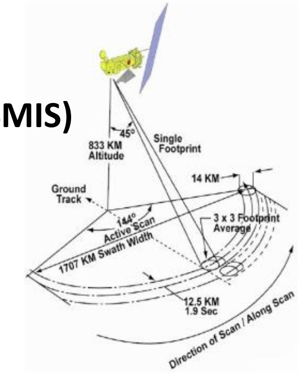
Title:	Mapping Sea Ice using a Microwave Imager/Sounder (SSMIS)
	Part I: Download and import SSMIS data
	Part II: Calculate and Map Sea Ice Concentration
	Part III: Make corrections to sea ice map and compare to NASA product
Product Type:	Curriculum
Developer:	Helen Cox (Professor, Geography, California State University, Northridge): helen.m.cox@csun.edu Laura Yetter (Research Asst., Institute for Sustainability, California State University, Northridge)
Target audience:	Level 4 Graduate or undergraduate with some experience in remote sensing
Format:	Tutorial (pdf document)
Software requirements*:	ArcMap 9 or higher (ArcGIS Desktop) (Parts I, II, III), ArcGIS Spatial Analyst (Parts II, III), ERDAS Imagine 2010 or higher (Part I), Microsoft Excel 2003 or higher (Part II)
Data:	All data required are obtained within the exercise.
Estimated time to complete:	All parts: 7 hrs
	Part I: 2.5 - 3 hrs.
	Part II: 2.5 - 3 hrs.
	Part III: 1 hr.
Alternative Implementations:	• Parts I and II together provide a standalone exercise producing a sea ice concentration map • Parts I, II and Part III (starting at #4) together provide a standalone exercise producing a sea ice concentration map and comparing it to one produced by NASA • Completing all parts (I through III) produce a sea ice concentration map with corrections that is compared to one produced by NASA
Learning objectives:	Part I: • Understand relationship between sea ice and climate • Understand concept of brightness temperature • Learn about the SSMIS instrument and use of microwave data in remote sensing • Download, import and map SSMIS data in ERDAS Imagine and ArcGIS
	Part II: • Understand concepts of first year and multiyear ice • Understand and employ tie points for calibration • Build a model to calculate first year and multiyear ice concentration • Generate a map of total sea ice concentration
	Part III: • Apply quality control procedures to correct for spurious ice misclassification • Compare derived sea ice concentration map with NASA product

*Tutorials may work with earlier versions of software but have not been tested on them



Mapping Sea Ice using a Microwave Imager/Sounder (SSMIS)
Part II: Calculate and Map Sea Ice Concentration

Objective:

- Understand concepts of first year and multiyear ice
- Understand and employ tie points for calibration
- Build a model to calculate first year and multiyear ice concentration
- Generate a map of total sea ice concentration

The earth naturally emits microwaves and emission is related to the atomic structure of the emitting surface. Ocean and ice can be distinguished because they have different signatures in the microwave part of the spectrum, and within this spectrum first year ice and multiyear ice can be further distinguished from each other. First year ice is ice that newly formed during the winter and multiyear ice is sea ice that has survived one or more melt seasons and is present year round. There are important differences between these two although first year ice may still be plentiful in the Arctic, the disappearance of thicker multiyear ice is a striking manifestation of climate change. (http://www.youtube.com/watch?v=ZYaubXBfVqo&feature=youtu.be)

Open water emits only a small amount of microwave radiation, which is polarized. First year ice emits more microwaves which are less polarized. Multiyear ice has a signature that is somewhere between open water and first year ice. There is not a direct relationship between microwave emission and open water or first year ice signatures. Although 100% sea ice and 100% open water are distinct, mixtures are hard to discriminate. Therefore empirical relationships are used to derive sea ice concentrations. Gradient Ratios, GR (defined below) and Polarization Ratios, PR (see below) can be derived from microwave emissions at different frequencies and polarizations, and the relationship between these used to distinguish sea ice types and water (National Oceanic and Atmospheric Administration [NOAA], 2012).

