

National Aeronautics and
Space Administration



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

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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 climate hell', UN boss warns, as records are 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 consecutive month 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

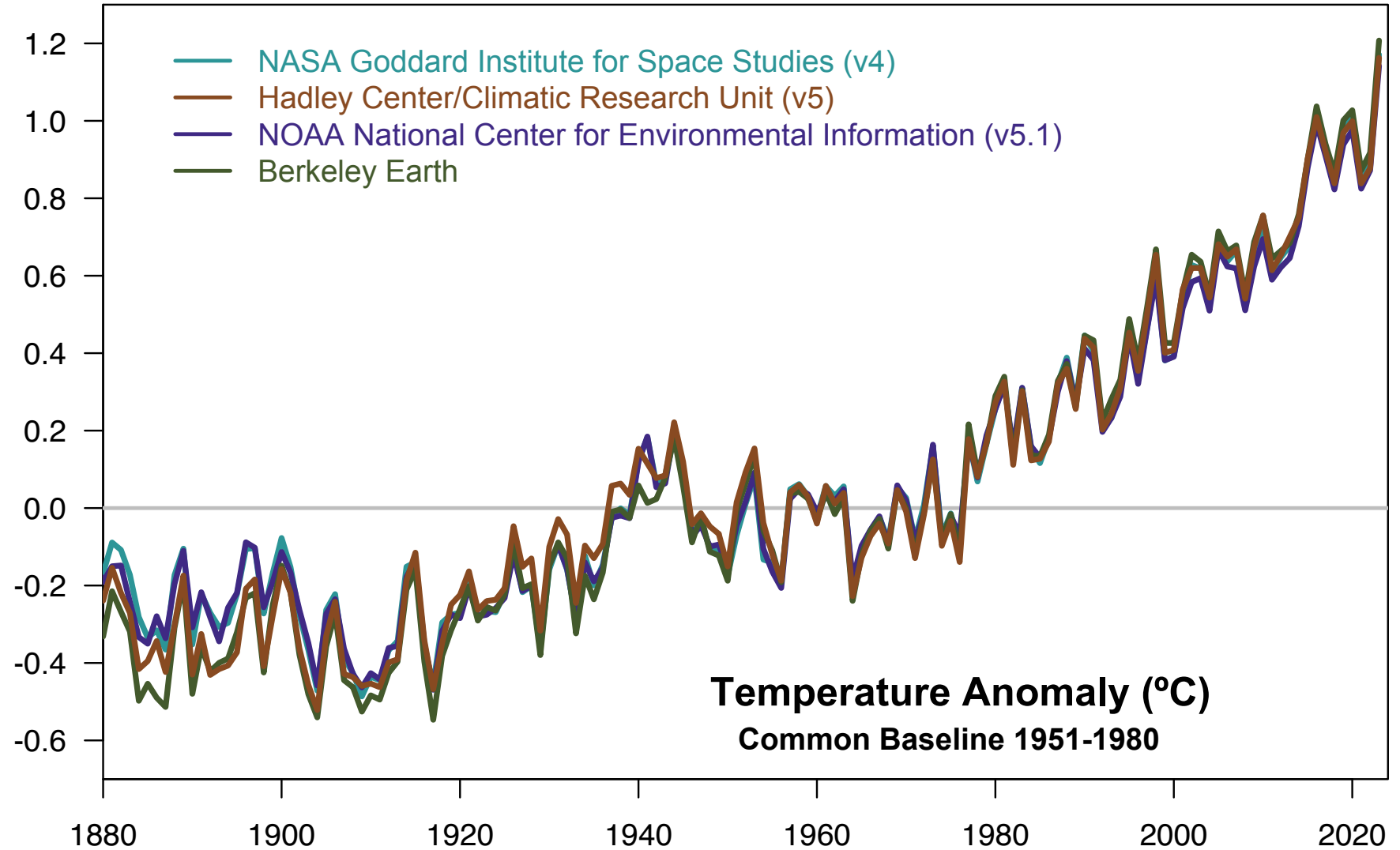
The background of the slide is a cosmic image featuring a dark space filled with stars and nebulae. The top half shows a blue and teal nebula, while the bottom half shows a bright orange and yellow nebula. A horizontal light blue band runs across the middle, containing the title text.

Climate Change: Long Term trends

Surface Temperature

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

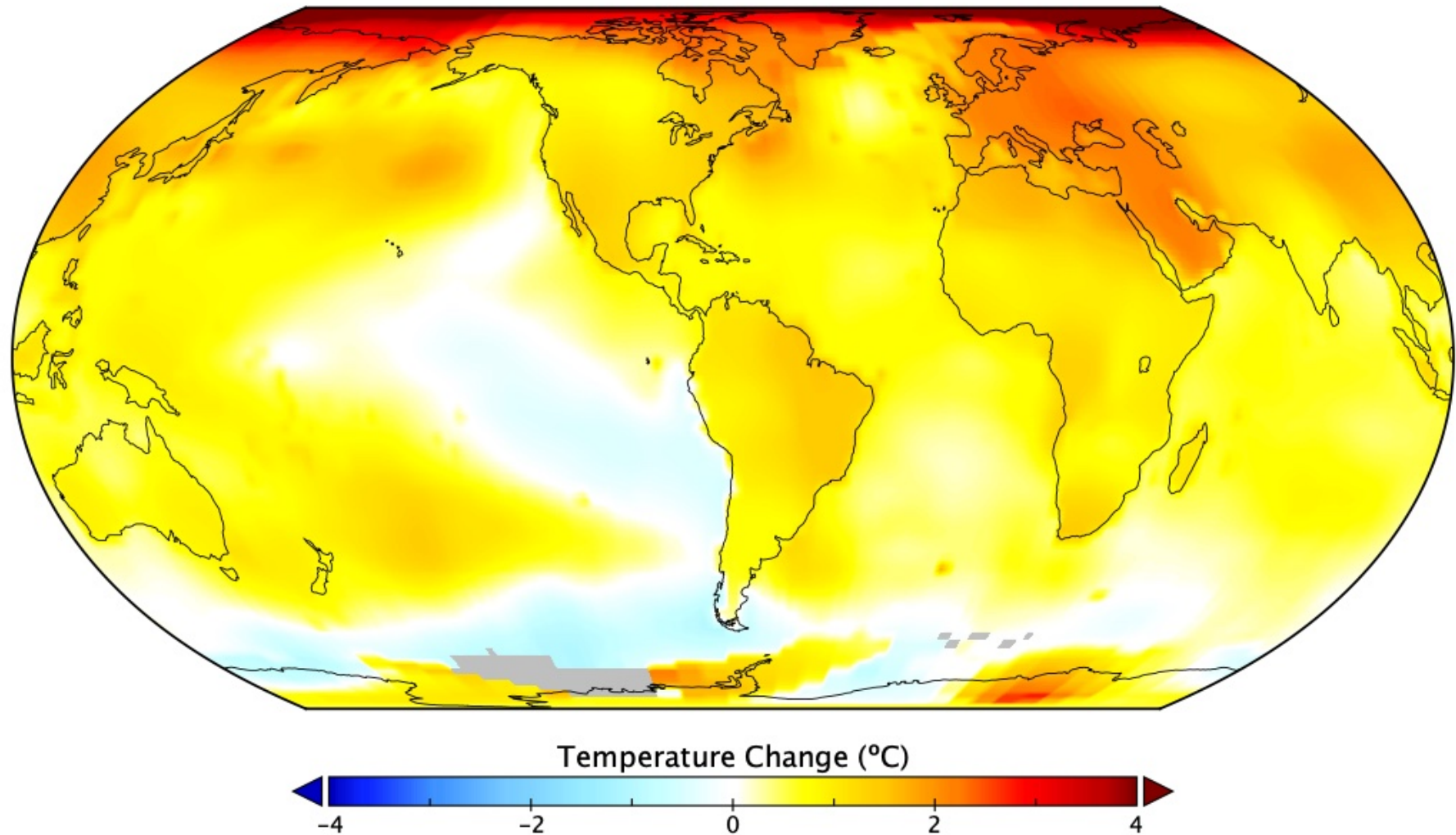
Warming of 1.4°C/2.5°F since the late 19th Century



GISTEMP: Trends 1979-2023

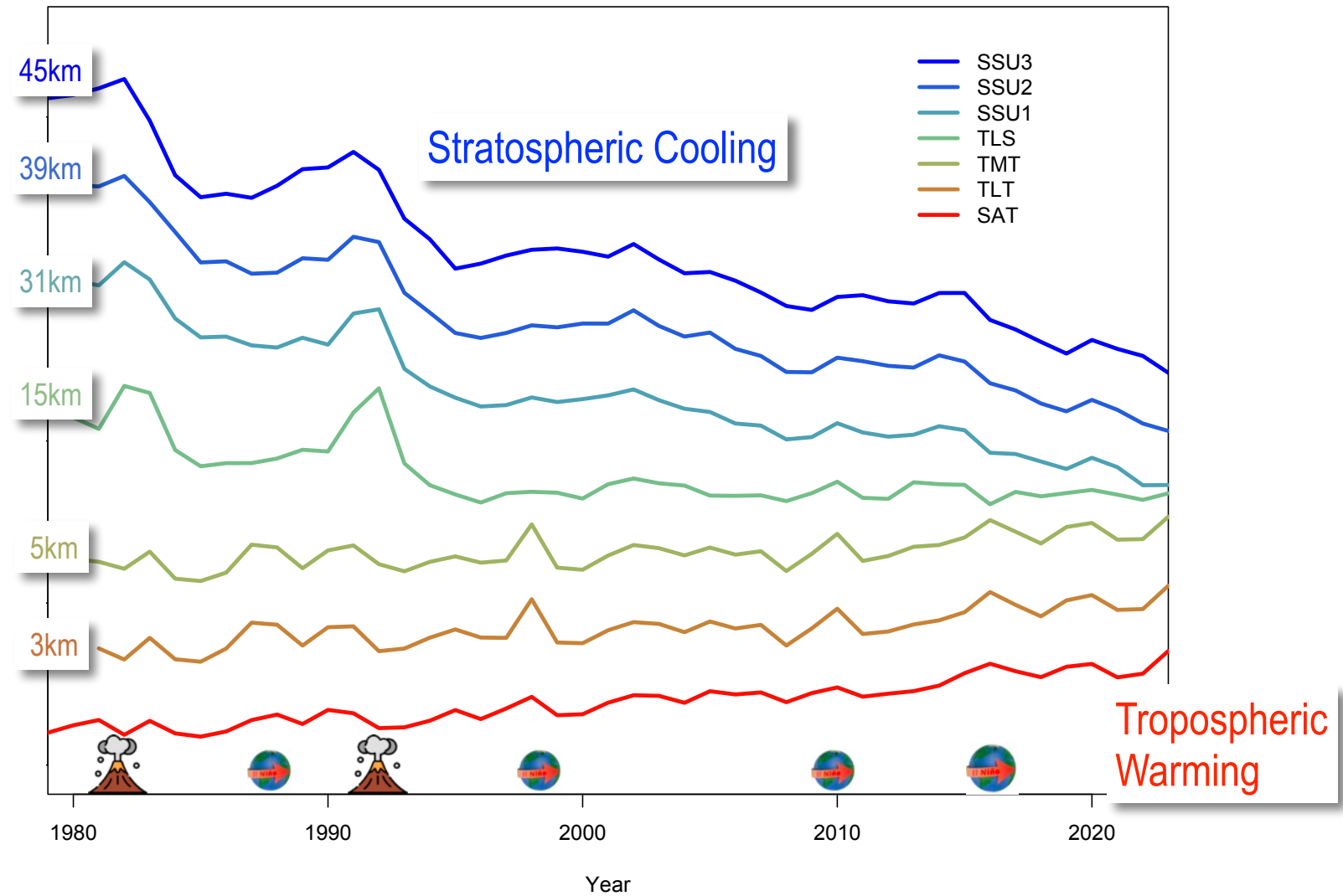
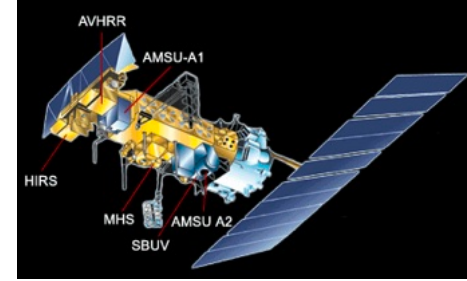
Surface Temperature

