Climate Change:
Observations, impacts and adaptation in high mountain areas

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Special Report on the Ocean and Cryosphere (SROCC)Outline

Chapter 1:	Framing and Context of the Report
Chapter 2:	High Mountain Areas
Chapter 3:	Polar Regions
Chapter 4:	Sea Level Rise and Implications for Low Lying Islands, Coasts and Communities
Chapter 5:	Changing Ocean, Marine Ecosystems, and Dependent Communities
Chapter 6:	Extremes, Abrupt Changes and Managing Risks

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SROCC – “High Mountains” chapter author team

Antisana Glacier, Ecuador
Sunday 11 February 2018

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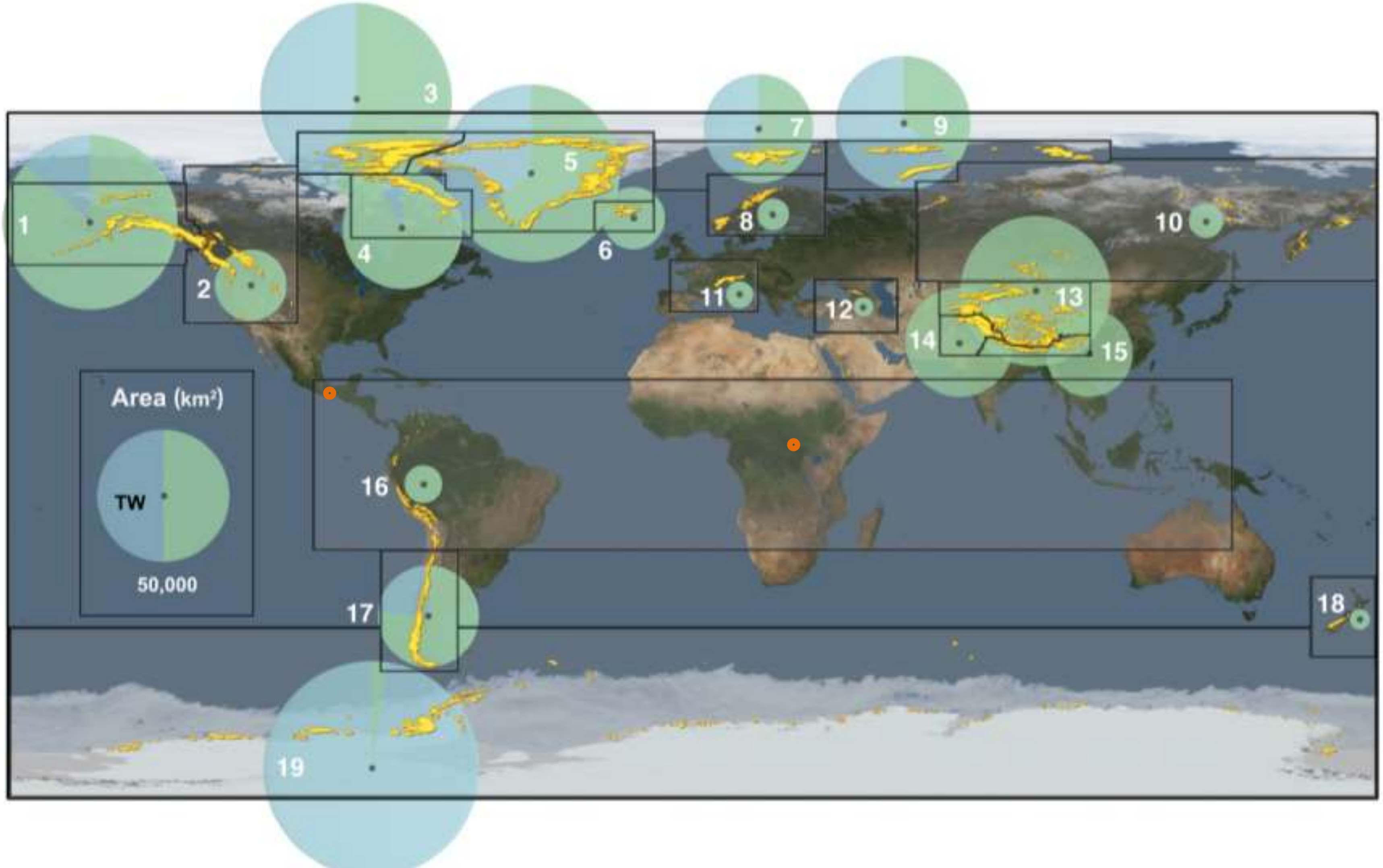
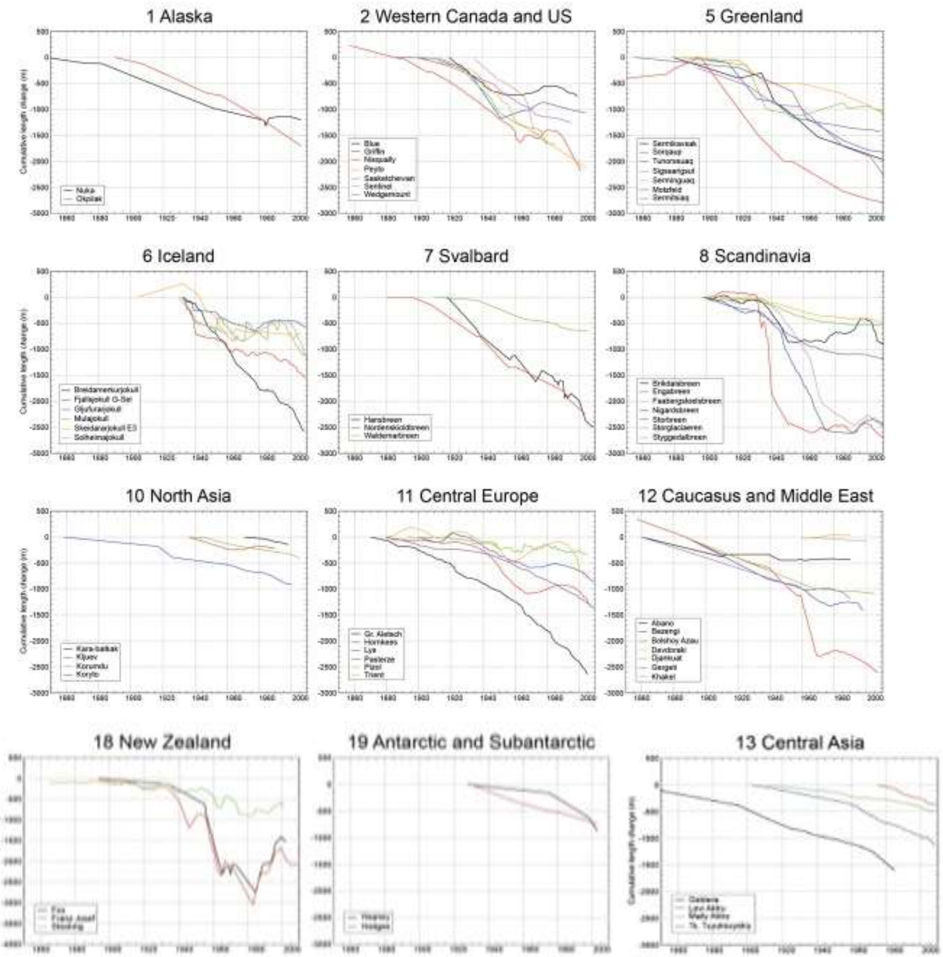
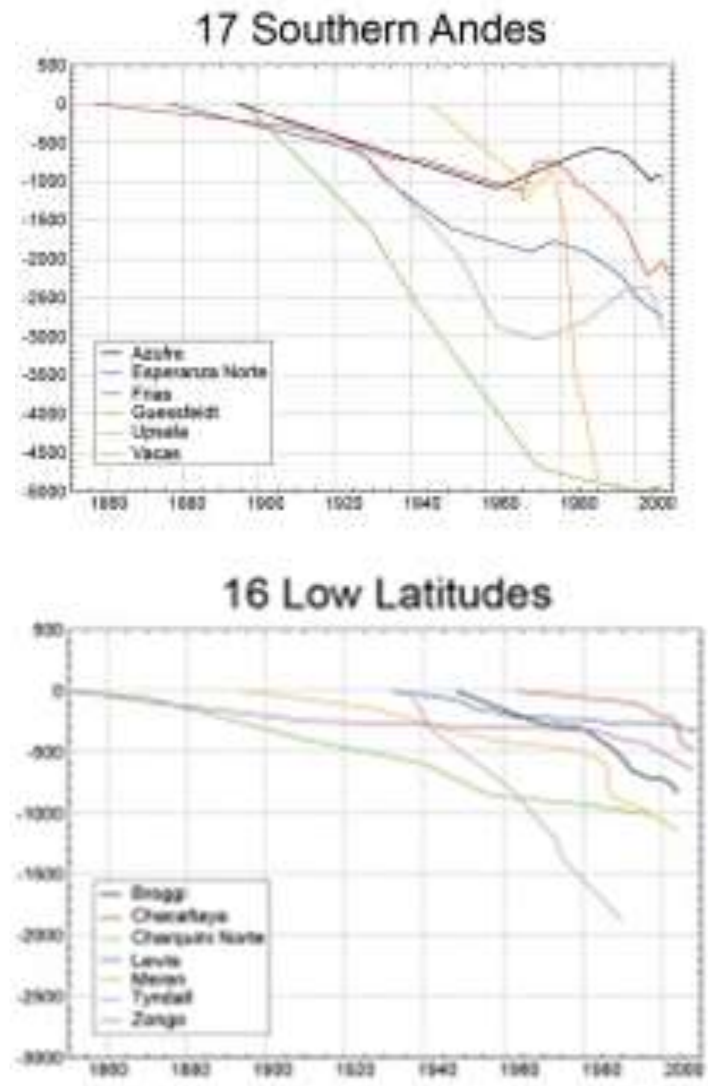
AR5 - Global distribution of glaciers

