Alaska Section, AWRA, 2011 Annual Meeting

Practical Applications of Ice Growth Simulation Tools to Help with Adaptive Water Management of Arctic Lakes

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Project Partners

- NETL/Arctic Energy Office (Main Funding)
- ConocoPhillips Alaska
- Alaska Department of Natural Resources
- Bureau of Land Management
- Geo-Watersheds Scientific
- University of Alaska Fairbanks
- NOAA, National Weather Service
- Alaska Department of Transportation and Public Facilities
- Mineral Management Service
- North Slope Borough

Presentation Outline

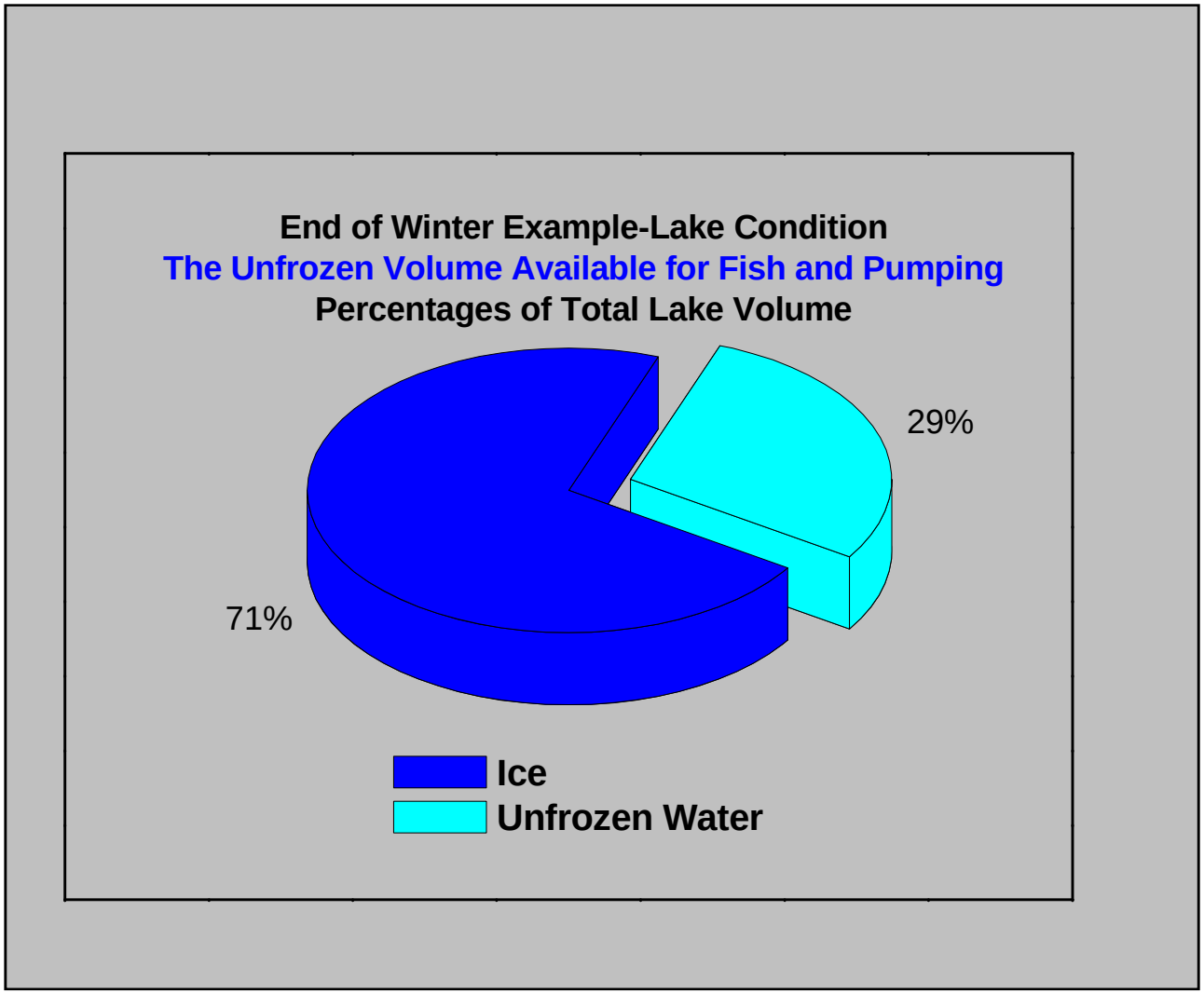
- Ice thickness and water management
- Lake ice characteristics
- Ice simulation approaches
- Results
- Future work

Water Use Tools and Lake Ice Thickness

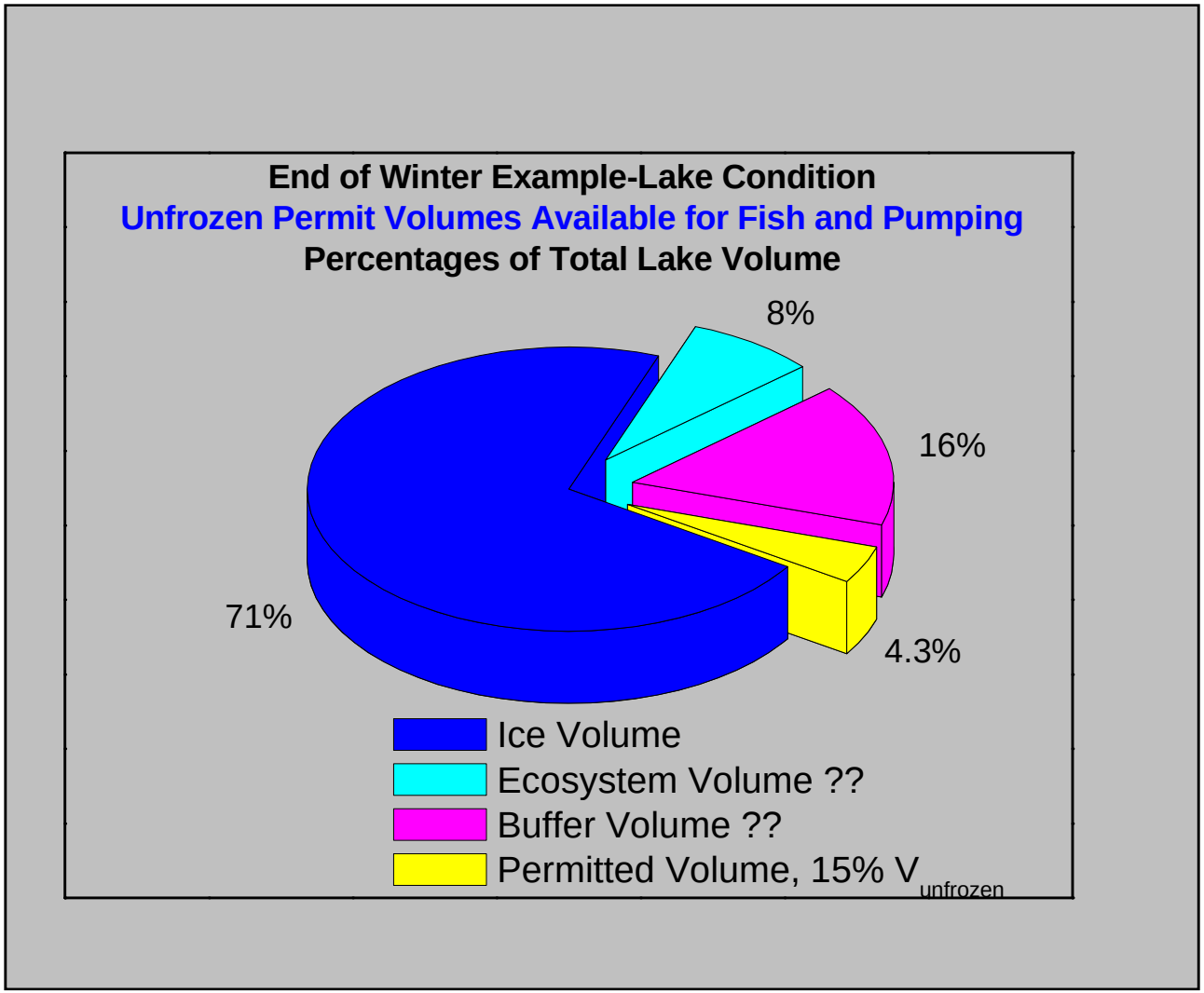
In Relation to Winter Lake Ice Thickness

- Permitting:
  - ✓ What are the right assumptions on ice thickness?
  - ✓ Do they vary geographically?
- Water User Management:
  - ✓ Do you know what you have now?
  - ✓ What will you have at end of winter?

