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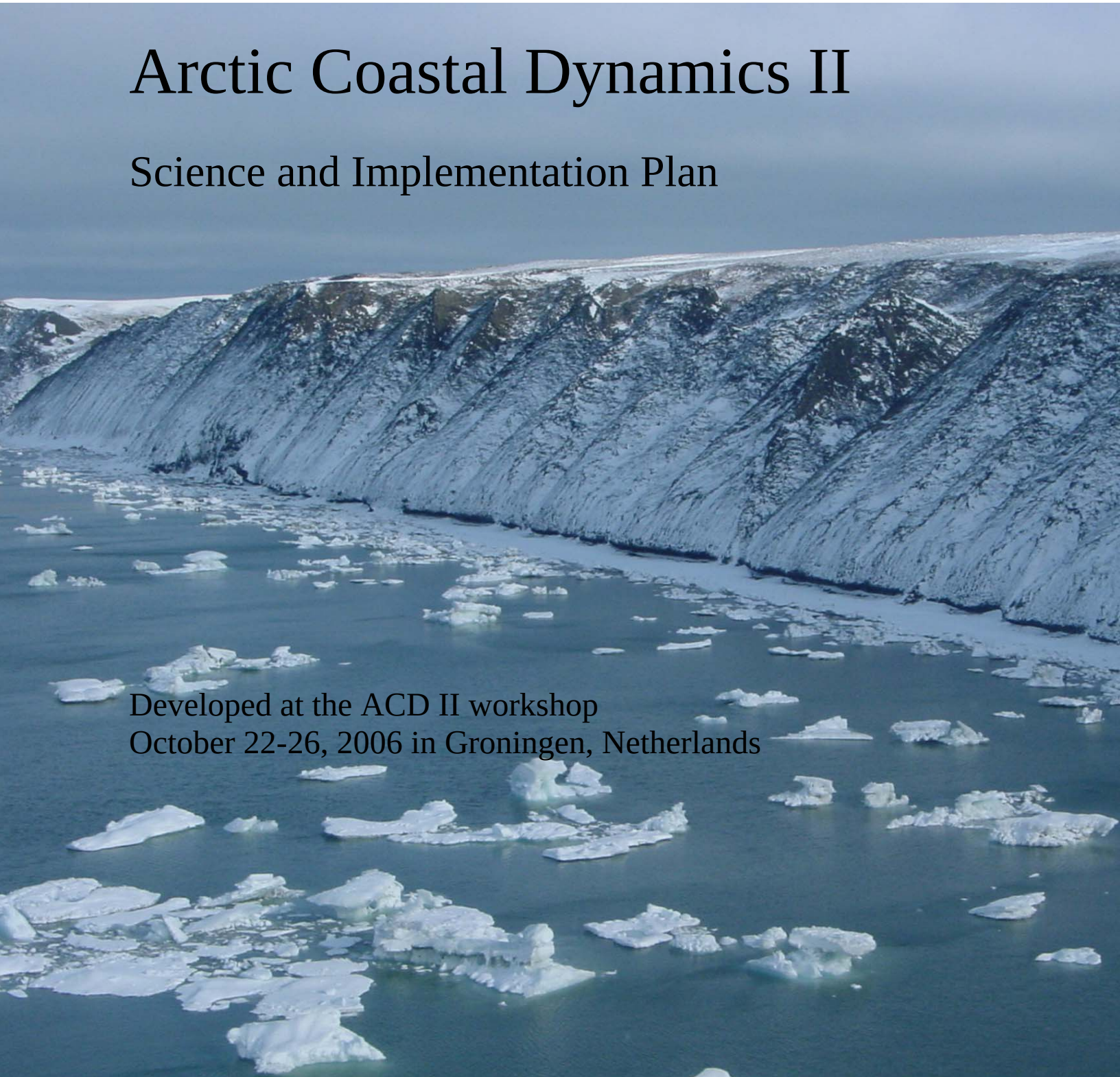

Arctic Coastal Dynamics II

Science and Implementation Plan

Developed at the ACD II workshop
October 22-26, 2006 in Groningen, Netherlands

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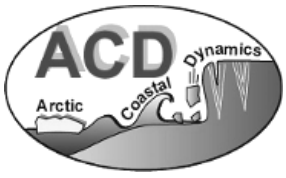
Arctic Centre, University of Groningen, Groningen, Netherlands

Alfred Wgeener Institute for Polar and Marine Research, Potsdam, Germany

International Arctic Science Committee

International Permafrost Association

Land-Ocean Interactions in the Coastal Zone



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1 Introduction

The coasts of the circumpolar Arctic region differ from their temperate and tropical counterparts, in particular due to the influence of ground ice, permafrost and sea ice. As is the case for southern coastlines, the Arctic coast is the site of human habitation, resource use, and transportation. However, changes to the global climate system are felt most keenly in the Arctic, where a small shift in temperature can mean transition to a permafrost and ice-free state. The greatest impacts are felt in environments that form the margins between ecoregions. This holds true for the coastal zone, which is defined as the region along the coastline within which marine processes directly affect the terrestrial realm, and vice versa. Given the relevance of this zone to human endeavour and its sensitivity to anthropogenic and natural change, it is of critical importance to understand the processes shaping the Arctic coastal zone and their responses to change.

