

PALSEA: 13 years of ice-sheet and sea-level science

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We provide an account of the past 13 years of activity of PALSEA, the PALeo constraints on SEA level rise (PALSEA) working group supported by PAGES and INQUA.

Prelude

Sea-level rise due to polar ice-sheet retreat in a warming world is one of the most important aspects associated with future climate change, yet remains challenging to project due to uncertainties in the dynamics of rapid ice-sheet retreat. The geologic record features major, and sometimes rapid, changes in ice sheets and sea level that offer an excellent opportunity to assess the rates, magnitudes, and processes involved in ice-sheet and sea-level change and how they are connected to climate forcing. The PALeo constraints on SEA level rise working group (PALSEA; pastglobalchanges.org/palsea) has developed an interdisciplinary network of paleoscientists who seek to pair the development and synthesis of datasets with geophysical modeling of ice and sea-level proxies. The overarching goal of PALSEA is to improve our understanding of the physical processes involved in ice-sheet dynamics and solid Earth responses, and to provide improved constraints for predicting sea-level rise in the future.

PALSEA started its activities in 2008 after the IPCC 4th Assessment Report: the working group was largely initiated by Mark Siddall, who gathered a group of paleoclimate scientists united by the goal of having a more coordinated role in the 5th Assessment Report. Today, PALSEA is a PAGES working group and an International Focus Group of INQUA (International Union for Quaternary Sciences; <https://www.inqua.org>). The following is the story of how PALSEA evolved over the past 13 years and its achievements in pushing the boundaries on paleo sea-level and ice-sheet science.

2008-2012: The early years

The first meeting of the newly formed PALSEA group was held 25-29 August 2008 in Bern, Switzerland (pastglobalchanges.org/calendar/past/2008-past/127-pages/1082), and was organized by Mark Siddall, Thomas Stocker, Bill Thompson, and Claire Waelbroeck. It brought together experts from across the community to address how studying past records of sea-level change can add to our understanding of the climate system, and in turn inform future projections of sea-level rise. To foster interdisciplinary discussions, scientists with diverse areas of expertise were invited to attend: Earth and climate modelers, field geologists, and geochronologists. The idea was to facilitate a meeting of these experts, together with a mix of early-career researchers (ECRs), in a friendly and informal environment, to develop new interdisciplinary collaborations. Participants realized the meeting only scratched the

surface regarding the various issues on paleo sea-level and ice-sheet reconstructions, some of which were summarized in a review paper (Siddall et al. 2010; Fig. 1).

One year later (21-25 September 2009; pastglobalchanges.org/calendar/past/2009-past/127-pages/1085), at Woods Hole, MA, USA (meeting organized by Bill Thompson, Mark Siddall, and Claire Waelbroeck), the working group met again to discuss the challenges of dating past interglacials. What had initially emerged during discussions at the first meeting became very clear: there was a need to establish a comprehensive Quaternary sea-level database, including standardized descriptions of dated samples and sea-level proxies. This goal would characterize PALSEA activities for the years to come.

The relaxed atmosphere of the first two meetings was in part attributable to the never-written "ground rule" of PALSEA: everyone should leave their ego at the door and should be ready to challenge and be intellectually challenged by others. The emphasis of PALSEA meetings was (and still is) community-building, and PALSEA strives to bring together people who are thinking about the same problem(s) but from different angles and using very different methodologies. Also, PALSEA has always had a strong emphasis on including a large contingent of ECRs.

During the 2010 meeting in Bristol, UK (organized by Glenn Milne, Mark Siddall, and David Richards; pastglobalchanges.org/calendar/past/2010-past/127-pages/1086), three other themes were brought to the

table: (1) how to best use paleodata to constrain glacial-isostatic adjustment; (2) how to achieve better integration of archaeological archives of sea-level change in broader sea-level research; and (3) how to use data from past warm periods to better understand the response of sea level to warmer climates. The first theme was dissected into several overlapping topics one year later (24-26 August 2011; pastglobalchanges.org/calendar/past/2011-past/127-pages/1137) at Harvard University in Cambridge, MA, USA (meeting organized by Mark Siddall, Peter Huybers, and Jerry Mitrovica). For three days, the PALSEA community focused on maximum sea levels reached during past epochs, namely the Last Interglacial and the mid-Pliocene, and discussed the geologic evidence for or against rapid sea-level rises or falls in the Last Interglacial and since the Last Glacial Maximum. PALSEA also tackled the issues around the processes that (de)stabilize ice sheets and on the interactions between the cryosphere and the climate system. Last but not least, the PALSEA community started to direct its attention to the implications of paleo sea-level studies on our ability to understand modern ice sheets and sea-level changes.

