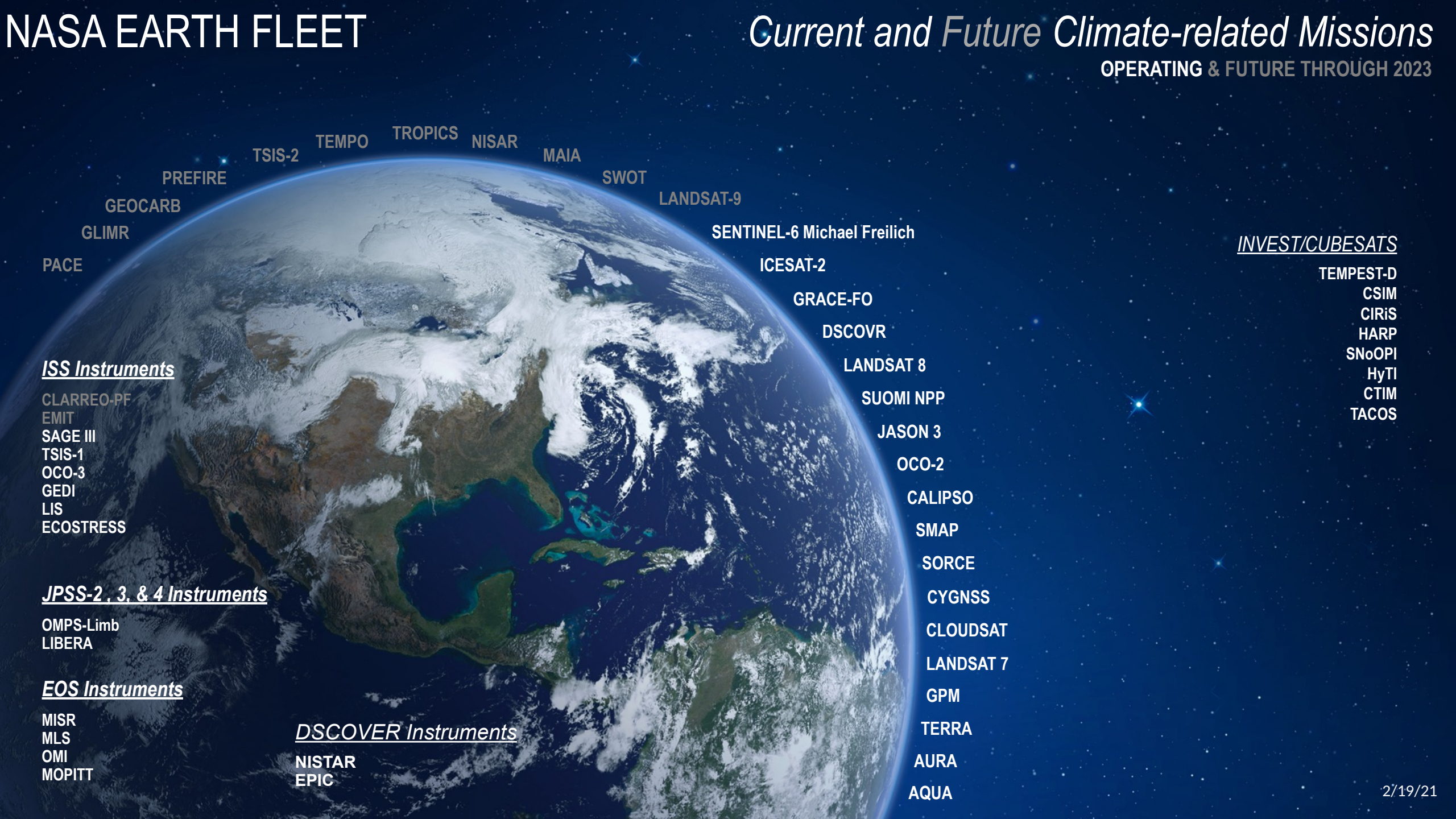


National Aeronautics and
Space Administration



CLIMATE CHANGE FROM SPACE

Gavin Schmidt
Sr. NASA Advisor on Climate
NASA Goddard Institute for Space Science



NASA EARTH FLEET

Current and Future Climate-related Missions

OPERATING & FUTURE THROUGH 2023

MAIA
NISAR
TROPICS
TEMPO
TSIS-2
PREFIRE
GEOCARB
GLIMR
PACE
LANDSAT-9
SWOT

SENTINEL-6 Michael Freilich

ICESAT-2

GRACE-FO

DSCOVR

LANDSAT 8

SUOMI NPP

JASON 3

OCO-2

CALIPSO

SMAP

SORCE

CYGNSS

CLOUDSAT

LANDSAT 7

GPM

TERRA

AURA

AQUA

INVEST/CUBESATS

TEMPEST-D
CSIM
CIRiS
HARP
SNoOPI
HyTI
CTIM
TACOS

ISS Instruments

CLARREO-PF
EMIT
SAGE III
TSIS-1
OCO-3
GEDI
LIS
ECOSTRESS

JPSS-2, 3, & 4 Instruments

OMPS-Limb
LIBERA

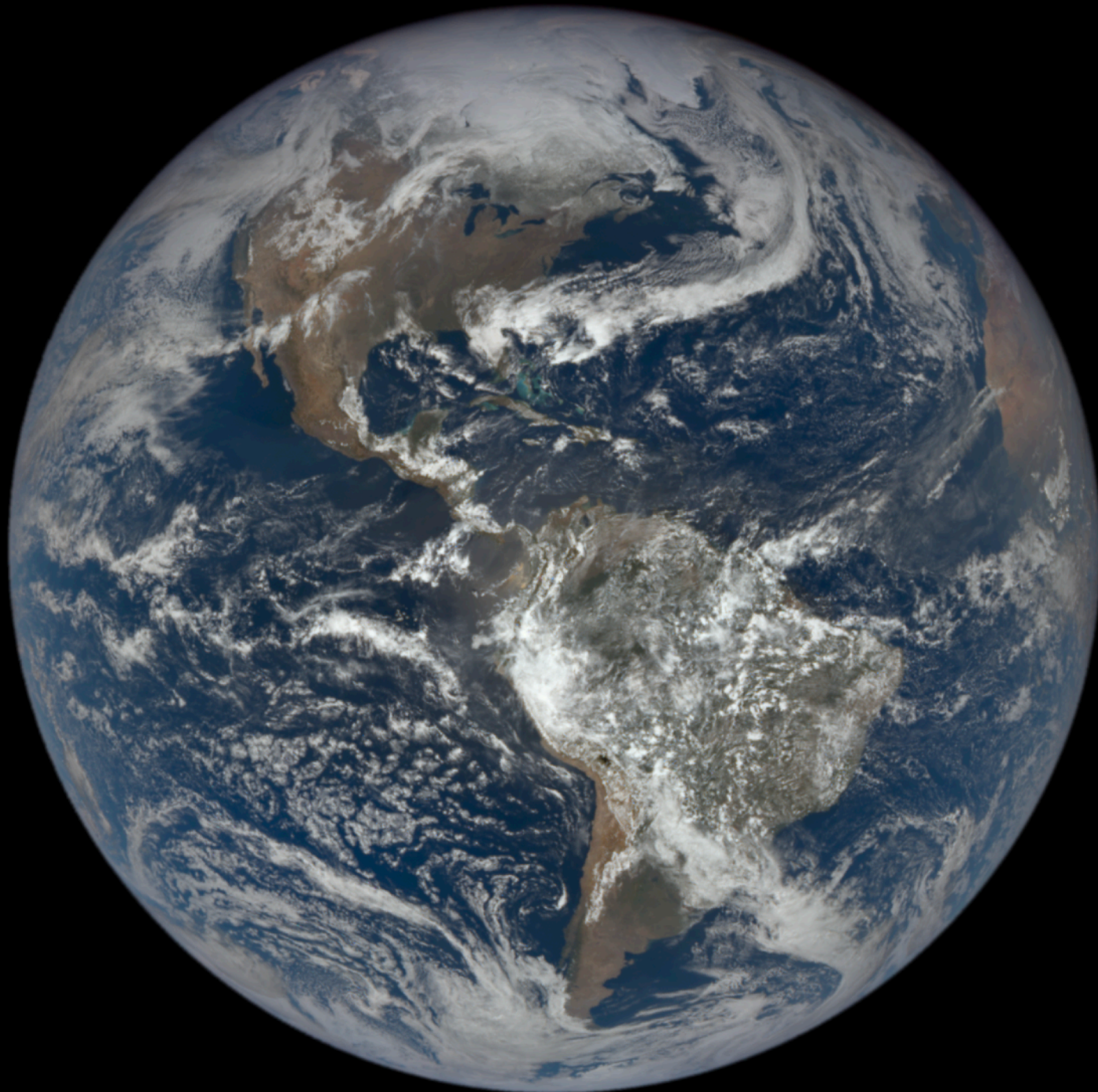
EOS Instruments

MISR
MLS
OMI
MOPITT

DSCOVR Instruments

NISTAR
EPIC

DSCOVER: EPIC



March 22 2021

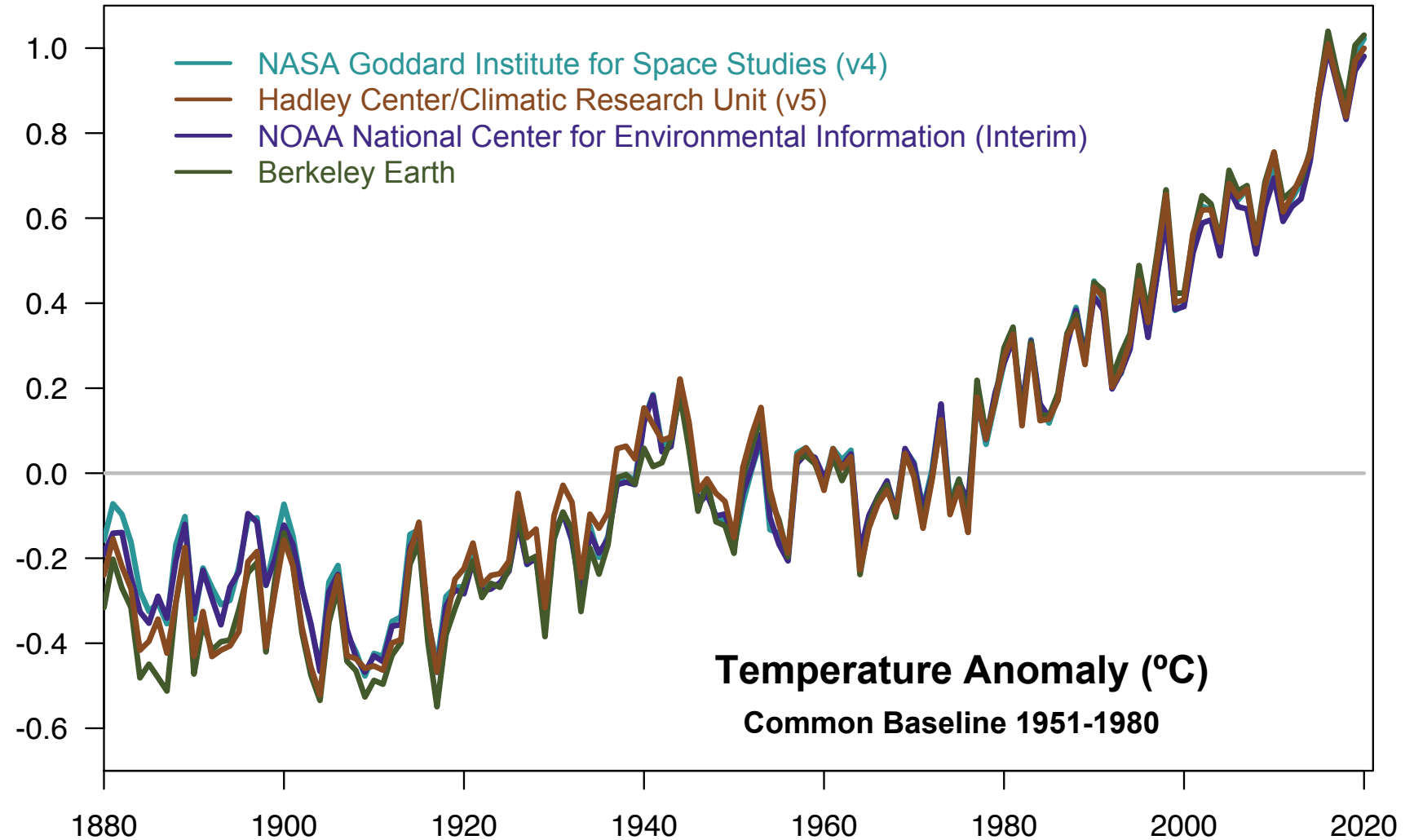
The background of the slide is a composite image of space. The top half features a dark blue and black sky with a bright, glowing blue nebula on the right side. The bottom half is a gradient of orange and yellow, also filled with numerous stars and some faint, wispy clouds. The text 'Climate Change: Observations' is centered in a white, sans-serif font across the middle of the image.

