
Updating California's
Sea-level Rise Guidance Document
Ocean Protection Council Meeting
April 26, 2017
Photo: Kris Hiemstra

State Sea-level Rise Guidance Document

- Incorporating sea-level rise projections into state and local decision-making.

- Updating guidance to reflect recent advances in ice loss science and projections of sea-level rise.

- Opportunities for engagement with state agencies, local governments, consultants, non-governmental organizations, tribes, vulnerable communities, and other constituents.

Process & Opportunities for Engagement

December 2016 - April 2017: State agency, local government and constituent engagement: interviews and five listening sessions; CO-CAT meetings

April 26th 2017: OPC Meeting: Science summary presented to the OPC

May - June 2017: Series of public workshops to solicit feedback on a draft framework for the *State Sea-level Rise Guidance Document*

October - November 2017: 30-day public comment period on a draft update to the *State Sea-level Rise Guidance Document*

January 2018: OPC Meeting: Potential approval by the OPC of the updated *State Sea-level Rise Guidance Document*

Public Workshops

South Coast · Tuesday, May 16 · 1 pm - 4 pm
Environmental Learning Center at Hyperion
12000 Vista Del Mar, Playa Del Rey, CA 90293

Bay Area · Monday, May 22 · 1:30 pm – 5:00 pm*
455 Golden Gate Ave, San Francisco, CA 94102
**a Safeguarding California Workshop will take place here earlier in the day at 9:30am - 12:30 pm*

North Coast · Thursday, June 8 · 9 am - 12 pm
Sequoia Conference Center
901 Myrtle Avenue, Eureka, CA 95501

San Diego · TBD

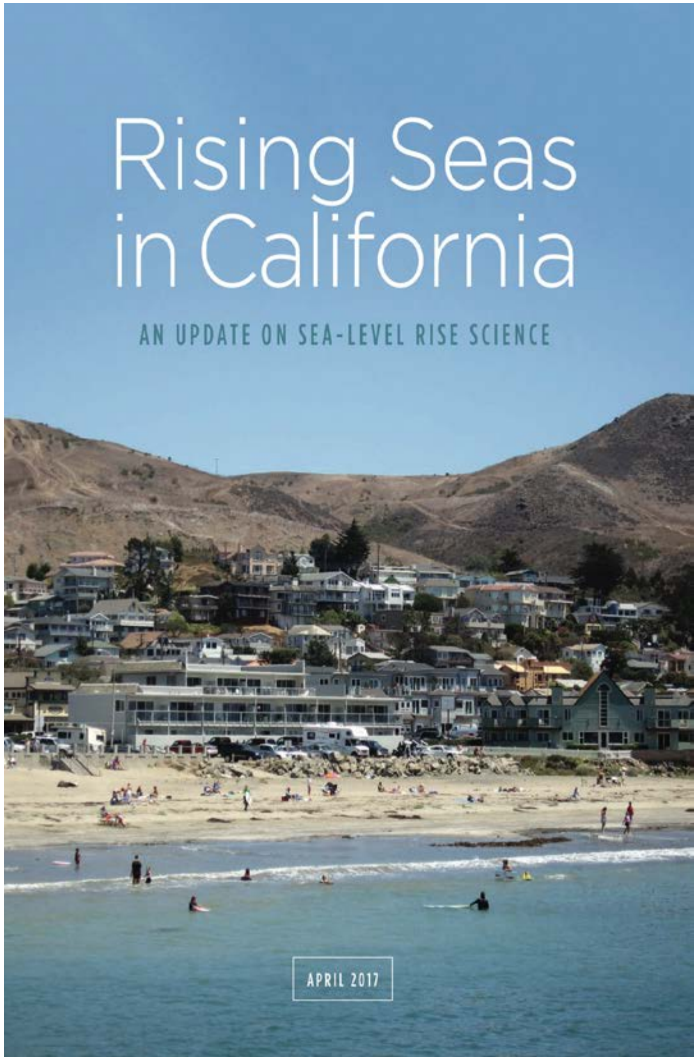
For more information, visit:
- http://www.opc.ca.gov/climate-change/updating-californias-sea-level-rise-guidance/
- http://www.oceansciencetrust.org/projects/updating-californias-sea-level-rise-guidance


Photo: Margaret Lindgren

Dr. Cayan

Photo: Lincoln Chu

Rising Seas in California: An Update on Sea-level Rise Science



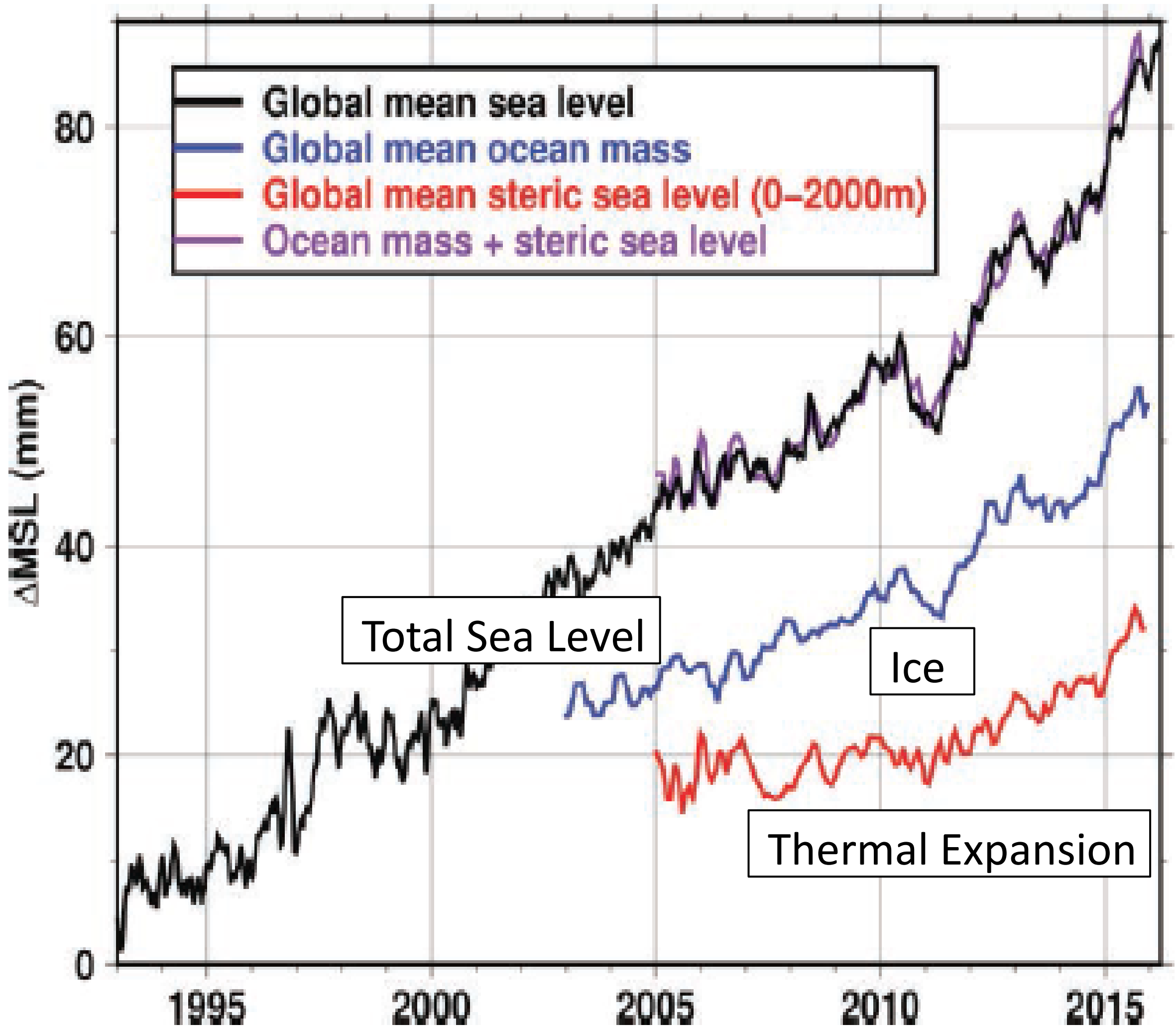
Ocean Protection Council Science Advisory Team (OPC-SAT) Working Group Members:

