

AC297r Fall 2019

Mid-term Summary

Optimal Real-time Scheduling for Black Hole Imaging

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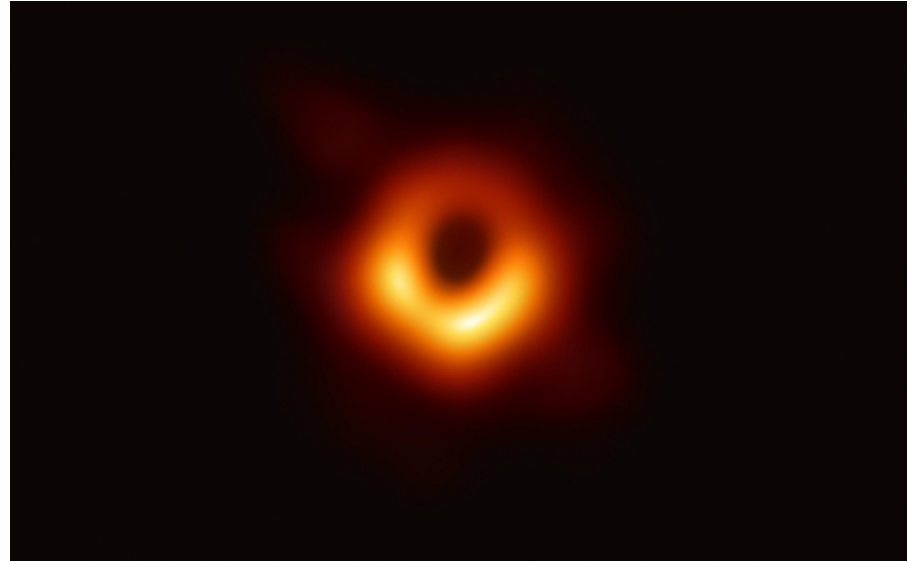
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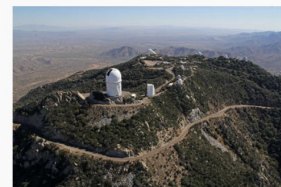
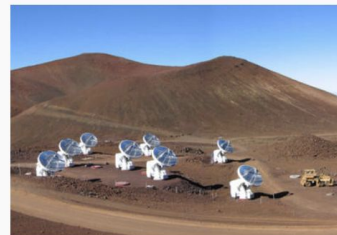
The Event Horizon Telescope is an international collaboration capturing images of black holes using a virtual Earth-sized telescope.



Event Horizon Telescope



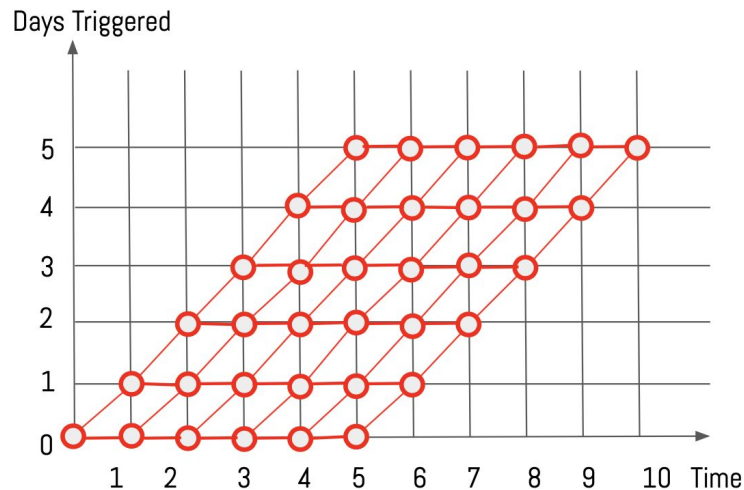
Introduction



Problem Statement

We are going to build a model that can:


1. In total, choose 5 days from a 10-day window
2. On each day, determine the optimal strategy for future remaining days
3. If possible, provide a confidence level on its suggestion
4. Also provide the second optimal strategy




Motivations


1. Improve the decision making process
2. Increase the chance of capturing the black hole

Data Source

**NOAA** NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Formerly the National Climatic Data Center (NCDC)... [more about NCEI](#) »



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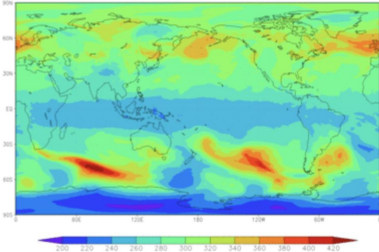
NARR

