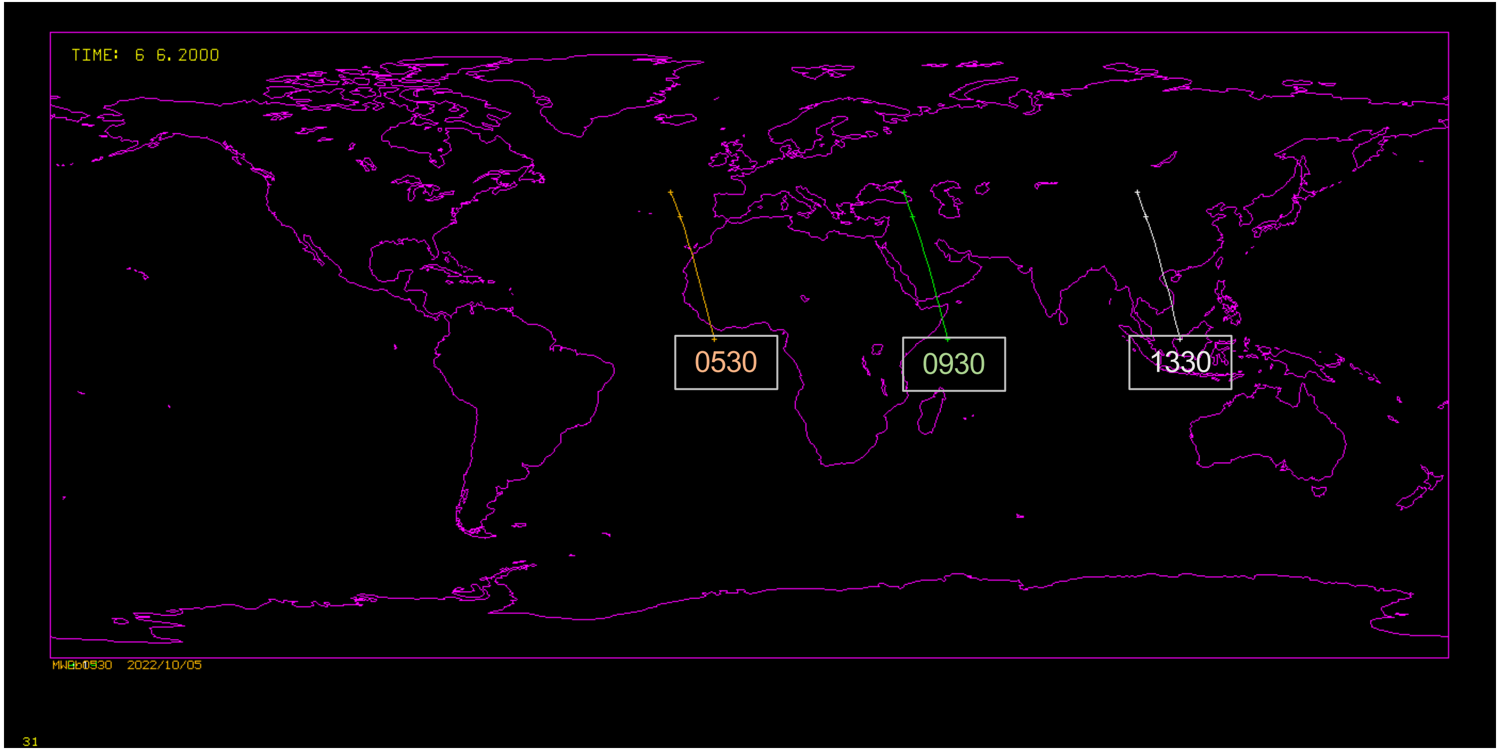
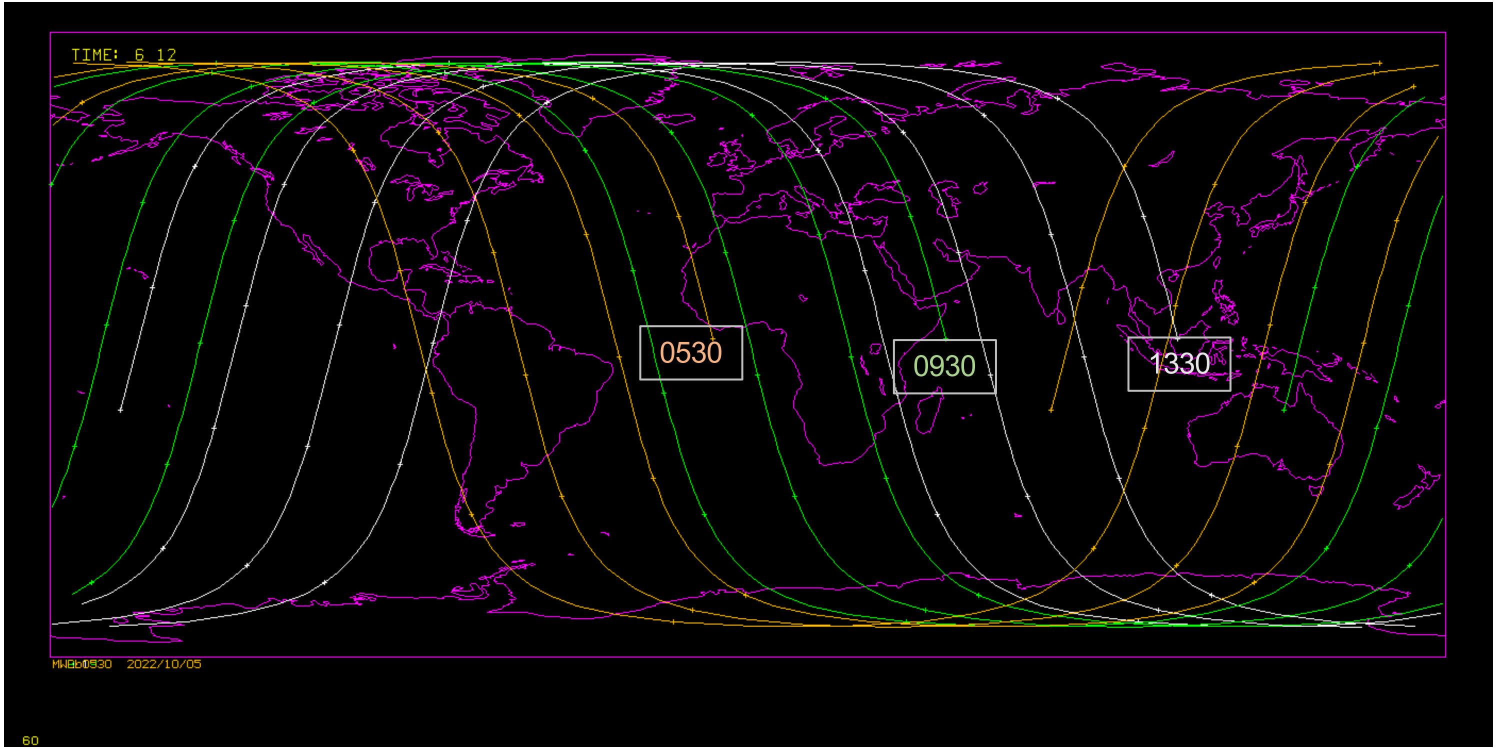