- Gary Griggs, *University of California Santa Cruz, OPC-SAT Working Group Chair)*
- Dan Cayan, *Scripps Institution of Oceanography, OPC-SAT*
- Claudia Tebaldi, *National Center for Atmospheric Research & Climate Central*
- Helen Amanda Fricker, *Scripps Institution of Oceanography*
- Joseph Arvai, *University of Michigan*
- Robert DeConto, *University of Massachusetts*
- Robert E. Kopp, *Rutgers University*

Recent scientific advances in our understanding of sea-level rise?

Photo: Shelli Kenlein

Changes in Primary Contributors to Sea-level Rise

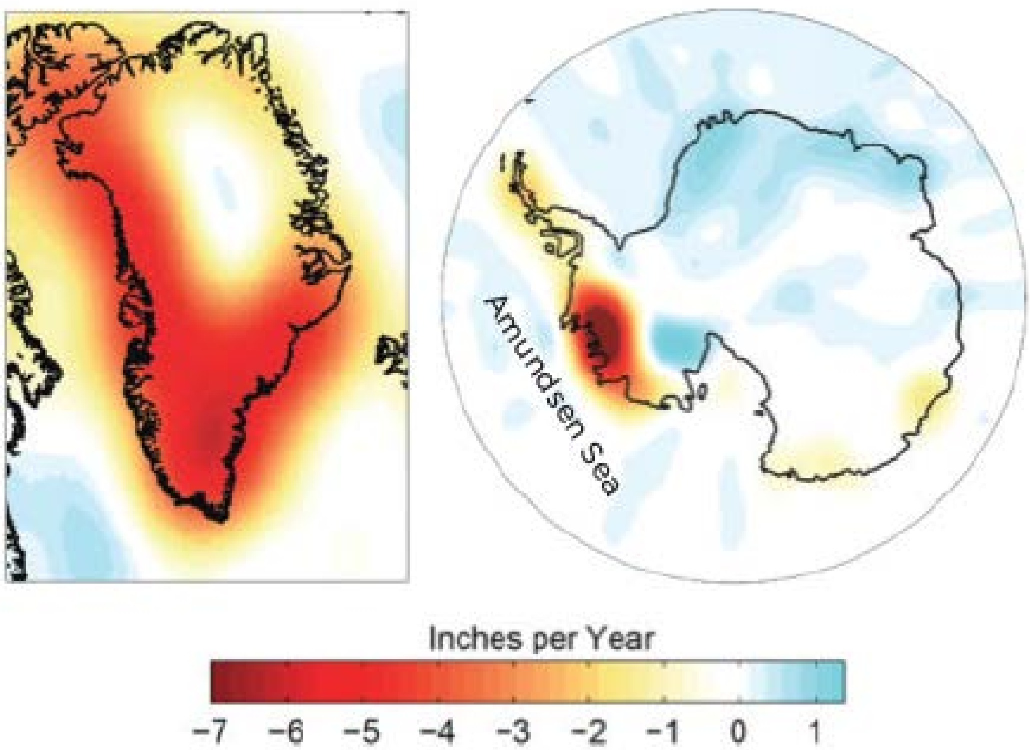


Recently, the loss of land ice has surpassed ocean thermal expansion as the largest contributor to sea-level rise.

Land ice includes glaciers, ice caps, and ice sheets (Greenland + Antarctica)

Greenland and Antarctic Ice Sheets

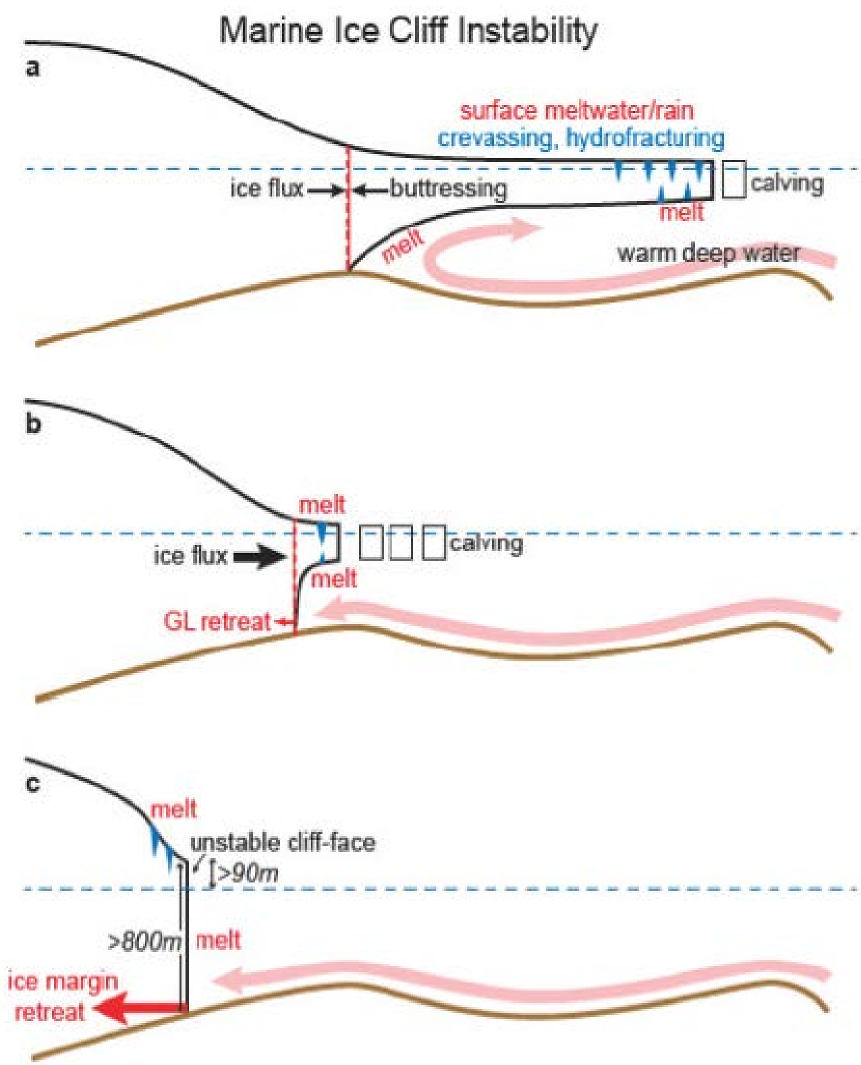
Greenland Ice Sheet **Antarctic Ice Sheet**



