

**Climate Change is Happening!**  
**The oceans are warming!**

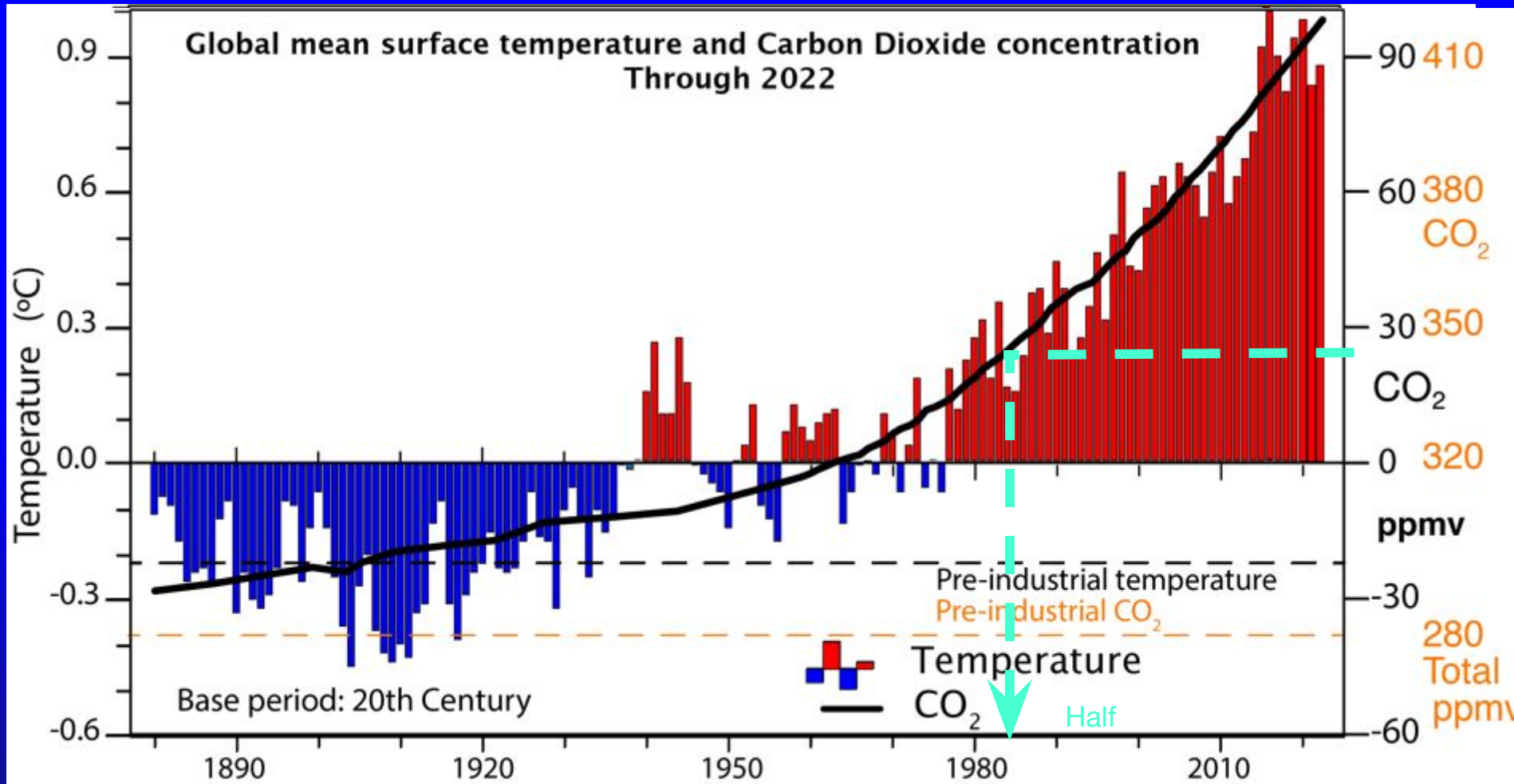
**Kevin E Trenberth**



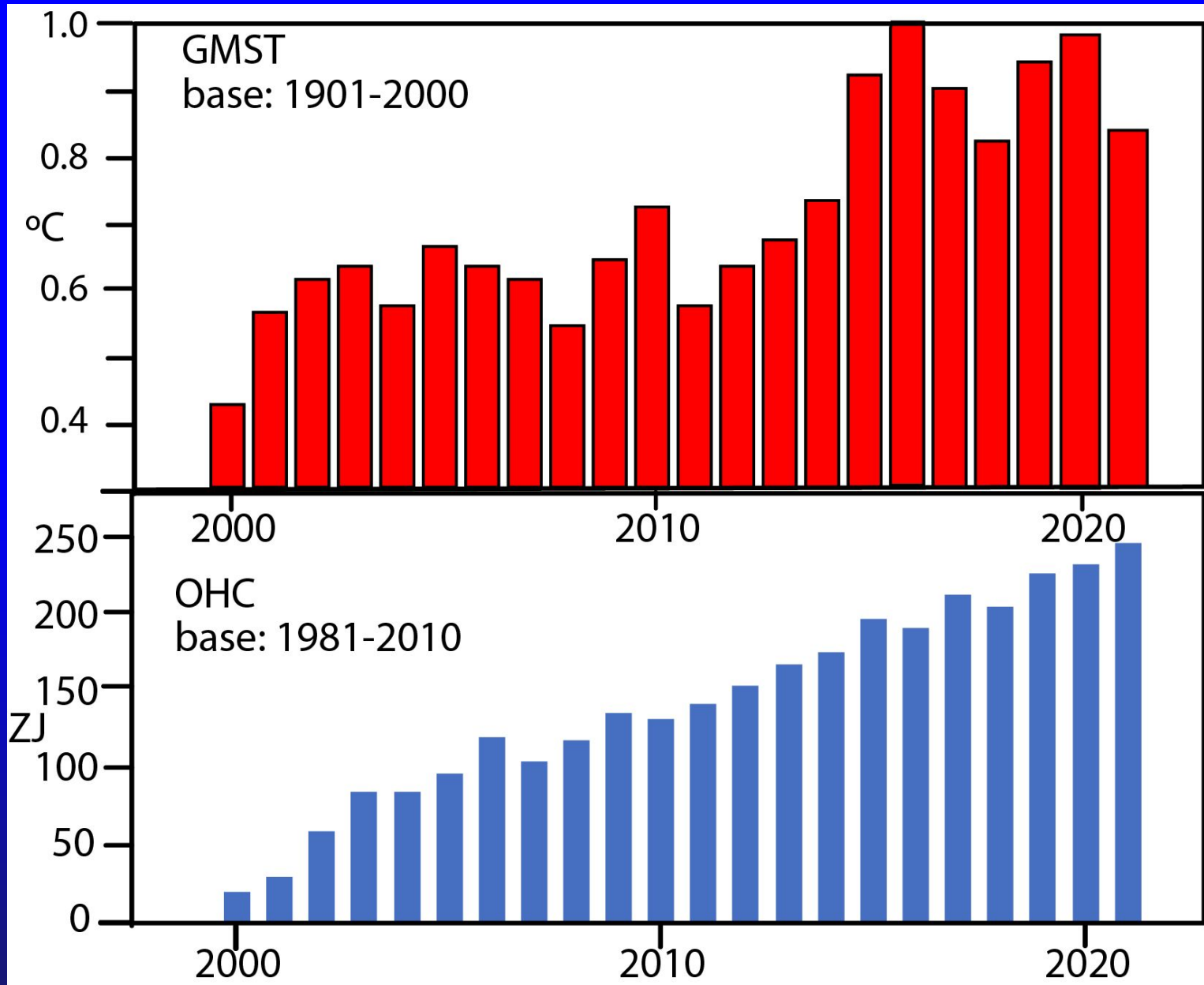
**NCAR and U. Auckland**

**Special thanks to Lijing Cheng, IAP, China**

# Global temperature and carbon dioxide: anomalies through 2022



# Relative variability in OHC vs GMST



# World Ocean Database: World's largest publicly available oceanographic profile database



a) bottle/reversing therm.

