Assimilation of the Middle Atmosphere Data in the FV3GFS and WAM: First Results and Impact on the Upper Atmosphere

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Outline:

1) **Middle Atmosphere (MA) data - observations of temp-re, winds, O_3, H_2O and tracers**

2) **MA data analysis in GSIWAM-600km and FV3GFS-80km**

3) **Impacts of MA data in operational systems and NWP/SW applications.**

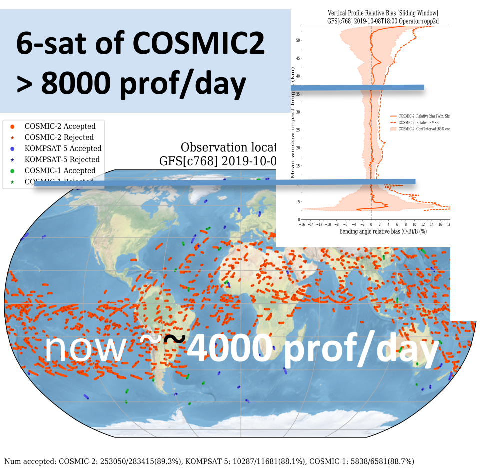
4) **Next steps, and why UFS may support the MA data analysis in NOAA models?**

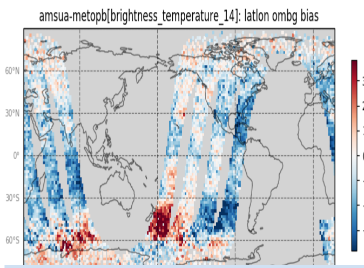
UFS User's Workshop, July 27-29 2020

Operational Upper Stratosphere Data (35~40/60 km): GPSRO (COSMIC-2,1) AMSUA/Ch-14, and ATMS/Ch-15

