NOAA Coral Reef Watch

From Near Real-time Monitoring and Seasonal Outlooks to an Historical Assessment of Coral Bleaching Heat Stress over 30 Years

NOAA Coral Reef Watch's Decision Support System for Tropical Coral Reef Management

Gang Liu, Jacqueline L. De La Cour, Erick F. Geiger, William J. Skirving, Roxana Vasile, Benjamin L. Marsh, C. Mark Eakin

CISESS Cooperative Institute for Satellite Earth System Studies

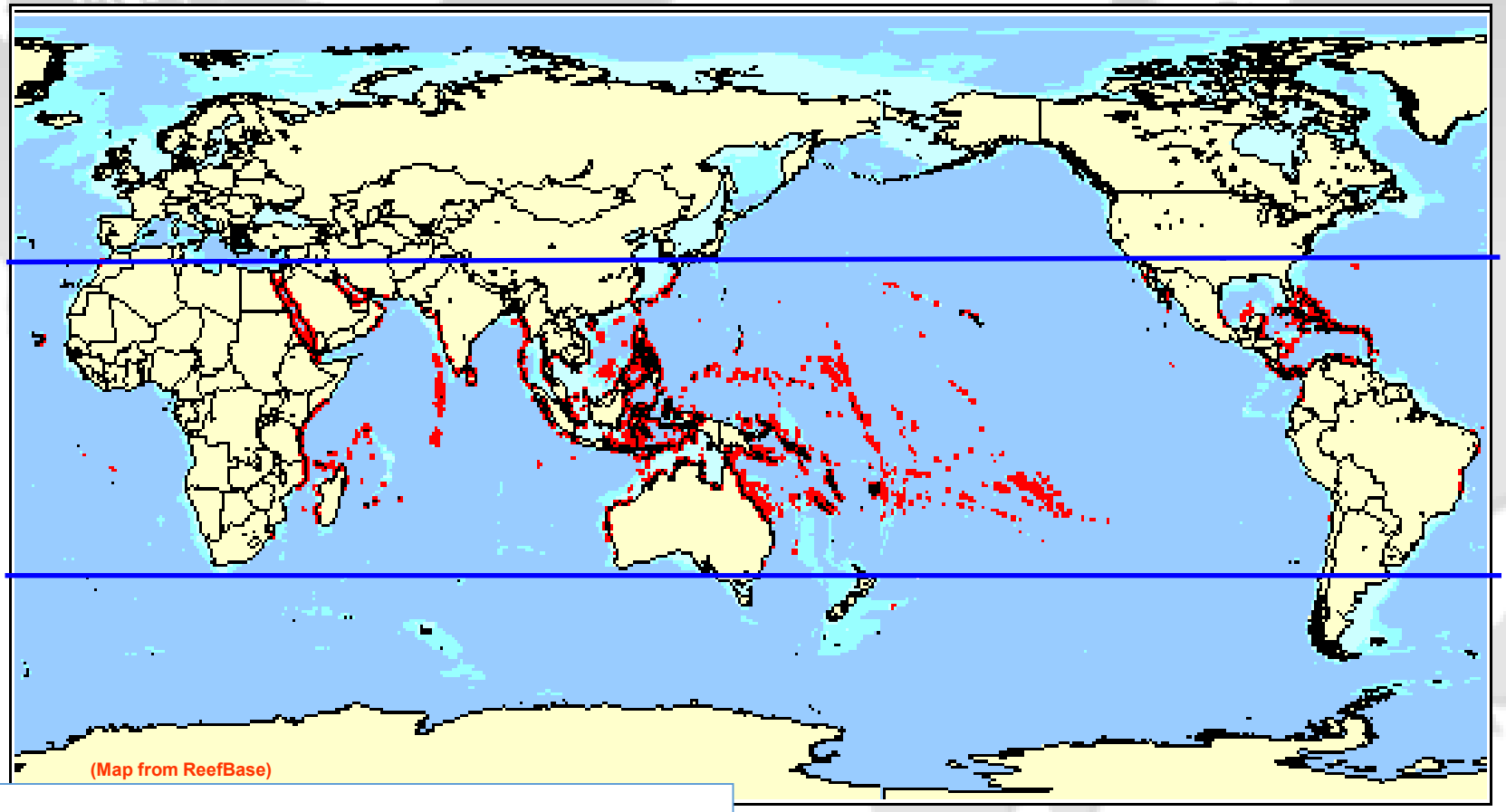
EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER ESSIC UNIVERSITY OF MARYLAND

NOAA CORAL REEF CONSERVATION PROGRAM

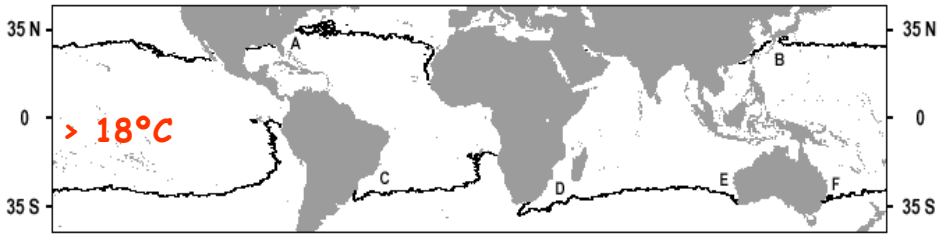
https://coralreefwatch.noaa.gov

UNIVERSITY OF MARYLAND

Distribution of World's Shallow Water Coral Reefs



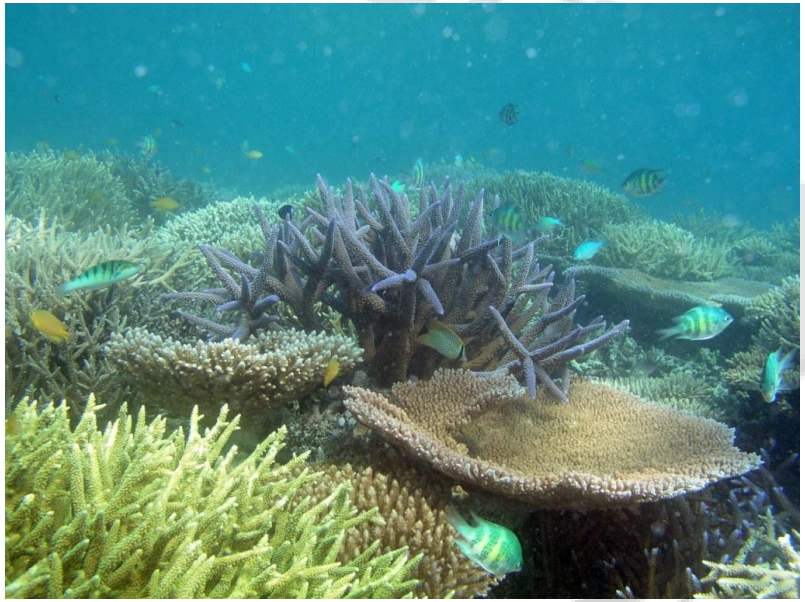
(35°S-35°N)



- In tropical regions, between 35°S-35°N, min. temp > 18°C
- Covering only 1/10 of 1% of ocean floor

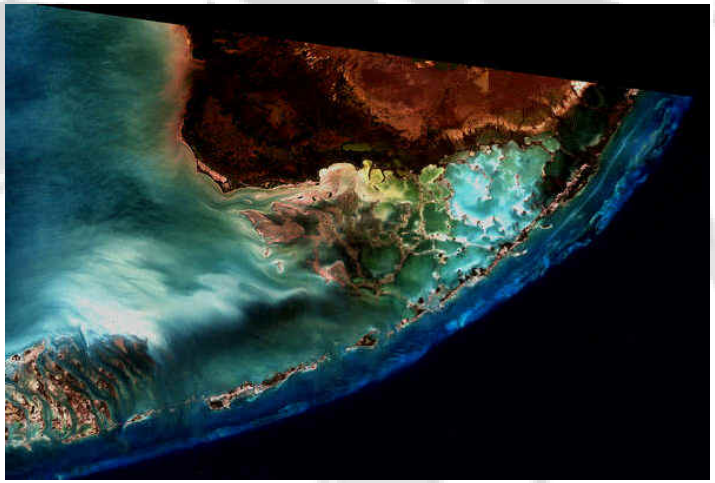
Coral Reefs

Tropical Rainforests of the Sea



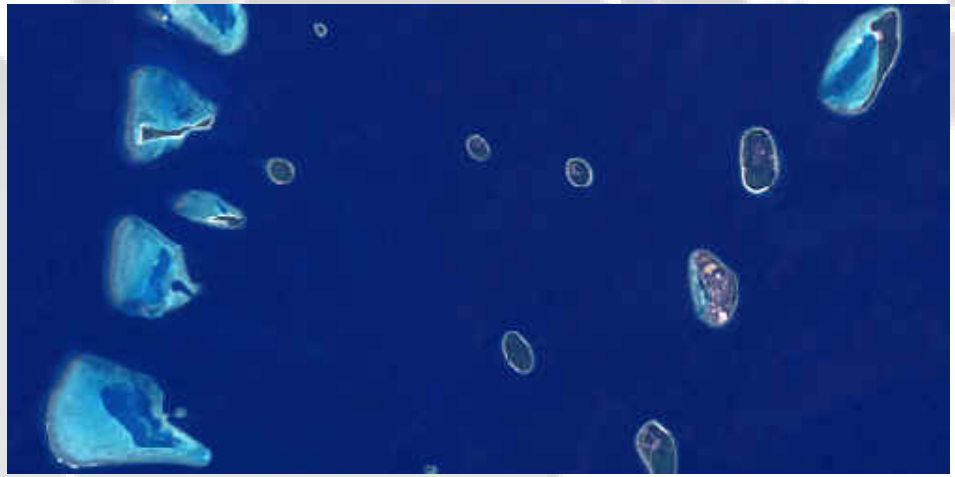
- One of the most diverse ecosystems on the earth
- Providing habitat for ~25% of all known marine species

Coral Reef Areas as Seen from Air & Space



Florida Keys

Great Barrier Reef, Australia



Maldives atolls

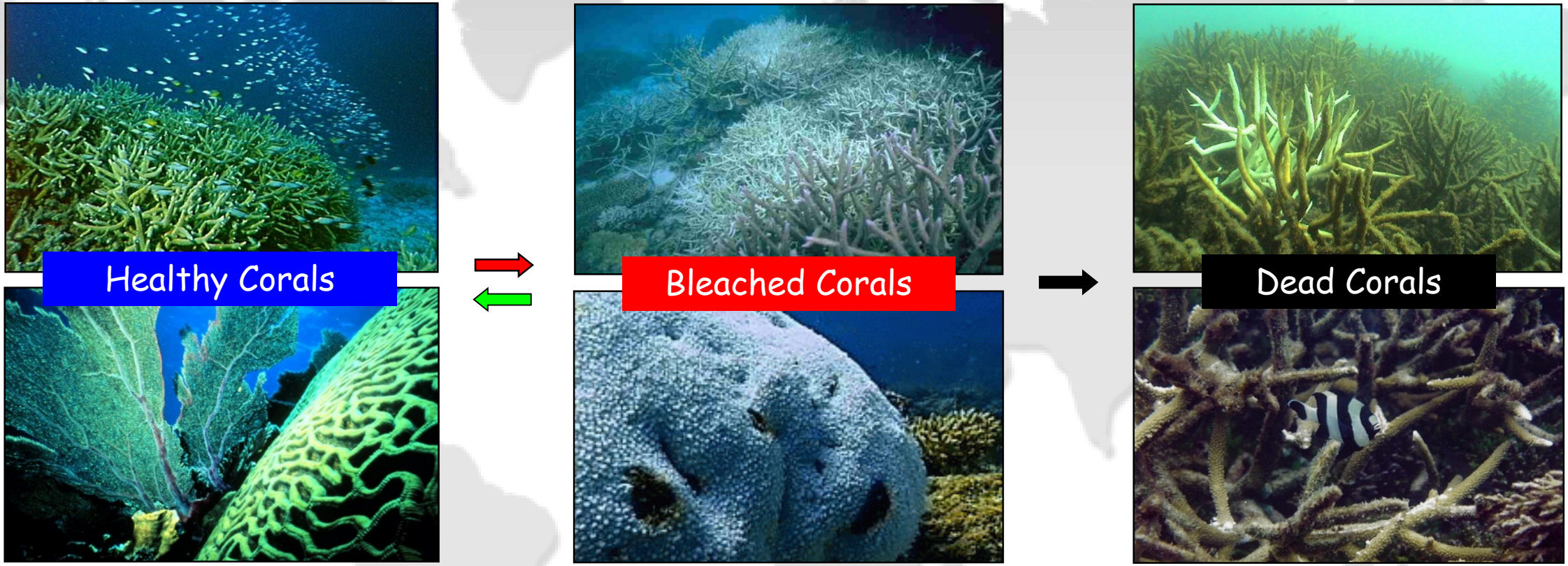
Rose Atoll, American Samoa

Johnston Atoll

Midway Atoll

Spatial scale of individual reefs: meters to tens of kilometers

Coral Bleaching & Coral Reefs in Crisis

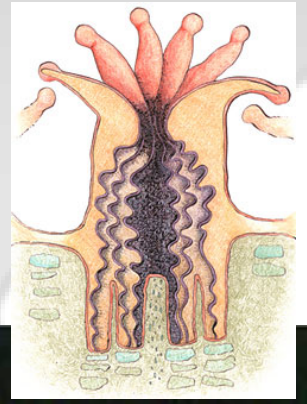


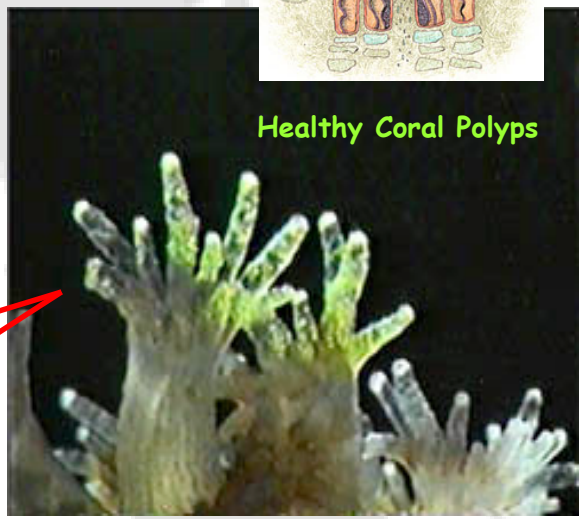
- High-temperature induced mass coral bleaching has increased in frequency & intensity over the past few decades
- A major threat to the world's coral reefs
- Dramatic long-term ecological and social consequences