Global Forecast System (GFS)

The Global Forecast System (GFS) is a weather forecast model produced by the National Centers for Environmental Prediction (NCEP). Dozens of atmospheric and land-soil variables are available through this dataset, from temperatures, winds, and precipitation to soil moisture and atmospheric ozone concentration. The entire globe is covered by the GFS at a base horizontal resolution of 18 miles (28 kilometers) between grid points, which is used by the operational forecasters who predict weather out to 16 days in the future. Horizontal resolution drops to 44 miles (70 kilometers) between grid point for forecasts between one week and two weeks.

[More...](#)

Product Types



GFS Entire Atmosphere Total Ozone [Dobson]
00Z14JUL2012+048Hrs

An animated image of GFS simulated total atmospheric ozone concentration, forecast from 00 UTC on July 12, 2012, to July 16, 2012, at 00 UTC—a four day forecast—in three hourly intervals. The lowest concentrations of ozone on the planet reside over the Antarctic during this period. This image was produced with the Grid Analysis and Display System (GRADS) and ImageMagick.

GFS provides:

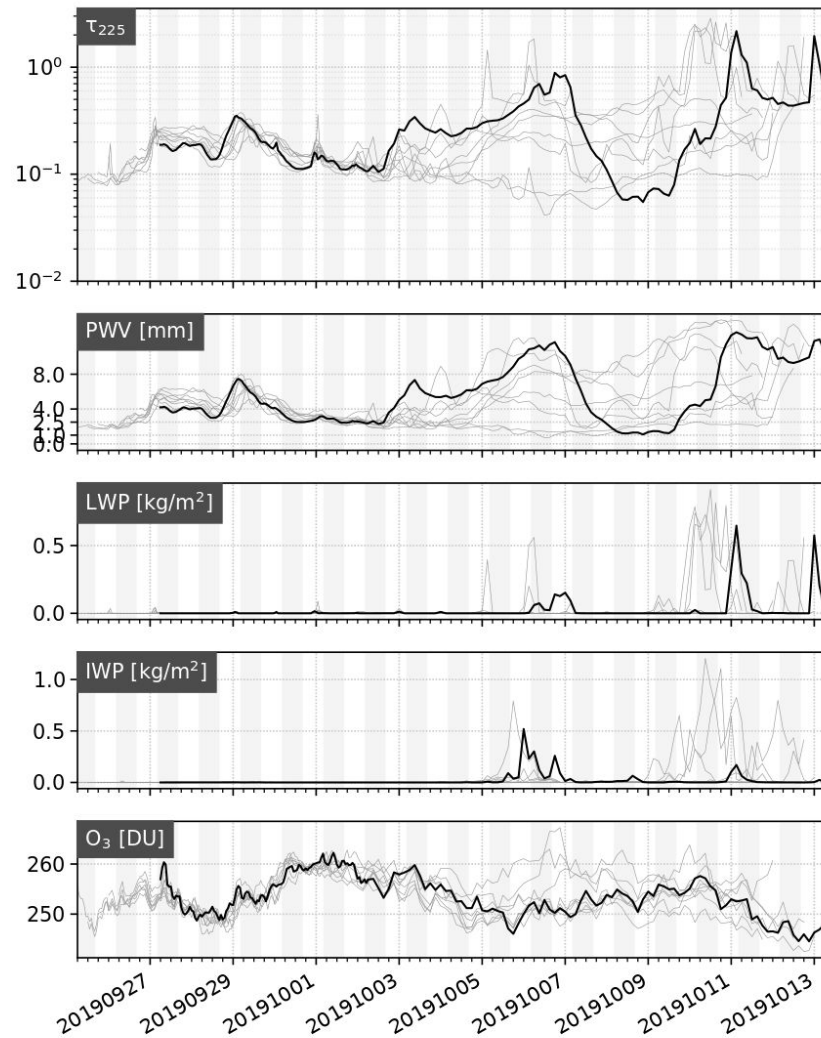
- ❖ Atmosphere's condition
- ❖ Layer-by-layer
- ❖ All over the globe

We pull data every 6 hours specifying:

- ❖ Longitude
- ❖ Latitude
- ❖ Altitude

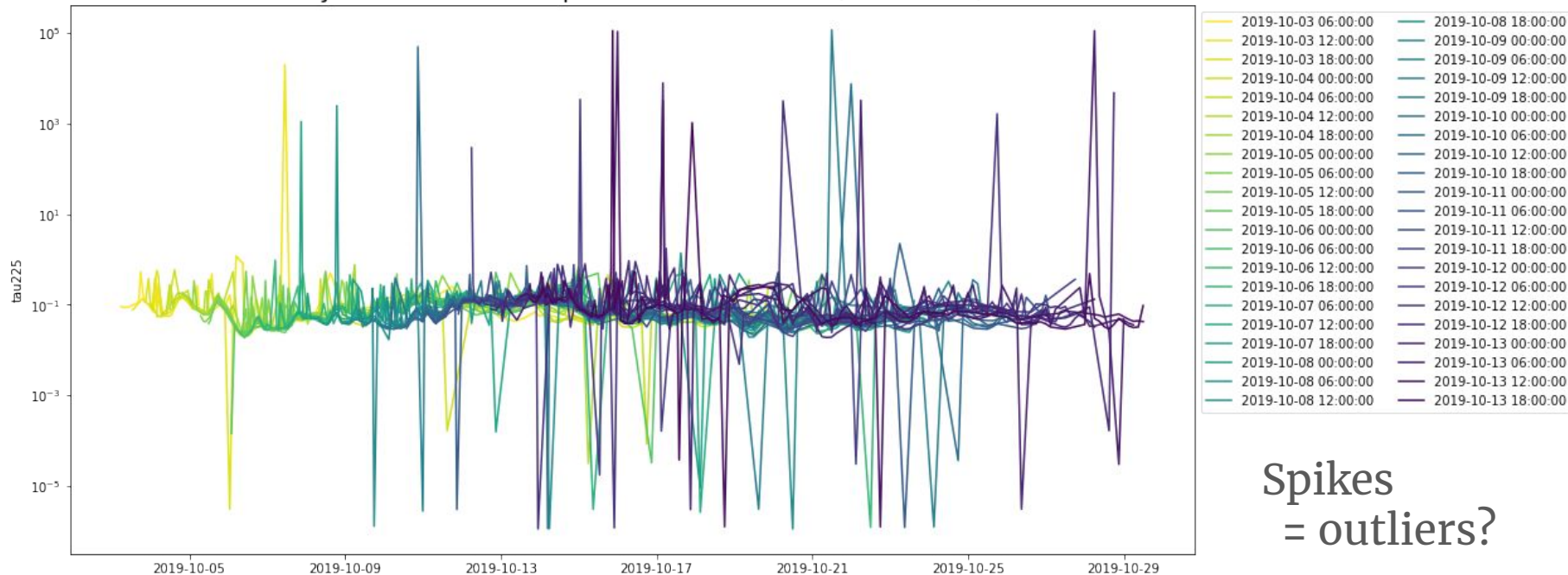
EDA

- Every 6 hours, we get 16-day atmosphere forecast from GFS.
- First 5-day forecast is pretty accurate.
- Variables: **Tau_225** (absorption directly above head, the lower the better), PWV, LWP, IWP (amount of water in different forms), **O₃**



EDA

16-day Tau225 Forecast predicted between 10/03 and 10/13



Spikes
= outliers?

Model Design

1. Reward Function

$f(i)$
reward at a single
telescope i .

$F(f(i))$
Total rewards for
all telescopes

2. Uncertainty Measurements

3. Optimization

4. Model Evaluation

Measure performance
based on real weather
afterwards.

Compare with:

1. Best path afterwards
2. Human-made decision

Baseline Model

1. Reward Function

$$f_i(\tau_{225}) = -\tau_{225}$$
$$F = \sum_i^{N_{telescope}} w_i f_i$$

where w_i is the weight for each telescope (total GBytes data sent from the telescope used by EHT).

2. Uncertainty Measurement:

None

Example – optimization

Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10
19.03	13.93	16.24	16.38	18.80	12.99	17.02	19.03	18.81	14.06

Example

Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10
19.03	13.93	16.24	16.38	18.80	12.99	17.02	19.03	18.81	14.06

Example

Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10
19.03	13.93	16.24	16.38	18.80	12.99	17.02	19.03	18.81	14.06

Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10
18.82	11.04	19.07	13.06	14.46	15.90	18.37	16.98	18.30

Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10
19.03	13.93	16.24	16.38	18.80	12.99	17.02	19.03	18.81	14.06

Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10
18.82	11.04	19.07	13.06	14.46	15.90	18.37	16.98	18.30

