# Supplementary Material

## Sea Ice, High-Latitude Convection, and Equable Climates

Dorian S. Abbot and Eli Tziperman

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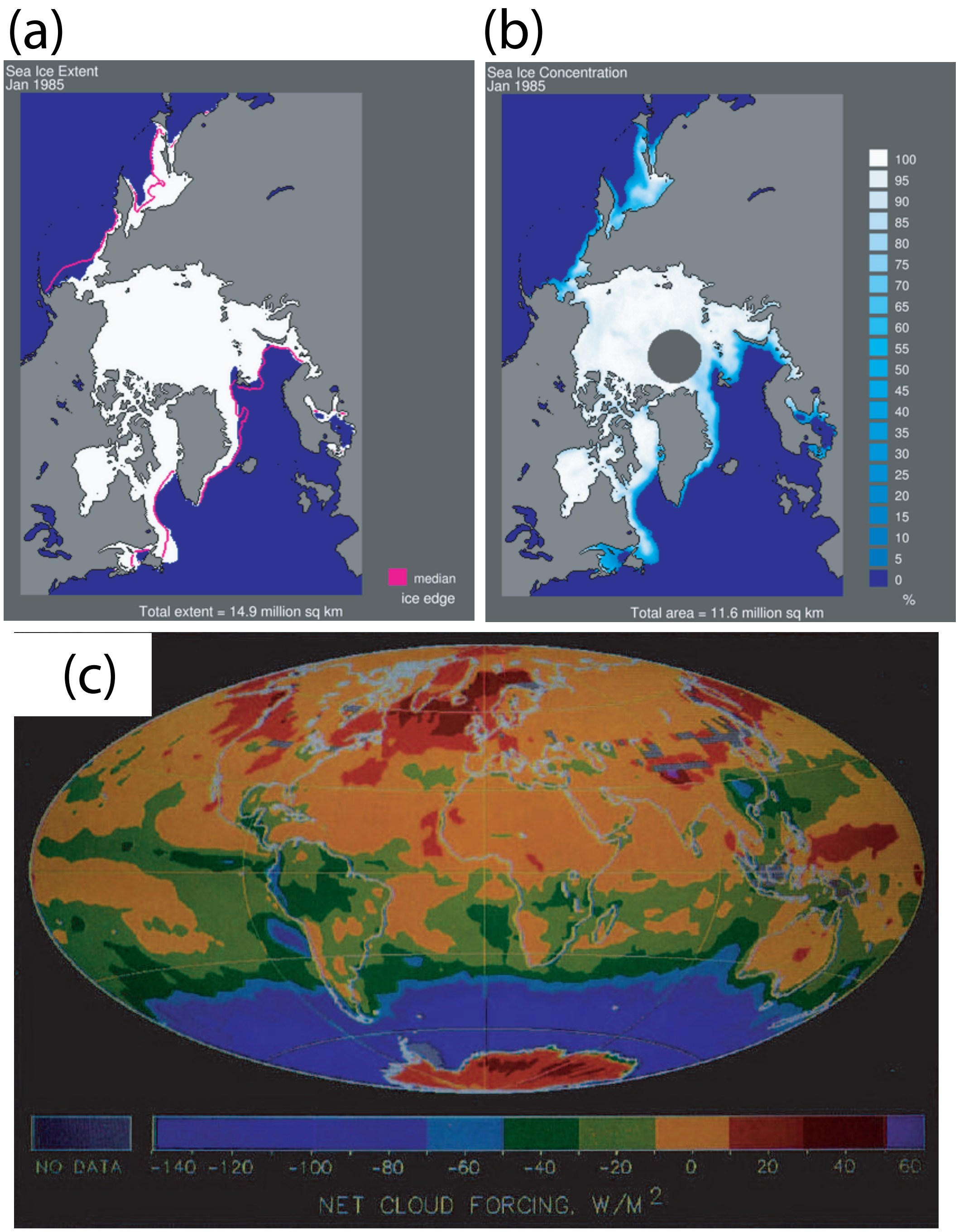


Figure S1: Cloud radiative forcing and sea ice data for January 1985. (a) Sea ice extent. (b) Sea ice concentration, *i.e.*, fraction sea covered by ice. (c) Net cloud radiative forcing. The sea ice plots were obtained from the National Snow and Ice Data center (Fetterer et al., 2002, updated 2007). The cloud radiative forcing plot is Plate 5b in Harrison et al. (1990).

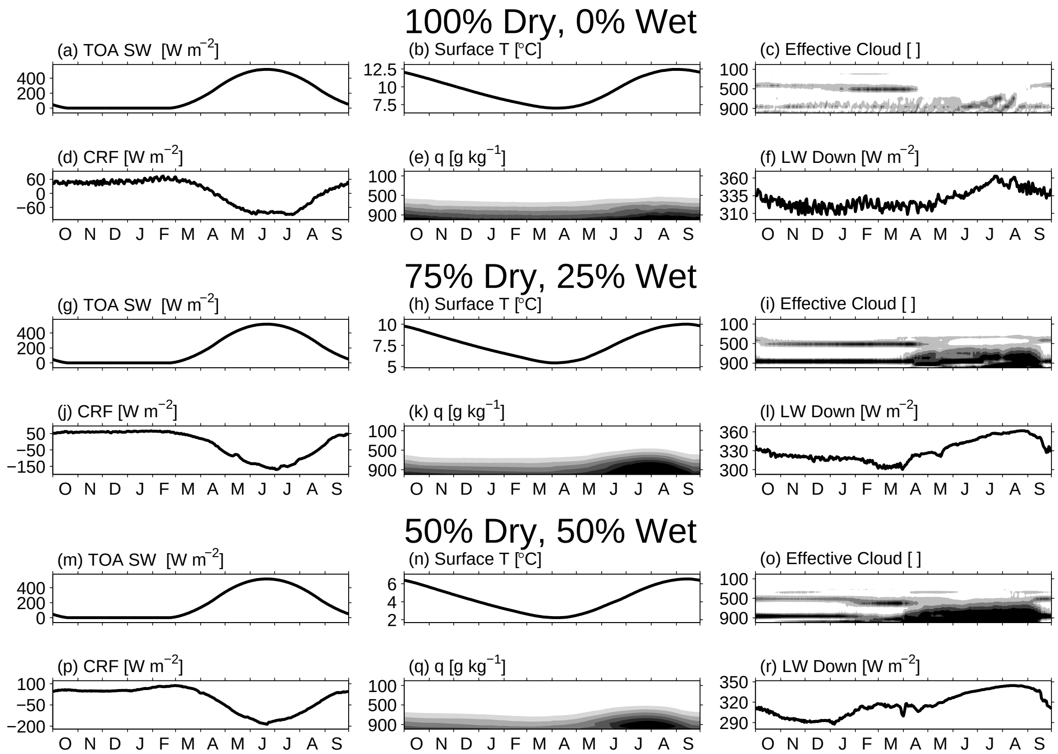


Figure S2: Seasonal cycle of important physical quantities in the ice-free state at 79.5° with wet and dry atmospheric heat transport accounting for the following percentages of the total: 100% dry, 0% wet (a-f, same as Fig. 1(a-f)); 75% dry, 25% wet (g-l); and 50% dry, 50% wet (m-r). In all cases the total specified atmospheric heat transport is 100 W m$^{-2}$, the specified convergence of ocean heat transport is zero, and the specified $CO_2$ concentration is 1000 ppm. Moist heat transport is applied equally by mass below 470 mb. Each panel displays the average values for the last 15 years of a 50 year model run. The panels contain (a,g,m) TOA SW, daily-averaged downward shortwave radiation at the top of the atmosphere, (b,h,n) Surface T, the surface temperature, (c,i,o) Effective Cloud, the product of the cloud fraction and the cloud emissivity, with shading intervals of 0.1, (d,j,p) CRF, the cloud radiative forcing at the surface, (e,k,q) q, the specific humidity, with shading intervals of 1 g kg$^{-1}$, (f,l,r) LW Down, downward longwave radiation at the surface. The ice-free state is stable in all cases; it is stable even when the atmospheric heat transport is 100% wet (not shown). In all cases winter convection is active and important in maintaining the ice-free state. The main effect of increasing the fractional moist heat transport is to increase the cloud amount, particularly during summer, which makes the summer cloud radiative forcing more negative and leads to cooler surface temperatures. The ice-state is also stable at all fractional moist heat transport levels.

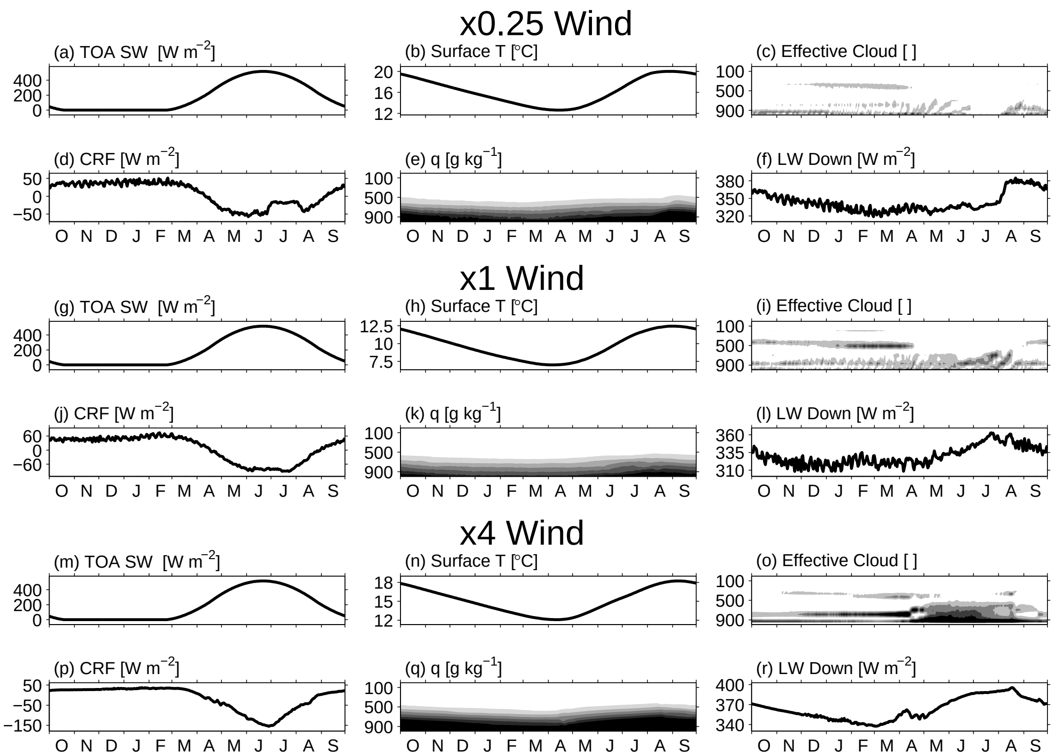


Figure S3: Seasonal cycle of important physical quantities in the ice-free state at 79.5° with the specified magnitude of the surface wind velocity 0.25 times the standard value (a-f), at the standard value (g-l, same as Fig. 1(a-f)), and 4 times the standard value. In all cases the total specified atmospheric heat transport is 100 W m$^{-2}$, the specified convergence of ocean heat transport is zero, and the specified $CO_2$ concentration is 1000 ppm. Each panel displays the average values for the last 15 years of a 50 year model run. The panels contain (a,g,m) TOA SW, daily-averaged downward shortwave radiation at the top of the atmosphere, (b,h,n) Surface T, the surface temperature, (c,i,o) Effective Cloud, the product of the cloud fraction and the cloud emissivity, with shading intervals of 0.1, (d,j,p) CRF, the cloud radiative forcing at the surface, (e,k,q) q, the specific humidity, with shading intervals of 1 g kg$^{-1}$, (f,l,r) LW Down, downward longwave radiation at the surface. The ice-free state is stable in all cases and winter convection is active and important in maintaining the ice-free state. We take this insensitivity as evidence that a wind-evaporation feedback (*e.g.*, Emanuel, 1987; Neelin et al., 1987), which cannot be included in a single-column model, would not markedly affect our results. When surface winds are varied between 0.5-2 times their standard value, there is almost no effect on the results (not shown). When surface winds are 4 times standard, winter deep convection and CRF are slightly lower than at lower surface wind values. The ice state is also stable at all surface wind levels shown here.

# References

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Fetterer, F., K. Knowles, W. Meier, and M. Savoie, 2002, updated 2007: Sea ice index, Boulder, CO: National Snow and Ice Data Center. Digital media. Available at http://nsidc.org/cgi-bin/wist/wist.pl?wcf=seaice_index&submit=Go%21.

Harrison, E. F., P. Minnis, B. R. Barkstrom, V. Ramanathan, R. D. Cess, and G. G. Gibson, 1990: Seasonal variation of cloud radiative forcing derived from the earth radiation budget experiment. *J. Geophys. Res.*, **95**(D11), 18,687–18,703.

Neelin, J. D., I. M. Held, and K. H. Cook, 1987: Evaporation-wind feedback and low-frequency variability in the tropical atmosphere. *Journal of the Atmospheric Sciences*, **44**(16), 2341–2348.