6-hour time window; orbits of 3 satellite trains at 0530, 0930, 1330 local time

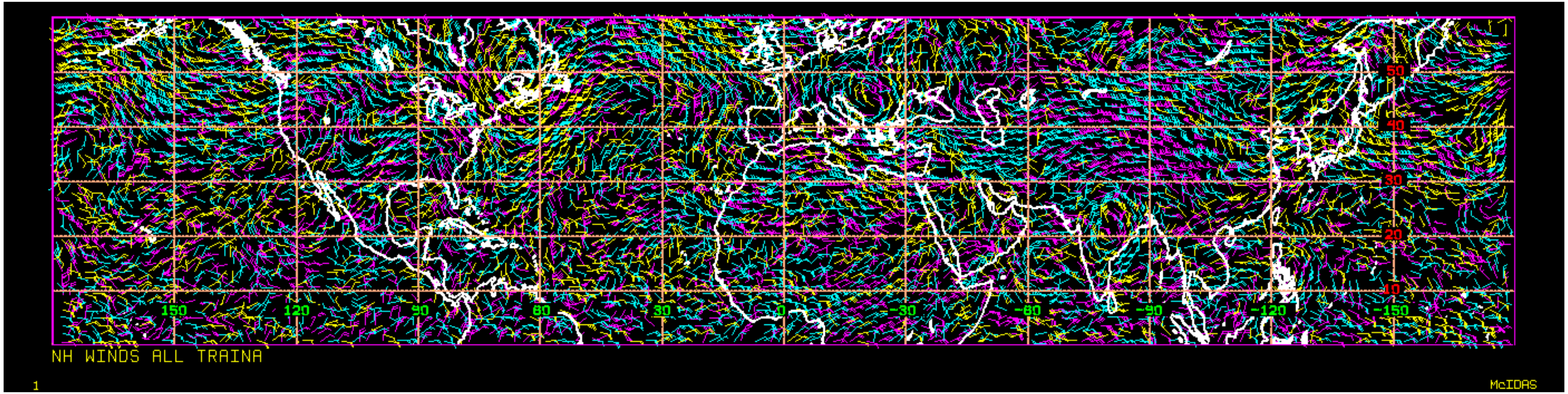
Satellite configuration
Exp 1



6-hour time window, corresponding to expected AMV coverage for an assimilation cycle

