Ice-Ocean Interaction: Greenland & Antarctica, Observations and Models
A Recent Sea-Level Change Event
Hurricane Sandy -
New York October 2012
The Goal:
Quantifying the Risk
Observations: The World Has Warmed

IPCC, 2007
Suggestion:

Warmer Climate Will Melt Ice Sheets:

Raise Global Sea Level
2

Sea-Level Basics
Recipe for Sea-Level Rise

Add Heat

Add Water
Media Ahead of Science?
Observations of Past Global Environment
Hockey Stick Graph
(Past 1000 Years)

from thermometers (red) and from tree rings, ice cores and historical records (blue).
Global Sea Level Change (Past 100 Years)

Recent Sea Level Rise

23 Annual Tide Gauge Records
- Three Year Average
- Satellite Altimetry

http://www.globalwarmingart.com/
The Nuance

Data of the past are (relatively) credible:
Air Temperature, Sea Level

Future projections are (reasonably) good:
Air Temperature, ...

But NOT Sea Level
Role & Relevance of Ice Shelves
Nomenclature:

- Bedrock
- Ice
- Shelf
- Ocean
- Ice Sheet
- Atmosphere
- Ice Front
- Front Cavity
- Slope
- Sea Ice
- Cavity
- Ocean
- Grounding Line
- Bedrock
Nomenclature: Northern Hemisphere Water Masses

Polar Surface Waters

Irminger Waters or Atlantic-Layer Waters

North Atlantic Deep Water
Nomenclature: Southern Hemisphere Water Masses

Polar Surface Waters

Circumpolar Deep Water or Warm Deep Water (WDW)

Antarctic Bottom Water
Nomenclature: Continental Shelf Water Masses

- High Salinity Shelf Water (HSSW)
- Ice Shelf Water (ISW)
Nomenclature: Northern Hemisphere Westerly Winds

NAO – North Atlantic Oscillation

Greenland Ice Sheet
Primary Objective:
Position of the Ice-Ocean Interface
1. Viscous-Sublayer: Molecular Exchange Rules

Holland & Jenkins, JPO, 1999
2. Ice Front Calving

(destabilizing)

reduces backpressure of iceshelf on inland ice
2. **Ice Front Calving:**

*Jakobshavn Isbrae, West Greenland*

5 June 2007

14:10 - 14:28 UTC

photos by Jason Amundson

Geophysical Institute, University of Alaska Fairbanks
3. **Marine Ice Sheet Instability**

(destabilizing)

cannot balance

grounding line flux with

inland accumulation on

reversed bedslope
4. ... and other processes...
Earth’s Ice Sheets
Earth’s Ice Sheets

Jakobshavn Icefjord

Pine Island Glacier
Anatomy of Disintegration

Are warm waters slipping beneath the ice sheets?
What to do?

Logic
(or perhaps foolishness)
dictates observing the
source of the concern

... and so we go to
Greenland and Antarctica.
Greenland /Antarctica: Some Differences
Some Differences Between Greenland / Antarctica
Differences between Greenland / Antarctica
Differences between Greenland / Antarctica
Differences between Greenland / Antarctica
Differences between Greenland / Antarctica
5

Greenland

Jakobshavn

Flushing Dynamics
Virtual Fly-In to Jakobshavn
Airborne Temperature Probe: Target Drop Location
Alternate Approach: Tagged Seals

Seal Tagging, Greenland
Environmental Monitoring Stations (EMS)
(EFDL)
Alternate Approach: Tagged Seals
Traditional Approach: Moorings
Not-So Traditional Approach: Mooring Ransom

You replied to this message on 8/22/2011 15:38.

From: Aqqalu Rosing-Asvid <aqr@natur.gl>
To: holland
Cc: Kathy Young
Subject: Your lost mooring

Fra: Dorthea Hansen [mailto:dorthea_hansen@hotmail.com]
Sendt: 19. august 2011 17:00
Til: Adm
Emne: imaanu misissuutit assitai. af Pavia Peter Hansen(Viders JoMo 22/8 afv AqRo) NaPe

Haluukkut.

matumuuna misissuutit assitaa ilissinnut nassiuqarpoq, anima Pavia Peter-p ningittangaarut akkingussimassaq. tassani timitaani allaqqasorgaarpoq ima: if fund David Holland Hotel Arctic aningga aamma attavigueqarsinnaavq anertunerusumik paasisaqarussuq. uunga paviapeter@hotmail.com

Inuss. Inuull.
Dorthea Hansen

Denne mail er scannet af Comendo A/S og fundet virusfri.
Greenland:
Remote Forcing of Ice-Ocean Interaction
Have the Deep Waters Always Been Warm?

... no ....

.... and, they warmed suddenly in 1997 ...
Ocean Temperature Change Observations from Shrimp Fisheries

Holland et al., 2008
Mechanics of *Fast Change*

Change in ...
- wind...
- ocean ...
- ice sheet ...
- sea level...

[http://www.asp.ucar.edu/](http://www.asp.ucar.edu/)
GLACIOLOGY:
Winds, Not Just Global Warming, Eating Away at the Ice Sheets
Richard A. Kerr

Too much. Ice coming off Jakobshavn Isbræ glacier surged after warm ocean water arrived.

CREDIT: BOB STRONG/REUTERS
But why did the winds change?
Antarctica: Remote Forcing of Ice-Ocean Interaction
Antarctica:
Pine Island Glacier (PIG) Flushing Dynamics
Marine Ice Sheet
Getting to PIG
PIG Science Plan
2007

Drill Through Floating PIG

Monitor Ocean Temperature Beneath PIG
Ocean Temperature Measurement on PIG
Antarctic Logistics: The Plan 2007
Antarctic Logistics: Failed Plan 2007
Antarctic Plans: Basler Incident
Installation of AWS Triangle on Nunataks surrounding PIG
Antarctic Logistics: **Plan 2013**
Antarctic Logistics:
Helo @ PIG, Jan 2013
Antarctic Logistics: Sites A, B, C @ PIG
Summary
To Make Real Progress

Need to be REALISTIC about present resources / capabilities
Stronger Computational Capability

Weaker Observational Capability
Projections: Global Sea Level

**SUSTAINED observations needed from Greenland and Antarctica**

**EXPLORATORY modeling useful for Greenland and Antarctica**