Climate Change: Observations

Surface Temperature

- GISTEMP (since 1981)
- Data from 1880
- Weather stations (GHCNv4)
- Ocean buoys/ship data (ERSSTv5)

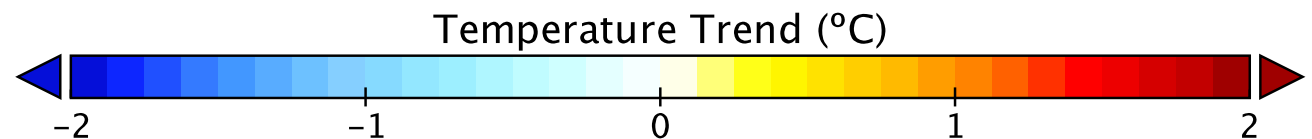
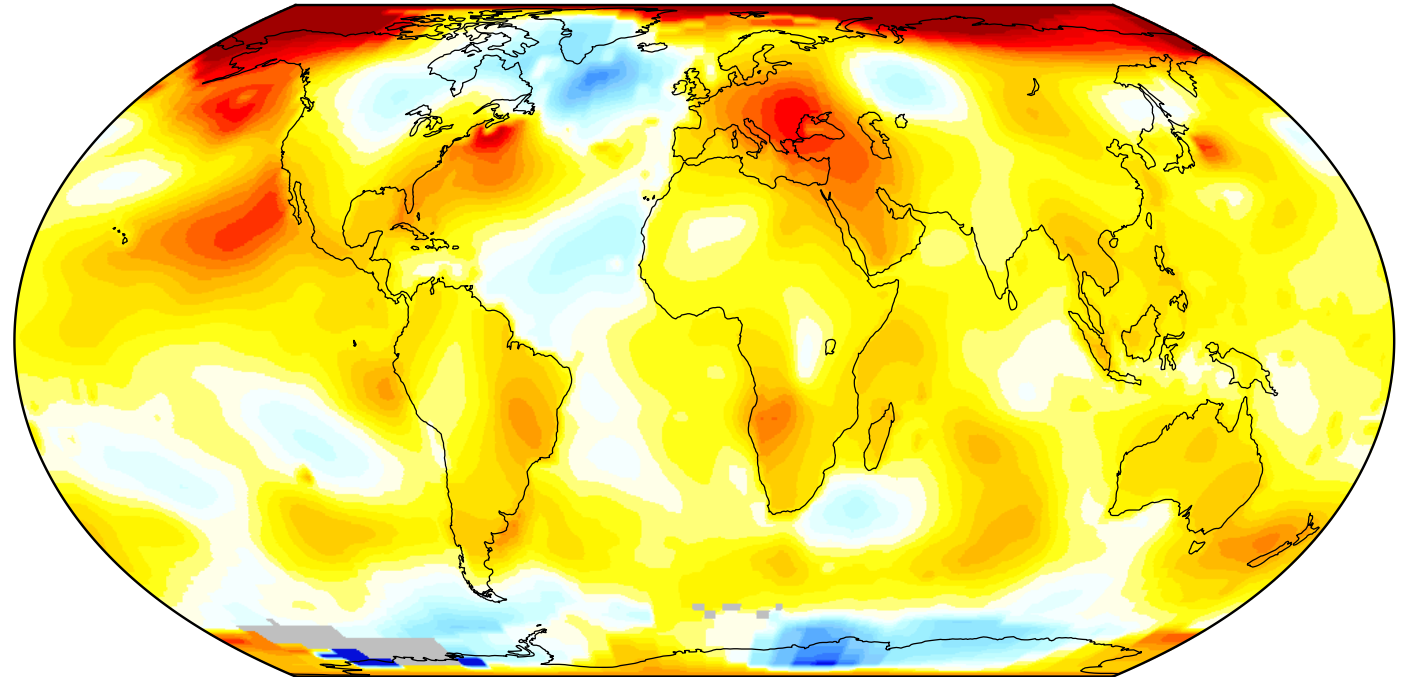
Warming of 1.2°C/2°F since the late 19th Century



Surface Temperature

- AIRS (since 2003) on Aqua
- 2003-2020 spatial trend compared to GISTEMP

GISTEMP

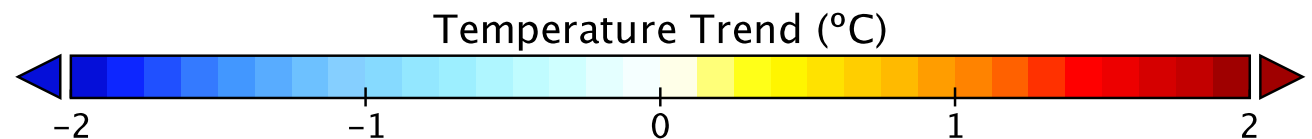
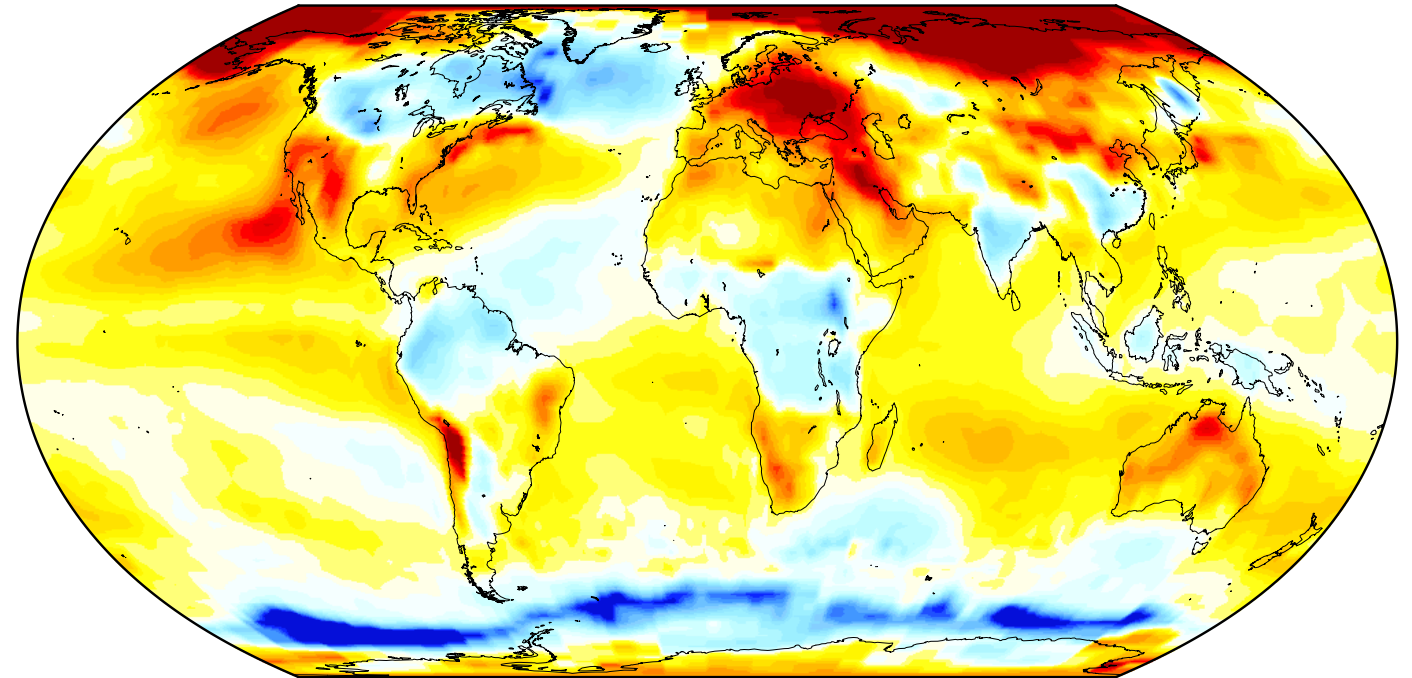


