

# Future Projection of Extreme Events

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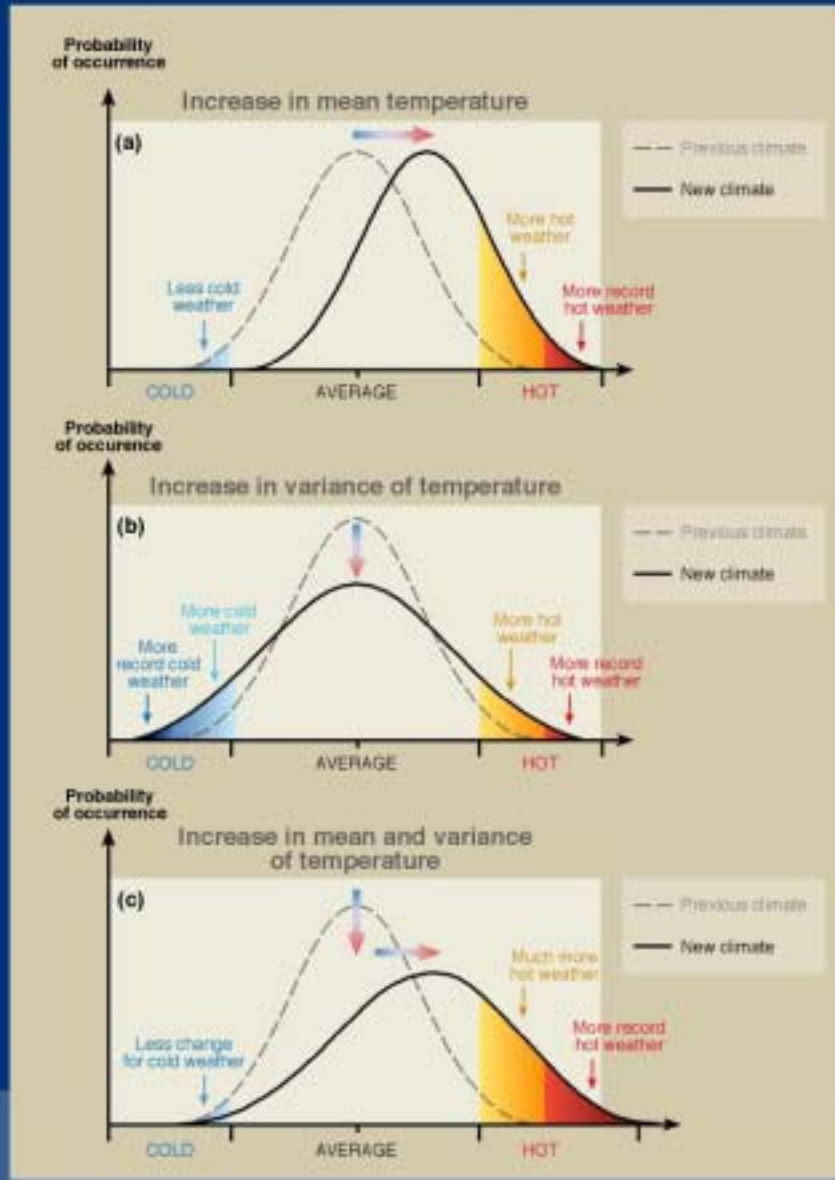


**JAPAN**

# Outline

- Introduction – what are extreme events?
- Projections of extreme events in IPCC AR4
- Relevance to ocean science
- High-resolution climate modeling
- Understanding and communicating extreme events
- Summary

# Effects on extreme temperatures



Change in mean

Change in variance

Change in both

SYR - FIGURE 4-1

# Various extreme events

## *Day-to-day variability*

Hot day, Cold day, Heavy rainfall/snowfall,  
Long consecutive dry days, Strong wind,  
Intense tropical/extratropical cyclone, ...

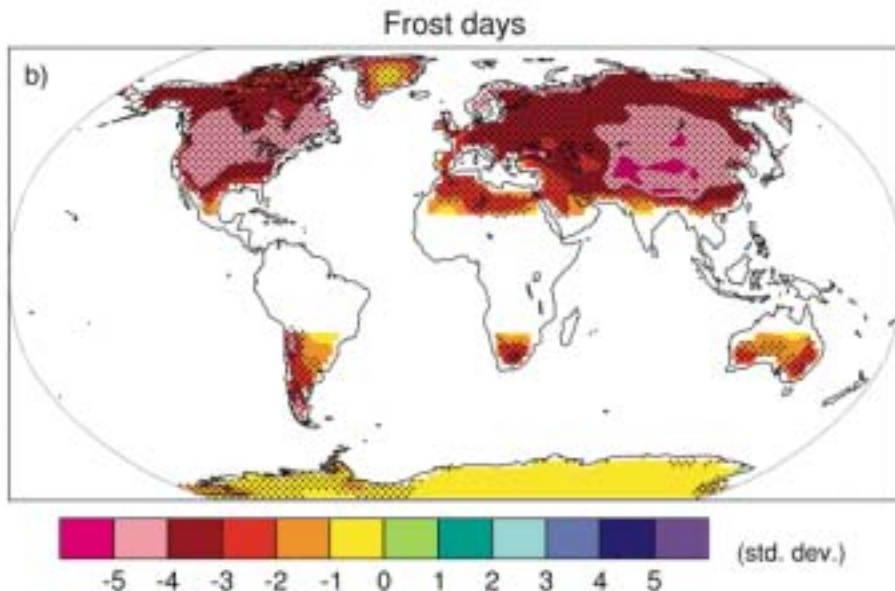
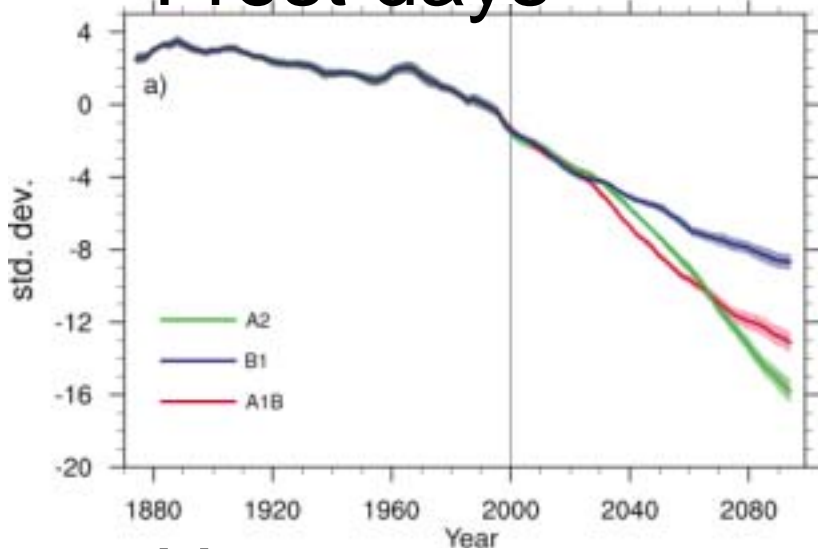
## *Year-to-year variability*

Hot summer, Cold winter, Wet/Dry,  
Strong El Niño, ...

