

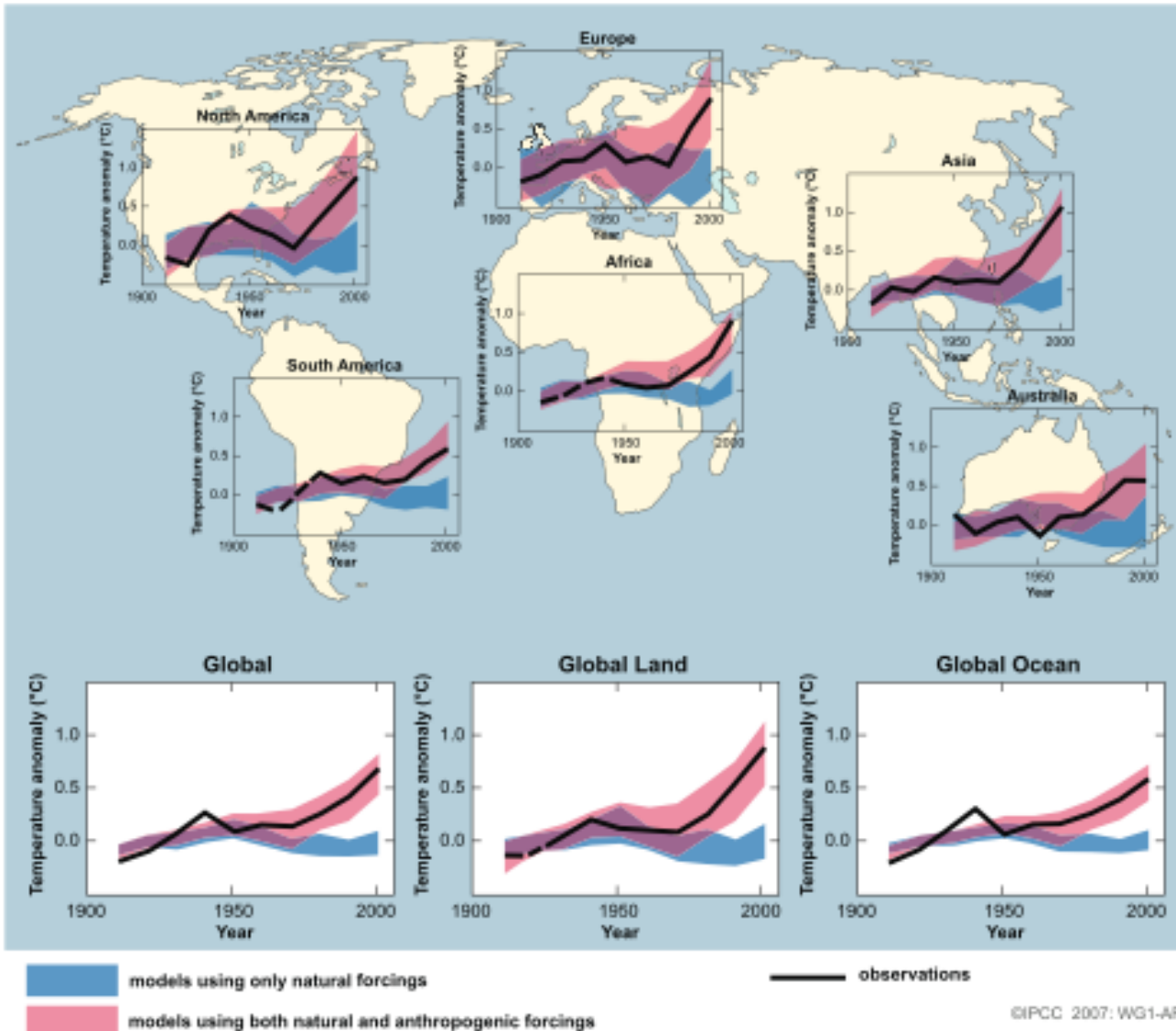
A satellite image of Earth from space, showing a large, swirling hurricane over the ocean. The sun is visible on the horizon, creating a bright glow and lens flare effect. The Earth's curvature is visible at the top of the frame.

# Attribution of Extreme Events

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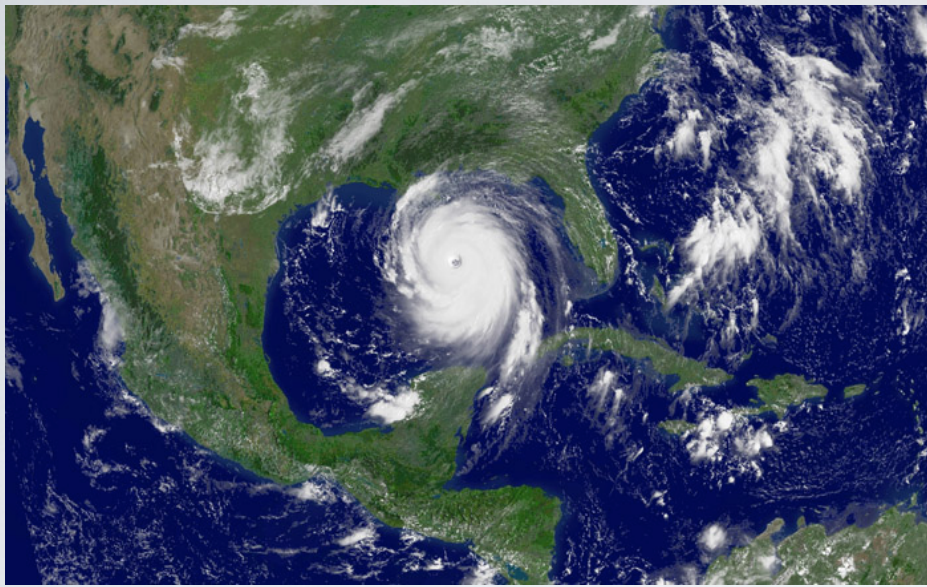
# Attribution of global and regional surface average temperature change



“Most of the observed increase in globally averaged temperatures since the mid-20<sup>th</sup> century is *very likely*\* due to the observed increase in anthropogenic greenhouse gas concentrations.”

\*very likely = 90-95% certainty

IPCC-AR4 (2007)



ROSS GELBSPAN

The Boston Globe

## Katrina's real name

By Ross Gelbspan | August 30, 2005

THE HURRICANE that struck Louisiana yesterday was nicknamed Katrina by the National Weather Service. Its real name is global warming.

