Problem Identification for **Alta Snowfall Analysis**

P

Context

Skiers love skiing in good snow conditions:

- **want fresh snow**
- **new snow covers more objects**
- **new snow softens up the surface they ski**
- **need to plan trips far in advance of forecasts**
- **skiers have heuristics to help them in this manner (Japanuary, March is Vail's snowiest month, Alta gets great snow all season)**
- **some ski areas do have snowfall patterns that could help plan a better vacation time for powder**
- **we examine the snowfall at Alta Ski Resort in Utah to look for snowfall patterns**

Specifics

- **Alta has operated since 1938**
- **NOAA snowfall data available from Nov 1944 onward from base area**
- **renown for its abundant and consistent snow**
- **We explore their data to see how consistent**

We turn to modeling for the solution….

P K M R S

Problem Statement for Alta Snowfall Analysis

P

How can we use daily snowfall data at Alta Ski Resorts to determine the best time to take a ski trip to either: A. maximize their chance for the most snowfall B. minimize their chance of having the worst conditions (no new snowfall).

Objectives

- Explore Snowfall at Alta to determine trends and variable effects
- Model snowfall at Alta based on available features
- Determine best times to ski Alta

Focus

- Time effect of seasonal snowfall
- Lag variables (temperatures and precipitation) that can be measured far enough to plan a trip
- Consider Pacific Decadal Oscillation and Atlantic Multi-Decadal Oscillation

Constraints

- snowfall and weather data available from Nov 1944 onward
- PDO and AMO only available monthly

Not considered:

- Short term variables (available close to measurement date)
- Southern Oscillation Index (El Nino / La Nina)
- Barometer readings
- Wind Data
- Sunshine measurements / cloud cover
- Salt Lake Levels / Temperature

P K M R S

Key Findings for Alta Snowfall Analysis

K

We found that snowfall at Alta was generally consistent throughout the ski season with our model performing only slight better than the dummy model of assuming the average. There is only a small advantage of planning a ski trip based on our model.

Model Accuracy

- Root Mean Squared Error for our model (avg for 3 years): 13.30in
- Root Mean Squared Error for dummy model: 13.90in
- Improvement: 0.60 in

Models used

- Final Model: Facebook's Prophet with Random Forest on Residuals
- Also tried:
  - Prophet with Regression
  - Prophet alone
  - Prophet with Regression and more variables

Possible Issues

- There is a lot of variability in the snowfall making it difficult to predict
- Snowfall is exponentially distributed, but we did not take the log before modeling
- Did not consider some lag variables that may improve our model
- Did include some short-term variables that could not be measured far enough from ski vacations
- Modeled on a 7-day snowfall sum; longer window may decrease variability

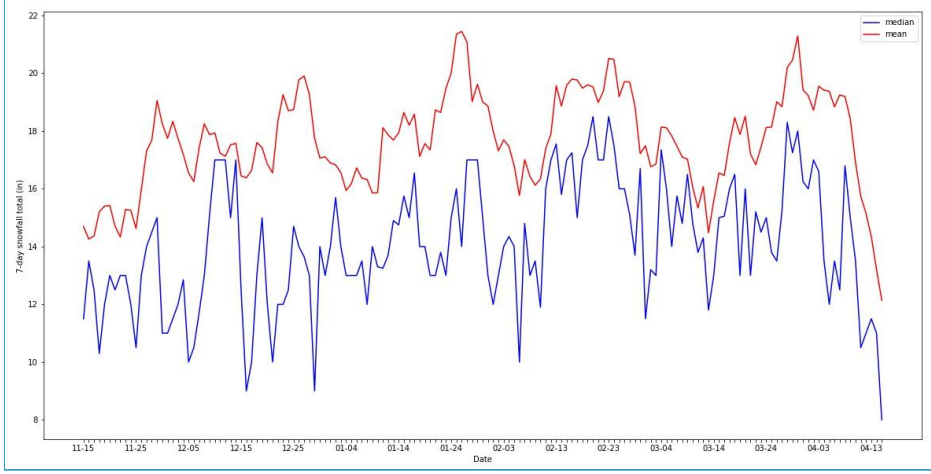
Exploratory Data Analysis for Alta Snowfall

K

Before we modeled Alta's snowfall over the season, we explored the data to find potential nuances.