- 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



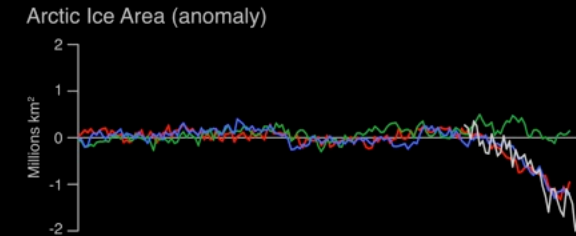
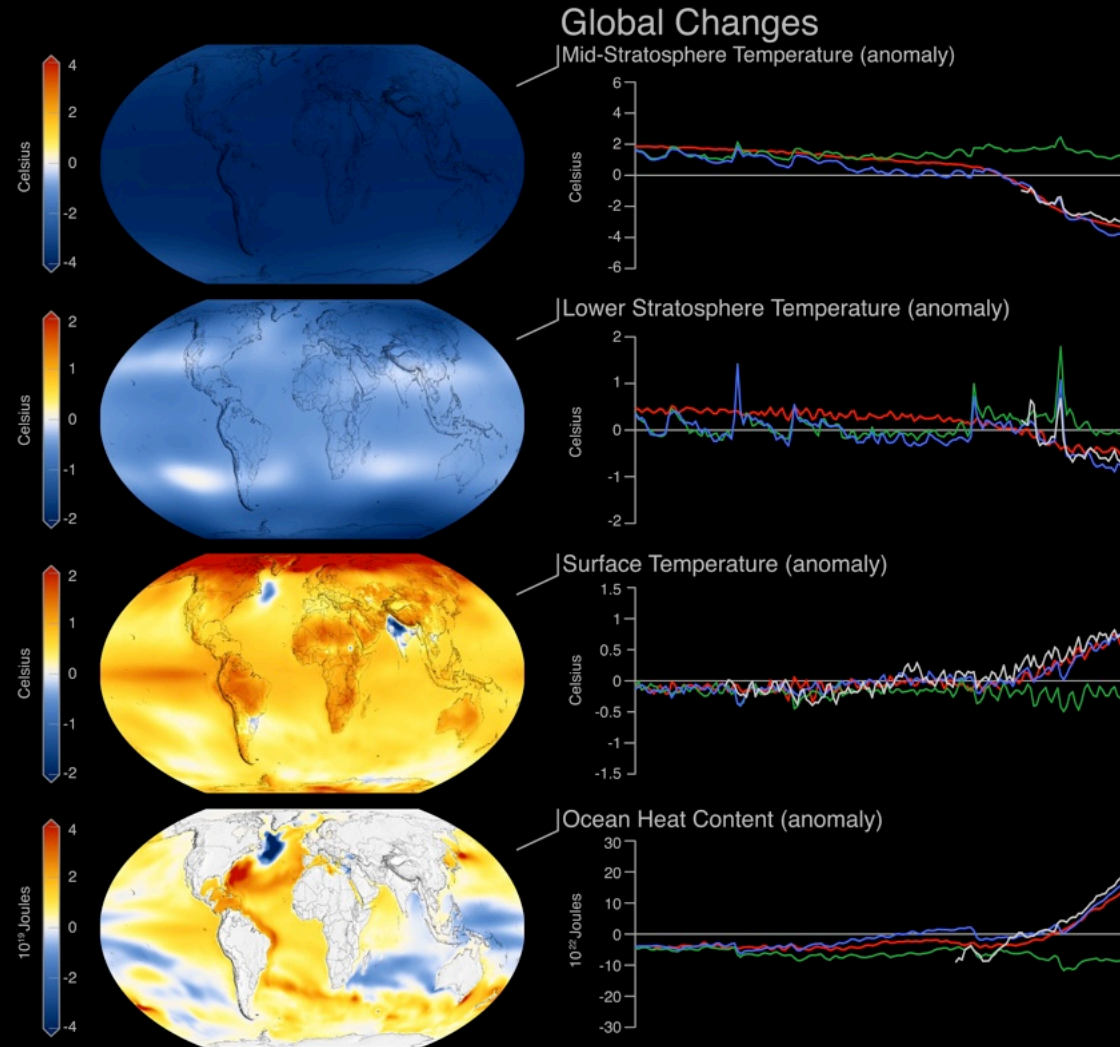
Atmospheric Temperature

- 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

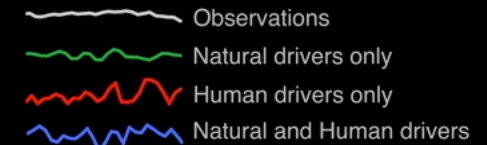
- GISS ModelE2.1 Ensemble simulations with individual drivers, natural-only, anthropogenic-only etc.
- Multi-variate comparisons to observed trends



