Arctic OSSEs and Beyond

Nikki Privé

13 February 2024

Numerical Weather Prediction (NWP) and Data Assimilation (DA)

Numerical Weather Prediction

Current conditions at

Baltimore, Baltimore-Washington International Airport (KBWI)

Lat: 39.17°N **Lon:** 76.68°W **Elev:** 135ft.

Mostly Cloudy

50°F

10°C

Humidity	52%
Wind Speed	SW 9 mph
Barometer	30.03 in (1016.8 mb)
Dewpoint	33°F (1°C)
Visibility	10.00 mi
Wind Chill	46°F (8°C)
Last update	1 Feb 11:54 am EST

More Information:
- Local Forecast Office
- More Local Wx
- 3 Day History
- Mobile Weather
- Hourly Weather Forecast

Extended Forecast for

Baltimore-Washington International Airport MD

Click here for hazard details and duration

Coastal Flood Advisory

NOW until 12:00am Fri	This Afternoon	Tonight	Friday	Friday Night	Saturday	Saturday Night	Sunday	Sunday Night
		30%	20%					
Coastal Flood Advisory	Mostly Sunny	Mostly Cloudy then Scattered Showers	Isolated Showers	Mostly Clear	Sunny	Mostly Clear	Sunny	Mostly Clear
	High: 52 °F	Low: 39 °F	High: 48 °F	Low: 30 °F	High: 47 °F	Low: 29 °F	High: 52 °F	Low: 30 °F

Detailed Forecast

This Afternoon	Mostly sunny, with a high near 52. Southwest wind around 9 mph.
Tonight	Scattered showers, mainly after 1am. Cloudy, with a low around 39. South wind around 5 mph becoming calm in the evening. Chance of precipitation is 30%.
Friday	Isolated showers before 10am, then isolated showers after 1pm. Mostly cloudy, with a high near 48. North wind 6 to 14 mph, with gusts as high as 22 mph. Chance of precipitation is 20%.
Friday Night	Mostly clear, with a low around 30. North wind 8 to 10 mph.
Saturday	Sunny, with a high near 47. North wind 7 to 9 mph.
Saturday Night	Mostly clear, with a low around 29.

Topographic

Click Map For Forecast

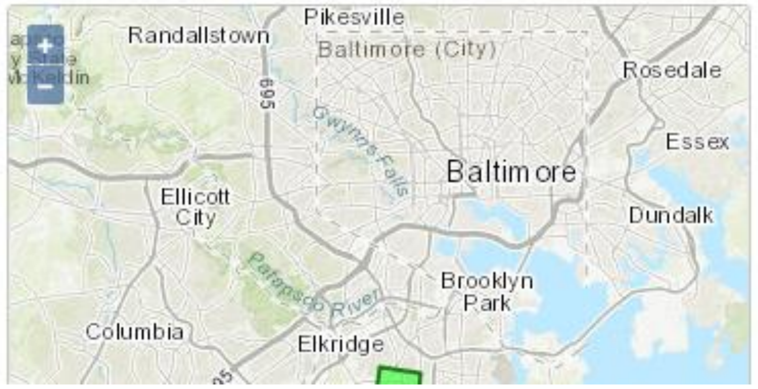
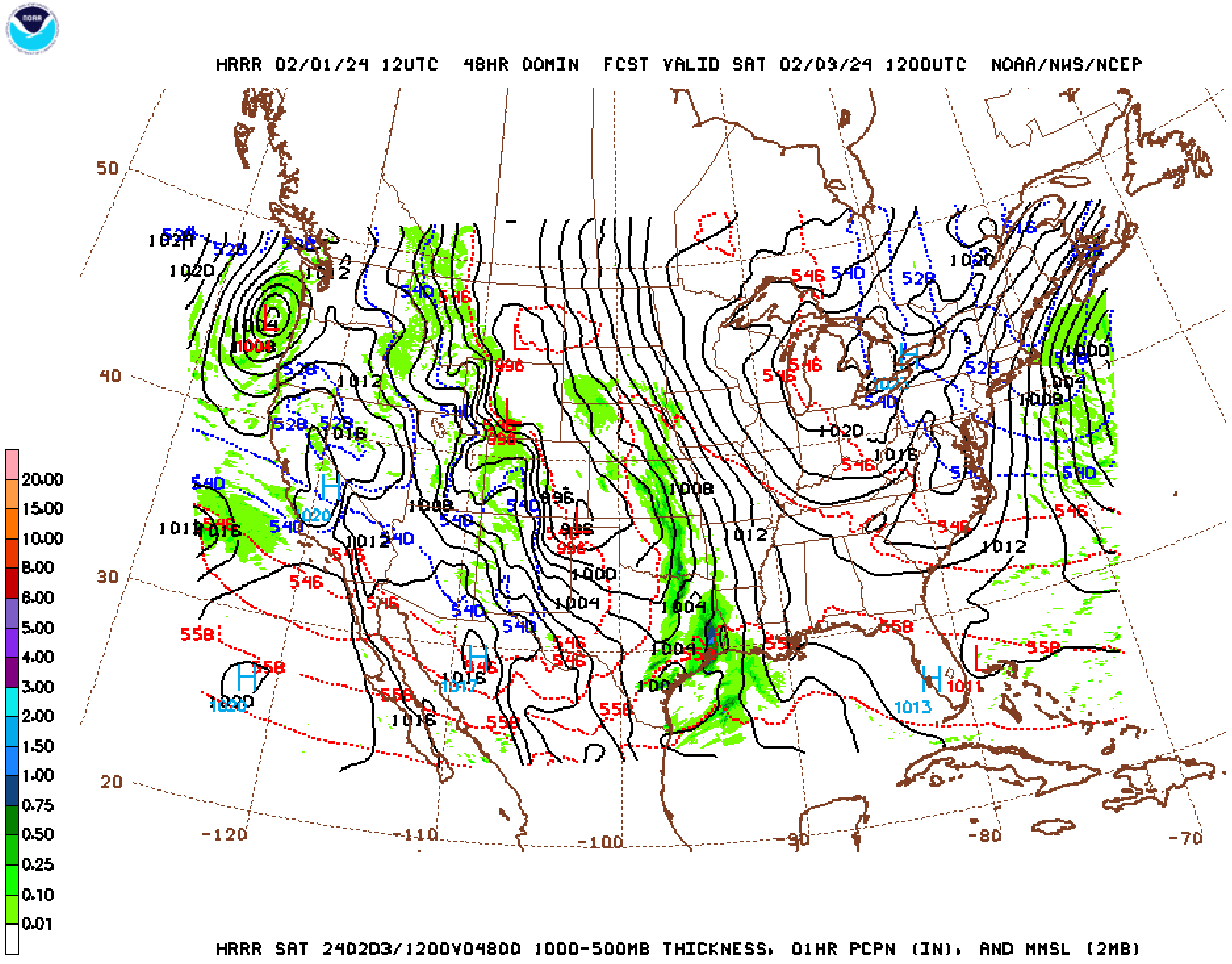
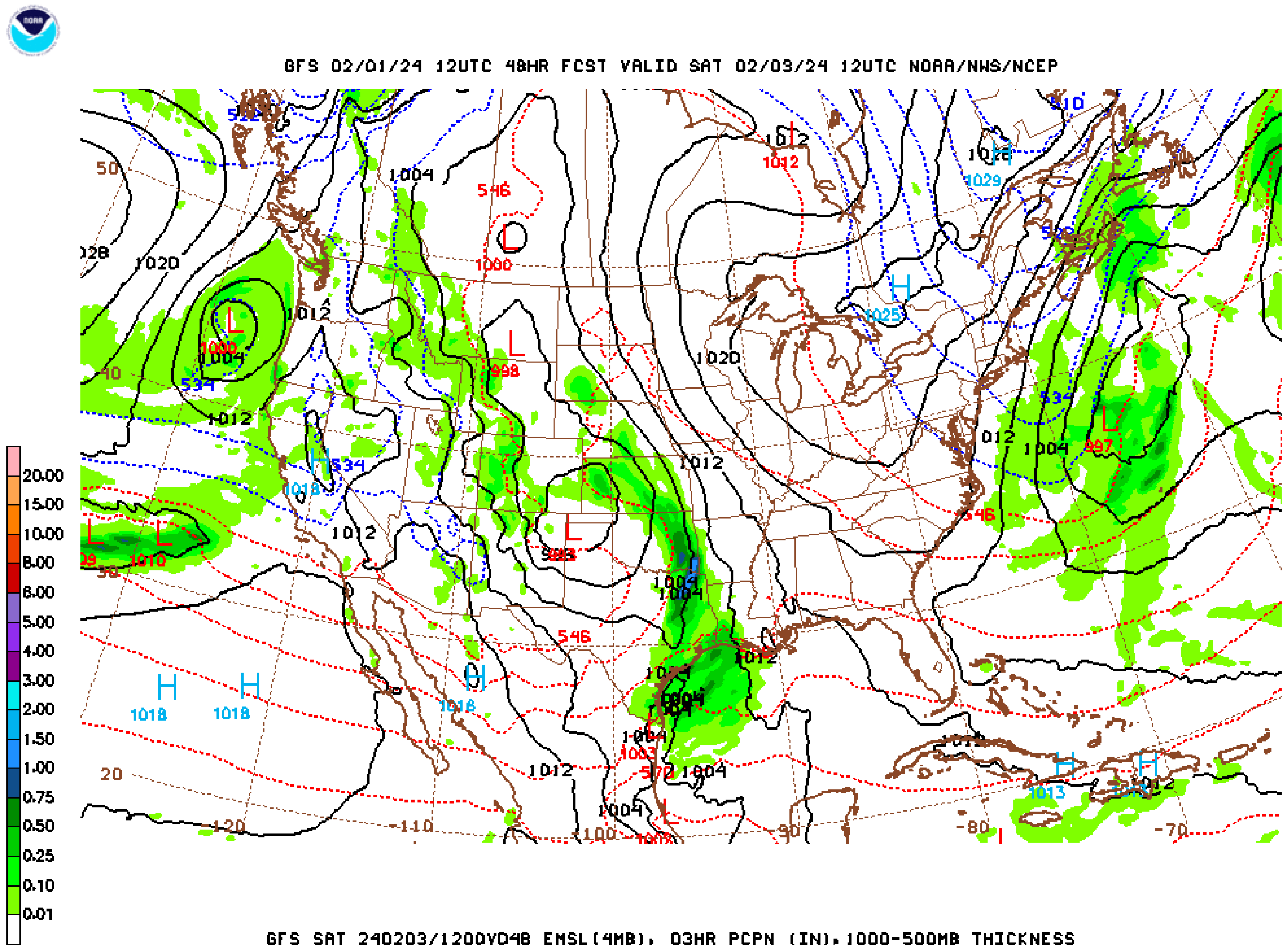


Image: NWS

Numerical Weather Prediction





Images: NOAA

Numerical Weather Prediction

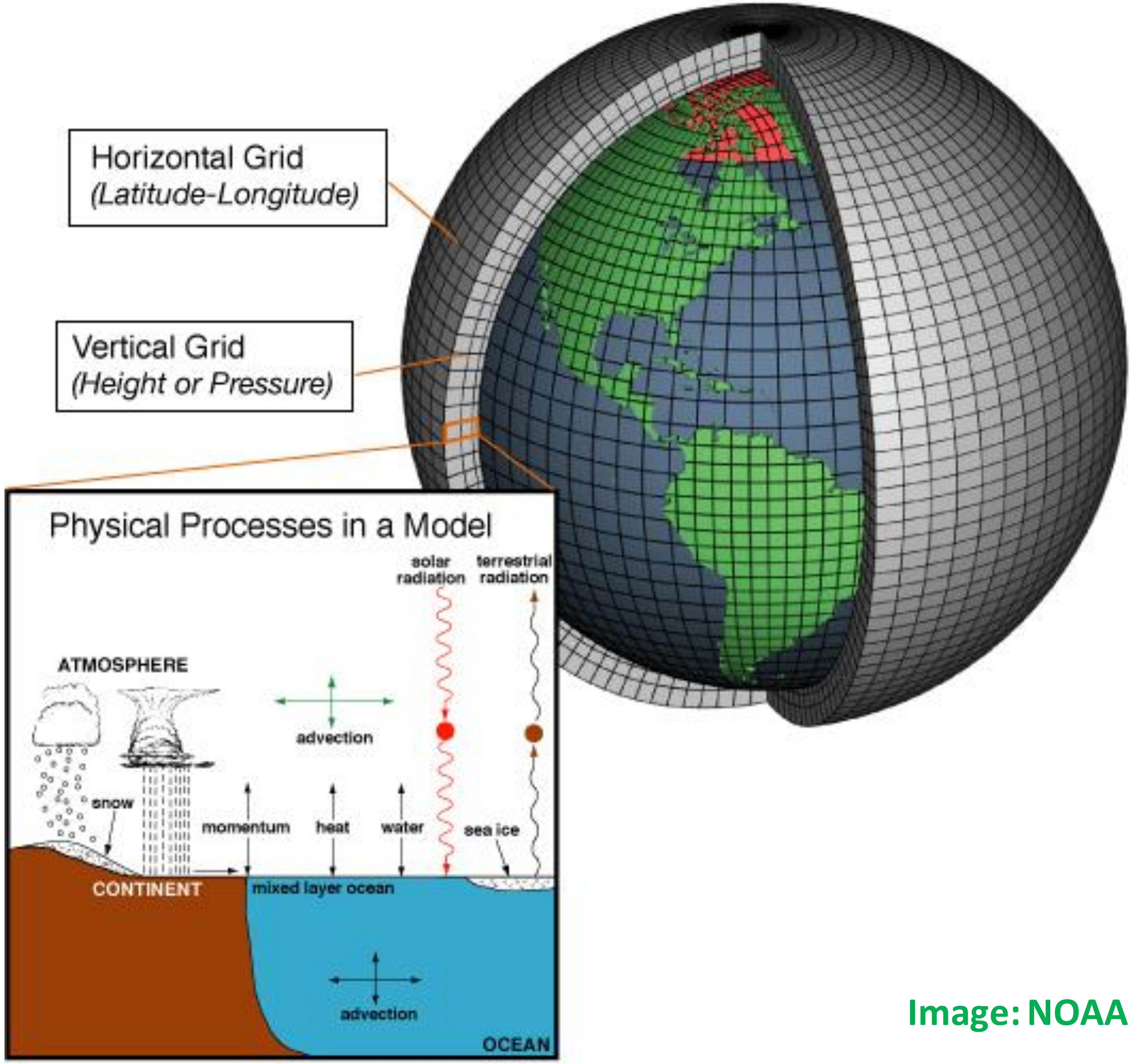
$$\frac{d}{dt}\mathbf{v} = -2\boldsymbol{\Omega}\times\mathbf{v} - \frac{1}{\rho}\nabla_3 p + \mathbf{g} + \mathbf{F}$$

$$C_v \frac{d}{dt}(\rho q) + p\frac{d}{dt}\left(\frac{1}{\rho}\right) = J$$

$$\frac{\partial}{\partial t}(\rho) = -\nabla_3 \cdot (\rho \mathbf{v})$$

$$\frac{\partial}{\partial t} = -\nabla_3 \cdot (\rho \mathbf{v} q) + \rho (E - C)$$

$$p = \rho R T$$



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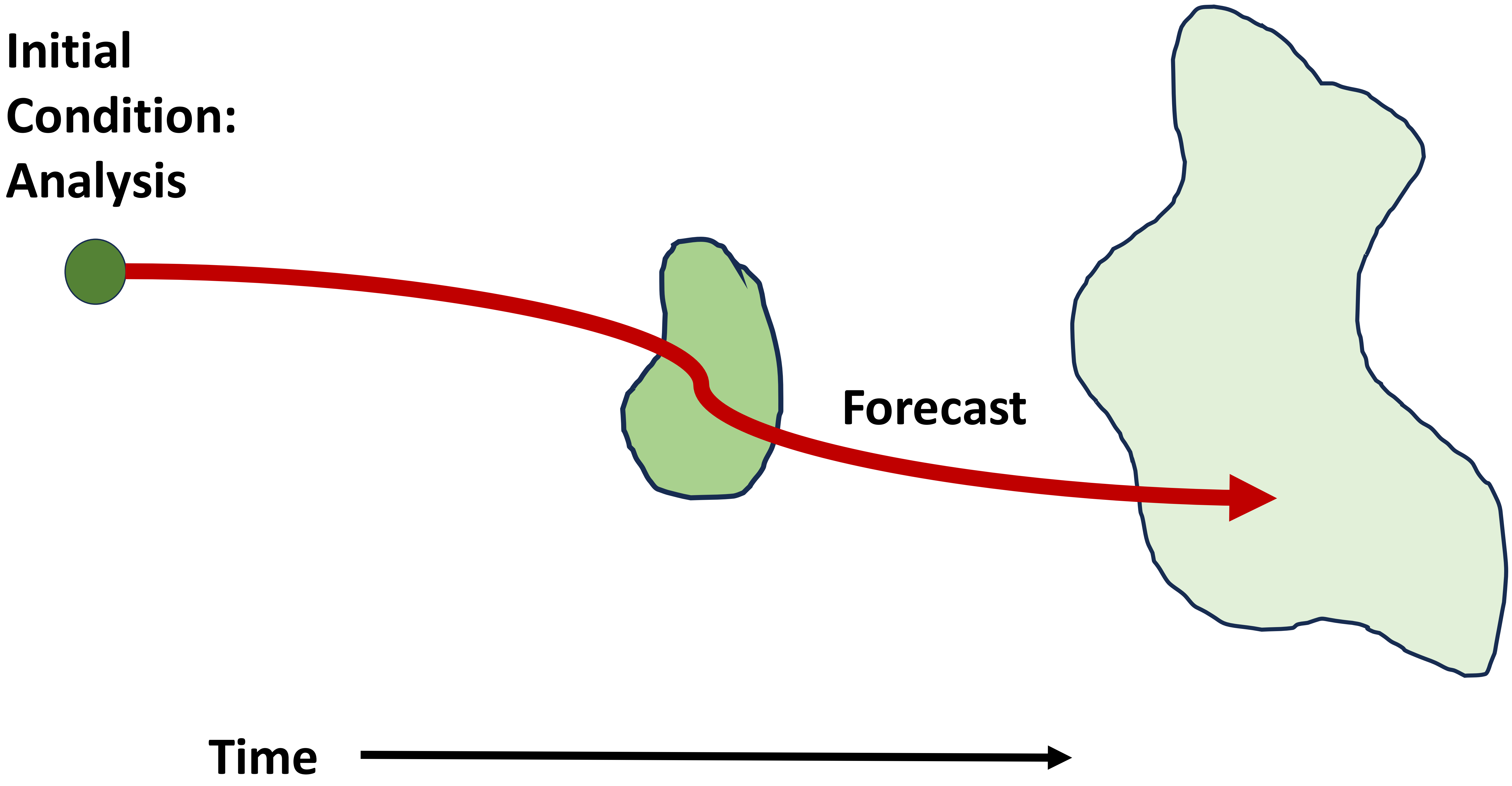
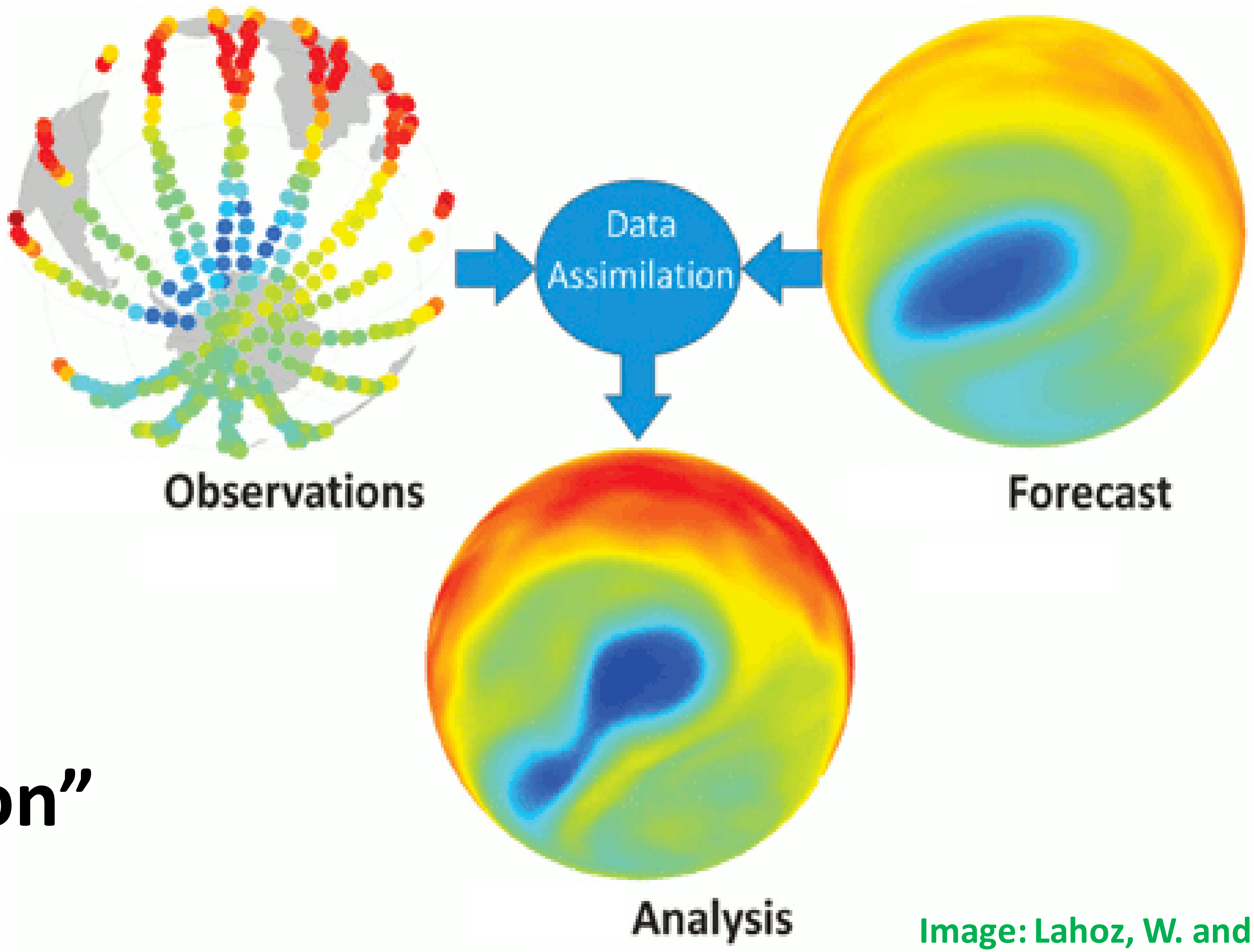
Numerical Weather Prediction



How NWP Uses Observations

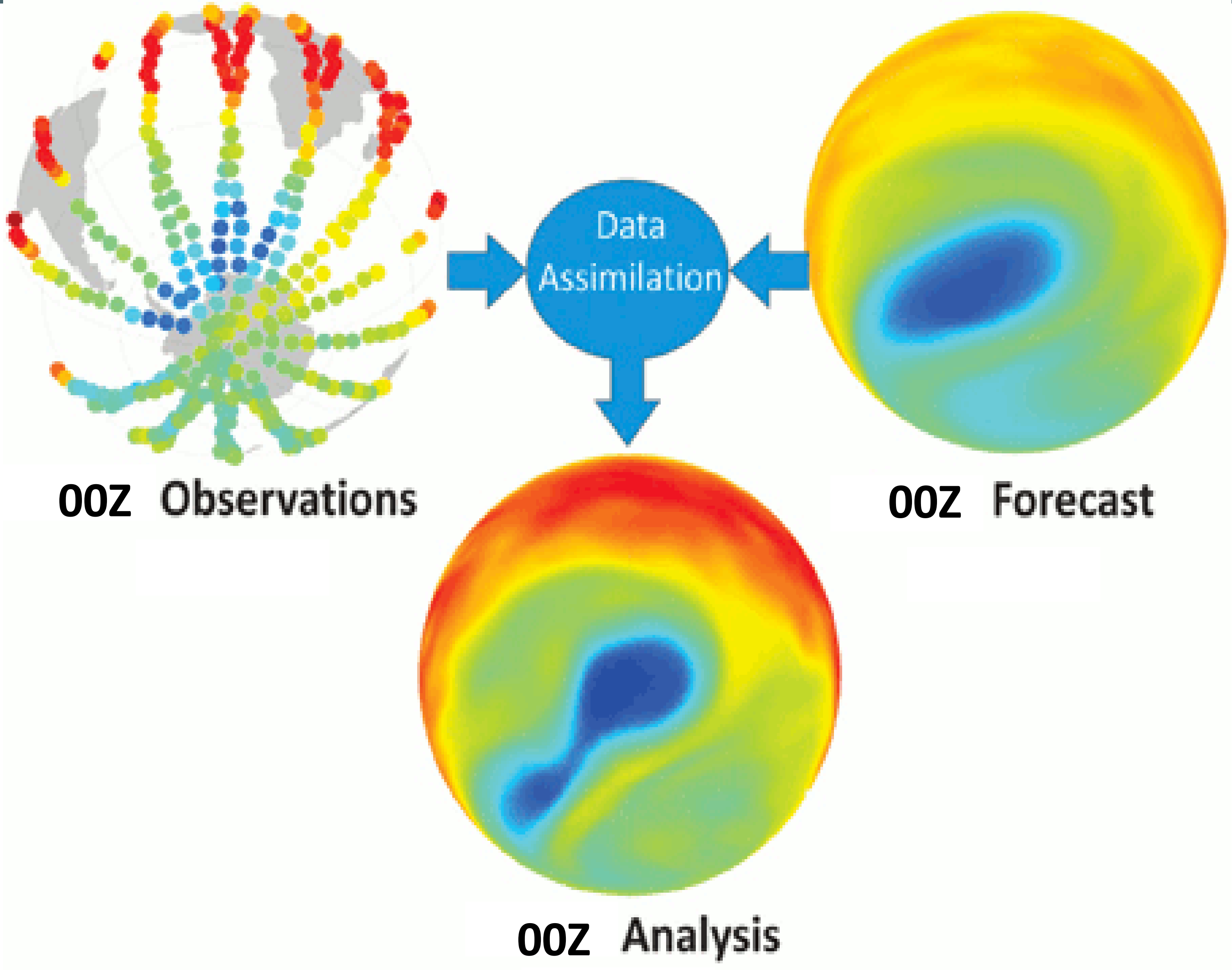


"Data Assimilation"

Image: Lahoz, W. and P. Schneider, Front. Environ. Sci., 2014, with permission

How NWP Uses Observations

"Cycling"