Surface Temperature

- AIRS (since 2003) on Aqua
- 2003-2020 spatial trend compared to GISTEMP

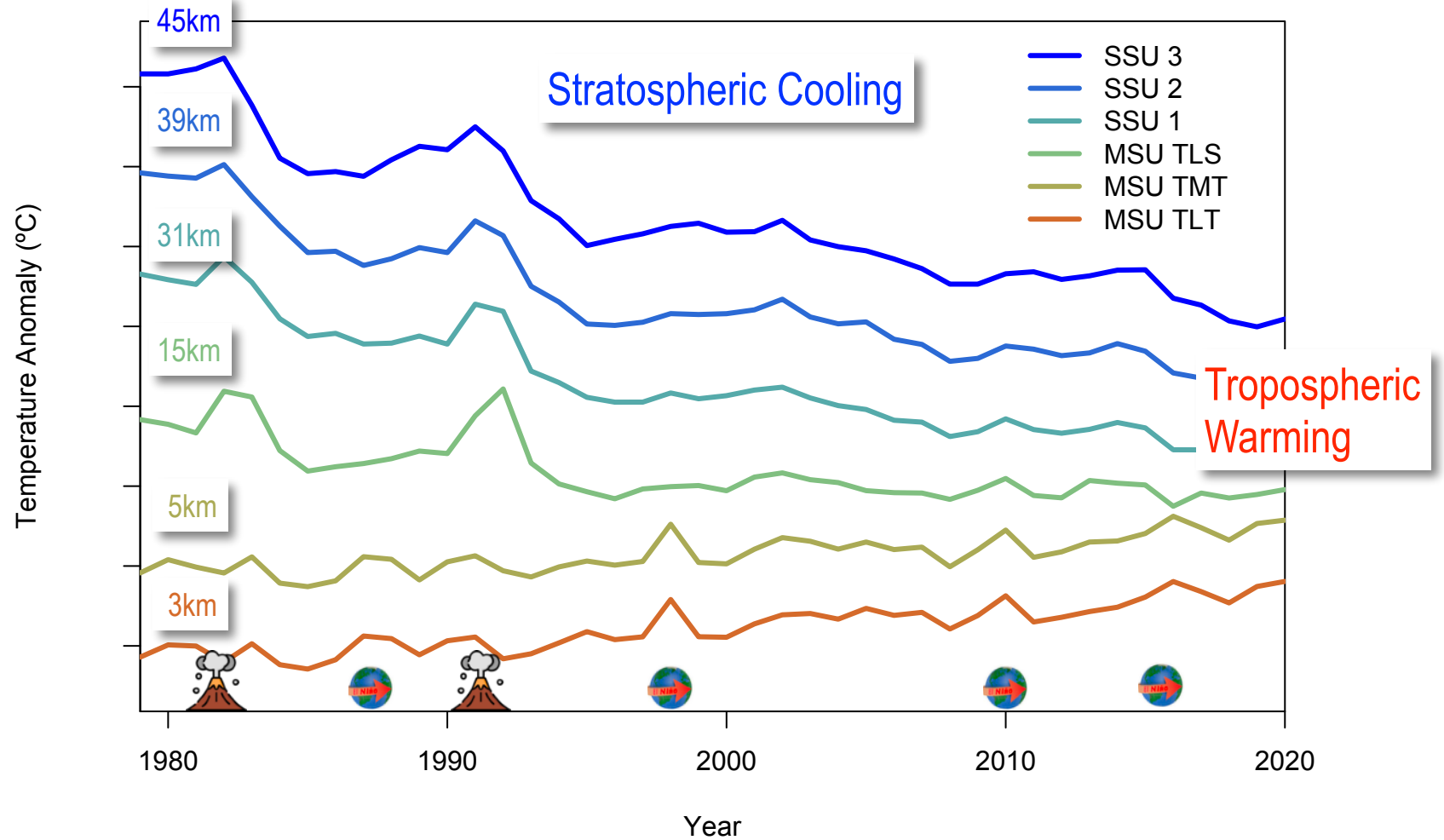
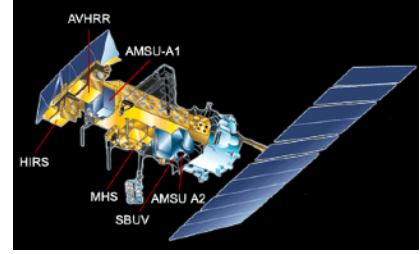
GISTEMP

AIRS (v7)



Atmospheric Temperature

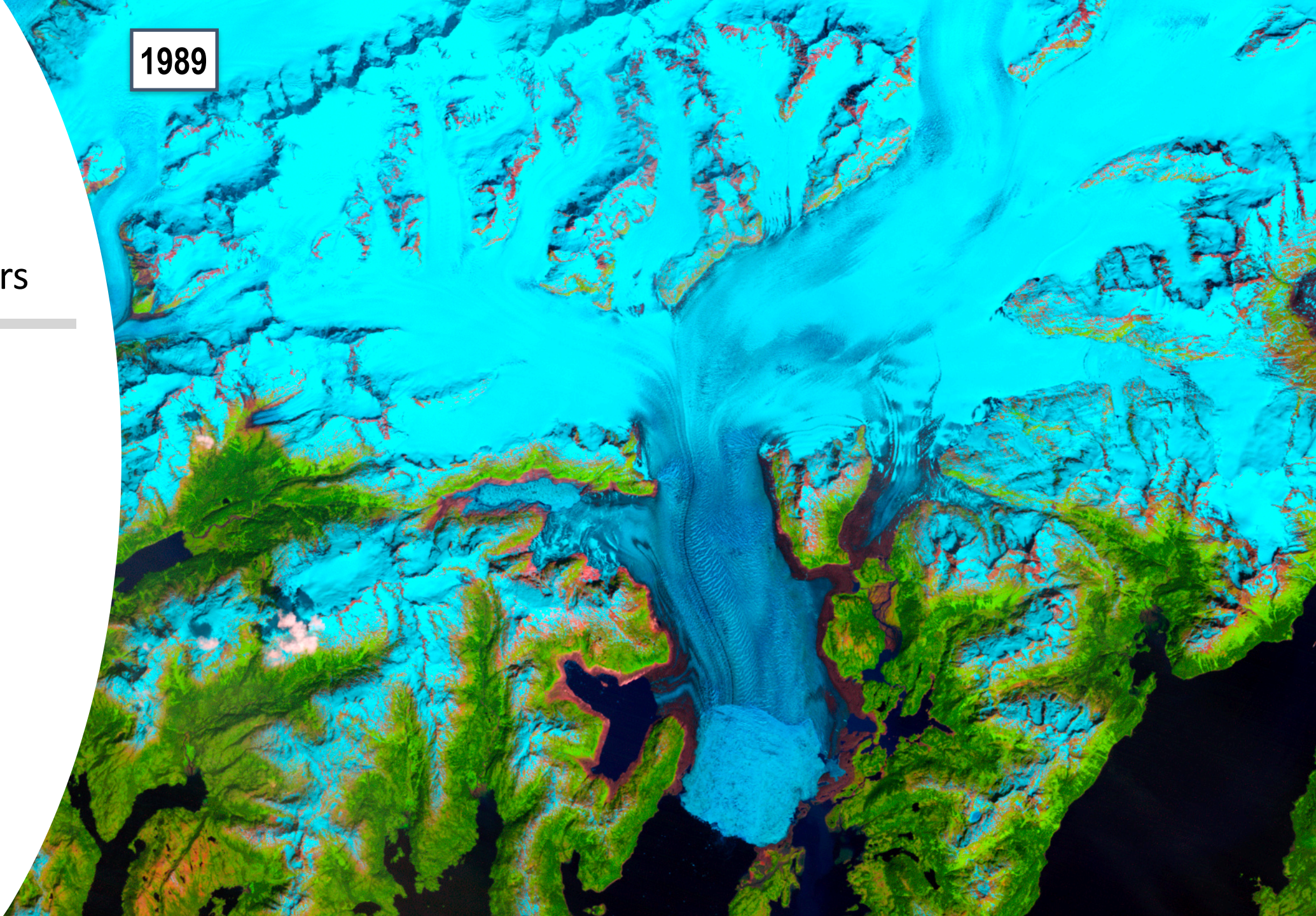
- MSU/SSU/AMSU (since 1979)
- TIROS-N
- NOAA-6/7/8/9/10/11/12/14/15/16/18/19
- METOP-A/B
- AQUA



1989

Mountain Glaciers

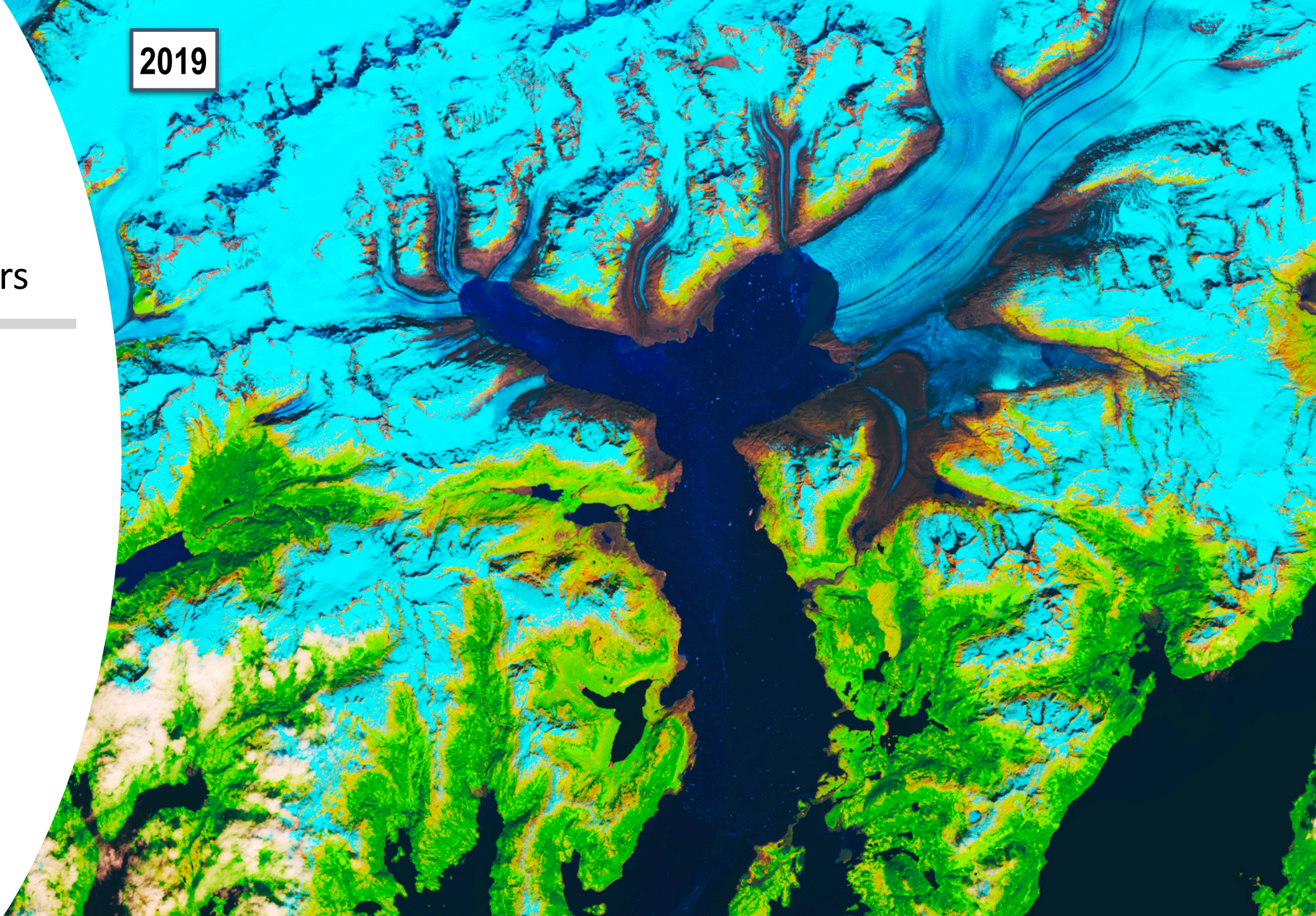
- Landsat (since 1982)
- LandSat 4/5/7/8
- Columbia Glacier, AK