## NOAA ATTRIBUTES RECENT INCREASE IN HURRICANE ACTIVITY TO NATURALLY OCCURRING MULTI-DECADAL CLIMATE VARIABILITY \*

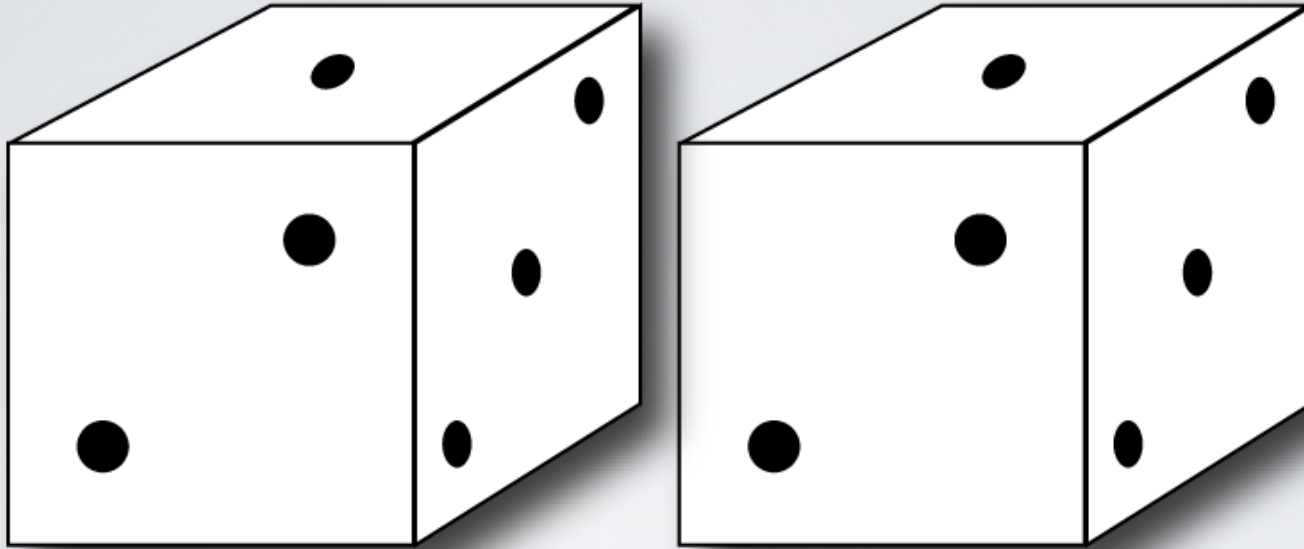


Nov. 29, 2005 — The nation is now wrapping up the 11th year of a new era of heightened [Atlantic hurricane activity](#). This era has been unfolding in the Atlantic since 1995, and is expected to continue for the next decade or perhaps longer. [NOAA](#) attributes this increased activity to natural occurring cycles in tropical climate patterns near the equator. These cycles, called “the tropical multi-decadal signal,” typically last several decades (20 to 30 years or even longer). As a result, the North Atlantic experiences alternating decades long (20 to 30

year periods or even longer) of above normal or below normal hurricane seasons. NOAA research shows that the tropical multi-decadal signal is causing the increased Atlantic hurricane activity since 1995, and is not related to greenhouse warming. ([Click NOAA](#)

Research by NOAA scientists [..] and [..], currently in press with the *Journal of Climate*, describes the tropical multi-decadal signal and shows that it accounts for the entire inter-related set of conditions that controls hurricane activity for decades at a time!

# Extreme events as rolling dice



Two fair, six-sided dice.

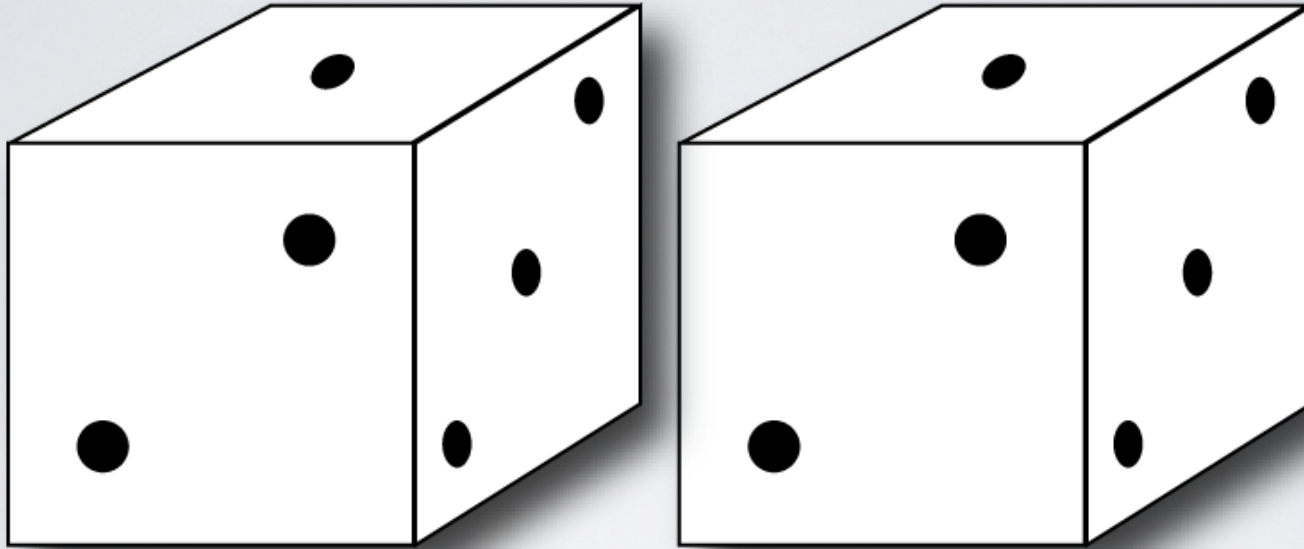
What is average roll?

What are odds of:

Roll  $\leq 3$ ?

Roll  $\geq 12$ ?

# Extreme events as rolling dice



Two fair, six-sided dice.

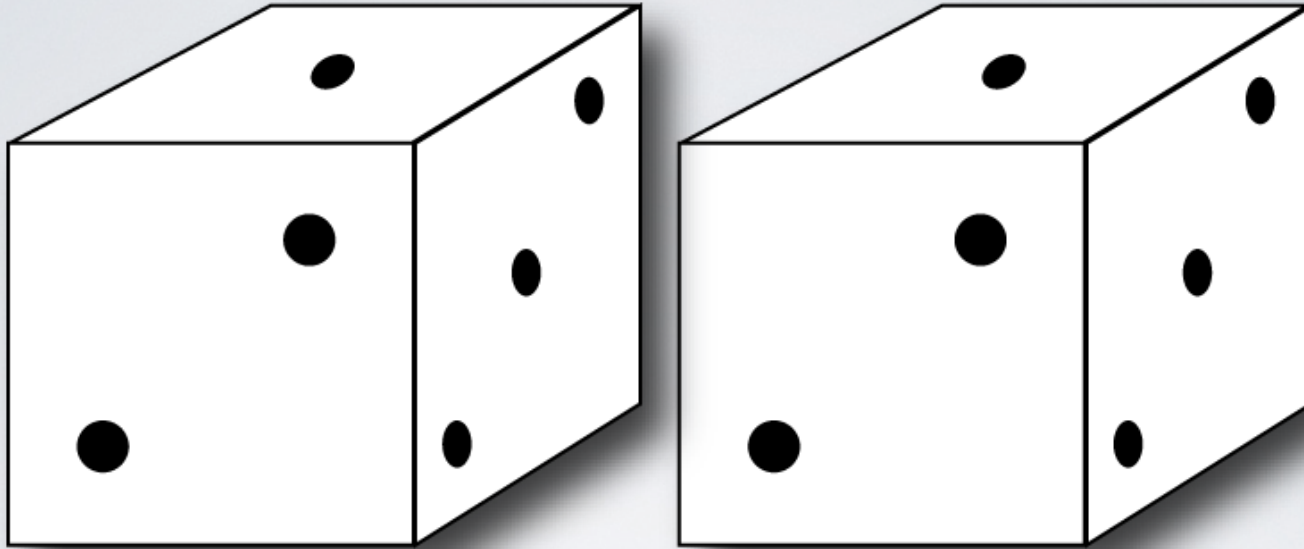
What is average roll? **7**

What are odds of:

Roll  $\leq 3$ ?

Roll  $\geq 12$ ?

# Extreme events as rolling dice



Two fair, six-sided dice.

