Improving NWP models with observations from the Iceland Greenland Seas Project

Ian Renfrew, Andy Elvidge, and many others…
An overview of the Iceland Greenland Seas Project
(I) surface drag over sea ice
(II) sea ice distribution
A coordinated atmosphere-ocean research project, centered on a rare wintertime field campaign to the Iceland and Greenland Seas, seeks to determine the location and causes of dense water formation by cold-air outbreaks.

See: Renfrew, Pickart, et al. (2019, BAMS)
R/V Alliance winter cruise

- 43 days from Reykjavik, Iceland
- February and March 2018

Meteorological instrumentation:
- Basic meteorology
- Radiosondes (100): Daily to 3-hourly
- HatPro radiometer: BL T profiles
- Windcube lidar: BL wind profiles
- Micro rain radar
- Water vapour isotopes (leg II)
R/V Alliance winter cruise

Oceanography instrumentation:
- CTDs, XCTDs & XBTs (total of 453 profiles)
- ADCP & underway CTD
- Argo and RAFOS floats
- Water sampling: salinity, $O_2$, CFC-12, & SF-6

Sections and surveys
Long-term observations

- Oceanographic mooring (2 years)
- Meteorological buoy (5 months)
- Sea gliders
Aircraft Campaign

- BAS Twin Otter
- 14 science flights
  - 11 Cold Air Outbreaks
  - 7 over/adjacent sea ice
  - 2 orographic flows
- 70 h flying
  - 500 mins at 20-40 m.
Forecasting tools

Met Office

- Global operational forecast (10 km)

- Global coupled forecast

- Convection-permitting forecast (2 km)
Forecasting tools

Met Office
- Global operational forecast (10 km)
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DMI/IMO
- Limited domain (2.5 km)
Forecasting tools

Ensemble Prediction System diagnostics based on ECMWF EPS

- CAO probability of occurrence
- CAO index: $\theta_{SST} - \theta_{850}$
- Surface sensible heat flux
- Plots: Lukas Papritz (ETH)
Case study: Development of a Cold Air Outbreak

- 28 February to 2 March 2018
- A cold-air outbreak develops
- Captured via
  - co-ordinated sampling of atmosphere and ocean
  - several research flights
  - 3 hourly radiosondes from the R/V Alliance
  - Repeated CTD/XCTD surveys
1 March 2018
Flight 294

- Map CAO airmass upstream & downstream of ship
1 March 2018
Flight 294

• Map CAO airmass upstream & downstream of ship
An overview of the Iceland Greenland Seas Project
(I) surface drag over sea ice
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Parameterize 10-metre neutral drag coefficient, $C_{dn10}$, and account for surface type (skin drag) and surface roughness (form drag).

$$C_{dn10} = (1-A)C_{dw} + AC_{di} + C_{df}$$

$C_{df}$ can be parameterized as a function of Ice fraction

(The simplest conceptual model)

Representing surface exchange over sea ice

ACCACIA Field campaign – March and April 2013

Drag Coefficient versus Ice Concentration

- 195 data points
- Doubles previously available data

Drag Coefficient versus Ice Concentration: All flights (195 data points)

$c_e = \text{effective resistance coefficient}$

$\beta = \text{sea-ice morphology exponent (describing the dependence of } D_i \text{ (floe length) on } A)$

<table>
<thead>
<tr>
<th></th>
<th>$c_e$</th>
<th>$s$</th>
<th>$D_{\text{min}}$</th>
<th>$D_{\text{max}}$</th>
<th>$h_{\text{min}}$</th>
<th>$h_{\text{max}}$</th>
<th>$\beta$</th>
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<tr>
<td>L2012</td>
<td>0.3</td>
<td>0.5</td>
<td>8 m</td>
<td>300 m</td>
<td>0.286 m</td>
<td>0.534 m</td>
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<td>E16A</td>
<td>0.17</td>
<td>&quot;</td>
<td>&quot;</td>
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<td>E16B</td>
<td>0.1</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>0.2</td>
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</table>
Model parameterizations

IFS change was 2015
Impacts of MIZ drag on the atmosphere

MetUM MIZ Drag Experiments:
- **Rough**: a large $z_0$ (Operational till Sep 2018)
- **L12E16** (New scheme; GL8)
- **Smooth**: a small $z_0$ (HadGEM3)

Impacts of MIZ drag on the atmosphere: Wind speed

MetUM MIZ Drag Experiments:
- **Rough**: a large $z_0$ (Operational till Sep 2018)
- **L12E16**: (New scheme; GL8)
- **Smooth**: a small $z_0$ (HadGEM3)

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<th>Bias</th>
<th>RMS Error</th>
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<tbody>
<tr>
<td>Rough</td>
<td>0.51</td>
<td>-0.51</td>
<td>2.14</td>
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<tr>
<td>L12E16</td>
<td><strong>0.53</strong></td>
<td>-0.06</td>
<td><strong>2.09</strong></td>
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<tr>
<td>Smooth</td>
<td>0.52</td>
<td>0.28</td>
<td>2.14</td>
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Impacts of MIZ drag on the atmosphere: Temperature

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<td></td>
<td>Rough</td>
<td>L12E16</td>
<td>Smooth</td>
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<tr>
<td>T</td>
<td>0.86</td>
<td>0.93</td>
<td>0.93</td>
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</table>
Conclusions of MIZ drag studies

• A new sea-ice drag parameterization has a significant impact on the atmospheric boundary layer, changing the:
  – surface momentum flux by 0.1-0.2 N m\(^{-2}\) \textit{(comparable to the mean)}
  – and low-level temperatures by 2-3 K near the MIZ

• Comparing against aircraft observations over and downwind of the MIZ the new ‘L12E16’ drag scheme has the lowest bias and lowest root-mean-square errors

• In global simulations the atmospheric response is relatively widespread – impacting most of the Arctic and Antarctic sea-ice areas

• L12E16 became operational at the Met Office in September 2018 and in next configuration of climate model (GA8)

Impact of sea-ice representation: distribution

- Most forecasting systems use very smooth sea-ice analyses, e.g. OSTIA
  - Dramatic impacts locally
  - Impacts downstream?
  - Impacts on atmospheric forecasts?
- 7 flights from IGP
• IGP Case Study
  – OSTIA sea-ice
  – MetUM ice fraction
  – Distribution smoothed
• IGP Case Study
  – SAR image
  – aircraft ice fraction
  – sharp gradients
• IGP Case Study
  – SAR image
  – aircraft ice fraction
  – sharp gradients
Over sea-ice and marginal-ice-zone:

- MetUM systematically over-estimates sensible heat flux
- Similar for latent heat flux

Preliminary results!
- Exchange coefficients for heat (and moisture) are too large over MIZ
- Ok for drag over MIZ
- BUT only one value is used for 100% sea-ice

Preliminary results!
IGP Analysis

• Characterising Cold Air Outbreaks
• Turbulent flux evaluation (in vicinity of MIZ)
• Evaluation of meteorological analyses
  – Model deficiencies on a thematic basis
• Leeside fluxes, wakes & gravity waves
• Coupled atmosphere-ocean investigations
• Regional climate & ocean modelling
Variability within the dataset: Barents Sea

- 99 data points
- small, deformed, pancake ice with raised edges.
Variability within the dataset: Fram Strait

- 101 data points
- Homogenous, non-deformed ice