All-Sky Geostationary Satellite Radiance Data Assimilation in JEDI Using CRTM

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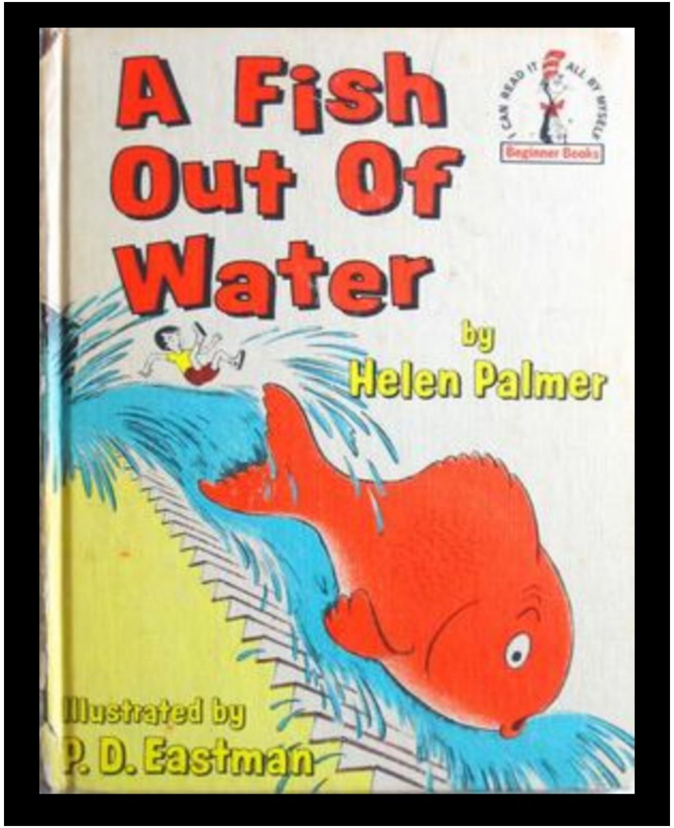
NWP and cloud physics



Hydrometeor effective radii updated

Radiative effective radius, R_e, defined by 3rd moment divided by 2nd moment of the particle size distribution

Using the generalized gamma distribution:

$$N(D) = N_0 D^{\mu} e^{-\lambda D}$$

produces:

$R_e = ½(3 + \mu) / \lambda = ½ [3 + \mu] * \{ [6/(\pi*\rho_{water})] * [\Gamma(\mu+1)/\Gamma(\mu+4)] * (Q_c/N_c) \}^{1/3}$

where Q_c is the liquid water content (kg/m^3), N_c is the droplet number concentration (#/m^3), ρ_{water} is 1000 kg/m^3 water density, and μ is the "shape parameter," N_0 is the "intercept parameter," and λ is the "slope parameter."

Microphysical Parameterization

Hydrometeor species

Mass mixing ratios of:

- Cloud water (small cloud drops generally less than 50 microns diameter)
- Cloud ice (small?, shape?)
- Snow (spherical?, plate-like?)
- Rain (drizzle or rain generally larger than 50 microns diameter)
- Graupel (heavily rimed snow and/or hail)
- Hail (sometimes separate category from graupel; often not)

One-moment or two-moment

Predicting total number concentration in addition to mass mixing ratio

Does not really matter, because we can always formulate a one-moment scheme to appear like two-moment in mathematics to diagnose a total number concentration.

Particle Size Distributions

"Old School" distribution assumptions

$$N(D) = N_0 \, D^{\mu} \, e^{-\lambda D}$$

Most one-moment schemes utilize constant N_0

Classical Marshal-Palmer distribution N_0 = 8 x 10^6 m^{-4}

Most one-moment schemes use $\mu = 0$ [inverse exponential]

New code is more generic

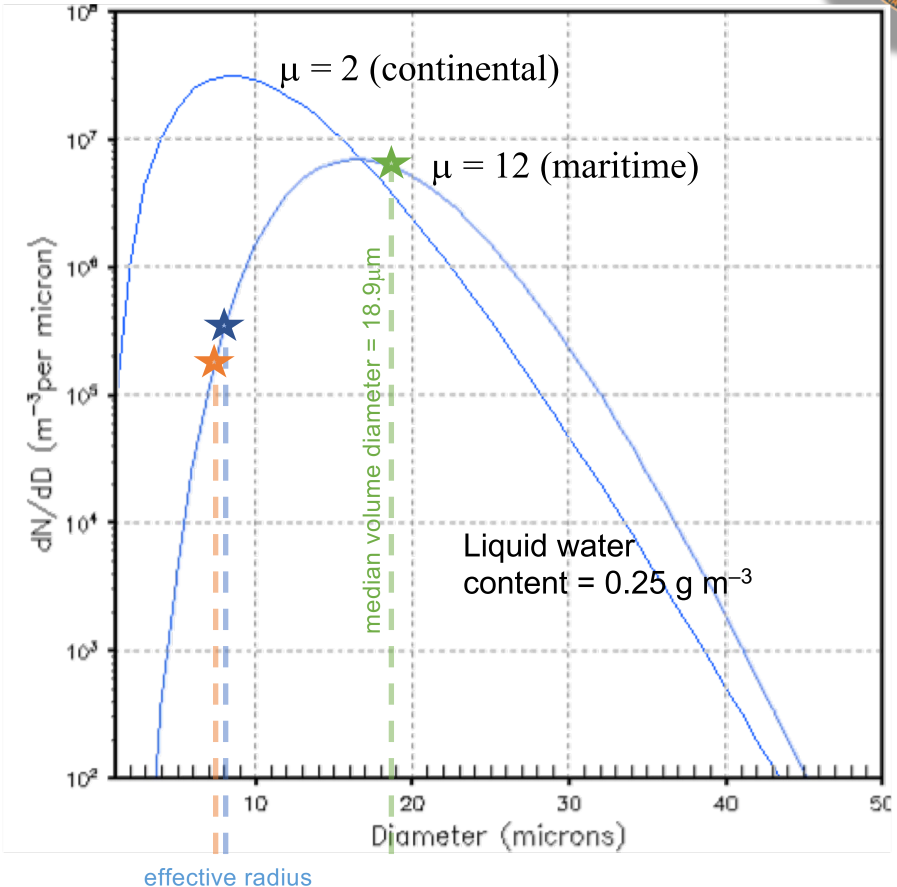
$\boldsymbol{N_0}$ can be diagnosed from other variables, e.g., Thompson graupel scheme