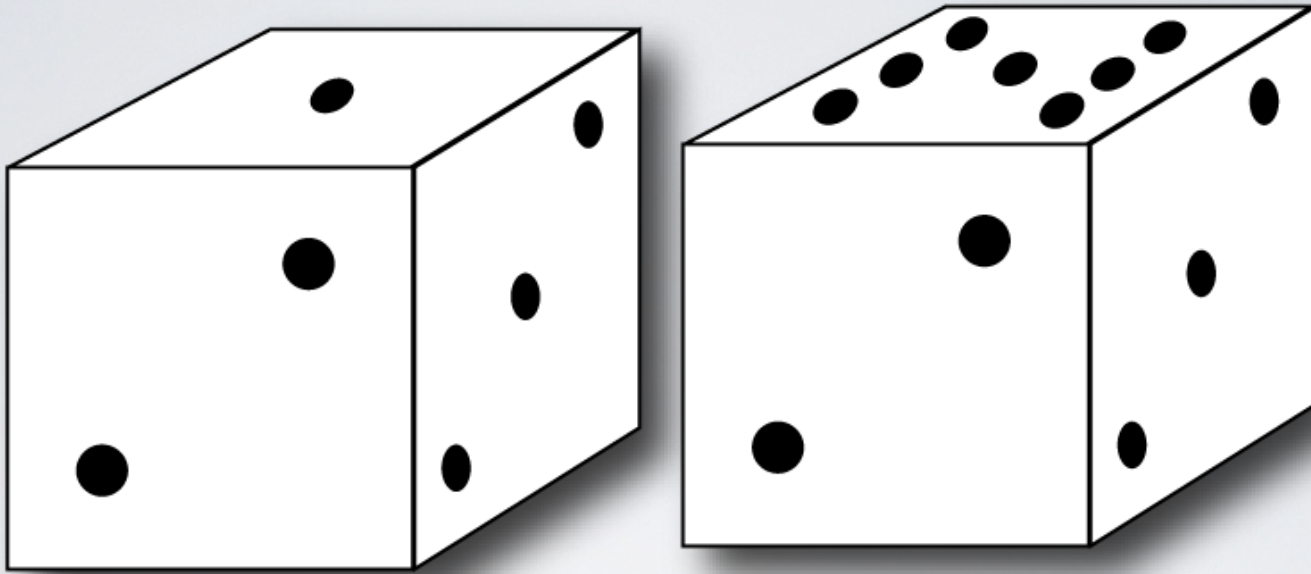
What is average roll? **7**

What are odds of:

Roll  $\leq 3$ ? **3/36**

Roll  $\geq 12$ ? **1/36**

# Extreme events as rolling dice



What is average roll?

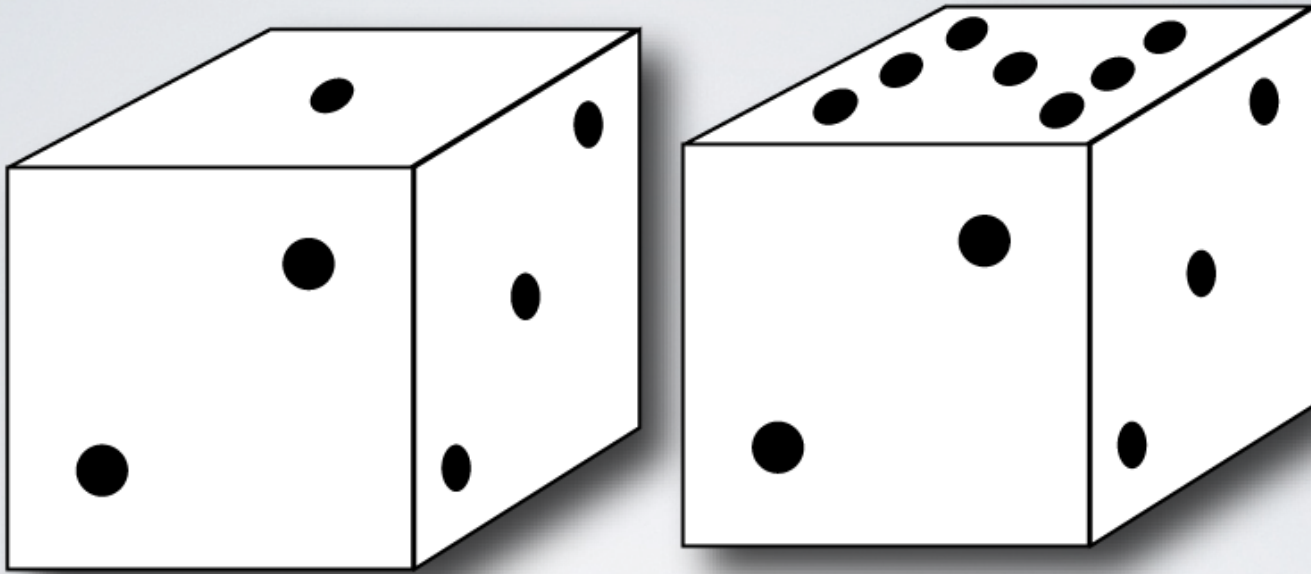
What are odds of:

Roll  $\leq 3$ ?

Add a dot to every side  
of one die.

Roll  $\geq 12$ ?

# Extreme events as rolling dice



What is average roll?

**8**

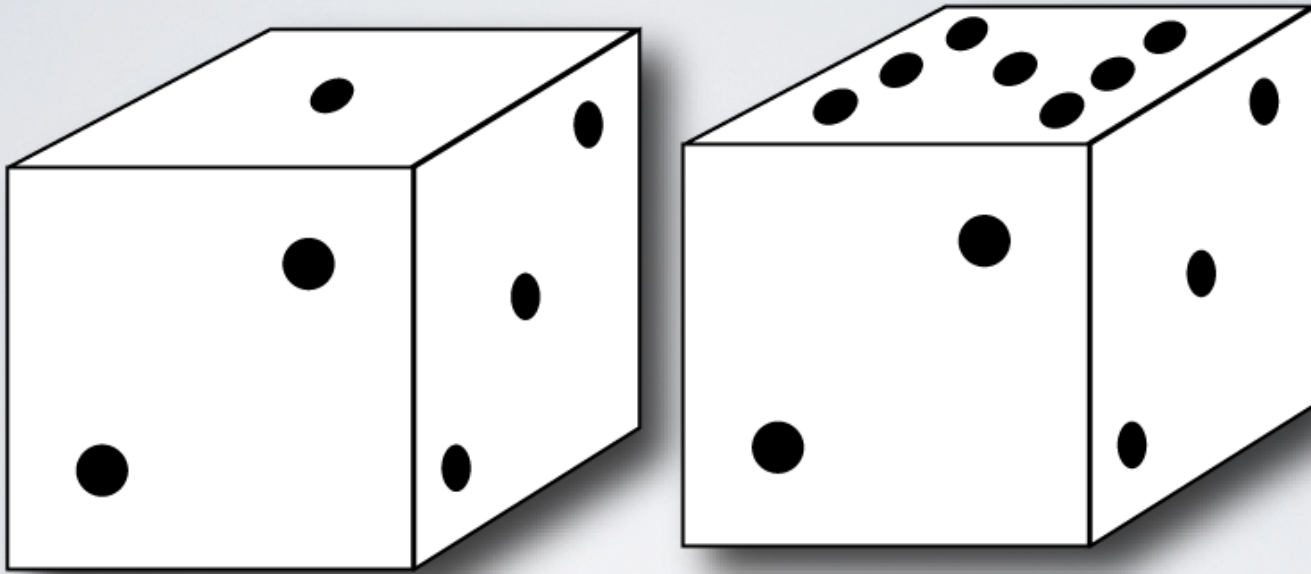
Add a dot to every side  
of one die.

What are odds of: (+1 or +14%)

Roll  $\leq 3$ ?

Roll  $\geq 12$ ?

# Extreme events as rolling dice



What is average roll?

**8**

Add a dot to every side of one die.

