Tropospheric ozone data assimilation in the NASA GEOS Composition Forecast Modeling System GEOS-CF v2.0 including direct assimilation of thermal infra-red radiances

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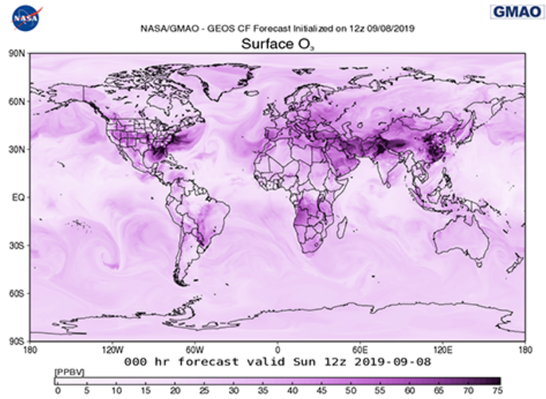
GEOS-CF is a powerful tool for global chemical analyses and forecasts

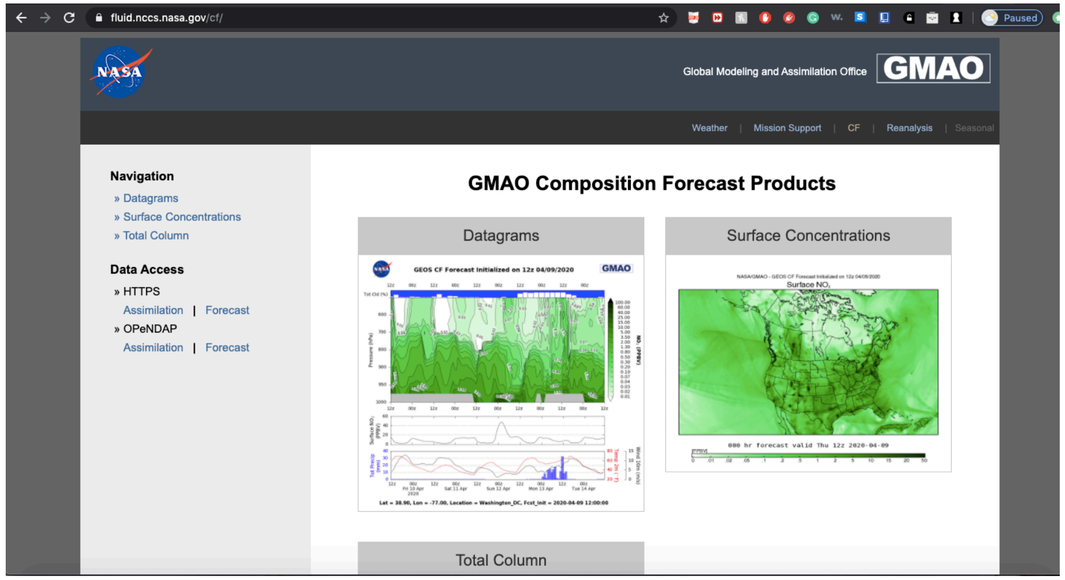
GEOS Chem + GMAO =

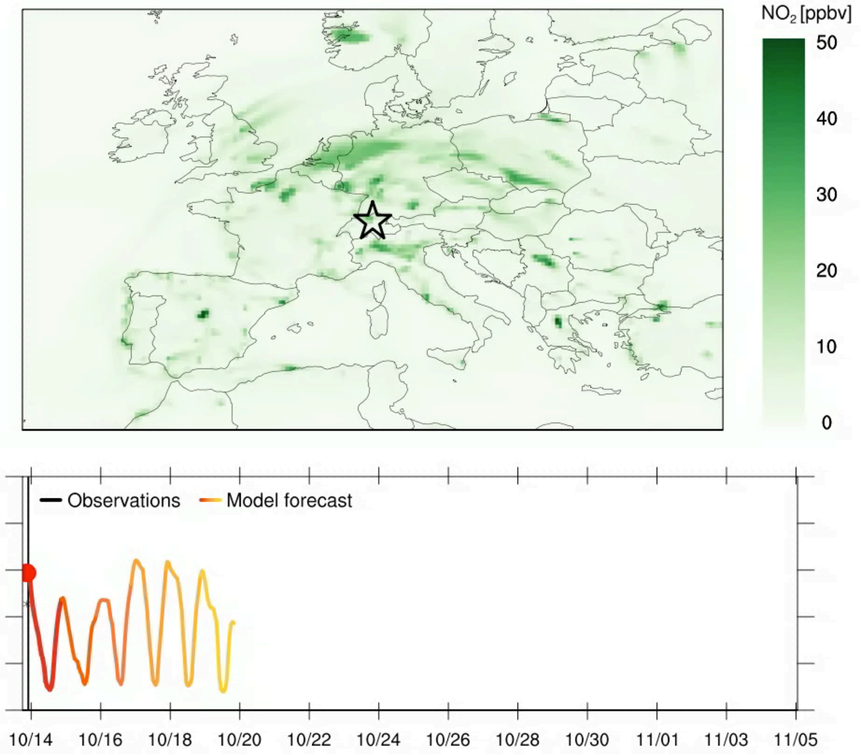


State-of-science chemical module

GEOS Earth system model

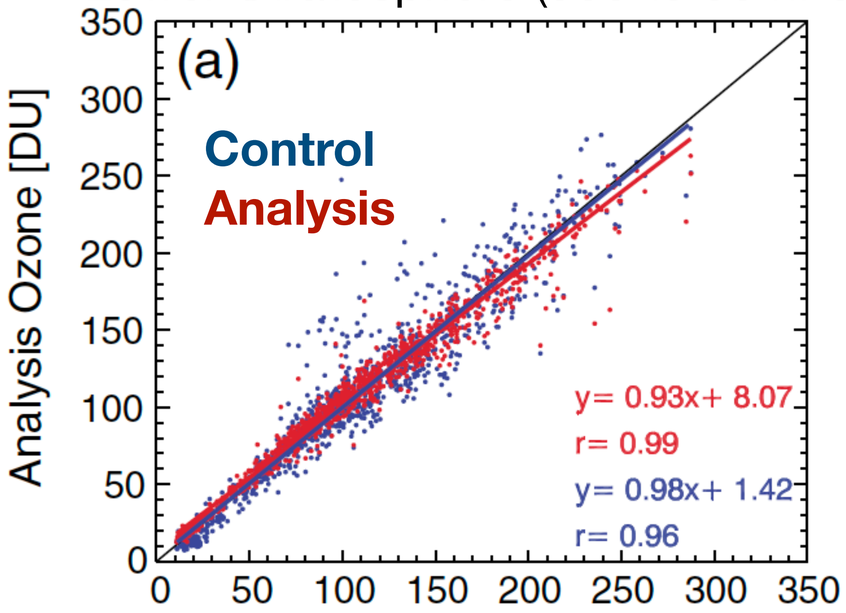
"online" GEOS-CF



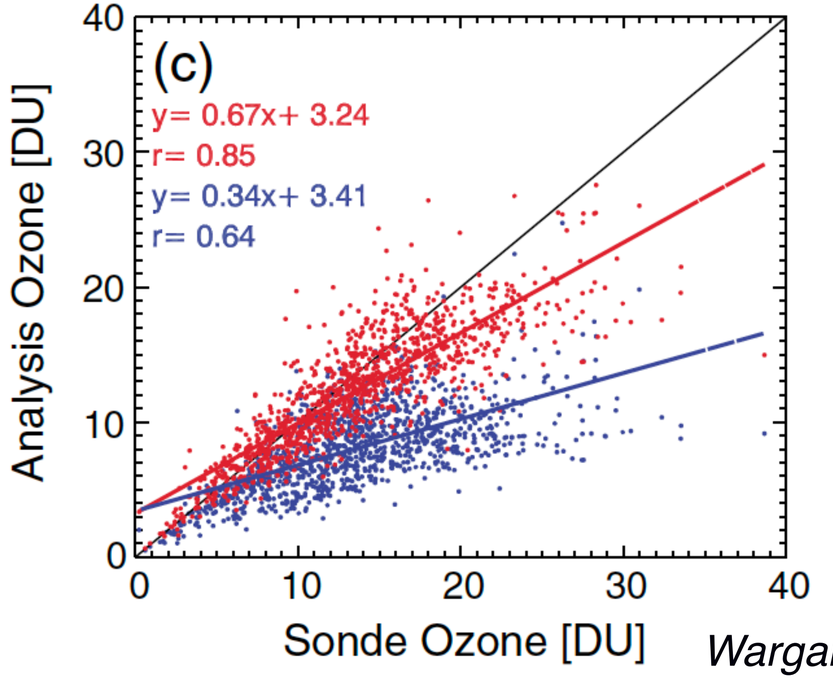


Keller et al., 2021

Lower Stratosphere (500 to 50 hPa)



Upper Troposphere (tropopause to 500 hPa)



Wargan et al., 2015

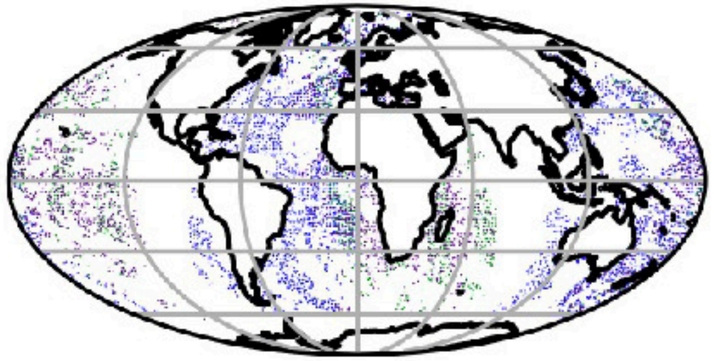
Current generation of GEOS-CF v1.0 lacks chemical data assimilation (CDA) capabilities

- Building off of GEOS-FP data assimilation system (Wargan et al., 2015 + others):
  - Assimilate OMI, MLS ozone
  - No chemical P or L in trop., only dry deposition
  - Lower strat. ozone variability driven by assimilated winds
  - Upper trop. ozone fit much worse because chemistry is a large driver
- GEOS-CF v1.0: Stratospheric ozone only nudged toward GEOS-FP (MLS + OMI)
  - Include chemical P and L in trop.