The Arctic Coastal Dynamics (ACD) project of the International Arctic Science Committee (IASC) and the International Permafrost Association (IPA) was created in 1999 to improve our understanding of circum-Arctic coastal dynamics under the influence of environmental changes and geologic controls. Members of the Arctic coastal research community developed a science and implementation plan to guide the first 5-year phase of the project (ACD I). During that time, progress towards achieving the plan's objectives was reviewed and furthered through annual workshops. The results of ACD I, achieved between 1999 and 2005, are presented in a series of workshop reports, numerous journal articles, a special issue of the journal *GeoMarine Letters*, a forthcoming volume on regional and process-based studies entitled *Arctic Coasts - Circum-Polar Processes and Dynamics*, and a GIS Internet Map Server which includes a detailed characterization of geomorphology and processes for the entire circum-Arctic coast.

The second phase of the Arctic Coastal Dynamics project (ACD II) seeks to further develop knowledge about coastal processes and to extend the focus of ACD I within the context of the International Conference on Arctic Research Planning II (ICARP II), and in particular, of the science plan developed by the coastal working group at that conference. Key themes in the ICARP II science plan include:

1. continued identification of critical natural processes and changes currently underway in those processes (e.g. permafrost, sea-ice, coastal morphology, changing biological community structure and productivity, or environmental stressors.)

2. changes in human activities (e.g. shipping, mineral and hydrocarbon exploitation, construction of infrastructure, fisheries, hunting and herding, or tourism).

In order to focus the next phase of ACD activities, an international workshop was held at the Arctic Centre, University of Groningen, Netherlands, on October 22-26, 2006. The result of that workshop was the development of a phased, five-year science and implementation plan to further the objectives of ACD II. The plan is presented in the following pages.

2 ACD I Objectives and Outcomes

2.1. Overall Objectives

Since the initial ACD I objectives represent the starting point for ACD II, the results of the first phase of the ACD project are reviewed below, along with an assessment of the degree to which each objective was met:

1. Establish the rates and magnitudes of erosion and accumulation of Arctic coasts.
   Status: a coastal segmentation and classification for the Arctic coast in GIS database format has been created and includes estimates and measurements of rates.
2. Develop a network of long-term monitoring sites including local community-based observational sites.
   Status: key monitoring sites were established, but most do not include community-based observations.
3. Identify and undertake focused research on critical processes.
   Status: a number of such research projects have been undertaken and have either been completed or are ongoing.
4. Estimate the amount of sediments and organic carbon derived from coastal erosion.
   Status: first estimates derived from the ACD GIS have been published.
5. Refine and apply an Arctic coastal classification in digital form.
   Status: the GIS classification was completed (alpha release), but requires data quality assessment and agreement on the part of data providers for release. The Greenland and Svalbard coasts were classified but not segmented.
6. Extract and utilize existing information on relevant environmental forcing parameters.
   Status: completed (for wind speed, storm counts, melt season, melting degree days, first order wave energy)
7. Produce a series of thematic and derived maps (e.g. coastal classification, ground ice, sensitivity etc.).
   Status: data have been compiled, but maps have not yet been produced.
8. Develop empirical models to assess the sensitivity of Arctic coasts to environmental variability and human impacts.
   Status: several models have been developed, but have not yet been systematically applied.

2.2 Outcomes and Products

2.2.1. Publications

Much of the results from work conducted during ACD I is available in published form.

- A special issue of the journal *Geo-Marine Letters* (Volume 25, Number 2-3, June 2005) is devoted to ACD. The issue contains 15 articles which summarize the project's scientific results to that point.
- A listing of other peer-reviewed journal articles is available on the ACD website: http://www.awi-potsdam.de/acd/publist.htm.

- A volume entitled *Arctic Coasts - Circum-Polar Processes and Dynamics* is slated for publication during the International Polar Year. It contains chapters on the dominant regional processes in the seas of the Arctic Ocean, as well as a series of thematic chapters that examine specific aspects of coastal dynamics in the Arctic.
- The proceedings of the ACD workshops contain extended abstracts of ACD-related activities and are published in the journal *Reports on Polar and Marine Research / Berichte zur Polar- und Meeresforschung* (2002 Number 413; 2003 Number 443; 2004 Number 482; 2005 Number 506)
- A listing of almost 800 Russian-language articles related to Arctic coastal processes has been compiled and is available on the ACD website.

2.2.2. Geographic Information System (GIS)

An important outcome of ACD I was the segmentation and characterization of the entire circum-Arctic coastline by regional experts. This detailed evaluation has been compiled into a geographic information system (GIS) which contains data on coastal morphology, composition, dominant processes, ground ice, and environmental forcing parameters such as wind speed, storm counts, melt season, and wave energy. A listing of the variables included in the coastal classification can be found in Appendix A. This information is available for over 800 segments, covering the coastline of all eight regional seas of the Arctic Ocean. The length of individual segments is variable (median length is 38 km), and depends on classification parameters and data availability. The segmentation format is scalable, allowing the adoption of future digital coastlines and the integration of additional data at higher spatial resolution. An assessment of the data quality for the more important quantitative variables has just been completed and the data will be publicly released on an internet map server (IMS). The goal of the IMS will be to allow individual users to prepare their own maps displaying the region and variables of interest.

