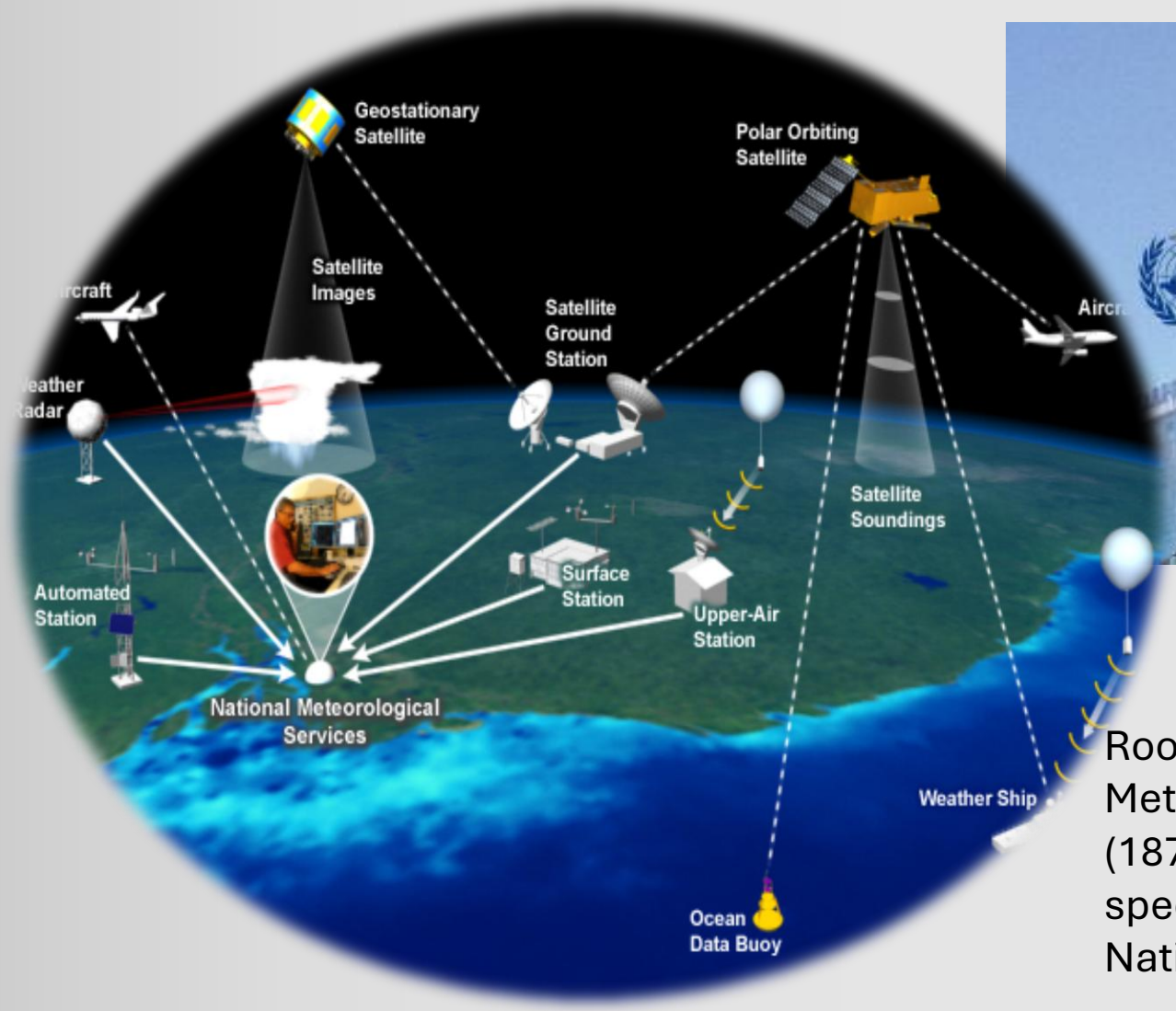
El Cambio Climático, la Incertidumbre, y su Manejo en Sistemas de Energía Altamente Hídricos

Roberta Boscolo, Responsable de Clima y Energía en la Organización Mundial de Meteorología

Séptimo foro

Contenido



Rooted in the International Meteorological Organization (1873) and transformed into a specialized agency of the United Nations in 1951

Prof. Celeste Saulo, Secretary General

193 Member States and Territories

WMO Members represented by the National Meteorological and Hydrological Services (NMHSs) that contribute to the safety and welfare of societies

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Background

- **1993:** Reporting on the global State of the Climate began
- **2016:** Reports structured around key climate indicators and submitted to COPs
- **2019:** Regional State of the Climate Reports initiated

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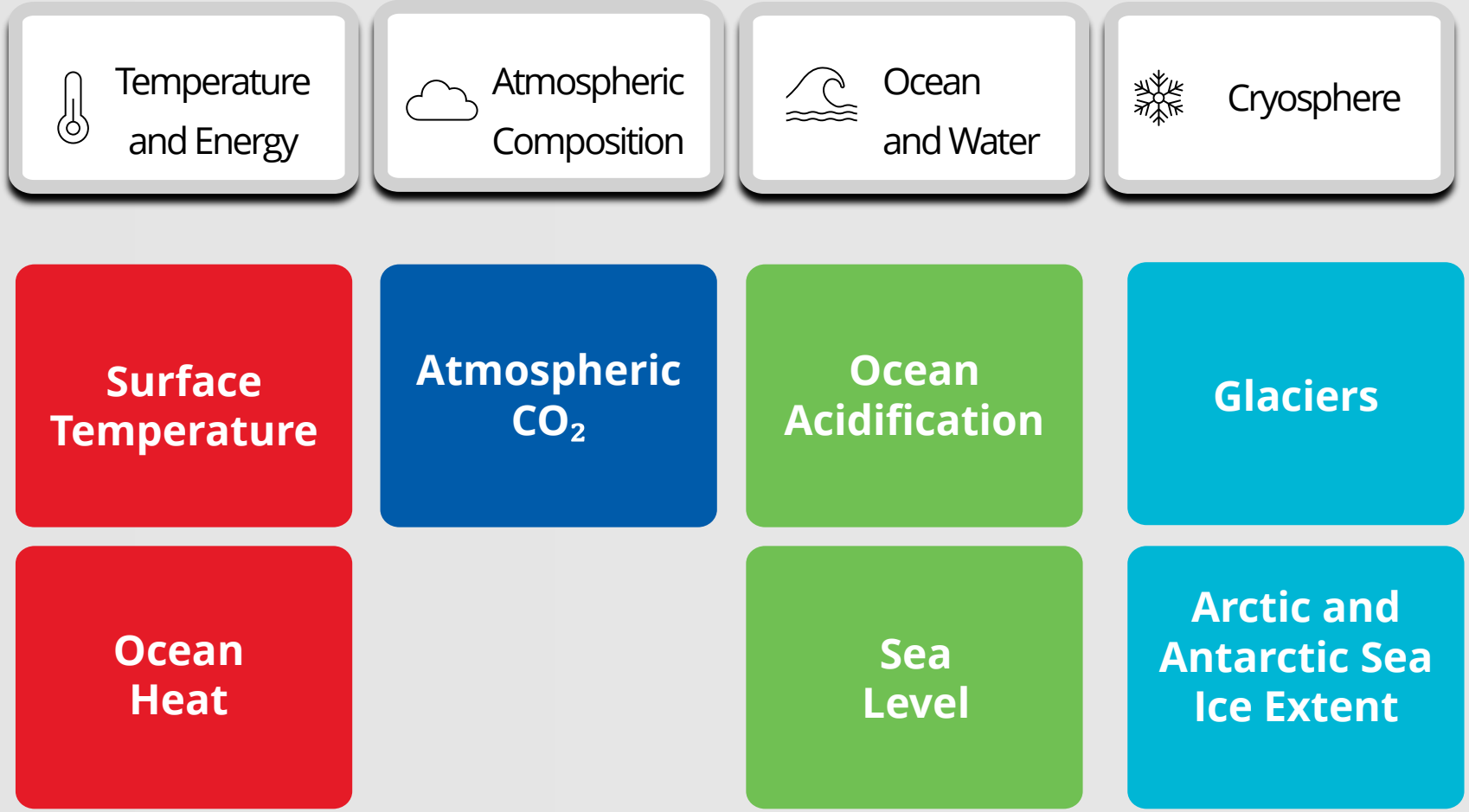
Key climate indicators monitor long term changes to the global climate system



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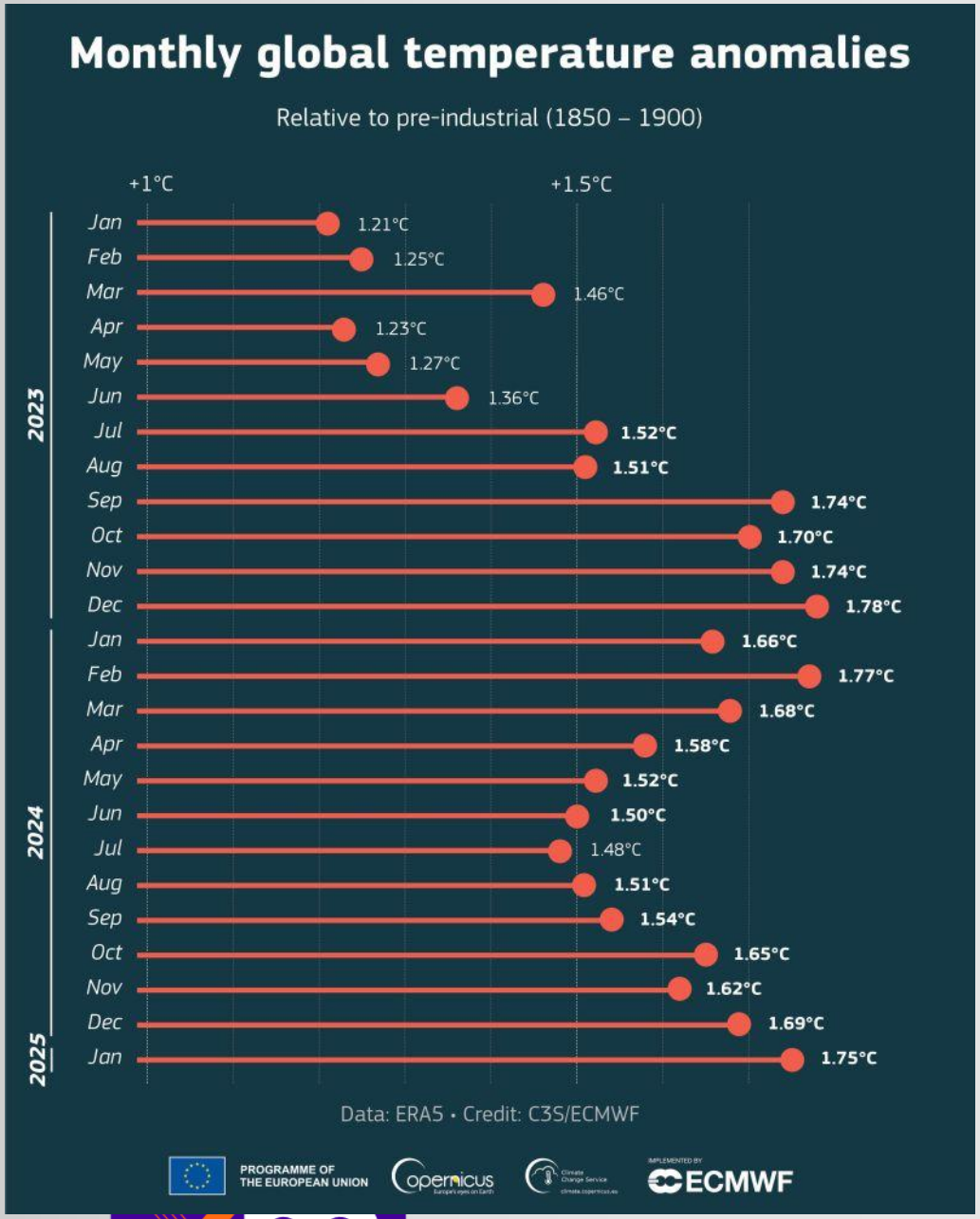
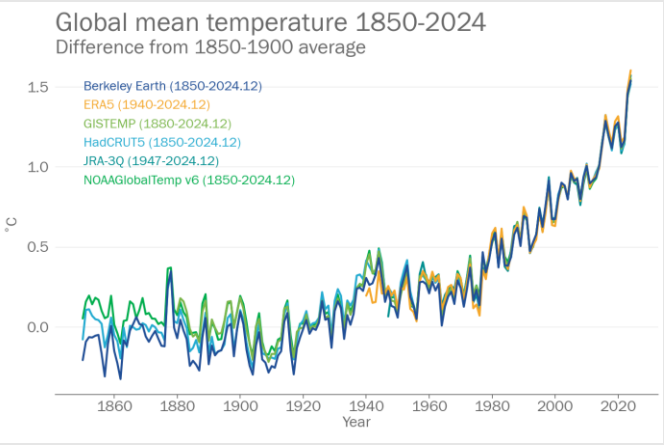
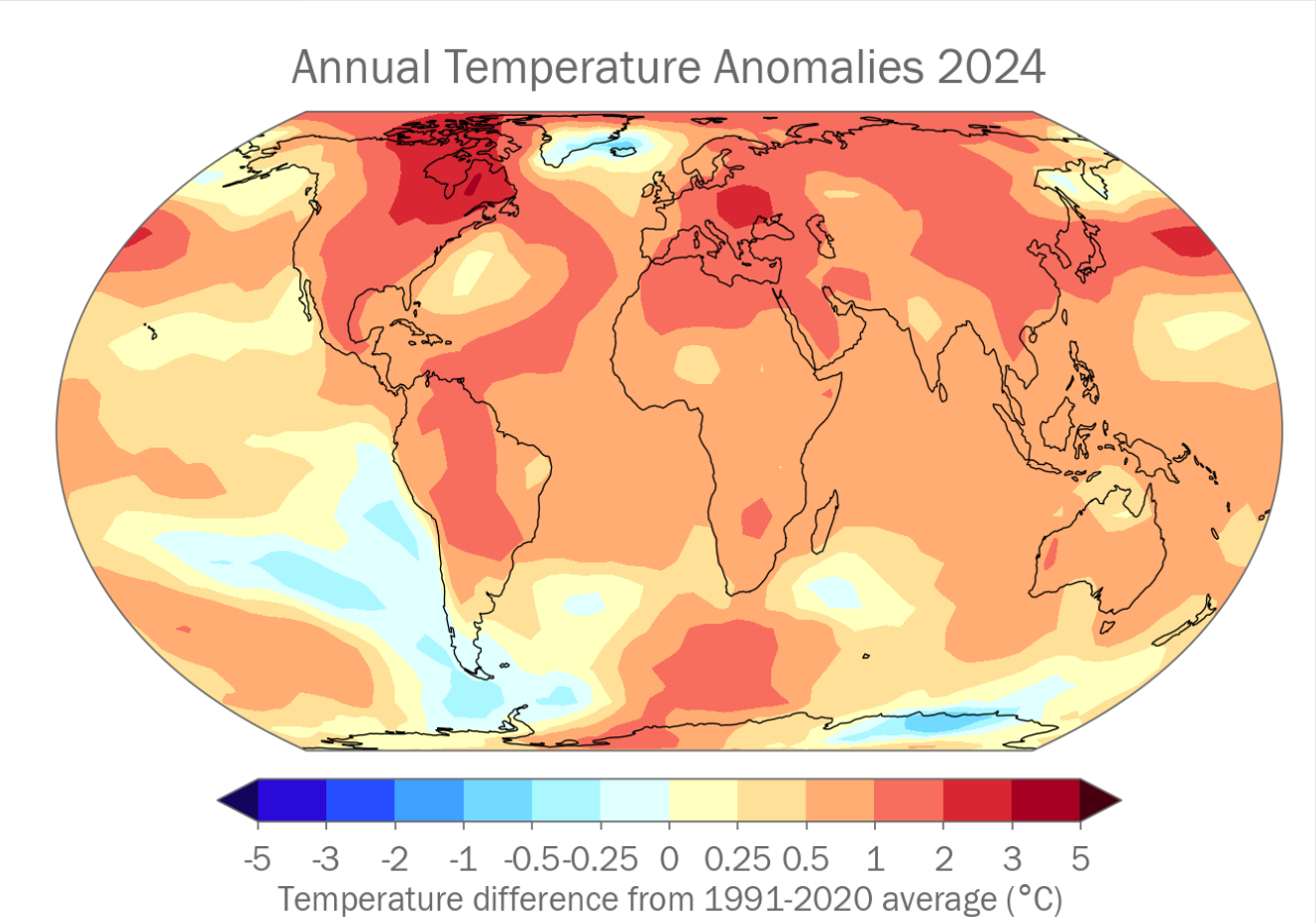


