Emissions (GtC/yr) $\rightarrow$ Concentrations (ppmv) $\rightarrow$ Climate ($^\circ$C) $\rightarrow$ Impacts

- Sea-level rise
- Heat waves
- Drought
- Extremes
- etc.
Emissions (GtC/yr) \rightarrow Concentrations (ppmv) \rightarrow Climate (°C) \rightarrow Impacts

- Sea-level rise
- Heat waves
- Drought
- Extremes
- etc.

\[
\text{Climate Sensitivity (°C/ppmv)}
\]
- Cloud feedbacks
- Non-linear
- Depends on timescale!
Emissions (GtC/yr) → Concentrations (ppmv) → Climate (°C) → Impacts

- Sea-level rise
- Heat waves
- Drought
- Extremes
- etc.

- Carbon Cycle
  - Ocean uptake
  - Land uptake
  - Feedbacks etc.

- Climate Sensitivity (°C/ppmv)
  - Cloud feedbacks
  - Non-linear
  - Depends on timescale!
Carbon Cycle
• Ocean uptake
• Land uptake
• Feedbacks etc.

Climate Sensitivity
(°C/ppmv)
• Cloud feedbacks
• Non-linear
• Depends on timescale!

Carbon-Climate Response
(°C/GtC)
• Function of cumulative emissions
• Basis for carbon budget, Paris, etc.

Emissions (GtC/yr) → Concentrations (ppmv) → Climate (°C) → Impacts
• Sea-level rise
• Heat waves
• Drought
• Extremes
• etc.
Atmospheric CO$_2$ concentration

Ocean heat content/thermal expansion

Temperature response

Solomon 2009, PNAS
Solomon 2009, PNAS

\[ \text{Atmospheric CO}_2 \text{ concentration} \quad + \quad \text{Ocean heat content/thermal expansion} \quad = \quad \text{Constant temp. response!} \]
Ocean carbon uptake + Ocean heat uptake = Constant temp. response!

Ceasing emissions today will fix surface temperatures at today’s values, for hundreds of years.
Atmospheric CO₂ concentration

Ocean heat content/thermal expansion

Temperature response

Ocean carbon uptake + Ocean heat uptake = Constant temp. response!

Ceasing emissions today will fix surface temperatures at today’s values, for hundreds of years.

(sea level and deep ocean temps, however, will continue to rise)
Value of CCR?

Williams 2017, *Journal of Climate*
CCR for model ensemble under emissions consistent with 1%/yr CO$_2$ increase
Carbon Cycle
- Ocean uptake
- Land uptake
- Feedbacks etc.

Climate Sensitivity
- Cloud feedbacks
- Non-linear
- Depends on timescale
- Ignores carbon cycle

Emissions (GtC/yr) → Concentrations (ppmv) → Climate (°C) → Impacts
- Sea-level rise
- Heat waves
- Drought
- Extremes
- etc.

Carbon-Climate Response (°C/GtC)
- Function of cumulative emissions
- Basis for carbon budget, Paris, etc.
- Timescale-independent
- Accounts for carbon cycle