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How NWP Uses Observations

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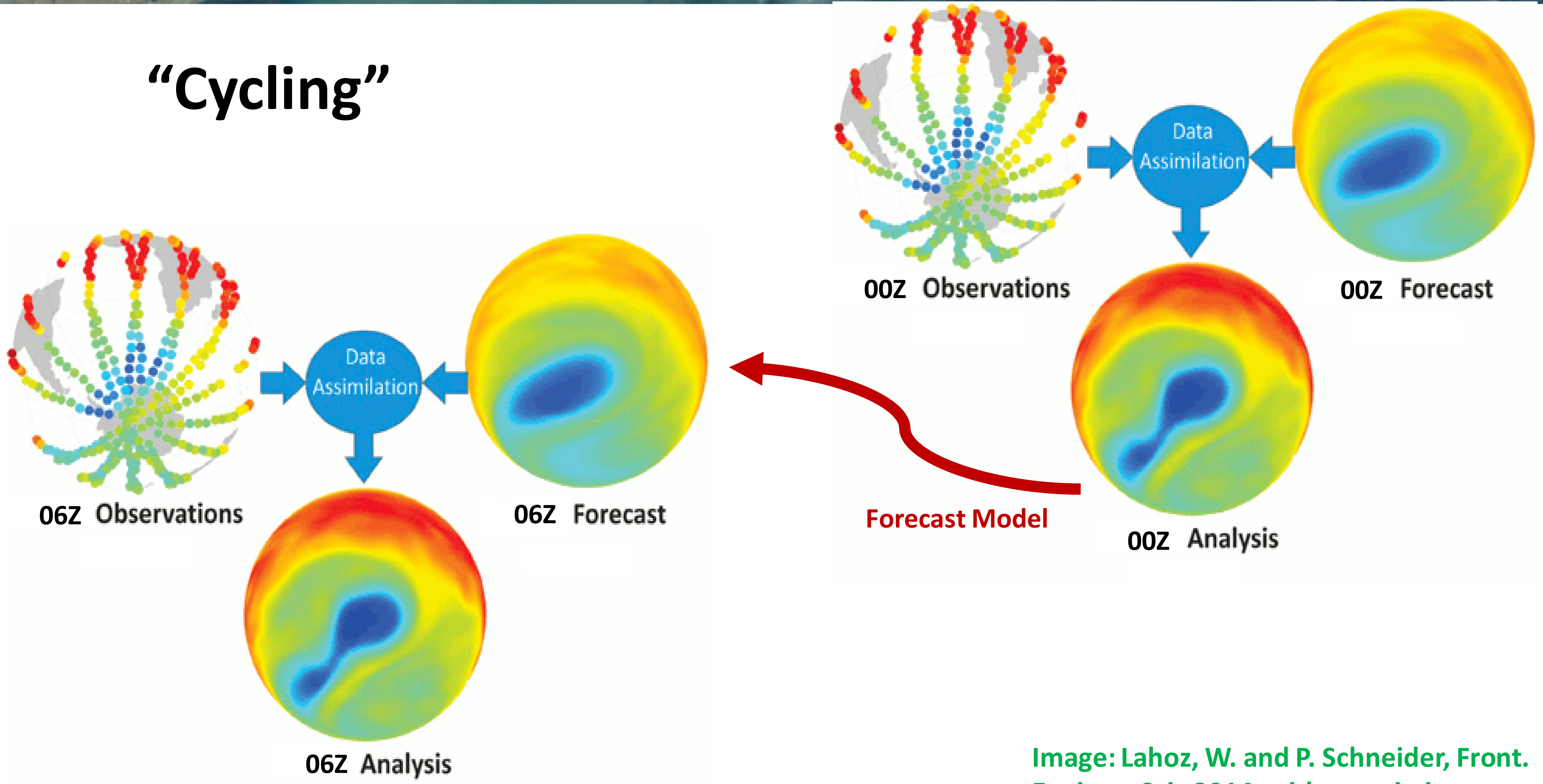
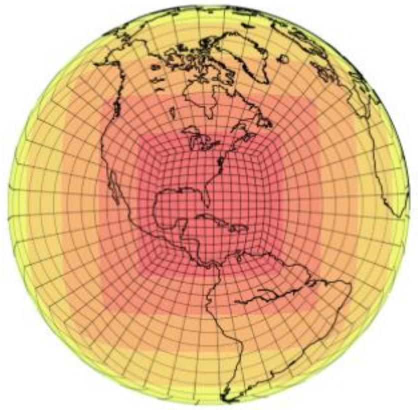


Image: Lahoz, W. and P. Schneider, Front. Environ. Sci., 2014, with permission

Data Assimilation Weights

250K



High Error,
Low Weight

260K

Low Error,
High Weight

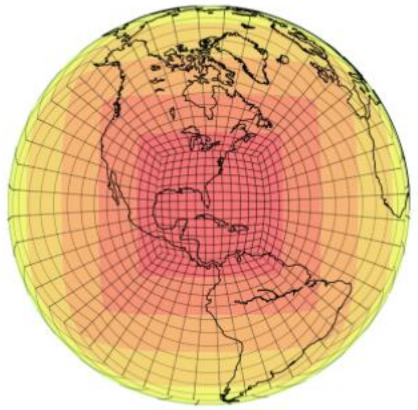
Analysis

Images: NOAA

Data Assimilation Weights

250K

High Error,
Low Weight



260K

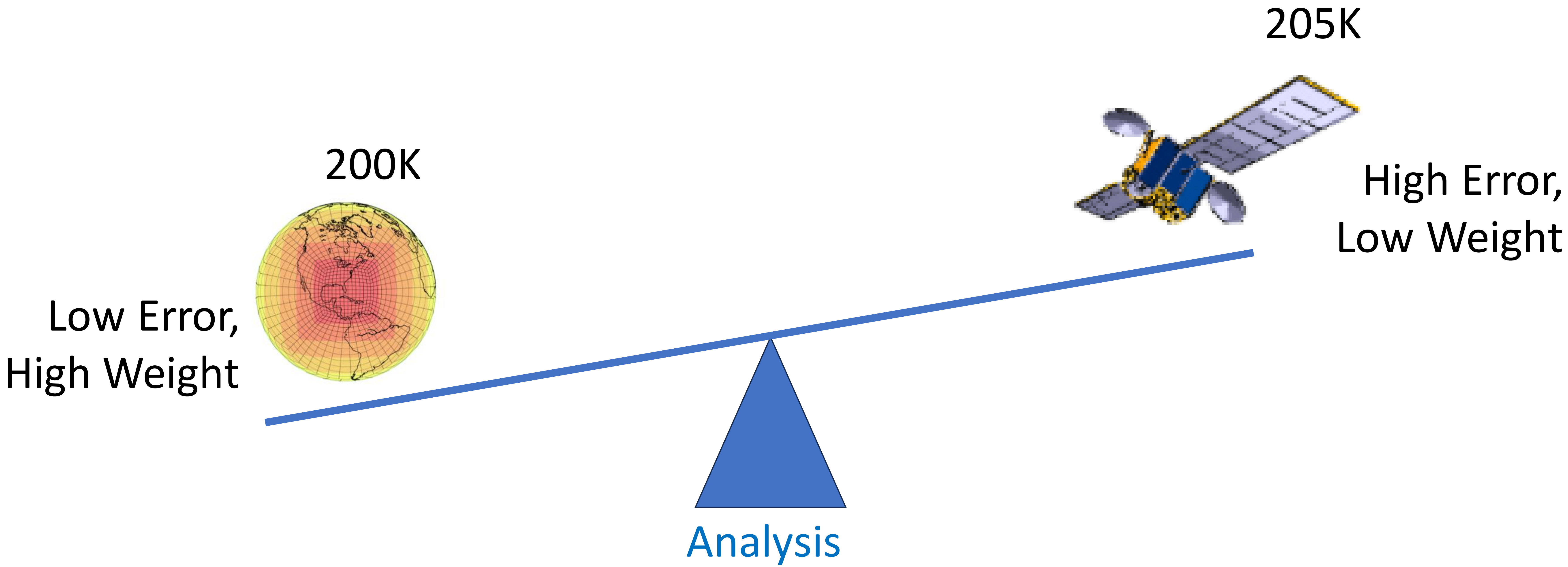
Low Error,
High Weight

Analysis

258K

Images: NOAA

Data Assimilation Weights



Images: NOAA

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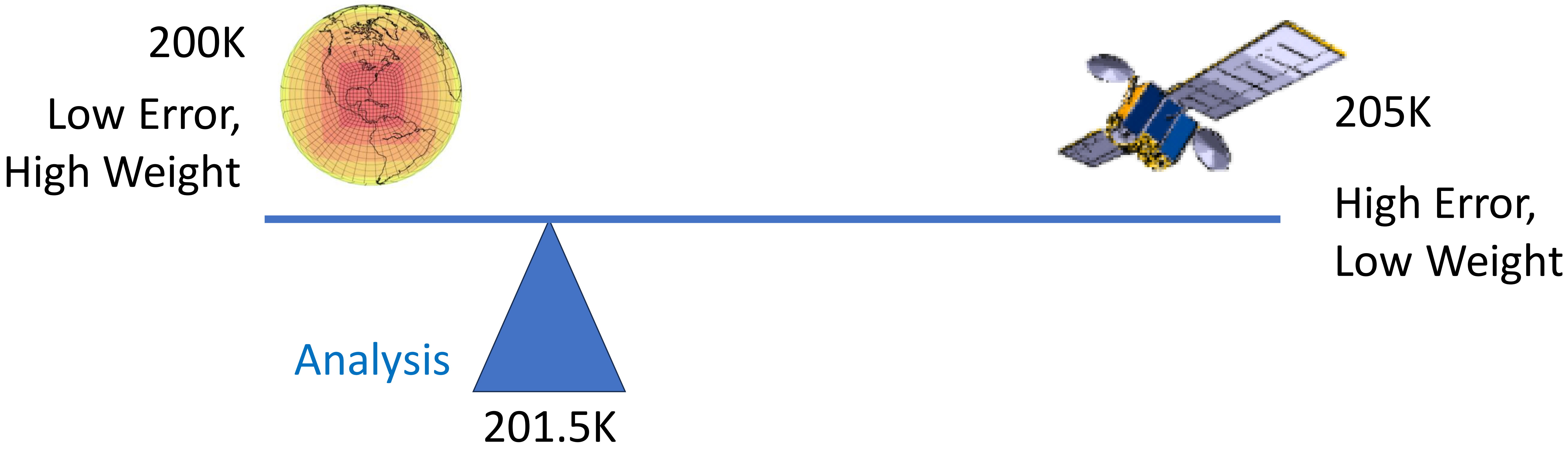

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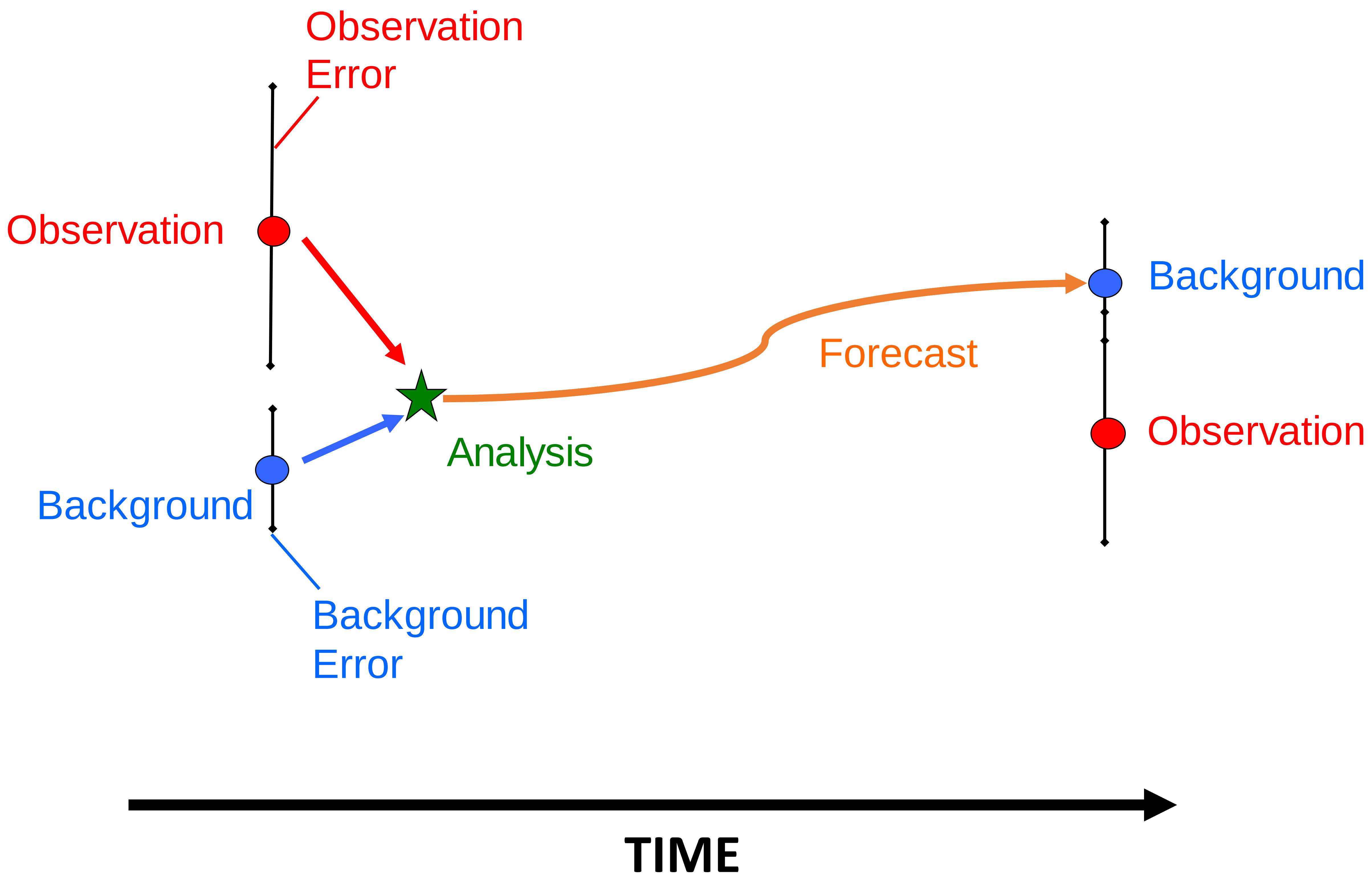
Data Assimilation Cycling



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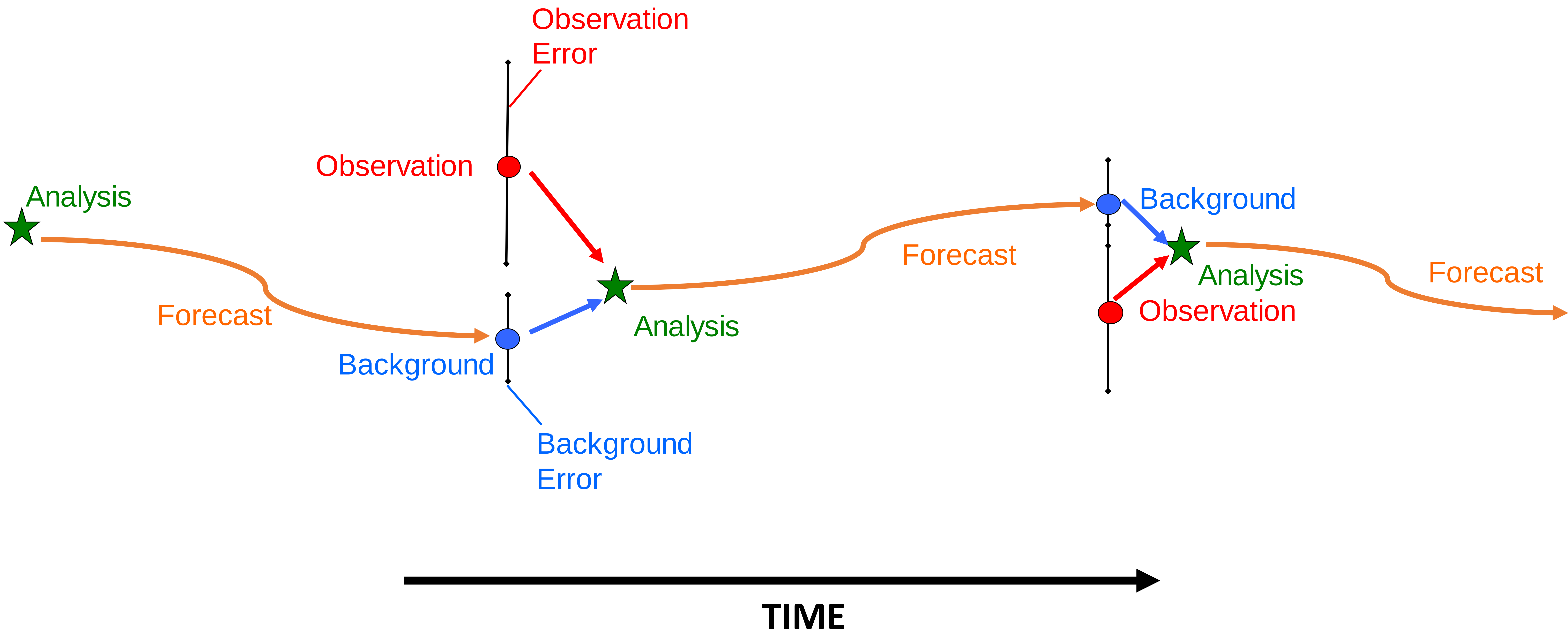


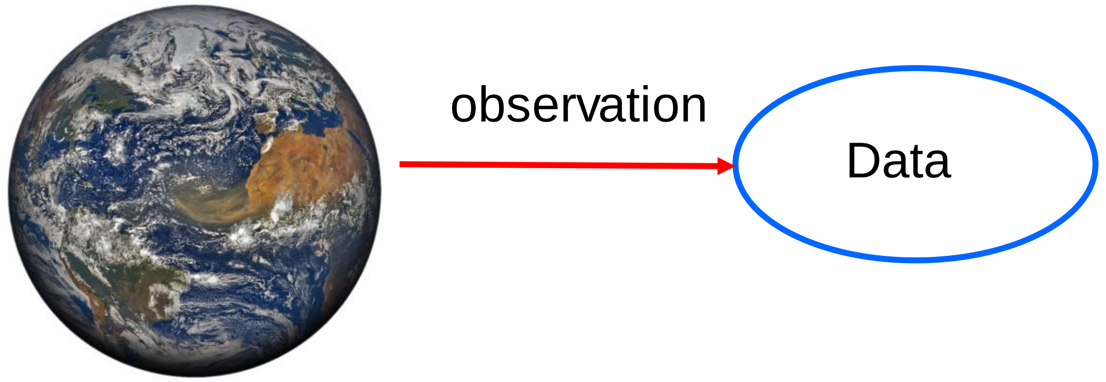
Observing System Simulation Experiments (OSSEs)

What is an OSSE?

Real world

What is an OSSE?

Real world



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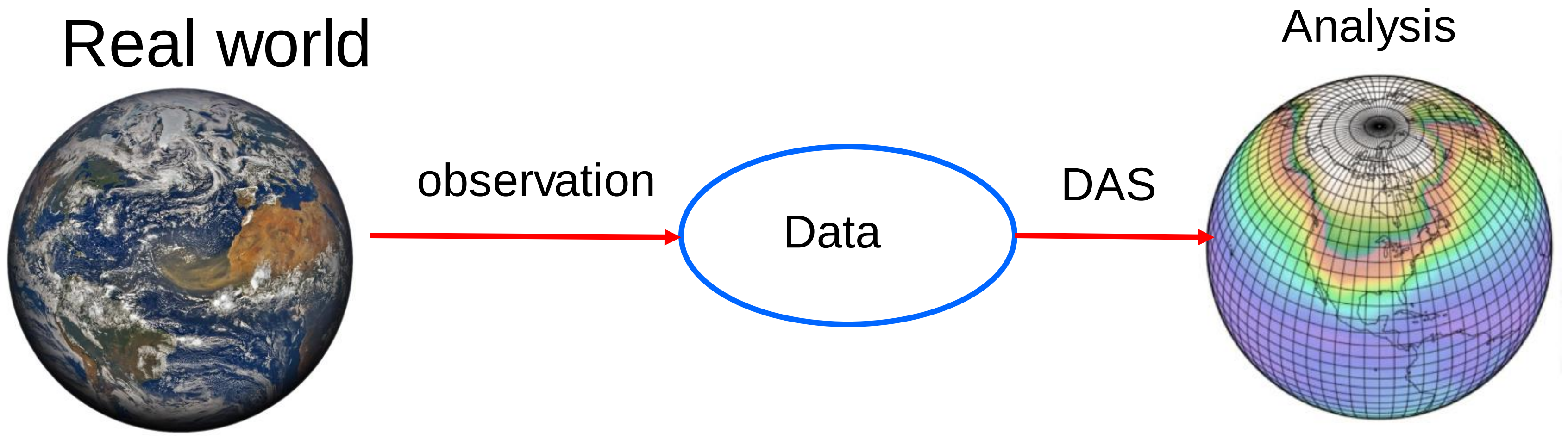

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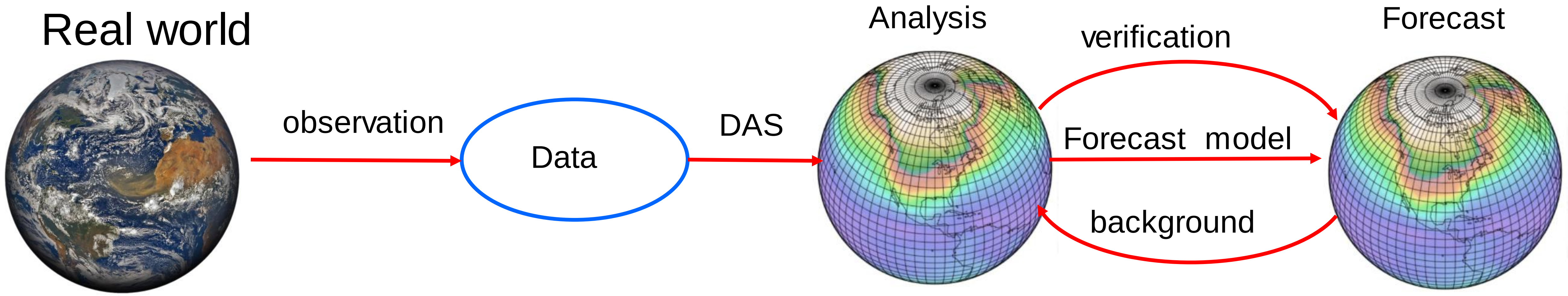

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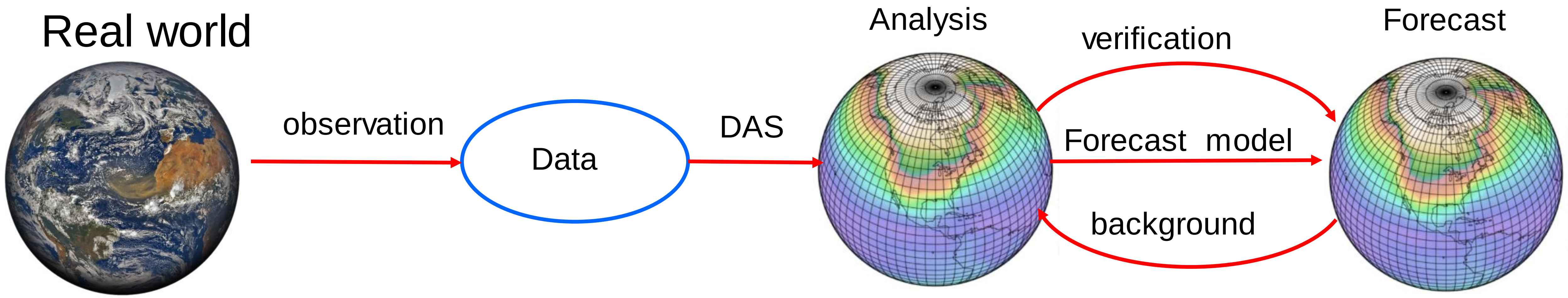
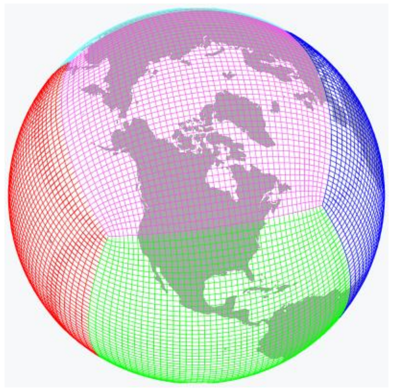


OSSE



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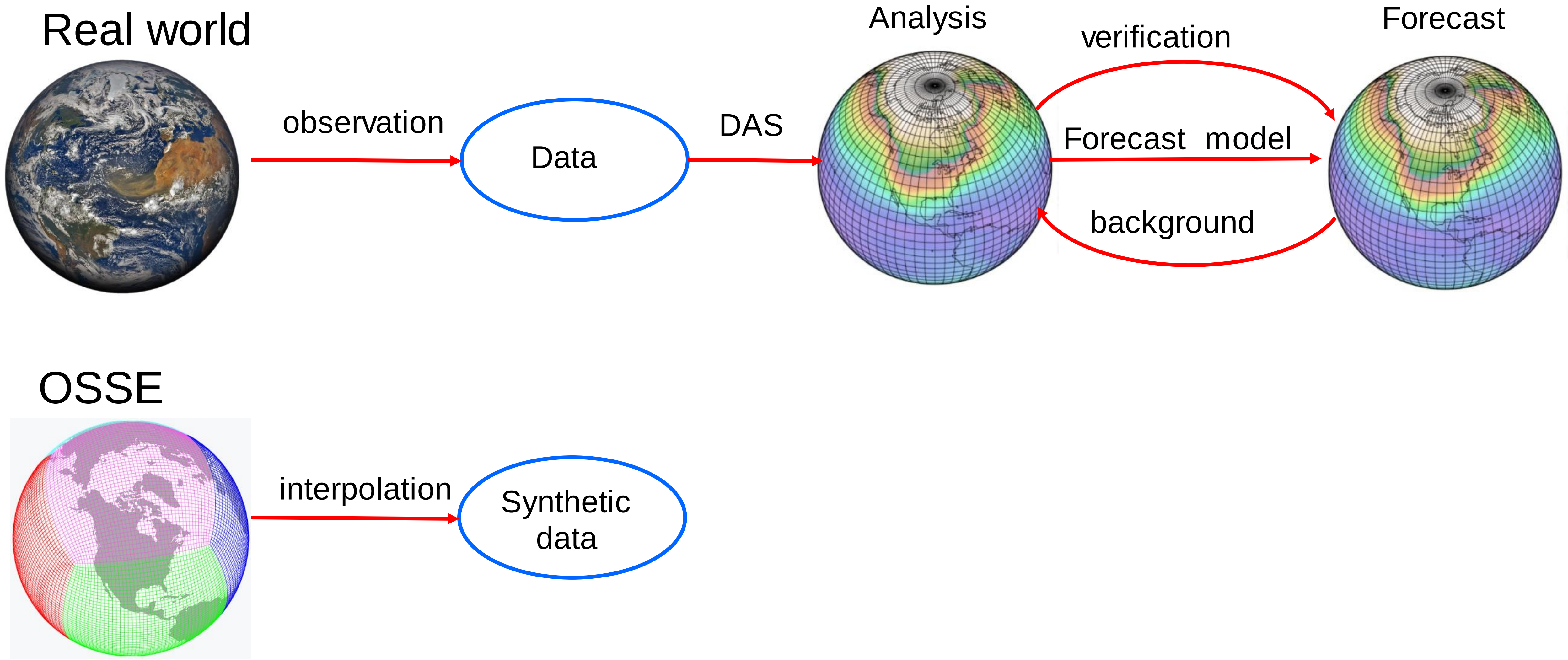