Worldwide, **2024 was the hottest year on record.**

1.55 ± 0.13 °C



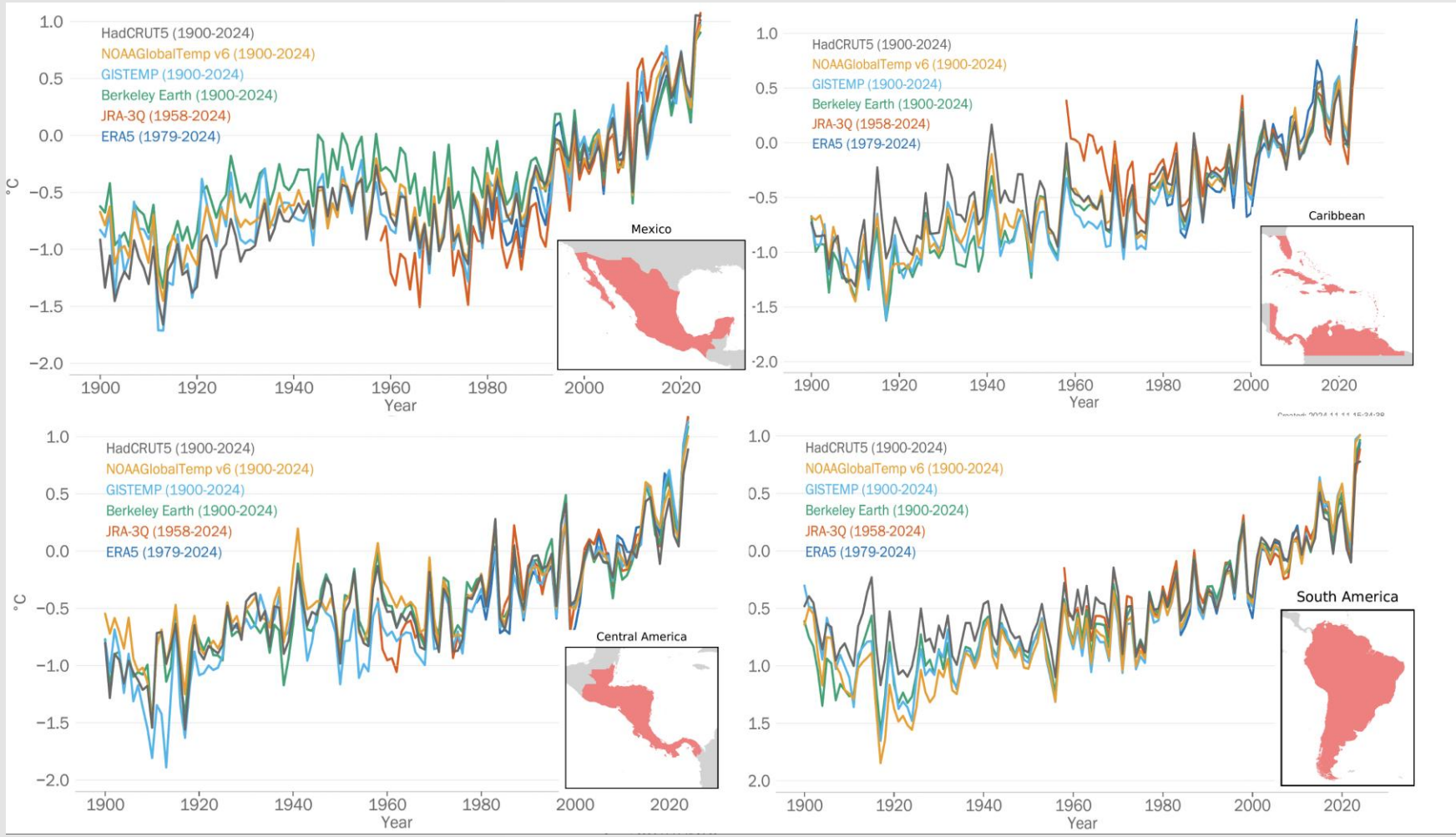


Regionally, 2024 was approximately:

+0.90 °C

above the 1991-2020 average.

the highest, or second highest on record.



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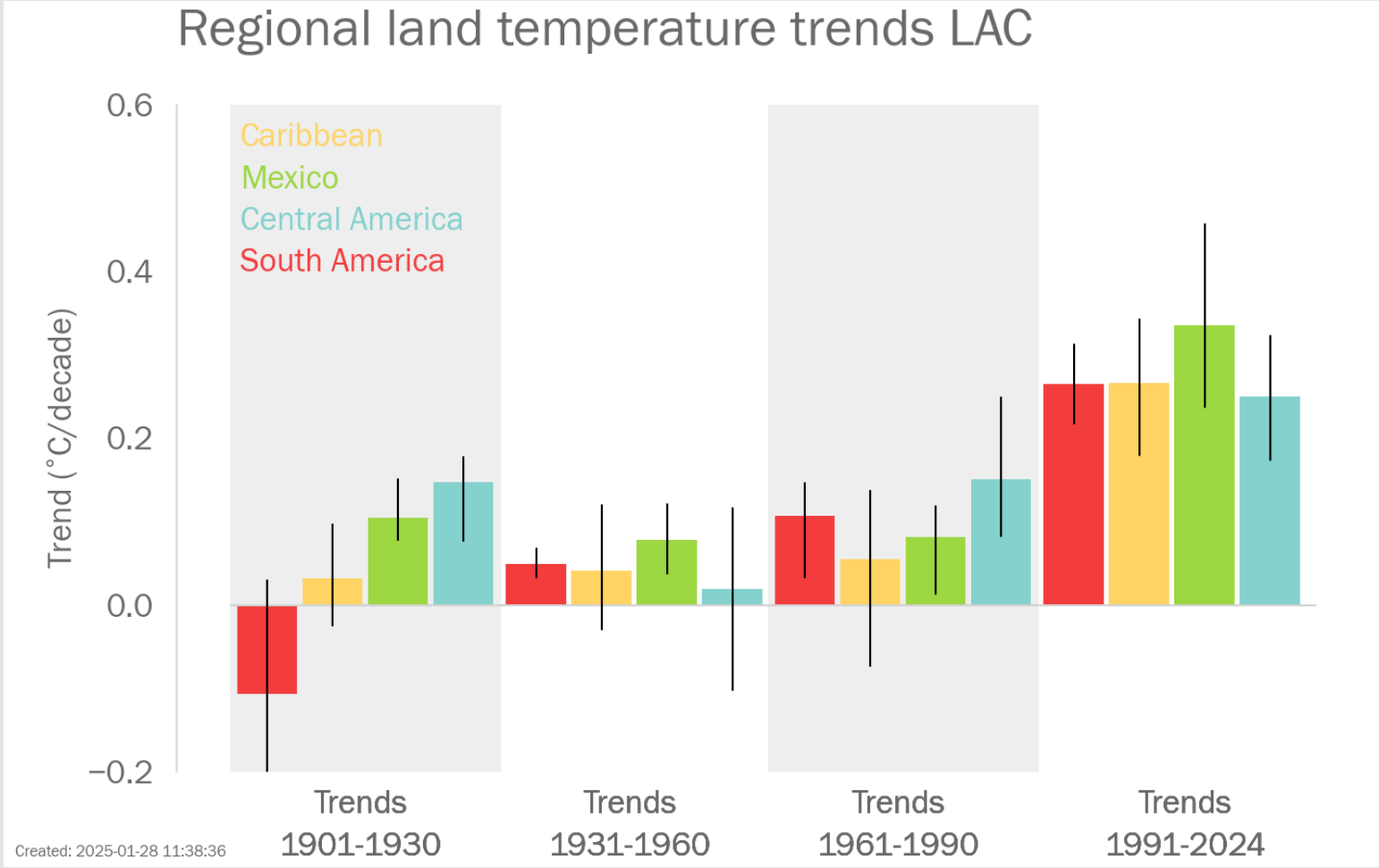
Variations in surface temperature have a large impact on natural systems and on human beings.

The last 3 decades were the warmest since 1900

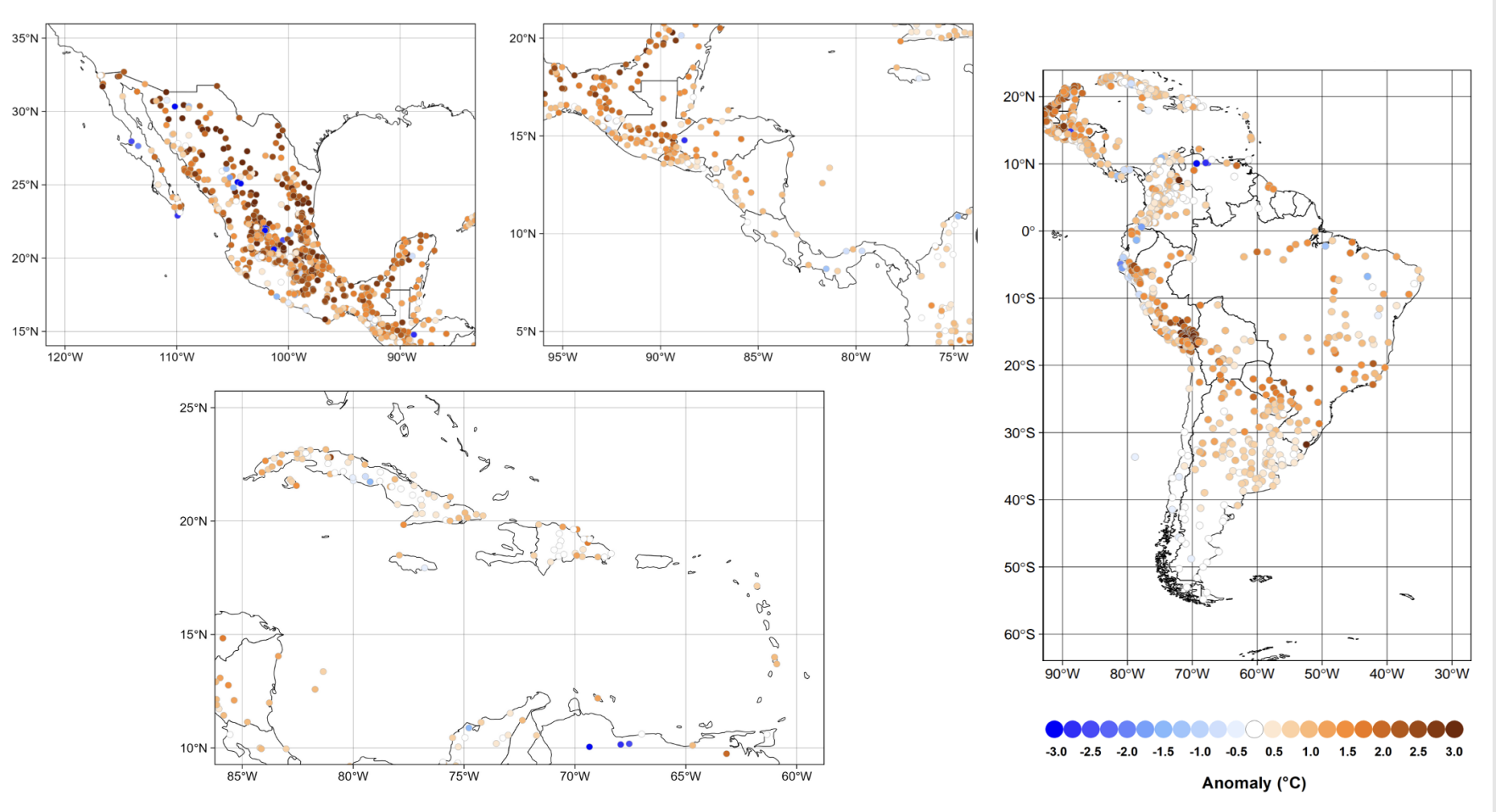


Above-normal temperature :

Central and Western Mexico, Across the Caribbean, Northern South America, western Amazonia, southern Andes of Peru, Bolivia, Paraguay, and parts of eastern Brazil.

