CLIMATE CHANGE IN 2024: What's happening and why?

Gavin Schmidt
NASA Goddard Institute for Space Science

Last 12 months have been exceptional

WORLD

World hits 12 straight months of record-high temperatures – but as warming continues, it'll be "remembered as comparatively cold"

World must exit 'highway to clim hell', UN boss warns, as records a again broken

Battle to limit temperature rise will be 'won or lost' this decade, says António Guterres

The long-term global average temperature rise of 1.19C during the industrial era has worsened floods, heatwaves, fires and droughts © AFP/Getty Images

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WEATHER NEWS | Published June 5, 2024 10:30am EDT

Earth records hottest May on record in 12th consec onth of record heat

'Gobsmackingly bananas': scientists stunned by planet's record September heat

The carbon emissions driving the climate crisis and rapid arrival of an El Niño event are to blame, researchers say

The Guardian

What we do (& don't) know

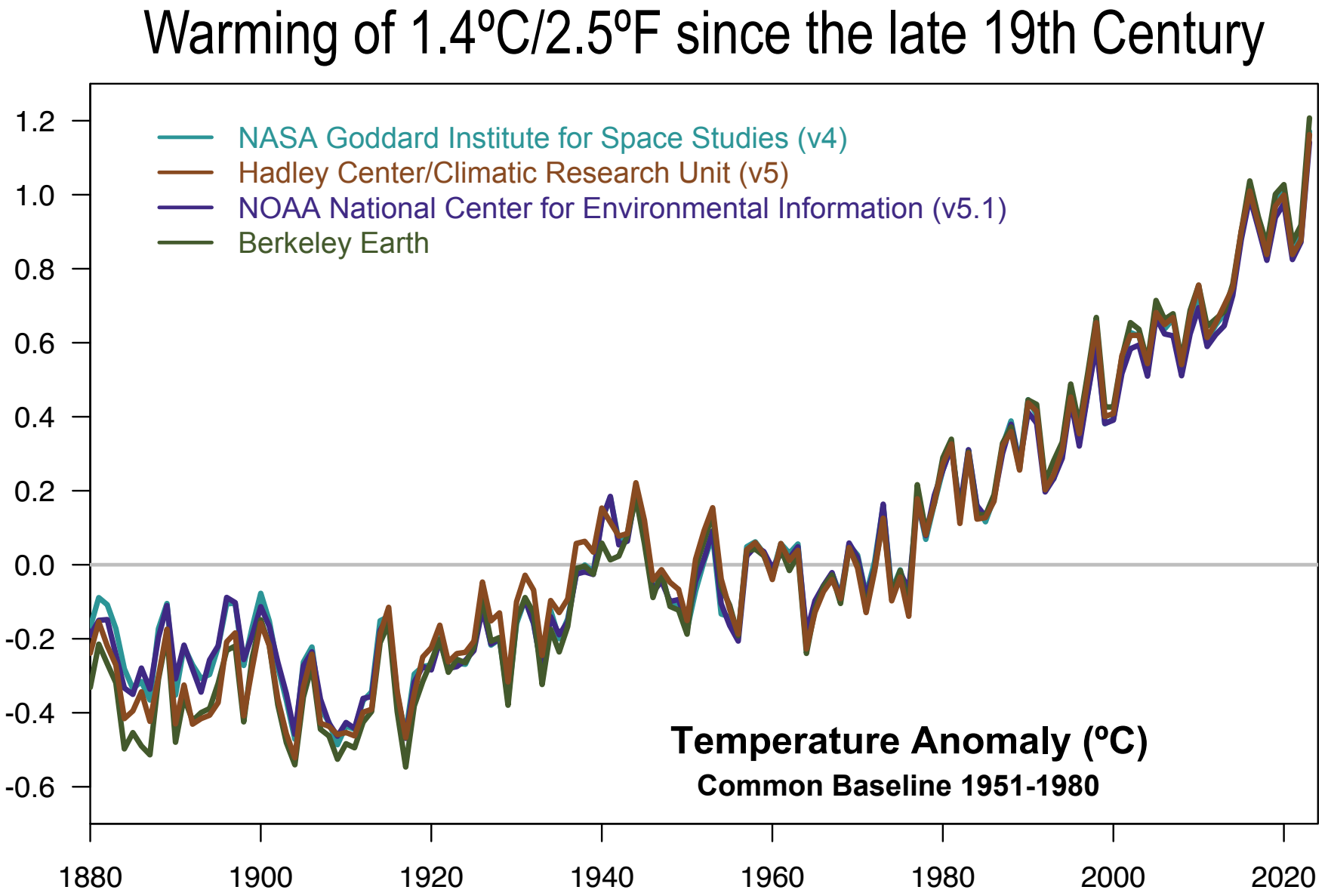
- Long-term changes in climate are understood in terms of increasing anthropogenic forcing
  - But w/intriguing regional anomalies
- Specifics of 2023 (and 2024) patterns and magnitude of heat are anomalous
- Many theories that are being worked on
- No reconciliation (yet)
- Unclear what (if any) implications for long term

Climate Change: Long Term trends

Surface Temperature

- GISTEMP (since 1981)
- Data from 1880

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



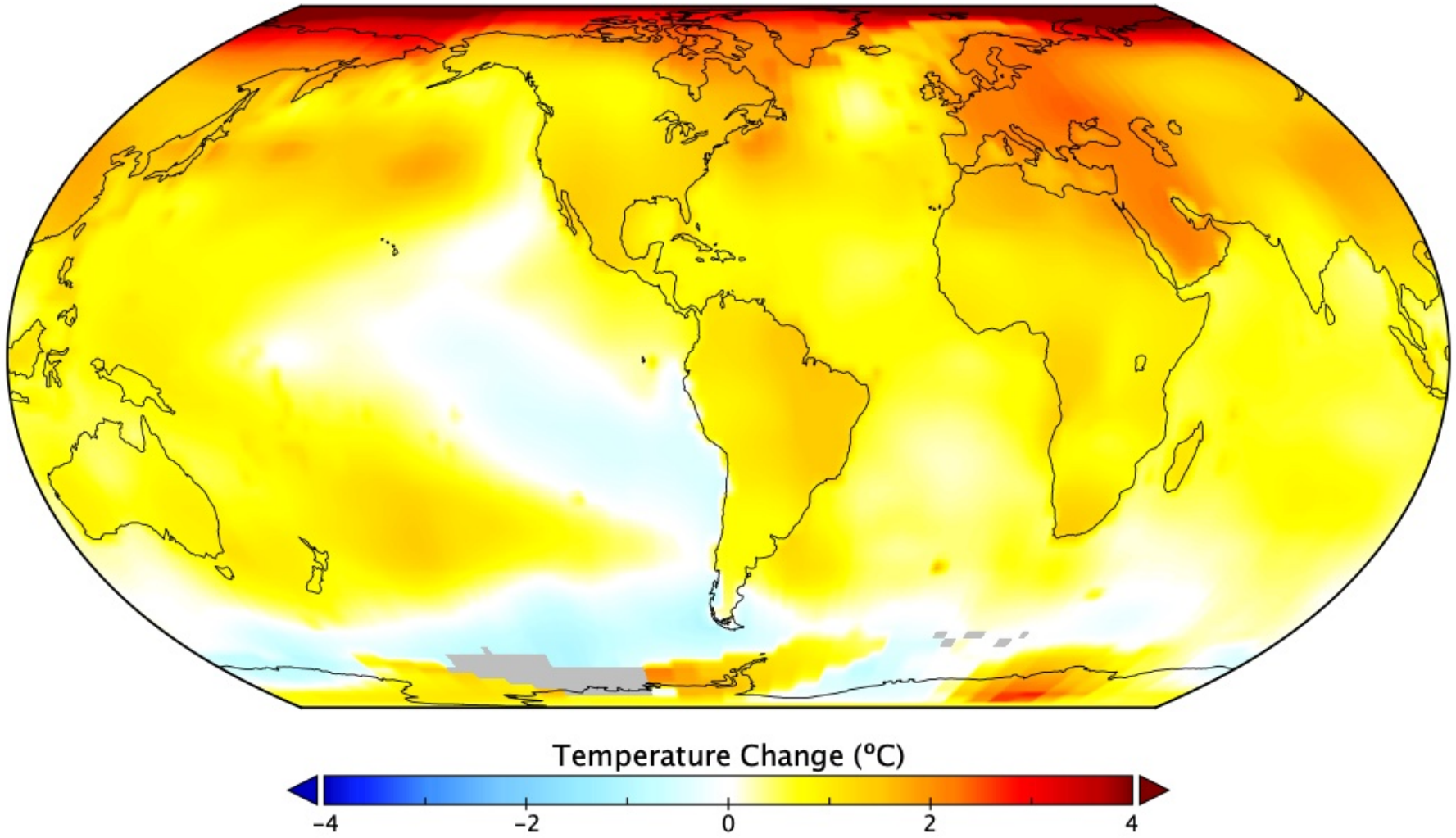
Surface Temperature

- Long term trends are clear
  - Surface products
  - Satellite products
  - Reanalysis

- Warming more over land than ocean
- More in the North than the South
- Arctic most of all

- Some relatively cool spots:
  - Southern Ocean
  - Eastern Tropical Pacific
  - mid-North Atlantic