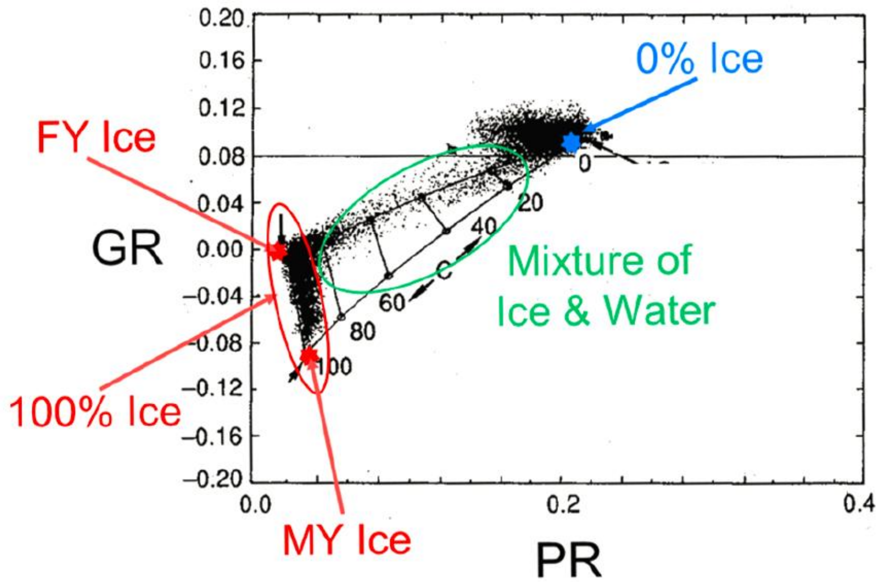


Figure 1. From NOAA (2012) When the gradient ratio (GR) and the polarization ratio (PR) are graphed against each other and points of 0% ice and 100% ice are added sea ice concentration can be derived. Open water or 0% ice is represented by the blue point. 100% ice is circled in red with first year ice (FY) clustering at the top and multiyear ice (MY) clustering at the bottom. Areas of mixed ice and open water are circled in green.

In order to maintain an accurate measure of sea ice concentration between hemispheres and different sensors, tie points are introduced. These tie brightness temperatures (or radiances) to sea ice observations and provide an empirical method for relating microwave data to known ice-free ocean, first-year sea ice, and multiyear ice for each of the three SSM/I channels. Because ice emissivity properties are variable and are different between hemispheres there are hemispheric and regional differences in these calibration values, which have been established by aircraft flights and in-situ observations. These tie-point temperatures are used in computing polarization and spectral gradient ratios, which are then employed in calculations of ice concentrations (adapted from NOAA 2012 and the NSIDC NASA Team webpage http://nsidc.org/data/docs/daac/nasateam/index.html).

1. Data Preparation

Convert band 19h, 19v, 22v and 37v raster images into .tif files and change the pixel value to **32 bit float** to allow for decimal numbers that will be computed.

ArcToolbox>Data Management> Raster > Raster Dataset> Copy Raster

In the Output Raster Dataset box be sure to add .tif to your file. Change the raster to 32_BIT_FLOAT under Pixel Type. Do this for all your layers except the ocean mask and the product sea ice map. (Optional: You may consider creating a model to complete this step.) Use these 32 bit floating point rasters in the sea ice algorithm below. You will be using Model Builder to compute this.

2. Tie-points and coefficients

In computing sea ice concentrations using Model Builder you will first compute a set of coefficients using the relevant tie points in Excel. Satellite instruments have changed from year to year and thus the tie points have changed. Make sure you know the date for your temperature brightness measurements and choose the tie points that correctly match your data.

Platform	Availability
F-8	July 09 1987 to Dec 31 1991
F-11	Dec 03 1991 to May 31 1995
F-13	May 03 1995 to June 30 2008
F-17	Dec 14 2006 to present

For F-8, F-11 or F-13 tie-points visit
http://nsidc.org/data/docs/daac/nsidc0051_gsfc_seaice/TM104647.html

The Daily Polar Gridded Brightness Temperature .bin file that you originally downloaded will also list the satellite the data was collect from in its name. ex. tb_f17_20110831_v4_n19h.bin.

F-17 tie points are provided in the table below (NOAA 2012).