Below-normal temperature:

Extreme south of Argentina and Chile, Parts of North of Mexico and Baja California



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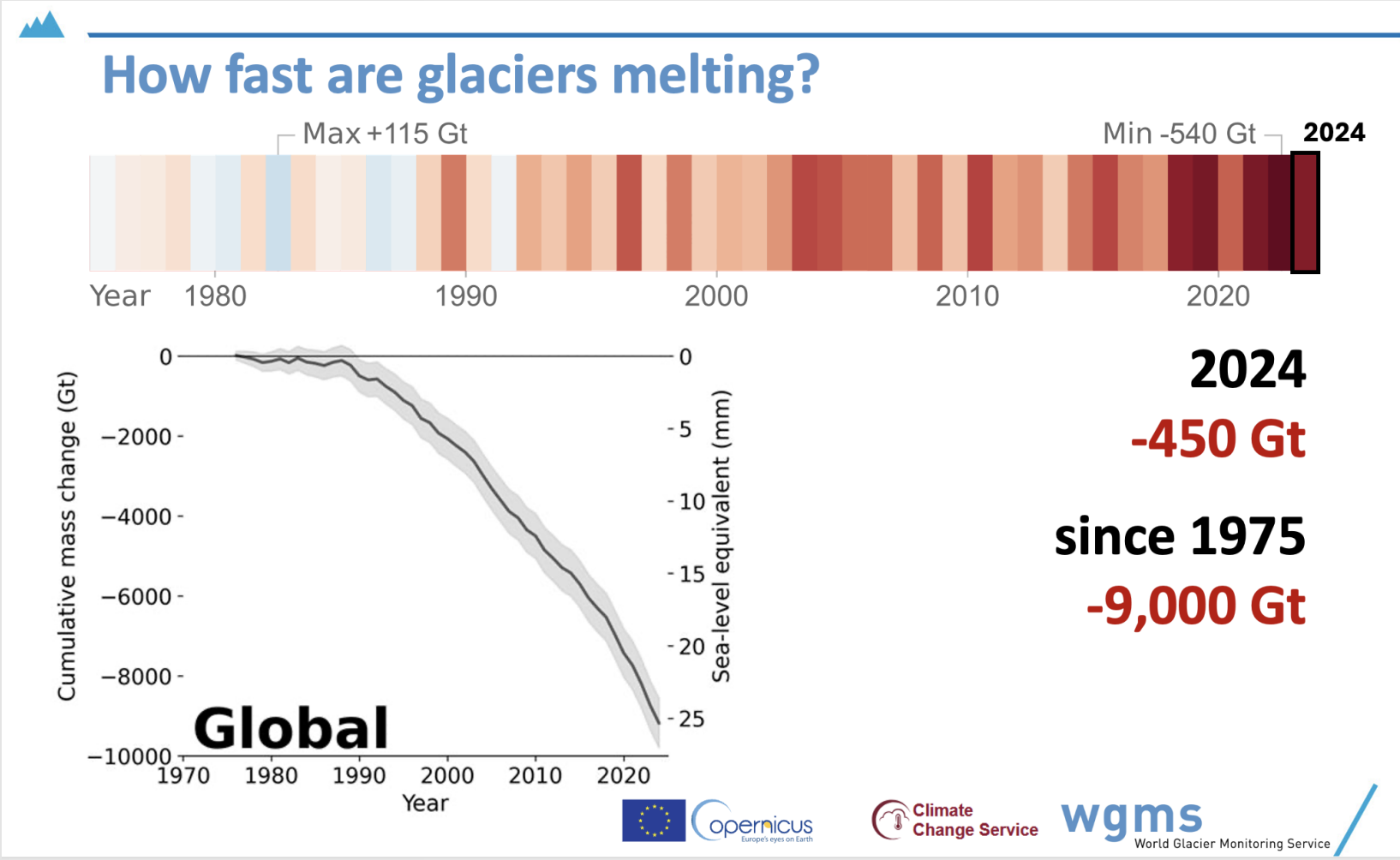
With the disappearance of Humboldt, its last remaining glacier, **the Bolivarian Republic of Venezuela became the second country in the world to lose all its glaciers.**

NASA Earth Observatory

Glacier mass loss from 2021-2024 was the most negative three-year glacier mass balance on record.

Exceptional losses were experienced in Norway, Sweden, Svalbard and the tropical Andes.



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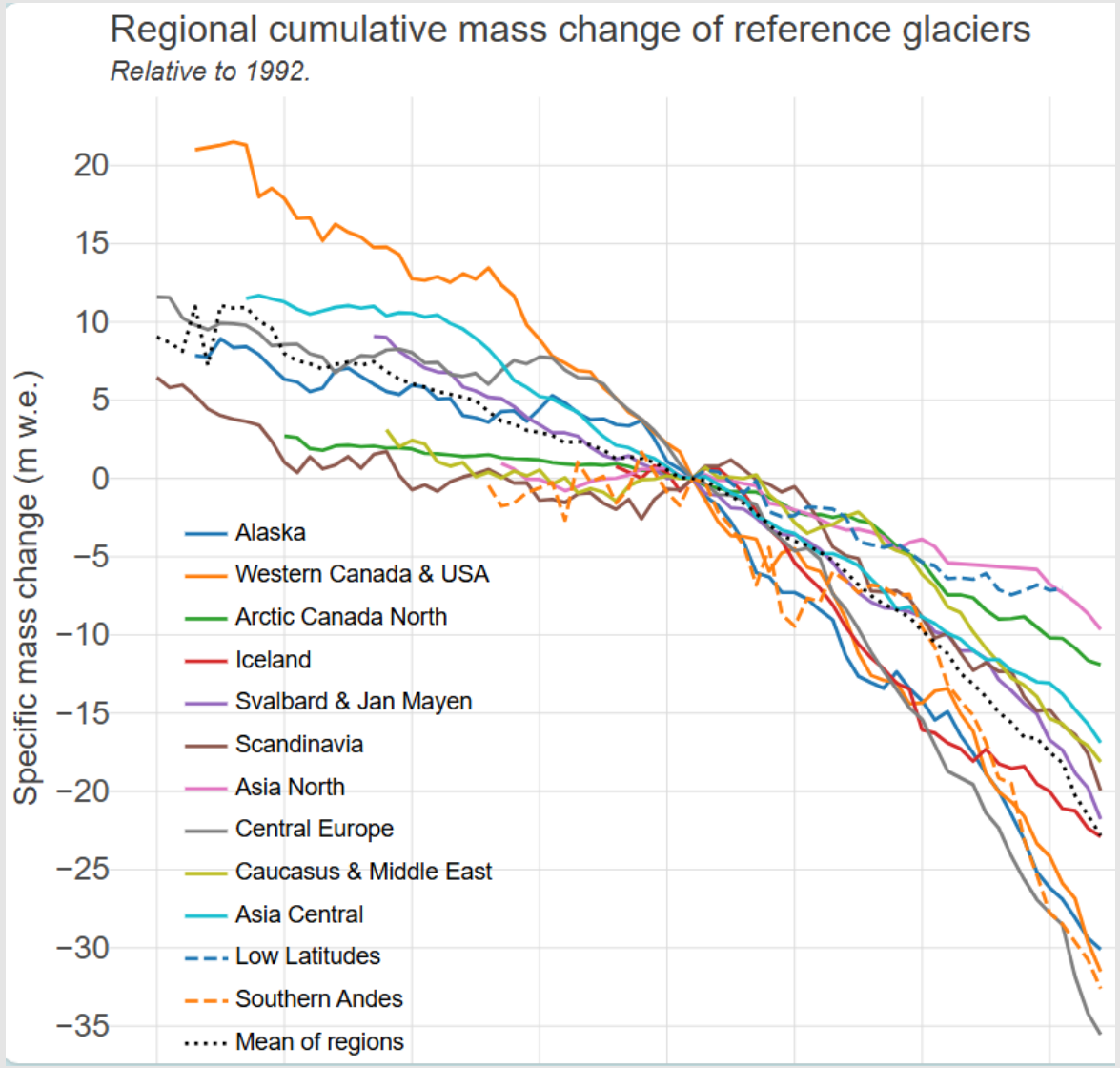
For the 2023–2024 hydrological cycle, **reference Andean glaciers had averaged higher losses** (–1.68 m water equivalent (m w.e.) **than the global average** (–1.35 m w.e).



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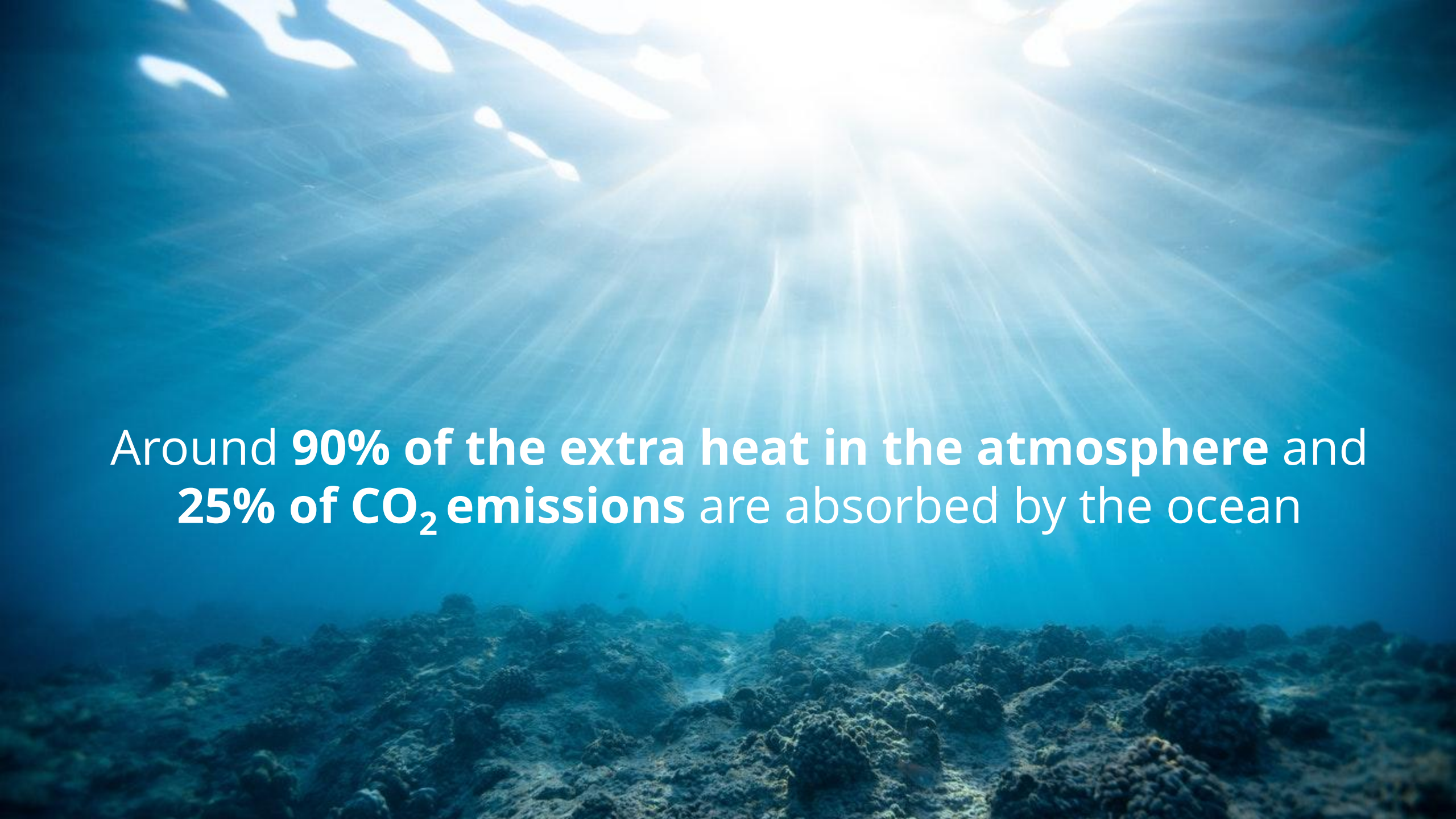
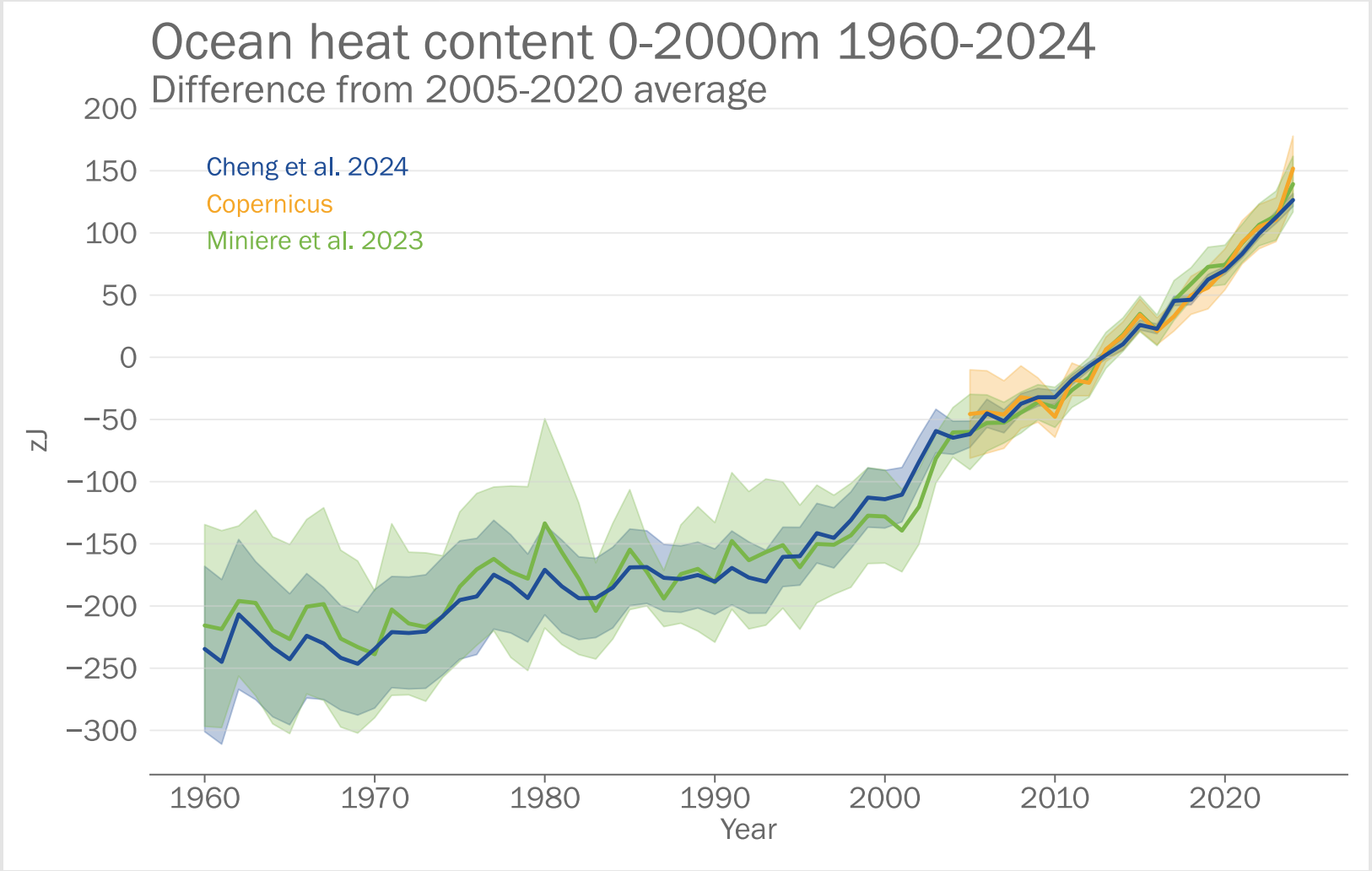

Around **90% of the extra heat in the atmosphere** and
25% of CO_2 emissions are absorbed by the ocean

In 2024, ocean heat content reached the highest level in the 65-year observational record.

