Glaciers_cci

Achievements (data production and use)

F. Paul (GIUZ) for the Glaciers_cci consortium

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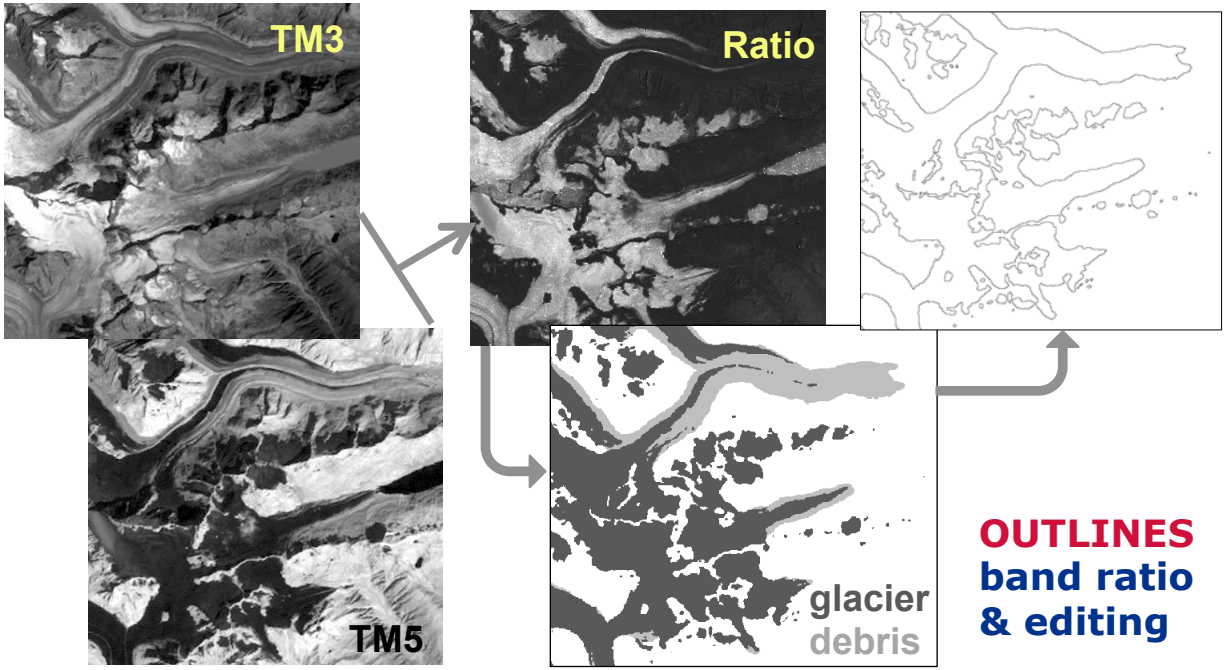
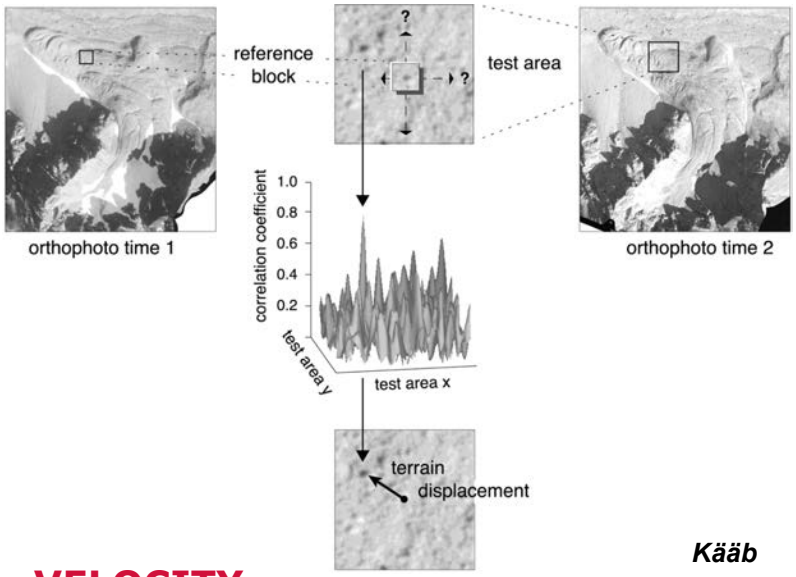
GAMMA REMOTE SENSING

Products: How? (methods)



OUTLINES
band ratio & editing

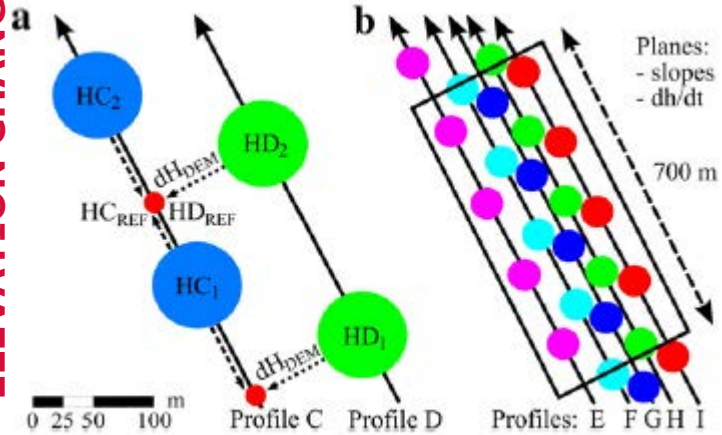


Kääb

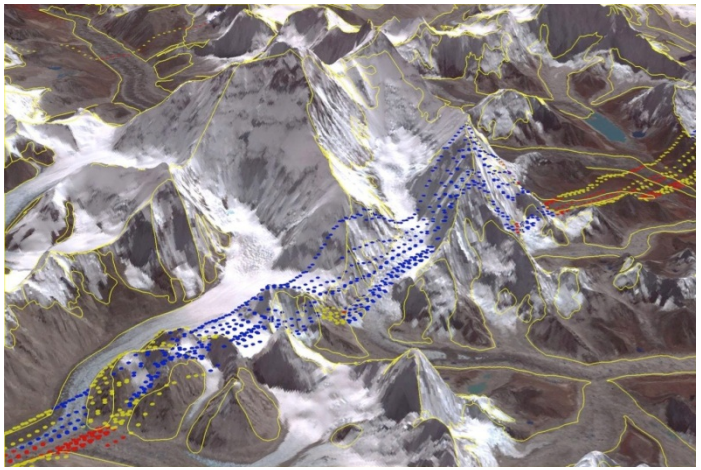
VELOCITY
cross-correlation (offset tracking)