(OW = ocean water, FY = first-year ice, MY = multi-year ice)

DMSP SSMIS F-17 Tie-points				
Arctic		**19H**	**19V**	**37V**
	OW	113.4	184.9	207.1
	FY	232.0	248.4	242.3
	MY	196.0	220.7	188.5
Antarctic				
	OW	113.4	184.9	207.1
	FY	237.8	253.1	246.6
	MY	211.9	244.4	212.6

Once you have the correct set of tie points, use Excel to calculate coefficients a0 through a5 and b0 through b5 in the formula below. Use these to calculate the coefficients for first year ice (f0-f3), multi-year ice (m0-m3), and d (d0-d3) as shown below (Cavalieri et al. 1984).

a0= -tb19V OW + tb19H OW
a1= tb19V OW + tb19H OW
a2= tb19V MY - tb19H MY - tb19V OW + tb19H OW
a3= -tb19V MY - tb19H MY + tb19V OW + tb19H OW
a4= tb19V FY - tb19H FY- tb19V OW + tb19H OW
a5 = -tb19V FY - tb19H FY + tb19V OW + tb19H OW

b0 = -tb37V OW + tb19V OW
b1 = tb37V OW + tb19V OW
b2 = tb37V MY - tb19V MY - tb37V OW + tb19V OW

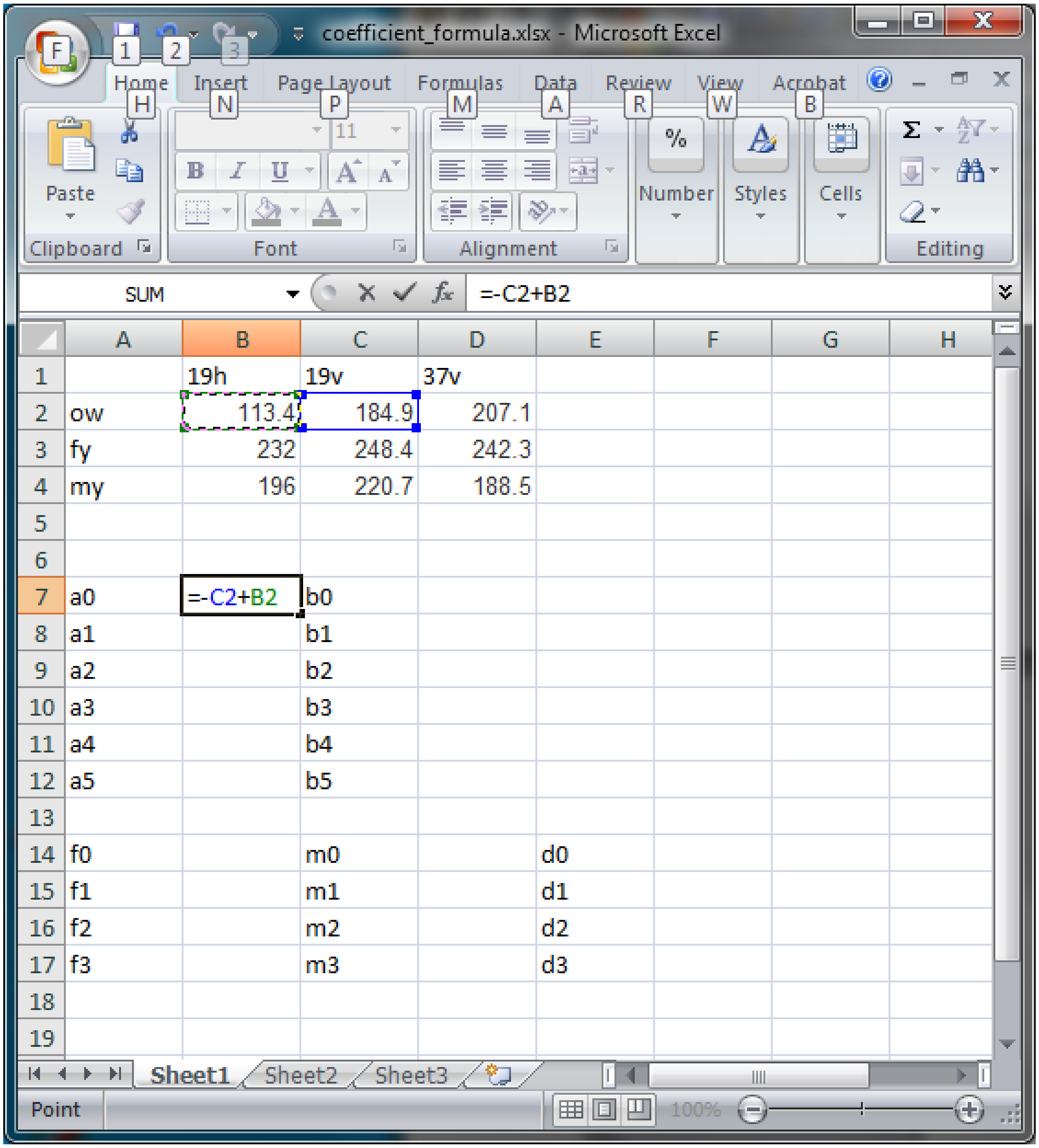
b3 = -tb37V MY - tb19V MY + tb37V OW + tb19V OW
b4 = tb37V FY - tb19V FY - tb37V OW + tb19V OW
b5= -tb37V FY- tb19V FY + tb37V OW+ tb19V OW