3 ACD II Science Initiatives

Building on the achievements of ACD I, the purpose of this plan is to outline steps to be supported and undertaken by the Arctic Coastal Dynamics community over the next five years. The plan is the product of presentations, discussions and reports created by the ACD community at its 6th workshop in Groningen, Netherlands in October, 2006. At the Groningen workshop, plans were outlined for expanding the ACD key sites into a larger international network of Arctic coastal observatories, beginning with an IPY initiative nested within a cluster of interdisciplinary projects on coastal observations. In addition, working groups were established for the following five areas of study:

1) social and economic dimensions
2) coastal subsea permafrost
3) nearshore zone processes
4) environmental forcing factors
5) remote sensing

Each of the Groningen working groups discussed the major Arctic coastal zone science questions that remain unanswered. Outlined below are some of the key questions and a series

of science initiatives that were recommended to address them. Some of these initiatives serve to continue work begun during ACD I, while others are new. Taken together, these goals and the strategies for achieving them form the ACD II Science and Implementation Plan. Details on the working group discussions are published in the workshop report. Biodiversity is recognized as an important element of coastal dynamics, but is the focus of Arctic Coastal Biodiversity (AC-Bio), a parallel project initiated by IASC and incorporated in the Coastal Working Group of the ICARP II initiative.

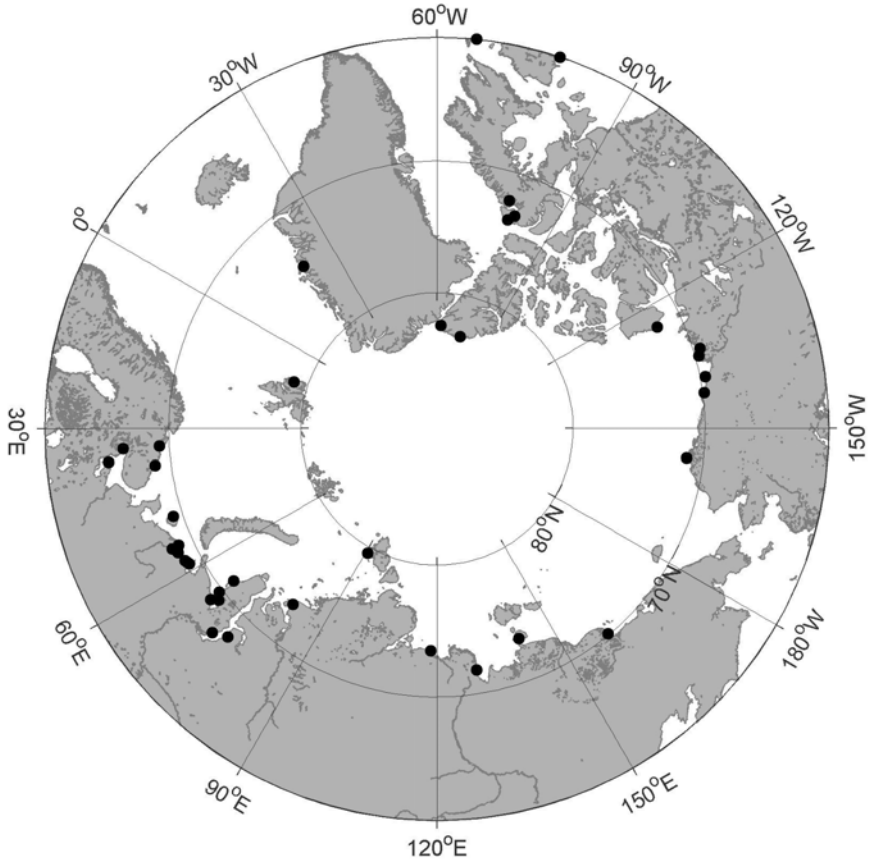

Figure 1. ACD key sites and ACCO-Net candidate sites. These will serve as the starting points for a circum-Arctic network of coastal observatories to monitor physical, ecological, biogeochemical, and socio-economic parameters. Details on site locations are available on the ACCO-Net website (www.acconet.org).

3.1 Coastal Observatories

Key question: How to expand the ACD I key sites into a more comprehensive and integrated network?

- Establish an internationally coordinated circum-Arctic network of coastal observatories to monitor physical, ecological, biogeochemical, and socio-economic parameters and processes. The network will be based on ACCO-Net (IPY full proposal #90), where possible, and feed into the Sustained Arctic Observing Network (SAON) initiative.
- Using the ACD I key sites as a starting point, identify gaps in geographical or process-related coverage and seek funding and/or personnel to establish sites at these additional locations. Coordinate these activities with local communities and already established national and international projects.
- Conduct initial site characterization by compiling existing information and processing available remotely sensed imagery.
- Develop a set of primary parameters to be monitored at all sites. Establish an additional secondary set of parameters for sites where resources permit expansion of monitoring activities (see Appendix B).
- Identify and compile existing protocols or standard operating procedures for monitoring parameters, and make available on ACD website. Establish protocols for parameters for which no standards currently exist.
- Develop data and information management strategies which include metadata standards, Arctic spatial data infrastructure, web accessible databases and products, and data accessibility to local and scientific communities.
- Monitor identified parameters to detect changes and to identify interdependencies between them. Synthesize data to formulate models at multiple levels in order to predict future impacts on physical, biological, and human systems.