It was with this focus in mind that the community met 4-8 June 2012 in Madison, WI, USA (meeting organized by Anders Carlson and Mark Siddall; pastglobalchanges.org/calendar/past/2012-past/127-pages/970). This meeting was centered on dissecting the current knowledge on ice-sheet and climate interactions at multiple timescales (Holocene to Pliocene) and in different regions (Greenland and Antarctica). Five years after the first PALSEA meeting, the Madison

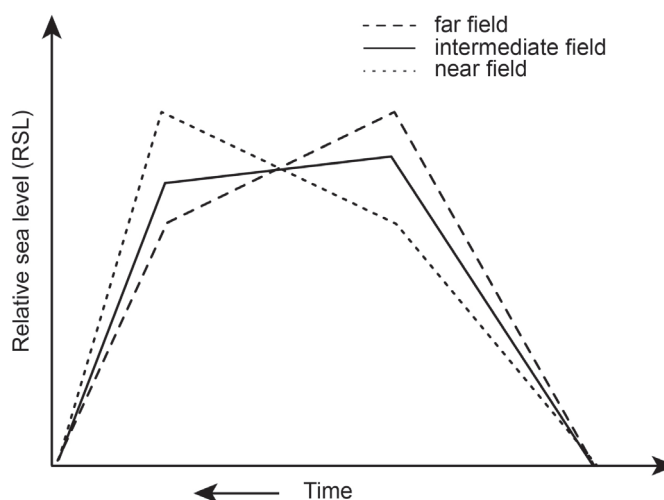


Figure 1: An illustrative sketch of how the relative sea-level record can vary at different sites across the globe across an interglacial sea-level highstand (modified from Siddall et al. 2010). Understanding the links between relative sea level and global mean sea level has been a theme within PALSEA since its inception.

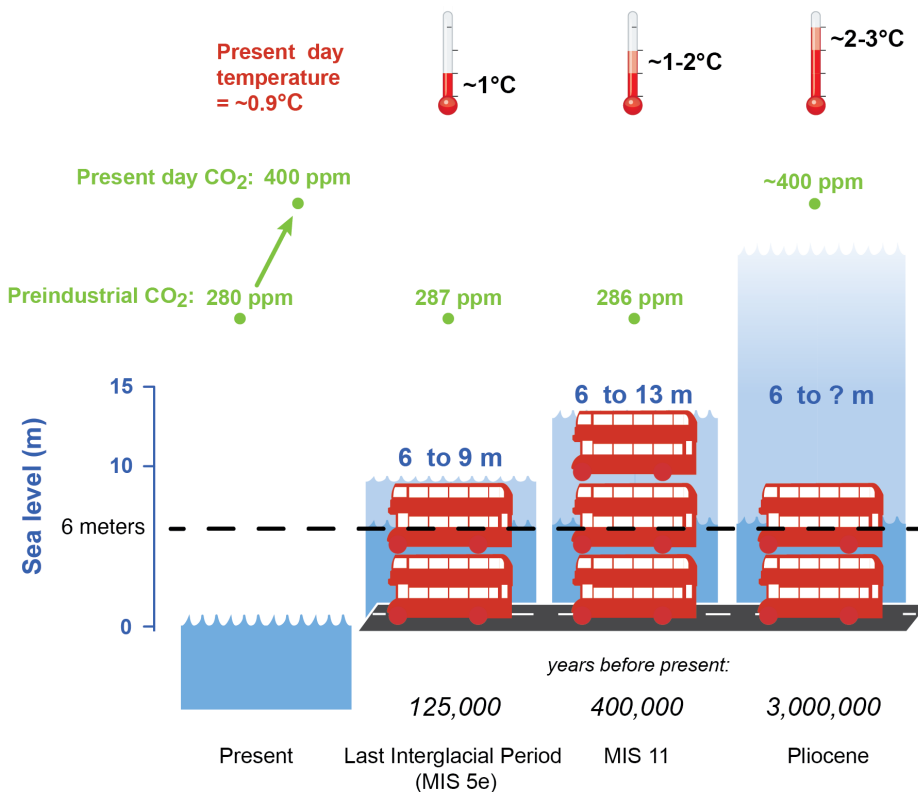


Figure 2: Comparing the magnitude of peak sea level during recent past warm periods. Modified from Dutton et al. (2015).