NRT-MLS data and UA observations in the stratosphere-mesosphere-thermosphere

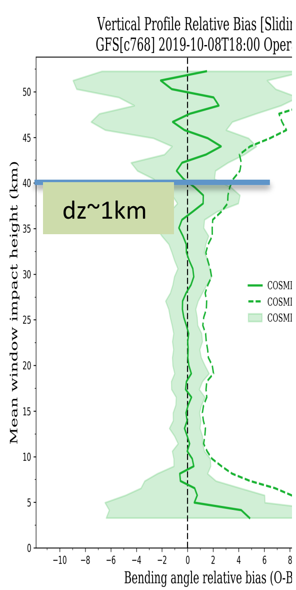
6-sat of COSMIC2
> 8000 prof/day

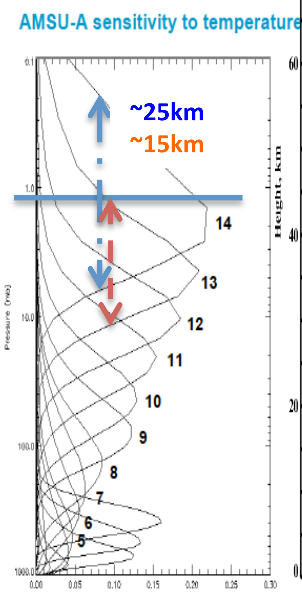


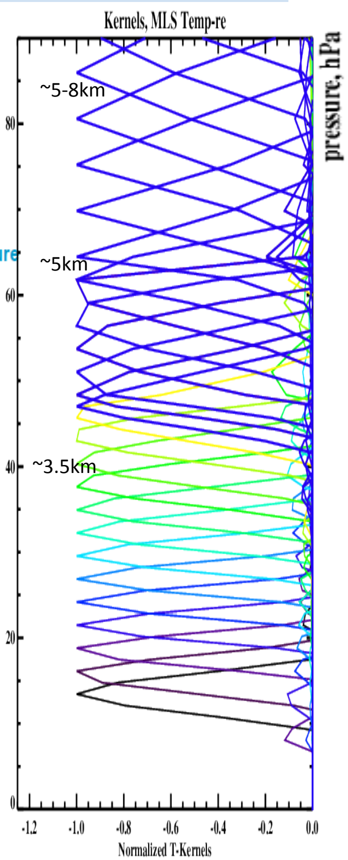


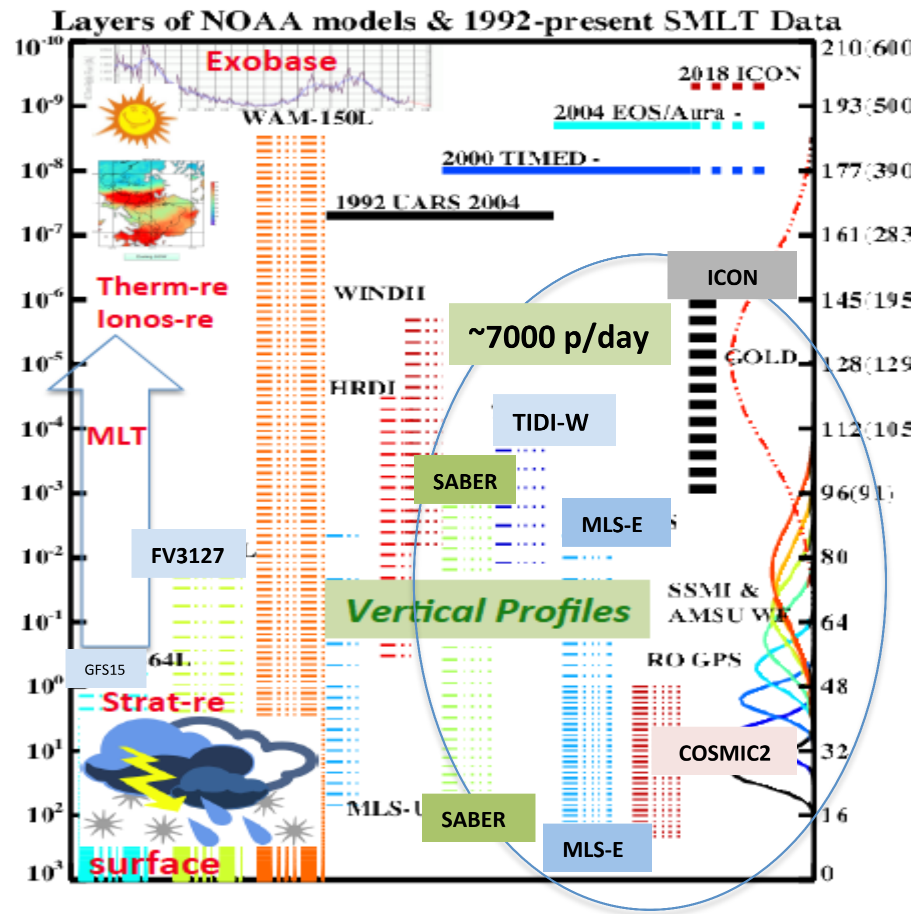
millions points/day

http://nrt.jcsda.org/hofx





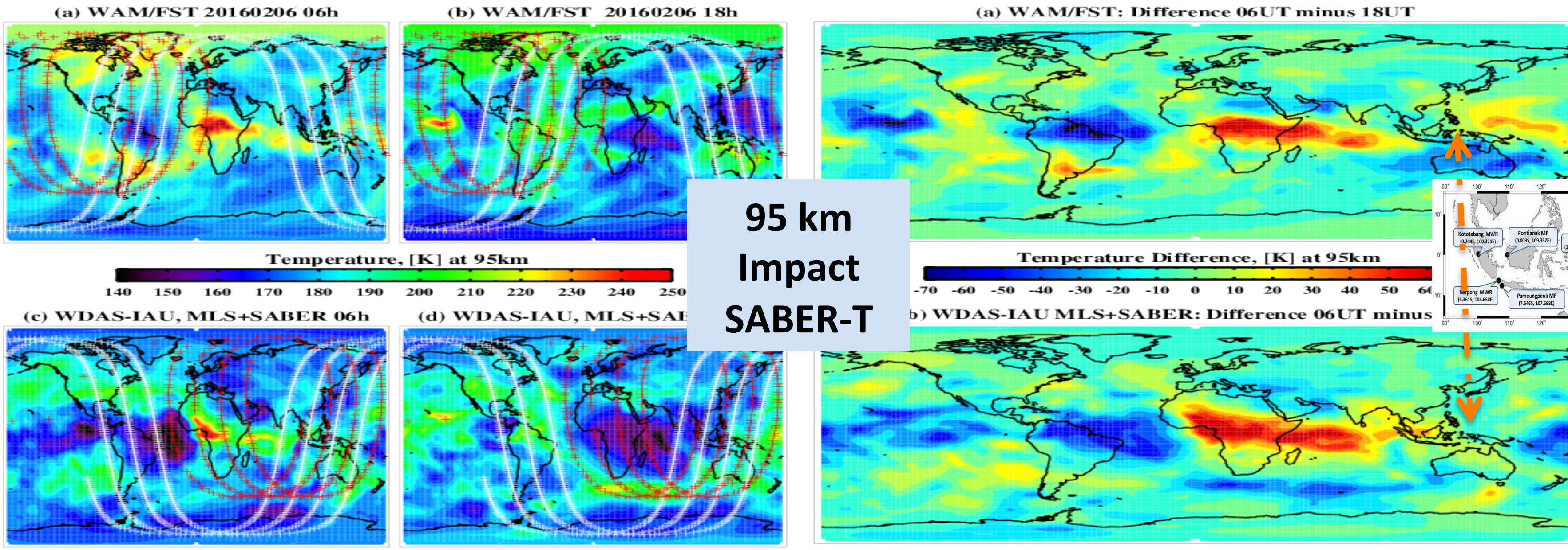




MA limb profilers: **MLS (2004-present, 4000 prof/day) SABER (1450 prof/day)** , TIDI (2000-present) , and ICON (2019-present).

https://discnrt1.gesdisc.eosdis.nasa.gov/opendap/Aura_MLS_NRT; *http://saber.gats-inc.com/*

Middle Atmosphere Data Analysis of Limb Observations in GSI-WAM and GSI-FV3GFS



MLS-NRT (v4.2): T, O_3, H_2O and 4 species

~4000 prof/day of Temp-re (15- 90km)

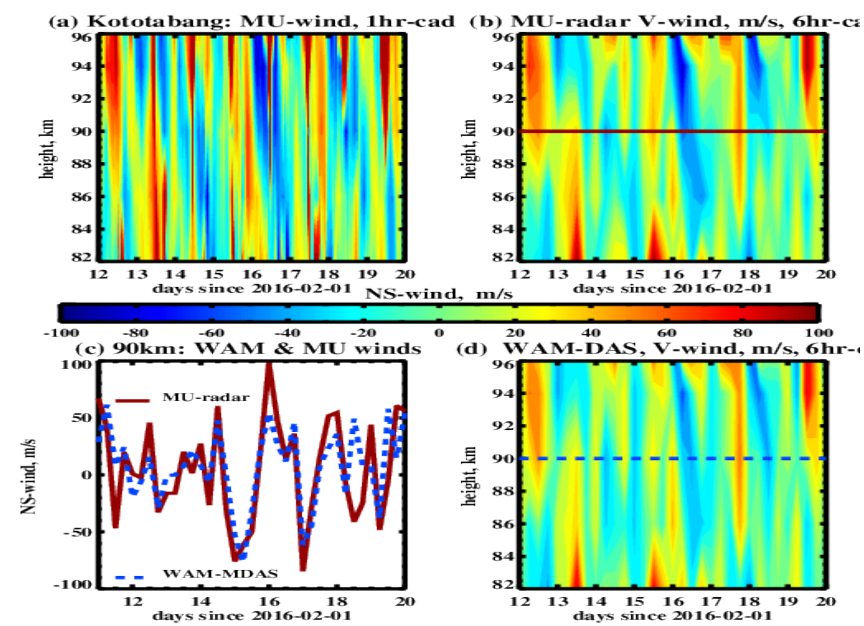
SABER (v2.0): T, O_3, O, H_2O (T: 15-110km)

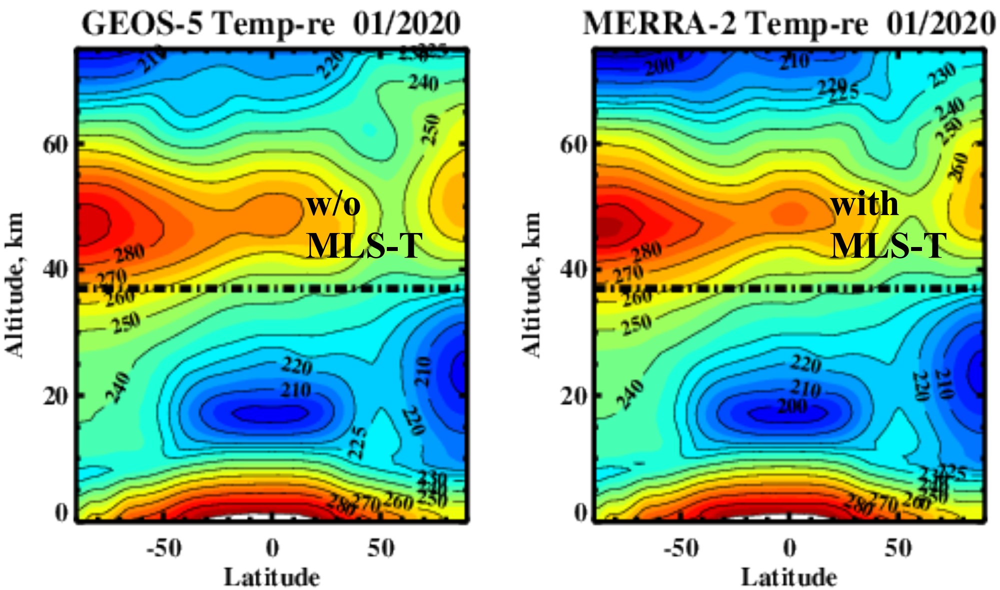
~1450 prof/day (latency ~ 5-7 days; retroDA)

DA of MLS and SABER in WAM can constrain: prevailing flow, diurnal cycles, tides & mixing.