Year
2018

Human and Natural Drivers
of Climate Change

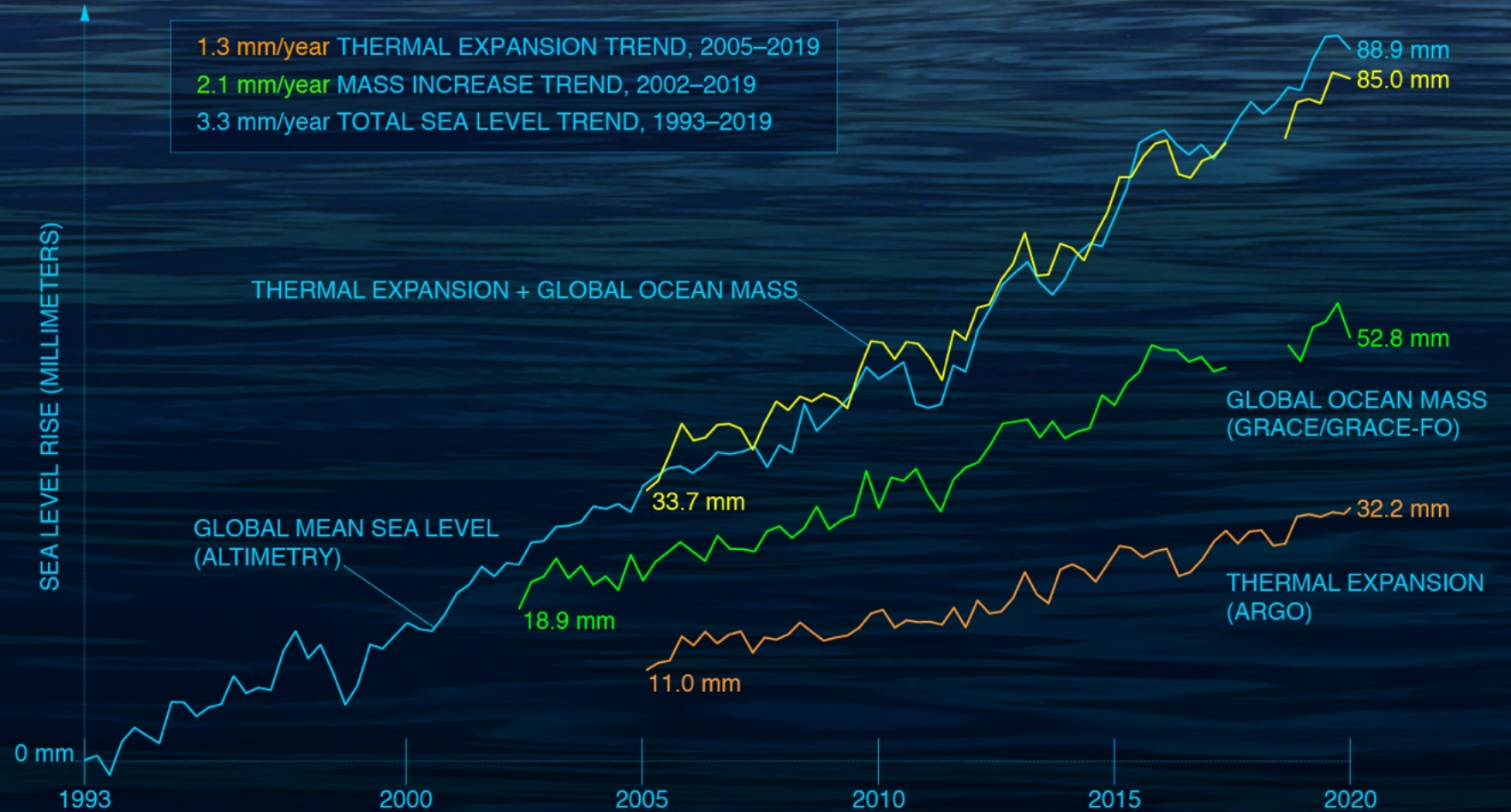
GISS ModelE 2.1-G



Global Sea Level Rise

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

- 2005-2019



Sources: GSFC/PO.DAAC; JPL; NOAA

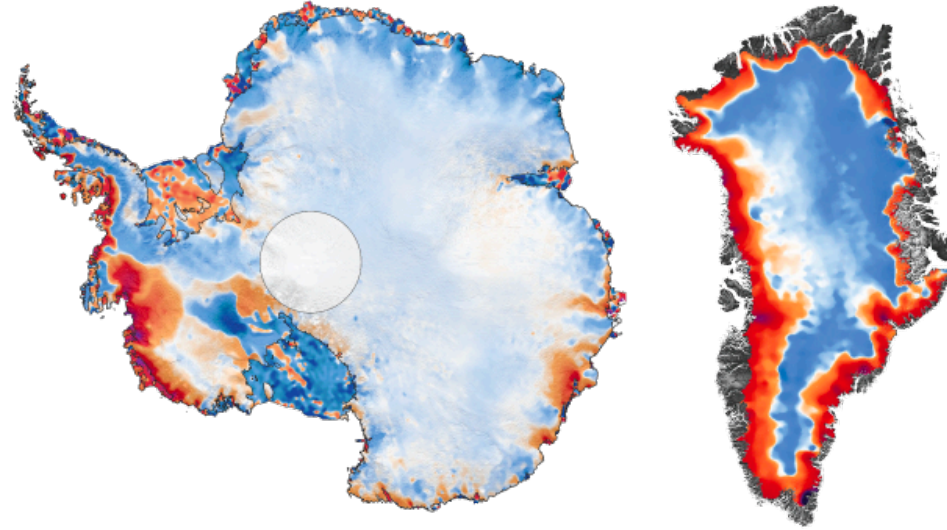
Ice Sheet Mass

- GRACE (2002-2017)
- GRACE-FO (since 2018)
- Trends April 2002-Dec 2023



Antarctica

Greenland



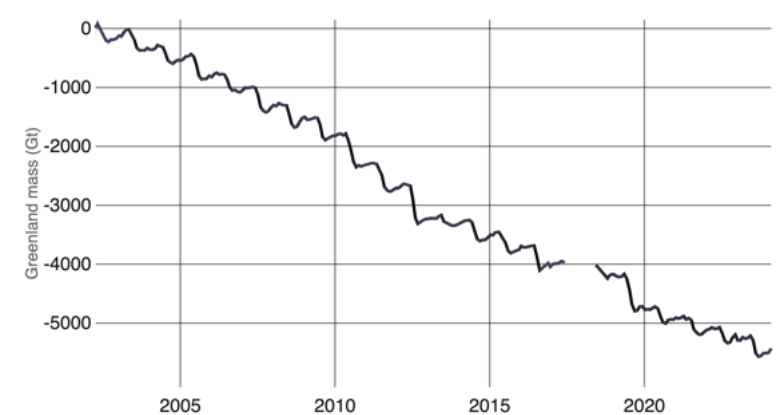
-140 Gt/yr

Change in ice thickness per year

-268 Gt/yr

-10.0 -6.0 -3.0 -1.0 0 +0.5

Meters



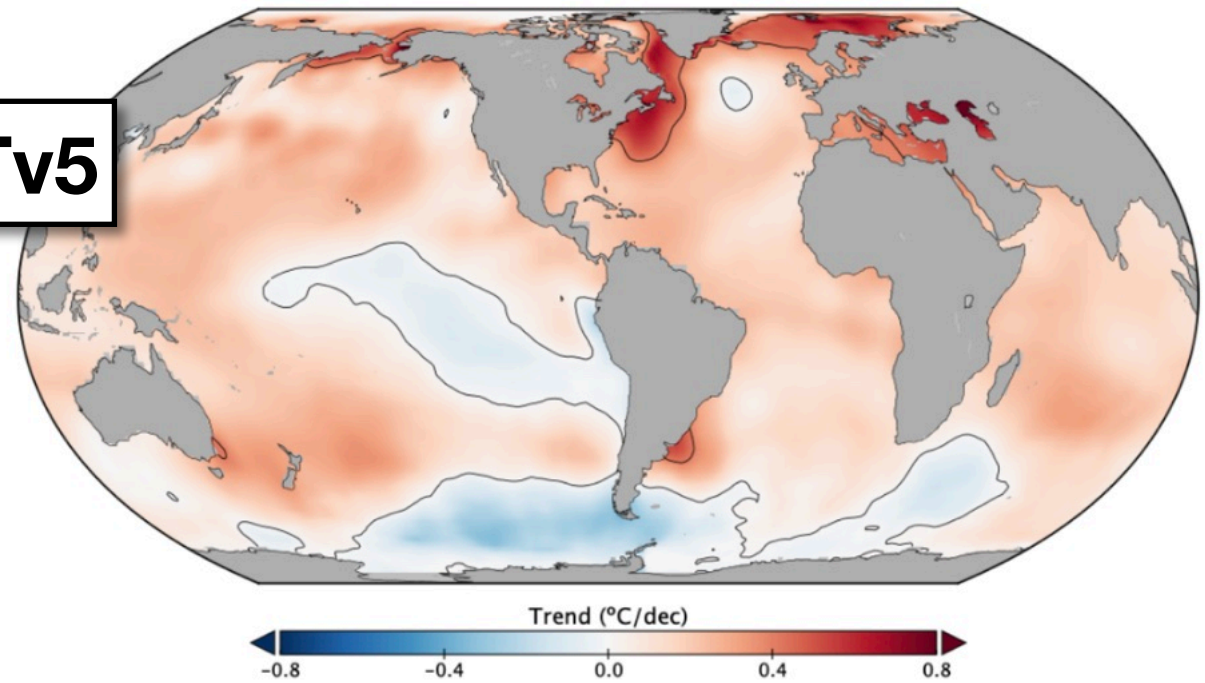
The background of the slide is a cosmic image featuring a dark space filled with stars and nebulae. In the upper right, there is a bright blue nebula. In the lower right, there is a greenish-blue nebula. The lower left is dominated by a large, bright orange and yellow nebula. The text is centered in a white horizontal band across the middle of the image.

Climate Change: Long Term Discrepancies

Some anomalies in recent SST trends

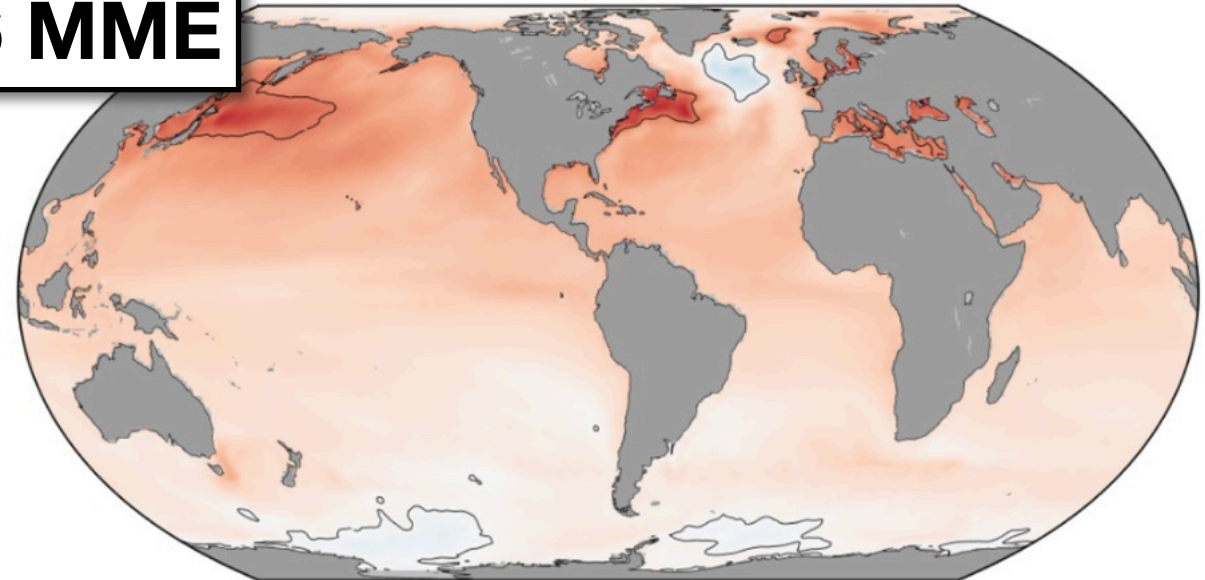
- 1990-2019
- Eastern Tropical Pacific
- Southern Ocean
- North Atlantic

ERSSTv5



CMIP6 MME

CMIP6 Multimodel SST Trends
Historical + SSP245 (1990-2019)



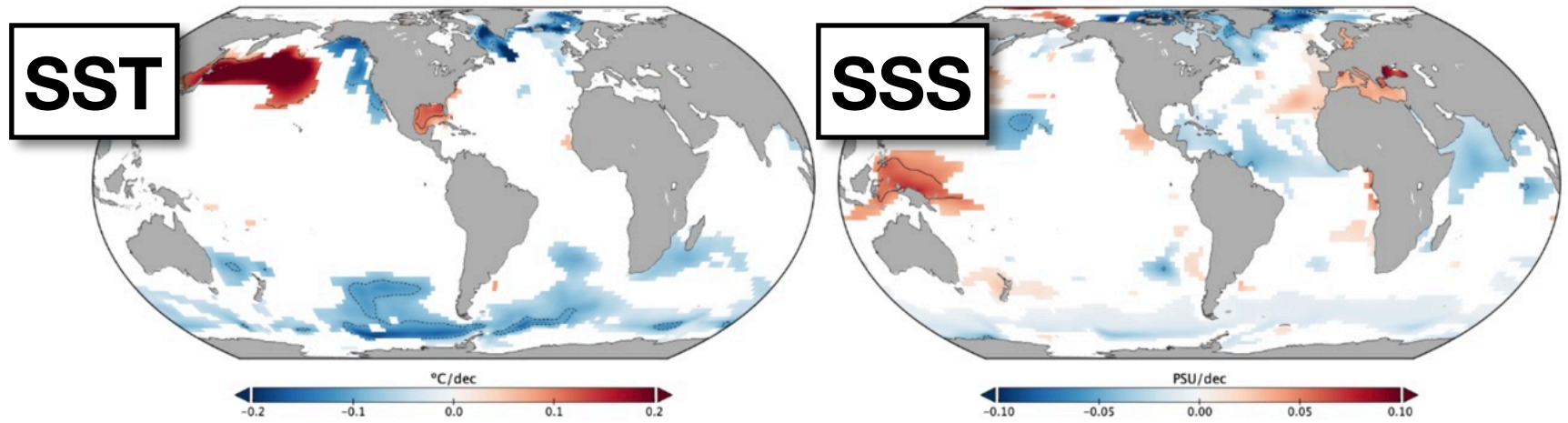


Tropical Ocean Possibilities?