meeting was also the opportunity for the PALSEA founders to pass the baton to a new leadership team, who would lead PALSEA for the years to come.

The first five years of PALSEA ended with the Madison meeting. During the timeframe 2008–2012, lively discussions at the PALSEA workshops inspired several papers. Among them, an appraisal of ice-sheet responses to past climate forcings (e.g. Carlson and Winsor 2012; Gregoire et al. 2012) and several papers exploring past changes in sea level (e.g. Andersen et al. 2010; Raymo and Mitrovica 2012; Dutton and Lambeck 2012). Within its first five years, PALSEA also benefited from additional funding from the Worldwide Universities Network (WUN) and INQUA, which further enabled the group to support wide and diverse participation, particularly by ECRs. INQUA has remained a devoted supporter of PALSEA since these early years.

2012–2017: Exploring new grounds

The new PALSEA leaders were Anders Carlson, Andrea Dutton, Glenn Milne, and Antony Long. At the group meeting in Rome (21–24 October 2013, organized by Andrea Dutton and Marco Anzidei; pastglobalchanges.org/calendar/past/2013-past/127-pages/853), the community tackled the issue of estimating rates and sources of sea-level change during past warm periods and the Holocene. The workshop included a field excursion where participants had the opportunity to jump into the Mediterranean Sea and snorkel around fish tanks dating back to the Roman age that were often used as common-era sea-level indicators. Additional support was provided to ECRs with the help of CliC, the Cryosphere and

Climate project within the World Climate Research Programme (WCRP). One outcome of this meeting was a review paper that summarized the current state of knowledge from an interdisciplinary perspective concerning sea level during past warm periods (Dutton et al. 2015; Fig. 2).

One year later (16–23 September 2014), PALSEA met in a slightly colder, yet equally interesting location. Antony Long and Natasha Barlow organized a workshop in north-west Scotland, in the remote town of Lochinver (pastglobalchanges.org/calendar/past/2014/127-pages/846). Here, the participants had the opportunity to work in a relaxed and informal atmosphere (the meeting was hosted in a lodge, and some participants decided to camp on the lake!), working out the best ways to tackle one of the long-lasting PALSEA goals: documenting paleo sea-level and ice-sheet extent and building sea-level/ice-sheet databases (Fig. 3). The discussions were intense and fruitful, leading to the draft of a paper on strategies and perspectives on sea-level databases that would become, in the following years, a handy guide for those wishing to build new sea-level databases (Düsterhus et al. 2016).

Sea-level and ice-sheet databases have been (and still are) a central topic within PALSEA, mostly due to their importance for the validation of glacial isostatic adjustment (GIA) and ice-sheet models. For this reason, the Scotland meeting was followed by a workshop from 22–24 July 2015 focused on data-model integration and comparison (pastglobalchanges.org/calendar/2015/127-pages/1390), organized by Glenn Milne, Ayako Abe-Ouchi, and Yusuke Yokoyama.

The trio took advantage of the 2015 INQUA conference in Nagoya, Japan, and hosted the workshop at the University of Tokyo. For the first time, a PALSEA conference was held outside of Europe or the US. In three intense days, the problems and opportunities related to using sea-level and ice-sheet data in conjunction with ice and GIA models were discussed for different timescales: the Pliocene, Pleistocene interglacials, and the Holocene.

