

Statistical Decision Model for Snow Making at a Ski Resort in the Southwest US in a Changing Climate

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Anisotropic Banana

Master of Arts Program in
Climate and Society

Background

- Skier / Snowboarder demand depends largely on snow conditions for the day and season
- Ski Industry since since 1980s:
 - Small increase in number of ski trips in US
 - Drop in total number of ski areas
- Recent decline in overall snowpack levels
- As a result, many resorts are using snowmaking to improve snow conditions

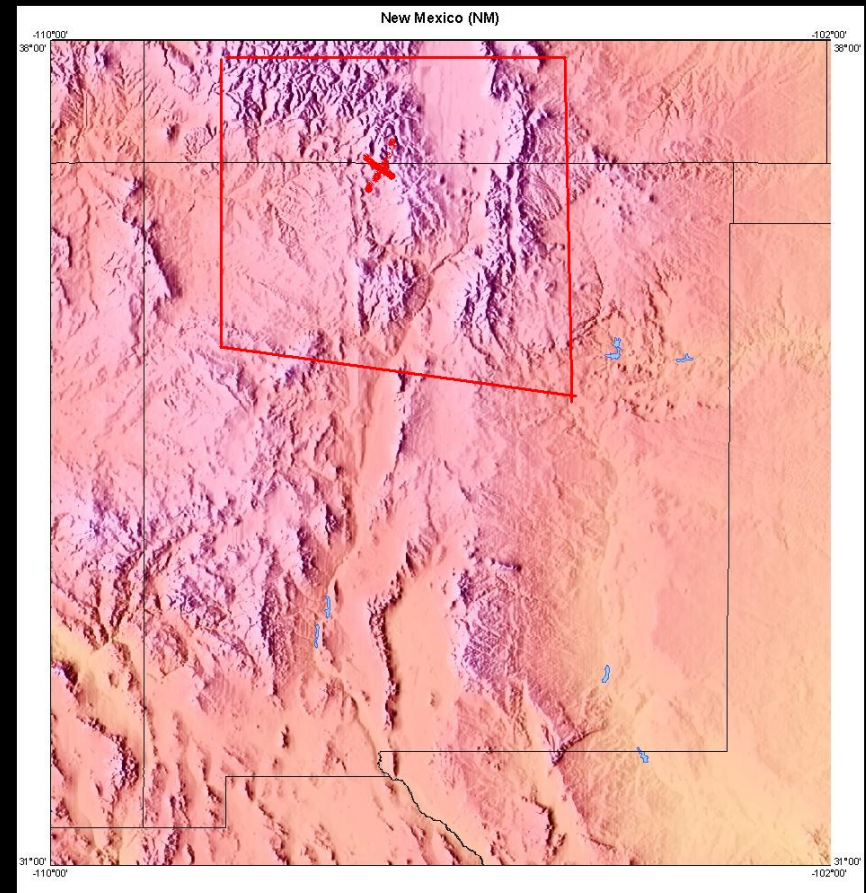
Englin and Moeltner, 2004: The Value of Snowfall to Skiers and Boarders, *Environmental & Resource Economics* **29**, 123-136.

Bunting, Wagner, Jones, 2005: The Economic Impact of Ski Areas Represented by the Inland Northwest Ski Association, *Inst. For Public Policy and Economic Analysis*.

Bark-Hodgins and Colby: Climate Variability and Change: The Economic Vulnerability of the Skiing Industry and Surrounding Communities in Arizona USA, Draft Report.

Goals and Objectives

- “Create” a new average size ski-resort in the Southwest region.
- Analyze yearly snow pack trends, and project them into the future.
- Make Decision Model to determine whether to invest in snow-making equipment, and when to operate snow machine given different yearly scenarios.