Ice mass loss (inches of water equivalent lost per year between 2003 and 2012) over Greenland and Antarctica from GFACE satellite.

- Loss of ice from the Greenland and Antarctic ice sheets will become the dominant source of sea-level rise, surpassing contributions from mountain glaciers and ocean thermal expansion
- Greenland Ice Sheet (GIS) is currently losing mass at a faster rate than the Antarctic Ice Sheet (AIS), but, *emerging science suggests that ice loss from the Antarctic Ice Sheet poses the greatest potential risk to California coastlines over the next 100 years.*

Ice Sheet Mass Loss at Marine Interface



- Ice shelf seaward flow is inhibited by "buttressing." **Buttressing ice shelves** are vulnerable to climate change.
- Many marine-based Antarctic outlet glaciers rest on bedrock that have reverse-sloped beds. In places with this reverse-sloped geometry, the ice sheet is susceptible to a **Marine Ice Sheet Instability**.
- Another glaciological process: **Marine Ice Cliff Instability,** not previously considered at the continental ice-sheet scale, was shown to have a profound effect on ice sheet simulations in climates warmer than today.

Sea-level Fingerprint of West Antarctic Ice Sheet Mass Loss

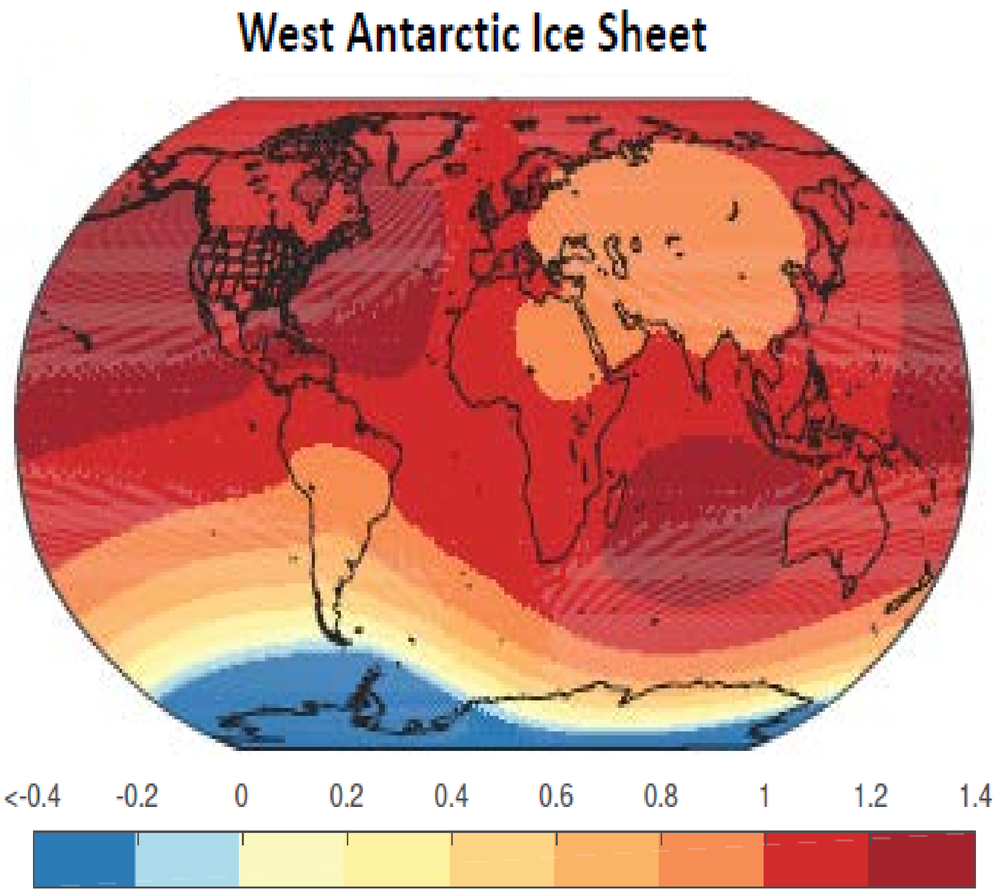
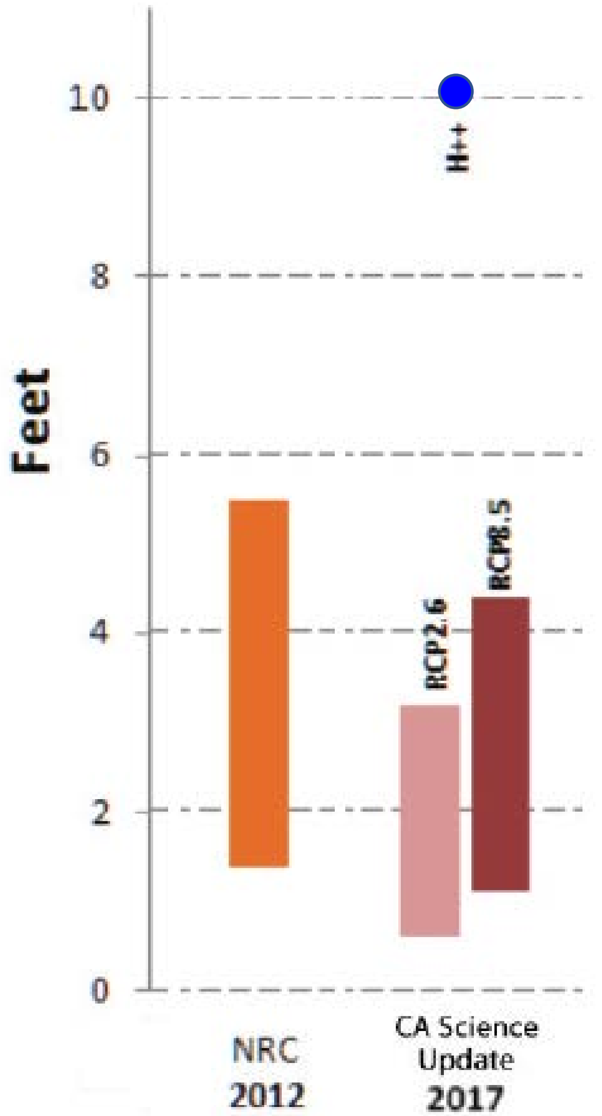


Figure 1. Sea-level 'fingerprints' resulting from the distribution of ice and water around the Earth and ensuing gravitational and rotational effects.