What are odds of: **(+1 or +14%)**

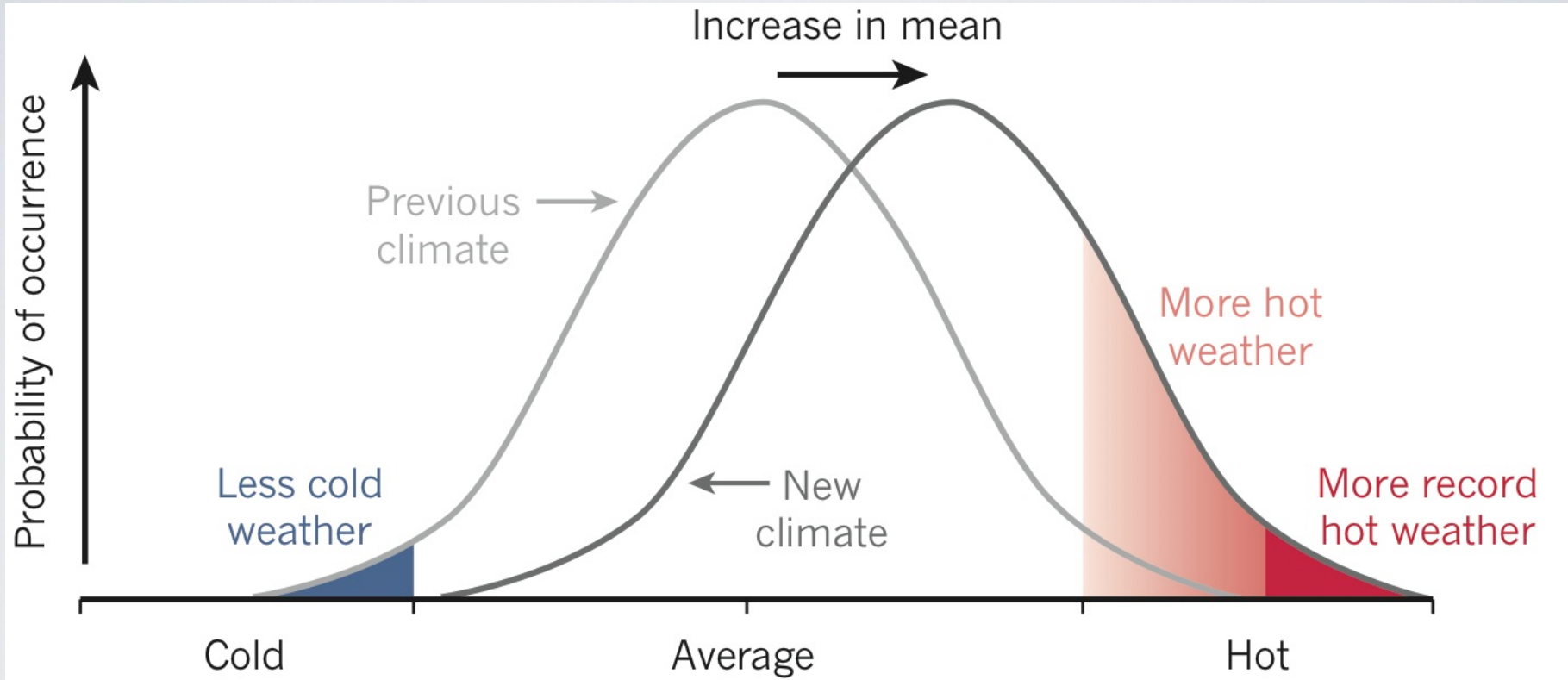
Roll  $\leq 3$ ? **1/36**

**1/3 as likely or 66% less**

Roll  $\geq 12$ ? **3/36**

**3x likelier or 200% more**

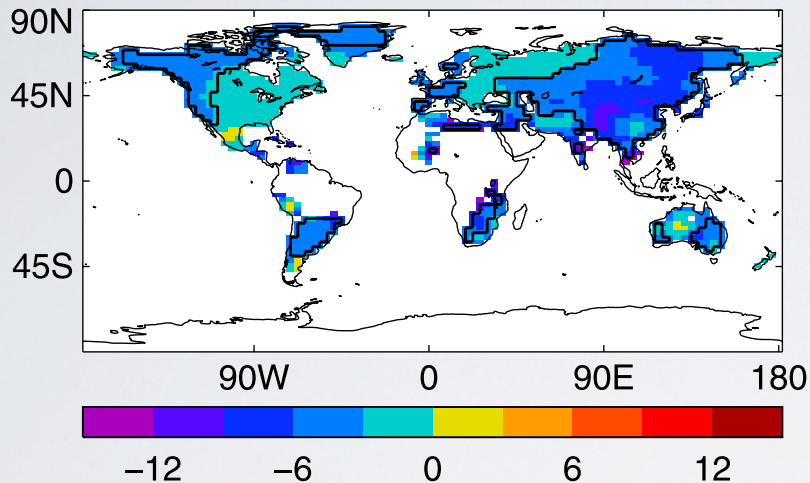
# Changing the mean climate can change the odds of extremes



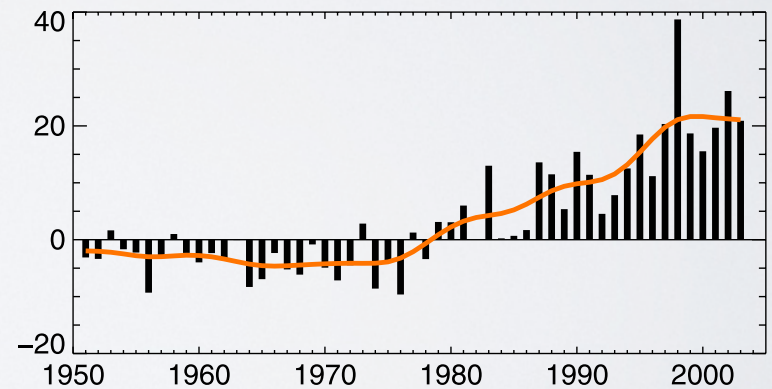
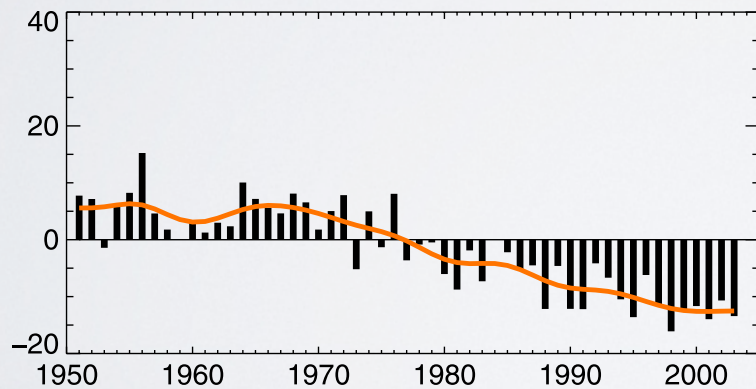
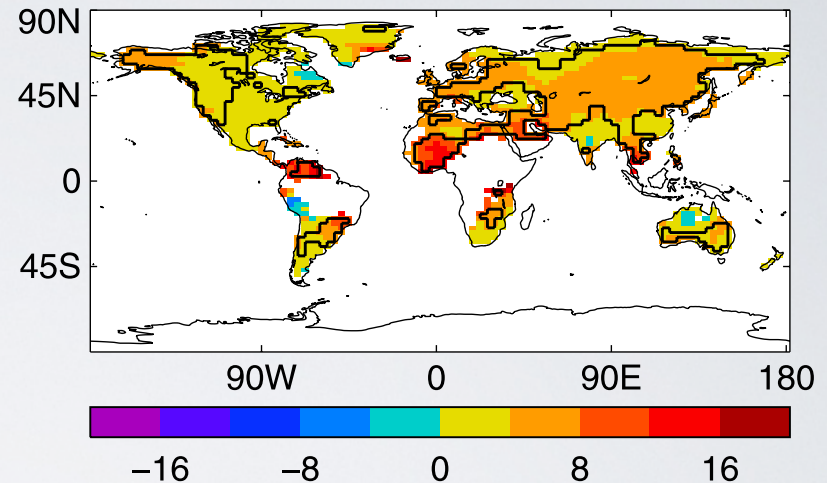
IPCC(2007)