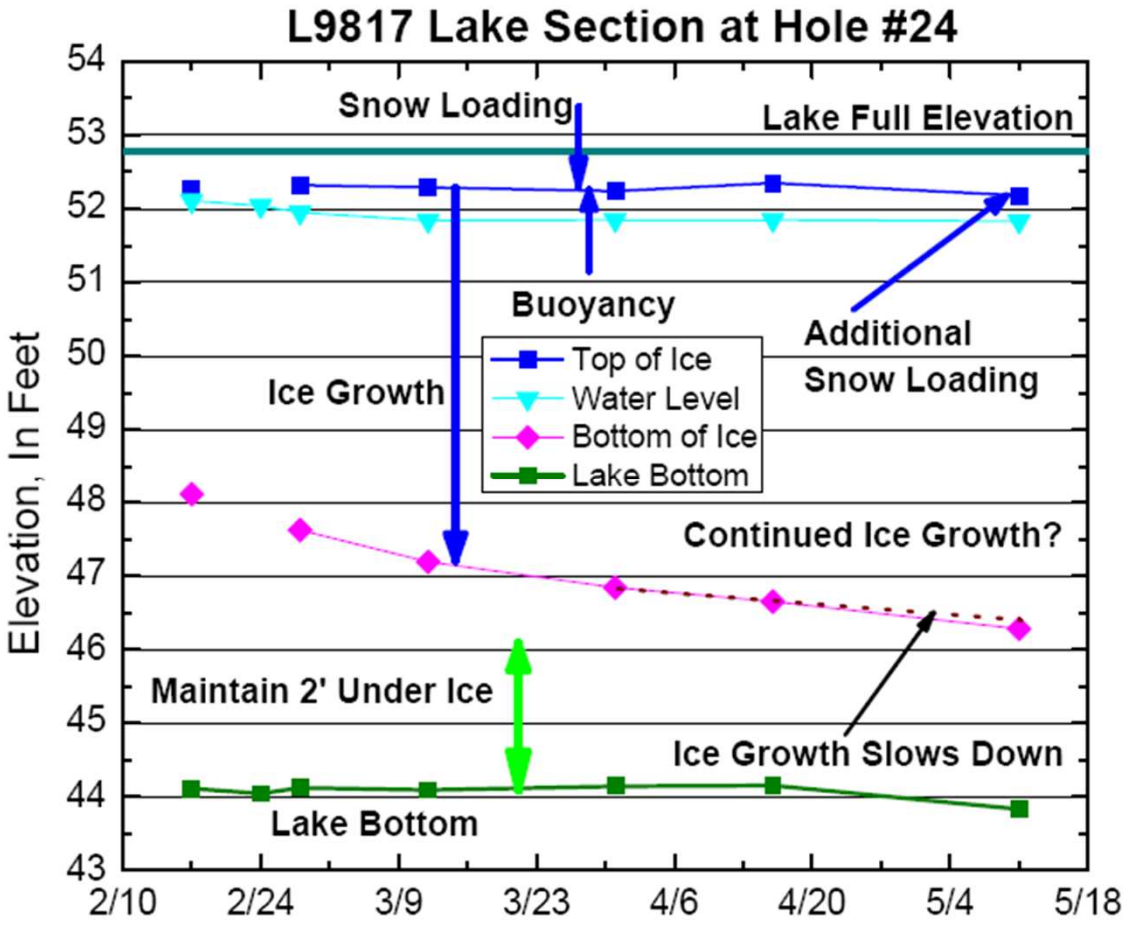
Lake Water Volumes and Uses



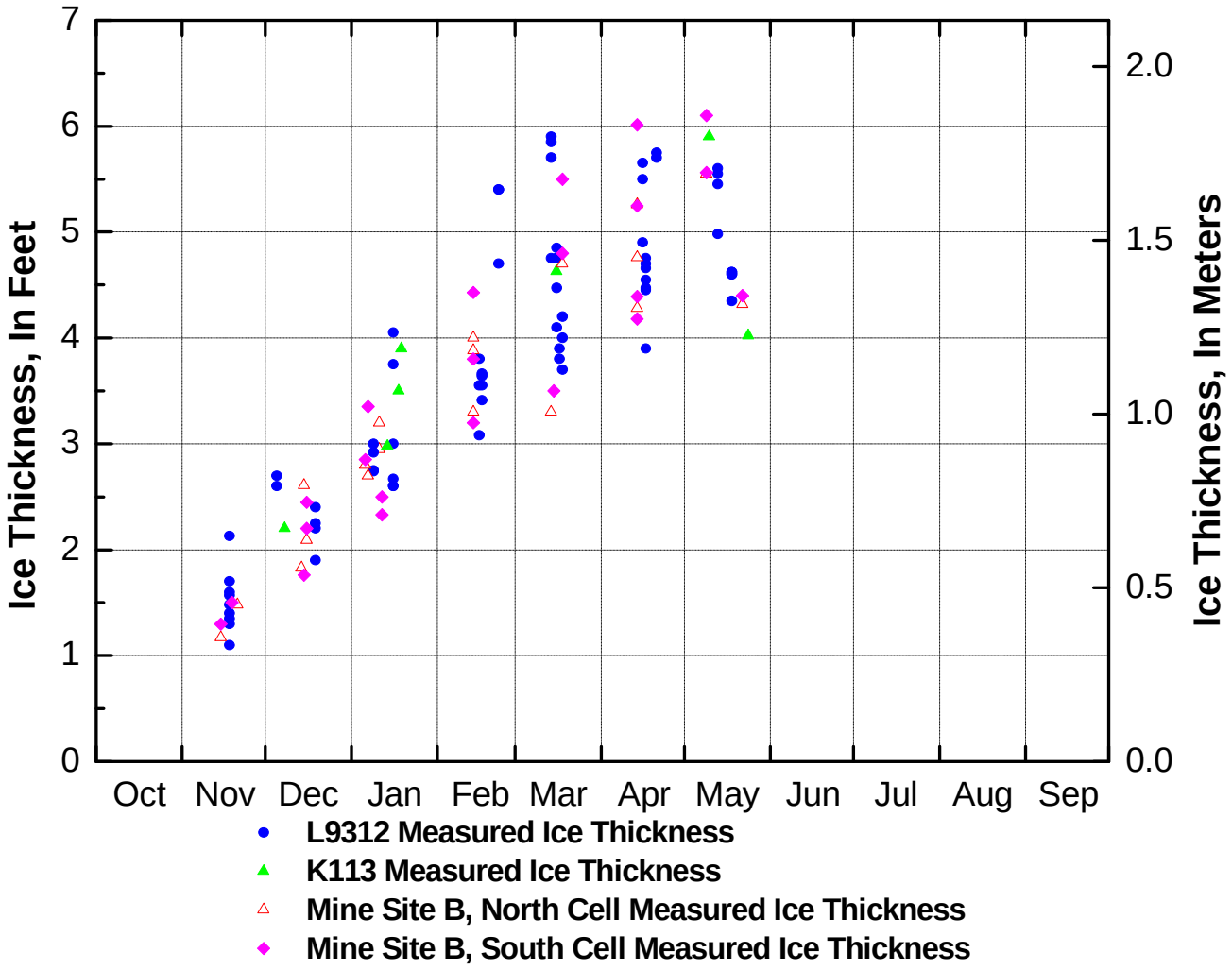
Lake Water Volumes and Uses



Winter Lake Parameters



Lake Ice Thickness Characteristics



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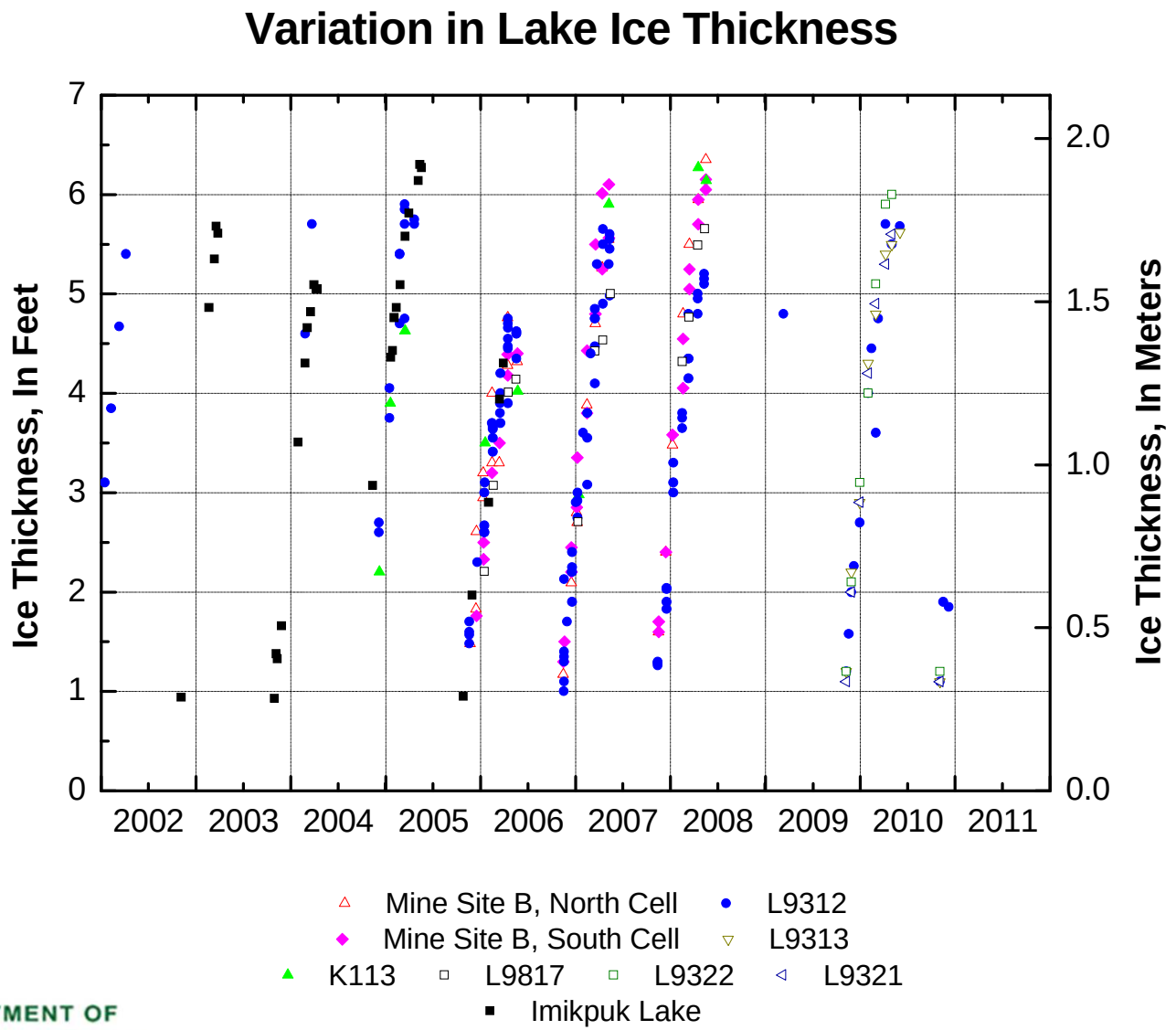
Lake Ice Thickness Characteristics