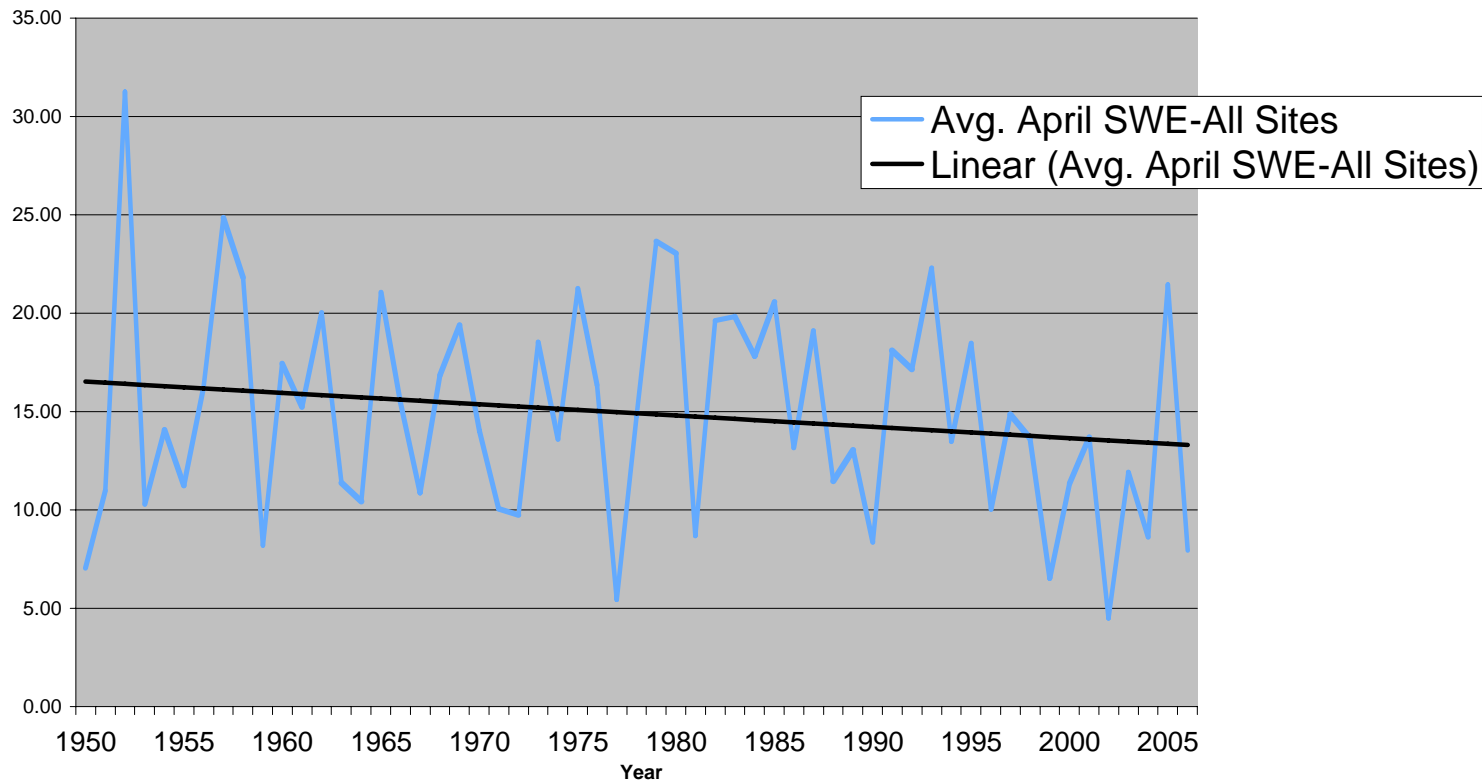


Climate Data

- Requirements
 - Measure of yearly snowfall for location
 - 1st of April Snow water equivalent (inches)
 - USDA NRCS Snotel Data
 - Average Winter Temperature over region
 - Chose Spatially averaged NDJFM Temp
 - NOAA NCEP-NCAR CDAS-1 MONTHLY Gridded Temperature
 - ENSO Index
 - <http://www.cdc.noaa.gov/people/klaus.wolter/MEI/table.html>
 - PDO Index
 - <http://jisao.washington.edu/pdo/PDO.latest>