b) MBT

c) XBT

d) CTD



e) towed CTD

f) profiling float

g) moored buoy

h) ice-tethered profiler

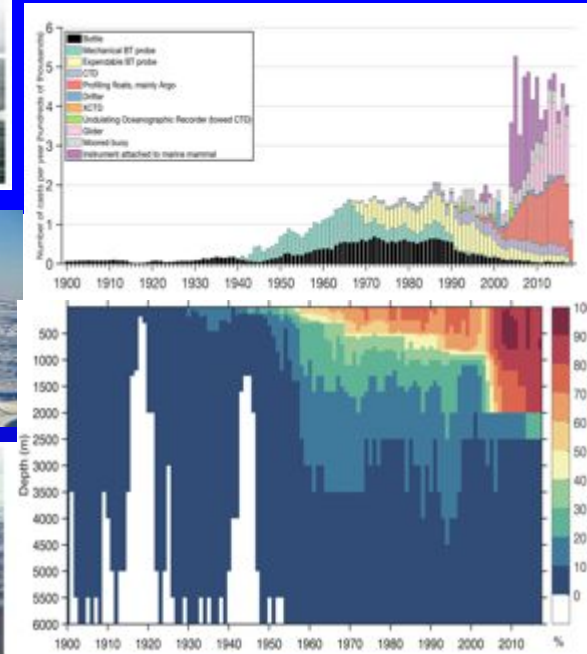


i) instrumented animal

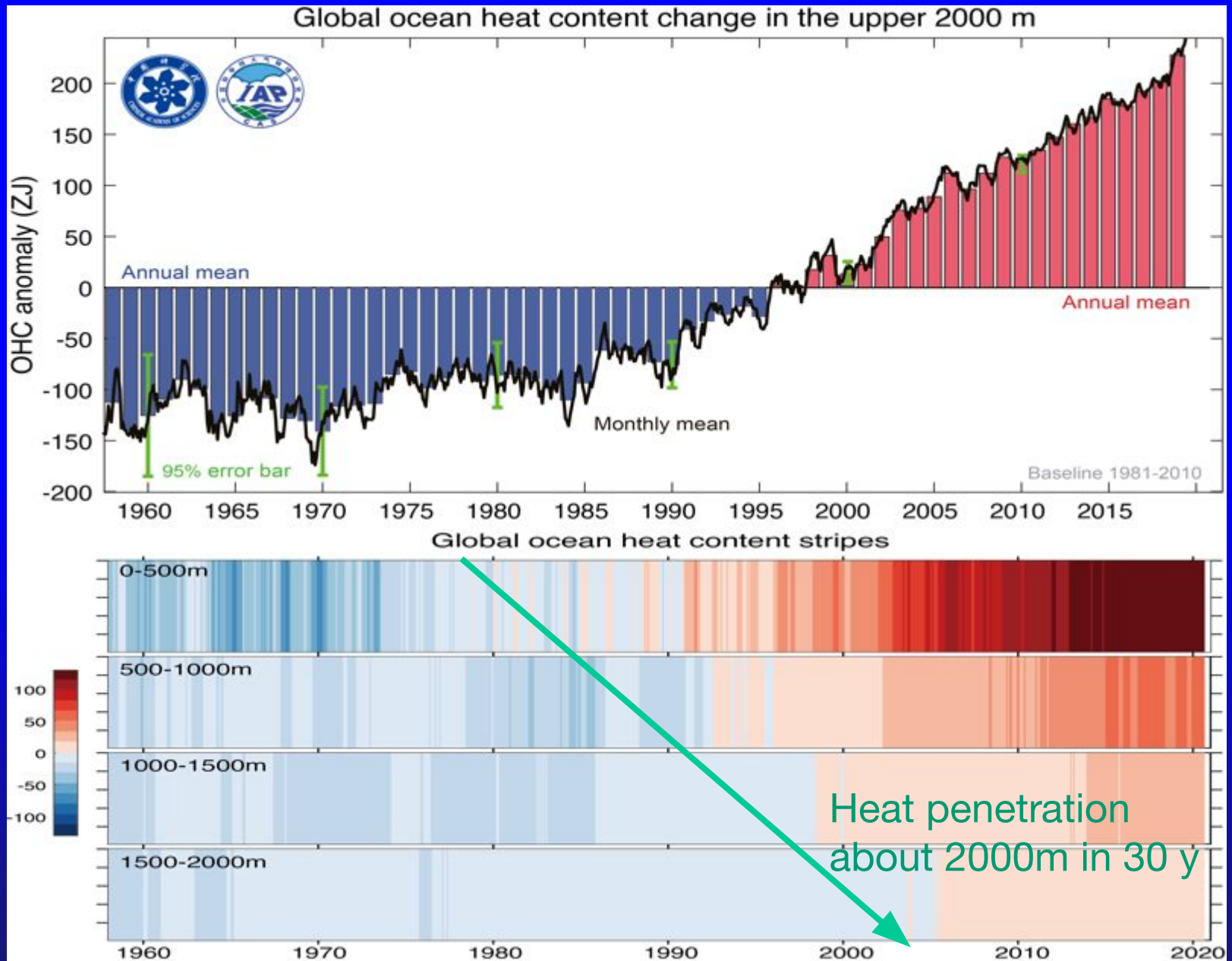
j) glider

k) surface

j) Plankton tow

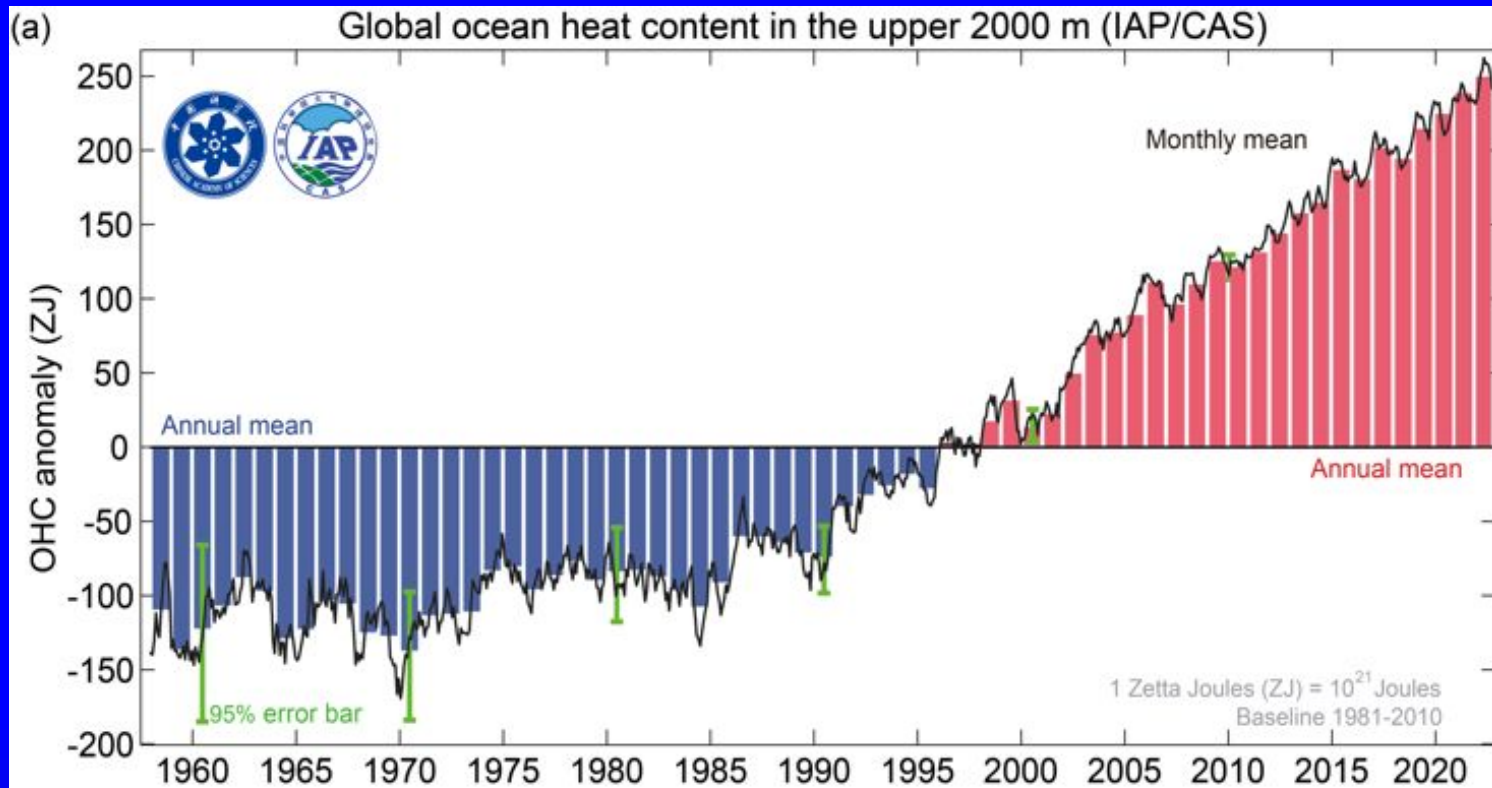