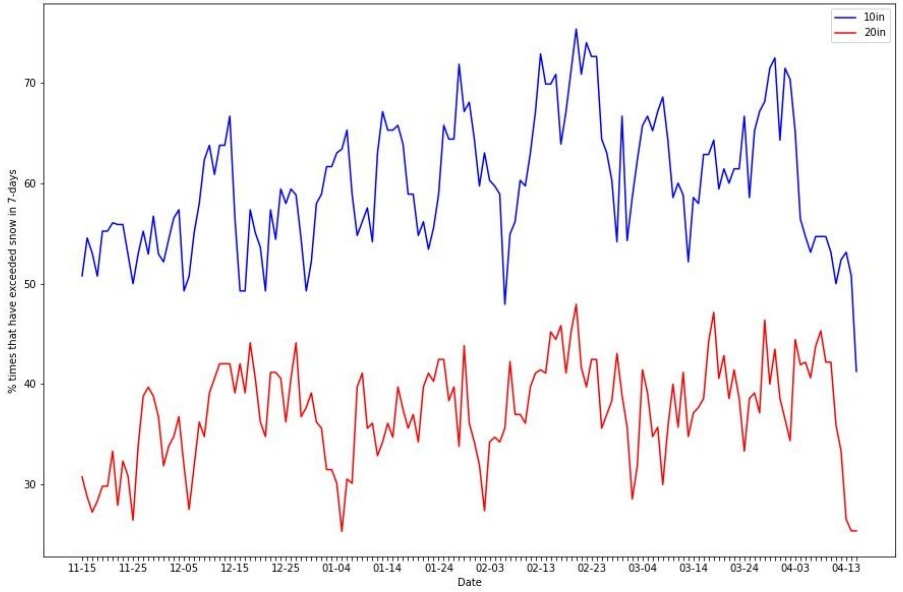
7-day mean & median

- We computed the 7-day rollaway sum of snowfall for reach day of the winter
- Below are the mean and median of those 7-day sums
- These values are still extremely variable, but we can see times of greater snowfall: late January, mid to late February, late March



7-day chance of accumulation

- We look at snowfall for consistency: in what percentage of years did 7-day snowfall exceed 10 or 20 inches?
- Similar results with February shining more in this approach



P K M R S

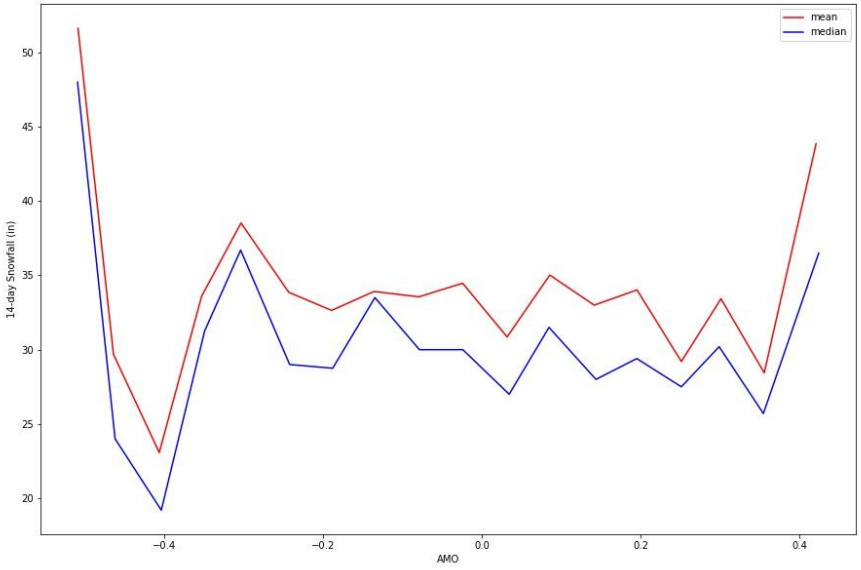
More Exploratory Data Analysis for Alta Snowfall

K

We looked at Atlantic Multi-Decadal Oscillation (AMO) and Pacific Decadal Oscillation (PDO)