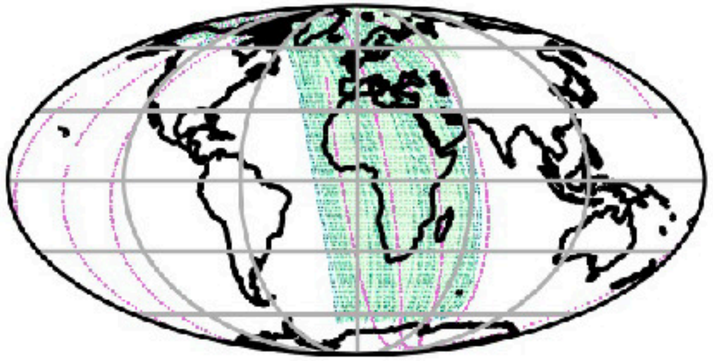
In GEOS-CF v2.0, we can assimilate satellite UV-Vis observations, thermal IR radiances, and apply full chemistry to the troposphere in a 3D-Var CDA framework

Spatial Coverage

Hyperspectral 1200 UTC



UV/Microwave 1200 UTC

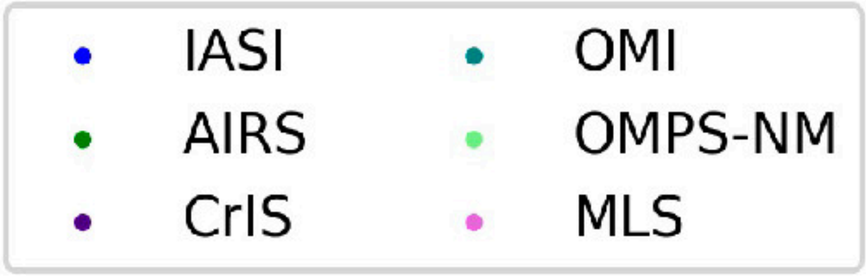


# of obs per D.A. window:

OMI: 2.5 x10^3

MLS: 2.7 x 10^4

IR radiances (AIRS, IASI): 1.2 x 10^6



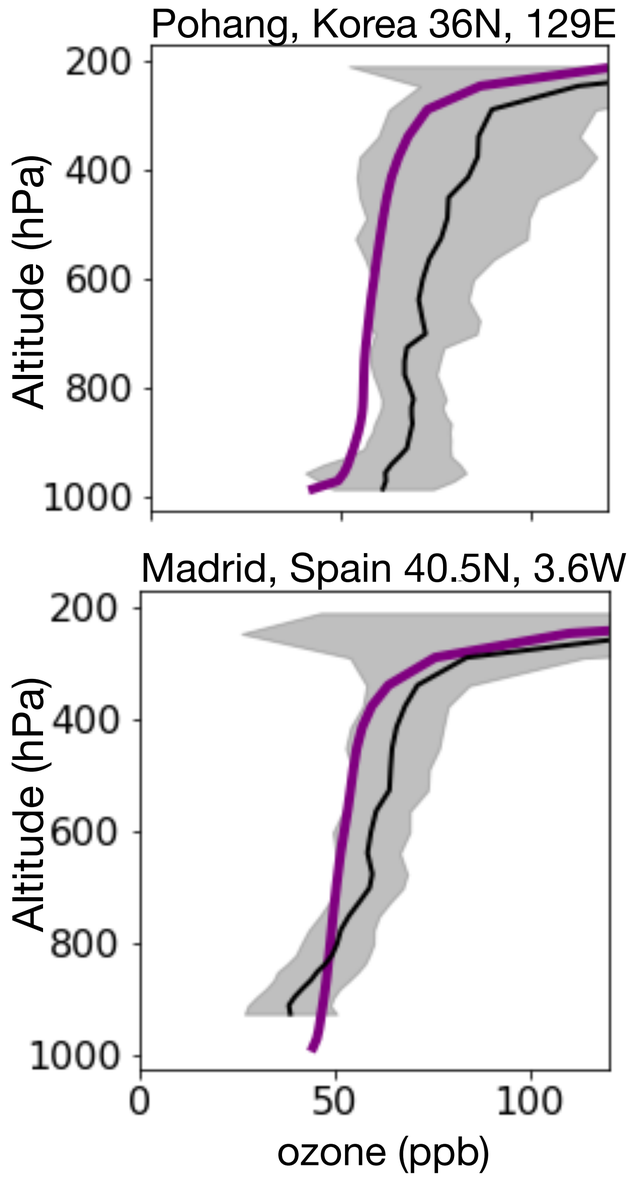
+	Observations at Night
+	Greater spatial coverage
+	Bypass 3rd-party retrieval
+	Higher sensitivity into trop (500 hPa)
+	Real-time latency
-	Computationally expensive radiative calculations

Karpowicz et al., 2021

CDA experiments for a year-long 2018 simulation

MAM 2018

Sonde +
Uncertainty
Control



(1) Control run with no assimilation or nudging
-GEOS-Chem v 13.4
-Sea-salt aerosol debromination turned off
-No updated aerosol nitrate photolysis