$\boldsymbol{\mu}$ can be non-zero and/or diagnosed from other variables, e.g., Thompson cloud water scheme

Cloud Liquid Water Drop Size

Importance: Cloud water

Allowing **μ** to shift provides far greater range of cloud droplet effective size found in clean maritime airmasses distinct from heavily polluted airmasses.



Cloud Ice Size

Cloud ice

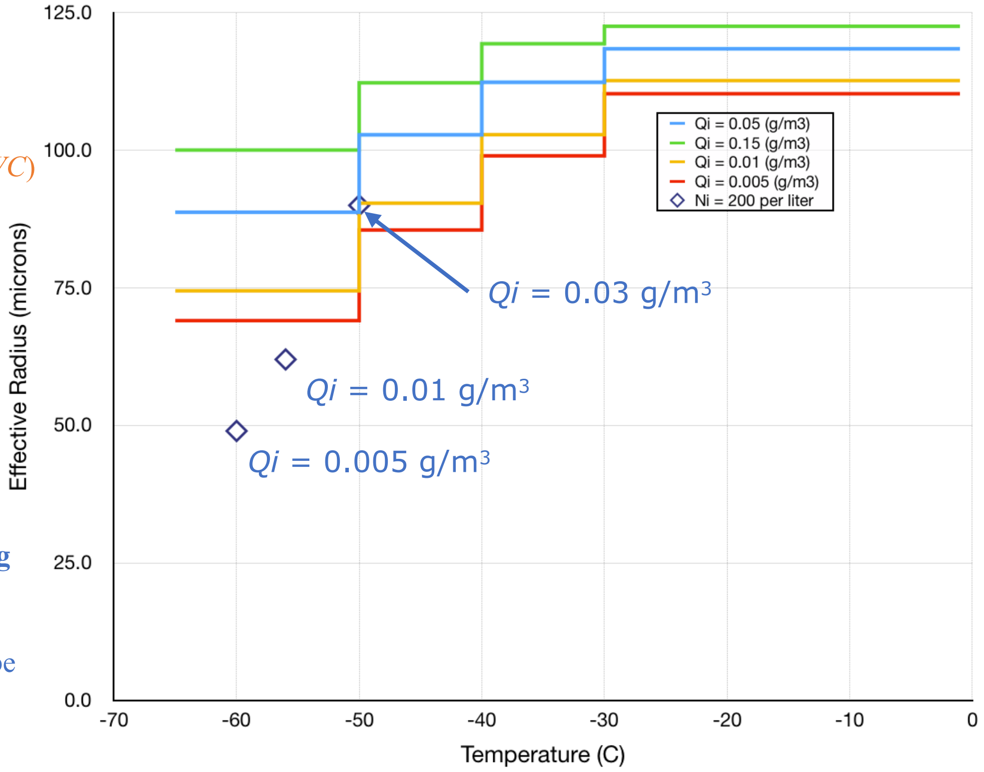
GFDL microphysics:

- does not specify a functional form of particle size distribution
- calculates ice size solely from temperature and ice water content (*IWC*)
- has step functions corresponding to temperature
- final computed value held between 10 and 150 μm
- example with $IWC = 0.05$ g/m³ and $T = -10$ °C produces 118.4 μm

Thompson microphysics:

- double moment so N_i is variable in space/time
- $\mu = 0$ is assumed
- final computed value held between 2.5 and 100 μm
- example with $IWC = 0.05$ g/m³ and $N_i = 100$ L^{-1} produces 84.5 μm
- there is no explicit temperature dependence, but **natural size sorting** causes the ice size to be smallest aloft and largest at lower altitudes
- since ice is double-moment, the number concentration greatly impacts the size such that the entire graph space (in the figure) can be included; examples holding $N_i = 200$ per liter and changing *IWC* are shown