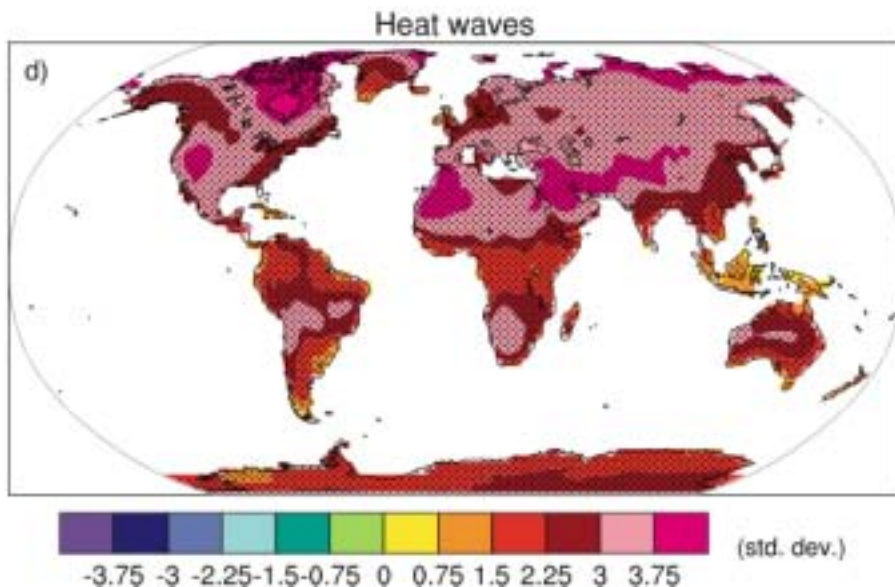
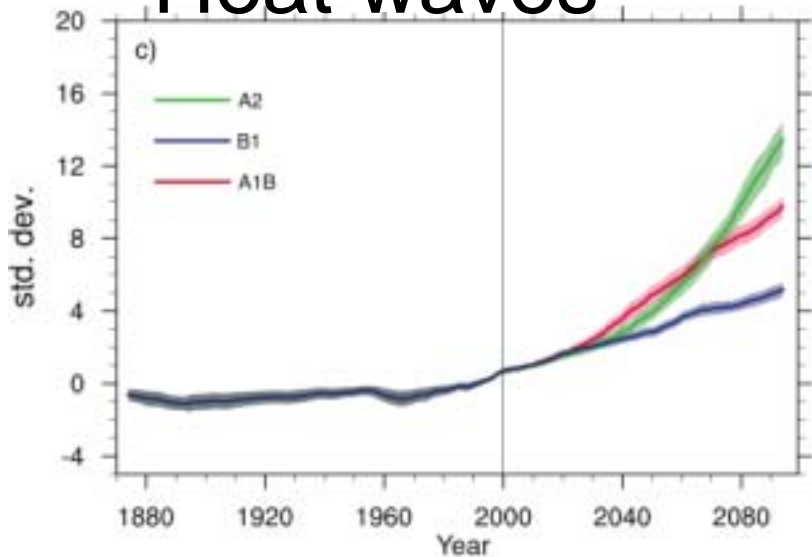
Phenomenon <sup>a</sup> and direction of trend	Detection	Attribution	Projection
<b>Decreasing Cold Days</b>	<i>Very likely<sup>c</sup></i>	<i>Likely<sup>d</sup></i>	<b><i>Virtually Certain</i></b>
<b>Increasing Hot Days</b>	<i>Very likely<sup>e</sup></i>	<i>Likely (nights)<sup>d</sup></i>	<b><i>Virtually Certain</i></b>
<b>Increasing Heat Waves</b>	<i>Likely</i>	<i>More likely than not<sup>f</sup></i>	<b><i>Very Likely</i></b>
<b>Increasing Heavy Rainfall</b>	<i>Likely</i>	<i>More likely than not<sup>f</sup></i>	<b><i>Very Likely</i></b>
<b>More Droughts</b>	<i>Likely in many regions since 1970s</i>	<i>More likely than not</i>	<b><i>Likely</i></b>
<b>Intense TCs</b>	<i>Likely in some regions since 1970</i>	<i>More likely than not<sup>f</sup></i>	<b><i>Likely</i></b>
<b>Increasing High Tides</b>	<i>Likely</i>	<i>More likely than not<sup>f,h</sup></i>	<b><i>Likely</i></b>

*IPCC (2007)*

# Frost days

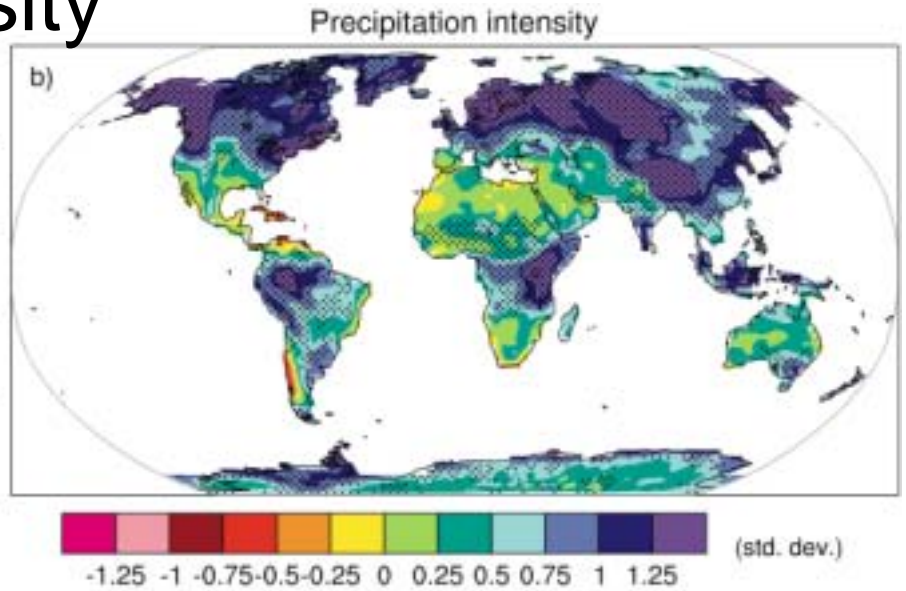
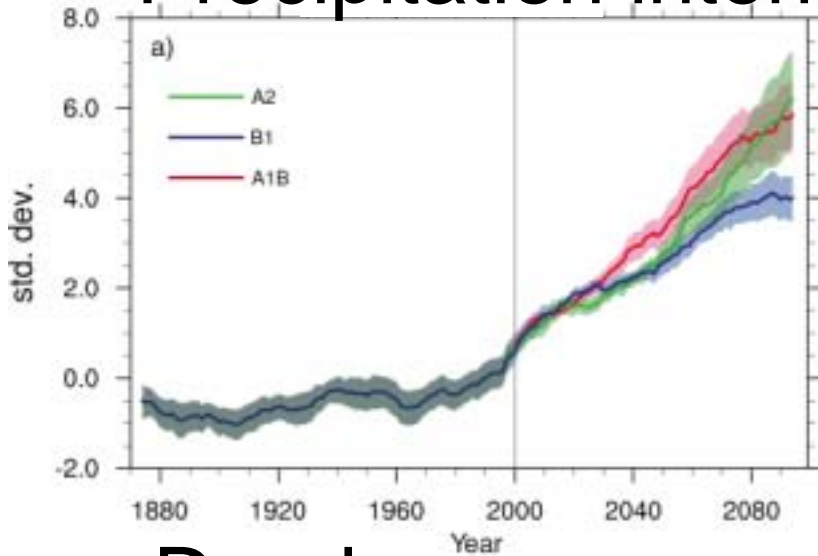