The rate of warming from 2005–2024 is more than twice that observed from 1960–2005.



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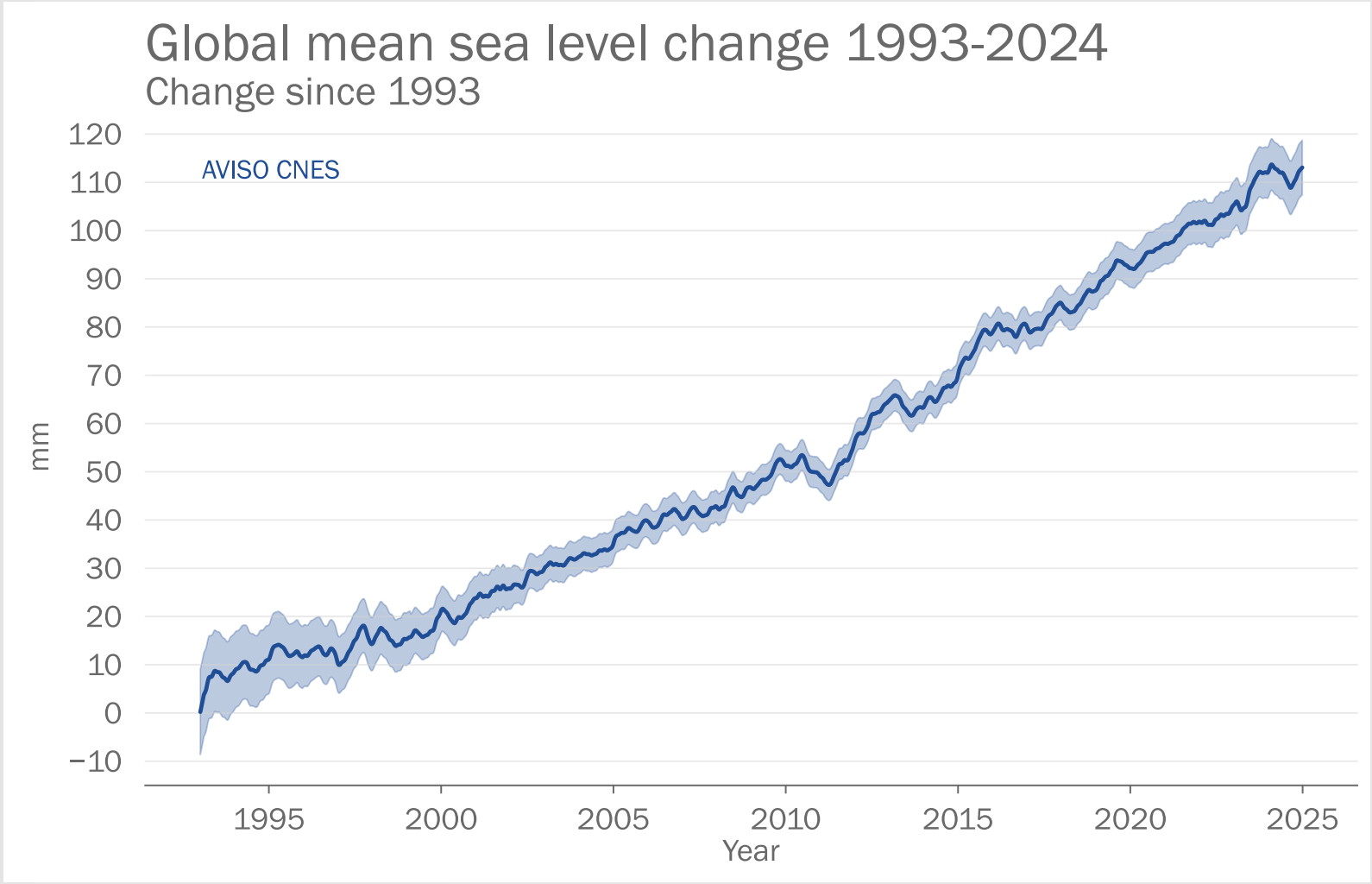
In 2024, global mean sea level reached a record high in the satellite record.

From 2015-2024, sea level rose at an annual rate of 4.7mm, compared to 2.1mm from 1993-2002.



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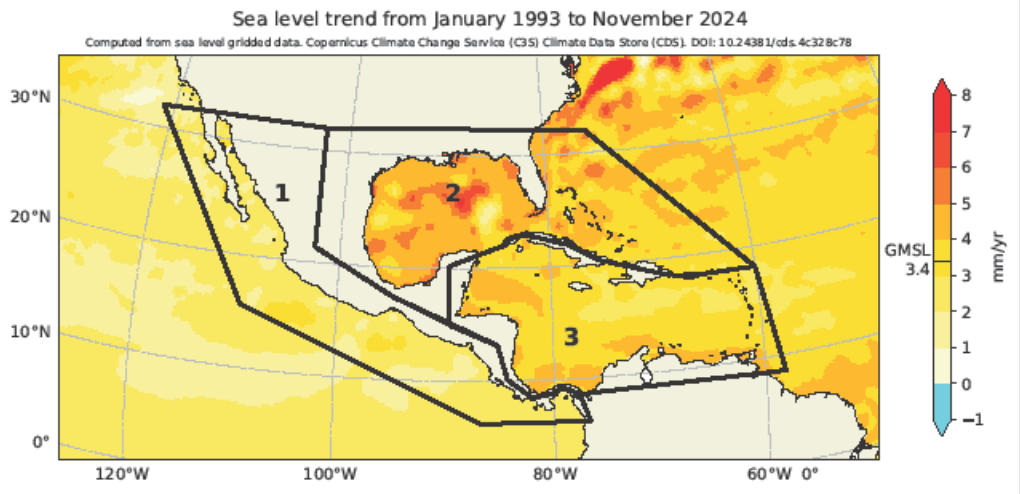
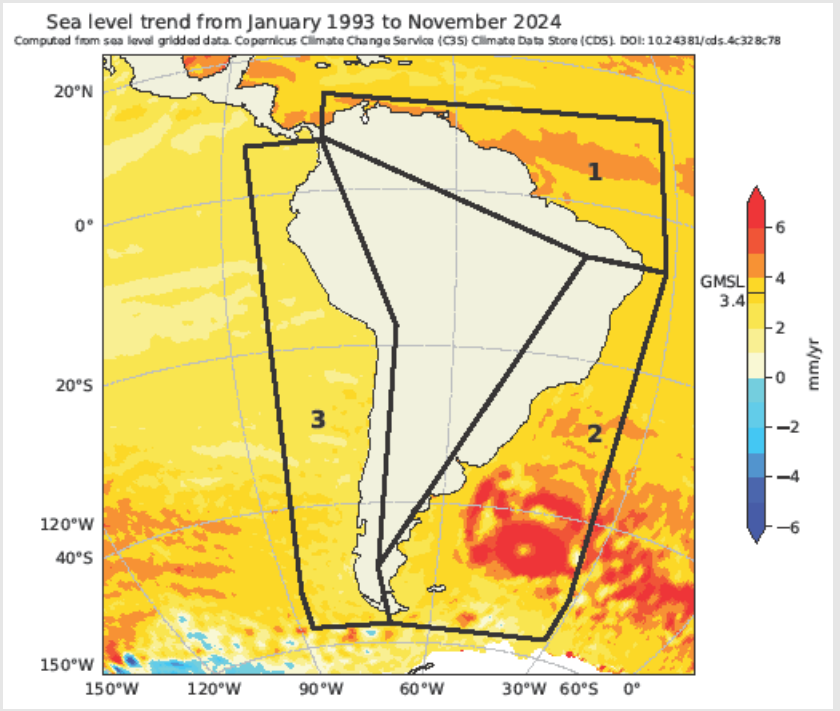
Sea level rise along the Atlantic side of South America was significantly higher than the global mean around 4.0 mm/year.

In contrast, along the Pacific side of Central and South America, the rate of sea-level rise was significantly lower than the global mean.

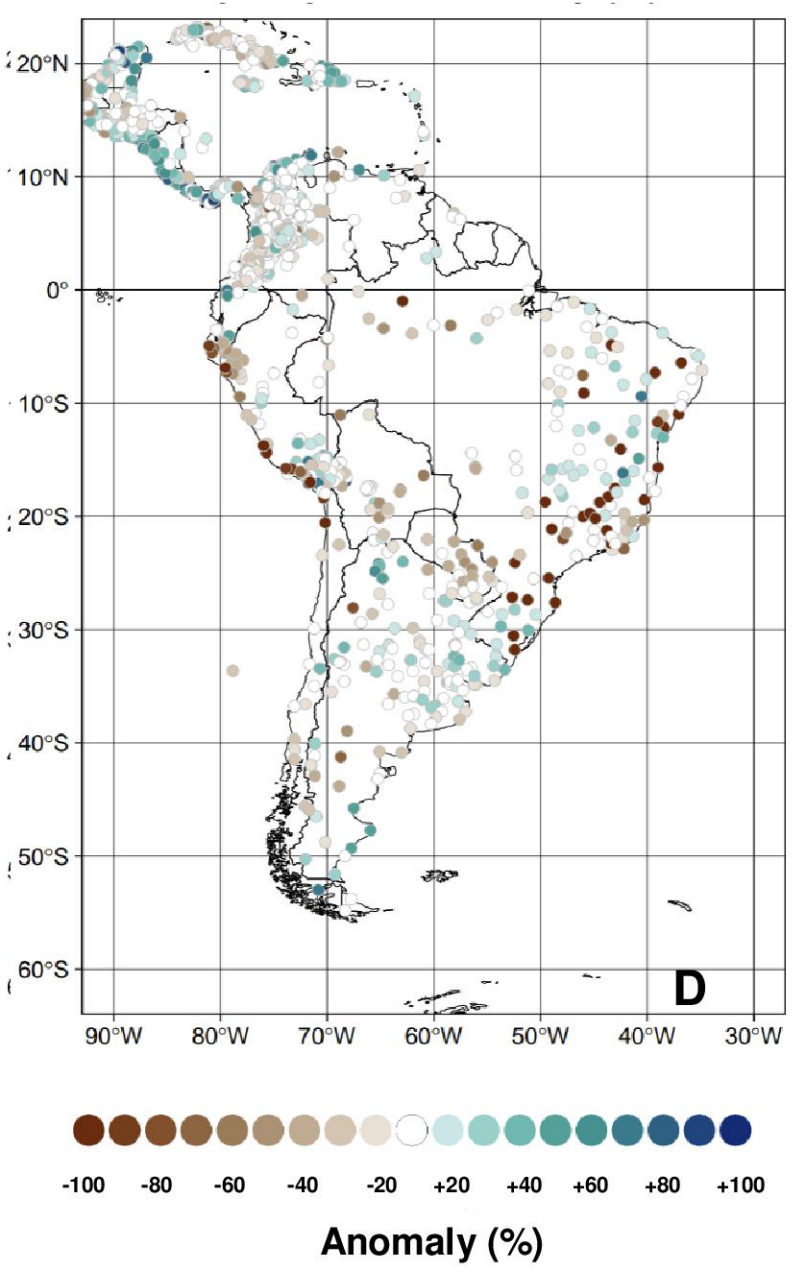
- South Atlantic reaching **2.93** mm / year
- Subtropical North Atlantic and Gulf of Mexico **4.0** mm/ year





Below-normal rainfall :
Northern Peru, Ecuador, central and southwestern Amazonia, Pantanal, Bolivia, Paraguay, western Venezuela, southern Uruguay, and parts of eastern Argentina.

Above-normal rainfall:
Southeastern South America, parts of eastern Brazil and Patagonia, as well as northern Argentina and Chile, with Central Chile



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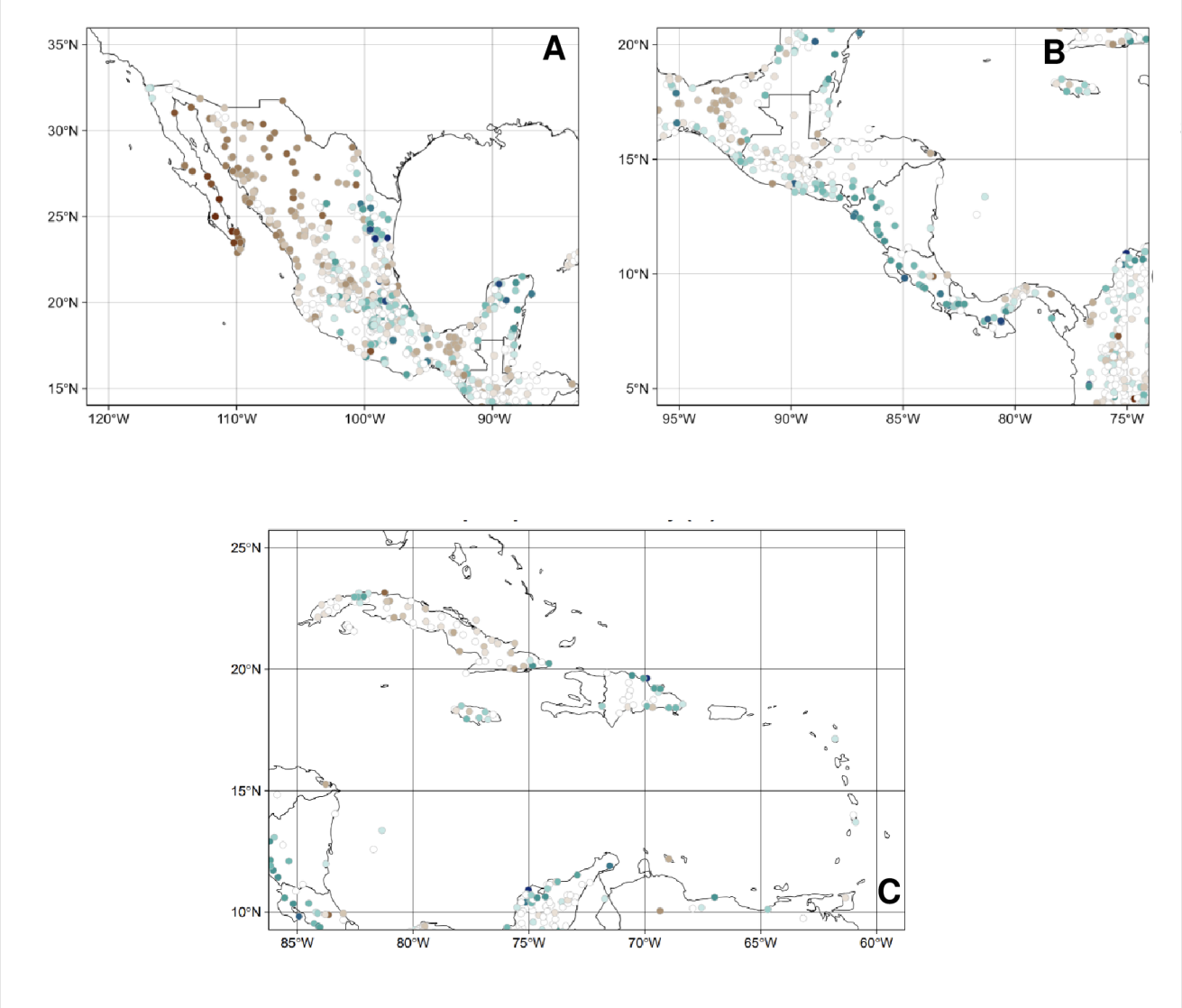
Below normal rainfall

Most of central and northwest Mexico, Baja California, and Cuba, with deficits ranging from 20% to 50%.

