Investigation of Seasonal Landscape Freeze/Thaw Cycles in Relation to Cloud Structure in the High Northern Latitudes

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Introduction/Abstract

The seasonal freezing and thawing of Earth's cryosphere (the portion of Earth's surface permanently or seasonally frozen) has an immense impact on Earth's climate as well as on its water, carbon and energy cycles. During the spring, snowmelt and the transition between frozen and non-frozen states lowers Earth's surface albedo. This change in albedo causes more solar radiation to be absorbed by the land surface, raising surface soil and air temperatures as much as 5ºC within a few days. The transition of ice into liquid water not only raises the surface humidity, but also greatly affects the energy exchange between the land surface and the atmosphere as the phase change creates a latent energy dominated system. There is strong evidence to suggest that the thawing of the cryosphere during spring and refreezing during autumn is correlated to local atmospheric conditions such as cloud structure and frequency. Understanding the influence of land surface freeze/thaw cycles on atmospheric structure can help improve our understanding of links between seasonal land surface state and weather and climate, providing insight into associated changes in Earth's water, carbon, and energy cycles that are driven by climate change.

Information on both the freeze/thaw states of Earth's land surface and cloud characteristics is derived from data sets collected by NOAA's Special Sensor Microwave/Imager (SSM/I), the Advanced Microwave Scanning Radiometer on NASA's Earth Observing System (AMSR-E), NASA's CloudSat, and NASA's SeaWinds-on-QuickSCAT Earth remote sensing satellite instruments. These instruments take advantage of the microwave spectrum to collect an ensemble of atmospheric and land surface data. Our analysis uses data from radars (active instruments which transmit a microwave signal toward Earth and measure the resultant backscatter) and radiometers (passive devices which measure Earth's natural microwave

emission) to accurately characterize salient details on Earth's surface and atmospheric states. By comparing the cloud measurements and the surface freeze-thaw data sets, a correlation between the two phenomena can be developed.

Goals and Purpose of the Project

Prior to last summer, the Climate Physics Group that analyzes cloud data at JPL and the Water and Carbon Cycles Group that looks at surface freeze-and-thaw data were working mostly independently. My project during the summer of 2010 was to combine data sets from both groups into one directory and then to process and analyze the data, exploring any correlations I discovered. By finding correlations between the two data sets, I would hopefully find out how atmospheric characteristics such as climate are affected by ground freeze and thaw states. By the end of the summer, however, I had only managed to create an efficient method for processing and graphing the data. My 2011 summer project builds upon the framework I created in 2010.

The CloudSat data I have been using is organized with respect to fifteen variables by satellite orbit. A few of the variables which are more useful to my project include the latitude and longitude of each data point, as well as the pressure at that point (from which height above the earth's surface can be derived), the ice water content (IWC), the liquid water content (LWC), the cloud type, and the temperature. Meanwhile, the SSM/I data is given in a matrix format, where each cell of the matrix corresponds to a latitude/longitude pair and contains a value representing one of the following ground states: frozen, non-frozen, transitional (frozen in the morning, non-frozen in the afternoon), inverse transitional (non-frozen in the morning, frozen in the afternoon), water, or mask (vegetation, etc) (Figure 1). During my first summer, I used a mapping between the coordinates of both data sets so that I could use them together in my analysis. By the end, I reached a point at which I could graph cloud profiles over different types of land (defined by the

SSM/I land types) for any given day. My routines plotted CloudSat and SSM/I data onto an Earth map (e.g. Figure 2) as well as generating graphs that, for example, show ice water content versus altitude for the air directly above the six different types of surface states defined within the SSM/I data for a specific day (Figure 3).

