From Corals to Canyons: The Great Barrier Reef Margin

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Development of a Pan-Arctic Database for River Chemistry

More than 10% of all continental runoff flows into the Arctic Ocean. This runoff is a dominant feature of the Arctic Ocean with respect to water column structure and circulation. Yet understanding of the chemical characteristics of runoff from the pan-Arctic watershed is surprisingly limited. The Pan-Arctic River Transport of Nutrients, Organic Matter, and Suspended Sediments (PARTNERS) project was initiated in 2002 to help remedy this deficit, and an extraordinary data set has emerged over the past few years as a result of the effort. This data set is publicly available through the Cooperative Arctic Data and Information Service (CADS) of the Arctic Observing Network (AON). Details about data access are provided below.

Sampling programs were established on six rivers that account for more than half of all river discharge from the pan-Arctic watershed. Starting in western Siberia and moving eastward around the pan-Arctic domain, these rivers are the Lena, Yenisey, and Kolyma in Russia, the Yukon in Alaska, and the Mackenzie in Canada’s Northwest Territories. In addition to the parameters highlighted in the PARTNERS acronym, the project also has measured many other parameters, including major ions, trace elements, and isotopic ratios. While a variety of studies by PARTNERS scientists and others have focused on the chemistry of individual rivers, difference methods and parameters measured have hampered river intercomparisons and understanding at the pan-Arctic scale. Furthermore, most previous studies of large Arctic rivers were conducted only during summer. Thus, implementation of standard protocols, including seasonally representative sampling, was a key consideration for the PARTNERS project.

The PARTNERS data set provides an essential baseline for detecting changes in the pan-Arctic watershed. The six rivers capture runoff from 10.34 million square kilometers, and thus changes in the chemistry of these rivers would indicate widespread changes in watershed processes such as permafrost dynamics, soil weathering, and microbial activity. While elucidation of specific mechanisms behind changes in river chemistry requires direct study of major rivers, river chemistry provides an integrative signal that helps to constrain the possible mechanisms and thereby to develop informed hypotheses in support of more focused studies. For example, an increase in the age of river-borne dissolved organic carbon would point toward mobilization of ancient organic matter from thawing permafrost. High-quality baseline data also support better-informed studies of how changes in river export may influence ocean ecosystems.

One of the primary goals of PARTNERS was to improve estimates of chemical parameters used to differentiate freshwater sources in the Arctic Ocean. These parameters include the isotopic composition of hydrogen, oxygen in water molecules as well as concentrations of barium and alkalinity that have been used to track river water in the Arctic Ocean. The resolution of freshwater sources has been relatively coarse due to uncertainties in estimation of tracer values for individual rivers. The PARTNERS data contain these estimates by capturing seasonal dynamics and by facilitating the calculation of flow-weighted averages that reflect more realistic transport pathways.

The full PARTNERS data set includes approximately 90 parameters. Twenty-four of these parameters are shown in Figure 1, where values for high flow in each river are expressed relative to the average for all rivers. This representation of the data highlights major differences in chemistry between the North American and Eurasian rivers. In particular, concentrations of uranium, barium, calcium, sulfur, and total alkalinity are much higher in the North American rivers.

From Corals to Canyons: The Great Barrier Reef Margin

The significance of submerged coral reefs as important archives of abrupt global sea level rise and climate change has been confirmed by investigations in the Caribbean [Fairbanks, 1985] and the Indo-Pacific (see Montaggioni [2005] for a summary) and by recent Integrated Ocean Drilling Program (IODP) activities in Tahiti [Cenoy et al., 2007]. Similar submerged (60–130 meters) reef structures are preserved along the margin of the Great Barrier Reef (GBR), but they have not yet been systematically studied.

The submerged reefs have the potential to provide critical new information about the nature of past global sea level and climate variability and about the response of the GBR to these past and perhaps future environmental changes [Brunner et al., 2008]. Equally important for GBR Marine Park managers is information about the role of the reefs as habitats and substrates for modern biological communities.

Here we summarize the highlights and broader implications of a September–October 2007 expedition on the R.V. Southern Surveyor (Australian Marine National Facility, voyage SS07/007) to investigate the shelf edge, upper slope, and submarine canyons along the GBR margin.

GBR Reefal Reefs

The multibeam, seismic, and autonomous underwater vehicle (AUV) imagery provides a comprehensive view of the morphology and spatial distribution of the fossil reefs and terraces along the shelf edge between 40 and 130 meters (Figure 1). The shelf edge is where the GBR has spent about 85% of its time over the past approximately 500,000 years as climate varied and sea level fluctuated back and forth across the shelf edge.