Above normal rainfall

Eastern Mexico, the Yucatán Peninsula, Guatemala, El Salvador, Costa Rica, Honduras, Nicaragua, and parts of Jamaica and Haiti, with anomalies between 10% and 40%.



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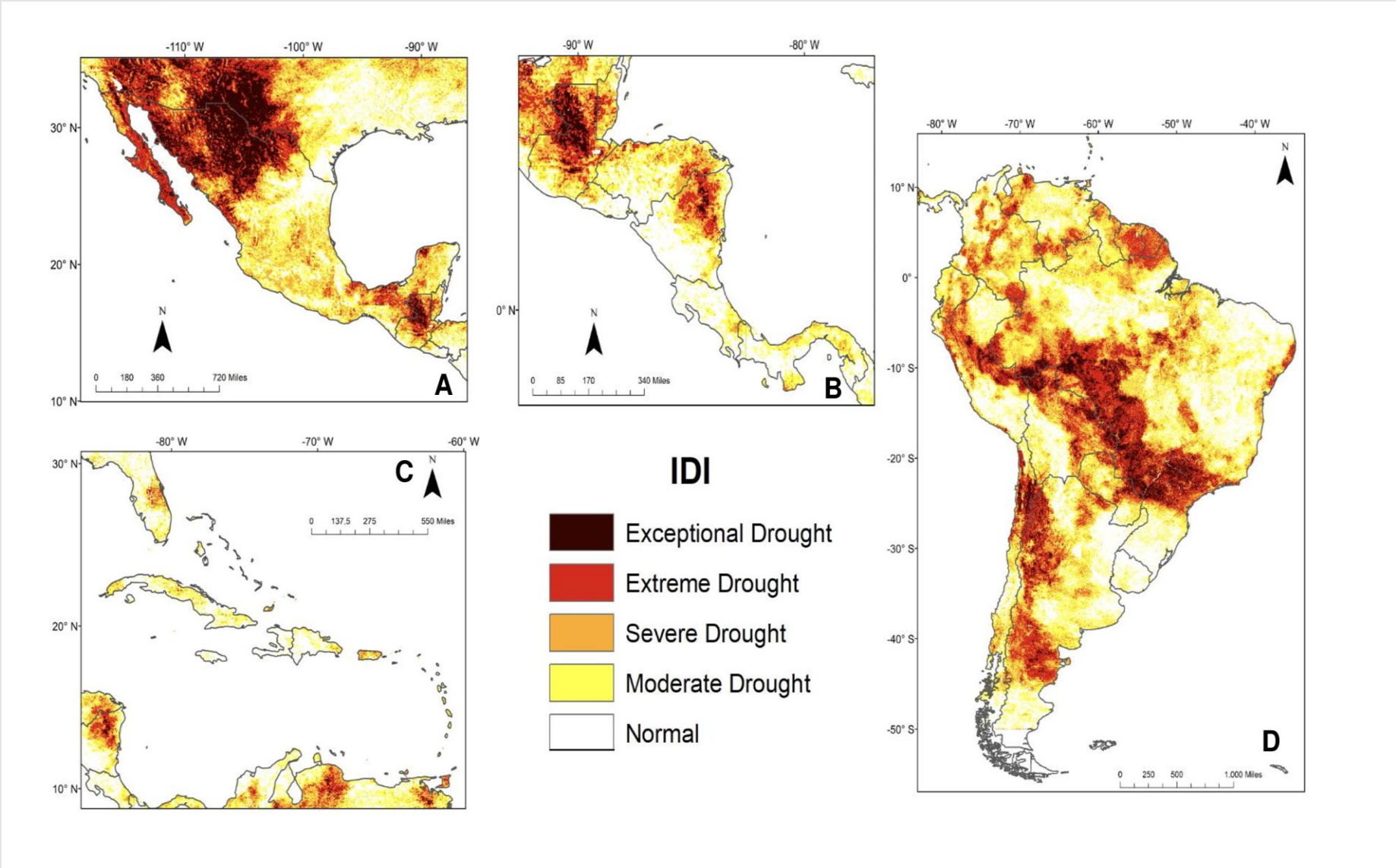
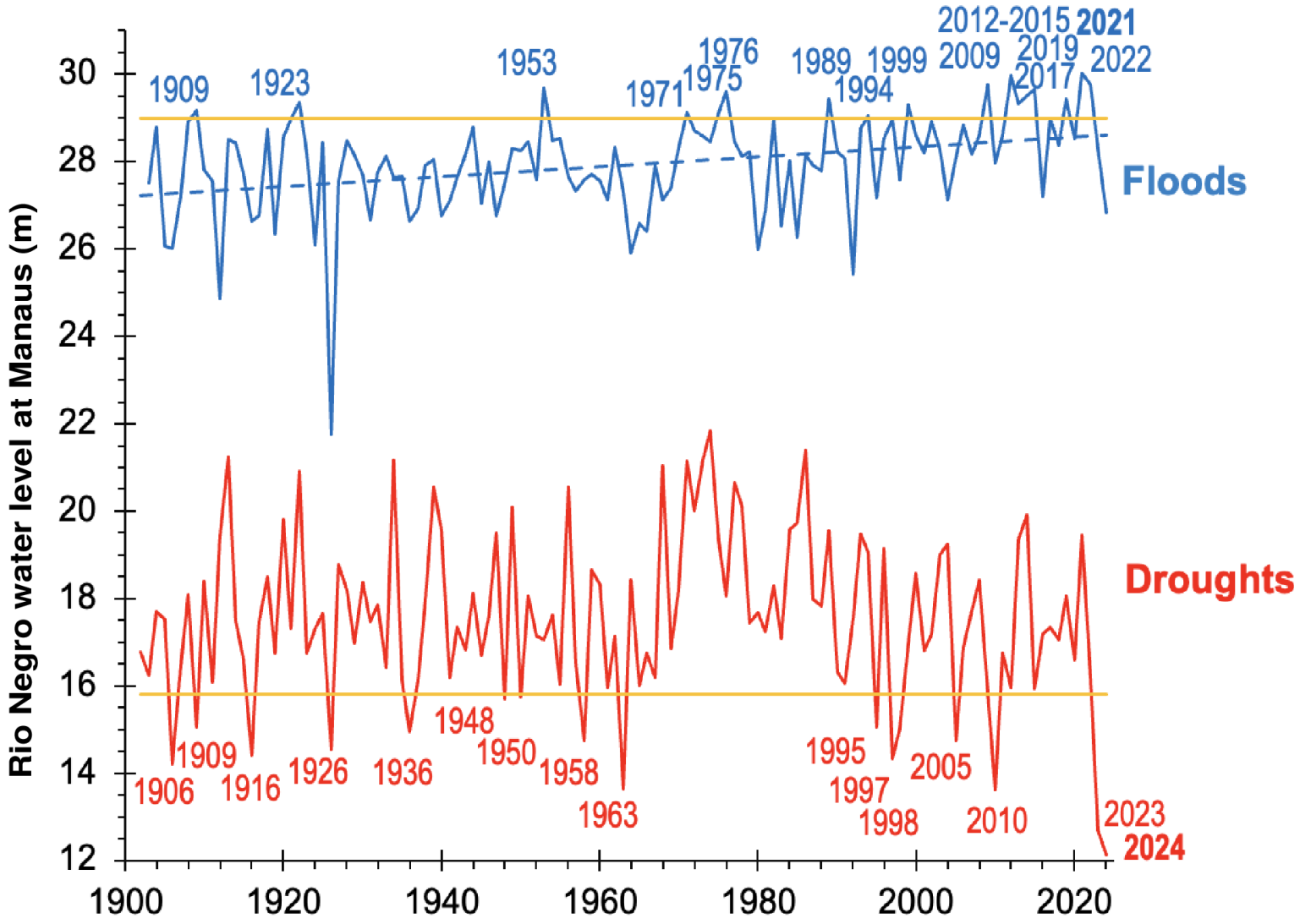
Drought in LAC

Drought overt most of northwestern Mexico and the Yucatan peninsula, parts of Central America and the Caribbean, the Amazon and Pantanal regions, central and northern South America, western Argentina, and northern and central Chile



El Niño conditions in the first half of the year contributed to widespread drought across Amazonia and the Pantanal.

The level of the Rio Negro at Manaus fell to 12.11 m on 10 October, the lowest in 112 years of record.



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Wildfires in Canada
Floods in Valencia, Spain
Heatwaves Europe, SE Asia, Middle East
Cold and Snow in Pakistan, Afghanistan, Iran
Hurricane Helene and Hurricane Milton
Heavy rain and floods, Sahel and East Africa
Typhoon Yagi
Drought in Central and South America
Drought in southern Africa
Flooding in Brazil
Cyclone Chido
Wildfires in Chile
Low Antarctic Sea-ice Extent

Colombia:
Condiciones secas en la región del Orinoco, con precipitaciones entre un 20 % y un 60 % por debajo de la media. Crecidas en febrero.

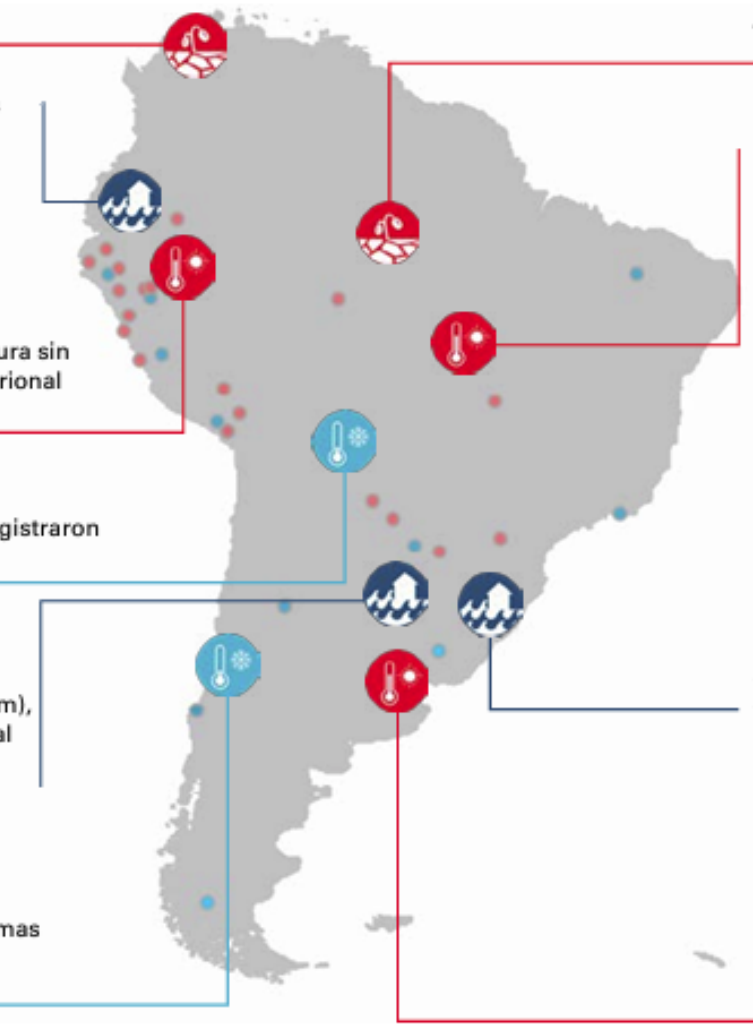
Ecuador:
Lluvias intensas, crecidas y deslizamientos de tierra en mayo y junio: 19 fallecidos y 275 desplazados. El 29 de septiembre casi la mitad del Ecuador había experimentado apagones a causa de la peor sequía en 61 años.

Perú:
En febrero de 2024 se llegó a una temperatura sin precedentes de 40,6 °C en la región septentrional de la Amazonia peruana.

Estado Plurinacional de Bolivia:
A raíz de una ola de frío el 14 de julio se registraron –1,2 °C en Tarija y 0,7 °C en Santa Cruz.

Paraguay:
En septiembre, el río Paraguay alcanzó en Asunción niveles mínimos históricos (73 cm), lo que alteró la navegación por la vía fluvial Paraná-Paraguay.

Chile:
Santiago enfrentó bajas temperaturas sin precedentes durante varios días, con mínimas cercanas a los 0 °C. El de 2024 fue el mes de mayo más frío desde 1950.



Brasil:
La cuenca del Amazonas sufrió una de las sequías más graves de su historia, que afectó a 745 000 personas hasta finales de septiembre. Los humedales del Pantanal enfrentaron su segunda peor sequía y su segunda peor temporada de incendios.

Brasil:
Del 15 al 18 de marzo, una ola de calor sin precedentes afectó al sur del Brasil. El 27 de abril empezó una ola de calor severa en el centro y sur del país que se prolongó durante cinco días. Entre finales de agosto y la primera semana de septiembre, varias olas de calor afectaron a partes de la región centroccidental del Brasil, en las que se registraron temperaturas 7 °C más altas de lo normal.

Brasil:
Entre abril y mayo de 2024, las crecidas sin precedentes en el estado meridional de Rio Grande do Sul llegaron a 478 de sus 497 municipios, afectaron a 2 398 255 personas y causaron 183 víctimas mortales y 27 desaparecidos. Los niveles récord del lago Guaíba (5,35 m el 5 de mayo) propiciaron las inundaciones en la capital Porto Alegre.

Argentina:
Buenos Aires registró su temperatura más alta de la historia (38,6 °C el 11 de marzo) y el mes de agosto más cálido en 117 años (30 °C el 30 de julio).

- Olas de calor, sequías e incendios forestales
- Periodos lluviosos, olas de frío, tormentas de nieve y granizo
- Inundaciones, mar gruesa y oleaje intenso
- Ciclones tropicales, tornados y relámpagos

Heatwaves

Heatwaves affected **Mexico** between April and June. Maximum temperature in Mexico City reached a new record of 34.7 ºC on 25 May-1,937 heat-related cases and 90 deaths due to heat strokes and dehydration.