- There is no worse place for California for land ice to be lost than from the West Antarctic Ice Sheet, because of globally-uneven gravitational and rotational effects.
- For every foot of global sea-level rise caused by the loss of ice on West Antarctica, sea-level will rise about 1.25 feet along the California coast.

Working Group Sea-level Rise Projections

Projections from Existing Guidance Document & Projections from this Rising Seas Report



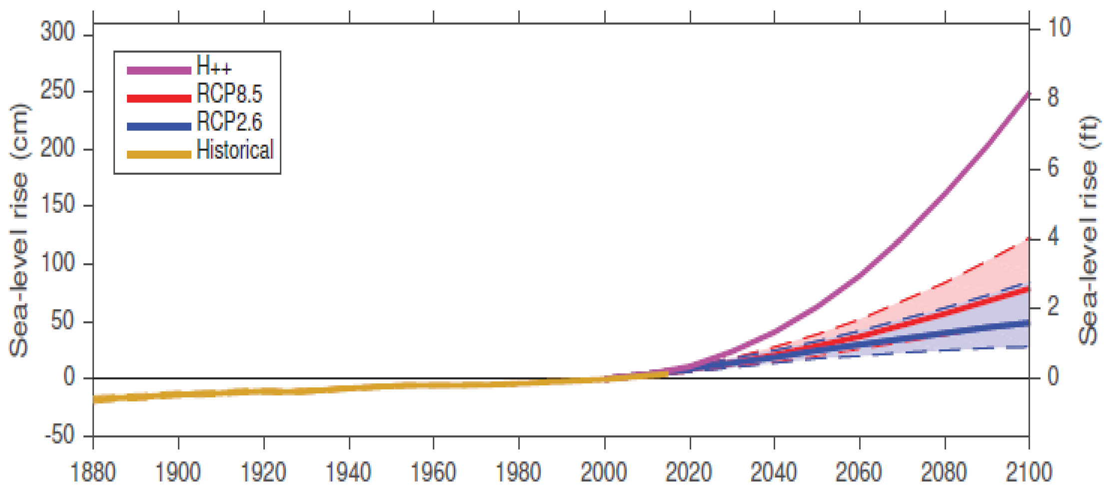
Sea-level rise projections for 2100

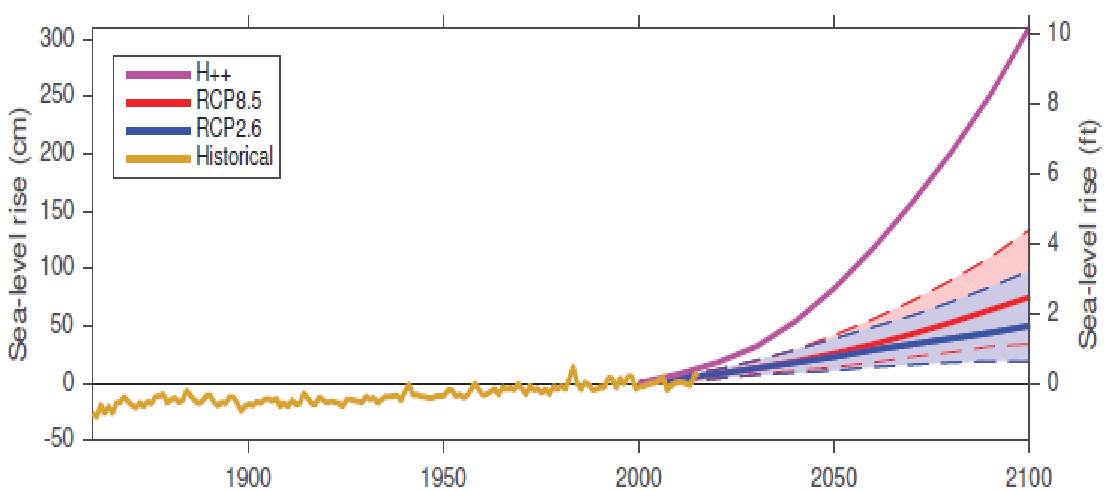
Orange: the National Research Council (NRC) 2012 projections (in the existing guidance document), which do not assign probabilities

Pink: the California Science Update (this science report) – 5th - 95th percentile for San Francisco using the Kopp et al., 2014 probabilistic framework and the H++ scenario (●) from NOAA 2017.

Working Group Sea-level Rise Projections

Global Mean Sea Level





- Probabilistic projections are specific to emissions scenario. Projections for RCP 8.5 and RCP 2.6 are calculated using the methodology of Kopp et al. (2014). Shaded areas bounded by the dashed lines denote the 5th and 95th percentiles.
  (RCP 4.5 projections not shown)
- H++ scenario corresponds to the extreme scenario of Sweet et al. (2017) and represents a world consistent with rapid Antarctic ice sheet mass loss; *there is not a probability associated with the H++ scenario.*

Projected Sea-level Rise (measured in feet)

(Table 1b from the report)

San Francisco, Golden Gate

Feet above 1991-2009 mean	MEDIAN	LIKELY RANGE	1-IN-20 CHANCE	1-IN-200 CHANCE
Year / Percentile	*50% probability SLR meets or exceeds…*	*67% probability SLR is between…*	*5% probability SLR meets or exceeds…*	*0.5% probability SLR meets or exceeds…*
2030	0.4	0.3 — 0.5	0.6	0.8
2050	0.9	0.6 — 1.1	1.4	1.9
2100 (RCP 2.6)	1.6	1.0 — 2.4	3.2	5.7
2100 (RCP 4.5)	1.9	1.2 — 2.7	3.5	5.9
2100 (RCP 8.5)	2.5	1.6 — 3.4	4.4	6.9
2100 (H++)	10			
2150 (RCP 2.6)	2.4	1.3 — 3.8	5.5	11.0
2150 (RCP 4.5)	3.0	1.7 — 4.6	6.4	11.7
2150 (RCP 8.5)	4.1	2.8 — 5.8	7.7	13.0
2150 (H++)	22			

San Francisco, RCP 8.5 in 2100

Please note that projections are also provided for Crescent City and La Jolla

Probability that sea-level rise at San Francisco will meet or exceed a particular height (feet) in a given year

(Table 4a from the report)