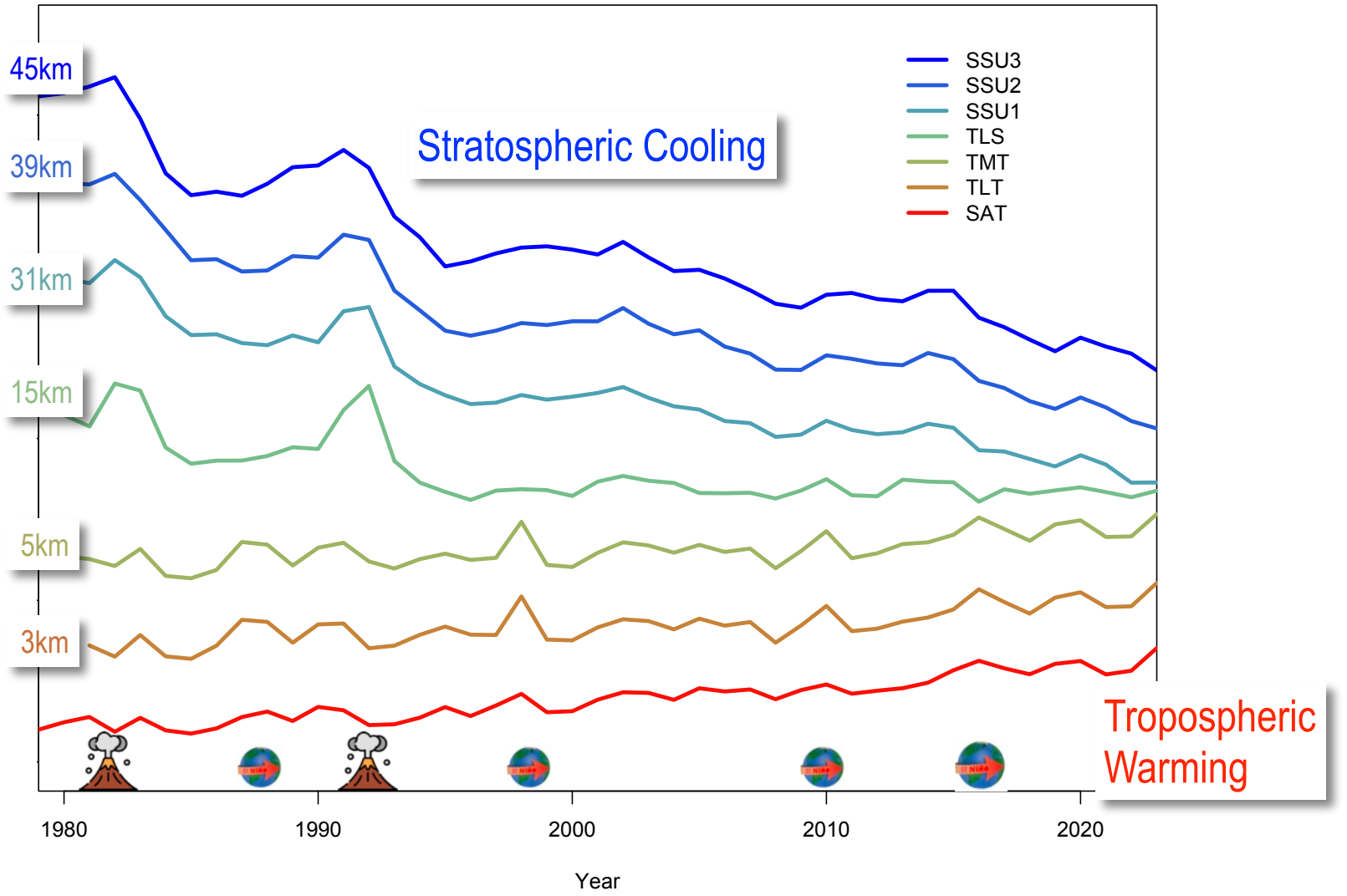
GISTEMP: Trends 1979-2023



Atmospheric Temperature

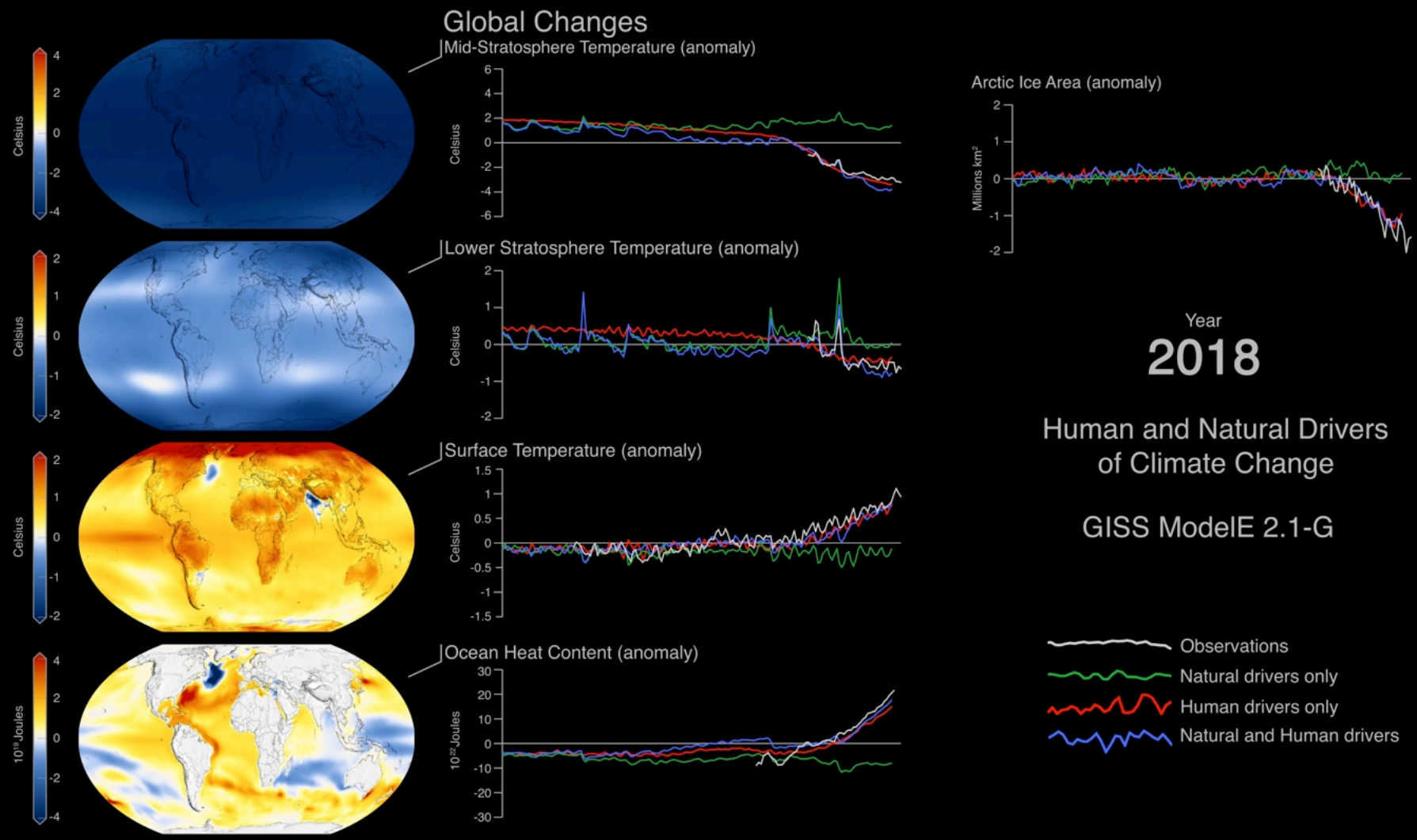
- MSU/SSU/AMSU (since 1979)

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



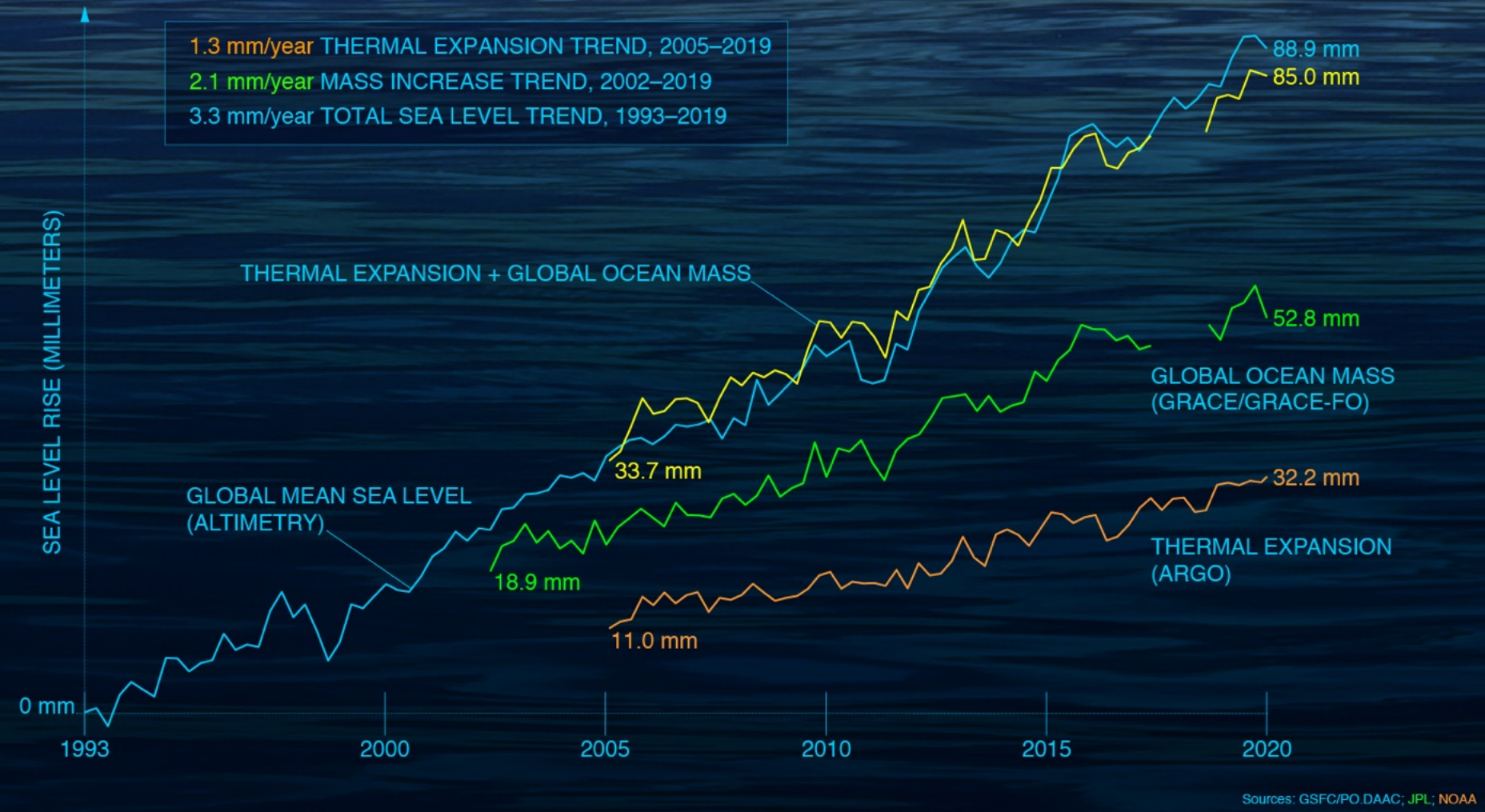
Climate Drivers

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



Global Sea Level Rise

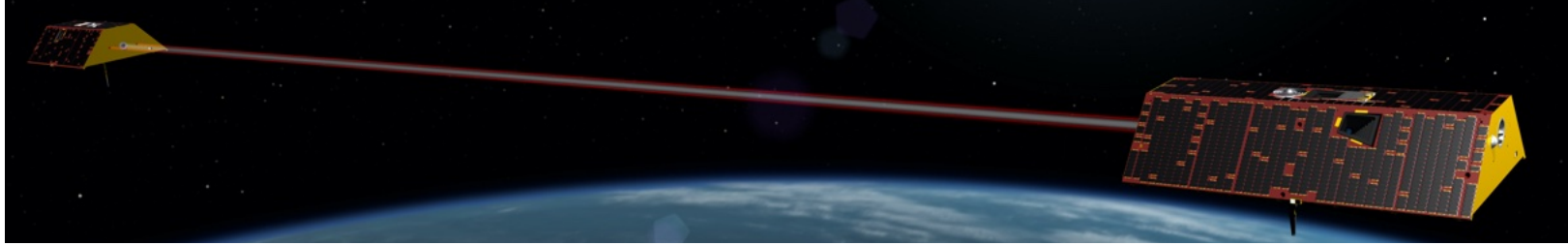
- Altimeter data matches estimates from Argo (thermal expansion) + mass addition from melting ice and groundwater extraction
- 2005-2019