ELEVATION CHANGE

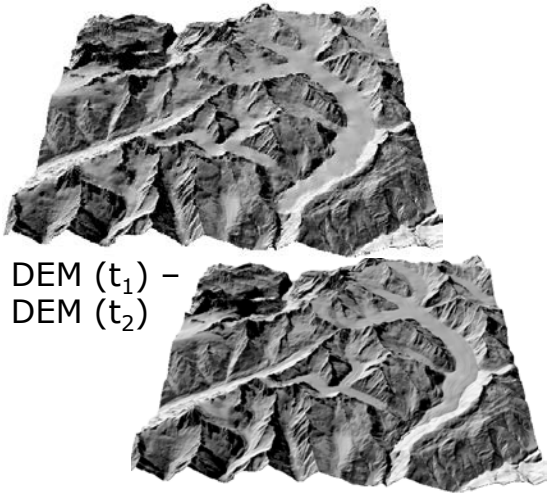
(1) Repeat Altimetry



(2) Altimetry-DEM

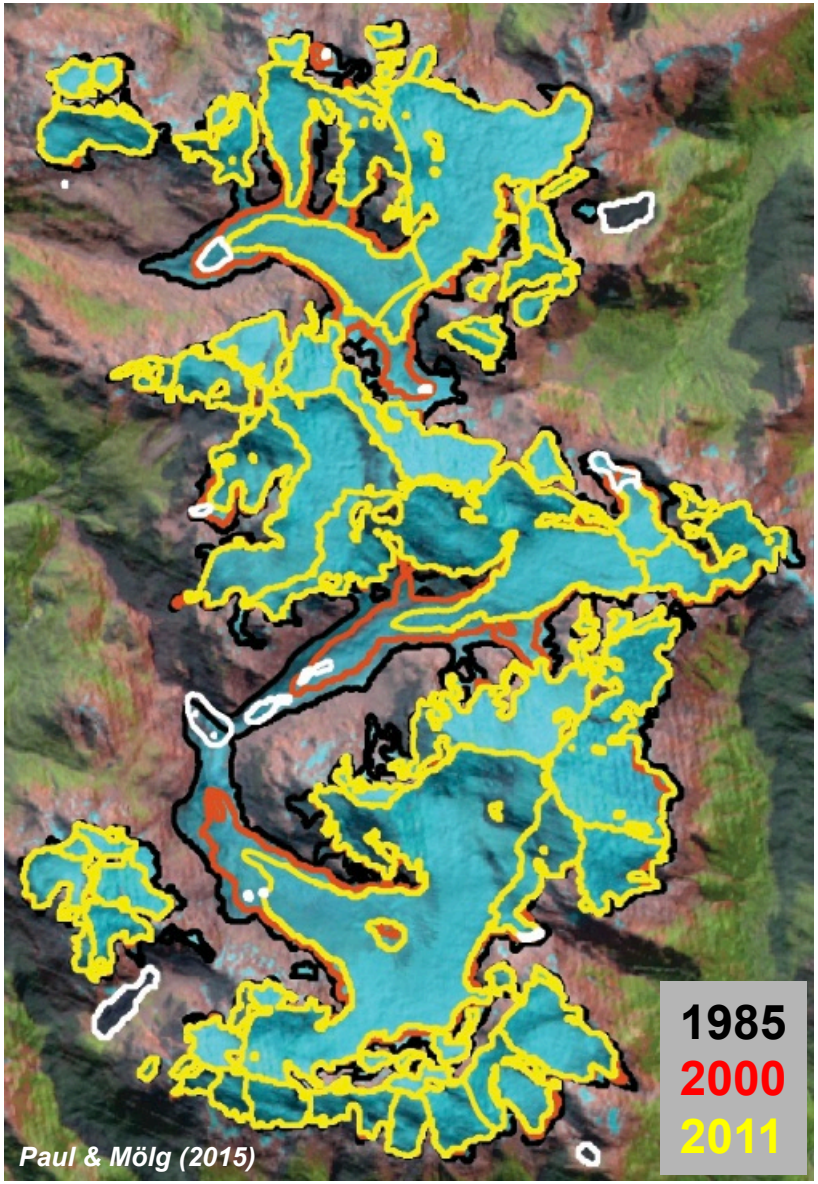


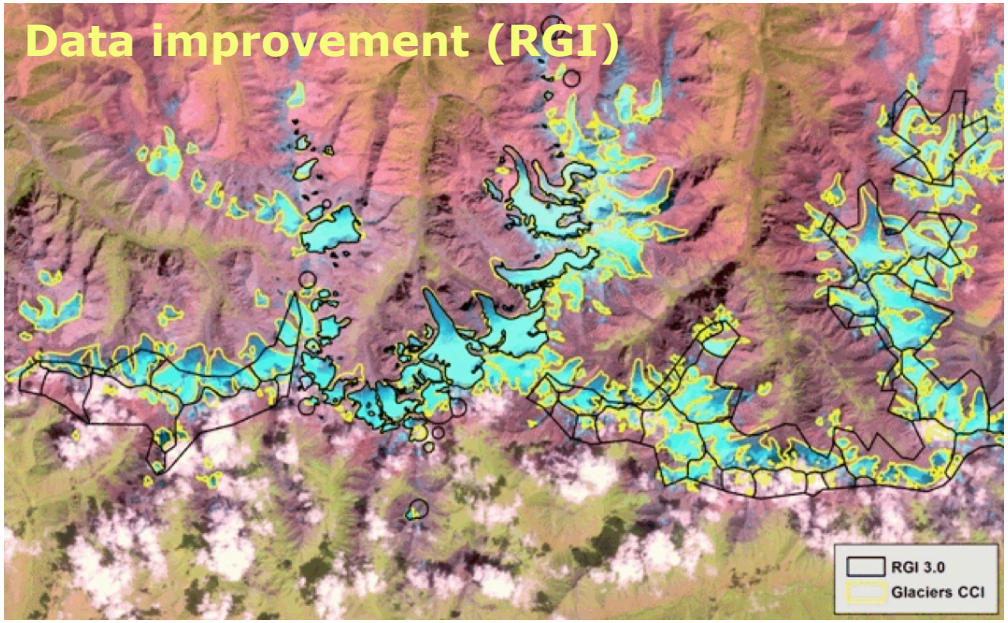
(3) DEM differencing

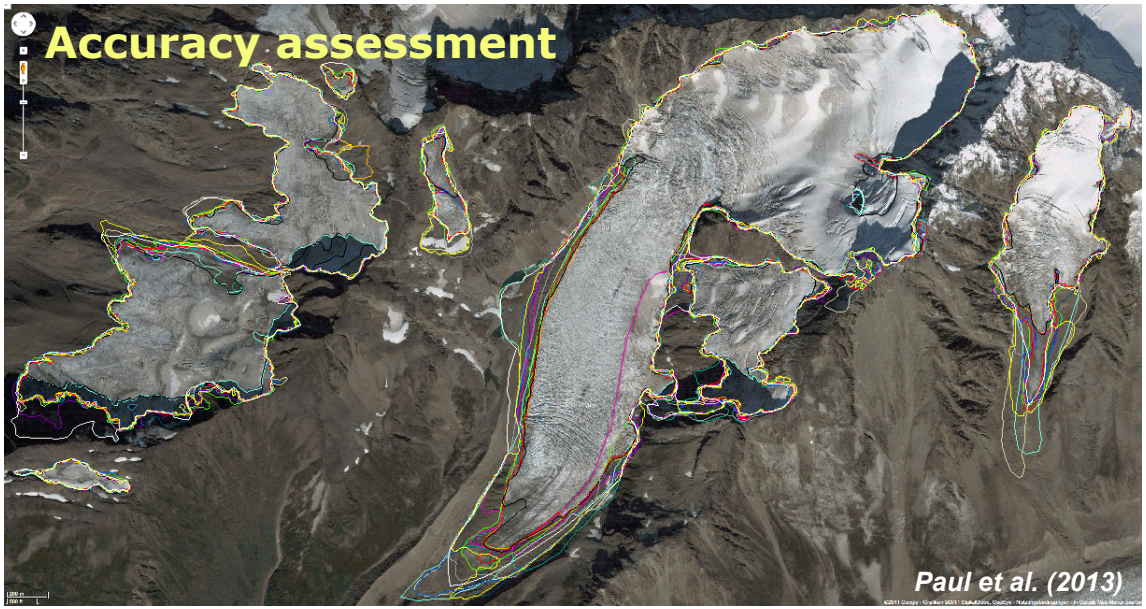


Products: What? (area)

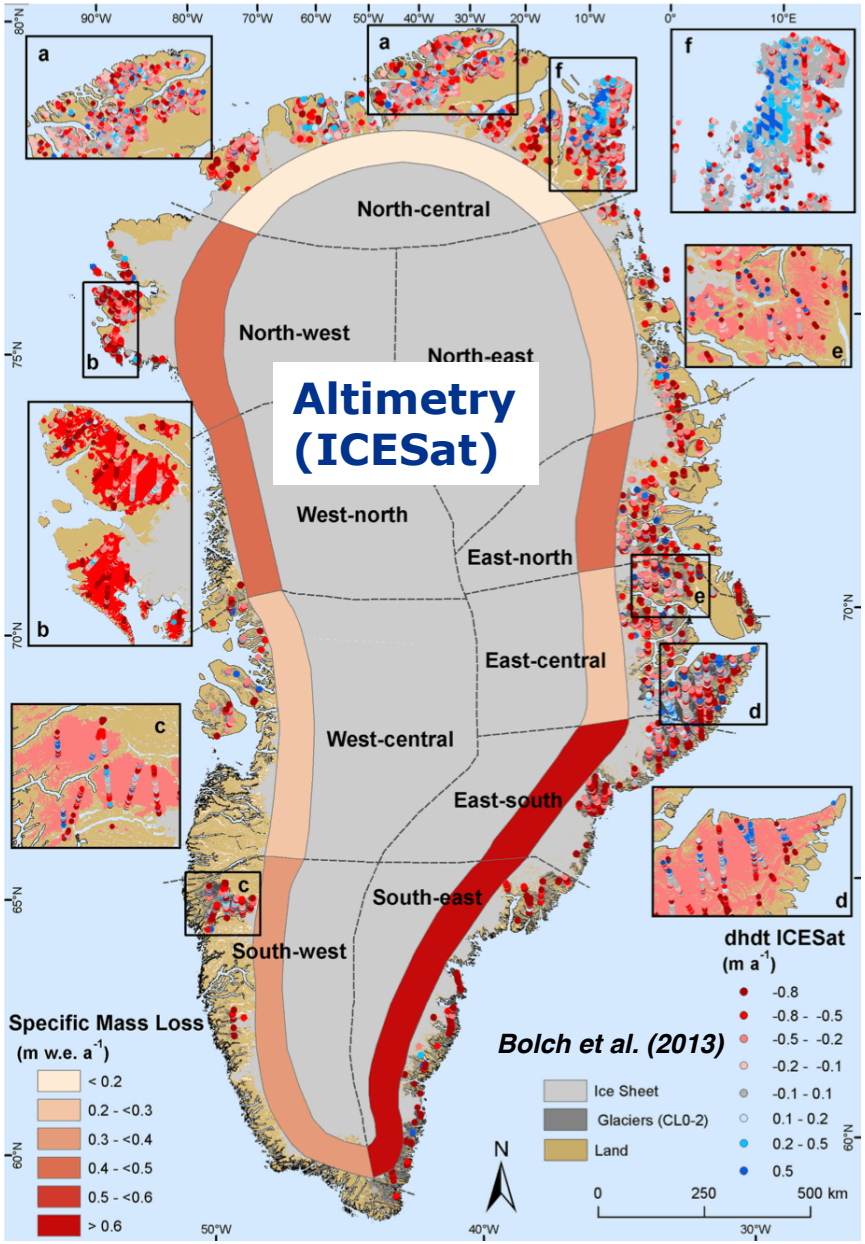
Change assessment

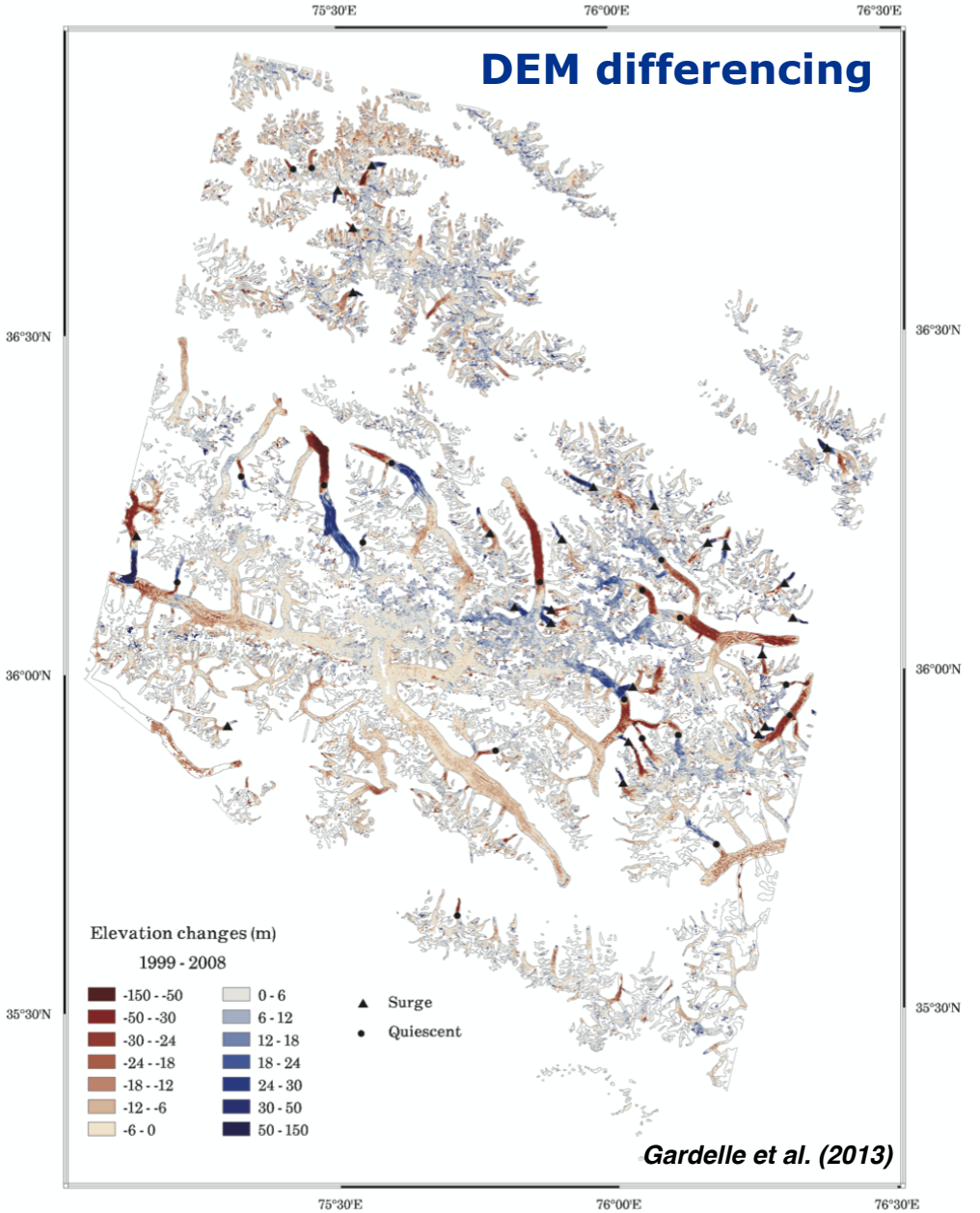






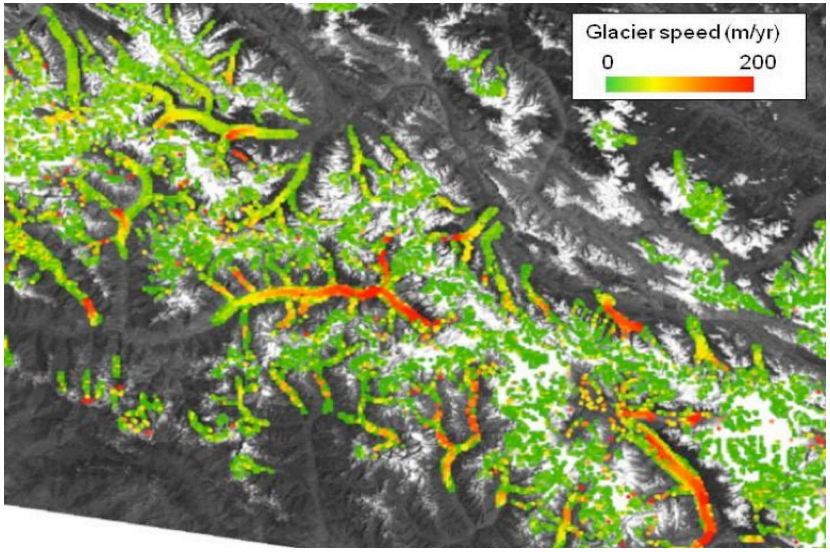
Products: What? (elevation change)



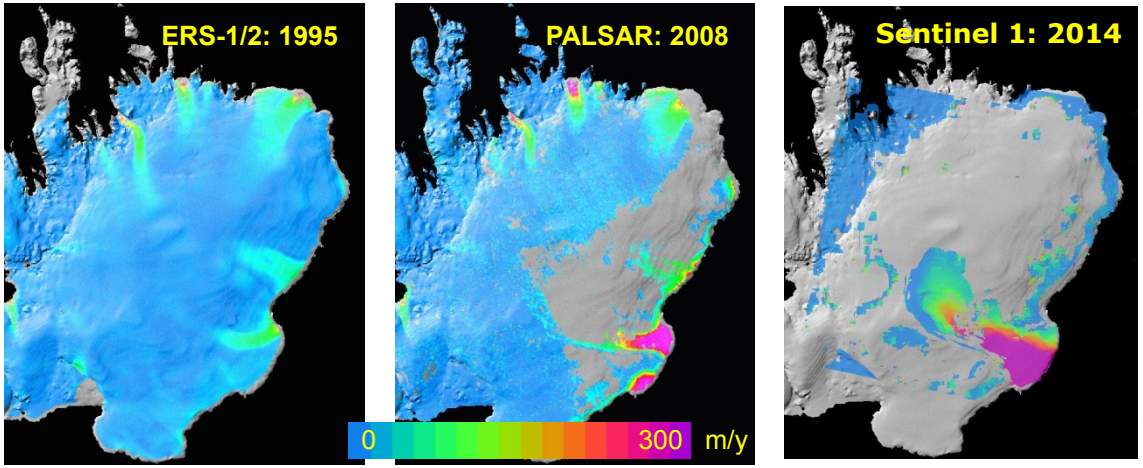


Products: What? (velocity)