RCP 8

(a) RCP 8.5

	1 FT.	2 FT.	3 FT.	4 FT.	5 FT.	6 FT.	7 FT.	8 FT.	9 FT.	10 FT.
2020										
2030	0.1%									
2040	3.3%									
2050	31%	0.4%								
2060	65%	3%	0.2%	0.1%						
2070	84%	13%	1.2%	0.2%	0.1%					
2080	93%	34%	5%	0.9%	0.3%	0.1%	0.1%			
2090	96%	55%	14%	3%	0.9%	0.3%	0.2%	0.1%	0.1%	
2100	96%	70%	28%	8%	3%	1%	0.5%	0.3%	0.2%	0.1%
2150	100%	96%	79%	52%	28%	15%	8%	4%	3%	2%
2200	100%	97%	91%	80%	65%	50%	36%	25%	18%	13%

San Francisco, RCP 8.5 in 2100

Extreme Sea-level Rise Scenario (H++)

- The Kopp et al. (2014) projections may underestimate the likelihood of extreme sea-level rise, particularly under high-emissions scenarios, so the Working Group included the H++ extreme sea-level rise scenario alongside the Kopp et al. (2014) probability distributions for RCPs 2.6, 4.5 and 8.5.
- Quantifying West Antarctic mass loss from ice cliff and instabilities depends heavily on a single recent modeling study and does not provide truly probabilistic information.
- At this point, it is scientifically premature to estimate the probability that the H++ scenario will come to pass, and, if so, when the world will move onto the H++ trajectory.

Key Findings

1. **Scientific understanding of sea-level rise is advancing at a rapid pace.**
   Periodic updates of SLR Guidance will be necessary.

2. **The direction of sea level change is clear.**

3. **The rate of ice loss from the Greenland and Antarctic Ice Sheets is increasing.**

4. **New scientific evidence has highlighted the potential for extreme sea-level rise.**