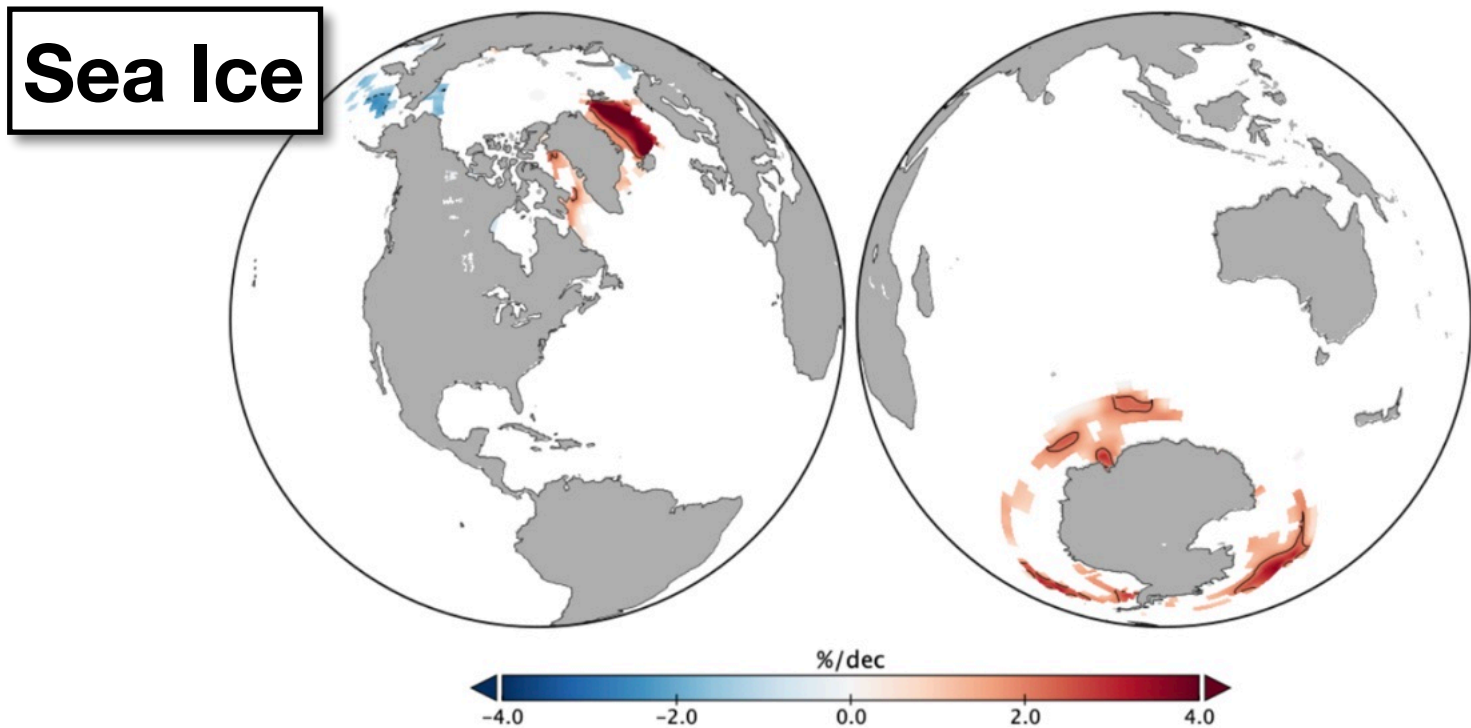
- A short-term forced response (but not captured sufficiently in models)
- A long-term forced response asymmetric in El Niño /La Niña
- Internal variability (models don't have enough)
- Evidence for each, but not definitive

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)



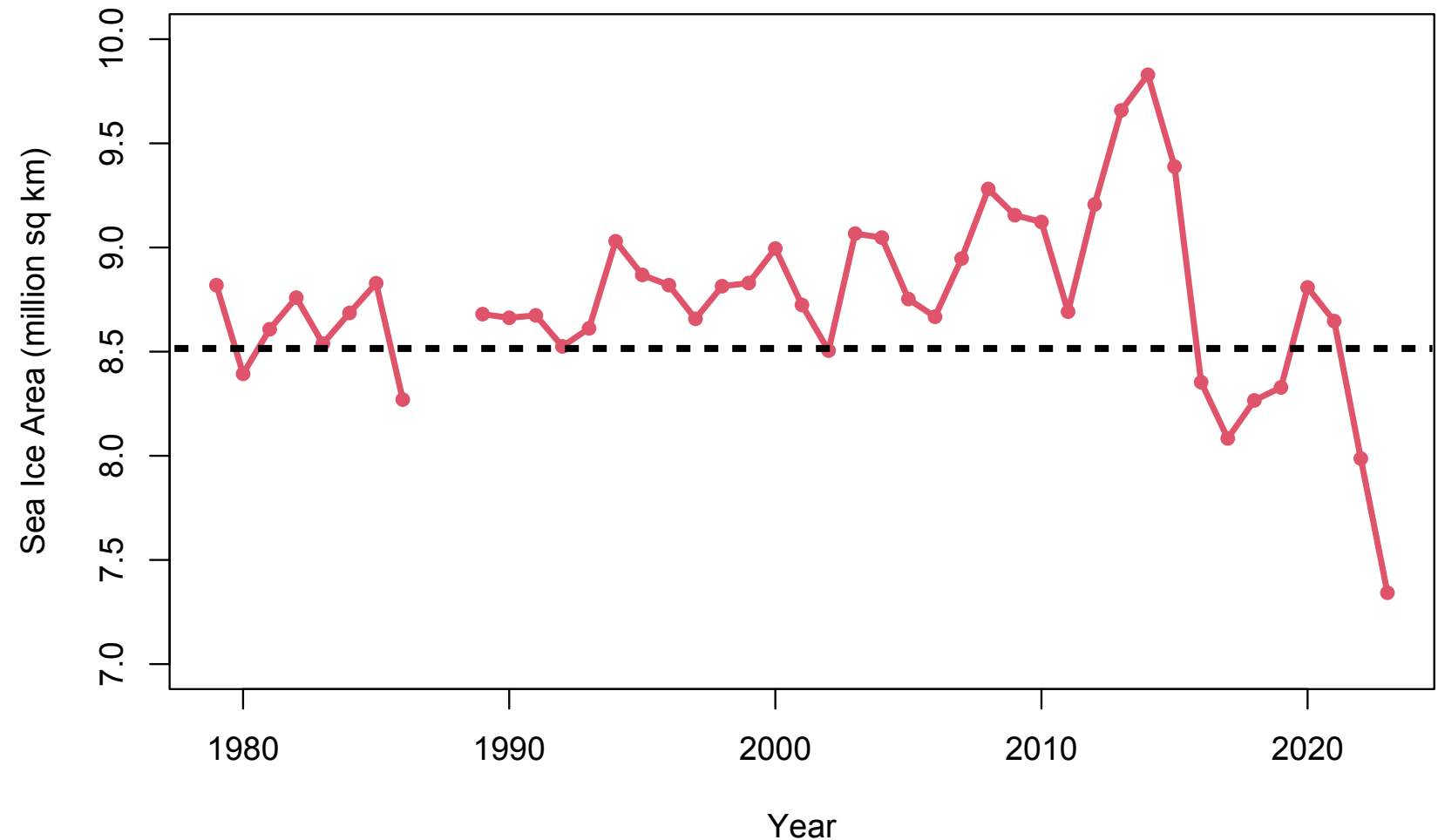
e)



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...?

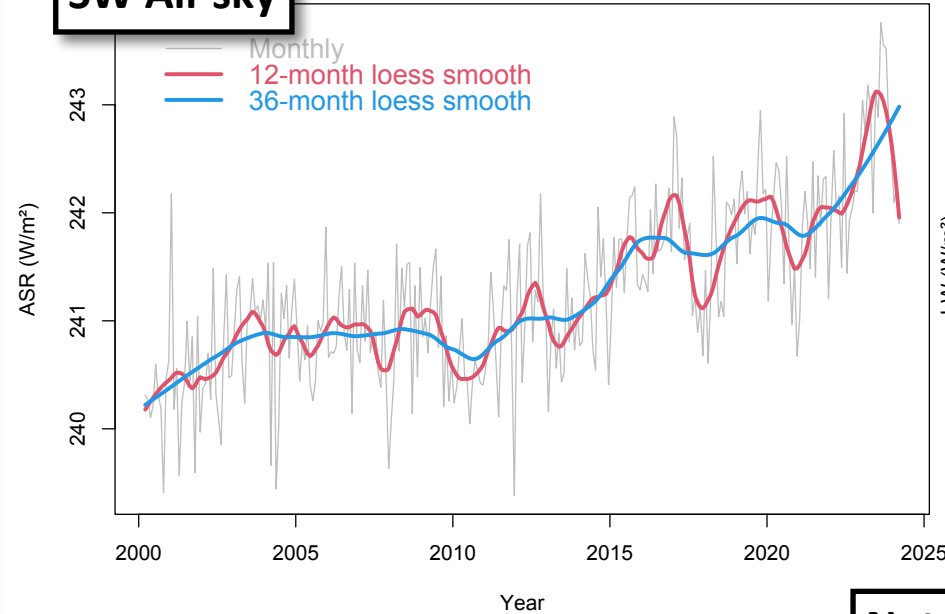
Antarctic Sea Ice



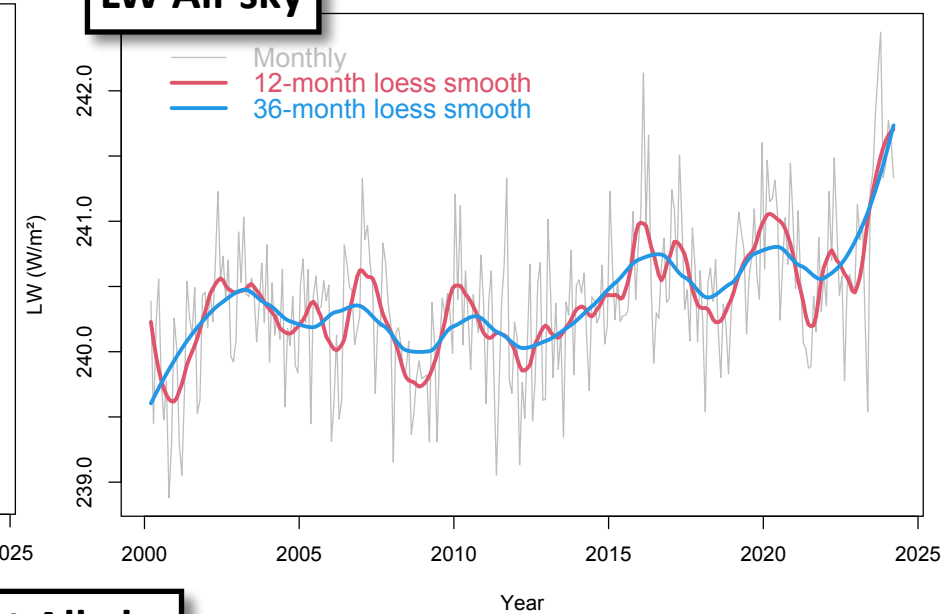
Earth's Energy Imbalance

- 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...