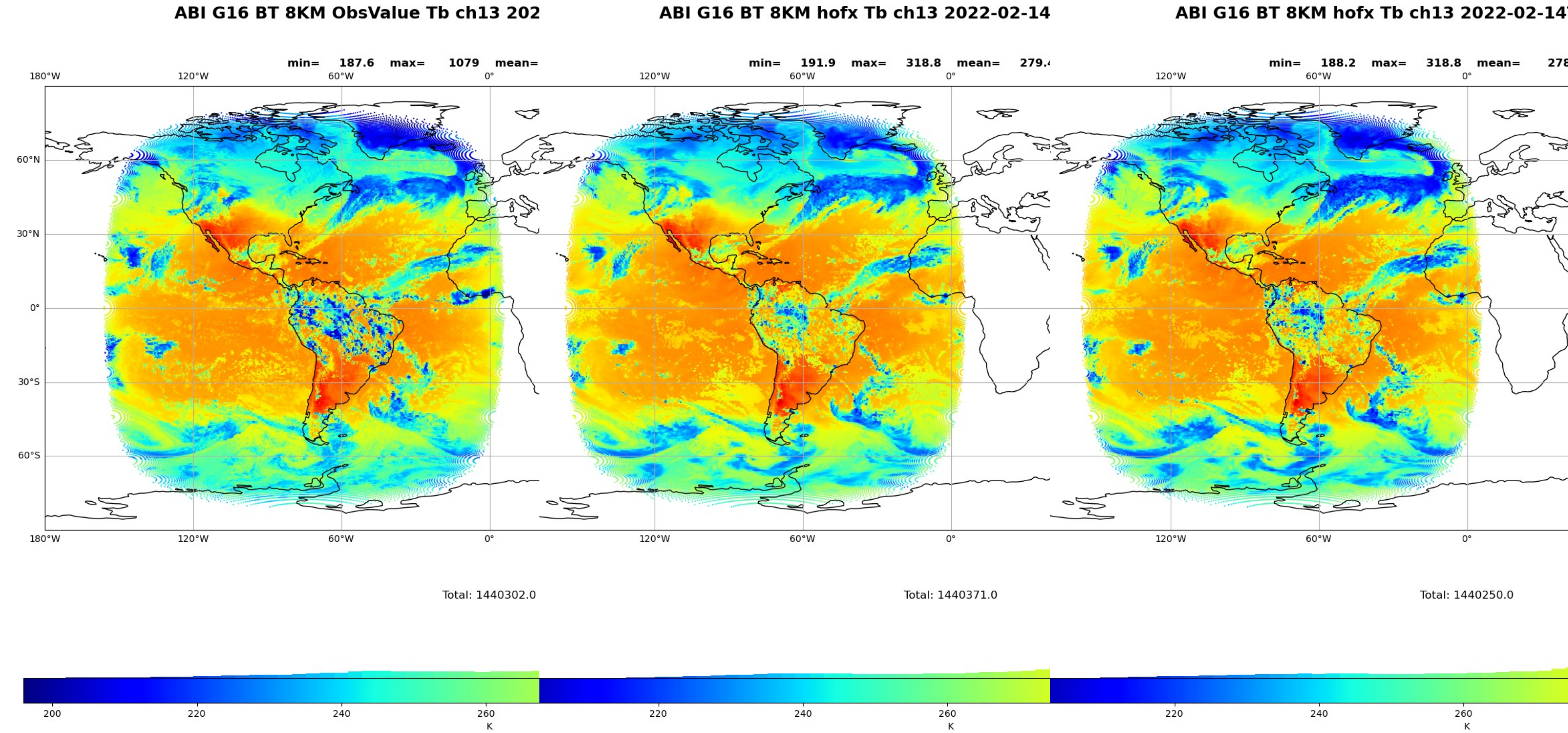
GFDL ice radii (lines)