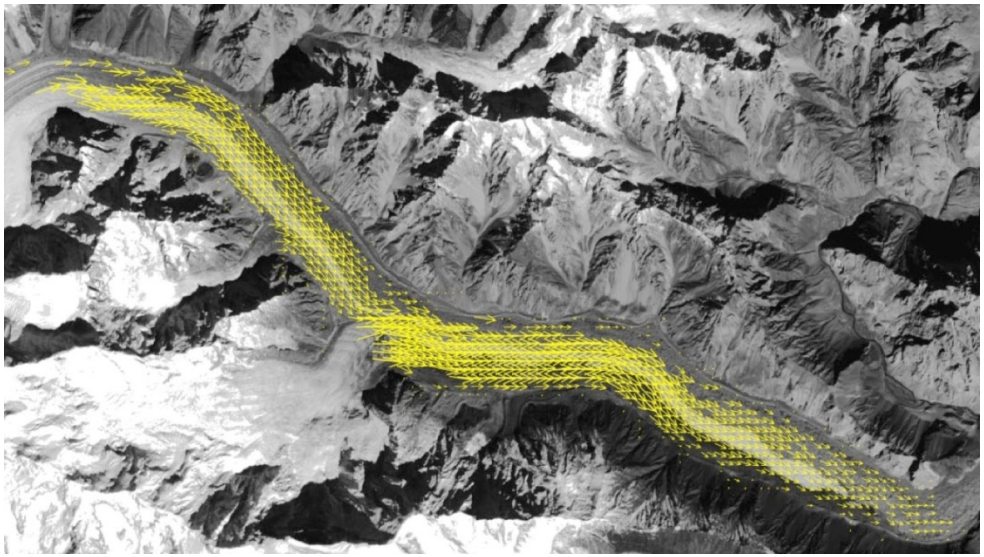
Velocity fields



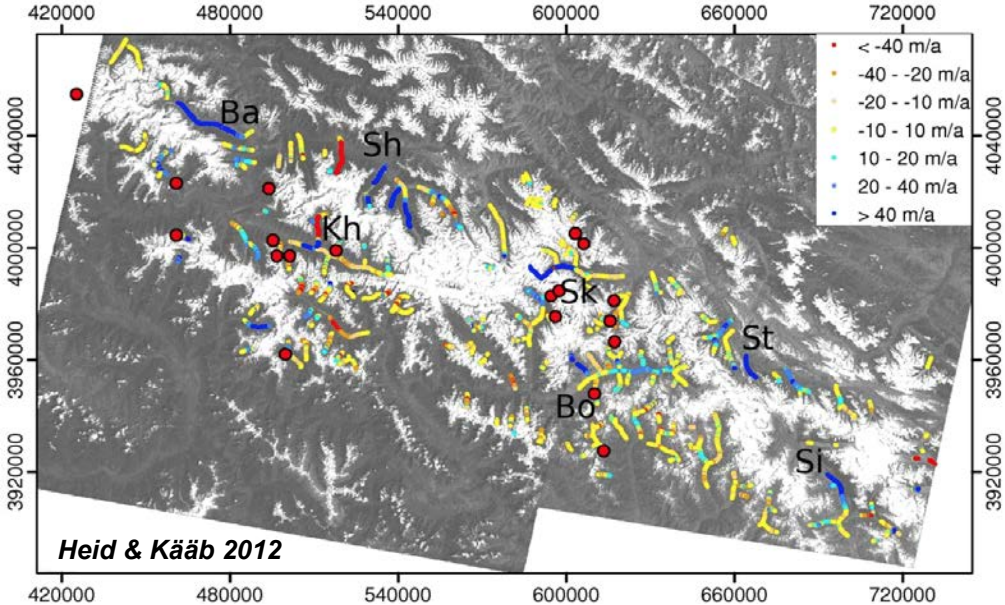
Velocity: time series



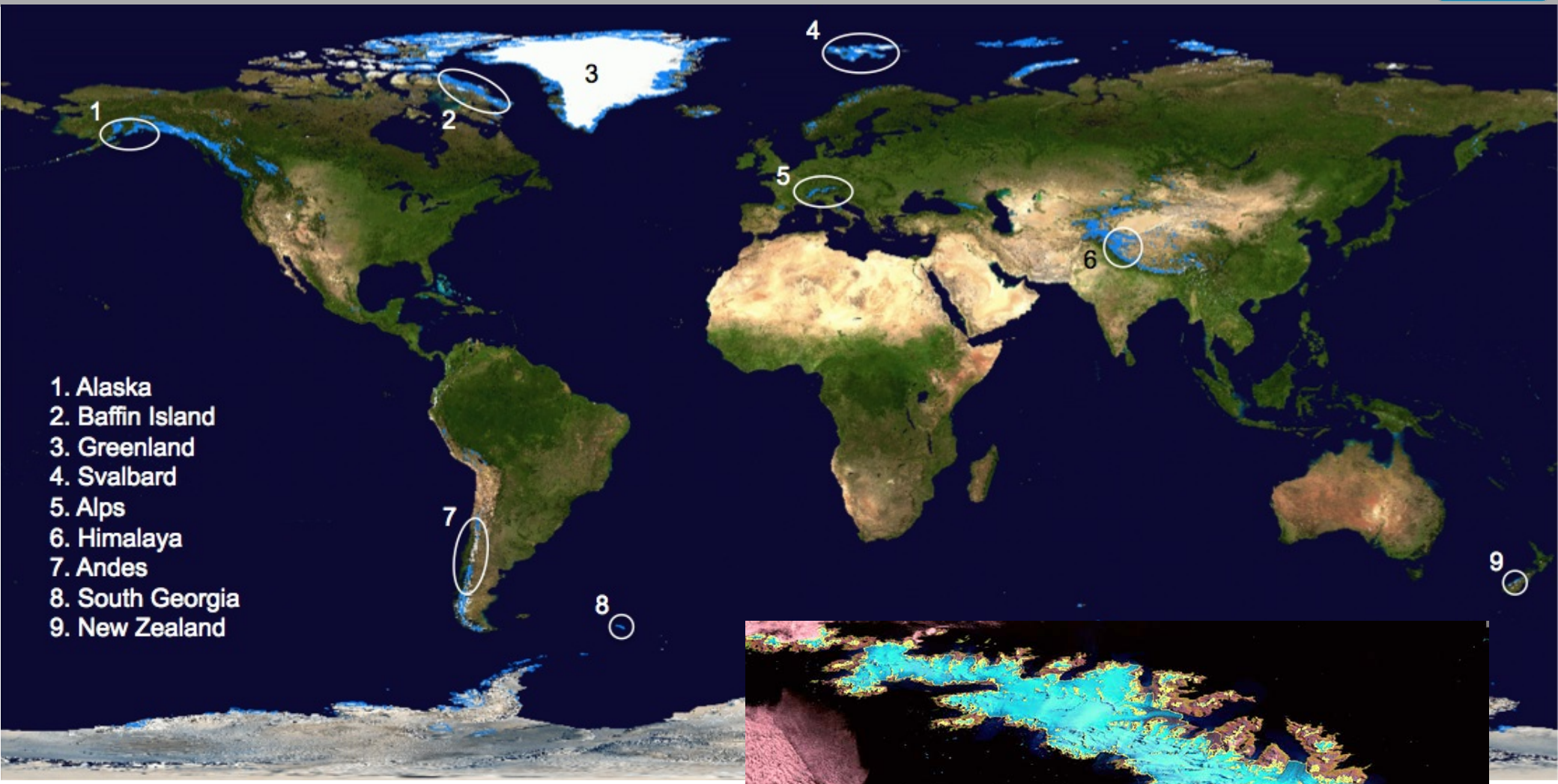
Velocity vectors

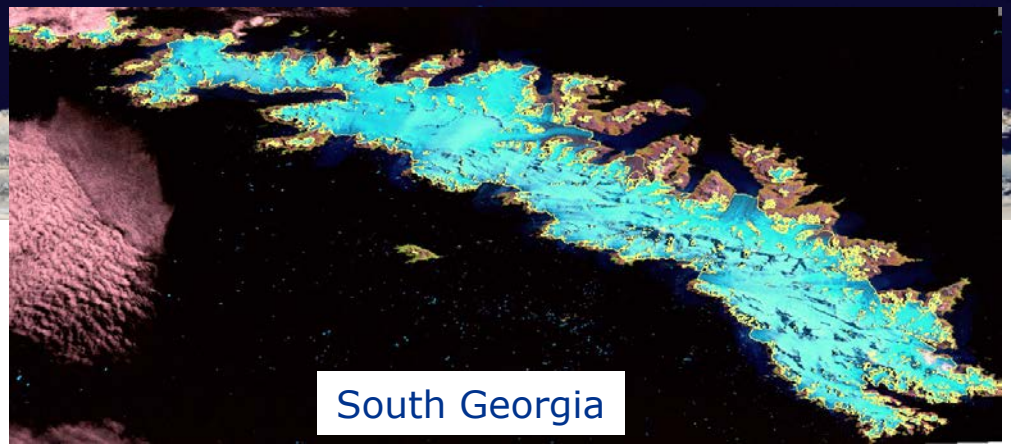


Velocity: decadal trends



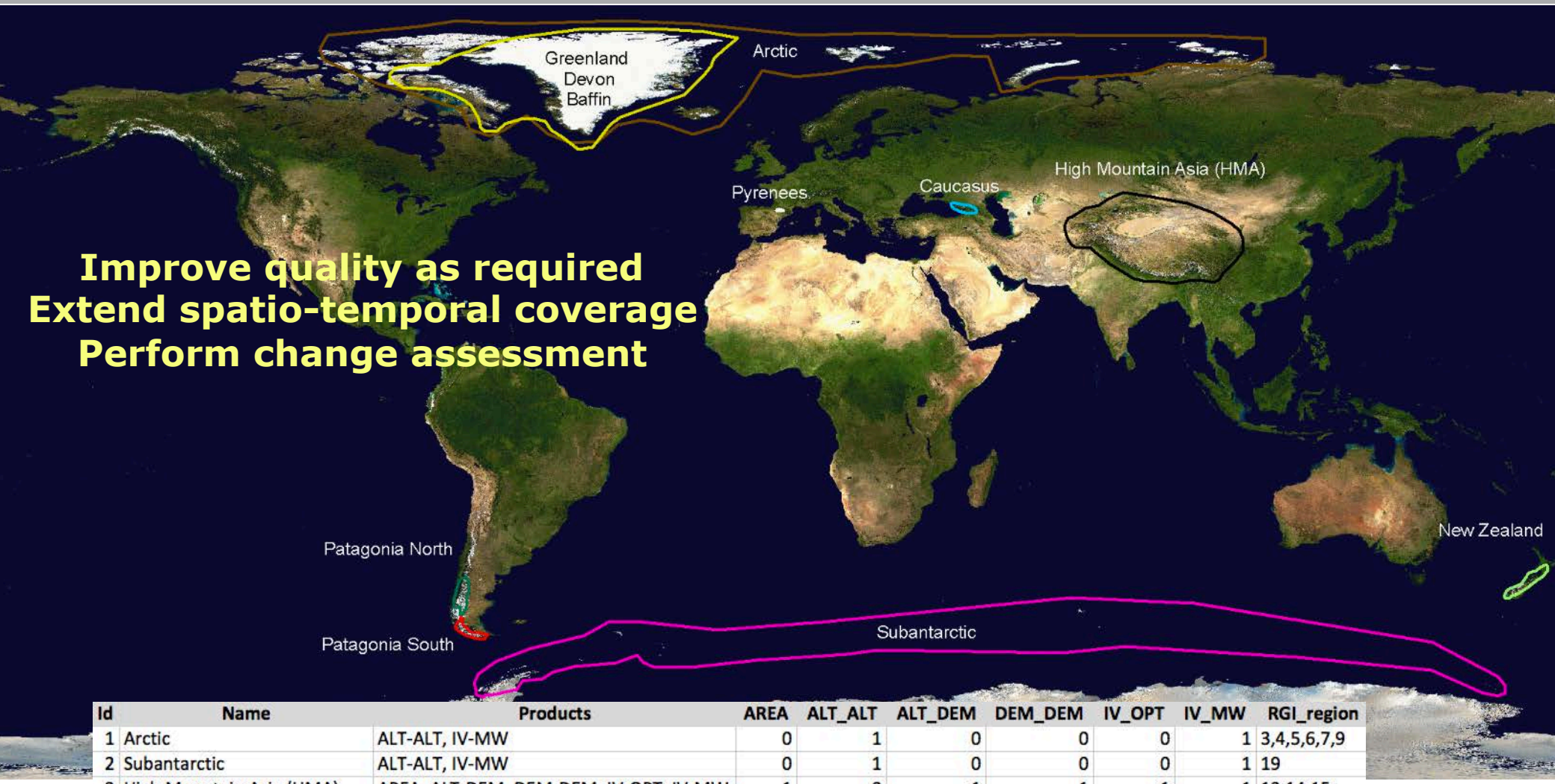
Products: Where? (phase 1 regions)





Randolph Glacier Inventory (RGI)
is merged from GLIMS, DCW, WGI data and numerous new contributions

Products: Where? (phase 2 regions)



