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

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

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

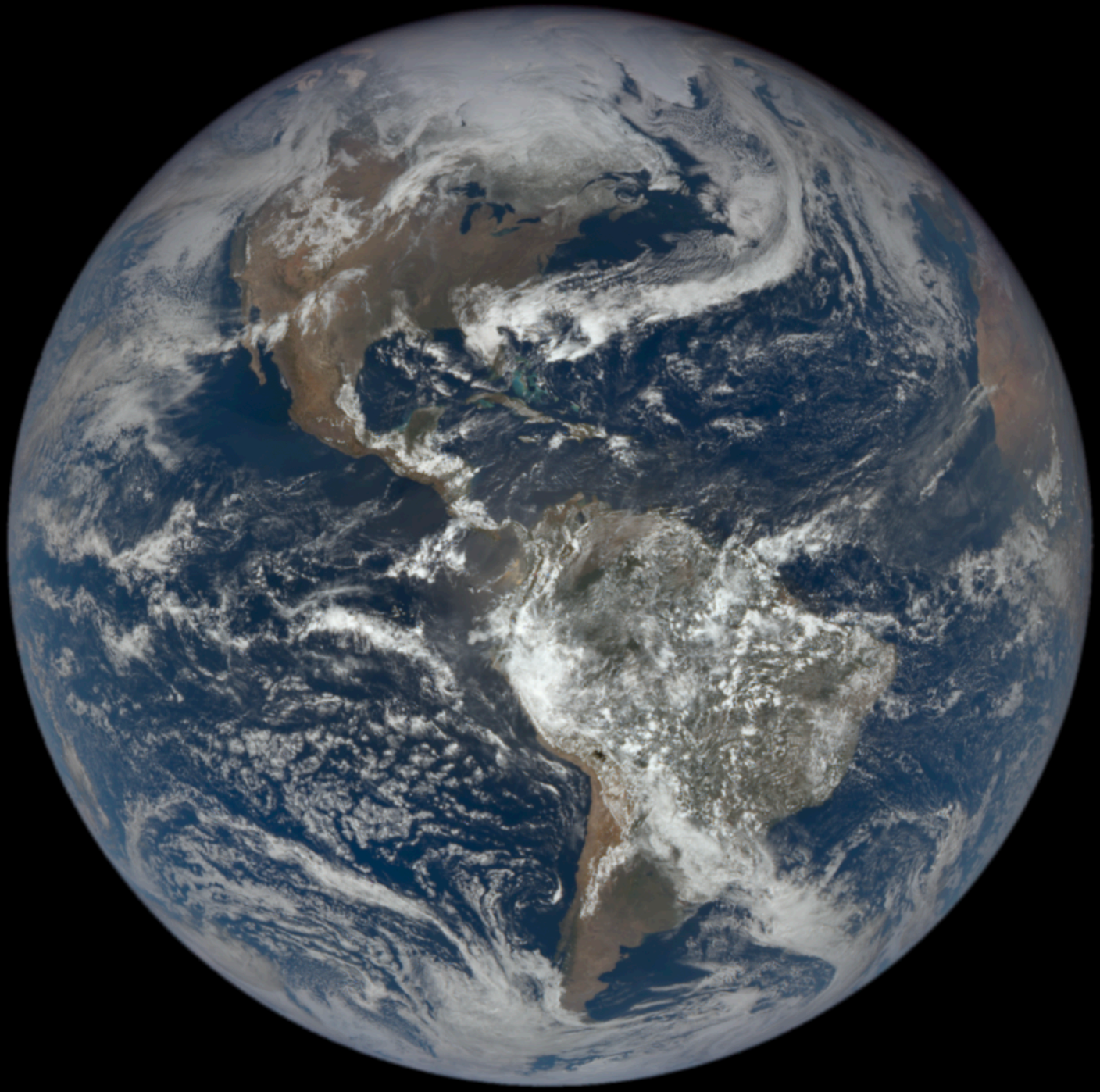
DSCOVER Instruments

NISTAR
EPIC

INVEST/CUBESATS

TEMPEST-D
CSIM
CIRiS
HARP
SNoOPI
HyTI
CTIM
TACOS

DSCOVR: EPIC



March 22 2021

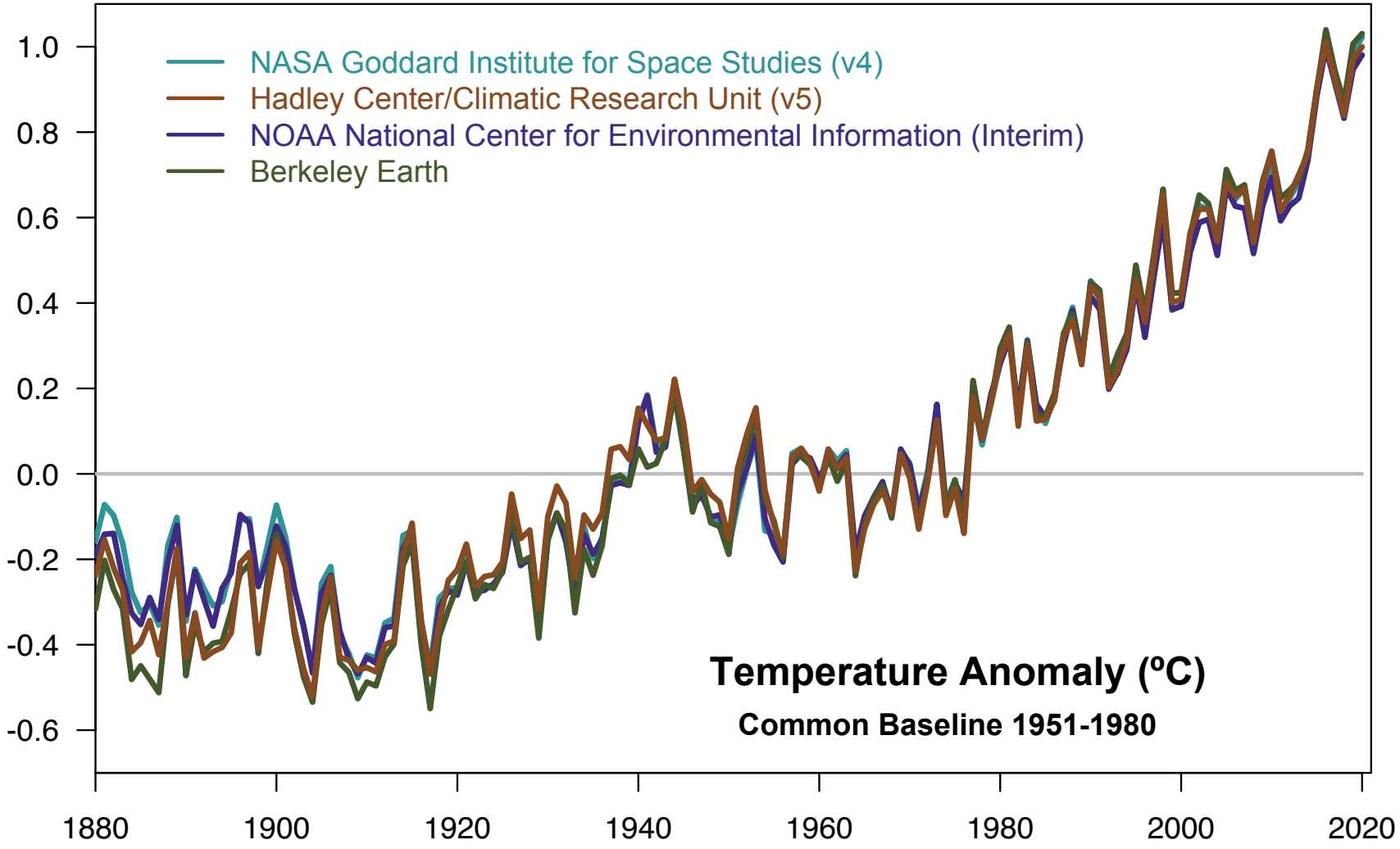
Climate Change: Observations

Surface Temperature

- GISTEMP (since 1981)
- Data from 1880

- Weather stations (GHCNv4)
- Ocean buoys/ship data (ERSSTv5)

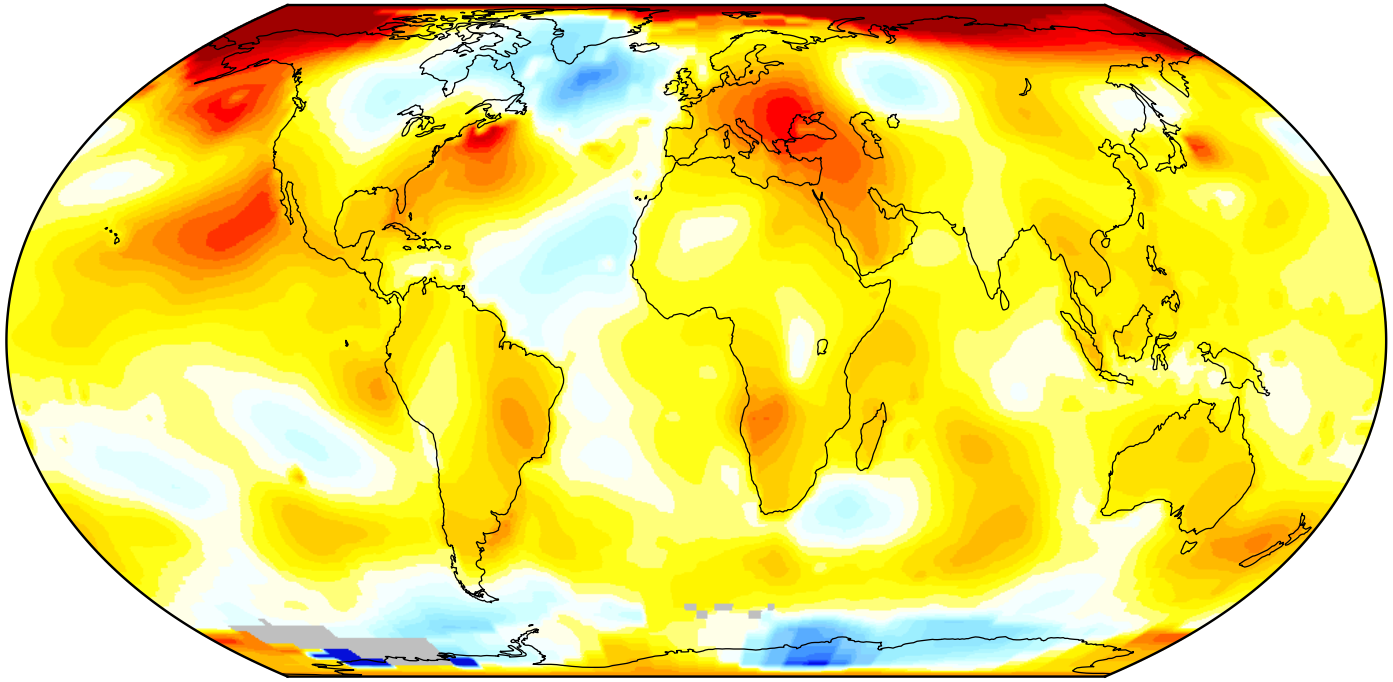
Warming of 1.2ºC/2ºF since the late 19th Century

