

Summer 2020 Intern Presentation

Joseph Adamson

*University of California, Santa Cruz, California
Ames Research Center, Moffett Field, California*

Felipe Borja

*Virginia Polytechnic Institute and State University, Blacksburg Virginia
Ames Research Center, Moffett Field, California*

Natallia Urieva

*California State Polytechnic University, Pomona, California
Ames Research Center, Moffett Field, California*

Eric Chen

*University of California, Los Angeles, California
Ames Research Center, Moffett Field, California*

Jahan Claes

*University of Illinois at Urbana-Champaign, Illinois
Ames Research Center, Moffett Field, California*

Emily Deardorff

*Western Washington University, Washington
Ames Research Center, Moffett Field, California*

Natalie Glines

*University of California, Santa Cruz, California
Ames Research Center, Moffett Field, California*

Rowan Huang

*Brigham Young University, Utah
Ames Research Center, Moffett Field, California*

Ang Li

University of California, Berkeley, California
Ames Research Center, Moffett Field, California

Saehong Park
University of California, Berkeley, California
Ames Research Center, Moffett Field, California

Fanruiqi Zeng
Georgia Institute of Technology, Georgia
Ames Research Center, Moffett Field, California

August 2020

NASA STI Program ... in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

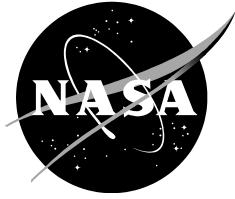
The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NTRS Registered and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA Programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.
- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include organizing and publishing research results, distributing specialized research announcements and feeds, providing information desk and personal search support, and enabling data exchange services.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at <http://www.sti.nasa.gov>
- E-mail your question to help@sti.nasa.gov
- Phone the NASA STI Information Desk at 757-864-9658
- Write to:
NASA STI Information Desk
Mail Stop 148
NASA Langley Research Center
Hampton, VA 23681-2199



Summer 2020 Intern Presentation

Joseph Adamson

*University of California, Santa Cruz, California
Ames Research Center, Moffett Field, California*

Felipe Borja

*Virginia Polytechnic Institute and State University, Blacksburg Virginia
Ames Research Center, Moffett Field, California*

Natallia Urieva

*California State Polytechnic University, Pomona, California
Ames Research Center, Moffett Field, California*

Eric Chen

*University of California, Los Angeles, California
Ames Research Center, Moffett Field, California*

Jahan Claes

*University of Illinois at Urbana-Champaign, Illinois
Ames Research Center, Moffett Field, California*

Emily Deardorff

*Western Washington University, Washington
Ames Research Center, Moffett Field, California*

Natalie Glines

*University of California, Santa Cruz, California
Ames Research Center, Moffett Field, California*

Rowan Huang

*Brigham Young University, Utah
Ames Research Center, Moffett Field, California*

Ang Li

University of California, Berkeley, California
Ames Research Center, Moffett Field, California

Saehong Park
University of California, Berkeley, California
Ames Research Center, Moffett Field, California

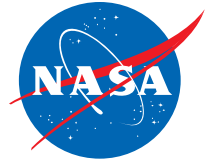
Fanruiqi Zeng
Georgia Institute of Technology, Georgia
Ames Research Center, Moffett Field, California

Prepared for
2020 Summer Intern Virtual Presentations
Conference Sponsor(s)

National Aeronautics and
Space Administration

*Ames Research Center
Moffet Field, California 94035-1000*

August 2020



UAV System for Autonomous Wind Tunnel Inspection

Joseph Adamson

University of California, Santa Cruz

Mentor: David Murakami

Branch: AOX (Fluid Mechanics Laboratory)

Summer 2020

Background & Motivation

- NASA Ames Research Facility is home to the largest wind tunnels in the world, at the National Full Scale Aeronautics Complex (NFAC)
 - 80' x 120' and 40' x 80' test sections
 - Powered by 40' diameter fans on 23,500 HP motors (6 of them!!)
 - Really really huge
- The facility started in the 1940's and showing its age; regular inspection ensures safe operation. Current inspection methods require high amounts of time and manual labor, including skilled inspectors and trained rope climbers
- Defects of interest include cracked or missing panels and failing/missing rivets, among others
- Funded by an Internal Research and Development (IRAD) grant proposed by Dr. Murakami