One of the outcomes of this meeting was the understanding that PALSEA was missing one specific part of the community: scientists working with instrumental records of change. Therefore, for the 18–21 September 2016 meeting in Mt. Hood, OR, USA (organized by Anders Carlson; pastglobalchanges.org/calendar/2016/127-pages/1540), the participation of scientists working with modern sea-level and ice-sheet changes was encouraged. This led to a series of presentations which aimed to stimulate new ideas on the best ways to bridge paleo and modern records, delving mostly into data from the Late Holocene, the Common Era, and the last two centuries. The day before the official workshop start, Nicole Khan (leader of the HOLSEA project, under the umbrella of PALSEA within INQUA; <https://www.holsea.org>) united several colleagues interested in contributing to a global database of Holocene sea-level indicators. On that day, the group started to define what three years later would lead to the first standardized global sea-level database (Khan et al. 2019). Also the PALSEA team working on Pleistocene sea levels started to work on sea-level databases, with a series of papers dedicated to addressing issues on the data structure (Dutton et al. 2017; Rovere et al. 2016) and releasing a database of dated corals with associated sea-level metadata (Hibbert et al. 2016).

Pleistocene corals took center stage from 6–9 November 2017 in Playa del Carmen, Mexico, for the meeting closing PALSEA's first decade (organized by Andrea Dutton and Paul Blanchon; pastglobalchanges.org/calendar/2017/127-pages/1715). To delve into the issues related to the phasing of ice-sheet and sea-level responses to past climate change, participants explored the fossil reefs exposed at Xcaret, between talks and presentations. The lively discussions were centered on whether these reefs preserved imprints of sea-level oscillations, and how large these changes were. Once more, the possibility to have discussions in the field, among scientists at different career stages and from different backgrounds, proved a winning formula for PALSEA, and a source of inspiration for several new avenues of research. Therefore, it is not by chance that the second five years of PALSEA generated a large number of debates and ideas, which led to more than 80 scientific articles. The problems and advances fostered by PALSEA in its first decade are well summarized in a seminal paper by Dutton et al. (2015), that represents the outcome of several discussions and interactions within the PALSEA community.