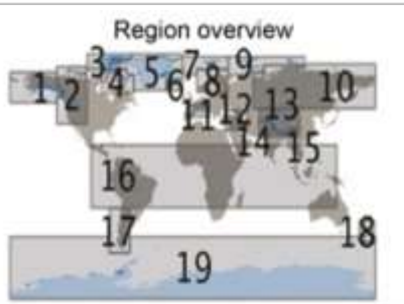


Source: IPCC – Climate Change 2013,
The Physical Science Basis. Chapter 4

AR5 - Selection of long-term cumulative glacier length changes as compiled from in situ measurements







Source: IPCC – Climate Change 2013
The Physical Science Basis. Chapter 4
WGMS. et.al., 2008-2012

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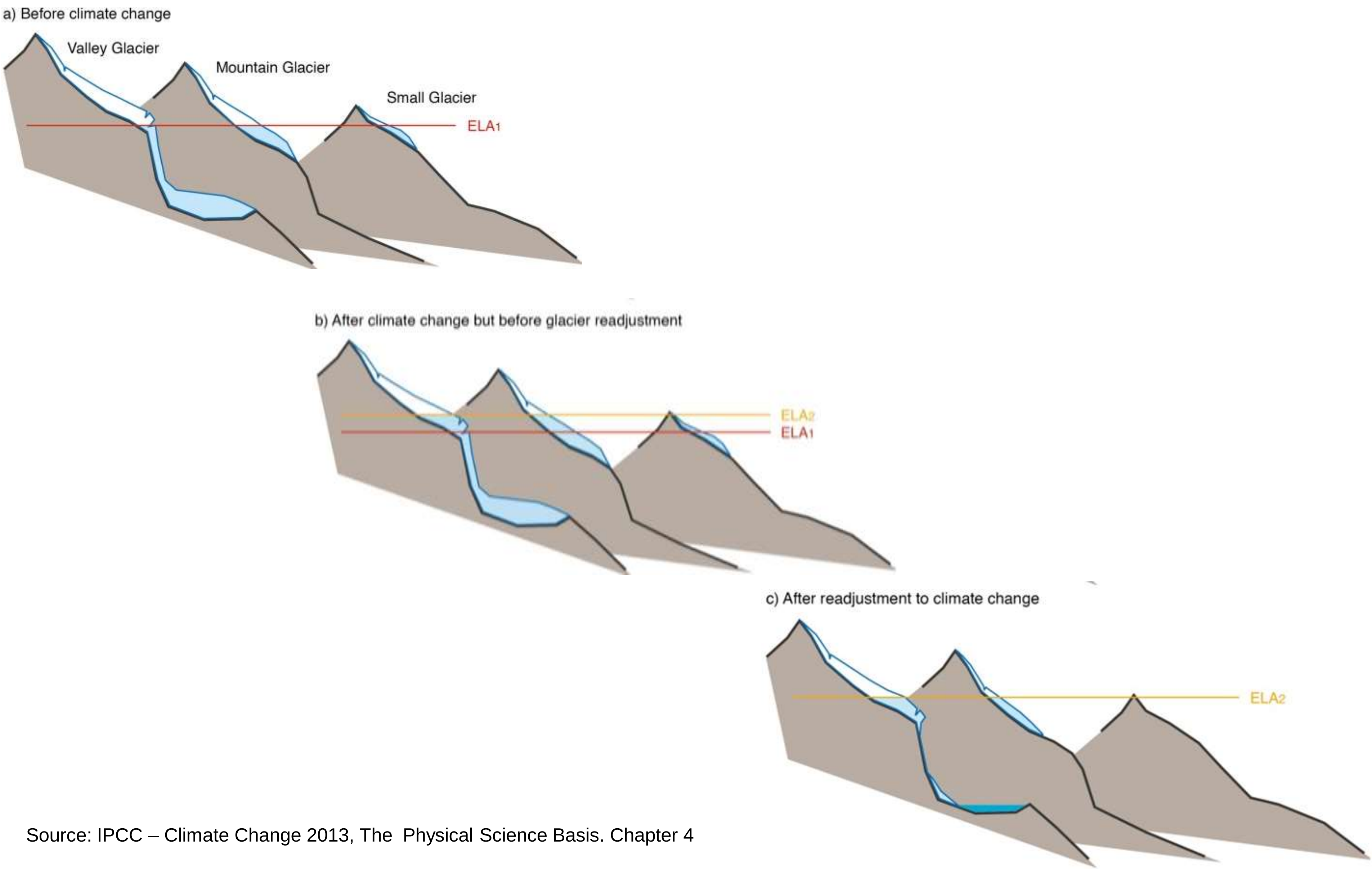
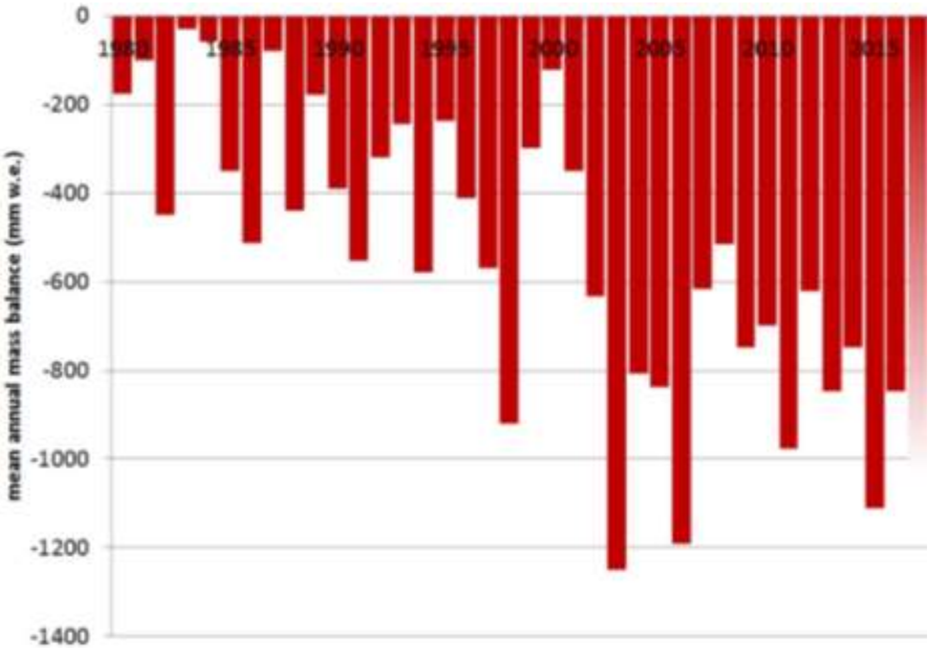
AR5 - Schematic of three types of glaciers located at different elevations, and their response to an upward shift of the equilibrium line altitude (ELA).