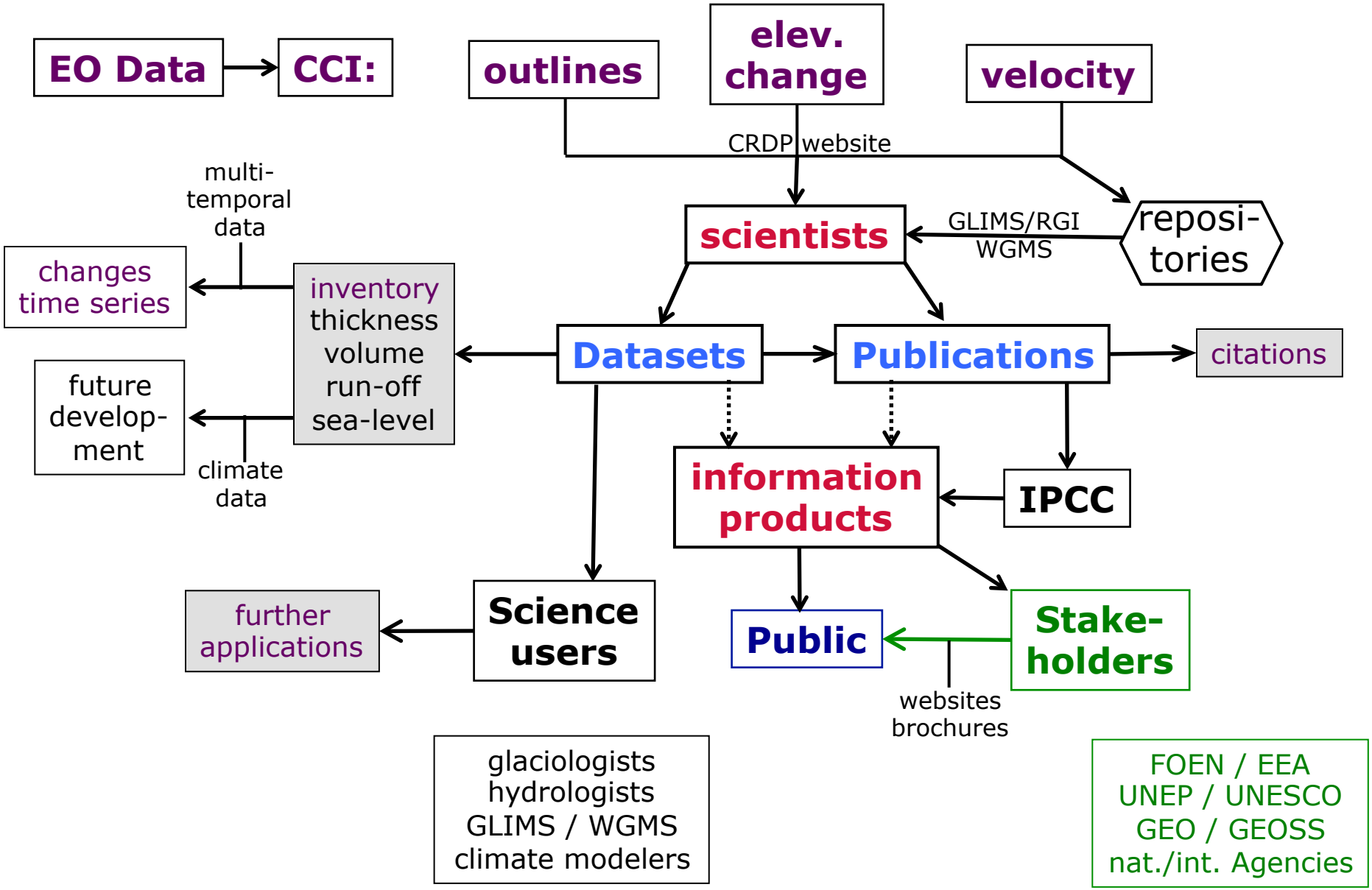
Improve quality as required
Extend spatio-temporal coverage
Perform change assessment

Id	Name	Products	AREA	ALT_ALT	ALT_DEM	DEM_DEM	IV_OPT	IV_MW	RGI_region
1	Arctic	ALT-ALT, IV-MW	0	1	0	0	0	1	3,4,5,6,7,9
2	Subantarctic	ALT-ALT, IV-MW	0	1	0	0	0	1	19
3	High Mountain Asia (HMA)	AREA, ALT-DEM, DEM-DEM, IV-OPT, IV-MW	1	0	1	1	1	1	13,14,15
4	Caucasus	DEM-DEM, IV-OPT	0	0	0	1	1	0	12
5	Pyrenees	AREA	1	0	0	0	0	0	11
6	Baffin Devon Greenland (BDG)	AREA, ALT-ALT, IV-OPT; IV-MW	1	1	0	0	1	1	3,4,5
7	Patagonia North	AREA, DEM-DEM, IV-OPT	1	0	0	1	1	0	17
8	Patagonia South	AREA, ALT-DEM, DEM-DEM, IV-OPT, IV-MW	1	0	1	1	1	1	17
9	New Zealand	AREA, DEM-DEM, IV-OPT	1	0	0	1	1	0	18

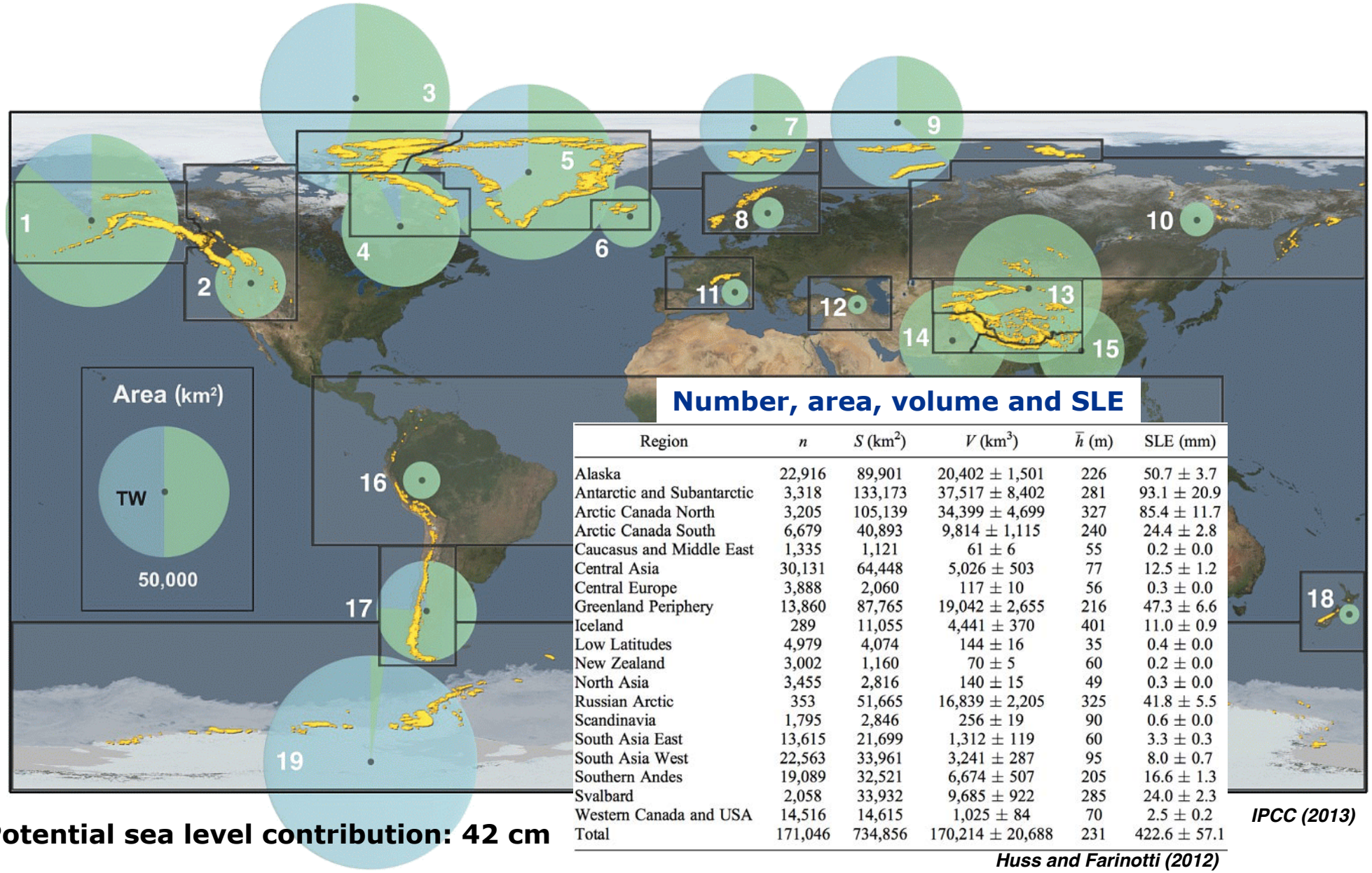
Glaciers_cci products: Who? (users)

- **Glacier outlines** are used as a key input dataset for all other glacier-specific calculations as well as for change assessment
- Our outlines are **integrated** in a global dataset (GLIMS/RGI)
- Key applications of the **RGI** are determination of total glacier volume, past changes in volume, future glacier evolution and impacts of changing glaciers on hydrology/run-off
- **Elevation/mass changes** inform all of the above of changes in water resources, run-off and sea-level contribution
- Data are used directly or for spatial interpolation / up-scaling
- **Flow velocities** and their changes inform directly on dynamic instabilities (surges) and mass fluxes but also on total volume
- Data are assimilated in models, results are interpreted visually

Glaciers_cci products: Who? (users)



RGI applications 1: Baseline dataset



Number, area, volume and SLE

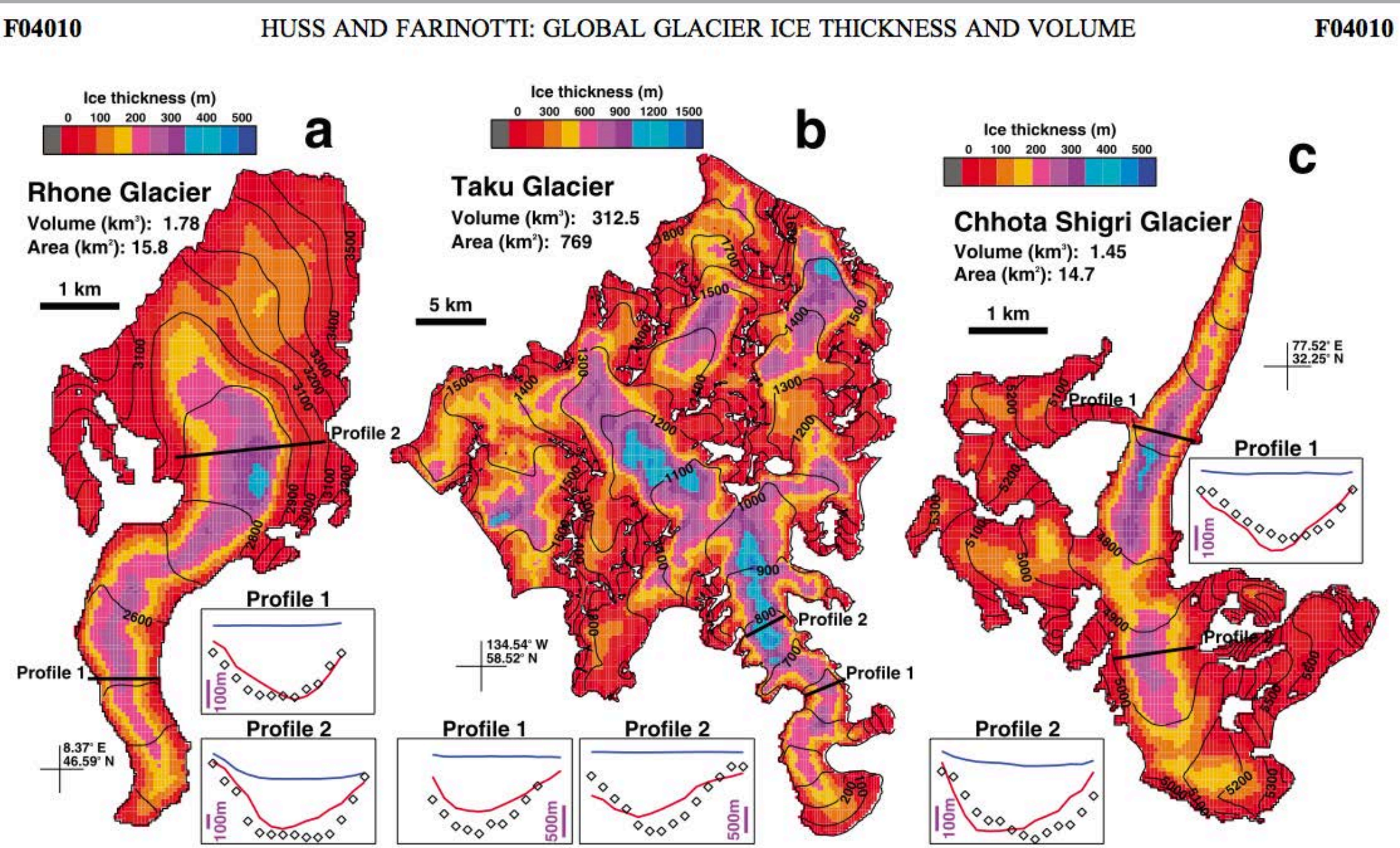
Region	n	S (km^2)	V (km^3)	$\bar{h}$ (m)	SLE (mm)
Alaska	22,916	89,901	20,402 ± 1,501	226	50.7 ± 3.7
Antarctic and Subantarctic	3,318	133,173	37,517 ± 8,402	281	93.1 ± 20.9
Arctic Canada North	3,205	105,139	34,399 ± 4,699	327	85.4 ± 11.7
Arctic Canada South	6,679	40,893	9,814 ± 1,115	240	24.4 ± 2.8
Caucasus and Middle East	1,335	1,121	61 ± 6	55	0.2 ± 0.0
Central Asia	30,131	64,448	5,026 ± 503	77	12.5 ± 1.2
Central Europe	3,888	2,060	117 ± 10	56	0.3 ± 0.0
Greenland Periphery	13,860	87,765	19,042 ± 2,655	216	47.3 ± 6.6
Iceland	289	11,055	4,441 ± 370	401	11.0 ± 0.9
Low Latitudes	4,979	4,074	144 ± 16	35	0.4 ± 0.0
New Zealand	3,002	1,160	70 ± 5	60	0.2 ± 0.0
North Asia	3,455	2,816	140 ± 15	49	0.3 ± 0.0
Russian Arctic	353	51,665	16,839 ± 2,205	325	41.8 ± 5.5
Scandinavia	1,795	2,846	256 ± 19	90	0.6 ± 0.0
South Asia East	13,615	21,699	1,312 ± 119	60	3.3 ± 0.3
South Asia West	22,563	33,961	3,241 ± 287	95	8.0 ± 0.7
Southern Andes	19,089	32,521	6,674 ± 507	205	16.6 ± 1.3
Svalbard	2,058	33,932	9,685 ± 922	285	24.0 ± 2.3
Western Canada and USA	14,516	14,615	1,025 ± 84	70	2.5 ± 0.2
Total	171,046	734,856	170,214 ± 20,688	231	422.6 ± 57.1