f0 = (a0*b2) - (a2*b0)
f1 = (a1*b2) - (a3*b0)
f2 = (a0*b3) - (a2*b1)
f3 = (a1*b3) - (a3*b1)

m0 = ((a0*b4) - (a4*b0))*-1
m1 = ((a1*b4) - (a5*b0))*-1
m2 = ((a0*b5) - (a4*b1))*-1
m3 = ((a1*b5) - (a5*b1))*-1

d0 = ((a2*b4) - (a4*b2))*-1
d1 = ((a3*b4) - (a5*b2))*-1
d2 =((a2*b5) - (a4*b3))*-1
d3 =((a3*b5) - (a5*b3))*-1

*** The coefficient equations presented here differ by a factor of -1 from the published coefficients (Cavalieri et al 1984) for m and d which were in error.



These coefficients will be added to Model Builder as value variable to calculate the NASA Team Algorithm.

3. NASA Team Algorithm

Use the Raster Calculator in Model Builder to calculate the NASA Team Sea Ice Concentration Algorithm given below (NASA Team Sea Ice Algorithm webpage).

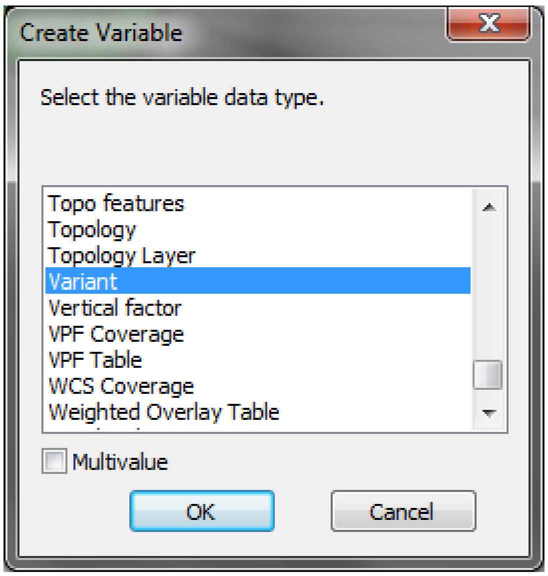
1. Polarization (PR)= (19v-19H)/(19v + 19h)
2. Spectral Gradient Ratio (GR)= (37v- 19v)/(37v+19v)
3. D= (d0 + (d1* PR) + (d2 * GR) + ((d3 *PR) * GR))
4. First Year Ice (FY)= (f0 + (f1 * PR) + (f2 * GR) + ((f3 * PR) * GR))/ D

5. Multi Year Ice (MY)= (m0 + (m1 * PR) + (m2 * GR) + ((m3* PR) * GR))/ D
6. Total Ice Concentration (CT)= FY+ MY

Also Calculate GR22v/19v that will be used later in a quality control procedure:

GR22v/19v = (22v - 19v)/(22v + 19v)

To input the coefficients (d0-3, f0-3, and m0-3) as value variable> right click an empty spot in the model> click on Create Variable> then select the variable data type 'Variant' and click OK> when the variable circle appear in the model double click it and input the coefficient value, rename it appropriately and repeat for all 12 coefficients.



Note you can copy and paste the variant circle instead of repeating the above steps over again.