# Heat waves

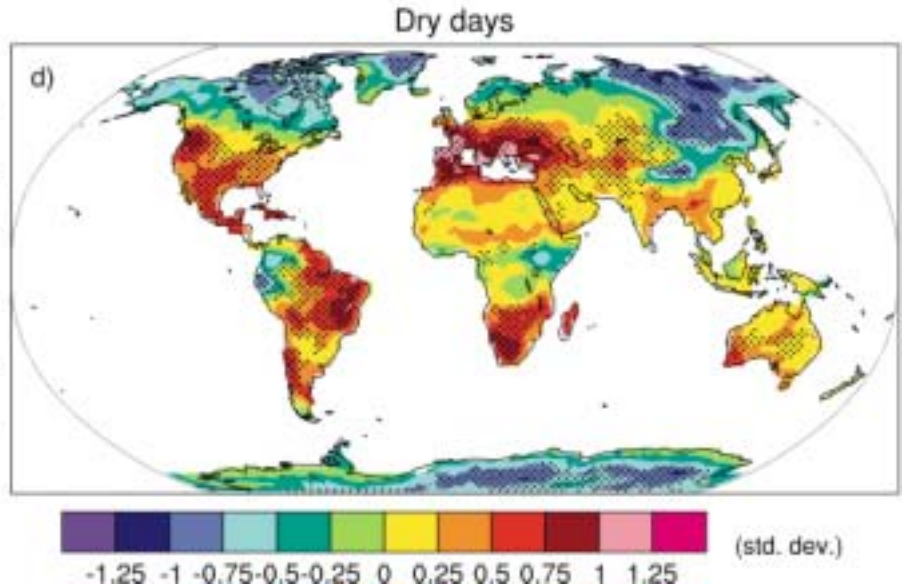
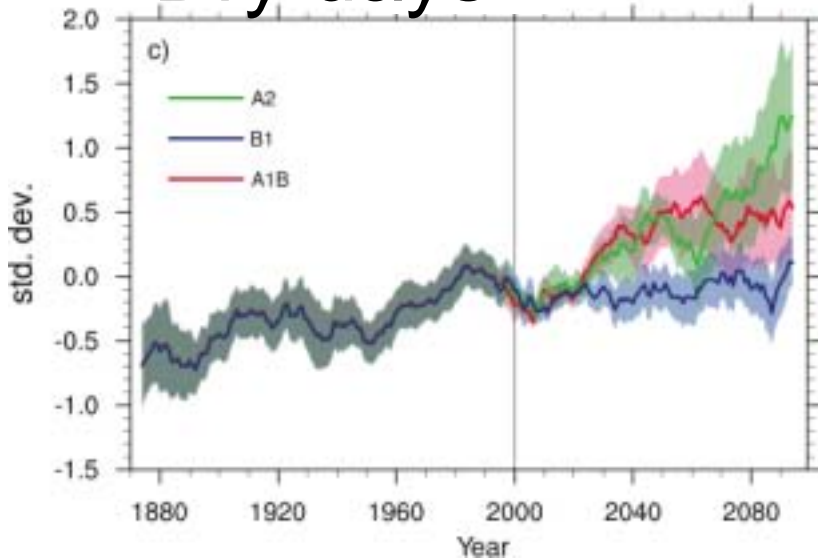


IPCC (2007)

# Precipitation intensity



# Dry days



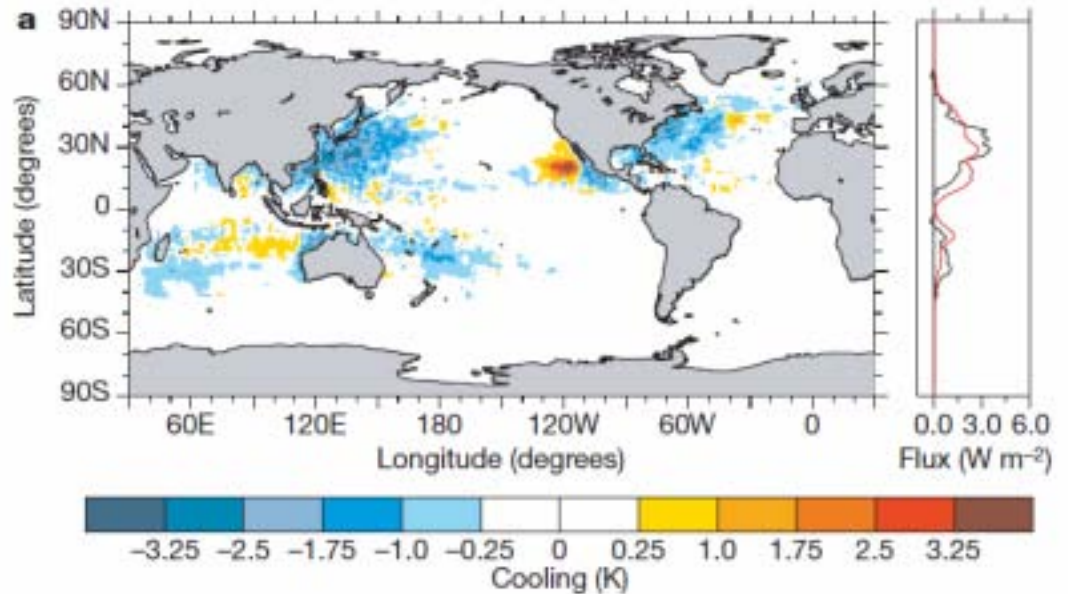
IPCC (2007)