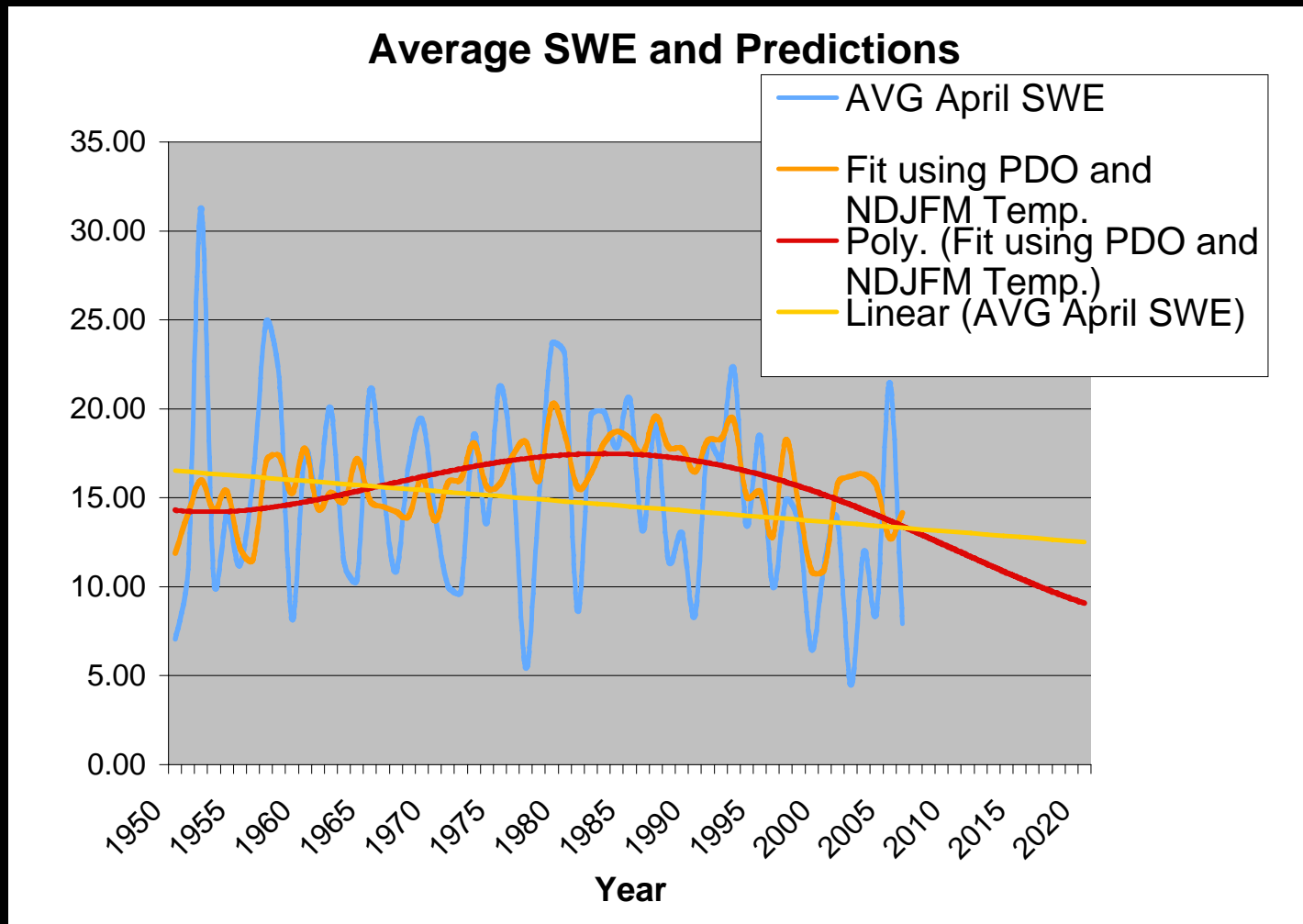
Regional SWE 1950-2006

Average 1st of April Snow Water Equivalent



- T-test: Avg. SWE (50-89) statistically different from SWE (90-06), at 5% significance level.