In **Brazil, o**n 22 September Palmas measured 41.6°C respectively, both breaking previous records.

Other heatwave episodes were observed in the **Amazon region of Peru and in Argentina**, where 45.7°C were registered in Santiago del Estero on 03 February.

Between the end of July and the first days of August, a winter heatwave brought high temperatures in parts of northern and central **Chile**, and temperatures reached 38.9 ºC and the warmest day in 72 years.

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Heatwave in the city of São Paulo, Brazil

Heatwave in Mexico: in Tabasco and Chiapas howler monkeys deaths due to heat-related stress

Floods in Rio Grande do Sul: Brazil's worst climate-related disaster

Floods triggered by heavy rainfall caused economic losses of approximately USD 7 billion and more than 180 fatalities.

While timely warnings and evacuations helped mitigate the impacts, improved understanding of disaster risks among authorities and the public is needed.

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Wildfires: Chile's worst climate-related disaster

Fires through central and southern Chile resulted in the deaths of more than 130 people along the coastal towns of the country. The Government of Chile declared that these fires caused the country's worst natural disaster since the 2010 Chile earthquake

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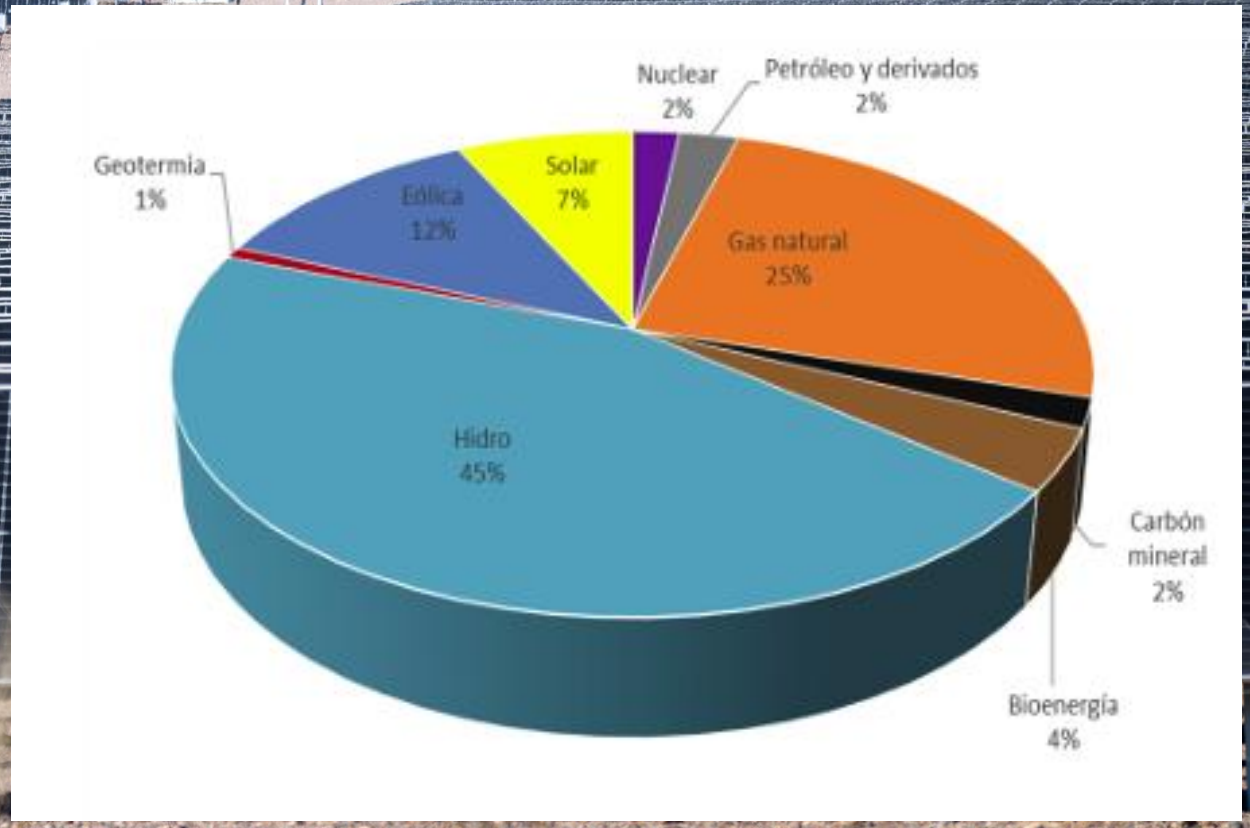
In 2024, renewable energy in Latin America and the Caribbean was nearly 69% of the region's energy mix, with renewable energies such as solar and wind experiencing a remarkable 30% increase in capacity and generation compared to 2023 .

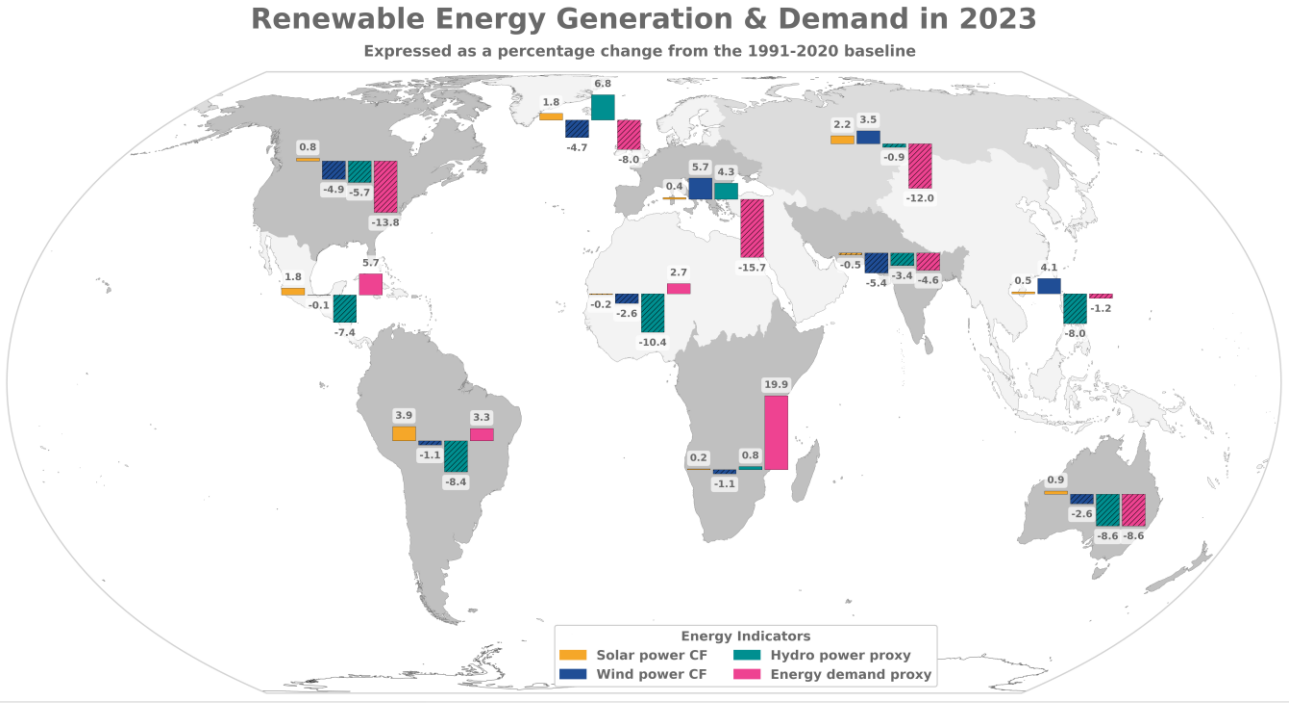


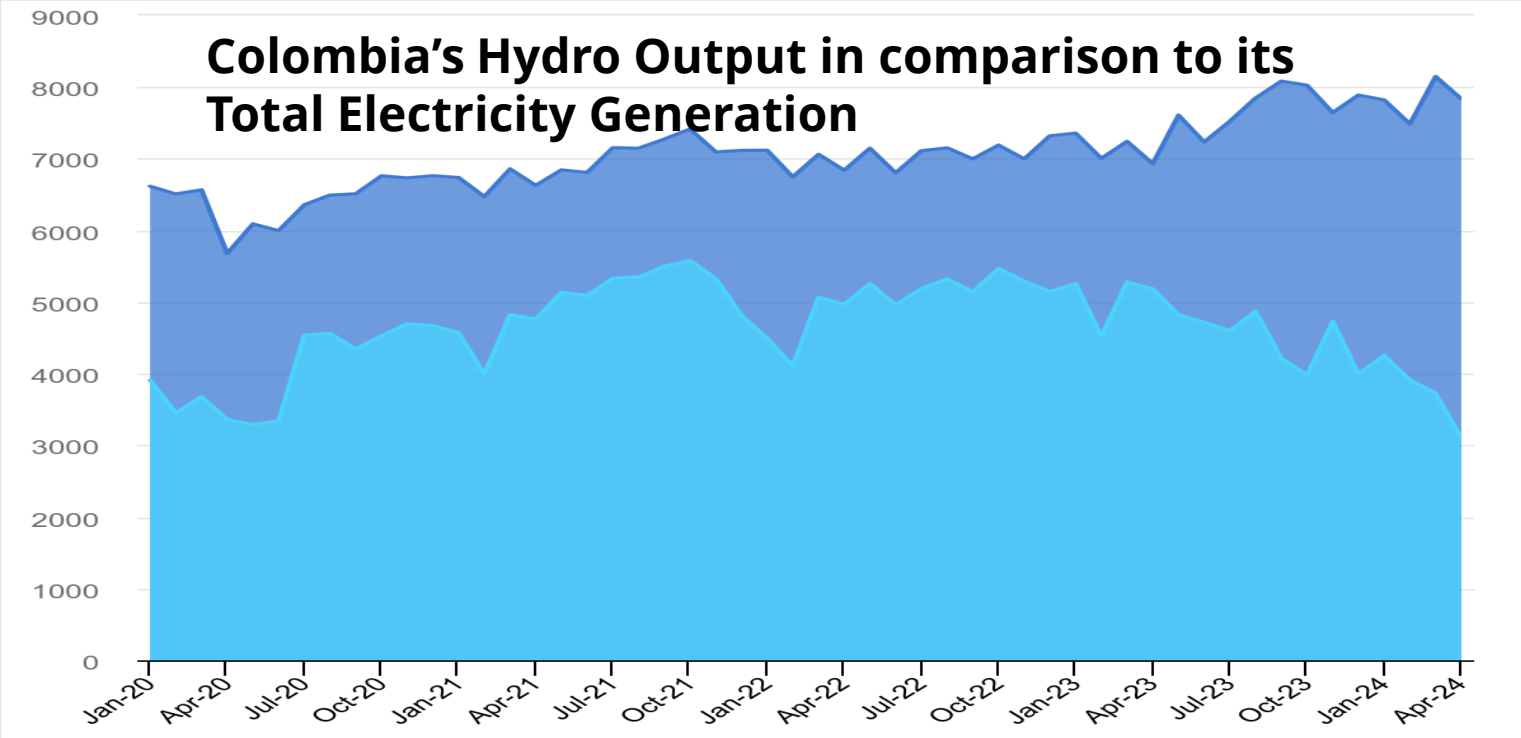
Hydropower

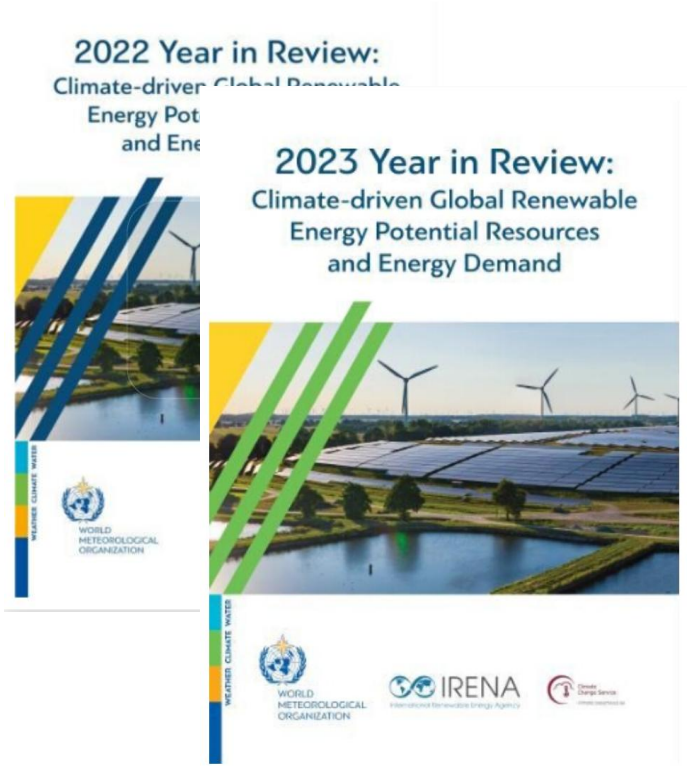
Hydropower remains a cornerstone of Latin America's energy mix, contributing approximately 45% of the region's electricity supply.