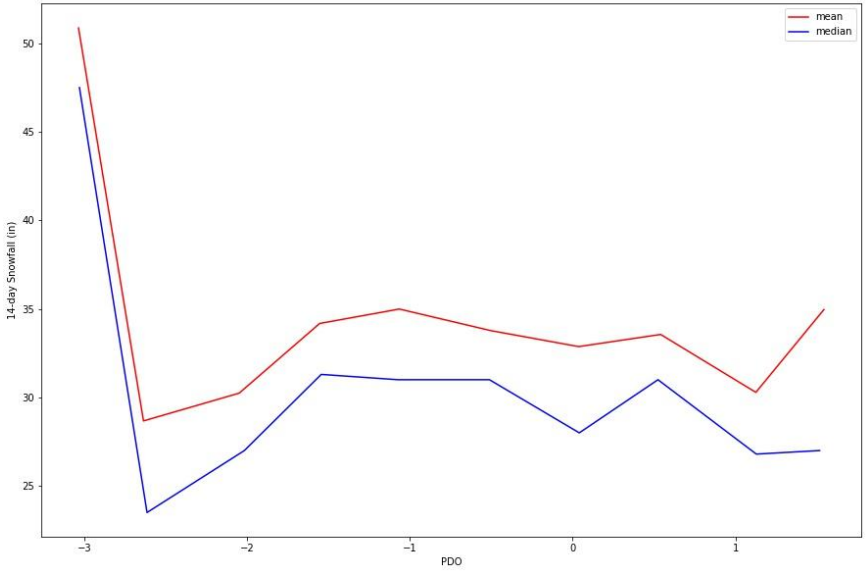
AMO vs. snowfall

- Looks like high or low values could impact snowfall
- AMO was only below -0.484 twice
- AMO was only above 0.384 twice
- this snowfall was not necessarily from AMO



PDO vs. snowfall

- Looks like low values of PDO result in more snowfall
- PDO was only below -2.9 four times
- this snowfall was not necessarily from PDO; low correlation



P K M R S

Modeling for Alta Snowfall Analysis

M

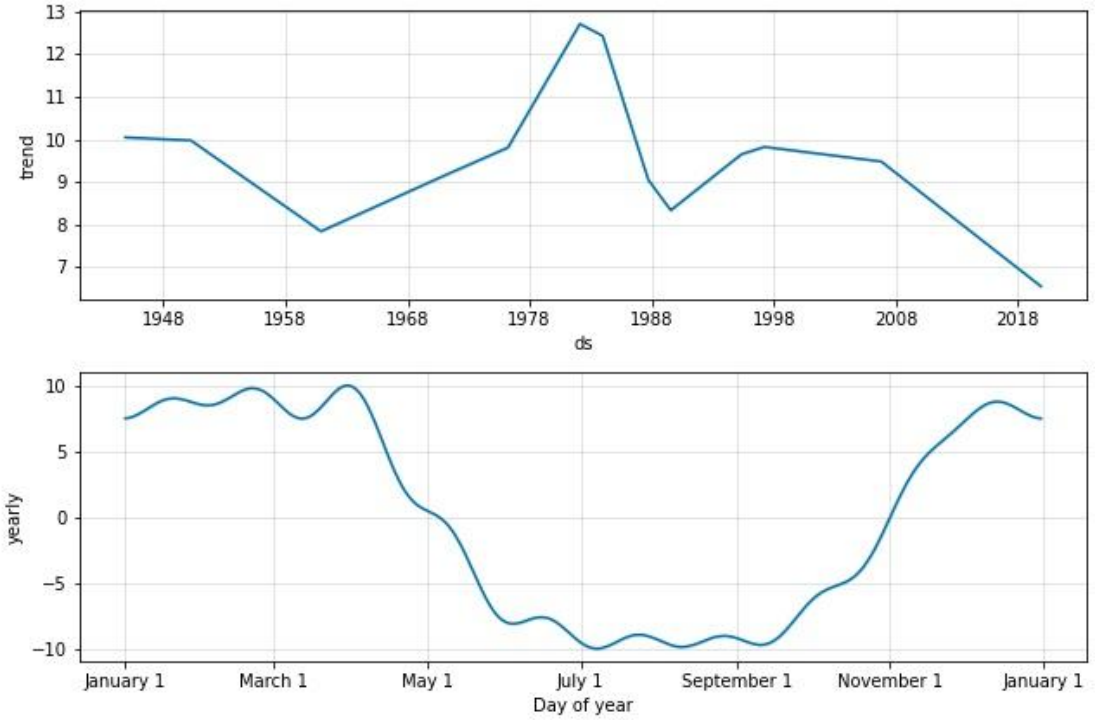
Since we have such variability in snowfall, we used the 7-day snowfall total as the target value in modeling and composed a time-series model using Facebook's Prophet.