2019

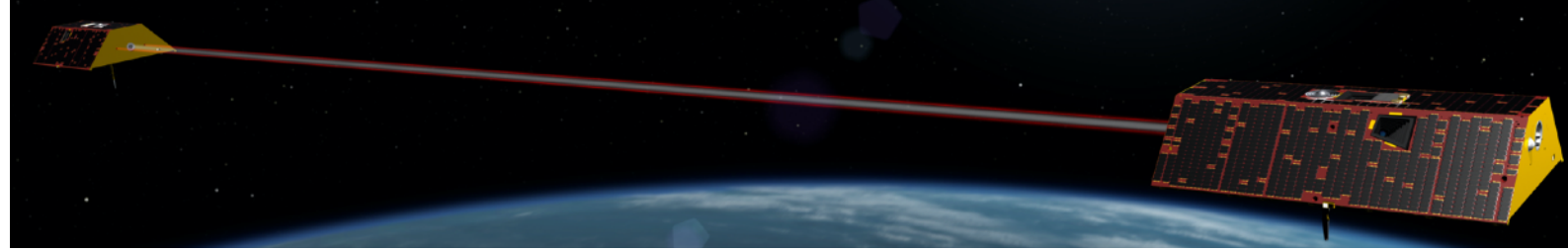
Mountain Glaciers

- Landsat (since 1982)
- LandSat 4/5/7/8
- Columbia Glacier, AK



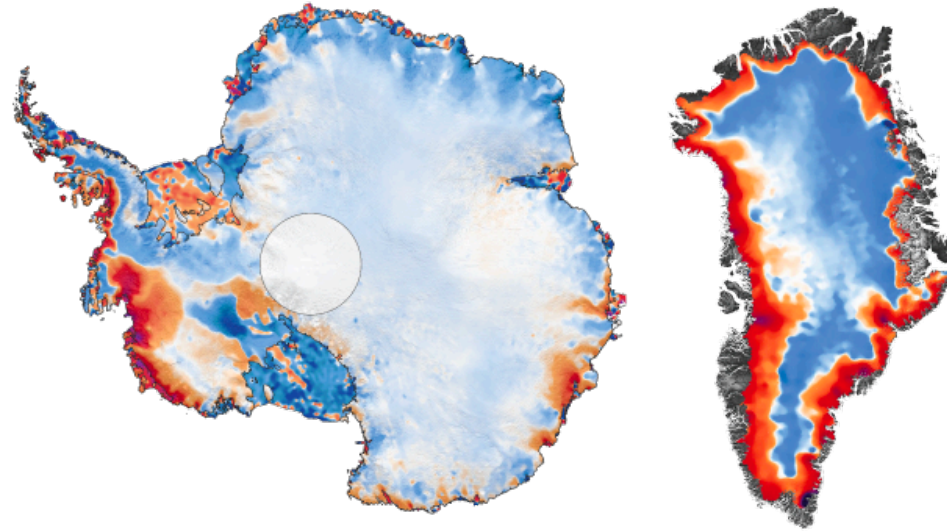
Ice Sheet Mass

- GRACE (2002-2017)
- GRACE-FO (since 2018)
- Trends April 2002-Dec 2020



Antarctica

Greenland

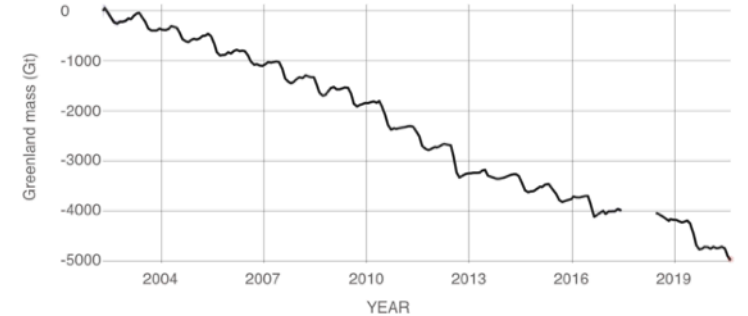
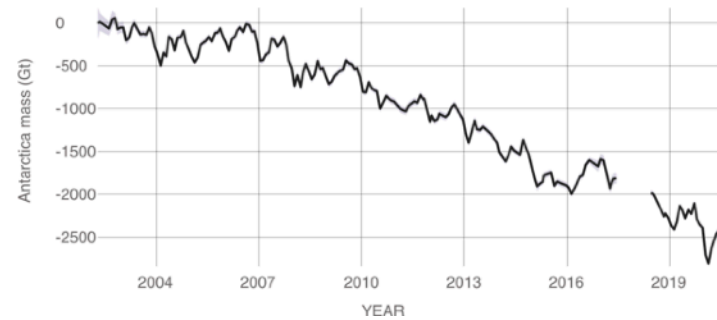


-148 Gt/yr

-280 Gt/yr

Change in ice thickness per year

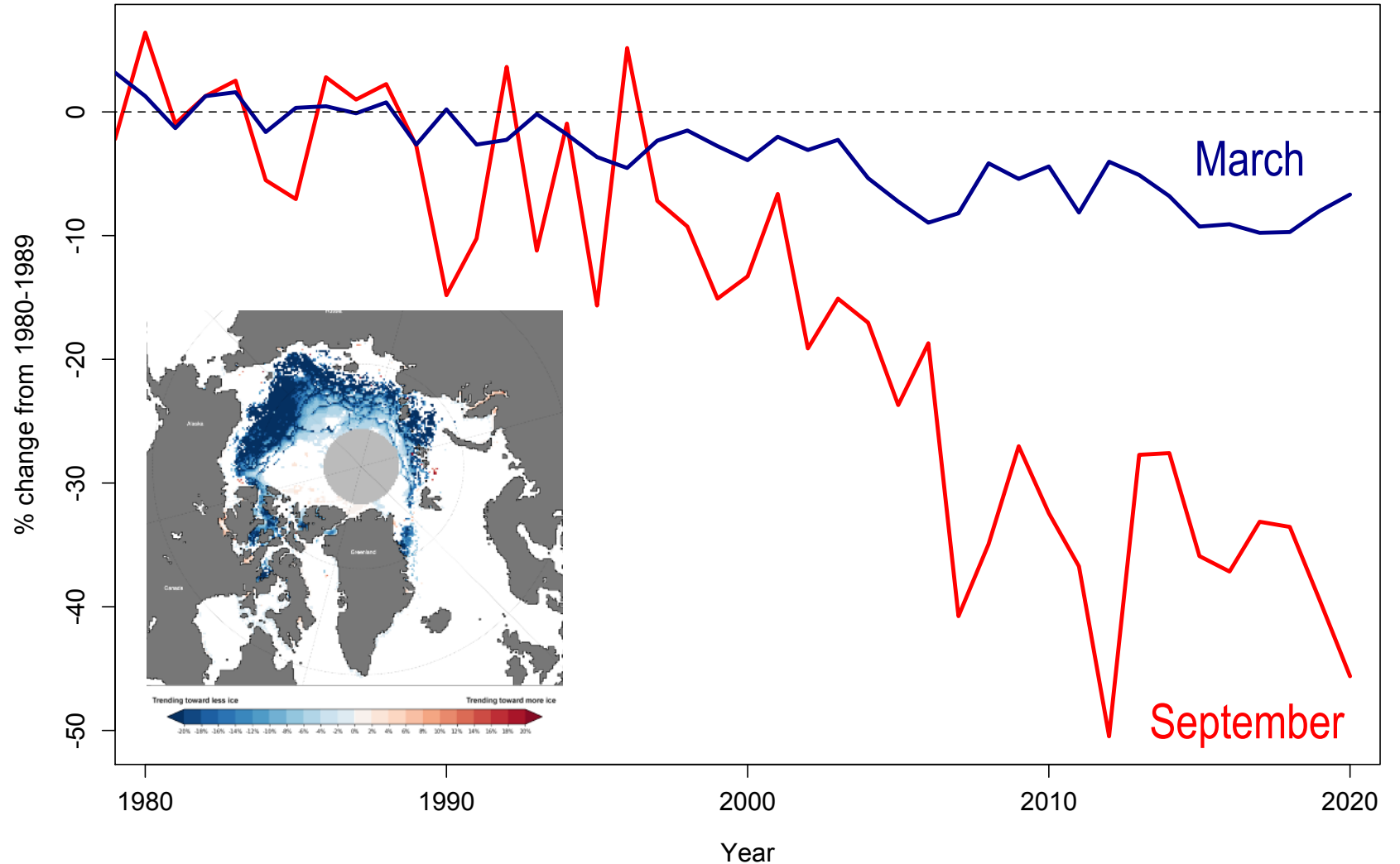
-10.0 -6.0 -3.0 -1.0 0 +0.5
Meters



Arctic Sea Ice Extent

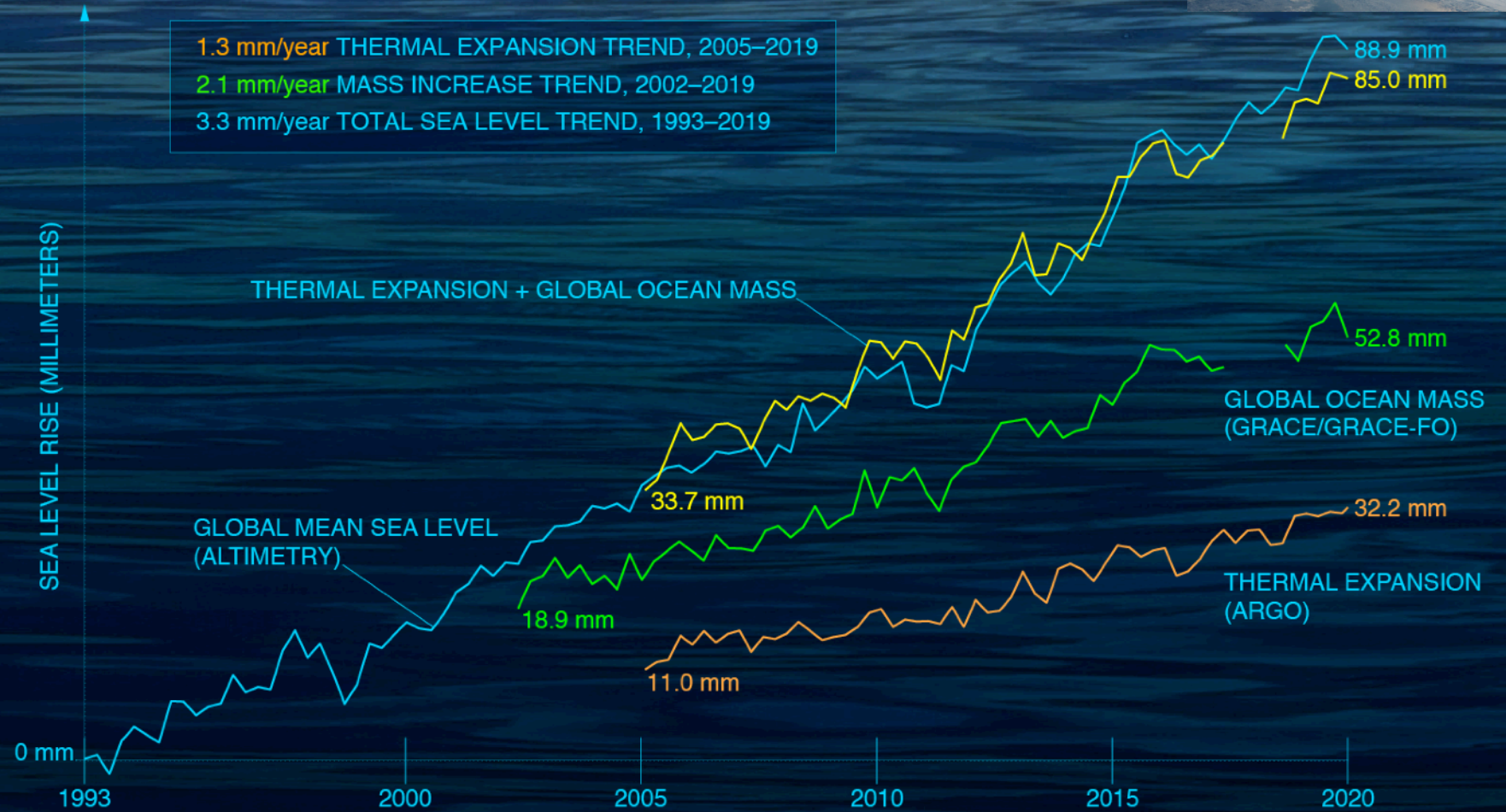
- NSIDC (since 1978)
- DMSP, DMSP 5D-3/F17, DMSP 5D-3/F18,
- Nimbus-7