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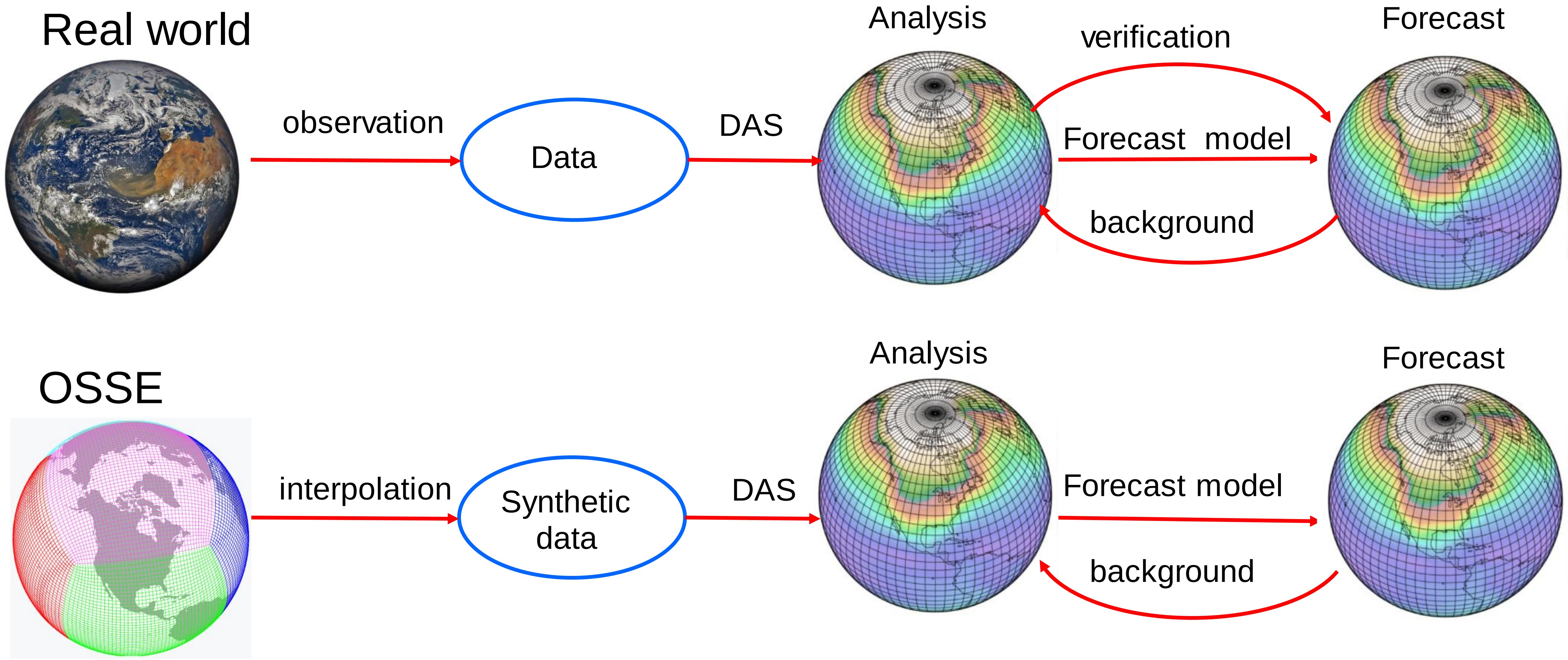

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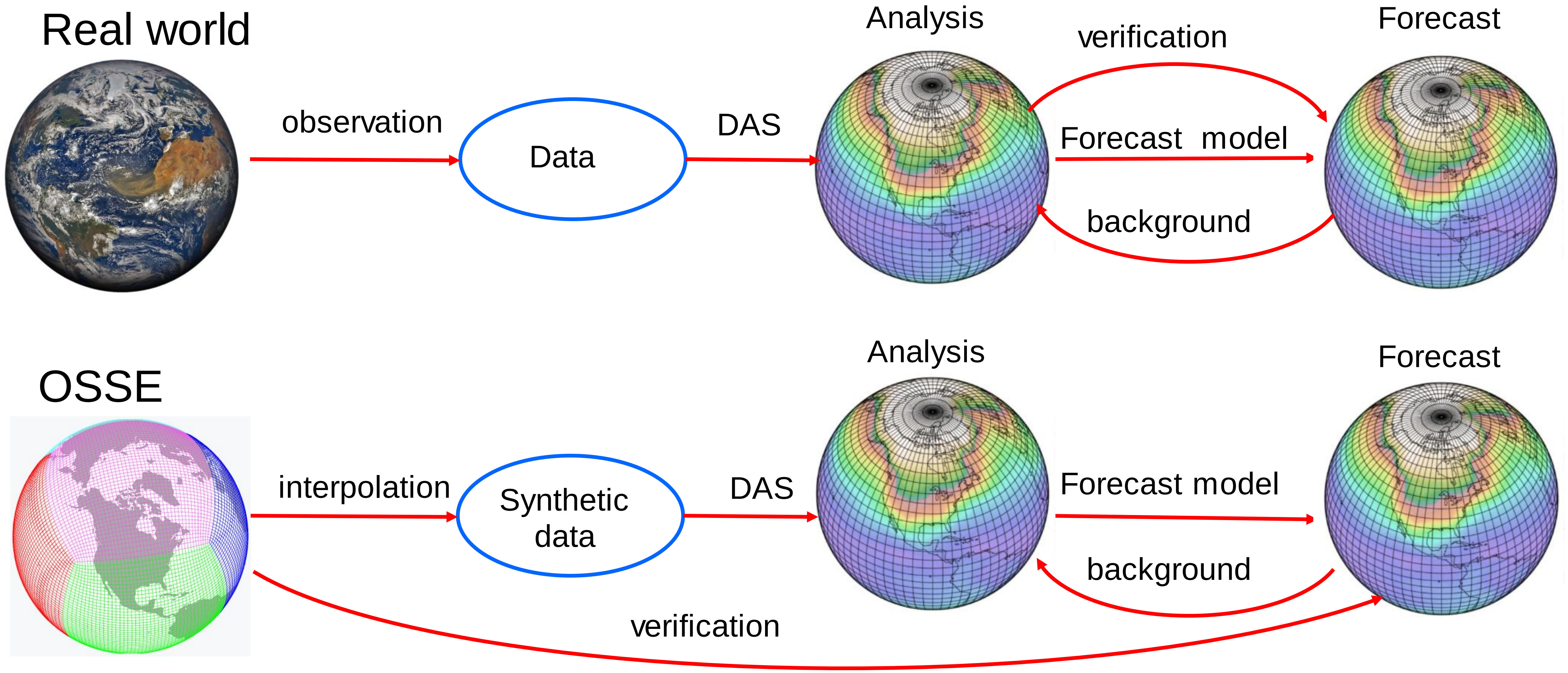
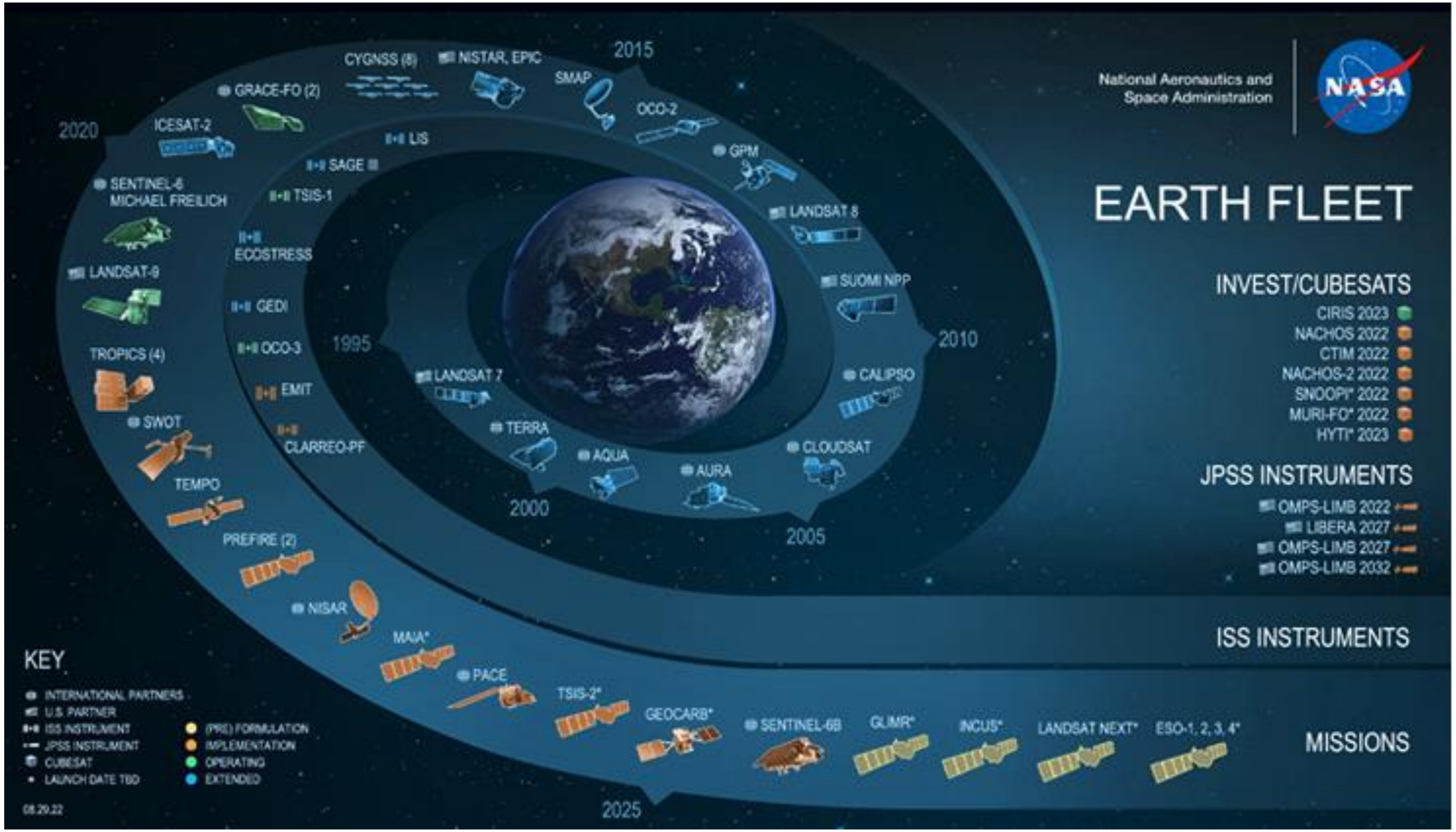


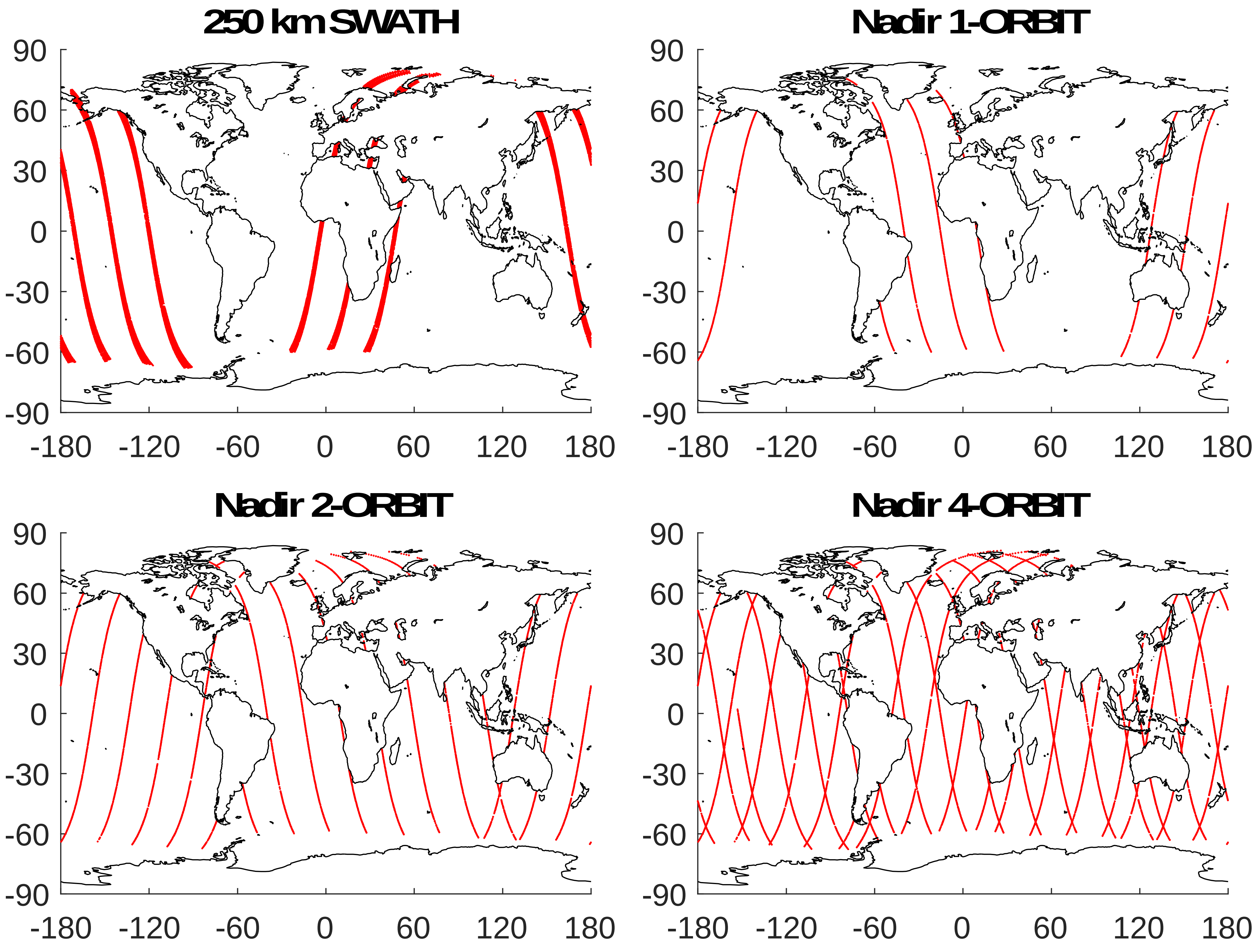
Why do an OSSE?

Evaluate proposed new instruments



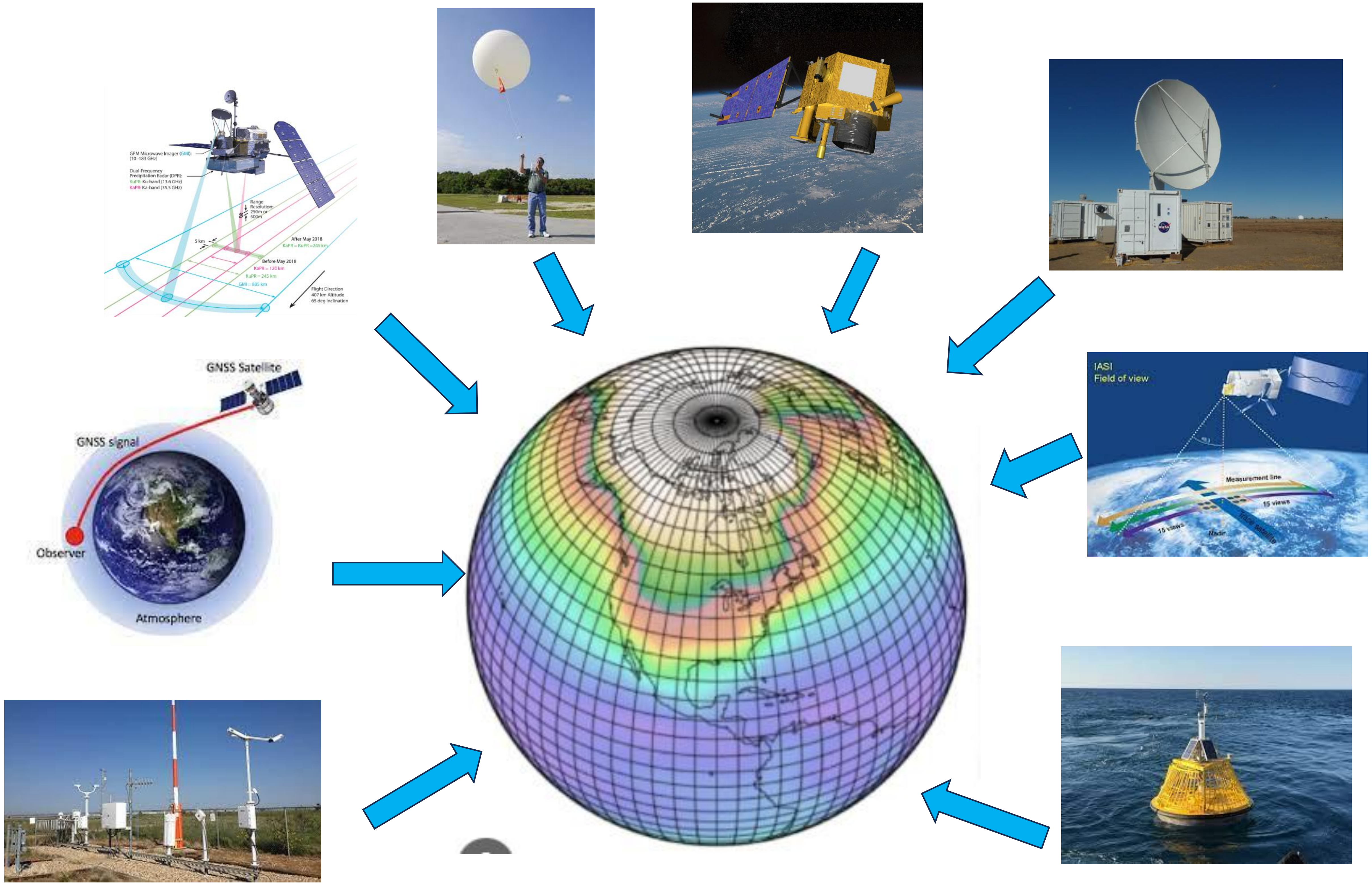
Why do an OSSE?

Design decisions

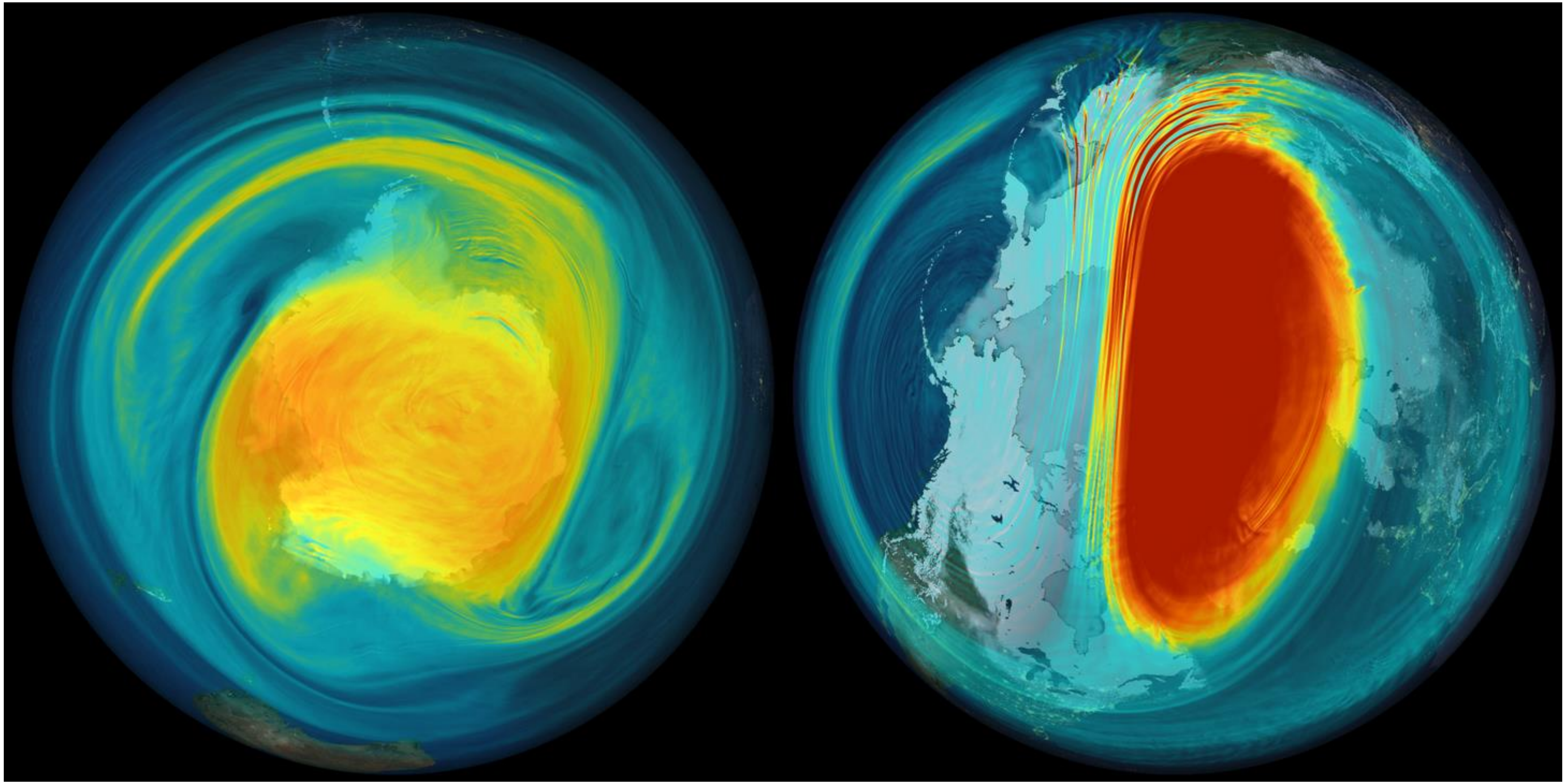


Why do an OSSE?