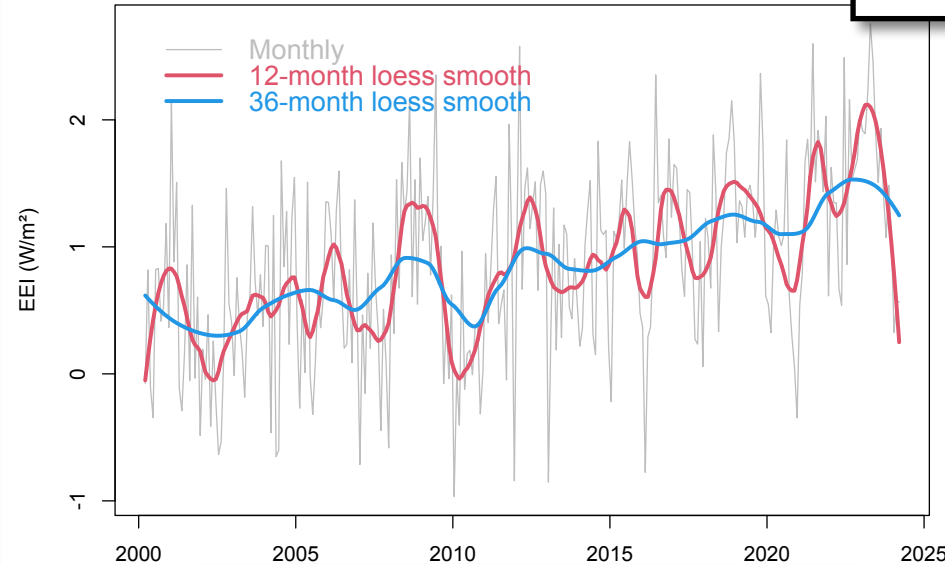
SW All-sky



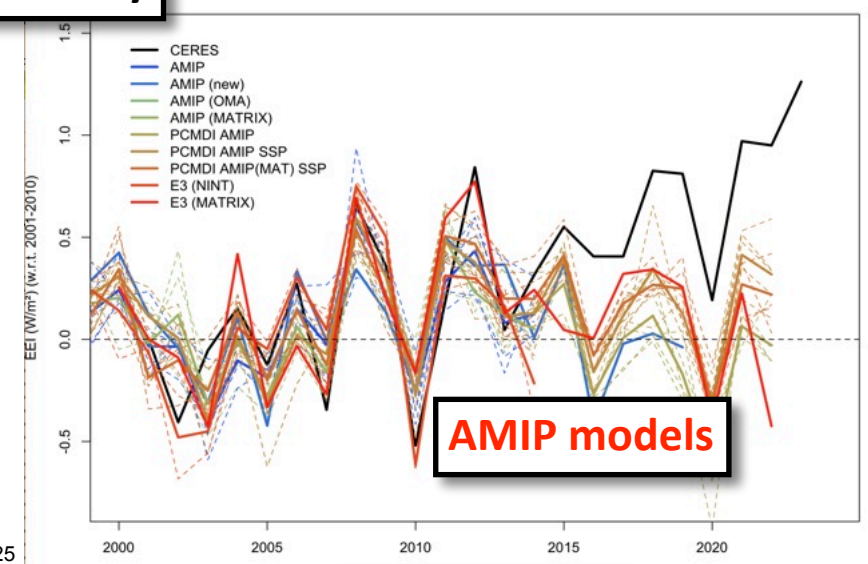
LW All-sky



Net All-sky



Monthly + 12/36 month smooth



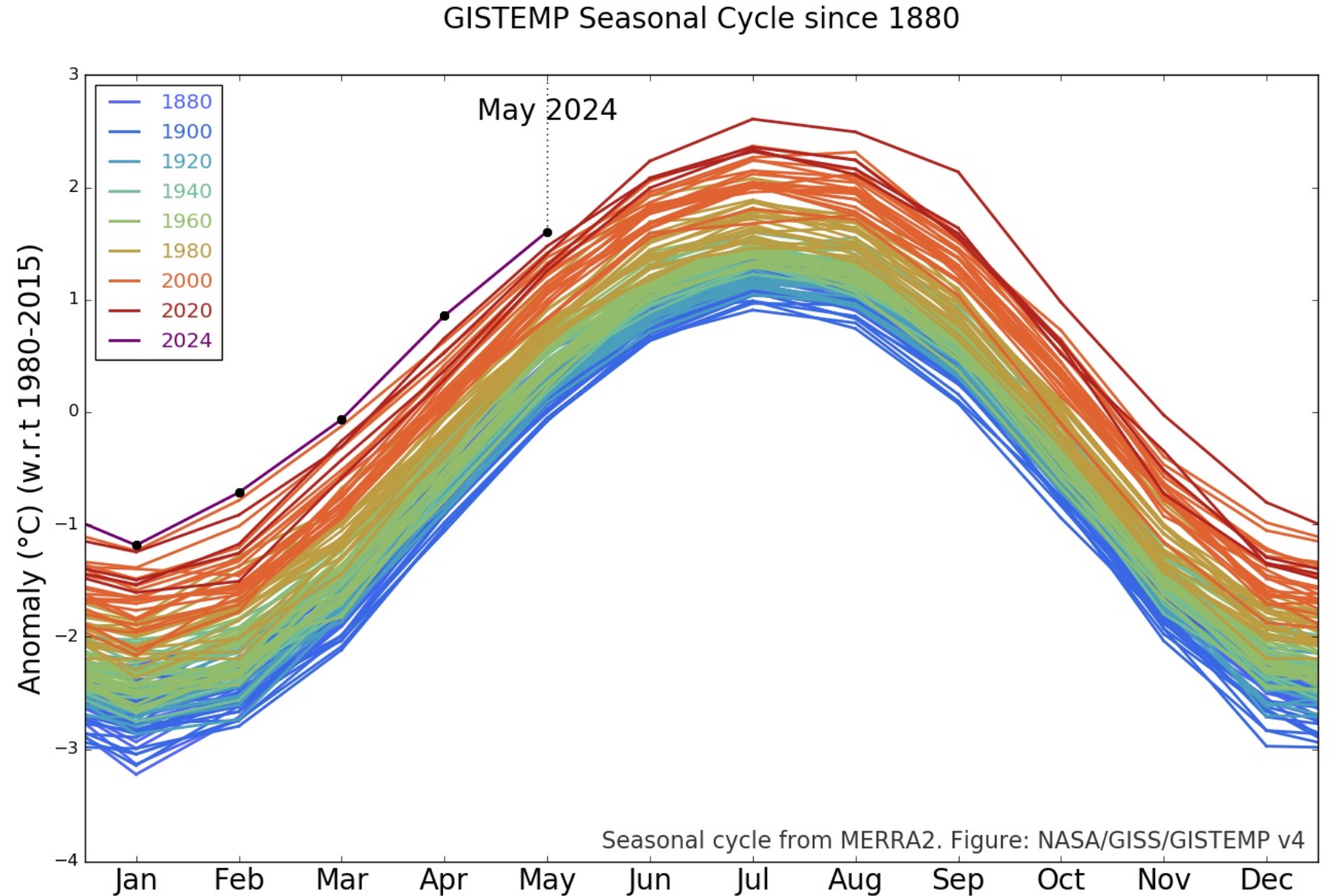
Annual Mean

The background of the slide is a cosmic image featuring a blue nebula in the upper right and an orange/yellow nebula in the lower left, separated by a light blue horizontal band. Numerous stars are visible throughout the scene.

Climate Change: What happened in 2023?

Record-breaking last 12 months

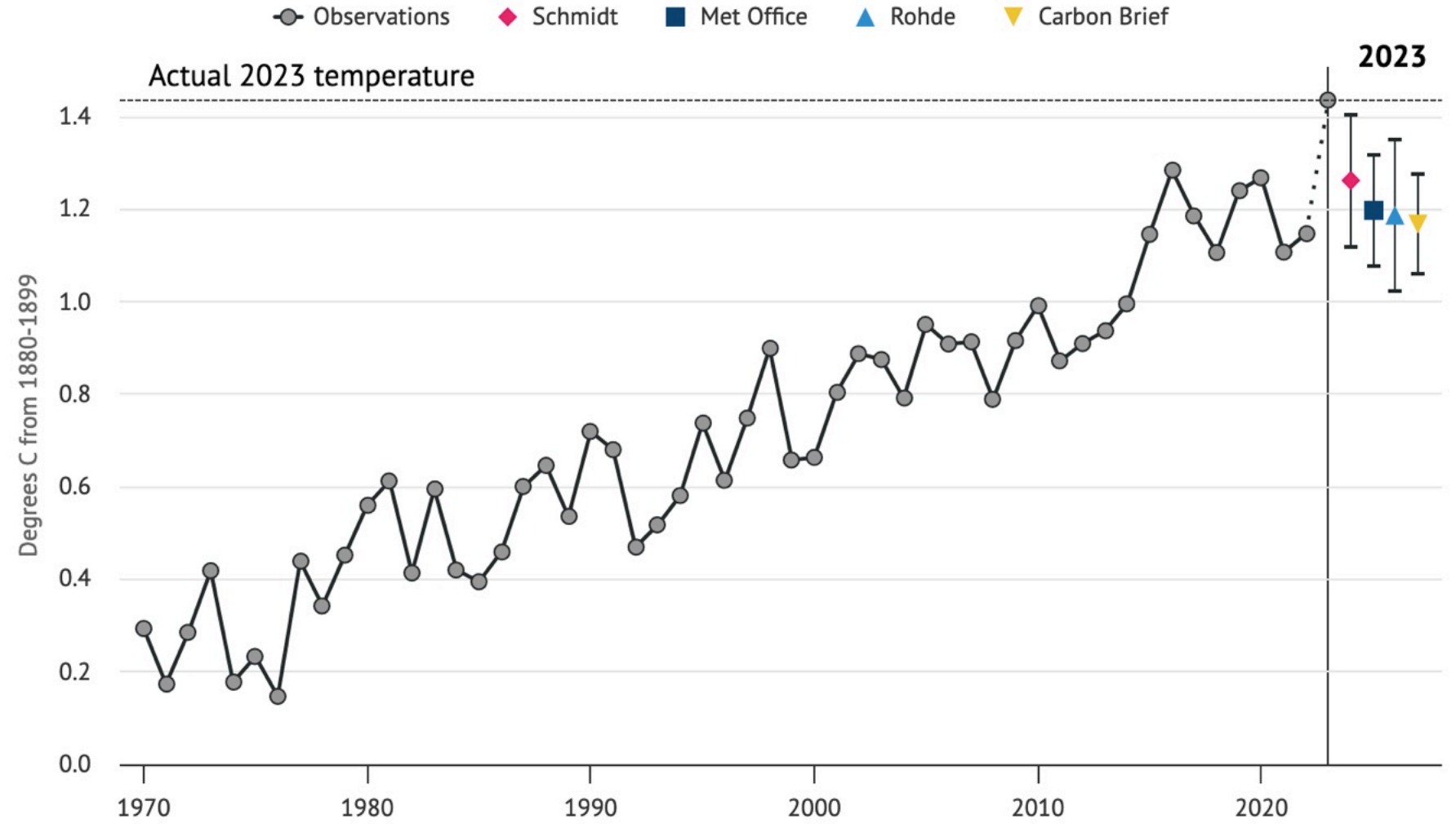
- GISTEMP results replicated by reanalyses, NOAA, AIRS, and MSU



Predictions at end of 2022 failed

- Simple statistical models
- Large scale initialized GCMs
- All methods were taken by surprise by 2023 warmth

