CLIMATE CHANGE IMPACTS ON OCEANS AND RELATED ECOSYSTEMS

Expert Group Meeting on Oceans, Seas and Sustainable Development:
Implementation and follow-up to Rio+20
18-19 April 2013

Climate Analytics

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Joeri Rogelj (ETH), Olivia Serdeczny (PIK)
Observed warming:
Land and Ocean annual temperature (°C)
(anomalies relative to 1851-1880)

Long-term warming trend modified by internal (e.g. red – El Niño and blue – La Niña) and external (e.g. volcanic eruptions) variability

Jones et al. (2012); Morice et al. (2012) for temperature record, ENSO years from NOAA
Arctic Sea Ice Extent
(area of ocean with at least 15% ice)

Late-summer minimum of 2012

http://nsidc.org/arcticseaicenews/
Observed sea level change at top of range projected in IPCC assessment reports

(Rahmstorf et al., 2012)
Accelerating loss from ice-sheets

- A recent review revealed accelerating mass loss from both polar ice sheets Greenland and Antarctica.
- Contributes 20% to total sea-level rise since 1992.

Shepherd et al. 2012
Global Carbon Project: Emissions on the rise

- Global total CO₂ emissions:
  - 3% up from 2010 to 2011
  - 2.6% up from 2011 to 2012
  - 58% above 1990 in 2012

Peters et al., Nature Climate Change, 2012
Warming projections: Heading towards 4°C?

Current pledged actions September 2010:
- virtually certain to exceed 2°C; 50% chance above 3°C

Lowest standardized emission scenario ran by climate models for IPCC AR5:
- likely below 2°C (15% chance above 2°C; 60% above 1.5°C)

Global sudden stop to emissions in 2016:
- likely below 1.5°C

Low-emission scenario with negative CO₂ emissions from upper half of literature range in 2nd half of 21st Century

Geophysical inertia

Business as usual:
- likely to exceed 3°C

Effect of current proposals

Reduction from current proposals to lowest standardized AR5 scenario

Schellnhuber et al., 2012
Delays and time scales in the climate system’s response to greenhouse-gas emissions

CO₂ concentration, temperature, and sea level continue to rise long after emissions are reduced

Magnitude of response

- CO₂ emissions peak 0 to 100 years

Time taken to reach equilibrium

- Sea-level rise due to ice melting: several millennia
- Sea-level rise due to thermal expansion: centuries to millennia
- Temperature stabilization: a few centuries
- CO₂ stabilization: 100 to 300 years

IPCC (2000) TAR SPM
How are temperature and sea level linked?

Initial linear regime where \( \frac{dH}{dt} \sim \Delta T \)

Adjustment timescale: centuries to millennia

Rahmstorf, Science 2007
Reconstruction of past Sea Level

Outer Banks, North Carolina

Distribution intrinsically linked to sea level and the tides
Distinctive pattern of floral zonation (tolerance of frequency and duration of inundation)
Thick sedimentary sequences are archives of sea-level change

Fotos: S. Rahmstorf
Sea Level reconstruction vs semi-empirical model

Kemp et al., 2011
Validation for 20th century

(a) Temp. anomaly (K)

(b) Sea level anomaly (cm)

Legend:
- Mann et al. (2008) temperature proxies with 1 σ bound
- KE11 proxy data (9-degree polynomial fit) with 1 & 2 σ bound
- KE11 proxy data points
- JE08 data with Chao et al. (2008) & Konikow (2011) correction
- JE08 data ssatrend smoothed
- Semi-empirical fit with 90% confidence interval
- Semi-empirical forecast with 90% confidence interval

Bittermann et al., 2013
Rate of Sea-level rise projections 21st century

Schaeffer et al., 2012; Schellnhuber et al., 2012
Sea-level rise projections 21st century

Schaeffer et al., 2012; Schellnhuber et al., 2012

Graph showing sea level rise projections for the 21st century, including various scenarios and emission pathways.
Can sea level rise be held below 1m?

- The difference in sea-level rise between a stabilized 2°C and a “well below” 1.5°C scenario is less than 10 cm by 2100, but rate of rise is very different by then, so that difference in sea-level rise between scenarios diverges to over 1 m by 2300.
- Sea-level rise may be halted in 2300 for a “well below” 1.5°C scenario, in sharp contrast to a 2°C stabilization scenario.

Schaeffer et al., 2012
Regional deviations from global SLR

Perrette et al., 2012; Schellnhuber et al., 2012
How are species affected by ocean acidification?

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Response</th>
<th>Mean Effect</th>
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<tbody>
<tr>
<td>Calcifying algae</td>
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<td>Development</td>
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<td>Abundance</td>
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<td>Diatoms</td>
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<td>Photosynthesis</td>
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<td>Abundance</td>
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Kroeker et al. (2013)
How rapidly does acidification increase?