# Relevance to Ocean Science?

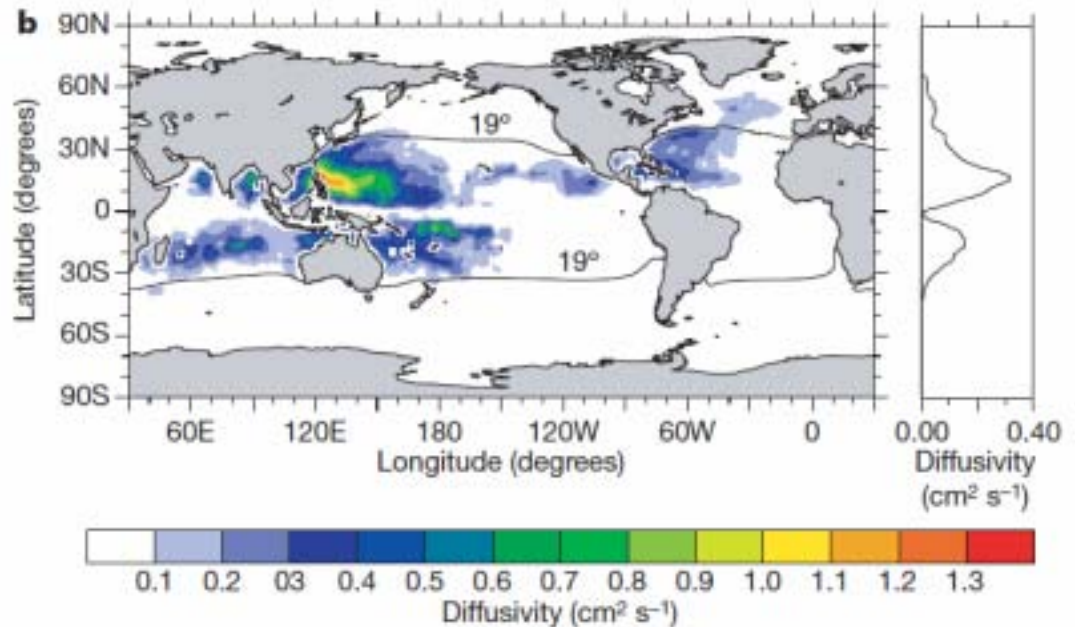
- Projections of extreme events tend to focus on land areas where people live.
- Changes in terrestrial rainfall would be of interest to coastal ocean science.
- Oceans would be the *CAUSE* of some extreme events including intense tropical cyclones induced by high SST.
- Changes in tropical cyclones would affect global-scale ocean circulation.