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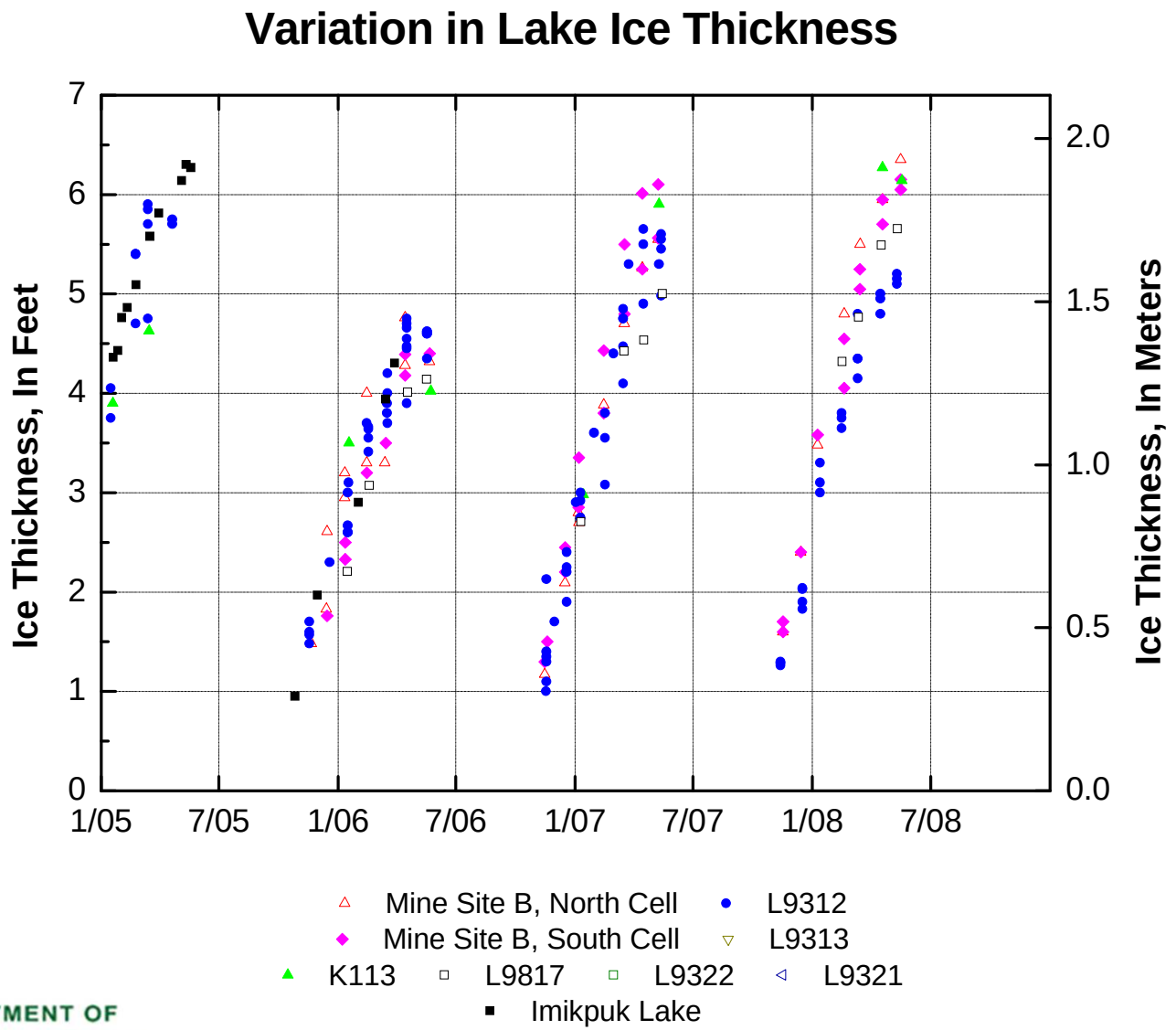

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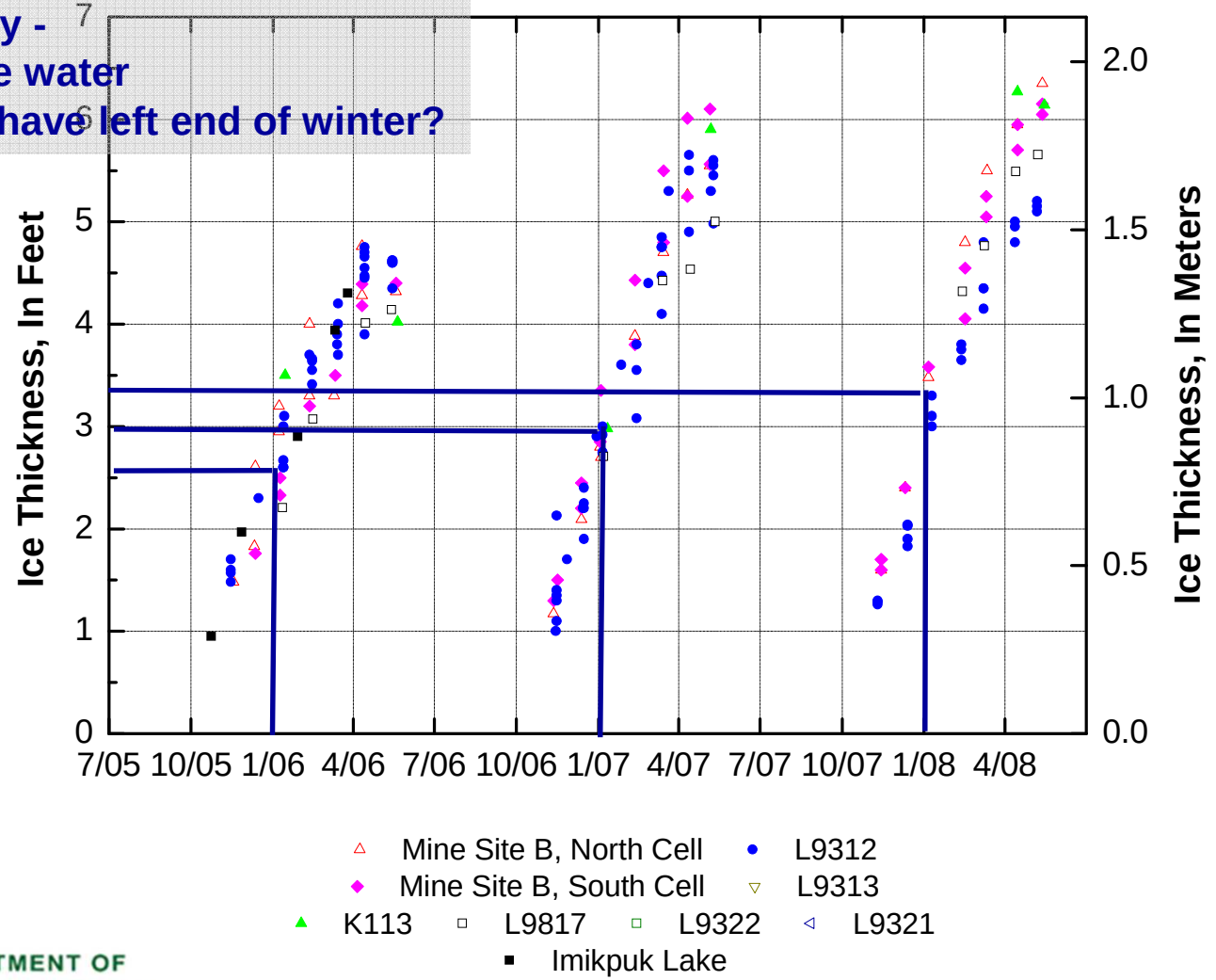
Water Use Management ?

It is January -
I need more water
What will I have left end of winter?



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ATN Field Areas

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Ice growth is a function of temperature and…

Snow density

Snow distribution

Snow cover

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Stefan Equation for Ice Thickness

$$dh/dt = \frac{1}{\rho L} \frac{T_m - T_a}{h/k_i + h_s/k_s + 1/H_a}$$

Where: ***h*** denotes ice thickness

t denotes time

Ta denotes air temp

Tm denotes ice/ water interface temp

Ki denotes thermal conductivity of ice

Ks denotes thermal conductivity of snow

Ha denotes a heat transfer coeff.