Initial model results

- You can see the annual trend in snowfall over the years as well as the seasonal trend
- Dates that we highlighted before have higher snowfall in the model - as expected
- When tested versus last 3 years of snowfall, the model had a 0.02 in RMSE better than the dummy model of assuming the average
- Maybe we can improve these results by considering other features

7-day accumulation Prophet Model

- To get the expect snowfall sum the trend and yearly results



P K M R S

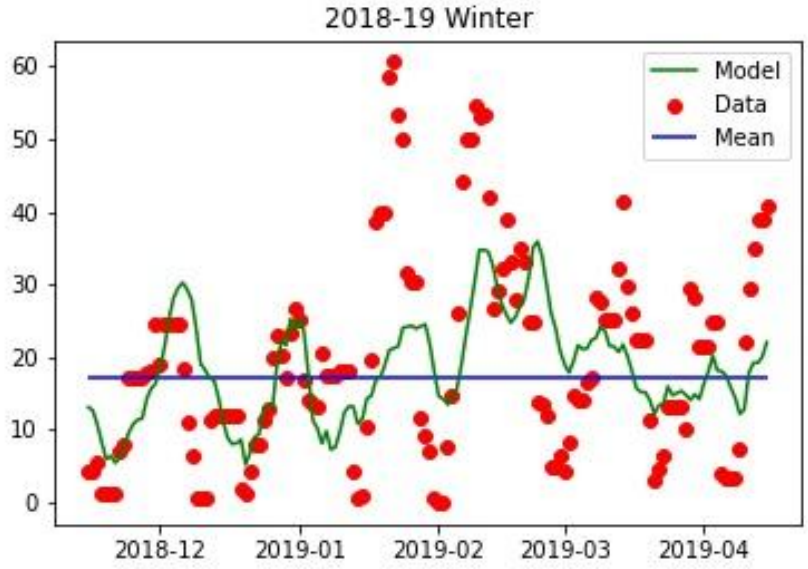
Modeling for Alta Snowfall Analysis

M

We also modeled using a Time Series plus Linear Regressor and Time Series plus a Random Forest Regressor; both of these produced much better results.

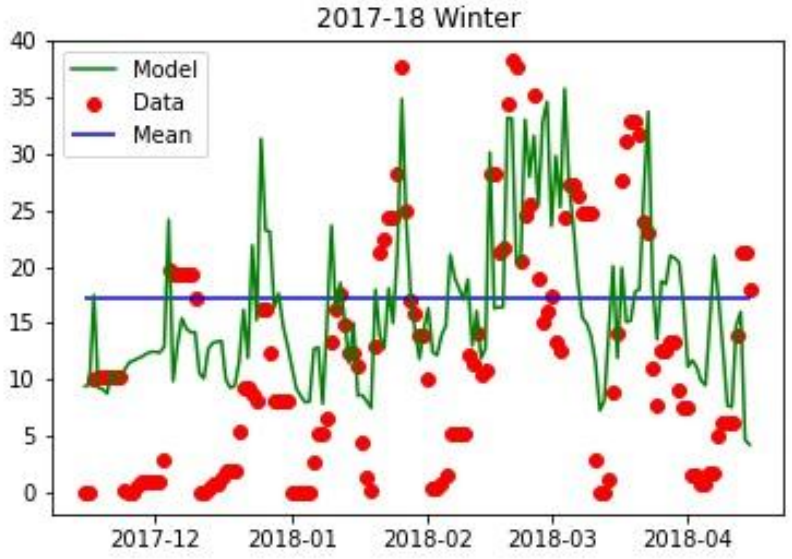
Time Series plus Regression

- **This improved model performance to an average of 11.07 RMSE over 3 years**



Time Series plus RF Regressor

- **Time series then Random Forest Regressor on the Residuals; RMSE of 10.78 in over 3 years**



