Global scale change: temperature and sea level

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If you had to pick only two numbers to represent the most important features of climate change...

What would they be?
If you had to pick only two numbers to represent the most important features of climate change…

1. How much will climate warm in response to a doubling atmospheric CO2 concentrations. (Also called equilibrium climate sensitivity.)

2. How much will sea level rise by 2100?
Estimates of equilibrium climate sensitivity are discrepant.

Estimates from historical instrumental observations: 1 to 3 °C

Estimates from paleoclimate studies and model simulations: 2 to 5 °C

“No best estimate for equilibrium climate sensitivity can now be given because of a lack of agreement on values across assessed lines of evidence and studies.”

-Footnote 16, IPCC AR5 Summary for Policymakers.
Climate 101: A framework for estimating equilibrium climate sensitivity

\[ \Delta F = \Delta H + \Delta R \]

\[ \Delta F = \Delta H + \lambda \Delta T \]
Imagine atmospheric CO$_2$ doubles instantly: heat uptake increases, but no warming yet.

\[ \Delta F = \Delta H + \Delta R \]

\[ \Delta F = \Delta H + \lambda \Delta T \]

\[ \Delta H(t = 0) \]
After some years, warming leads to less heat uptake and more radiation sent out to space.

\[
\Delta F = \Delta H + \Delta R
\]

\[
\Delta F = \Delta H + \lambda \Delta T
\]
Historically-based estimates linearly extrapolate the heat-radiation relationship to equilibrium.

\[
\Delta F = \Delta H + \Delta R
\]

\[
\Delta F = \Delta H + \lambda \Delta T
\]
But model simulations show a heat-radiation relationship that is curved.
Curvature arises from slow adjustment of oceanic regions with strong upwelling

Fraction of warming realized between modern and equilibrium temperature
Applying linear versus curved heat-radiation relationships accounts for discrepant estimates

Emulation of historical instrumental estimates

Best estimate of model equilibrium climate sensitivity

Global warming (°C)

Frequency

1 to 3 °C

2 to 5 °C
Applying linear versus curved heat-radiation relationships accounts for discrepant estimates.

Emulation of historical instrumental estimates

Best estimate of model equilibrium climate sensitivity
Global sea level rise

1. **Equilibrium climate sensitivity**: How much will climate warm in response to a doubling atmospheric CO2 concentrations?

2. **Global mean sea level**: How much will sea level rise by 2100?

“The public is largely unaware of the intense debates within climate science. At a recent national laboratory meeting, I observed more than 100 active government and university researchers challenge one another as they strove to separate human impacts from the climate's natural variability. **At issue were not nuances but fundamental aspects of our understanding, such as the apparent--and unexpected--slowing of global sea-level rise over the past two decades.**”

-Steven Koonin, *Wall Street Journal*, April 21st 2017
Is global sea level decelerating?

(after Fasullo et al., 2016)
Is global sea level accelerating?
Is global sea level accelerating?

(reconstruction from Hay et al., 2015)
Conclusions

1. Estimates of equilibrium climate sensitivity based on historical instrumental records are consistent with those derived from paleoclimate records and simulations, once they are properly compared.

2. Rates of sea level rise have accelerated over the last century, suggesting more rapid rise going forward.

3. The climate system is complex, but much of the confusion about its fundamental behavior can be resolved through careful examination of the data.