P denotes snow density

L denotes latent heat of fusion of ice

Modified Stefan Equation

$$t_i = C\sqrt{AFDD}$$

Where t_i denotes the ice thickness in inches

C denotes a coefficient ranging from 0.5to 0.8, depending upon weather and snow conditions

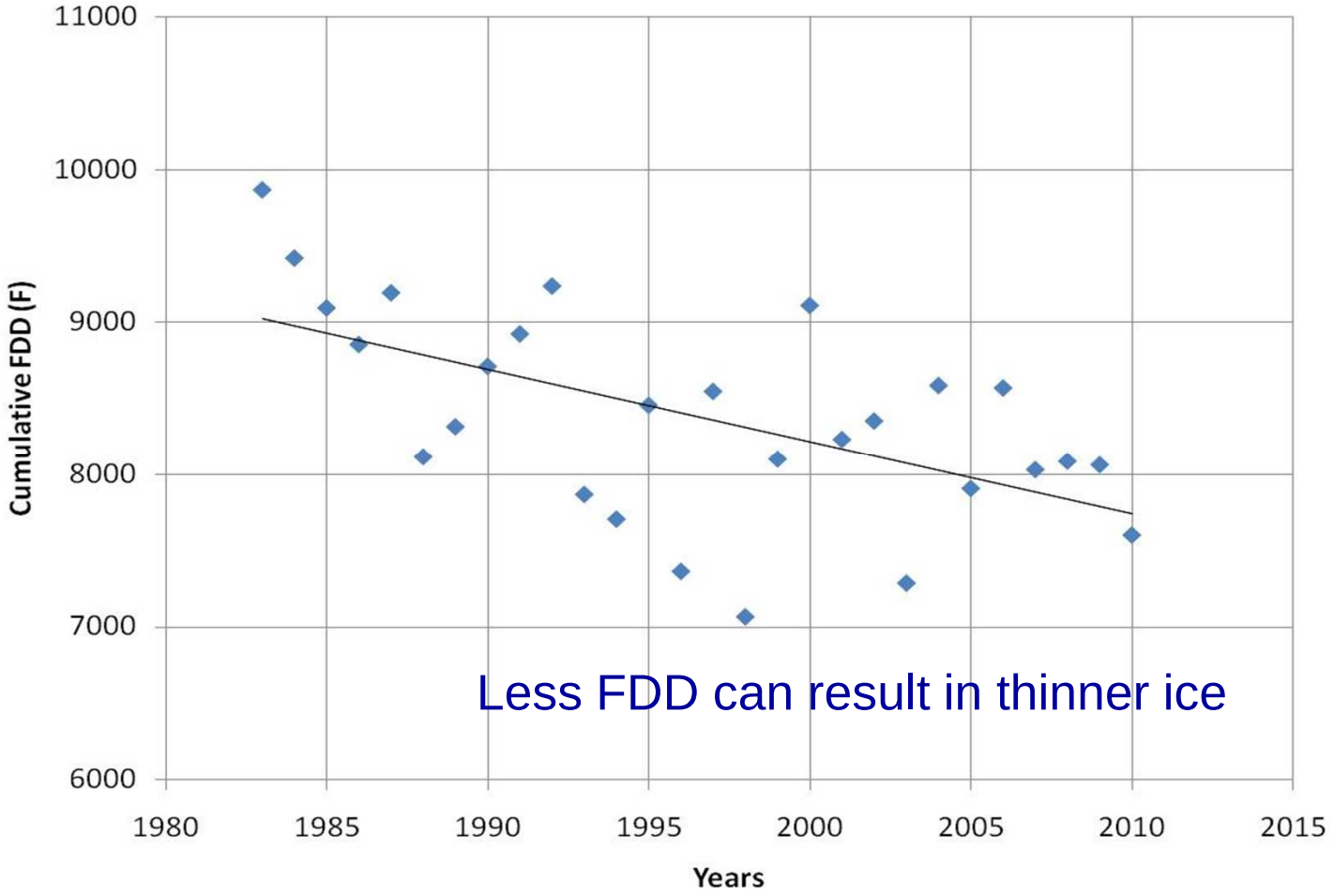
AFDD denotes the accumulated freezing degrees days in F.

Freezing degrees days, *FDD*, can be calculated as:

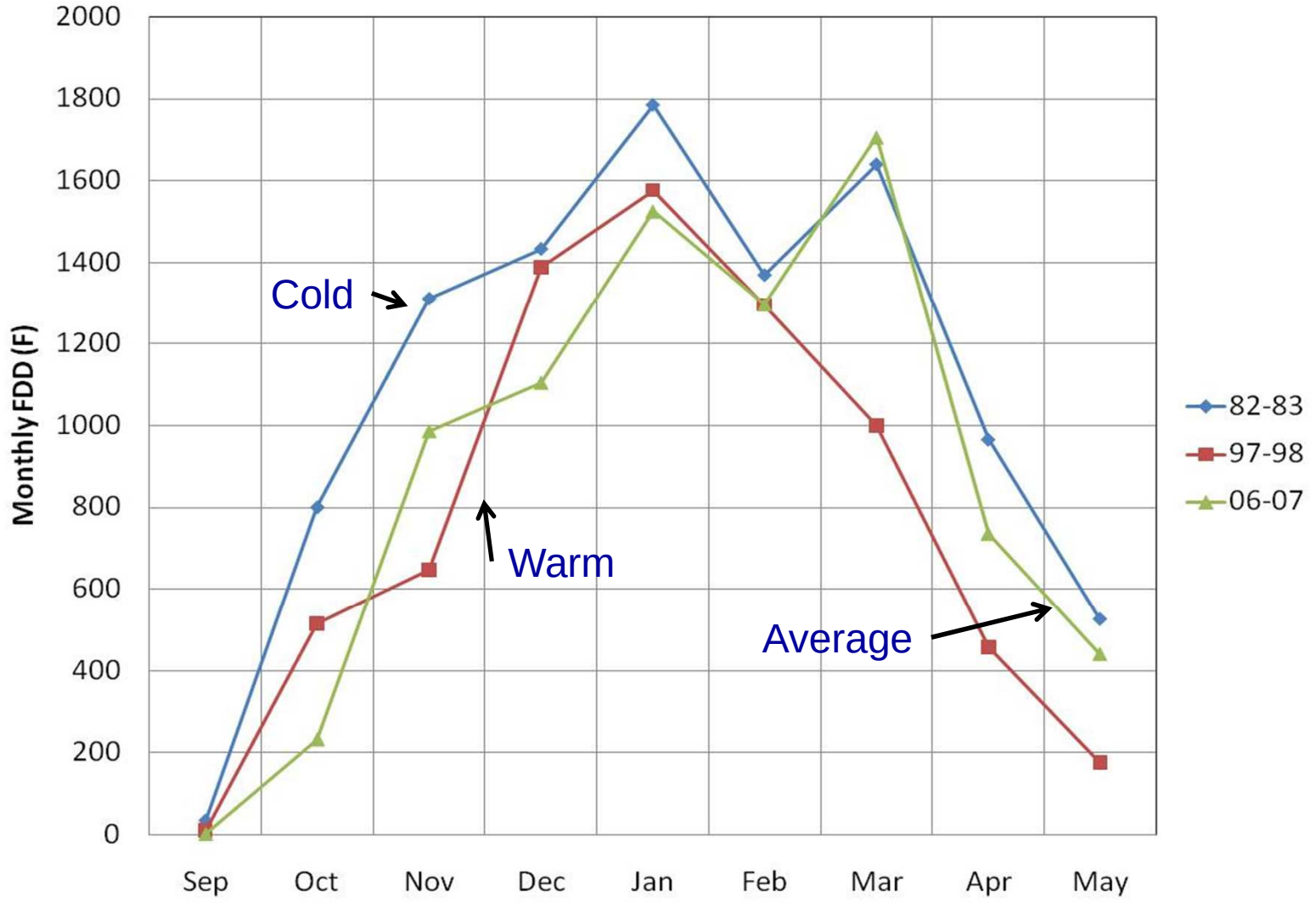
$$FDD = (32 - T_a)$$

Where T_a is the average daily air temperature in degrees Fahrenheit.