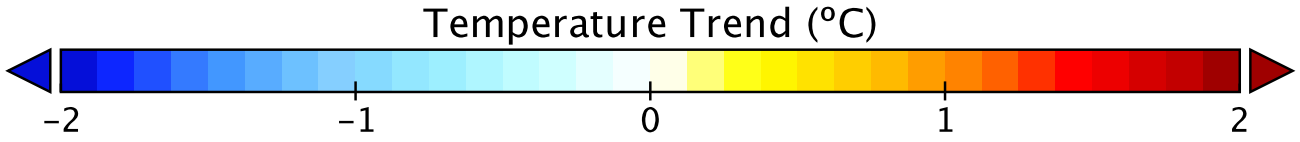


Surface Temperature

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

GISTEMP





Surface Temperature

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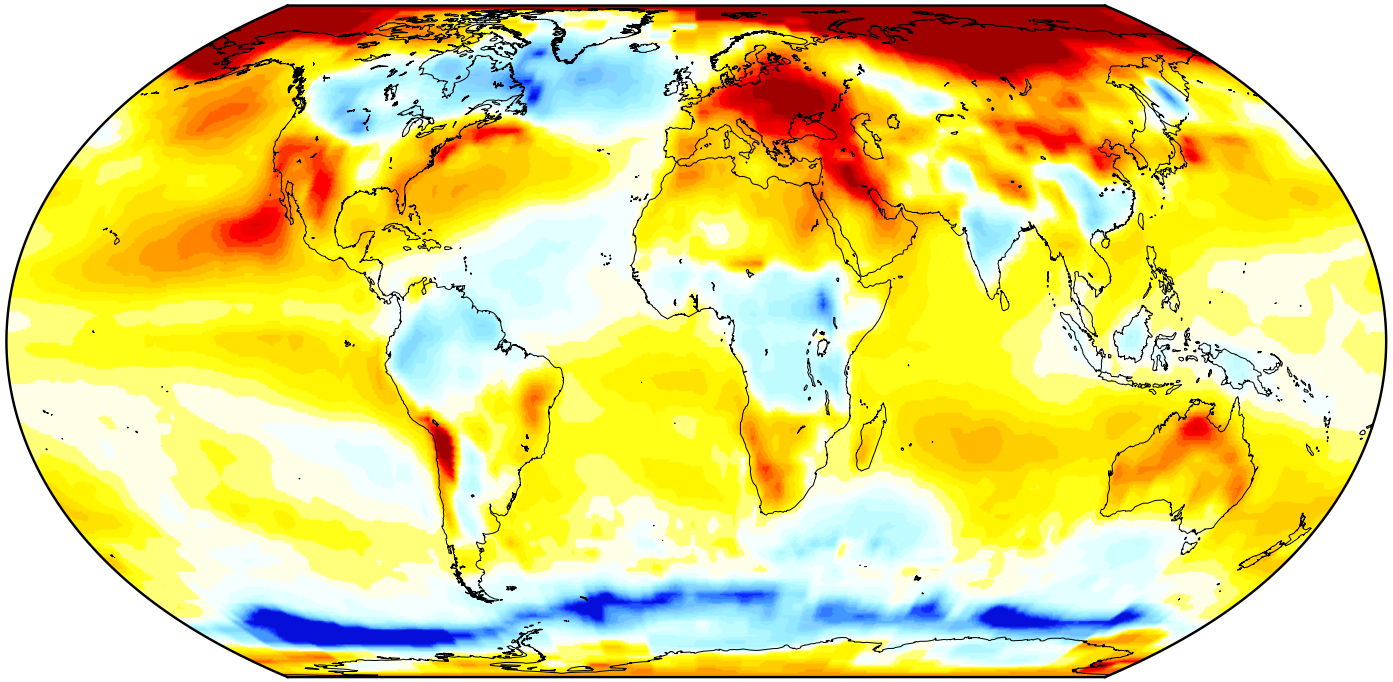
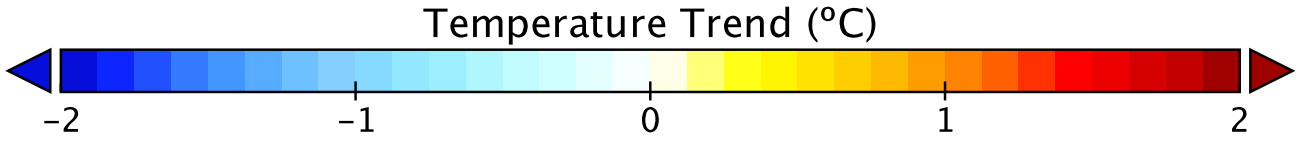
GISTEMP

AIRS (v7)

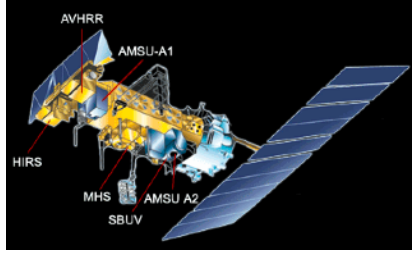


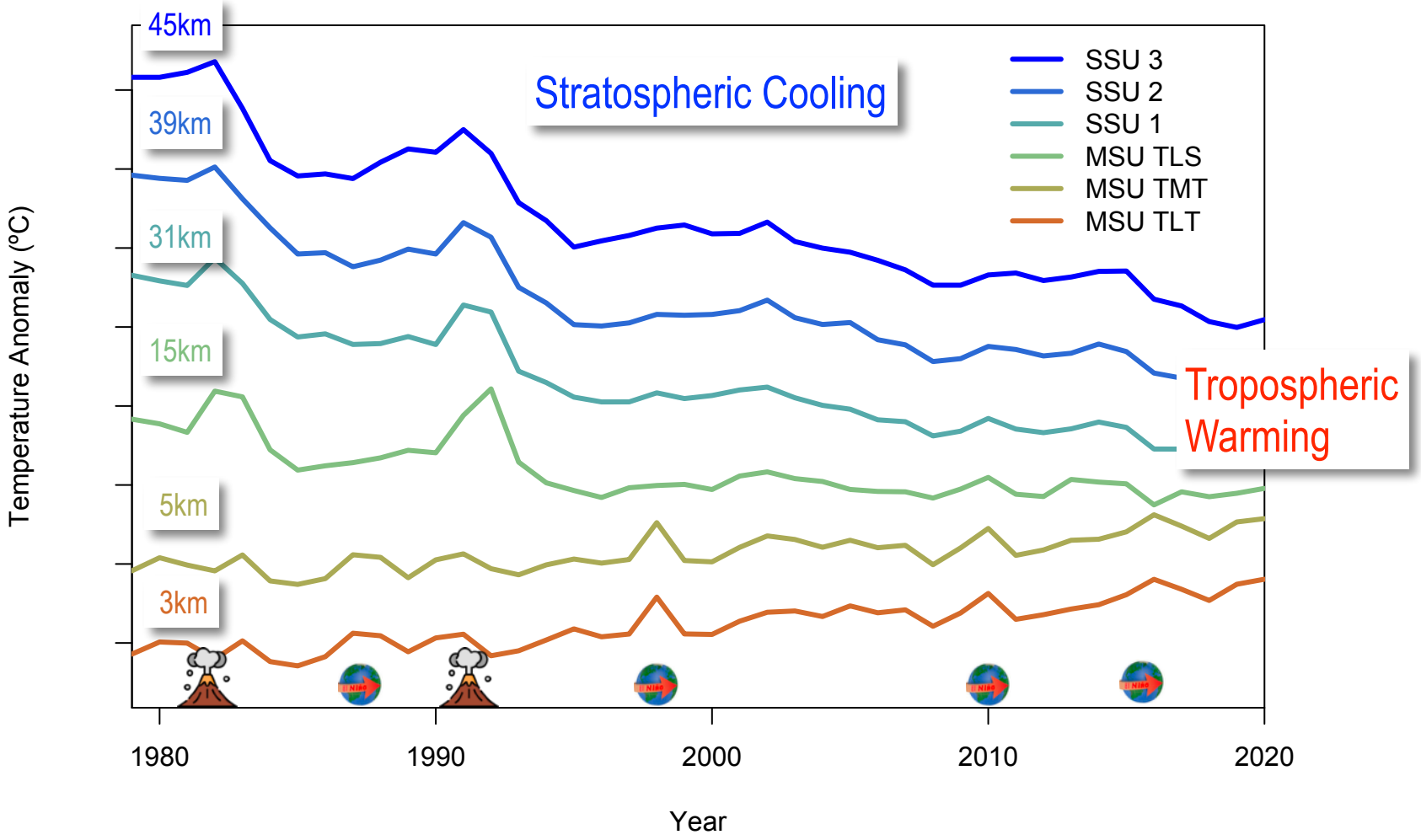


Atmospheric Temperature

- MSU/SSU/AMSU (since 1979)