Huss and Farinotti (2012)

IPCC (2013)

Potential sea level contribution: 42 cm

RGI applications 2: Ice thickness distribution

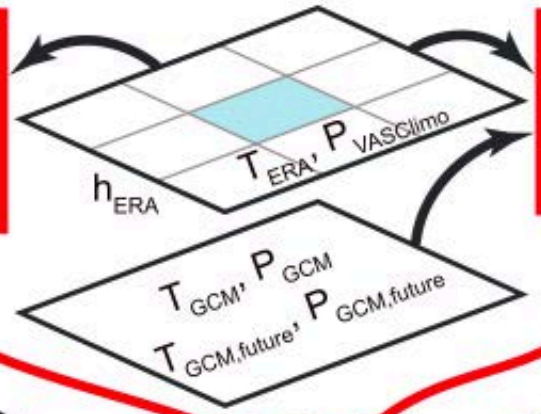


RGI applications 3: Climate model coupling

Past climate bias correction:

$$T_{past} = T_{ERA} + lr_{ERA}(h_{max} - h_{ERA})$$

$$P_{past} = k_P P_{VASClimo}$$



Future climate bias correction:

$$T_{future} = T_{GCM,future} + (\overline{T_{ERA}} - \overline{T_{GCM}}) + lr_{ERA}(h_{max} - h_{ERA})$$

$$P_{future} = k_P P_{GCM,future} \overline{P_{VASClimo}} / \overline{P_{GCM}}$$

Climate extrapolation to elevation *h*:

$$T = T_{past/future} + lr(h - h_{max})$$

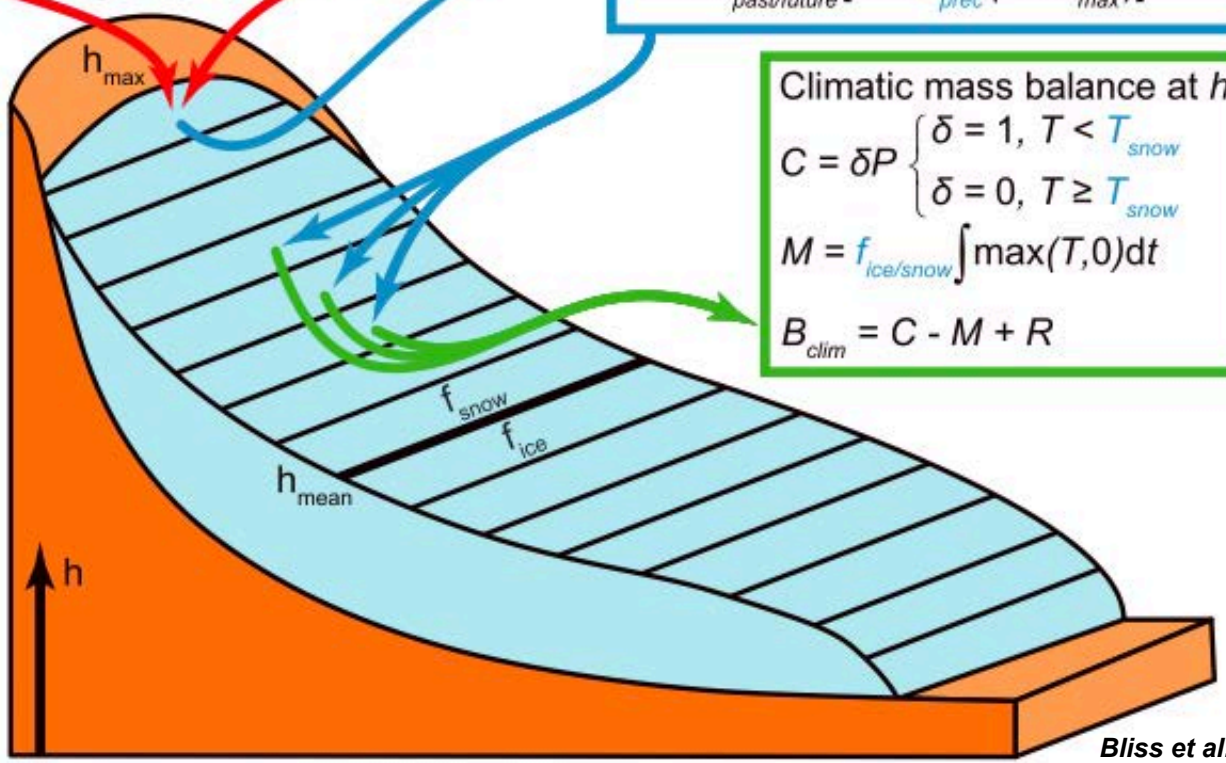
$$P = P_{past/future}[1 + d_{prec}(h - h_{max})]$$

Calibration:

1) Find optimal parameter values for lr, k_P, d_{prec}, T_{snow}, f_{snow}, f_{ice}, and initial guess for lr_{ERA} using glaciers with observed mass balance profiles.

2) Extrapolate parameters to all glaciers using transfer functions (*Radić et al.*, 2013).

3) Calculate B_{clim} then iterate, adjusting lr_{ERA}, until modeled regional mass balance matches area-averaged measurements (*Cogley*, 2009).



Climatic mass balance at *h*:

$$C = \delta P \begin{cases} \delta = 1, & T < T_{snow} \\ \delta = 0, & T \geq T_{snow} \end{cases}$$

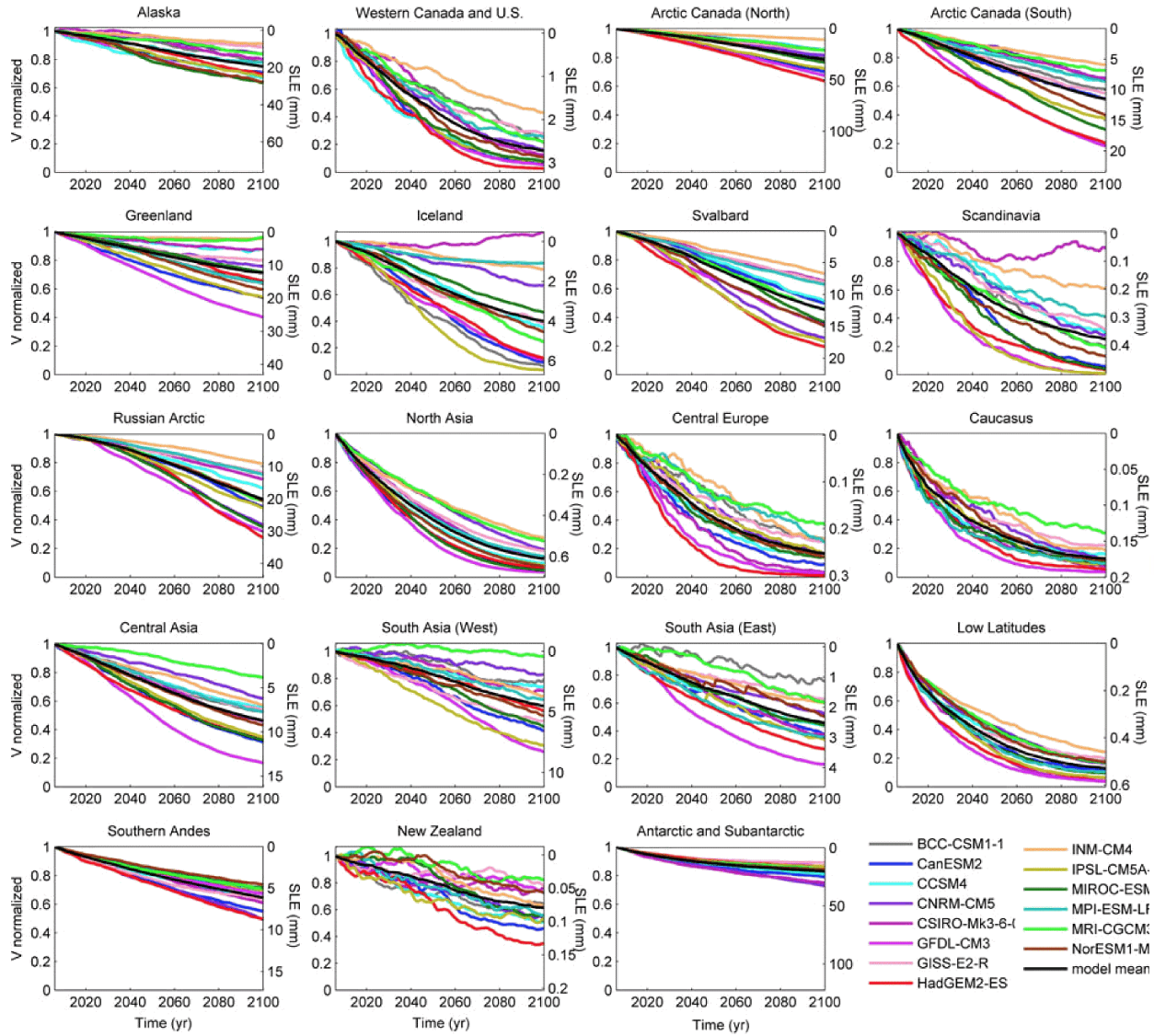
$$M = f_{ice/snow} \int \max(T, 0) dt$$

$$B_{clim} = C - M + R$$

Bliss et al. (2014)