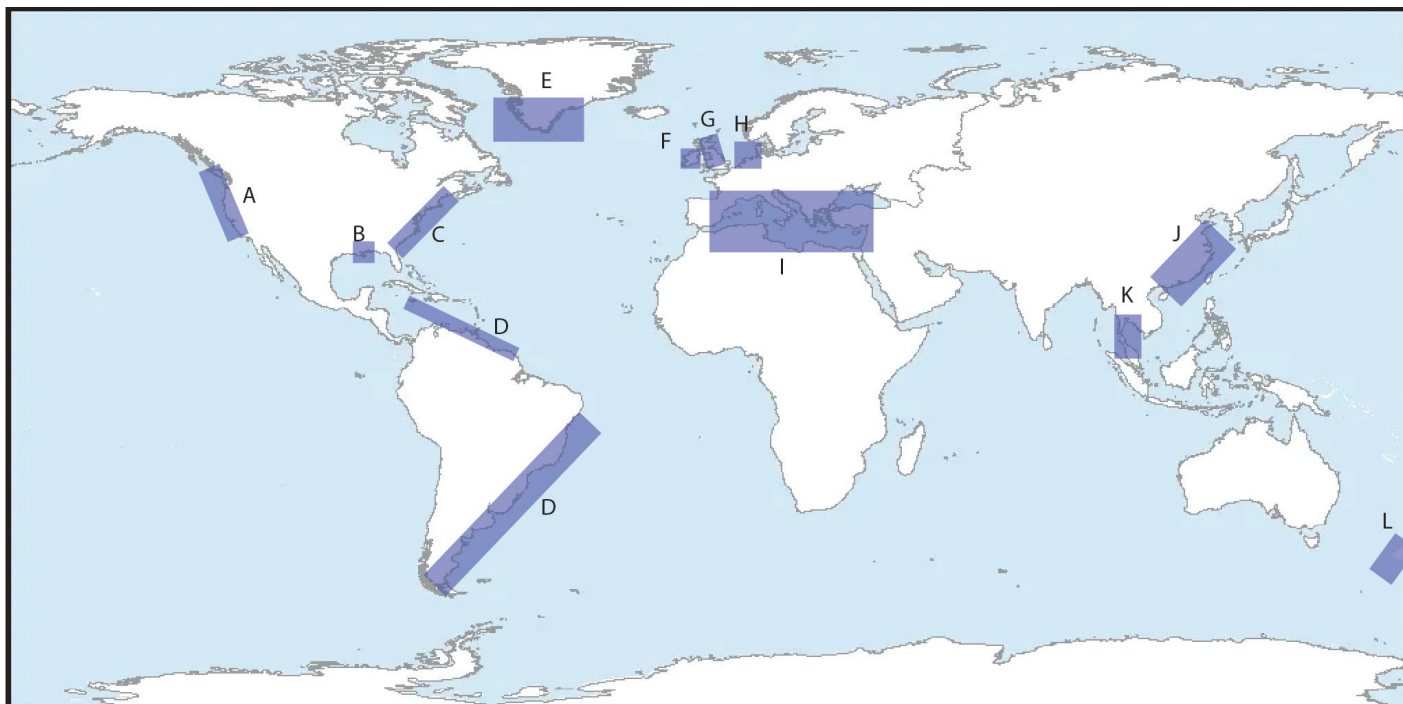


Figure 3: Map showing published regional sea-level databases as of 2014. Modified from Düsterhus et al. (2016).

2018-2020: Going forward

In Mexico, the transition was made to a new leadership, composed of then-ECRs who took part in several PALSEA activities in the previous years: Jacqueline Austermann, Natasha Barlow, Alessio Rovere, and Jeremy Shakun. The first meeting of this new cycle was organized in collaboration with QUIGS (PAGES-PMIP Working Group on Quaternary Interglacials; pastglobalchanges.org/quiqs), another long-running PAGES working group. The meeting was held 24-27 September 2018 in Galloway, NJ, USA (organized by Emilie Capron, Robert E. Kopp, and Alessio Rovere; pastglobalchanges.org/calendar/2018/127-pages/1759). The efforts of these two communities were used to define "lessons learned" in these years, resulting in a paper with the self-explanatory title: "Challenges and research priorities to understand interactions between climate, ice sheets and global mean sea level during past interglacials" (Capron et al. 2019). A particularly refreshing aspect of this meeting was the input of new ideas from scientists from the QUIGS community, who had never before participated in a PALSEA meeting.

Given the success of the New Jersey meeting, the 21-23 July 2019 PALSEA meeting in Dublin, Ireland (organized by Natasha Barlow and Robin Edwards; pastglobalchanges.org/calendar/2019/127-pages/1821) also aimed to expand the involvement of those with complementary expertise: several ecologists and geochemists were invited to discuss how to improve proxy-based paleo sea-level reconstructions. Embedded within this meeting was the presentation of the final version of the HOLSEA database (Khan et al. 2019) and the inception of the World Atlas of Last Interglacial Shorelines, an effort to standardize MIS 5e sea-level proxies, that is now underway (Rovere et al. 2020). Some members of the PALSEA community also participated in the INQUA-PAGES ECR workshop on impacts of sea-level rise from past to present (iSLR) in 2018.

The COVID-19 pandemic shocked the world and thwarted plans for the PALSEA meeting in Palisades, NY, USA, in September 2020. The ambitious aim for this meeting was to bring together the Earth and ice modeling communities to define and create

a standardized way to share and analyze model results. The meeting was being co-organized with another very active community, SERCE (Solid Earth Response and influence on Cryospheric Evolution), and is currently postponed until September 2021. In order not to lose the possibility to meet and exchange ideas, PALSEA organized a virtual "express" meeting from 15-16 September 2020 (led by Jacky Austermann and Alexander Simms; pastglobalchanges.org/calendar/2020/127-pages/2043). The meeting was held at different times to allow people from different timezones to join. The result was the most well attended PALSEA meeting ever (Fig.4!)

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PALSEA
@PALSEAgroup

#PALSEAexpress in numbers

237 people* (46% ECRs)

34 countries

22 posters (96% ECRs)

8 invited speakers (63% ECRs, 3F/5M)

5 organisers (100% getting older by the day 😊)

@PAGES_IPO @PAGES_ECN @INQUA @INQUA_CMP
@INQUA_ECR

Figure 4: Tweet by PALSEA (@PALSEAgroup) summarizing the numbers of the 2020 virtual meeting.