- TIROS-N
- NOAA-6/7/8/9/10/11/12/14/15/16/18/19
- METOP-A/B
- AQUA

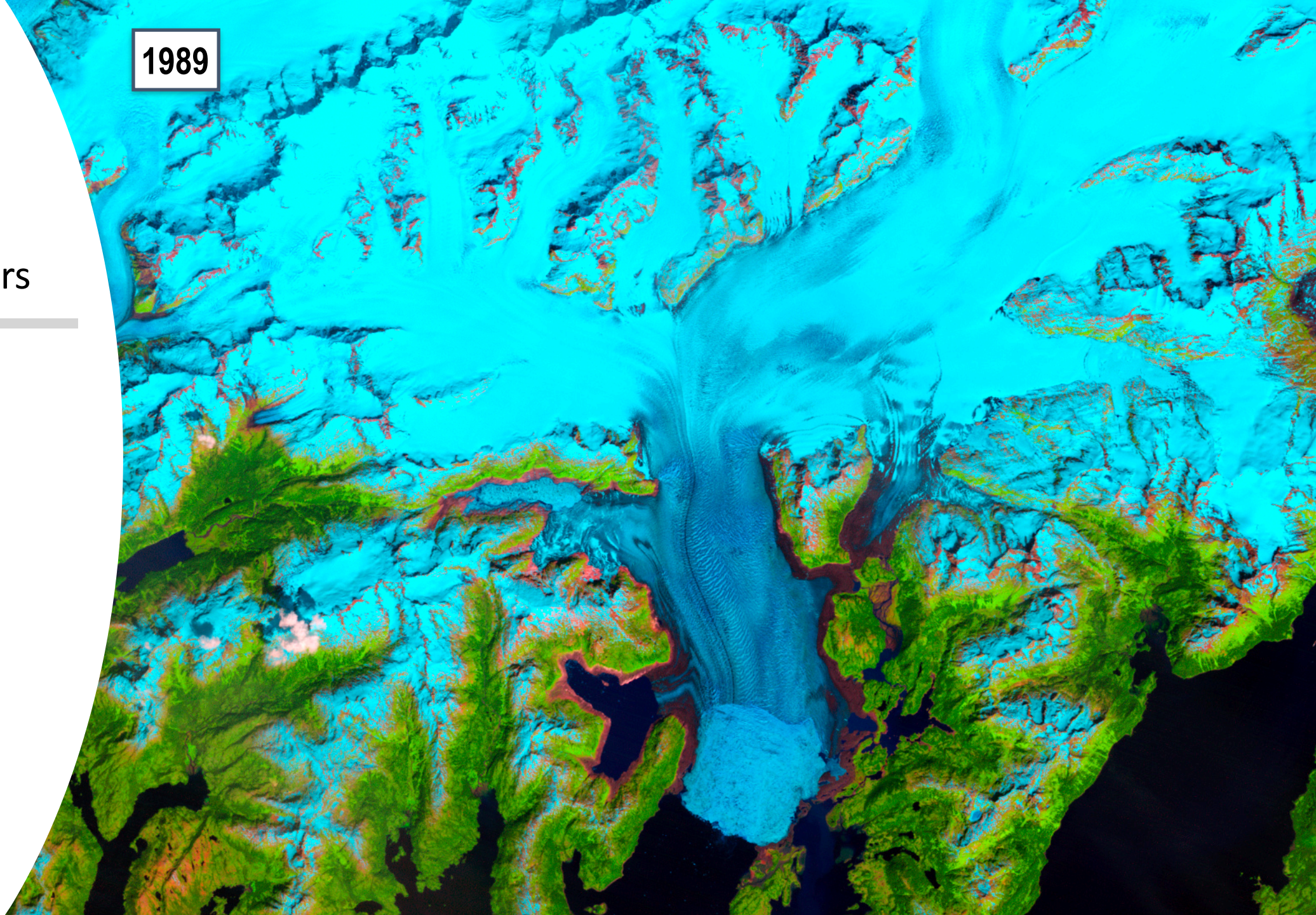




Mountain Glaciers

- Landsat (since 1982)
- LandSat 4/5/7/8

- Columbia Glacier, AK



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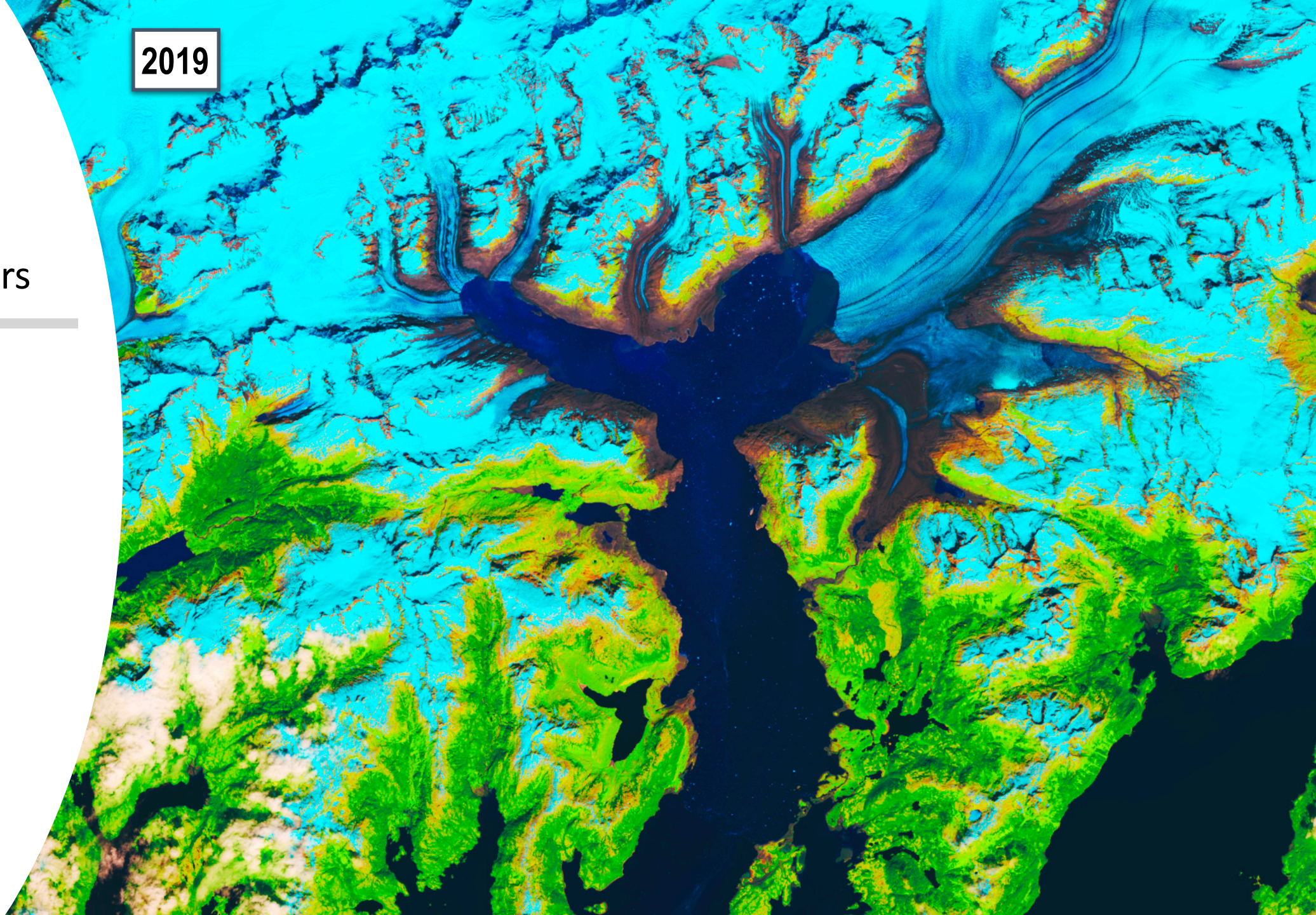
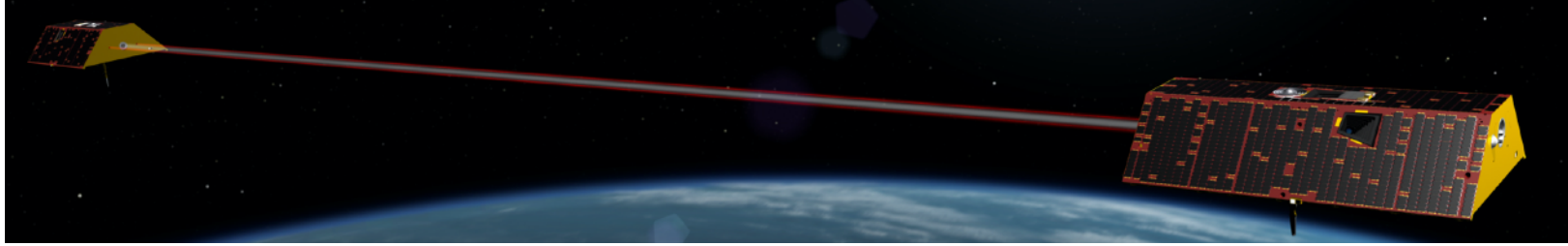
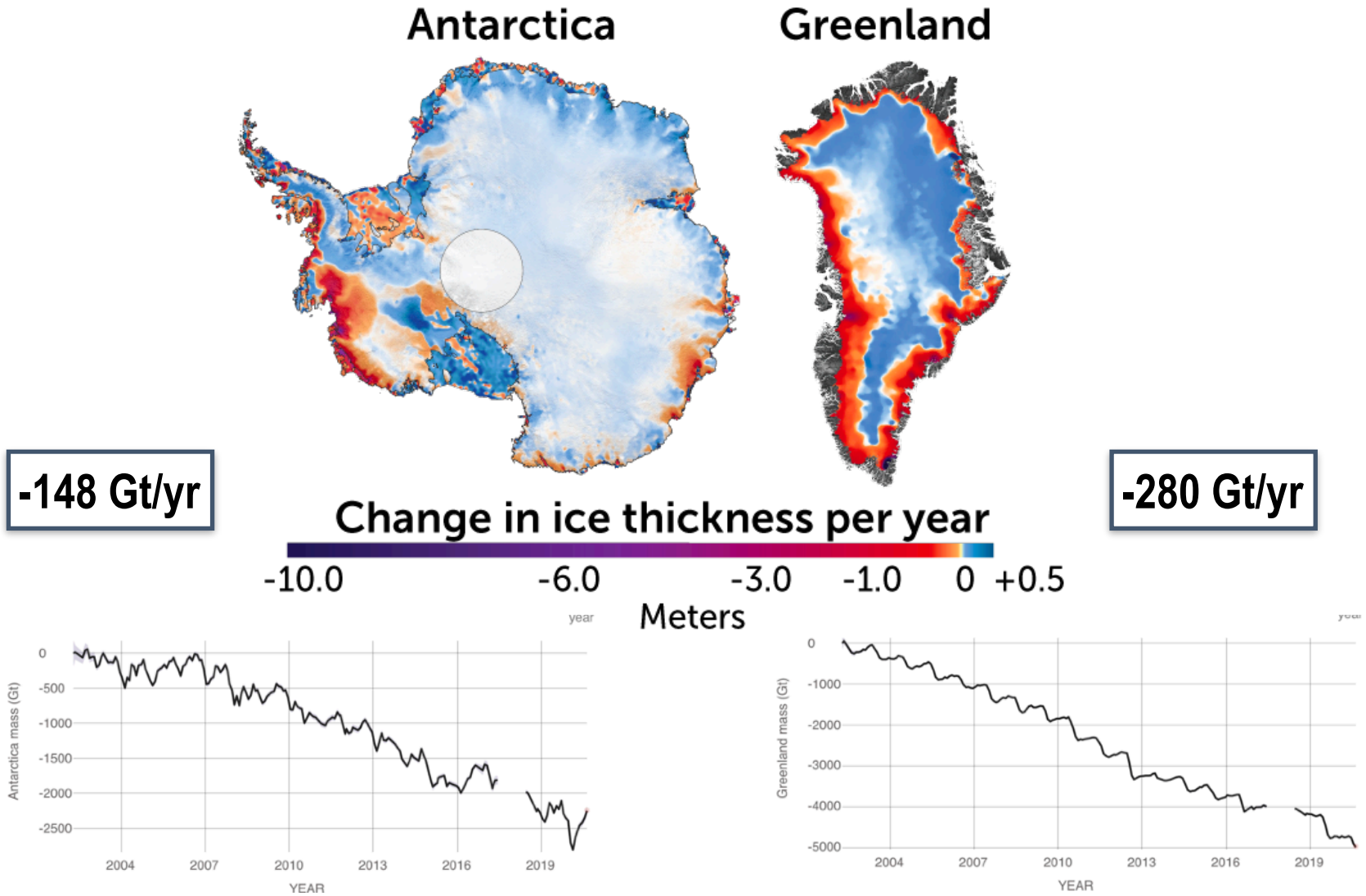