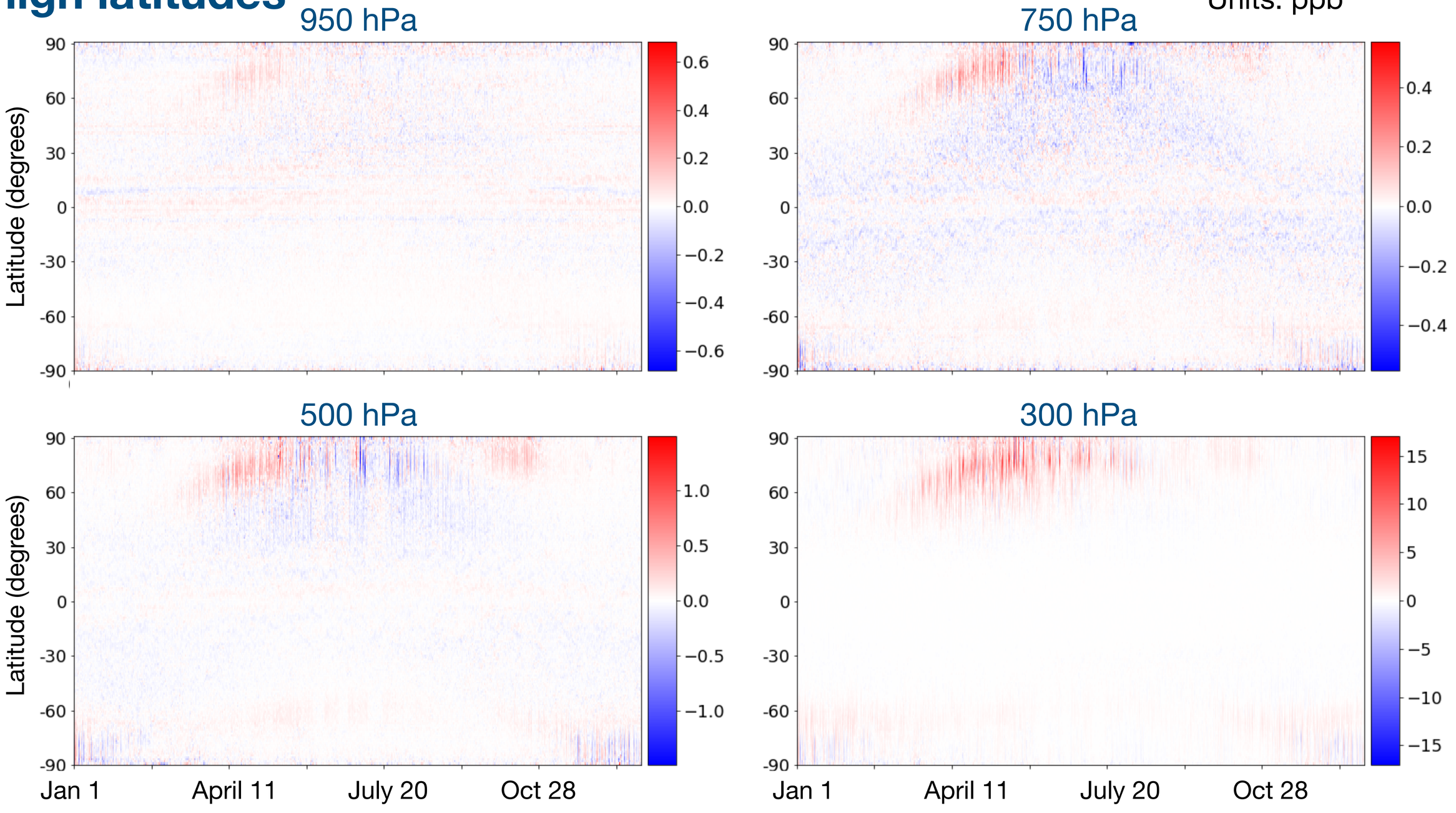
(2) Nudged run where stratospheric ozone is nudged to
GEOS-FP ozone
-Approximately equivalent to GEOS-CF v1.0

(3a) 3D-Var assimilation with OMI + MLS
(3b) 3D-Var assimilation with Radiances (IASI, AIRS)

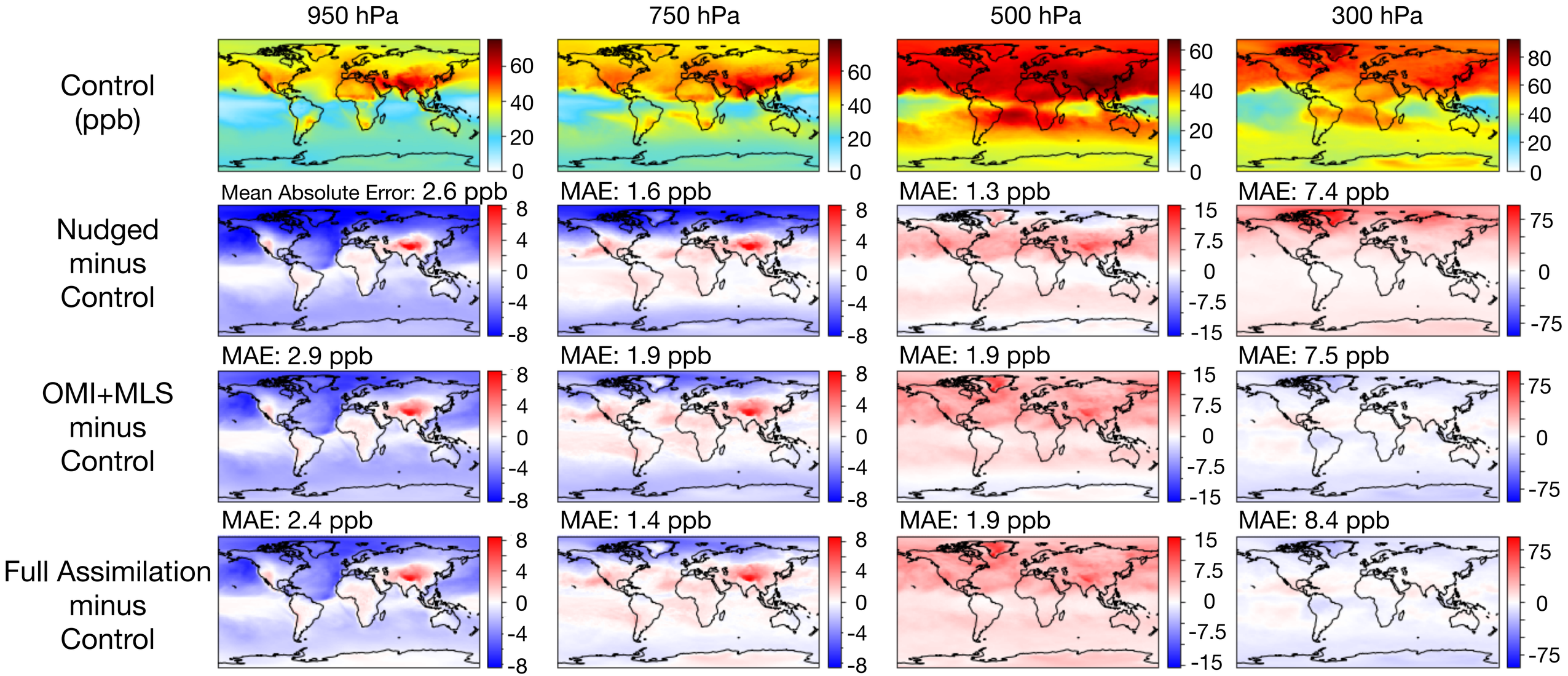
(4) 3D-Var Full Assimilation with OMI, MLS, and radiances