Third Global Coral Bleaching Event on Record (June 2014 – May 2017)

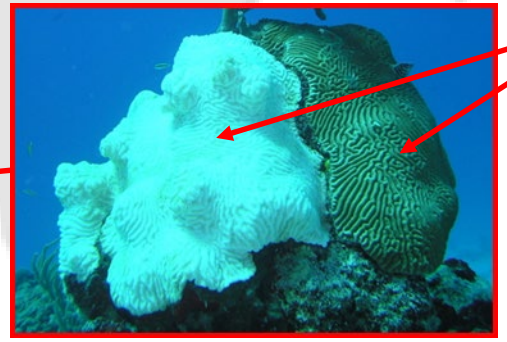
Photos courtesy of The Ocean Agency/
XL Catlin Seaview Survey

Coral Reef, Coral Colony, and Coral Polyp





Coral Polyp
(Translucent coral tissue)

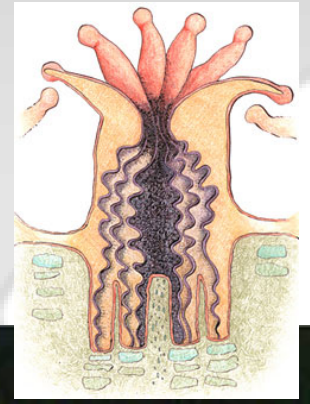


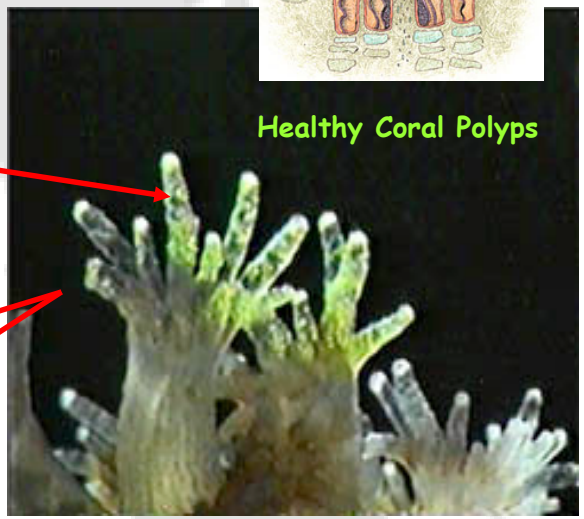
Coral Colony
(Calcium carbonate skeleton)

Coral Reef
(Ecosystem)

Coral and Symbiotic Algae (Zooxanthellae)

Symbiotic Algae
(Zooxanthellae)





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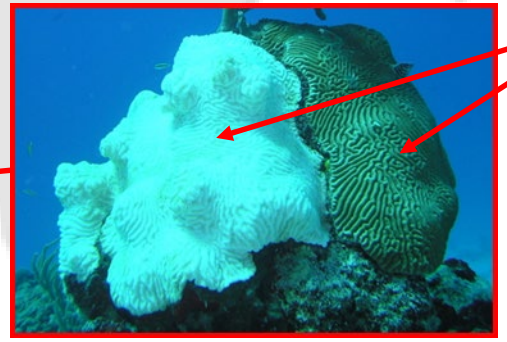


Coral Colony
(Calcium carbonate skeleton)

Coral Reef
(Ecosystem)

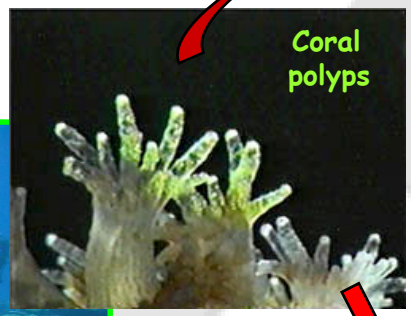
Coral Bleaching

Under certain environmental stresses:

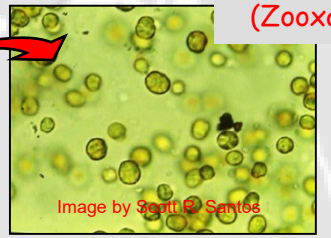
- Host coral expels symbiotic algae living inside it;
- Host coral's underlying white skeleton is revealed through its translucent tissue;

- Severe or long-lasting stress leads to coral death;
- Bleached corals are susceptible to disease outbreaks.

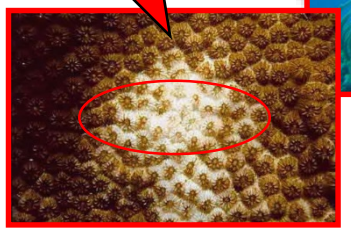
Expelling

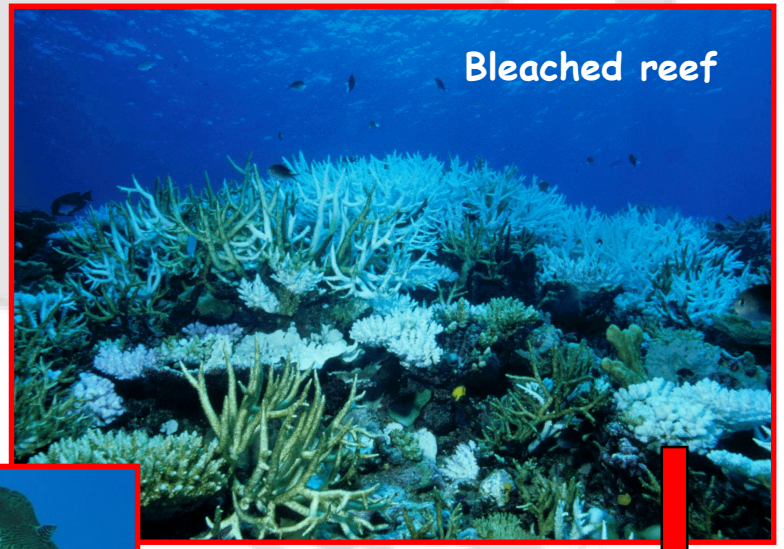


Symbiotic algae (Zooxanthellae)



Bleaching





Presentation Outline

NOAA Coral Reef Watch's Coral Bleaching Heat Stress Products:

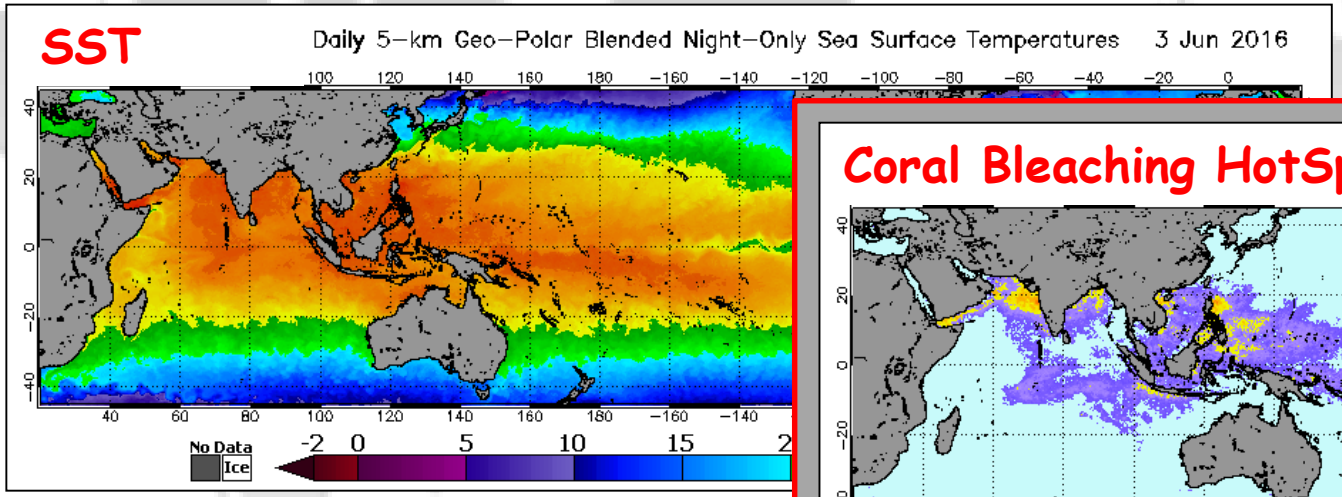
Present: Satellite bleaching heat stress monitoring products
(near real-time)

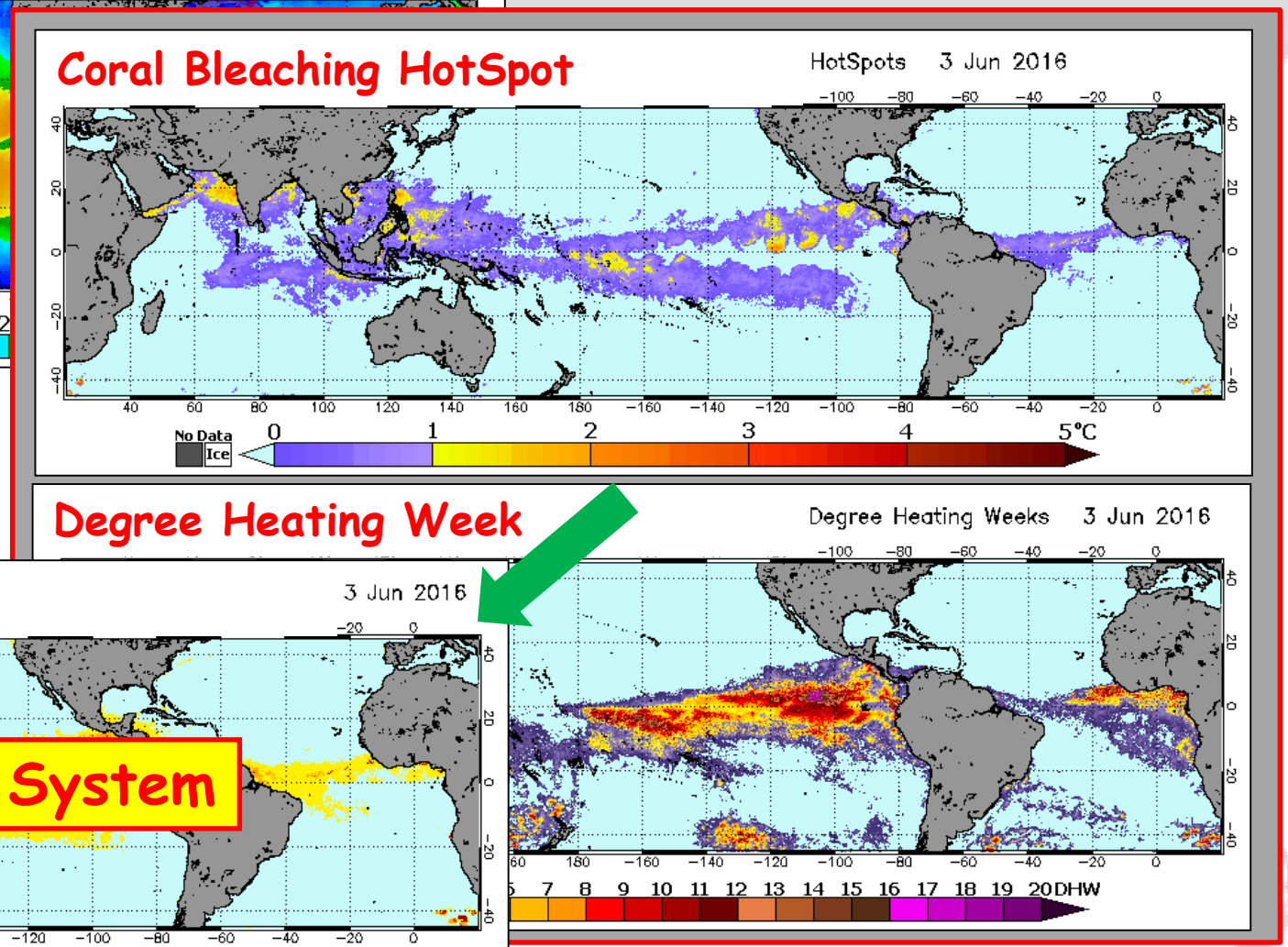
Future: Modeled bleaching heat stress forecast products
(subseasonal to seasonal)