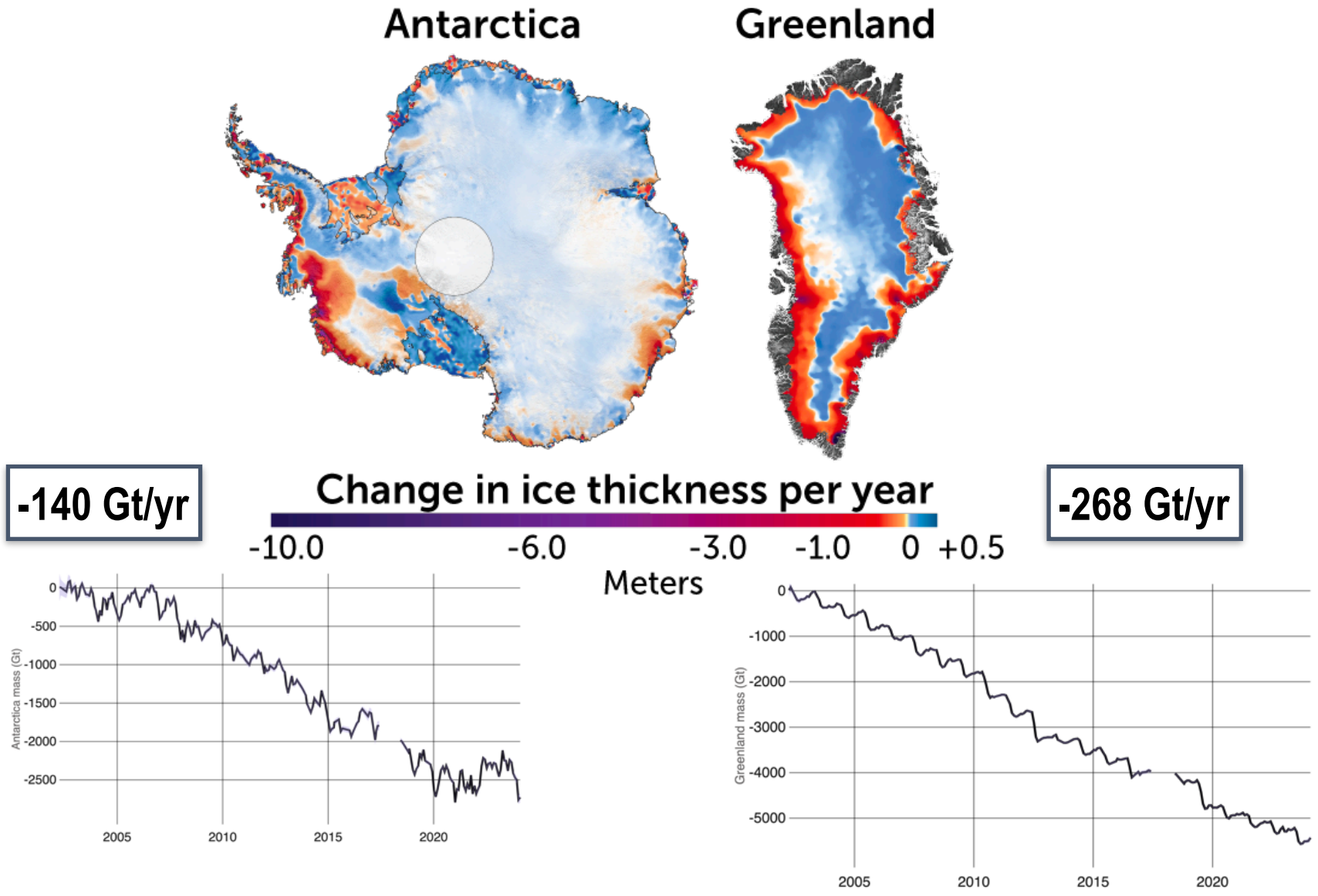


Ice Sheet Mass

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

- Trends April 2002-Dec 2023



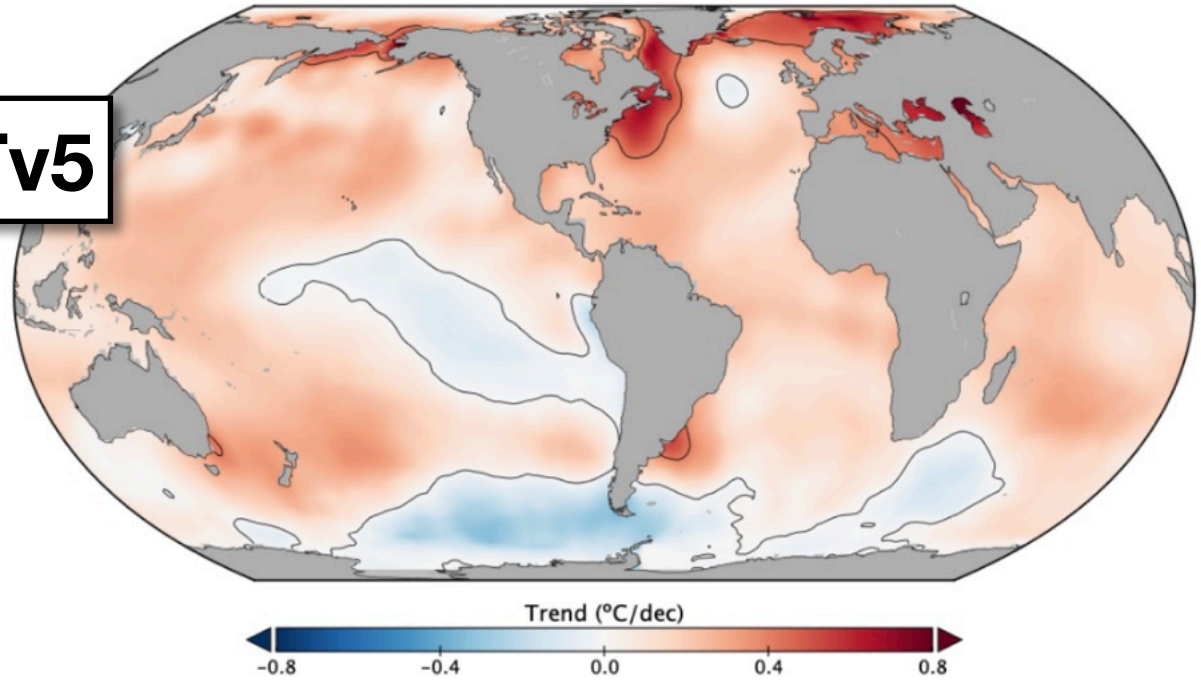


Climate Change: Long Term Discrepancies

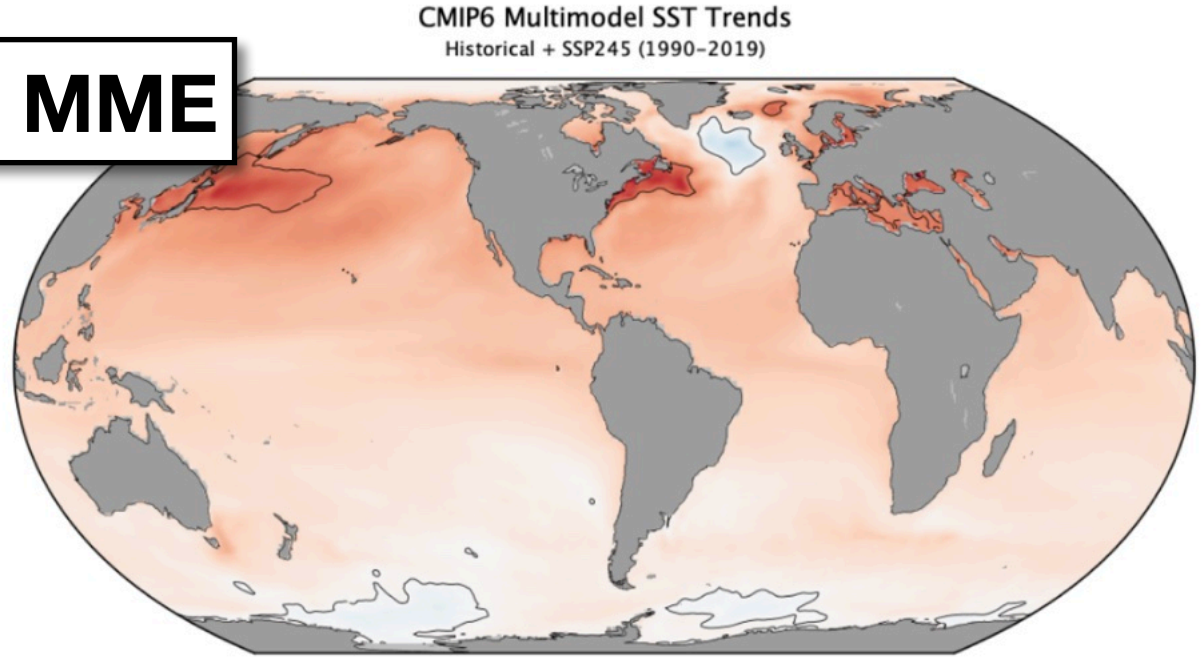
Some anomalies in recent SST trends

- 1990-2019
- Eastern Tropical Pacific
- Southern Ocean
- North Atlantic

ERSSTv5



CMIP6 MME

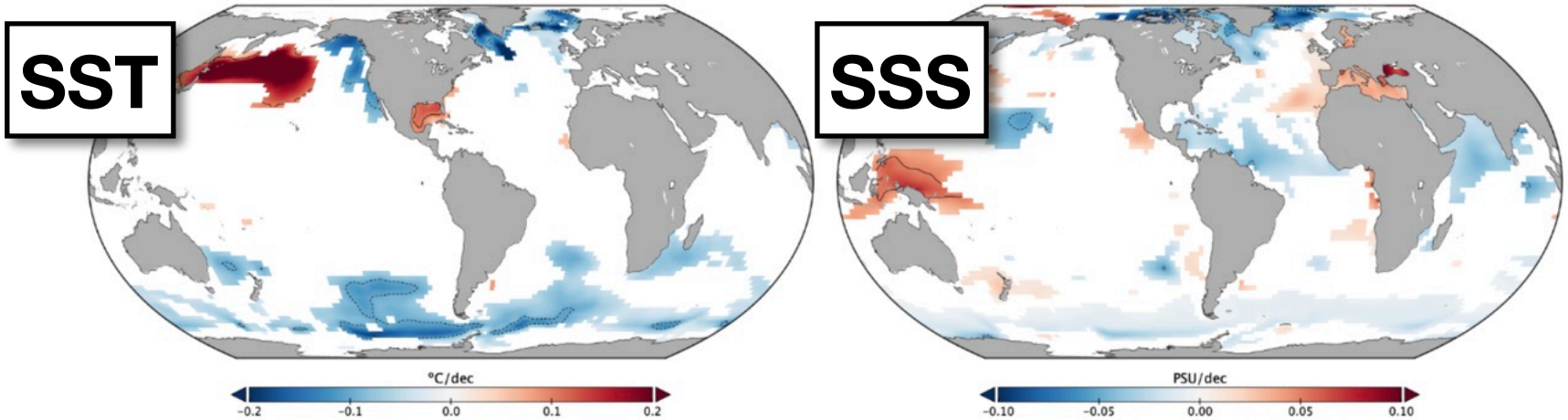


Tropical Ocean Possibilites?