Ice Sheet Mass

- GRACE (2002-2017)
- GRACE-FO (since 2018)

- Trends April 2002-Dec 2020

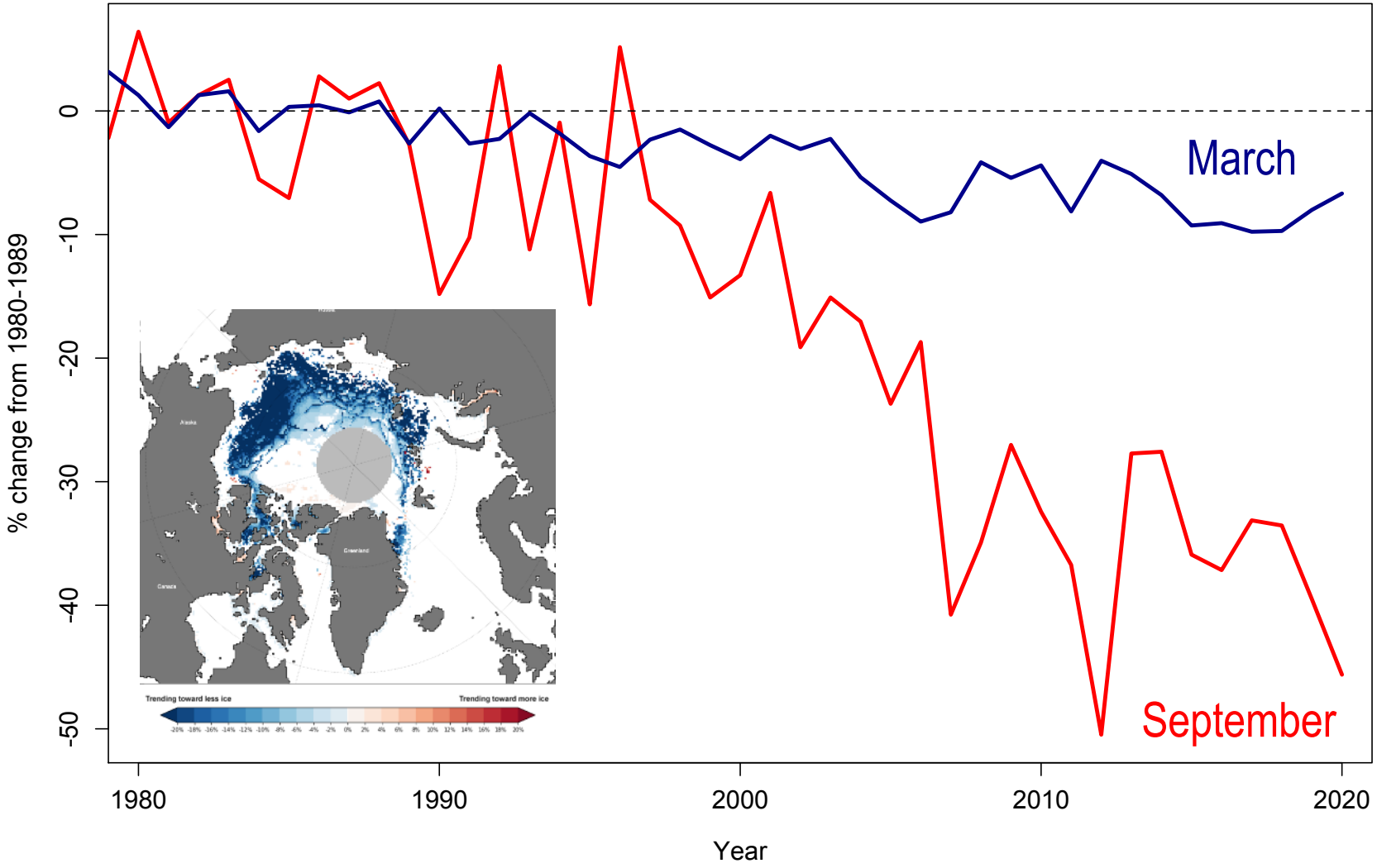




Arctic Sea Ice Extent

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

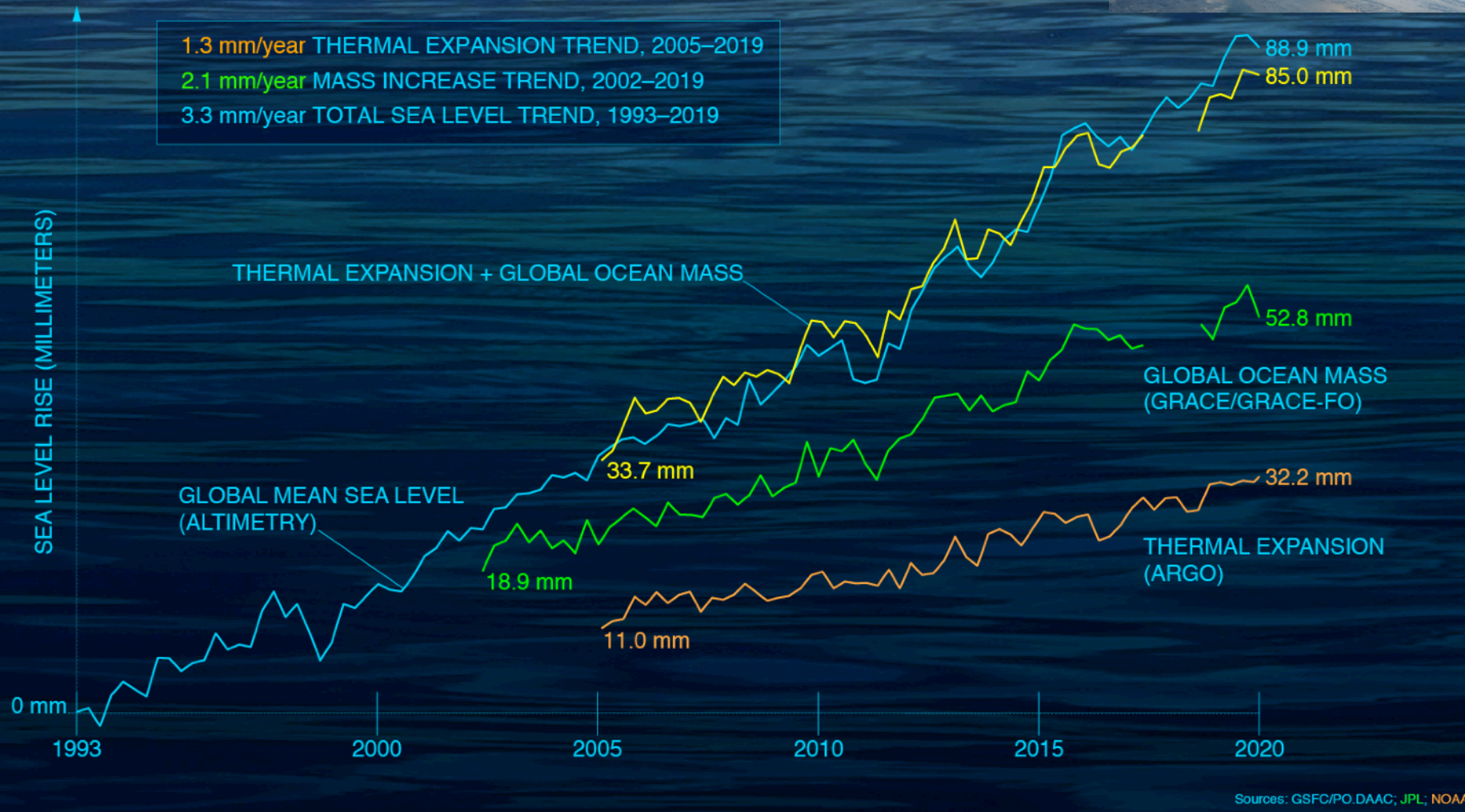