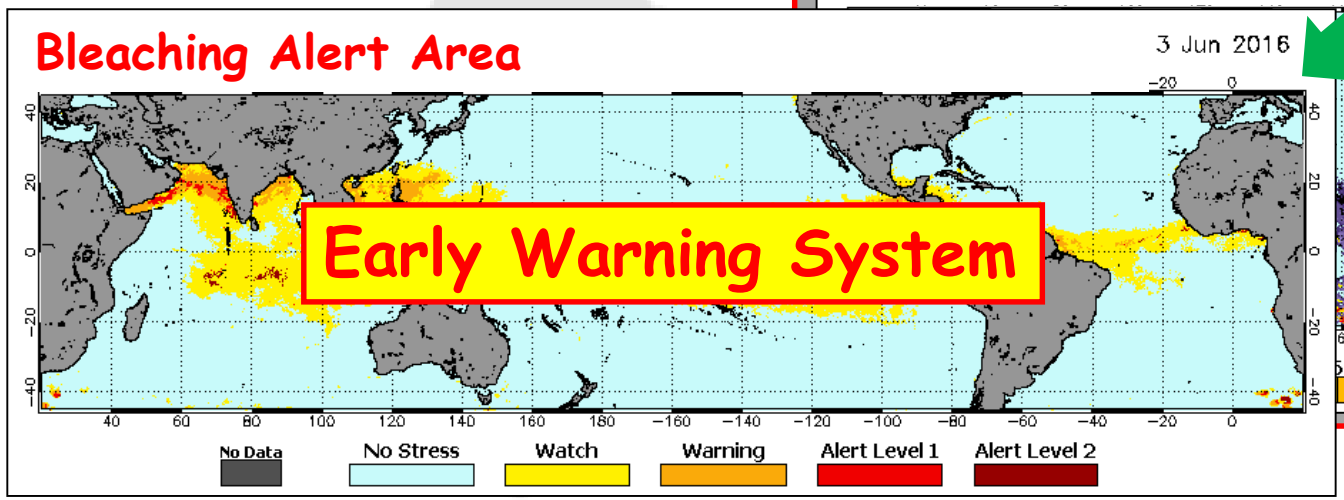
Past: Change in bleaching heat stress from 1985 - 2018
(~ three decades)

NOAA Coral Reef Watch

Satellite Coral Bleaching Heat Stress Monitoring







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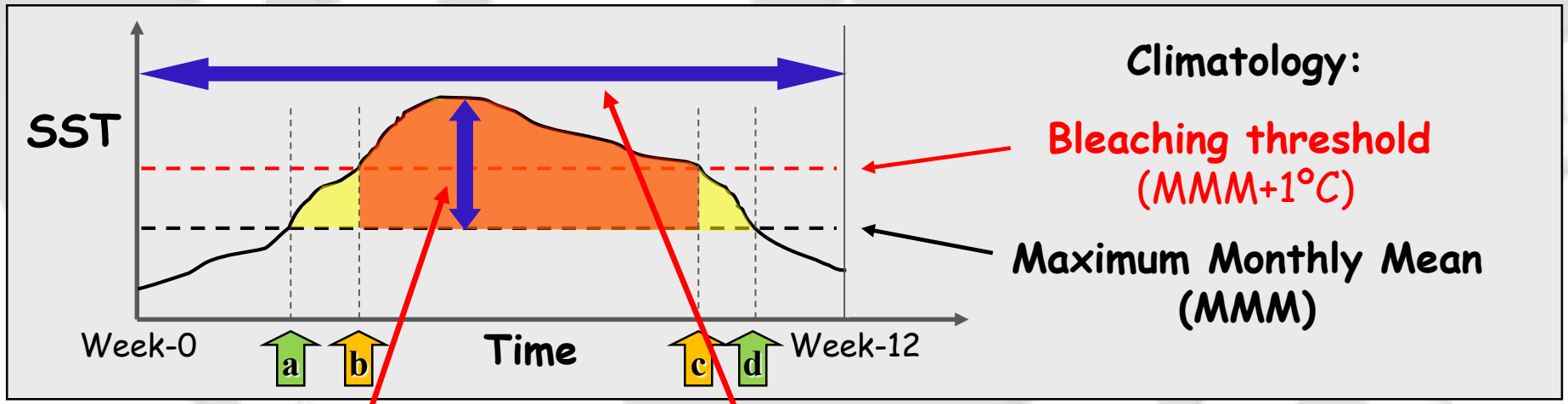
Satellite Coral Bleaching Heat Stress Monitoring



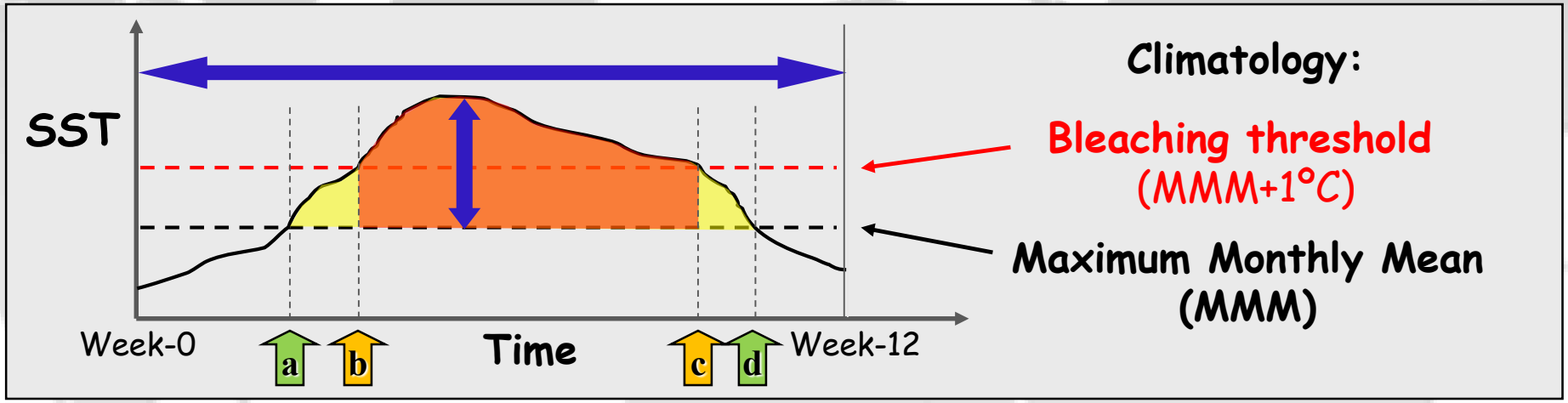
HotSpot
instantaneous stress

Degree Heating Week

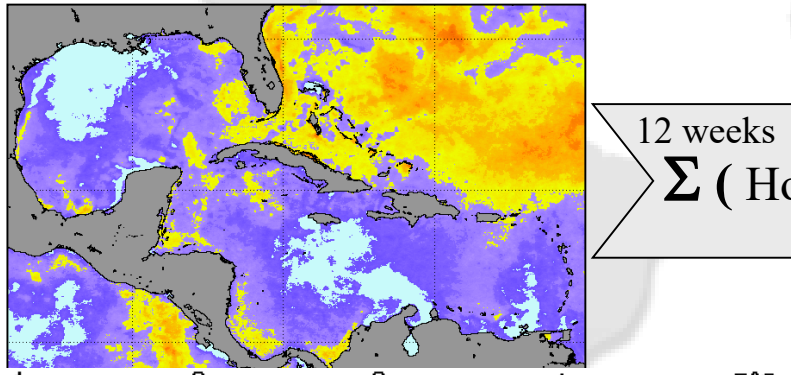
Cumulative measure of heat stress intensity and duration during the most-recent 12-week period

NOAA Coral Reef Watch

Satellite Coral Bleaching Heat Stress Monitoring



HotSpot: instantaneous stress



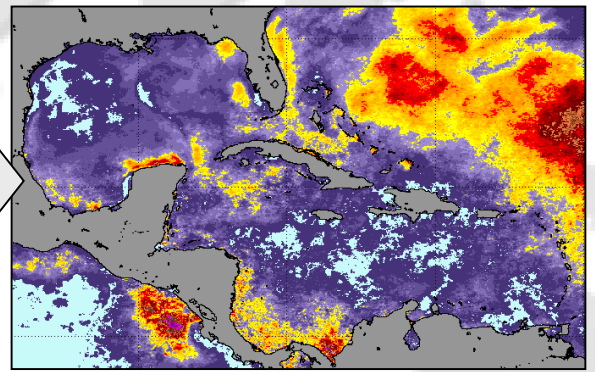
0 1 2 3 4 5°C

≥ 1 °C → to be accumulated into DHW

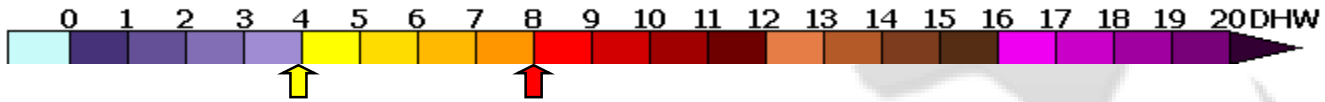
12 weeks

$$\Sigma \left(\text{HotSpot value} \times \text{duration} \right)_{\geq 1^\circ C}$$

Degree Heating Week



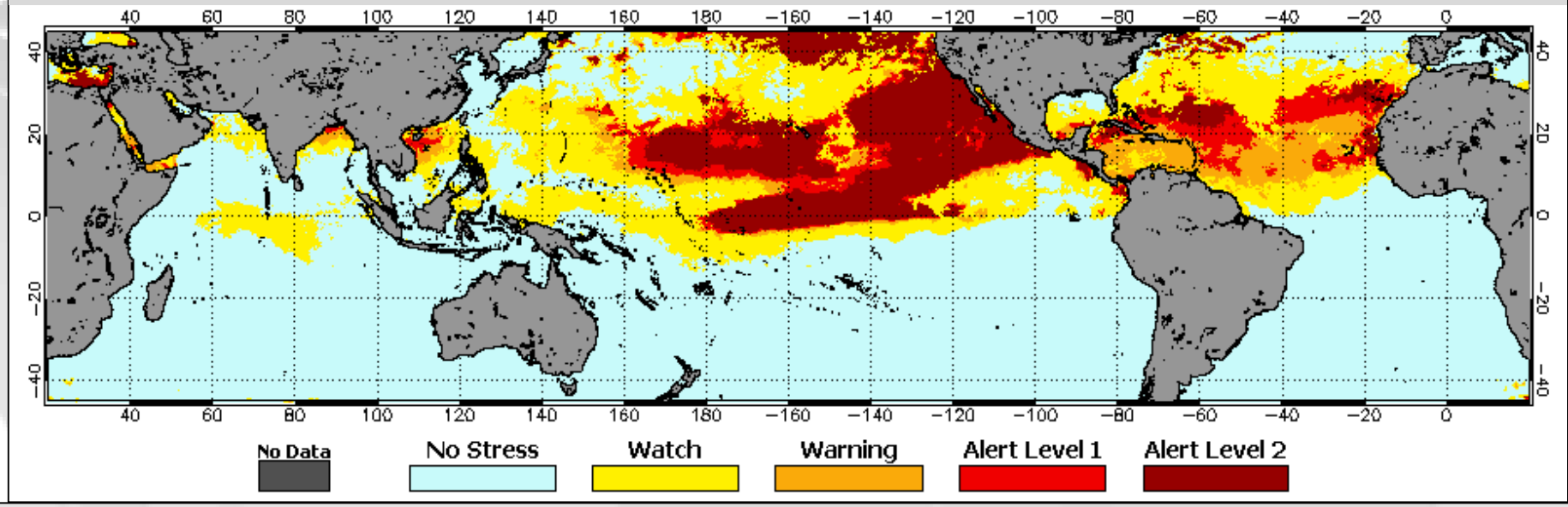
Cumulative measure of heat stress intensity and duration during the most-recent 12-week period



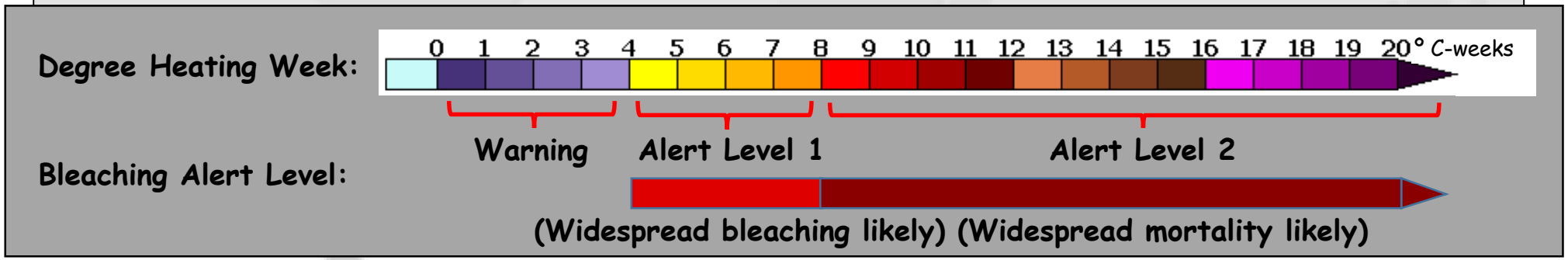
≥ 4 °C-weeks → widespread coral bleaching

