Experience from Arctic field campaigns: Weather forecasting and evaluations, and model comparisons

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Data without **models** is chaos...

...but models without data is guesswork

(Patrick Crill, Stockholm Uni.)

On the utility of field observations for NWP:

- To help formulate the conceptual models, shaping how we think about processes that need parameterization

- To reveal the process relationships, the understanding of the system, necessary to improve model formulations

- Evaluate models – in several different ways
Conceptual models 1: Mixed-phase clouds in cold climates...
Conceptual models 2: Lower-troposphere vertical structure...

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<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
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Inversion base < 15 m

Inversion base > 15 m
Tjernström & Graversen 2009

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Inversion base < 15 m

Inversion base > 15 m

Composite from four different summer campaigns
Coupled

Decoupled

Stable

Solid – IFS (Cy40HR)
Dashed – observations

Coupled
Decoupled
Stable

Sotiropoulou et al. 2014

Day of August 2008

Ri-class

Stockholm University
Process relationships 1:

Turbulent surface fluxes (this is really old)...

Flux $\sim C_x U \Delta$

Shape and spread!

Observations

Models

Tjernström et al. 2005
Process relationships 2:

Cloud/radiation interactions

$LT S = \theta_e(950hPa) - \theta_e(sfc)$

Courtesy Sedlar et al. 2005
$LTS = \theta_e(950\text{hPa}) - \theta_e(sfc)$
Model evaluations: "Climate"

SHEBA/ARCMIP

ACSE/CORDEX

Liquid water path (kg m$^{-2}$)

Relative probability (%)

Relative frequency [%]

Tjernström et al. 2007
Courtesy Sedlar et al. 2005
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On the utility of NWP for field Arctic observations:

- When operating on the ice in the Arctic Ocean, safety is the paramount issue; for this accurate NWP is key.

- Planning logistics like operations helicopter flights or snowmobiling on the ice requires accurate NWP.

- Deployment of observing systems, such as UAVs or tethered platforms require accurate and detailed information on PBL structure and clouds.
Arctic Ocean 2018
1 August – 21 September
Cloud radar

Scanning lidar & microwave profilers

Weather station, visibility, surface temperature, clouds & radiation

Aerosols
Forecasting on board:
• Ship’s operational forecasting for helicopter flights and general safety and logistics (visibility & clouds, winds & precipitation)
• Science planning, special forecasts provided by APPLICATE (PBL structure and clouds)
Forecasting on board:

• Low bandwidth – think about methods..
• Cultural differences – think about education...
• Forecast quality (subjective evaluation of IFS):
  • Cloud forecasts essentially *useless*
  • Temperature forecasts *less than useful*, probably partly because of clouds
  • Major precipitation is *good* but often ”drizzling” a little in between
  • Moisture forecasts *very useful* – mostly for fog & cloud forecasting
  • Winds were scarily *accurate*!
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**Forecast quality (objective evaluation of IFS):**
• Using our own weather station (@ 20 m) & sondes in near-real-time
• Weather station data averaged over ~10 minutes, centered on model time
• Model results vertically interpolated to sounding resolution(!)
• Soundings released 30 minutes prior to nominal time; no time interpolation
• Median bias, 25-75 percentiles, pdf
Some near-surface (@20 m) variables
Boundary layer warm bias, \( \sim 1 \, ^\circ C \) below \( \sim 300 \) m

Middle troposphere warm bias, \( \sim 0.5 \, ^\circ C \) 3 to 6 km

Lower troposphere cold bias, \( \sim -1 \, ^\circ C \) 0.5 to 3 km

 Thermal structure
Moisture structure

Same layering, moist bias in the PBL and dry above, but around zero where moisture is low. Also a weird periodicity ~1km that seems to grow.
Scalar wind speed

High bias in PBL, low down partly a measurements artifact but also real

Also note weird periodicity at PBL top
Wind direction

[Two contour maps showing wind direction over time and altitude. The maps are color-coded with a legend on the right side indicating wind direction values from 0 to 90 degrees.]
Diurnal cycle?

Inertial oscillation?
Some parting thoughts...

• Field campaign observations comes in all along the whole chain of developing model physics:
  • Discovery and understanding
  • Parametrization, closure and calibration
  • Testing and evaluation

This is often (always?) an iterative process

• Accurate forecasting is vital for any field campaign but needs to be adapted to particular conditions. Arctic field campaigns have special problems (keep it simple dummy!); there is no one size fits all

• In Arctic summer IFS has a severe cloud problem, a mysterious PBL warm bias with a diurnal cycle that does not exist, and some other strange oscillations