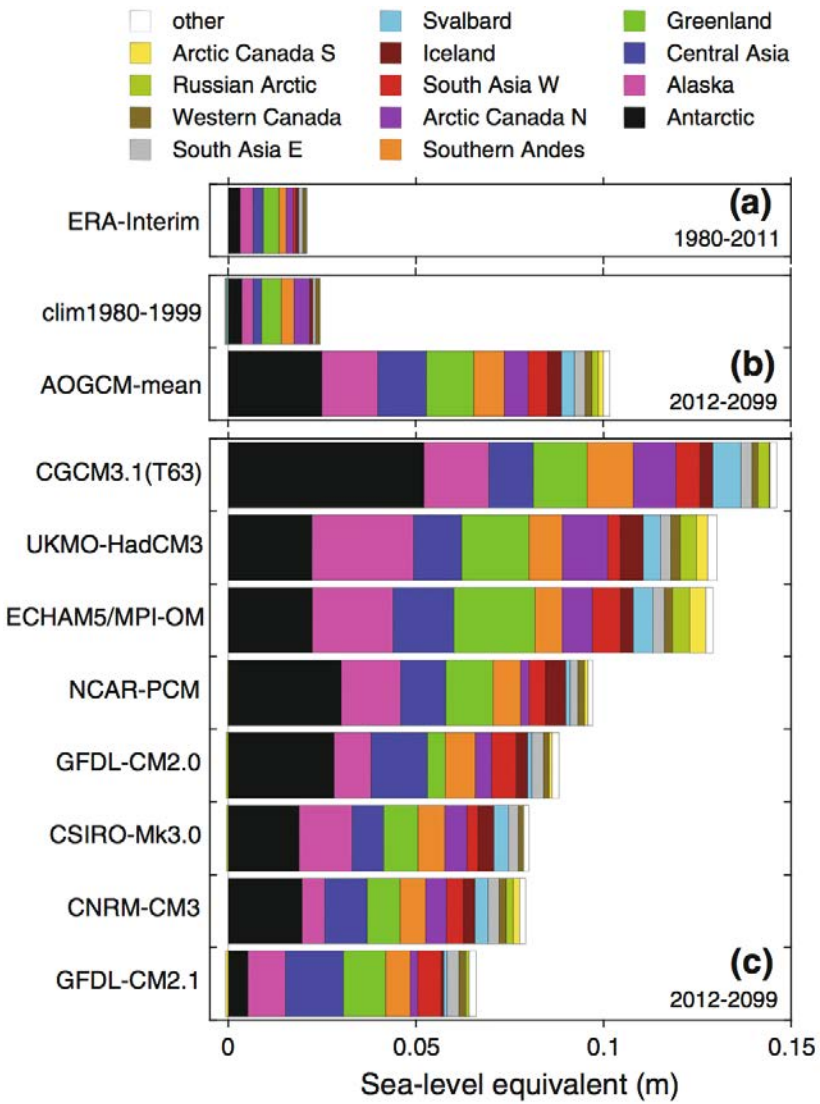
RGI applications 4: Future glacier change

Transient evolution of global glacier volumes



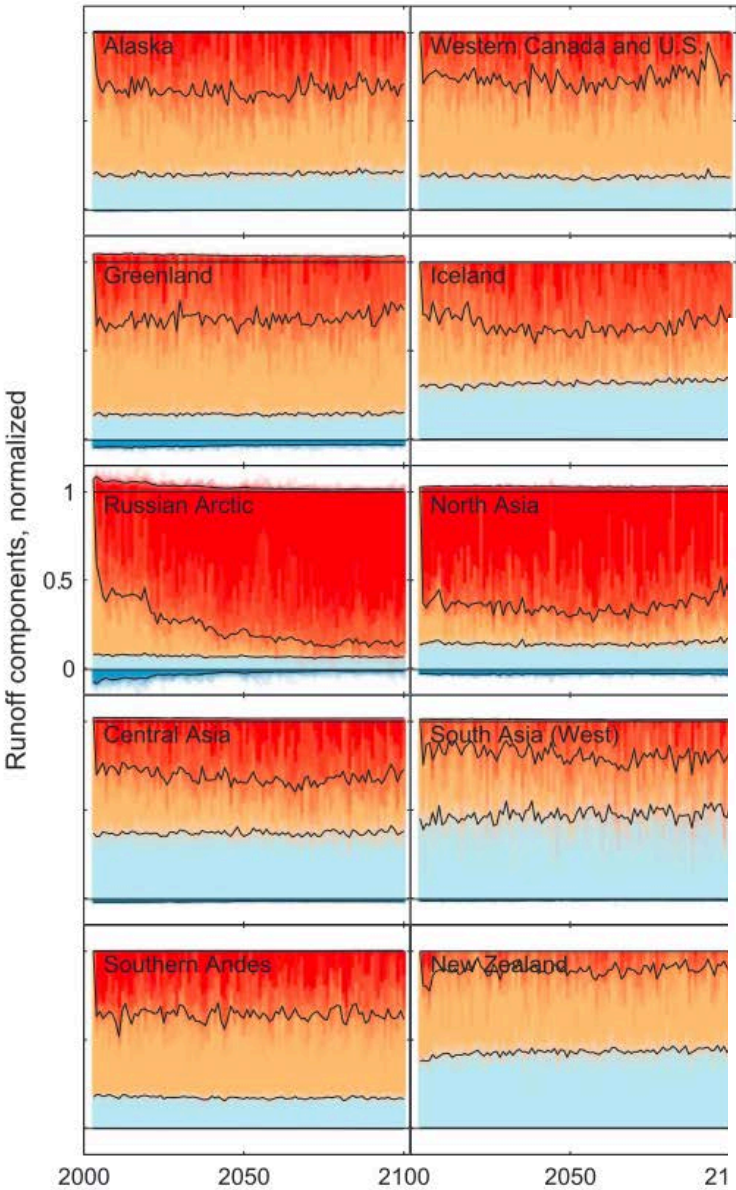
Radic et al. (2013)

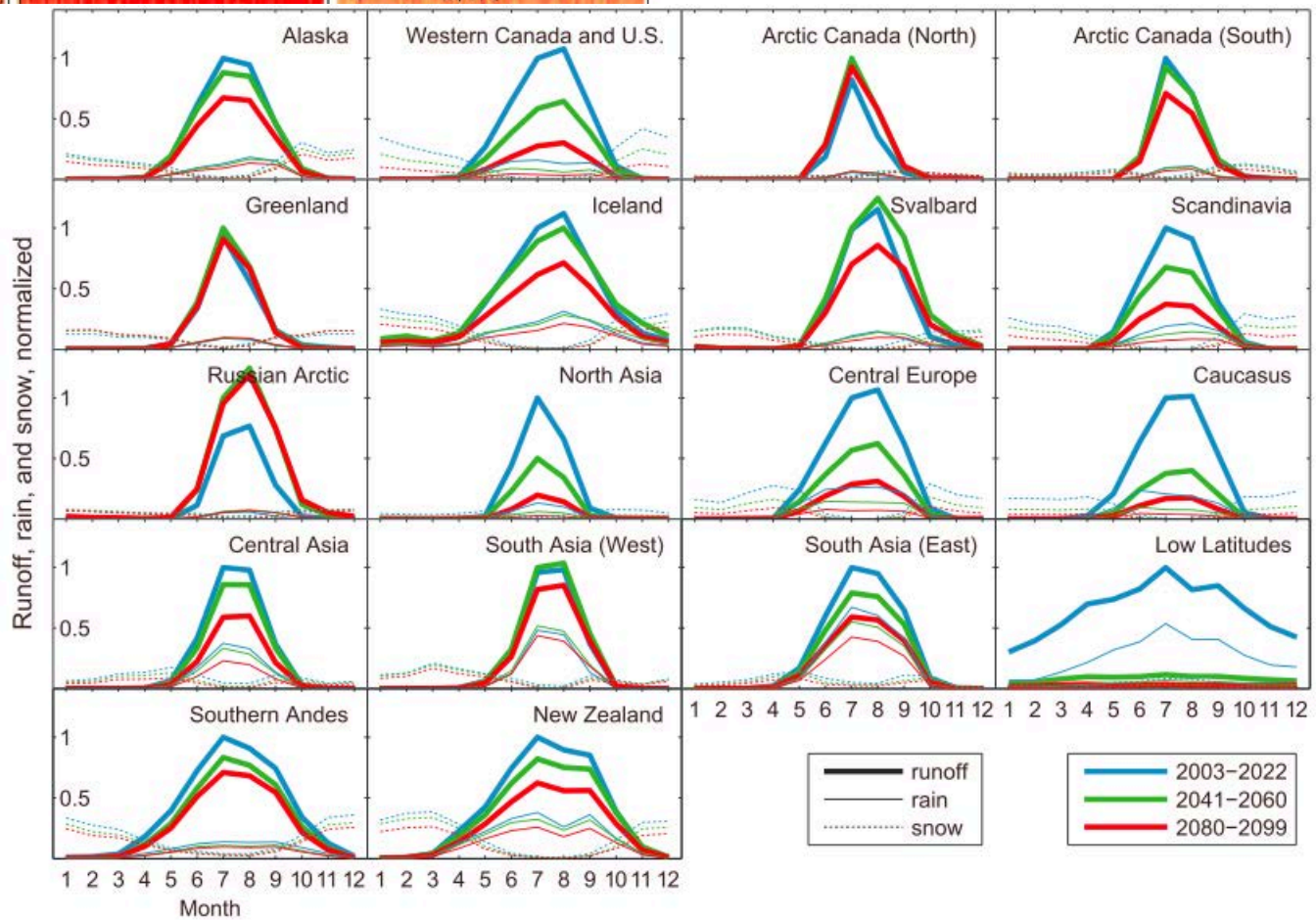
Future sea-level rise contribution



Giesen and Oerlemans (2013)