≥ 8 °C-weeks → significant bleaching & widespread mortality

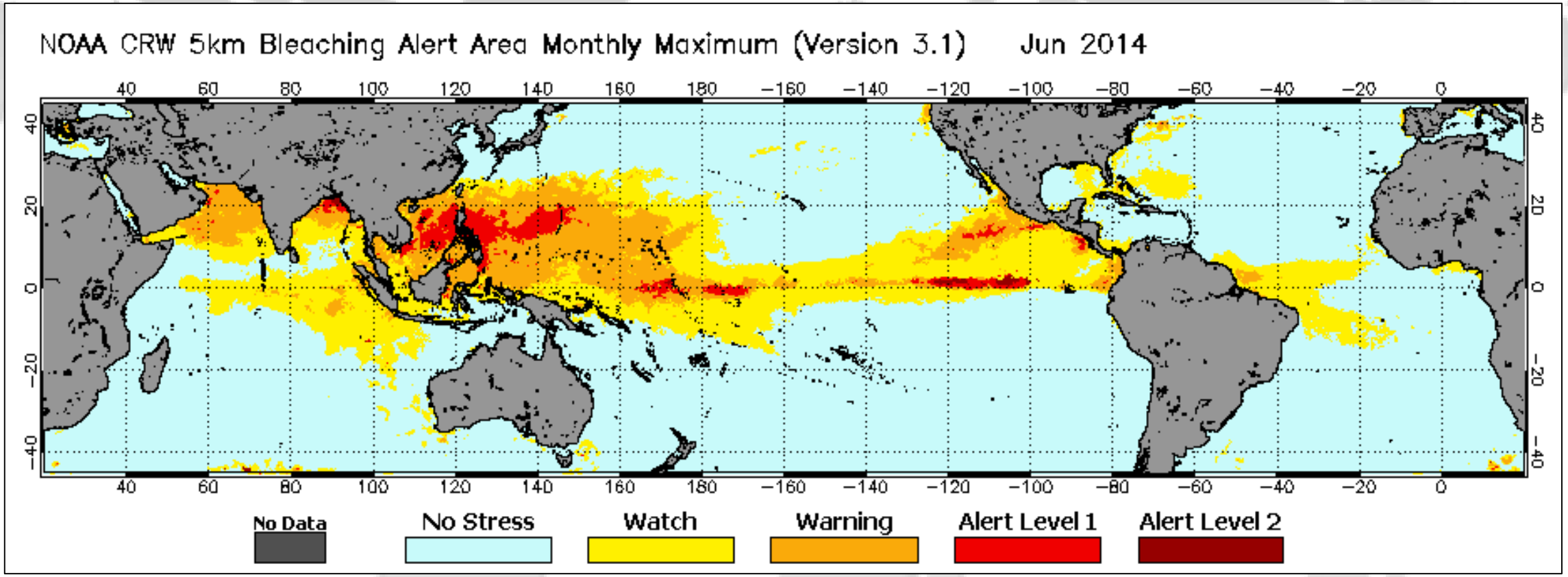
NOAA Coral Reef Watch Daily Global 5km Bleaching Alert Area



Stress Level	Definition	Potential Bleaching Intensity
No Stress	HotSpot ≤ 0	No Bleaching
Bleaching Watch	0 < HotSpot < 1	
Bleaching Warning	1 ≤ HotSpot and 0 < DHW < 4	Possible Bleaching
Bleaching Alert Level 1	1 ≤ HotSpot and 4 ≤ DHW < 8	Widespread Bleaching Likely
Bleaching Alert Level 2	1 ≤ HotSpot and 8 ≤ DHW	Widespread Mortality Likely

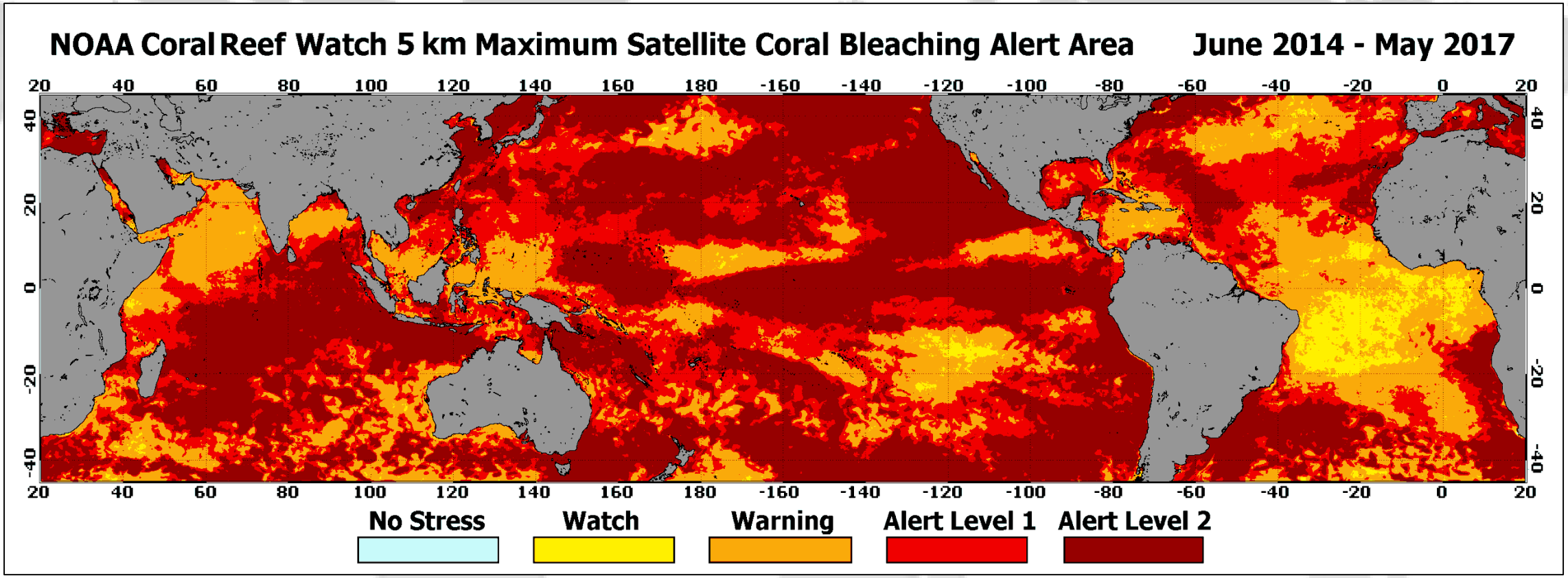


Third Global Coral Bleaching Event on Record (June 2014 – May 2017)



- Spread across all three ocean basins in a rolling fashion
- Affected most major international coral reefs and all U.S. reefs
- Many reefs were hit more than once during the three-year event
- Some reefs experienced longer exposure to heat stress than ever recorded

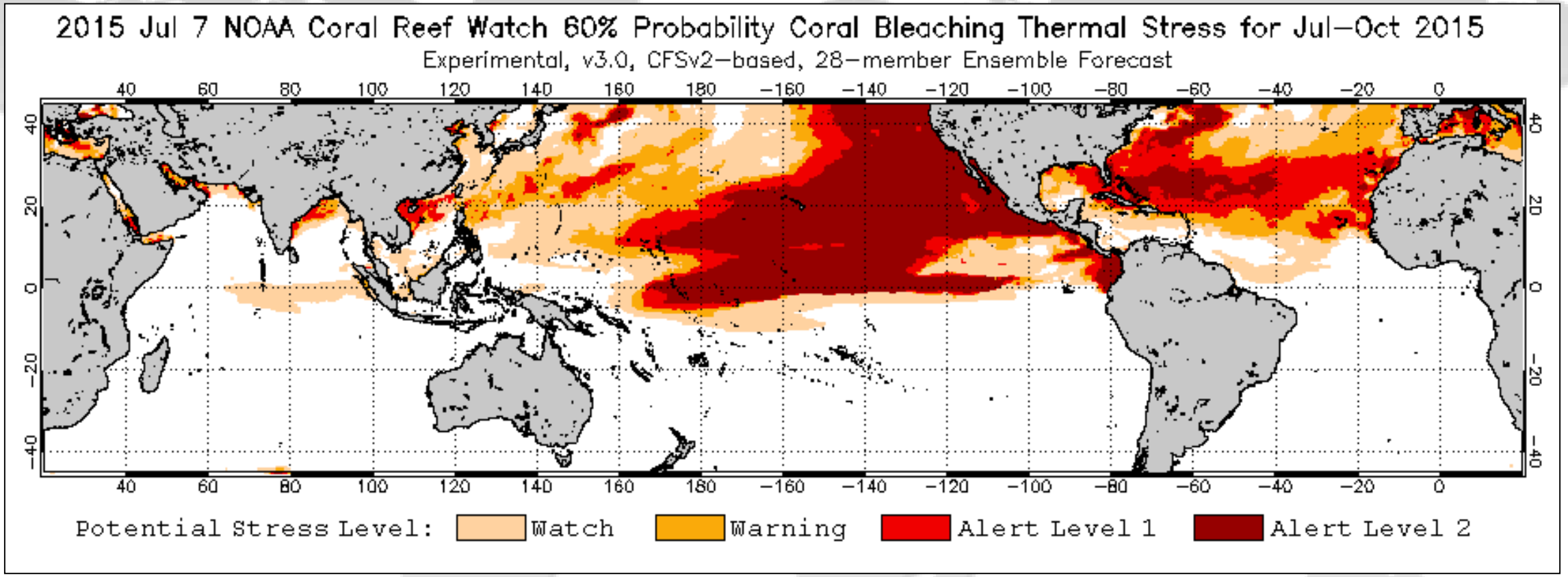
Third Global Coral Bleaching Event on Record (June 2014 – May 2017)



- Record-level/worst bleaching on many major reefs (GBR, Kiritimati, Jarvis Island)
- Tied to "Warm Blob", El Niño, and climate-driven increases in ocean temperature

NOAA Coral Reef Watch

Four-Month Coral Bleaching Outlook (probabilistic forecast)

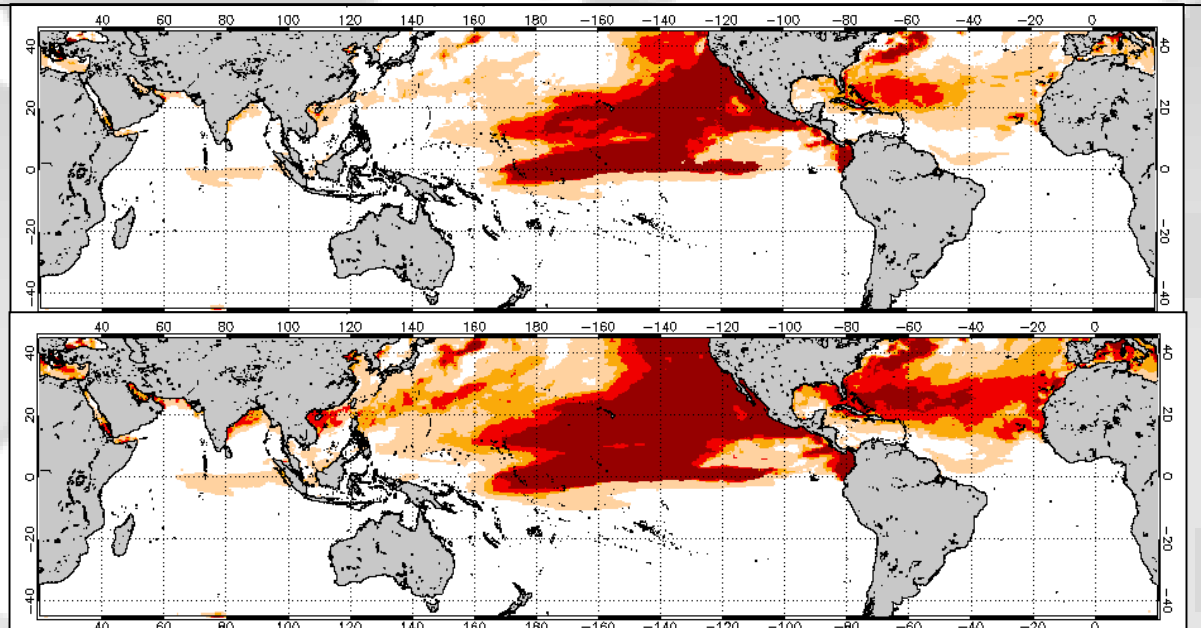


- Based on SST predictions from NOAA's operational Climate Forecast System v2 (CFSv2)
- Up to 112 ensemble members: daily SST predictions from 16 runs/day over a week