P K M R S

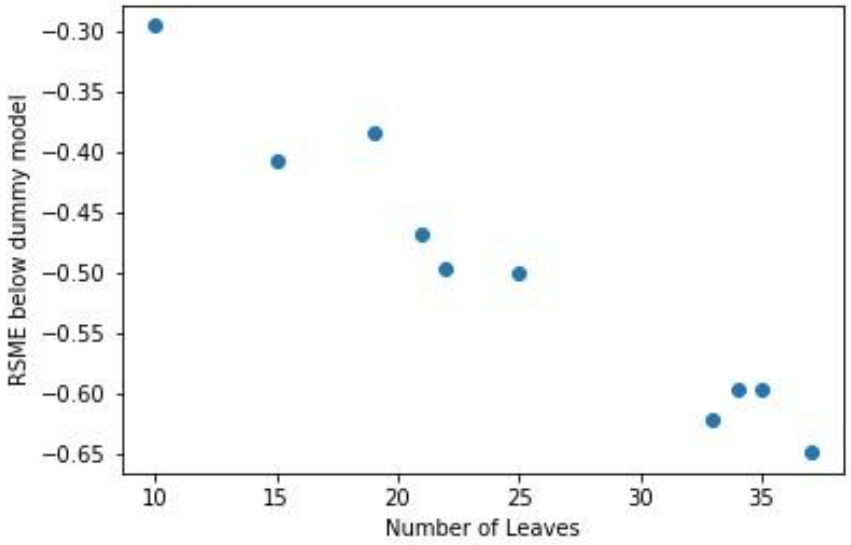
Modeling for Alta Snowfall Analysis

M

- **The previous model were great**
- **But relied on measurement (temperature and precipitation) available too close to the start of the model**
- **weather forecasts available by then**
- **we model again using just features available 30 days in advance**

Tuning the RF Regressor

Time series then Random Forest Regressor on the Residuals; "elbow" of 33 leaves looks the best



This long range model is better than the dummy, but not by much and in 2018-19, it performed worse.

Year	RMSE Model	RMSE Dummy
2016-17	16.00in	16.27in
2017-18	10.39in	11.38in
2018-19	14.68in	14.03in
Average RMSE	13.69in	13.90in

The "dummy" model of assuming the average is challenging to beat with long range models.

P K M R S

Modeling for Alta Snowfall Analysis

M

- **In modeling the snowfall, we tried 7 different models**
- **Below are the model and results**

Models for Alta Snowfall

Model	3-year avg RMSE
Dummy (16.7 in average for 7-day snowfall)	13.96in
Time Series in Prophet	13.88in
Time Series plus regression (using short term variables)	11.21in
Time Series plus regression with more variables (using short term variables)	11.07in
Time Series plus regression (using long-term variables)	13.64in
Time Series plus Random Forest (using short term variables)	10.78in
Time Series plus Random Forest (using short term variables and different hyperparameters)	10.83in
Time Series plus Random Forest (using long-term variables)	13.69in

We tried a number of short-range models to see if knowing the information closer to the ski day improved prediction

Ultimate had to chose a model that predicts snowfall far enough in advance for skiers to plan their ski vacation

P K M R S

Recommendations for Skiers and Modelers

R

When should we ski Alta?!?
What action can we take to improve the model?

Best times to ski

- Differences are so slight
- Suggested times:
  - Late March (week of Mar 23-29 had snow every year; Mar 18 - April 9 performs well)
  - Mid-Late February (7- 28)
  - Late January (15-31)
- Only better than other dates slightly more than 50% of the time

Other potential model

Just based on historic: a skier select a week and we compare the rest of the season to that week to see in how many years other weeks have better snowfall

Improved Modeling Approach

- Since snowfall has an exponential distribution; model the log of snowfall
- Substitute values for zero snowfall to enrich the model
- Include Southern Oscillation Index (SOI) for La Nina / El Nino effects
- Include more lag variables
- Try different ensemble models
- Try other mountains with snowfall that varies more throughout their winter
- Model a larger window of snowfall accumulation
- Try this as a classification problem with “bins” of snowfall

Summary and Conclusion for Alta Snowfall Analysis

S

- Explored snowfall data for Alta
- Constructed a model for snowfall at Alta
- Model performed only slightly better than dummy (average)
- Ideas for future models

Data used in Model Building

- Snowfall data for Alta since 1944
- PDO and AMO monthly values
- Explored many aspects and effects on snowfall
- FB Prophet to model for time series
- Used both regression and RF Regressor added to time series

Model Performance

- Average RMSE: 13.69 inches
- Dummy RMSE: 13.90 inches
- Dummy (assume average all winter) is a pretty good model
- Would only depend on our model if no other constraints for vacation

Improved Approach Proposed

- Take log of snowfall
- substitute values for zero snowfall
- Include Southern Oscillation Index
- Try different lag variables (temp)
- Use different ensemble models
- Model a larger snowfall window (14 days instead of 7)
- Perhaps use classification to sort snowfall into “bins”

Special Thanks to

- Springboard TA’s
- Springboard Mentor, Raghu

P K M R S