Data Assimilation Systems

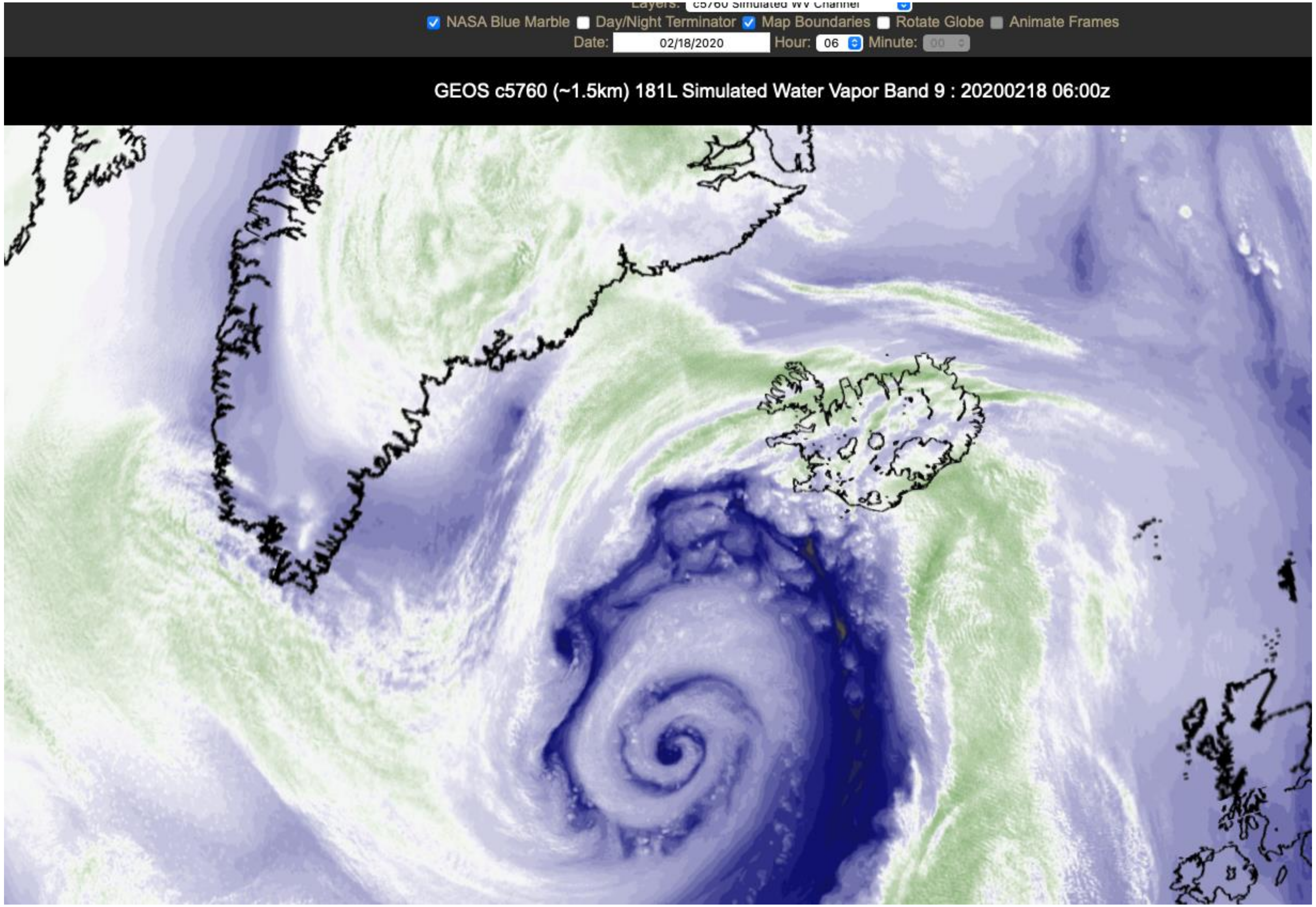


Nature Runs



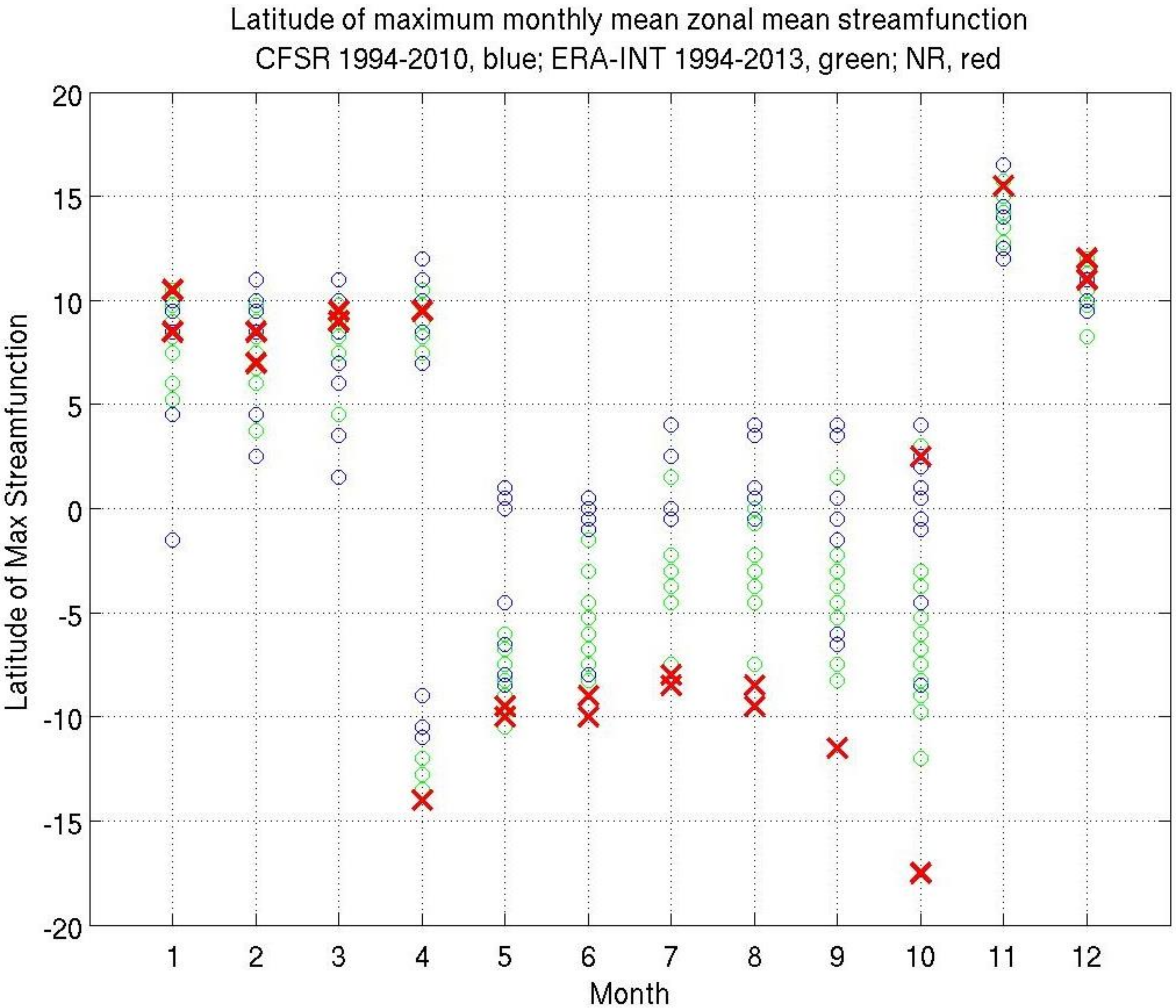
7km G5NR snapshot of EPV, March

Nature Runs



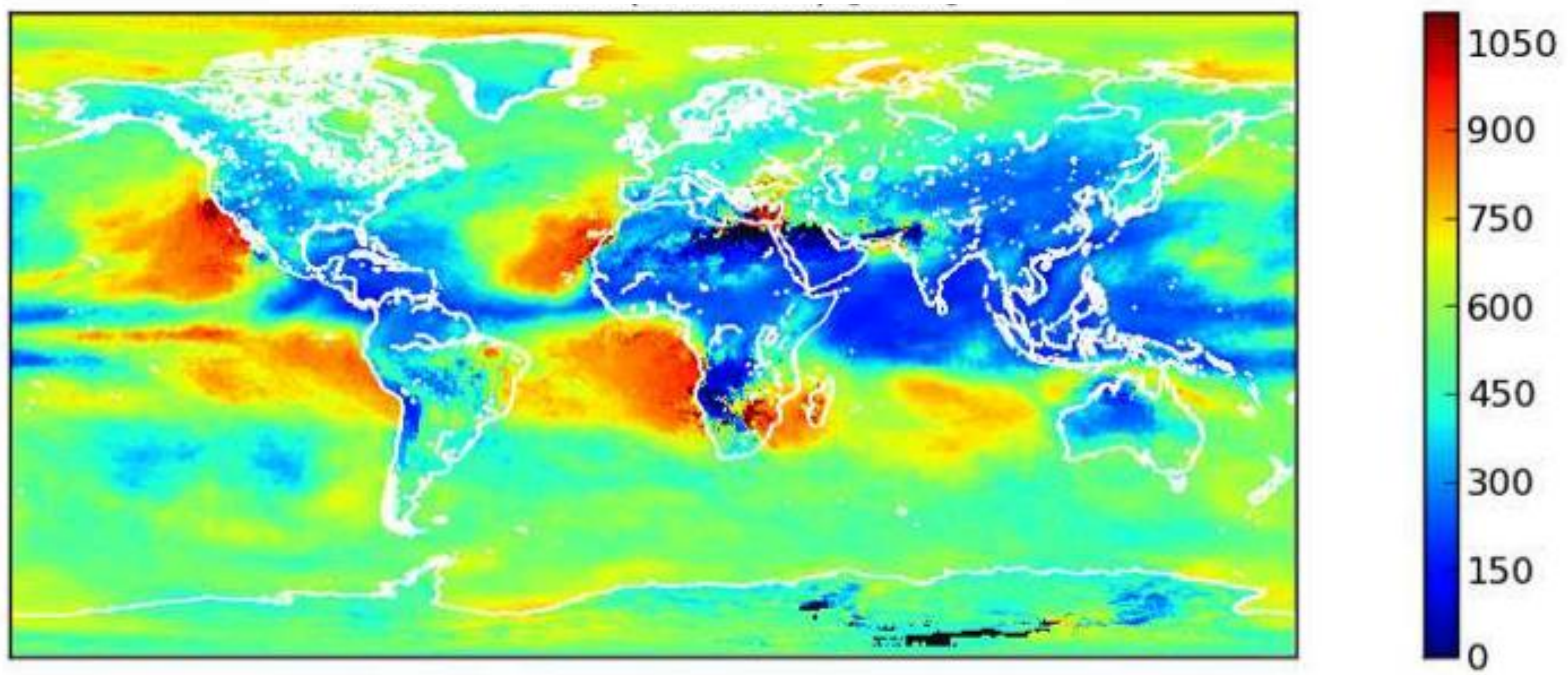
DYAMOND 1.5 km simulated radiance

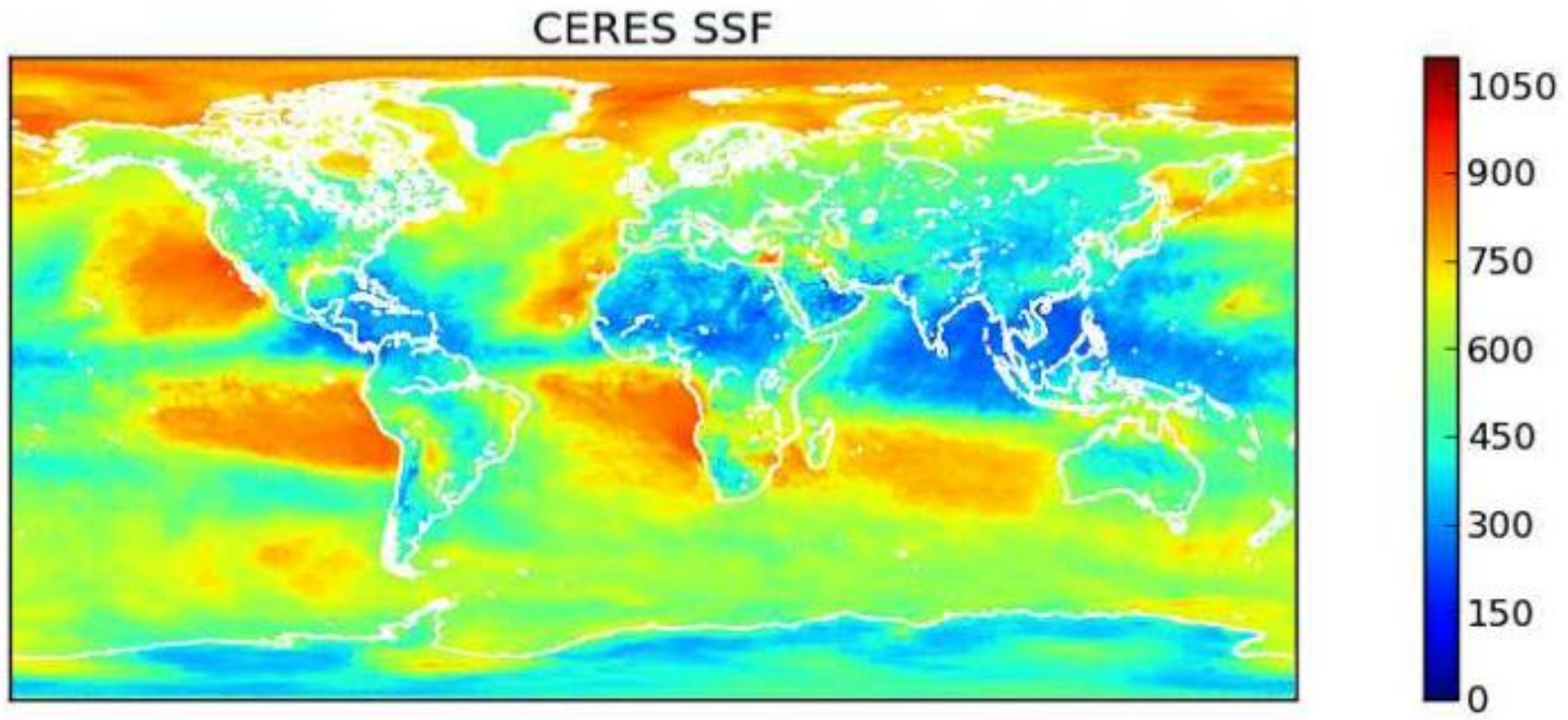
Nature Run Validation



Nature Run Validation

G5NR





Fields needed for simulating observations are especially important

Cloud top heights, G5NR

Nature Runs: Arctic

Arctic Challenges:

Sea ice

Snow

Melt

Boundary Layer

Clouds

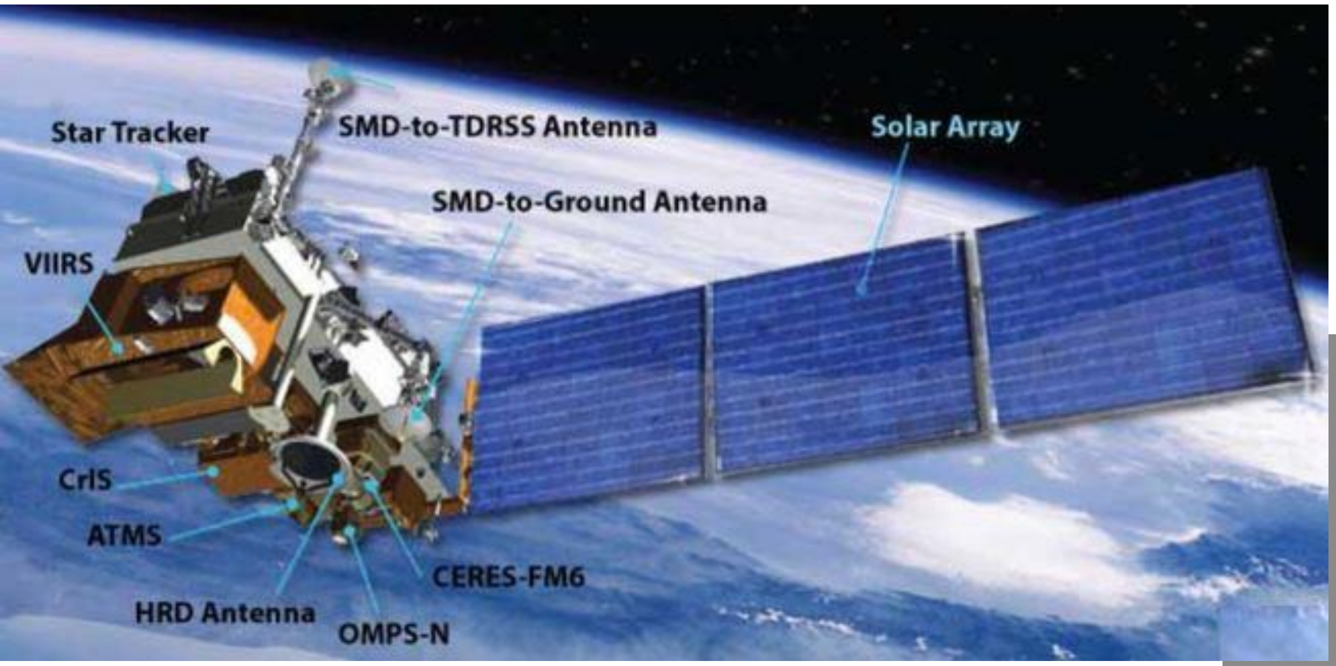
Ocean Coupling

Cryosphere Coupling

Upper Atmosphere

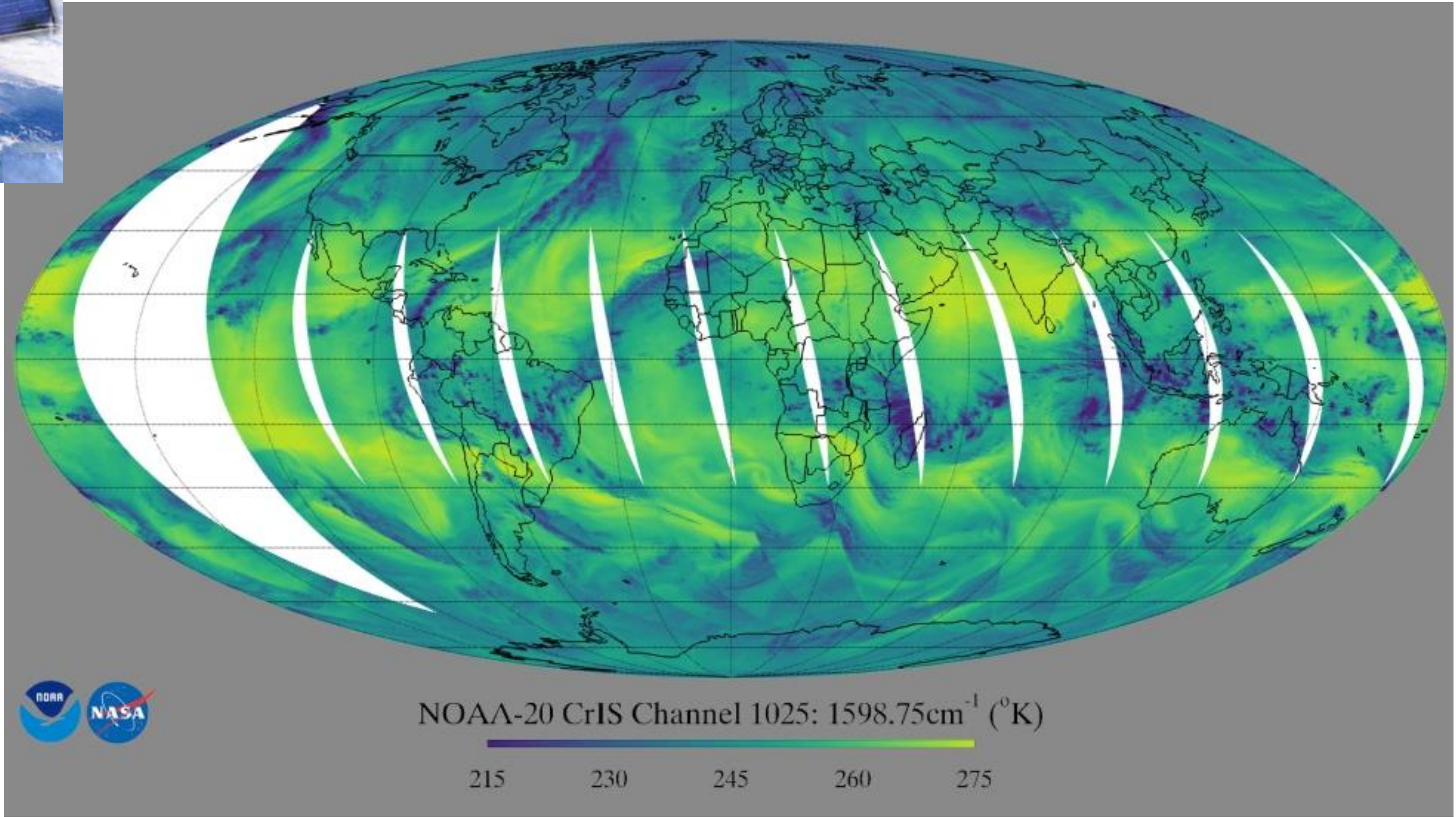
Images: NOAA

Synthetic Observations



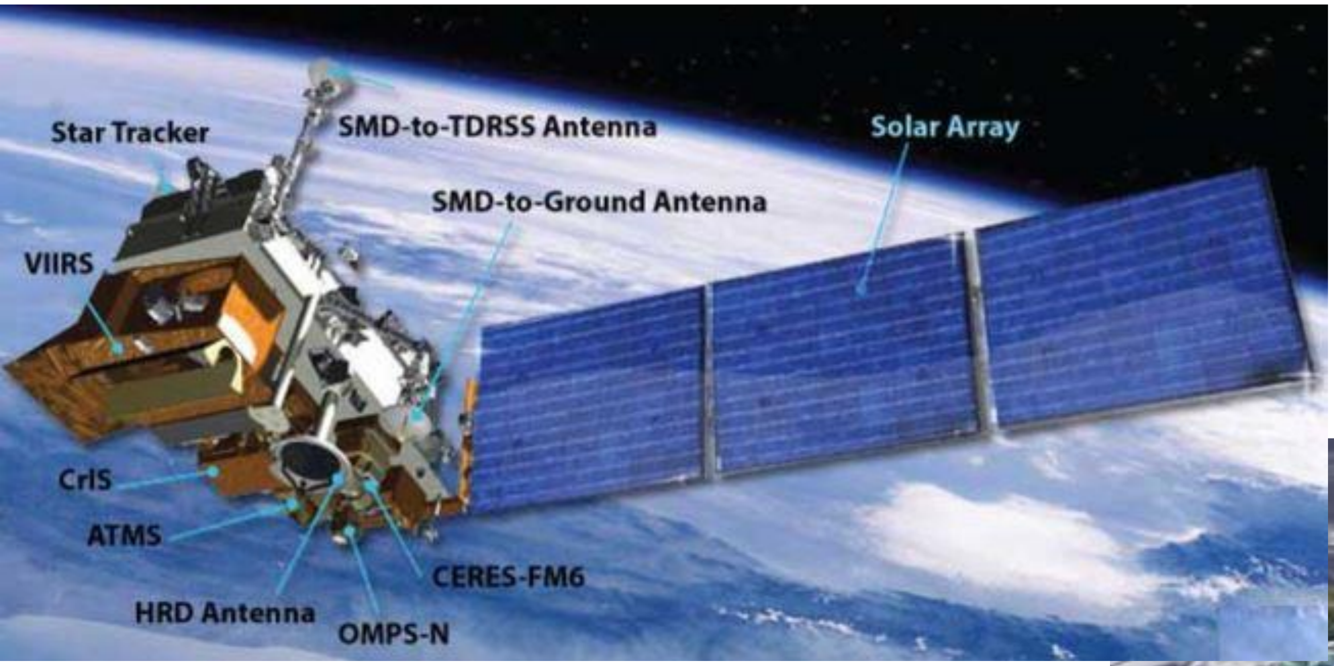
Real Satellite Instruments

Real Satellite Observations

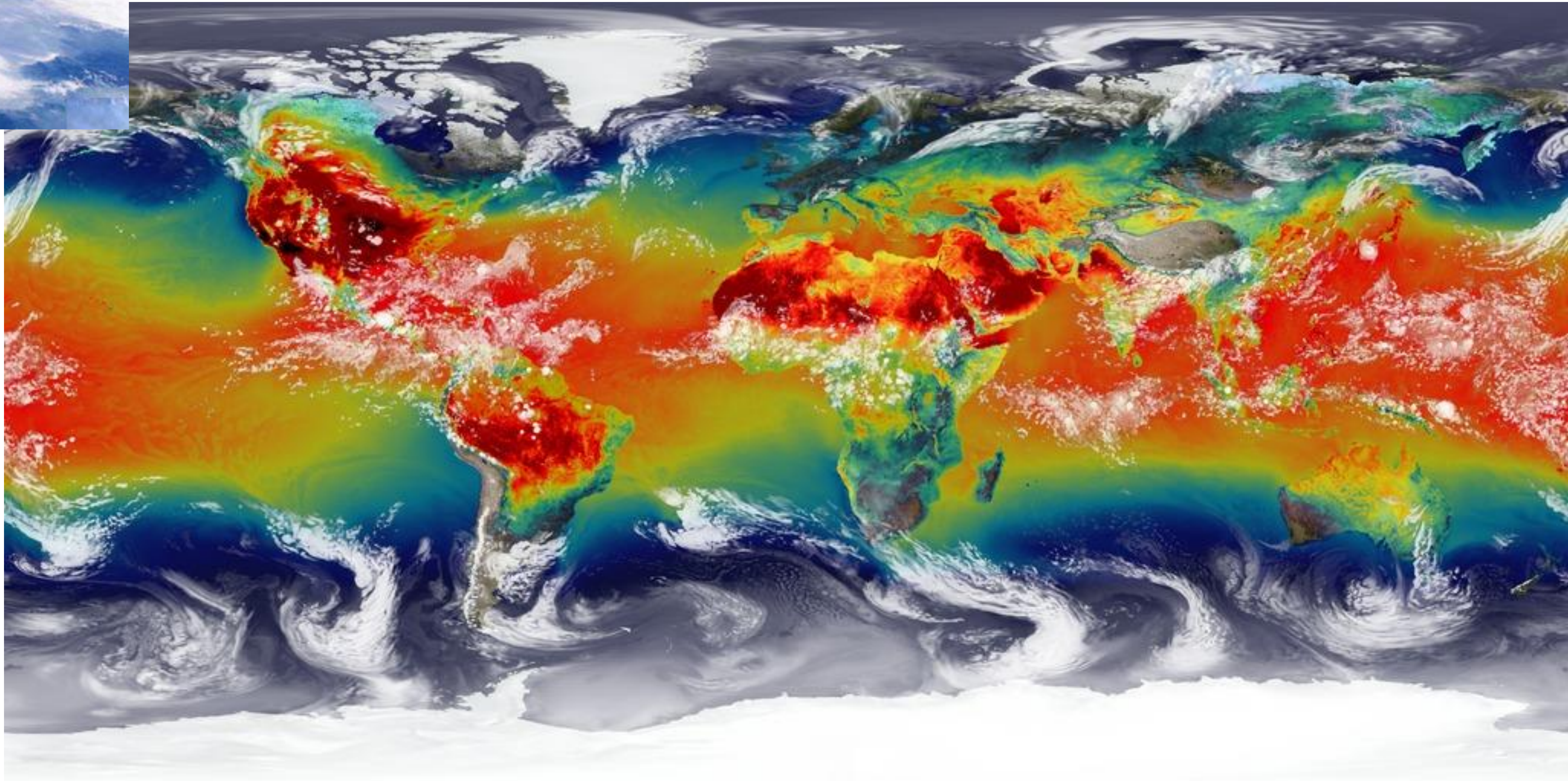


Images: NASA

Synthetic Observations



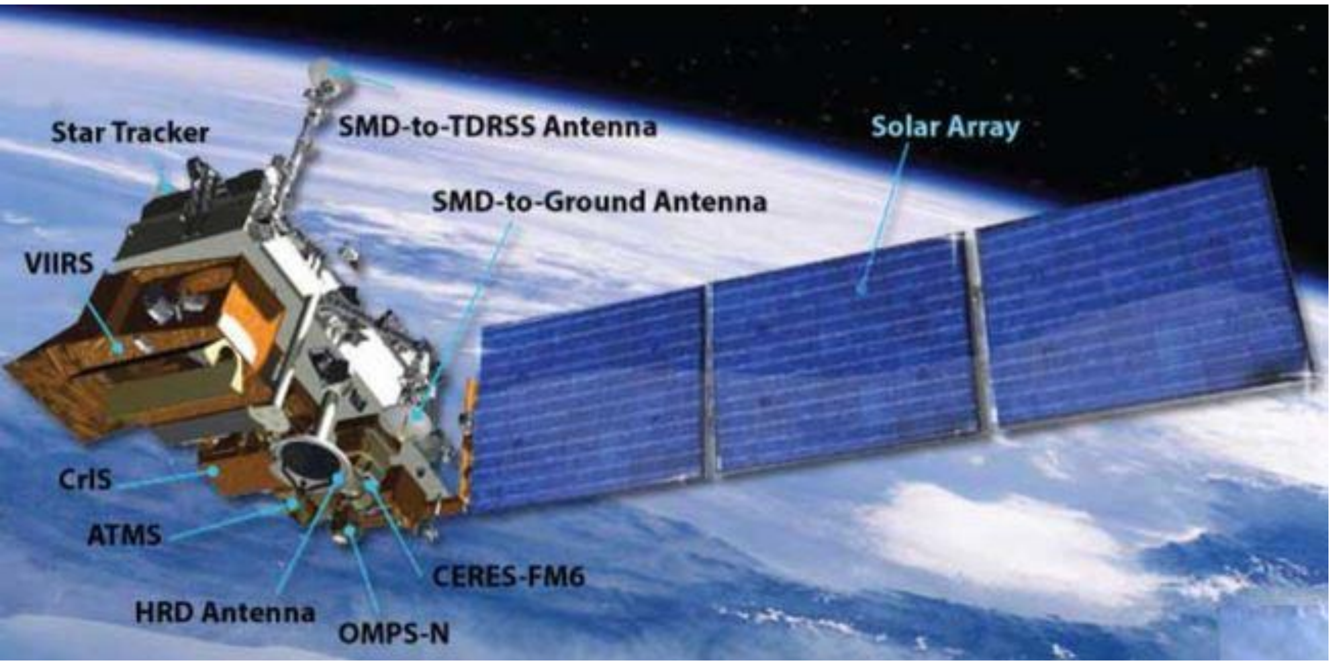
Nature Run



Simulated Satellite Instruments

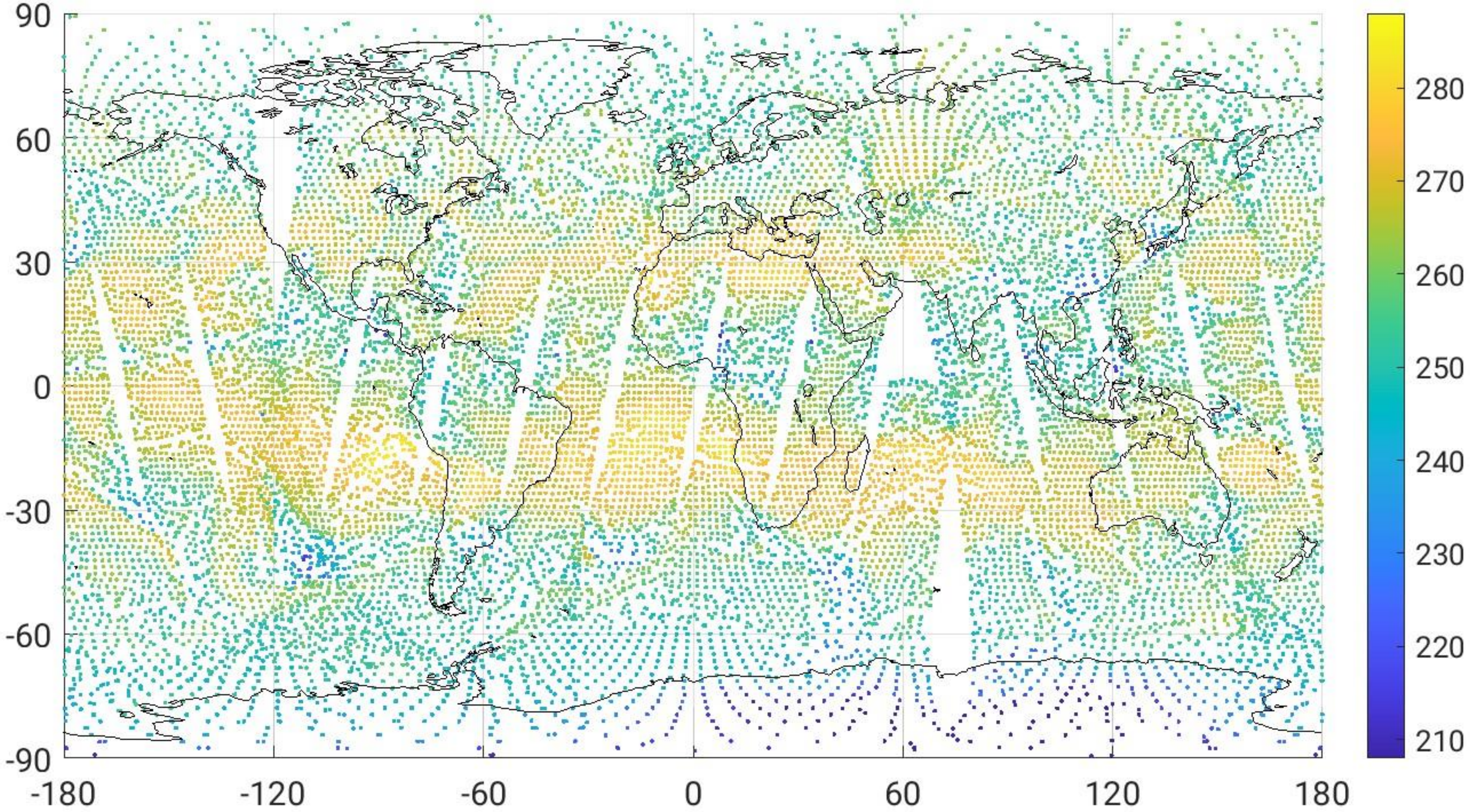
Images: NASA

Synthetic Observations



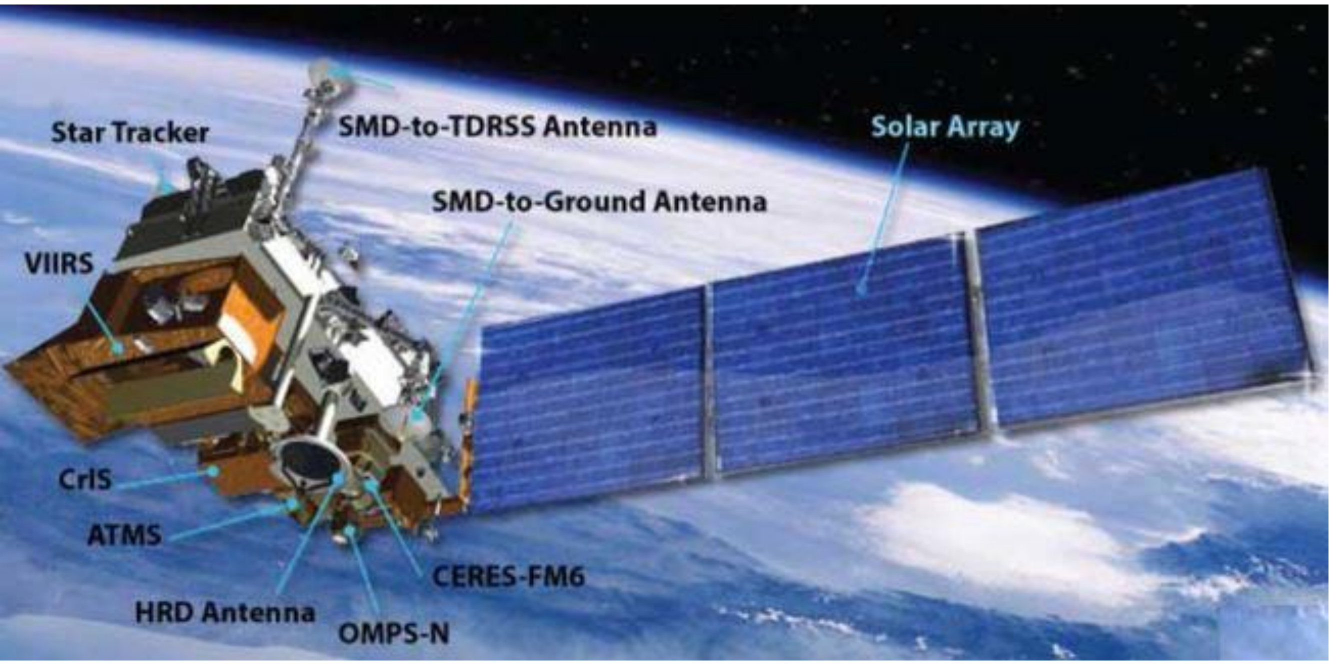
Real Satellite
Instruments

Real Satellite Observations



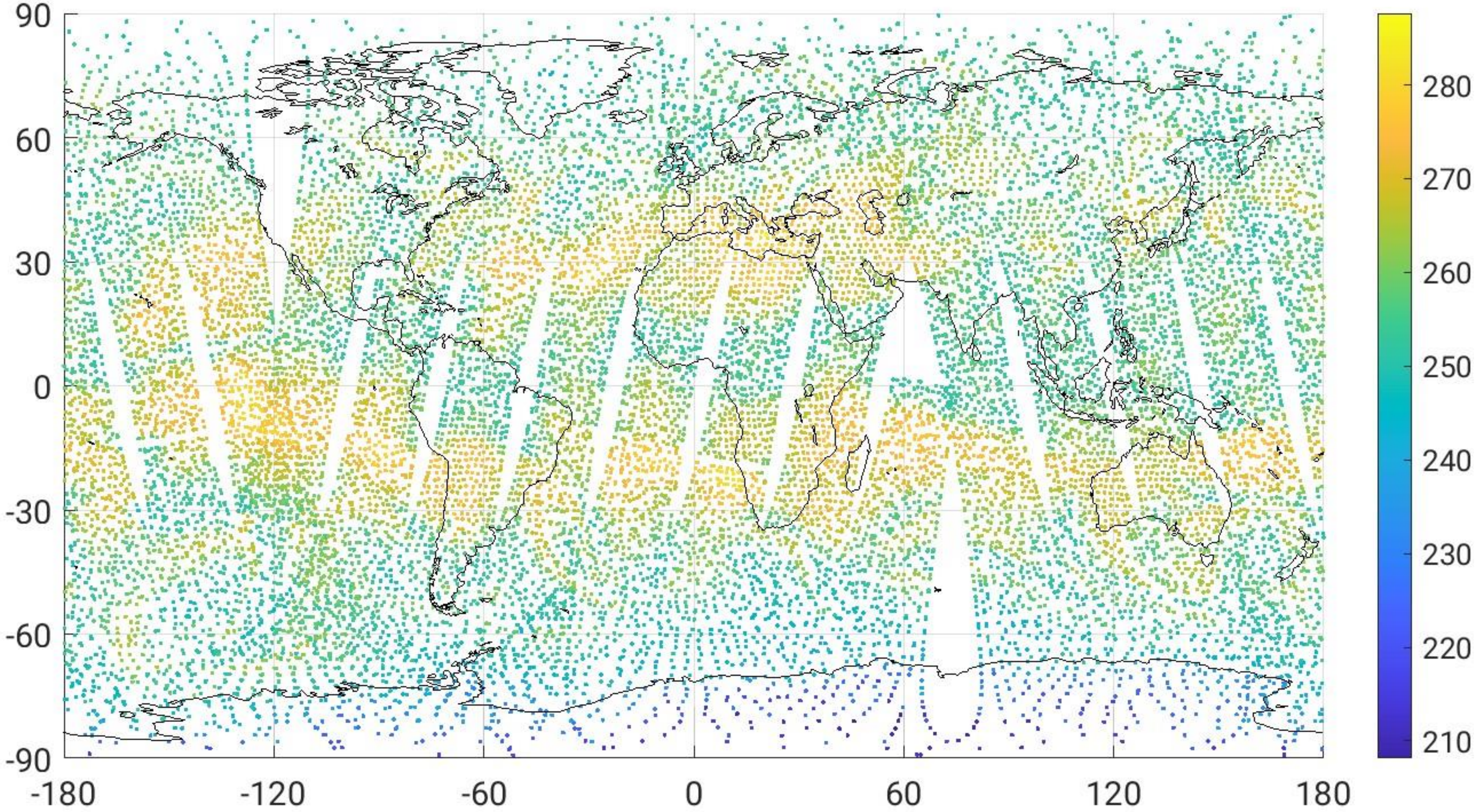
Images: NASA

Synthetic Observations



Simulated Satellite Instruments

Simulated Observations



Images: NASA

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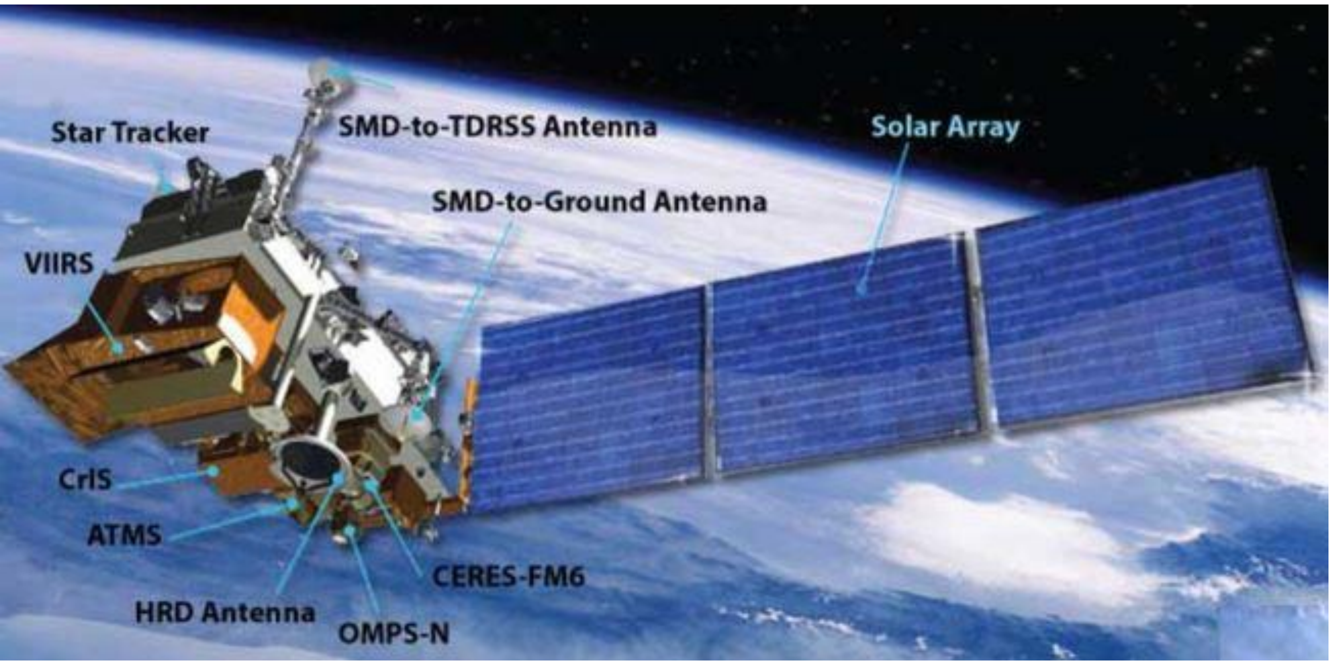
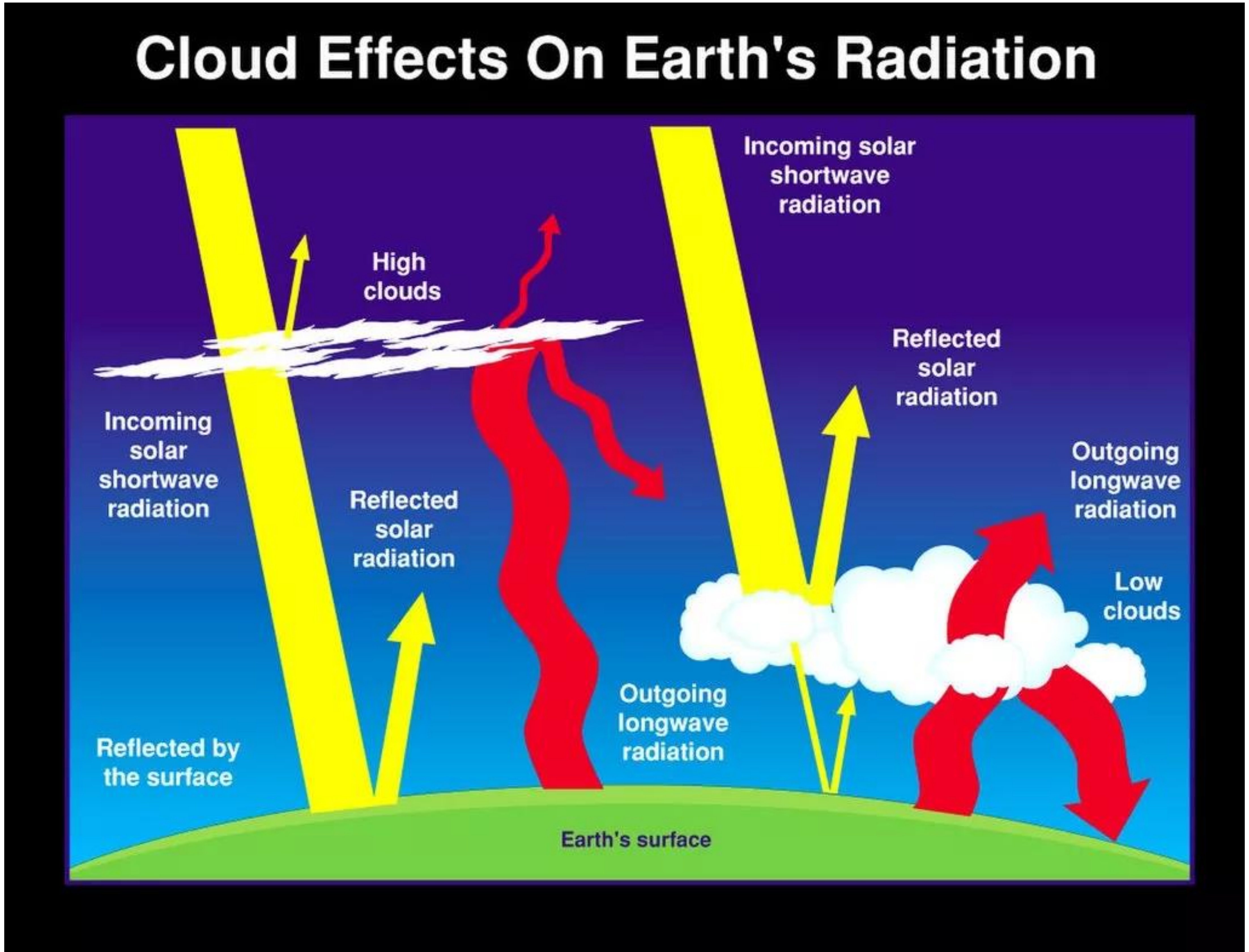


Simulated Satellite Instruments

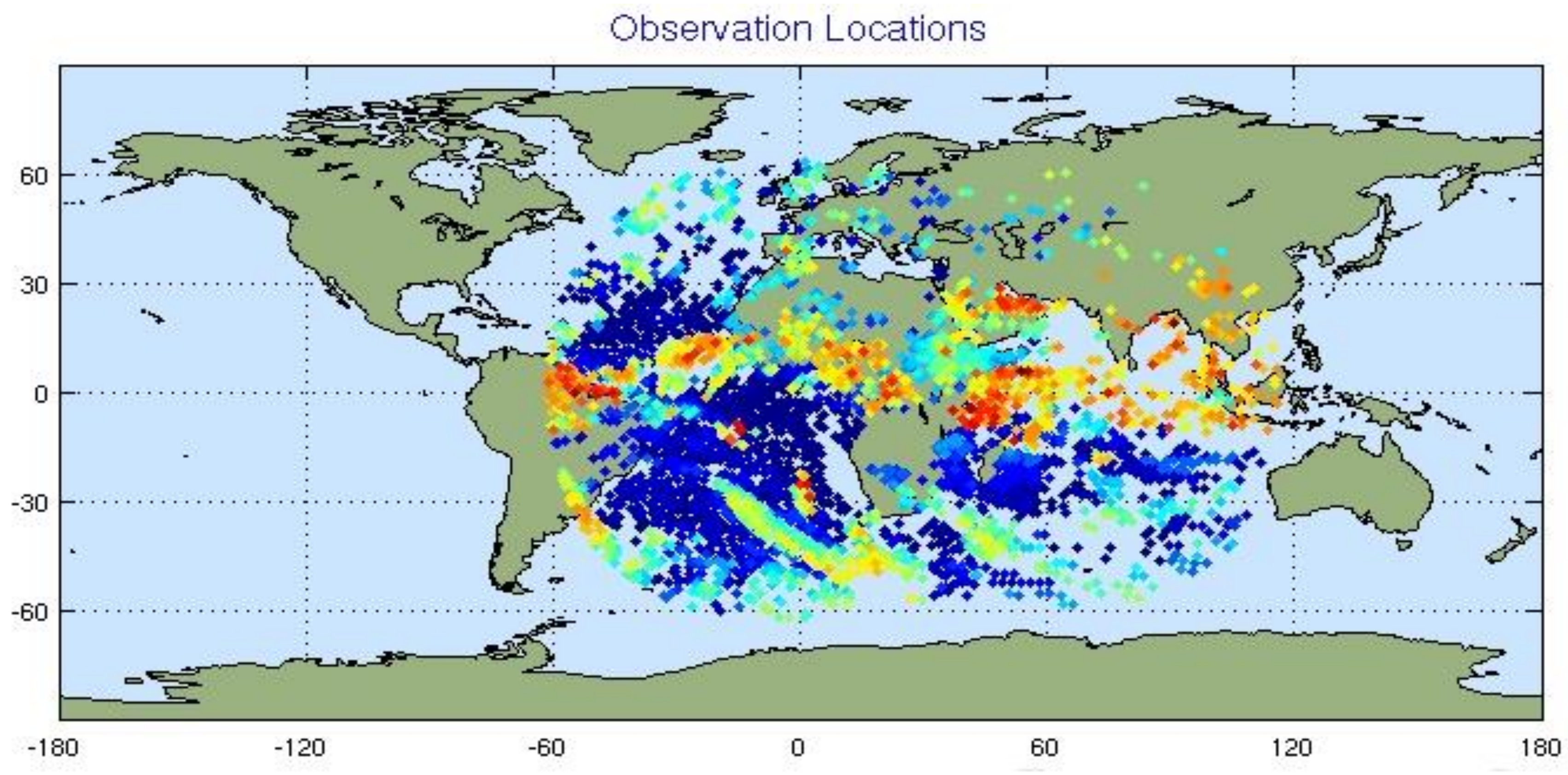
Clouds are Hard



Images: NESDIS

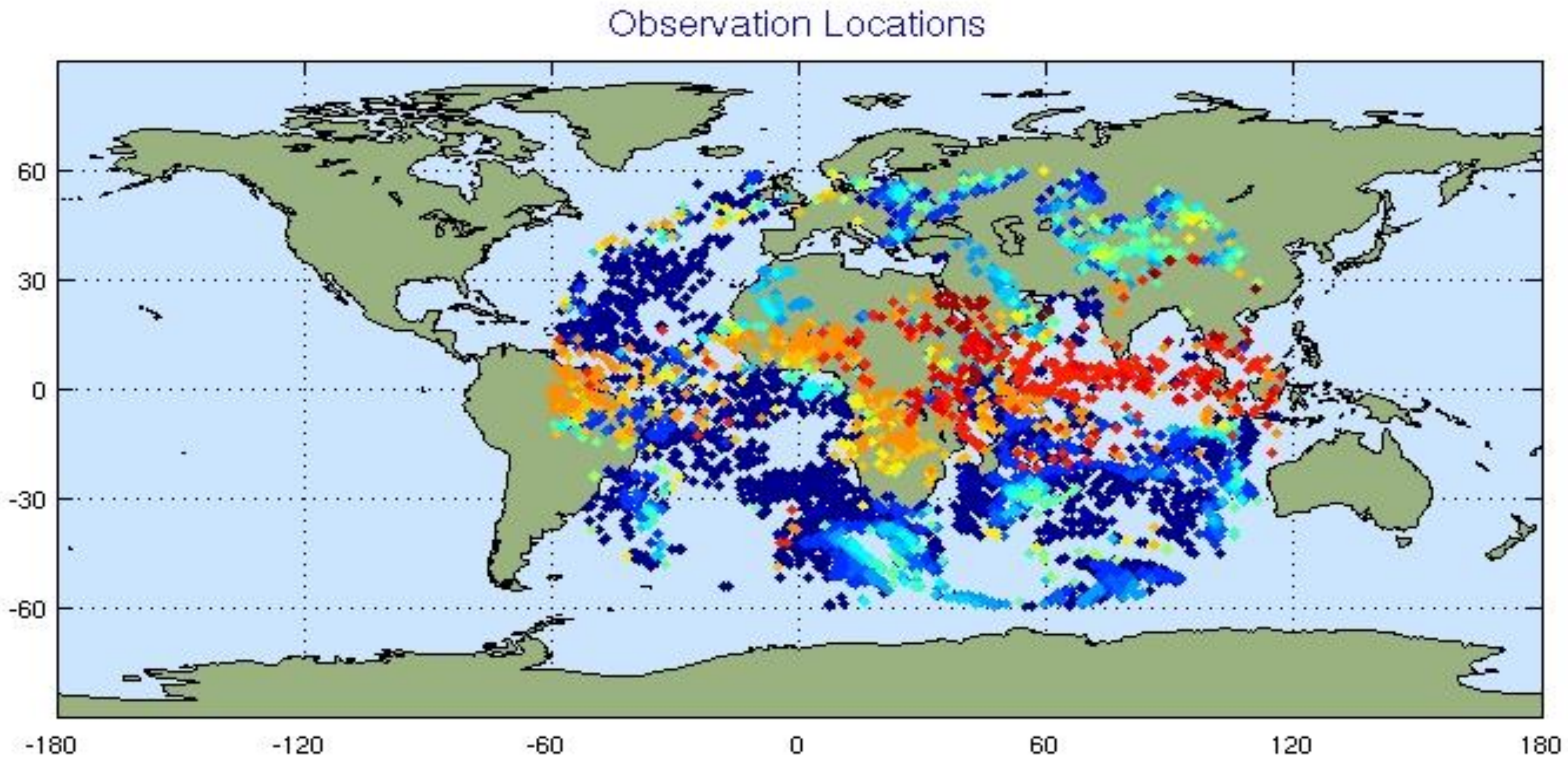
Synthetic Observations

Atmospheric
Motion Vectors



Real

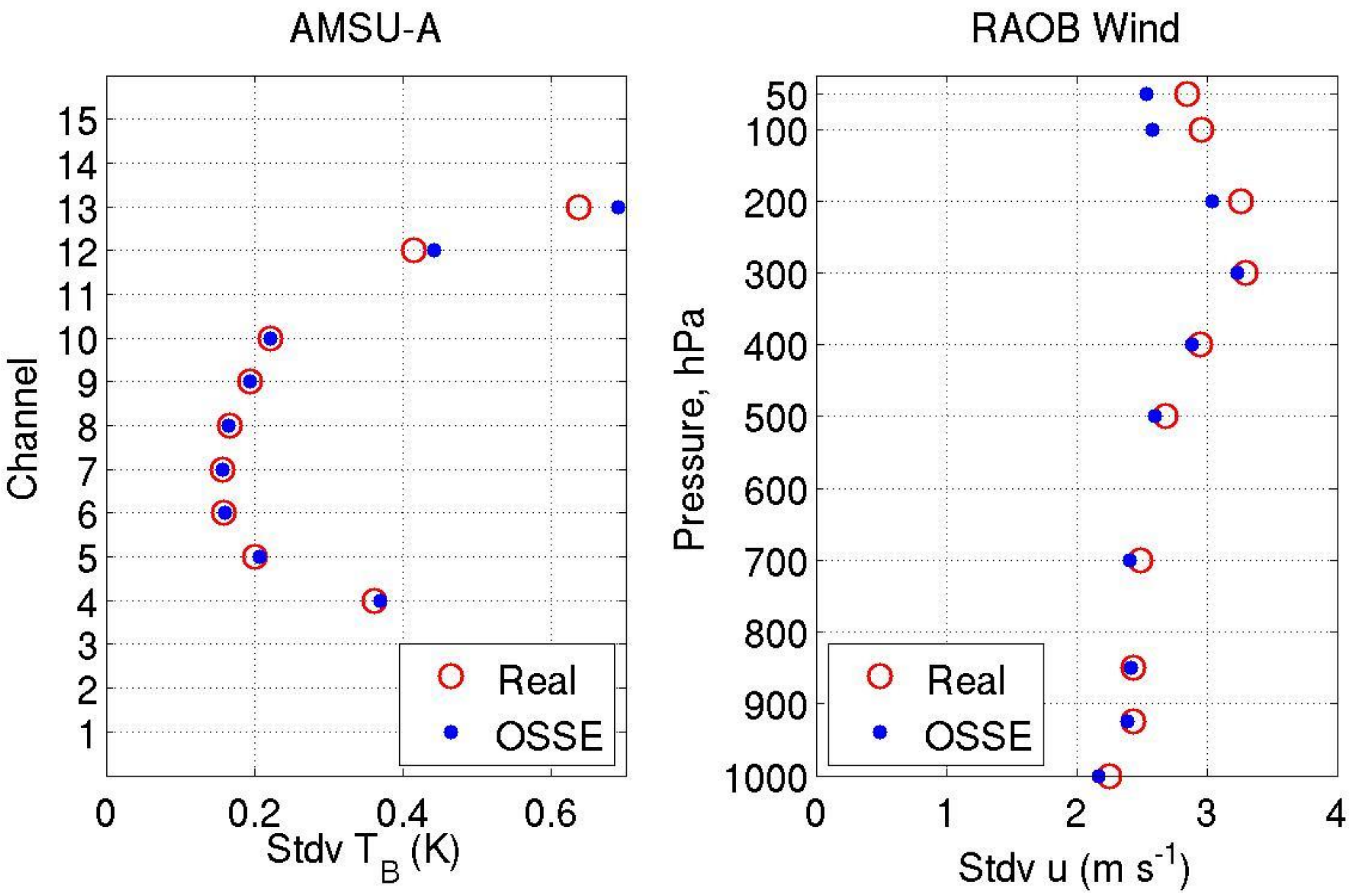
Clouds are Hard



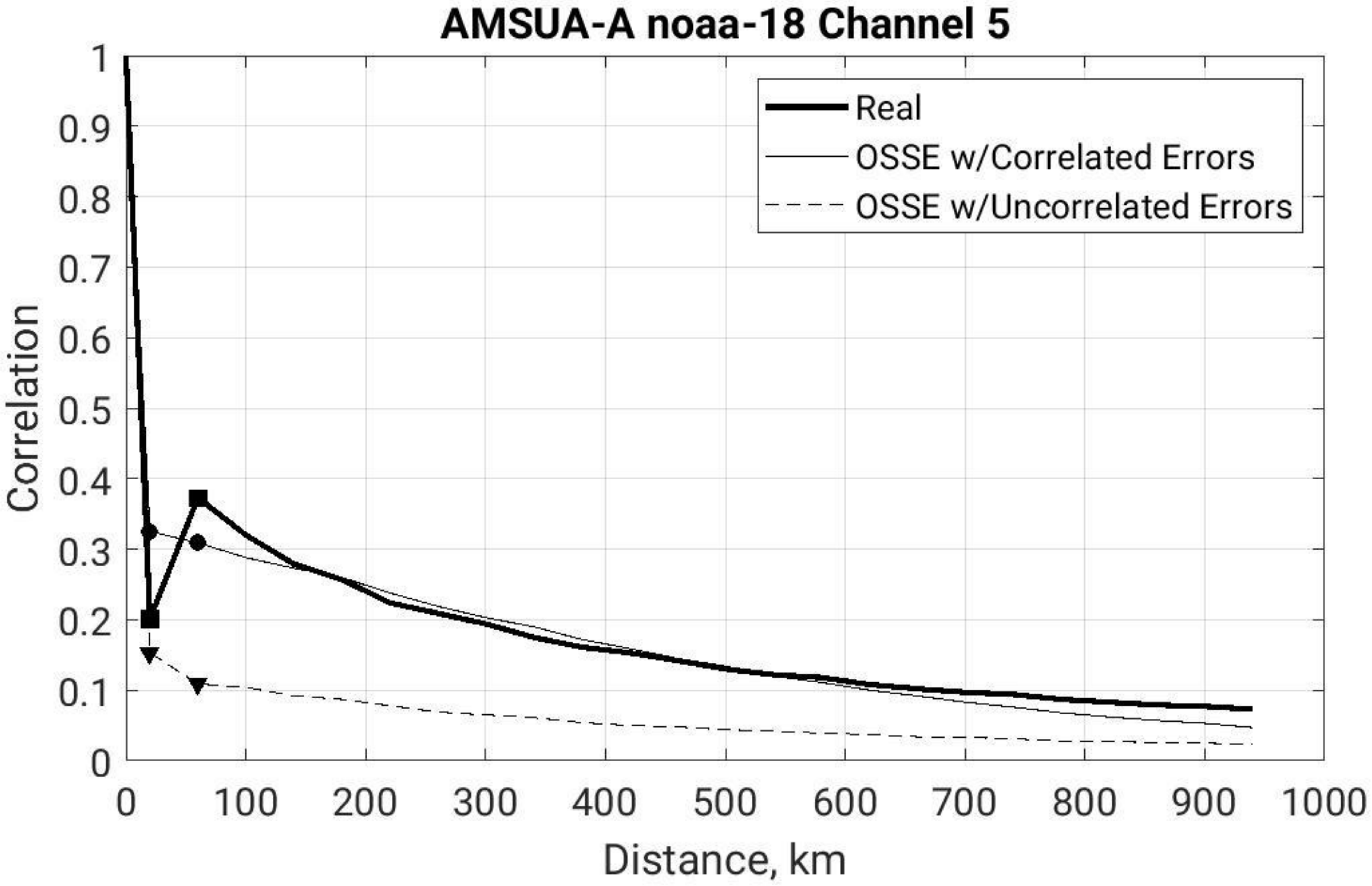
Simulated

Simulated Observation Errors

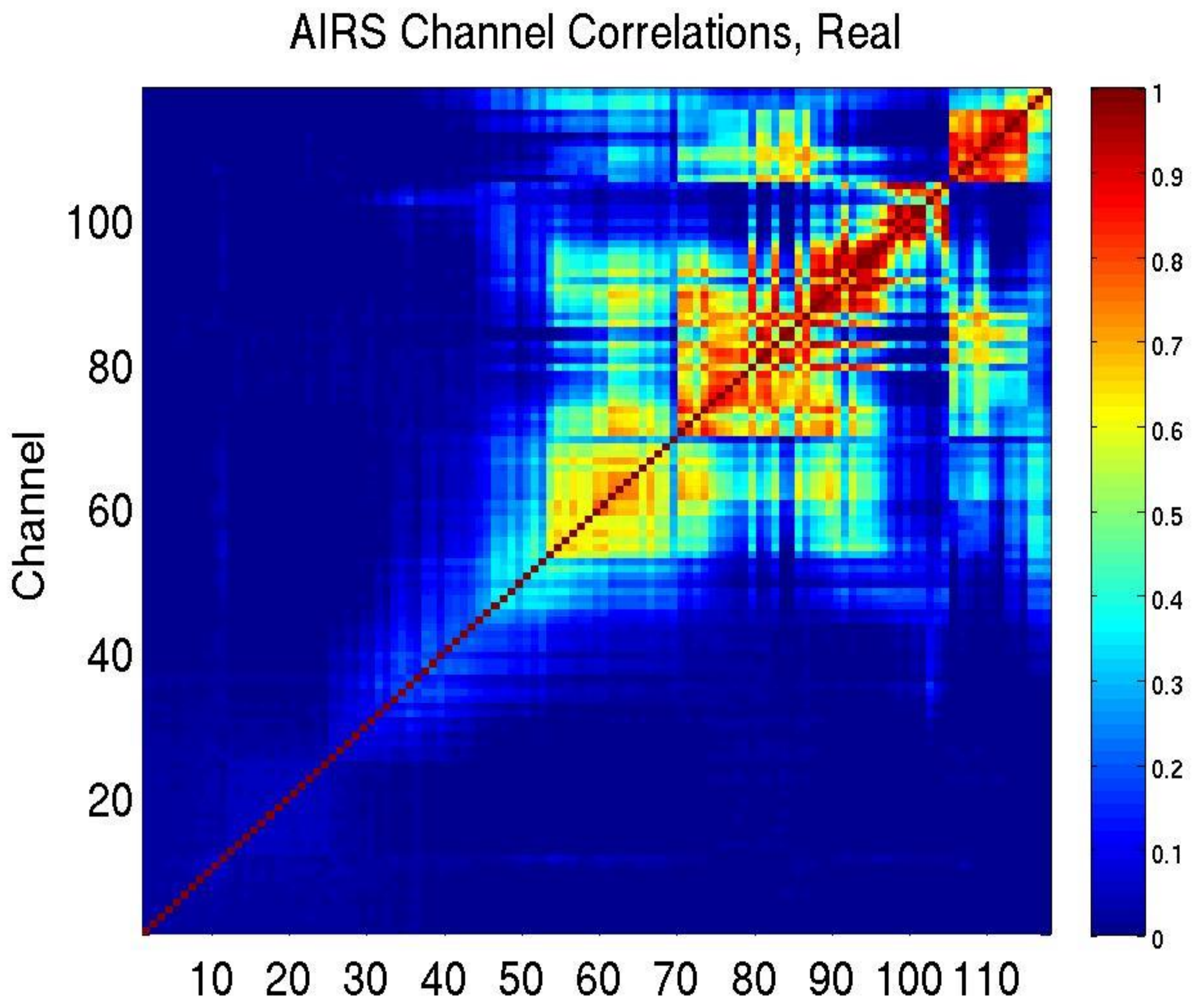
Match Real StDev(O-F)