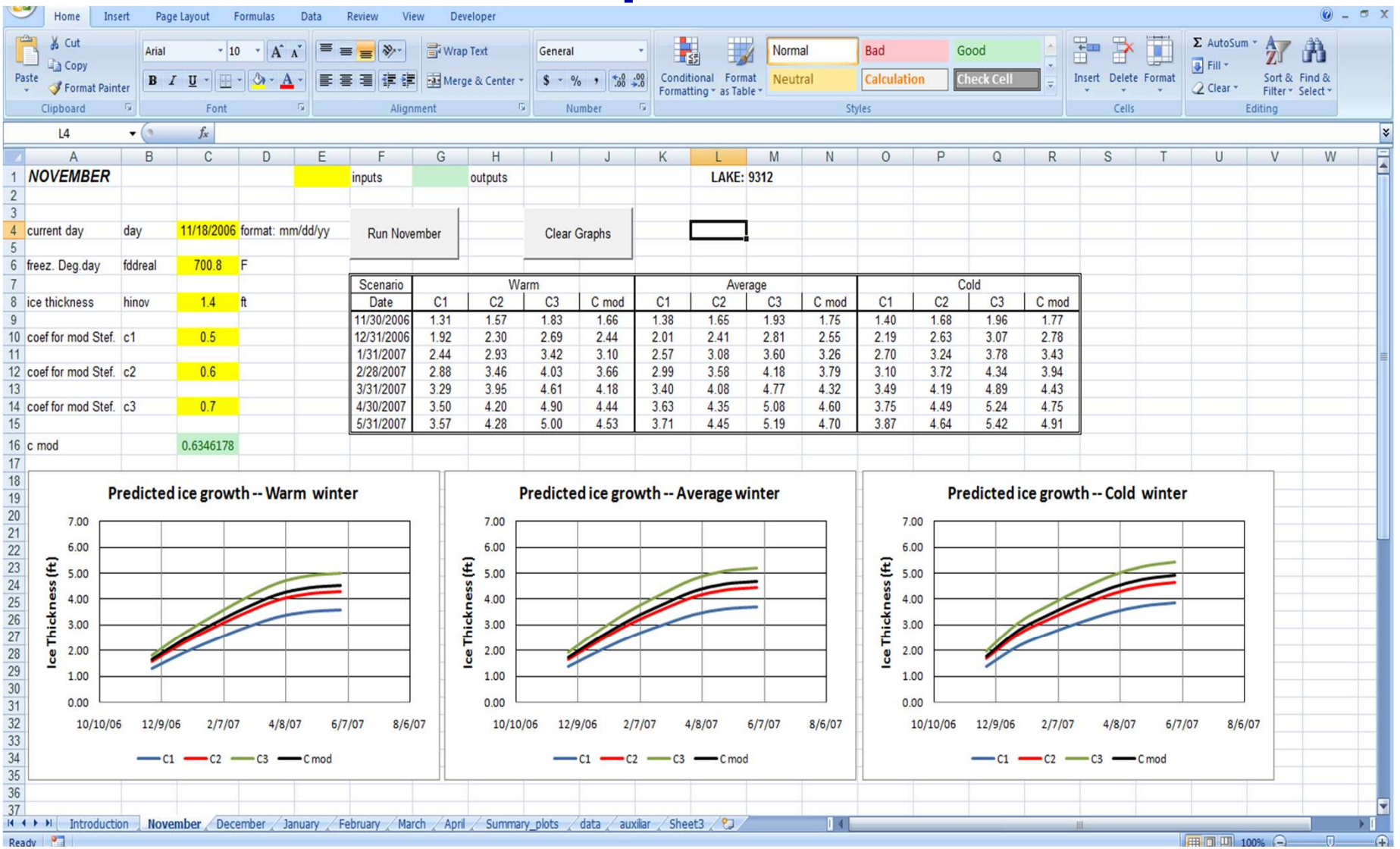
NOAA Deadhorse Station
Winter Air Temperature 1982 – 2010



Scenarios: Cold, Average and Warm Winters



Ice Growth Tool – Simple Excel file + Visual Basic



NOVEMBER

inputs | outputs | LAKE: 9312

current day	day	11/18/2006	format: mm/dd/yy
freez. Deg.day	fddreal	700.8	F
ice thickness	hinov	1.4	ft
coef for mod Stef.	c1	0.5	
coef for mod Stef.	c2	0.6	
coef for mod Stef.	c3	0.7	
c mod		0.6346178	

Run November | Clear Graphs

Scenario	Warm				Average				Cold			
Date	C1	C2	C3	C mod	C1	C2	C3	C mod	C1	C2	C3	C mod
11/30/2006	1.31	1.57	1.83	1.66	1.38	1.65	1.93	1.75	1.40	1.68	1.96	1.77
12/31/2006	1.92	2.30	2.69	2.44	2.01	2.41	2.81	2.55	2.19	2.63	3.07	2.78
1/31/2007	2.44	2.93	3.42	3.10	2.57	3.08	3.60	3.26	2.70	3.24	3.78	3.43
2/28/2007	2.88	3.46	4.03	3.66	2.99	3.58	4.18	3.79	3.10	3.72	4.34	3.94
3/31/2007	3.29	3.95	4.61	4.18	3.40	4.08	4.77	4.32	3.49	4.19	4.89	4.43
4/30/2007	3.50	4.20	4.90	4.44	3.63	4.35	5.08	4.60	3.75	4.49	5.24	4.75
5/31/2007	3.57	4.28	5.00	4.53	3.71	4.45	5.19	4.70	3.87	4.64	5.42	4.91

Introduction | November | December | January | February | March | April | Summary_plots | data | auxiliar | Sheet3

Ready

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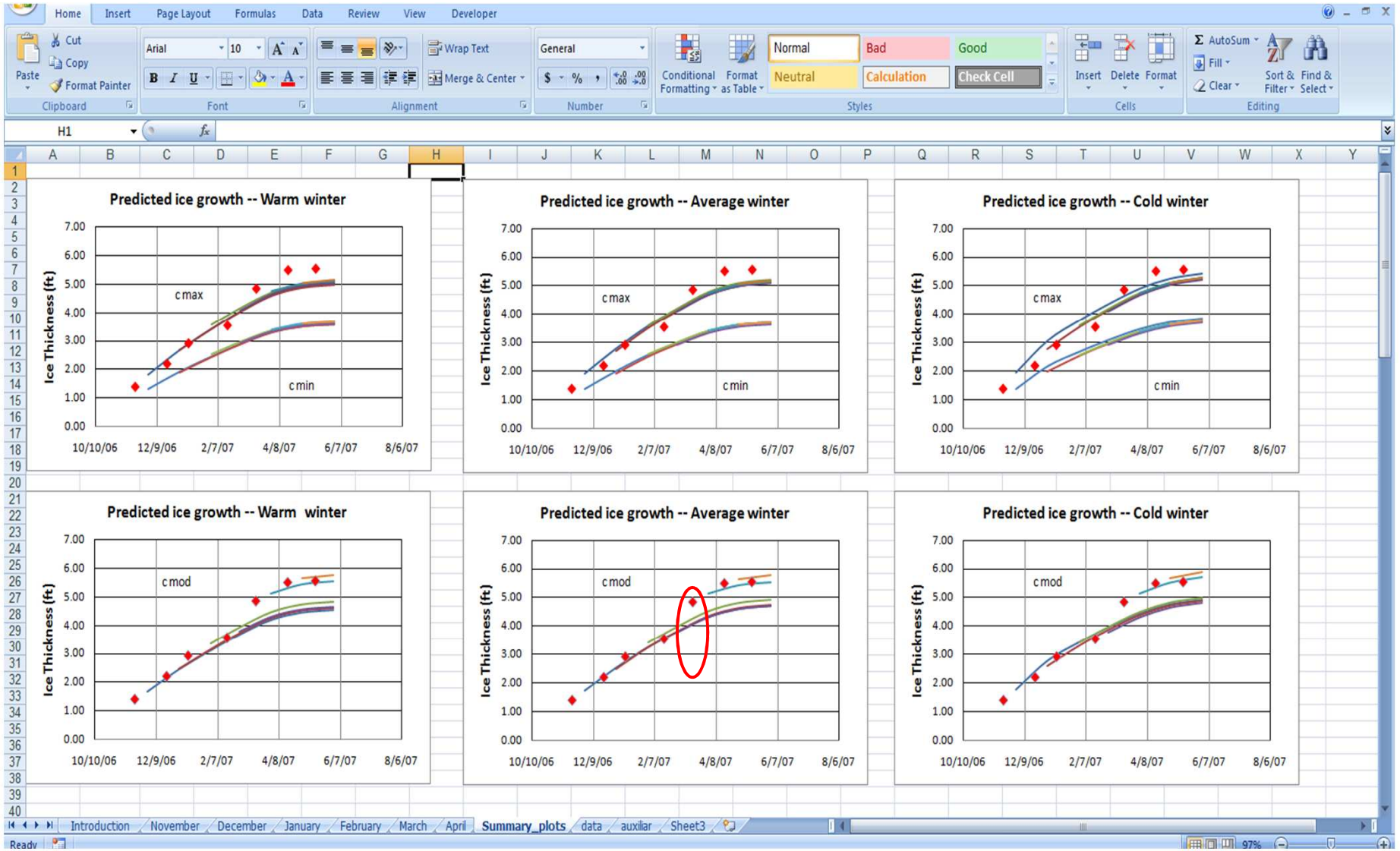
Ice Growth Tool – Summary Plots