WAM advantage – no sponge layers (TL-500km in diffusive domain)

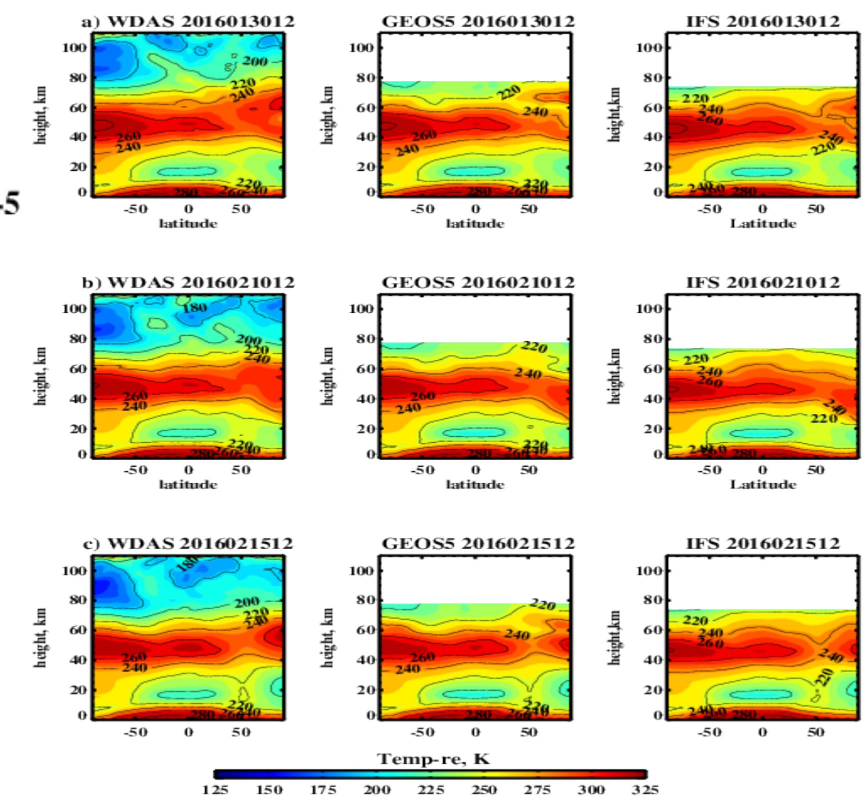
Analysis of SABER and MLS data in WAM ***=> DA and Forecast of FV3GFS-80km can be calibrated by MA data between 40-80 km.***



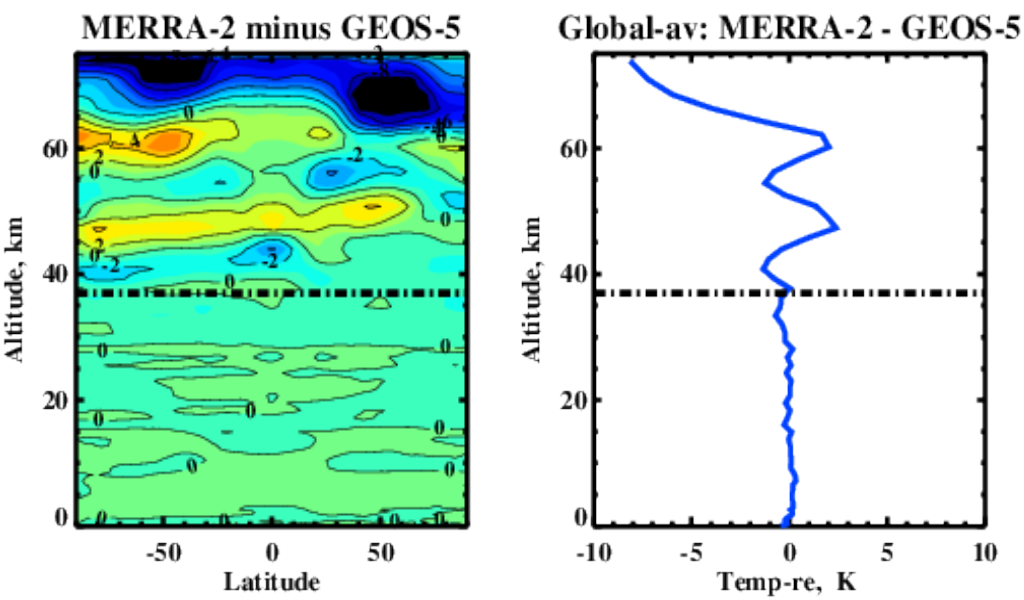


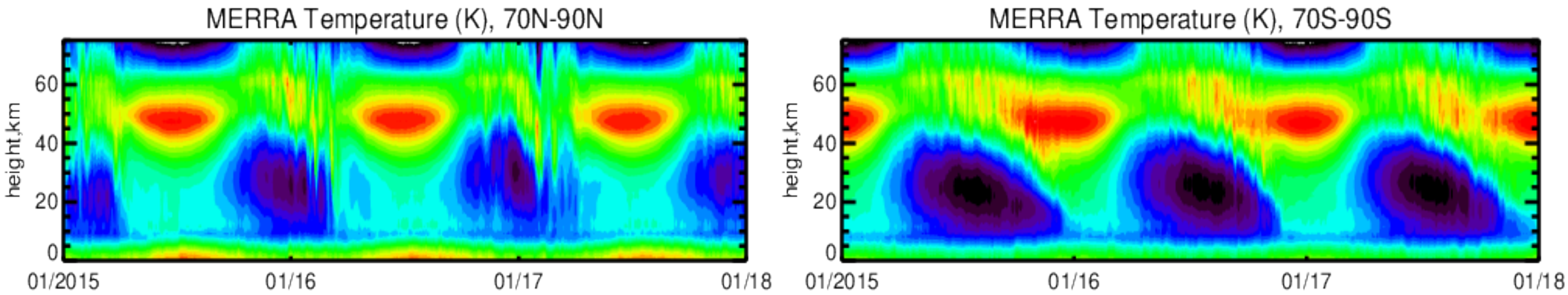
WARM BIAS near the TL of NWP models with RDA of AMSU-A and ATMS (60-80 km), *while "use" of MLS-T in reanalysis (MERRA-2) can bring the realism in the upper layers (remove ~5-10 K warm bias)*