# OHC: 2020

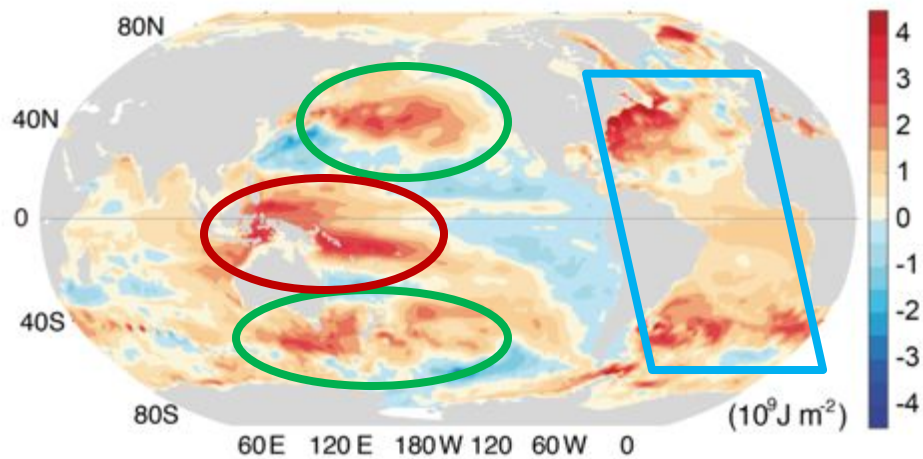


Cheng et al.

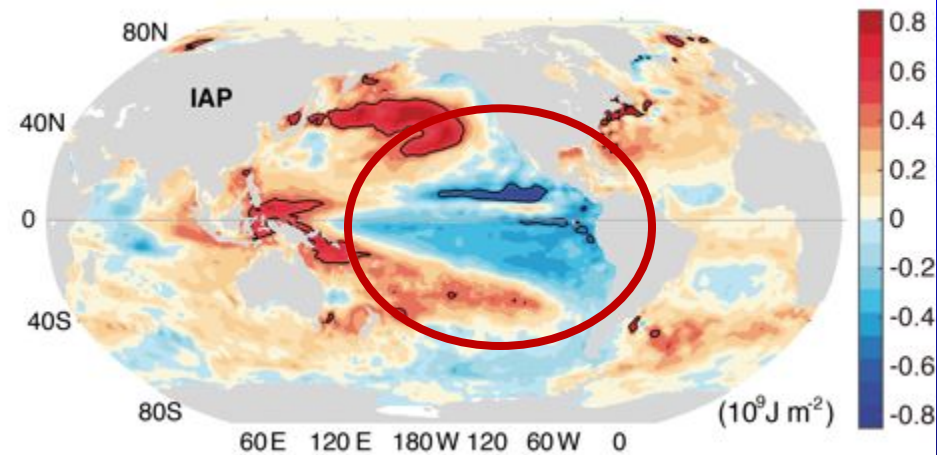
# OHC through 2022



(a) 2022 OHC anomaly (0-2000m) relative to 1981-2010 baseline (IAP/CAS) (a) 2022 OHC 0-100m anomaly relative to 1981-2010 baseline (IAP/CAS)