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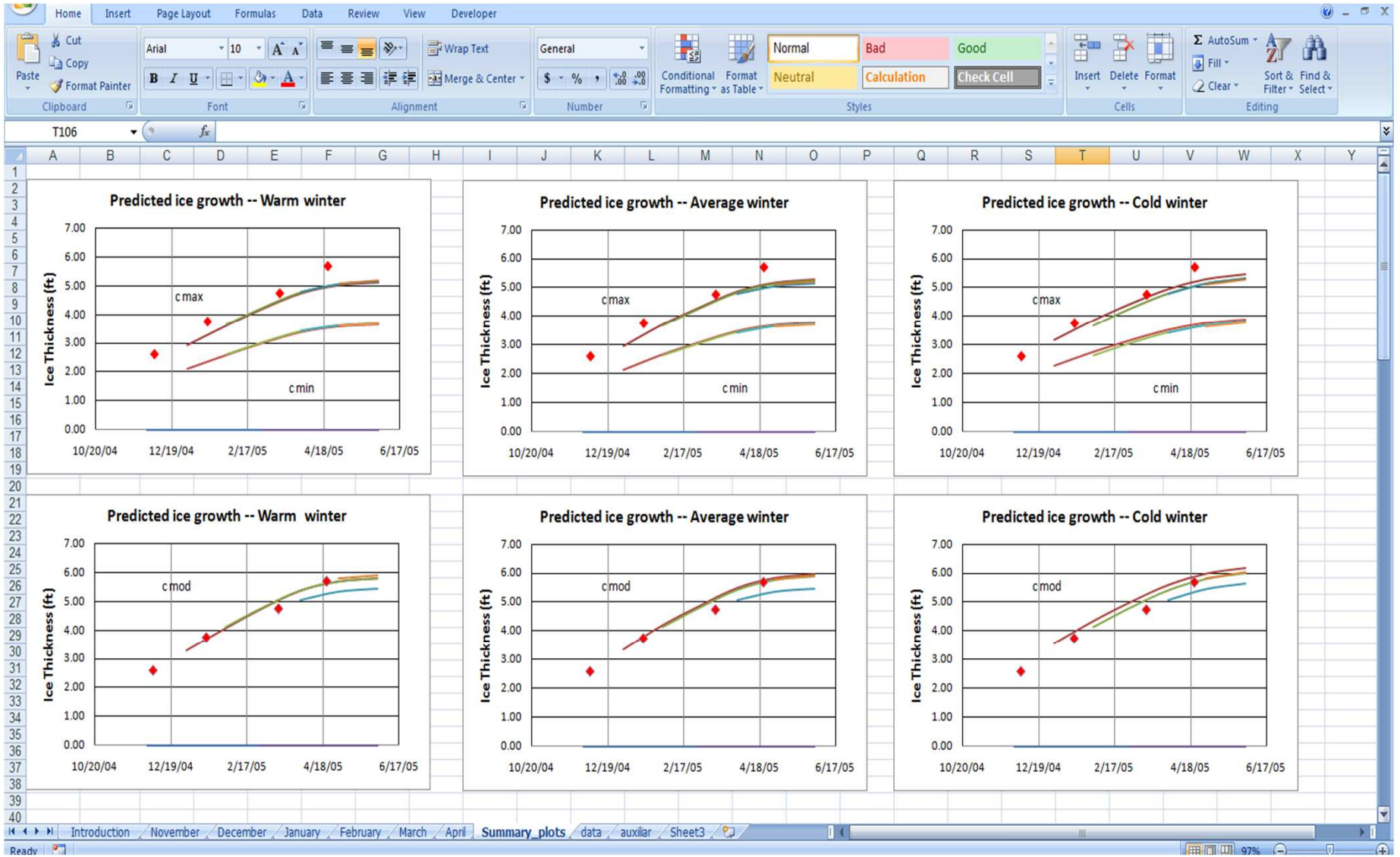
Ice Growth Tool – Other Examples



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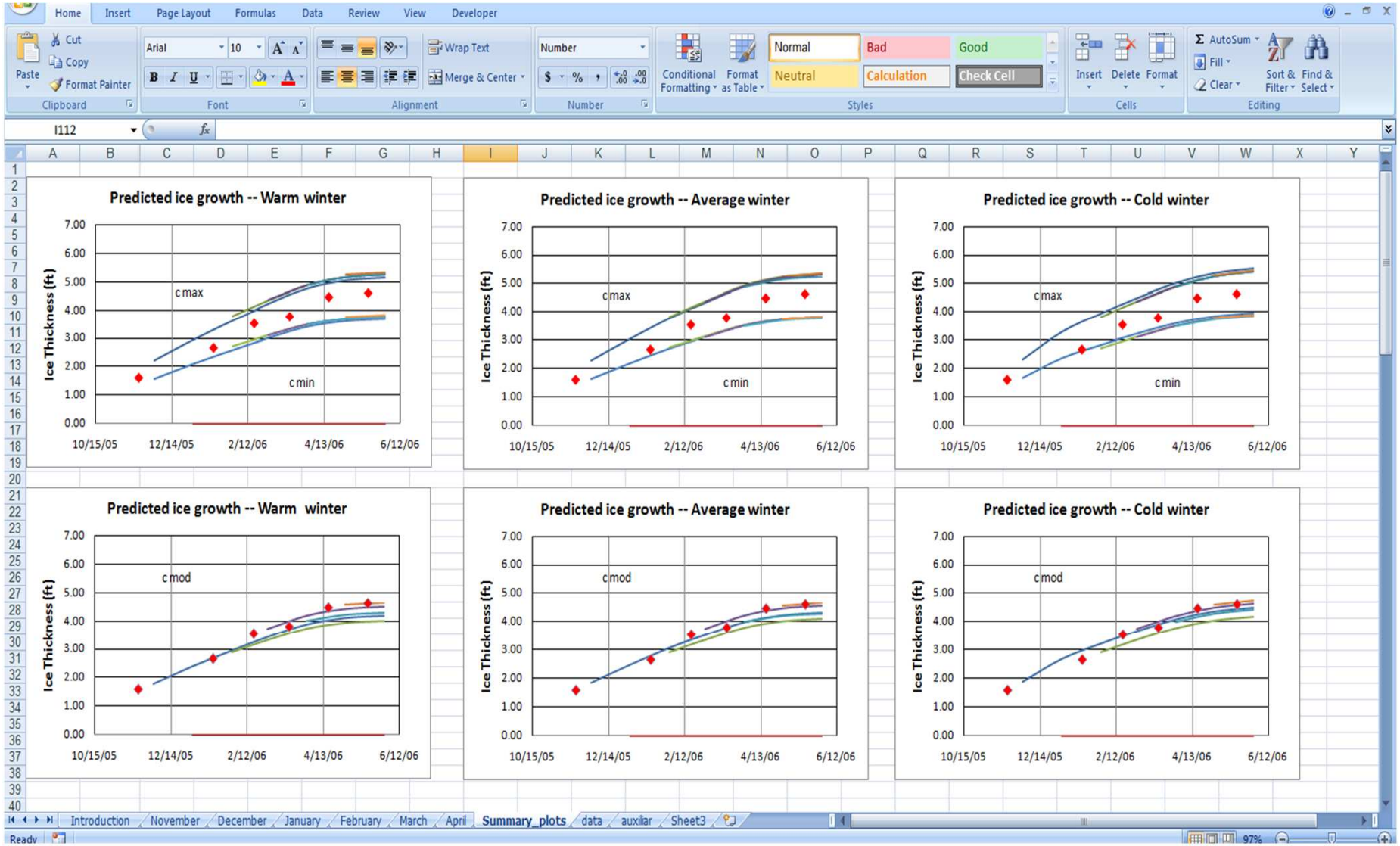
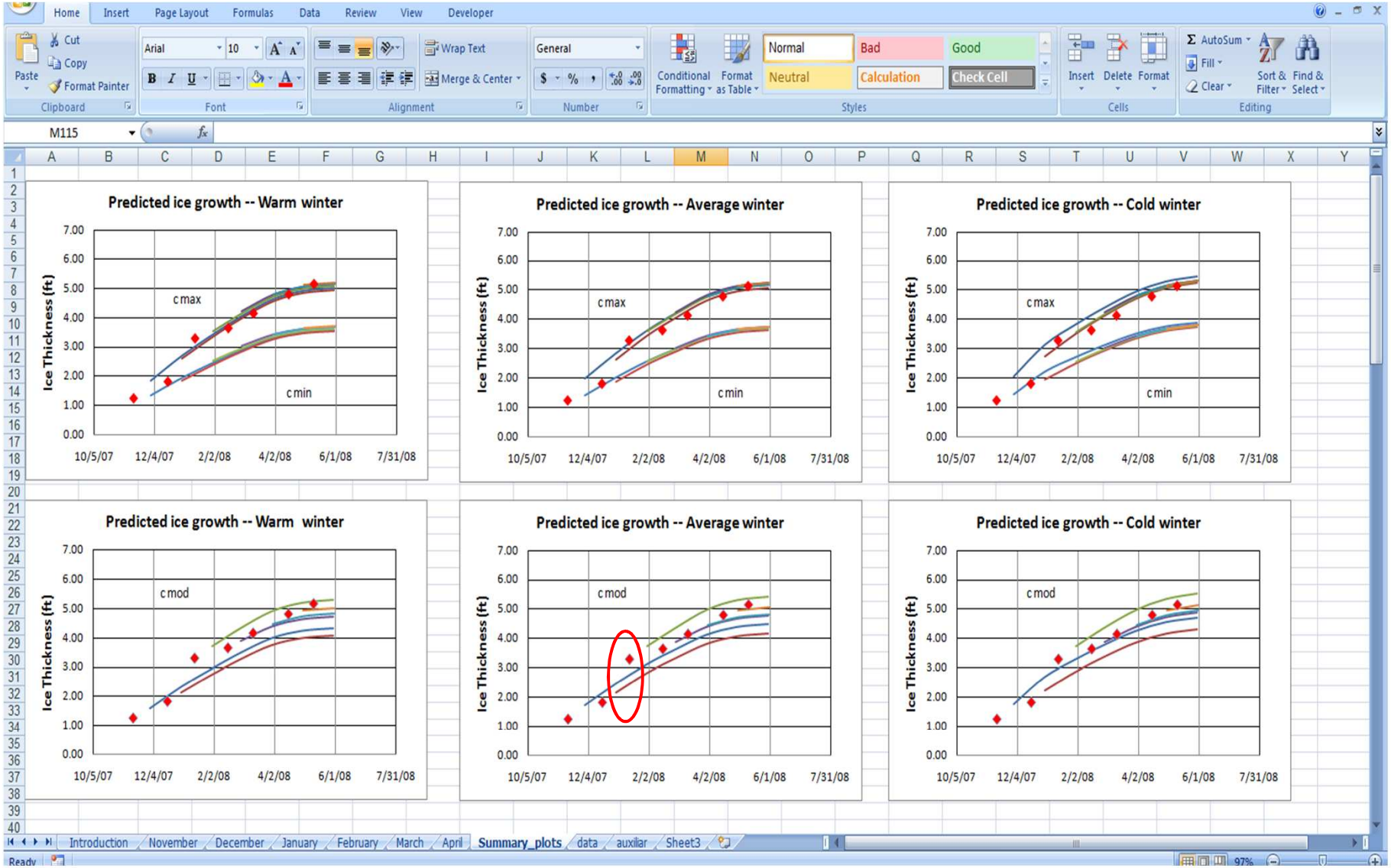
Ice Growth Tool – Other Examples