During 2011, I expanded on this initial analysis by analyzing deposits of 8 to 16 days of CloudSat data instead of one. First of all, this gives a more reliable representation of what the freeze/thaw states at specific coordinates around the globe really are by averaging them out over a longer time period. Secondly, since the CloudSat satellite takes data in a swath that tracks lines around the Earth approximately eight times a day, this 16-day deposit allows the CloudSat data to cover more of the Earth and therefore create a more complete data set for a specific group of days. At first, this task seemed infeasible since I would have to analyze 16 days worth of data at a time (where just a single day's analysis had been taking me tens of minutes last summer)! After researching some of IDL's built-in functions, however, I managed to whittle the analysis time down from several hours to several minutes. Space issues also became a problem as I approached IDL's several-gigabyte limit on array sizes. There wasn't a clean way to solve this issue for global analyses of the data, but for analyses of smaller regions I was able to only store a subset of the 16 days of CloudSat data and thereby avoid this issue.

The result of my 2011 analysis was the ability to encapsulate much more data within each of my outputted graphs. Instead of single-day graphs, I created graphs that spanned the full 15 months of CloudSat data that I had to work with (Figure 4). Despite this, I ended up outputting many more graphs than I had the last summer as I experimented with different ways to make the graphs more readable as well as creating graphs for different permutations of regions, freeze-thaw states and CloudSat variables. I have yet to fully analyze and draw conclusions from all of these graphs.

Impact of the MUST Internship on my Career Goals

My research experience at JPL has helped me define my educational and professional goals. Although it was frustrating at times, I enjoyed developing a deeper understanding of IDL as a programming language. Furthermore, I liked that my mentor would supplement my programming with papers from related research experiments.

During this summer, I worked more independently than last summer. Although I've received guidance from several people, all of whom have been enthusiastic about the results of my analysis, I have largely been making my own decisions on what to code and how analyze the data. My mentor, along with people working on other components of the project, have helped point me towards resources from which I can figure out the next steps I must take to complete my project. When I do get stuck at some point, I know that there are people I can go to who will help me solve the problem.

This summer's main byproduct was a deeper understanding of IDL. I had thought that my analysis code was efficient last summer, only to find out that I could improve it vastly when confronted with even larger data sets this summer. Overall, the whole project experience has been very worthwhile since what I learned can be applied to many other areas of research and academia that I may want to pursue.

Acknowledgements

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	CloudSat	SSMI
Data Products	• Latitude • Longitude • Temperature • Pressure • Ice water content • Liquid water content • Cloud type • Cloud percentage • Precipitation flag • LWCDe • LWCNc • Humidity • SST	• Latitude • Longitude • Frozen • Non-frozen • Transitional • Inverse-transitional • Water • Mask (vegetation, etc)

Figure 1: Data products from the satellite instruments used in this analysis (CloudSat and SSM/I).