Over 40% decline in September Arctic sea ice



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

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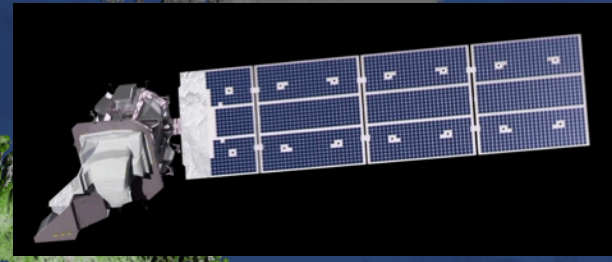
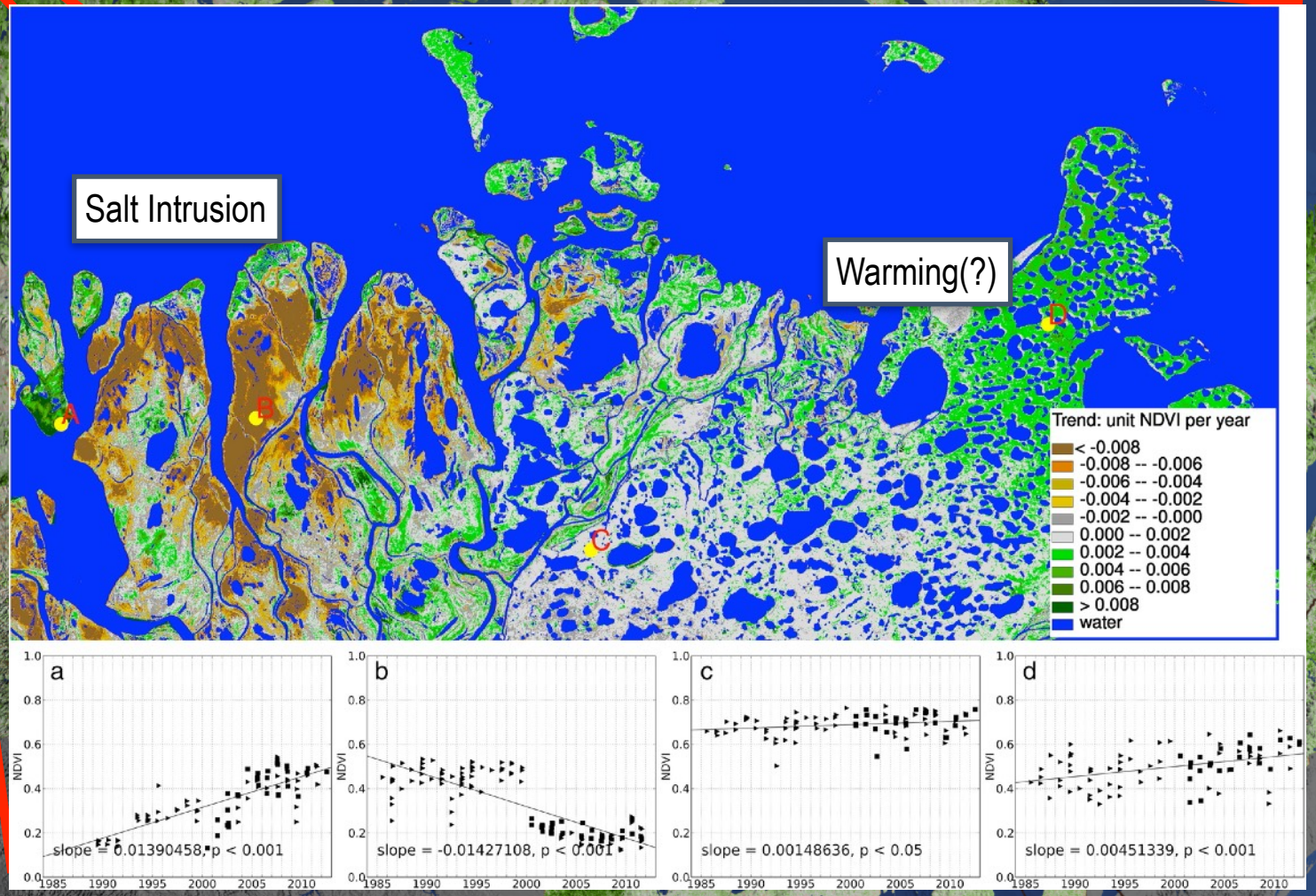
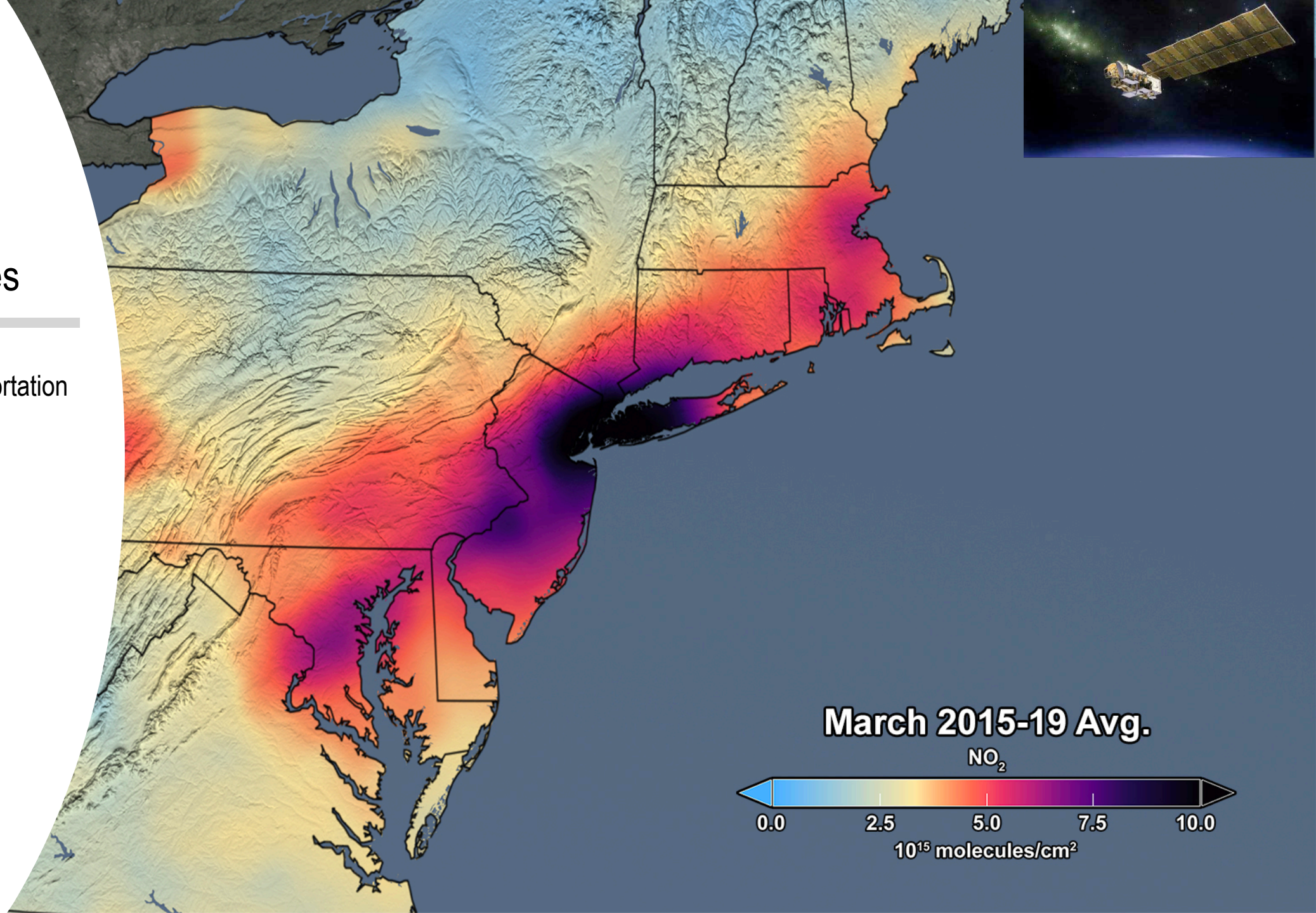