Your model should look like this:

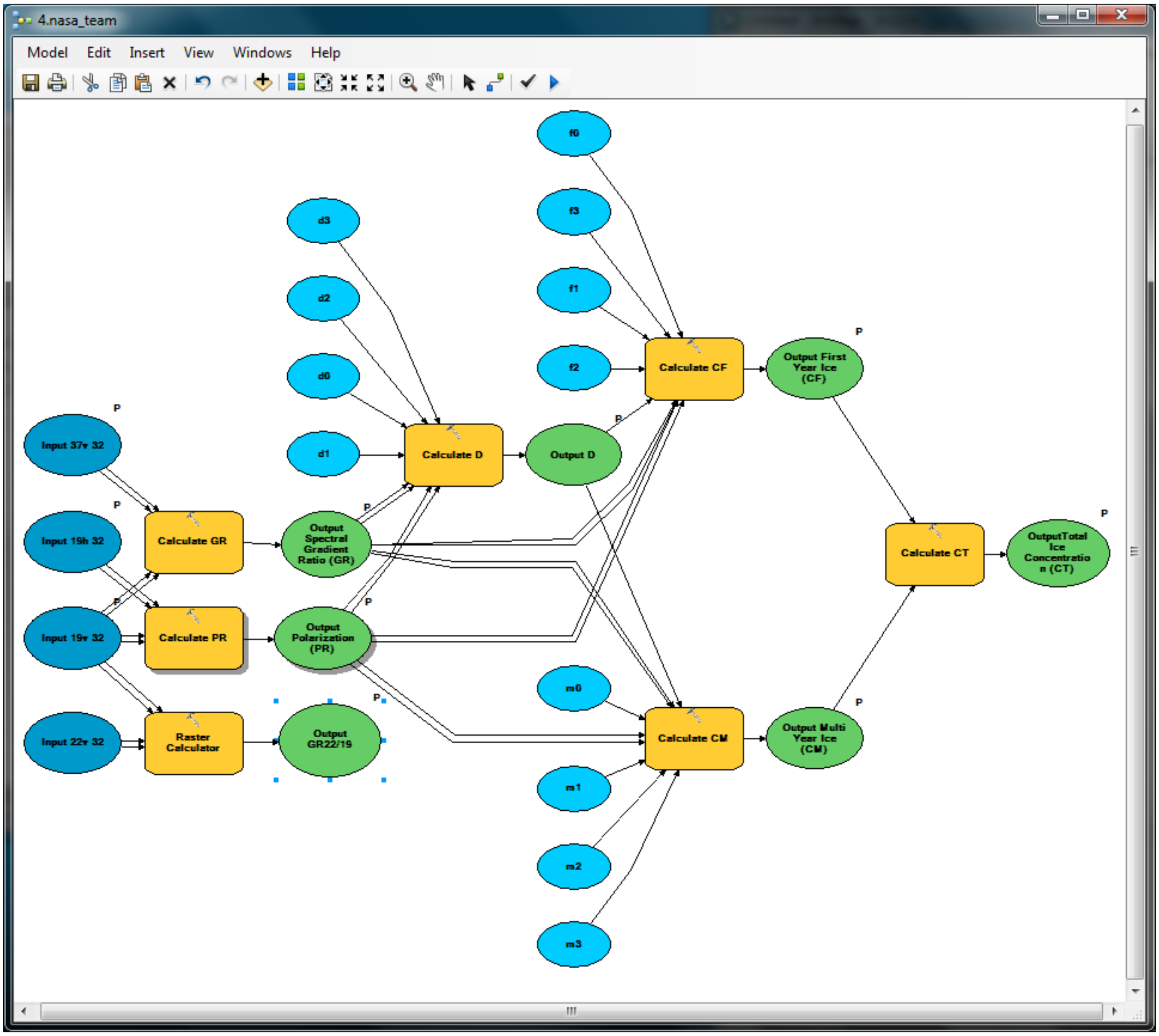


Figure 2. NASA Team Algorithm in Model Builder.

Run the model. In Arcmap examine the total sea ice concentration (CT) results and add a base layer showing the continents to your map.