Illustrative low-emission scenario with strong negative CO₂ emissions
Global sudden stop to emissions in 2016
RCP3PD
50% chance to exceed 2°C
Current Pledges
Reference (close to SRES A1B)
IPCC SRES A1FI

Schellnhuber et al., 2012
Coral reefs projected “chemical” and “thermal” stress

Reefs in blue have a less-than-10% probability of experiencing a severe bleaching event and live in areas with annual mean open ocean seawater aragonite saturation above 3.3. Orange reefs are thermally stressed experiencing a severe bleaching event at least once every 10 years. Light blue reefs are chemically stressed (annual mean seawater aragonite saturation below 3.3), and reefs in red are both thermally and chemically stressed.
Closing remarks

• Climate change poses a risk to ocean-based or ocean-dependent systems through warming, sea-level rise and acidification

• Several aspects (Backup Slides) not discussed here, e.g.:
  – Tropical cyclone intensity
  – Weakening Thermohaline circulation
  – Changes in patterns of variability in ocean, atmosphere and combined (e.g. ENSO, NAO)

• Current emission trends, observations and inadequacy of proposed emission reductions lead to projected high risks
Thank you

www.climateanalytics.org
Backup slides

further information and “other aspects” of climate change & oceans
Correlation between hurricane power and tropical sea-surface temperatures

Figure 3 | Power dissipation index for North Atlantic tropical storms linked to tropical sea surface temperature in the main development region for Atlantic hurricanes. Red line denotes North Atlantic tropical storms; blue line denotes tropical Atlantic sea surface temperature. For comparison, the evolution of Northern Hemisphere mean temperature from NASA Goddard Institute for Space Studies is also shown (dotted line).  

Coumou and Rahmstorf (2012)
Thermohaline circulation or “great conveyor belt”

Consistent global warming signal in line with IPCC projections
Global carbon-dioxide emissions increase by 1.0 Gt in 2011 to record high

24 May 2012

Global carbon-dioxide (CO2) emissions from fossil-fuel combustion reached a record high of 31.6 gigatonnes (Gt) in 2011, according to preliminary estimates from the International Energy Agency (IEA). This represents an increase of 1.0 Gt on 2010, or 3.2%. Coal accounted for 45% of total energy-related CO2 emissions in 2011, followed by oil (35%) and natural gas (20%).

The 450 Scenario of the IEA’s World Energy Outlook 2011, which sets out an energy pathway consistent with a 50% chance of limiting the increase in the average global temperature to 2°C, requires CO2 emissions to peak at 32.6 Gt no later than 2017, i.e. just 1.0 Gt above 2011 levels. The 450 Scenario sees a decoupling of CO2 emissions from global GDP, but much still needs to be done to reach that goal as the rate of growth in CO2 emissions in 2011 exceeded that of global GDP. “The new data provide further evidence that the door to a 2°C trajectory is about to close,” said IEA Chief Economist Fatih Birol.
...and so is CO$_2$ concentration
Core findings:

– 2010 global total emissions: 50 GtCO2e/yr (95% range: 45.6-54.6)

– Current “emissions gap” for 2°C (>66% chance) 8 to 13 GtCO2e/yr, depending on:
  • unconditional/conditional pledges: 2 GtCO2e/yr improvement
  • lenient/strict accounting rules: 3 GtCO2e/yr improvement

– Emissions gap increased by ca. 2 GtCO2e/yr relative to 2011 estimate
  • due to updated BaUs for developing countries (higher expected emissions)
  • due to inclusion and accounting for the effect of double counting of offsets

– 2020 emissions:
  • in line with 2°C (>66% chance) remain at 44 GtCO2e/yr (41-47 GtCO2e/yr)
  • in the few 1.5°C scenarios emerging in literature: around 43 GtCO2e/yr
  • Based on the pledges: 52-57 GtCO2e/yr, depending on conditionality and accounting rules

– Also “later action” pathways emerge in literature
  • higher near-term emissions (lower near-term costs)
  • Higher technology dependence on any mitigation option (for example, CCS)
  • Higher long-term (and overall) costs
  • Higher pressure on future policy requirements (participation, climate vs water/biodiversity)
  • Increased climatic risks: emission budget used more quickly, temperature rate and overshoot

– Highlights importance of energy efficiency to keep many options open
The Emissions Gap Report 2012
A UNEP Synthesis Report

Likely (>66%) temperature increase (T) during 21st century associated with emission pathways

Pledge range:
- 20 to 80 percentile
- medians

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Regional SLR projection time series

Schellnhuber et al., 2012
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Schellnhuber et al., 2012