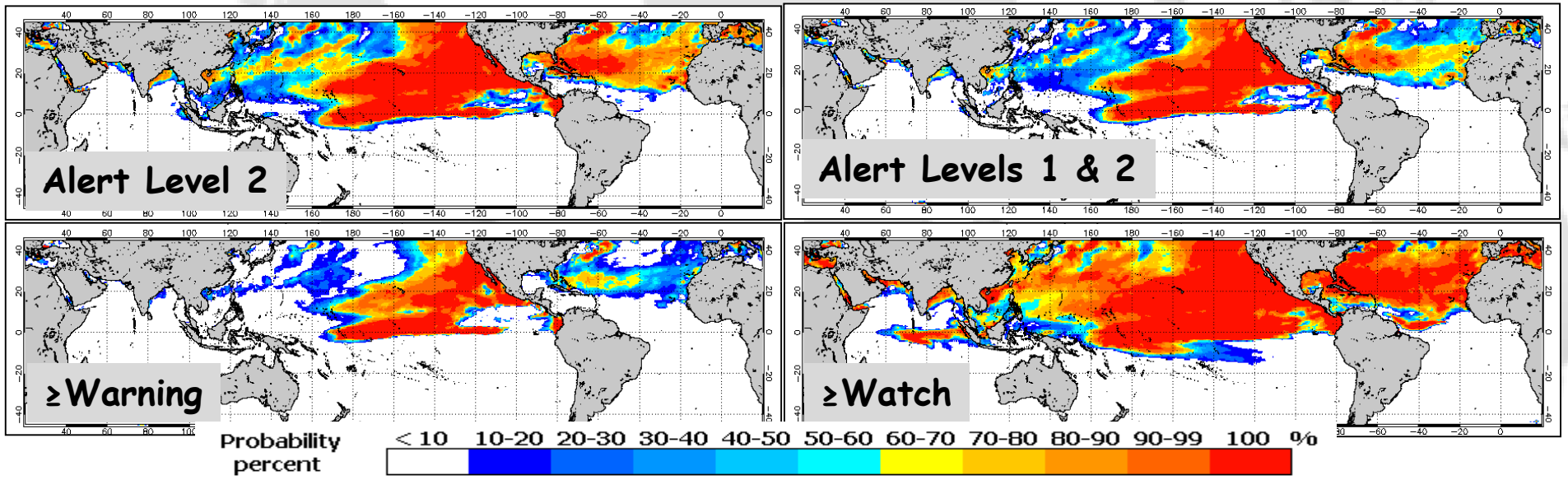
(A collaboration with NOAA/National Centers for Environmental Prediction)

Four-Month Bleaching Outlook (CFSv2 based)

July 7, 2015 Probabilistic Outlook for Jul-Oct 2015



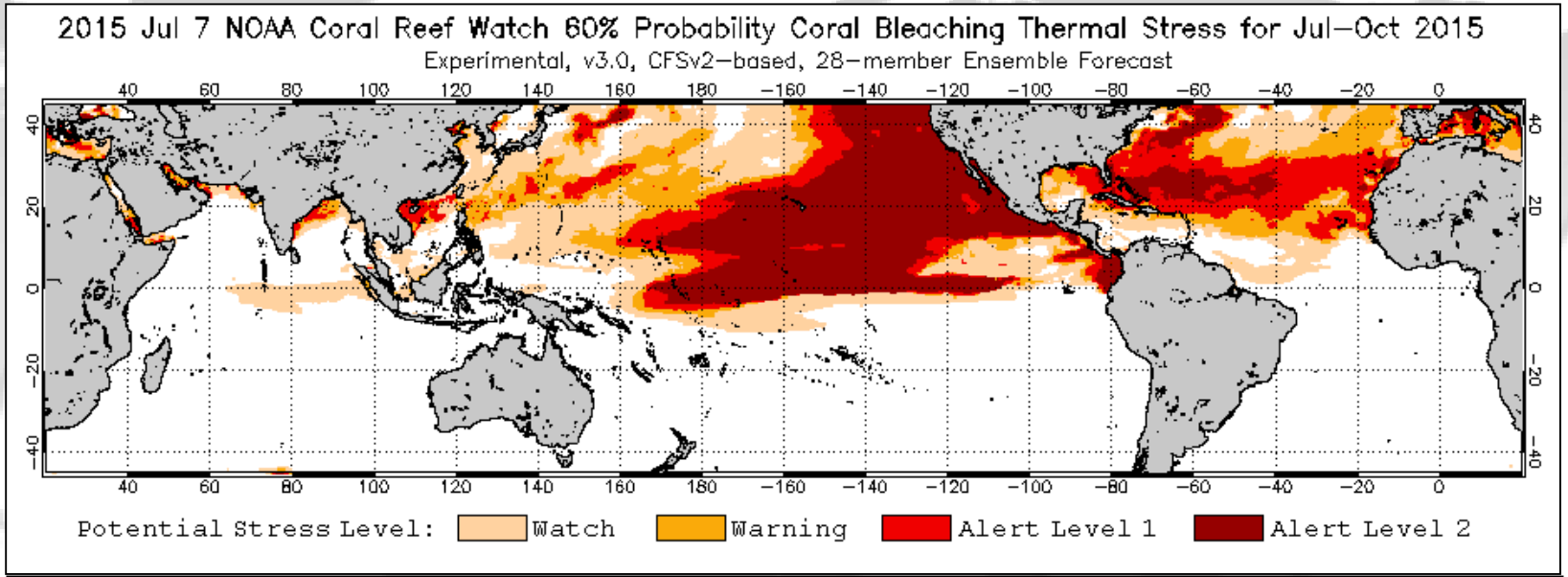
Probabilistic outlook for each stress level:



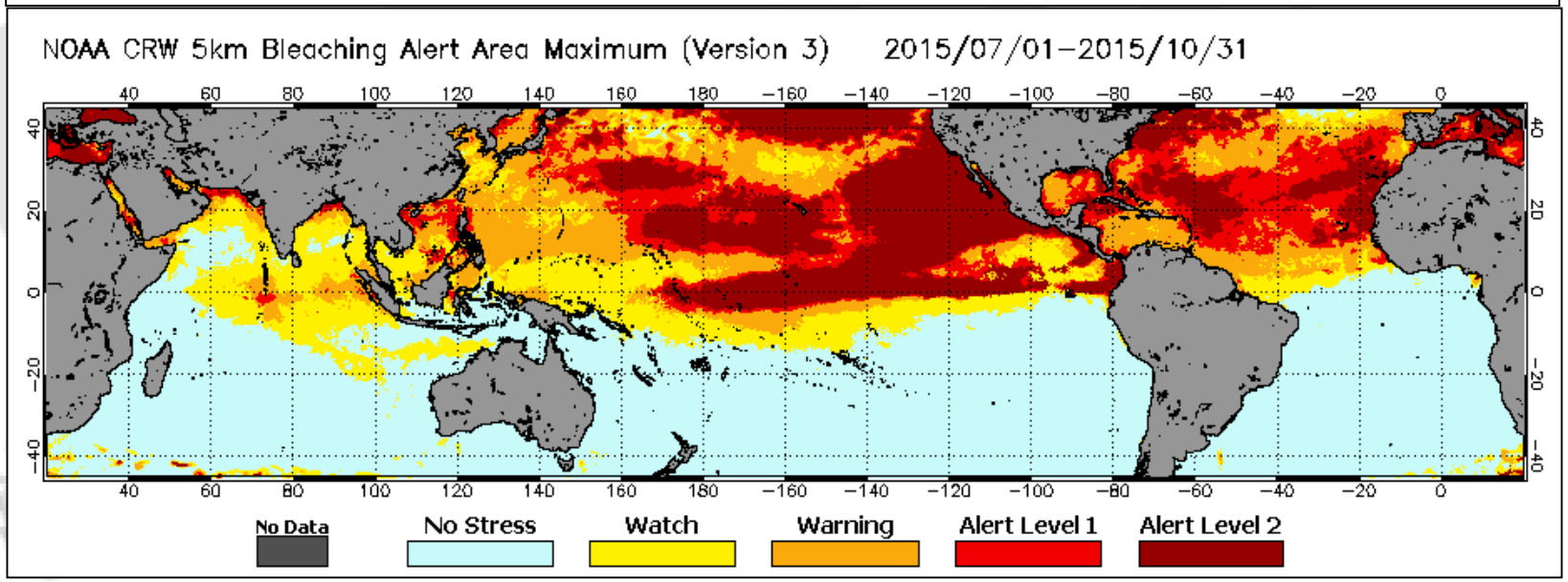
NOAA Coral Reef Watch

Outlook vs. Satellite Observations

July 7, 2015 Probabilistic Outlook for Jul-Oct 2015



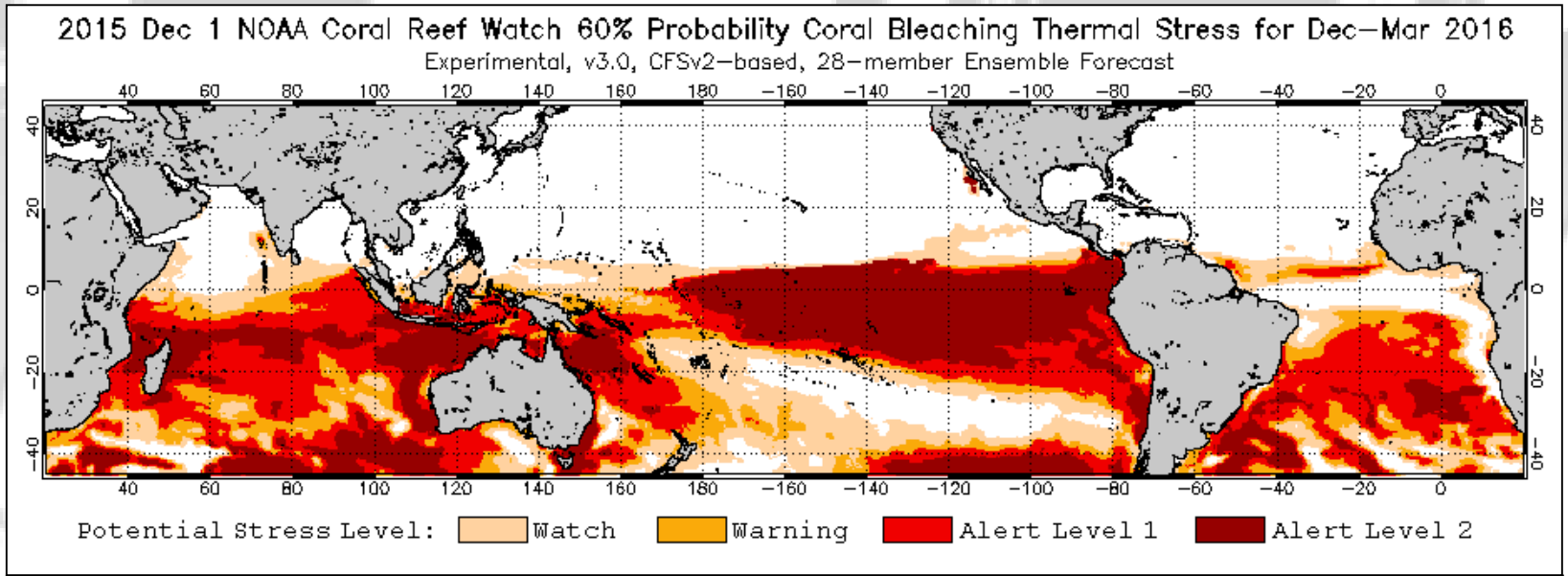
Satellite Bleaching Alert Areas of Jul-Oct 2015