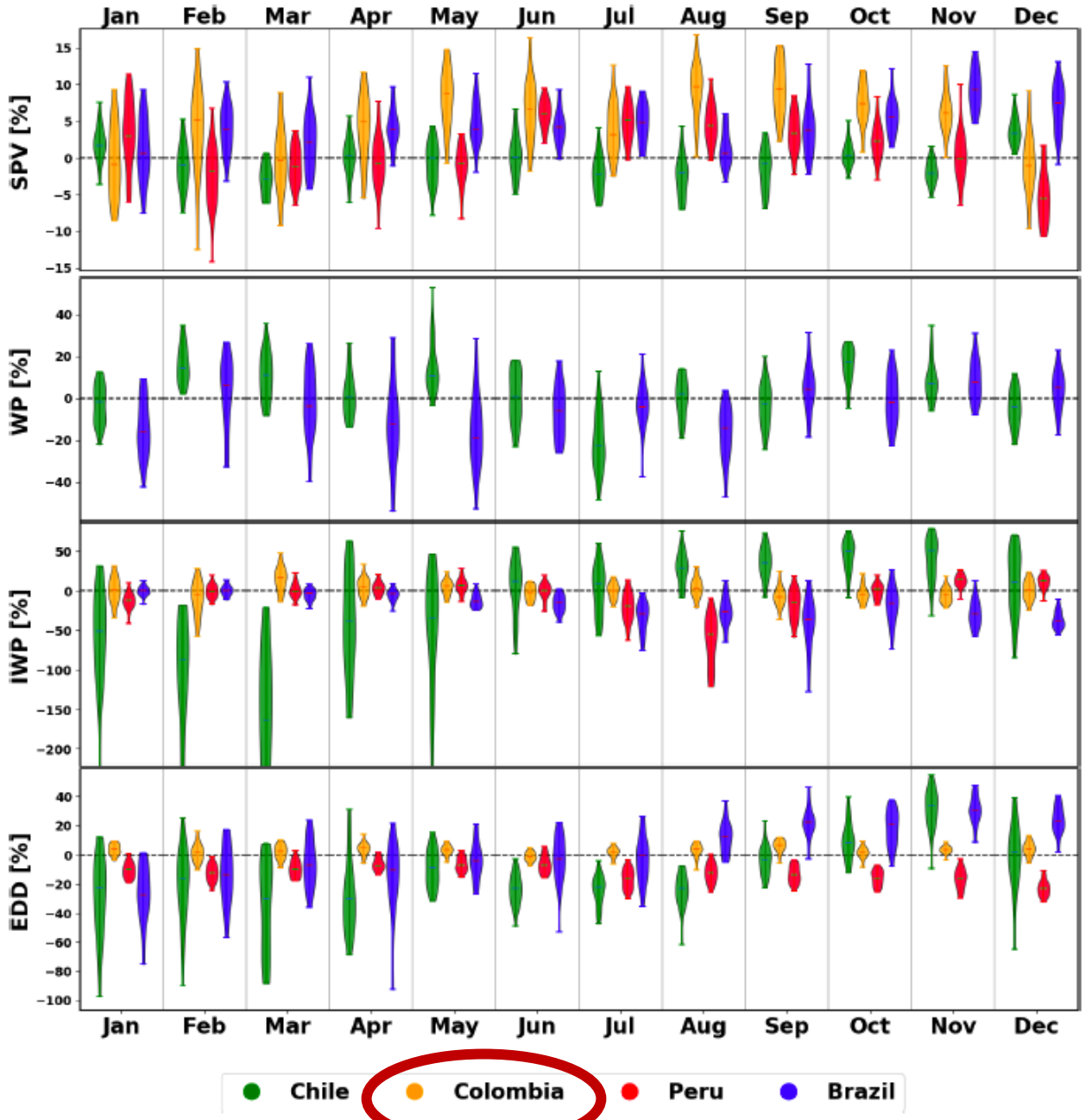
Despite its significance, **hydropower faces challenges due to climate variability,** including droughts and changing precipitation patterns.

Drought Impact: Severe drought conditions in 2024 led to historically low reservoir levels, impacting hydropower generation and causing energy shortages.





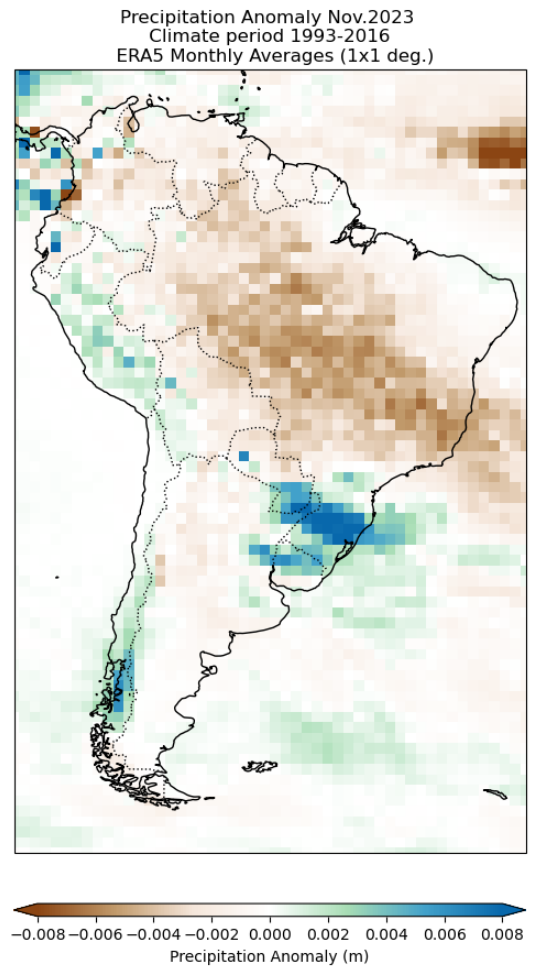


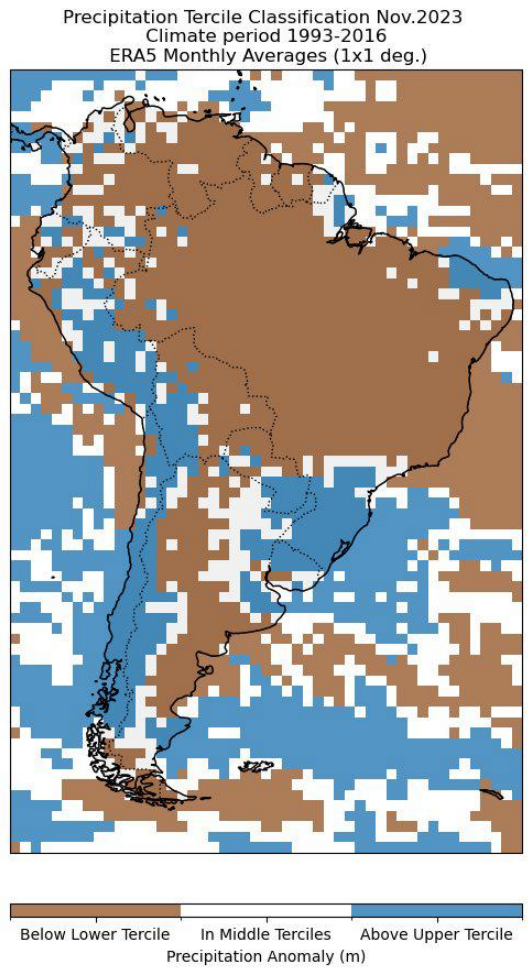


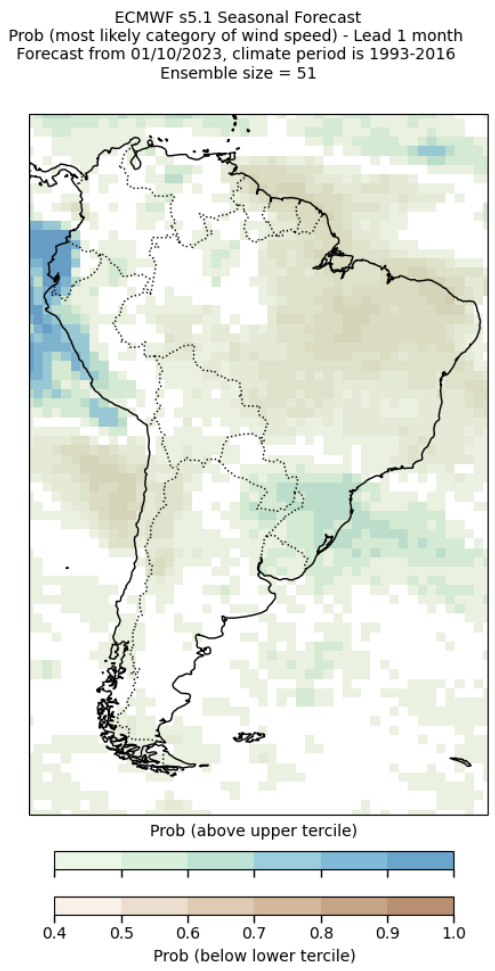
- **Informe anual 2024 de la OMM-IRENA: lanzamiento en julio de 2025**
- Los cambios mensuales en 2024, en comparación con el mismo mes del periodo climatológico 1991–2020, se muestran para cada indicador energético (Energía solar, eólica, hidroeléctrica y de consumo eléctrico)

WORLD METEOROLOGICAL ORGANIZATION

Adaptation to climate variability with seasonal climate forecasts







Maps of precipitation in South America (from a global model) for November 2023.

- **Left**: observed anomaly based on the ERA5 reanalysis
- **Centre**: the tercile classification derived from ERA5
- **Right**: the most likely tercile category from the seasonal forecast at a lead time of one month

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Key messages

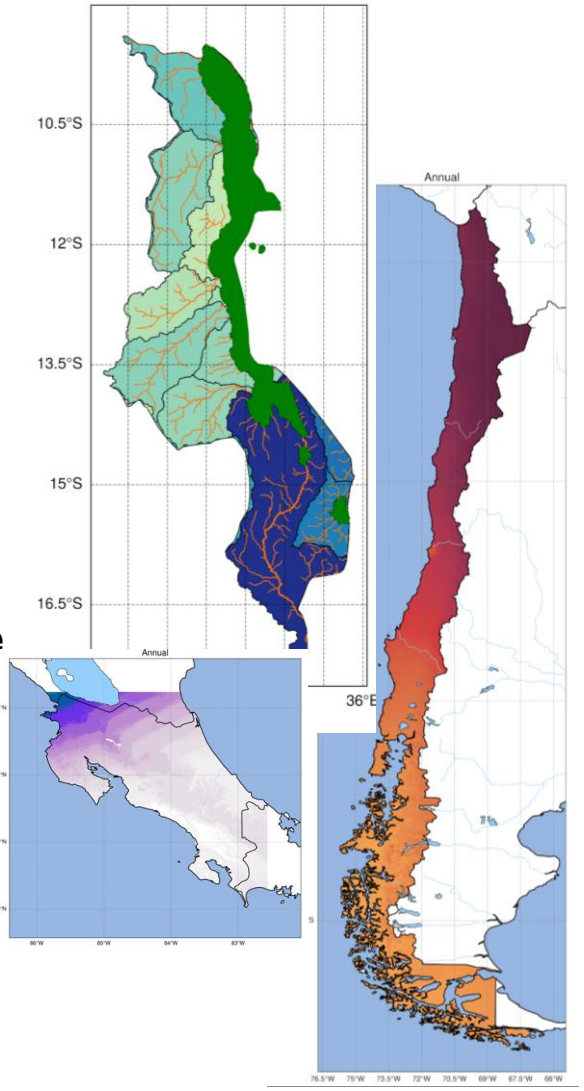
- Climate Variability and Change Significantly Affects Energy Indicators
- Understanding Climate Drivers is Crucial for Energy Resilience
- Climate Variability Information Needs to be Mainstreamed into Energy Systems for Planning and Management
- Flexible Market Structures are Crucial for the Energy Transitions
- Resilience should be Enhanced Through Diversification and Fostering Regional Collaboration.
- Comprehensive Energy Data Collection and Sharing are Critical

Séptimo foro

Servicios Energéticos de la OMM como Asistencia Técnica para los Miembros (Mini proyectos de Energia):

Pronóstico, Resiliencia y Planificación Estratégica

1. **Pronóstico a corto plazo con IA para plantas solares y eólicas**
   Modelos con IA integrando predicción numérica del tiempo y datos observacionales para mejorar el despacho, operación y mantenimiento de hasta 5 plantas. *(Eficiencia energética y acceso)*
2. **Pronóstico climático Sub-Estacional a Estacional (S2S) para hidroeléctricas**
   Modelos hidro-meteorológicos localizados para mejorar la gestión del agua y garantizar generación más confiable. *(Eficiencia energética y acceso)*
3. **Pronóstico de impactos y alerta temprana para infraestructura energética**
   Modelos localizados para alertas ante eventos extremos y planificación de resiliencia. *(Resiliencia energética)*
4. **Proyecciones climáticas de alta resolución para sectores clave**
   Proyecciones a largo plazo para evaluar riesgos climáticos y apoyar la planificación estratégica. *(Energía, agua, agricultura)*
5. **Evaluación del potencial de energía renovable en un clima cambiante**
   Proyecto de Atlas de la OMM (apoyo a los países para desarrollar atlas de alta resolución de viento, solar e hidroenergía con datos de proyecciones climáticas)
6. **Estimación de evaporación en paneles solares flotantes**
   Herramientas para evaluar pérdidas por evaporación y mejorar eficiencia y riesgos en sistemas flotantes.
7. **Plataforma digital como caja de herramientas climática sectorial**
   Plataforma escalable para servicios operativos sectoriales, incluyendo interfaz, integración de datos y desarrollo de capacidades.



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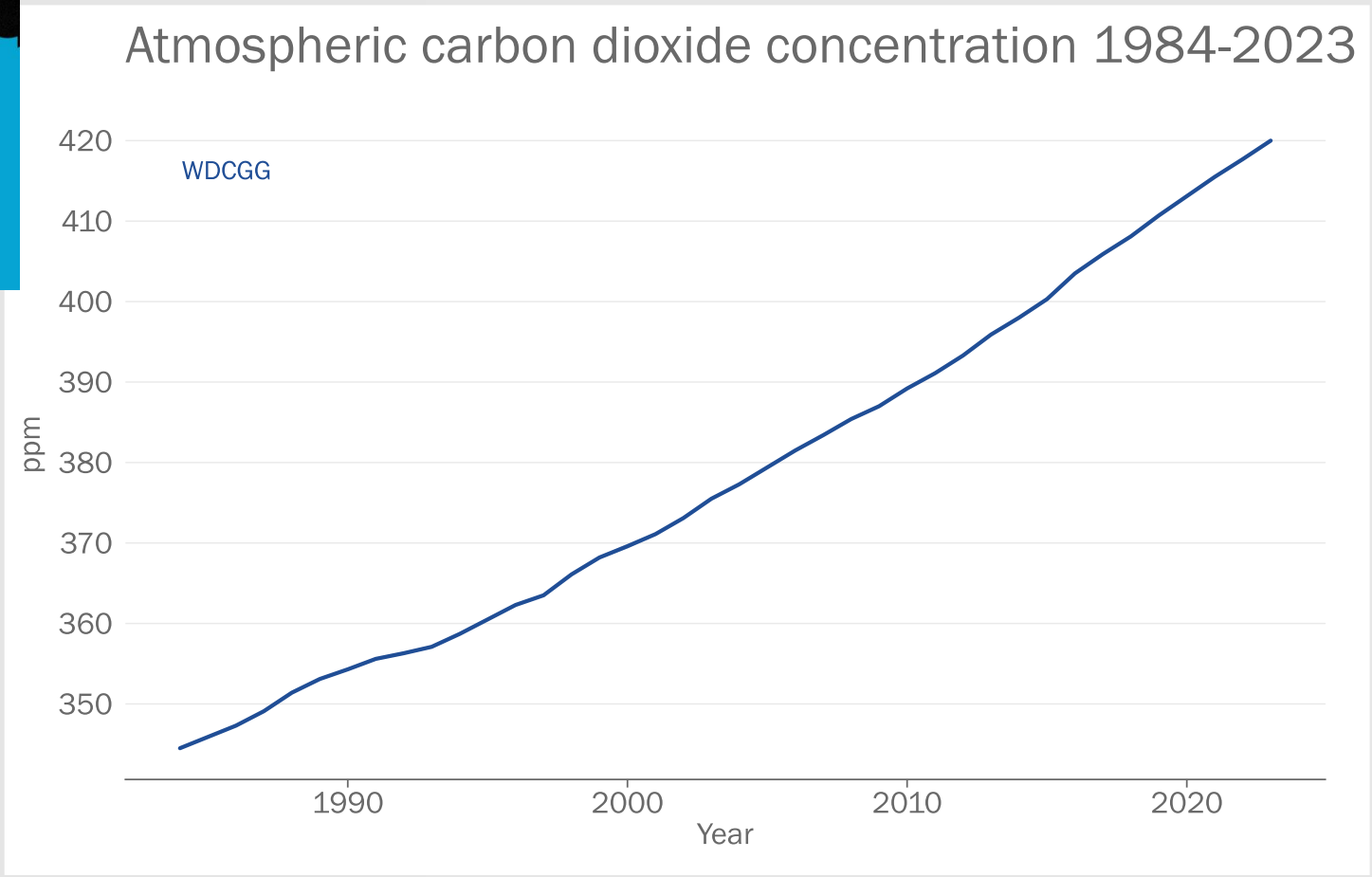
In 2023, atmospheric CO_2, methane and nitrous oxide **reached the highest levels in the last 800 000 years**