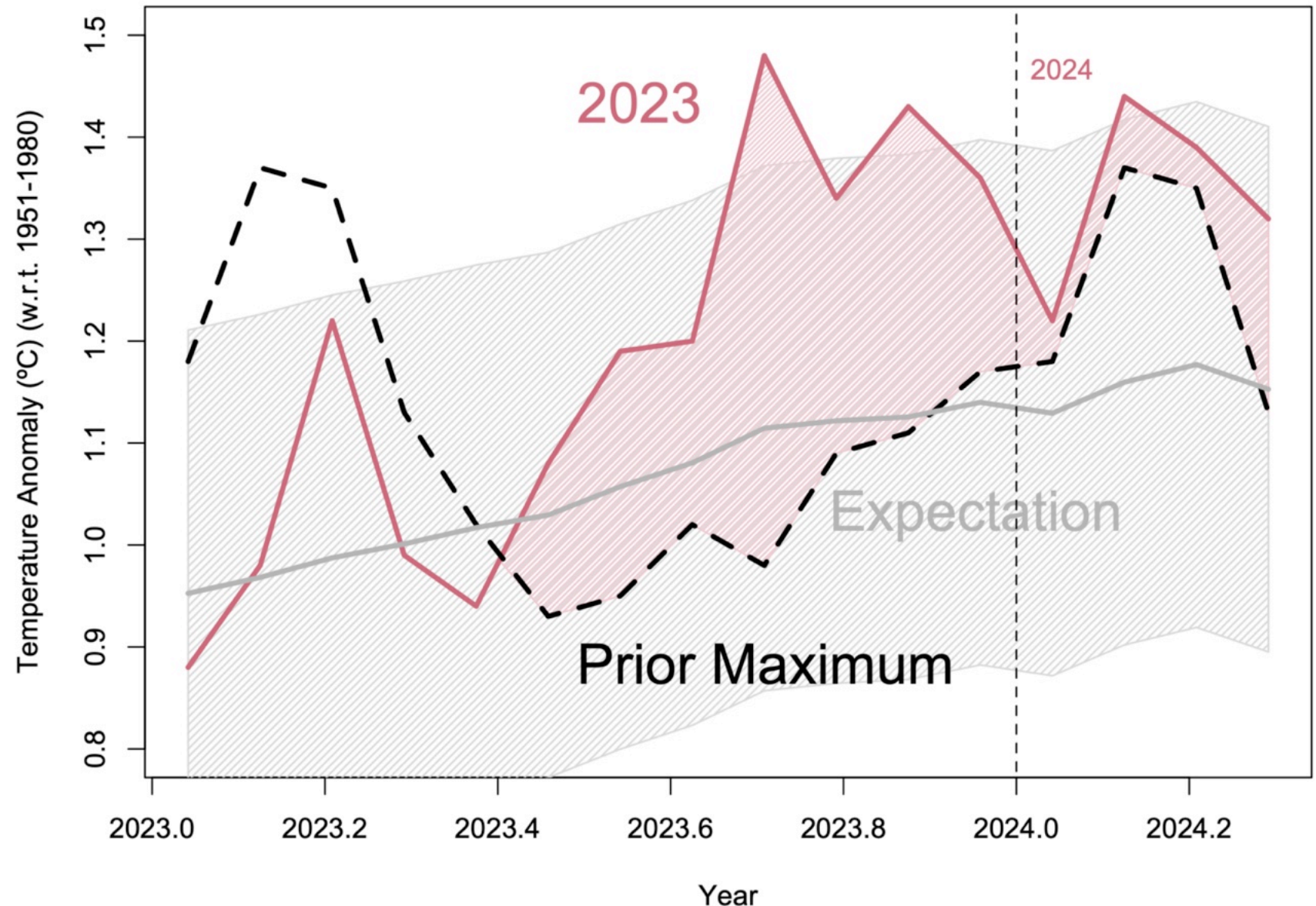
Comparing Different 2023 Temperature Projections



2023 was anomalous

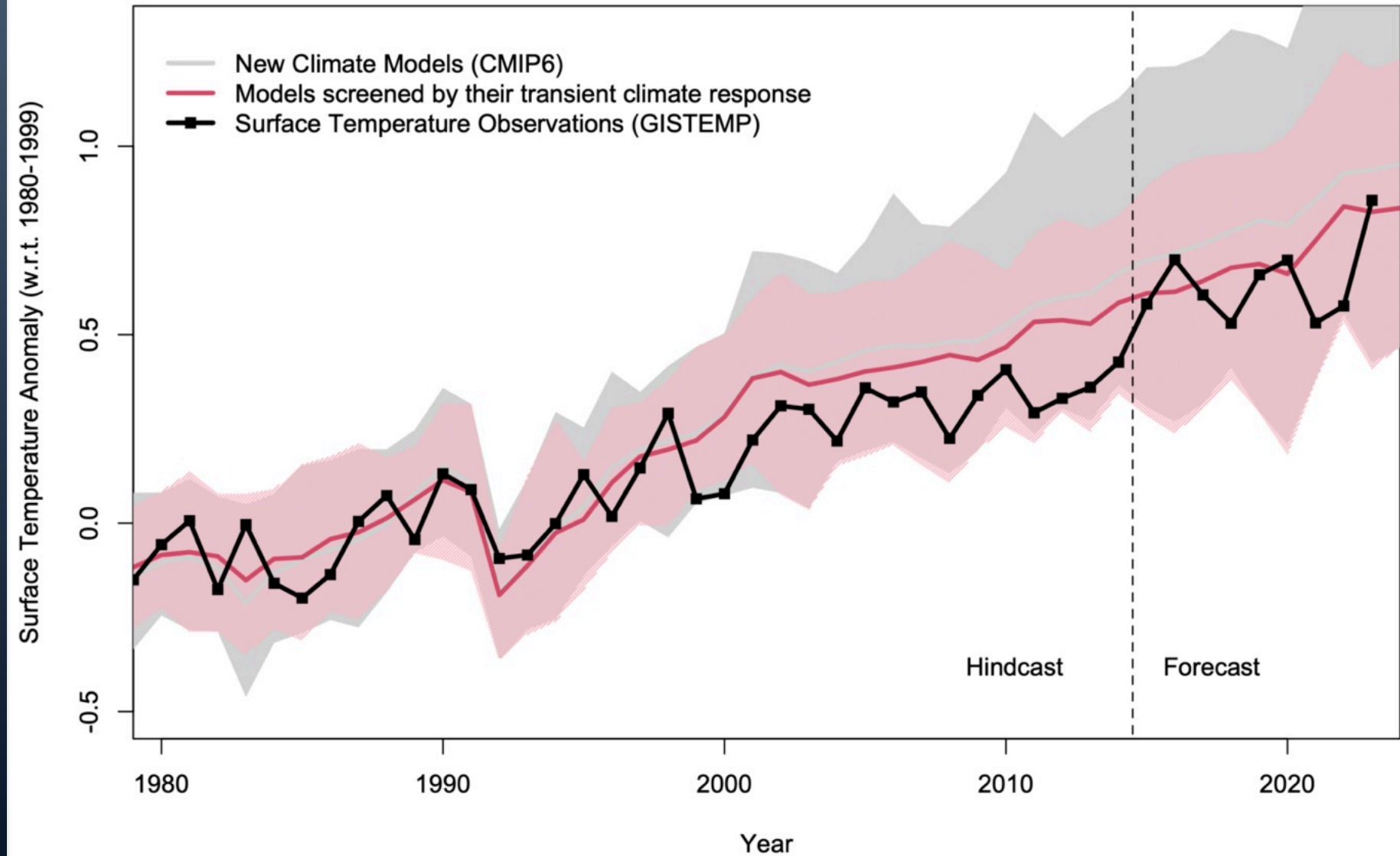
- Roughly 0.2°C to be explained beyond long-term trends and ENSO
- Possibilities:
 - Hunga Tonga Hunga Ha'apai
 - IMO2020 regulations
 - Aerosol emissions from China falling
 - Solar cycle earlier/larger than predicted

How strange was 2023?



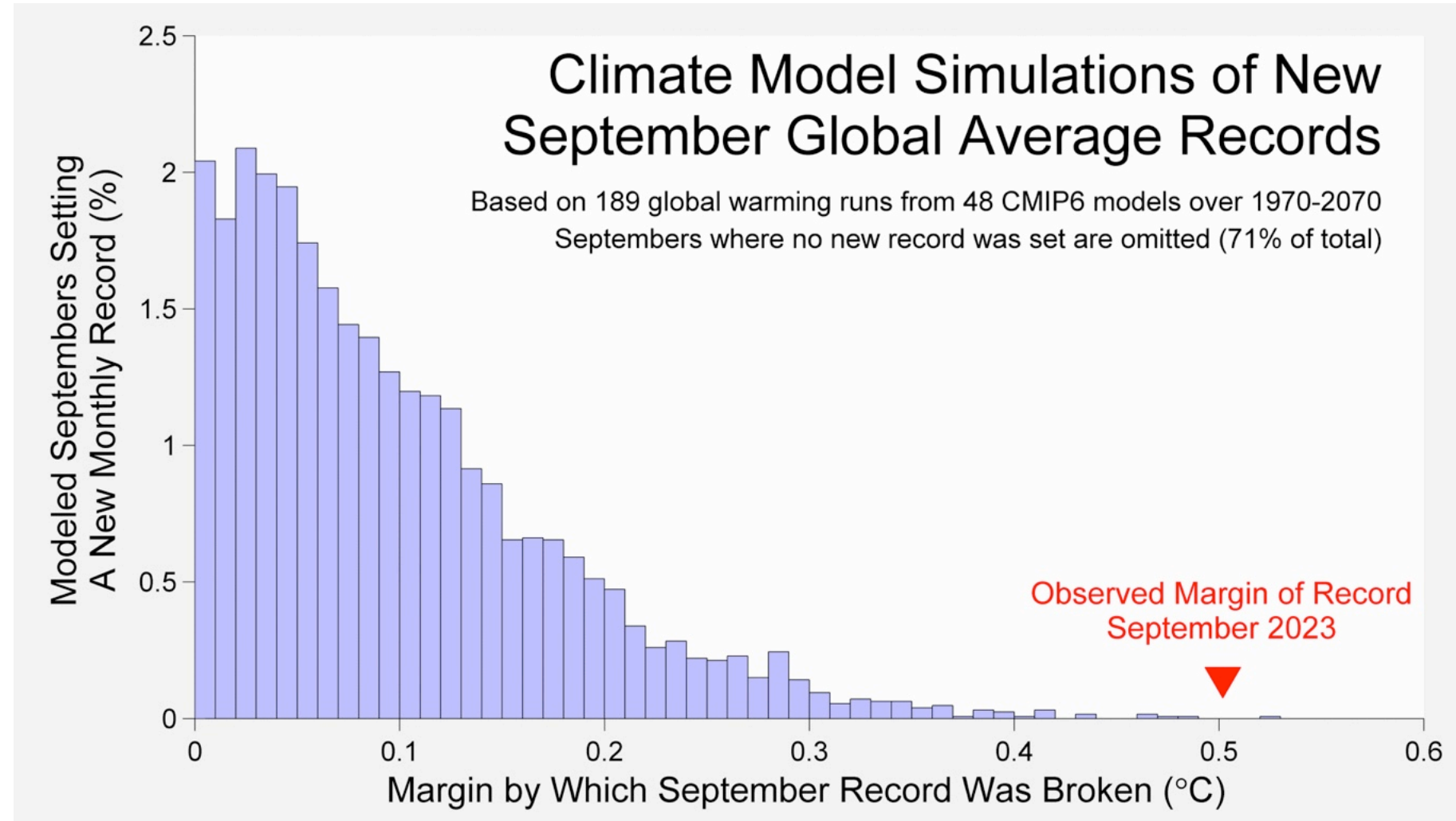
CMIP6 Multi-model Ensemble

- 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.