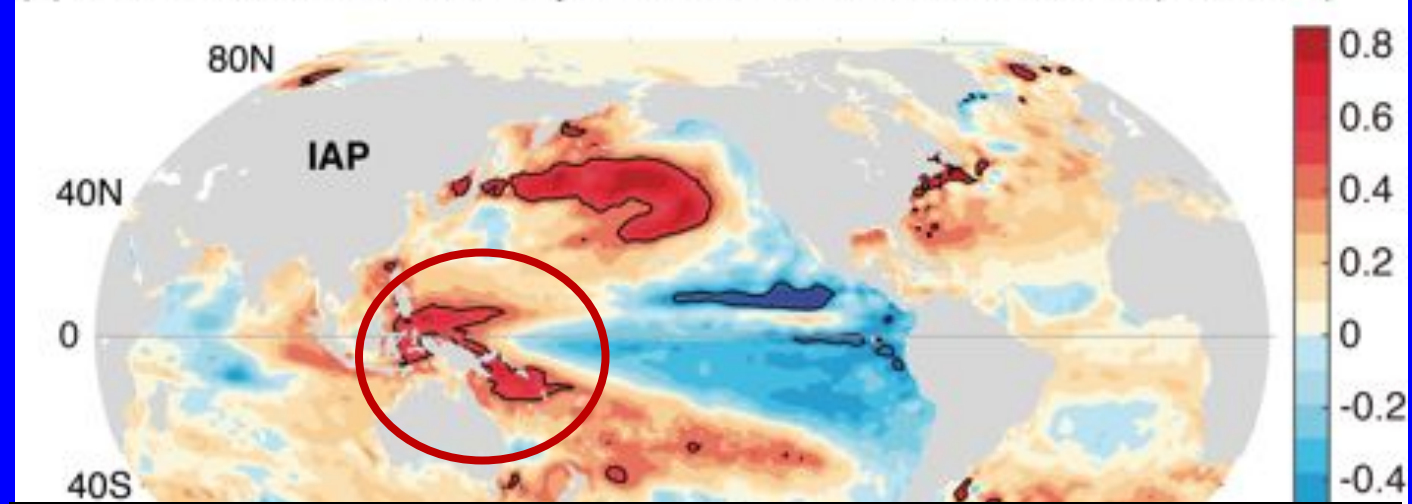
0-2000m



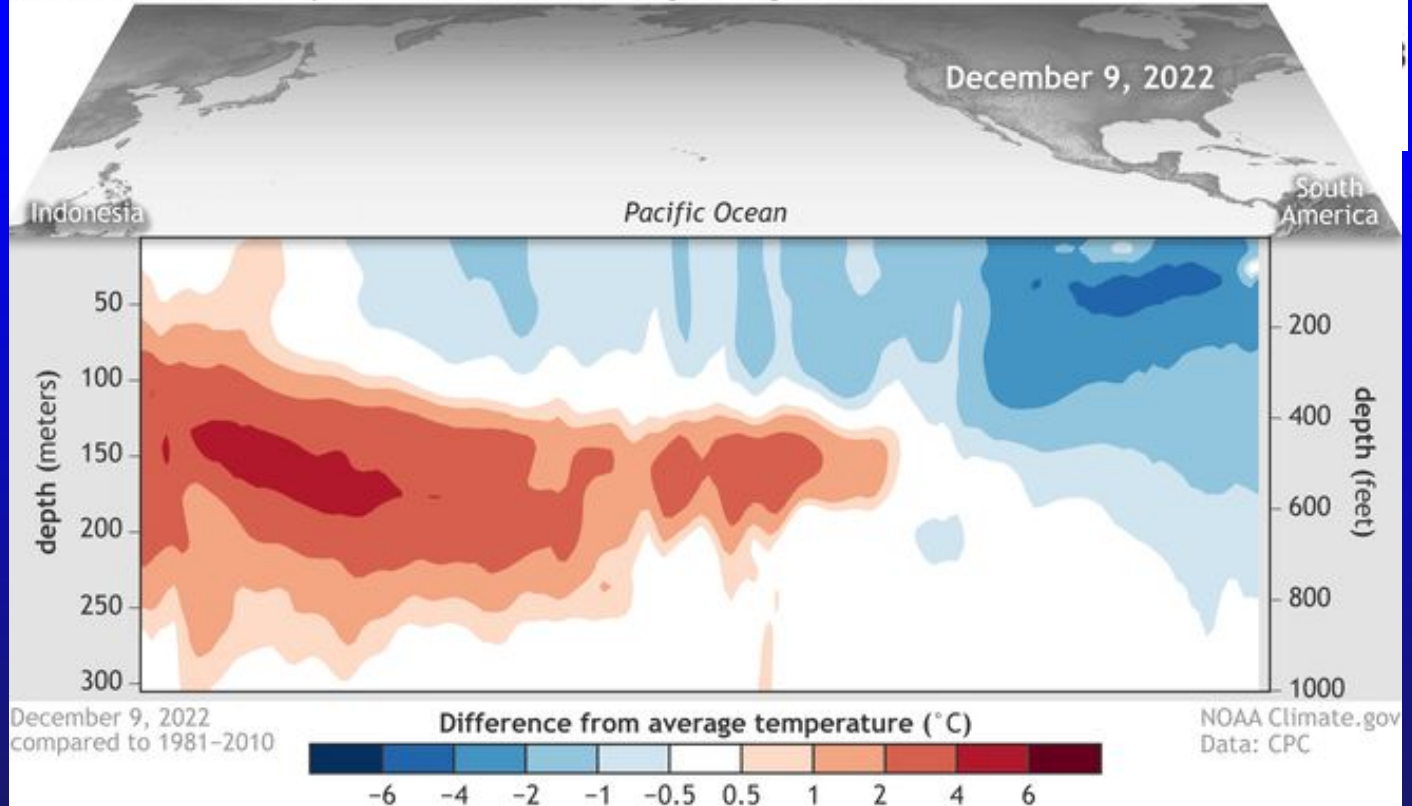
0-100m

# OHC through 2022 top 100m

(a) 2022 OHC0-100m anomaly relative to 1981-2010 baseline (IAP/CAS)



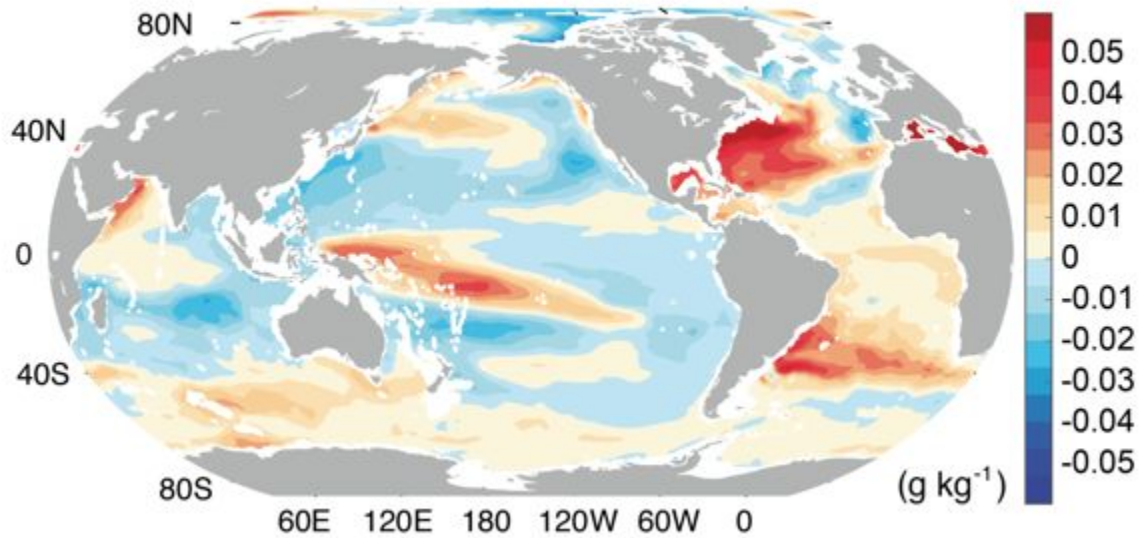
Below-surface cold pool in eastern Pacific growing smaller



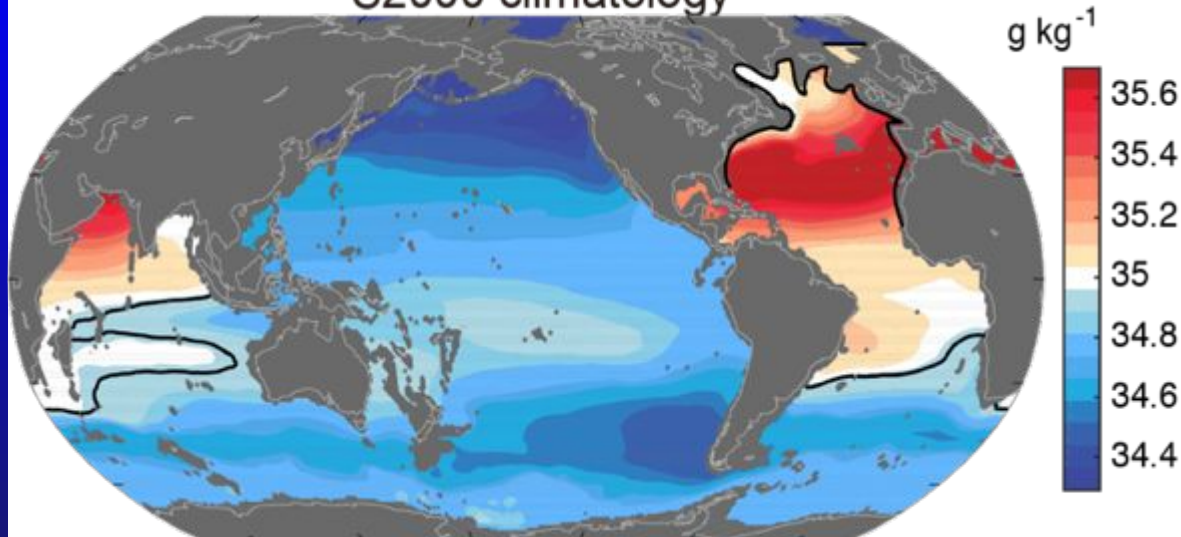
The next  
El Nino

# Salinity anomaly

(a) 2022 salinity anomaly (0-2000m) relative to 1981-2010 baseline (IAP/CAS)