Full assimilation ozone increments (every 6 hours) are primarily added at mid-high latitudes

Units: ppb



CDA and Nudging improve upon known CF's overestimate of surface ozone and underestimate in mid-latitude upper trop. ozone during MAM 2018



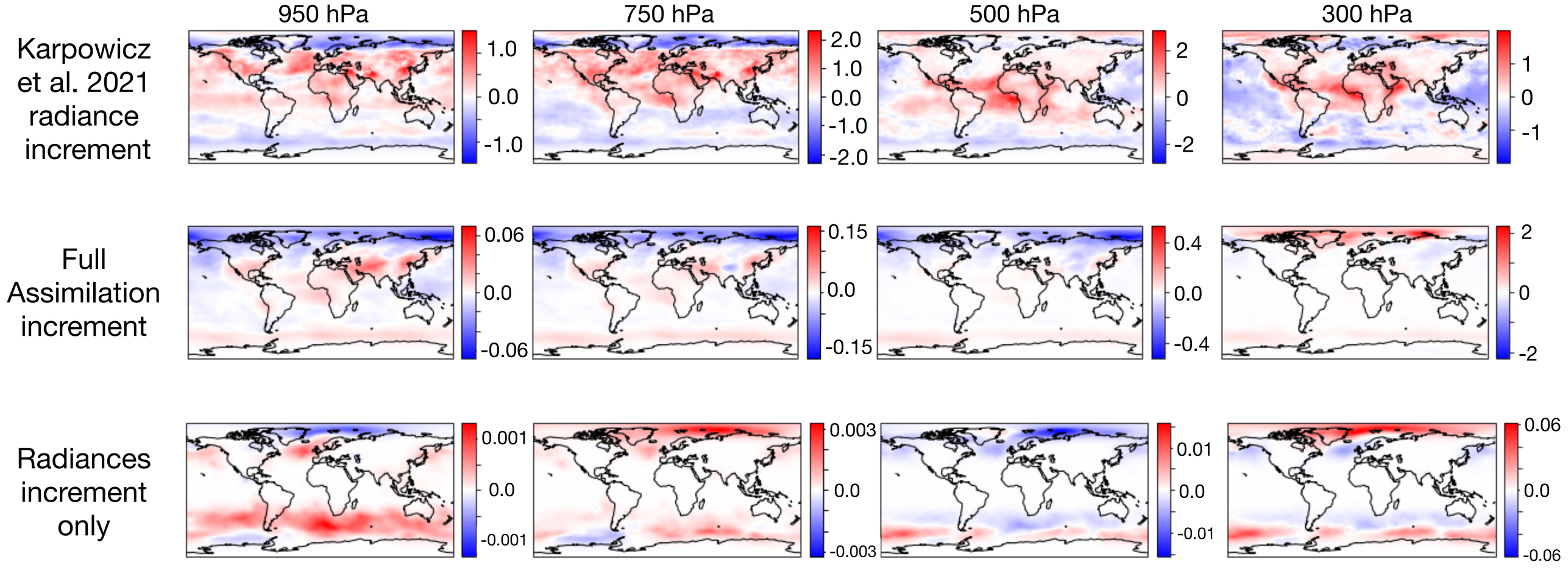
Blue = Native forecast (Control) is too high, **Red** = Native forecast (Control) is too low

Units: ppb

We find radiances add relatively smaller increments in the troposphere compared to previous implementations due to CF's 1) better prior ozone background, and 2) uniform rather than scaled background error between strat. and trop.

July 2018

Units: ppb



CDA moves model ozone closer to ozonesondes than the Control, closer than Nudged in the upper trop.