Background & Motivation



<https://www.nasa.gov/centers/ames/multimedia/images/2005/nfac.html>

Solution: UAV and Machine Learning

- The NFAC is largely composed of empty warehouse-like sections, many stories tall. This environment lends itself to small UAVs flying an automated mission
- A drone equipped with a high resolution camera can capture diagnostic images of entire walls suitable for analysis via photogrammetry and machine learning
- Early proof of concept walkthroughs used a handheld camera rig capturing images at a fixed rate, walking along tunnel section
 - Fellow team member, Nicholas Califano, working on ML portion
 - Properly identifying missing and non-missing fasteners

Environment Challenges

- GPS and Magnetometer Denial
 - Typical autonomous drone: GPS and Magnetometer
- Very low light (pitch black in some sections)
- Poison Walls
- Foreign Object Damage

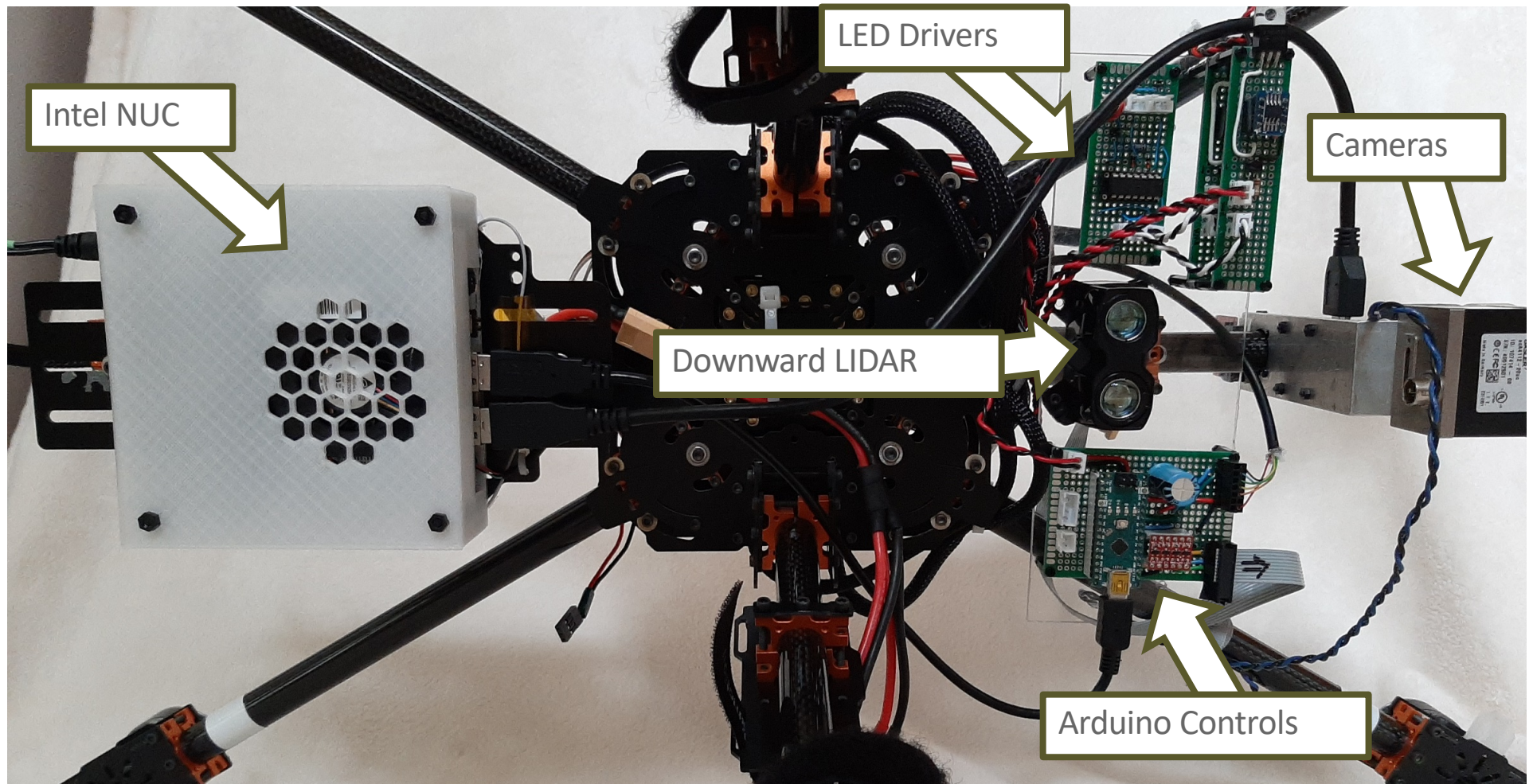
UAV



Hardware Architecture / Payload

- System uses two cameras:
 - High resolution (12MP) camera for taking images
 - Low resolution (2MP) for localization (more on that later)
- High intensity LEDs + driver circuitry
- Pixhawk flight controller (plus standard drone components)
 - Onboard IMU, controllers, position filters
- Intel NUC onboard computer for main processing
- Sensor package: long- and short-range LIDAR distance sensors serialized via Arduino
- Target payload weight: **1kg**

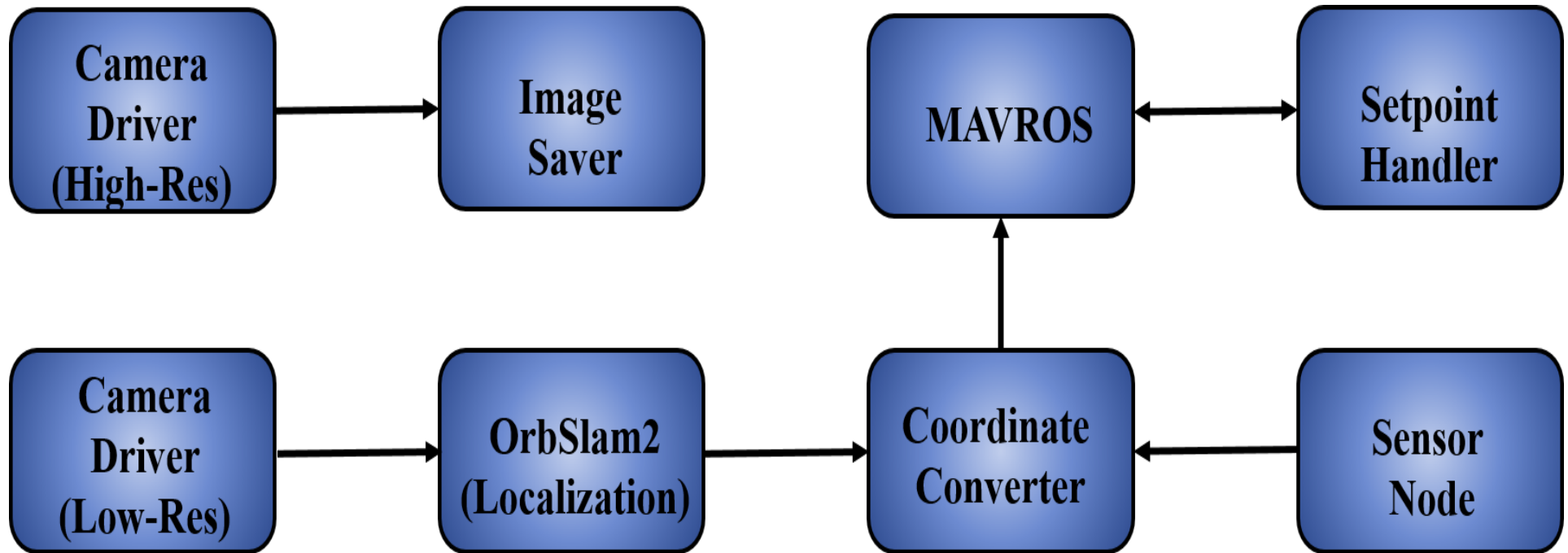
Underbelly View



Software Architecture: ROS

- ROS is a common middleware layer facilitating programming of robotic and other systems
- Consists of interconnected executables (*nodes*) communicating across specific channels (*topics*) using standardized data types (*messages*)
- Highly modular and widely supported