5. **Probabilities of specific sea-level increases can inform decisions.**

6. **Current policy decisions are shaping our coastal future.**

7. **Waiting for scientific certainty is neither a safe nor prudent option.**


Photo: Linda Dron

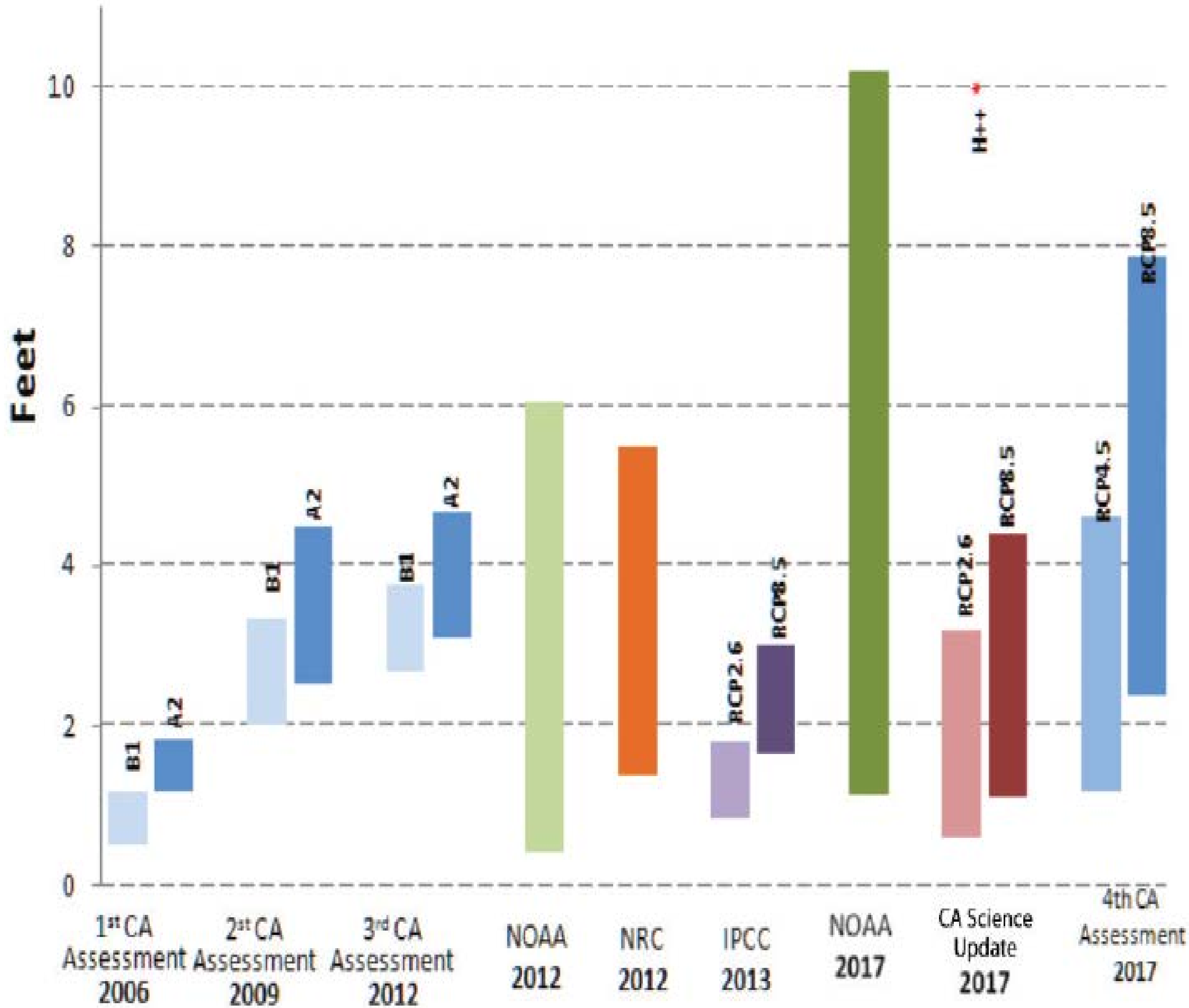
Reserve Slides

Table 2b, San Francisco, Golden Gate

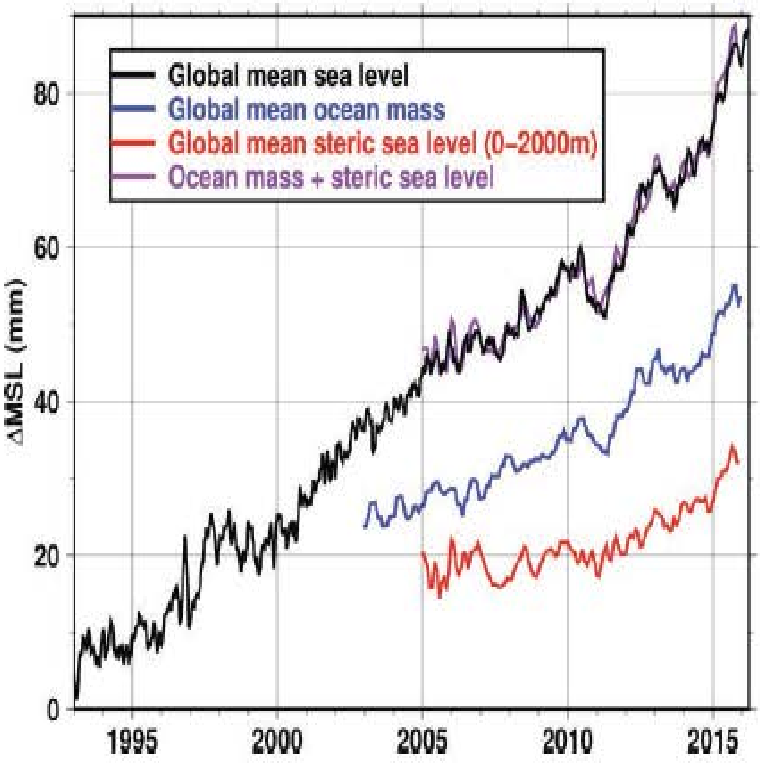
mm / yr	MEDIAN	LIKELY RANGE	1-IN-20 CHANCE	1-IN-200 CHANCE
Year / Percentile	*50% probability SLR meets or exceeds...*	*67% probability SLR is between...*	*5% probability SLR meets or exceeds...*	*0.5% probability SLR meets or exceeds...*
2010-2030	4.7	3.8 – 5.7	6.5	8.4
2030-2050 (RCP 2.6)	5.1	3.1 – 7.4	9.6	15
2030-2050 (RCP 4.5)	5.8	4.2 – 7.7	9.5	14
2030-2050 (RCP 8.5)	6.7	4.5 – 9.3	12	17
2030-2050 (H++)	26			
2080-2100 (RCP 2.6)	5.2	2.3 – 9.1	14	28
2080-2100 (RCP 4.5)	6.5	3.1 – 11	15	29
2080-2100 (RCP 8.5)	11	6.0 – 16	22	37
2080-2100 (H++)	55			

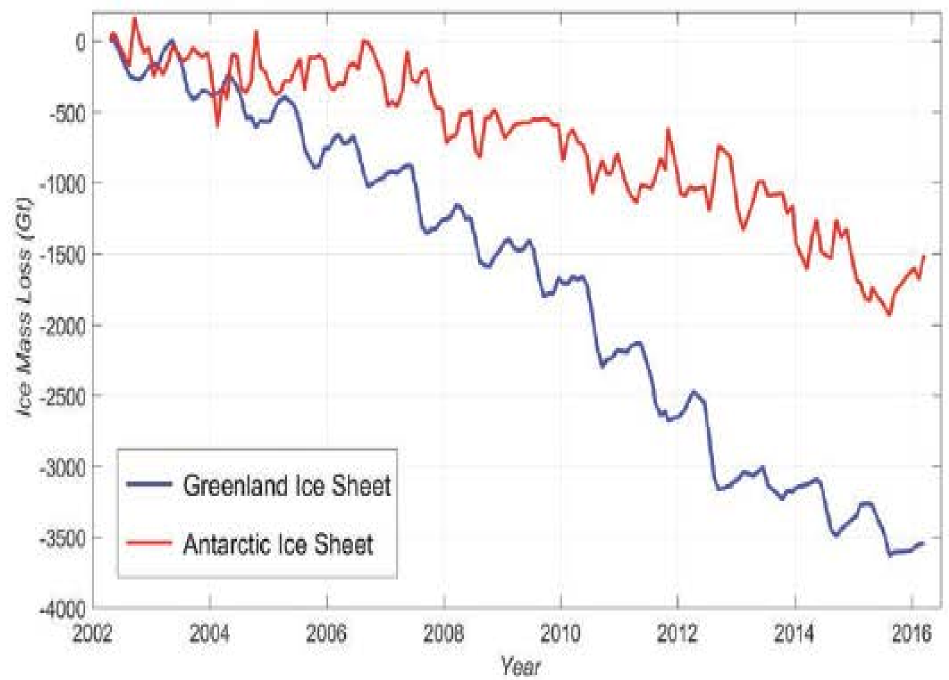
Table 4b, San Francisco, Golden Gate, RCP 2.6

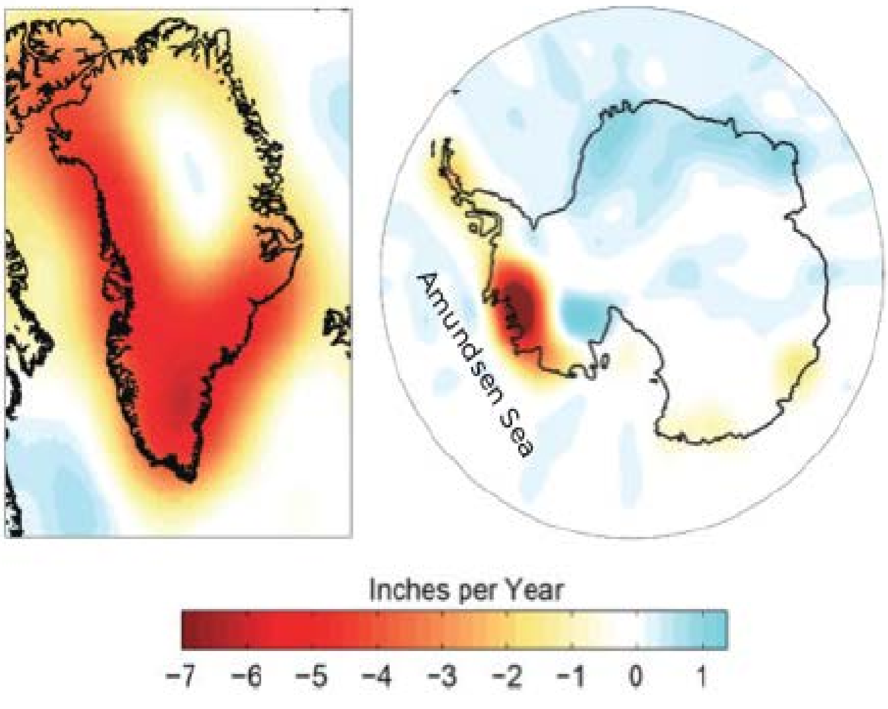
	1 FT.	2 FT.	3 FT.	4 FT.	5 FT.	6 FT.	7 FT.	8 FT.	9 FT.	10 FT.
2020										
2030										
2040	3.1%									
2050	19%	0.3%								
2060	43%	1.4%	0.2%							
2070	62%	4%	0.6%	0.2%						
2080	74%	11%	2%	0.4%	0.2%	0.1%				
2090	80%	20%	3%	1.0%	0.4%	0.2%	0.1%	0.1%		
2100	84%	31%	7%	2%	0.8%	0.4%	0.2%	0.1%	0.1%	
2150	93%	62%	31%	14%	7%	4%	2%	2%	1%	1%
2200	93%	68%	42%	22%	12%	7%	5%	3%	2%	1%