# Observed temperature extremes moving towards warm: fewer cold nights, more warm nights

(a) Cold nights

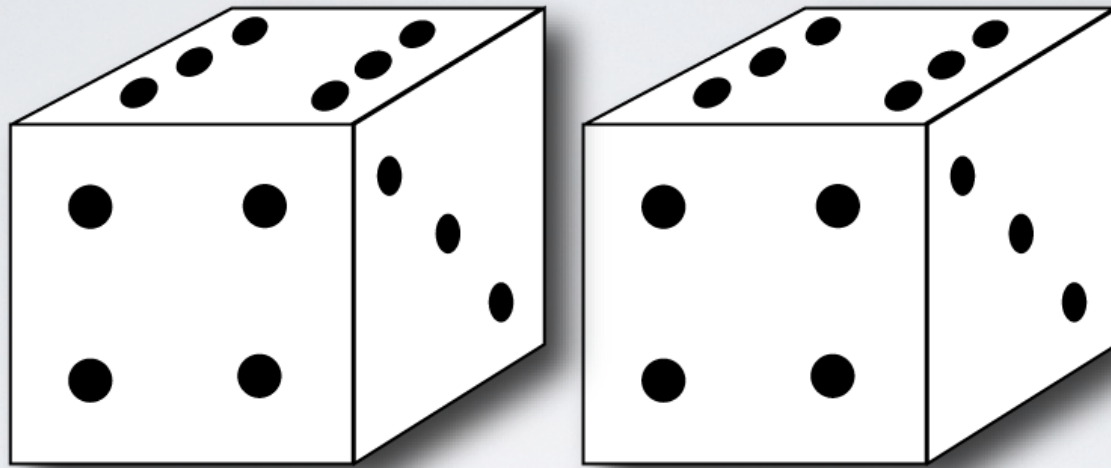


(b) Warm nights



*Alexander et al. (2006, J. Geophys. Res.)*

But, if you roll “boxcars”:  
can you tell which set of dice you rolled?



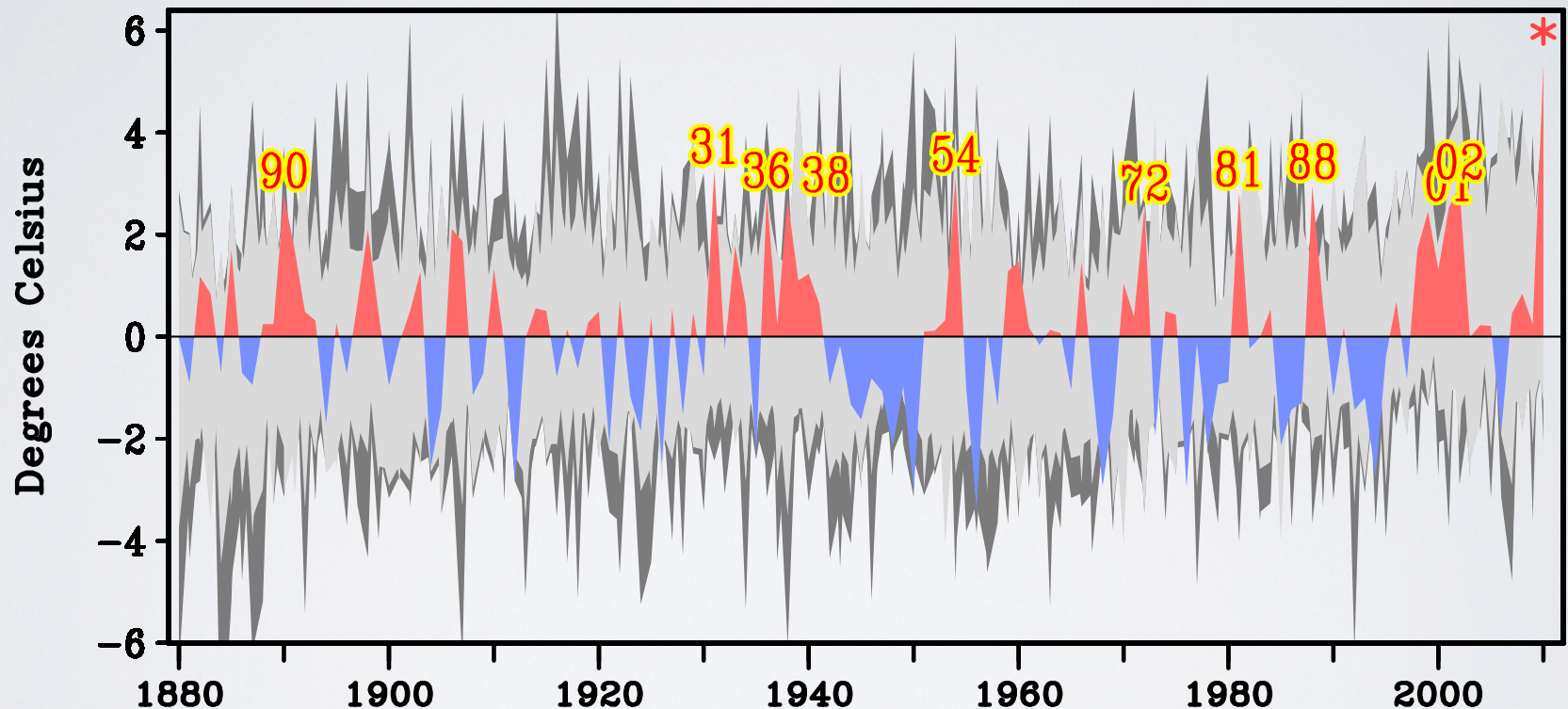
Even if we knew it was a modified pair of dice  
(e.g., roll 13), do we know:

When they were switched?

Who switched them?

2010 Russian heat wave was extreme but not completely impossible event, by some estimates. So: Can we attribute to AGW? Can we exclude AGW?