# Cooling due to Tropical Cyclones

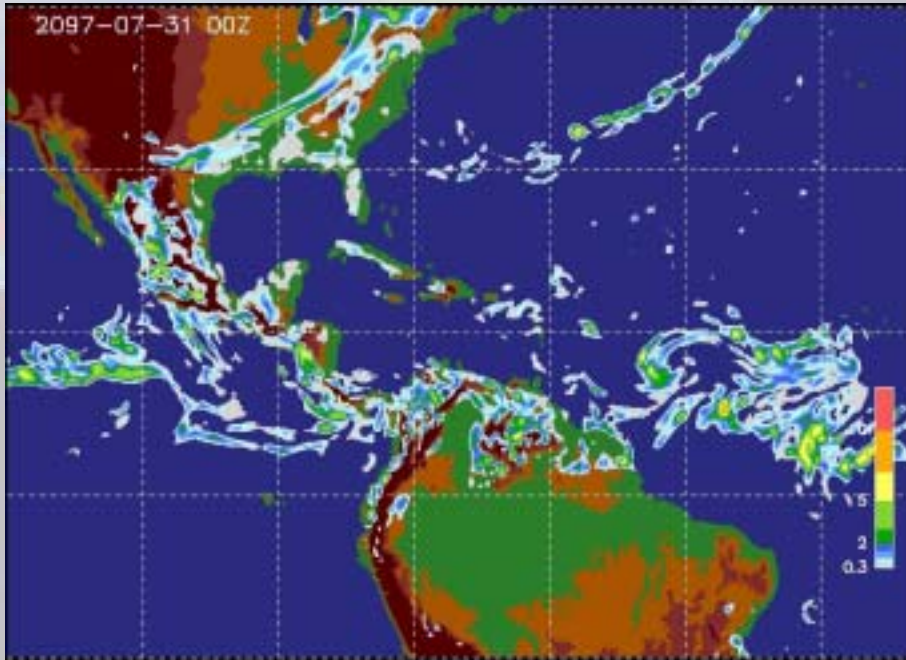


# Diffusivity due to Tropical Cyclones



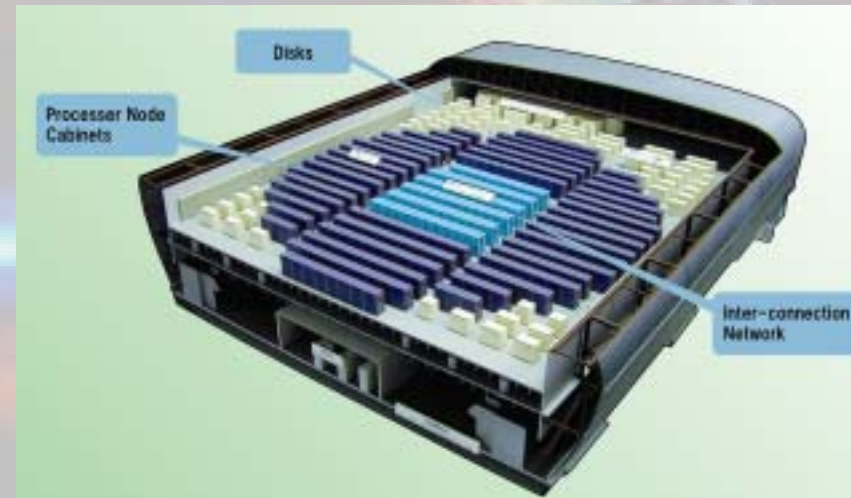
*Sriver and Huber  
(2007)*

# Does a high resolution help?



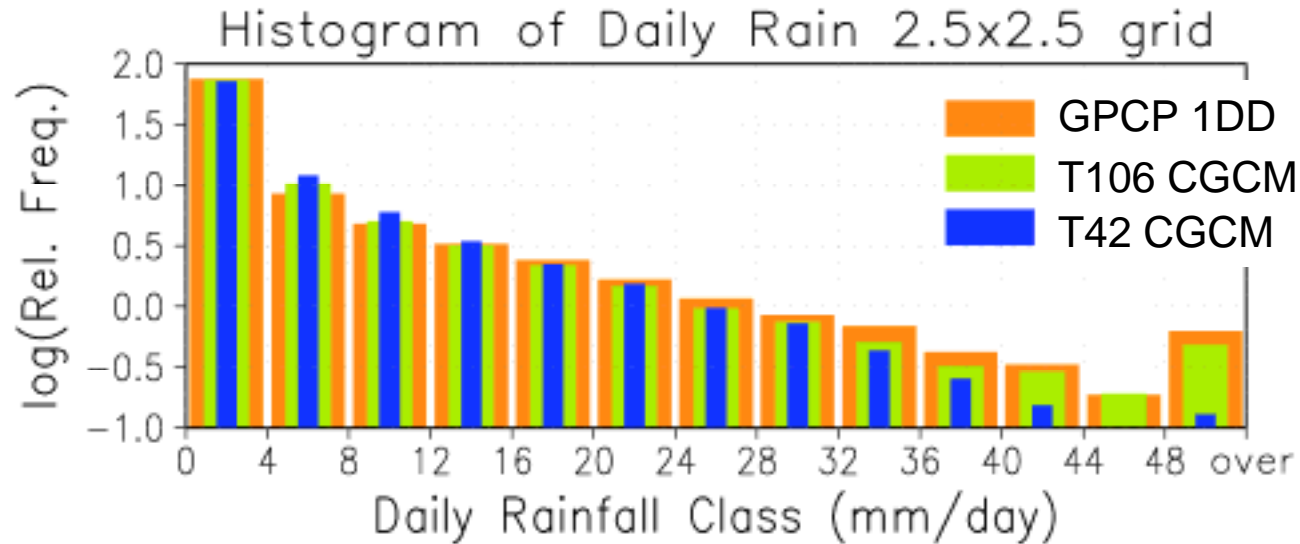
20km global atmospheric model  
(MRI/JMA/AESTO)

## The Earth Simulator

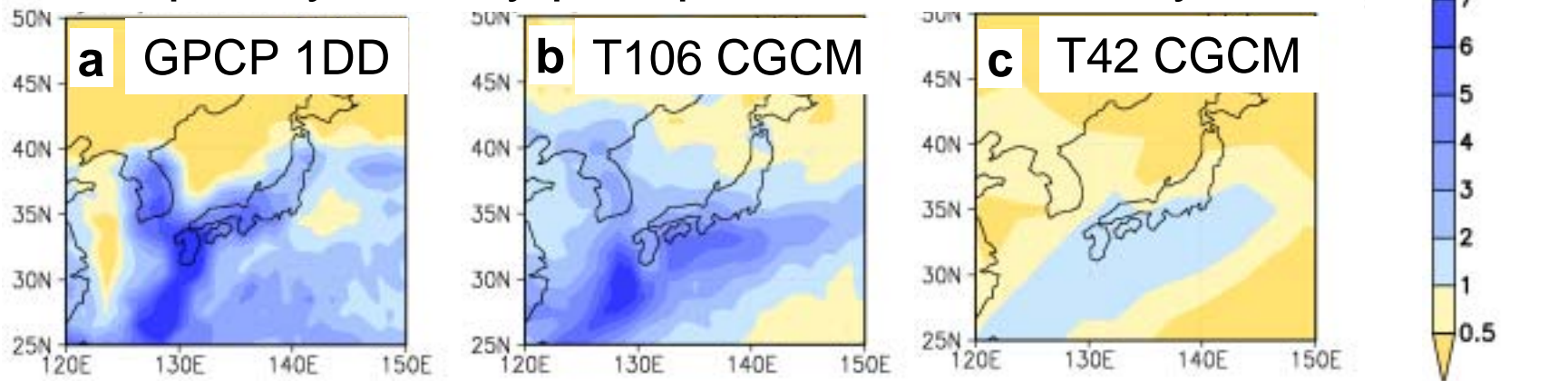


Extreme events in terms of day-to-day variability are often associated with small-scale phenomena.

# High-resolution is *NECESSARY* for extremes



## Frequency of daily precipitation > 50mm/day



*Kimoto et al. (2005)*

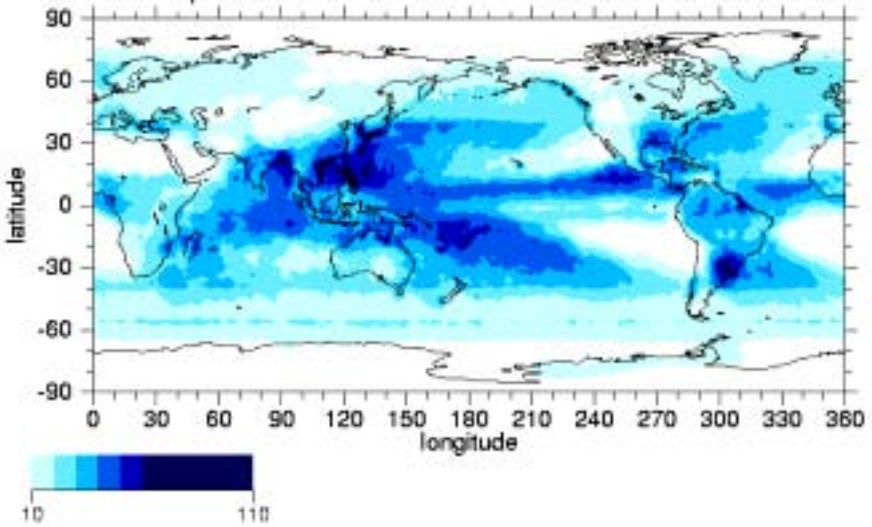
# High-resolution is *NOT SUFFICIENT* for extremes