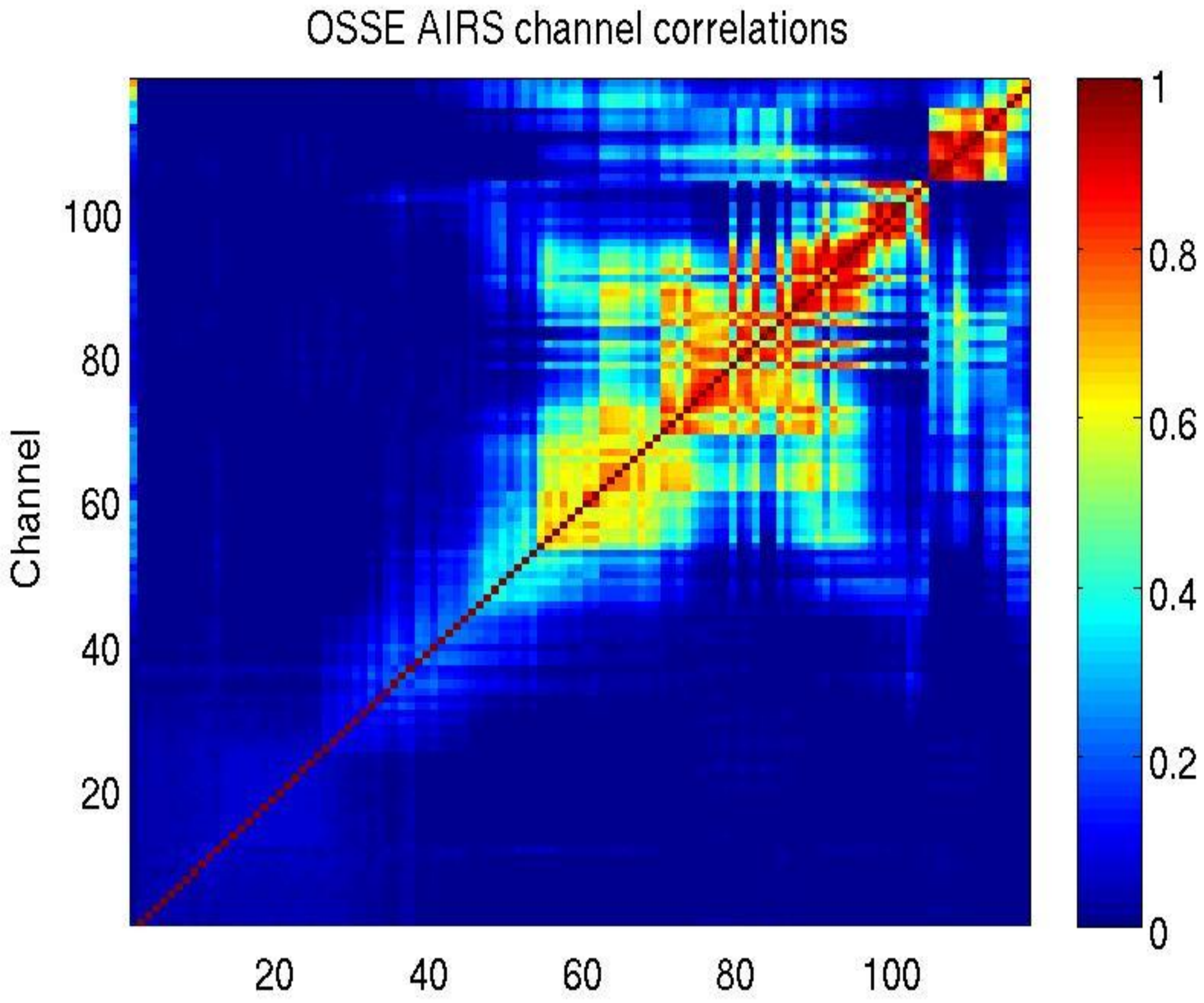


Obs Errors: Correlations



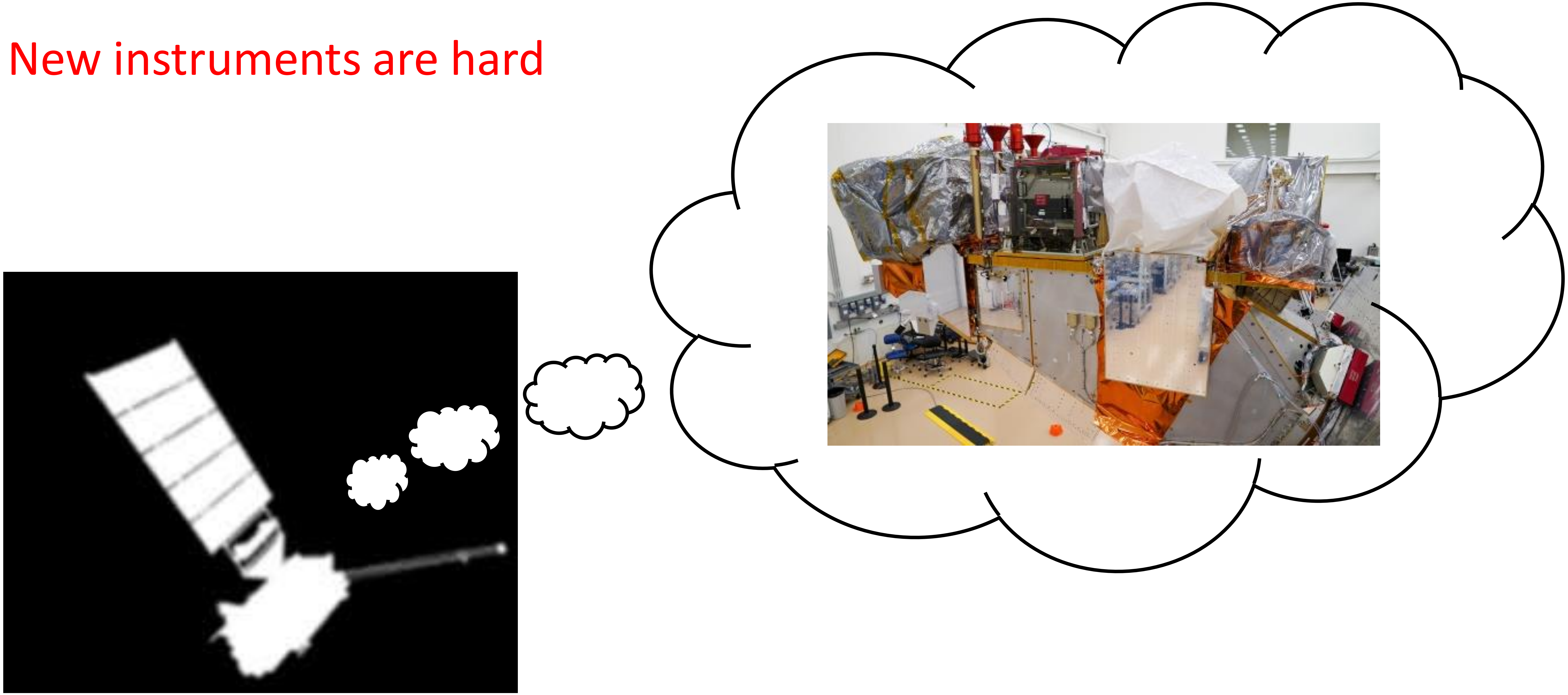
Obs Errors: Correlations





New Observation Types

New instruments are hard



Images: NOAA

Arctic Observations: Challenges

- Arctic clouds are hard
  - Polar stratospheric clouds
  - Thin ice clouds

Image: NASA

Image: NOAA

Arctic Observations: Challenges

- Ice is very hard
  - Emissivity
  - Melt over ice
  - Sea ice
  - Snow

Images: NOAA

Arctic Observations: Challenges

- MODIS-type winds are hard (orbit calculations)

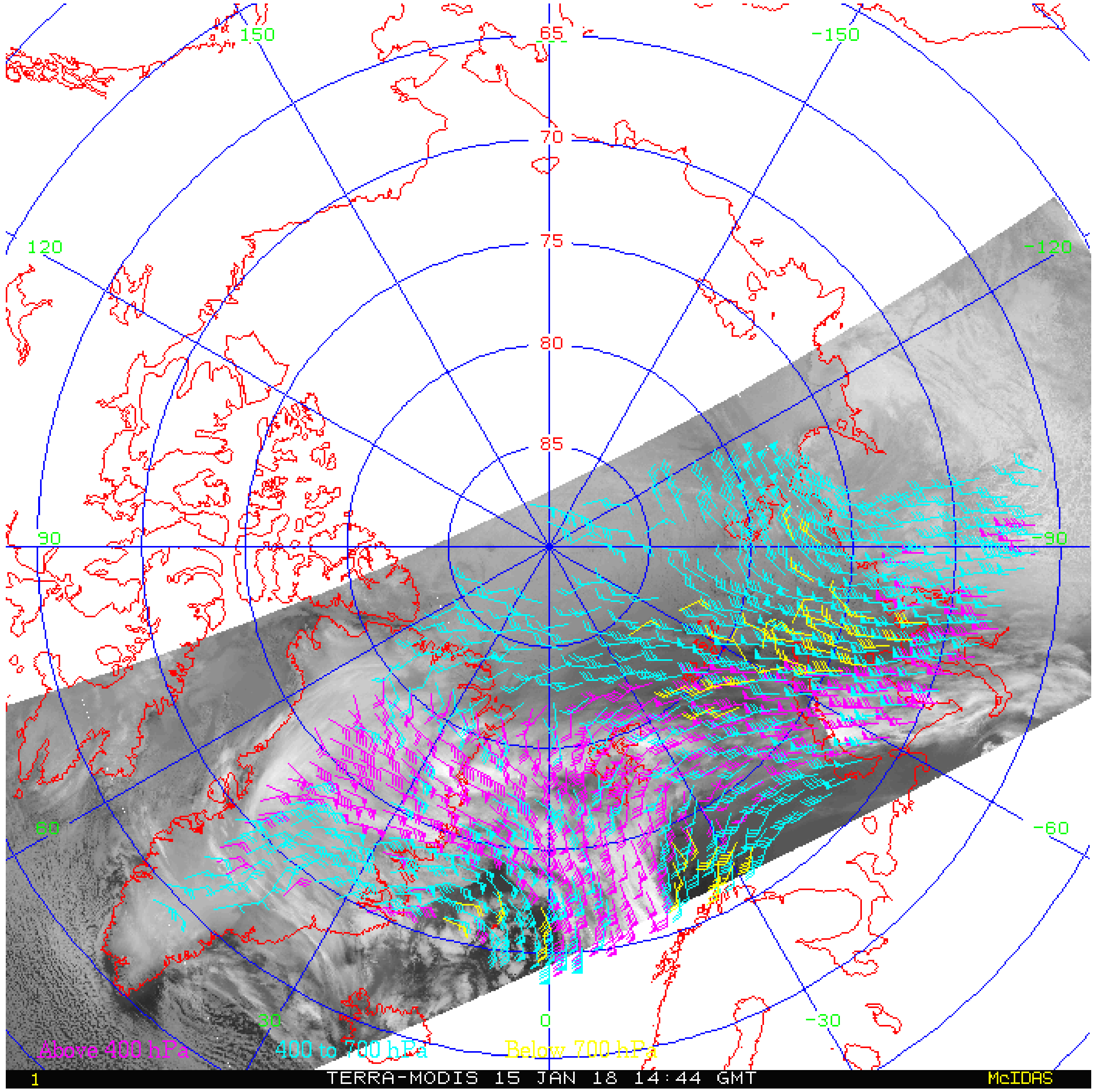


Image: NOAA

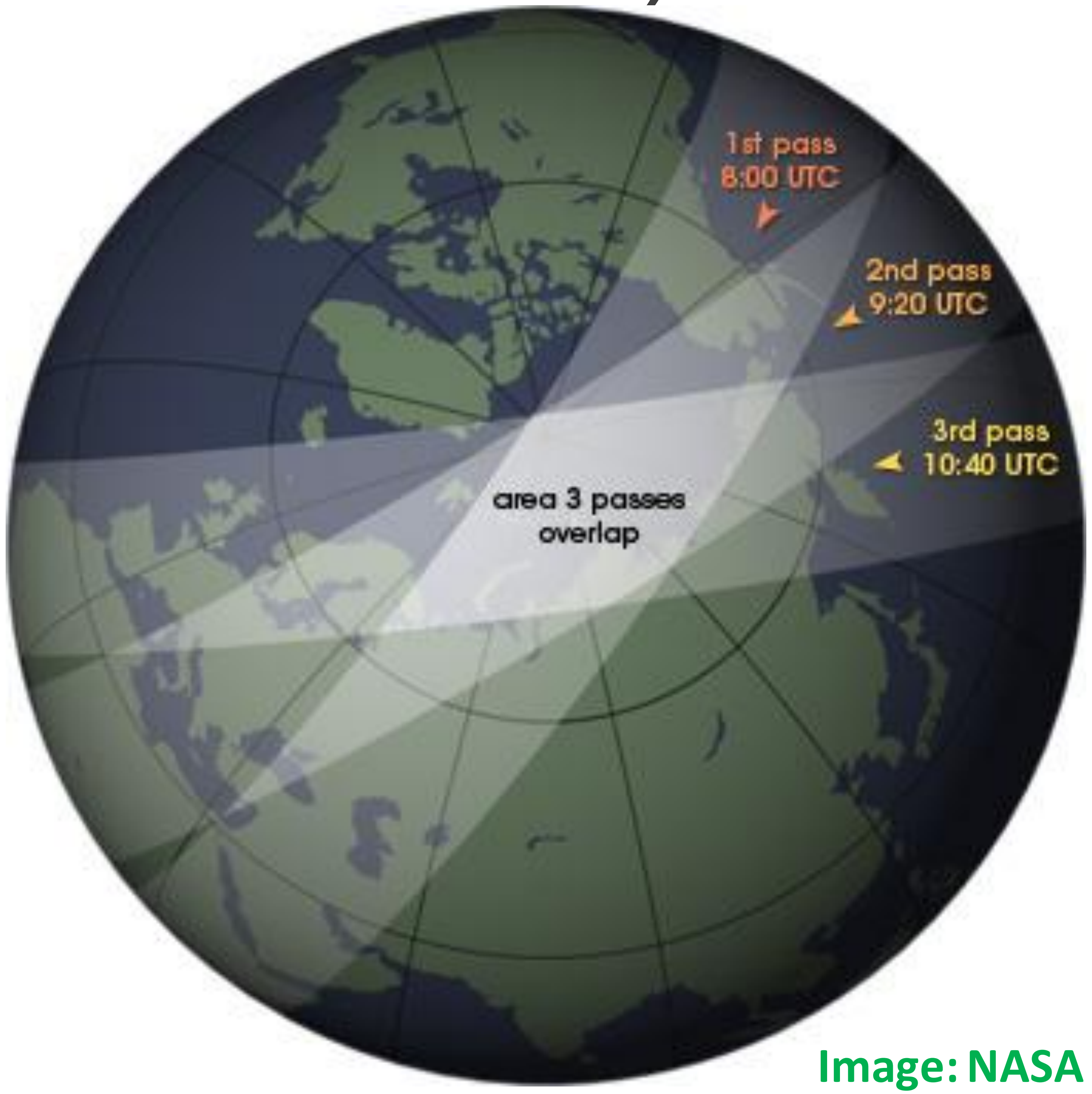
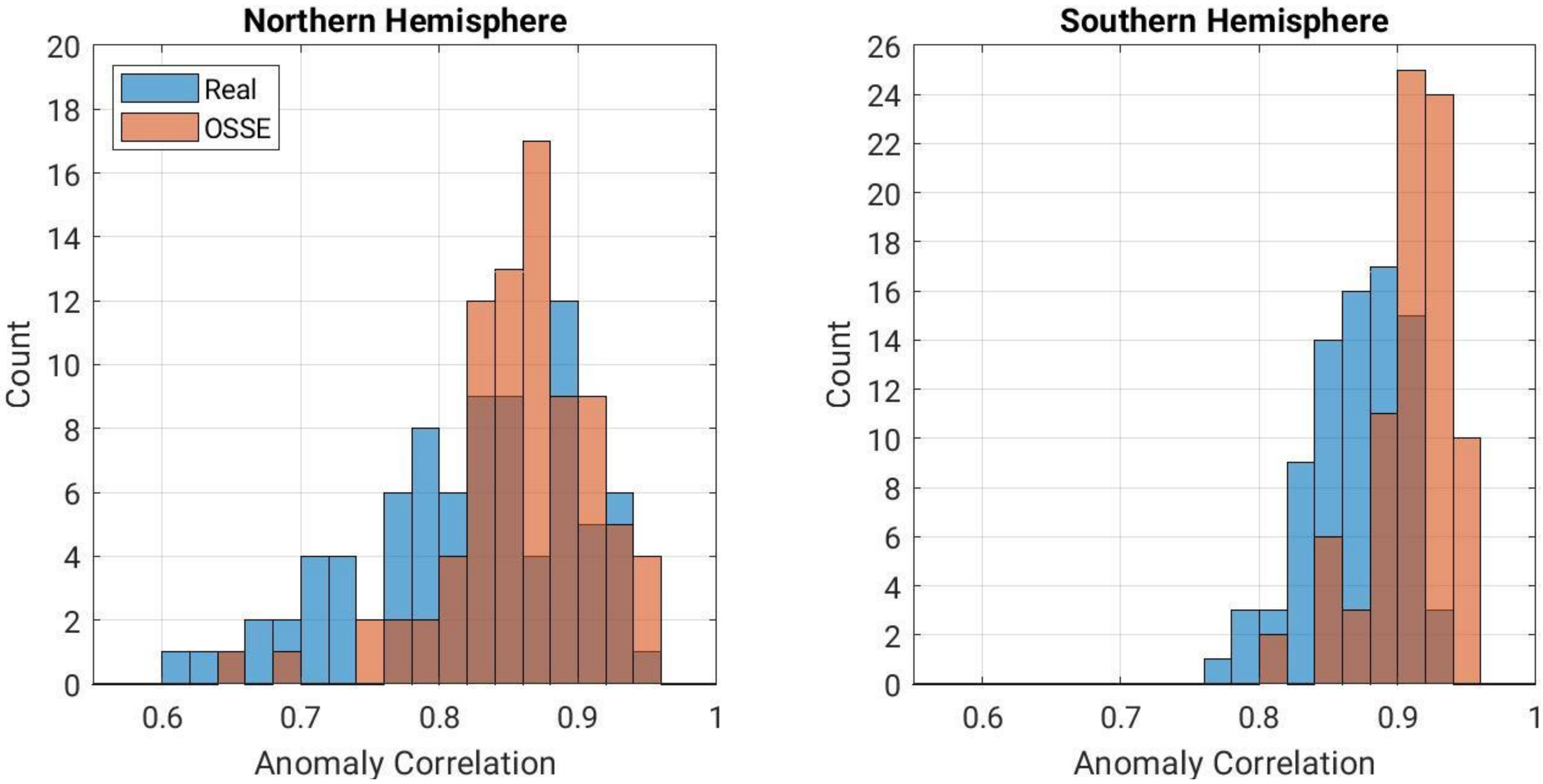


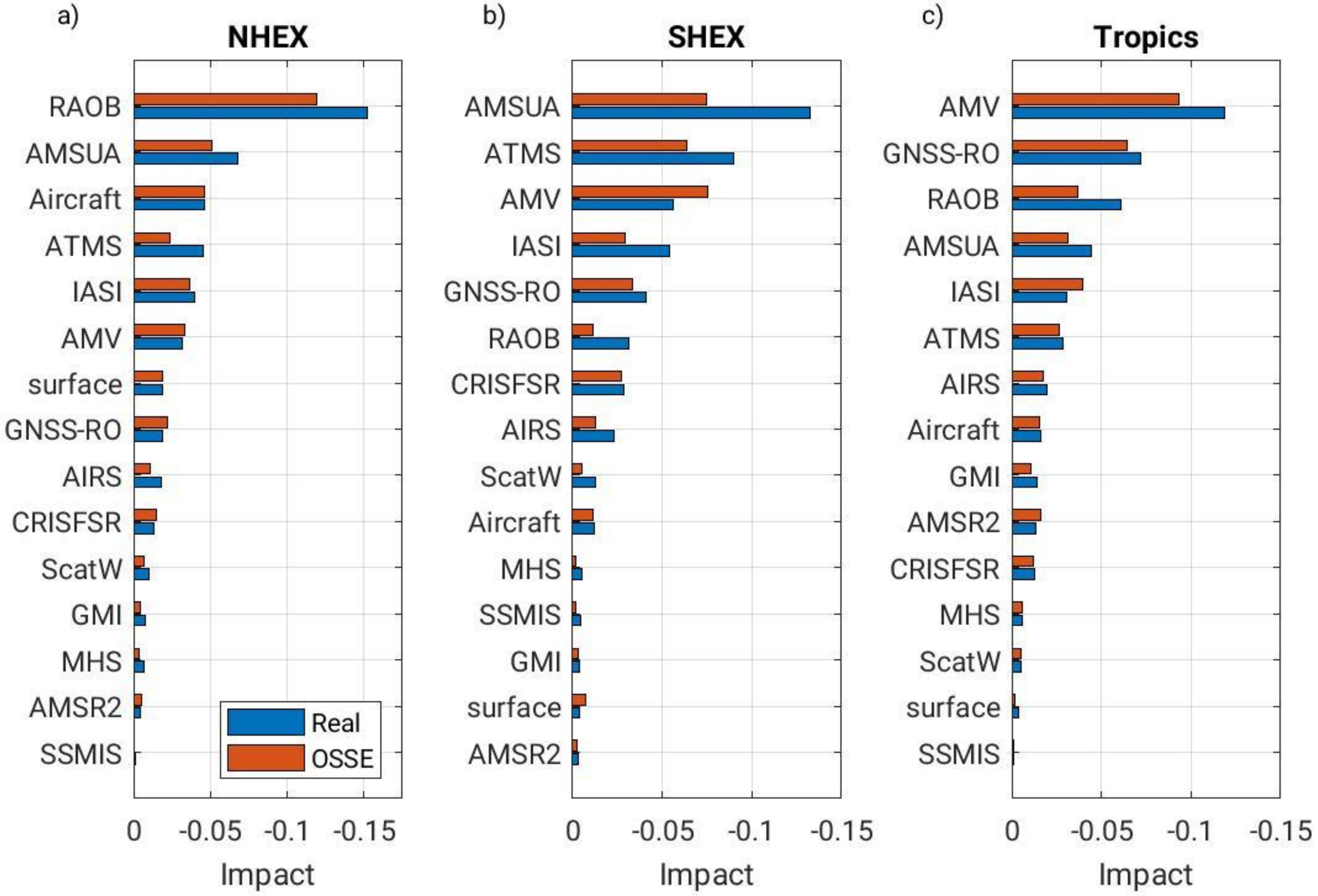
Image: NASA

Calibration: Forecast

500 hPa anomaly correlation of geopotential height at 120 hr



Why Believe OSSE Results?