COVID-19 changes

- NO_2 from surface transportation
- OMI instrument on Aura

- #NitrogenTuesday



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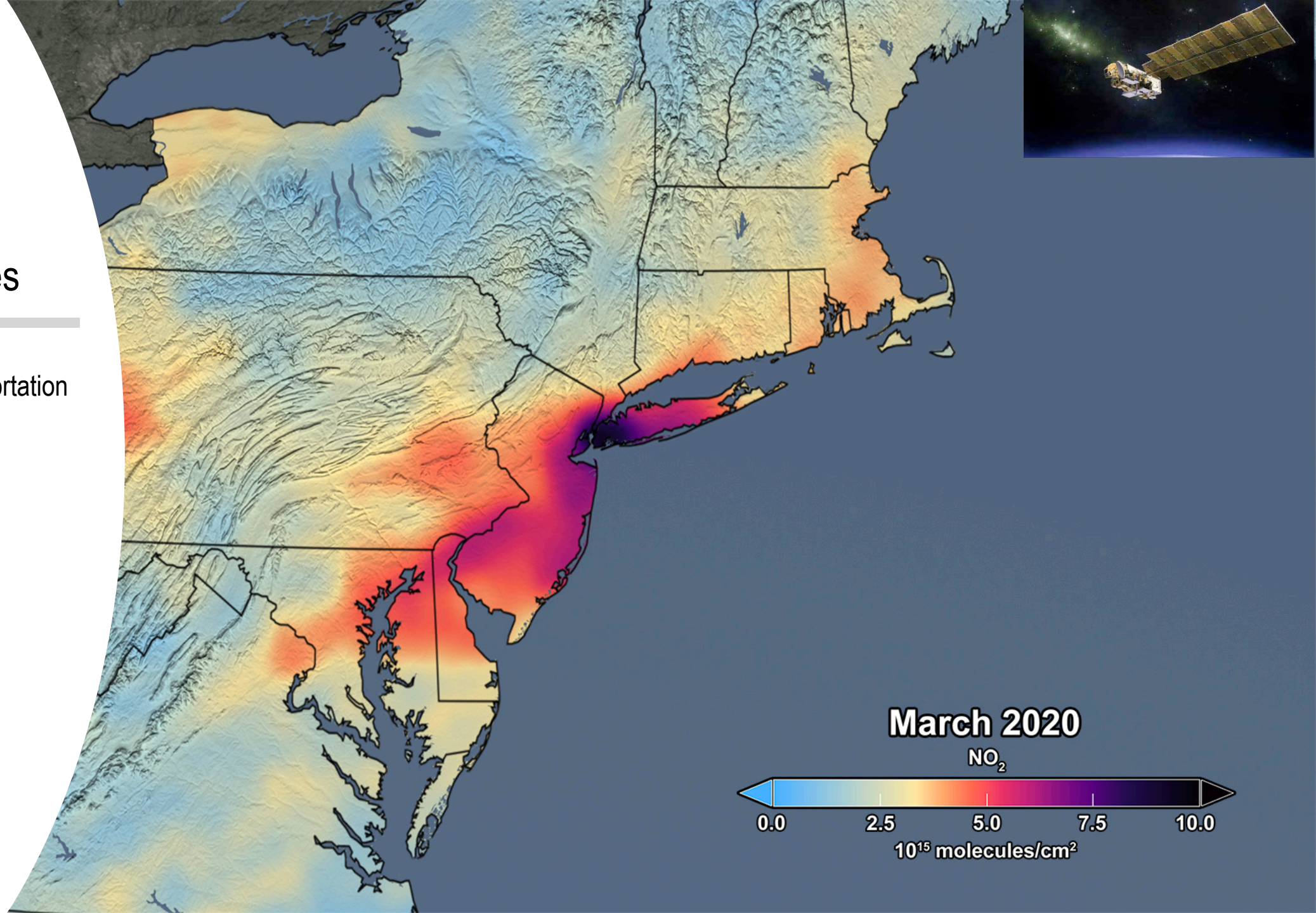
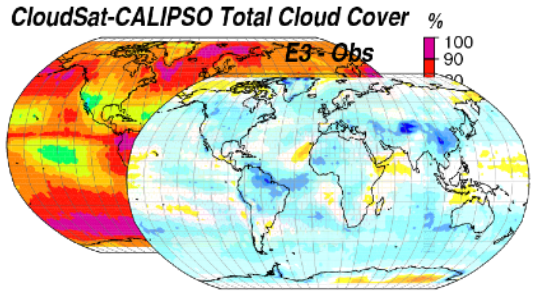


Climate Change: Processes and Attribution

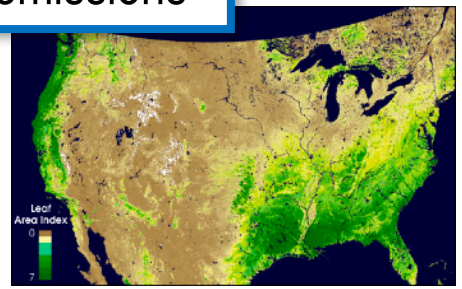
Climate Models

- 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

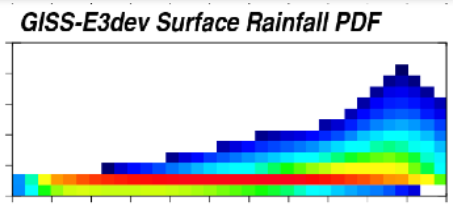
Land surface properties topography, emissions



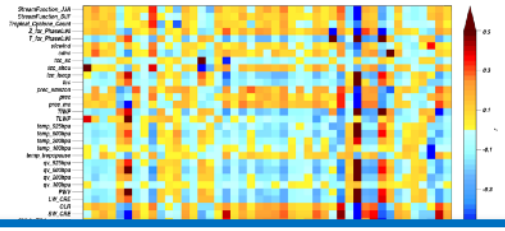
Model inputs

Parameterization development

Process-related diagnostics from low earth orbit and flight campaigns



Global tuning



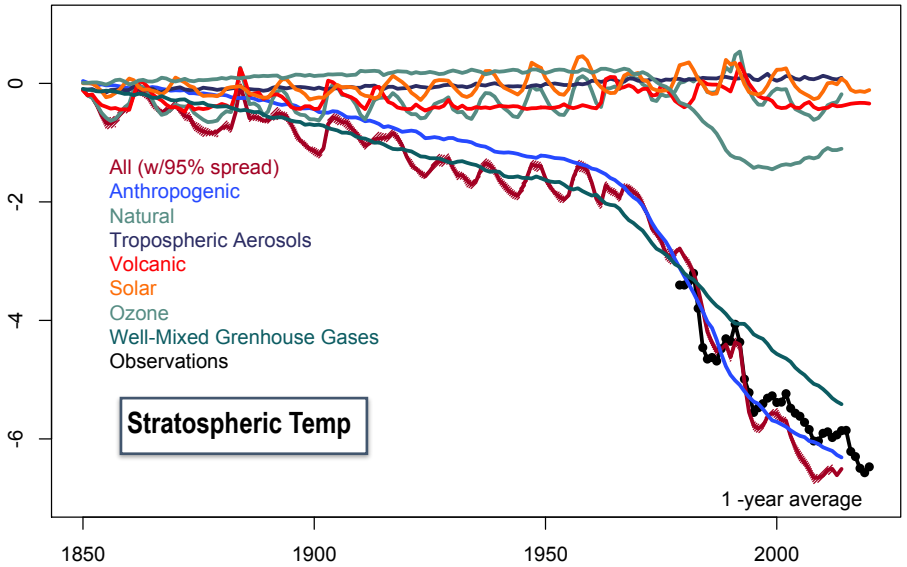
Perturbed physics ensembles plus Machine Learning to match satellite metrics (with uncertainties) across 40+ model parameters

