OCEANOGRAPHIC TIME SERIES FROM DIRIGIBILE ITALIA MOORING IN KONGSFIORDEN: A SYNTHESIS OF ITALIAN ACTIVITIES AND A PLATFORM FOR COLLABORATION

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CNR-ISMAR, La Spezia - Italy

CNR is the Italian National Research Council

ISMAR was evaluated as the **excellence institute** of the CNR Earth System Science Department

- Headquarter in **Venice**, plus 6 regional branches
- 180 Permanent Staff;
- About 80 people in training (PhD, postdoctoral)

[www.ismar.cnr.it]
Project structure

- WP1 - The integrated atmosphere-hydrosphere-cryosphere system
- WP2 - Evolution and Dynamics of the glacial cap and outlet glaciers in Greenland
- WP3 - Reconstruction of extreme meltwater events
- WP4 - Conceptual model and distributed system for the management, use and dissemination of data
WP1 - The integrated atmosphere-hydrosphere-cryosphere system

**Fjords**

- Shape and origin
- Most distributed at high latitudes
- Amplification of the climate change in the Arctic Ocean, but fjords even more sensible
- Only 0.1% of the world's ocean surface but account for 11% of annual OC burial

*Smith et al., 2015*
- NW Spitsbergen Island (Svalbard)
- ca. 20 km long, 4-10 km wide
- outer fjord > 200 m deep - sill - shallower inner part (< 100 m deep).  

Ny-Ålesund research centre
- 11 research stations in Ny-Ålesund
- research projects and monitoring activities all year round
- coordinated by NySMAC (Ny-Ålesund Science Manager Committee)
Base Dirigibile Italia
- CNR Labs, surface 330 m² with offices and labs, up to 7 researchers
- Open all year round
- Researches on atmospheric chemistry and physics; **marine** biology; physics of the high atmosphere; technological research, geology and geophysics; glaciology and permafrost; paleoclimate; **oceanography** and limnology; terrestrial ecosystems; human impact on the environment, human biology and medicine.

From 2009-10, setup of 3 multidisciplinary observation platforms:

a) Amundsen-Nobile Climate Change Tower (CCT),

b) Aerosol and Gruvebadet interface processes lab (GVB)

c) **Oceanographic** mooring MDI in the Kongsfjorden.
Integrated measurements at the main interfaces of the fjord

Main parts of the system
1. Fjord
2. Glaciers
3. Sea ice
4. Ocean
5. Land
6. Atmosphere
7. Sediment

Flux measurements
- Water
- Salt
- Heat
- Dissolved and
- Particulate matter
Mooring Dirigibile ITALIA (MDI)

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Thanks www.kartverket.no for the base map
Mooring Dirigibile ITALIA (MDI)

Ancillary CTD casts

MDI

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Mooring Dirigibile Italia (MDI) June 2015 - VII Deployment

| Deployment | 23 June 2015 10:23 LT
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>78°54.815’ N, 012°14.899, w. depth 101 m</td>
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</table>

<table>
<thead>
<tr>
<th>Recovery</th>
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<table>
<thead>
<tr>
<th>Ropes above sea floor</th>
<th>Below sea level</th>
<th>Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 m</td>
<td>Red rope</td>
<td>67.7 m</td>
</tr>
<tr>
<td>20 m</td>
<td>Red rope</td>
<td>65.2 m</td>
</tr>
<tr>
<td>6 m</td>
<td>Red rope</td>
<td>44.7 m</td>
</tr>
<tr>
<td>6 m</td>
<td>Red rope</td>
<td>38.7 m</td>
</tr>
<tr>
<td>10 m</td>
<td>Red rope</td>
<td>28.7 m</td>
</tr>
<tr>
<td>10 m</td>
<td>Steel buoy McLane 30°</td>
<td></td>
</tr>
<tr>
<td>2 m</td>
<td>Current meter Nortek Aquadopp (s/n AQD1006)</td>
<td></td>
</tr>
<tr>
<td>20 m</td>
<td>SBE 56 (s/n 576)</td>
<td></td>
</tr>
<tr>
<td>6 m</td>
<td>SBE 56 (s/n 1173)</td>
<td></td>
</tr>
<tr>
<td>2 m</td>
<td>Resinex buoy</td>
<td></td>
</tr>
<tr>
<td>2 m</td>
<td>Sediment trap Technicap PPS 4/3 (s/n 9109)</td>
<td></td>
</tr>
<tr>
<td>4.5 m</td>
<td>T C &amp; conductivity recorder SeaCat SBE16 (s/n 1561) Sensors downward</td>
<td></td>
</tr>
<tr>
<td>1 m</td>
<td>ADCP RDI Sentinel V S100 300 kHz sn 23118 (looking upward)</td>
<td></td>
</tr>
<tr>
<td>1 m</td>
<td>ADCP RDI Sentinel V S100 300 kHz sn 23118 (looking upward)</td>
<td></td>
</tr>
<tr>
<td>2 m</td>
<td>Acoustic Release EdgeTech 8042 (s/n 20896)</td>
<td></td>
</tr>
<tr>
<td>2 m</td>
<td>Sand Ballast in n. 3 barrels. total 0.6 cubic m 1200 kg in air (600 kg water)</td>
<td></td>
</tr>
</tbody>
</table>