Regression Results



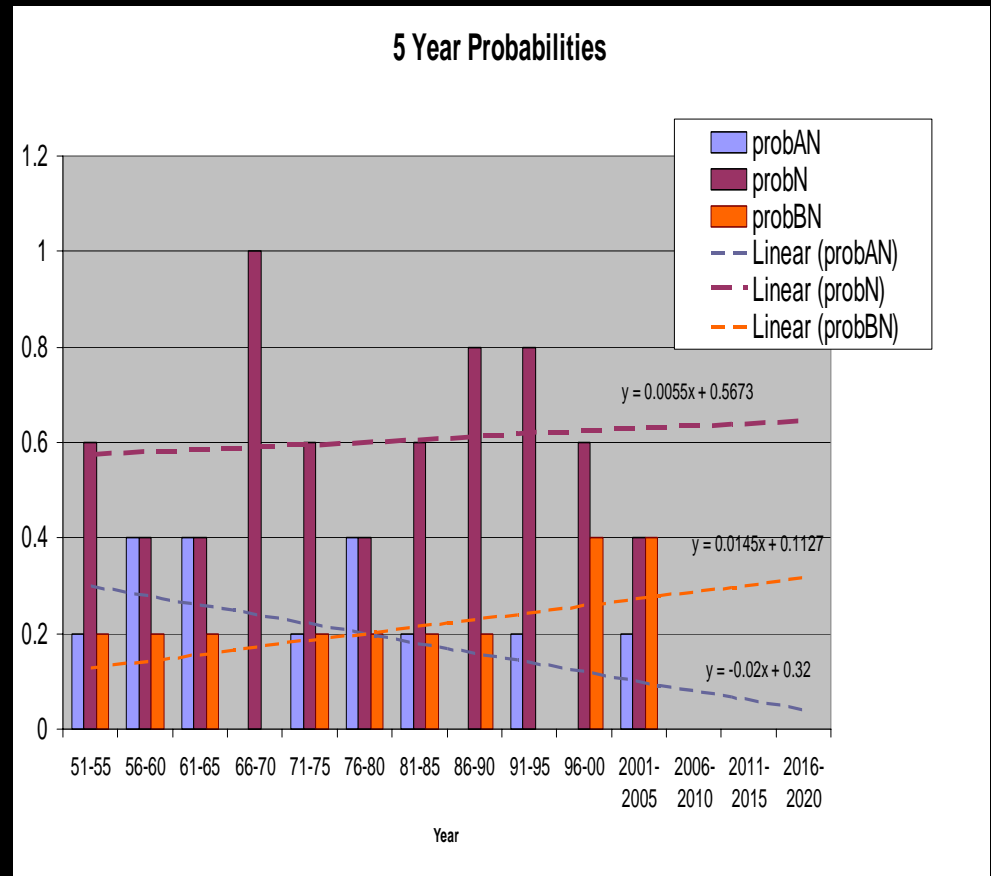
- **ENSO not good predictor!**
- **Best Regression using Oct. PDO and NDJFM AVGTemp as Predictors**
 - **$R = 0.395$, $R^2 = 0.156$. Better than 5% significance level.**

Probabilities and Trends

- Define Above Normal, Normal, and Below Normal **Ski Season.**
 - For 1950-1980 (baseline) AN occurs ~25%, BN~25%, and N ~50%
 - For Avg SWE (50-80) of 15 in., Define seasons:
 - AN: ≥ 20 inch w/ Prob. of 26%
 - N: 10.5-20 inch w/ Prob. of 51%
 - BN: 0-10.5 inch w/ Prob. of 23%
 - How do probabilities shift into future?

Future Probabilities

- Found 5 yr avg. probability for AN, N, BN SWE from 1950-2006
- Fit each category w/ linear trendline.
- Extrapolated probabilities from trendlines out to 2025



Predicted Future

- 2006-2010
 - AN~8%, N~63%, BN~29%
- 2011-2015
 - AN~6%, N~64%, BN~30%
- 2016-2020:
 - AN~4%, N~64%, BN~32%
- 2021-2025:
 - AN~2%, N~65%, BN~33%



Retro Ken: “Uh oh, look at that trend!”

Economic Data and Sources

- Ski Area Info
 - Acquired based on average regional ski area characteristics
 - Area: 500 Acres
 - Maximum Capacity: 5000 people per day
- Ski Area Economics
 - Operating Costs: ~ \$4 million per season
 - Snowmaking Capital Costs: ~\$10,000 per acre
 - Snowmaking Operations: ~\$1,000 per acre-foot
 - Revenue: ~\$45 per person per day

Sources:

Articles cited on slide 2

A Snowmaking Proposal for Pajarito Mountain Ski Area, April 2006.