Differences between T-analyses (WAM-MDAS, GEOS-5 and IFS) > 40 km

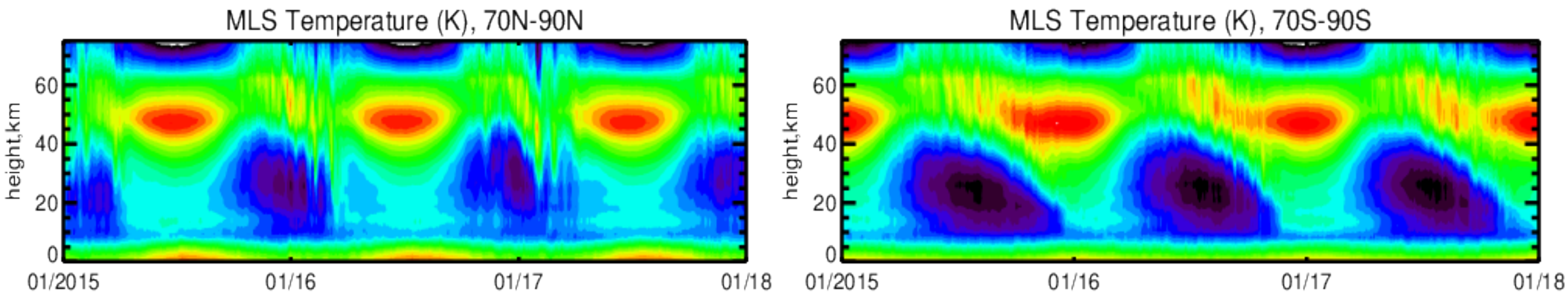


Impact of MLS-T data in MERRA-2 (above 5hPa)



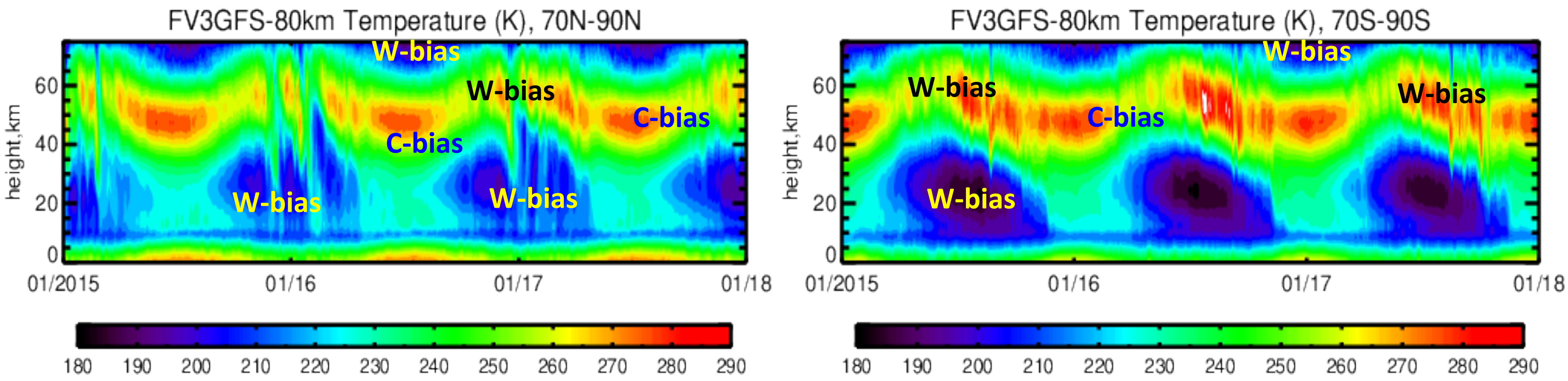


Polar Temperatures of MERRA-2 and MLS display striking agreements above the tropopause