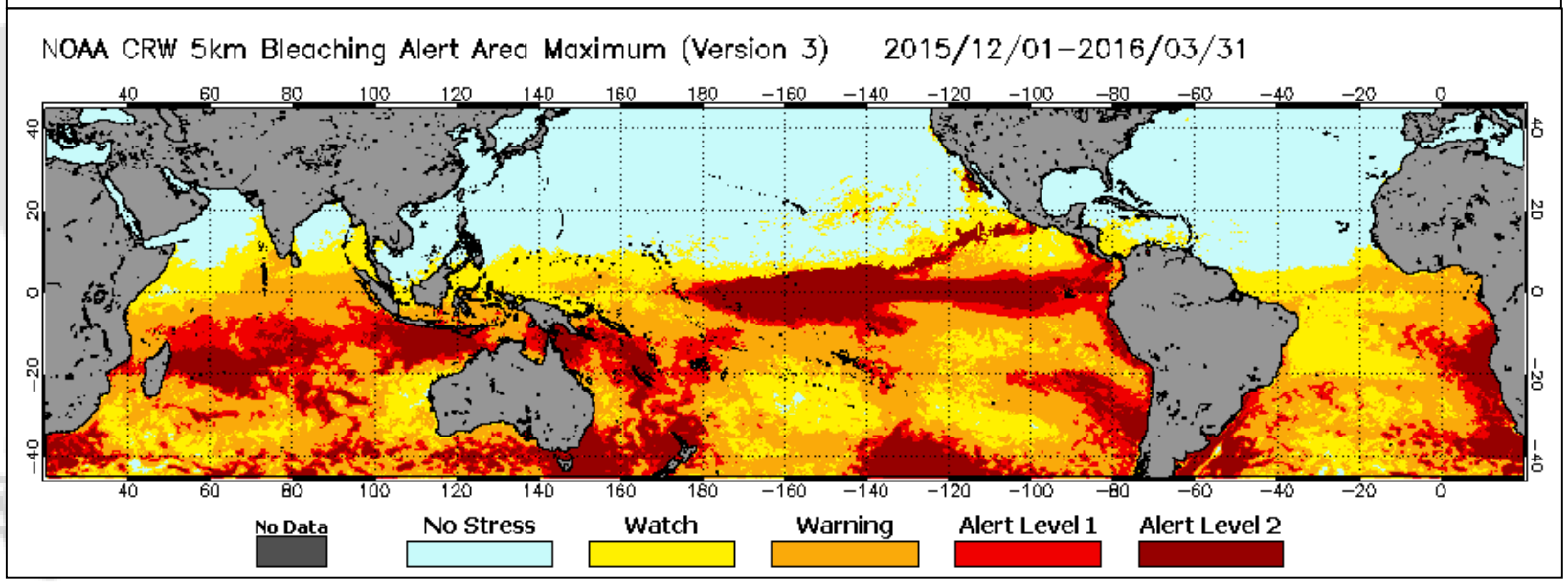
NOAA Coral Reef Watch

Outlook vs. Satellite Observations

Dec 1, 2015 Probabilistic Outlook for Dec-Mar 2016



Satellite Bleaching Alert Areas of Dec-Mar 2016



Historical Coral Bleaching Heat Stress Analysis

Recorded global-scale bleaching events

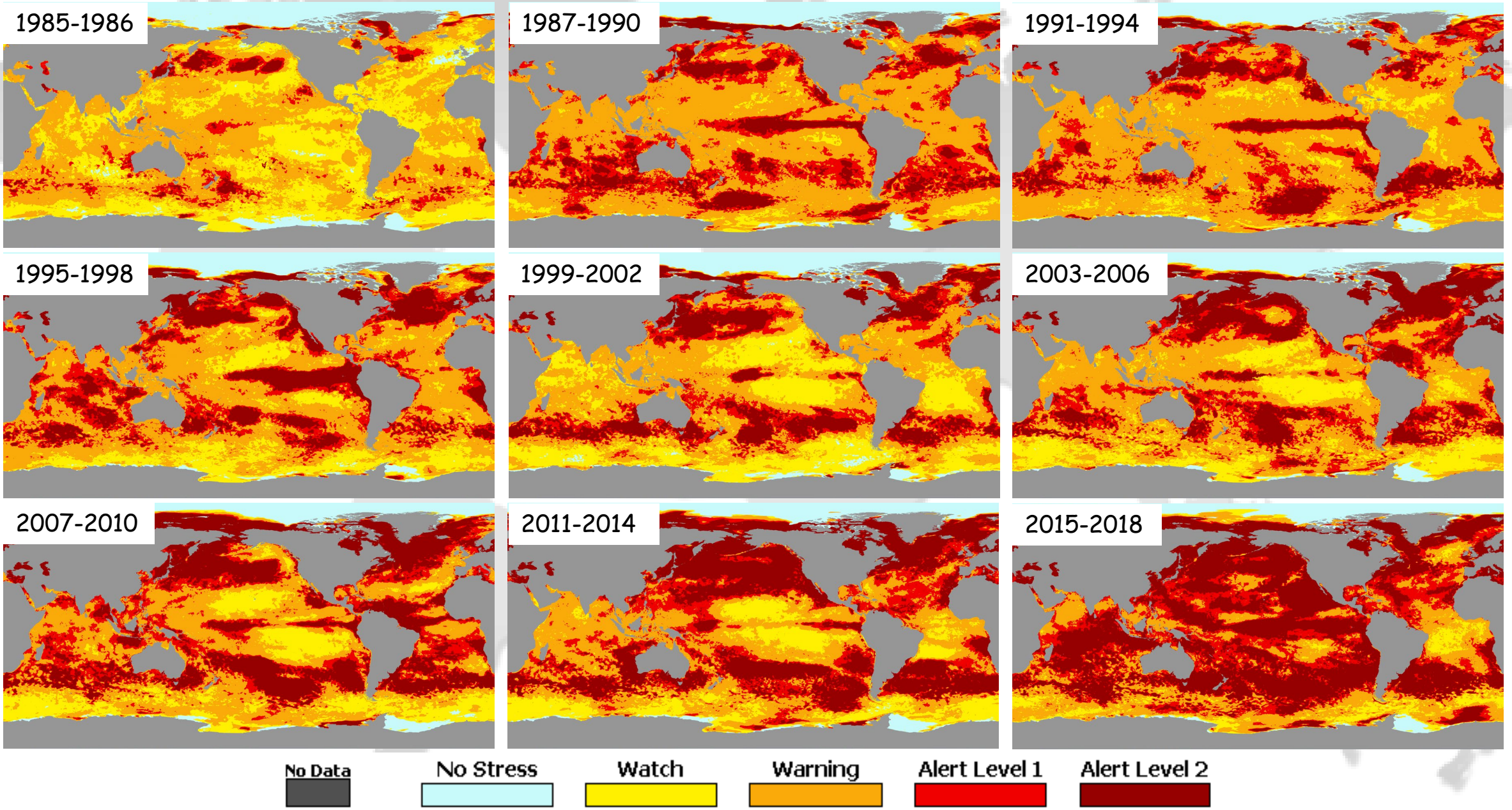
1982-1983: Widespread bleaching
1998: 1st Global Bleaching Event
2010: 2nd Global Bleaching Event
2014-2017: 3rd Global Bleaching Event

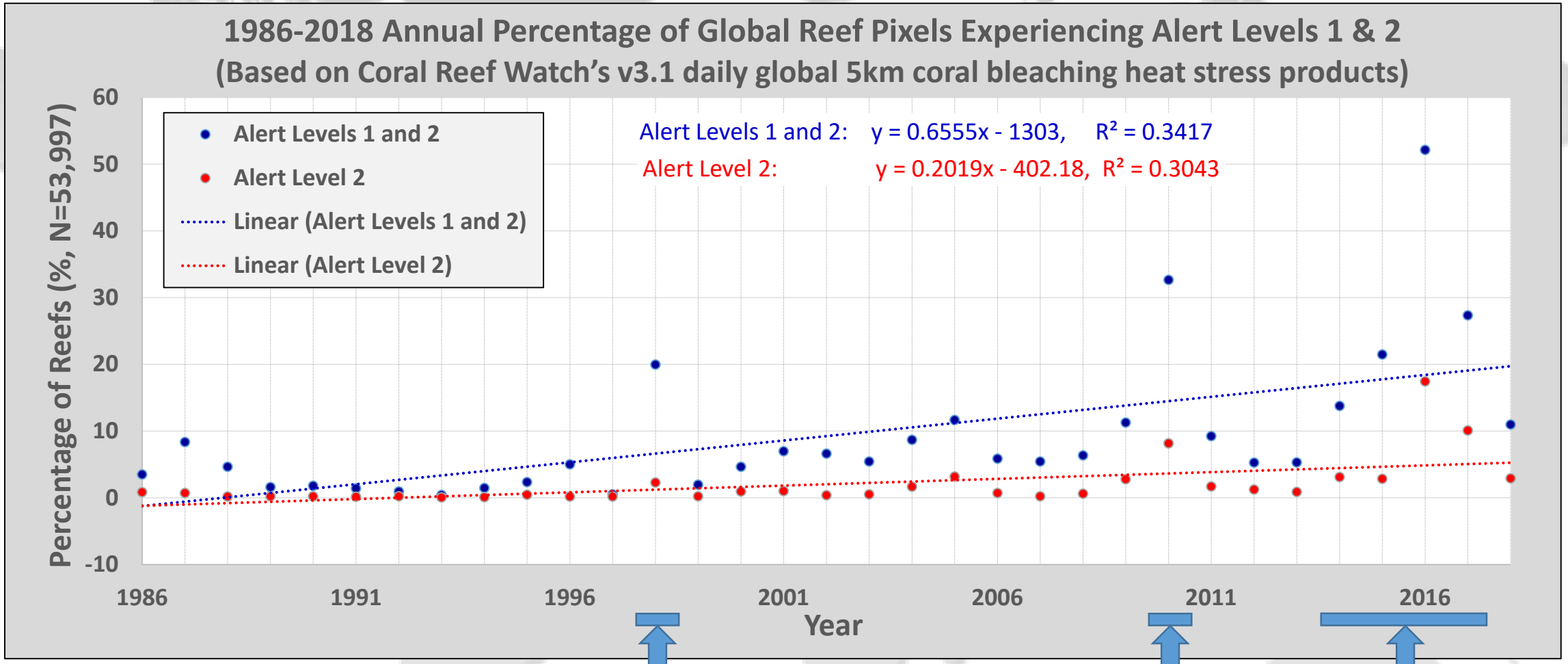
How has global bleaching heat stress changed over the past decades?

NOAA Coral Reef Watch Daily Global 5km SST ('CoralTemp')

1985-2018 (34 years)

Four-year Maxima of Daily Global 5km Bleaching Alert Area 1985-2018 (34 years)




1986-2018 Annual Percentage of Global Reef Pixels Experiencing Alert Levels 1 & 2
(Based on Coral Reef Watch's v3.1 daily global 5km coral bleaching heat stress products)
Percentage of Reefs (%, N=53,997)
60
50
40
30
20
10
0
-10
1986
1991
1996
2001
2006
2011
2016
Year
Alert Levels 1 and 2
Alert Level 2
Linear (Alert Levels 1 and 2)
Linear (Alert Level 2)
Alert Levels 1 and 2: y = 0.6555x - 1303, R² = 0.3417
Alert Level 2: y = 0.2019x - 402.18, R² = 0.3043
1998
2000
2014-2017
Recorded Global Coral Bleaching Events:
First
Second
Third

Ongoing and Future Research and Development:

- Validate satellite products using bleaching observations collected during the 2014-2017 global coral bleaching event;
- Perform skill analysis for latest version of the bleaching forecast;
- Construct a new global 5km SST timeseries (1982-present);
- Construct a new climatology for satellite monitoring;
- Adjust and/or potentially develop a new coral bleaching heat stress detection algorithm for satellite monitoring (and also forecast);
- Develop and implement satellite marine heatwave monitoring products;
- Develop and implement subseasonal-to-seasonal marine heatwave forecast.

Thank you from the NOAA Coral Reef Watch Team!!

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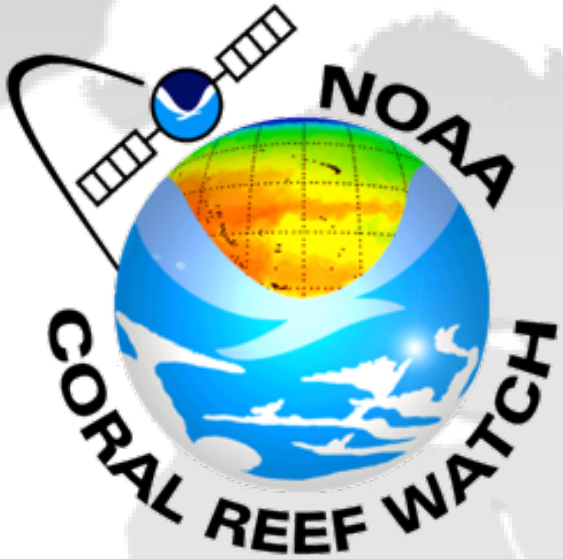
Ben Marsh (ReefSense)

Rob Warner (NOAA/NOS)

William Hernandez Lopez (UPR-Mayagüez & EMC)

Andrea Gomez (CUNY & NOAA-CREST)

https://coralreefwatch.noaa.gov



https://coralreefwatch.noaa.gov

Coral Reef Watch @CoralReefWatch

coralreefwatch@noaa.gov

Coral Reef Watch: A NOAA/NESDIS program, funded predominantly by the NOAA Coral Reef Conservation Program (CRCP) through a cooperative agreement with the University of Maryland.

Importance of Coral Reefs

Photos by Anthony Picciolo (top) and Heidi Schuttenberg (bottom)

Value of Reefs:

* USD$9.8 Trillion value (USD$352,249/hectare) per year worldwide in fish, seafood, tourism, and coastal protection

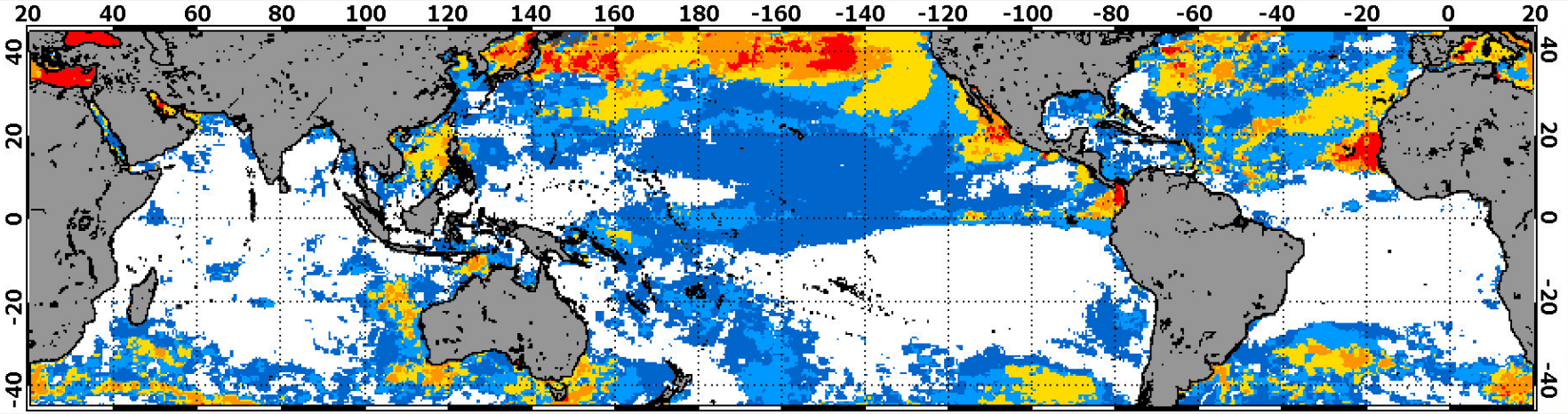
* >USD$1.8 Billion in US coastal storm flooding protection