3.2. Social and Economic Dimensions

Key question: How do humans interact with coastal environments in the Arctic and what information do they need to assist in social and economic decision-making processes?

- Characterize coastal geohazards in the context of industrial and community development (e.g., ports and harbours, oil and gas, shipping, water supplies, cultural resources).
- Incorporate the human dimension into the existing ACD GIS through the development of new layers. Information to be displayed should include community locations, jurisdictional/political boundaries, key infrastructure, indigenous/local land use, and subsistence/commercial marine use.
- Catalogue existing local and regional monitoring programs to ensure that information in new GIS layers can be further cross-referenced with ongoing social science research.
- Liaise with communities prior to establishing new coastal monitoring sites to gather local input on parameters of interest, data availability and community resource integration. Examples include ground ice contents which may affect the emplacement of new infrastructure, or local wind conditions, since this affects sea ice movement and safety of hunters.

- Make available a guide for coastal researchers in the form of an on-line bibliography and listing of web links to address such matters as plain language reporting, research licensing, incorporating traditional knowledge in research, and human research ethics.
- Link ACD II activities with planned International Polar Year (IPY) initiatives of concern to communities such as nutrient/contaminant fluxes, or vulnerability of human systems to coastal changes.
- Mount an interdisciplinary pilot project on *Vulnerability and Resilience of Human Systems* which will focus on active collaboration between physical and social scientists at several of the proposed coastal observatory sites to address this research need.

3.3. Coastal Subsea Permafrost

Key question: What effect does subsea permafrost have on coastal processes and vice versa?

- Compile, synthesize, and digitize existing data on subsea permafrost via the creation of maps at global, regional (1:1 000 000) and local, site-specific scales.
- Model and validate subsea permafrost at key sites on the basis of extensive drilling and geophysical data.
- Incorporate modelled data into mapping efforts.
- Launch studies on nearshore processes (e.g., bottom-fast ice formation, sea ice retreat, sediment fluxes, shoreface morphodynamics) that have the potential to rapidly affect permafrost state after inundation in submergent or erosional environments.
- Investigate sediment porewater geochemistry and stable isotope composition to elucidate the factors on which the mechanisms, rates and spatial distribution of the geochemical degradation of subsea permafrost depend.
- Investigate the interdependence of gas hydrates and permafrost degradation.
- Extend the GIS segmentation database seaward to include the slope of ice-bonded sediment, for correlation with coastal retreat rates and other environmental factors.

3.4. Nearshore Zone Fluxes

Key question: How are materials transported and transformed in the coastal zone and what are the results?

- Continue periodic measurements of shoreline position to monitor coastal erosion and to better clarify its episodic nature.
- Develop a first approximate model to understand how erosion and deposition affect coastal morphology and sediment and carbon balances in the shallow water zone.
- Examine transformation of coastal material prior to denudation (grain size, quality/lability of organic matter, water content, bulk density) and following erosion (remineralization of carbon, oxidation of low-valency metals) to better understand the effects of the addition of this material to coastal waters.

- Extend the estimates of organic fluxes by developing a detailed database of actual organic carbon measurements in the coastal zone.

3.5 Environmental Forcing

Key question: How do environmental forcings control Arctic coastal dynamics and how are they likely to change in the future?

- Expand the GIS database through the addition of layers on precipitation, wind and wave energy data, sea ice historical and current observational data.
- Develop downscaling techniques to integrate GCM forecasts into regional/local ACD modelling efforts.
- Develop strategy for establishing frequency, distribution and likelihood of ice push events for input into erosion models.
- Determine appropriate course of action to better represent surge dynamics in the Arctic.
- Develop an empirical/statistical prediction system for land fast ice formation and disappearance.
- Characterize the importance of marine thermokarst processes to wave energy and other near-shore processes.
- Examine the potential role of swell in an ice-free summer Arctic on coastal processes.

3.6 Remote Sensing

Key question: - How can we effectively expand the use of remotely sensed data for monitoring coastal change?

- Ensure that acquisition of remotely sensed imagery is coordinated and standardized to increase the availability of comparable datasets. Elaborate on current standards for the storage, retrieval and treatment of ACD II imagery.
- Develop a set of basic geospatial datasets for each coastal observatory location including a network of ground control points, a digital elevation model (DEM), and a terrain unit map.
- Obtain high resolution imagery for shoreline positioning and monitoring, and use to develop a new high resolution digital shoreline for the circum-Arctic.
- Use Moderate Resolution Imaging Spectroradiometer (MODIS) products for monitoring sediment load and dispersal, and ice breakup and overflow.
- Map bottom fast ice using radar imagery.
- Monitor relative sea level using submersible water level recorders and, where possible, install instrumentation for recording absolute sea level (i.e., incorporate measurements of continuous or epoch GPS measurements on heave-proof benchmarks to measure vertical motion).
- Install time-lapse cameras to monitor shoreline movement as well as wave, storm surge and sea-ice dynamics.
- Map nearshore morphology and bathymetry using side-scan sonar and swath techniques (e.g. interferometric sidescan sonar or sweep systems) where possible.

4 Outcomes and Products

A number of products from ACD II research activities are planned:

- In order to normalize and coordinate monitoring activities at coastal observatory sites, a standardized set of remote sensing products will be assembled, a reference list of standard operating procedures will be compiled, and a monitoring template will be developed. The results from monitoring activities will be contained in a catalogue of the observatory sites.
- A listing of resources for cementing links between Arctic communities and coastal researchers will be developed and made available on the ACD website. A pilot project examining the human response to coastal vulnerability will be launched within the scope of IPY.
- A series of maps of nearshore subsea permafrost will be generated at various scales by extending existing data with validated model results.
- Maps of coastal geohazards (e.g., erosion, deposition, nearshore thermokarst, strudel scour, or coastal wave climate) will be developed.
- Models of nearshore zone processes will be extended or developed into a simple coastal change model to explain sediment and carbon transport and storage, as well as changes and response in the nearshore environment. The model should be generic enough to be broadly applied and should be integrated with the ACD GIS database.
- Other outputs generated by these activities are anticipated to include a detailed database of organic carbon, downscaled GCM datasets, time-lapse shoreline records, and geospatial datasets for each coastal observatory. This information will be published in scientific journals, made available on the ACD website, or incorporated into an expanded ACD GIS database.

5 Implementation Timeline

A significant framework for the ACD II implementation timeline is the International Polar Year, which extends from March 2007 to April 2009. Specific ACD initiatives will thus feed into and draw from a backdrop of intense polar research. The initial stages for implementing ACD's science goals will coincide with similar ones for the IPY.

Phase 1: Wrap up of ACD I activities (mid 2007 to early 2008)

Although many of ACD II's plans build upon achievements and research begun during the first five years of the project, it is nevertheless important to ensure that concluding results from that first phase are published. To that end, a GIS mini-workshop was convened in Potsdam in May 2007 to create and integrate segmentation and classification data from Svalbard into the GIS, together with regional experts. In addition, the data quality assessment performed by regional experts and data providers for all seas, a necessary step before final release of the GIS, has begun and is being incorporated. A data policy and a data release agreement has been developed by the steering committee in concert with the GIS data centre,