Ice Growth Tool – Other Examples



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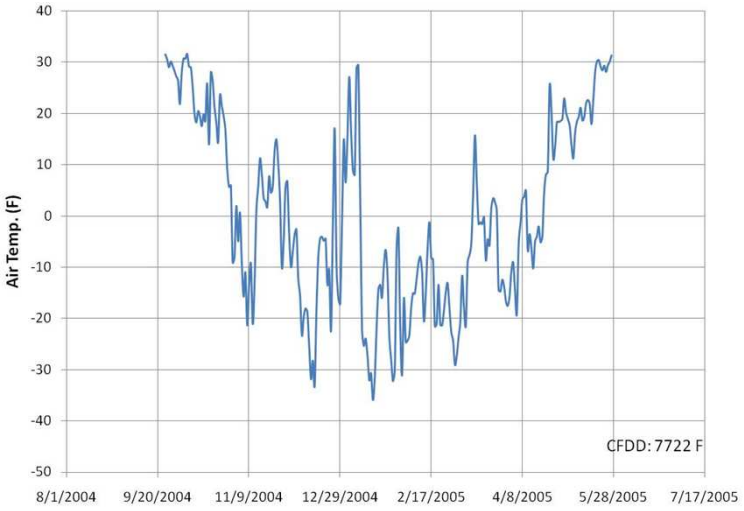
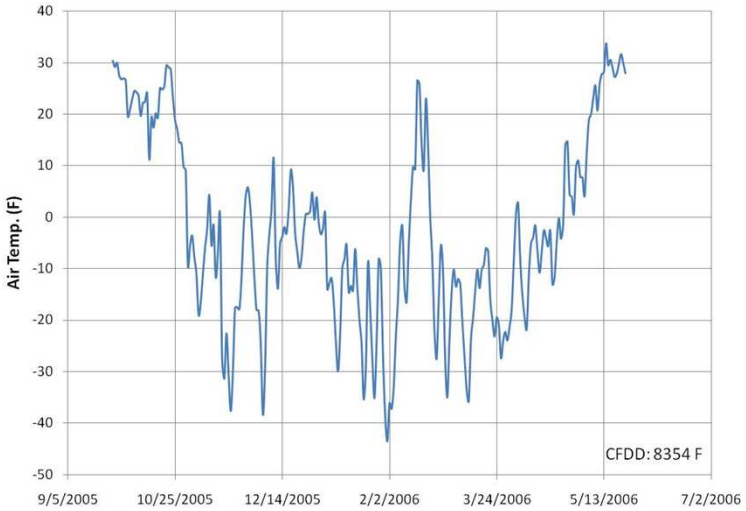
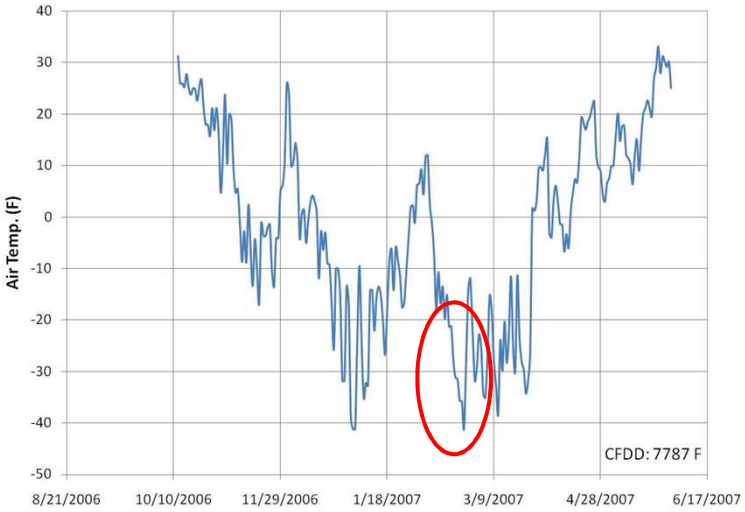
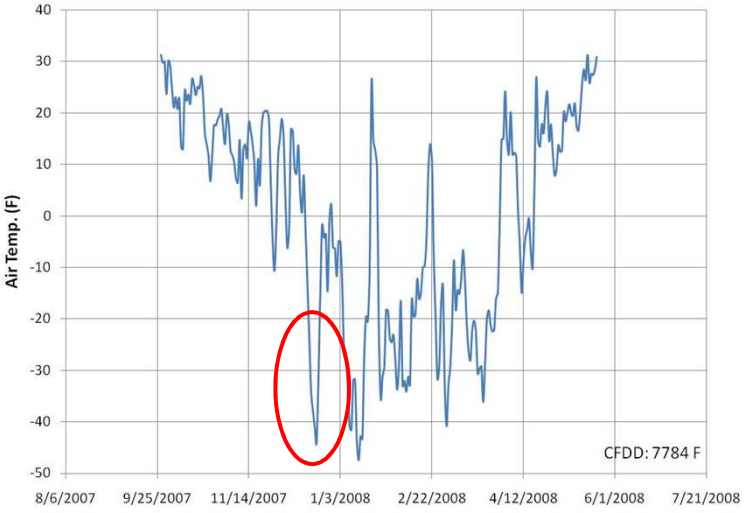
NOAA Alpine -- Air Temperature