* One billion people rely on reef fish for food globally

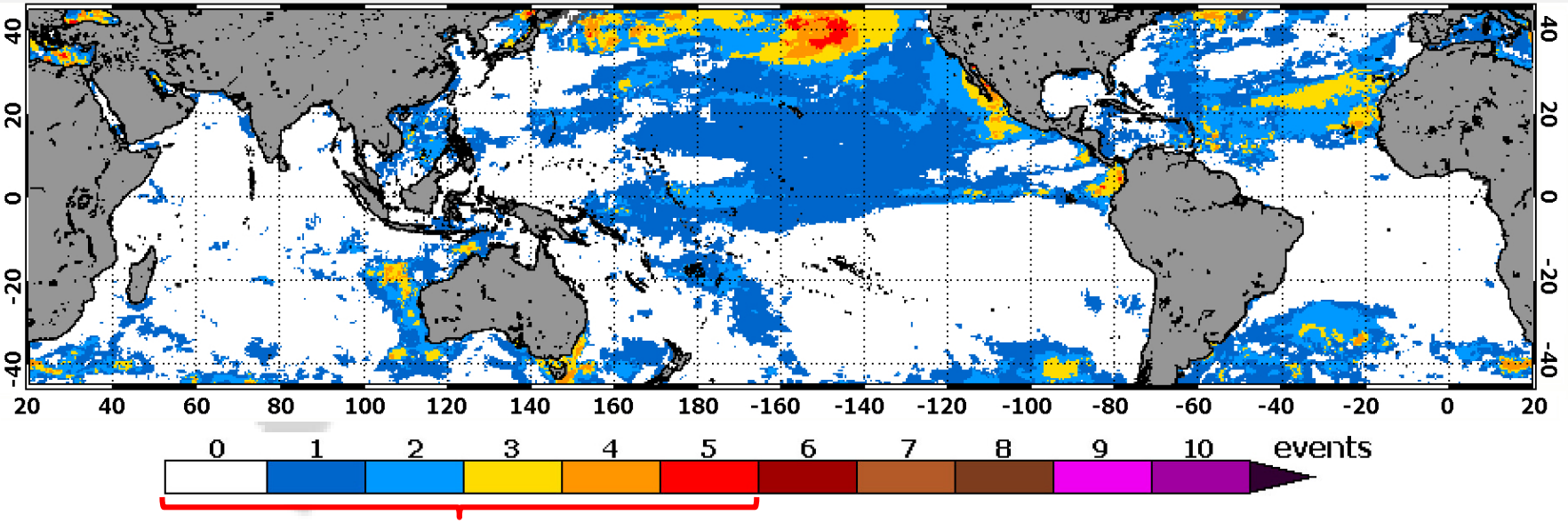
NOAA Coral Reef Watch

Outlook Accuracy Analysis (Apr 2011-Dec 2015)

of bleaching events identified by CRW's satellite monitoring



of hits (60% Probabilistic Outlook, lead-time of 5 weeks)



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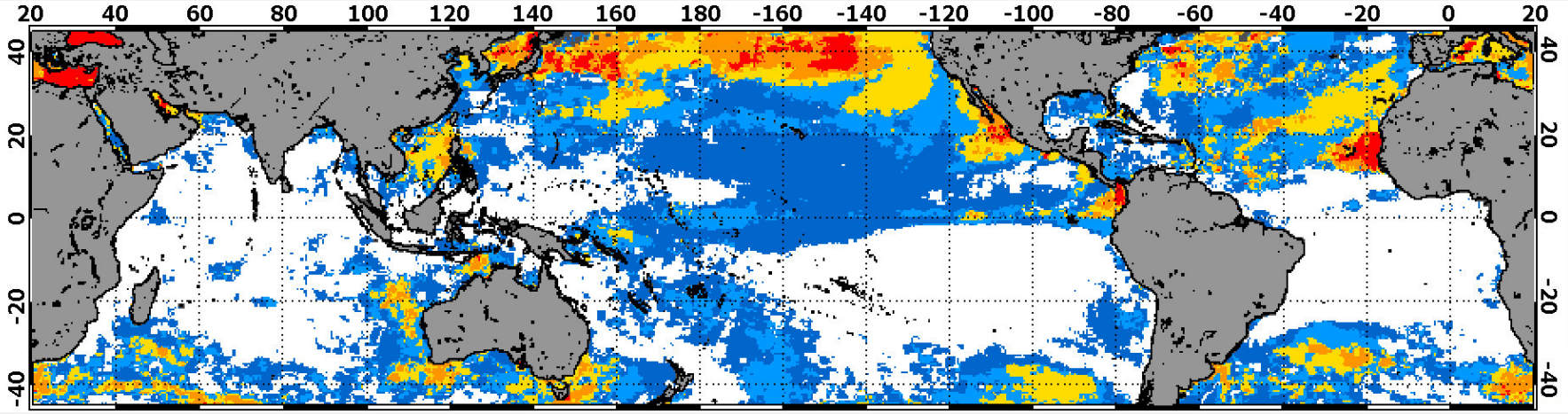
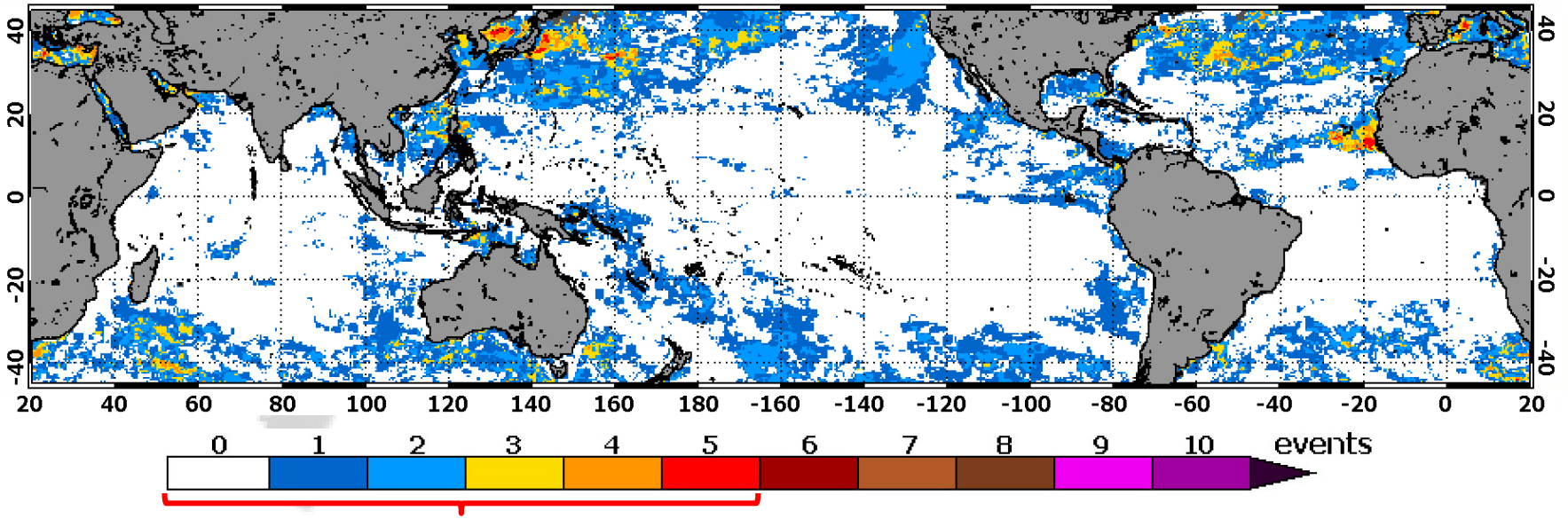


of misses (60% Probabilistic Outlook, lead-time of 5 weeks)



NOAA Coral Reef Watch

Outlook Accuracy Analysis (Apr 2011-Dec 2015)

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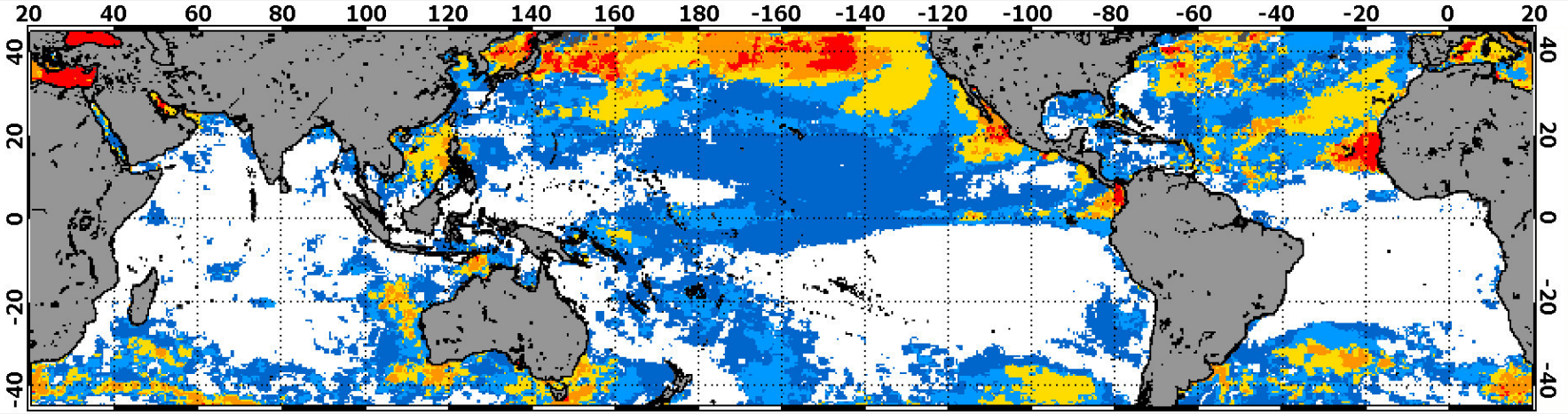
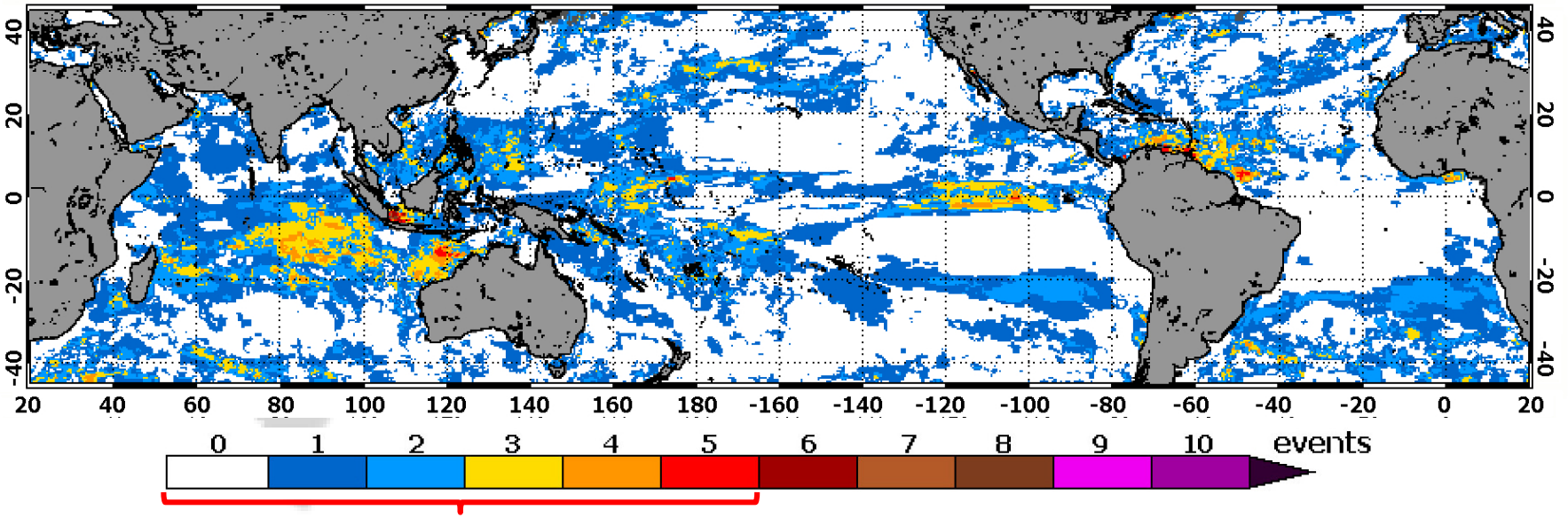
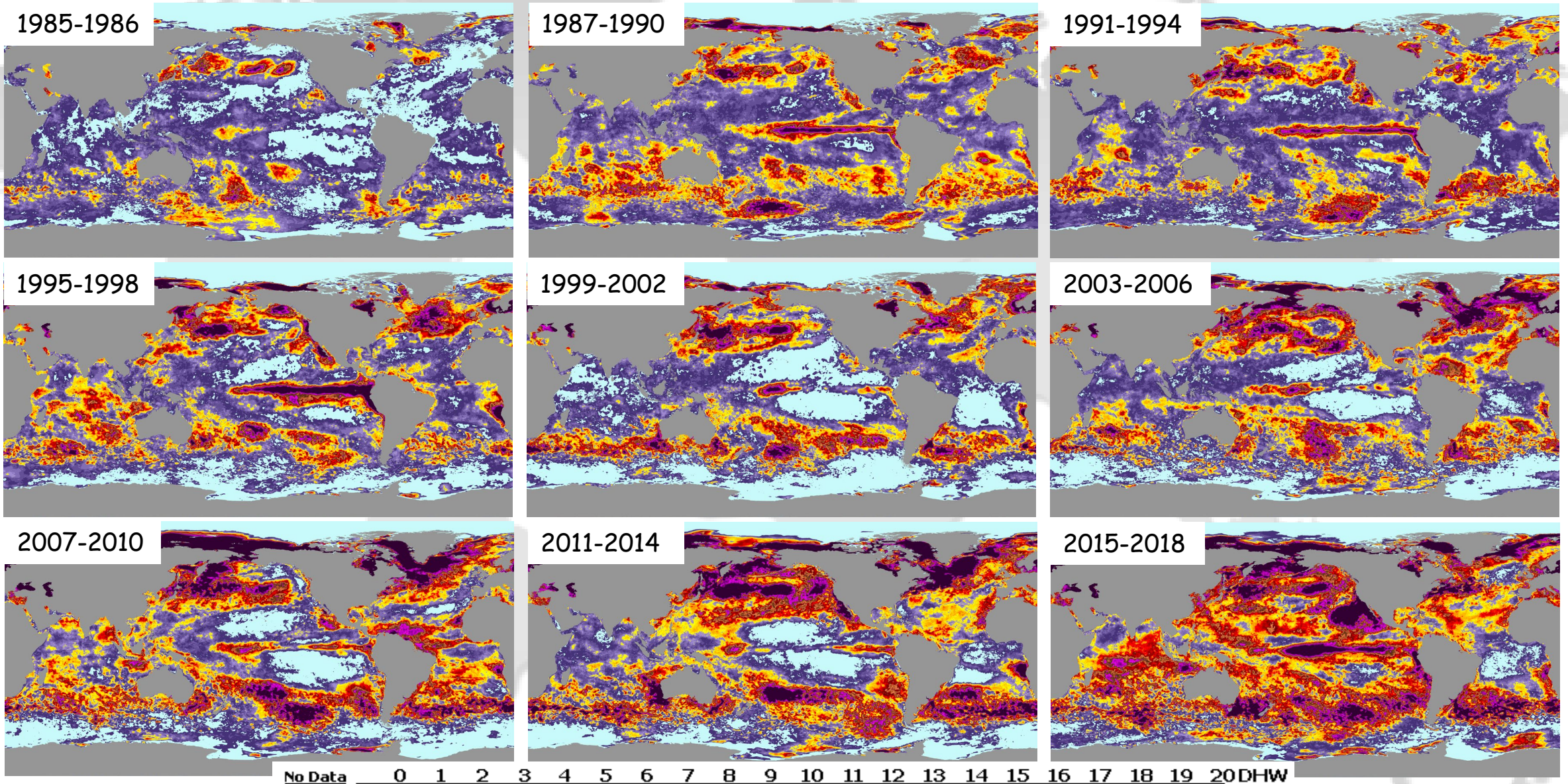