S2000 climatology

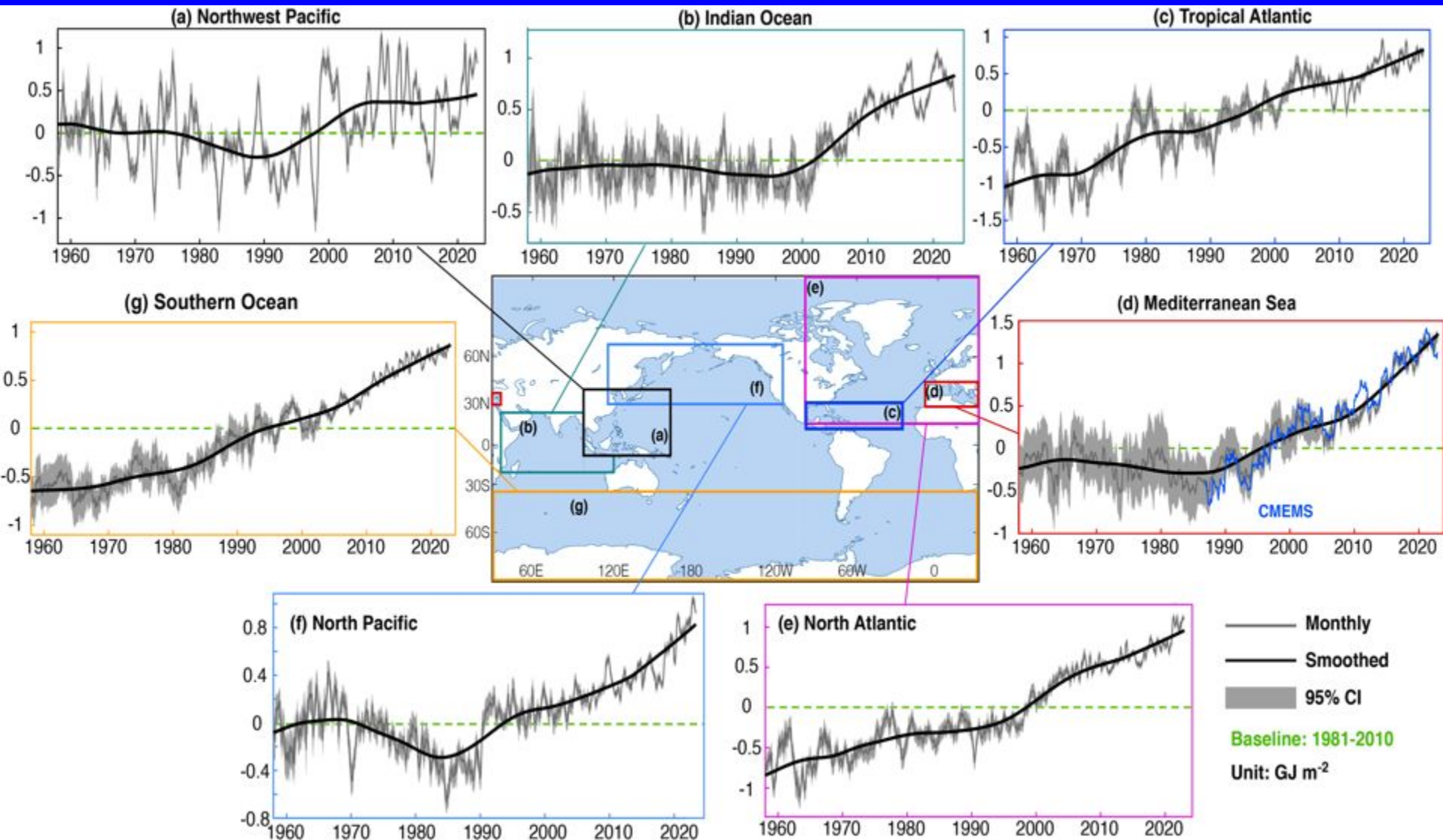


Salty areas get saltier, fresh areas get fresher:

Wet areas get wetter and dry areas get drier.



# Regional OHC changes



# Some consequences of high OHC

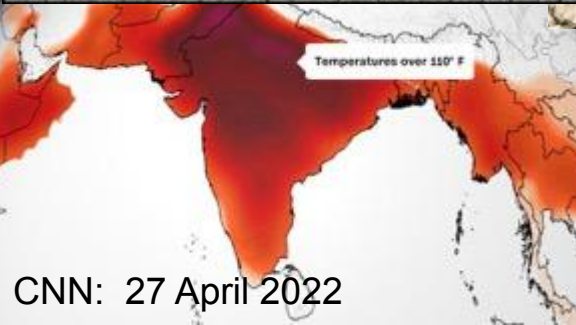
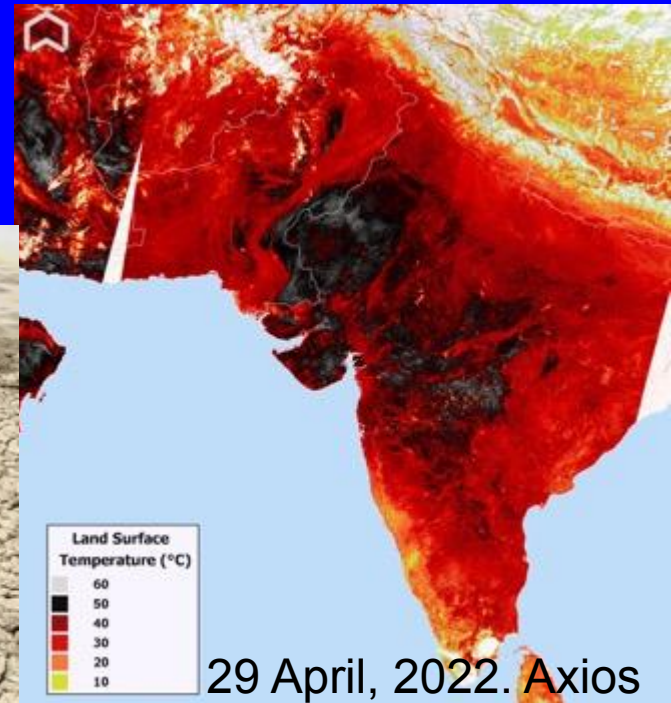
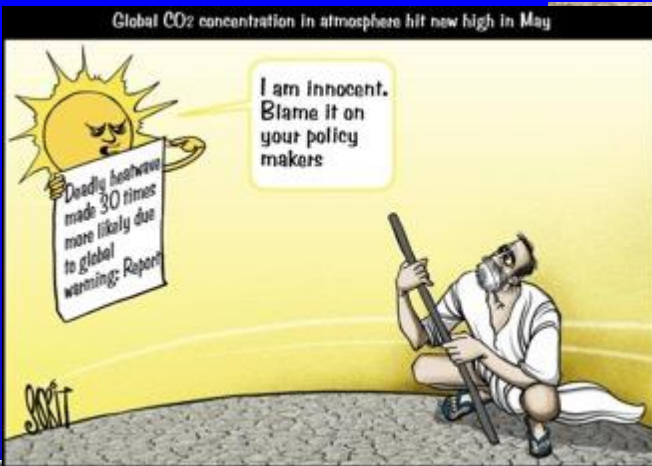
Many **hot spots** self-destruct by attracting convection and storms, and thereby lose heat by evaporative cooling, meanwhile fueling the storms

- California floods Jan 2023
- Pakistan floods July-August 2022
- Australia flooding events 2022
- NZ floods 2022-23
- Sao Paulo 21 Feb 2023: 23+ inches in 24 h