### Western Russia July Surface Temperature



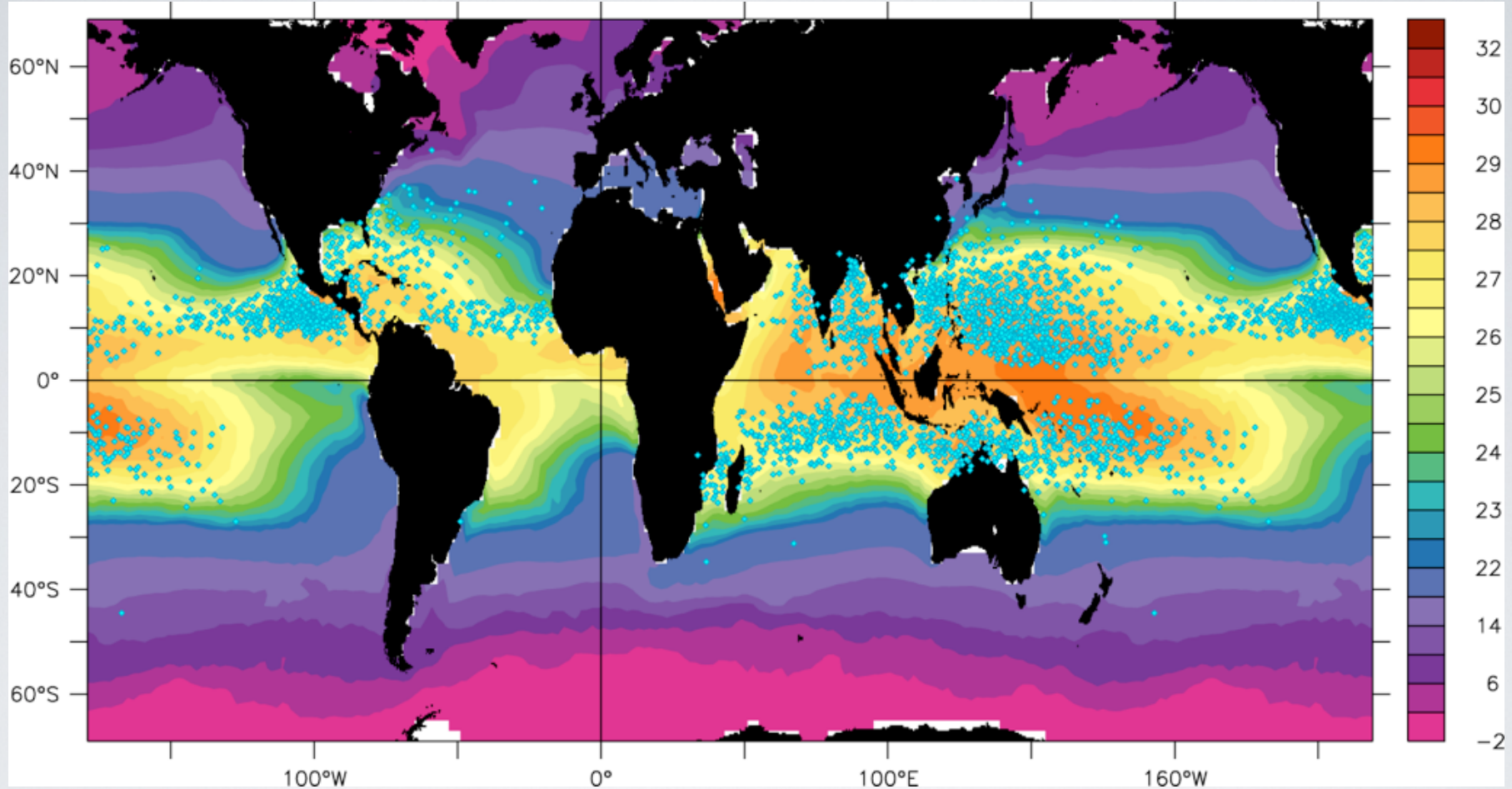
*Dole et al. (2011, Geophys. Res. Lett.)*

# Extreme events as rolling dice



Climate doesn't just have six-sided dice,  
and we could be changing their shape.

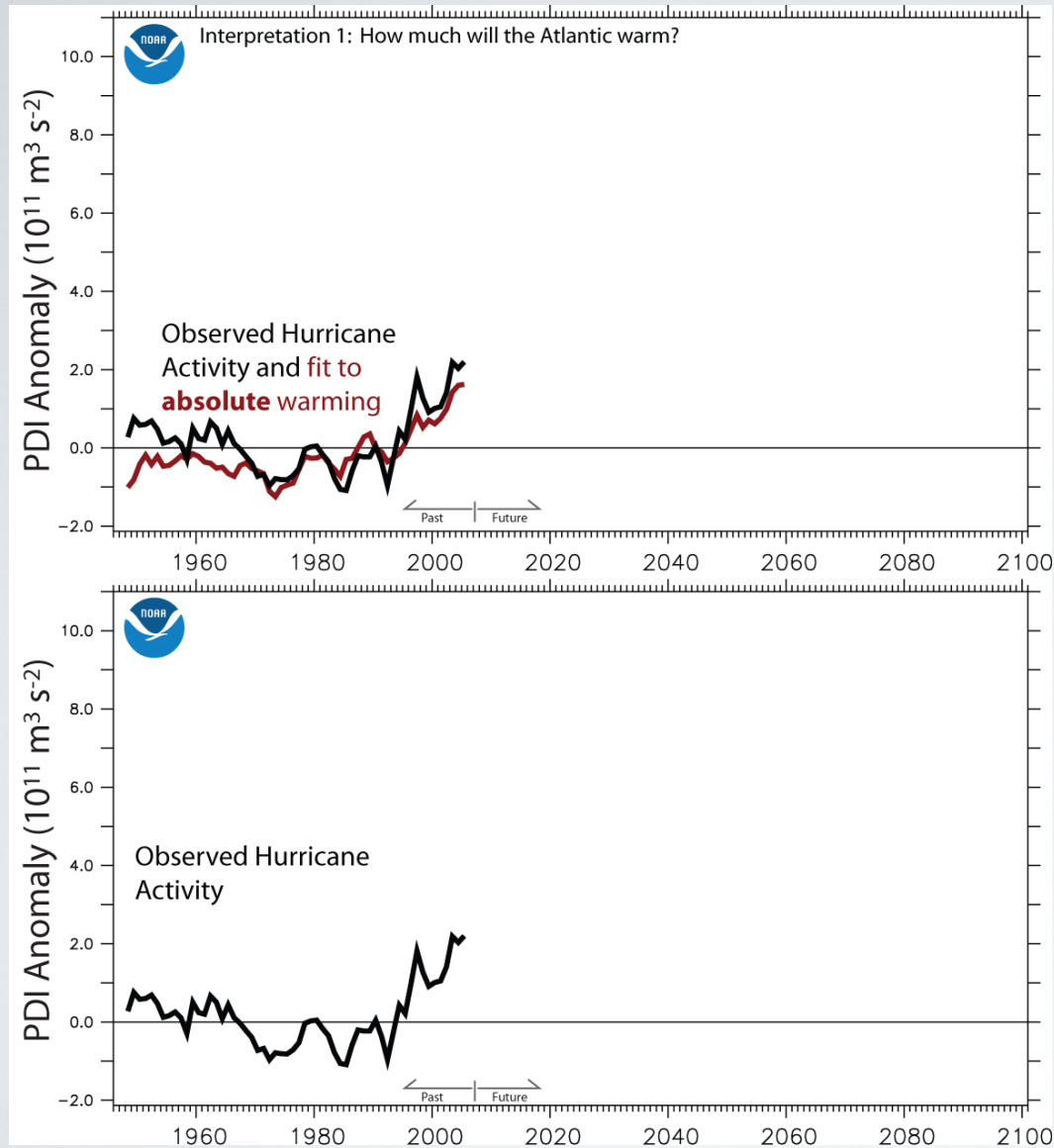
# Historically, Tropical Cyclones Form Over Warm Water



But warm water not enough, e.g. cyclones “like” an environment without strong wind shear to disrupt them, a moist mid-troposphere and a cool upper atmosphere.

