Comparison of aircraft observations and PWRF simulations in the Canadian tundra

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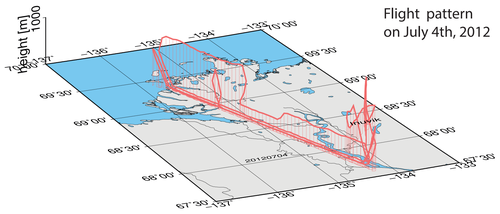
Motivation of the study

Mackenzie delta in NW-Canada, Modis image, 2012/07/29 (NASA). Short edge approx. 200km

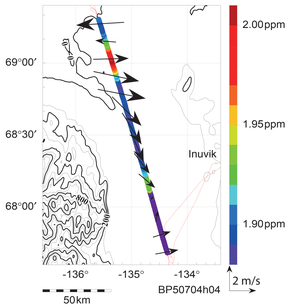
In July 2012, the campaign AirMeth of AWI and GFZ (Potsdam, Germany) collected meteorological data in the Mackenzie delta (NW Canada). The Polar5 (P5) aircraft measured temperature, wind vector and methane concentration along horizontal flight tracks in low altitudes and along steep ascends and descends through the boundary layer.



Flight pattern on July 4th, 2012

On July 4th, a reversal in wind direction on the horizontal flight track was observed during two hours (three overpasses). The instruments also recorded a local increase in methane concentration.

It was assumed that a small vortex had formed, which was not resolved in the synoptic weather charts.

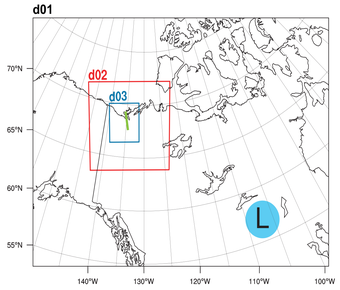


Wind speed (arrows) and methane concentration (colour) along one horiz. flight track on July 4th

Polar5 (P5) aircraft (photo C. Lüpkes, AWI)

We present high-resolution model simulations
- to investigate the hypothesis of the vortex,
- to compare aircraft data with model data.

Model configuration



Model domain 1 with inset domains 2 and 3. Blue circle: position of the prevailing low pressure system. Green line in d03: flight track.

We use the PolarWRF (Version 3.4.1) of NCAR/OSU in three domains of 24, 8, and 2.67 km resolution (two-way nesting).

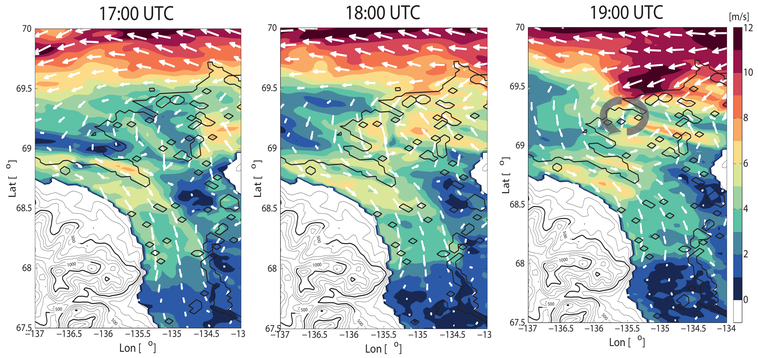
Starting time of the innermost domain is 2012/07/04 00 UTC, with each parent domain starting 6 hours earlier.

Boundary layer scheme is QNSE (Sukoriansky et al 2005). As vertical resolutions, we use:

a) 55 vertical levels total, 7 in the lower 1km.
b) 47 vertical levels total, 14 in the lower 1km.

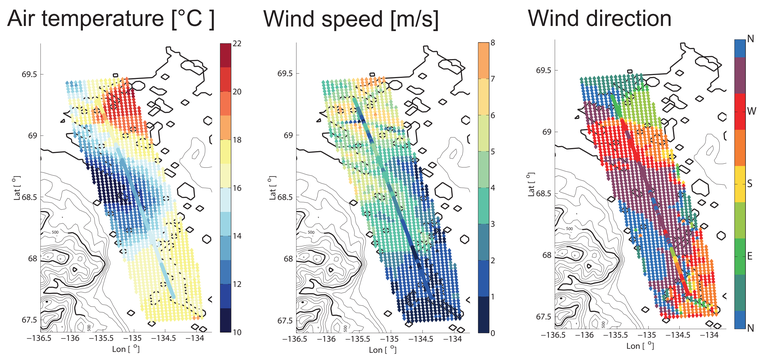
Wind vortex in the model

The model simulations (QNSE-a) show the development of a wind vortex. The vortex is most pronounced around 19 UTC (local time zone is UTC - 6). The reversal of the wind direction has been observed by the aircraft also at earlier times.
The north-easterly wind at the coast is deflected southwards by the mountain range.