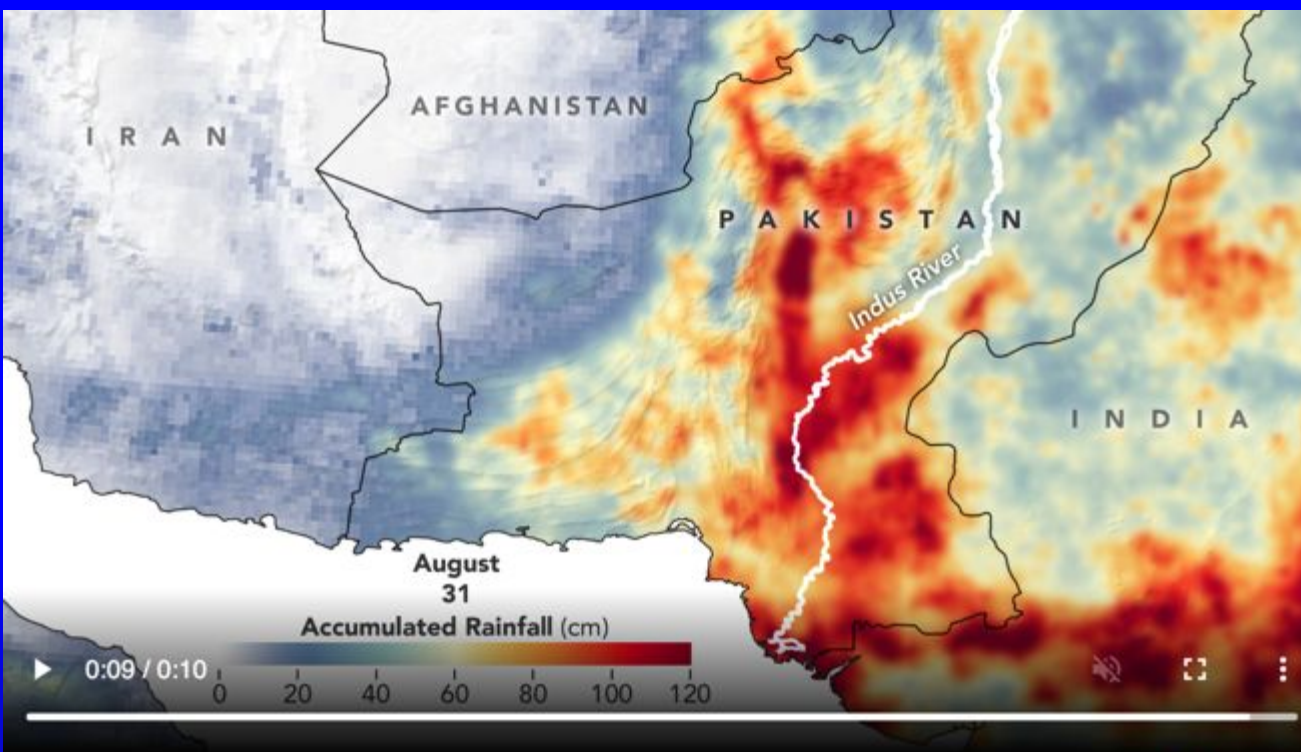
# Blistering heat waves in India and Pakistan

## March-May 2022

Record heat (49°C in Delhi)  
>90 dead  
Birds falling from sky  
Crops ruined



# Flooding Pakistan July-August 2022



July 1 - August 31, 2022



1700 dead +

# Catastrophic flooding East Australia

Early March 2022

**Rain Bomb;** intense rains in slow moving small system

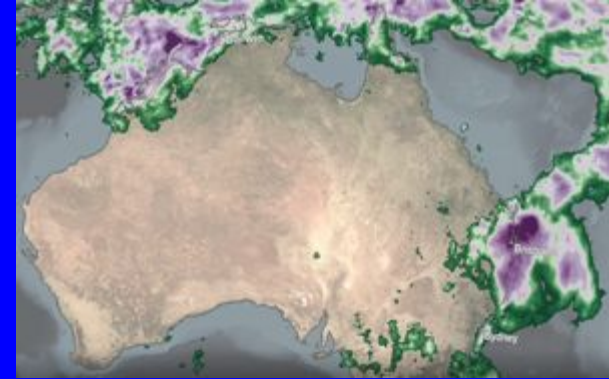
Brisbane: record 790 mm rain in week to 28 Feb.

Began in Queensland progressed to NSW.

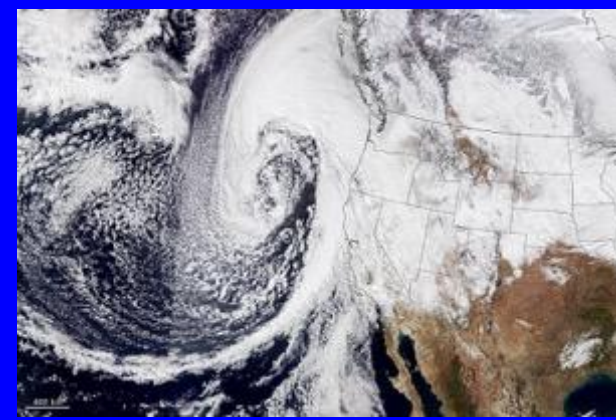
Lismore: river rose 14.4m on 28 Feb;

2m higher than ever before

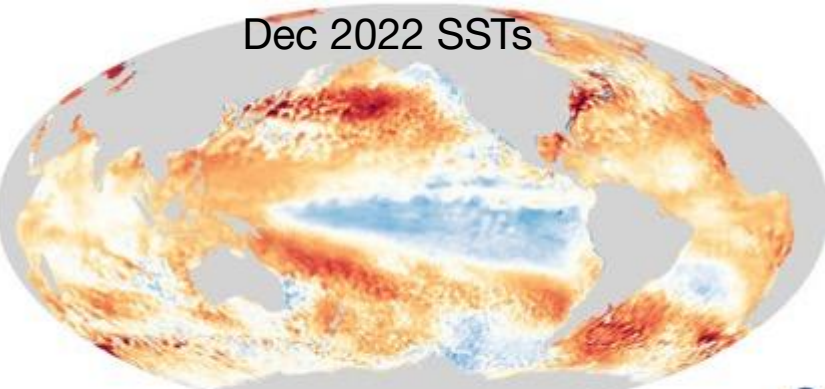
21+ deaths



# California flooding Jan 2023



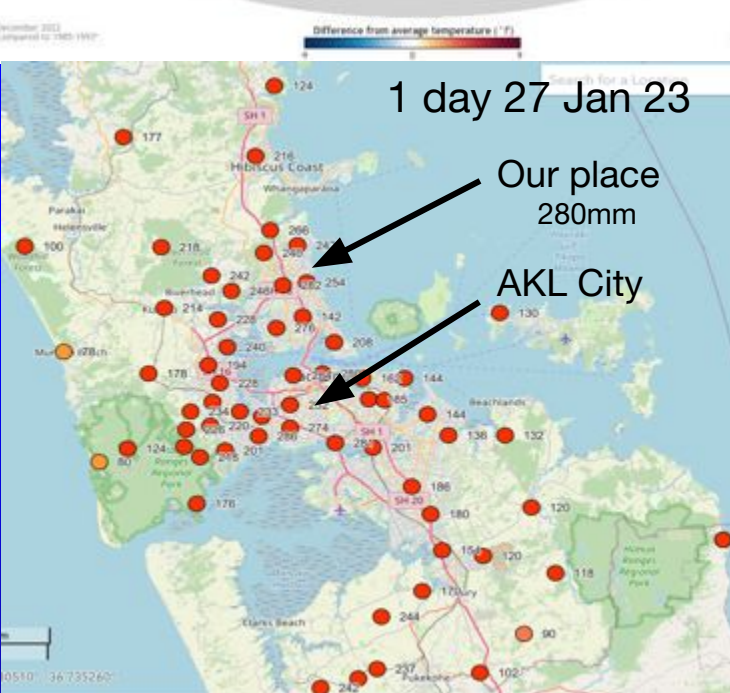
Dec 2022 SSTs



# Auckland flooding

27 January 2023

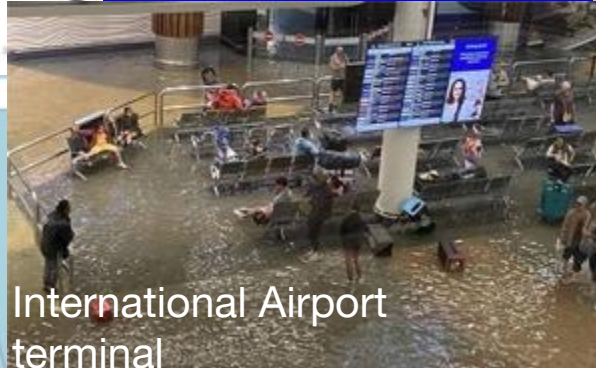
Over 12 inches of rain in 36 h some areas including where we live.