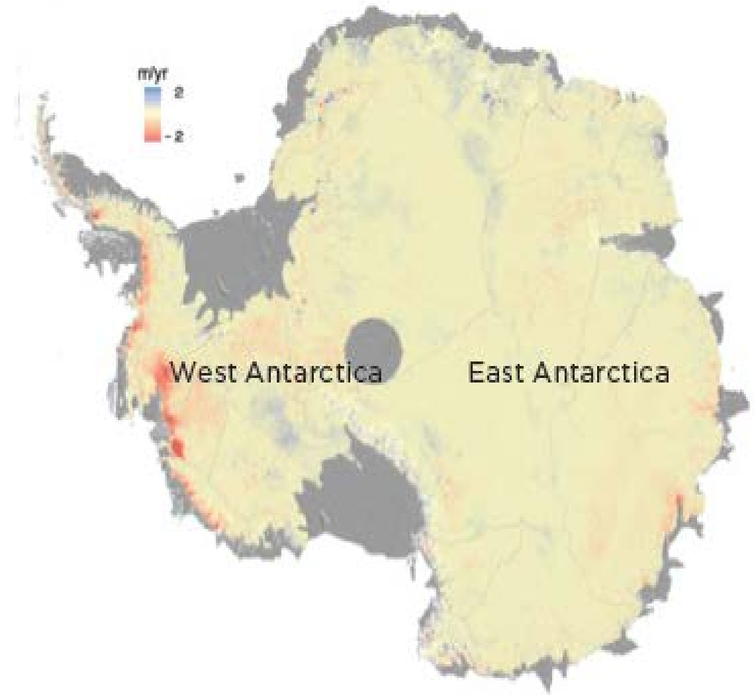


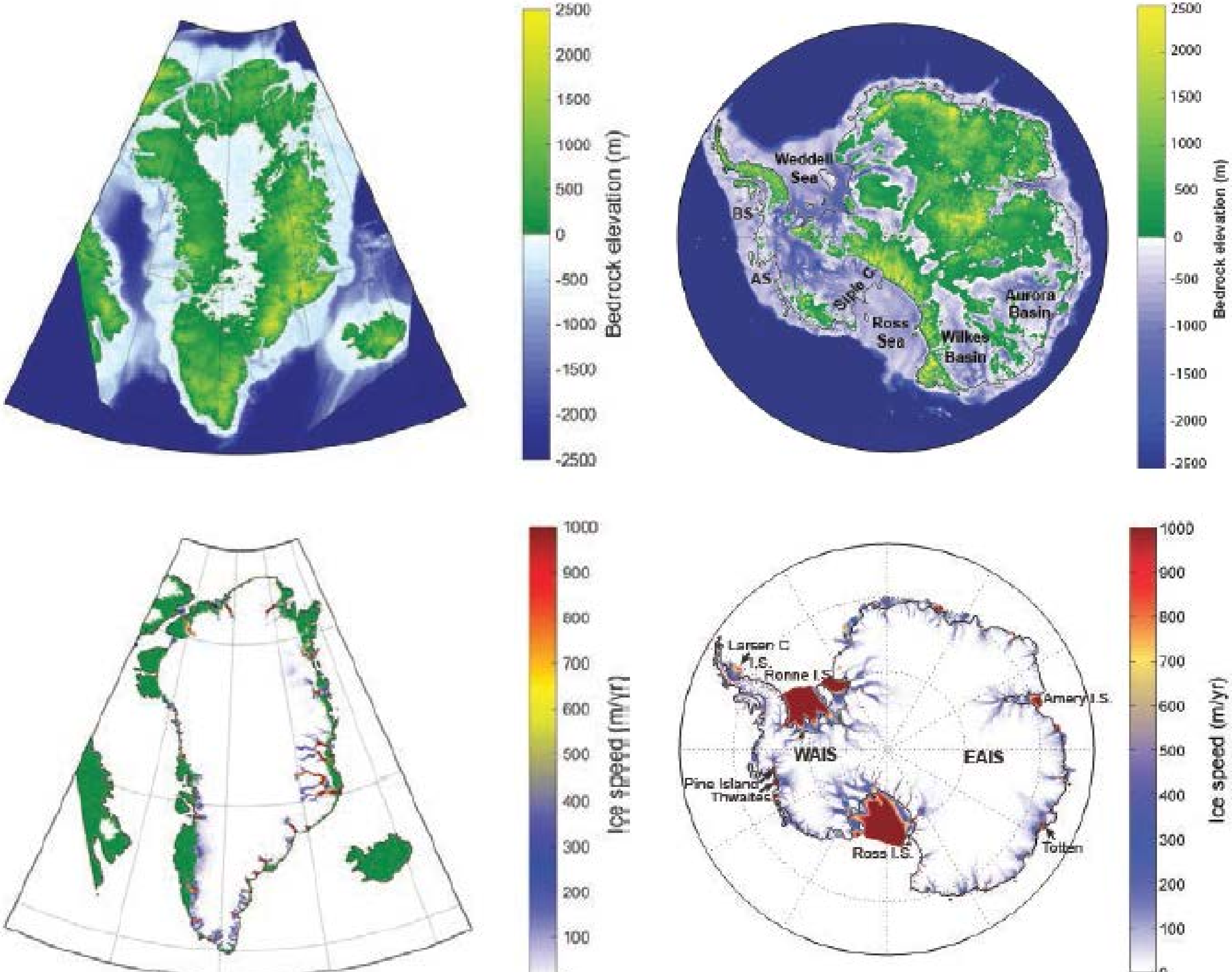
Feet
10
8
6
4
2
0
H++
B1
A2
B1
A2
B1
A2
RCP2.6
RCP8.5
RCP2.6
RCP8.5
RCP4.5
RCP8.5
1st CA Assessment 2006
2nd CA Assessment 2009
3rd CA Assessment 2012
NOAA 2012
NRC 2012
IPCC 2013
NOAA 2017
CA Science Update 2017
4th CA Assessment 2017