*“Physics” matters!*

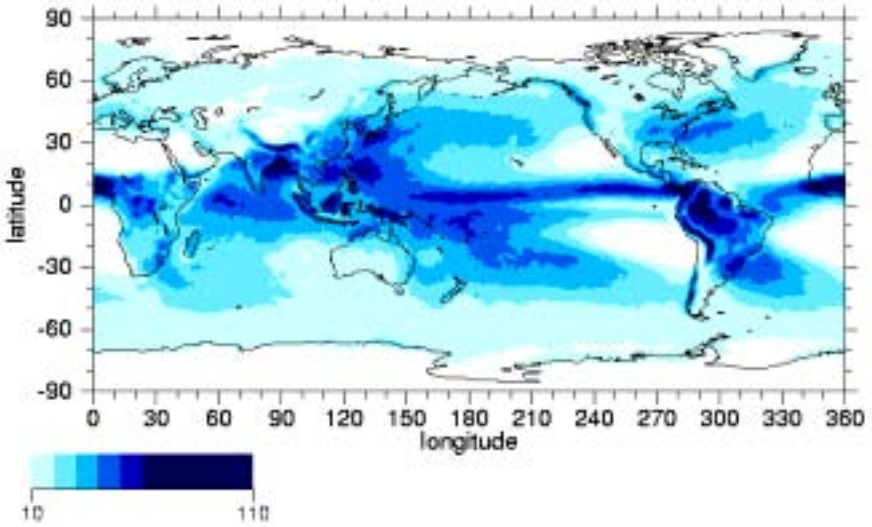
99<sup>th</sup> %ile daily precipitation intensity

*Emori et al. (2005)*

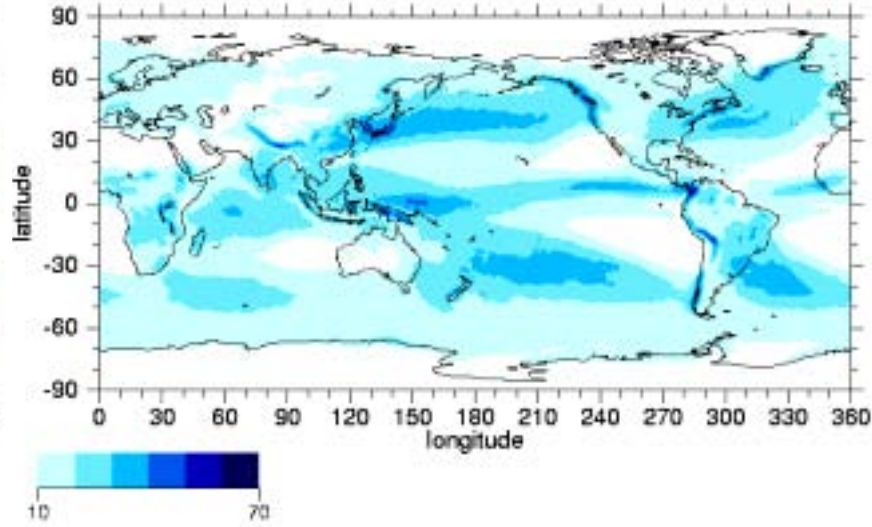
GPCP 1DD



T106 CGCM (RHC=0.8)



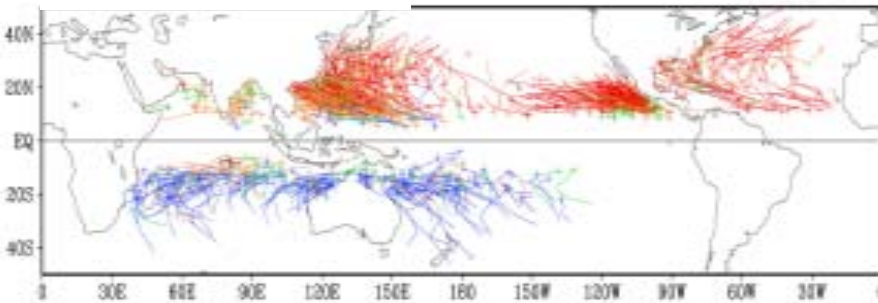
T106 CGCM (RHC=0.0)