1 day 27 Jan 23

Our place  
280mm

AKL City



International Airport terminal



Outside terminal

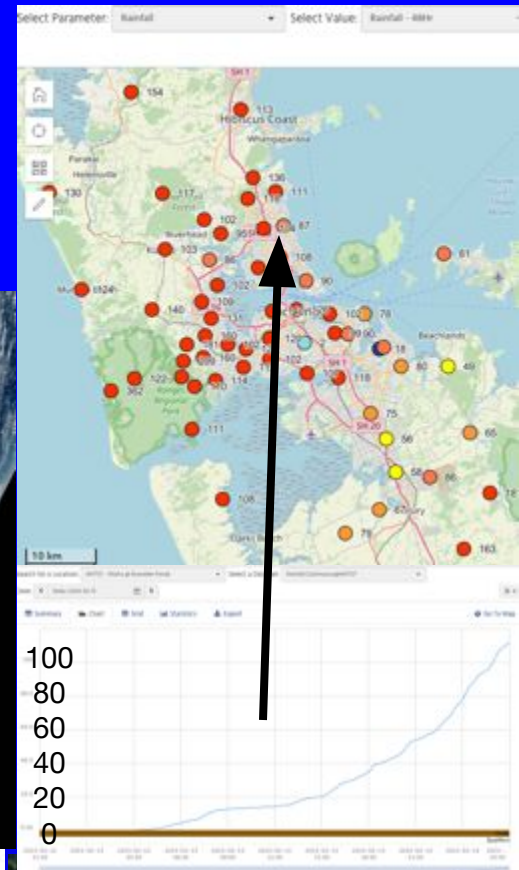
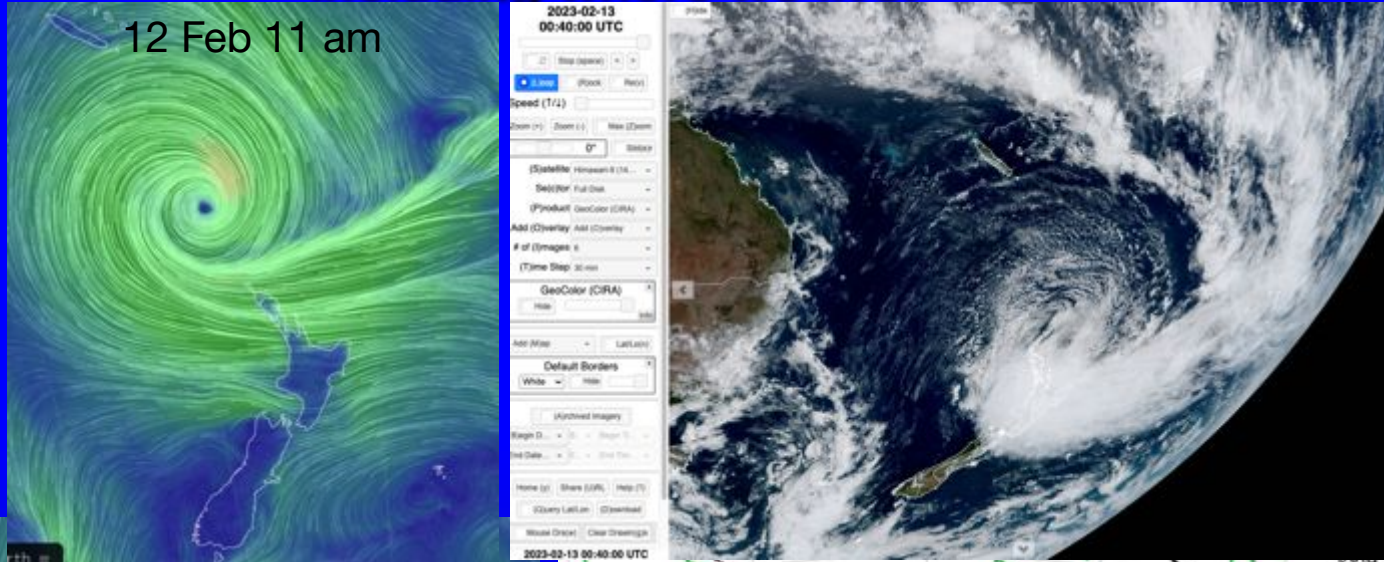


# NZ: Cyclone Gabrielle

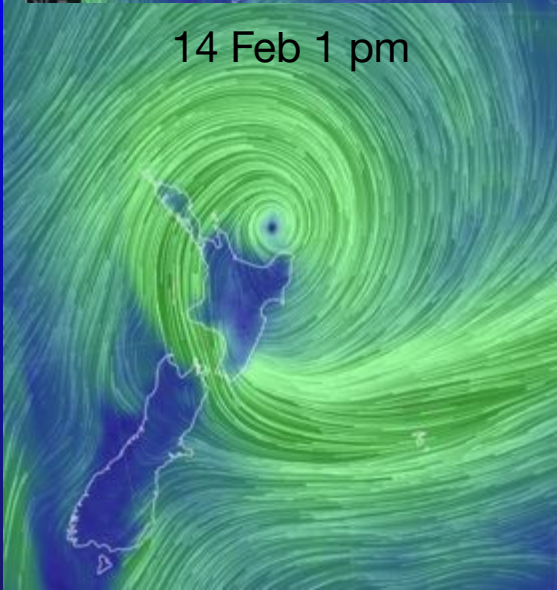
13-14 February 2023

Widespread heavy rain and strong gales including where we live.

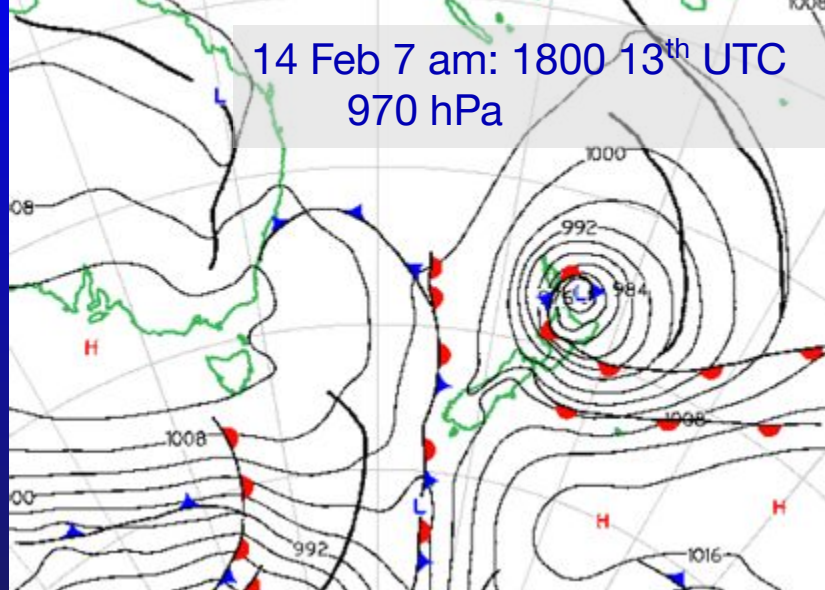
12 Feb 11 am



14 Feb 1 pm



14 Feb 7 am: 1800 13<sup>th</sup> UTC  
970 hPa





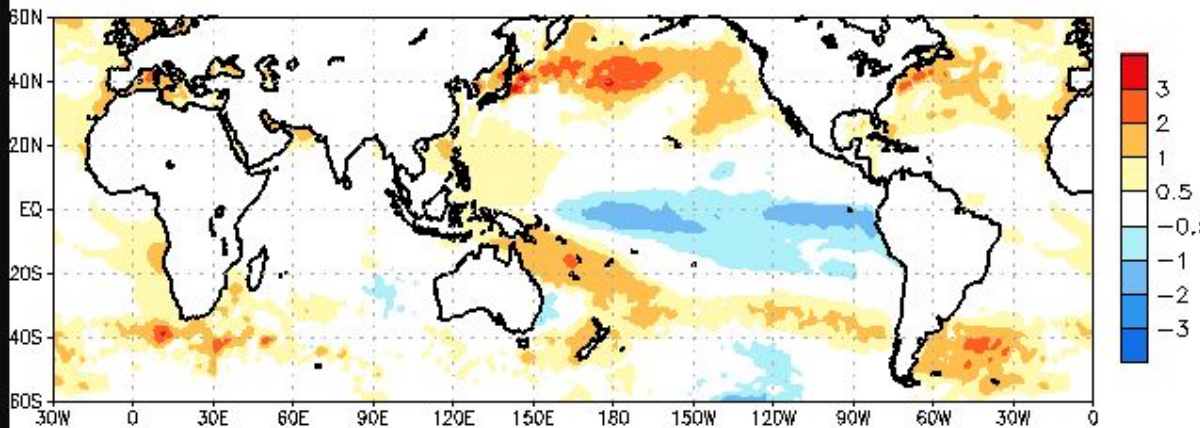
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13-14 February 2023