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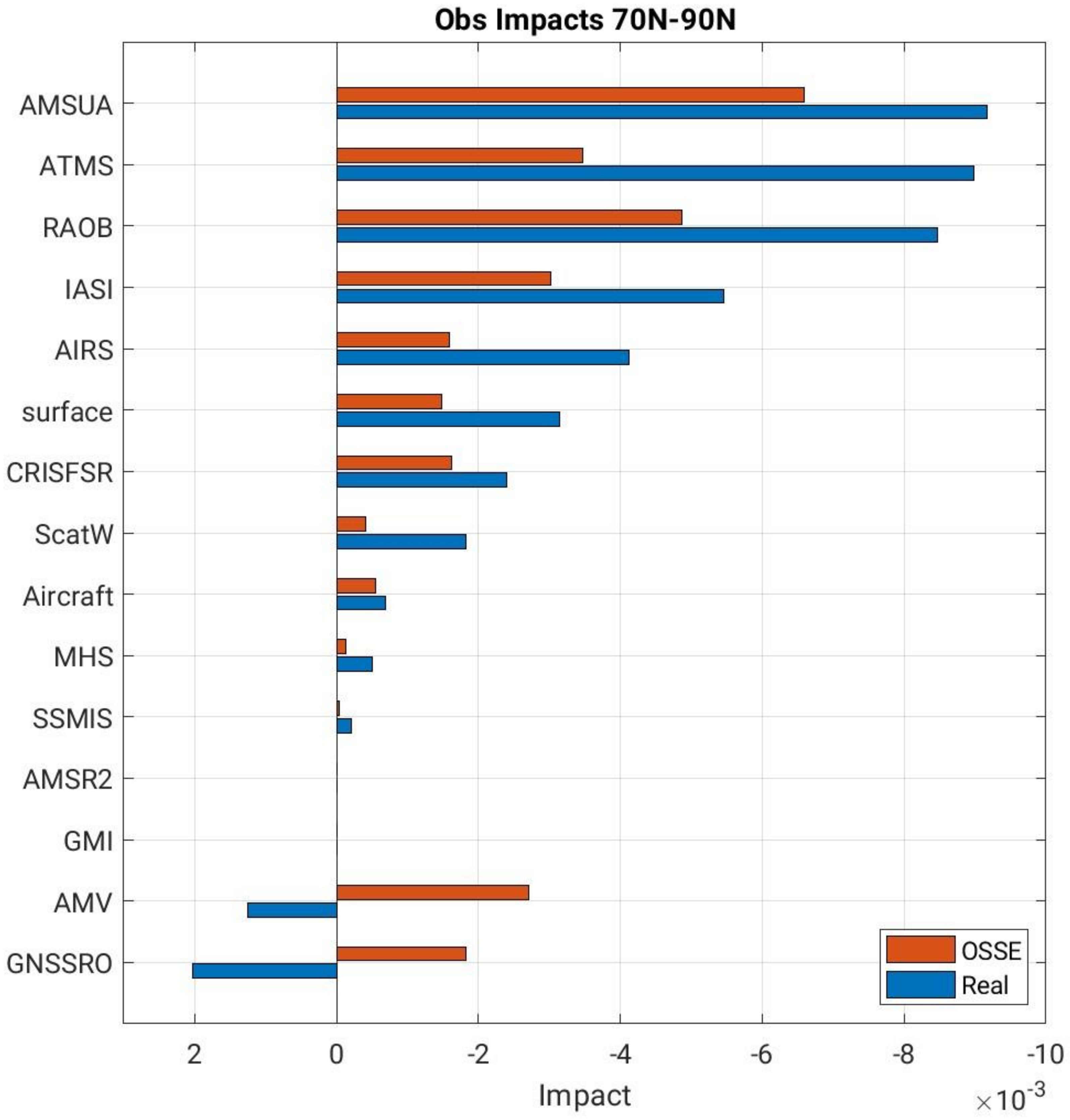


Some Examples

Experiments

Control

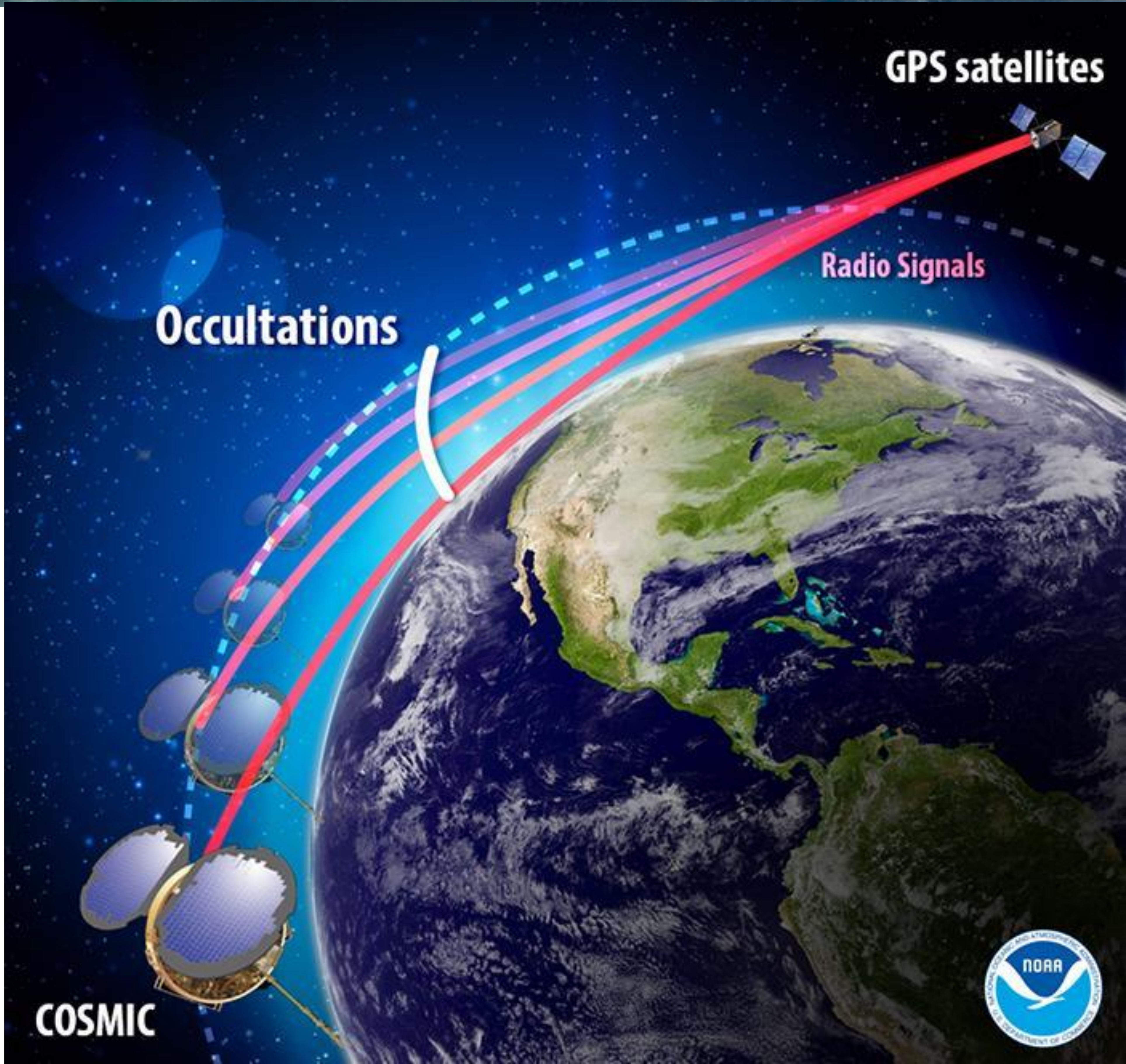
- Atmospheric Motion Vectors
- Aircraft
- Surface types – land and marine
- Rawinsonde
- ScatWind
- GNSS-RO
- CrIS-FSR
- AMSU-A
- AIRS AQUA
- ATMS
- IASI
- MHS (allsky)
- GMI (allsky)
- AMSR-2 (allsky)
- SSMIS f17

Experiment

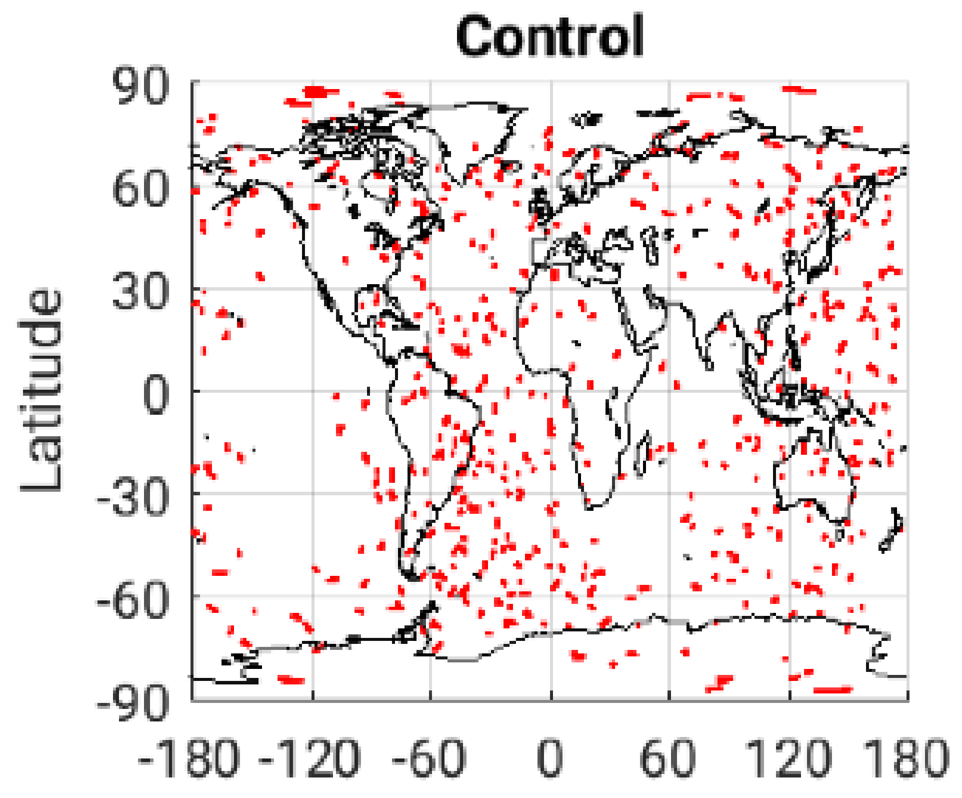
- All Control types
- New Instrument

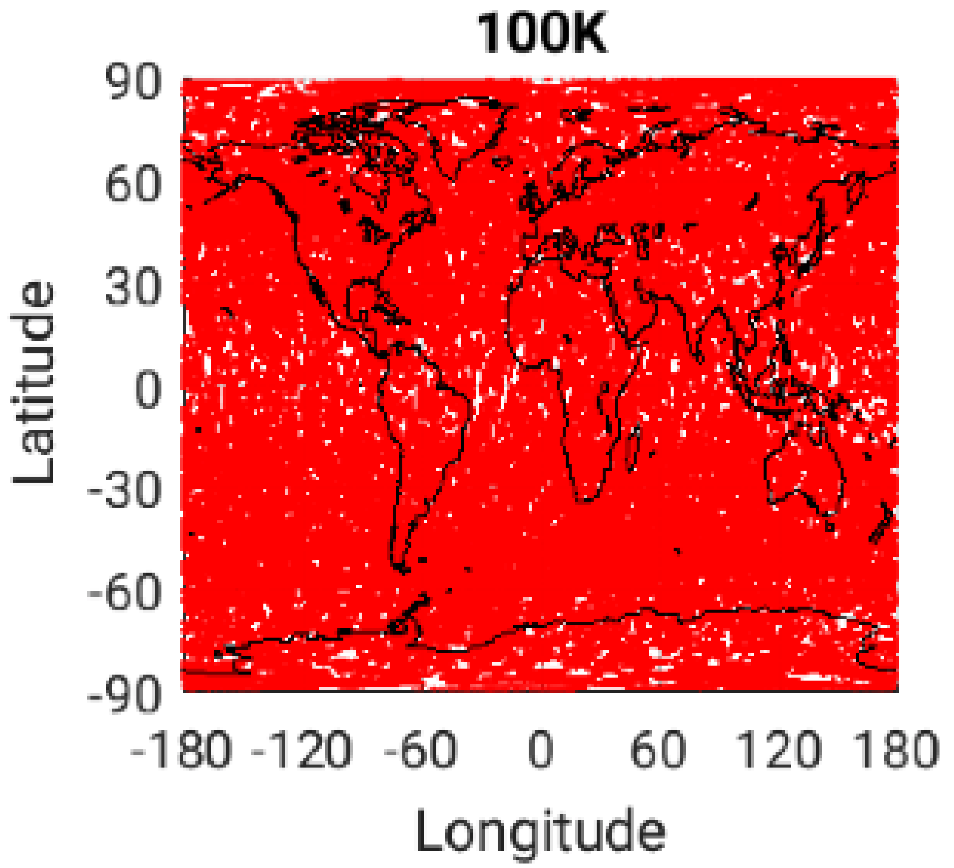
GNSS-RO OSSE

GNSS (GPS) radio occultations generate soundings of temperature and humidity.



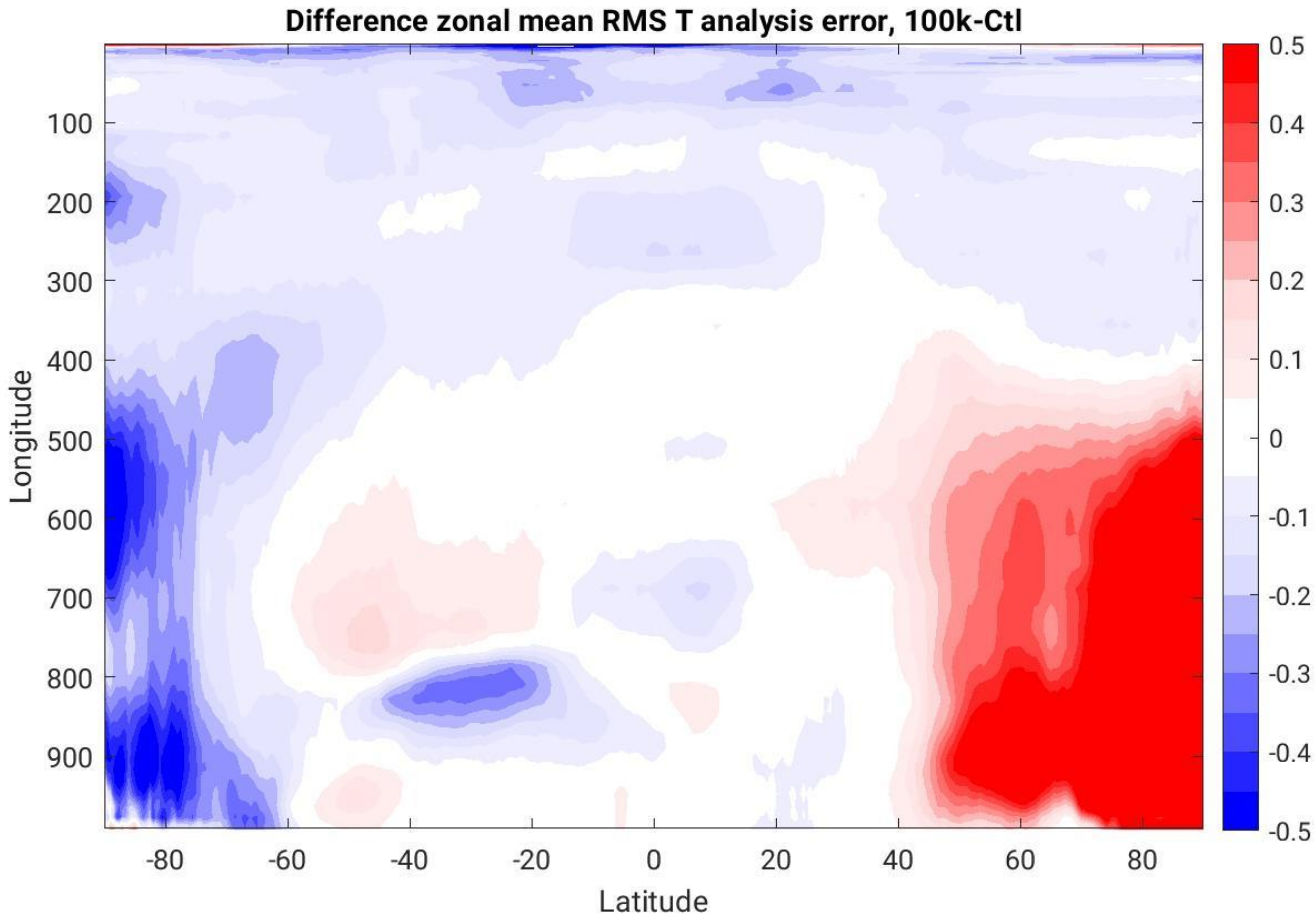
Experiments: 100k GNSS-RO





GNSS-RO OSSE

- Control
- Control + 100k RO profiles/day



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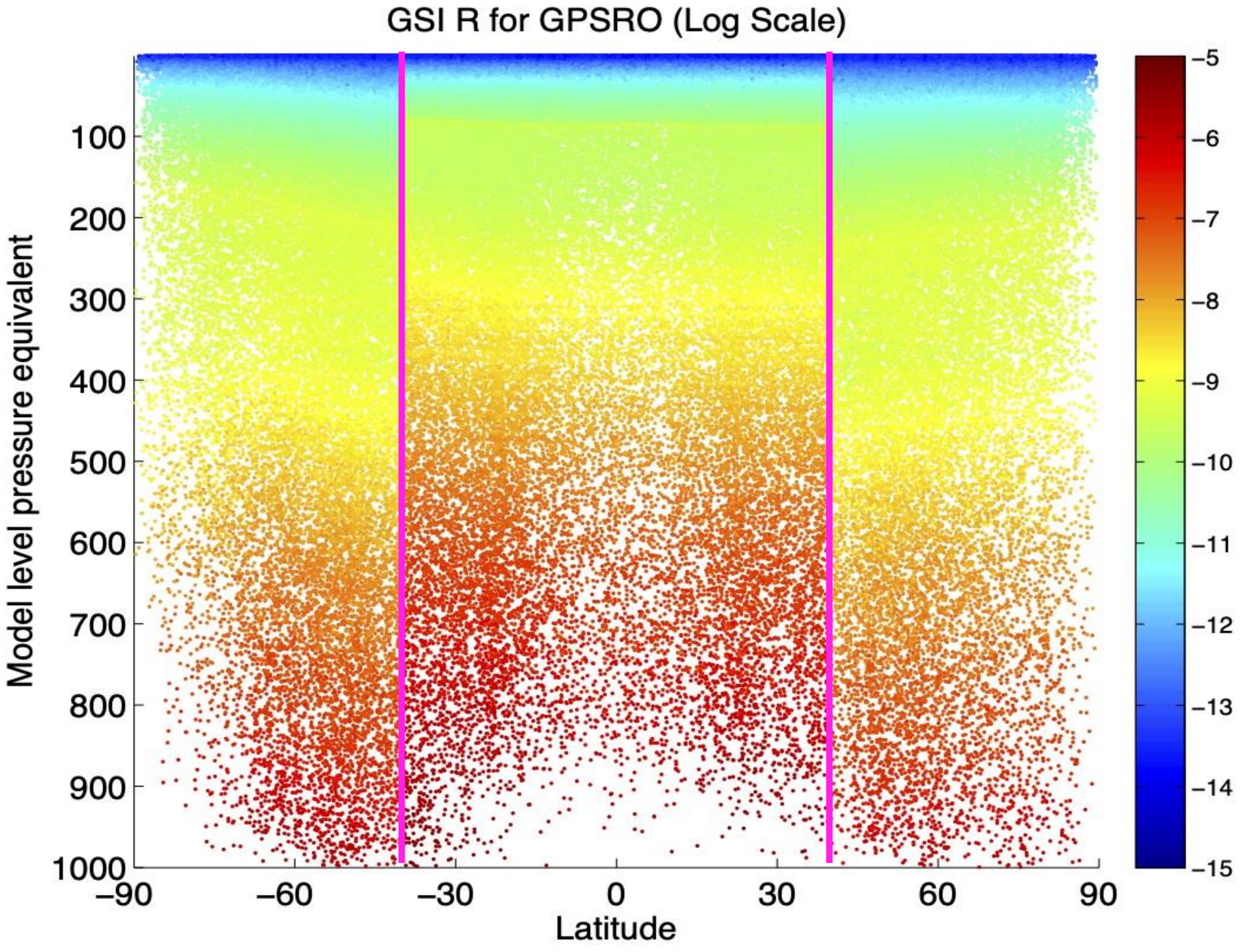
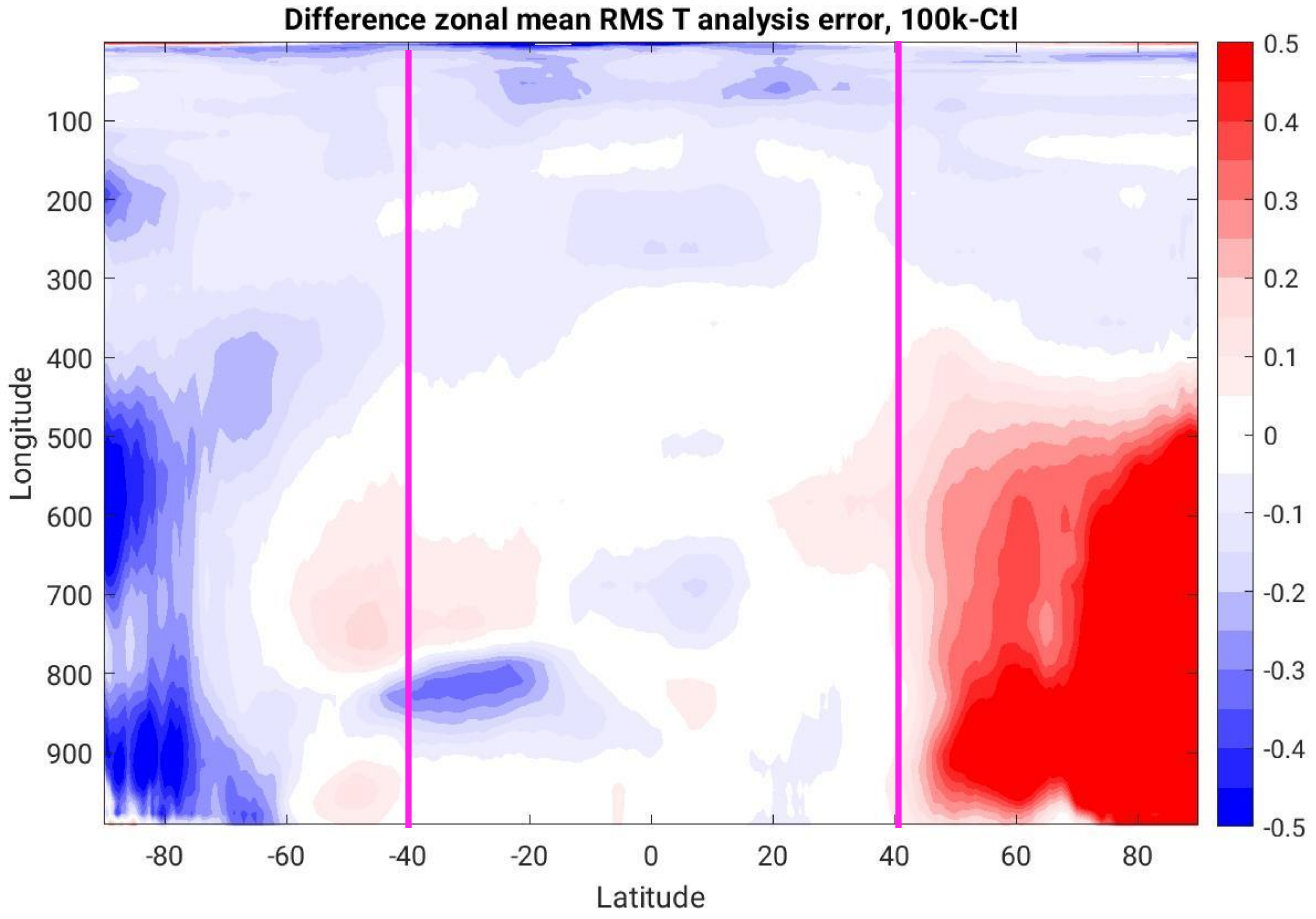
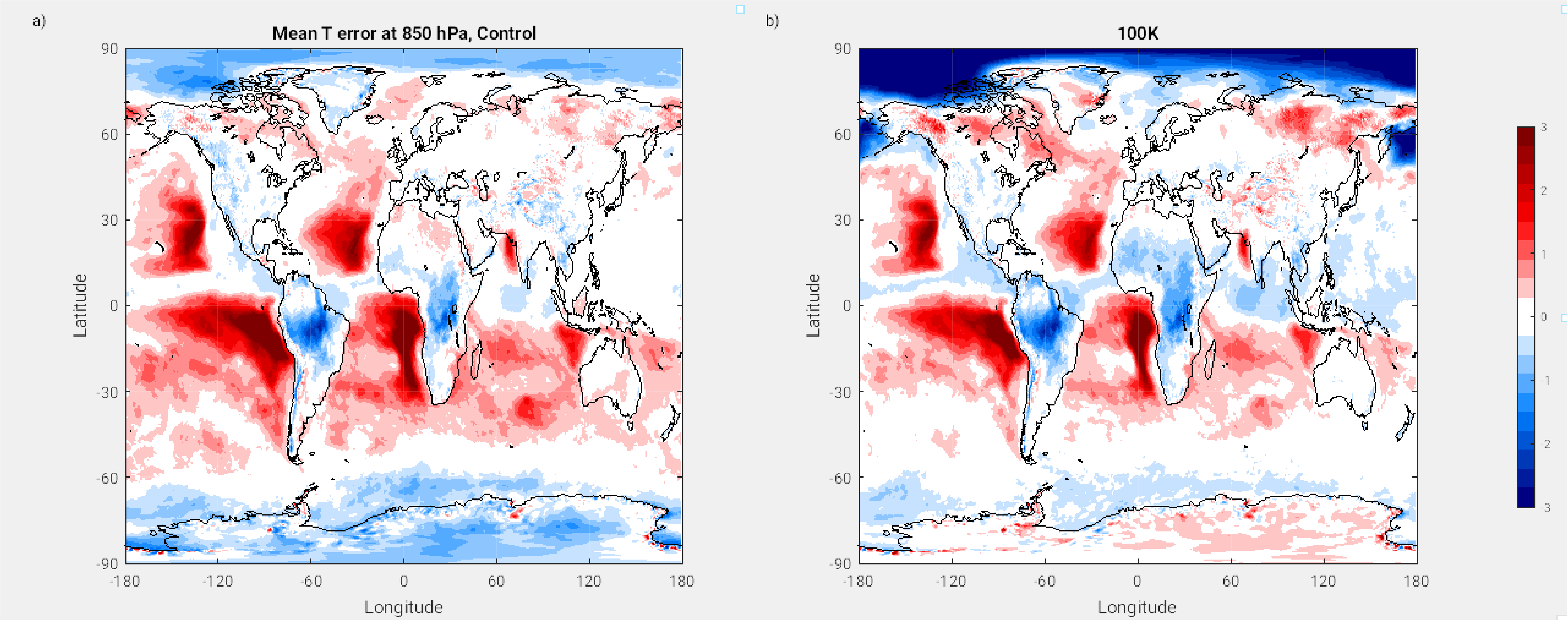