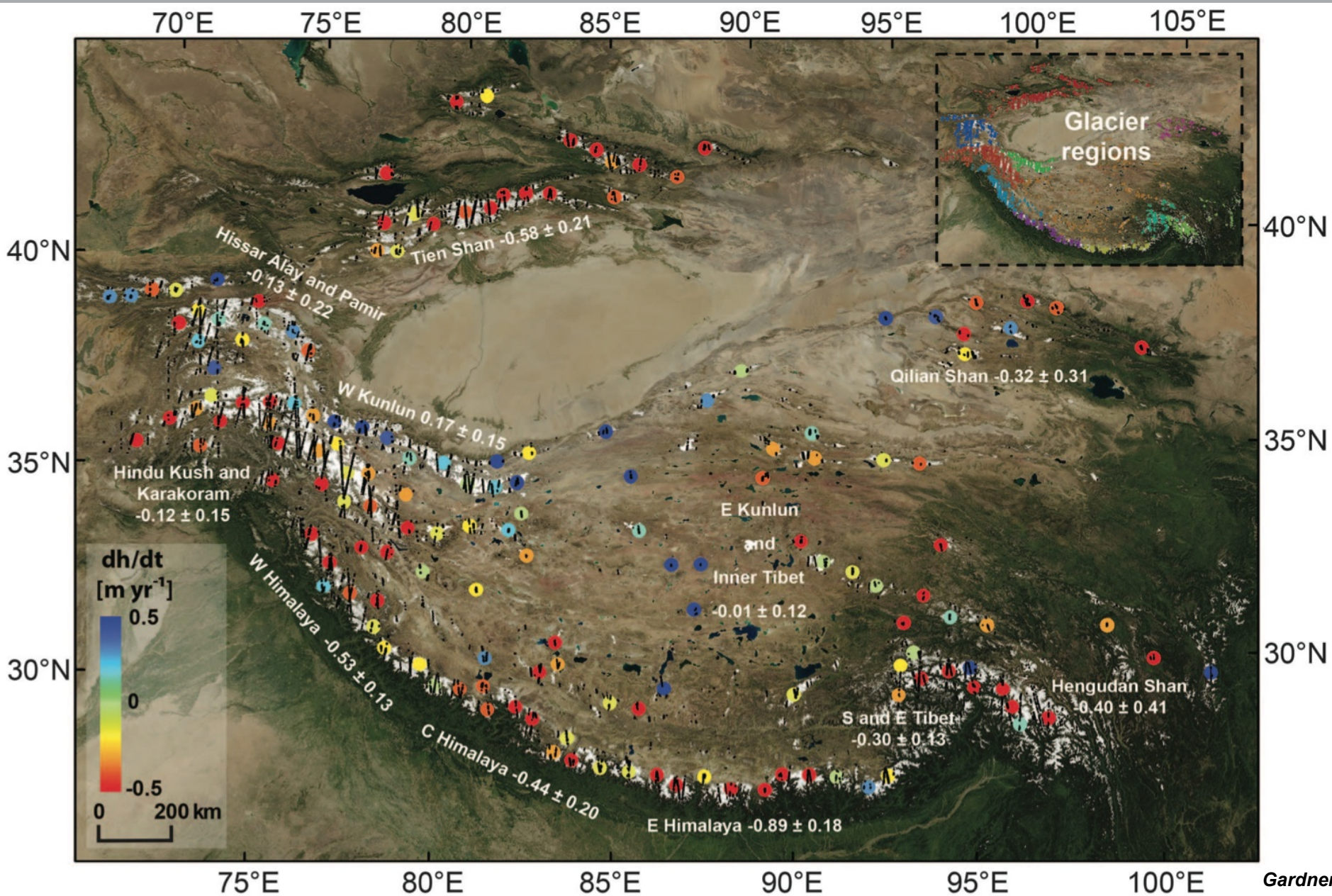
Current applications: Future runoff





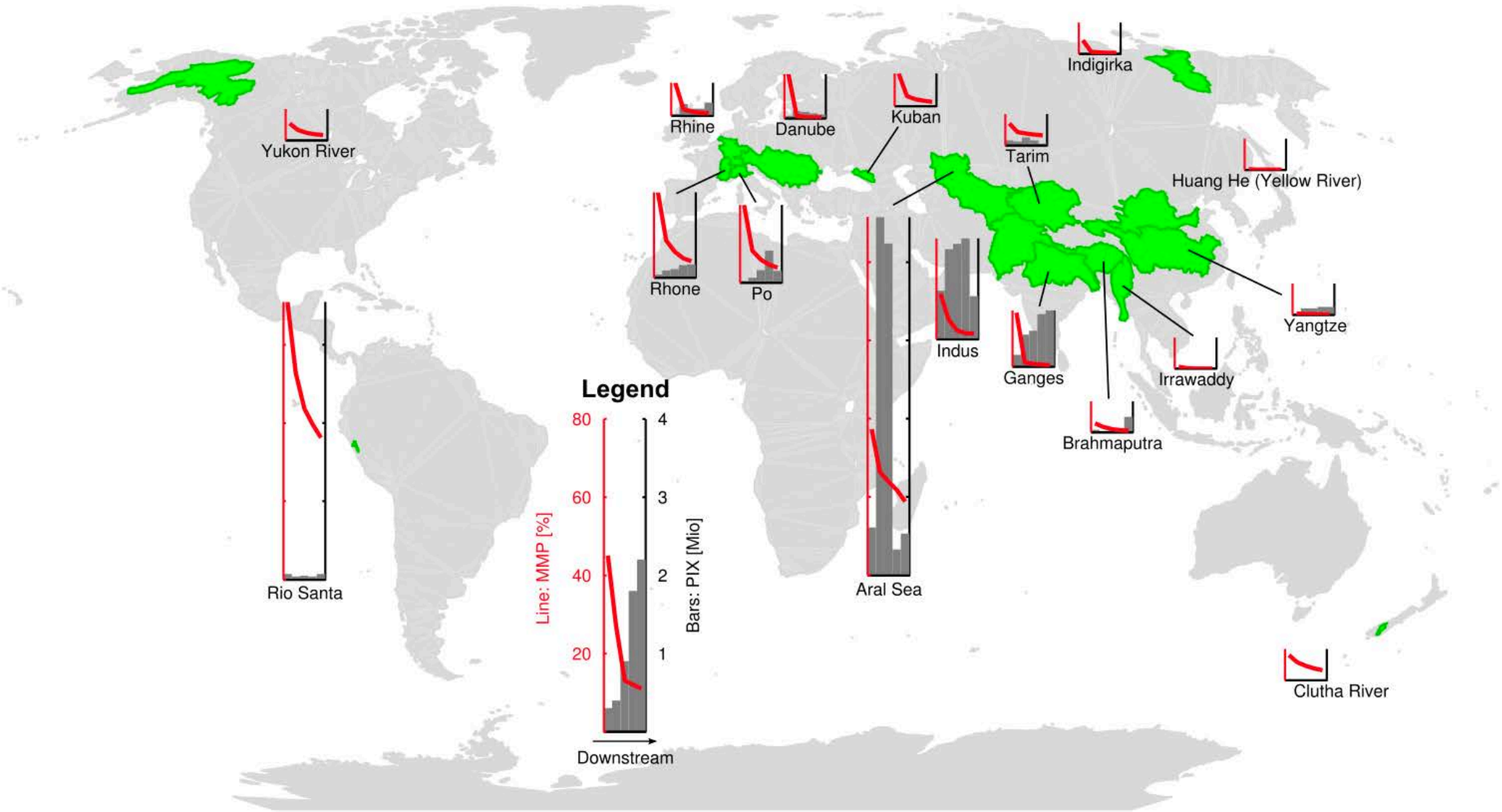
Bliss et al. (2014)

Elevation change 1: Mass change variability HMA



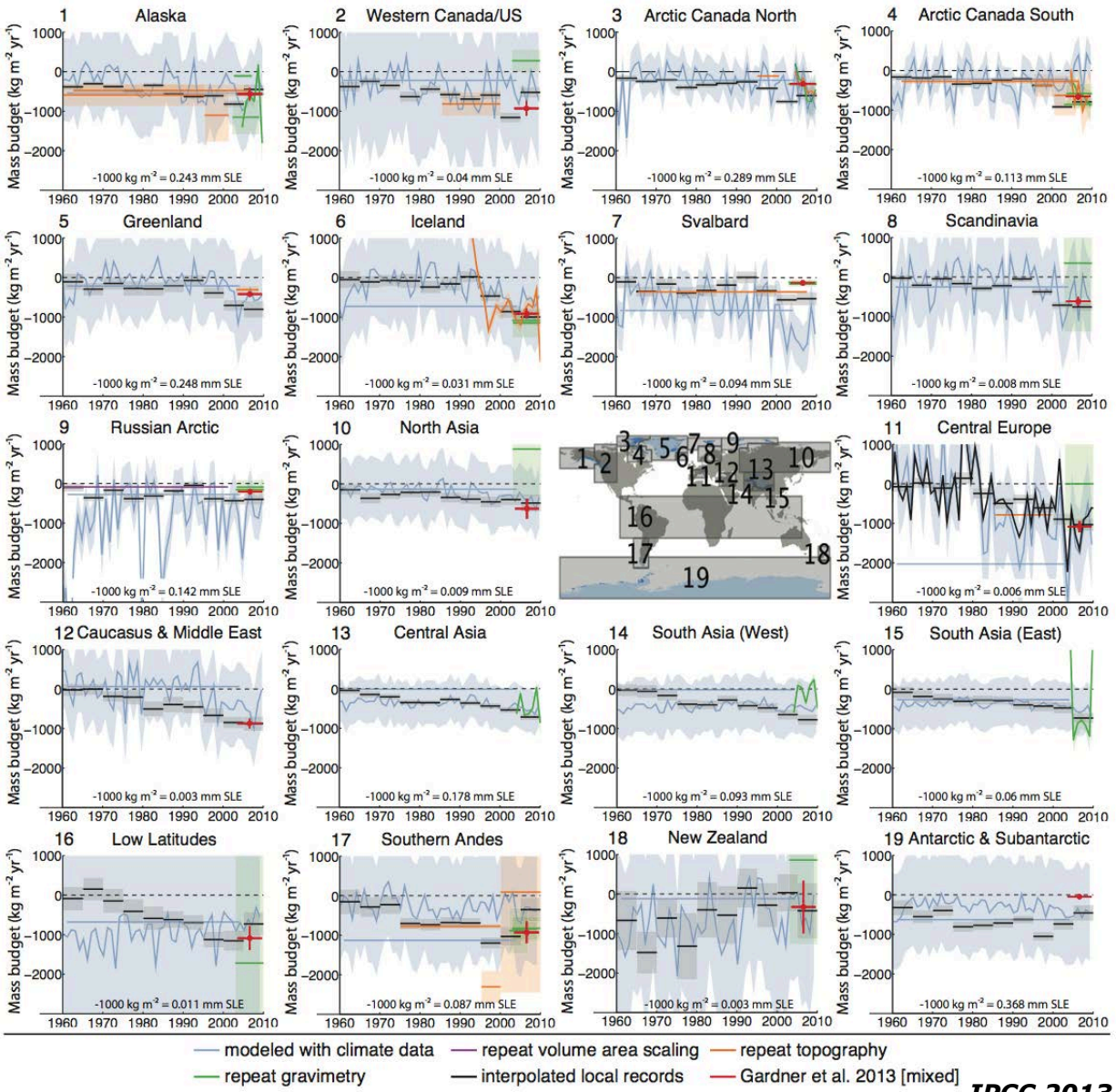
Gardner et al. (2013)