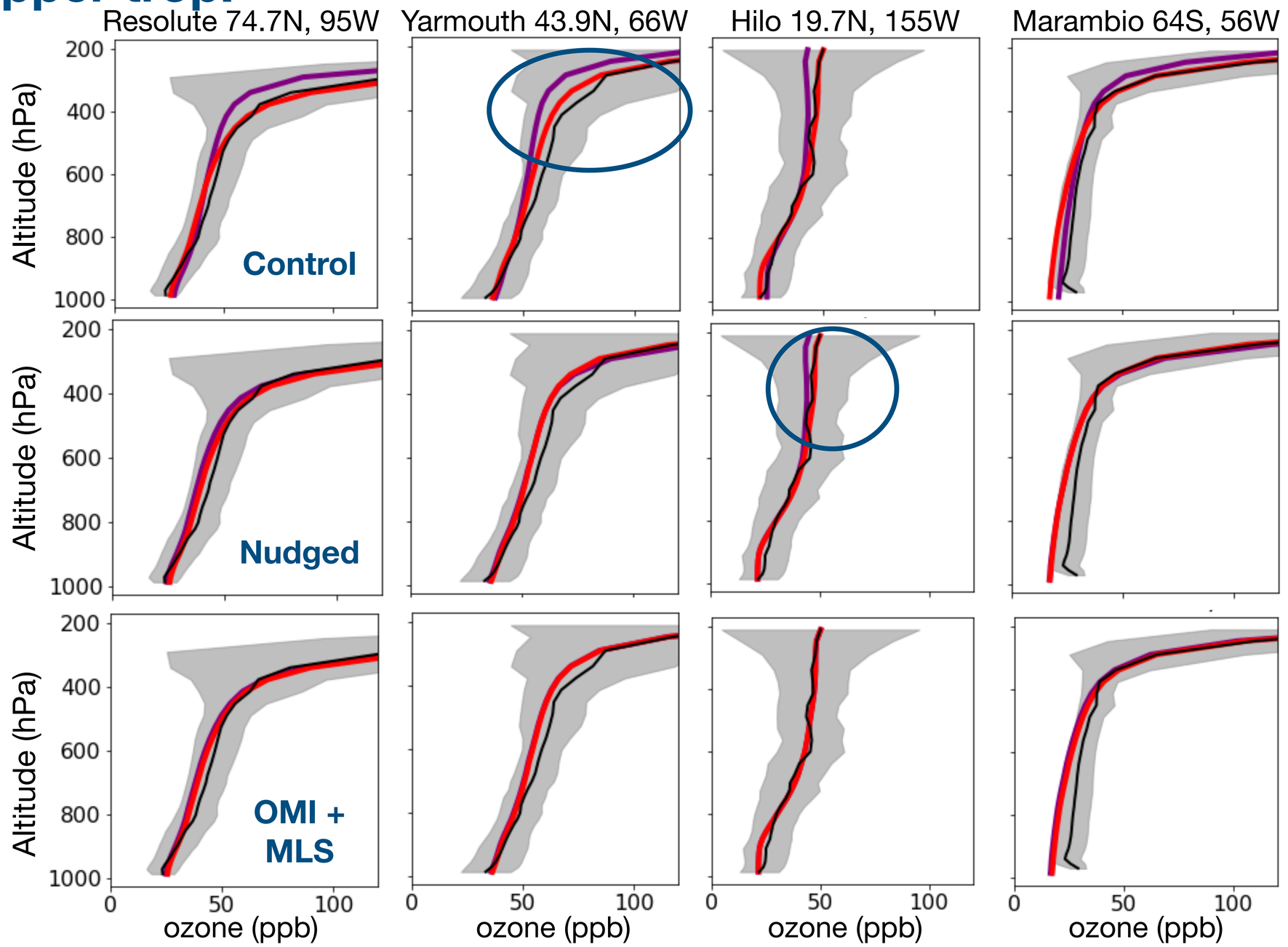
Year 2018

Sonde + Uncertainty

Full Assimilation

*differences larger at >400 hPa

*minor differences in upper trop



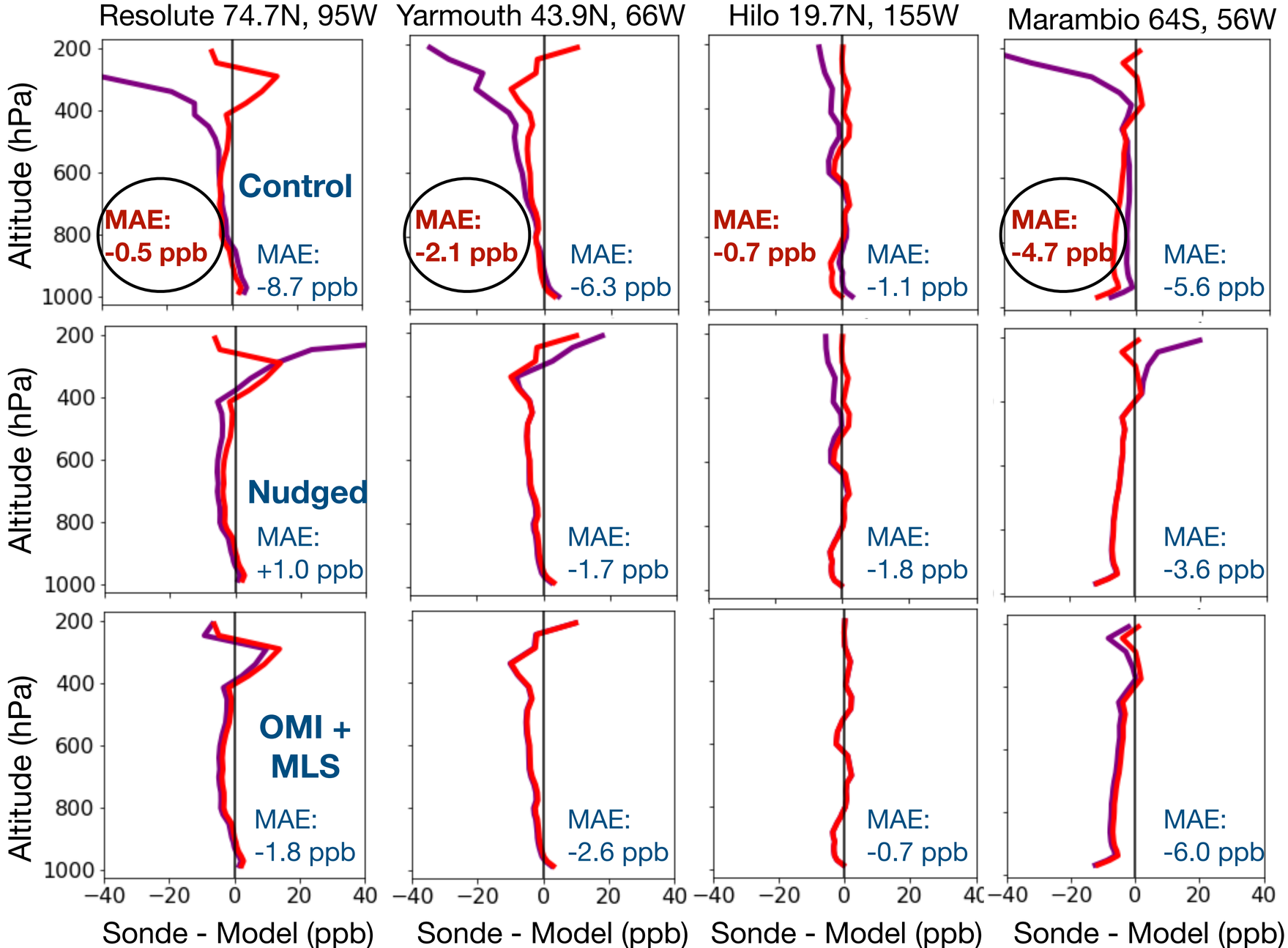
Differences from sonde data suggest that Full Assimilation and OMI + MLS similar from surface to ~500 hPa, radiances may act as a constraint in the upper trop.