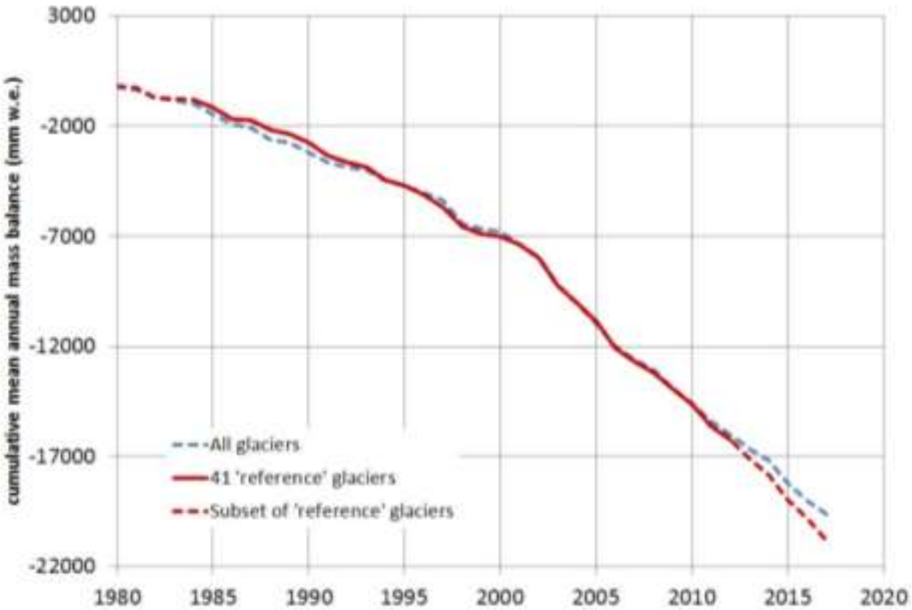


Source: IPCC – Climate Change 2013, The Physical Science Basis. Chapter 4

New studies since AR5 - Evolution over mass balance: Period 1980-2016



Mean annual mass balance of reference glaciers
Source: WGMS (2017)



Mean cumulative mass balance for 140 reported glaciers (blue line) and the reference glaciers 30 (red line).
Source: WGMS (2017)