# Frequency of tropical cyclones

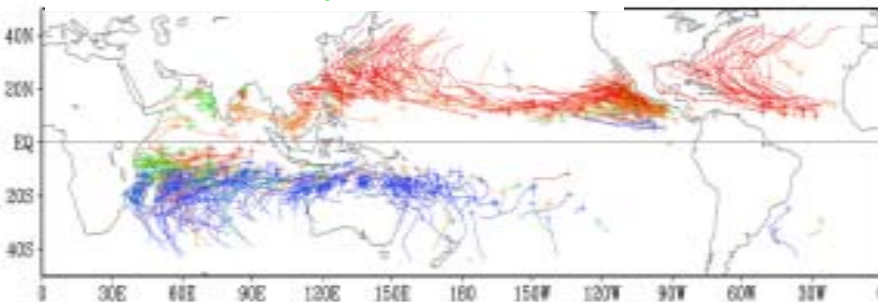
Observation

10 years



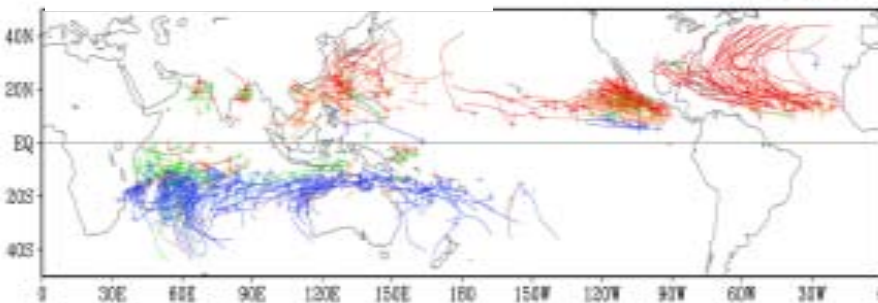
Present day simulation

10 years



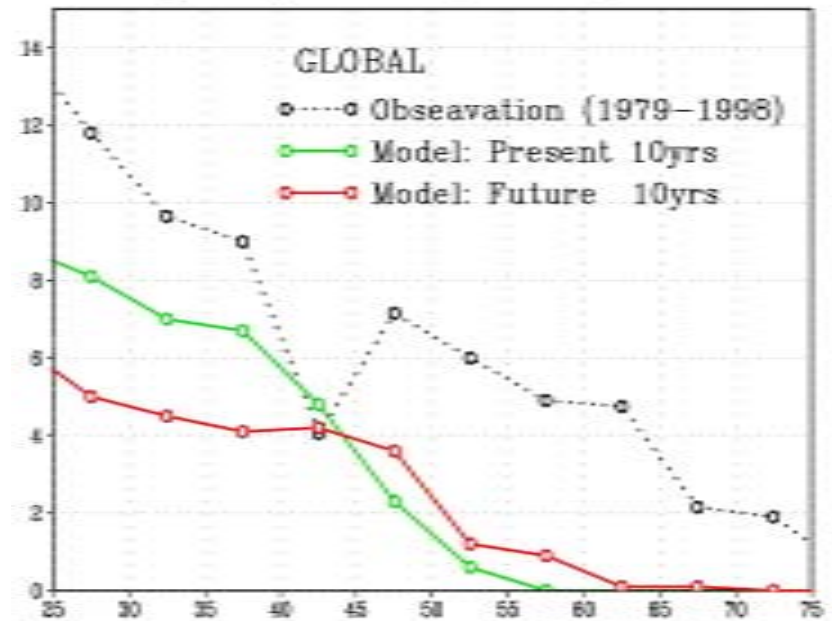
Future simulation

10 years



Less frequent in total,  
but more frequent  
for strong ones

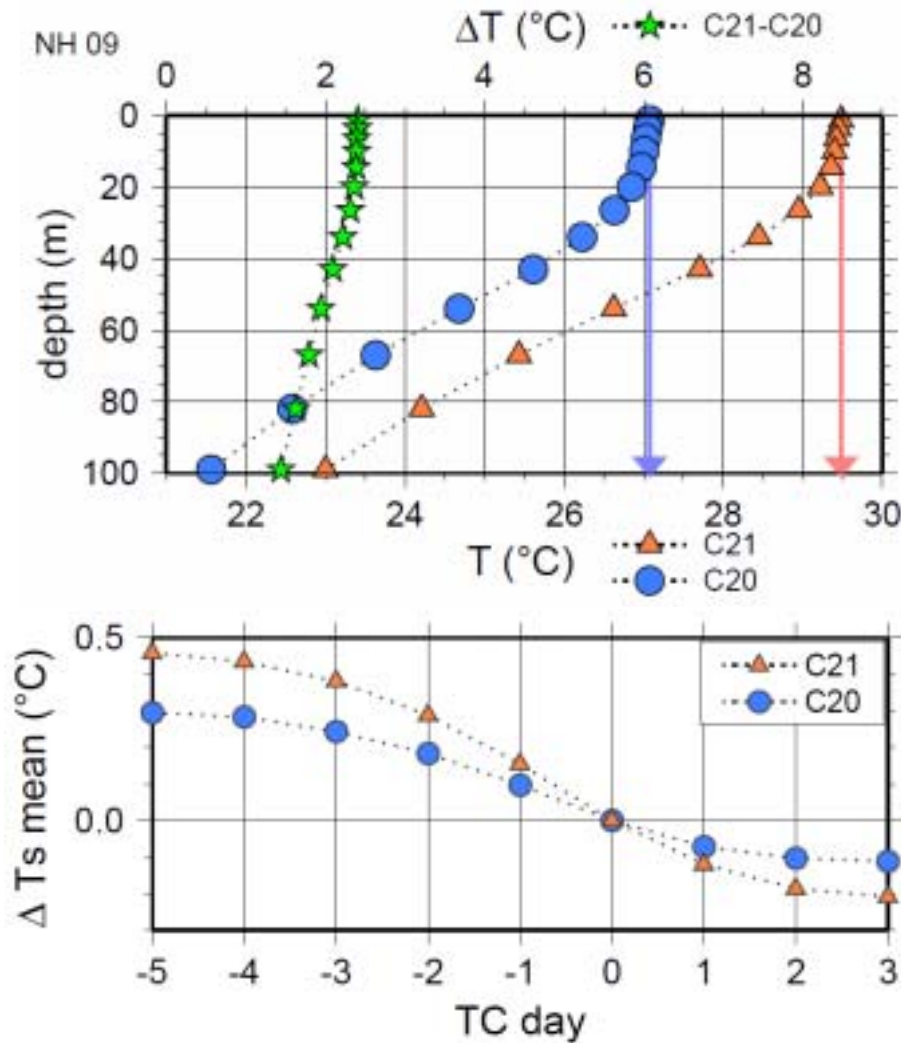
Frequency of tropical cyclones



Max surface wind speed (m/s)

*Oouchi et al. (2005)*

# Air-sea coupling suppresses the projected increase in strong TCs



Stronger stratification  
in a warmer climate

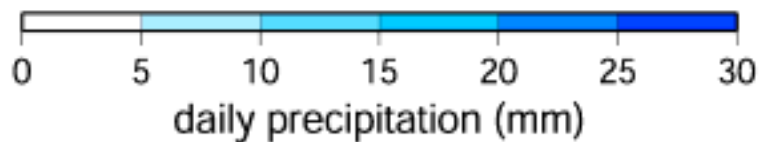
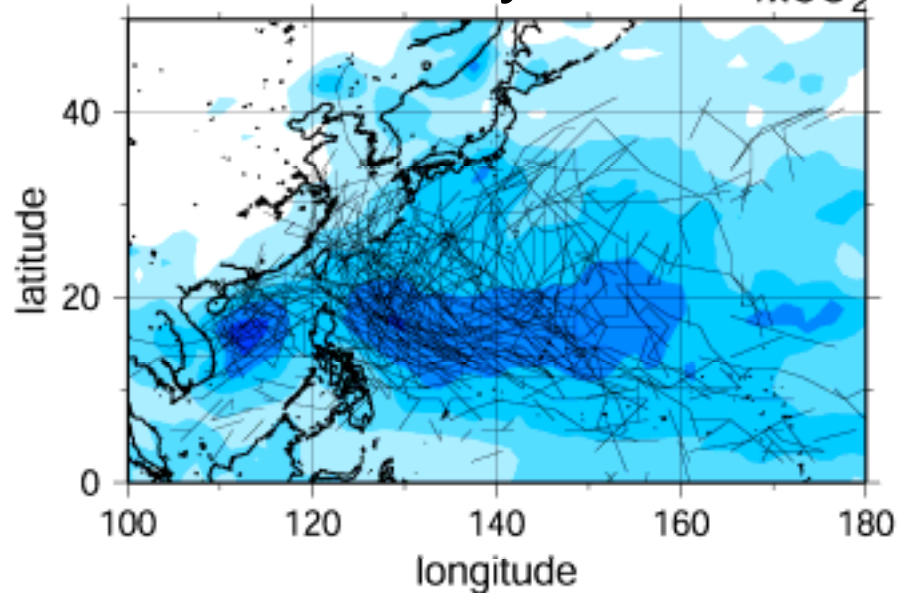
Larger SST cooling  
due to TC passage  
in a warmer climate