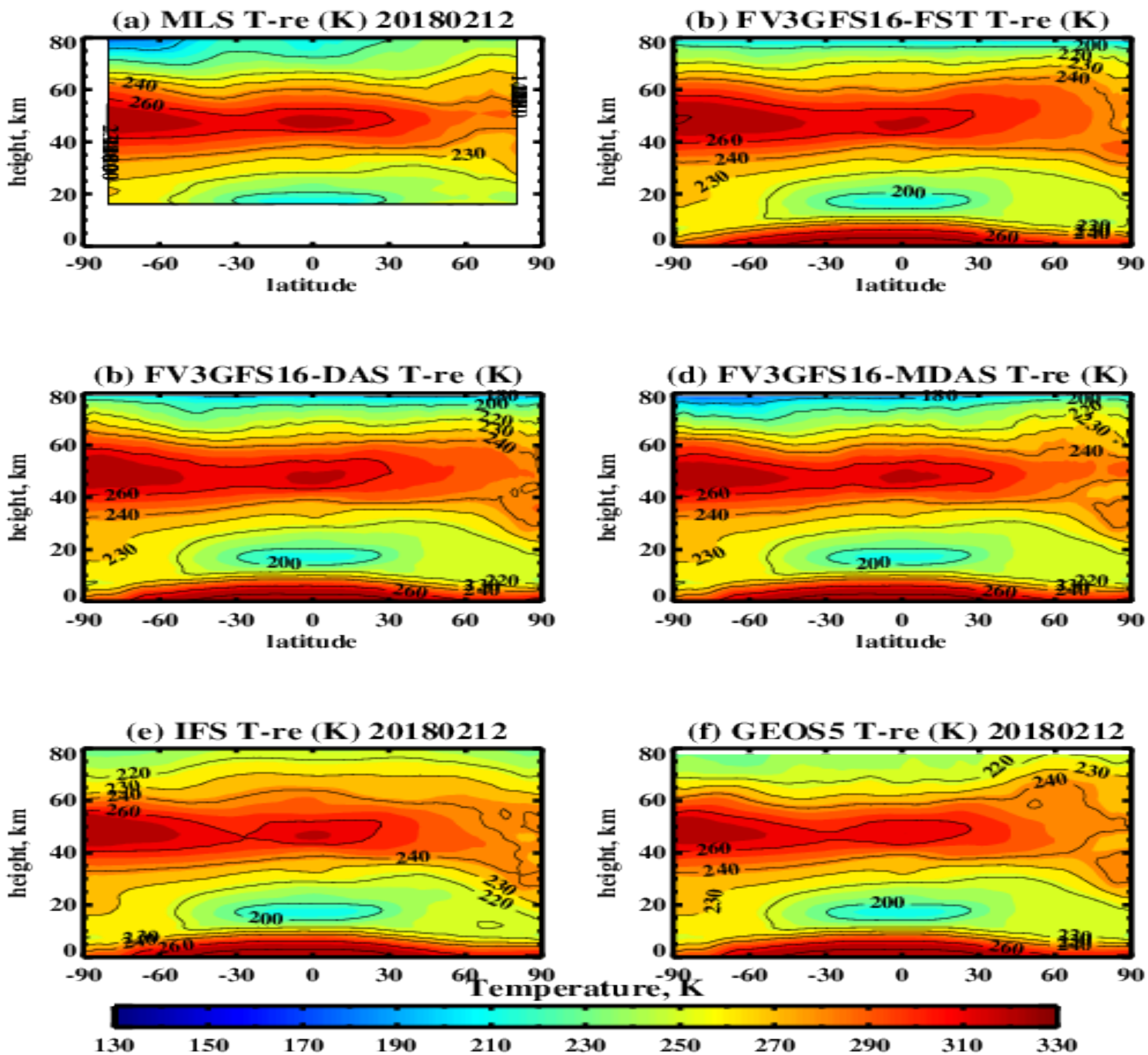


FV3-biases < 40 km can be removed by GDAS

Warm bias > 40km needs data anal. in upper layers



Temperature Analysis and Forecast in FV3GFS-80km

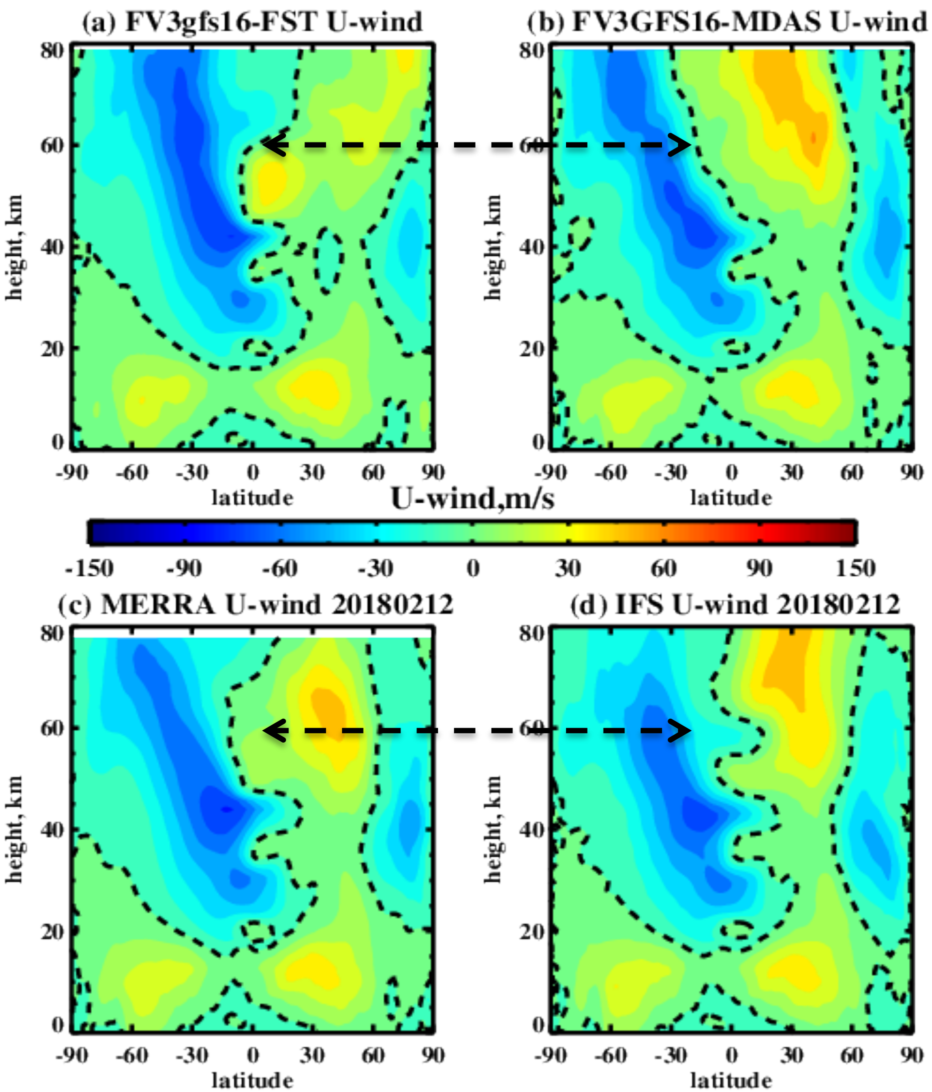


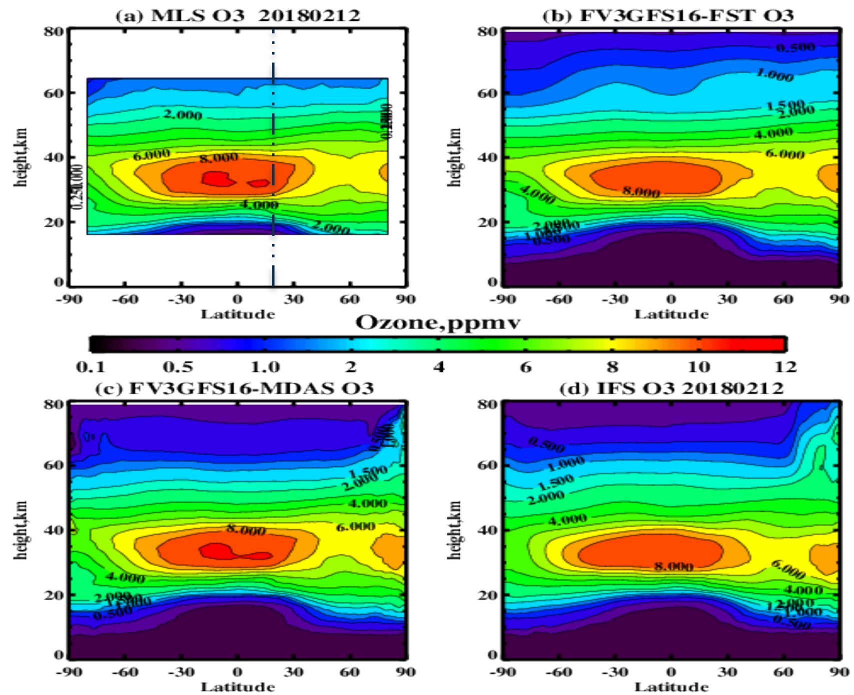
MLS-v4.2 data and FV3GFS-FST 10d from MERRA-2 (ICs)
FST-10d can predict SSW, but produce warm bias > 60 km.