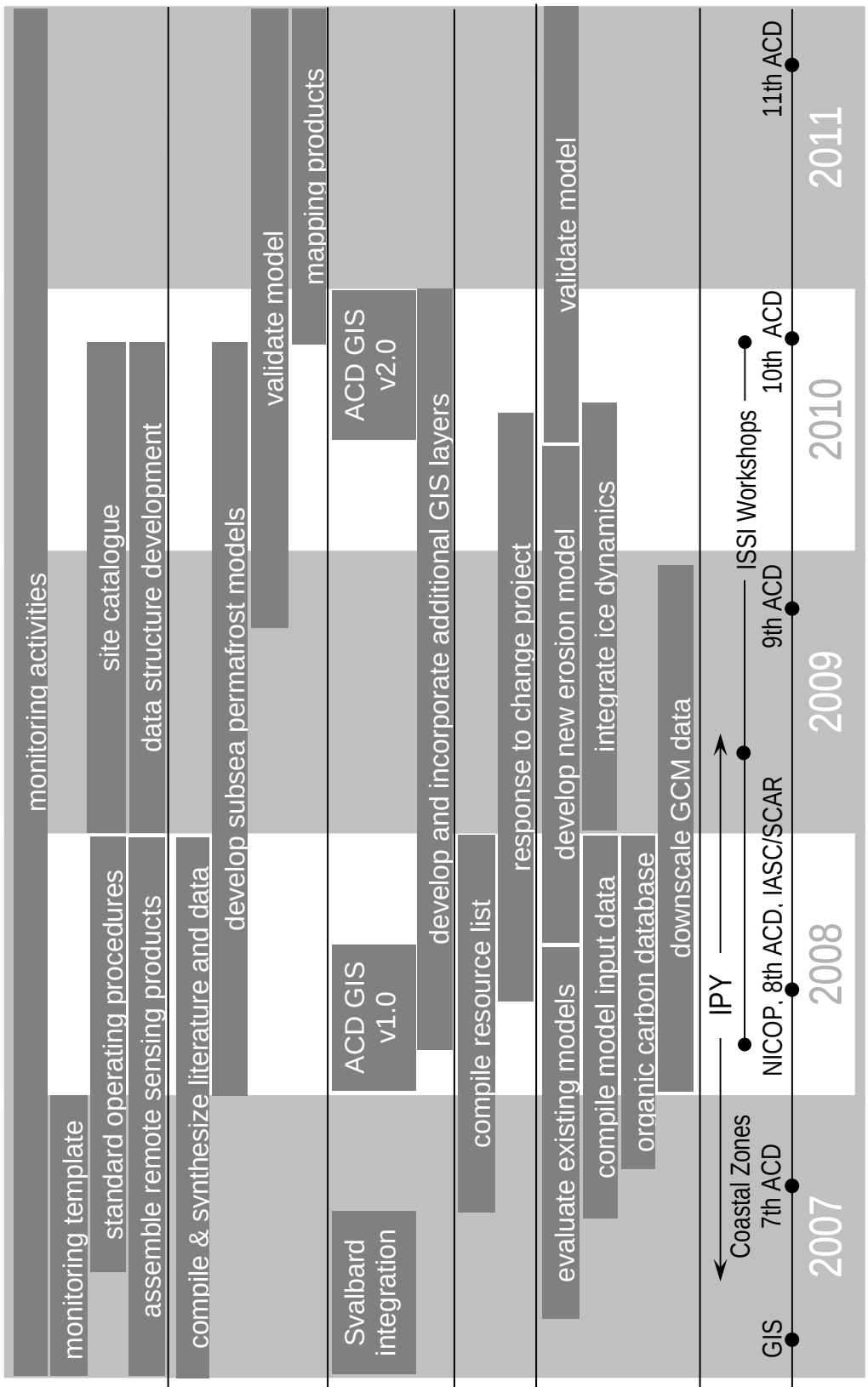

Figure 2. ACD II implementation timeline.

and will allow release of the first version of the ACD GIS in early 2008. Revisions on chapters for the book *Arctic Coasts - Circum-Polar Processes and Dynamics* are underway and several manuscripts synthesizing the science results of the ACD project are in preparation. It is anticipated that these publications will be completed by late 2007 or early 2008.

Phase 2: Compilation of data for ACD II initiatives (late 2007 and 2008)
This phase involves identifying what existing data are necessary for planned ACD II activities and designating working groups to compile them.

Coastal observatory network: The circum-Arctic coastal observatory network is centred on existing ACD key sites. Monitoring will continue at these sites, but additional observatory sites are to be added as resources become available, especially via IPY-funded projects. To help standardize monitoring efforts across all of the observatory sites, the 6th ACD workshop adopted a template of primary and secondary monitoring parameters and set guidelines for measurement frequency (Appendix B). Standard operating procedures for these monitoring parameters will be culled from existing standards (e.g., Thermal State of Permafrost (TSP) and Global Terrestrial Network - Permafrost (GTNP), Terrestrial Ecosystem Monitoring Sites), or created. A grant from the European Space Agency's (ESA) IPY program will provide visible and infrared remote sensing imagery for 41 of the existing and planned coastal observatory locations. Archived images will need to be selected, as will exact locations and acquisition times for new imagery.

Social dimensions: Elements of human use or occupation of Arctic coastal zones need to be better defined in order to properly incorporate regions of interest or concern into process studies. Relevant information to be gathered includes demographic information, community locations, jurisdictional or political boundaries, key infrastructure (transportation, dwellings, industry, cemeteries, archaeological sites, sacred places) and indigenous/local land use. Much of this data can be gleaned from existing archives (e.g., Nunavut Land Use Survey, Alaskan Coastal Zone Mapping Project, Saami Council, community-specific research on local or regional land use).

Subsea permafrost: Subsea permafrost mapping is in its infancy, and requires a substantial effort in compiling relevant data from a variety of sources, including borehole logs, seismic profiles, geological mapping, borehole temperature records, estimates of past sea level, ice cap histories at the regional level, and coastal field studies. Geological maps relevant to permafrost distribution have been digitized and are available for most of the Russian seas. Existing literature on modelling methods will be compiled and synthesized as a part of model development.

Flux model and environmental forcings: Existing models of nearshore processes need to be examined for their suitability as a basis for a generic quantitative coastal erosion model. The model needs to be applicable to a broad range of coastal types, along a process continuum that ranges from pure thermal denudation at one end to pure thermal erosion at the other. Inputs for the model need to be collected, such as bathymetric data (either from surveys, radar or Lidar imagery). Several existing datasets of other environmental parameters that can be useful inputs are available, including digital layers of sea ice data from various national sources,

historical sea ice data in the *Sea Ice Atlas of the Arctic*, and observational data on land-fast ice on/off dates from Russ-Hydromet stations. Statistical data from coastal sites, such as wind roses and extreme event recurrence, need to be compiled. The suitability of precipitation data from the University of Delaware or British Climate Research Unit data sets will be investigated and an appropriate interpolation method decided upon. Detailed data on organic carbon contents need to be collected for compilation into a database.

Phase 3: Development of ACD II initiatives (2008 to 2009)
This phase of the project will use the compiled data to begin full implementation of the ACD II initiatives.

- A catalogue of observatories and a data management structure for the monitoring data will be developed.
- Standardized geospatial datasets from the ESA remote sensing products will be generated, including land cover classifications, vegetation indices, and digital elevation models. A grant from the International Space Science Institute (ISSI) has been secured to provide support for three workshops to define, standardize and coordinate analysis of the imagery.
- Work will begin on the pilot project looking at the vulnerability and resilience of Arctic coastal population and communities to change. The focus will be on regions where physical processes are of most interest or concern (e.g., travel routes over ice, infrastructure threatened by erosion, boating or shipping corridors).
- Subsea permafrost models will be developed, with initial efforts focussed on reproducing permafrost profiles in the coastal zone, and then extended to include three dimensional permafrost state and distribution. The scale of initial mapping efforts will be large (1:1 000 000) and can be refined regionally based on available data.
- Commence development of a generic coastal erosion model, including specific improvements to wave energy data that have been identified by the Environmental Working Group.
- Downscale GCM data
- Start to develop new GIS layers

Phase 4: Synthesis (post-IPY)
In this final phase of ACD II, the data gathered during the project will be analyzed and synthesized. Models will be validated and products from the project's activities will be generated (e.g., maps of subsea permafrost, erosion forecasts, organic carbon database). A second, updated version of the GIS will be prepared. Results will be published in scientific journals and on the ACD website.

