Moving from Global to Regional Projections of Climate Change

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Long Term Climate Change: Projections, Commitments and Irreversibility

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Global Mean Surface Air Temperature Change

(a) Global average surface temperature change

Anomalies w.r.t 1986-2005 average
Global Temperature Assessment

• The transient climate response is *likely* in the range of 1.0°C to 2.5°C (*high confidence*) and *extremely unlikely* greater than 3°C
• The CMIP5 models coincide with this range
• The RCPs are dominated by greenhouse gas forcing by the end of the century
• Associate the 5-95% range of model simulations (+/- 1.64 standard deviations) with the *likely* range (66-100%)
• Only valid for *likely* (66-100%)
• Only valid for global mean temperature in long-term
Global Mean Surface Air Temperature Change

Assessing uncertainty and robustness in projections is much more than just counting CMIP models.
Changes Conditional on Global Mean Temperature Rise

• High northern latitudes expected to warm most
• Land warms more than ocean surface
• More hot and fewer cold extremes
• Global mean precipitation increases but regional patterns of change not uniform
• Contrast between wet and dry regions and seasons to increase (with regional exceptions)
• Tropical atmospheric circulations expected to weaken, subtropics creep polewards
• Arctic summer sea-ice to melt back – ice free conditions *likely* by mid century under RCP8.5
• Permafrost and snow cover to retreat
• Atlantic Meridional Overturning Circulation (AMOC) to weaken but not collapse
• N. Hemisphere storm track changes – *low confidence*
Cryosphere

Requires the use of physical understanding in quantifying changes
How large is the projected change compared with internal variability?

**Stippling:** changes are “large” compared with internal variability (greater than two standard deviations of internal variability), and at least 90% of models agree on sign of change.

**Hatching:** changes are “small” compared with internal variability (less than one standard deviation of internal variability).
Surface Air Temperature Change: CMIP5 Std. Dev

SAT Change 2081–2100 minus 1986–2005

Global Mean Removed

Land–Sea Contrast Removed

Polar Amplification Removed

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For Regional Surface Air Temperature Changes:

- Mean pattern of change and its uncertainty is largely driven by ‘thermodynamic’ processes; global mean, land-sea contrast, polar amplification
- We could build a quantitative theory of thermodynamic changes

\[ \Delta T(x,y,t) = \Delta T_g(t)[P(x,y)L(o,l)] + R(x,y,t) \]

- ‘Dynamical’ SAT changes seem much smaller – although of crucial importance in the tropics (e.g. Xie et al., 2010)
Changes Tropical Precip + Atmospheric Circulation

\[ \omega = \frac{P}{q} \]

\[ P = \omega q \]

\[ P \neq \omega q \]
Tropical Precipitation Changes: Chadwick et al., 2013

(a) \( \Delta P \)

- Moisture availability \( \Delta P_T \)

- RH changes \( \Delta P_{RH} \)

- Circulation changes \( \Delta P_{spat} \)

- Circulation weakening \( \Delta P_{div} \)

- \( \Delta P_T + \Delta P_{div} \)

- Difference

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For Regional Precipitation Changes:

• Global mean changes are sub-Clausius-Clapeyron, constrained by tropospheric energy balance and lead to a weaker tropical circulation

• Regionally the reduced circulation is largely balanced by moisture availability leaving other factors as important drivers of regional change; SST changes, land-sea contrast, land-surface feedbacks, …

• Dynamics clearly important here – long time-scale coupling?

• In mid-latitudes, precipitation increase is largely due to increased moisture availability with relatively unchanged storminess. Confidence in storminess projections is low
• El Niño-Southern Oscillation very likely remains as the dominant mode of interannual variability in the future and due to increased moisture availability, the associated precipitation variability on regional scales likely intensifies….. natural modulations of the variance and spatial pattern of El Niño-Southern Oscillation are so large in models that confidence in any specific projected change in its variability in the 21st century remains low.
Extreme El Niños

Changing El Niño Teleconnections

Chung, Power, Arblaster, Rashid, Roff, Climate Dynamics, 2014

Atmosphere model simulations

Power, Delange, Chung, Kociuba, Keay, Nature 2013

CMIP5
Global Warming ‘Pause’ or ‘Hiatus’

Chapter 9, Box 9.2
Warming hiatus periods in CMIP5 control experiments

Hiatus periods in piControl experiments identified by generation of *pseudo ensembles*

Realization of internal variability from piControl + Estimate of forced response from scenario ensemble mean = Pseudo ensemble member

*Pseudo ensemble* hiatus selection criteria:
Period since 2001 with trend in global surface temperature ≤ 0.00 °C/yr

Equivalent piControl hiatus selection criteria:
10 year period with trend in global surface temperature ≤ -0.16 °C/yr

*Methods 1/2*
CMIP5 historical + RCP4.5 pseudo ensembles

Global mean surface temperature in historical rcp45

- Scenario ensemble mean
- 2001-2010 negative trend (11.5 %)
- All ensemble members
- 2001-2015 negative trend (0.8 %)

Results 2/12
Spatial trends in surface temperature during hiatus decades

Model hiatus decades shifted by +0.16 °C/yr for comparison with observations
Trade Winds Strengthening

See also Kosaka and Xie, 2013
Summary

• Large-scale ‘thermodynamic’ response of temperature relatively well understood in terms of global + land/sea + polar amplification. Could build a quantitative theory
• Global precipitation change understood in terms of energy balance and offset between weakening circulation and increase humidity
• Regional precipitation in the tropics more determined by circulation changes and coupled(?) to ‘dynamical’ SST changes in tropics (RH contribution over tropical land)
• Robust mid-latitude thermodynamic precipitation response but low confidence in dynamical features
• Challenge is to combine information from imperfect models with our (sometimes quite good) understanding of physical processes