# One Temperature Predictor of Atlantic Hurricane Activity

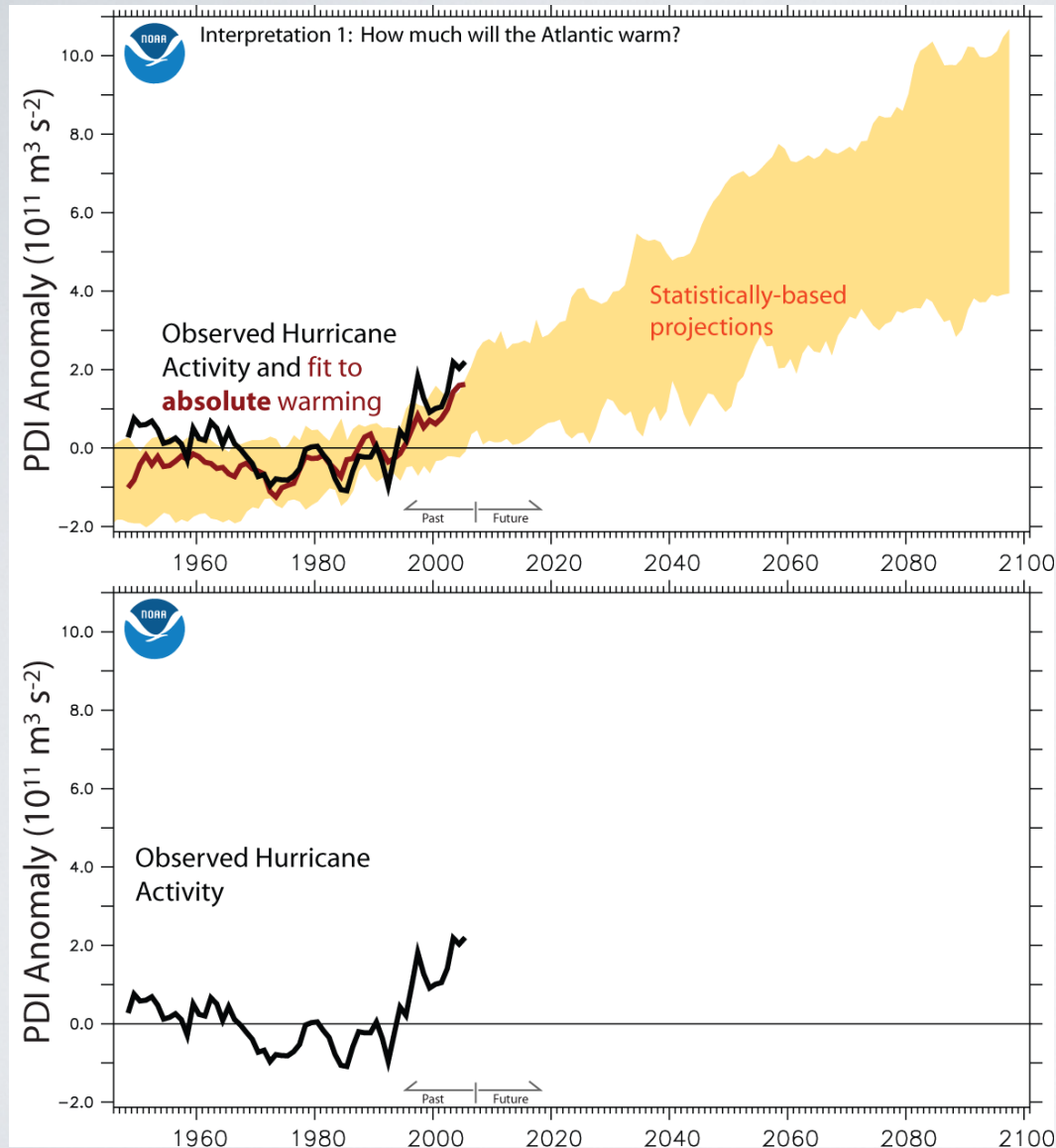
Observed Activity  
Absolute Atlantic  
Temperature



Vecchi, Swanson and Soden  
(2008, Science)

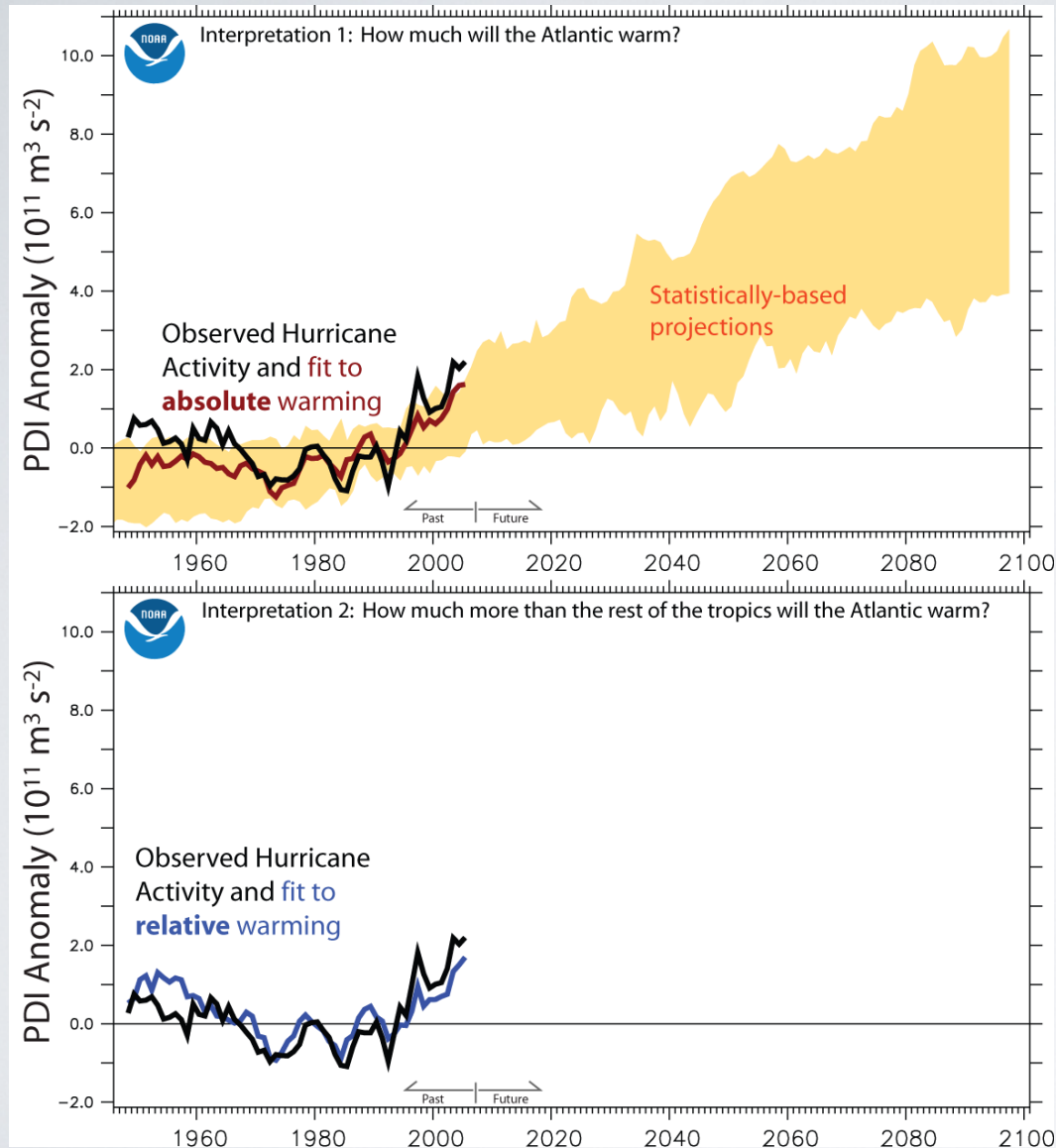
# One Temperature Predictor of Atlantic Hurricane Activity

Observed Activity  
Absolute Atlantic  
Temperature



Vecchi, Swanson and Soden  
(2008, Science)