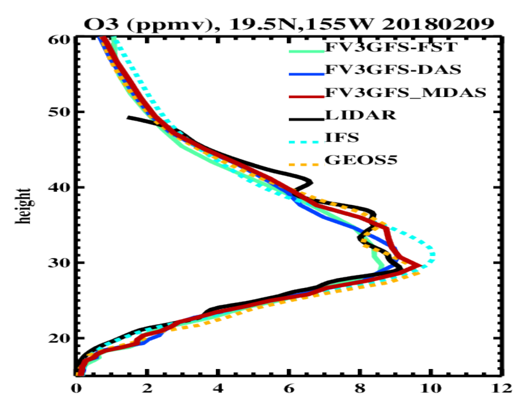
FV3DAS-3Dvar with and without SABER and MLS T-data (w/o AMSUA-Ch14 and ATMS-Ch15 radiances).
Both DA prevent warming in upper layers.

Operational analyses of IFS (ECMWF) and GEOS-5 with AMSUA/14 & ATMS/15 radiances, but w/o MLS data.
RDA in IFS and GEOS-5 can't prevent warm bias (>60km), correcting slightly warm bias below 2 hPa (~50-40 km)

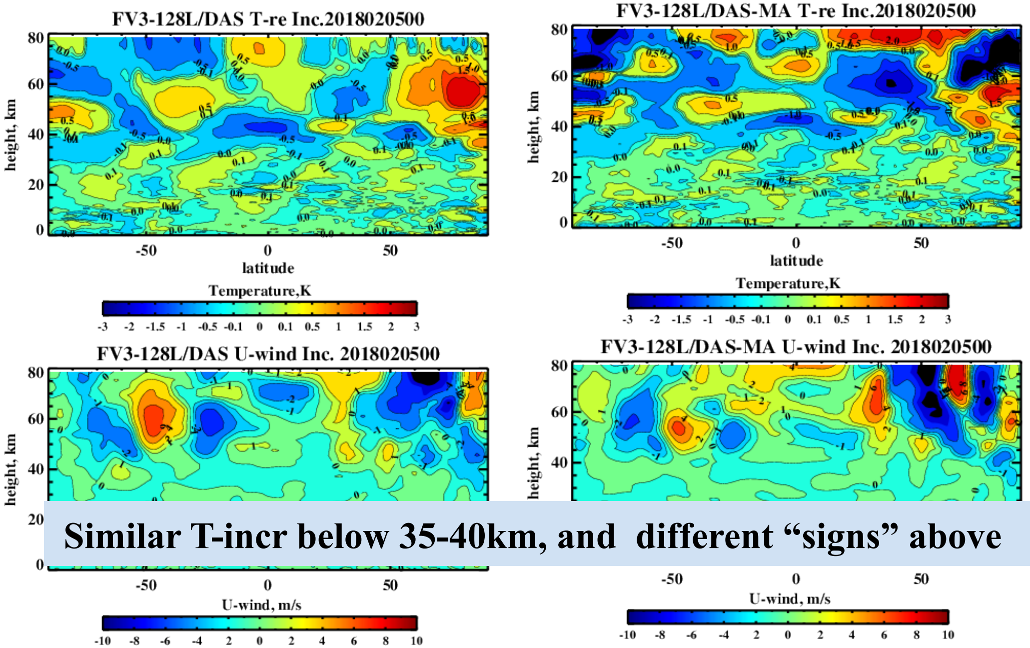
Zonal Wind and O_3 Analyses and Forecasts in FV3GFS-80km, 20180212 (SSW-onset)



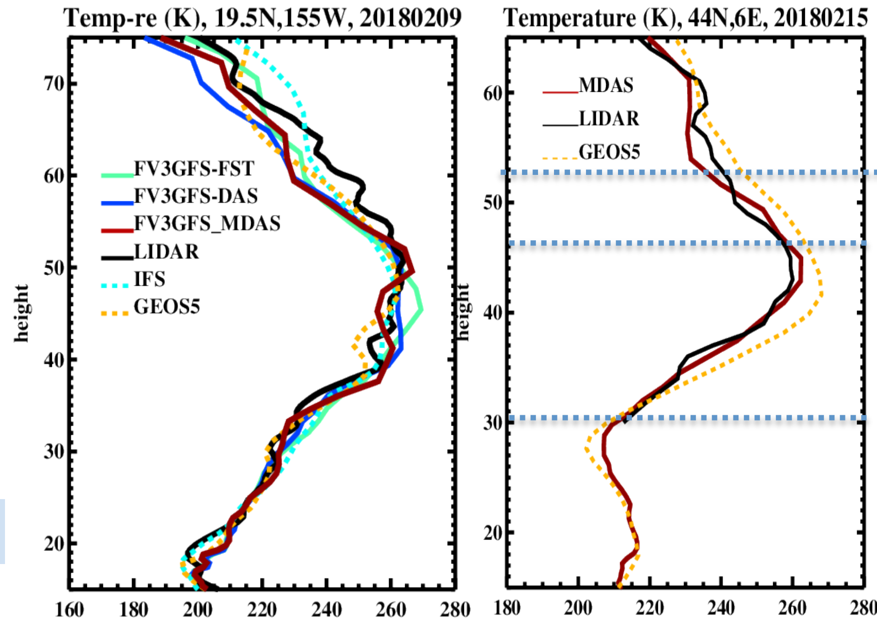




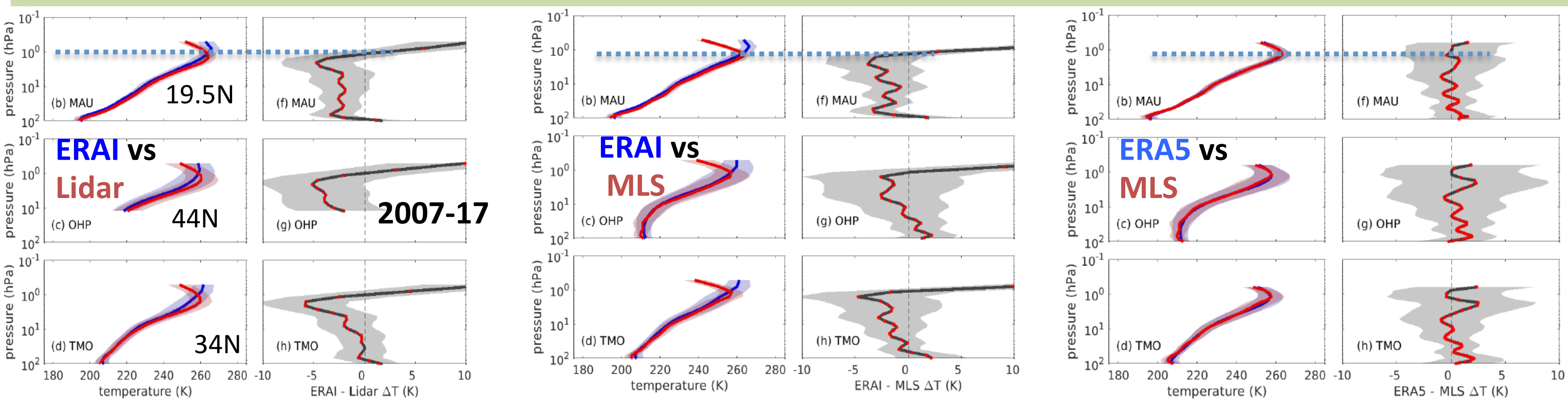
Analysis Increments with and w/o DA of SABER and MLS in FV3GFS-v16 (3DVar, C192) Feb 2018 and T-Lidars