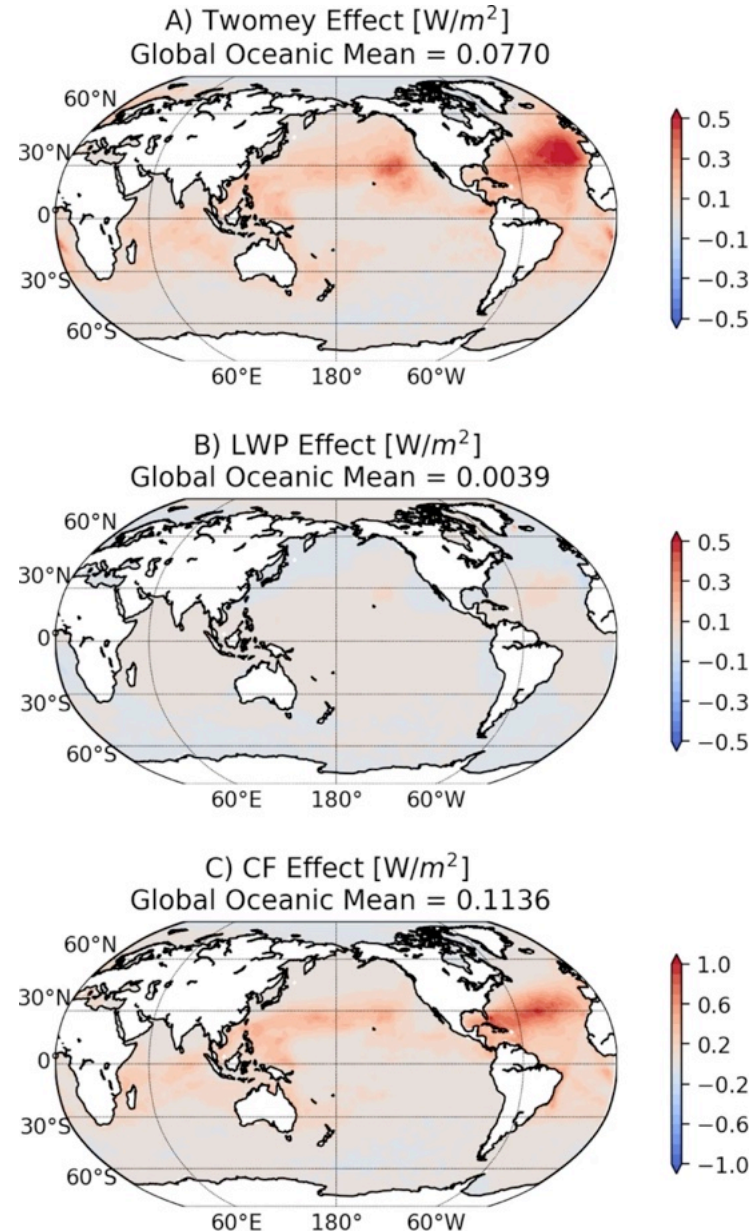
Specifics of 2023 not captured in CMIP6 MME

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

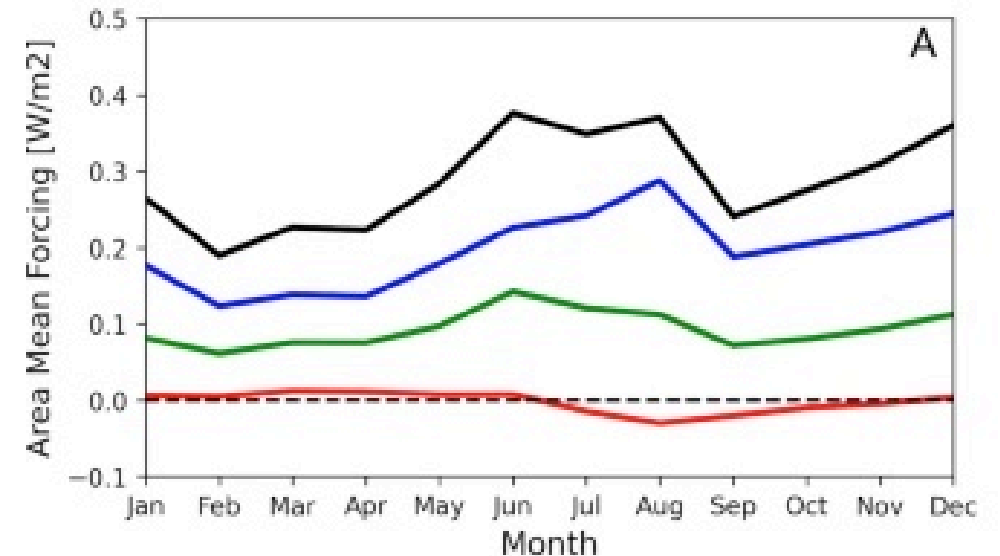


Impacts of IMO2020

- Abrupt change in marine shipping emissions in Jan 2020
- Yuan et al (2024)
- Forcing of 0.14 W/m^2 globally
- $\Rightarrow \sim 0.1^\circ\text{C}$ warming
- New papers/estimates ongoing



Seasonality and spatial pattern



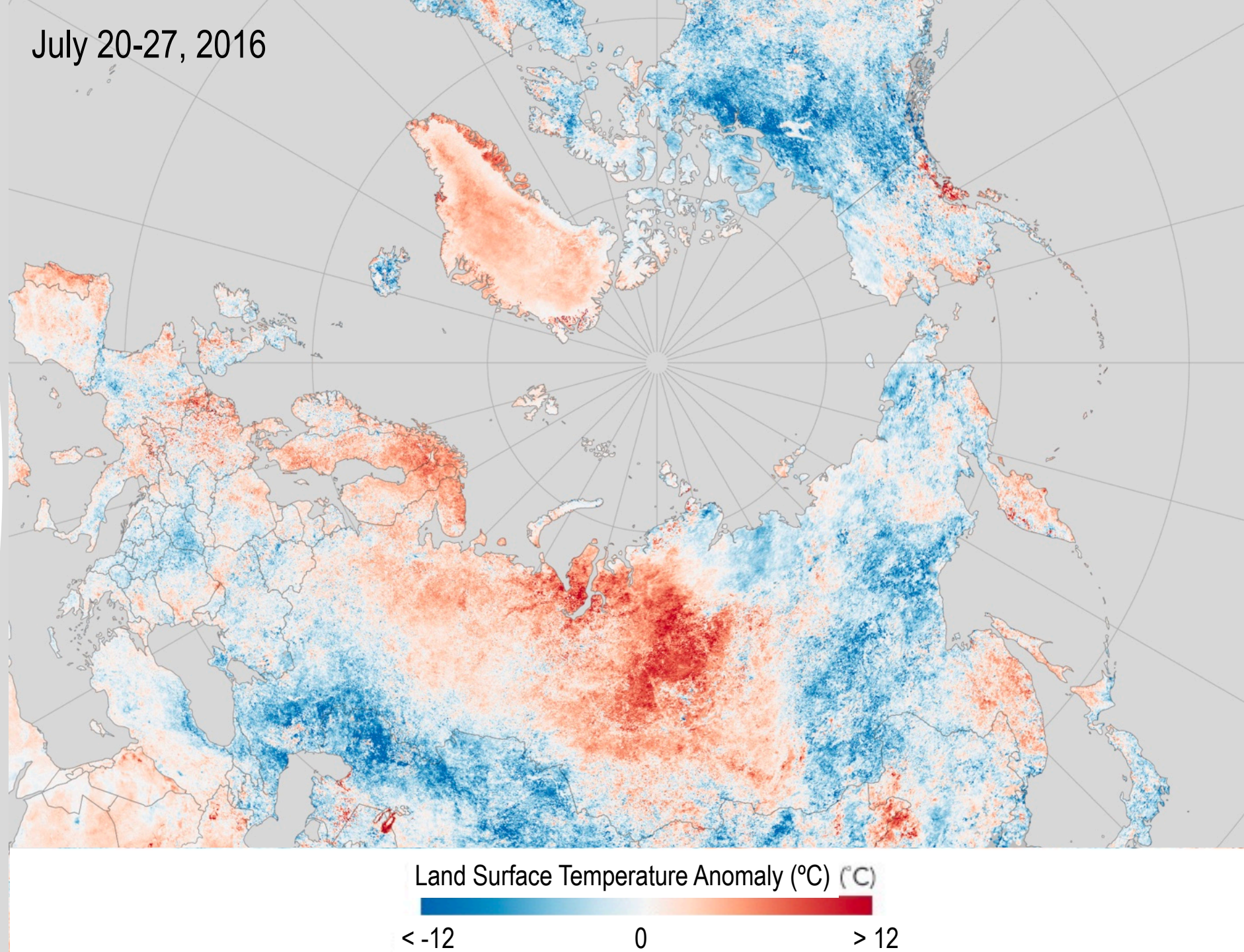
The background of the slide is a cosmic scene. The top half features a dark blue and black space filled with numerous small, bright stars. A prominent, wispy blue nebula is visible in the upper right corner. The bottom half of the image transitions into a vibrant orange and yellow glow, suggesting a different celestial region or a distant galaxy. In the center of this transition, there are more stars and some faint, greenish-yellow nebulae. The overall effect is a sense of vastness and the beauty of the universe.