Year 2018

Sonde

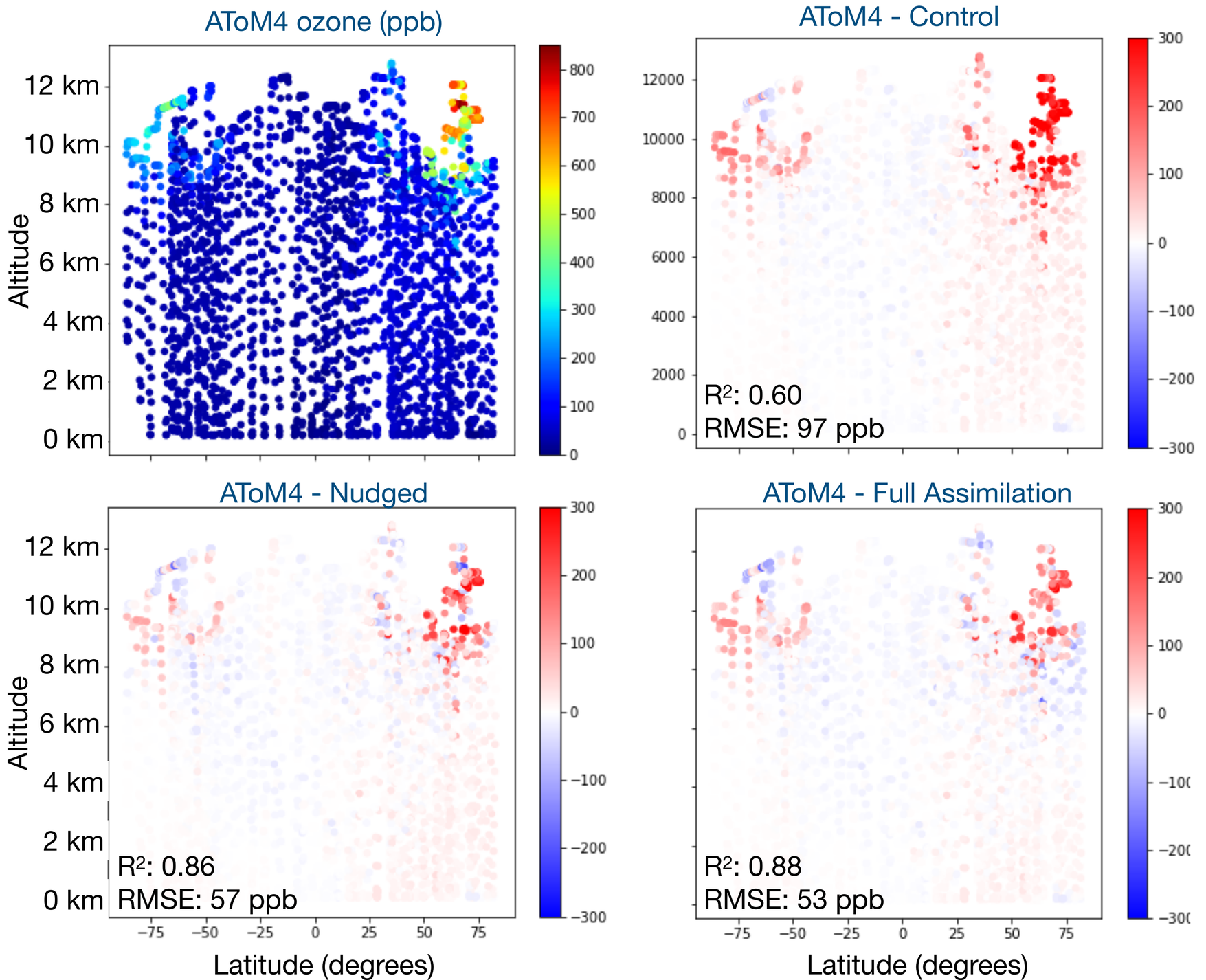
Full Assimilation

Radiances adding UT information



CDA moves GEOS-CF ozone closer to AToM4 observations, but nudging alone captures substantial corrections in upper trop

*OMI + MLS similar to Full Assimilation



Takeaways

-Chemical data assimilation improves model ozone over a native forecast (no assimilation, control) when compared against ozonesondes and AToM4
  -Largest ozone improvements in the northern and southern midlatitudes.