- A short-term forced response (but not captured sufficiently in models)
- A long-term forced response asymmetric in El Niño /La Niña
- Internal variability (models don’t have enough)
- Evidence for each, but not definitive

Is Freshwater Addition from ice sheets a significant forcing?

- GISS ModelE2.1
- W and w/o observed rates of melt
- Impacts on sea level, salinity, temperature and sea ice in Southern Ocean
- Impact on East Coast sea level in North Atlantic
- Schmidt et al (2023)



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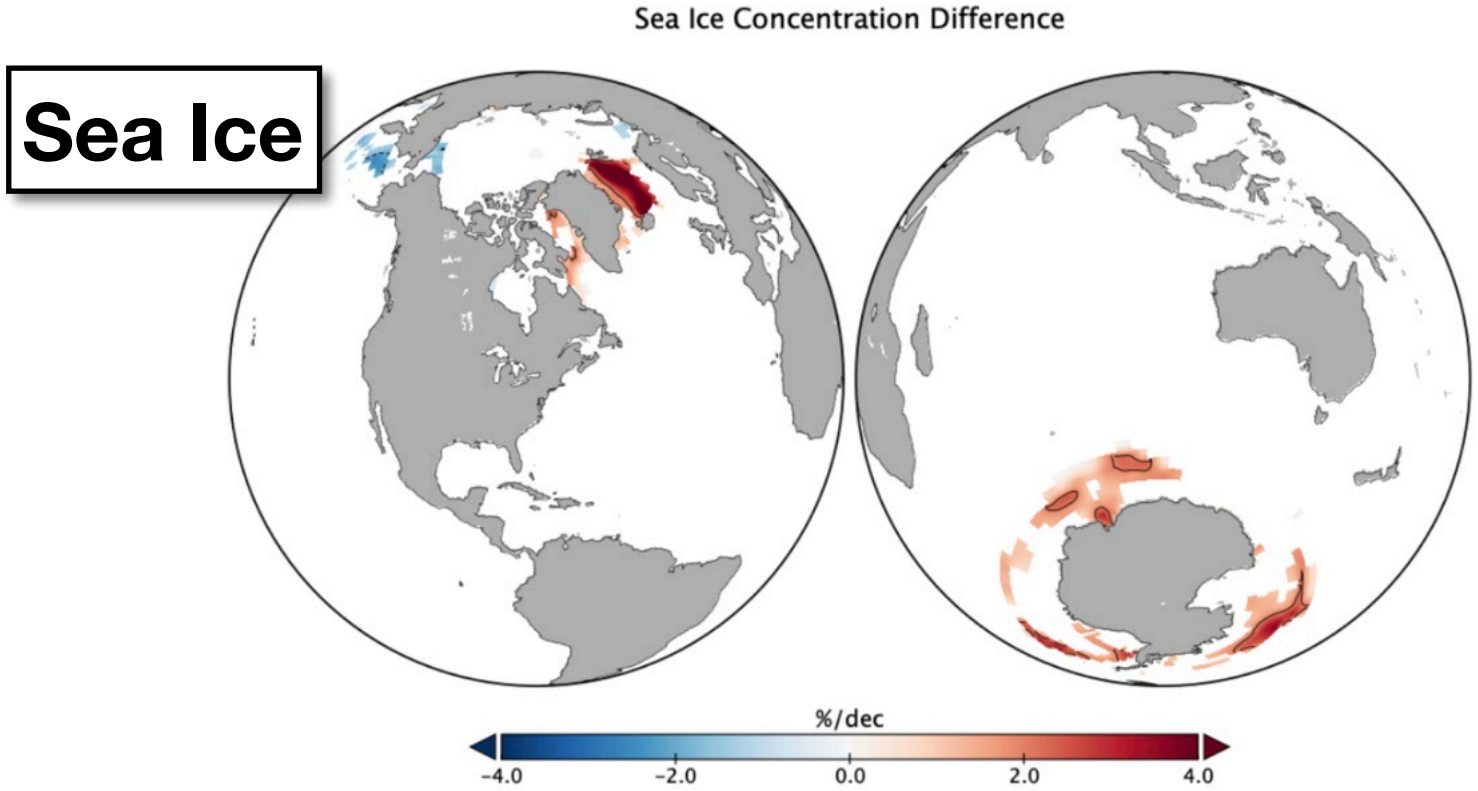
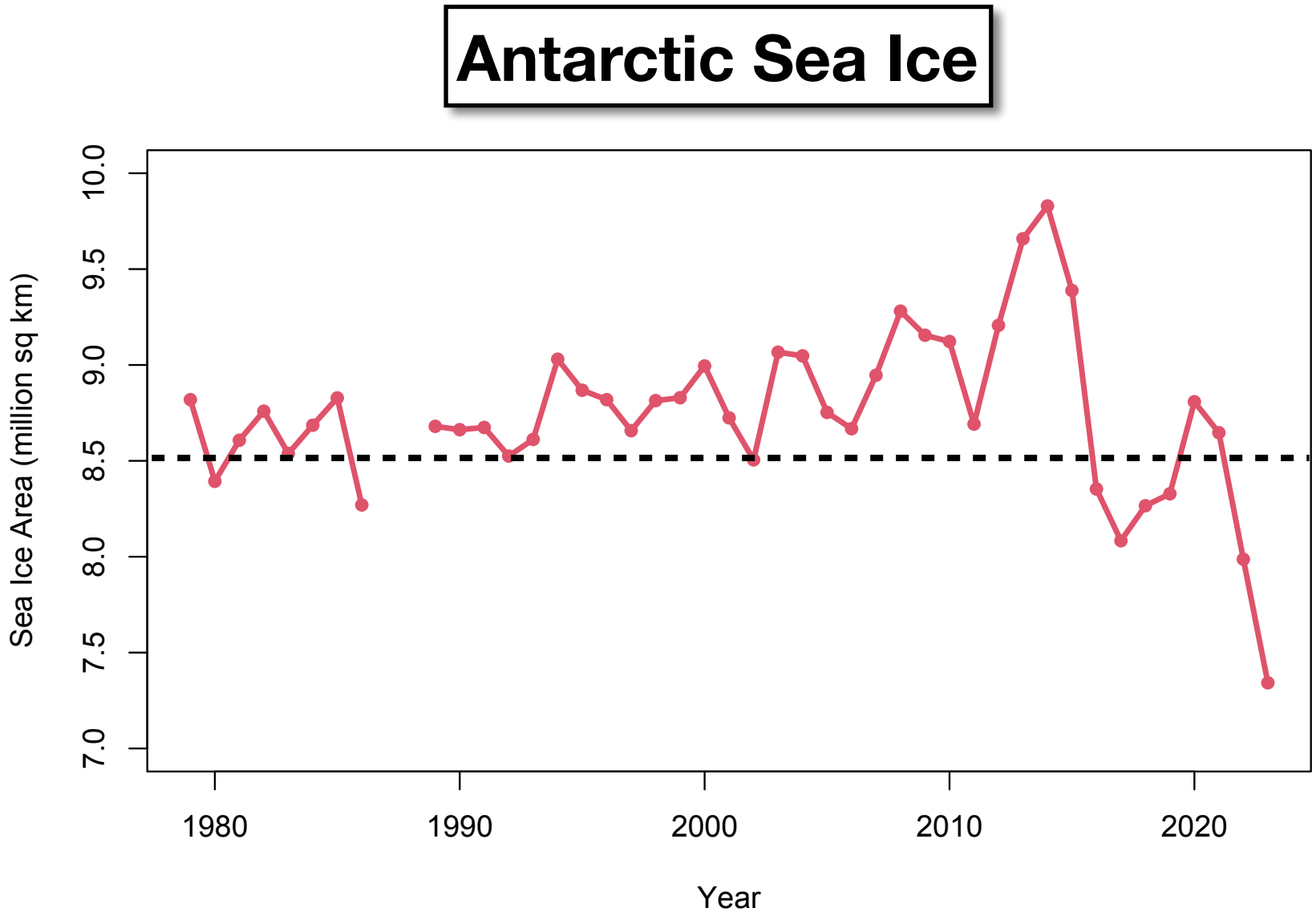


Recent Antarctic Sea Ice reached record lows

- SH Winter ice area was ~1 million sq km lower than normal.
- If increasing trend to 2015 was related to freshwater forcing, what cause the seeming regime change in 2022/2023…?