Over 40% decline in September Arctic sea ice



Sea Level Rise

- Since 1993
- TOPEX/POSEIDON
- JASON-1
- JASON-2
- JASON-3
- Sentinel-6 Mike Frielich





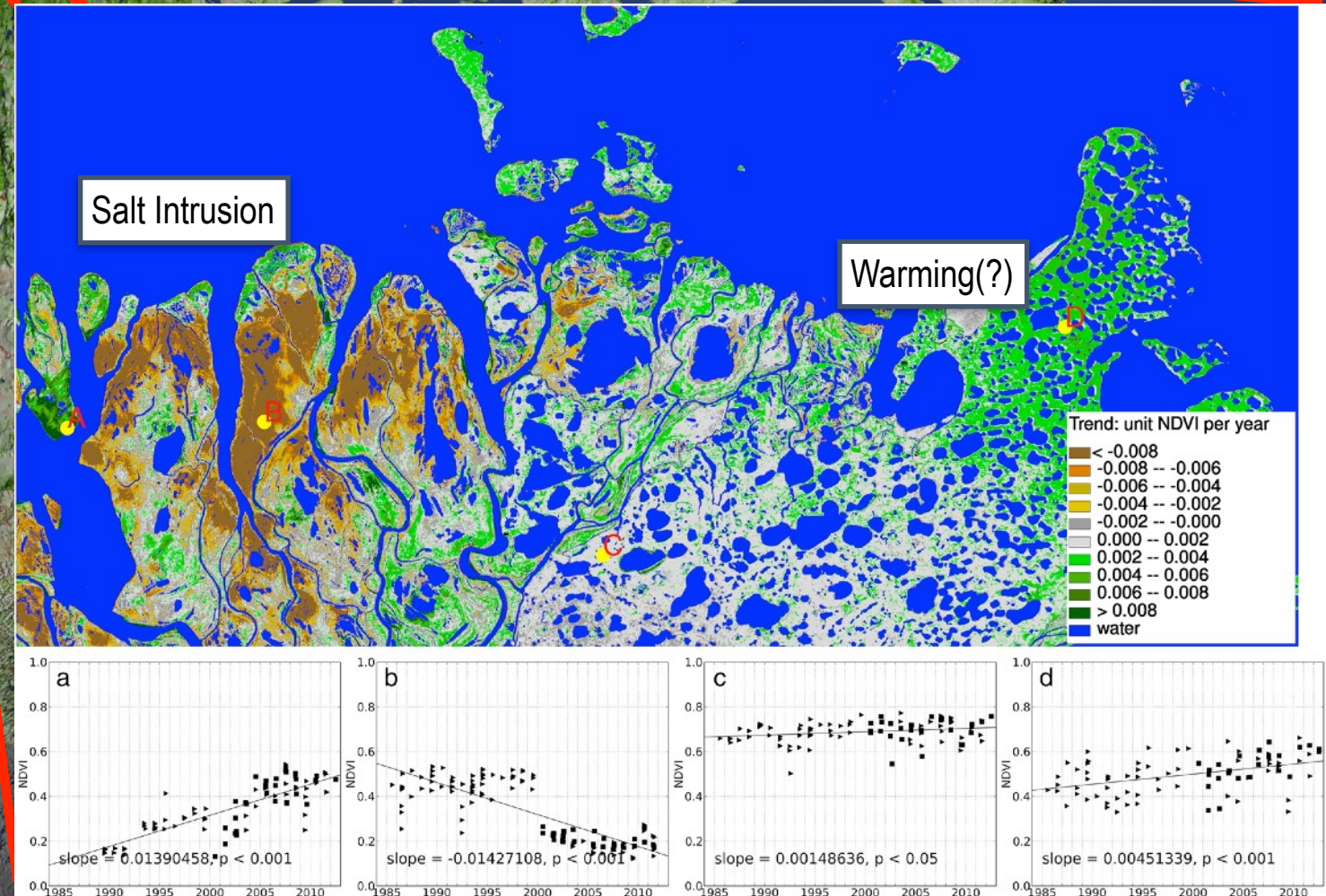
Vegetation Changes

- LandSat (since 1982)
- LandSat 4/5/7/8
- 1984-2018 spatial trend



Vegetation Changes

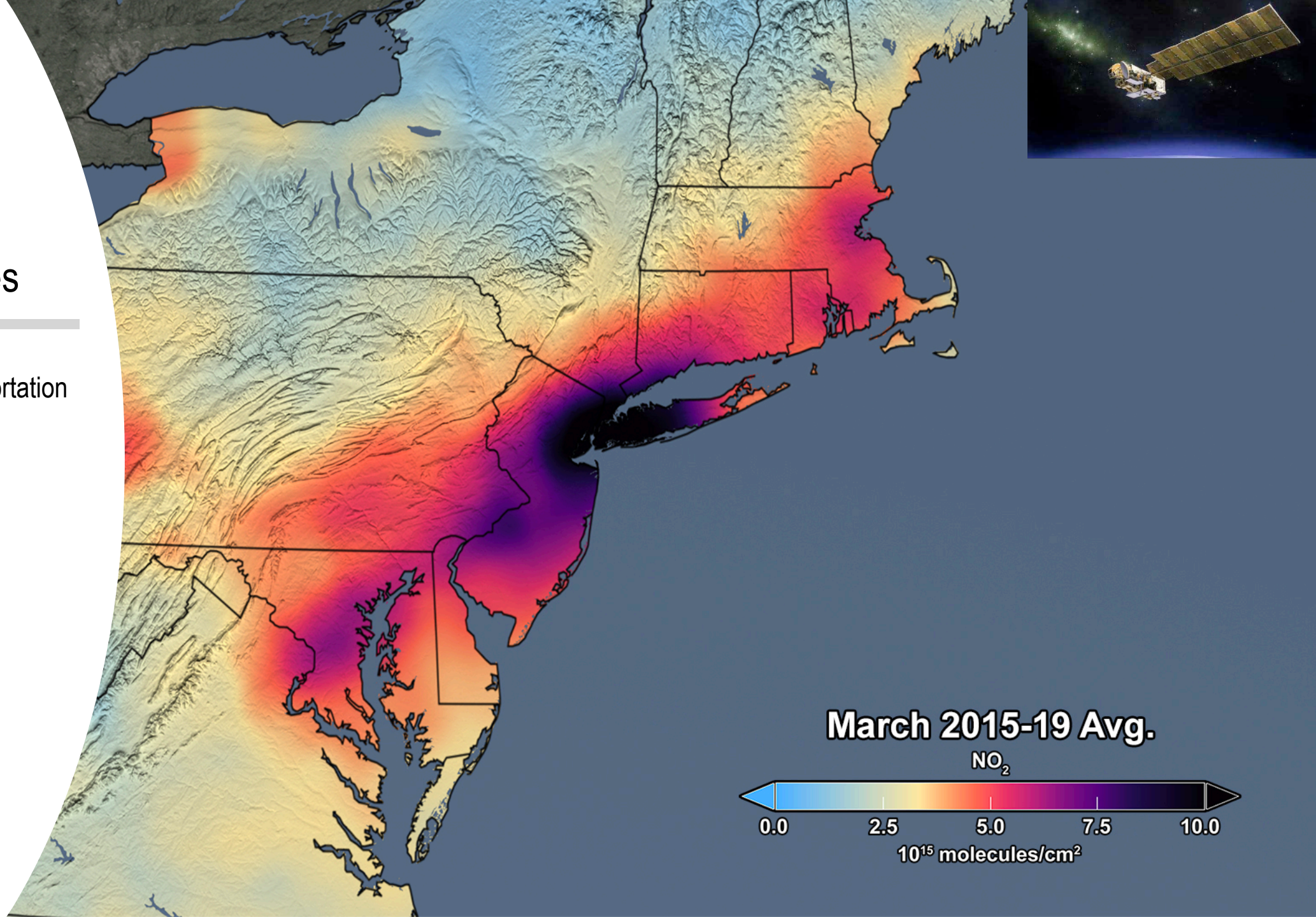
- LandSat (since 1982)
- LandSat 4/5/7/8
- 1984-2018 spatial trend



COVID-19 changes

- NO₂ from surface transportation
- OMI instrument on Aura

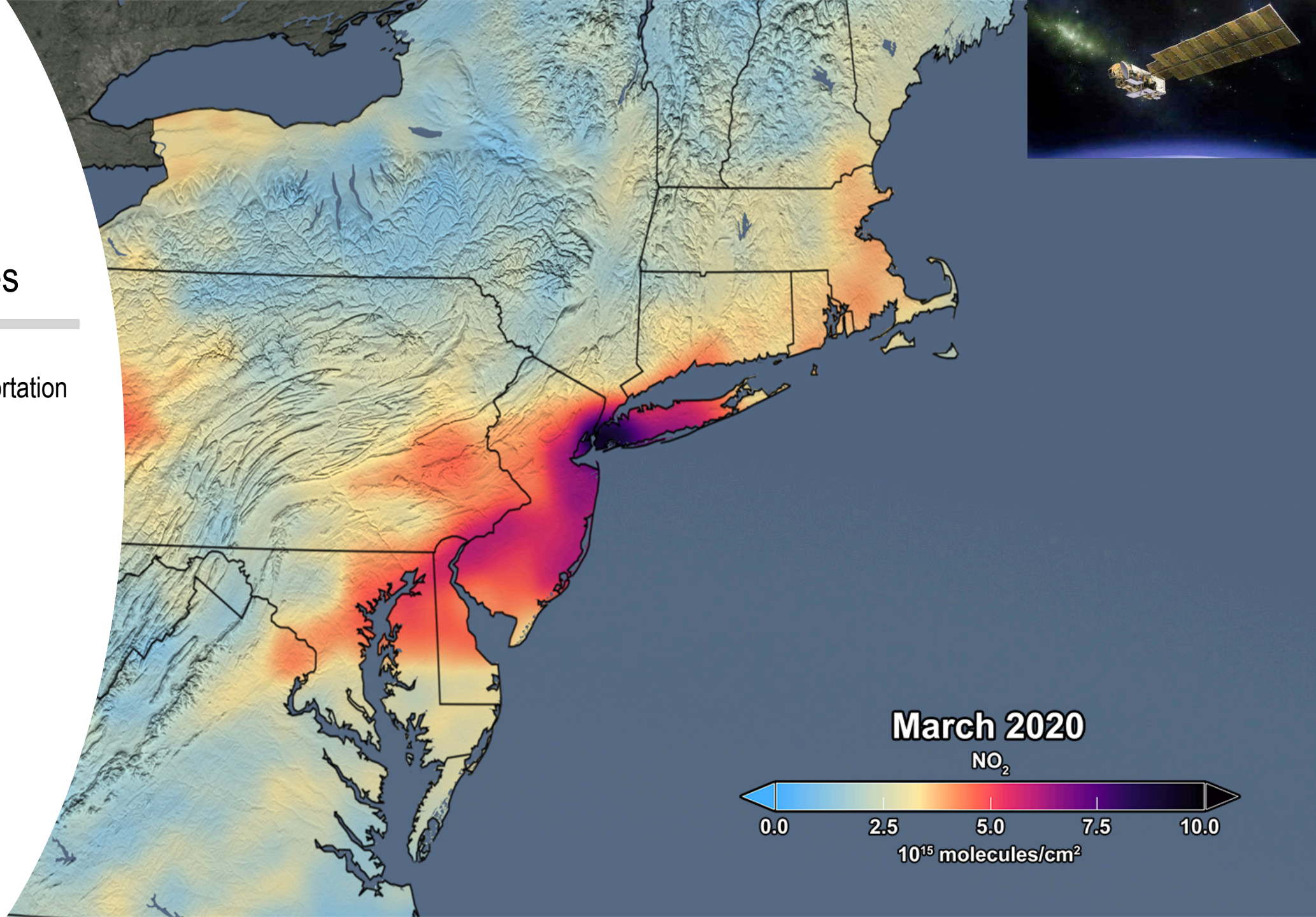
- #NitrogenTuesday



COVID-19 changes

- NO₂ from surface transportation
- OMI instrument on Aura

• #NitrogenTuesday

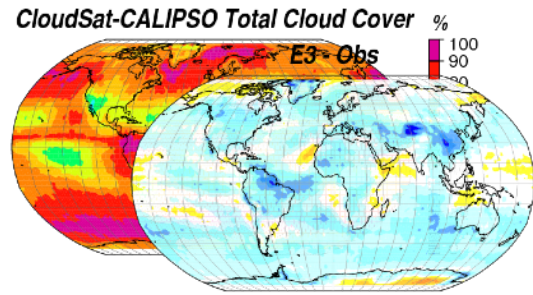


The background of the slide is a composite image of space. The top half features a dark blue and black nebula with bright, star-like points of light. The bottom half is a gradient of orange and yellow, also filled with numerous small, bright stars. A horizontal light blue band runs across the middle, containing the title text.

Climate Change: Processes and Attribution

Climate Models

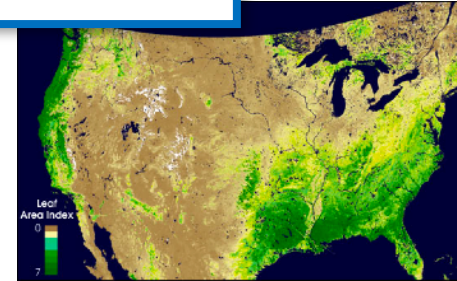
- Need *process-level* information, boundary conditions, drivers.
- e.g. GISS ModelE, NCAR CESM, GFDL CM, etc.
- Tuning/Calibration best done without looking at trends.



Global and regional evaluation across multiple variables & teleconnections

Model inputs

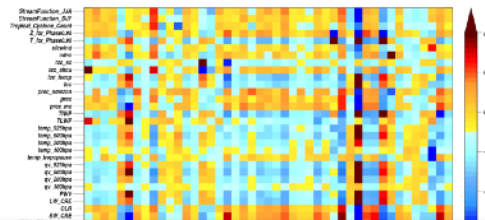
Land surface properties
topography, emissions



Model evaluation

Parameterization development

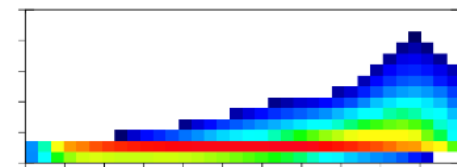
Process-related diagnostics
from low earth orbit and
flight campaigns



Perturbed physics ensembles plus
Machine Learning to match satellite
metrics (with uncertainties) across
40+ model parameters

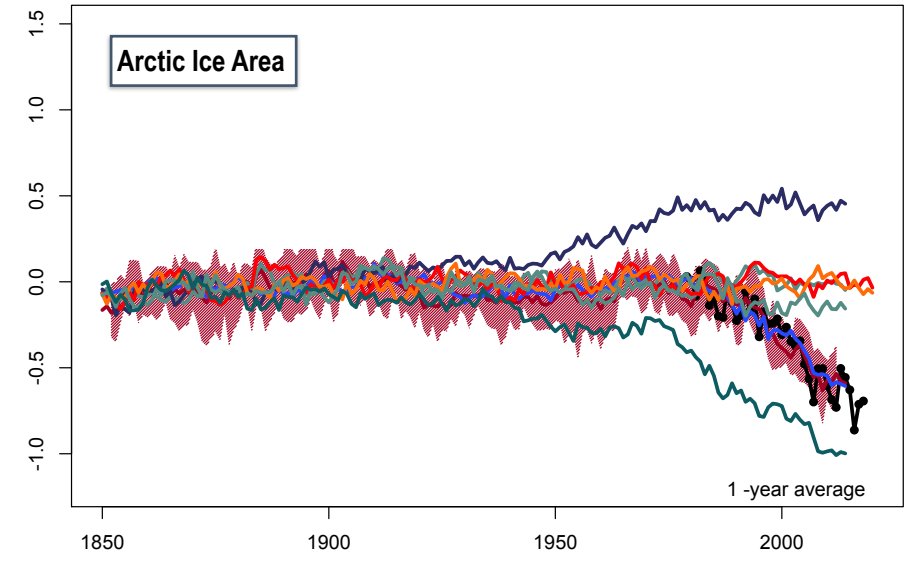
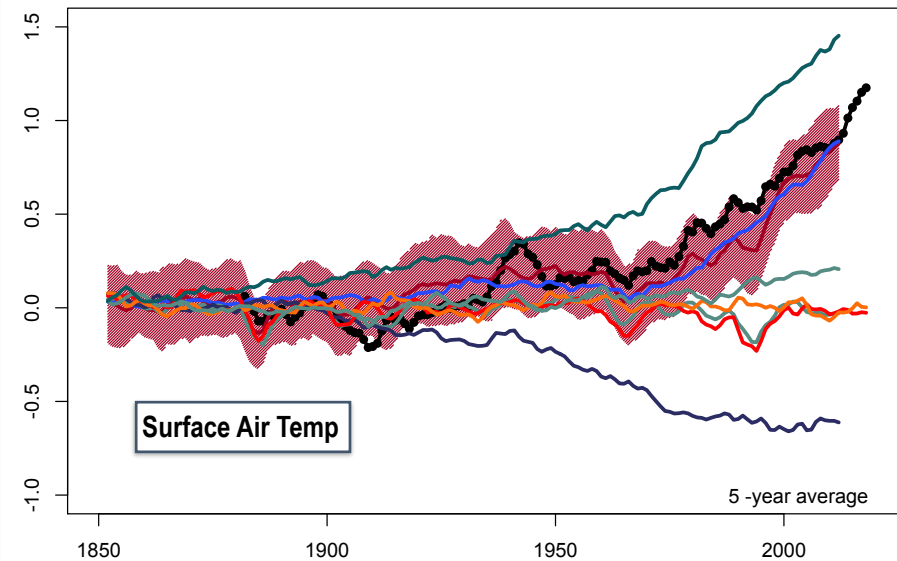
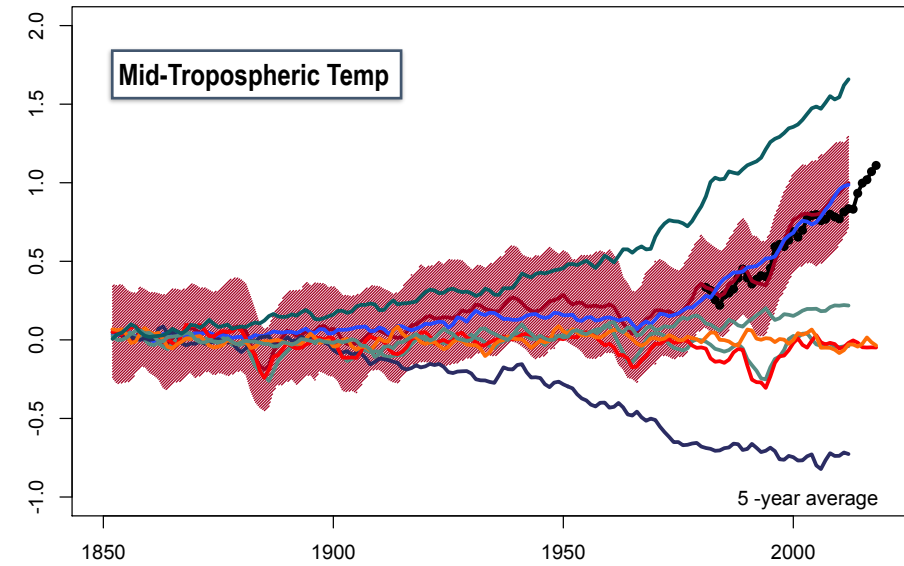
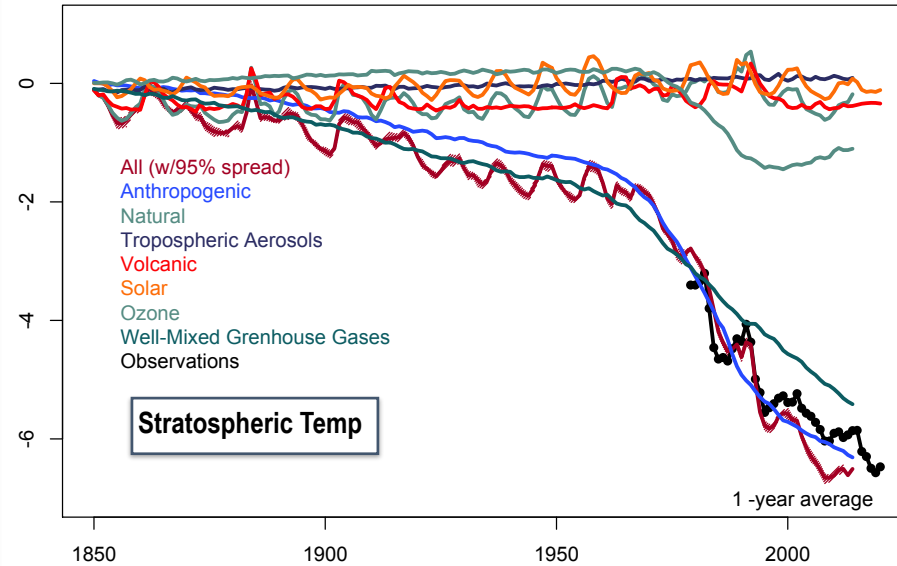
Global
tuning