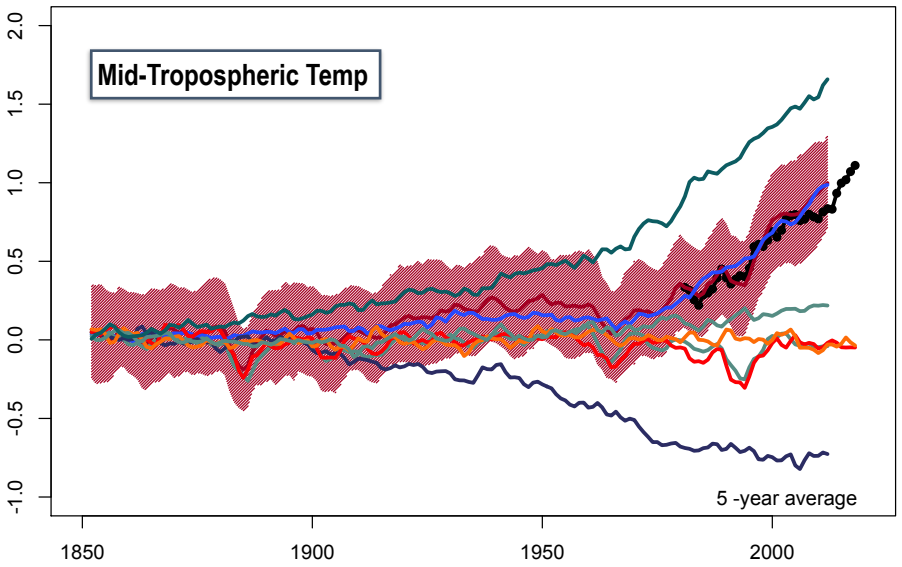
Model evaluation

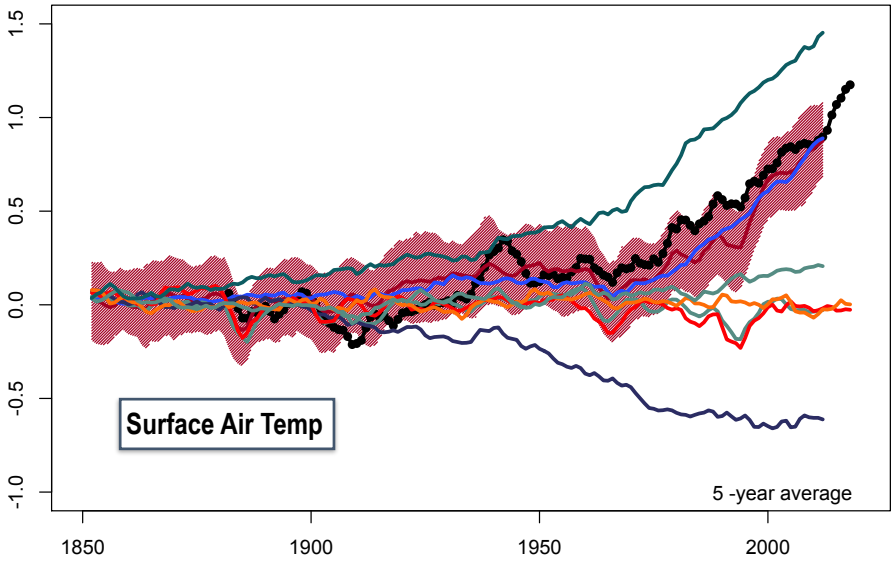
Attribution

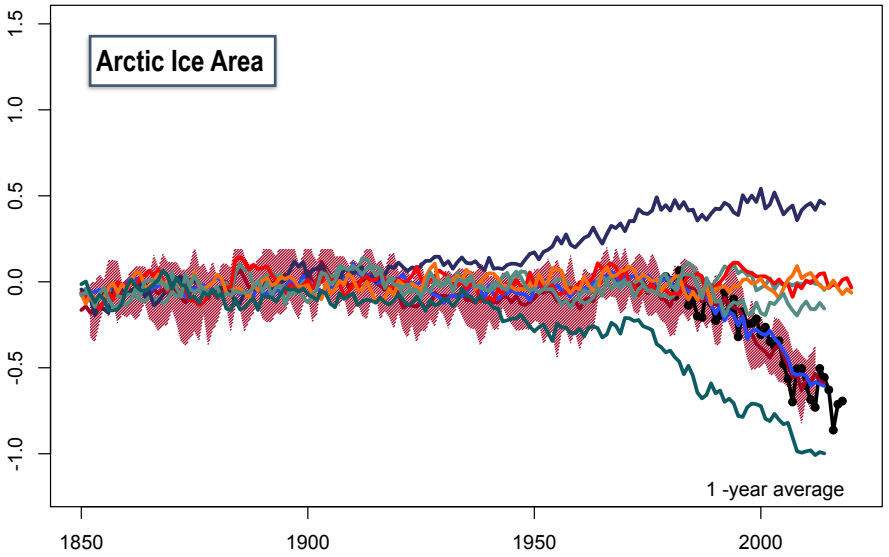
- GISS ModelE2.1 Ensemble simulations with individual drivers, natural-only, anthropogenic-only etc.

- Multi-variate comparisons to observed trends









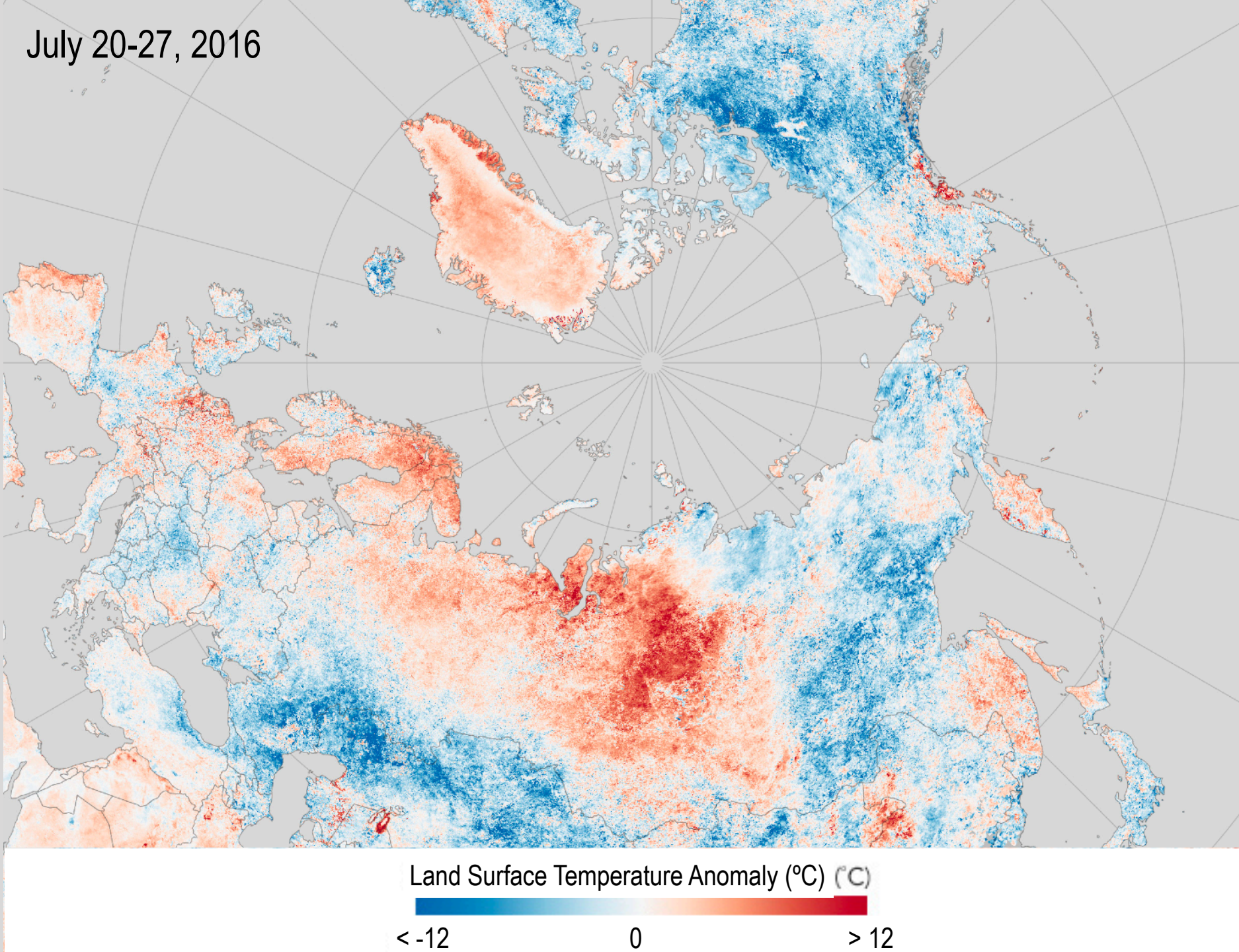
What about extremes?

Heat Waves

- MODIS instrument
- Terra (since 2000)
- Aqua (since 2003)

- Record breaking heat waves in 2016, 2018, 2020

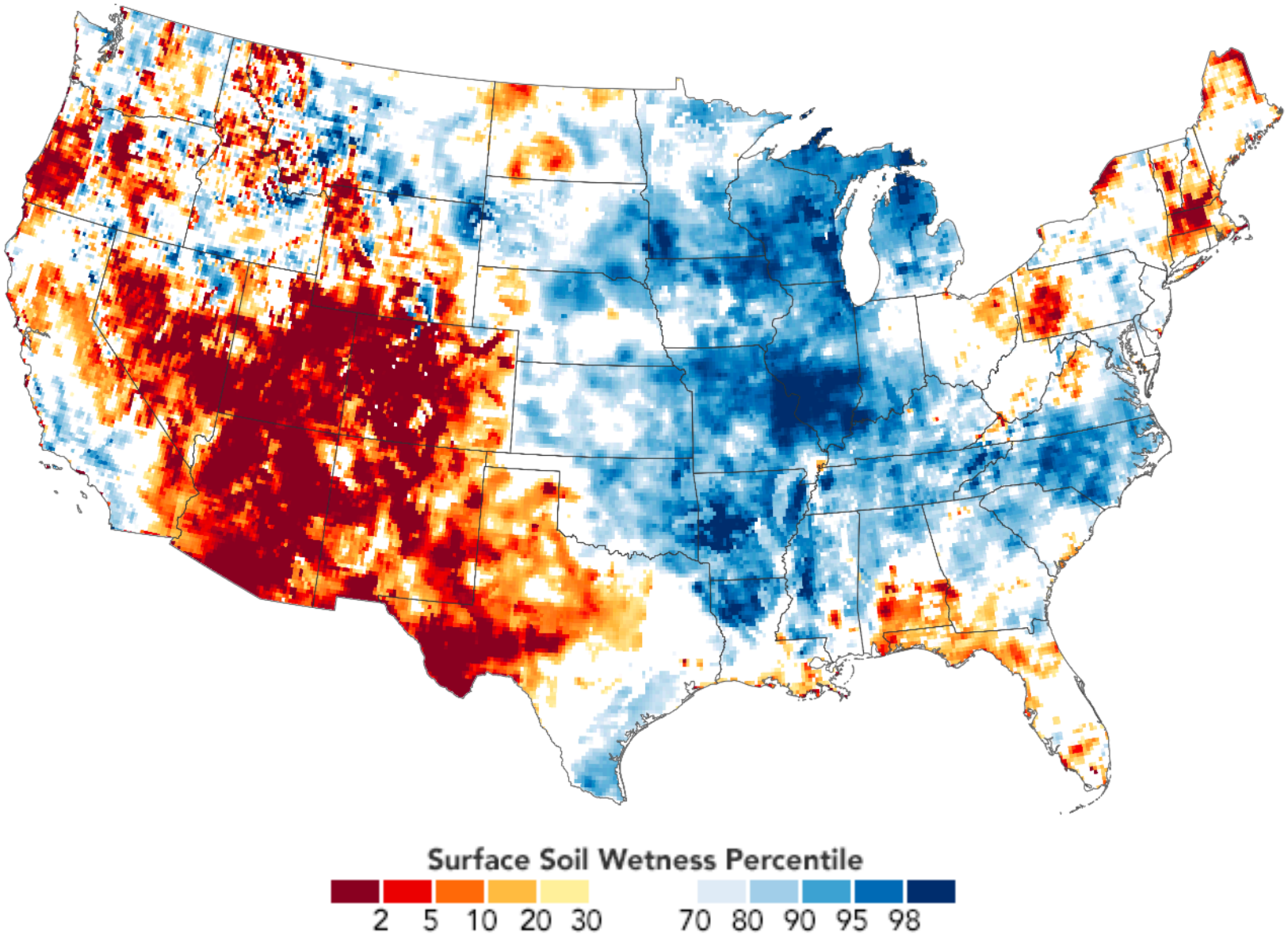
- Clear trends in heatwave incidence and cumulative intensity since 1960