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CO_2

420 ± 0.1 ppm

151% of pre-industrial

CH_4

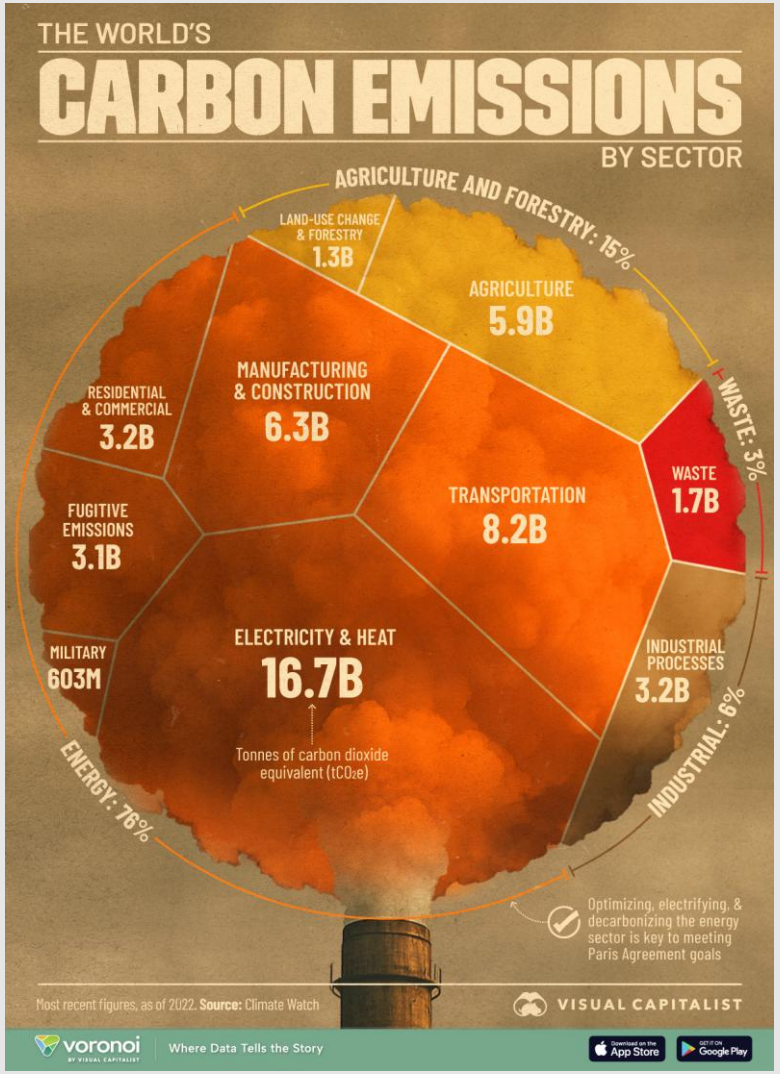
1934 ± 2 ppb

265% of pre-industrial

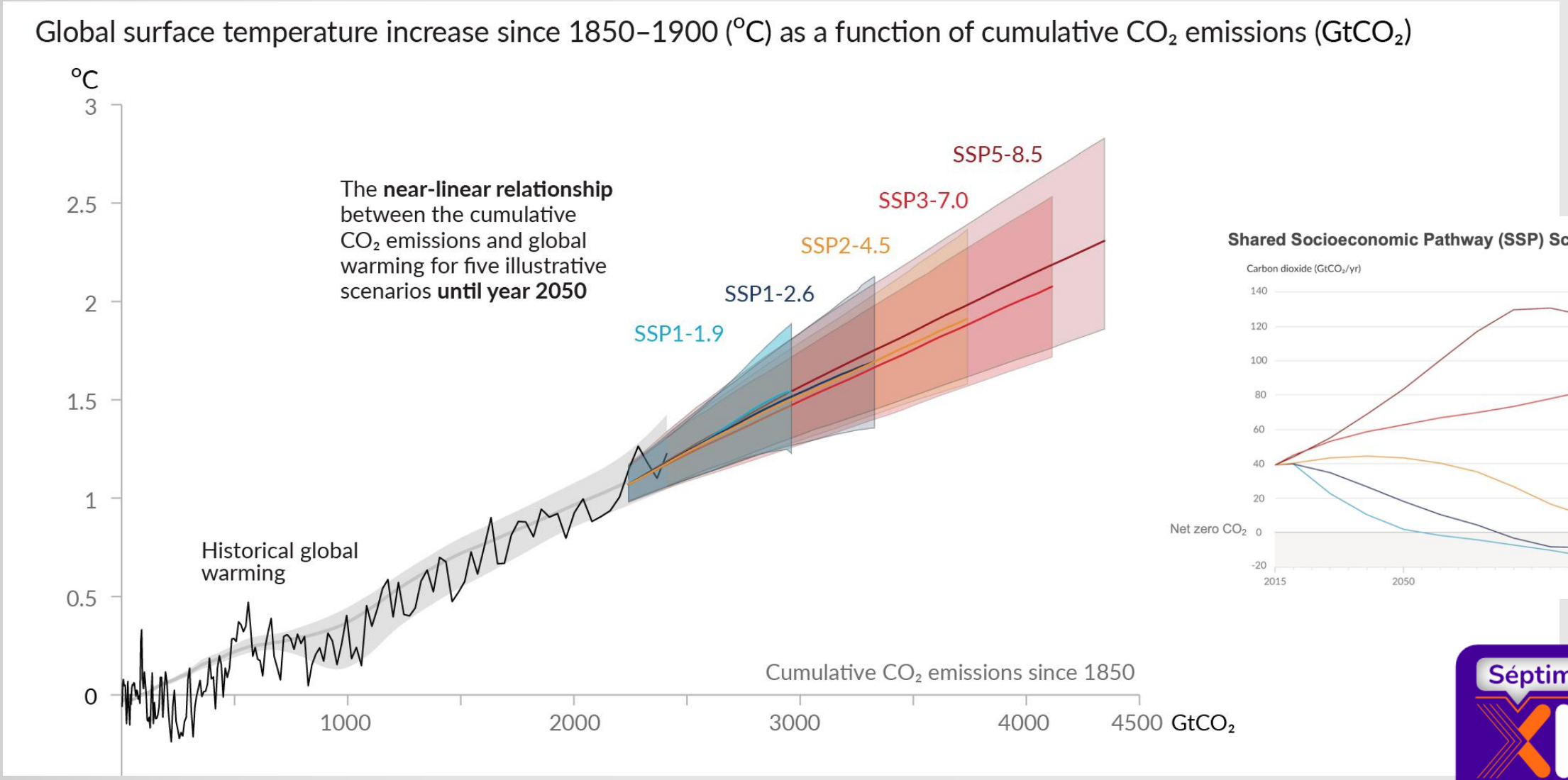
N_2O

336.9 ± 0.1 ppb

125% of pre-industrial



Every ton of CO_2 in the atmosphere contributes to the global warming



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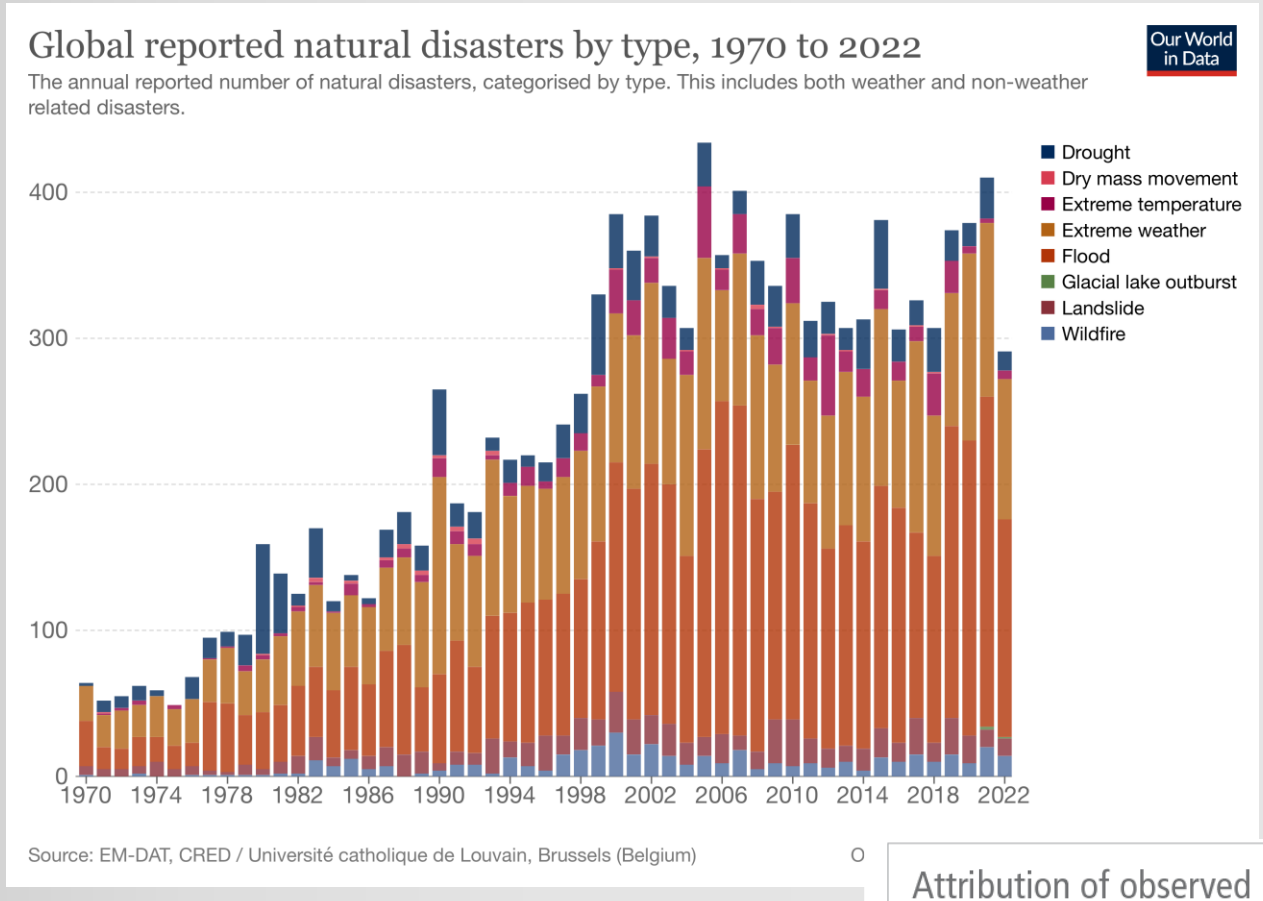
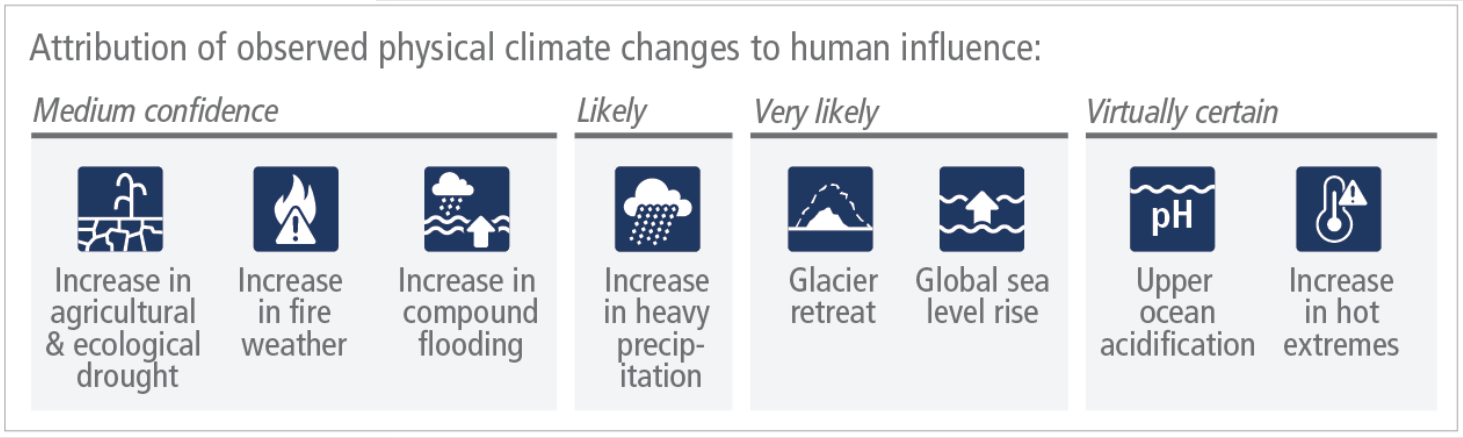
Climate Change will Continue to Intensify Extreme Events





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Key Takeaways

Climate Uncertainty is a structural risk to Colombia's Energy Security

Con más del 70 % de la electricidad dependiente de la hidroelectricidad, los cambios en los patrones de lluvia y sequía amenazan directamente la confiabilidad del sistema energético, su asequibilidad y el bienestar de la población.

Managing Uncertainty Requires Forecasts and Resilient Systems

Resiliencia significa integrar inteligencia climática en tiempo real, diversificar la matriz energética y habilitar una gestión flexible de la red.

Colombia must invest in climate-smart infrastructure and policy coordination

Construir un sistema energético preparado para el futuro implica modernizar la infraestructura hidroeléctrica, escalar las soluciones de almacenamiento y alinear a las instituciones nacionales —como UPME, XM, IDEAM y el Ministerio— con una planificación informada por el clima

¡Gracias!

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xm