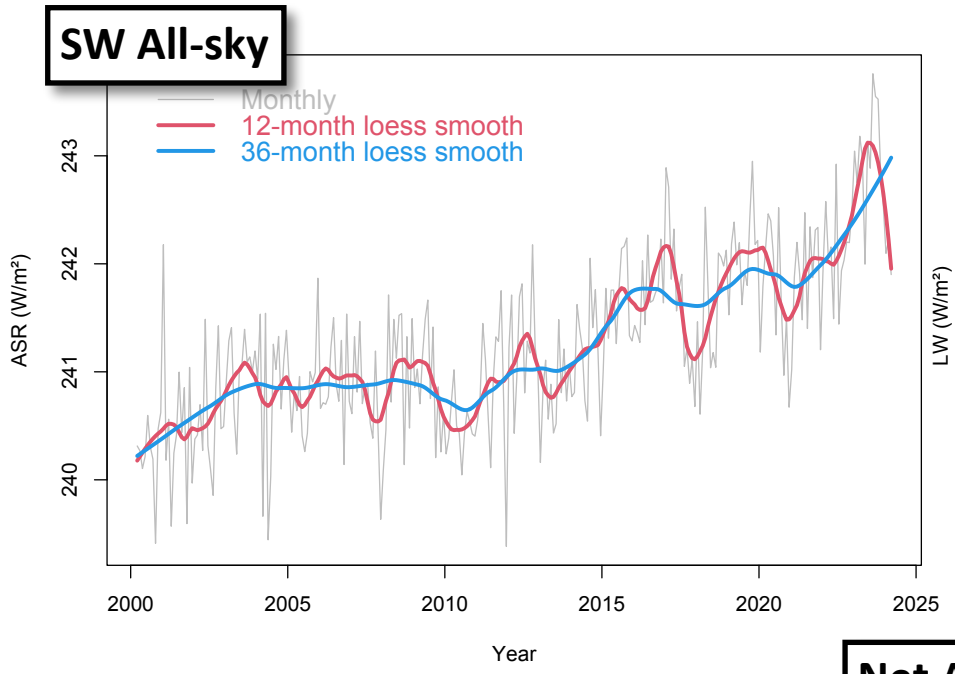


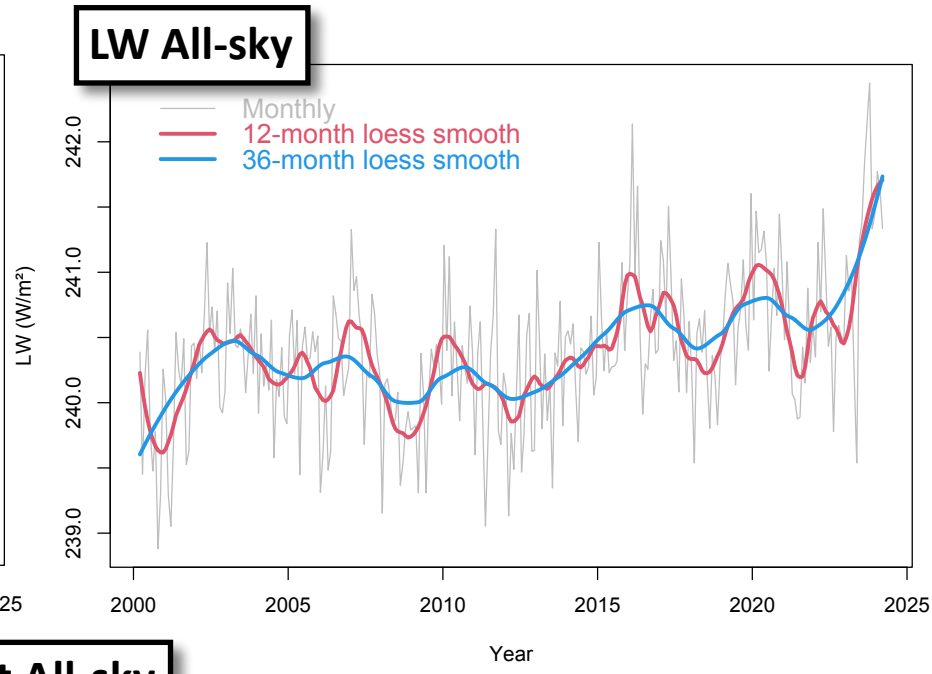
Earth's Energy Imbalance

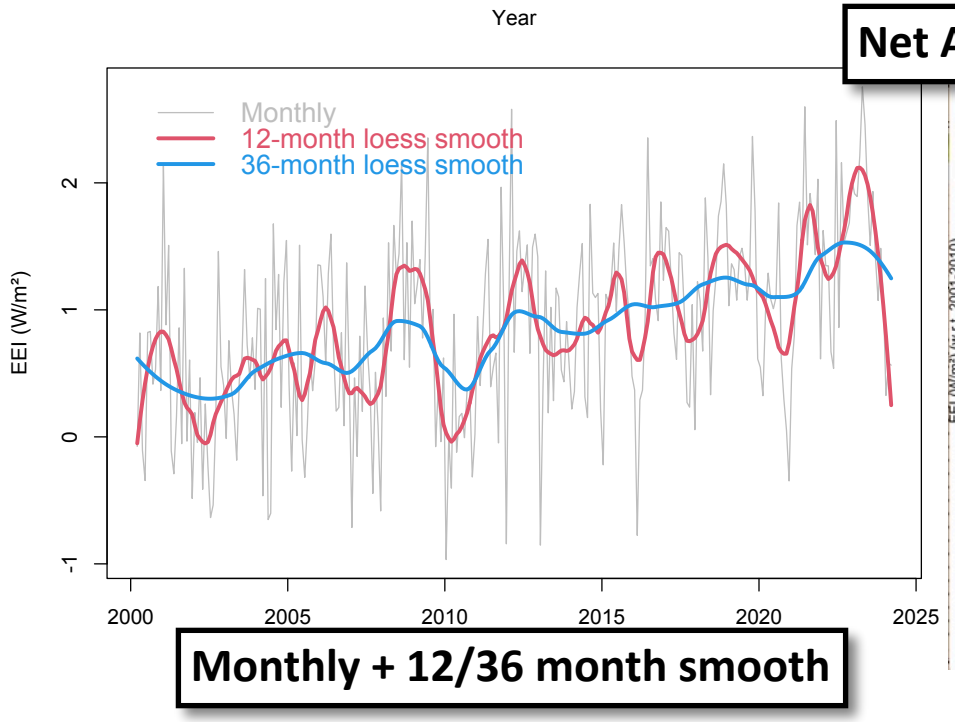
- Has accelerated in recent years (since about 2015)
- Acceleration not matched in magnitude by GCMs

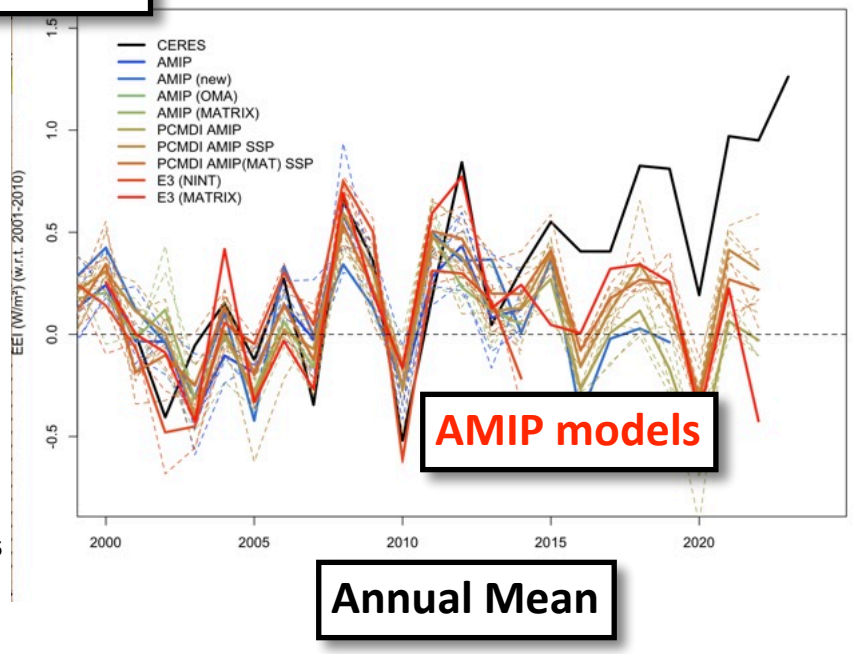
- Comparison is not quite right
  - Historical data to 2014 (2019)
  - Scenarios 2015-2023

- Updates needed to aerosol emissions, solar input, volcanoes…





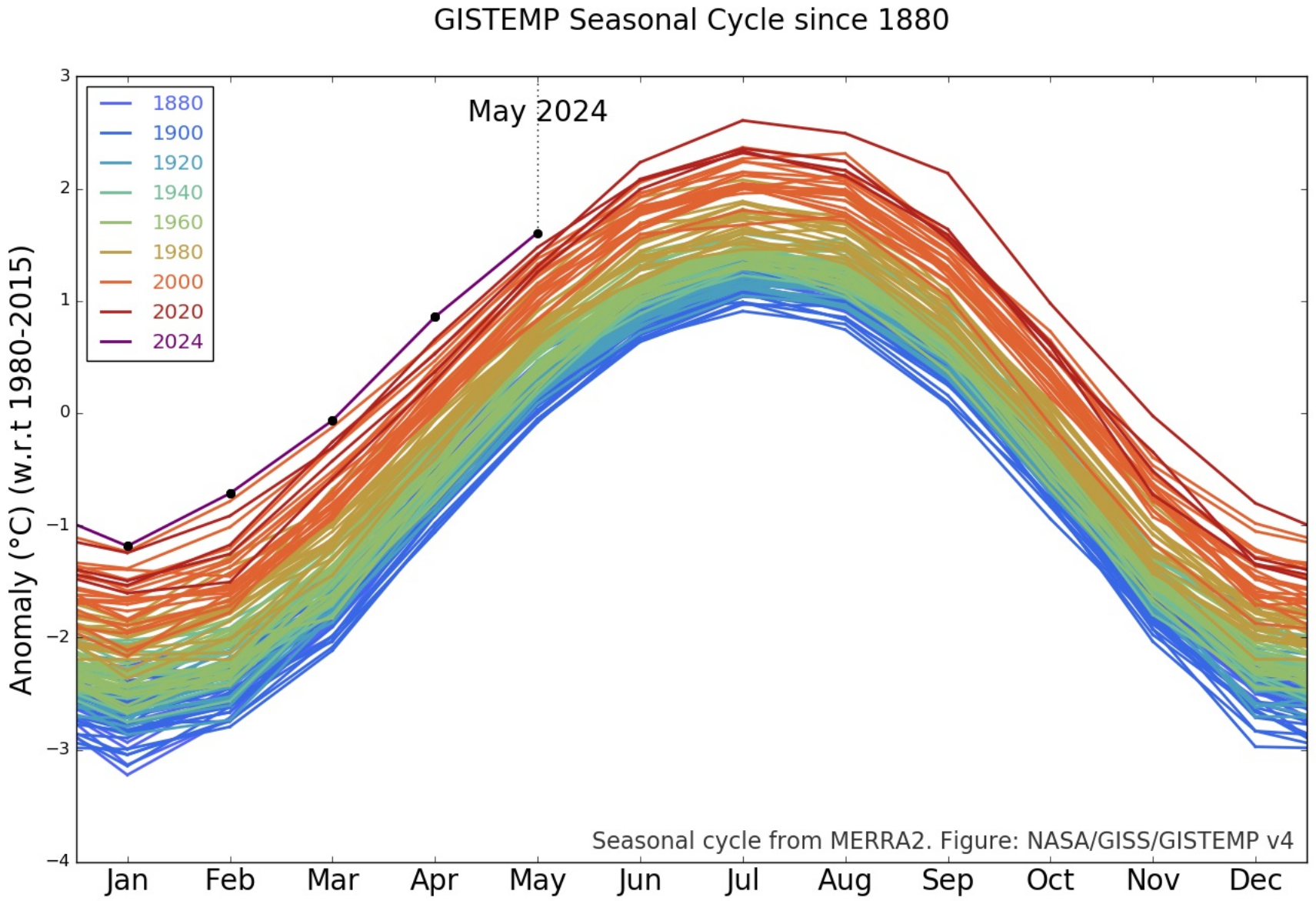




Climate Change: What happened in 2023?