Climate Change: Impacts

July 20-27, 2016

Heat Waves

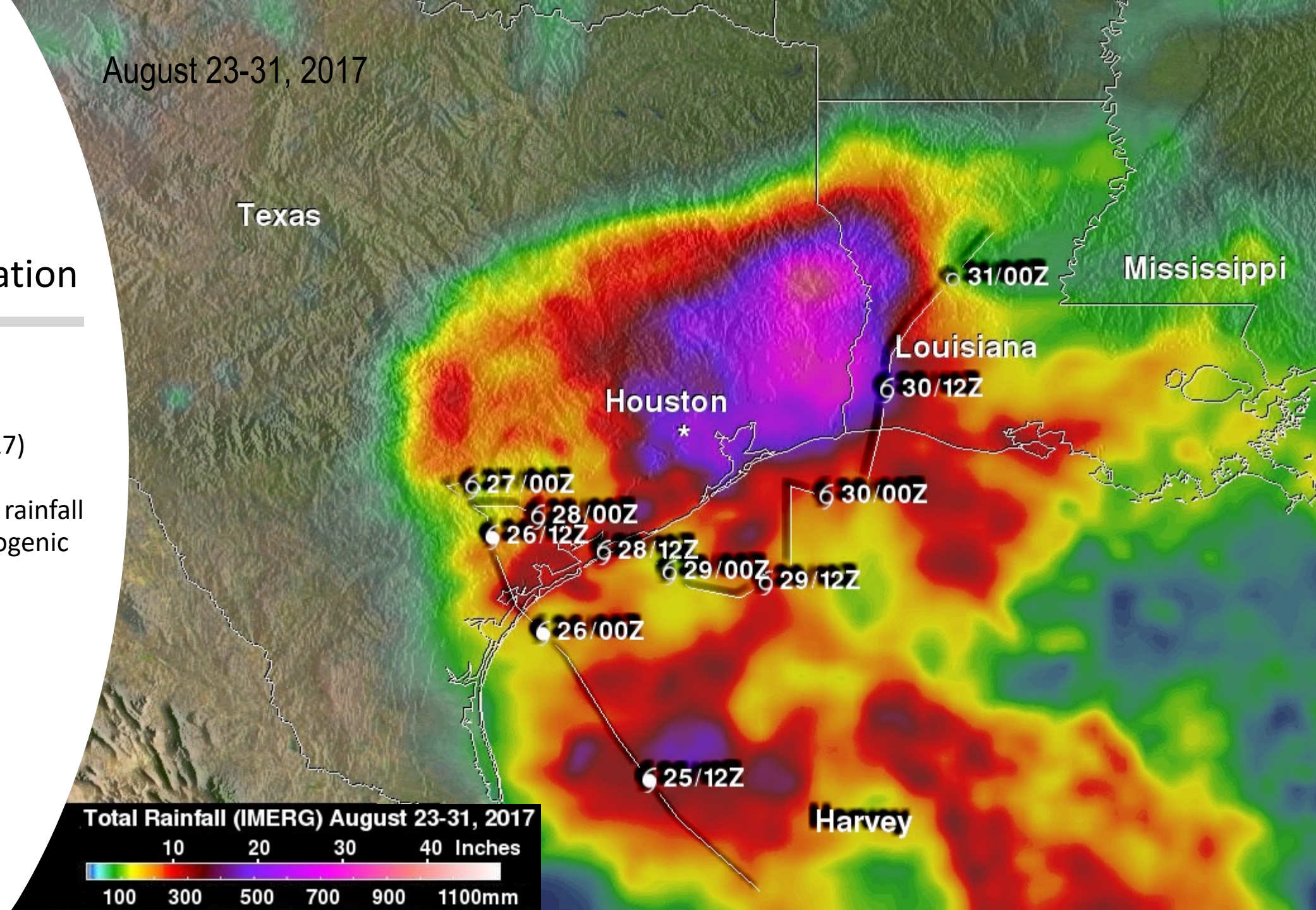
- MODIS instrument
- Terra (since 2000)
- Aqua (since 2003)
- Record breaking heat waves in 2016, 2018, 2020
- Clear trends in heatwave incidence and cumulative intensity since 1960



August 23-31, 2017

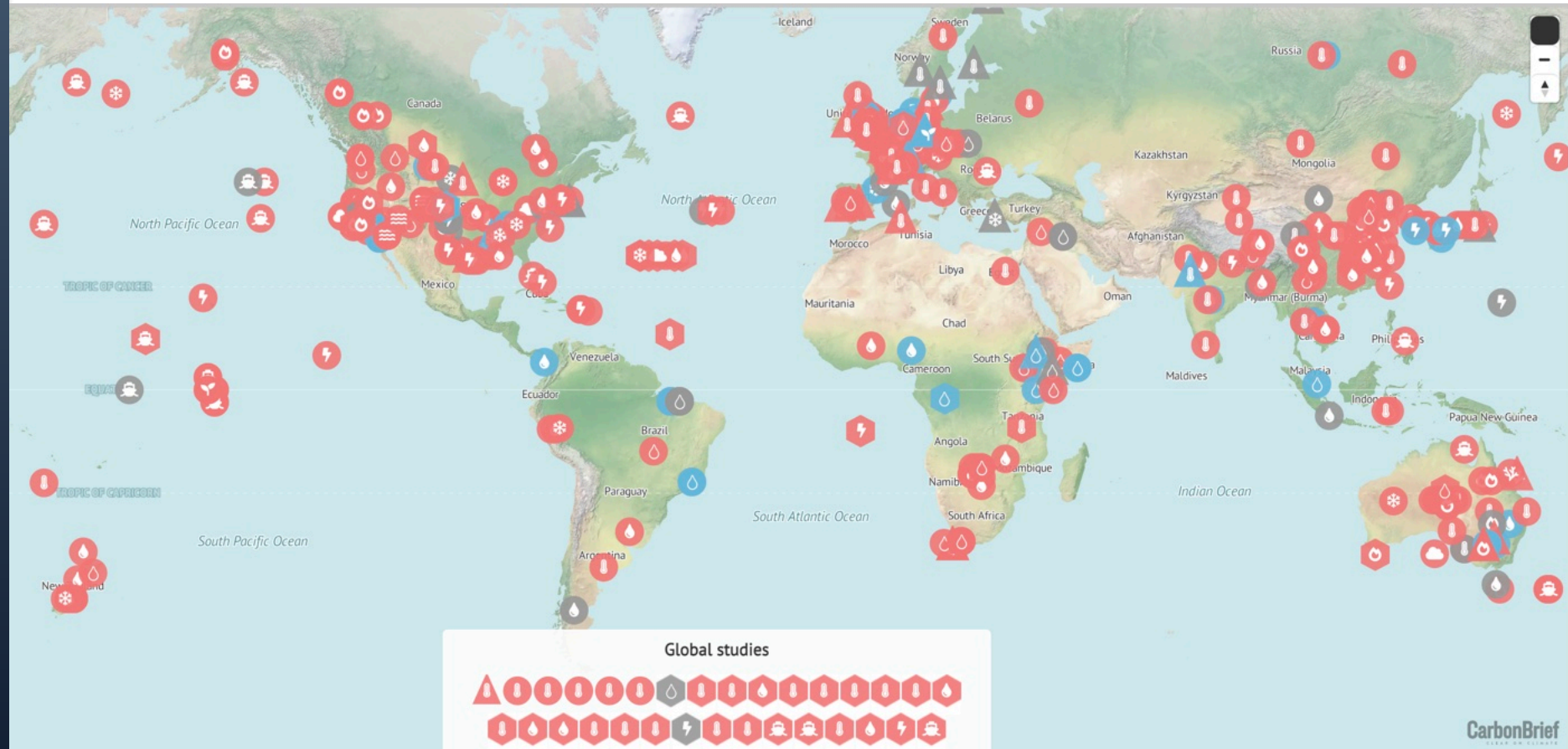
Intense Precipitation

- 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



☁ Atmosphere ❄ Cold, snow & ice 🌊 Coral bleaching
☪ Drought 🌿 Ecosystem function 🔥 Heat
🌊 Oceans 💧 Rain & flooding 🌊 River flow
⚡ Storm ☀ Sunshine 🔥 Wildfire

● Human influence found ● No human influence found
● Inconclusive



What we do (& don't) know

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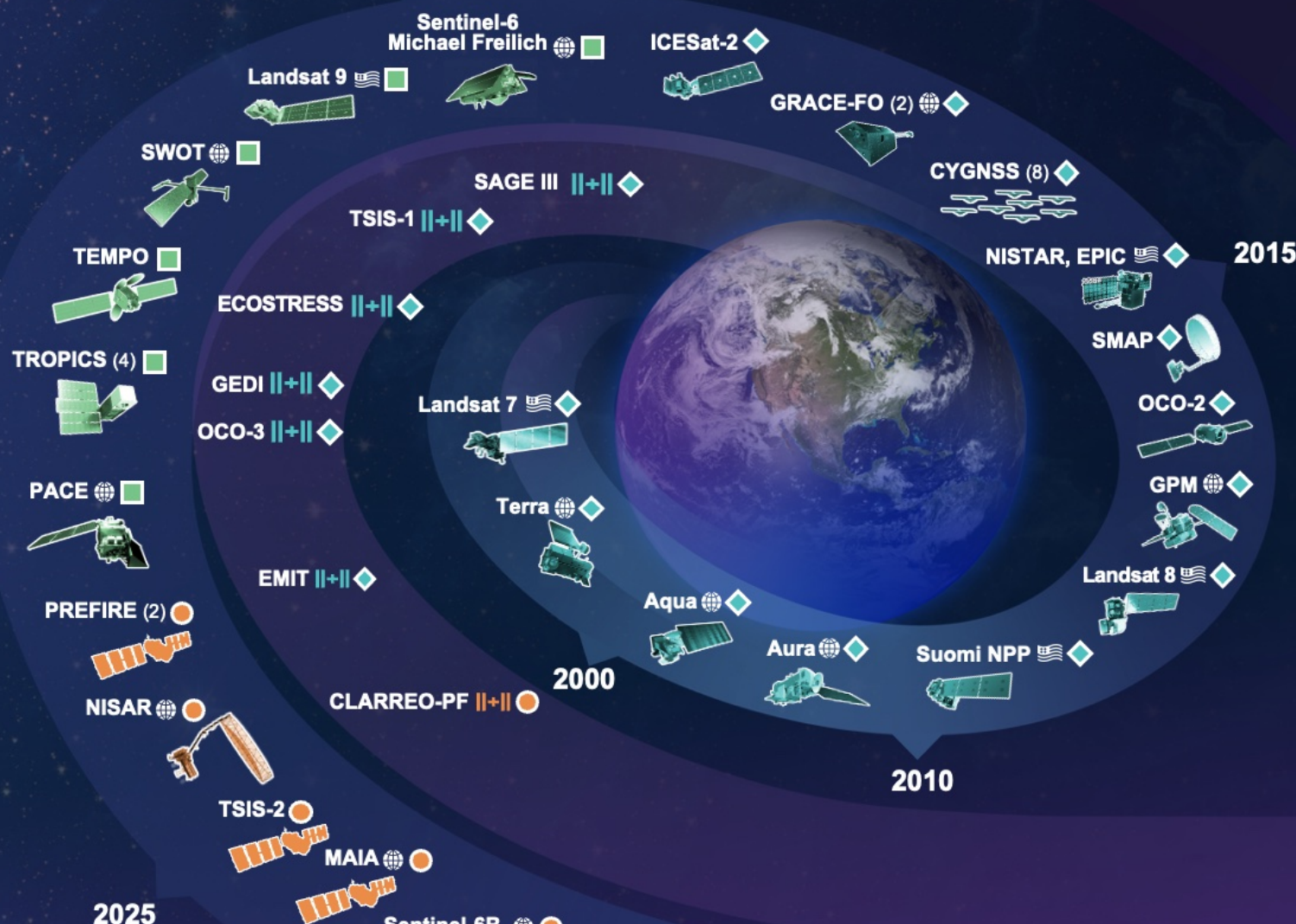


What we need to do

- 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



EARTH FLEET



Key	Invest/CubeSats
International Partners	NACHOS 2022
U.S. Partner	CTIM 2022
ISS Instrument	NACHOS-2 2022
JPSS Instrument	MURI-FD 2023
Cubesat	SNOOPI* 2024
Launch Date TBD	HYTI* 2024
Earth System	ARGOS* 2024
Observatory Mission	
(Pre) Formulation	
Implementation	
Operating	
Extended	

JPSS Instruments

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

ISS INSTRUMENTS



MISSIONS

The background of the slide is a composite of two cosmic images. The top half features a dark space with a prominent blue and cyan nebula on the right side, with several bright stars visible. The bottom half shows a vast field of stars against a warm, orange and yellow nebula. A solid light blue horizontal band runs across the middle of the image, serving as a backdrop for the text.

Thank you!