Observations

GFDL effective radii method

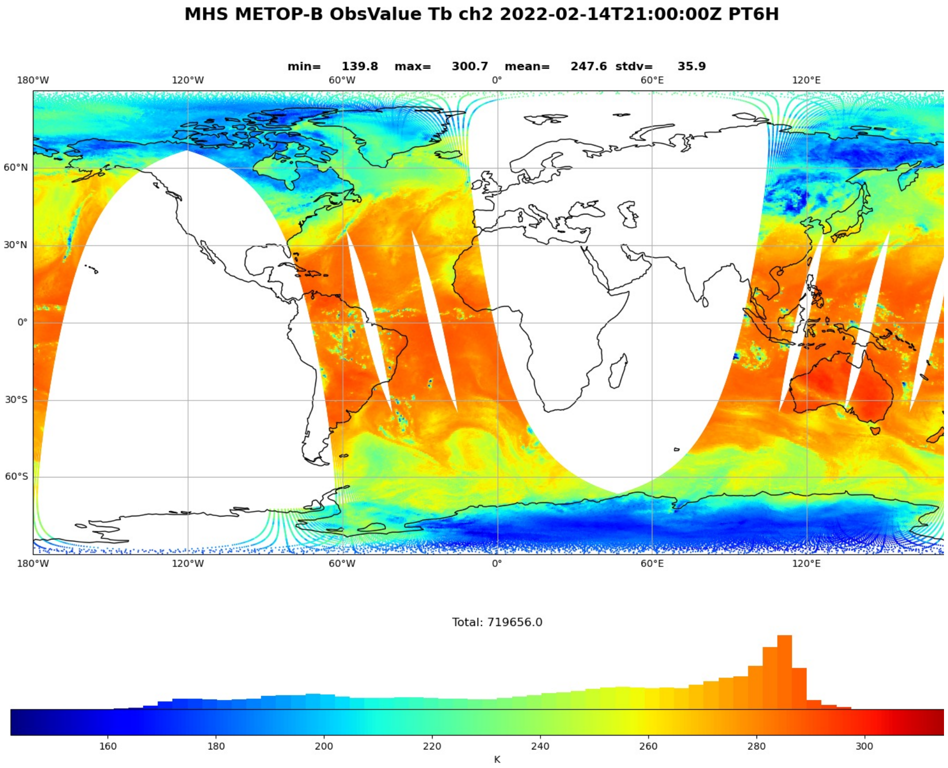
Thompson effective radii method



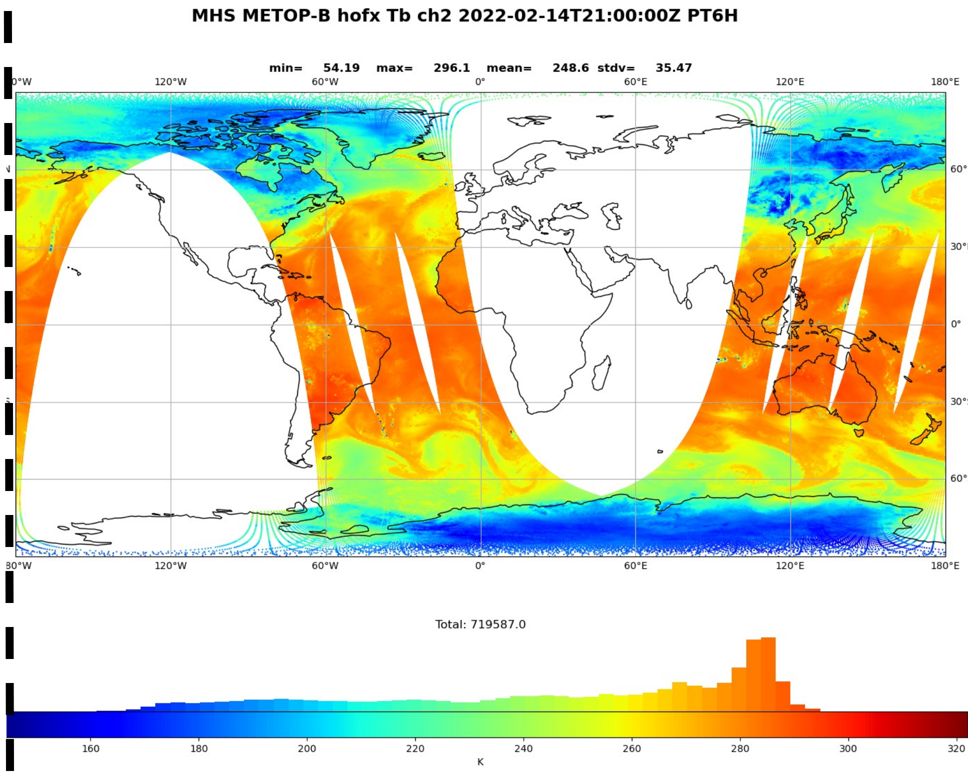
MHS (metop-b)