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Ave. SST Anomalies (°C) 05 OCT 2022 - 28 DEC 2022



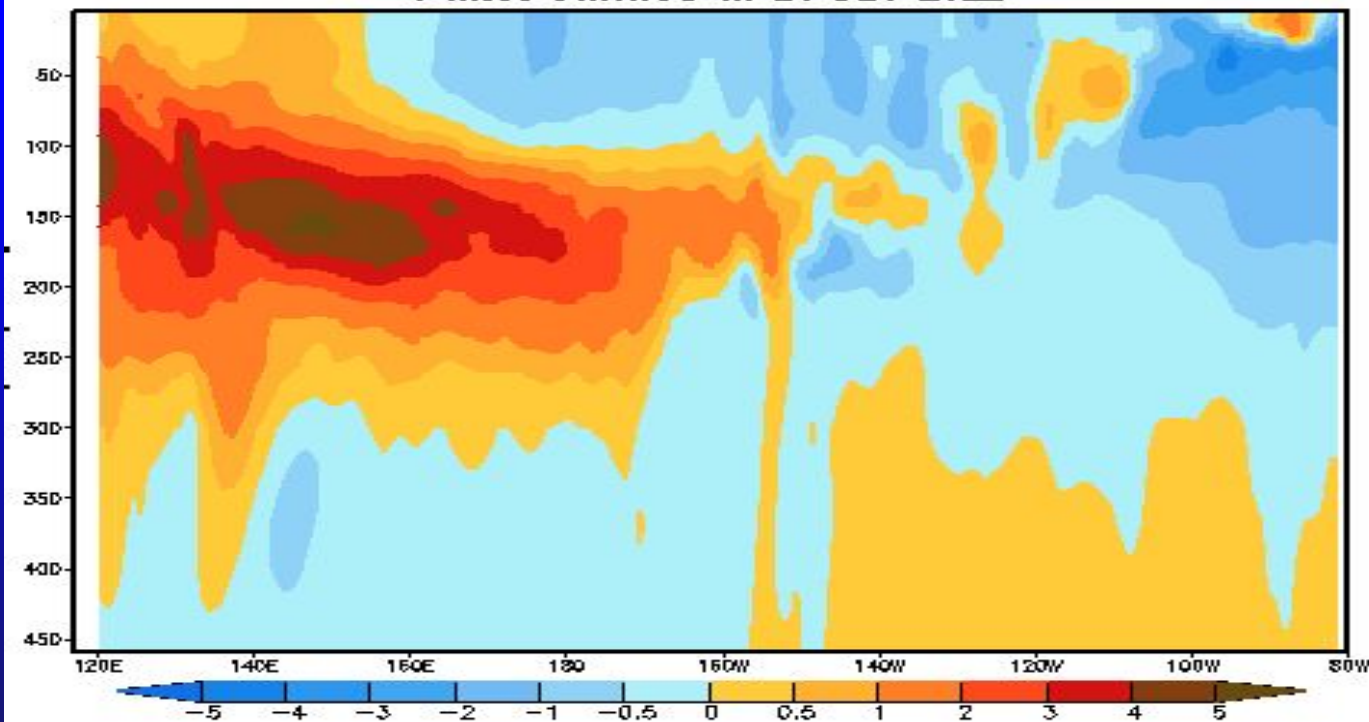
Data Source: NCEP Global Sea Surface Temperature Analyses  
Climatology (1991-2020)

SSTa OND 2022

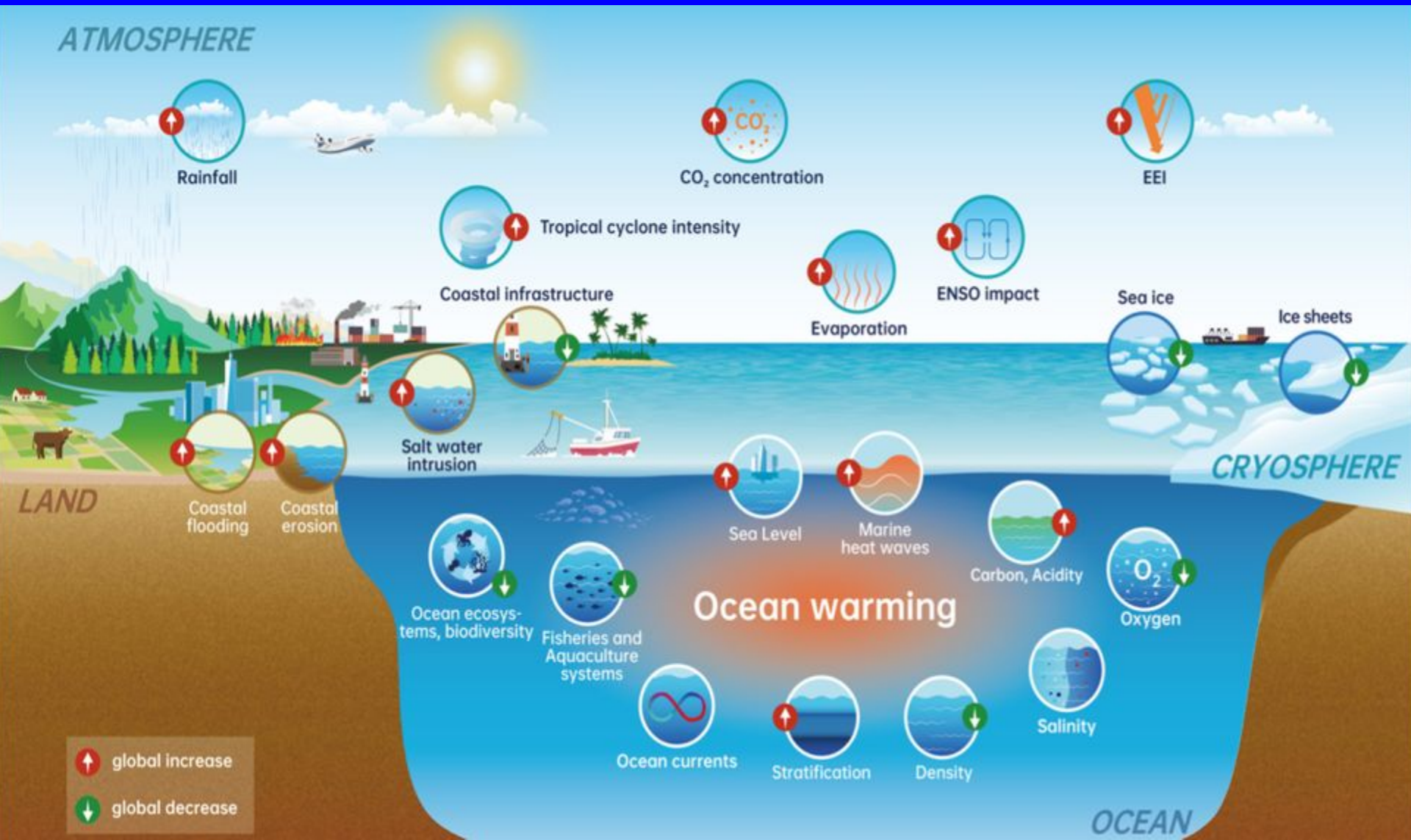
Along equator:  
late Dec 2022

Equatorial Temperature Anomaly (°C)  
Pentad centered on 24 DEC 2022

Depth



# Global Heating



*Contact  
information*

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Hurricane Eta

Nov 5, 2020

# *The* **Changing Flow** *of* **Energy** **Through** *the* **Climate System**

KEVIN E. TRENBERTH