Experiments: 100k GNSS-RO

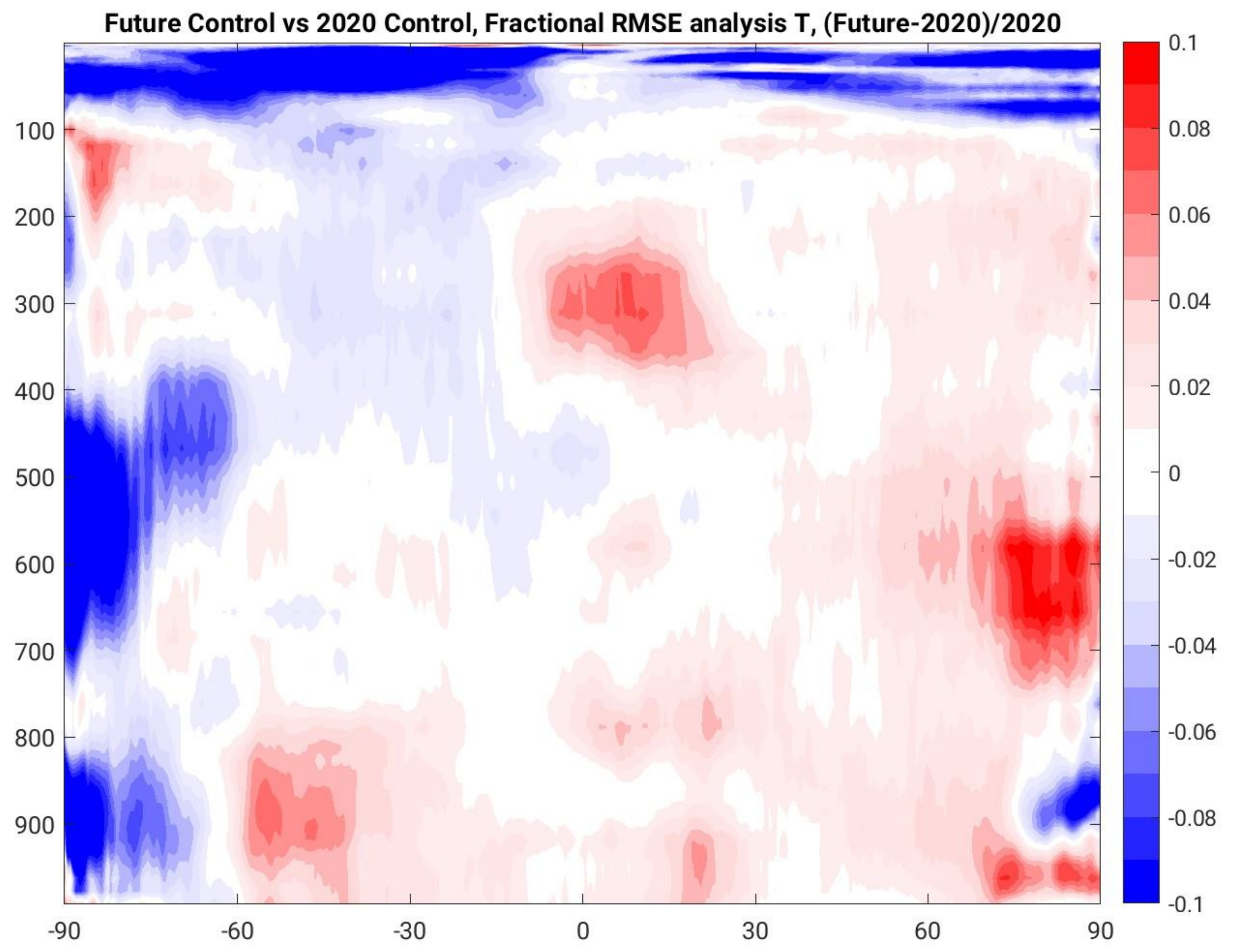
GNSS-RO induces cold temperature bias over Arctic marine surfaces at lower levels



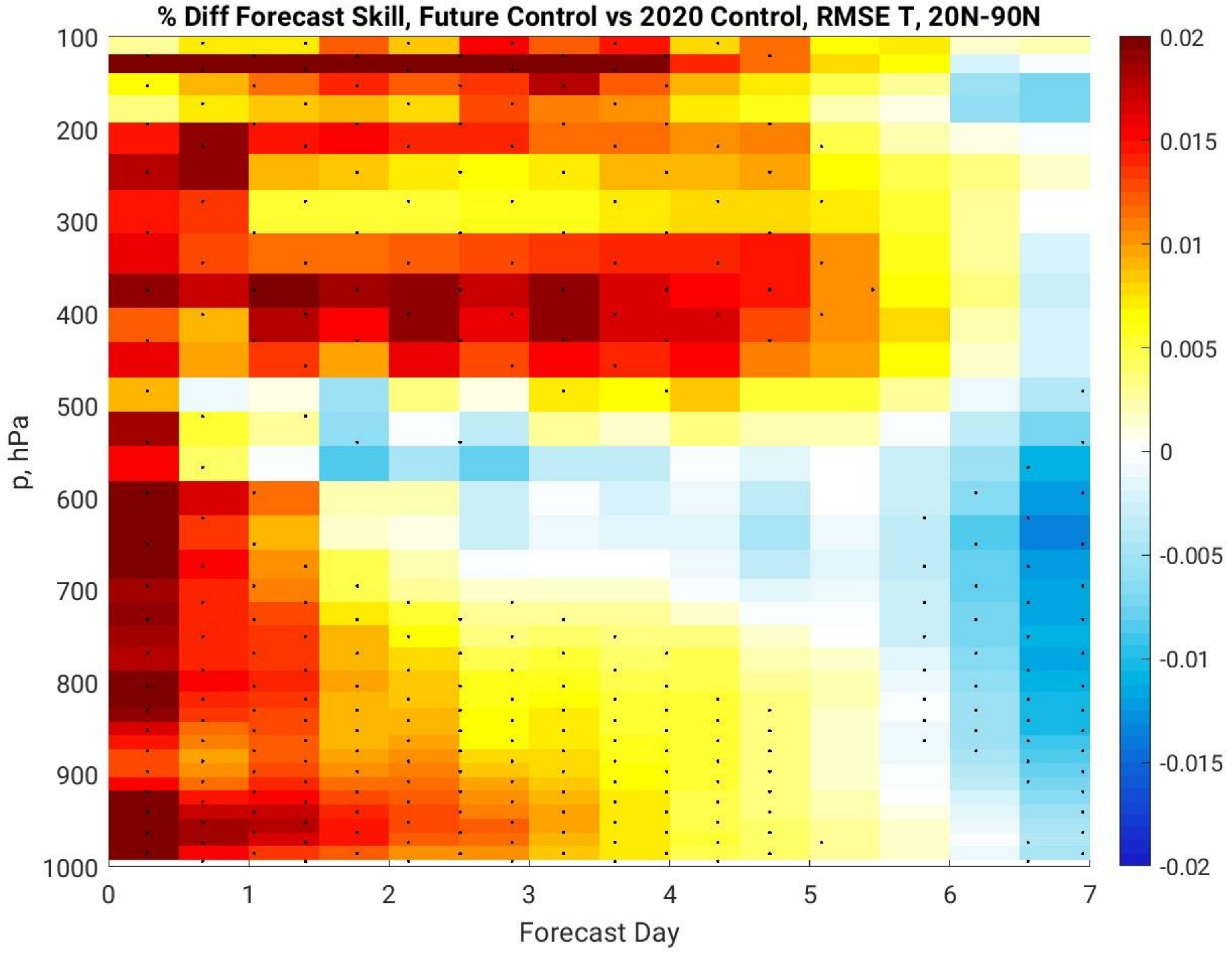
Experiment: Future Global Obs

Future Control:
Reduced LEO
GEO-IRS 3-Sat Ring

Analysis T: Future vs 2020

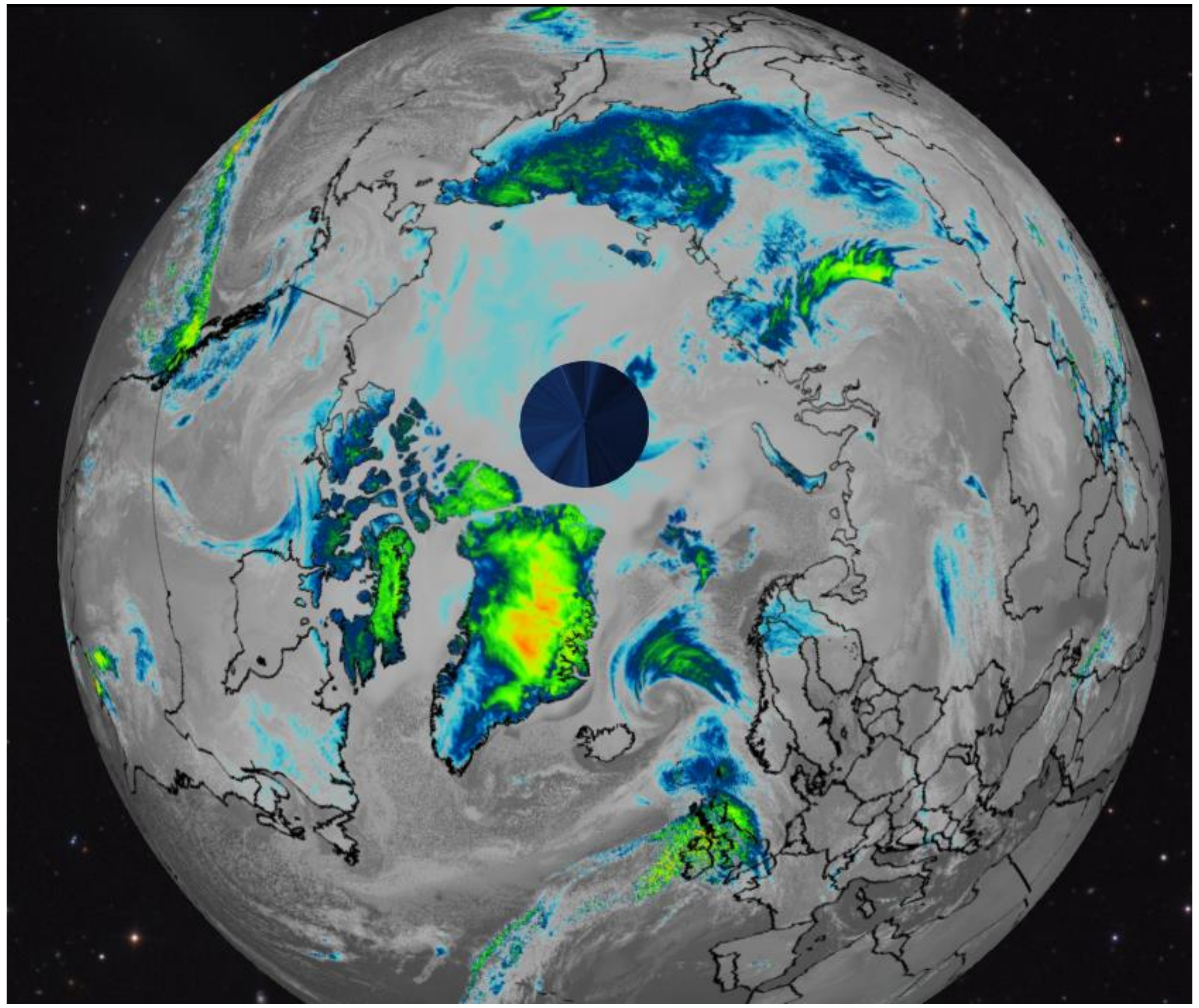


Forecast T: Future vs 2020



Future Directions

- Transition to JEDI-based architecture
- Higher horizontal and vertical resolution
  - More sophisticated treatment of clouds
  - More sophisticated treatment of observation errors



Arctic OSSEs: Challenges

- Nature Run should have realistic arctic processes
  - Coupled sea ice/ocean
  - Arctic clouds
  - Boundary layer dynamics – ex. correct representation of inversions
  - Snow and surface characteristics, including melt

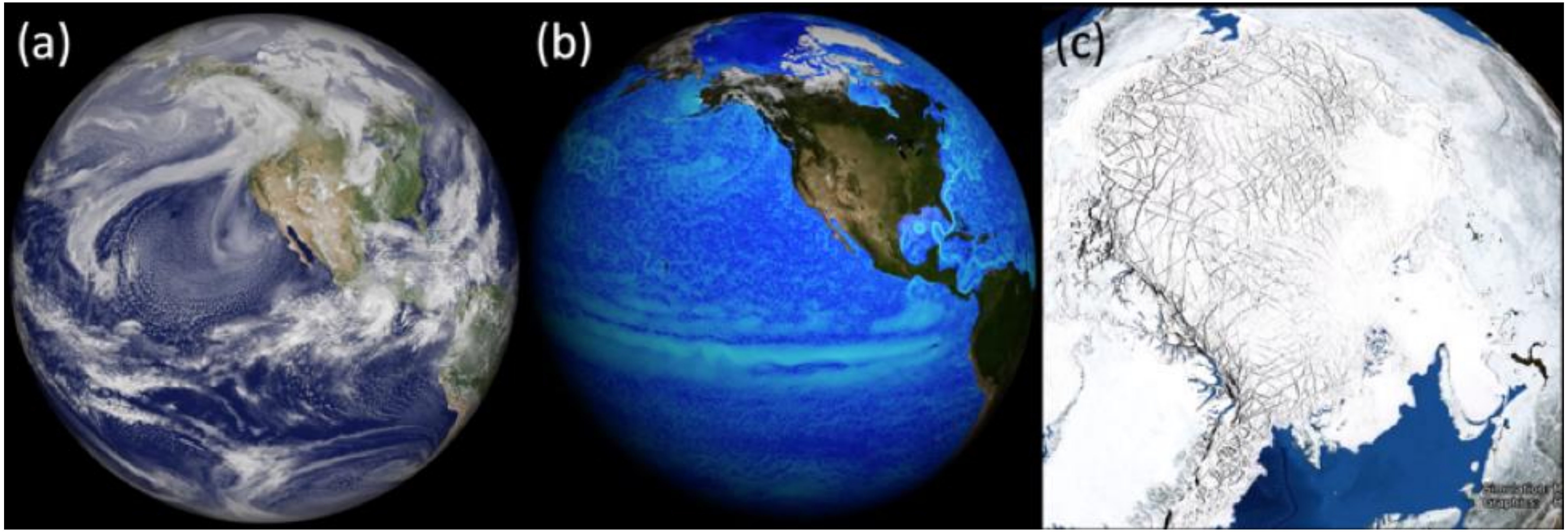
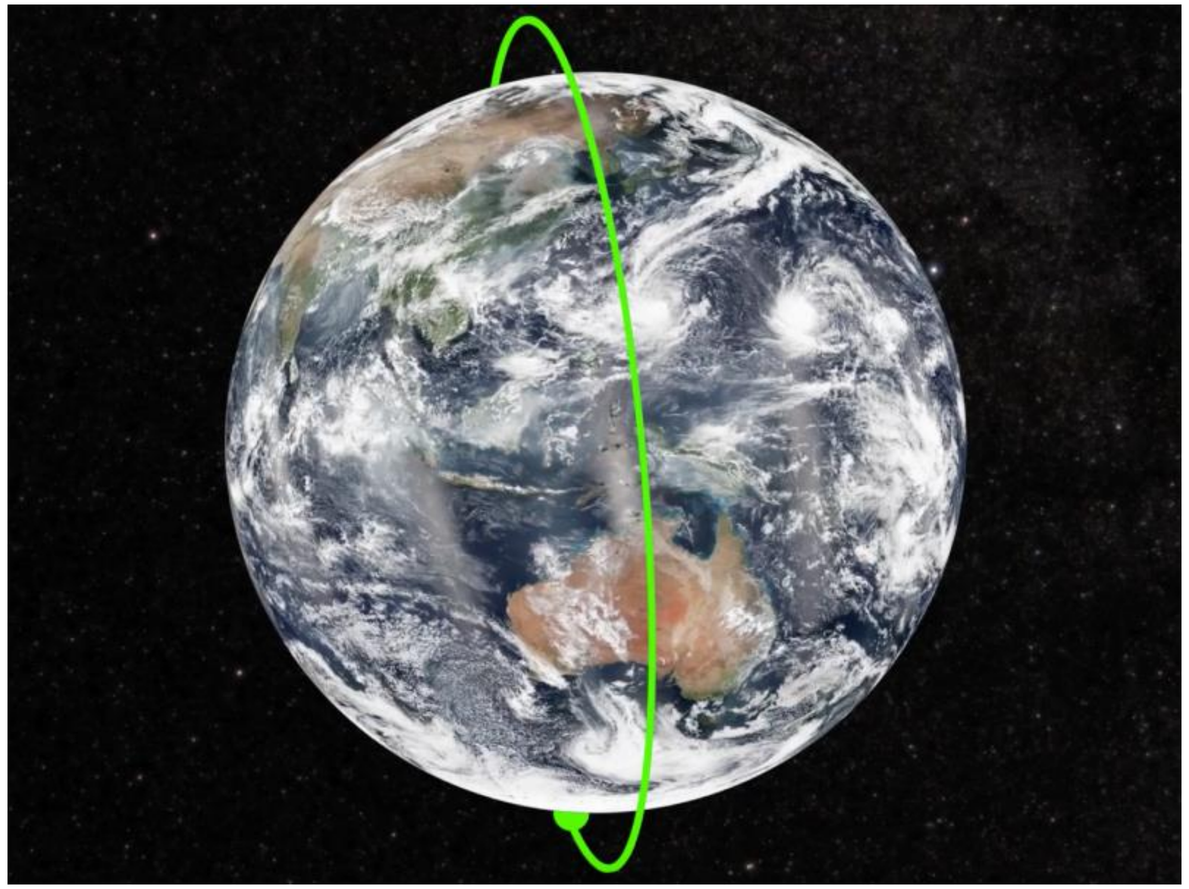
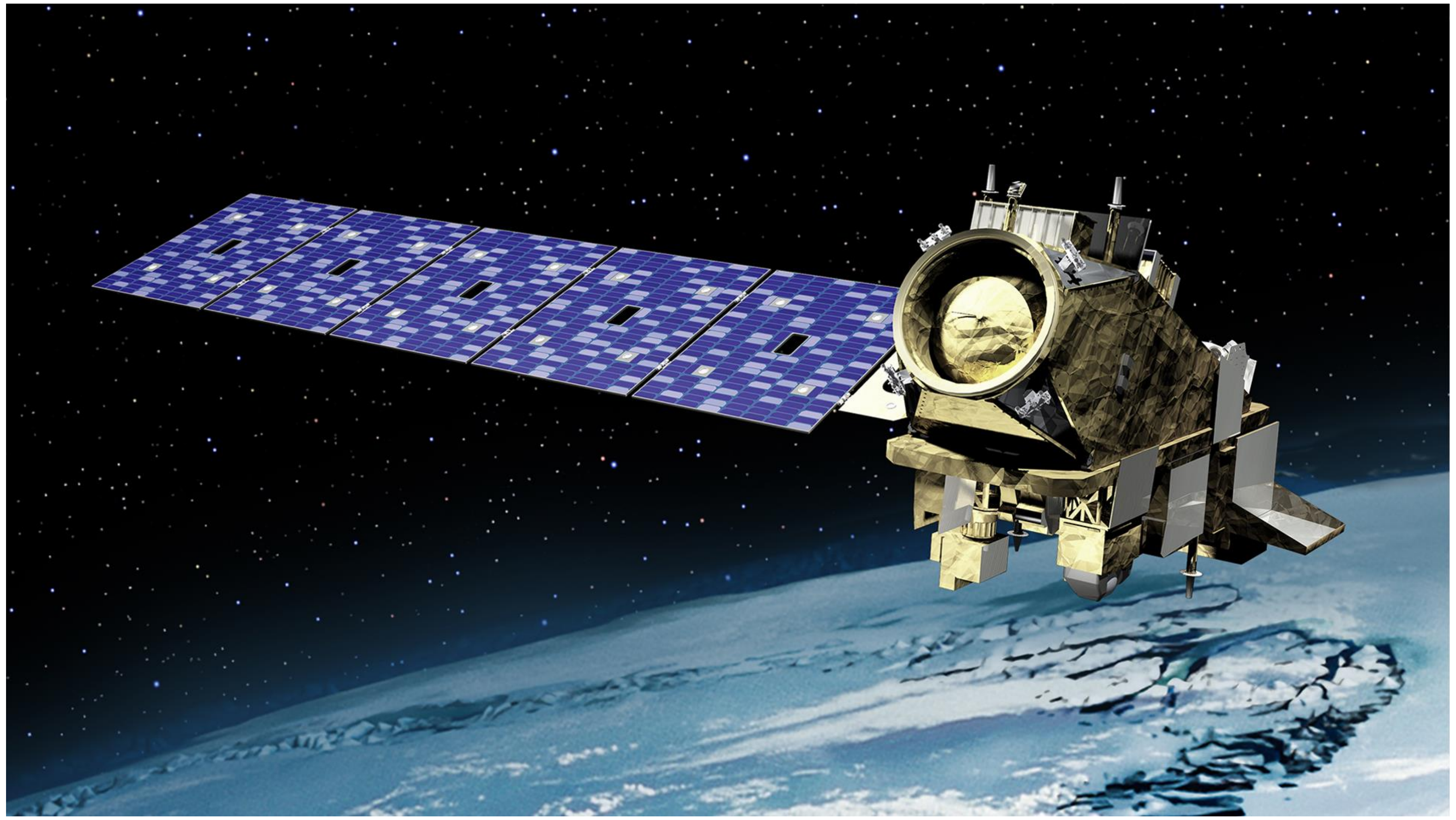


Image: NASA

Arctic OSSEs: Challenges

- Simulated observations
  - Surface emissivities over ice and snow
  - Orography (Antarctica and Greenland)
- Data assimilation handling of arctic observations may need development

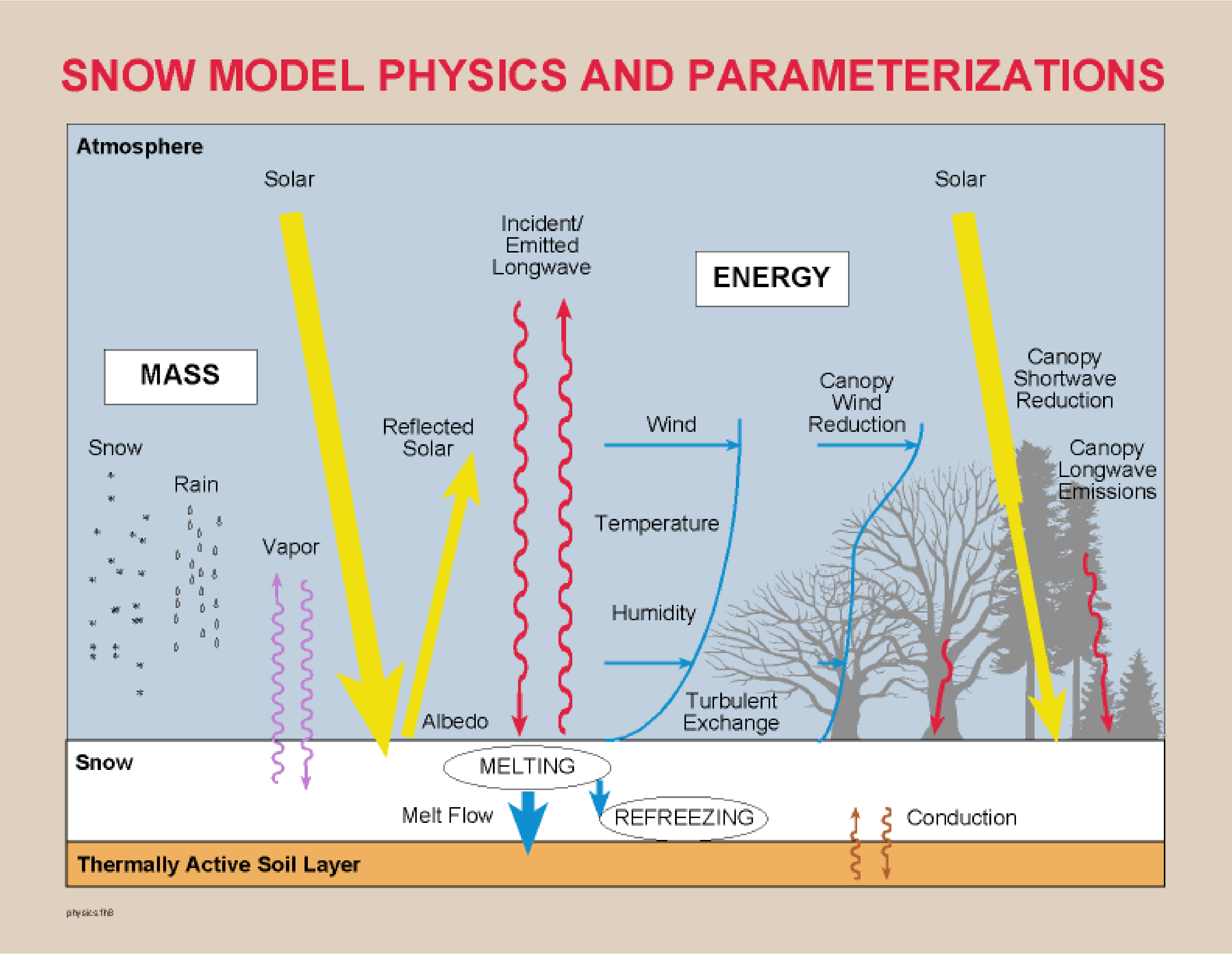


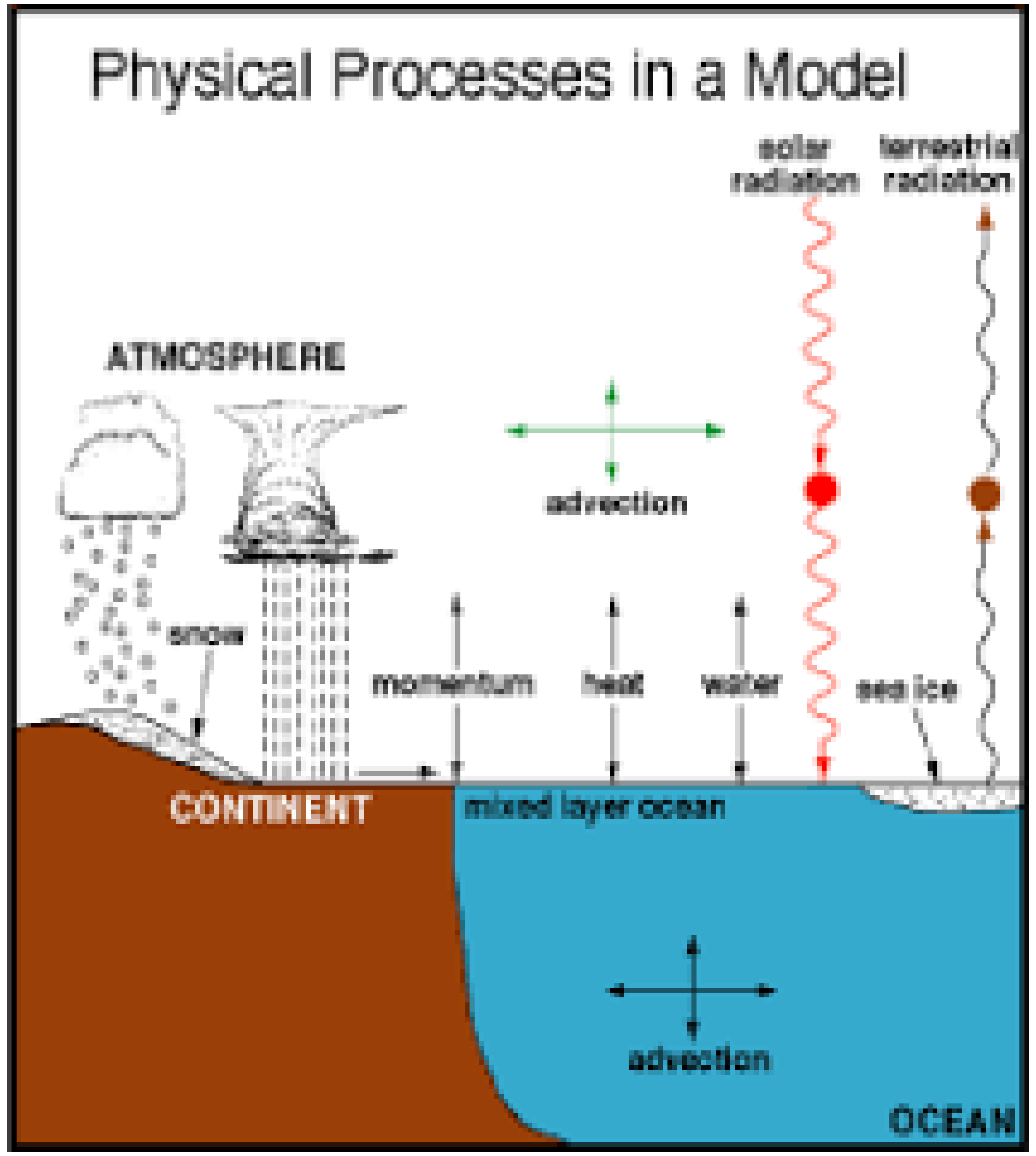


Images: NASA

Arctic OSSEs: Challenges

- Experiment forecast model needs to be sufficiently different from NR model, especially physics parametrizations





Images: NOAA

Arctic OSSEs – lots of opportunity for development