# Two Temperature Predictors of Atlantic Hurricane Activity

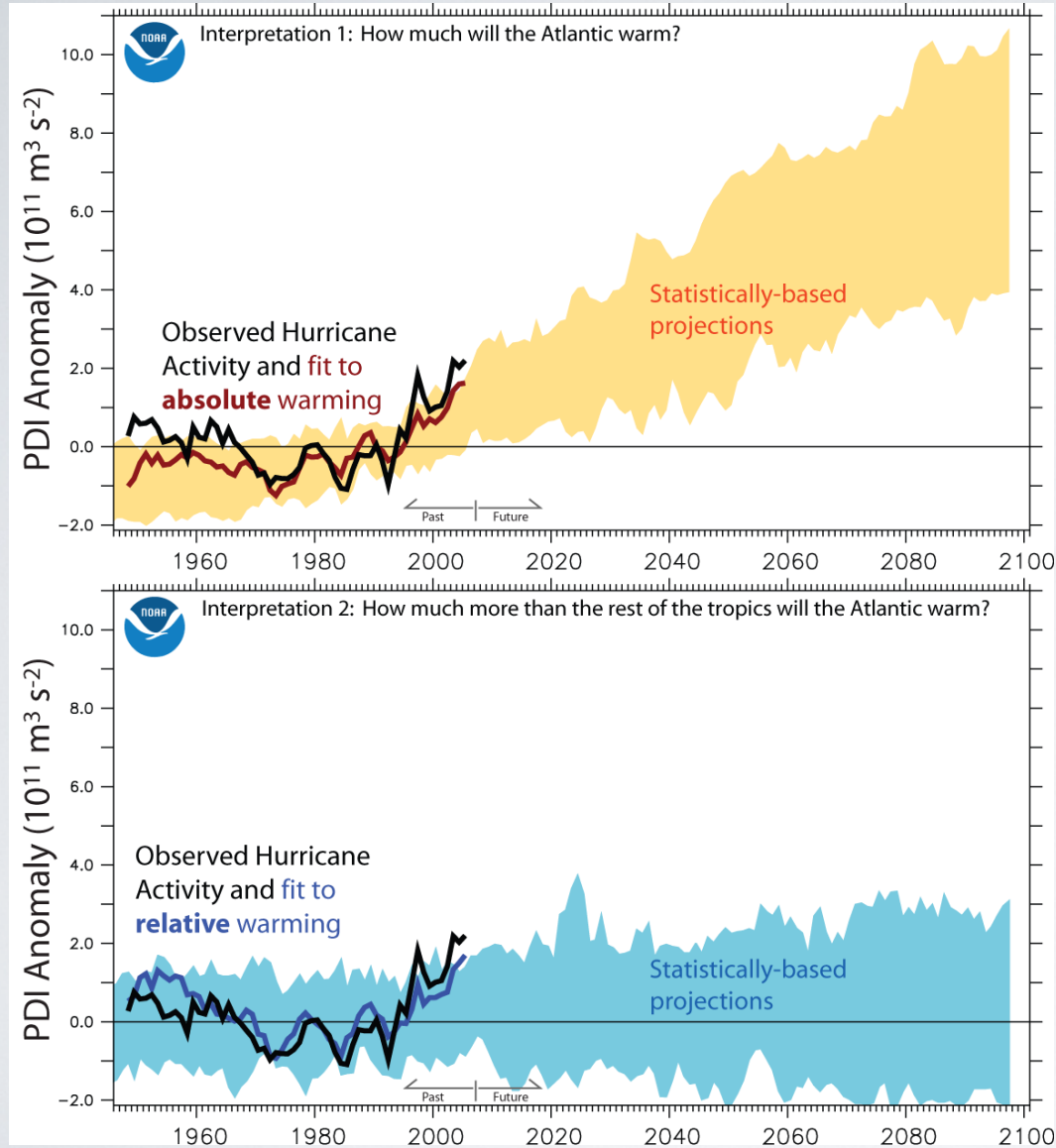


Observed Activity  
Absolute Atlantic  
Temperature

Observed Activity  
Relative Atlantic  
Temperature

Vecchi, Swanson and Soden  
(2008, Science)

# Two Statistical Projections of Atlantic Hurricane Activity

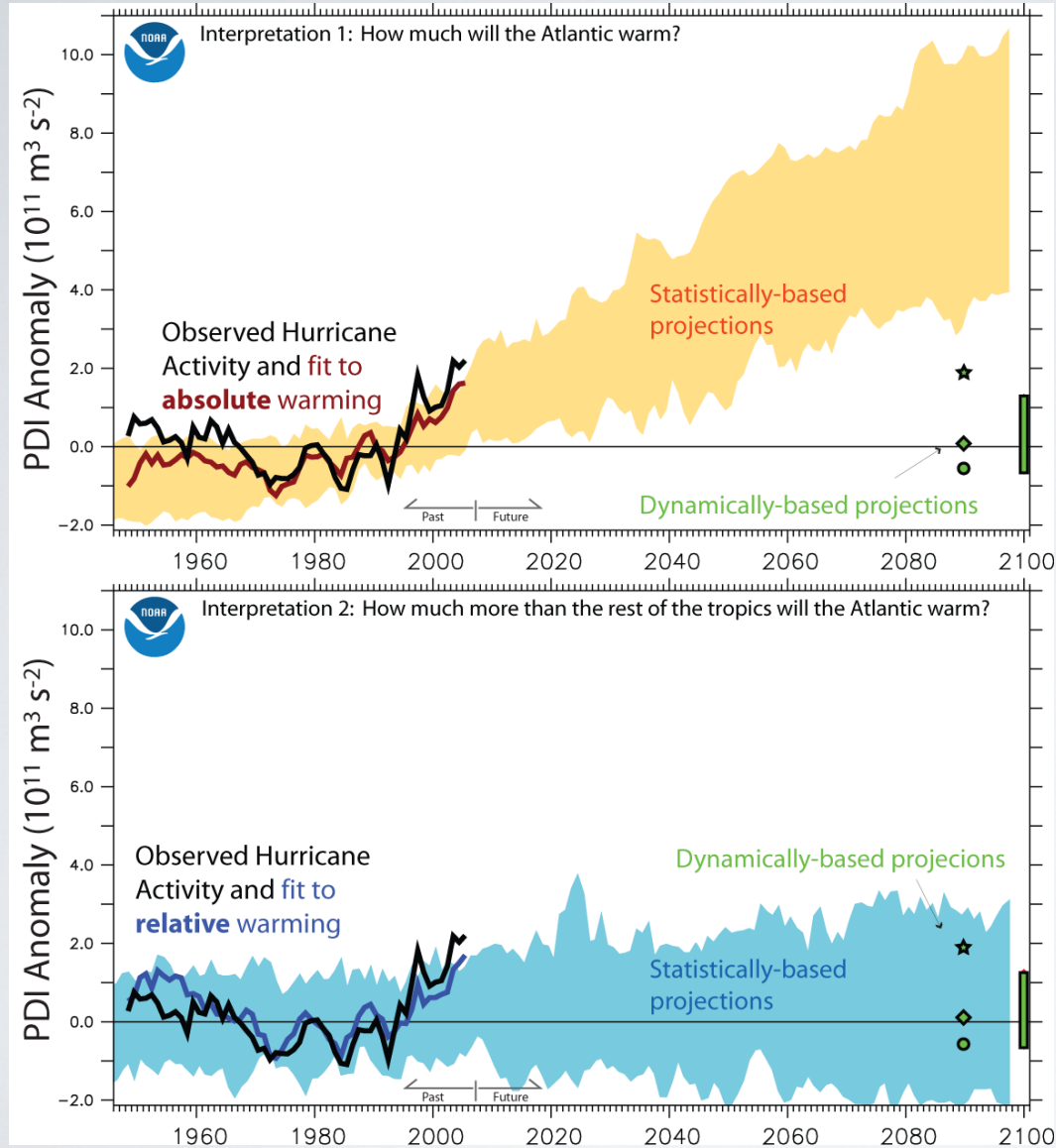


Observed Activity  
Absolute Atlantic  
Temperature

Observed Activity  
Relative Atlantic  
Temperature

*Vecchi, Swanson and Soden  
(2008, Science)*

# ...Add Dynamical Projections of Atlantic Hurricane Activity



Observed Activity  
Absolute Atlantic  
Temperature

Dynamical Model  
Projections

Observed Activity  
Relative Atlantic  
Temperature

Vecchi, Swanson and Soden  
(2008, Science)

# Summary

- Observations, models and physical understanding allow attribution of global and continental temperature changes
- Extreme temperature events (also precipitation) can be expected to change as planet warms: more warm extremes, fewer cold ones
- For other extreme events (e.g., hurricanes) the expected influence of warming more uncertain
- For single events, attribution is problematic:
  - Cannot attributed uniquely to AGW (fraction of risk maybe)
  - Cannot completely exclude AGW
- We don't confidently know odds of rare events even w/o AGW.