6 Meetings

The annual ACD workshops will continue to serve as a focal point for the project's activities and provide a basis for ACD II to coordinate and develop its research program and share results. This is especially important given the impending physical changes that are expected and the increasing access to Arctic regions and resources. Several of the workshops are planned to coincide with other conferences of interest to the project members. Several meetings at the International Space Science Institute (ISSI) are also planned to coordinate work with the ESA remote sensing imagery. The tentative schedule is:

- May 2-4, 2007: GIS mini-workshop, Alfred Wegener Institute, Potsdam, Germany
- October 1-4, 2007: Arctic Coastal Zones at Risk, and 7th ACD workshop, Polar Environmental Centre, Tromsø, Norway
- April (2nd week), 2008: ACCO-Net ESA Imagery Workshop, International Space Science Institute (ISSI), Bern, Switzerland
- June 29 - July 3, 2008: Ninth International Permafrost Conference (NICOP) and 8th ACD workshop, Fairbanks, USA
- July 8-11, 2008: SCAR/IASC Open Science Conference: Polar Research – Arctic and Antarctic Perspectives in the International Polar Year, St. Petersburg, Russia
- March 2009: ACCO-Net ESA Imagery Workshop, International Space Science Institute (ISSI), Bern, Switzerland
- Autumn 2009: 9th ACD workshop
- Autumn 2010: ACCO-Net ESA Imagery Workshop, International Space Science Institute (ISSI), Bern, Switzerland and 10th ACD workshop
- Autumn 2011: 11th ACD workshop

7 Project Management and Coordination

The International Permafrost Association (IPA) and the International Arctic Science Committee (IASC) have been the sponsoring organisations for ACD. ACD II is an affiliated project of the Land-Ocean Interactions in the Coastal Zone (LOICZ II) project of the International Human Dimensions Program (IHDP) and the International Geosphere-Biosphere Program (IGBP). ACD seeks to co-ordinate observatory sites at both the community level and within a pan-Arctic multidisciplinary observatory network, such as the emergent Sustained Arctic Observatory Network (SAON) effort.

Day-to-day management and coordination of ACD II activities are handled by the ACD secretariat which is shared between the Alfred Wegener Institute for Polar and Marine Research (AWI), Potsdam, Germany and the Department of Geography, McGill University, Canada. The project co-leaders are Pier Paul Overduin (AWI) and Nicole Couture (McGill). The co-leaders work in consultation with an international Steering Committee. Coordination of activities among ACD members will continue through periodic newsletters, the annual workshops, and meetings of opportunity.

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8 Potential Users and Funders

Users of information generated by ACD activities include industry, governments at local, regional and national levels, environmental organizations interested in coastal habitats or contaminant movements (e.g., CAFF, WWF, AMAP), policy organizations involved in assessments (e.g., IPCC, ACIA, LOICZ), and scientists from other disciplines. Although a number of national-level IPY initiatives associated with the ACCO-Net project did not receive support, several other sources of funding for the coastal observatories are being pursued and have, in some cases, been awarded. Opportunities for sharing resources with other IPY projects continue to be explored. Additionally, funding for all ACD activities will be sought from a variety of sources including national research agencies; logistics providers; regional, multinational and international organizations; industry partners and other private sources.

Appendix A: Variables Included in the ACD Coastal Classification

The coastlines of the eight regional seas bordering the Arctic Ocean have been segmented by regional experts, based on physical characteristics and data availability. For each of the more than 800 resulting segments, the ACD GIS database contains fields for the following variables:

Field	Description
segment identifier	
segment name	official or descriptive name
segment code	2 digit regional sea code and 4 digit segment number
onshore (direction landward from the sea)	
onshore form	delta=d, lowland (<10m)=l, upland (10-500m)=u, highland (>500m)=h, wetland=w
onshore comment	additional text if necessary
backshore (upper part of the active beach above the normal reach of the tides, but affected by large waves occurring during a high water event)	
backshore form	cliff=c, slope=s, flat=f, ridged/terraced=r, anthropogenic=a, complicated=x
backshore elevation	in metres
dq backshore elevation	data quality assessment for this field: high=h, medium=m, or low=l
backshore material 1	lithified=l, unlithified=u
backshore material 2	mud-dominated=m, sand-dominated=s, gravel-dominated=g, diamict=d, organic=o, mixtures= e.g mg, sg
backshore comment	text to be added if backshore_form=r or backshore_form=x
shore (strip of ground bordering the sea which is alternately exposed, or covered by tides and/or waves)	
shore form	beach=b, shore terrace=t (created by the action of waves and shore currents, it may become land by uplifting of shore or lowering of the water), cliff=c, complicated=x
beach form	(to be filled if shore_form=b) fringing=f, barrier=b, spit=s
shore material 1	lithified=l, unlithified=u
shore material 2	mud-dominated=m, sand-dominated=s, gravel-dominated=g, diamict=d, organic=o, mixtures= e.g mg, sg
shore comment	text to be added if shore_form = x
offshore	
depth closure	in metres, maximum storm wave base (i.e., point at which cross-shore sediment transport due to coastal processes becomes nil)
distance 2m isobath	in metres
distance 5m isobath	in metres
distance 10m isobath	in metres