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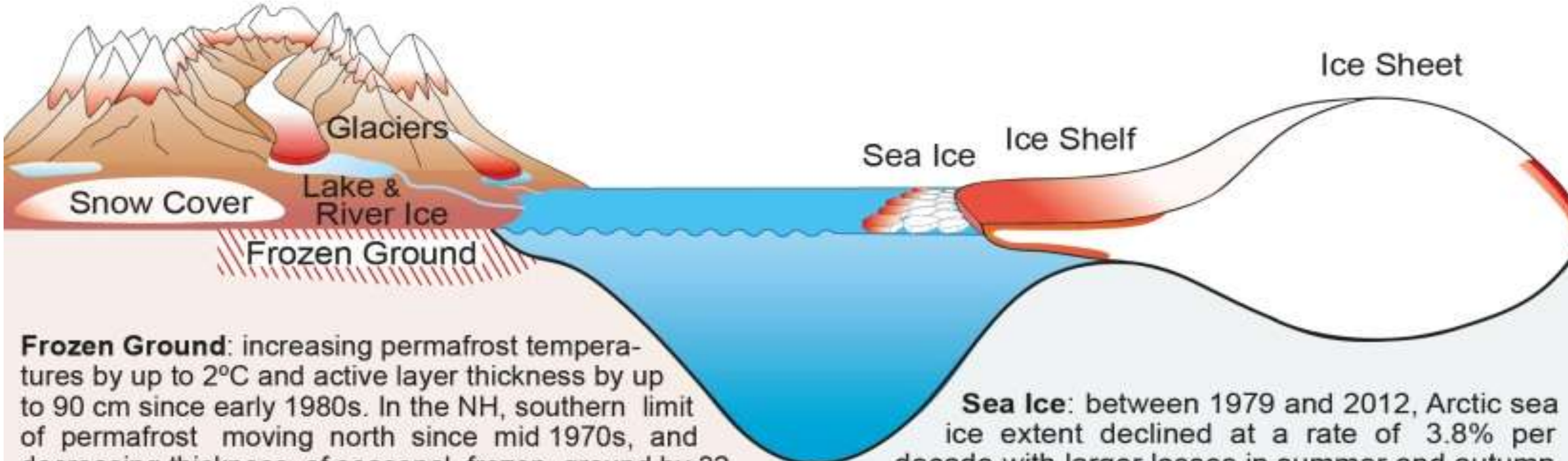
AR5 – Changes in the Cryosphere



Frozen Ground: increasing permafrost temperatures by up to 2ºC and active layer thickness by up to 90 cm since early 1980s. In the NH, southern limit of permafrost moving north since mid 1970s, and decreasing thickness of seasonal frozen ground by 32 cm since 1930s.

Snow cover: between 1967 and 2012, satellite data show decreases through the year, with largest decreases (53%) in June. Most stations report decreases in now especially in spring.

Lake and river ice: contracting winter ice duration with delays in autumn freeze-up proceeding more slowly than advances in spring break-up, with evidence of recent acceleration in both across the NH.

Glaciers: are major contributors to sea level rise. Ice mass loss from glaciers has increased since the 1960s. Loss rates from glaciers outside Greenland and Antarctica were 0.76 mm yr^{-1} SLE during the 1993 to 2009 period and 0.83 mm yr^{-1} SLE over the 2005 to 2009 period.

Sea Ice: between 1979 and 2012, Arctic sea ice extent declined at a rate of 3.8% per decade with larger losses in summer and autumn. Over the same period, the extent of thick multiyear ice in the Arctic declined at a higher rate of 13.5% per decade. Mean sea ice thickness decreased by 1.3 - 2.3 m between 1980 and 2008.

Ice Shelves and ice tongues: continuing retreat and collapse of ice shelves along the Antarctic Peninsula. Progressive thinning of some other ice shelves/ice tongues in Antarctica and Greenland.

Ice Sheets: both Greenland and Antarctic ice sheets lost mass and contributed to sea level change over the last 20 years. Rate of total loss and discharge from a number of major outlet glaciers in Antarctica and Greenland increased over this period.