The Art of Making Snow, *Snowmass Village Sun*,

<http://www.snowmassvillagesun.com/home.php?content=article&article=1453>

Reading et al: Impacts of Climate Change on the Economic Viability of Selected PNW Ski Areas,

<http://www.cses.washington.edu/cig/res/sd/cciskiareas.shtml>

Assumptions for Modeling Economics

- This Ski Area has similar costs to other areas in the region
 - NM and Arizona studies were primarily used
- The number of skiers can be interpolated based on:
 - The snowfall category for the year
 - The average number of visitors per day, and days per year, for a given snowfall category
 - The amount of snowmaking up to the next category and the percent of the mountain covered

Below Normal

SWE:	7.5
Days Open:	66
Nominal % cap:	0.2

Normal

SWE:	14.5
Days Open:	120
Nominal % cap:	0.3

Above Normal

SWE:	22.8
Days Open:	135
Nominal % cap:	0.4

Above Normal +

SWE:	25
Days Open:	135
Nominal % cap:	0.45

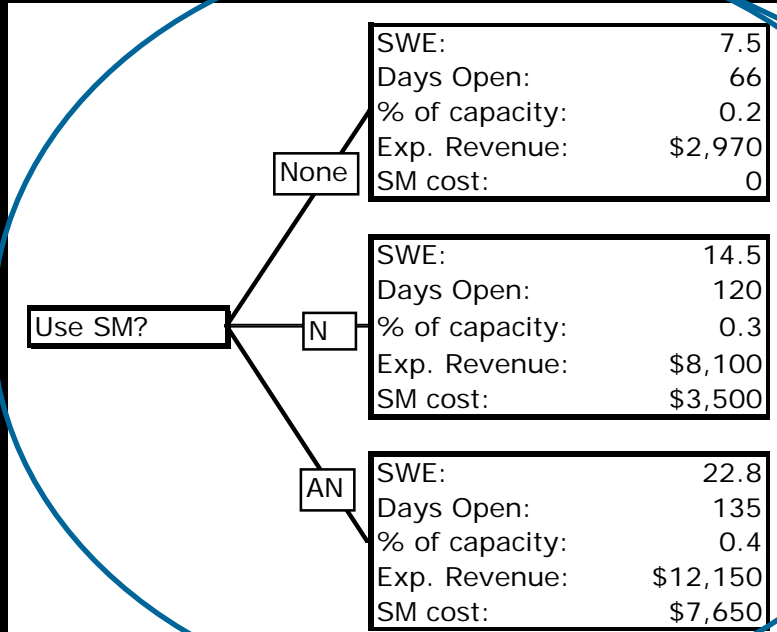
Decision System

- All values can be changed to simulate different ski area characteristics
- Current probability density functions or future projections can be input
- Decisions:
 - Buy Snow Making Equipment or not?
 - Use Snow Making for a given year or not, and if so, how much?
- Output (EMV):
 - Yearly Average Revenue
 - no consideration of capital snow making equipment costs
 - 5 Year Average Profit
 - simple consideration of capital snow making equipment costs
 - Lifetime Profit for the Snow Machine
 - All outputs are considered against decision not to buy Snow Machine

Decision System

Below Normal Probability: 0.33
 Normal Probability: 0.65
 Above Normal Probability: 0.02

Ski Area Info:
 Area (acres) 500
 Max capacity: 5000
 % SM: 100
 Op. Cost: 4000
 SM life (yrs): 20
 SM cap Cost: 5000
 Rev/person: 0.045

