Effects of Midwinter Arctic Leads on Clouds and the Surface Energy Budget

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MOTIVATION

- Extreme air-water temperature difference (20 – 40℃) and large vertical moisture gradients exist over leads during winter
- Leads may induce extensive plumes and low-level clouds
- Leads and the ensuing clouds jointly have significant impacts on the wintertime large-scale Arctic surface heat budget
- Accurate determination of the Arctic surface energy budget is particularly important because of the sensitivity of sea ice thickness to the surface radiation fluxes and the ice-albedo climate feedback mechanism
- However, properly representing lead-induced boundary layer clouds and the associated large-scale fluxes remains difficult in climate models due to the unresolved small size of leads and the scarcity of observations in the Arctic etc.

An example of lead and associated clouds. Photo was taken on a flight over the Beaufort Sea, October 12, 1994, by T. Arbetter, University of Colorado

METHODS

Due to the limited observations, previous studies mostly utilized model simulations only to examine the clouds generated by a lead and the associated effects on surface fluxes (e.g., Glendening et al., 1992; Pinto and Curry, 1995; Zulauf and Krueger, 2003a, 2003b). Our study used both observations and modeling simulations:

(1) Observational data from ARM were used to derive the statistical associations between lead distributions and the cloud occurrence

- Barrow radiosondes (*T, P, RH*) and surface measurements (*T, P, RH, V*), MMCR reflectivity and AMSR-E derived lead fraction
- Jan-Apr, Nov-Dec, 2008-2011

(2) Three dimensional cloud-resolving model (CRM), System for Atmospheric Modeling (SAM), was then used to understand the observed lead-cloud associations

References

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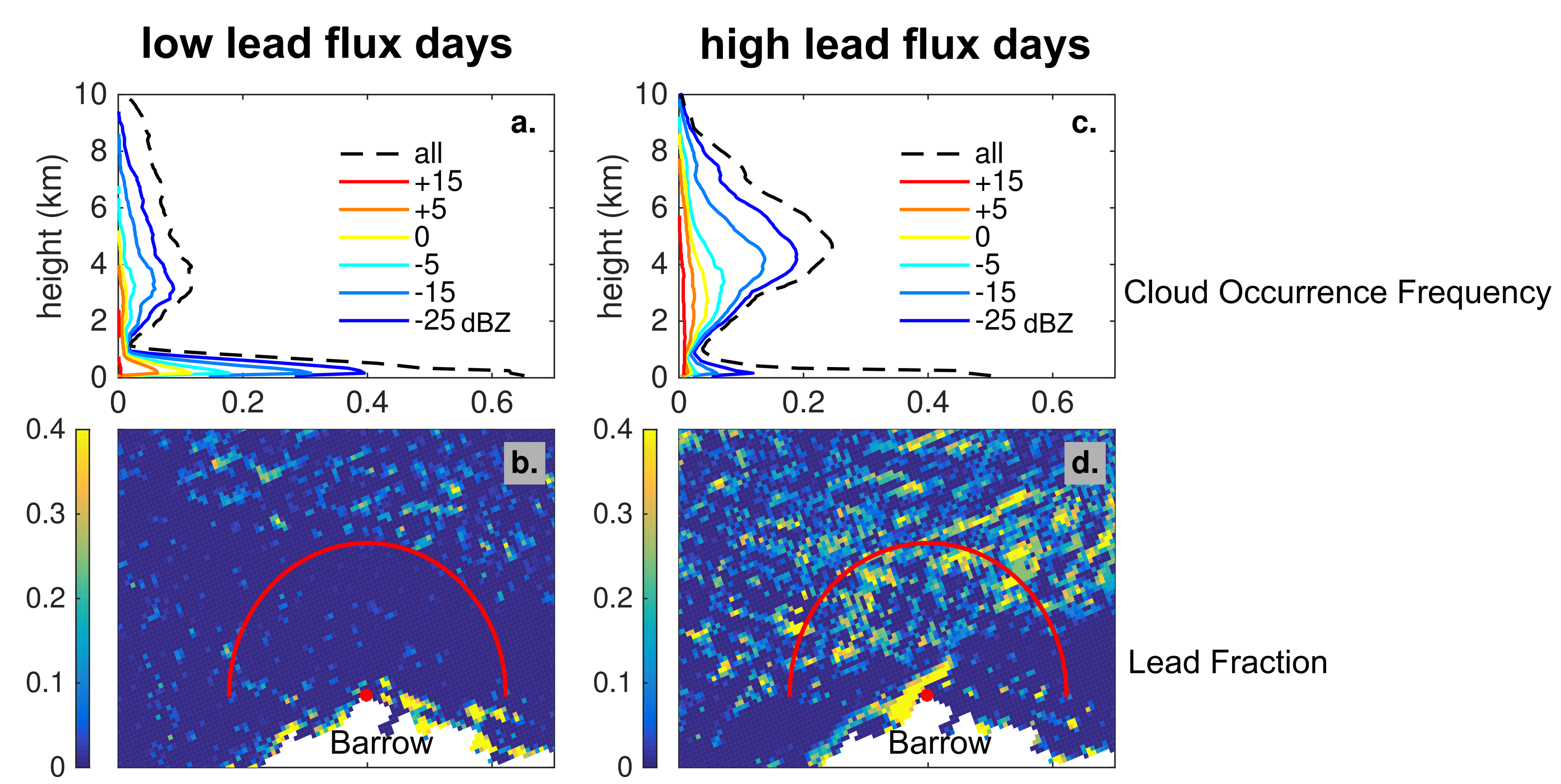
OBSERVED LEADS VS. CLOUDS



