Arctic Atmosphere: Weather and Climate Variability

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With contributions from
D.Atkinson, U.Bhatt, V.Kattsov, J.Walsh, X.Zhang and V.Alexeeev
Main research topics

• Detailed evaluation of climate models (focus on understanding/reducing uncertainty)
• Changing Arctic climate patterns from observations and models (Rapid Arctic Change, Rapid Ice Loss Events)
• Arctic Climate Change: Local vs. Global (polar amplification, Arctic clouds, heat transports)
• Study of local processes and changes (arctic inversions, river run-off)
Change in *annual* surface air temperature, 1957-2006

(a) observed

(b) IPCC models

J. Walsh
Towards model discrimination

R.m.s. errors (1981-2000)

Surface air temperature (60-90°N)  Sea level pressure (60-90°N)

Model discrimination challenge:
Best in simulation of one variable/region may be worst in simulation of another

V.Kattsov, J.Walsh
Projected Arctic temperature change (2070-90) vs. model rank

(a) surface air temperature

21st-century projected temperature change (°C)

model ranking
If the N models with the *smallest* RMSE are selected:

*(temperature, 60-90°N)*

**Composite GCM Sfc. air temperature RMSE**


J. Walsh
General remarks

✓ Using projection ensembles is essential, but simple averages are probably not the best use of the information.

✓ The end of “model democracy” is apparent, but the problem of model discrimination is not trivial: new diverse metrics and approaches are needed.

✓ “Objective” or “universal” discrimination of models is hardly possible: model selection for ensembles is application (i.e. region, variable, etc.) dependent.

✓ Increasing number and complexity of the models leave poor chances for decreasing projection uncertainties in the near future.

✓ Model discrimination – quite a challenge for IPCC AR5! For a number of reasons (observational, physical), Arctic is a particular challenge.
Recommendations for model selection
(Overland et al., 2010. J. Climate. Under revision)

✓ Starting with a set of model results obtained from an “ensemble of opportunity”, the core of the procedure for model discrimination is to select a subset of models through comparisons of model simulations with observations at both the continental and regional scale.
✓ The continental scale evaluation is a check on the large scale climate physics of the models, and the regional scale evaluates specific variables for the application of interest.
✓ Both within-model and between-model ensembles should be used to account for intrinsic variability and for model-to-model differences.
✓ Further consideration is given to model resolution, comprehensiveness of processes included in the model, and sophistication of the parameterizations.

✓ A user’s particular application, e.g. location and specification of ecological or societal importance of relevant variables, is a guide to the final selection and weighting of individual variables and models.
✓ For some applications, no model may be sufficiently qualified for a regional projection.

V.Kattsov
Correlations between Changes in Arctic Clouds and Moisture Forcing  
(across four 2xCO₂ simulations in CCSM3)

**Arctic-Global connection. Model studies**

More Evaporation $\iff$ More Low, Total Clouds  
More Moisture Import $\iff$ More Mid, High Clouds

Vavrus et al., 2010  
_in preparation_
Patterns of Rapid Arctic change. Model studies

Percentage of Autumn Sea Ice and Cloud Changes Realized during RILEs

RILE = Rapid Ice Loss Event

Cloud Variables

Vavrus et al., 2010

*Climate Dynamics*
Understanding formation of Arctic Rapid Change Pattern (ARP)

AO: measures circulation departure from its climatology; ARP: measures circulation departure from AO

Questions: Why did the atmospheric circulation shift and how did ARP form?

Preliminary results:

• Variance analysis shows that the ARP took over the NAO after mid-1990s.
• Correlation analysis between storm activity and the ARP index suggests strengthened storm activity over the Eurasian Arctic contribute to the circulation shift and the ARP formation.

X. Zhang
Arctic Rapid Change Pattern (ARP): Important Driver for the Record High Eurasian River Discharge

Eurasian river discharge

Snow Water Equivalent, 2006/07

Snow Water Equivalent, 1980-2007

ARP index

X. Zhang
1) Average Interior river breakup occurs about 8 days earlier over the last 60 years (1949-2008).

2) Breakup strongly correlated with Apr.-May SATs over Alaska, ENSO SST in N. Pac., and PNA-like pattern.

3) During ENSO, fewer storms enter the Gulf of Alaska during April-May, clearer skies, warmer AM temperatures over interior Alaska, and earlier breakup!

4) Predicting severity of winter temperatures does not shed light on breakup!

[Bieniek et al. 2010, J. Climate in revision]
1) Alaska surface-based temperature inversions were analyzed using radiosonde observations from Barrow, Fairbanks, McGrath, Anchorage, Kotzebue, Bethel and King Salmon from 1957-2008.  
2) Inversion depth, temperature difference, and frequency, have a long-term decreasing trend, which is not simply linear but displays multi-decadal variations.  
3) The relationship between Alaska inversions and the PDO changes over time and was found to be stronger before 1989 than in recent years.

[Bourne et al. 2010, Atmos. Research]
Detailed field observational study:
Life-cycles of strong surface radiation inversions

David E. Atkinson, IARC/UAF Dept. Atmospheric Sciences
Julie Malingowski, IARC/UAF Dept. of Atmospheric Science/NOAA

Objective: Gain more understanding into the life-cycle progression of these events – how they form, how they dissipate, and controls on their structure/evolution, including influence of large-scale changes in atmospheric circulation.

Reason: Low-level vertical structure is key to understanding surface exchange processes

These features are not reproduced even in meso-scale weather forecast models

D. Atkinson, J. Malingowski
Arctic-Global connection. Polar Amplification

GCM runs: ‘Wet Continent’, no albedo feedbacks

Continent points have 10 times lower heat inertia

Results:
1) Strong seasonality in polar amplification over land;
2) Land PA is amplified in winter, suppressed in summer

V. Alexeev
Products, Collaboration, Synthesis:

24 articles, 1 book chapter, 4 white papers

About half of the articles are co-authored by people from two or more different IARC projects

Other examples of collaboration/synthesis:
ASM report to the NSF – J.Walsh lead author, U.Bhatt, V.Alexeev contributing authors

Proposals submitted with other UAF and non-UAF units and institutes involved in collaboration with IARC
Products

Articles
10. Sporyshev, P., V. Kattsov, V. Matyugin, 2010: Coherency of temperature changes over the territory of Russia in model simulations and observations. Izvestia of the Russian Academy of Sciences; Physics of the Atmosphere and Ocean. (to be submitted)
Articles


**Book chapter:**

**White papers:**
Kattsov, V., V. Ryabinin, C. Bitz, A. Busalacchi, J. Overland, M. Serreze, M. Visbeck, J. Walsh, 2010: Rapid loss of sea ice in the Arctic. WCRP white paper. JSC-31/Doc.4.2/1
http://www.wmo.int/wcrpevent/jsc31/documents/jsc-31clic_artic_4.2.pdf