Source: IPCC – Climate Change 2013
The Physical Scince Basis. Chapter 4

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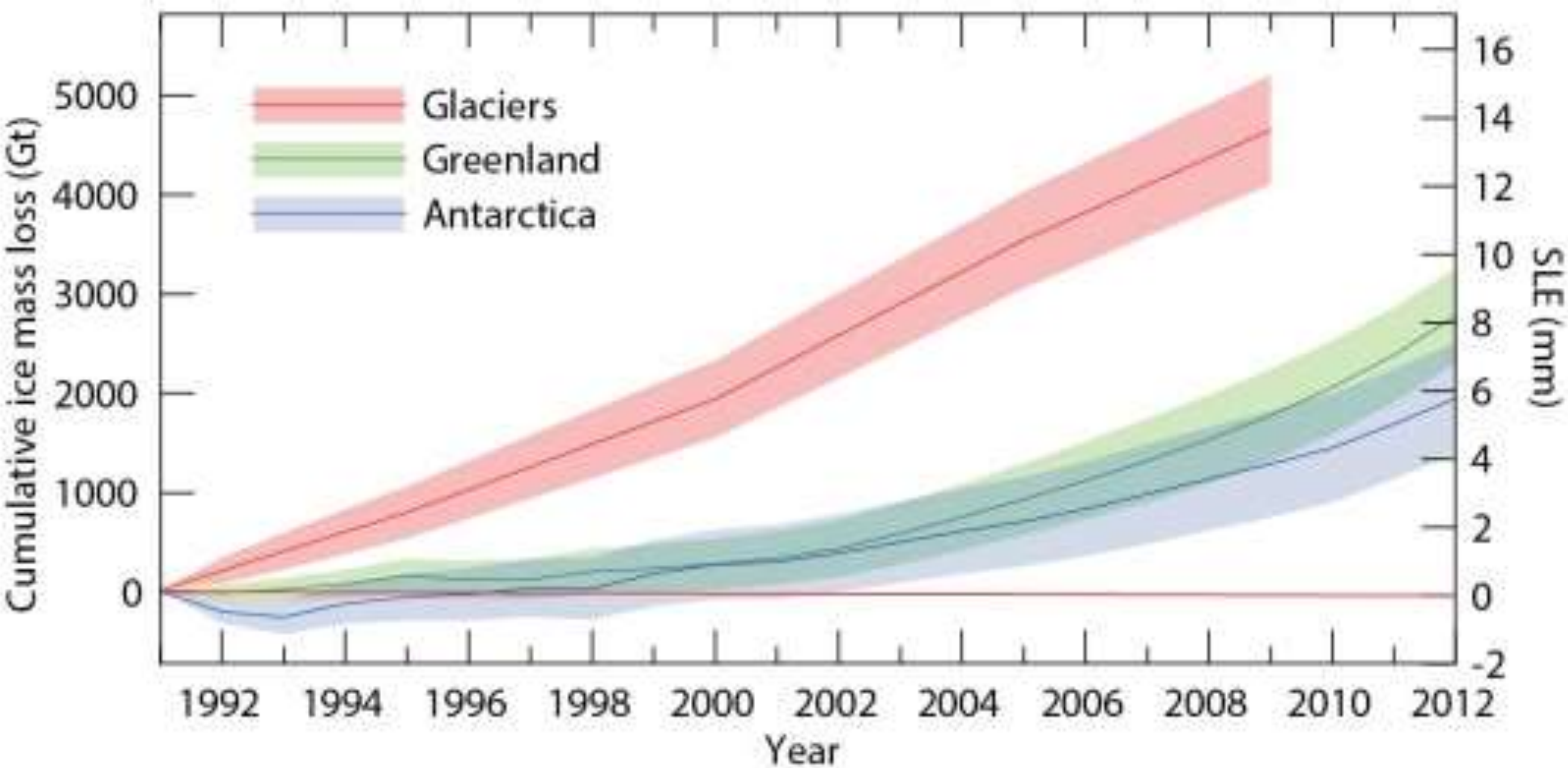
AR5 – Contribution of Glaciers and Ice Sheets to Sea Level Change



Cumulative ice mass loss from glacier and ice sheets (in sea level equivalent) is 1.0 to 1.4 mm yr^{-1} for 1993-2009 and 1.2 to 2.2 mm yr^{-1} for 2005-2009.

Source: IPCC – Climate Change 2013
The Physical Scince Basis. Chapter 4

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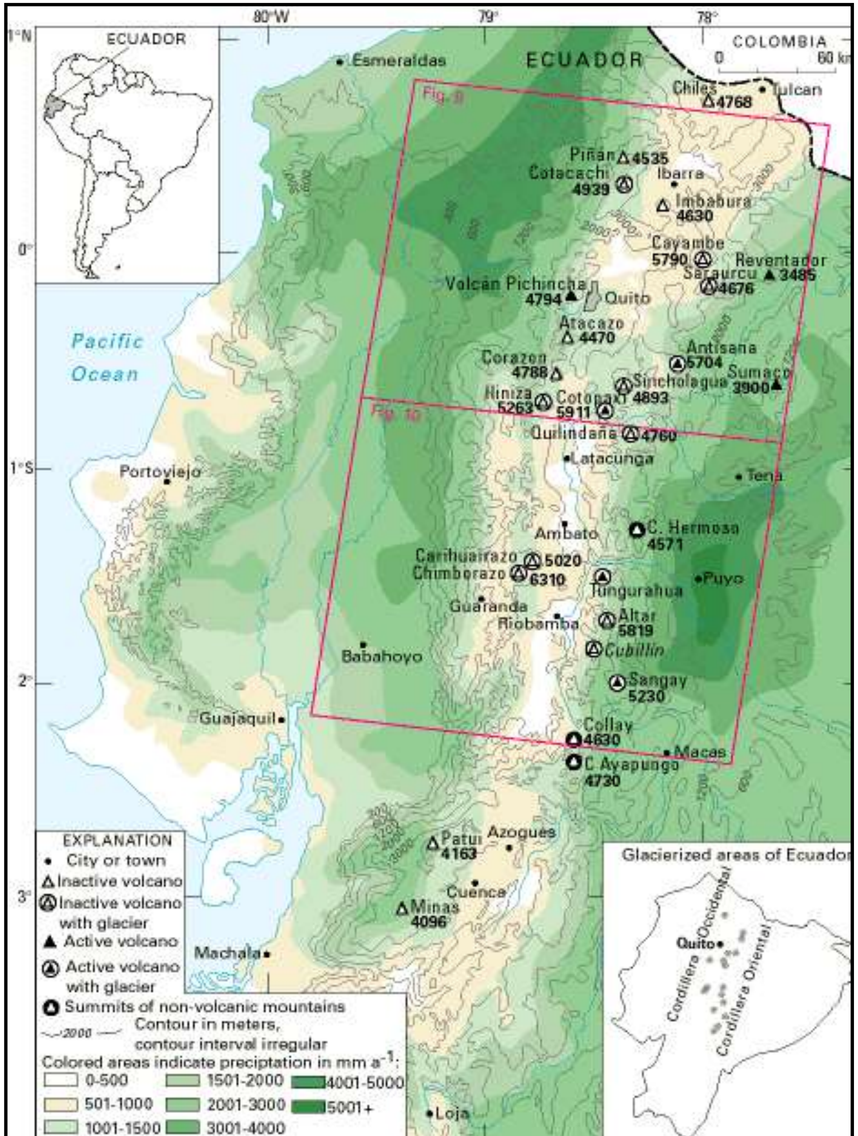
Cryosphere in Ecuador



Glaciers coverage in Ecuador
Seven ice caps

Chimborazo Ice cap. Photo B. Cáceres 2017

National Glacier Inventory

Year-Inventory (Aerial Photos)	Area (km^2)	Author-year
1960	97,2	*Hastenrath-Jordan 1999*
1997	60,7	*Cáceres-2010*
2015-2016	43,5	*Cáceres-2016-2017-2018*

Percent reduction 55.2%, period : 1960-2016

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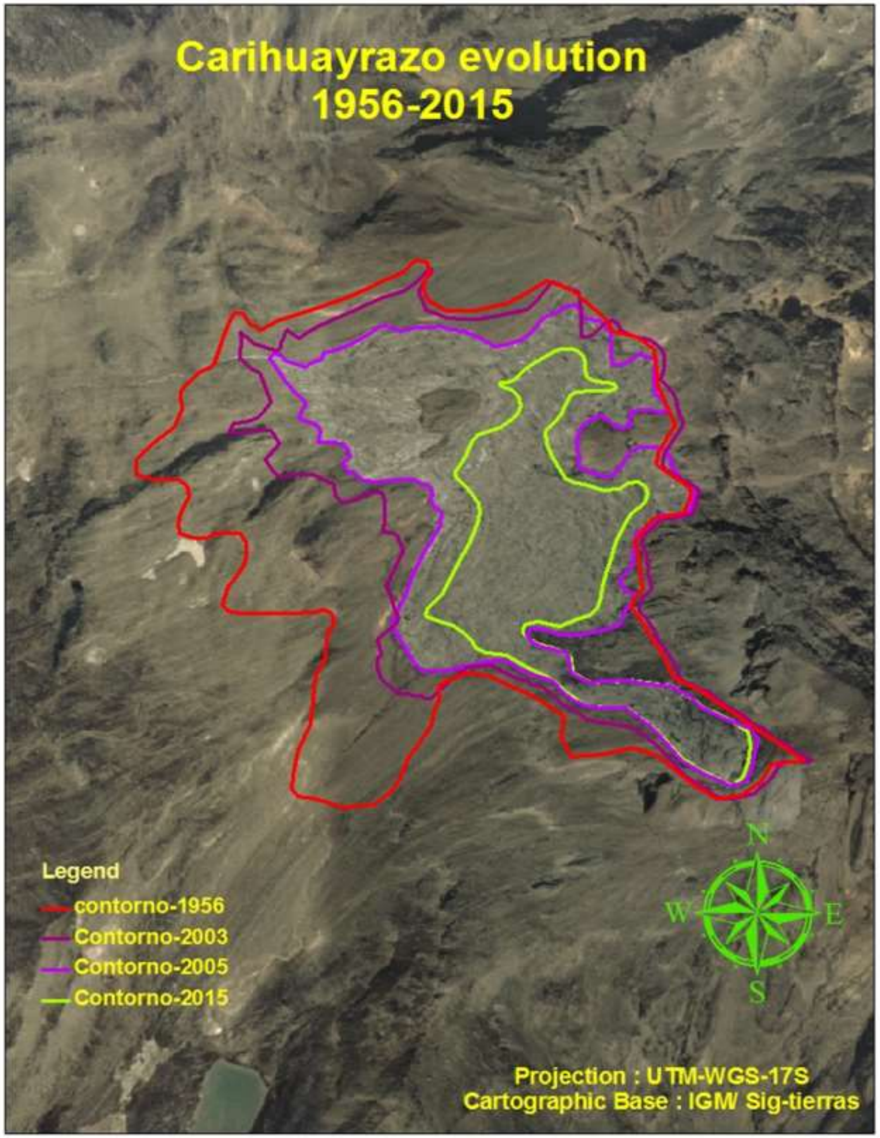
Cryosphere in Ecuador