channel 2: M/W 2022-02-14T21:00:00Z

Observations

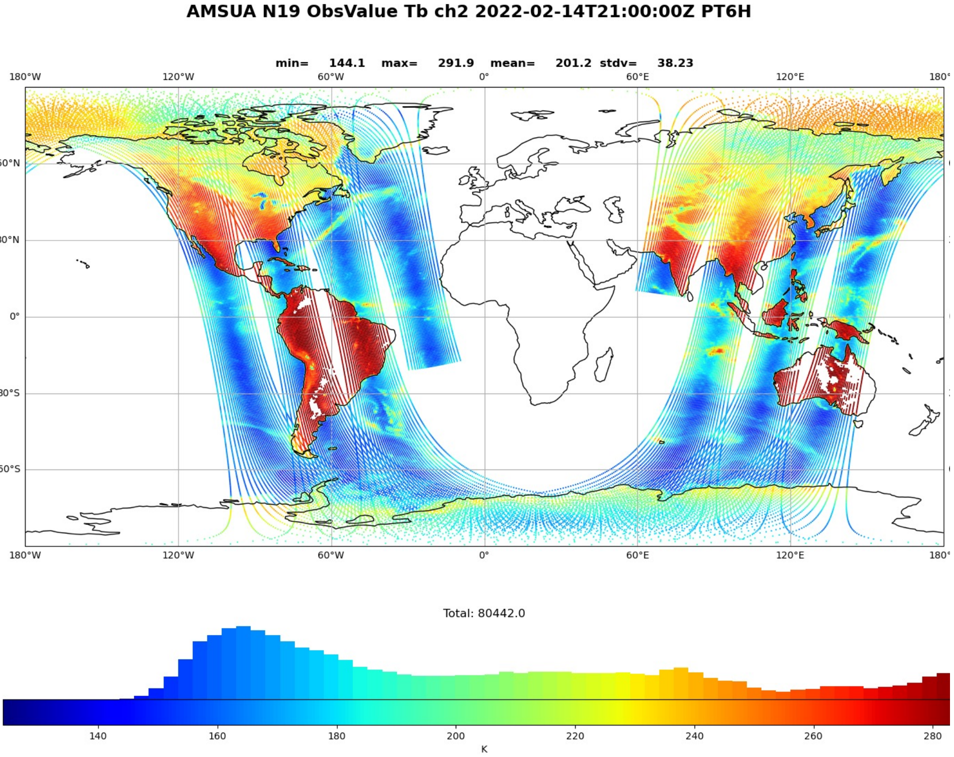


GFDL: Water, Ice, Rain, Snow, Graupel

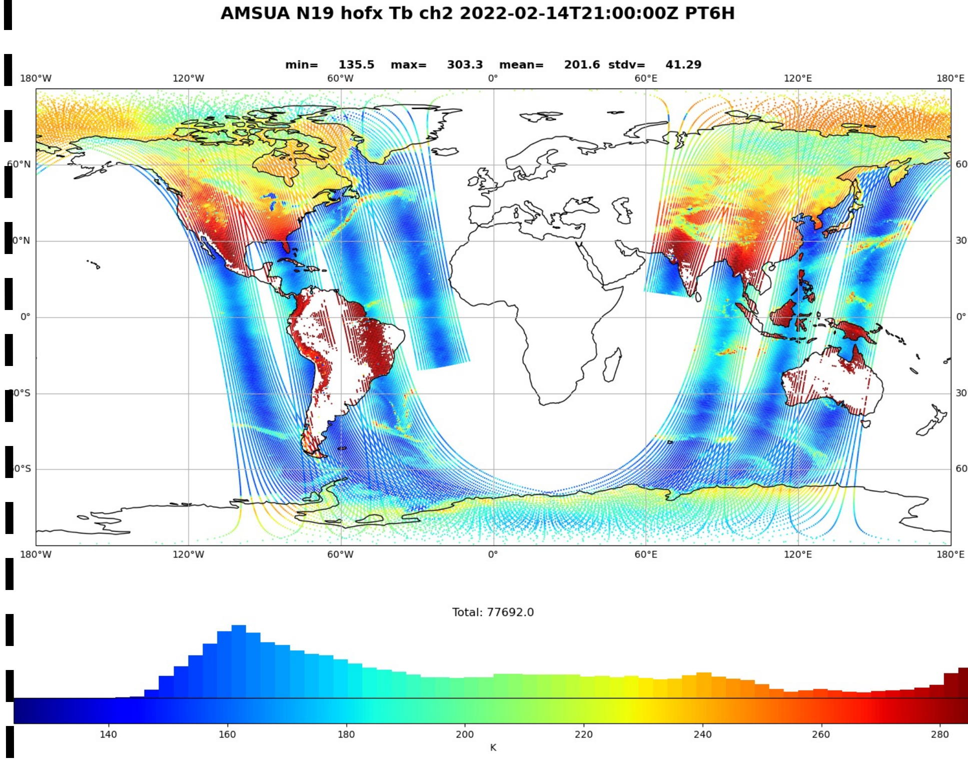


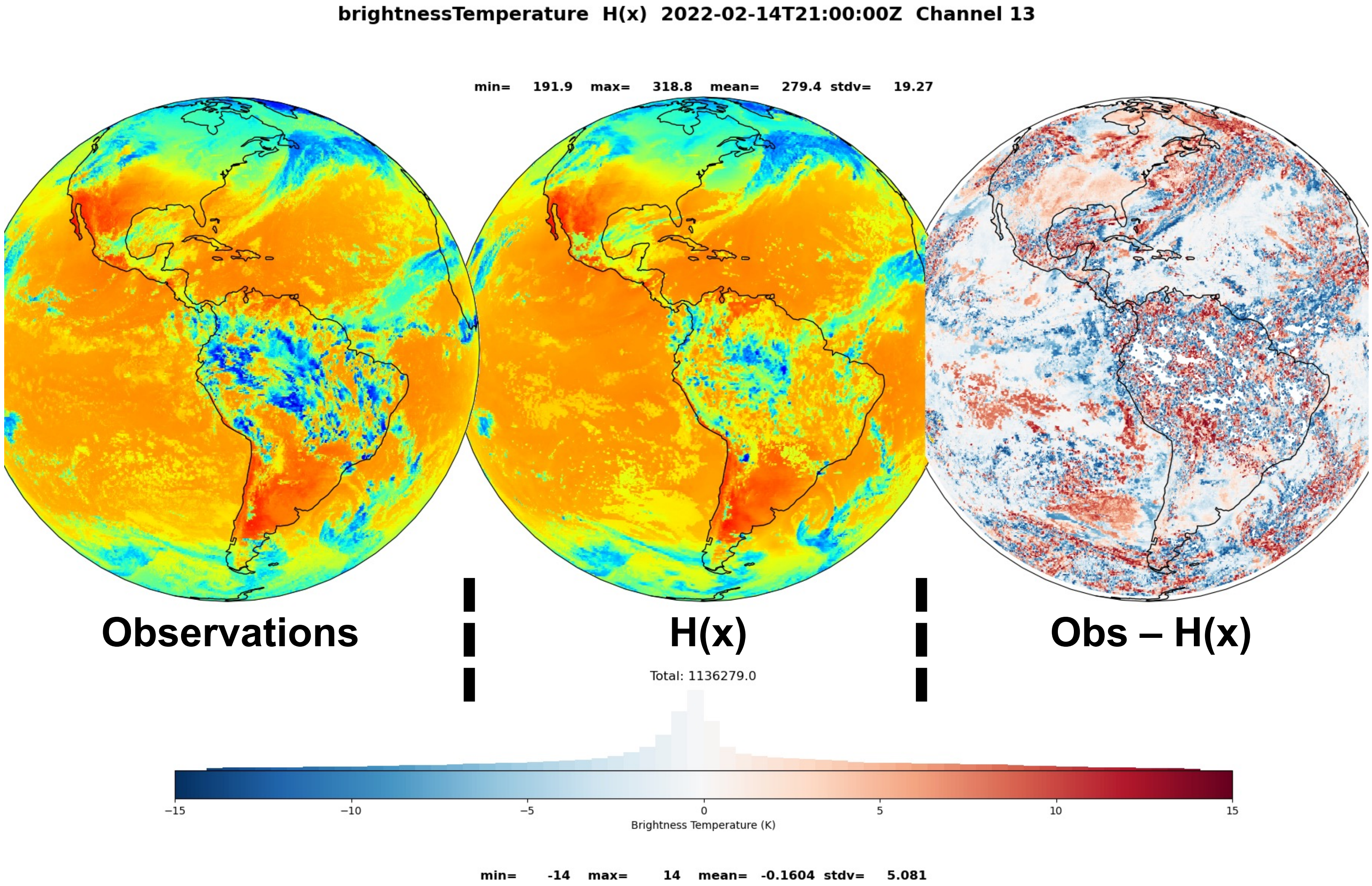
AMSU-A (noaa-19)
channel 2: M/W 2022-02-14T21:00:00Z