Wind speed (colours, [m/s]) and direction (arrows) in 100m height a.s.l. in the northern Mackenzie delta region. Non-coloured area has an elevation of more than 100m.

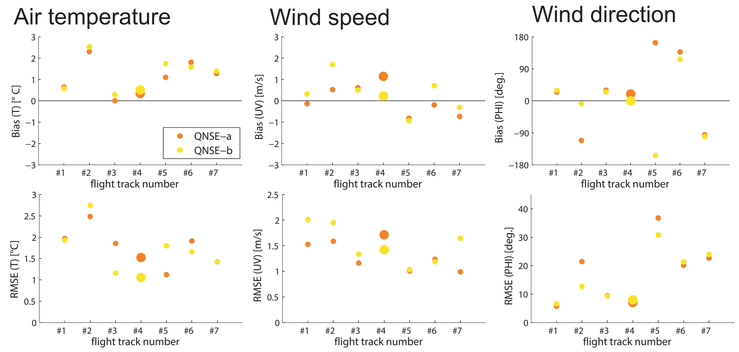
Comparison of P5 and PWRF data



Aircraft data (coloured line) and a subset of WRF data (QNSE-a) at matching vertical model level. Shown is a selected flight track from south to north, 18:00 to 18:30 UTC, at 100 m mean height a.s.l. .

- PWRF temperature data show a warm bias as also documented by Hines et al (2011). Note the overestimation of cold air inflow from the sea from north-west.
- Low wind speed inland is well reproduced by the model. Wind speeds at the coast are higher in PWRF than observed with P5.
- Simulated wind direction shows reversal at 135.5° W, 69.1° N as also seen in aircraft data.

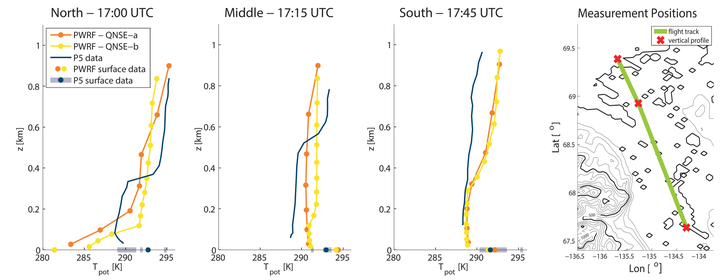
Statistics for low horizontal flights



Statistics are shown for horizontal flight tracks in chronological order (16 - 20 UTC) and in increasing heights (51, 29, 55, 102, 284, 495, 503m) as bias (PWRF - P5, first row) and root mean square error (RMSE, second row). Big dot for flight track shown before (#4).

- warm bias of PWRF exhibited on every flight track
- simulated wind speed mostly higher than observed
- direction of PWRF-wind often turned clockwise as compared to P5-wind
- no scheme (QNSE- a or b) has the lowest RMSE for all tracks or all shown quantities, so none can be preferred

Vertical profiles of temperature



Vertical profiles of potential temperature from P5 aircraft (descending flights) and PWRF (gridpoint of mean horizontal aircraft position), taken in north, middle and south of the long horizontal flight leg. P5 surface data is shown as measured at the lowest aircraft height (grey: range of measured surface temperature).

- different vertical model resolutions (a, b) are relevant near the coast.
- unstable boundary layer in the north is not captured in PWRF data.
- sharp temperature increase at 350 or 500m height is only seen in P5 data.

Summary

The observed wind vortex is resolved in the high-resolution PWRF simulations. The position of the vortex is well matched, but wind speed and temperature show some deviations. The selected vertical resolution significantly influences the results, as also does the selected PBL scheme (not shown). All in all, no configuration can be preferred.

References:
-- Sukoriansky S., B. Galperin, V. Perov, 2005: Application of a New Spectral Theory of Stably Stratified Turbulence to the Atmospheric Boundary Layer over Sea Ice. Bound.-Lay. Meteorol., 117
-- Hines et al, 2011: Development and Testing of Polar WRF. Part III: Arctic Land, J. Clim., 24
-- Statistics for the wind direction were partly done using the Circular Statistics Toolbox: P. Berens, CircStat, 2009: A Matlab Toolbox for Circular Statistics, Journal of Statistical Software, 31(10)
-- Map colors based on www.ColorBrewer2.org, by Cynthia A. Brewer, Pennsylvania State University

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