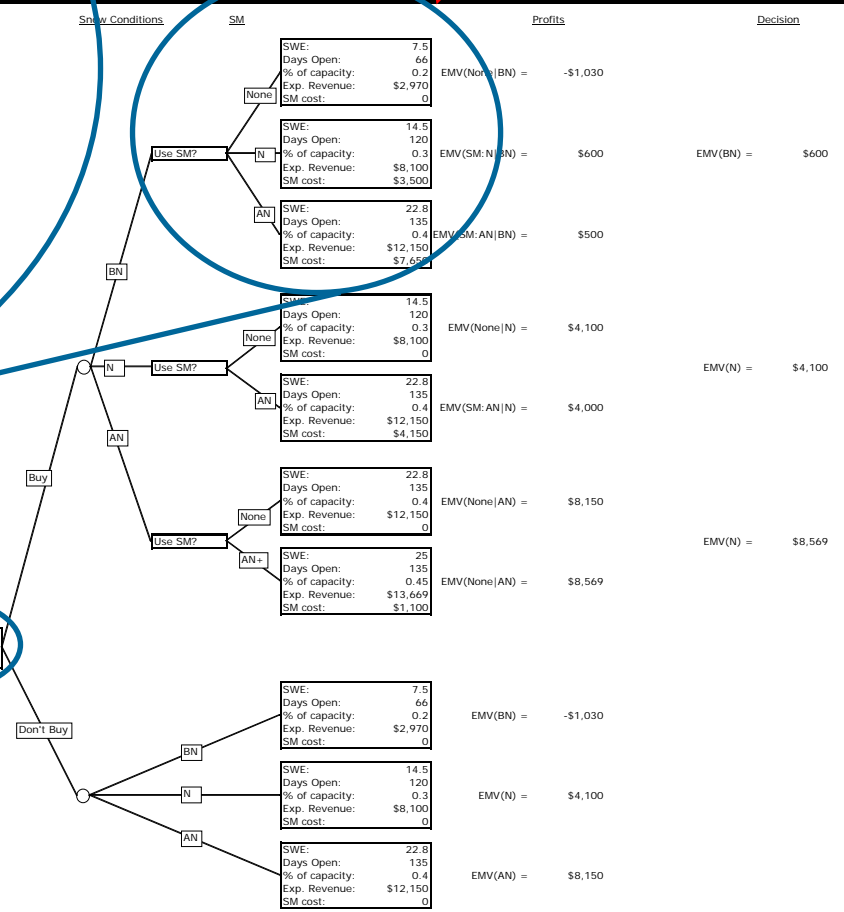


Buy SM or Not?
 Cost \$8,125
 Lifetime (yrs) 20

Buy SM or Not?
 Cost \$8,125
 Lifetime (yrs) 20

Yearly Average:
 5 year Avg:
 SM lifetime:

EMV(Buy):	EMV(Don't Buy)
\$3,034	\$2,488
\$13,922	\$12,441
\$55,688	\$49,762



Outcome of Decision System

1950 - 1980

Below Normal Probability:	0.13
Normal Probability:	0.61
Above Normal Probability:	0.26

Yearly Avg:
5 year Avg:
SM lifetime:

EMV(Buy):	EMV(Don't Buy):
\$4,807	\$4,486
\$22,784	\$22,431
\$91,138	\$89,722

1980 - Present

Below Normal Probability:	0.27
Normal Probability:	0.61
Above Normal Probability:	0.12

Yearly Avg:
5 year Avg:
SM lifetime:

EMV(Buy):	EMV(Don't Buy):
\$3,691	\$3,201
\$17,206	\$16,005
\$68,825	\$64,018

2006 - 2010

Below Normal Probability:	0.29
Normal Probability:	0.63
Above Normal Probability:	0.08

Yearly Avg:
5 year Avg:
SM lifetime:

EMV(Buy):	EMV(Don't Buy):
\$3,443	\$2,936
\$15,963	\$14,682
\$63,850	\$58,726

Total for 20 year lifetime
EMV(Buy): **\$59,769** EMV(Don't Buy): **\$54,244**

2011 - 2015

Below Normal Probability:	0.3
Normal Probability:	0.64
Above Normal Probability:	0.06

Yearly Avg:
5 year Avg:
SM lifetime:

EMV(Buy):	EMV(Don't Buy):
\$3,318	\$2,804
\$15,341	\$14,020
\$61,363	\$56,080

Value of Installing Snow Making Equipment
\$5,525 over 20 years

2016 - 2020

Below Normal Probability:	0.32
Normal Probability:	0.64
Above Normal Probability:	0.04

Yearly Avg:
5 year Avg:
SM lifetime:

EMV(Buy):	EMV(Don't Buy):
\$3,159	\$2,620
\$14,544	\$13,102
\$58,175	\$52,408

2021 - 2025

Below Normal Probability:	0.33
Normal Probability:	0.65
Above Normal Probability:	0.02

Yearly Avg:
5 year Avg:
SM lifetime:

EMV(Buy):	EMV(Don't Buy):
\$3,034	\$2,488
\$13,922	\$12,441
\$55,688	\$49,762

Conclusions

- Analyzing SWE data from 1950 - 2006 indicates trend of decreasing yearly snowpack
- Determining actual economics of the area is difficult and data is limited
- Using the model, the aspects of the ski area and the relationship between number of skiers and profits can be easily modified.
- The outcome can be projected into the future

Using available data, we determine the decision to buy a snow making machine to be appropriate for a new ski resort in this area.

Questions?