Record-breaking last 12 months

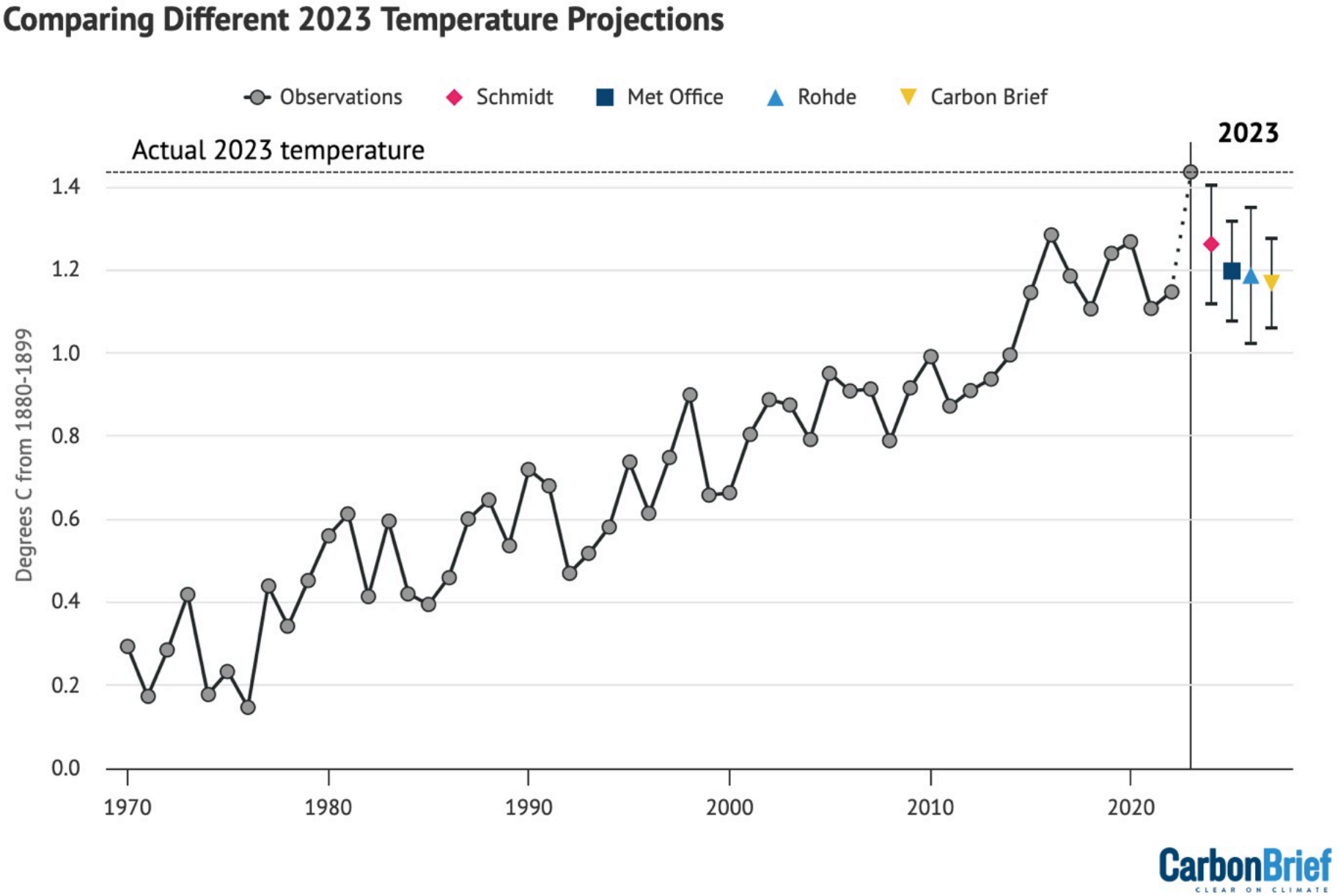
- GISTEMP results replicated by reanalyses, NOAA, AIRS, and MSU



Predictions at end of 2022 failed

- Simple statistical models
- Large scale initialized GCMs

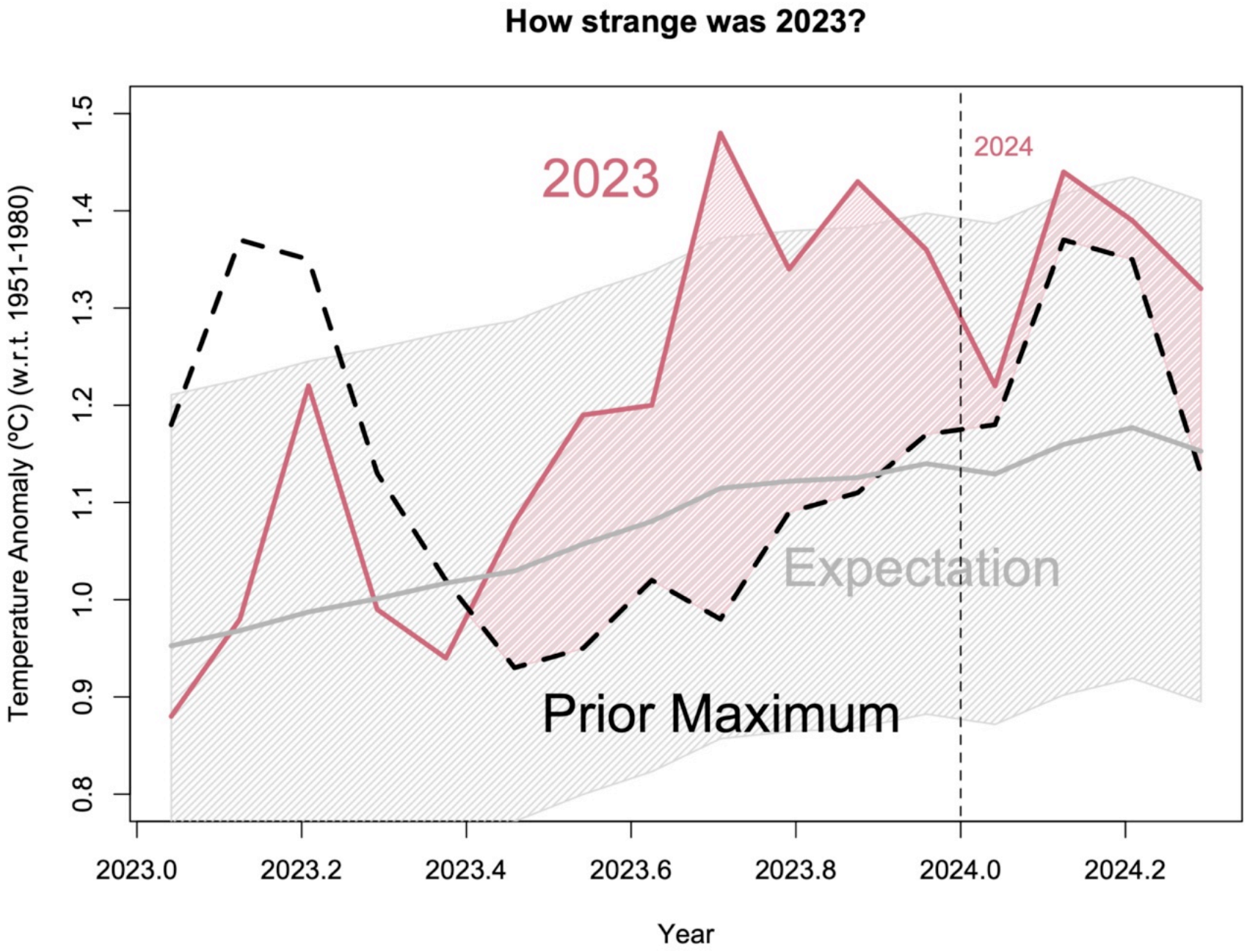
- All methods were taken by surprise by 2023 warmth



2023 was anomalous

- Roughly 0.2ºC to be explained beyond long-term trends and ENSO

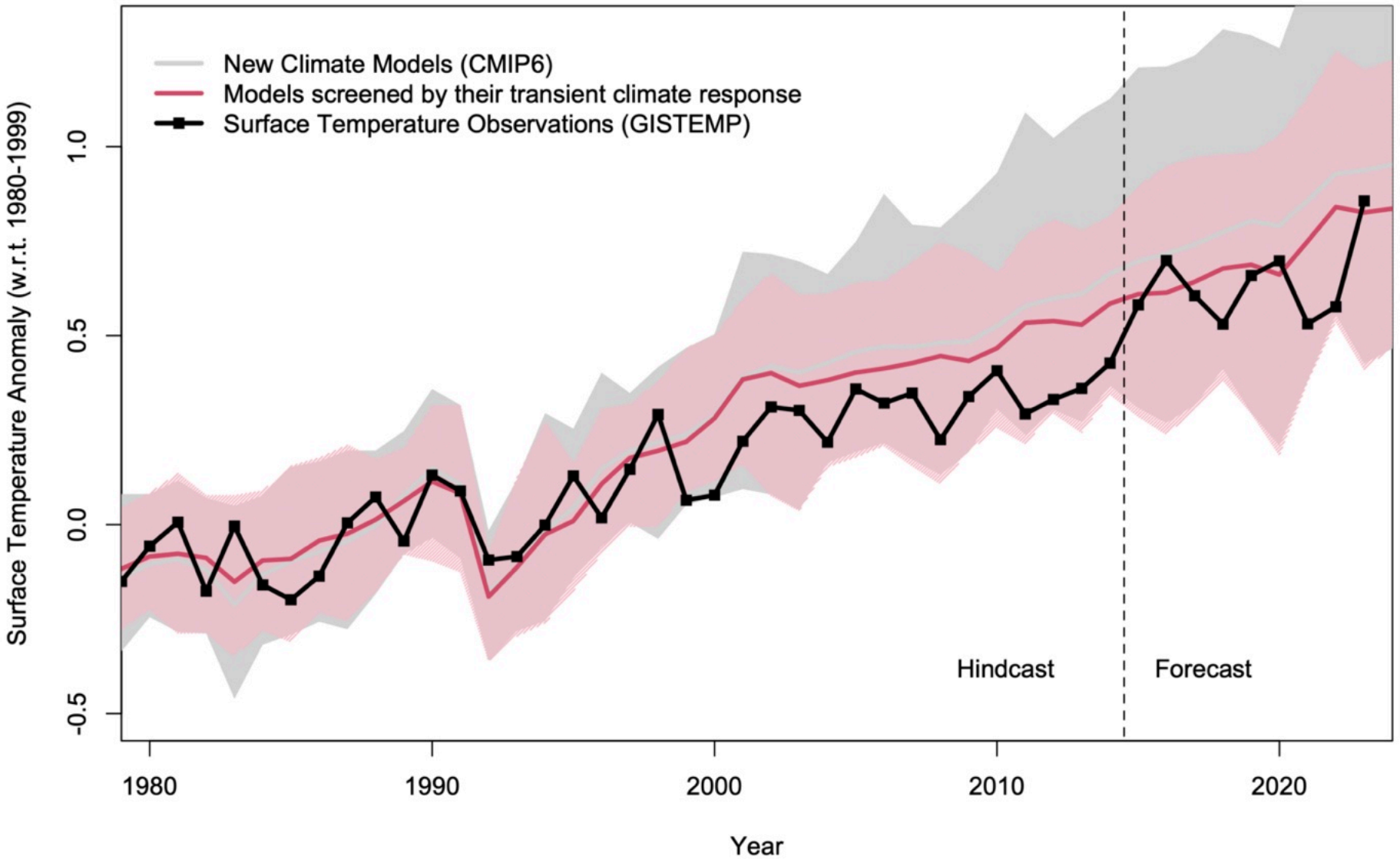
- Possibilities:
  - Hunga Tonga Hunga Ha'apai
  - IMO2020 regulations
  - Aerosol emissions from China falling
  - Solar cycle earlier/larger than predicted