N. Hemisphere Winds Derived from ECO1280 Nature Run
Equator to 60 deg. latitude

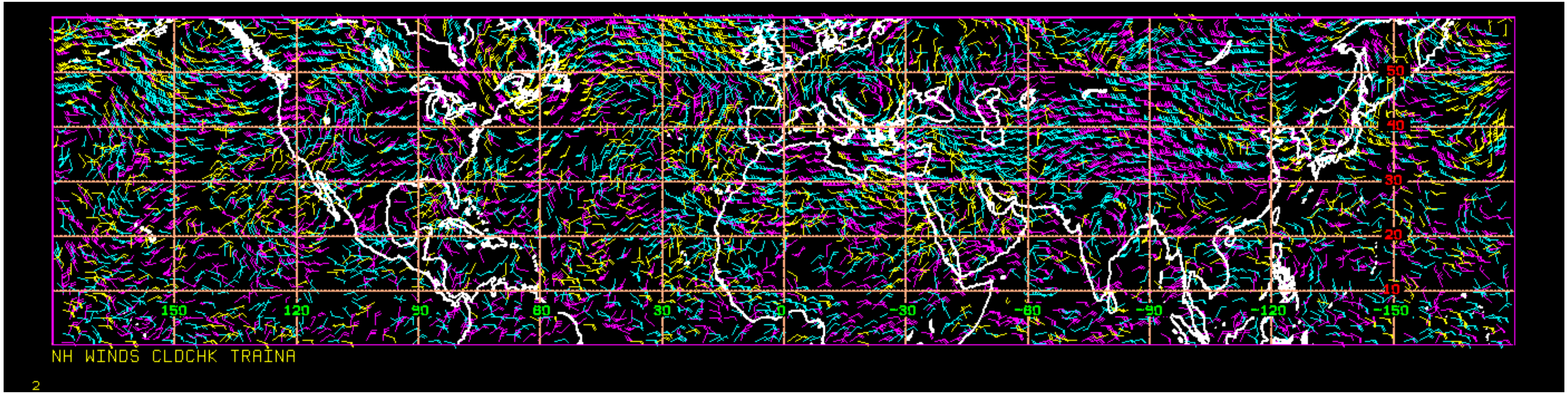
- All derived winds from Nature Run



0130 to 0430 UTC
Color-coded by height: Low (yellow), Middle (cyan), High (magenta)

N. Hemisphere Winds Derived from ECO1280 Nature Run
Equator to 60 deg. latitude

- All derived winds from Nature Run; screened by clouds
  - Note low-level clouds (yellow) greatly reduced; mid-level (cyan) thinned