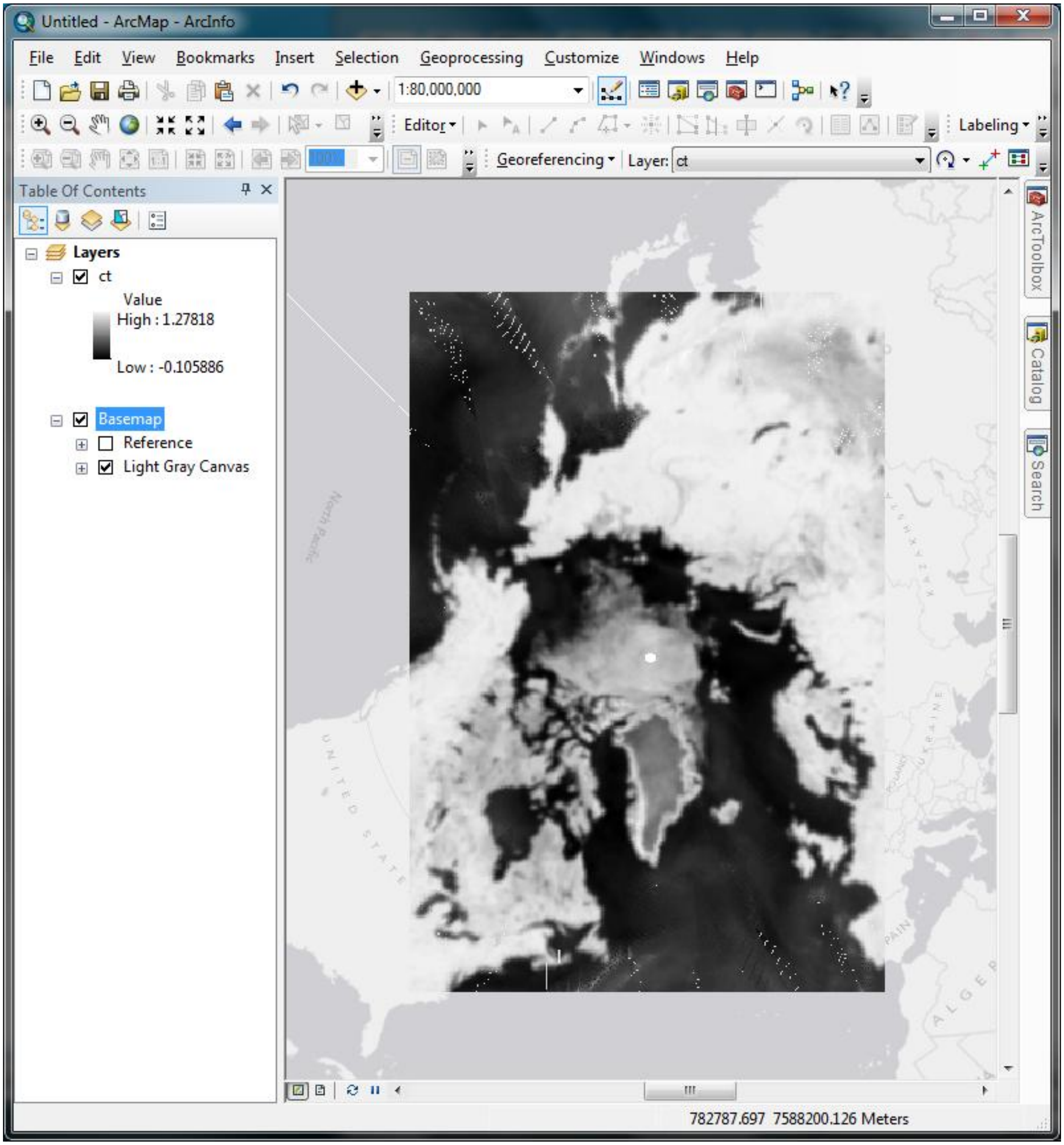


Figure 3. Total sea ice concentration results from August 31, 2011.

Total sea ice concentration values should range from 0 to 100% (0 to 1.0). Anything that is less than 15% (0.15) is not ice. Data can be a little higher than 100% or a little lower than 0 because this is a modeled rather than precisely measured parameter.

Save your model and all of your results.

References

Cavalieri, D.J., P. Gloersen, and W.J. Campbell. 1984. Determination of Sea Ice Parameters with the NIMBUS 7 SMMR. Journal of Geophysical Research (89) 5355- 5369.

NASA Team Sea Ice Algorithm. National Snow and Ice Data Center. 11 July 2012. http://nsidc.org/data/docs/daac/nasateam/index.html

National Oceanic and Atmospheric Administration. (2012). Climate Algorithm Theoretical Basis Document C-ATBD Passive Microwave Sea Ice Concentration (CDR Program No. CDRP-TMP-0006). Retrieved from http://nsidc.org/data/docs/noaa/g02202_ice_conc_cdr/pdf/SeaIce_CDR_CATBD_final.pdf.