Carihuayrazo glacier coverage
Period : 1956-2015

Carihuayrazo Glacier Inventory

Year	Area (m2)	Type of measurement	% reduction
1956	*333422*	*Photogrametry*	*0*
2003	*234249*	*Field measurements*	*29,7*
2004	*215019*	*Field measurements*	*35,5*
2005	*158967*	*Field measurements*	*52,3*
2006	*156553*	*Field measurements*	*53,0*
2007	*151150*	*Field measurements*	*54,7*
2008	*156870*	*Field measurements*	*53,0*
2009	*155685*	*Field measurements*	*53,3*
2010	*143456*	*Field measurements*	*57,0*
2011	*115559*	*Field measurements*	*65,3*
2012	*104676*	*Field measurements*	*68,6*
2013	*90061*	*Field measurements*	*73,0*
2014	*84764*	*Field measurements*	*74,6*
2015	*72746*	*Field measurements*	*78,2*

Source : Cáceres B. AGU 2015

Percent reduction 91%, April 2017

Source : Cáceres B. In preparation

Cryosphere change – personal observations

Ried Glacier, Valais, Swiss Alps – August 2015.
Photo: Carolina Adler

Ried Glacier, Valais, Swiss Alps – August 2015.
Photo: Carolina Adler

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AR5 - cryospheric change key impacts in the Andean region

Impacts of climate change on cryosphere at global scales

- Changing precipitation or melting snow and ice are **altering hydrological systems**, affecting water resources in terms of quantity and quality

In Central and South America

- Shrinkage of Andean glaciers
- Changes in extreme flows in Amazon River
- Changes in discharge patterns in rivers in western Andes

Photos: Carolina Adler

Source: IPCC, (2014). Summary for policymakers, in Climate Change 2014: Impacts, Adaptation, and Vulnerability.

AR5 - cryospheric change
Examples of adaptation responses in the Andean region

- Integrated water resource management
- Urban and rural flood management (including infrastructure), early warning systems, better weather and runoff forecasts, and infectious disease control
- Ecosystem-based adaptation including protected areas, conservation agreements, and community management of natural areas is occurring.
- Resilient crop varieties, climate forecasts, and integrated water resources management are being adopted within the agricultural sector in some areas.

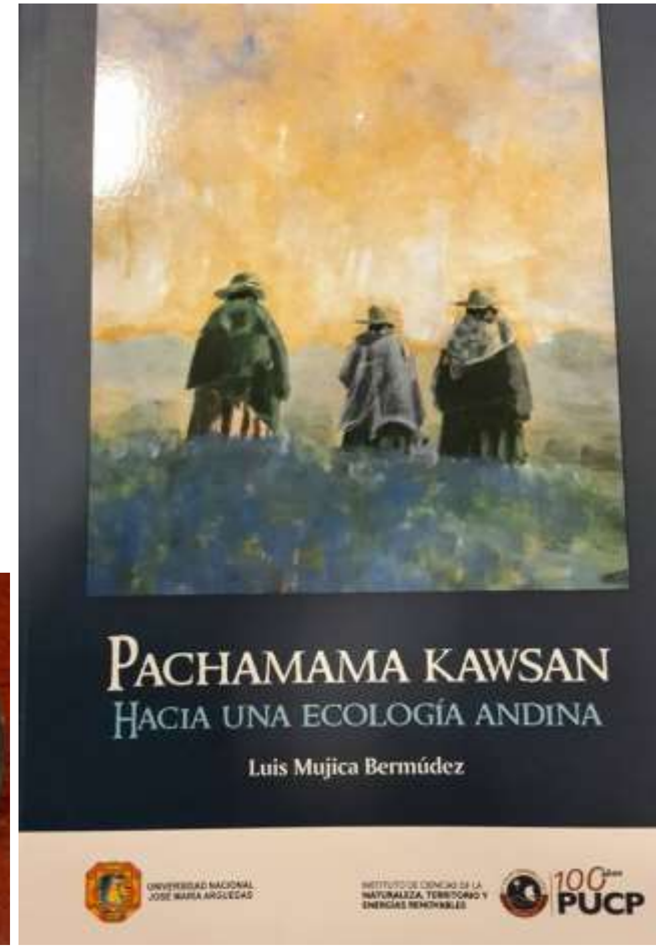


Photos: Carolina Adler

Source: IPCC, (2014). Summary for policymakers, in Climate Change 2014: Impacts, Adaptation, and Vulnerability.

Cryospheric change – impacts and adaptation New considerations for SROCC

- AR5 – a key adaptation issue for the Andean region entails "*strengthening traditional indigenous knowledge systems and practices*"
- New studies and publications in recent years document contributions from indigenous and local knowledge in the design and implementation of adaptation strategies



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Gracias!

Bolívar Cáceres & Carolina Adler
SROCC High Mountains authors team
Antisana Glacier, Ecuador, 11 February 2018

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THANK YOU FOR YOUR ATTENTION!

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