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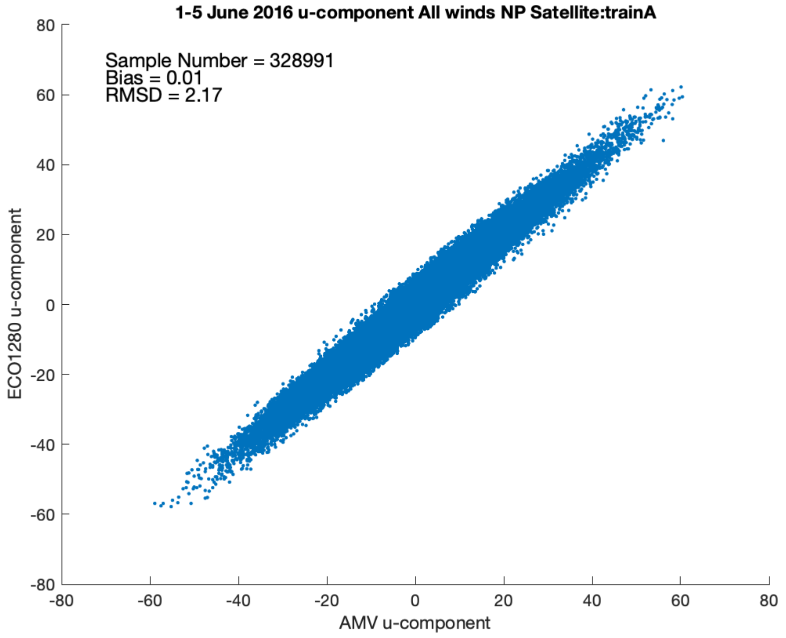
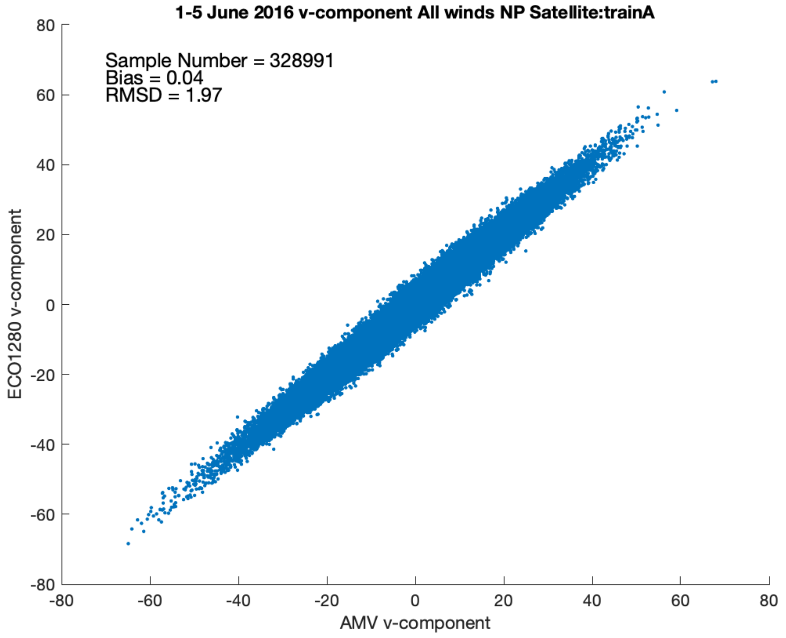
Wind derivation using ECO1280: Northern Pole sector
5 days (01-05 June 2016)



ECO1280 u-comp vs AMV u-comp (QC'd)



ECO1280 v-comp vs AMV v-comp (QC'd)

OSSE with active winds: Aeolus and Aeolus-2

BASELINE = Baseline control configuration
AEOLUS1 = Baseline + Aeolus-1
AEOLUS2 = Baseline + Aeolus-2

200 hPa RMS Wind error

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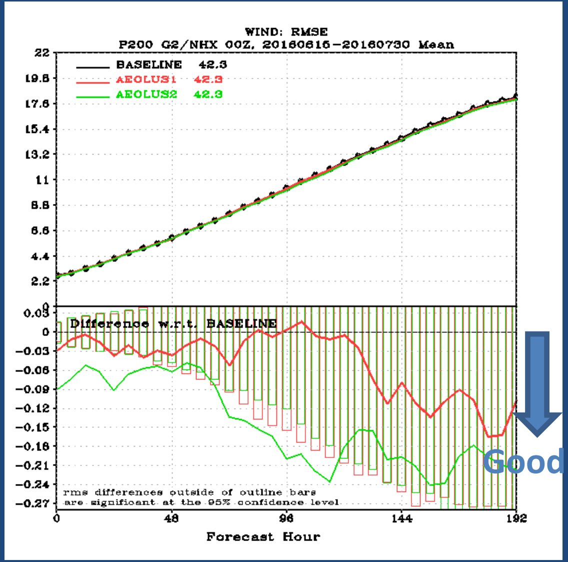

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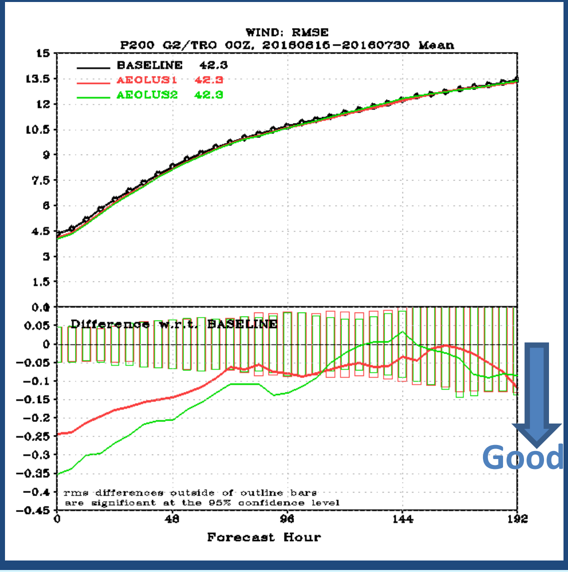