N.B.: not in scale!
Mooring Dirigibile ITALIA (MDI) - CTD Casts (September)
Mooring Dirigibile ITALIA (MDI) - Timeseries

7-year long time-series are now available

- Sediment Traps
- T and C data
- Water currents
The contribution of heat from the ocean at the interface between the fjord water and tidewater glaciers has been suggested as a possible trigger that destabilize the glacier front.

Ocean Heat Content (OHC) derived from the record of hydrographic profiles is usually neglected in most of papers on ocean tidewater glacier interaction.

The OHC does not depend only on temperature but also on the volume of water interacting with the ice front.
Seawater properties and Ocean Heat Content (OHC)

\[ H = \rho c_p V \bar{T} \]

where \( \rho = 1027 \text{ kg/m}^3 \) is water density, 
\( C_p = 4000 \text{ J/kg} \text{ C} \) is sea water specific heat capacity, 
\( V \) is the volume of the Atlantic water layer and 
\( T \) is the depth averaged temperature of the layer.

OHC summarizes the thermal property of the water column in a integrated value over a vertical profile.
Seawater properties and Ocean Heat Content (OHC)

Based on bathymetric survey and CTD casts, OHC was calculated for September 2014

$$H = \rho c_p V \bar{T}$$

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Estimated volumes of water in inner Kongsfjorden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volumes (km$^3$)</td>
<td>Cold water</td>
</tr>
<tr>
<td>From NYA to islets</td>
<td>0.18</td>
</tr>
<tr>
<td>Small basin west of islets</td>
<td>0.06</td>
</tr>
<tr>
<td>Area A</td>
<td>0.12</td>
</tr>
<tr>
<td>Area B</td>
<td>0.12</td>
</tr>
<tr>
<td>Area C</td>
<td>0.13</td>
</tr>
</tbody>
</table>

the input of heat in the innermost fjord was consistent with large ice melting.

Aliani et al., 2016 a & b
Seawater properties and Ocean Heat Content (OHC)

The thesis of student Valentina Ribezzo is **improving the idea** of the role of the sill using timeseries from MDI

- Bathymetric map
- CTD casts from different years provide different volumes
- MDI provides timeseries (assumptions are required)
In summer 2015, found high surface water pH values in Kongsfjorden (up to 8.6).

To maintain such a high value, pH of freshwater inputs discharging into the fjord should be alkaline.

In the longer term, when the meltwater discharge will decline, pH will decrease very rapidly, theoretically reaching a tipping point.

Necessary specific experiments to follow the temporal trend of pH and alkalinity.