-Nudging (CF v1.0) in stratosphere leads to significant improvement in trop. ozone, which might suggest that stratospheric ozone is too low in GEOS-CF

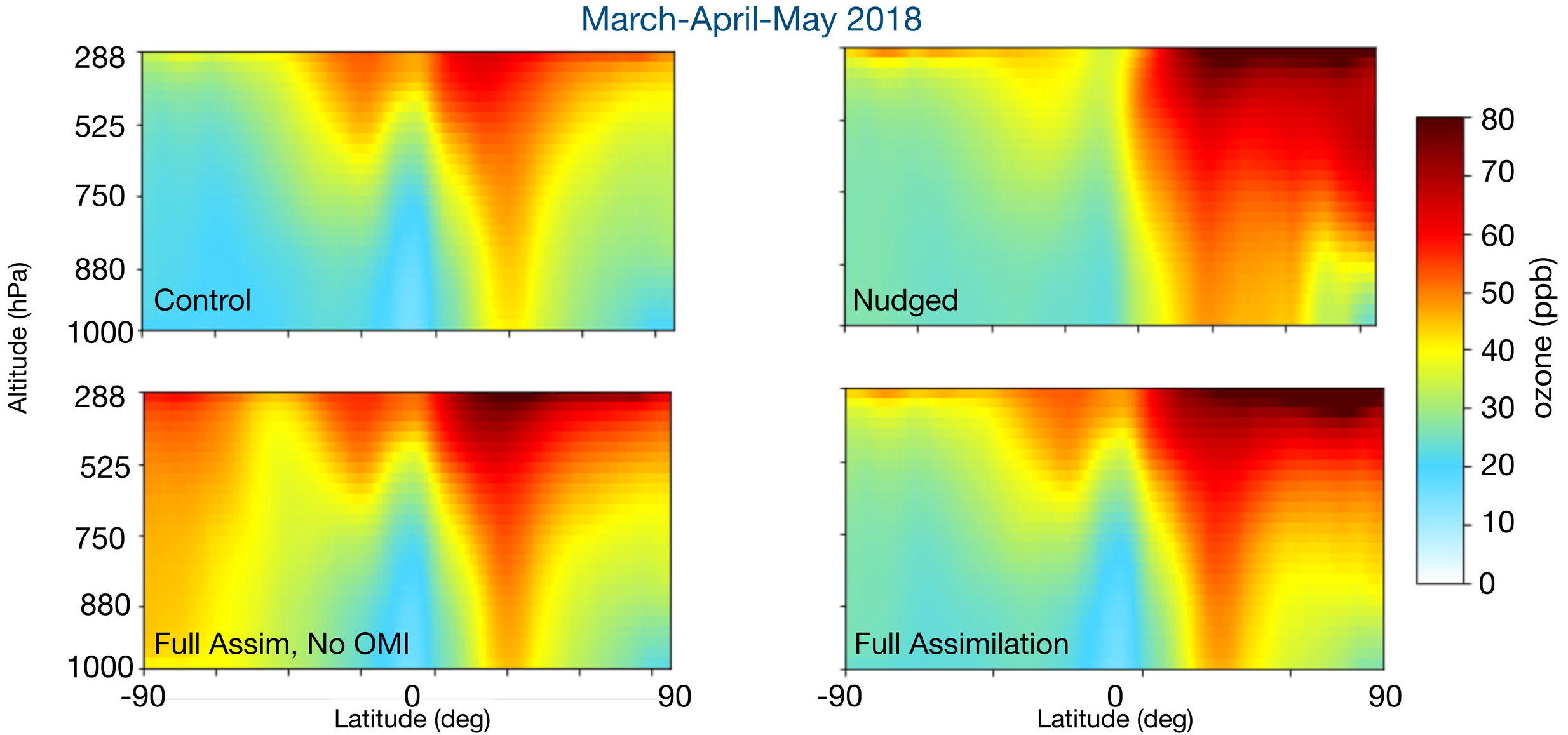
- IR radiances did not produce large increments here, but can be a worthwhile addition to an assimilation system.
  - Real-time latency + constraint in upper trop.

-Data assimilation can be used not only to improve accuracy of model simulations but also for benchmarking purposes

Makoto Kelp

Website QR code

Ozone increases from CDA extend throughout the column, OMI acts as an important constraint for lower trop. ozone



Karpowicz et al. 2021