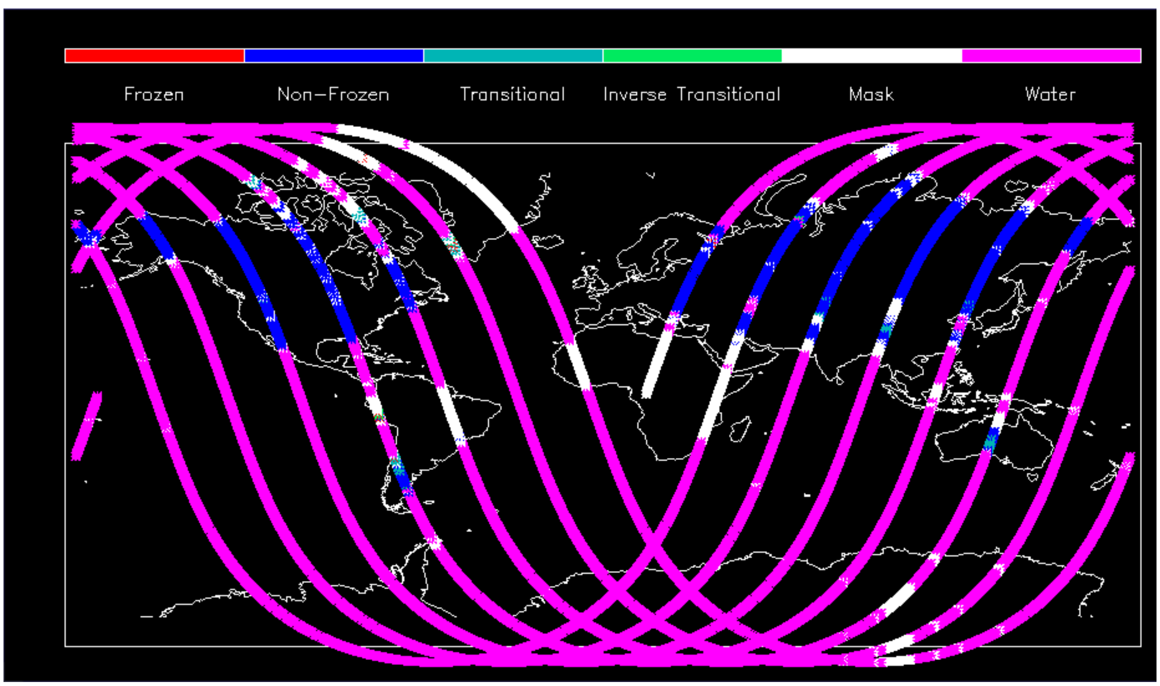

Figure 2: Freeze and thaw states at the latitudes and longitudes given by CloudSat data for June 15th, 2006. The satellite makes approximately seven trips around the globe on a single day.