Observations



GFDL: Water, Ice, Rain, Snow, Graupel

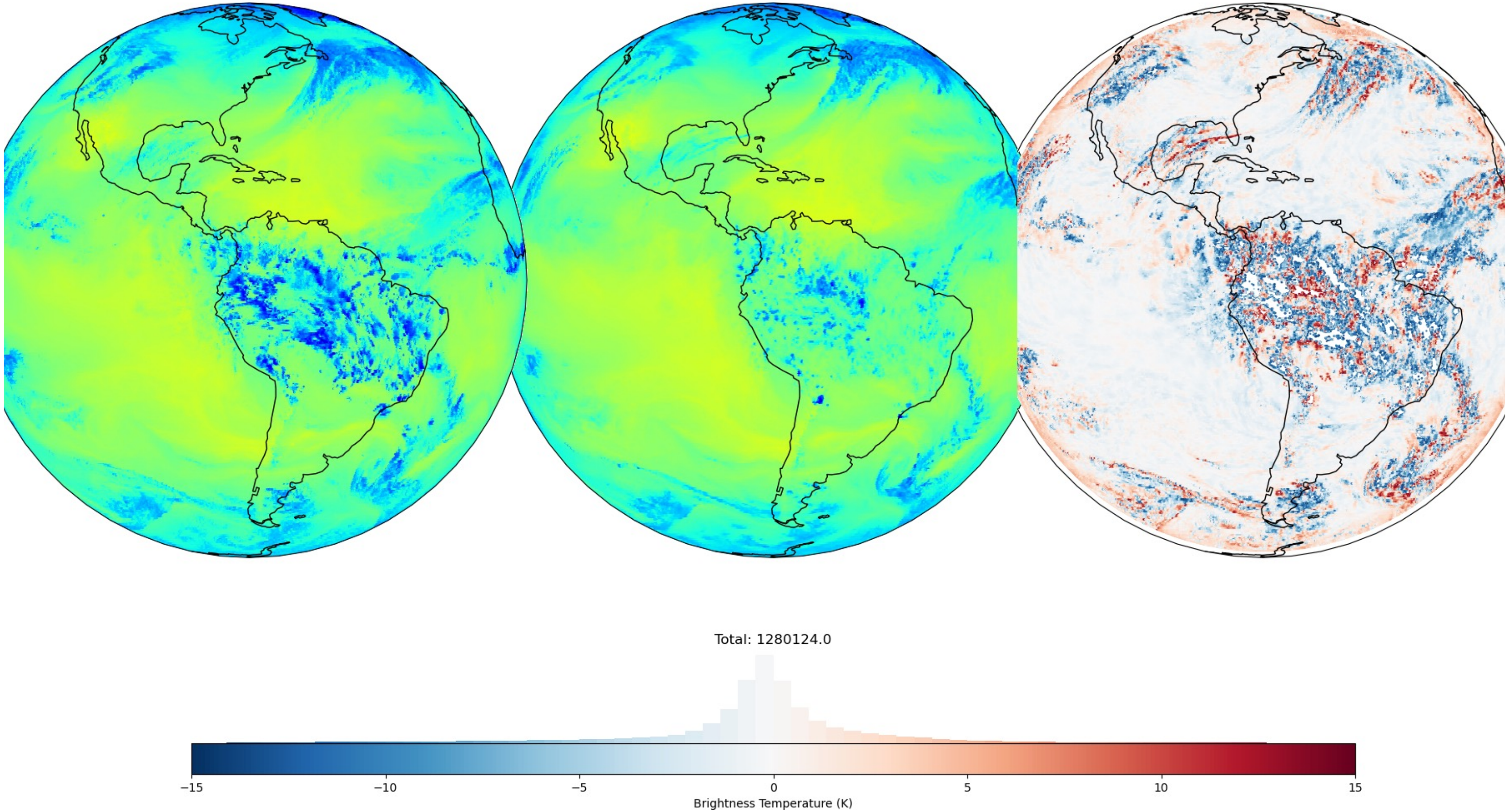




brightnessTemperature H(x) 2022-02-14T21:00:00Z Channel 13
min= 191.9 max= 318.8 mean= 279.4 stdv= 19.27
Observations
H(x)
Obs – H(x)
Total: 1136279.0
−15
−10
−5
0
5
10
15
Brightness Temperature (K)
min= -14 max= 14 mean= -0.1604 stdv= 5.081

