Multi-model comparison of Arctic freshwater volume and exports in PRIMAVERA coupled global models

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Objective

• To assess the impact of ocean and atmospheric model resolutions on Arctic freshwater and ice volume and exports,
  - We used three coupled global models participating in EU H2020 PRIMAVERA.
  - Using the same configuration at coarse and high model resolution
Arctic freshwater and ice transports from the Arctic

Figures from Haine et al. 2015
Impact of Fram Strait ice export on temperature and atmospheric pressure

Climate response to large ice exports through Fram Strait in a long simulation with a coupled climate model (annual anomalies)
<table>
<thead>
<tr>
<th>Model</th>
<th>Ocean resolution</th>
<th>Atmospheric resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECMWF-IFS-LR</td>
<td>ORCA1 (362 x 292 lon/lat). 75 vertical levels.</td>
<td>Gaussian grid equivalent to 200 lines between the pole and equator</td>
</tr>
<tr>
<td>ECMWF-IFS-MR</td>
<td>ORCA025 (1442 x 1021 lon/lat), 75 vertical levels</td>
<td>Gaussian grid equivalent to 200 lines between the pole and equator</td>
</tr>
<tr>
<td>ECMWF-IFS-HR</td>
<td>ORCA025 (1442 x 1021 lon/lat), 75 vertical levels</td>
<td>Gaussian grid equivalent to 400 lines between the pole and equator</td>
</tr>
<tr>
<td>CMCC-CM2</td>
<td>ORCA1</td>
<td>0.93° × 1.25°</td>
</tr>
<tr>
<td>CMCC-CM2</td>
<td>ORCA025</td>
<td>0.93° × 1.25°</td>
</tr>
<tr>
<td>HadGEM-GC3-L</td>
<td>ORCA025</td>
<td>N96 grid (192 x 144 lon/lat)</td>
</tr>
<tr>
<td>HadGEM-GC3-M</td>
<td>ORCA025</td>
<td>N216 grid (432 x 324 lon/lat)</td>
</tr>
<tr>
<td>HadGEM-GC3-H</td>
<td>ORCA025</td>
<td>N512 grid (1024 x 768 lon/lat)</td>
</tr>
</tbody>
</table>
Freshwater content in PRIMAVERA models

Reanalysis

Increase in ocean resolution

Increase in atmospheric model resolution

meters

-18 -12 -6 0 6 12 18
Ice volume in PRIMAVERA models

Reanalysis

Increase in ocean resolution

Increase in atmospheric model resolution
Ensemble of ECMWF-IFS model simulations at different atmospheric and ocean resolutions

- ECMWF-IFS-HR_r1/l1p1f1
- ECMWF-IFS-HR_r2/l1p1f1
- ECMWF-IFS-HR_r3/l1p1f1
- ECMWF-IFS-HR_r4/l1p1f1
- ECMWF-IFS-LR_r1/l1p1f1
- ECMWF-IFS-LR_r2/l1p1f1
- ECMWF-IFS-LR_r3/l1p1f1
- ECMWF-IFS-LR_r4/l1p1f1
- ECMWF-IFS-LR_r5/l1p1f1
- ECMWF-IFS-LR_r6/l1p1f1
- ECMWF-IFS-MR_r1/l1p1f1

- 6 LowRes
- 4 HighRes
- 1 MedRes

Sea Ice Concentration %
Differences in Sea Ice concentration in different ECMWF-IFS model resolutions

Increased ocean resolution

Increased atm resolution

Increased ocean and atm resolution

Differences in surface heat fluxes in different ECMWF-IFS model resolutions

Increased ocean resolution

Increased atm resolution

Increased ocean and atm resolution
Differences in surface temperature in different ECMWF-IFS model resolutions

- Increased ocean resolution
- Increased atm resolution
- Increased ocean and atm resolution

Differences in surface pressure in different ECMWF-IFS model resolutions

- Increased ocean resolution
- Increased atm resolution
- Increased ocean and atm resolution
Larger ice transport across straits at coarse ocean resolution
Atmospheric resolution does not show a strong impact on ice export
Strong ice export trend across North Baffin at coarse resolution
Freshwater export in different ECMWF-IFS model resolutions

- Larger freshwater transport across Baffin Bay at coarse ocean resolution
- Larger freshwater transport across Fram Strait at high ocean resolution
- Atmospheric resolution does not show a strong impact on freshwater export
- Strong freshwater export trend across North Baffin at coarse resolution, and small trends in all models across Fram Strait
Mixed layer depth in m in March, averaged over the 100 year-HadGEM3-GC2 simulations

- Higher freshwater transport towards the Atlantic across the Fram strait, afterwards impact showing less convection over the Labrador Sea.
Coupled GCMs have a dependency towards model resolution, showing with increased atmospheric model resolution:

- Higher freshwater volume over the Beaufort Sea and lower freshwater volume over the Laptev and East Siberian Seas,
- Lower ice transport and higher freshwater transport across the Fram strait,
- Lower convection at the Labrador sea.

With increased ocean model resolution:

- Lower freshwater and ice volumes over the Arctic
- Lower ice export from the Arctic towards the Atlantic
- Higher freshwater transport across Fram strait and lower freshwater export across Baffin Bay.

All the previous results shown also some model dependency.
Sensitivity of the Arctic freshwater content and transport to model resolution

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