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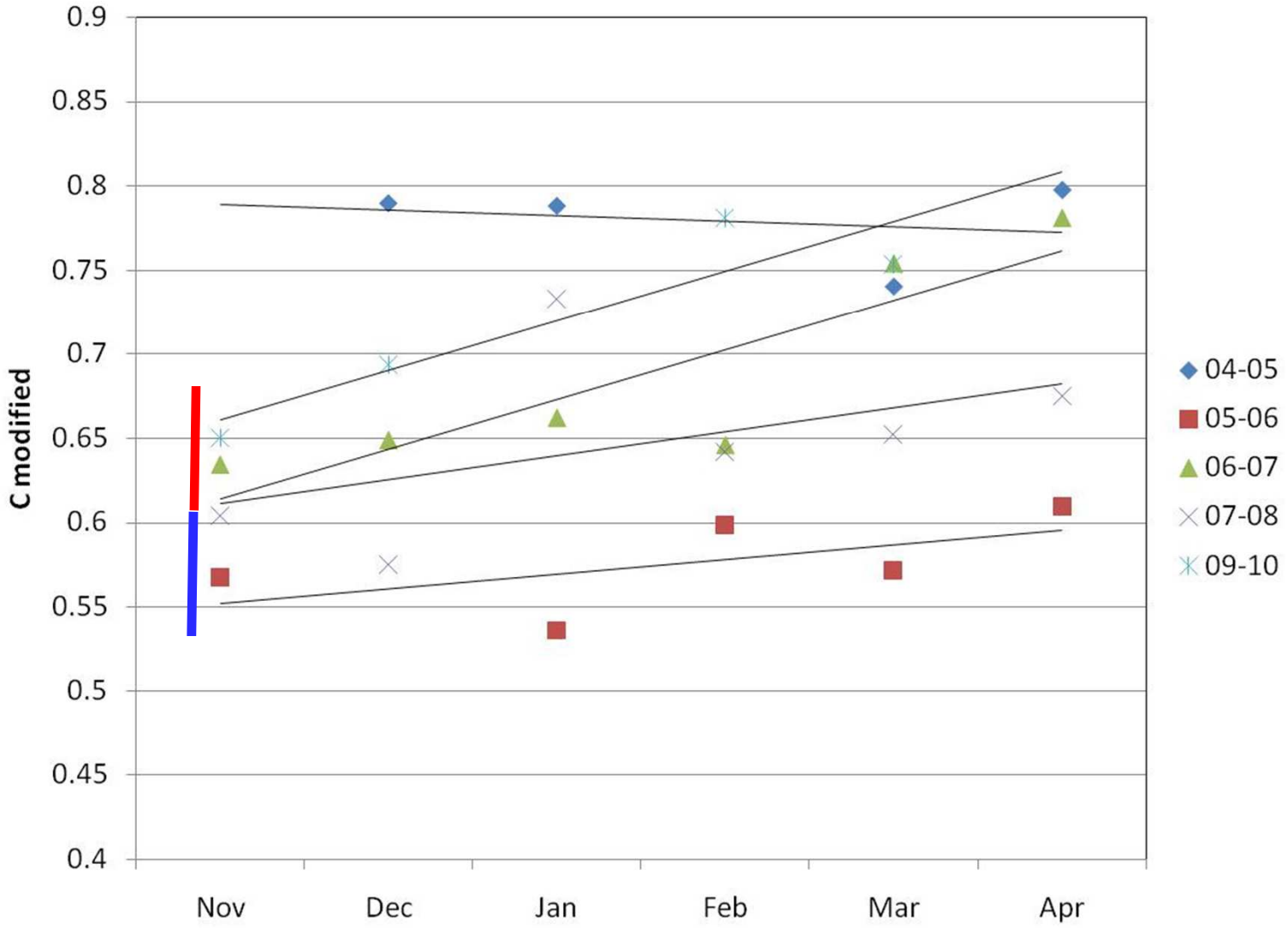
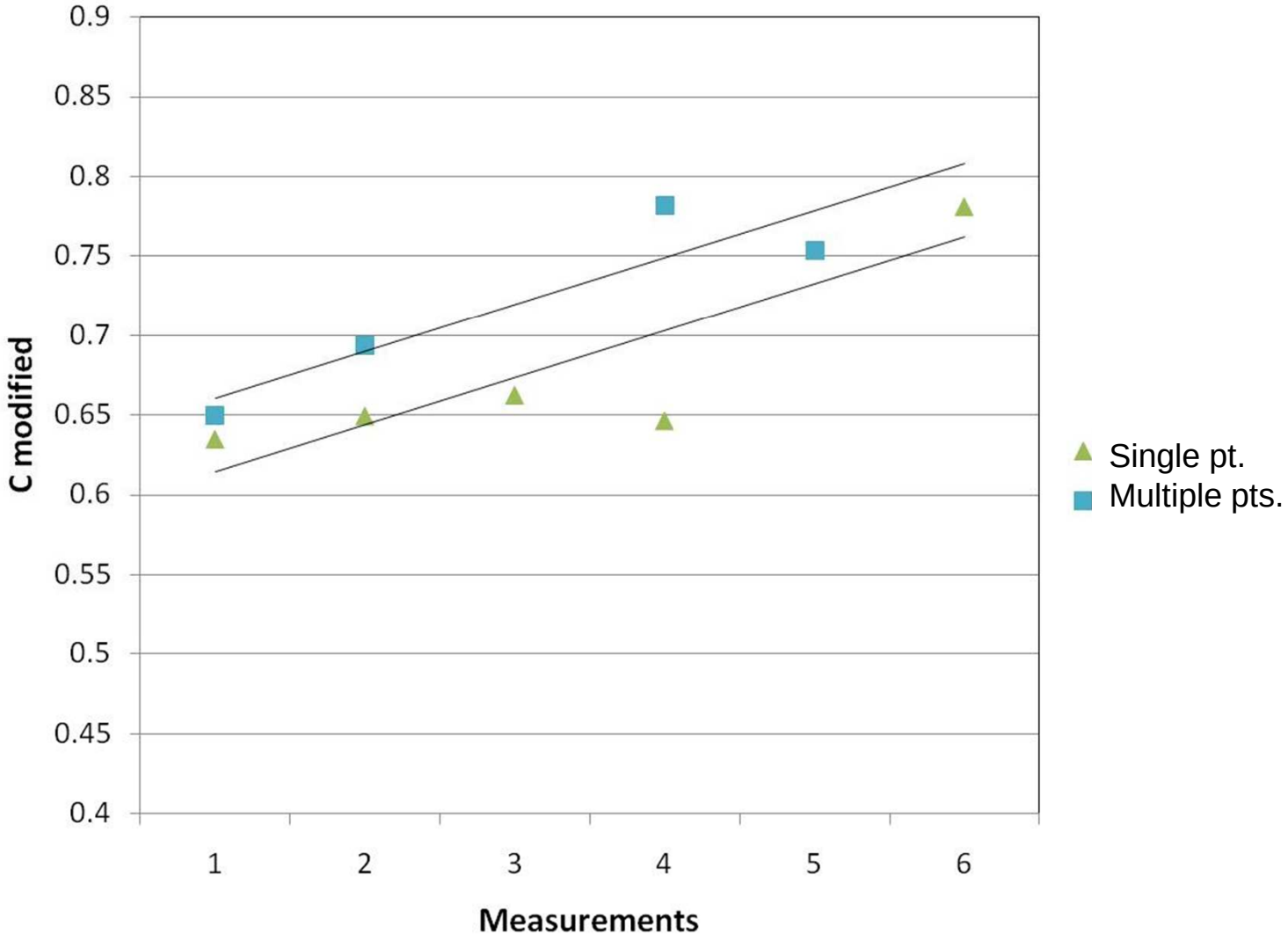
Results: Nearly Parallel Lines



Measurements: Single Point vs. Multiple Points

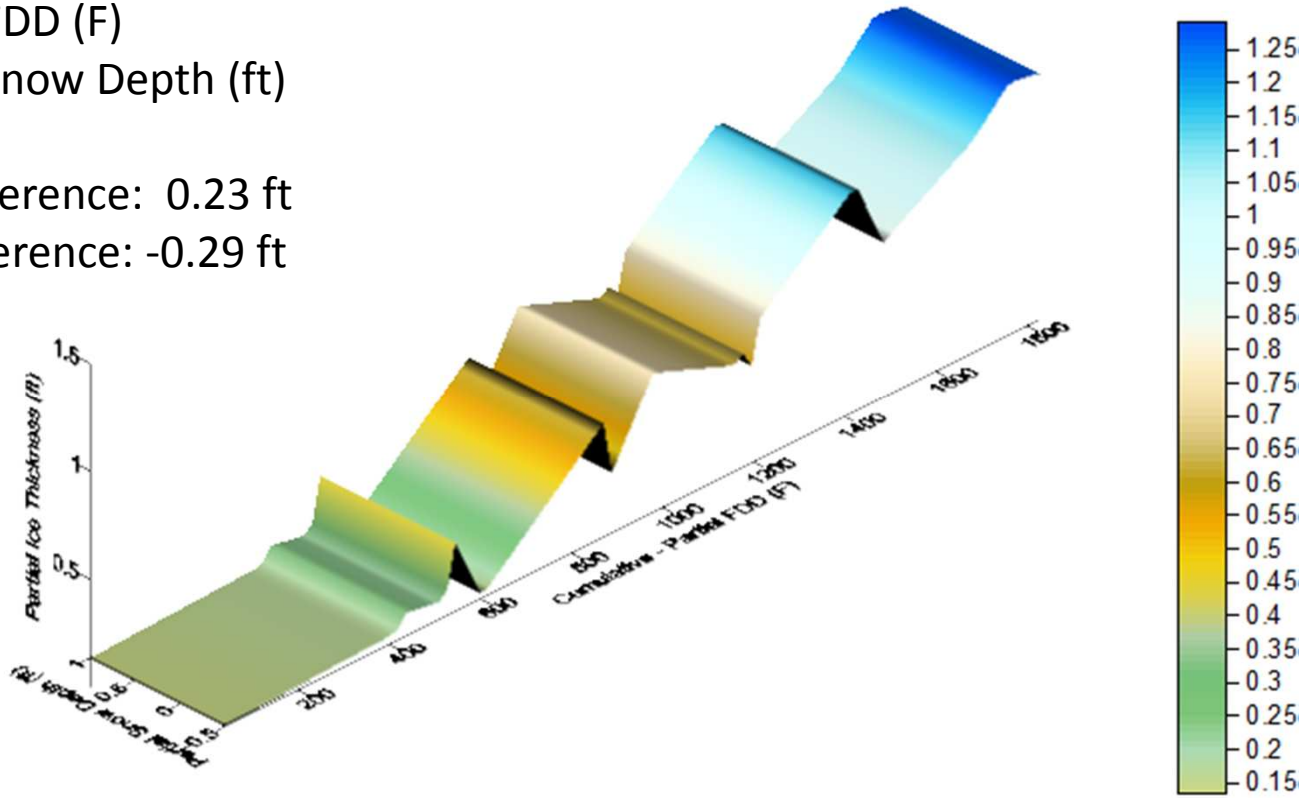


Incorporate Snow Depth – Statistical Analysis

Planar Regression: Z = AX+BY+C

Z = Partial Ice Thickness (ft)
X = Partial FDD (F)
Y = Partial Snow Depth (ft)

Max (+) difference: 0.23 ft
Max (-) difference: -0.29 ft



Ice Cover from Lake Cameras

Lake	Year	First ice on picture	Continuous ice	CFDD (F)
L9312	2008	1-Oct	3-Oct	28
	2009	22-Sep	25-Sep	17
L9817	2008	28-Sep	4-Oct	33
	2009	29-Sep	1-Oct	42

Summary

- **Modified Stefan equation:**
  - Change in coeff. “C”
    - From year to year
    - From month to month
  - Nearly parallel trends

- **Multiple vs. single measurements:**
  - Trends in “C” values are parallel

- **Statistical Analysis:**
  - Accounts for temp and snow
    - Small differences (0.3 ft)

Future Efforts

- ✓ Analysis of Foothills Lakes
- ✓ Improve User Interface for Excel Tool
- ✓ Validation of Tool with 2010/2011 and 2011/2012 Data
- ✓ Lake Ice and Snow Measurement Methods
- ✓ Adaptive Management Example Test Cases


Thank You
Questions?
http://www.arctic-transportation.org