CMIP6 Multi-model Ensemble

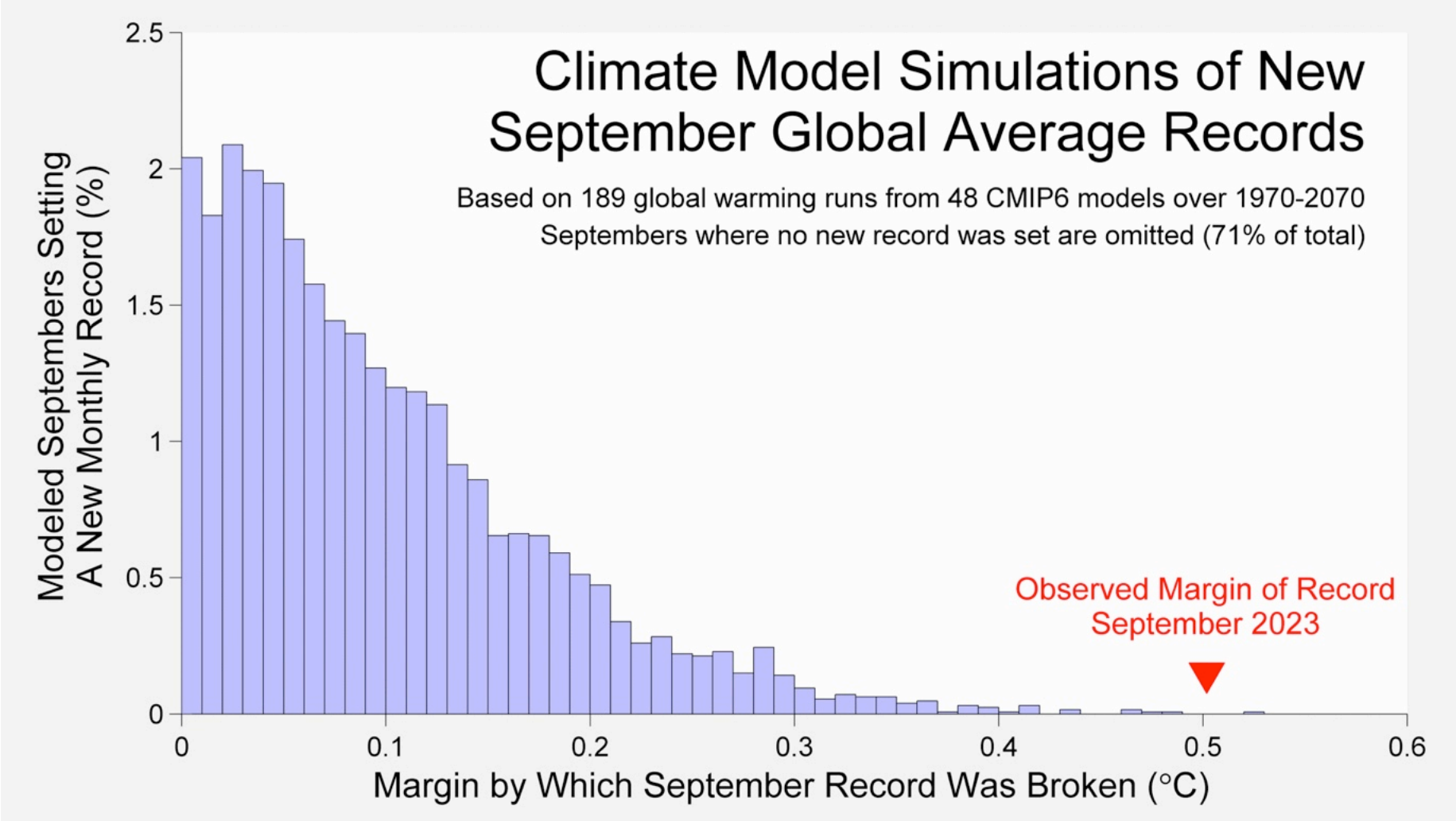
- Some models run hot
- Assessed projections are analogous to selecting models with reasonable sensitivities (pink)

- 2023 (and 2024) will be close to the subselected model mean.



Specifics of 2023 not captured in CMIP6 MME

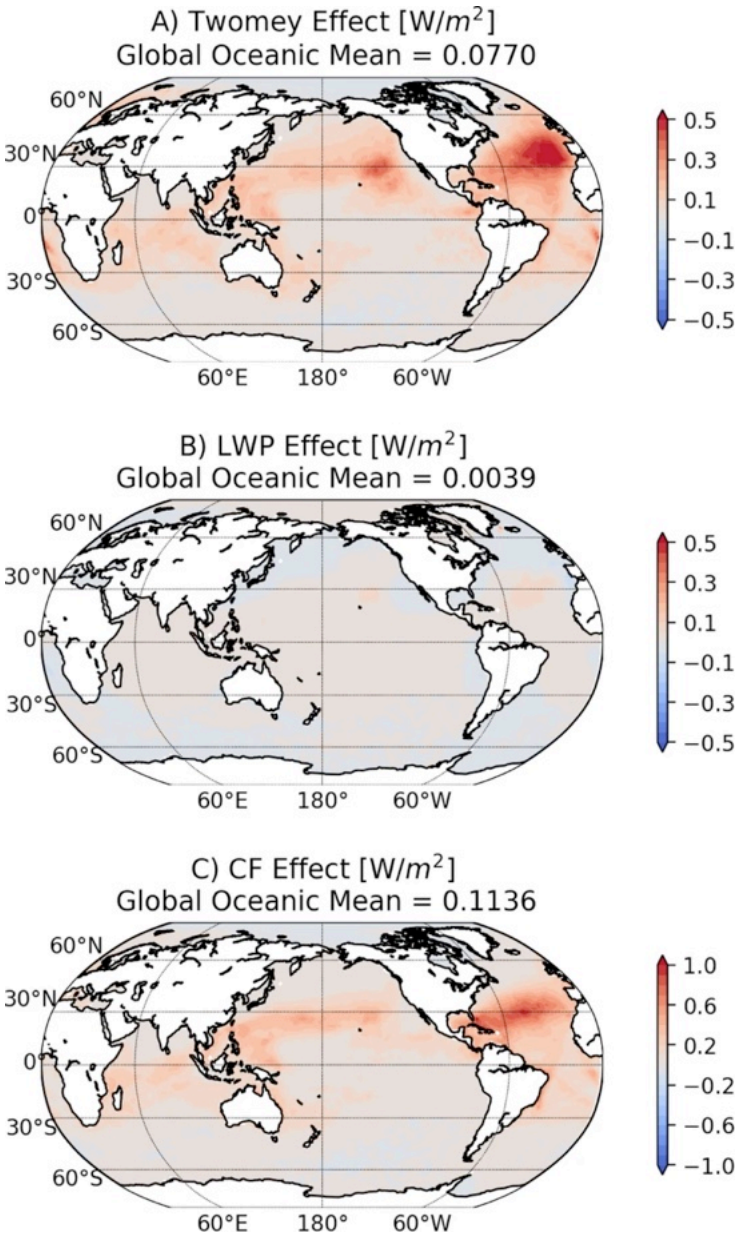
- September records as large as observed are very rare in the CMIP6 models.



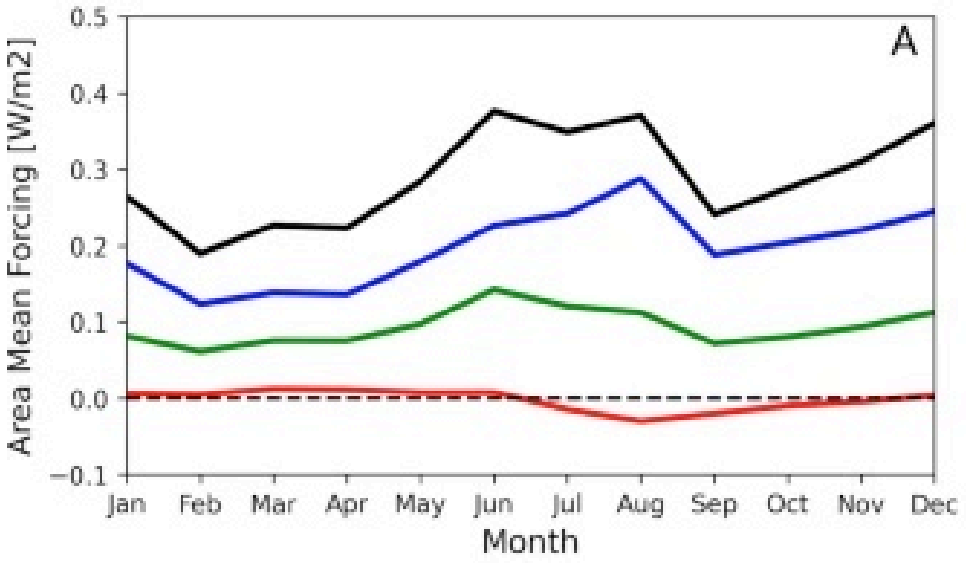
Impacts of IMO2020

- Abrupt change in marine shipping emissions in Jan 2020
- Yuan et al (2024)
- Forcing of 0.14 W/m2 globally
- => ~0.1ºC warming