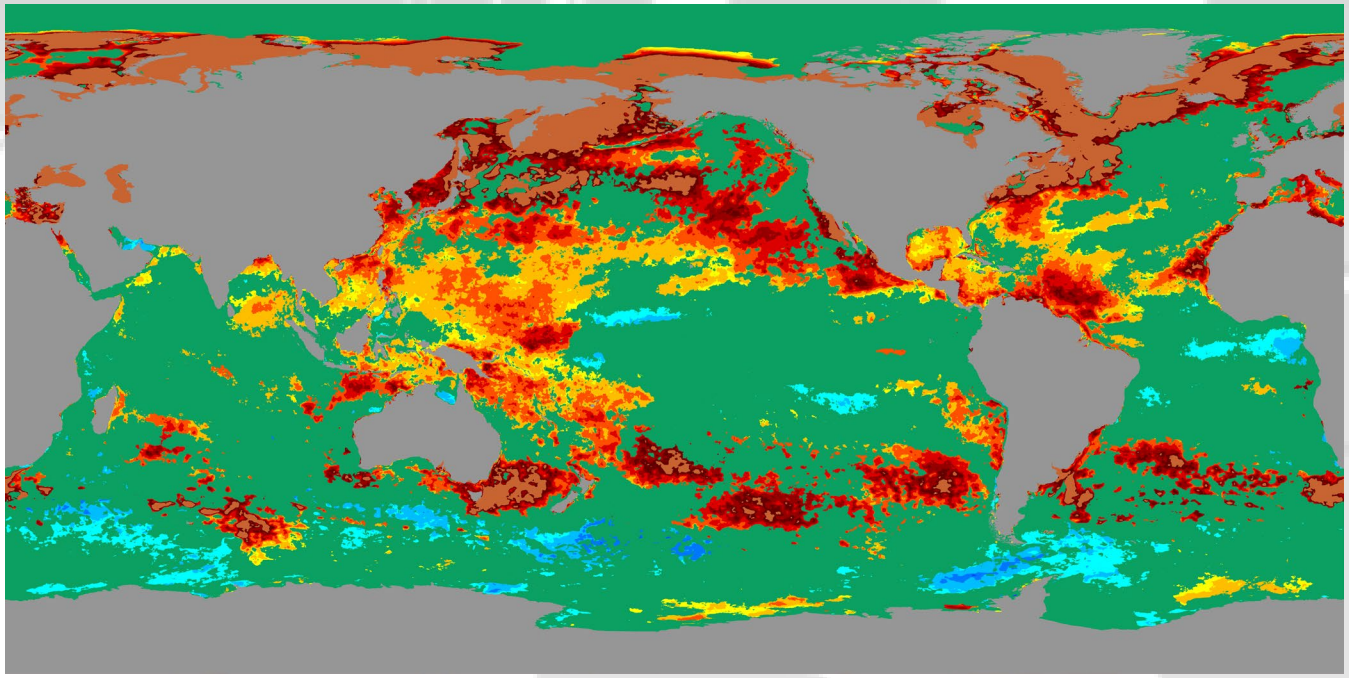
of false alarms (60% Probabilistic Outlook, lead-time of 5 weeks)

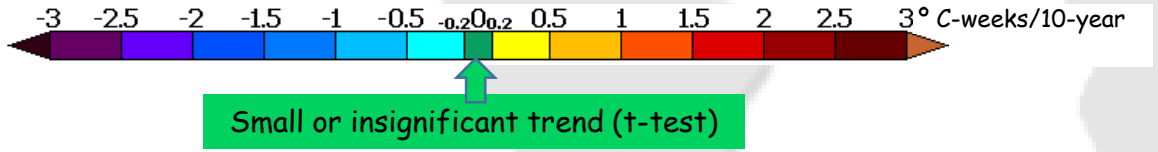


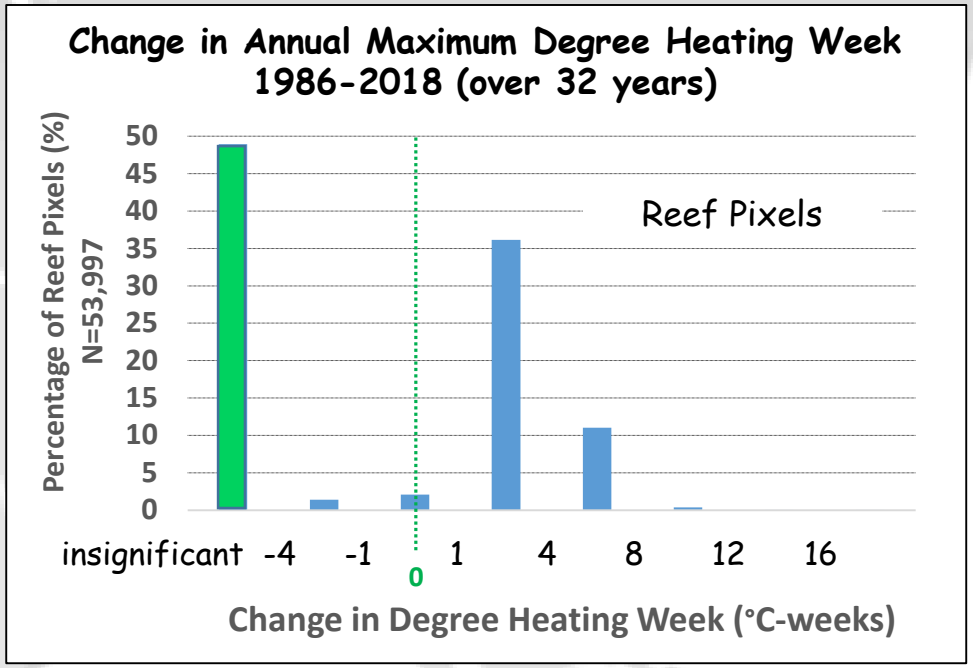
Four-year Maxima of Daily Global 5km Degree Heating Week 1985-2018 (34 years)

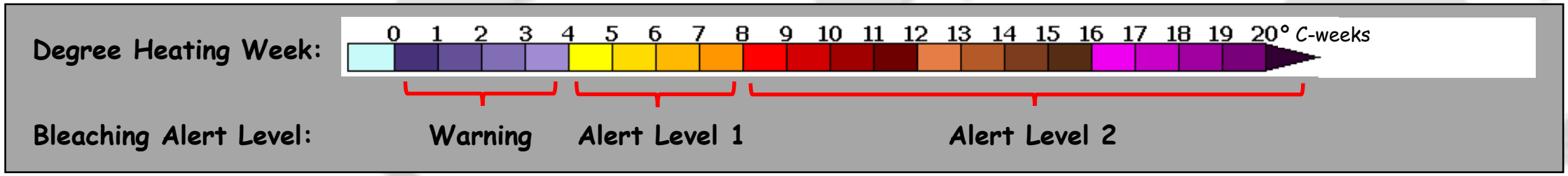


Trend of Annual Maximum Degree Heating Week: 1986-2018
(Linear regression)

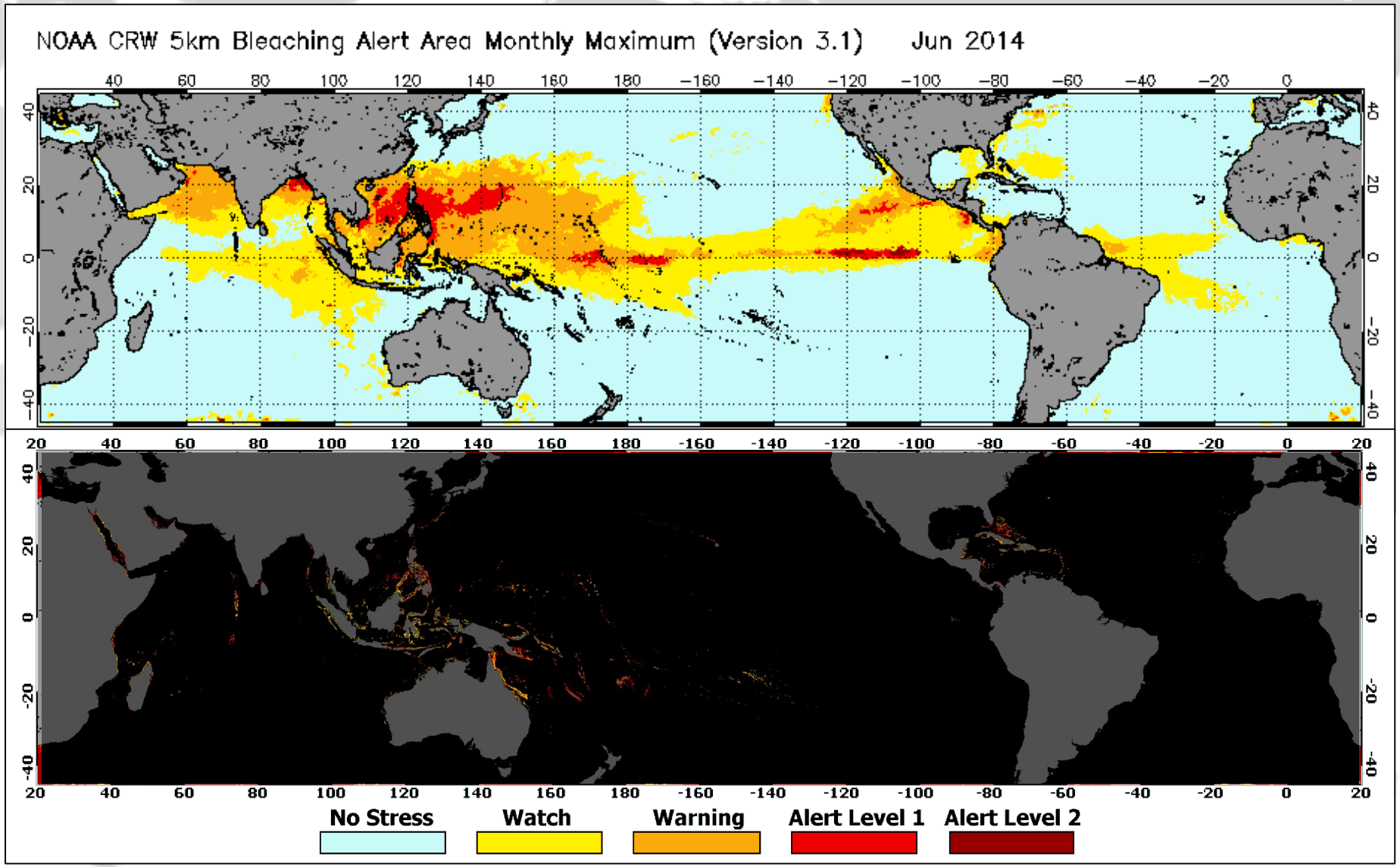








Coral Bleaching Heat Stress



Coral Reef Pixels Only