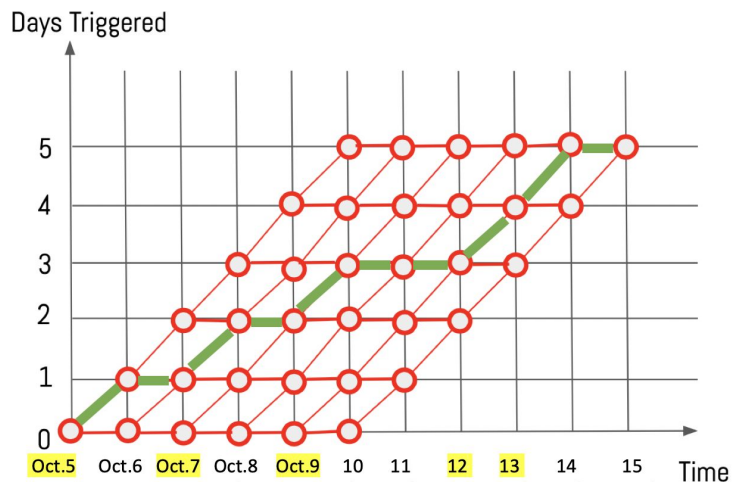
Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10
10.21	17.67	14.48	11.21	19.31	16.50	11.41	12.22

Day4	Day5	Day6	Day7	Day8	Day9	Day10
18.97	17.30	17.83	17.42	14.64	16.43	12.25

Baseline Model – evaluation

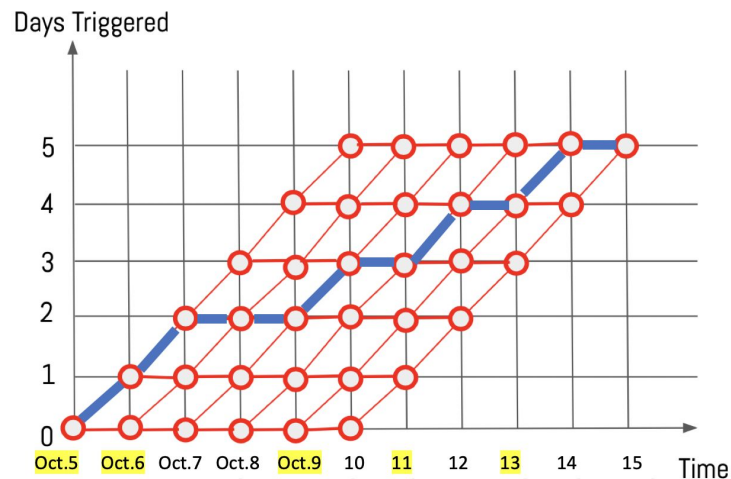
Choose 5 days From Oct.5 - Oct.14, 2019

Path suggested by Baseline



Total Reward: - 4,260,444

Ground-truth Best Path Afterwards



Total Reward: - 54,244

Next Steps

Adding Uncertainty Measurement

Possible Directions:

1. Discount Factors
 2. Probabilistic Distribution
-

Final Deliverables

- A python package implementing an optimal real-time scheduling algorithm



- Proper documentation explaining the algorithm.
- Nice to have: visualization of the path

Timeline

Date	Tentative Schedule
10/18/2019	<ul style="list-style-type: none">- Midterm Presentation- Short Report to EHT- EDA- Baseline Model with evaluation
10/25/2019	<ul style="list-style-type: none">- Second meeting with EHT- Get to understand files even more- Brainstorm uncertainty measurement
11/1/2019	<ul style="list-style-type: none">- Experiment with different reward functions- Incorporate uncertainty into the model
11/8/2019	<ul style="list-style-type: none">- Third meeting with EHT- Experiment with different uncertainty methods

Timeline

11/15/2019	<ul style="list-style-type: none">- Milestone 3 Presentation- Short report to EHT- Find ways to incorporate visualization into the output
11/22/2019	<ul style="list-style-type: none">- Build visualization around the output- Build GUI
12/6/2019	<ul style="list-style-type: none">- Finalize the advanced model- Get ready to ship the package
12/9/2019	<ul style="list-style-type: none">- IACS showcase
12/11/2019	<ul style="list-style-type: none">- Final presentation
12/12/2019	<ul style="list-style-type: none">- Final deliverables (slides, blog, self- and peer-evaluations)

Thank you!

10.15.2019

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