- New papers/estimates ongoing



Seasonality and spatial pattern



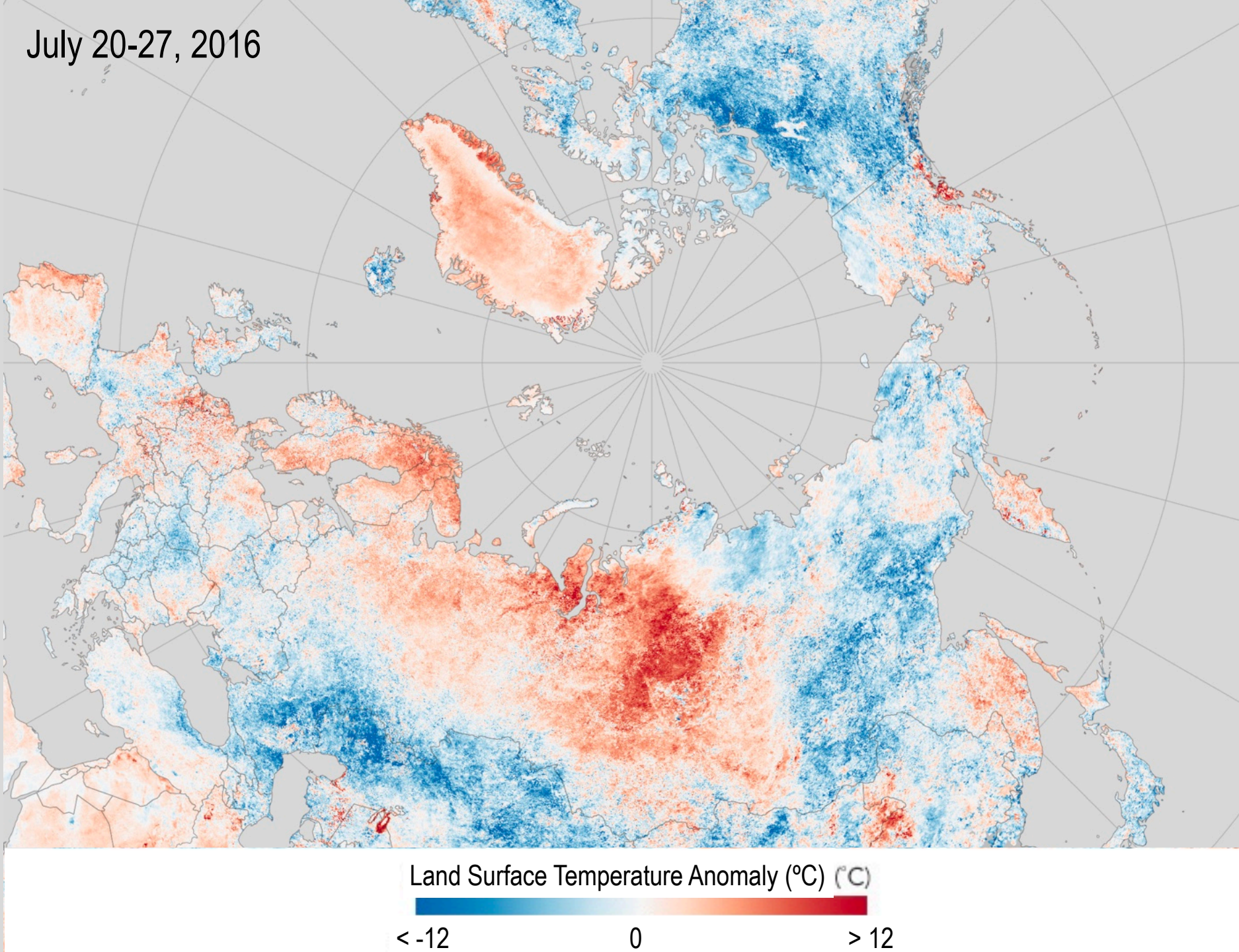
Climate Change: Impacts

Heat Waves

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

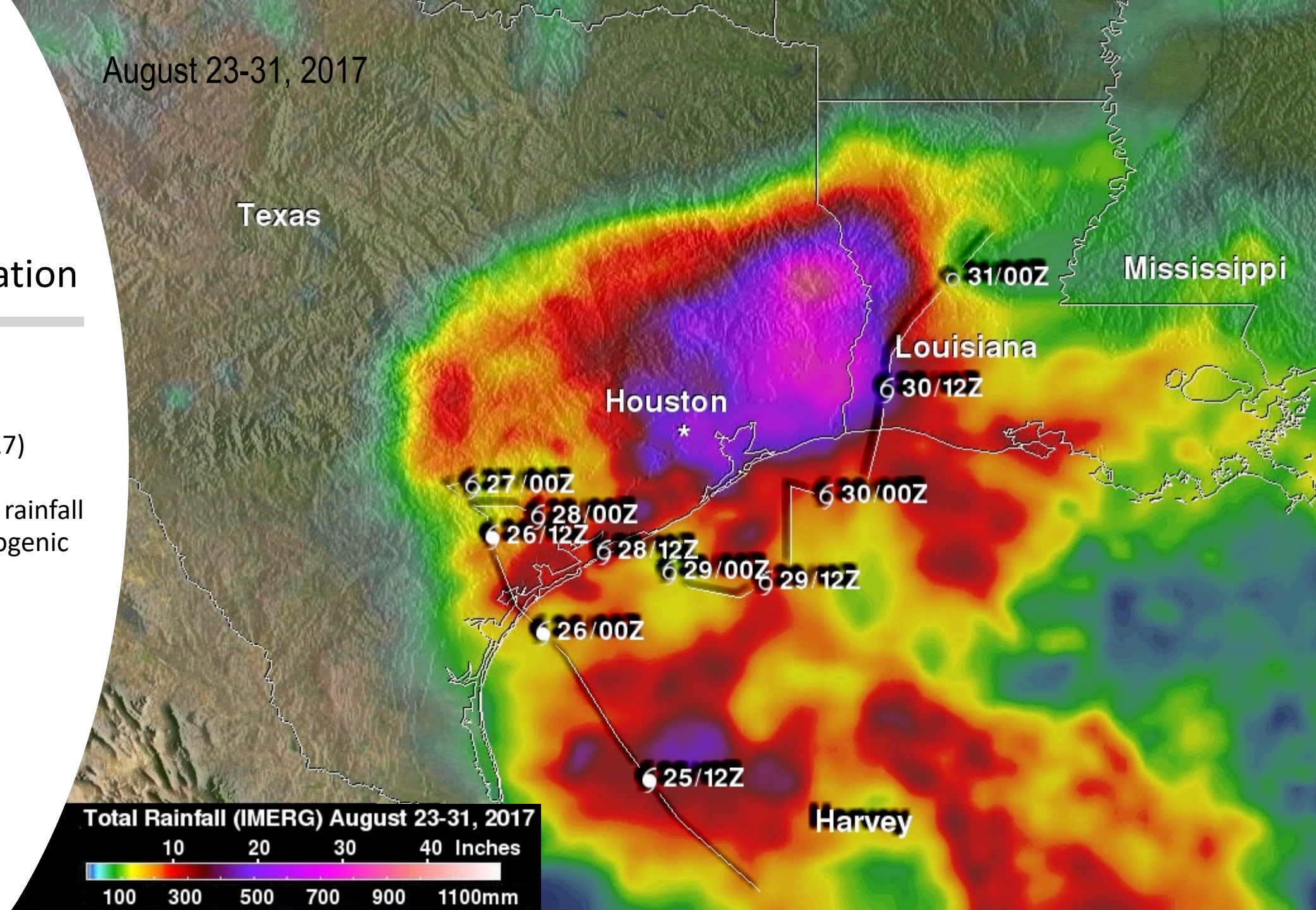
- Record breaking heat waves in 2016, 2018, 2020

- Clear trends in heatwave incidence and cumulative intensity since 1960



Intense Precipitation

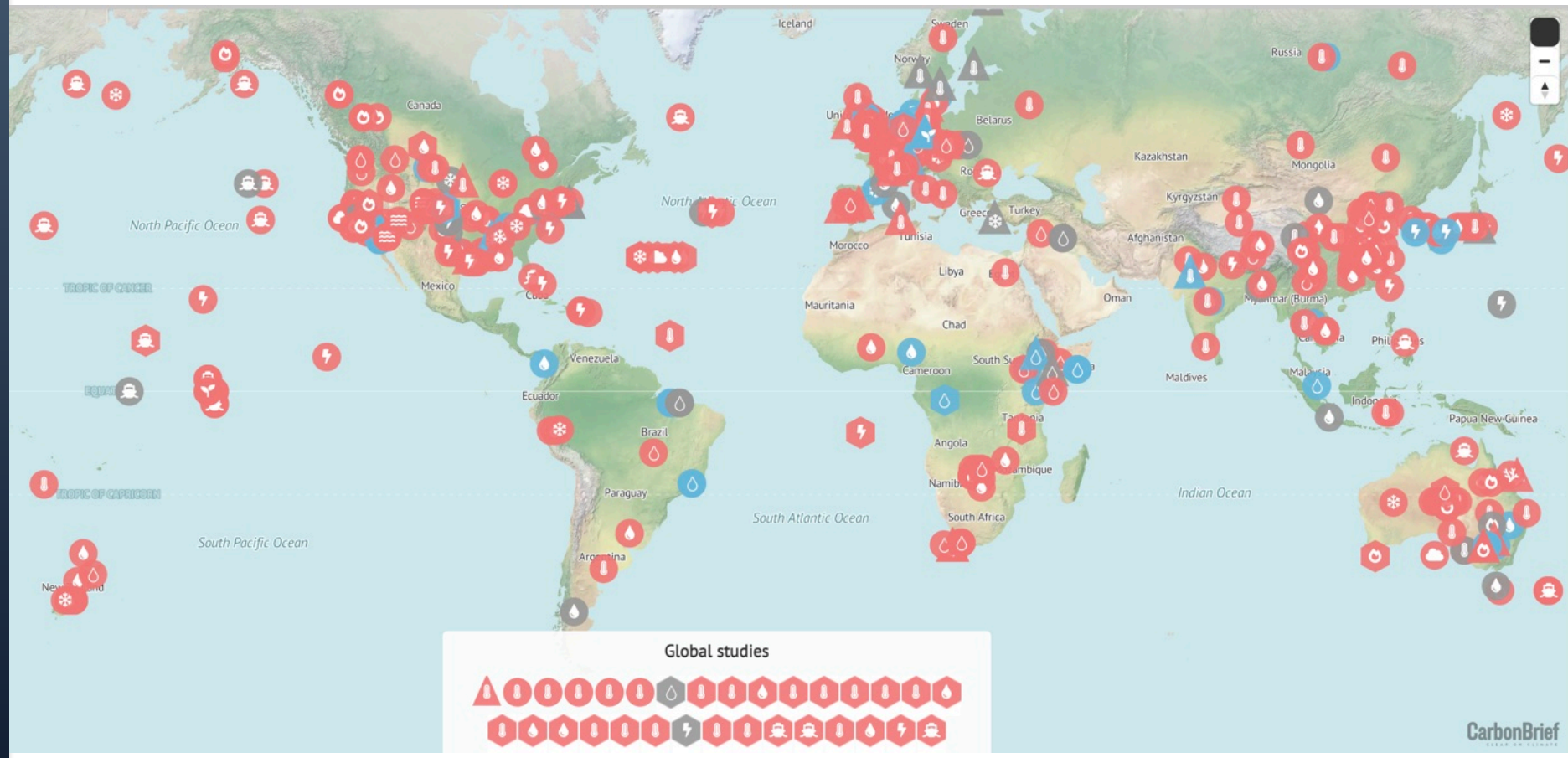
- GPM (since 2014)
- Hurricane Harvey (2017)
- Estimates are ~20% of rainfall attributable to anthropogenic causes.

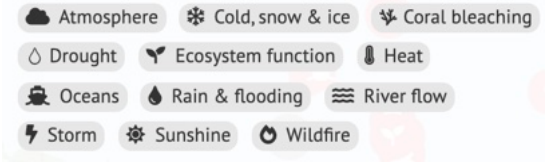


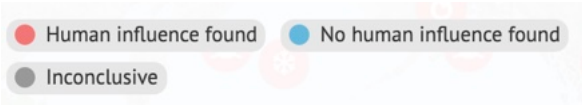
Attribution

- 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

What we do (& don't) know

- Long-term changes in climate are understood in terms of increasing anthropogenic forcing
  - But w/intriguing regional anomalies
- Specifics of 2023 (and 2024) patterns and magnitude of heat are anomalous
- Many theories that are being worked on
- No reconciliation (yet)
- Unclear what (if any) implications for long term

What we need to do

- Continue monitoring the climate and ensuring risks of gaps in climate data records are minimized
- “Operationalize” (some) climate modeling as service
  - Annual updates to input data (funded!)
  - Commitment from centers to update simulations on shorter timescales than IPCC cycles
  - More frequent updates to scenarios/assessed projections (perhaps via ML)
  - Continued development of structurally diverse models
- National-level data analytics facility to encourage better analyses, ML applications, and better access

National Aeronautics and Space Administration

EARTH FLEET

Key

- International Partners
- U.S. Partner
- ISS Instrument
- JPSS Instrument
- Cubesat
- Launch Date TBD
- Earth System Observatory Mission
- (Pre) Formulation
- Implementation
- Operating
- Extended

Invest/CubeSats

- NACHOS 2022
- CTIM 2022
- NACHOS-2 2022
- MURI-FD 2023
- SNOOPI* 2024
- HYTI* 2024
- ARGOS* 2024

JPSS Instruments

- OMPS-LIMB 2022
- LIBERA 2027
- OMPS-LIMB 2027
- OMPS-LIMB 2032

ISS INSTRUMENTS

MISSIONS

NASA earth

05.31.2024

Thank you!