Similar T-incr below 35-40km, and different "signs" above



ERA-I and ERA-5 (2007-17) vs MLS and Lidars, *Marlton et al. (2020)*; **Bias suppression in ERA-5 due to GPSRO**



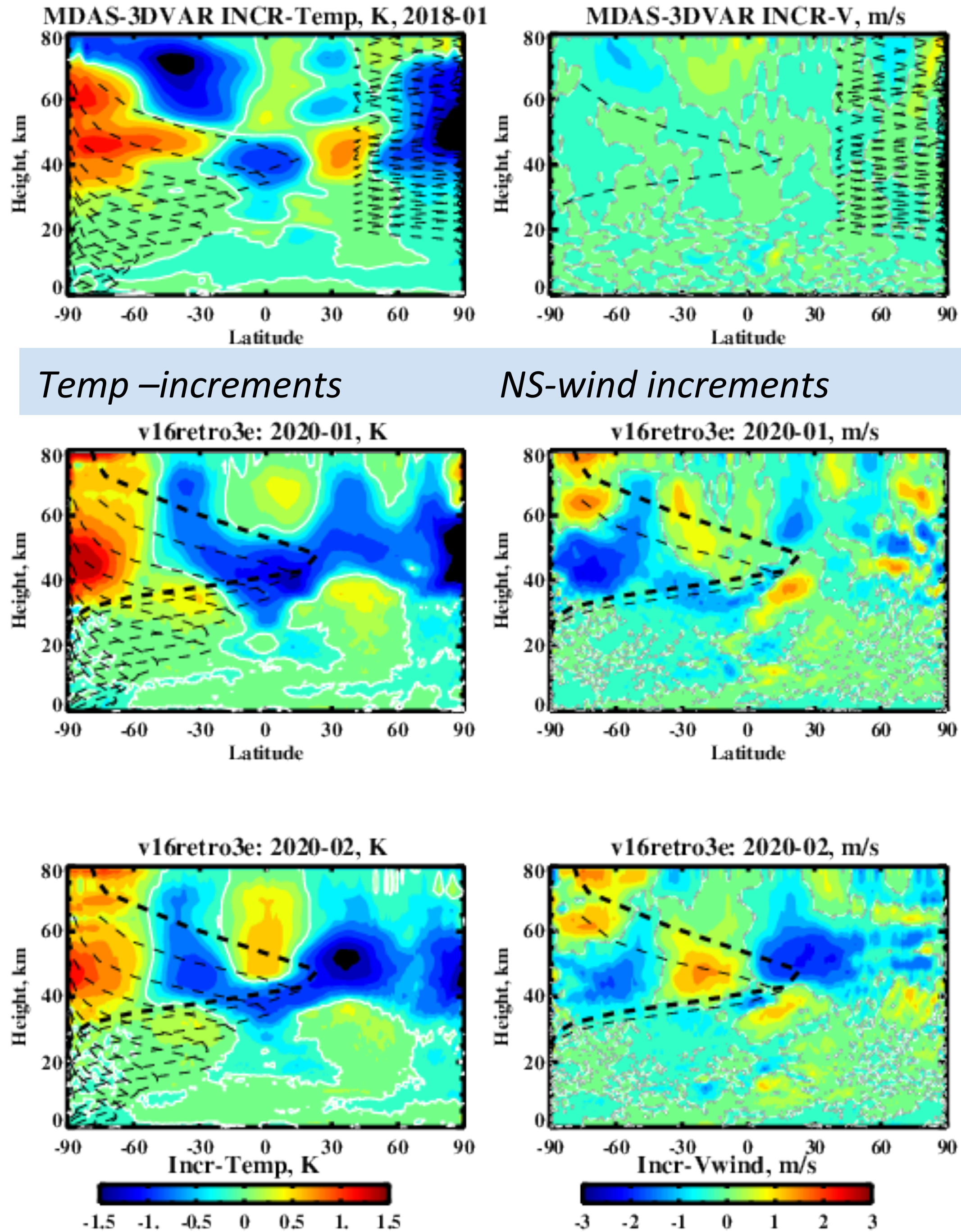
Monthly Analysis Increments of Temperature and Winds

3DVAR with MLS, Jan-2018 (above 40 km: weakest INCR-V; INCR-T display the expected Jan FV3-biases relative to MERRA-2).

V16Retro3e 4DEnVar-IAU without MLS, 2020-01, (enhanced INCR-V in the “data-blind” domain above 60 km; spread of INCR-T to the TL).

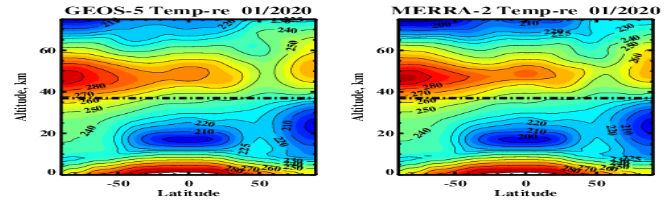
V16Retro3e, **2020-02,** Ensemble cross-correlations (V-T) and TLNM-balance can initiate largest wind increments from the high-peaked AMSU-A/ATMS ch at the top layers

Recipe: avoid vertically variable “wind” increments near the top especially for the FV3-NH dycore.

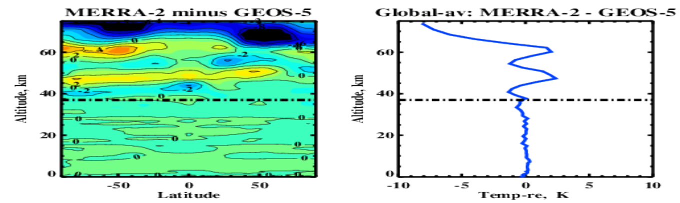


Concluding Remarks and Why UFS may Support MA Data Analysis with the Doubling Layers and Raise of the FV3 Top ?

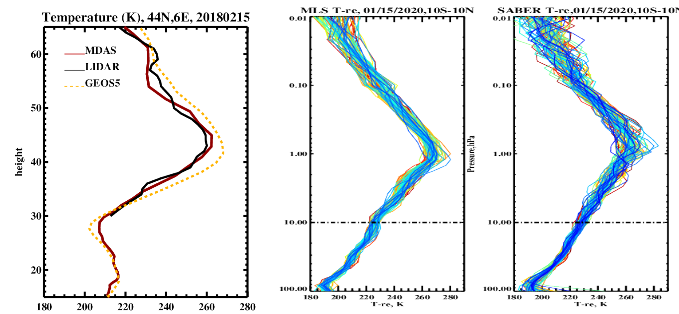
- **Both MLS and SABER vertical profiles can remove biases in GSMWAM and FV3GFS-80 km above ~35-40 km** (top bounds of radiosonde and RO profiles) and constrain the high top models towards the upper atmosphere climatology.