Mooring MDI since 2010 in Kongsfjorden

Time series of particle fluxes and composition

- Avg. TMF, ca. 20 g m\(^{-2}\) d\(^{-1}\) (7 to 100 g m\(^{-2}\) d\(^{-1}\) in winter and summer, in respectively)
- %OC peak spring-early summer by phytoplankton bloom (less negative \(\delta^{13}C\))
- TMF peaks in summer by glacier melting and surface runoff (turbid waters)
- High detrital carbonates (20-30%)
- High interannual variability (in 2013, TMF peak ca. 8 times higher than remaining years)

D’Angelo et al., 2016
Modern sediment distribution and composition

Sedimentation rate decreases with increasing distance from glacier termini (Kronebreen and Kongsvegen)

The geochemical fingerprint displays large along-fjord variability of both inorganic (Ca/Ti) and organic (OC) parameters

Miserocchi et al., 2016
Repeated sampling:

Suspended particulate matter: anthropogenic input by Atlantic water for some elements (Ba, Cr, Cu, Mn, Mo, Ni, Pb, Zn), natural input by glacial runoff for others (Al, Co, Fe, K, Ti, V), both higher in summer

Sediments: negligible anthropogenic impact for trace elements (although minor enrichment for As, Cd, Cr, Ni, V), only a small percentage is bioavailable (<5%, except for As, Cd)

Grotti et al., 2013, Bazzano et al., 2014 Ardini et al., 2016
ISMOGLAC Project

ISotopic and physical-chemical MOnitoring of GLACial drainages and sea water in the Ny-Ålesund area-Svalbard (start: June 2015)

*Doveri M., Lelli M., Baneschi I., Provenzale A. – IGG, PISA*

Investigates the dynamic processes of the glacial melting (supraglacial, englacial and subglacial outputs) and evaluates the consequent transfers of fresh water towards the Kongsfjorden

**Inland activities (glacial drainages)**

- Flow-rate measurements
- Water sampling and physical-chemical measurements

**Activities within Kongsfjorden**

Physical-chemical logs and sampling of water at defined depth

**Laboratory activities (IGG Pisa)**

Analysis of isotopic signatures ($\delta^{18}$O‰, $\delta^2$H‰, $^3$H and $\delta^{13}$C‰) and chemical concentrations (major and minor compounds)
Between 10-15 m depth, layer of colder water from the glacier melting

Extinction of the solar radiation observed in the first 5 m

In such conditions, photic layer available to the phytoplankton strongly limited
Development of integrated systems of unmanned surface vehicles (USV) for performing atmospheric, sea water and ice data sensing and water sampling.

To operate and transmit data in real time in dangerous sites, such as glacier fronts, or difficult to access to human beings.
Atmospheric observations at the Amundsen-Nobile Climate Change Tower
Vito.vitale@isac.cnr.it

The 34-m high Amundsen-Nobile Climate Change Tower (CCT) provides vertical profiles of meteorological parameters, since October 2009.

http://www.isac.cnr.it/~radiclim/CCTower/

7-year long time-series of radiation and energy budgets are now available

Mazzola et al., 2016
2 steps in the future

ARCA results are just a snapshot

- Next step → need to extend monitoring at longer time scale to obtain more reliable trends and establish how climate change is affecting the Kongsfjorden.

Open questions:

- Are fjords able to mitigate the effects of global change by locally reducing gradients with respect to the adjacent ocean?
- How sill affect OHC?

Some observations seem to confirm it:

- The increased fluvial runoff increased transfer of soil-derived OC to the fjord, and its mineralization in fjord waters could further increase the atmospheric CO$_2$ concentration. But fjords also behave as natural sediment traps, rapidly sequestering the terrestrial OC and reducing the potential negative effect.

- Due to very alkaline freshwater inputs, fjords can contribute to mitigate the ocean acidification, at least until the meltwater discharge will not decline.
What has to be done

In the project ARCA, an effort of integration between different Italian groups was pursued, but we still need to increase:

• Coordination among Italian groups
• Cooperation with groups of different nations
• Interdisciplinarity and multidisciplinarity
• Increase the sharing of infrastructures
• Upgrade instrumentation, adding new sensors (new parameters, more performing)
• Promote an integrated approach combining modelling and data acquisition via oceanographic cruises, autonomous stations (fixed, drifting, USV) and satellite
• Developing a new generation of small modular aerial and marine drones to collect data simultaneously
• Data sharing and databases
• Make constant the flow of funds (time series are continuously at risk of interruption)
Thanks for your attention

and thanks to
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CNR DTA
Kings Bay and Teisten
Sysselmann of Svalbard
All Ny Alesund colleagues