Rapid Changes in Glaciers and Ice Sheets and their Impacts on Sea Level

Subcommittee Members

Konrad (Koni) Steffen (ice sheet, climate; coordinate report)
Shawn Marshall (modeling)
Bob Thomas (ice sheet)
Peter Clark (paleo ice sheet)
Graham Cogley (glaciers)
Eric Rignot (ice sheet)
Jason Box (SMB modeling)
David Holland (ocean ice interaction)
Marika Holland (sea ice)

Chapter Outline
Summary and Outlook (Koni)

Paleo-Record of Ice Contribution to Rapid Sea Level Change (Peter)

Assessment of Current State
Techniques of assessment of total mass balance (Bob)
Mass budget
Altimetry
Gravity changes
Polar Ice Sheets (Bob / Eric / Koni)
Greenland
Antarctica
Glaciers and ice caps (Copley)

Potential Mechanism of Rapid Ice Response
Ocean-ice interactions (David Holland)
Ice shelf/ice stream interactions (Shawn / Eric / Bob)
Basal lubrication and glacier flow (Shawn / Bob / Koni)
Sea level feedback (Peter)

Summary and Recommendations (all)
Process observations and monitoring
Improving understanding
Model development

Abrupt Changes in Atmospheric Methane

Chapter for USGCRP Scientific Assessment Product 3.4

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Outline with proposed subsection authors initials in parentheses

1. Key Findings (E. B. coordinate)
2. Recommendations (box) (E. B. coordinate)
3. Introduction
    - *3.1. Basic framework of chapter (E. B.)*
    - *3.2. Methane and Climate (E. D.)*
        - 3.2.1. Greenhouse forcing
            - 3.2.1.1. Why methane is a greenhouse gas.
            - 3.2.1.2. Contribution to radiative forcing today
            - 3.2.1.3. Potential contribution in the future
        - 3.2.2. Modern methane budget
            - 3.2.2.1. Lifetime, total source, sink mechanisms and issues
            - 3.2.2.2. Modern budget, how determined and uncertainties
            - 3.2.2.3. Observational network, current limitations, particularly relative to the hydrate, permafrost and arctic wetland sources.
    - 3.3. Potential for large changes in atmospheric methane (E. B.)
    - 3.4. Motivating questions (E. B.)
4. *History of Atmospheric Methane (E. B.)*
    - 4.1. Anthropogenic increase
    - 4.2. Last 800,000 years from ice cores
    - 4.3. Abrupt methane changes during the last ice age
5. Evaluation of future potential for abrupt changes in atmospheric methane (E. B.)
    - 5.1. Introduction of three potential mechanisms (E. B.)
        - 5.1.1. Destabilization of methane hydrates
        - 5.1.2. Destabilization of permafrost hydrates
        - 5.1.3. Changes in arctic wetland extent and methane productivity
6. *Marine hydrate destabilization (D. A.)*
    - 6.1. Review of size of potential source

6.2. Mechanisms proposed to destabilize hydrates
6.3. Geologic data relevant to past hydrate release
6.4. Evidence for climate impact of hydrate release in the geologic record

Proposed Sidebar: Current status of LPTM hydrate hypothesis

6.5. Review model results addressing past and future methane hydrate destabilization
6.5.1. Quantity of methane potentially released
6.5.2. Climate impact of potential release
6.6. Conclusions about potential for abrupt release of methane from marine hydrates

7. Terrestrial hydrate (permafrost) (J. C., S. F., D. L.)
7.1. Review size of potential source
7.2. Mechanisms to destabilize terrestrial hydrates
7.3. Geologic data relevant to past terrestrial hydrate release?
7.3.1. Quantity of methane potentially released
7.3.2. Climate impact of potential release
7.4. Model results addressing terrestrial hydrate release?
7.4.1. Quantity of methane potentially released
7.4.2. Climate impact of potential release
7.5. Conclusion about potential for abrupt release of methane from terrestrial hydrates

8. Expansion of wetlands due to Arctic warming
8.1. Review carbon dynamics relevant to methane emissions.

9. Expansion of arctic methane wetland sources (J. C., S. F., D. L.)
10. Observations/Projections
11. Sidebar: Arctic terrestrial feedbacks
12. Conclusion about potential for abrupt release of methane from wetlands
13. Other Considerations
14. Changes in methane sink strength
15. Other?