- **Upper layer T-biases of NWP models and modern reanalyses can be removed by MLS data,** as displayed by comparisons of **GEOS-5 and MERRA-2**, along with evaluation of **ERA** by lidar/MLS data (*Marlton et al*., 2020).



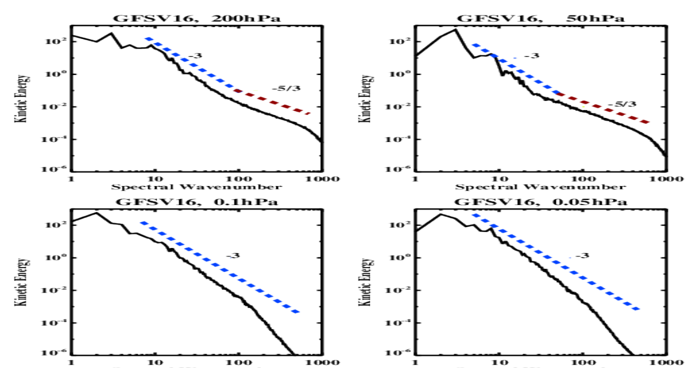
- **Next generation of NOAA reanalysis (127-Levels)** will be improved by considering **SABER (2000-present) and MLS (2004-present)** profiles in the stratosphere and mesosphere.



For GFS-operational systems:

- **Orchestration of MLS-T with ATMS-15 and AMSUA-14 radiances to address "biases" and control the ensemble spread above 40 km** can be alternative to the "enhanced" dycore damping of FV3 above 30 km **in GFSv16-17.**

- **The MLS-NRT profiles (T, O_3, and H_2O)** with 3-hr latency **can be ingested to improve the stratosphere-troposphere coupling for MER and S2S in GFS;** *doubling of GFS vertical resolution needs better utilization of vertical profile data: sondes, GPS-RO and MLS.*



Consistency between Vertical (dz) and Horizontal (dX) Resolutions of Observing Systems: Model and Data

Consistent Vertical and Horizontal Resolution

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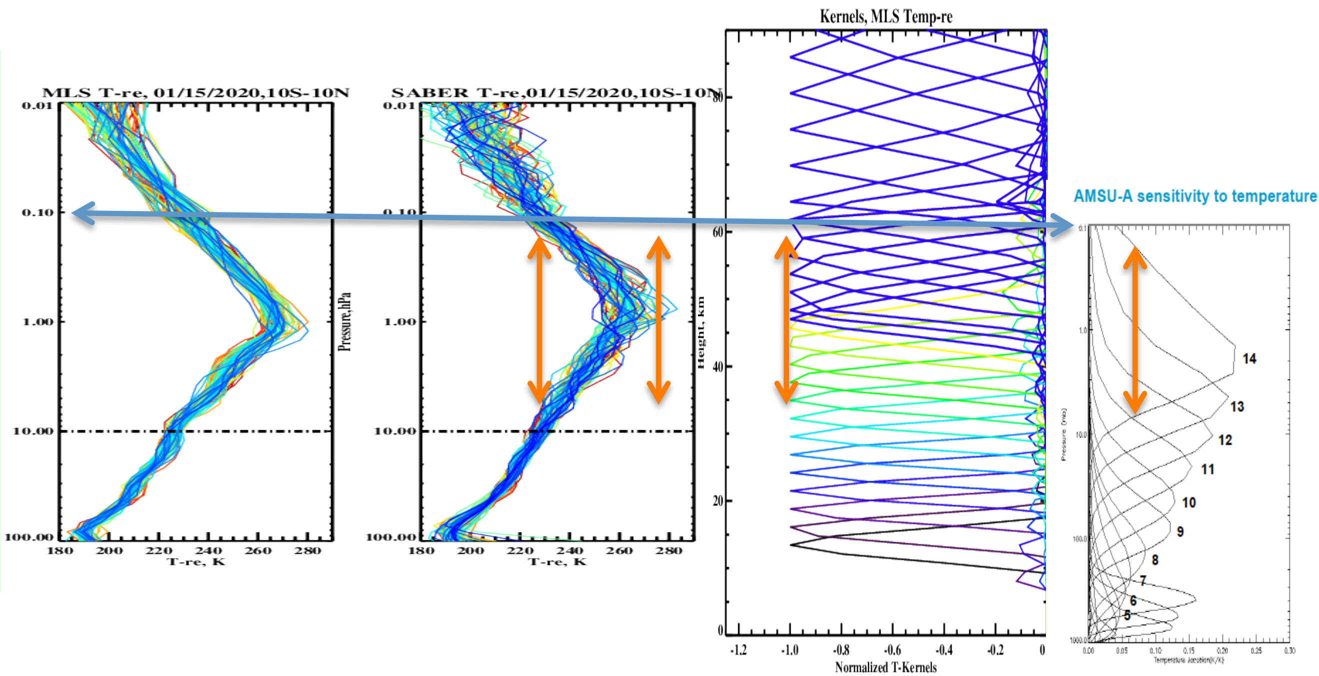
a. Quasi-geostrophic flows $\Delta L = \frac{N}{f_0}\Delta z.$ $\Delta z \approx 0.776\Delta\phi.$

AR= dX/dz ~ Tau_dyn/[5-min] ~ 10-100

b. Gravity waves $\Delta z_{\min} \approx \frac{\sigma_i}{N}\Delta L.$

Upper layer nadir sensors: Jacobian's vert. width > 2 pressure scales (15-25 km) and pixel size dX ~80 km; dZ_Jac ~ dX (AR=dX/dz ~ 1); data cannot resolve vertical propagation of PWs, tides, and GWs in the strato-mesosphere; ***radiance data can correct horizontal structures of layer-averaged temperatures (where T-profile values vary from ~225K to ~270K).***

Limb-viewing sensors
(MLS, SABER, & GPSRO with dz < 1-5 km and dX ~100-200 km; AR > 10) can "see" and constrain vertically propagated waves. Vertical resolutions of data and models are comparable; along limb view T-values vary on several K fort typical dT/dx.



Jan 2020, C384: Variability of FV3-climate run (1-YR) vs Ens Spread for “V16retro3e” Ensemble spreads are ~3-5 times larger, and likely dominated by “analysis” adjustments; no signatures of enhanced “wintertime”polar variability; vertical wind variance is larger and deeper; unexpected “resemblance” between U and V variances.