Achievements (data production and use)

F. Paul (GIUZ) for the Glaciers_cci consortium
Products: How? (methods)

1. Repeat Altimetry
2. Altimetry-DEM
3. DEM differencing

OUTLINES
- Band ratio
- Editing

VELOCITY
- Cross-correlation (offset tracking)

Kääb
Products: What? (area)

Change assessment

Data improvement (RGI)

Accuracy assessment

Products: What? (elevation change)

- Gardelle et al. (2013)
- DEM differencing
- Bolch et al. (2013)
- Altimetry (ICESat)

Altimetry (ICESat)
Products: What? (velocity)

Velocity fields

Velocity vectors

Velocity: time series

ERS-1/2: 1995
PALSAR: 2008
Sentinel 1: 2014

Velocity: decadal trends

Heid & Kääb 2012
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

<table>
<thead>
<tr>
<th>Id</th>
<th>Name</th>
<th>Products</th>
<th>AREA</th>
<th>ALT_ALT</th>
<th>ALT DEM</th>
<th>DEM DEM</th>
<th>IV OPT</th>
<th>IV MW</th>
<th>RGI_region</th>
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<tbody>
<tr>
<td>1</td>
<td>Arctic</td>
<td>ALT-ALT, IV-MW</td>
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<td>0</td>
<td>1</td>
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<td>1</td>
<td>13,14,15</td>
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<td>DEM-DEM, IV-OPT</td>
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<td>1,3,4,5</td>
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<td>AREA, ALT-DEM, DEM-DEM, IV-OPT, IV-MW</td>
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</table>
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)

- Glaciers_cci products
- Public
- Science users
- glaciologists
- hydrologists
- GLIMS / WGMS
- climate modelers
- Stakeholders
  - FOEN / EEA
  - UNEP / UNESCO
  - GEO / GEOSS
  - nat./int. Agencies
- EO Data
- CCI:
  - outlines
  - elevation change
  - velocity
  - CRDP website
- Datasets
  - inventory
  - thickness
  - volume
  - run-off
  - sea-level
  - multi-temporal data
  - climate data
- Future development
- Time series
- IPCC
- Publications
  - citations
- Information products
  -IPCC
- Scientists
  - GLIMS/RGI
  - WGMS
  - repositories
  - CRDP website
- Further applications

Datasets:
- CLS
- Climate data
- DMEs
- DMI
- CCI
- ESA
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    - DMEs
    - DMI
    - CCI
    - ESA

Potential sea level contribution: 42 cm
RGI applications 3: Climate model coupling

Past climate bias correction:
\[ T_{\text{past}} = T_{\text{ERA}} + l_r_{\text{ERA}}(h_{\text{max}} - h_{\text{ERA}}) \]
\[ P_{\text{past}} = k_p P_{\text{VASClimo}} \]

Future climate bias correction:
\[ T_{\text{future}} = T_{\text{GCM,future}} + (T_{\text{ERA}} - T_{\text{GCM}}) + l_r_{\text{ERA}}(h_{\text{max}} - h_{\text{ERA}}) \]
\[ P_{\text{future}} = k_p P_{\text{GCM,future}} P_{\text{VASClimo}} / P_{\text{GCM}} \]

Calibration:

1) Find optimal parameter values for \( l_r, k_p, d_{\text{prec}}, T_{\text{snow}}, f_{\text{snow}}, f_{\text{ice}} \), and initial guess for \( l_r_{\text{ERA}} \) using glaciers with observed mass balance profiles.

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

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

Climate extrapolation to elevation \( h \):
\[ T = T_{\text{past/future}} + l_r(h-h_{\text{max}}) \]
\[ P = P_{\text{past/future}} [1 + d_{\text{prec}}(h-h_{\text{max}})] \]

Climatic mass balance at \( h \):
\[ C = \delta P \begin{cases} \delta = 1, & T < T_{\text{snow}} \\ \delta = 0, & T \geq T_{\text{snow}} \end{cases} \]
\[ M = f_{\text{ice/snow}} \max(T,0) dt \]
\[ B_{\text{clim}} = C - M + R \]

Bliss et al. (2014)
RGI applications 4: Future glacier change

Transient evolution of global glacier volumes

Future sea-level rise contribution

Radic et al. (2013)

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

Legend

- Line: MMP [%]
- Bars: PIX [Mio]
- Downstream

Yukon River
Rhine
Danie
Kuban
Tarim
Indigirka
Huang He (Yellow River)
Yangtze
Irrawaddy
Brahmaputra
Clutha River

Kaser et al. 2010
Elevation ch. 3: Sea-level contribution

Cumulative sea level contribution

IPCC 2013
Velocity: Understanding glacier dynamics

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

Flow velocities Svalbard from Sentinel 1
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)