Software Architecture: ROS



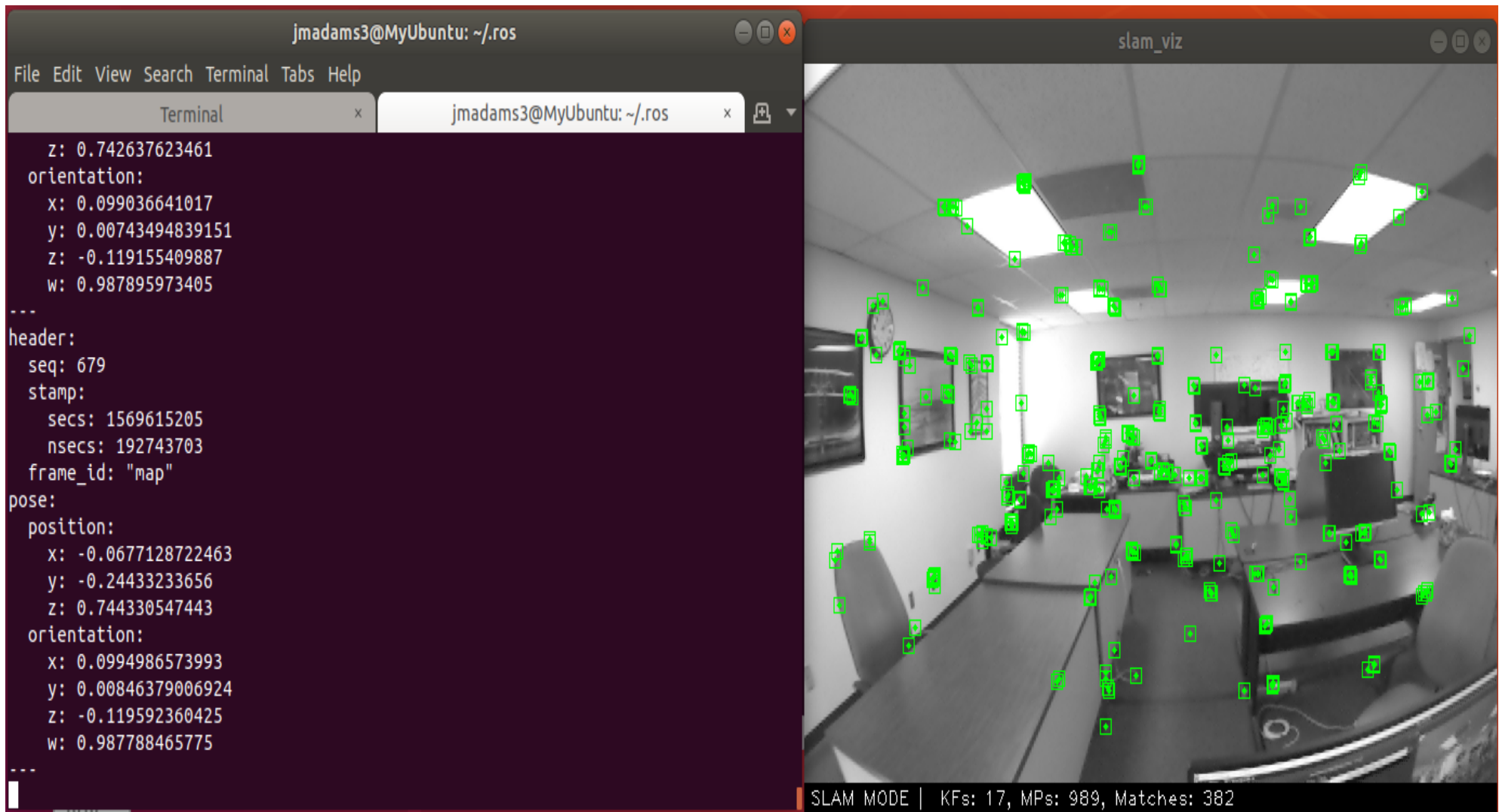
Localization: ORB-SLAM2 library

- We need to know and control our position without GPS or magnetometer
- ORB-SLAM2 is a camera-based Simultaneous Localization and Mapping (SLAM) solution using feature detection and triangulation

