Observed Atmospheric Profiles in the Arctic Seasonal Ice Zone and the Role of Synoptic Conditions

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Introduction

Unique features of the atmospheric profiles in the Arctic

- temperature and moisture inversion, low-level jet (LLJ)
- static stability, mixed-phase cloud, surface energy budget, Arctic amplification
- data-sparse Arctic over sea ice
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Seasonal Ice Zone Reconnaissance Survey

- USCG Arctic Domain Awareness flights in the Beaufort Sea
- Atmospheric and oceanic measurements: dropsonde, visible/IR imaging, Lidar, AXCTD, AXCP, UpTempO buoy, AXIB buoy
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Approach
- Polar WRF simulations forced by reanalysis/analysis
- examine the performance of analyses and Polar WRF
SIZRS transects and Polar WRF setting

Polar WRF setting:
- $\Delta x = 30/10$ km
- 54 vertical levels
- forcing: GFS/ERA-I
- baseline+7-member ensemble

Baseline physics:
- MYJ PBL+surface
- Goddard microphysics
- RRTMG radiation
- Grell-Devenyi cumulus
- nudging above 168 hPa
Observed and simulated mean profiles (22 total)

- General features reproduced
- Small ensemble spread
- Polar WRF ~ forcing
- Large differences between analyses and observations
- Low-level warm bias in ERAI, moist bias in ERAI and GFS
- Weaker LLJ and smaller wind turning angle in the analyses compared to the Polar-WRF and observations
Statistical significance of analyses biases (bootstrap)

(a) Temperature deviations from radiosonde observations for GFS and ERAI. 
(b) Relative humidity deviations from radiosonde observations for GFS and ERAI. 
(c) Wind speed deviations from radiosonde observations for GFS and ERAI. 
(d) Wind direction deviation from radiosonde observations for GFS and ERAI.
Analysis

Significantly improved LLJ in Polar WRF

- vertical resolution: improvement in low resolution runs too
- mixing: artificially enhanced mixing in GFS/ERAi
- LLJ weakens with enhanced mixing in Polar WRF
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Low-level warm bias in ERAI (consistent with previous obs.)

- ERAI Sea ice issue: set SIC to 0 when T > 274.26K

![Graphs showing data from GFS, ERAI, SSMI, and OSTIA]
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Low-level warm bias in ERAI (consistent with previous obs.)

- ERAI Sea ice issue: set SIC to 0 when T > 274.26K
- ERAI lateral + ERAI SST + GFS SIC: not sensitive
- ERAI lateral + GFS SST/SIC: like WRFG→SST or melt pond?
- warm bias over packed ice as well: ice model?
Conclusion so far

- General features reproduced in analyses and Polar WRF
- Biases in both ERAI and GFS
  - Weak LLJ and smaller turning angle due to too strong mixing
  - Low-level warm bias in ERAI: SST/melt pond/ice model?
  - Moist bias in ERAI and GFS
- Significantly improved LLJ in Polar WRF
- Polar WRF T/q follows forcing
- Large inter-model discrepancies as well as model biases → need more observations like SIZRS

Reference:
Mean profiles: 2013–2015 (89+22)
Statistical significance of analyses biases

![Graphs showing statistical significance of analyses biases for temperature (T), relative humidity (RH), wind speed (wspd), and wind direction (wdir).]
Synoptic classification using \( k \)-mean clustering

SIZRS observations show significantly different profiles: warm and dry, cold and moist

- Data: 6-hourly ERAI data at 6 levels from 1000 to 500 hPa
- Domain: 70\(^\circ\)N to 80\(^\circ\)N, 170\(^\circ\)W to 130\(^\circ\)W (red box).
- Variables: \( T \), \( q_v \), \( U \), \( V \), \( Z \)
Atmospheric profiles in different synoptic conditions

Baroclinicity and temperature advection ⇒ inversions & LLJ

- **State 1 (S01):** high pressure, strong baroclinicity, strong cold advection from the Arctic Ocean
- **S02:** low pressure, weak baroclinicity, and weak cold advection from west.
- **S03:** high pressure, strong baroclinicity, and strong warm advection from Alaska
- **S04:** moderate baroclinicity and warm advection

Next ...

- examine model performance under different conditions
- atmospheric profile ↔ cloud ↔ sea ice
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  • Moist bias in ERAI and GFS
• Significantly improved LLJ in Polar WRF
• Polar WRF T/q follows forcing
• Large inter-model discrepancies as well as model biases → need more observations like SIZRS
• Synoptic conditions have significant influence on the structure of the profile

Reference: