**May 2009 Atmospheric River Event in the Dronning Maud Land**

Maria Tsukernik[1], Amanda Lynch[1], Maya Wei[1], Irina Gorodetskaya[2]
*[1]Environmental Change Initiative, Dept. of Geological Sciences,*
*Brown University, Box 1951, Providence, RI 02912 USA*
*Maria_Tsukernik@brown.edu,*
*[2]K.U. Leuven, Department of Earth and Environmental Sciences,*
*Celestijnenlaan 200E, B-3001 Leuven-Heverlee, Belgium*

On the Antarctic continent, precipitation is the only significant source term in the ice sheet mass balance, counterbalancing ice discharge and basal melt (Krinner et al., 2007, Uotila et al., 2007). Precipitation is also particularly difficult to quantify in Antarctica - an extremely cold and dry environment, prone to high winds redistributing and sublimating snow.

Measurements by an automatic weather station installed in Dronning Maud Land at the northern foot of the Sør Rondane mountain range (at the Princess Elisabeth station, 71°057' S, 23°021' E, 1392m asl, 173 km inland) showed a particularly strong accumulation event on 19th May 2009 (Gorodetskaya et al., 2013). The mean sea level pressure map based on the European Center for Medium Weather Forecast reanalysis (ERA-Interim) data showed that this event was associated with a deep cyclone blocked on the east by a high pressure ridge. Figure 1 depicts this strong synoptic system as seen by the infrared satellite composite product, developed at the University of Wisconsin (Lazzara et al., 2011). The cyclone was long lived, and directed elevated amounts of moisture onto the continent along the 60°E meridian. Such systems have been observed in the Arctic (e.g. Inoue et al., 2010) but such analysis in the Antarctic is only just beginning.

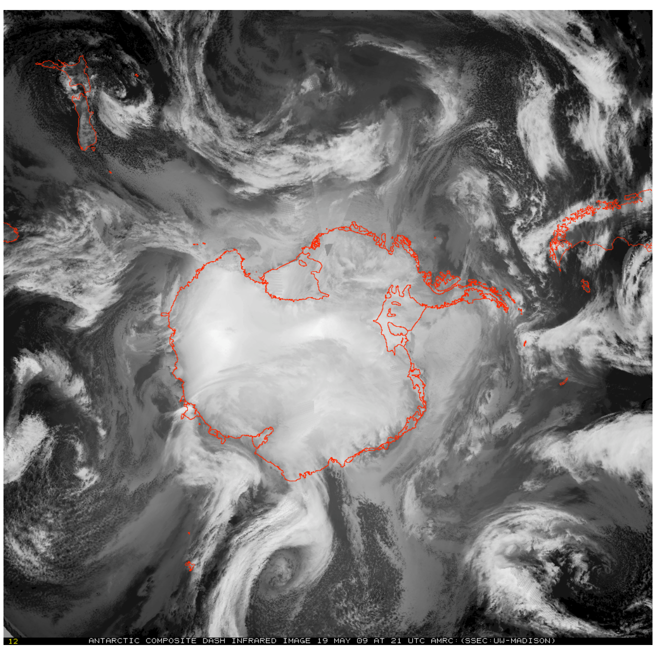


Figure 1. An infrared Antarctic composite image from May 19, 2009 at 21 UTC depicting a massive storm off Dronning Maud land (Courtesy of Dr. Matthew Lazzara, AMRC, University of Wisconsin).

SSM/I satellite data for May 19th 2009 reveal a narrow band of water vapor tracing meridionally across the Southern Ocean (Figure 2). Such a phenomenon is known as an “atmospheric river” in the Northern Hemisphere. Atmospheric rivers are relatively narrow regions in the atmosphere that are responsible for significant midlatitude transport of water vapor (e.g. Ralph and Dettinger, 2011; Ralph et al., 2011). This phenomenon has been extensively studied in western US and is responsible for up to 50% of the annual precipitation in the western states. Although it has been hypothesized that atmospheric rivers are common in other parts of the world, the May 2009 case presents a first direct observation of an atmospheric river reaching the Antarctic continent.

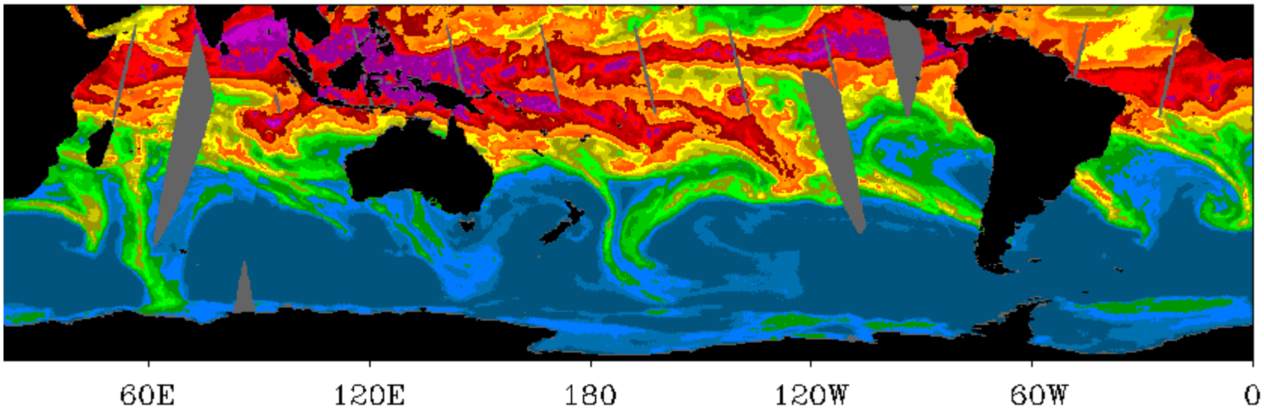


Figure 2. SSM/I Water Vapor (Wentz algorithm) for 19th May 2009, courtesy Gary Wick, NOAA. Note the narrow band of high water content around 60°E, stretching from the Indian Ocean mid-latitudes to the edge of the Antarctic continent.

Interestingly enough we became interested in May 2009 after performing the meridional moisture transport analysis (Tsukernik and Lynch, 2013) and noting a significant positive anomaly in total meridional moisture transport (Figure 3). Further calculations demonstrate that 18 separate synoptic events affected Dronning Maud Land in 2009, and that these accounted for 40% of the total annual accumulation at Princess Elisabeth AWS station that year (Gorodetskaya et al. 2013).

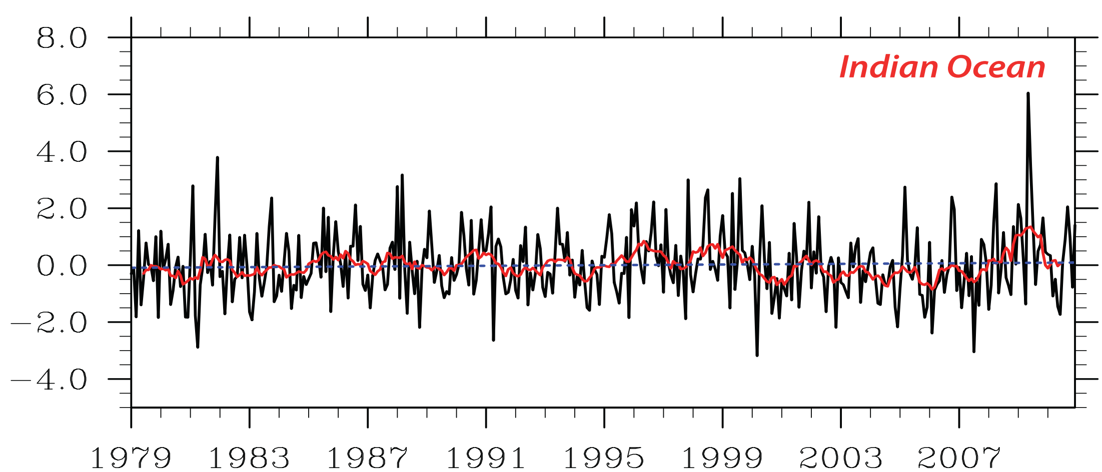


Figure 3. Transient eddy meridional moisture flux time series in the coastal zone of the Dronning Maud Land and surrounding area (Indian Ocean sector). Black line shows the monthly anomalies, red line shows interannual variability and the dashed blue line represents the long-term trend. Units are kg m-1 s -1.

In this study we performed a detailed analysis of the formation of the May 2009 atmospheric river. We employ the Weather Research and Forecasting (WRF) model to simulate the formation of the atmospheric river event. We also investigate the mechanisms important to the development of synoptic systems can be explored in an approximate form by using the quasi-geostrophic omega equation. In the quasi-geostrophic system, with no diabatic forcing, vertical velocity is forced solely by the divergence of the Q-vector (Hoskins et al. 1978). Departures from this regime can occur through contributions to the diabatic heating rate from surface sensible and latent heat fluxes and convection. We compute the relative contribution of these terms in the upper and lower levels (following the diagnostics developed by Lynch et al. 2003 and Bracegirdle and Gray 2008 for the Arctic cases) and discuss the implication of our results.

**References:**


Bracegirdle T.J., Gray S.L. 2008: An objective climatology of the dynamical forcing of polar lows in the Nordic seas. International Journal Of Climatology, **28**, 1903-1919

Gorodetskaya, I. V., N. P. M. Van Lipzig, M. R. Van den Broeke, A. Mangold, W. Boot, and C. H. Reijmer. 2013: Meteorological regimes and accumulation patterns at Utsteinen, Dronning Maud Land, East Antarctica: Analysis of two contrasting years, *J. Geophys. Res*. Atmos., **118**, doi:10.1002/jgrd.50177.

Hoskins, B.J., I. Draghici, H.C. Davies, 1978. A new look at the w-equation Quart. .I. R. Met. Soc. **104**, 31-38.

Inoue, J., Hori, M.E., Tachibana, Y., Kikuchi, T., 2010: A polar low embedded in a blocking high over the Pacific Arctic. Geophysical Research Letters **37**:L14808. DOI: 10.1029/2010GL043946.

Krinner, G., O. Magand, I. Simmonds, C. Genthon, J.-L. Dufresne, 2007: Simulated Antarctic precipitation and surface mass balance at the end of the twentieth and twenty-first centuries. Climate Dynamics **28**, 215-230.

Lazzara, Matthew A.; Coletti, Alex and Diedrich, Benjamin L. 2011. The possibilities of polar meteorology, environmental remote sensing, communications and space weather applications from Artificial Lagrange Orbit. Advances in Space Research, Volume 48, Issue 11, , pp.1880-1889

Ralph, F. M., P. J. Neiman, G. N. Kiladis, K. Weickman, and D. W. Reynolds, 2011: A multi-scale observational case study of a Pacific atmospheric river exhibiting tropical-extratropical connections and a mesoscale frontal wave. *Mon. Wea. Rev.*, **139**, 1169-1189, doi:10.1175/2010MWR3596.1.

Ralph, F.M., and M.D. Dettinger, 2011: Storms, Floods and the Science of Atmospheric Rivers. *EOS, Transactions, Amer. Geophys. Union.*, **92**, 265-266, doi:10.1029/2011EO320001.

Tsukernik M. and A. Lynch. 2013: Atmospheric meridional moisture flux over the Southern Ocean: a story of the Amundsen Sea. J Climate in press.

Uotila P., Lynch A.H., Cassano J.J., Cullather, R.I., 2007: Changes in Antarctic net precipitation in the 21st century based on Intergovernmental Panel on Climate Change (IPCC) model scenarios. Journal Of Geophysical Research-Atmospheres **112** D10107.