GISS-E3dev Surface Rainfall PDF



Attribution

- GISS ModelE2.1 Ensemble simulations with individual drivers, natural-only, anthropogenic-only etc.
- Multi-variate comparisons to observed trends



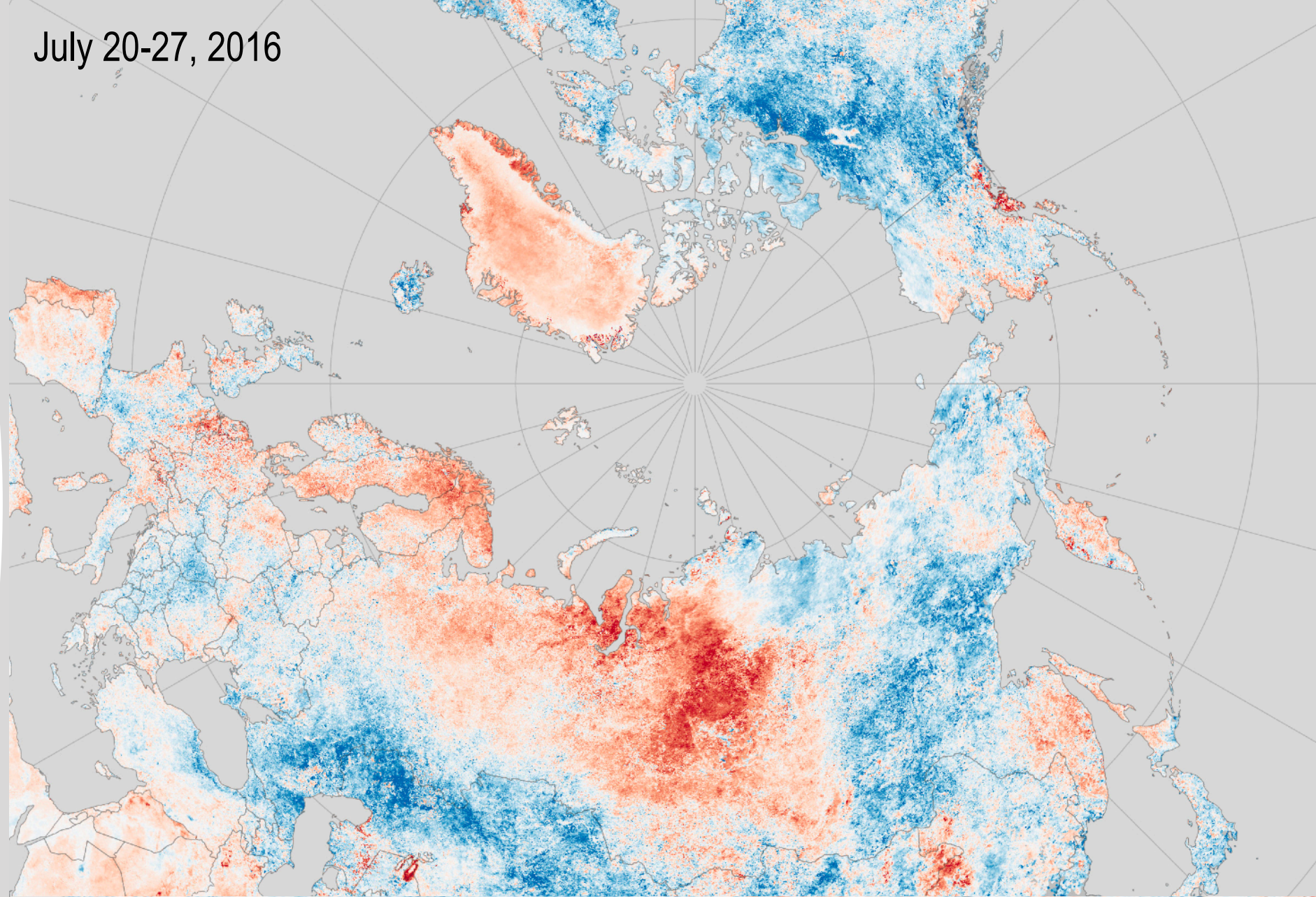
The background of the slide is a composite of two cosmic images. The top half features a dark space filled with numerous small, distant stars and a prominent, wispy blue nebula on the right side. The bottom half shows a similar starry field but with a large, vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right. A solid light blue horizontal band runs across the middle of the image, serving as a backdrop for the text.

What about extremes?

July 20-27, 2016

Heat Waves

- MODIS instrument
- Terra (since 2000)
- Aqua (since 2003)
- Record breaking heat waves in 2016, 2018, 2020
- Clear trends in heatwave incidence and cumulative intensity since 1960



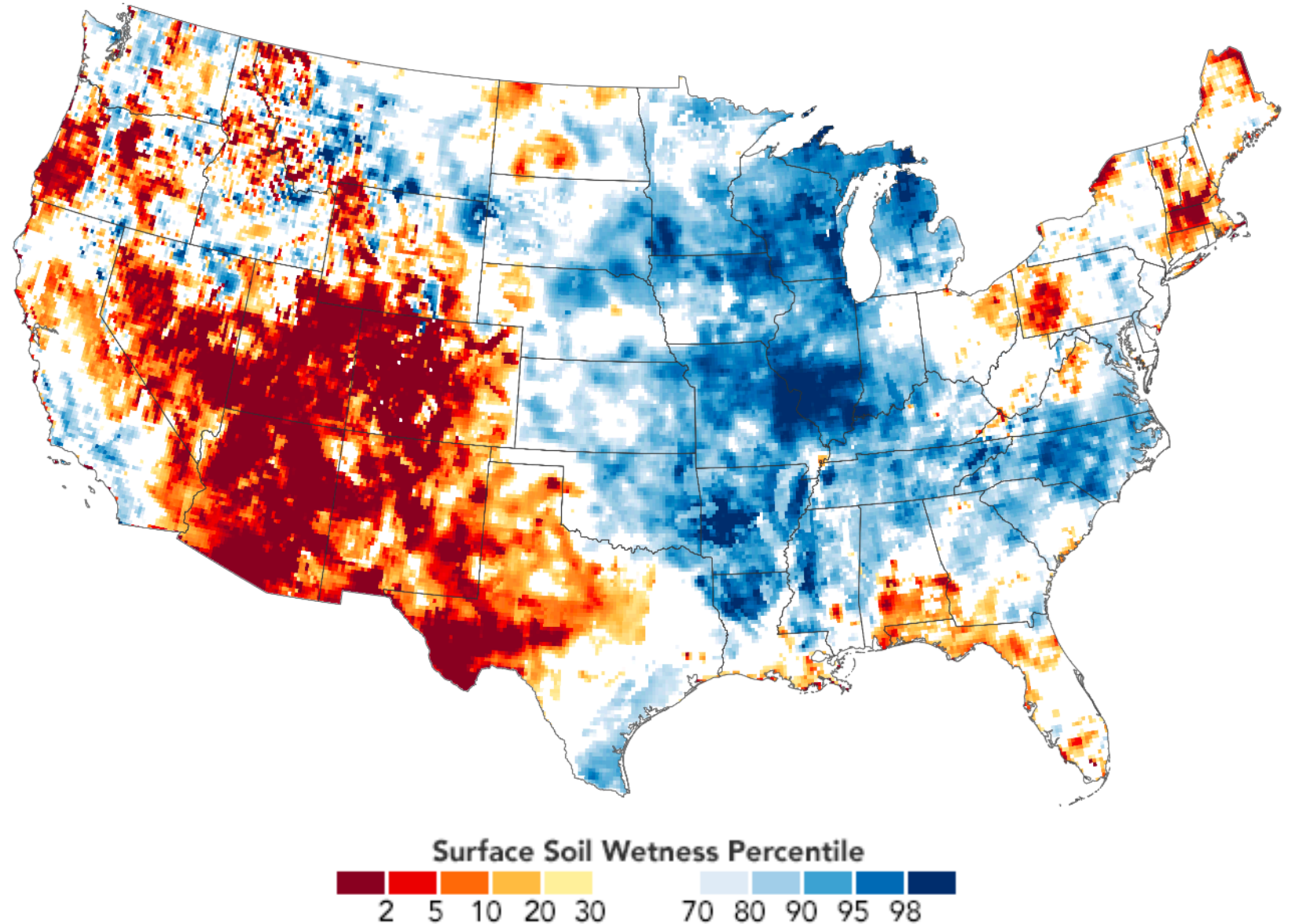
Land Surface Temperature Anomaly (°C) (°C)