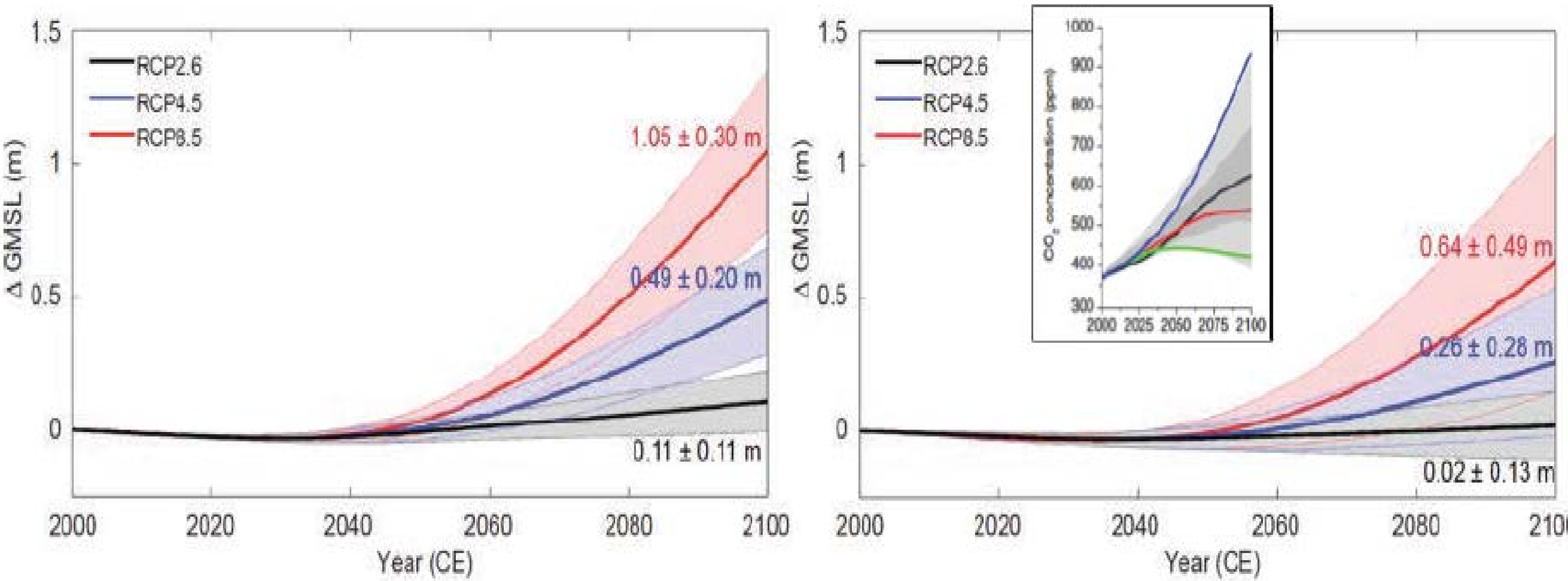

Global mean sea level
Global mean ocean mass
Global mean steric sea level (0–2000m)
Ocean mass + steric sea level
ΔMSL (mm)
0
20
40
60
80
1995
2000
2005
2010
2015


Greenland Ice Sheet
Antarctic Ice Sheet
Ice Mass Loss (Gt)
Year
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
2002
2004
2006
2008
2010
2012
2014
2016


Amundsen Sea
Inches per Year
−7 −6 −5 −4 −3 −2 −1 0 1

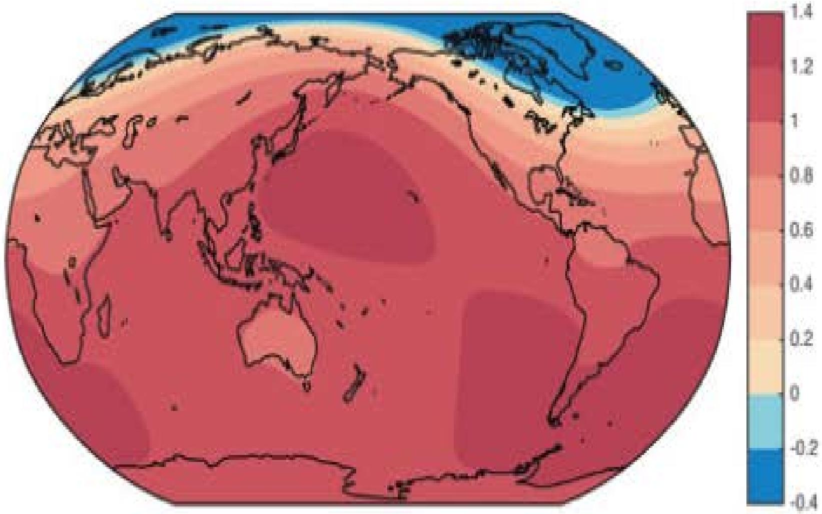

m/yr
2
-2
West Antarctica
East Antarctica


Bedrock elevation (m)
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
Weddell Sea
BS
AS
Siple C
Ross Sea
Aurora Basin
Wilkes Basin
Ice speed (m/yr)
1000
900
800
700
600
500
400
300
200
100
0
Larsen C I.S.
Ronne I.S.
Amery I.S.
WAIS
EAIS
Pine Island
Thwaites
Ross I.S.
Totten

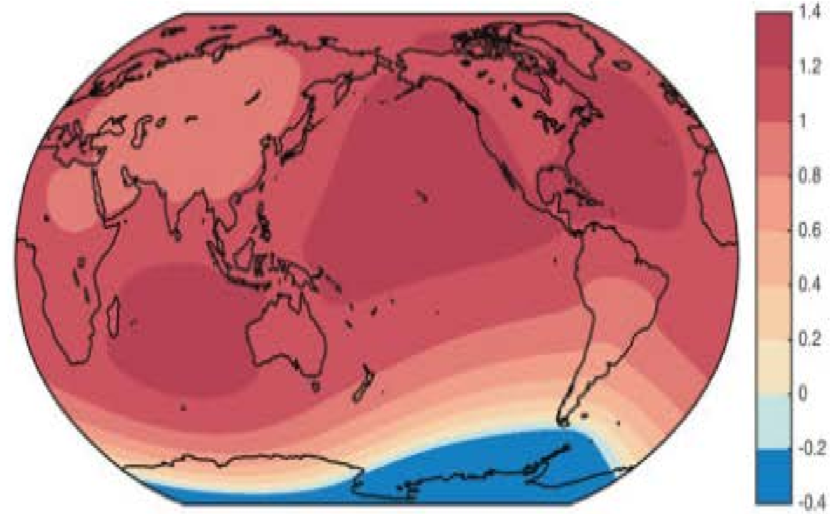


1.5
1
0.5
0
Δ GMSL (m)
RCP2.6
RCP4.5
RCP8.5
1.05 ± 0.30 m
0.49 ± 0.20 m
0.11 ± 0.11 m
2000
2020
2040
2060
2080
2100
Year (CE)
1.5
1
0.5
0
Δ GMSL (m)
RCP2.6
RCP4.5
RCP8.5
0.64 ± 0.49 m
0.26 ± 0.28 m
0.02 ± 0.13 m
2000
2020
2040
2060
2080
2100
Year (CE)
1000
900
800
700
600
500
400
300
2000
2025
2050
2075
2100

Contribution from Greenland Ice Sheet



Contribution from West Antarctic Ice Sheet



2.2. What are recent scientific advances in understanding sea-level rise?

2.2.1. New observations and understanding of climate changes

2.2.2. Advances in observing and modeling sea-level rise