*Hasegawa and Emori (2007)*

# Rainfall associated with TCs will be increased due to increased atmospheric water vapor

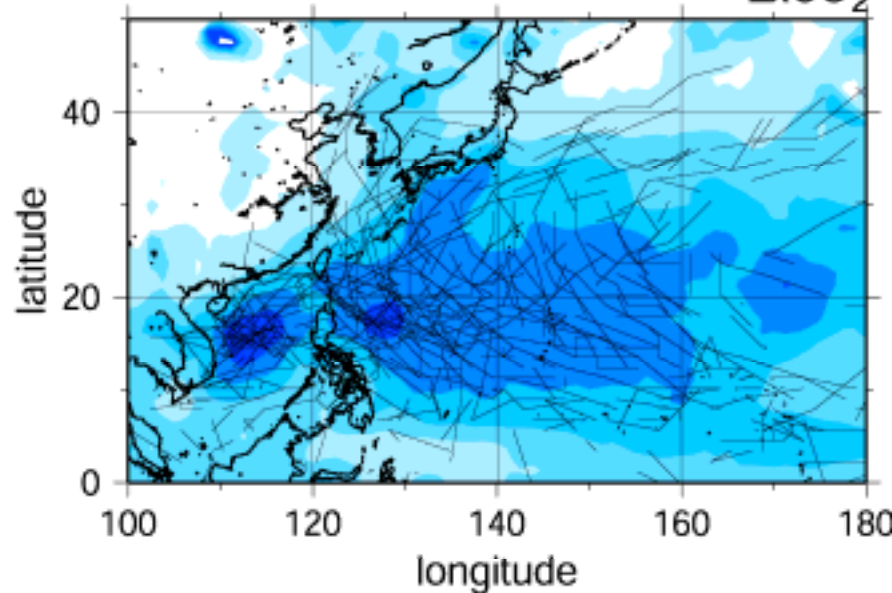
Present day

1xCO<sub>2</sub>



Future

2xCO<sub>2</sub>

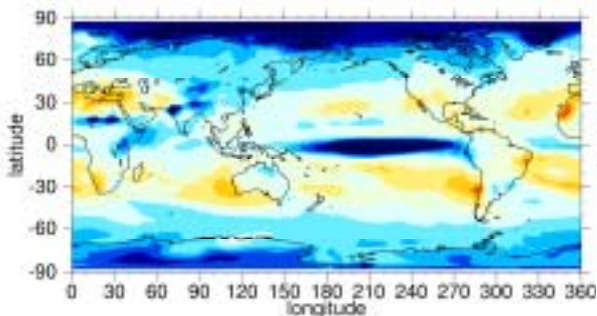


*Hasegawa and Emori (2005)*

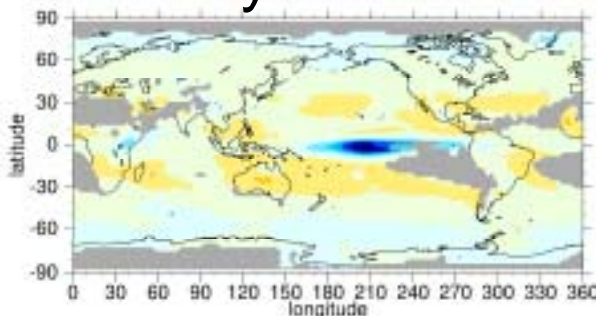
# Separation of dynamic/thermodynamic changes

## Mean Precipitation Change

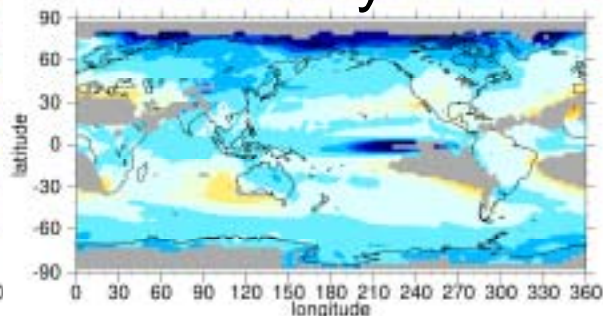
Total



Dynamic

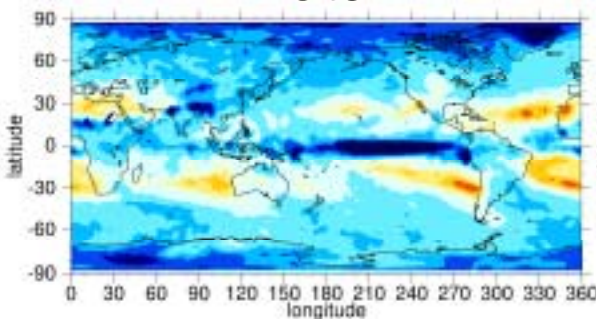


Thermodynamic

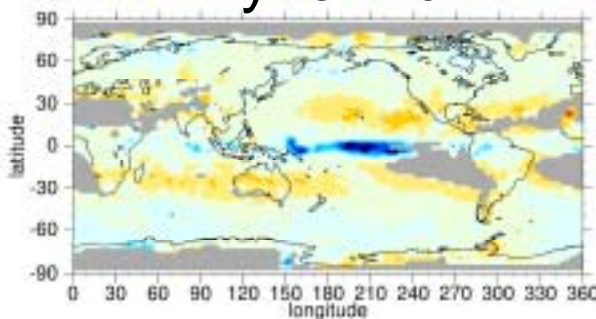


## Extreme Precipitation Change

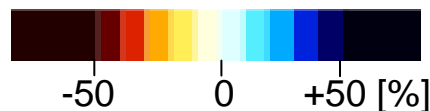
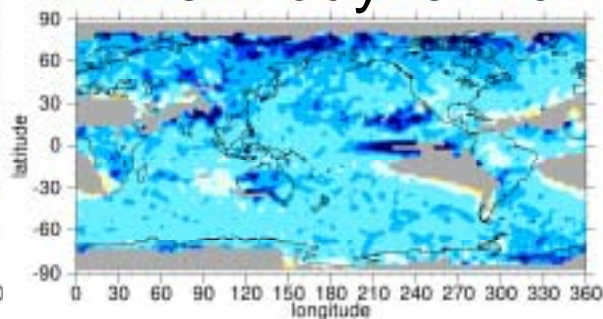
Total



Dynamic



Thermodynamic



*Emori and Brown (2005)*



Extreme events would cause extreme impacts,  
but ...

For communicating 'unbiased' climate  
change impact information, ...

- Quantitative uncertainty
- Non-climatic drivers
- Goods as well as bads
- Direct and indirect impacts
- Effect of adaptation
- Feedback/higher-order effects
- Possibility and impact of 'surprises'
- Dependence on value system



# Summary

- Increasing hot days, decreasing cold days and increasing heavy rainfalls are robustly projected in AR4.
- Heavy rainfalls and intense tropical cyclones would be of some relevance to ocean science.
- A high resolution is necessary but not sufficient for simulating extreme events.
- More work for understanding the mechanisms of extreme events is needed.
- For communicating impacts, a balanced perspective is needed.