The Potential for Abrupt Change in the Atlantic Meridional Overturning Circulation

- Key findings
- Recommendations

1. Introduction (Delworth)
2. What are the factors that control the overturning circulation? (Kuhlbrodt)
3. What is the present state of the MOC? (Johns)
4. What is the evidence for change in the overturning circulation in the past? (Lynch-Stieglitz)
5. How well do the current coupled ocean-atmosphere models simulate the overturning circulation? (Morrill)
6. What are the global and regional impacts of a change in the overturning circulation? (Zhang and Delworth)
7. What factors that influence the overturning circulation are likely to change in the future, and what is the probability that the overturning circulation will change? (Weaver)
8. What are the observational and modeling requirements required to understand the overturning circulation and evaluate future change? (All contribute, Delworth coordinates)
9. Summary and Discussion

<u>Potential Side Boxes</u>
(these topics could be somewhat redundant with the main text, but they would be brief, and at a very high level of discussion)

Question: Will a collapse of the AMOC lead to cooling of Europe and North America?

Question: How do we measure the AMOC?

Question: Do we anticipate that rapid changes in the Greenland ice sheet will shut down the AMOC?

Hydrological Variability and Change

Chapter Committee
Edward R. Cook
Richard Seager
Robert S. Webb

Chapter Sub-Committee
Patrick Bartlein
(Others to be added)

I. Key findings
II. Recommendations
III. Introduction – Statement of the problem
IV. Causes and impacts of hydrologic variability over the historical record
   a. What is our current understanding of the historical record?
      - Internal atmosphere-land variability
      - Coupled ocean-atmosphere forcing – ENSO, PDO, AMO
      - Land surface feedbacks on ocean forced and free variability
      - Historical droughts over North America and their impacts
   b. Global context of North American droughts
   c. Is there evidence yet for anthropogenic forcing of drought?
   d. Boxes on snowpack, snowmelt timing, and steamflow trends
V. North American drought over the past 2,000 years from tree rings
   a. Temporal and spatial properties of tree-ring reconstructed drought
   b. Megadroughts – what makes them stand out
      - Intensity and duration – Medieval Climate Anomaly (MCA) period megadroughts will be a major focus here – the closest thing to an abrupt change in aridity over North America
      - Spatial signatures of past megadroughts – where are they most likely
      - Changing frequency of occurrence from present to past
   c. Global context of late Holocene hydroclimatic variability
   d. Box on mid-Holocene aridity in North America
   e. Box on late-Holocene sand dune mobilization in the western US
   f. Scientific questions on the causes of past megadroughts
      - Can the megadroughts during the MCA period be attributed to external forcing?
      - Do megadroughts arise from certain preferred regions of the coupled ocean-atmosphere system?
      - Were the MCA megadroughts unique in the Holocene?
      - Box on paleoflood and drought records from earlier in the Holocene.
VI. Future subtropical drying: dynamics, paleo context, and implications for the future – questions to be addressed
   a. The scientific questions

- How serious is projected subtropical drying and how certain are the model projections?
- Does future drying in the southwestern US (and subtropics) arise from the same dynamical mechanisms as the MCA aridity period or is it dynamically distinct?
- What is the potential for predicting future hydroclimatic change, including that due to both natural variations and the response to anthropogenic forcing?
- Can we predict the onset of anthropogenic drying from climate models?
- Do anthropogenic and natural droughts have different signatures in the oceans and atmosphere that will allow identification of anthropogenic drying if and when it occurs?
- Is the tropical ocean-North America system response to radiative forcing linear or does it have thresholds?

b. Box on "The Perfect Ocean For Drought" – more global context

VII. Other aspects of hydroclimatic change

- How sure and important are projections of increases in precipitation intensity?
- What are the implications for floodings?
- What are the impacts of all aspects of change in the atmospheric branch of the hydrological cycle for ground water and river flow?
- What are the impacts of expected changes in snow cover and seasonal distribution of snow melt?

VIII. Conclusions