Aug 10, 2020

Drought

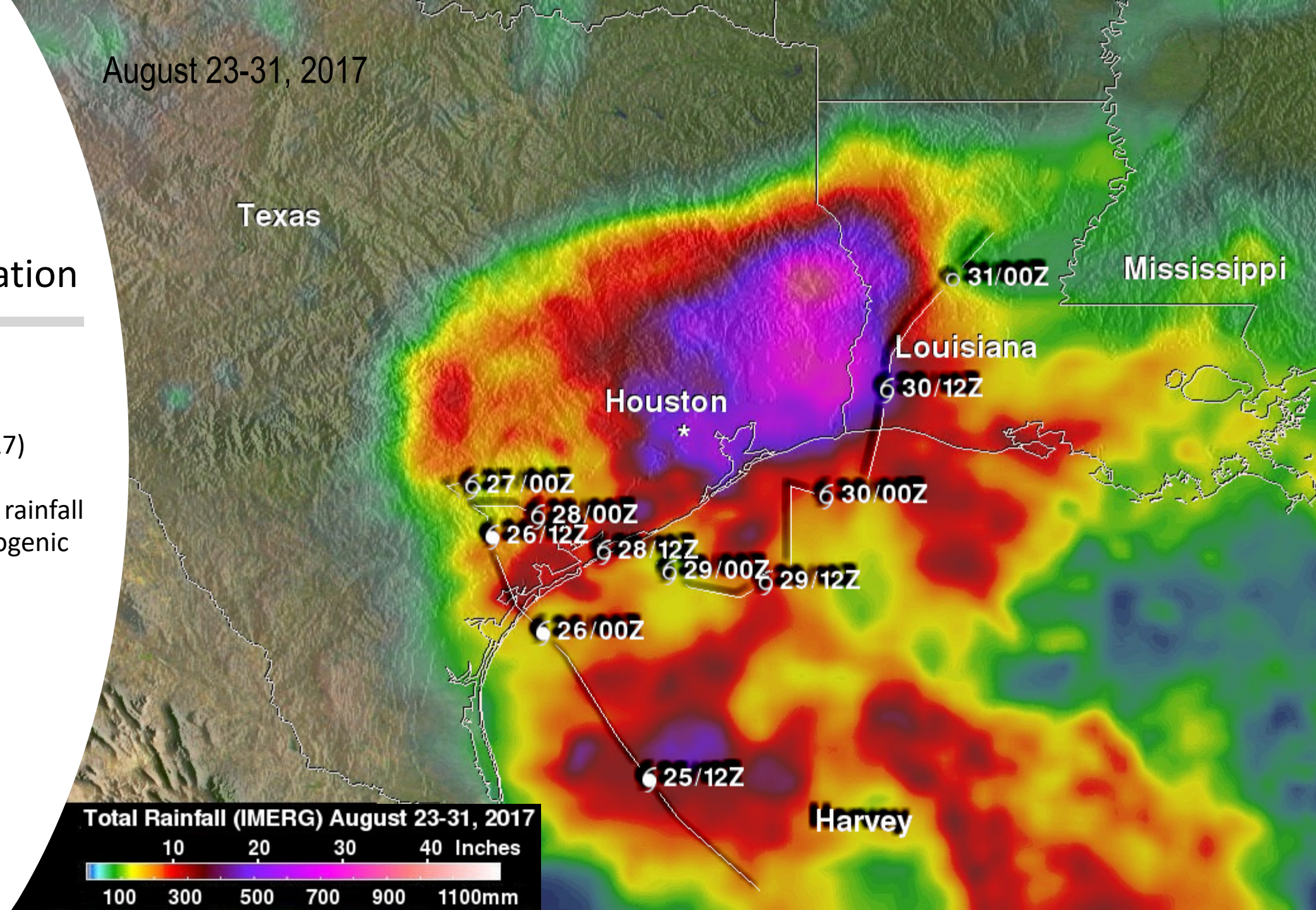
- GRACE-FO
- Soil moisture calculated from the gravity anomaly.
- 30-50% greater intensity through anthropogenic changes in temperature and relative humidity.



August 23-31, 2017

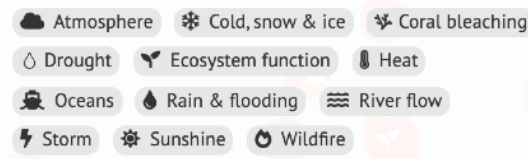
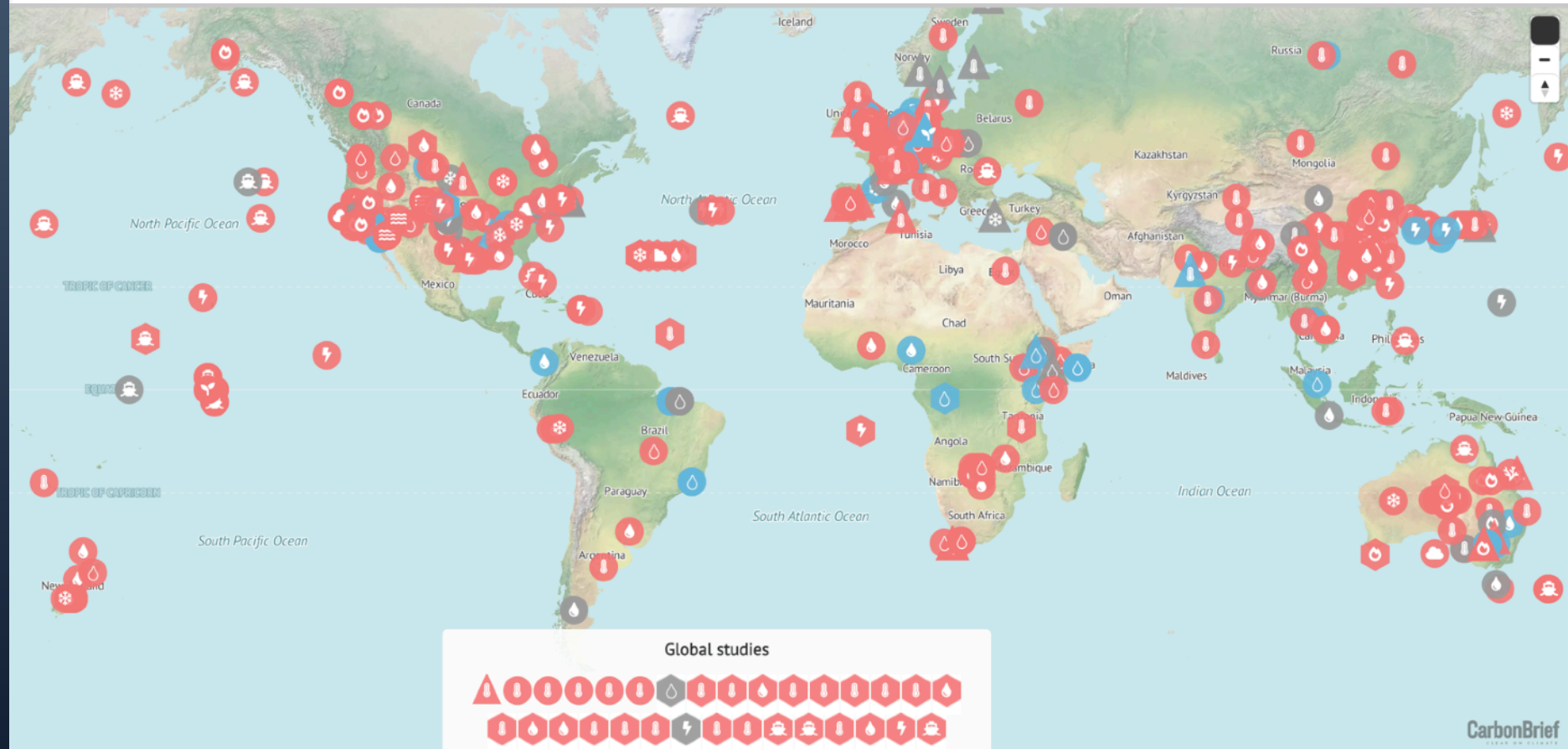
Intense Precipitation

- GPM (since 2014)
- Hurricane Harvey (2017)
- Estimates are ~20% of rainfall attributable to anthropogenic causes.

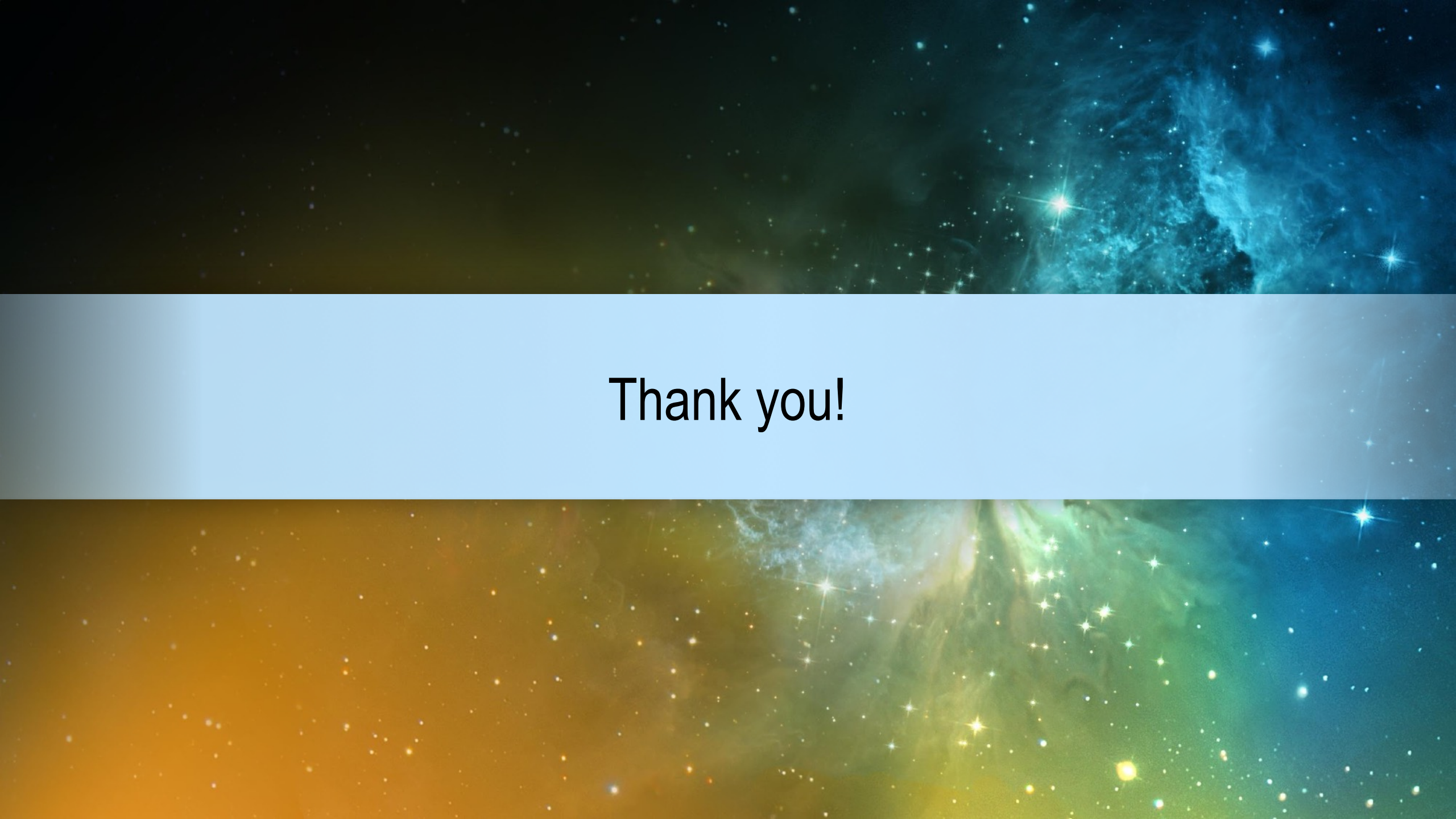


Attribution

- High resolution/large ensemble modeling of specific events w/ & w/o anthropogenic changes in ocean temperatures/modern composition.
- Big increases in likelihood for:
 - Marine and Land Heat waves
 - Intense precipitation
 - Drought Intensity
 - Wildfires



- 
- Climate change is clearly visible from space
 - Many key climate processes also
 - The combination of models & observations imply (almost) *all* current long-term trends are anthropogenic
 - We have increasing confidence there is an anthropogenic component to *many* (not all) extremes

The background of the slide is a composite of two cosmic images. The top half features a dark space filled with numerous small, distant stars and a prominent, wispy blue nebula on the right side. The bottom half shows a similar starry field but with a large, vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right. A solid light blue horizontal band runs across the middle of the image, serving as a backdrop for the text.

Thank you!