Field (continued)	**Description** (continued)
distance 100m isobath	in metres
offshore material	mud-dominated=m, sand-dominated=s, gravel-dominated=g, diamict=d, organic=o, mixtures= e.g mg, sg
general	
ground ice 1	low (2-20%)=l, medium (20-50%)=m, high (>50%)=h
ground ice 2	in % volume of total shoreface
dq ground ice 2	data quality assessment for this field: high=h, medium=m, or low=l
ground ice comment	additional text to be added if ground ice template was filled out
change rate	in metres/year (erosion < 0, accumulation > 0)
change rate interval	years of observation (e.g. 1956-1999)
dq change rate	data quality assessment for this field: high=h, medium=m, or low=l
dynamic process	erosive=e, stable=s, accumulative=a (interpretation, only to be filled out if change rate is not available)
dry bulk density	dry weight of material for a given field volume, in t/m3. If no data available use: clay=1.3, silt=1.5, sand=2, or mixtures, e.g. silty sand=1.8
dq dry bulk density	data quality assessment for this field: high=h, medium=m, or low=l
organic c	% of organic carbon by weight for the total shoreface volume
dq organic c	data quality assessment for this field: high=h, medium=m, or low=l
soil organic c	amount of soil organic carbon in the top 1 metre of soil, in kg/m2
dq soil organic c	data quality assessment for this field: high=h, medium=m, or low=l
data sources	sources or references(citation) of information (i.e. published, unpublished observations or reports)
comments	additional comments on classification, if any
dq comments	additional comments on data quality, if any
primary contact person	name, email
mappers	names of those who created and/or classified the segments

In addition to the above information which is included in the classification layer, the ACD GIS also contains environmental layers with information relevant to coastal processes. These include wind speed, storm counts, melt season starting and ending dates, melt season duration, melting degree days, and first order wave energy.

Appendix B: Circumpolar Coastal Observatory Monitoring Template

The template of monitoring parameters provides a means of standardizing coastal observatory networks and of ensuring data consistency between observatories. Monitoring parameters are categorized by two criteria. A rank (primary/secondary) system establishes a minimum set of observations to be made, and a measurement frequency establishes a minimum measurement interval. Primary parameters are those parameters to be monitored at all sites. A set of secondary parameters applies to those sites where resources permit expansion of monitoring activities. Standard operating procedures are to be compiled for all parameters. Metadata requirements will be outlined and will comply with ISO standards. The data policy currently in review for the ACD GIS will also apply to the data from the coastal observatories.

Establishment

Primary monitoring parameters
- •ground ice and carbon content and quality
- •borehole temperatures
- •high resolution vector shoreline
- •DEM or surveyed profiles
- •nearshore bathymetry
- •modified or engineered shorelines

Secondary monitoring parameters
- •coring transect and ground temperature profiles from onshore to offshore
- •landcover, landuse (seasonal) and settlement classification

Monitoring at high temporal resolution

Primary monitoring parameters
- •meteorology: precipitation, wind speed-direction, air temperature, relative humidity, radiation
- •borehole temperatures
- •active layer depths
- •soil moisture

Secondary monitoring parameters
- •current, water level, waves
- •time-lapse photography
- •water temperature, salinity, TSS, DOC, dissolved oxygen
- •sea ice distribution (duration, thickness, events, distance to pack ice edge, winter-time break-outs)
- •economic activities
- •thermokarst activity

Monitoring at annual to decadal time scale

Primary monitoring parameters
- •coastal change rate
- •vertical motion
- •damage inventory, hazards inventory (erosion, contaminants, ice, economic)
- •demographic information

Secondary monitoring parameters
- •cryogenic processes
- •fishing and hunting ground locations (may be proprietary, e.g. whale strikes)
- •education/outreach product (e.g., short video about network)
- •observatory-specific parameters

Appendix C: Abbreviations

ACCO-Net	Arctic Circumpolar Coastal Observatory Network
ACD	Arctic Coastal Dynamics
ACIA	Arctic Climate Impact Assessment
AMAP	Arctic Monitoring and Assessment Program
AWI	Alfred Wegener Institute for Polar and Marine Research
CAFF	Conservation of Arctic Flora and Fauna
CALM	Circumpolar Active Layer Monitoring
DEM	Digital elevation model
ESA	European Space Agency
GIS	Geographic information system
GCM	General circulation model
GTNP	Global Terrestrial Network - Permafrost
IASC	International Arctic Science Committee
ICARP II	Second International Conference on Arctic Research Planning
IPA	International Permafrost Association
IPCC	Inter-governmental Panel on Climate Change
IPY	International Polar Year
ISSI	International Space Science Institute
LOICZ	Land-Ocean Interactions in the Coastal Zone
NICOP	Ninth International Conference on Permafrost
SAON	Sustained Arctic Observatory Network
TSP	Thermal State of Permafrost
WWF	World Wildlife Fund

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Participants of the 6th International Workshop on Arctic Coastal Dynamics, Groningen, Netherlands, October 22-26, 2006 (Photo by Jerry Brown).