The new data reveal a diverse suite of surface and subsurface features that includes submarine terraces, complex reef flat forming barrier, patch reef, and lagoonal systems, and aggrading pelagic channels and debris fans. An example survey area near Cairns (Figure 1 inset) illustrates the high quality of the imagery and shows the relationship between a parade of channel systems and the lagoon reefs at the shelf edge. These features likely reflect a complex history of growth and erosion during periods of sea level change at lower sea levels relative to today. Preliminary observations of rock dredge samples suggest that the most recent reef surfaces may be capped by coral reef material deposited during the last deglaciation (20,000–10,000 years ago).

Deep Benthic Habitats

Little is known about the modern benthic communities associated with the shelf edge reefs, despite their widespread occurrence throughout the Great Barrier Reef World Heritage Area (GBR/WHA). The new AUV imagery shows a diversity of benthic communities and substrate types that include red algae-encrusted fossil rock, thriving hard and soft coral, gorgonian (sea whip or fan) and sponge communities, and vast fields of Halimeda (green algae) covered substrates. Postcruise analyses of the AUV and multibeam data, together with the rock dredge and sediment samples, will provide quantitative information about the substrate...
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American rivers. These are also many striking differences in chemistry among rivers within each continental grouping. In contrast, seasonal patterns in chemistry are remarkably similar among rivers. This seasonality is tightly coupled to hydrologic variations at all of the rivers, with individual parameters consistently showing positive or negative correlations with discharge (indicated in Figure 1 by plus or minus signs in front of parameter label). Recent analyses of dissolved organic carbon export from rivers to the Arctic Ocean using PPARTNERS data, including revised estimates of export quantity, age, and losses within the Arctic Ocean, are given by Couper et al. [2007] and Biro et al. [2007].

Sampling was conducted at Saikhood (OC), Duddinika (Yenisei), Zhagay (Lena), Cherski (Kolyma), Pilat Station (Yukon), and Tuigibich (Mackenzie). These sites are located far down on each river and thus capture flow contributions from the vast majority of each river’s watershed. PPARTNERS participants completed 17 sampling trips on each river between summer 2001 and fall 2016. The trips were distributed in time to capture low flow during late winter (under ice), high flow during spring melt, and intermittent flow during summer/fall. Protocols were established using U.S. Geological Survey (USGS) guidelines, including the use of depth/flow integrating samplers. PPARTNERS sampling on the Yukon was coupled with USGS work ongoing since 2001.

Funding for the PPARTNERS project ended in fall 2017, but sampling will continue at the sites established during PPARTNERS, at least through 2017, as a component of the overflown A0W. Within this network, the river sampling program is now identified as the Arctic Great Rivers Observatory (Arctic-GRO) project. The Arctic-GRO is an experimental study, led by a subset of the PPARTNERS participants, with Bruce Couper as the lead scientist. The importance of the AON is underscored by observations of widespread changes in the Arctic during recent years [Symon et al., 2005]. Many changes in the Arctic are coupled to the freshwater cycle and have feedbacks to global climate [White et al., 2007].

Routeline data for the Yukon River at Pilot Station are available at tay.ru/0YukonSA/0Yukon-SA01.htm. All other PPARTNERS data, including nonoxygenic data for the Yukon, are available on the CADIS Web site, under the Arctic-GRO heading (http://www.eol.ucar.edu/projects/non-oxy).

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References


Great Barrier Reef

Modern reefs and mesophotic communities are one of the world’s great natural wonders. These ecosystems are home to over 25,000 species of fish, and millions of people depend on them for food, recreation, and coastal protection. The Great Barrier Reef (GBR) is the world’s largest coral reef system, stretching for over 2,300 km along the northeastern coast of Australia. The GBR supports some of the most diverse marine life on Earth, including thousands of species of fish, corals, and invertebrates. It also provides a critical habitat for many species of marine mammals, birds, and reptiles. The GBR is a vital economic resource, providing millions of dollars in revenue each year through tourism and fishing. However, the GBR is facing significant threats from climate change, coastal development, and pollution, which could have severe consequences for the health and productivity of the reef system.

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modern reefs and mesophotic communities. These systems are characterized by the presence of corals, which are among the most biodiverse marine organisms on Earth. The Great Barrier Reef is home to over 500 species of corals, as well as many other marine invertebrates such as sponges, sea urchins, and mollusks. These systems are also home to a wide variety of fish species, including some that are endangered or critically endangered. In addition, the Great Barrier Reef is a critical habitat for many species of marine mammals, such as dugongs and dugong-like species, as well as many species of birds and reptiles. The Great Barrier Reef is also a major tourist attraction, with over 2 million visitors each year. The economic benefits of the Great Barrier Reef are significant, with the tourism industry alone contributing over $2 billion to the Australian economy each year.