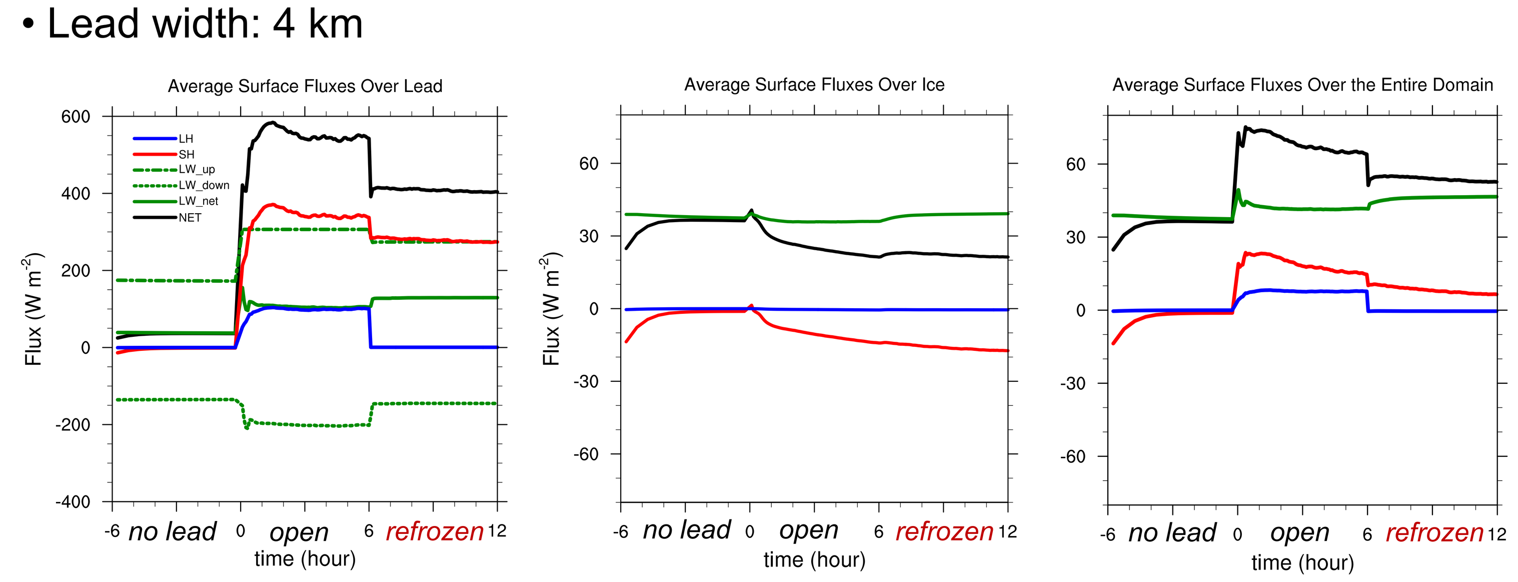
❖ **Counterintuitive results:**

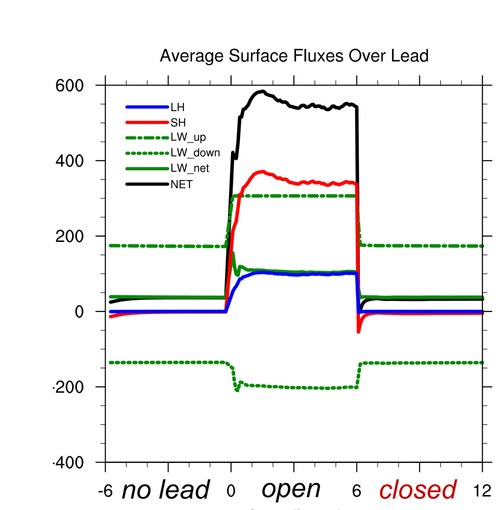
- **Abundant clouds below 1 km for composite of low-lead flux days**
- **Fewer clouds below 1 km for composite of high-lead flux days**

Here the lead flux means the large-scale turbulent sensible heat flux due to the lead. It is calculated following Andreas and Cash (1999); multiply the turbulent surface sensible heat flux from the leads by the lead fraction within 200 km of Barrow.

3D CRM SIMULATIONS

- Morrison 2-moment microphysics and interactive longwave radiation
- A Simplified Land Model (SLM) is coupled to SAM to study the land-atmos. interaction
- Initial conditions: observed midwinter conditions based on SHEBA field experiment
- Wind direction is approximately perpendicular to lead orientation
- Ice surface temperature is predicted in the simulations
- Lead width: 4 km