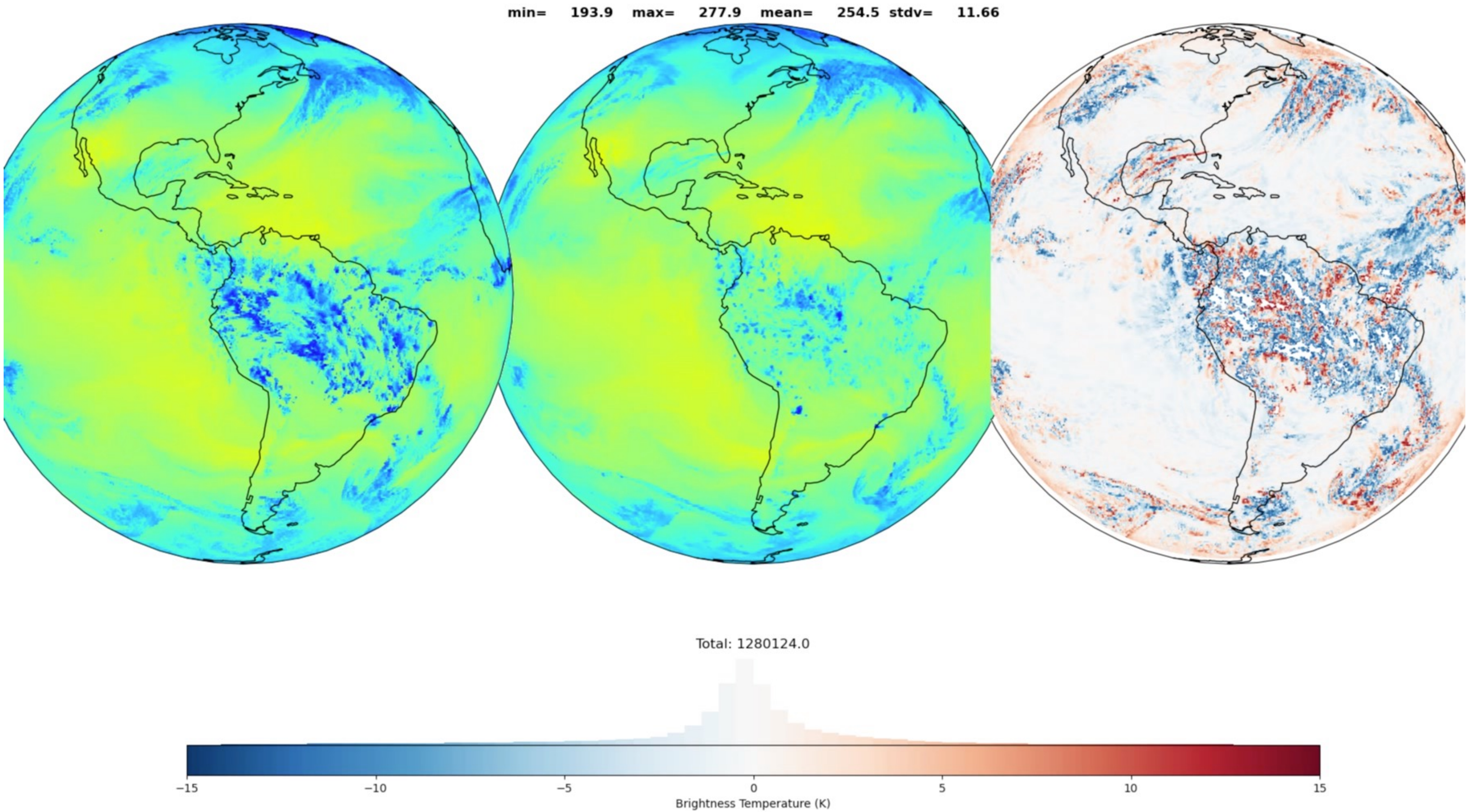
brightnessTemperature H(x) 2022-02-14T21:00:00Z Channel 10

min= 193.9 max= 277.9 mean= 254.5 stdv= 11.66



min= -14 max= 14 mean= -0.4002 stdv= 3.376

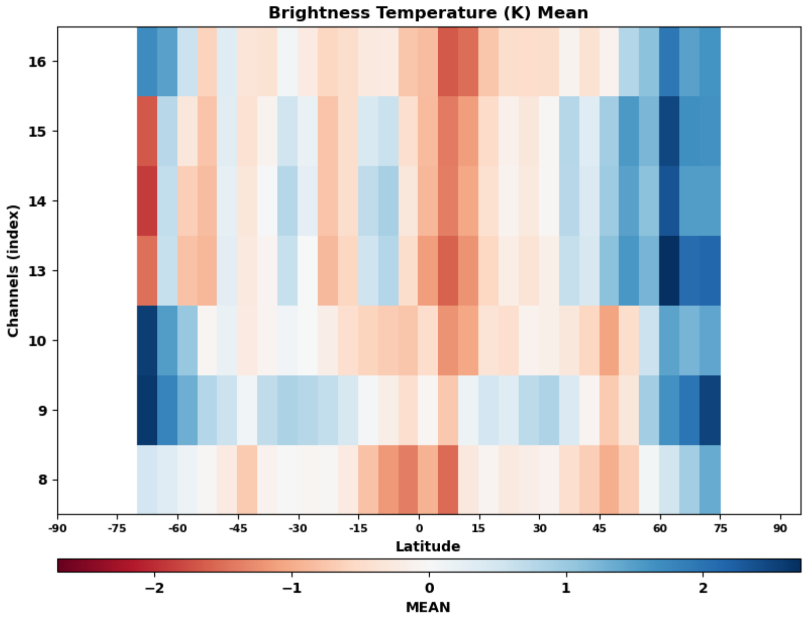
brightnessTemperature H(x) 2022-02-14T21:00:00Z Channel 10



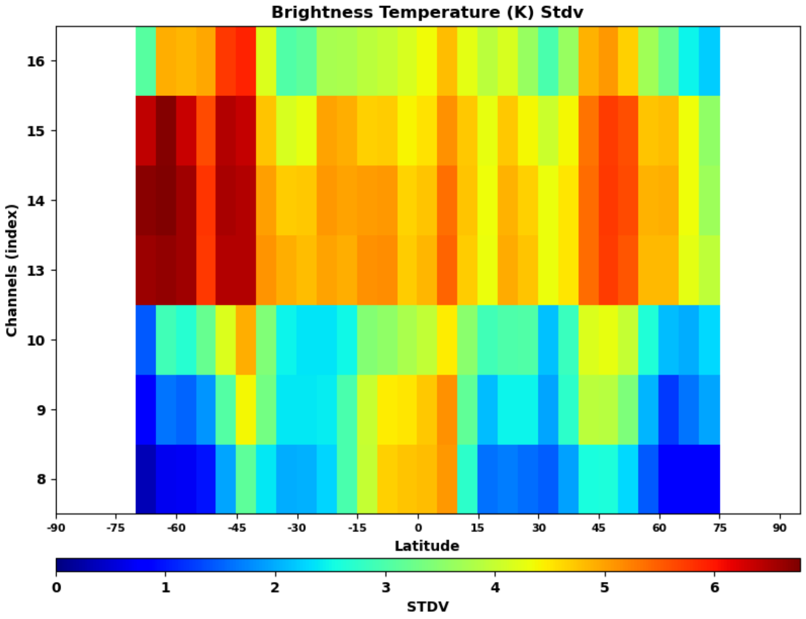
min=   -14   max=   14   mean= -0.4002 stdv=   3.376

First guess departures – GOES ABI

Mean

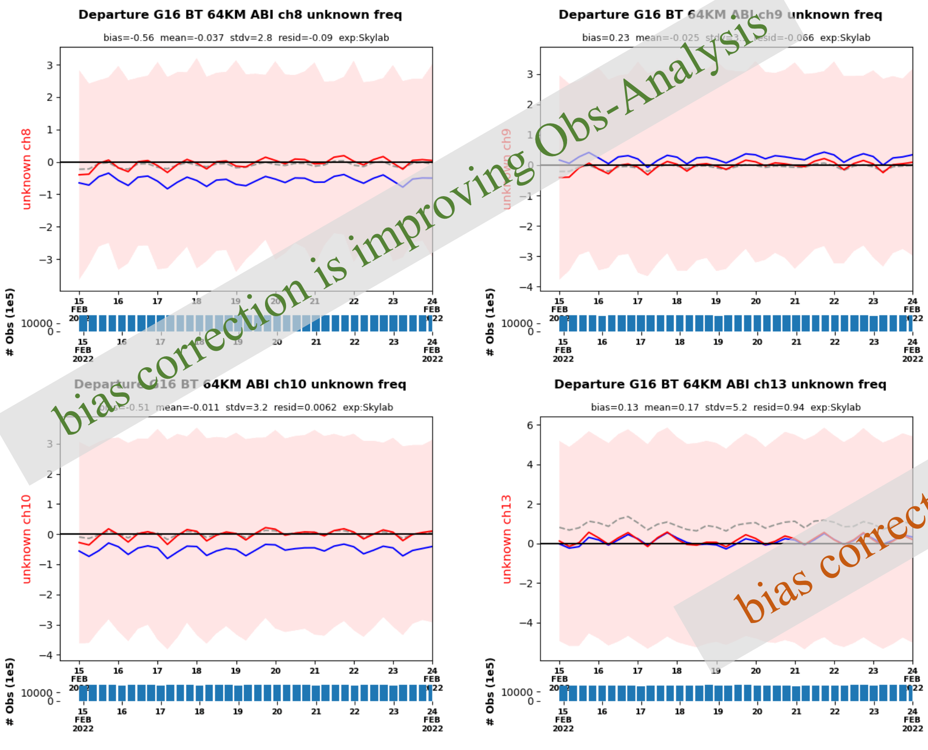


Standard deviation

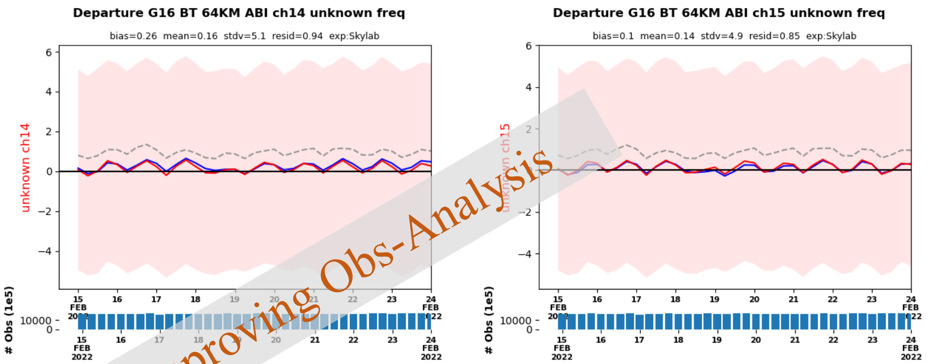


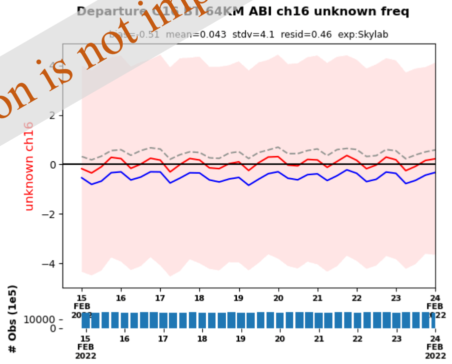
VarBC

Water vapor (ABI ch08-10)



Longwave IR (ABI ch13-16)





Key:

- blue: no bias correction
- red: with varBC
- gray, dashed: obs – analysis

Future Work

QC & BC

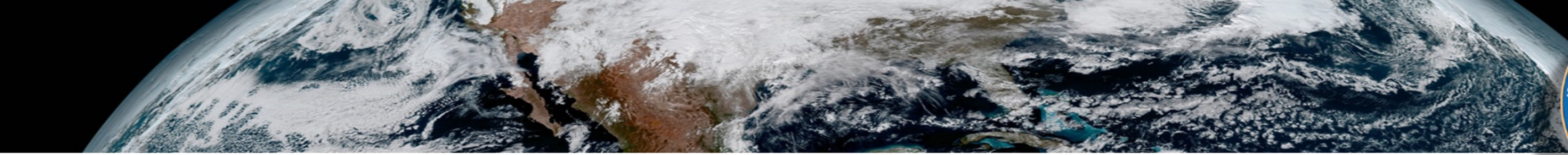
can we go "out on a limb?" – bias correct WV ~68-78^{o} sensorZenithAngle

cloud mismatches: obs vs. first guess

correlated errors

DA Sensitivity Experiments

- GOES-16 & GOES-17
- 15 Feb – 15 Mar 2022
- 01 – 31 Aug 2021
- 3-hourly vs. hourly
- 64 vs. 8 km subsampled data
- include visible wavelength



Thank you!

Questions