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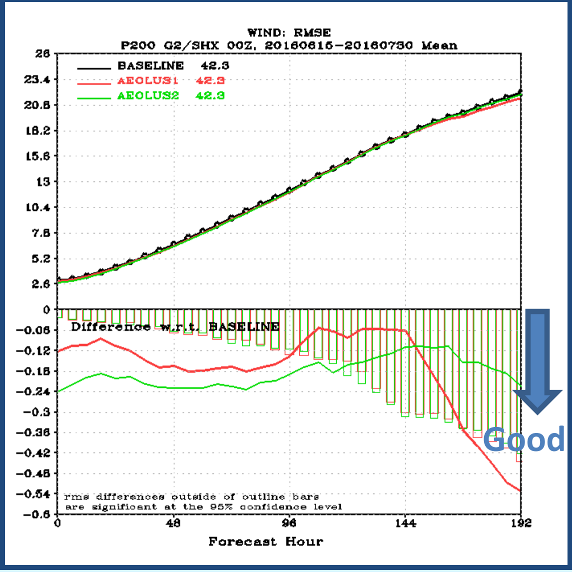

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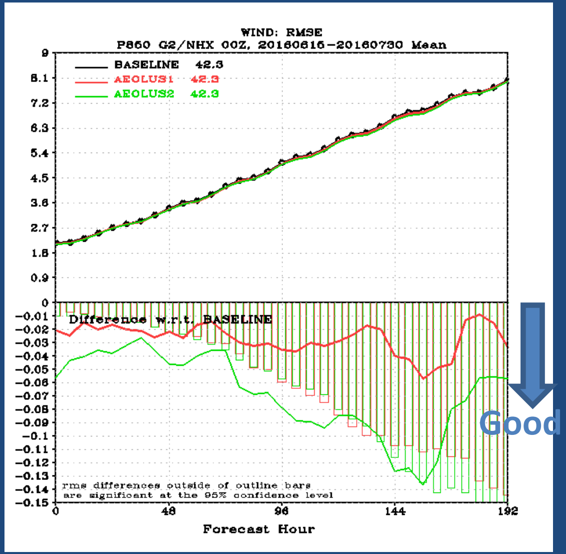

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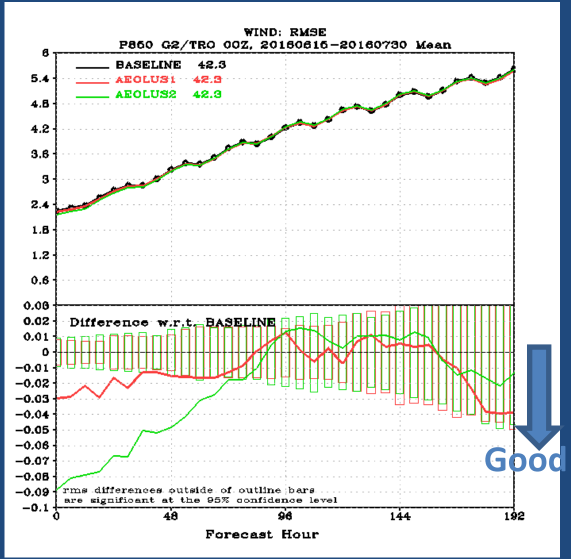

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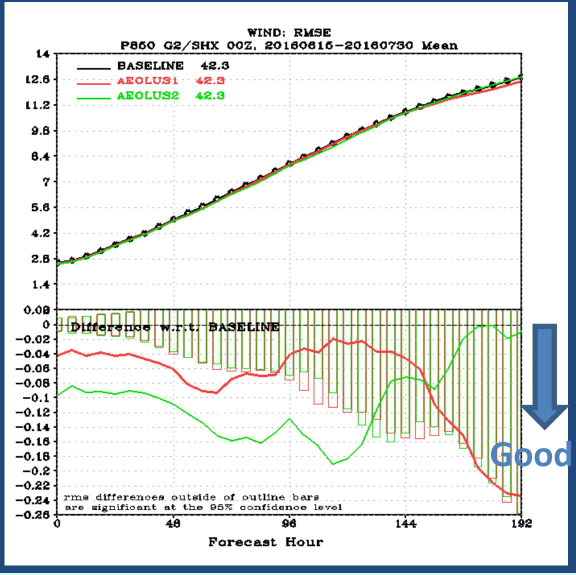


Questions?
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