Elevation ch. 2: Run-off contribution



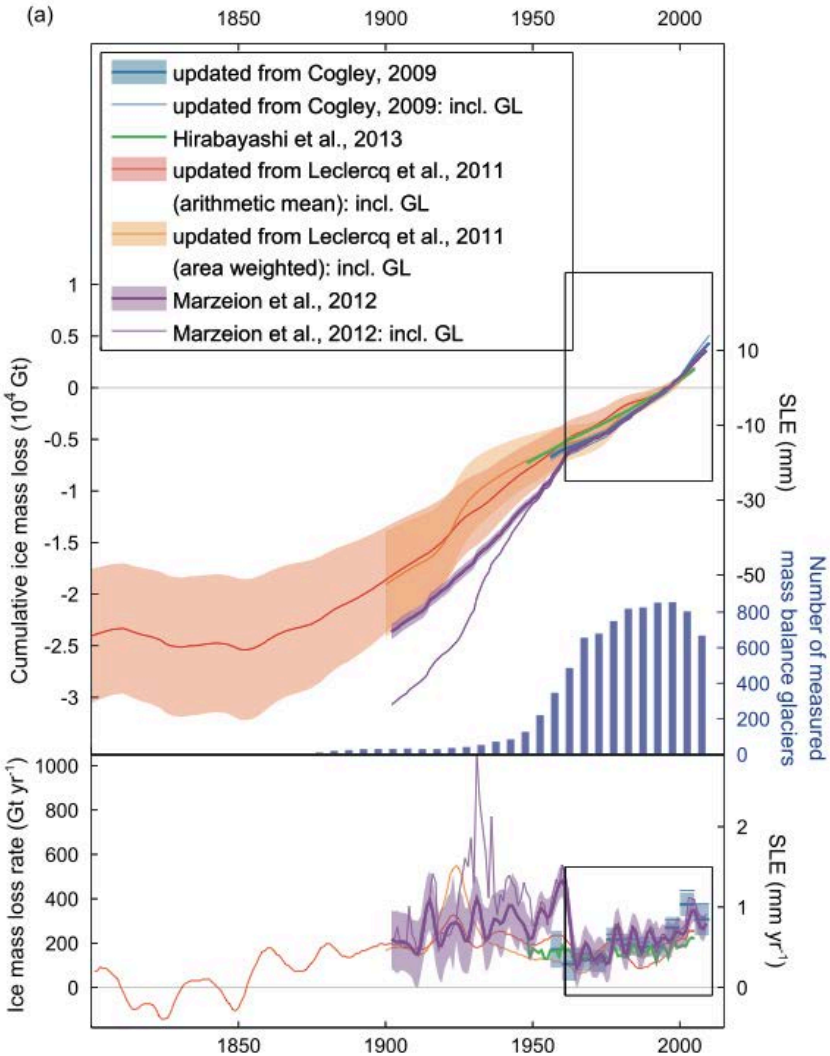
Kaser et al. 2010

Elevation ch. 3: Sea-level contribution



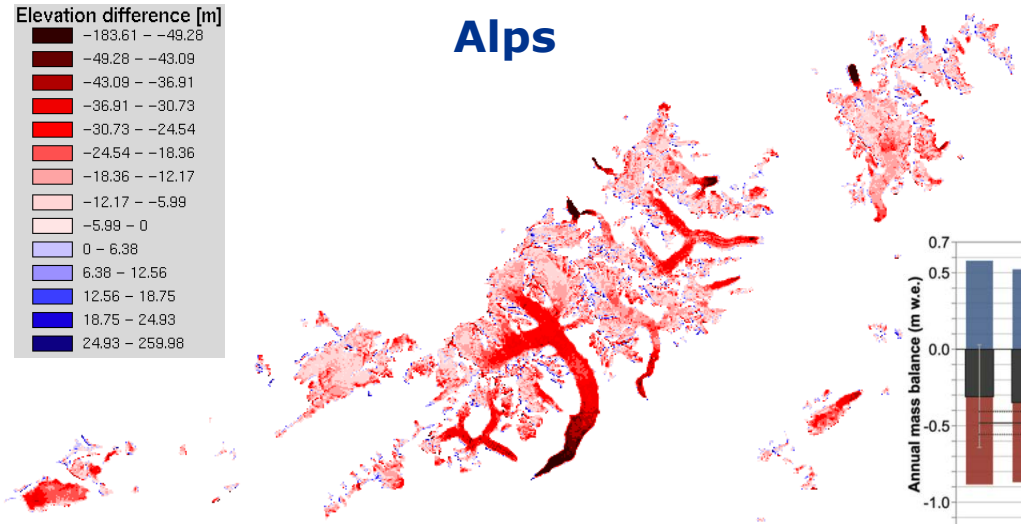
IPCC 2013

Cumulative sea level contribution

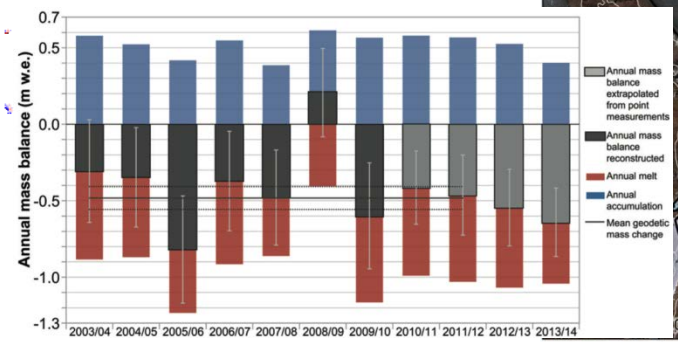


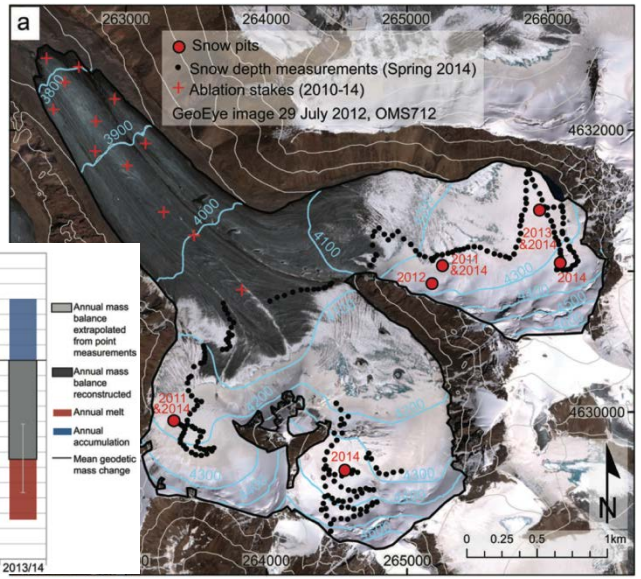
IPCC 2013

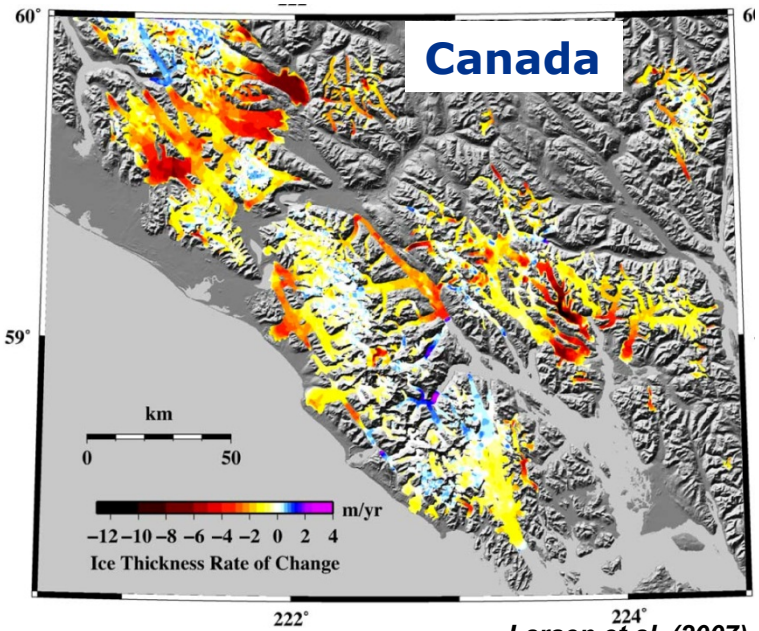
Elevation ch. 4: Process understanding & validation



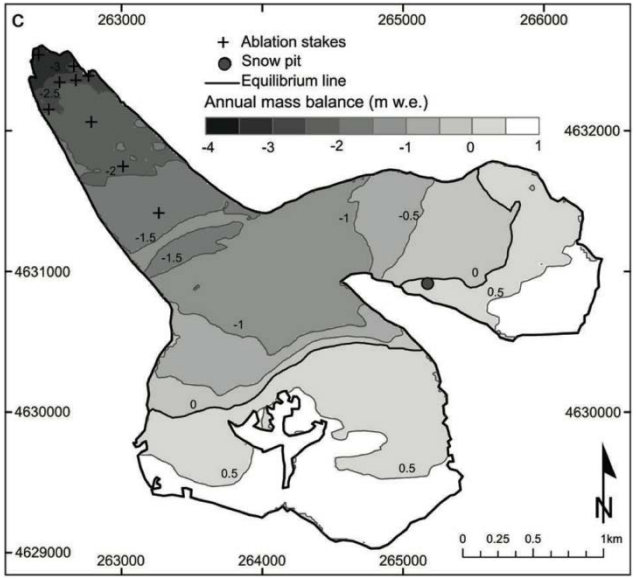
Paul and Haeberli (2008)

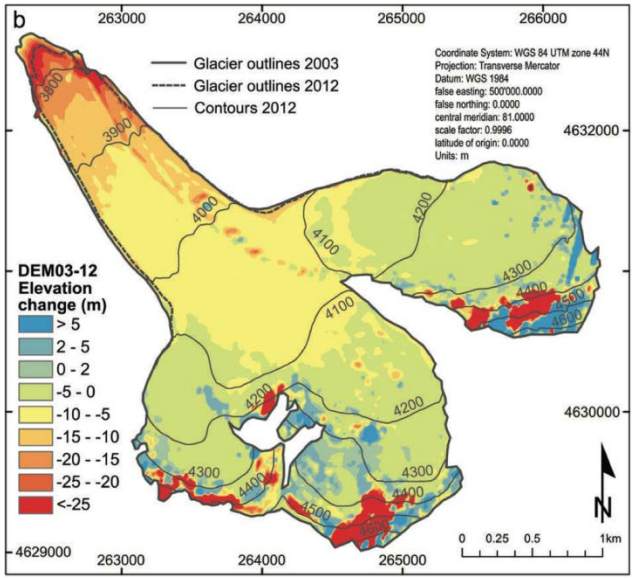






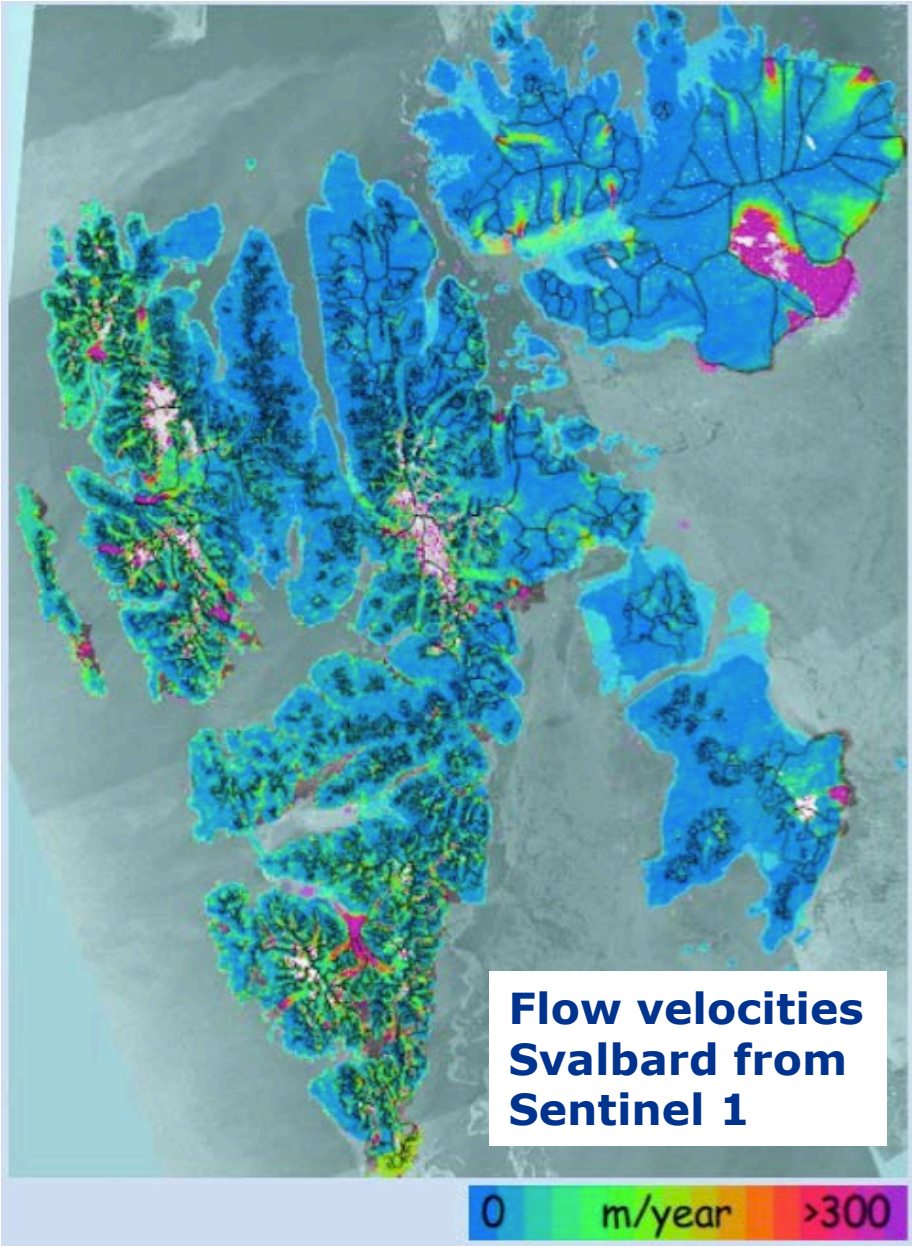
Larsen et al. (2007)



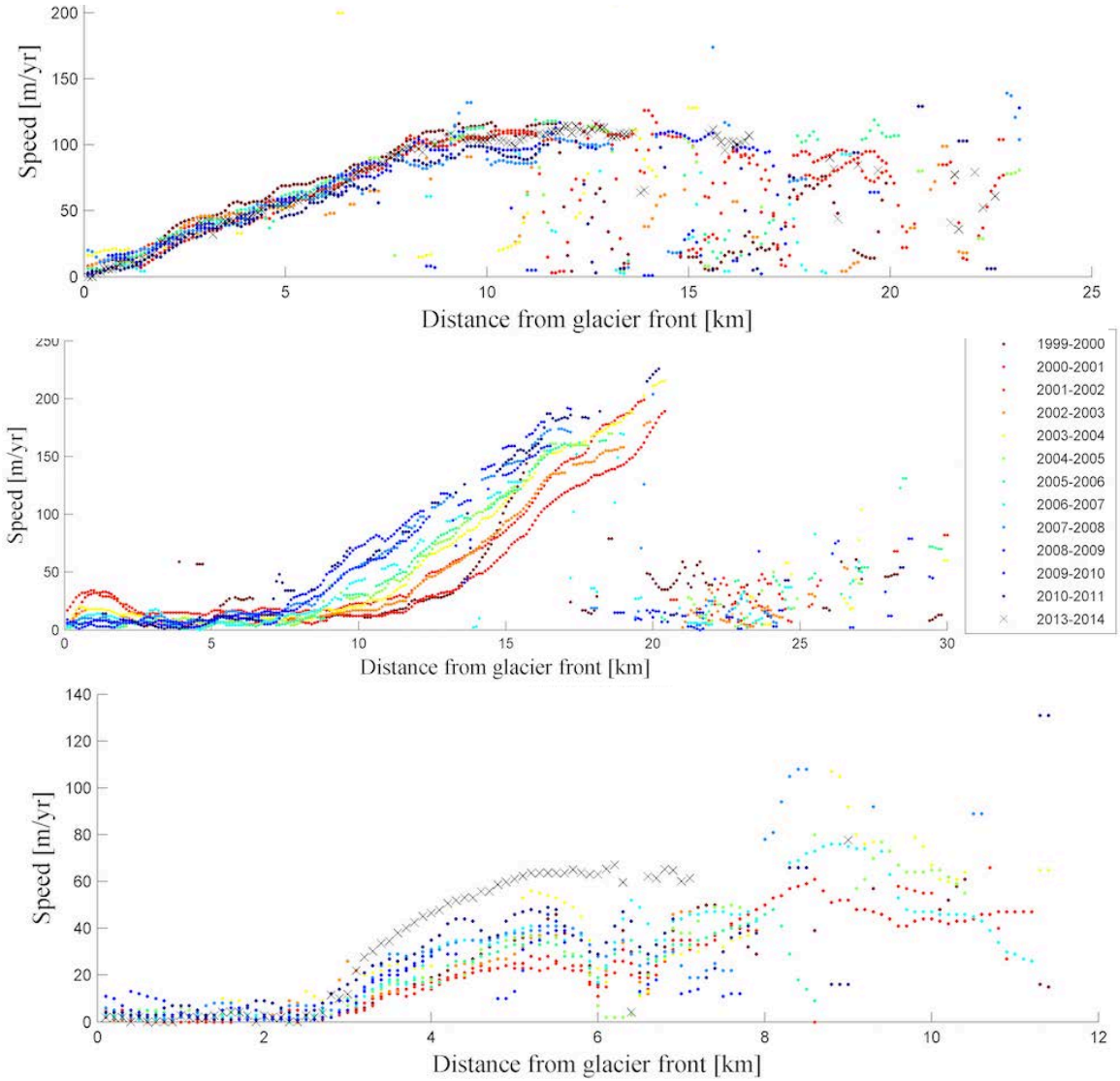


Kronenberg et al. (2015)

Velocity: Understanding glacier dynamics



Time series of velocity profiles for 3 glaciers in the Karakoram from various sensors



Summary

- The (data) products from Glaciers_cci are uptaken by the community and used for their specific applications
- The related publications inform the public about past, current and future global glacier changes and their impacts
  - e.g. on water resources, run-off, sea level change, climate change
- Conversion of data into information products is laborious and mostly done in publications and their summaries (IPCC)
- As all data are freely available, we count impact by citations
- Getting the higher-level datasets produced by others into public databases is challenging as all work is science-driven
- Everything will be even more intense in the future when considering new and upcoming sensors (Sentinels, ICESat2)