Drought

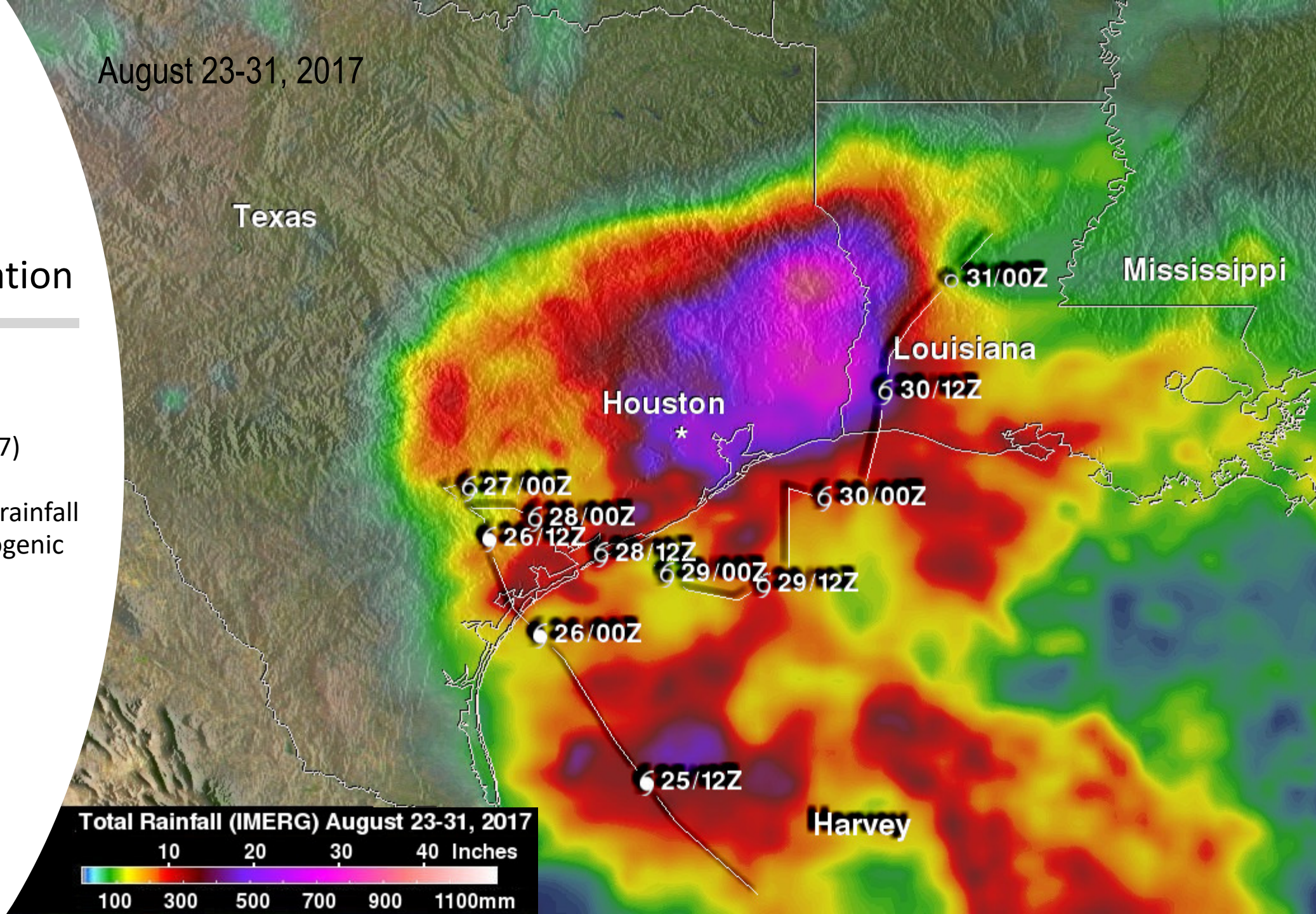
- GRACE-FO
- Soil moisture calculated from the gravity anomaly.
- 30-50% greater intensity through anthropogenic changes in temperature and relative humidity.

Aug 10, 2020



Intense Precipitation

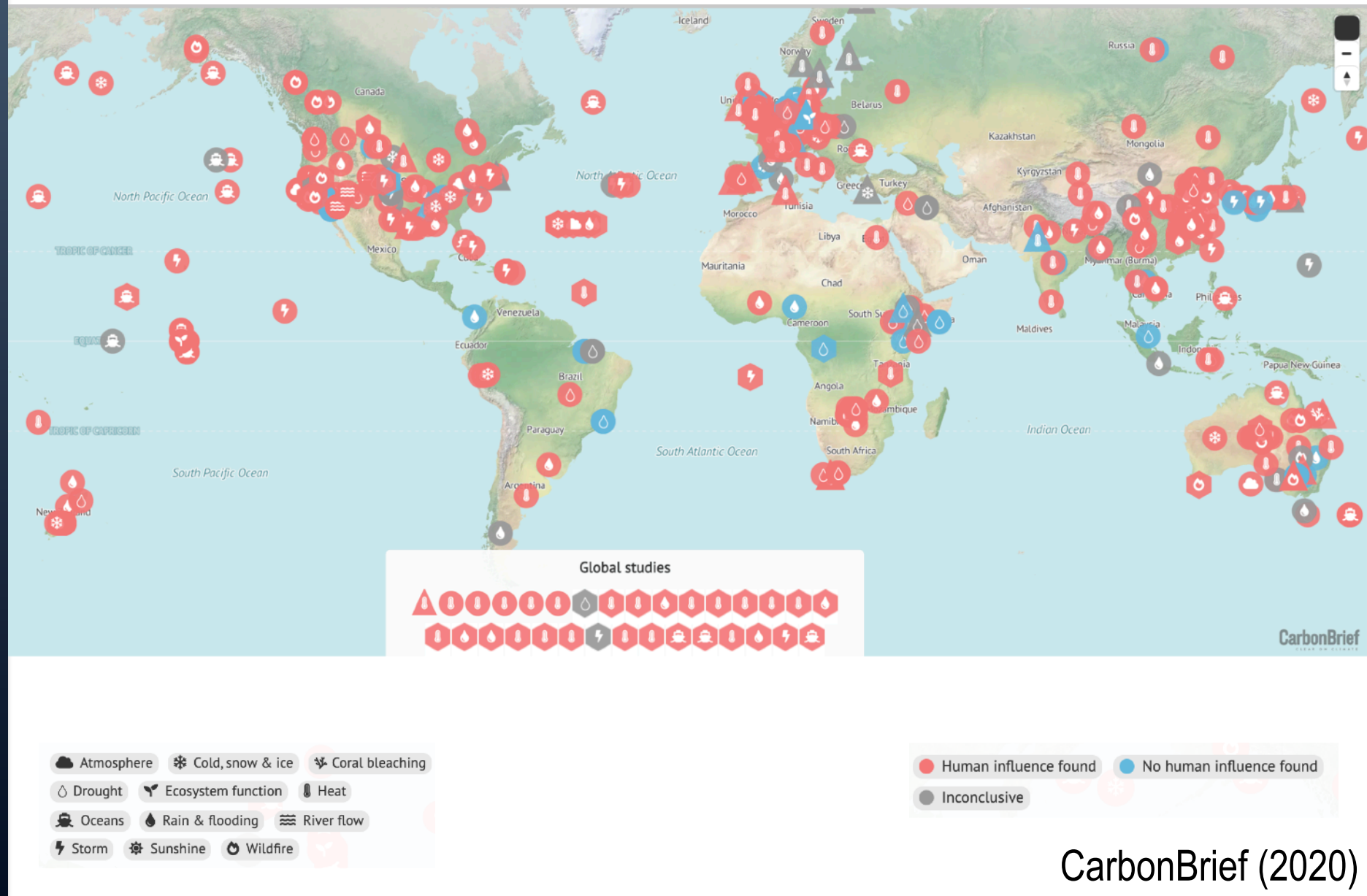
- GPM (since 2014)
- Hurricane Harvey (2017)
- Estimates are ~20% of rainfall attributable to anthropogenic causes.



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



CarbonBrief (2020)

- 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

Thank you!