❖ **All flux components increase over open lead**

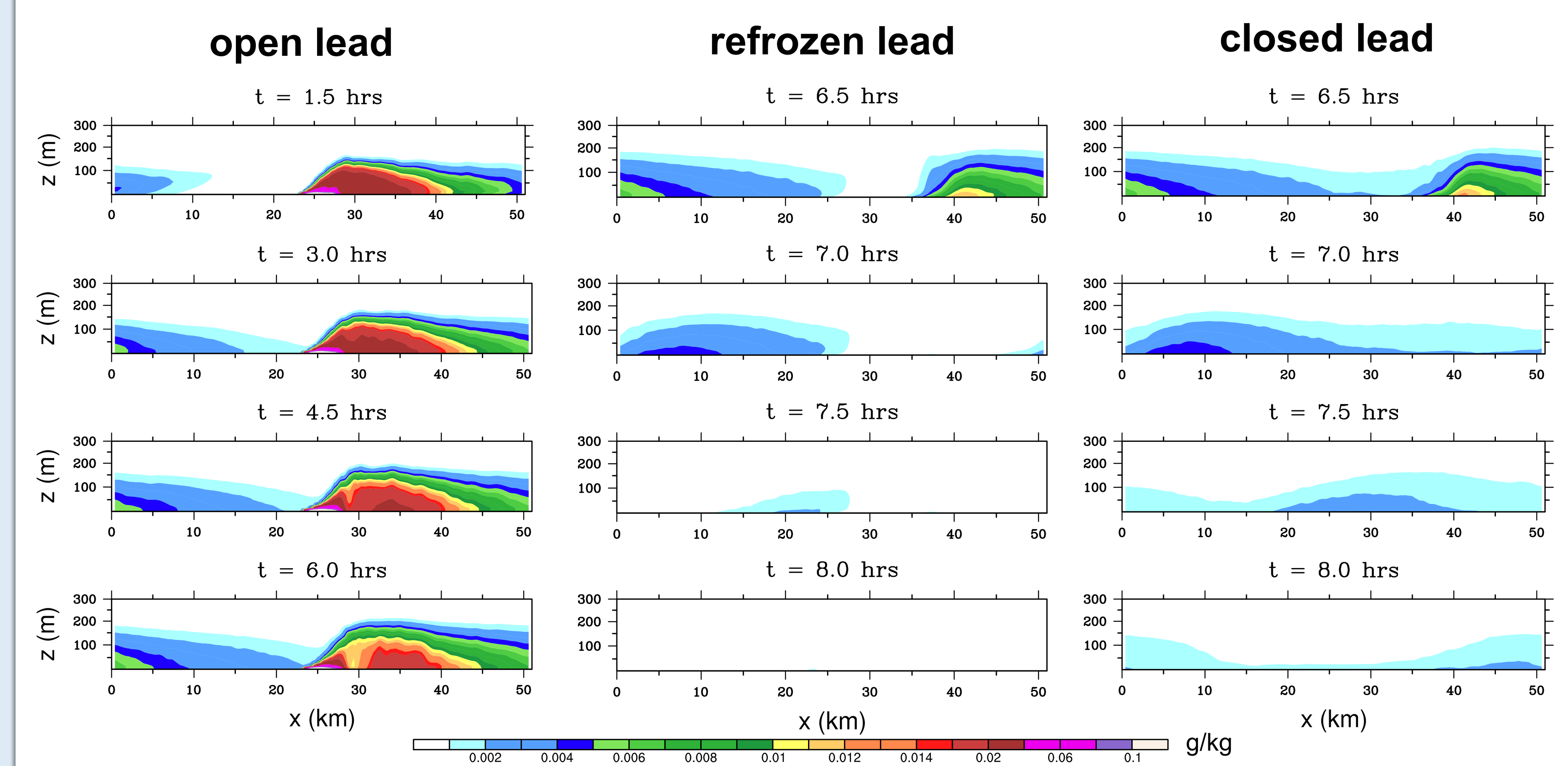
❖ **SH over ice increases in both open and refrozen cases due to the advection of clouds**

❖ **Over entire domain, open lead has impacts on the large-scale surface heat budget**

❖ **LH is entirely suppressed while SH remains largely intact over refrozen lead**

❖ **Both LH and SH are decreased to roughly zero over closed lead**

SIMULATED CLOUDS



❖ **In the open lead case, lead-induced boundary layer clouds are advected downstream over 50 km, which extends the impacts of open lead over a broader region by enhancing the downward SH and infrared radiative flux at the downwind surface**

❖ **Clouds dissipate within 1.5 hr in refrozen vs. 3 hr in closed lead**

❖ **Clouds cannot advect across the refrozen lead surface, but it can cross the closed lead surface**

CONCLUSIONS AND FUTURE WORK

Conclusions

❖ **Low-level clouds can dissipate very quickly when crossing over the refrozen lead surface, which is due to**

- Large SH over refrozen lead maintains strong convection, mixing clouds with ambient dry air
- Large SH increases air temperature, with suppressed LH, air becomes drier (i.e., relative humidity decreases)
- Lead-induced boundary layer clouds are quite sensitive to relative humidity of the environmental air, which facilitates the clouds depletion

❖ **The above findings provide a plausible explanation for the observed counterintuitive results, and suggest that high lead flux days may include a large portion of refrozen leads**

Future Work

Future work will focus on differentiating open leads with recently refrozen leads. And more case studies using multi-source observations (e.g., satellite, airborne and ground-based observations) will be analyzed and further be simulated to give a better understanding of the interrelationship between leads and low-level cloudiness and their effects on the large-scale surface energy budget.