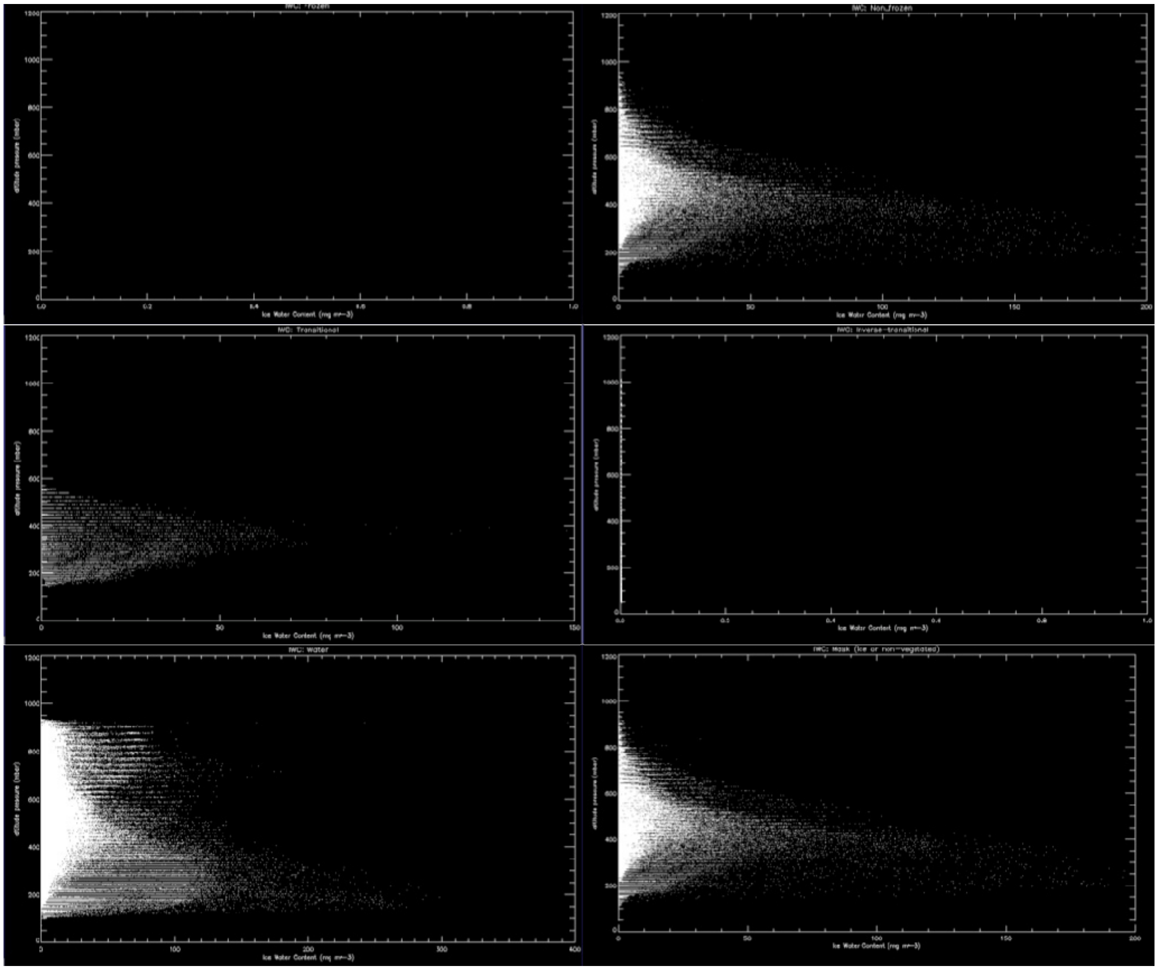

Figure 3: Ice water content versus altitude above surfaces with different freeze-thaw states on June 15th, 2006. From top-left to bottom-right reading left to right: Frozen, non-frozen, transitional, inverse-transitional, water, mask (vegetation, etc). The ice water content profiles differ above surfaces with different freeze-thaw states.

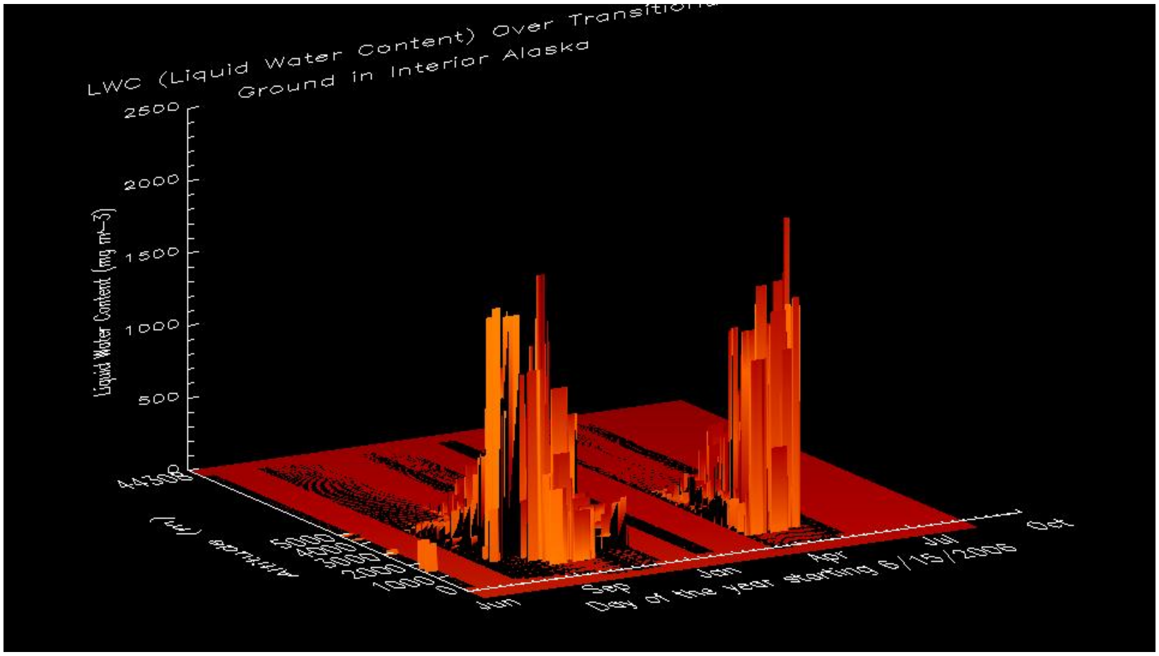

Figure 4: Liquid Water Content at different Altitudes above transitional ground in Interior Alaska from June 15th, 2006 to August, 2007.