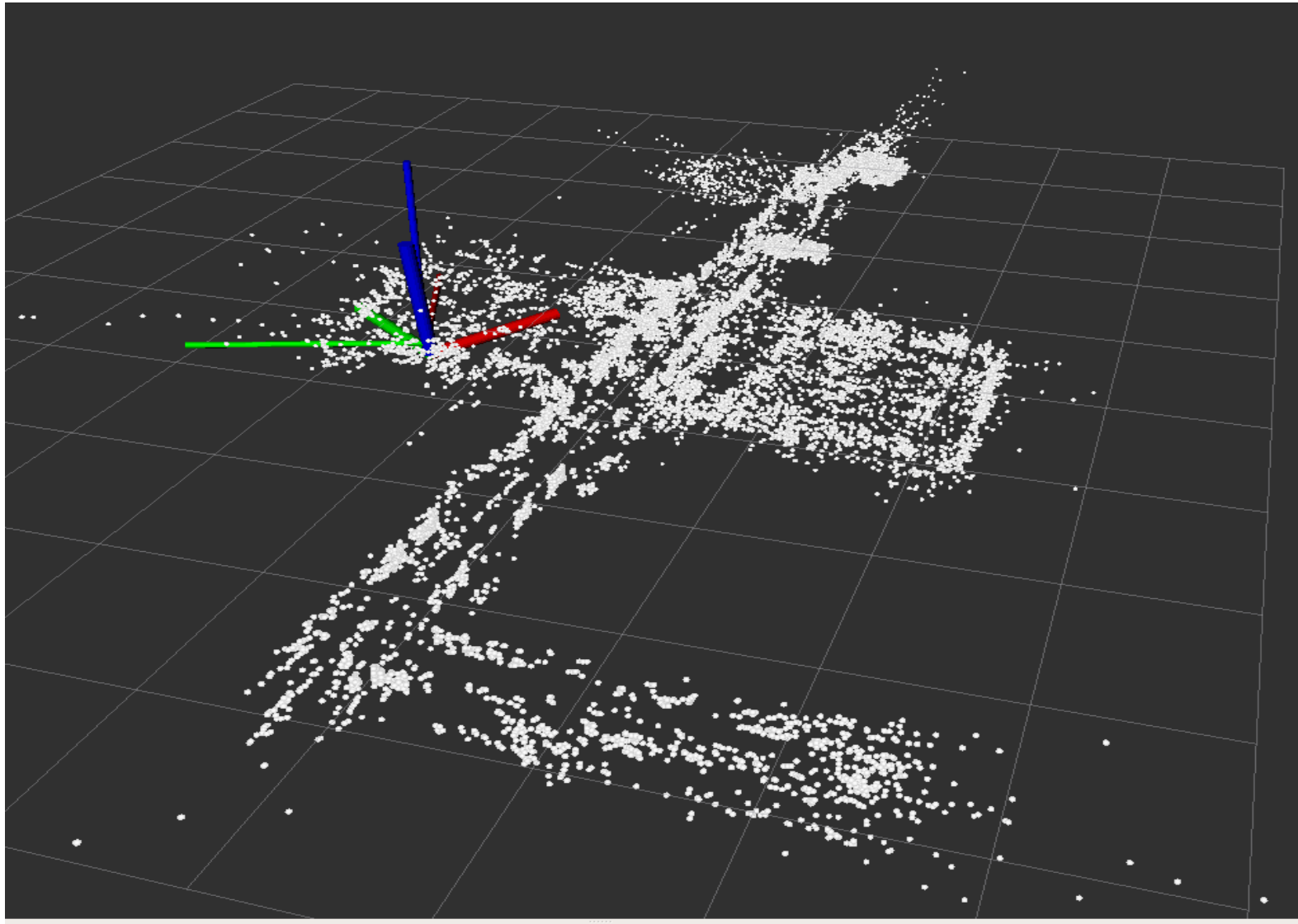
Other SLAM options include lidar, sonar

- Generates a 6-DOF position/attitude estimate (collectively, 'pose') and an internal point cloud map
- Use pose estimate in conjunction with Pixhawk position controllers to fly to desired locations

Localization: ORB-SLAM2 library



Localization: ORB-SLAM2 library

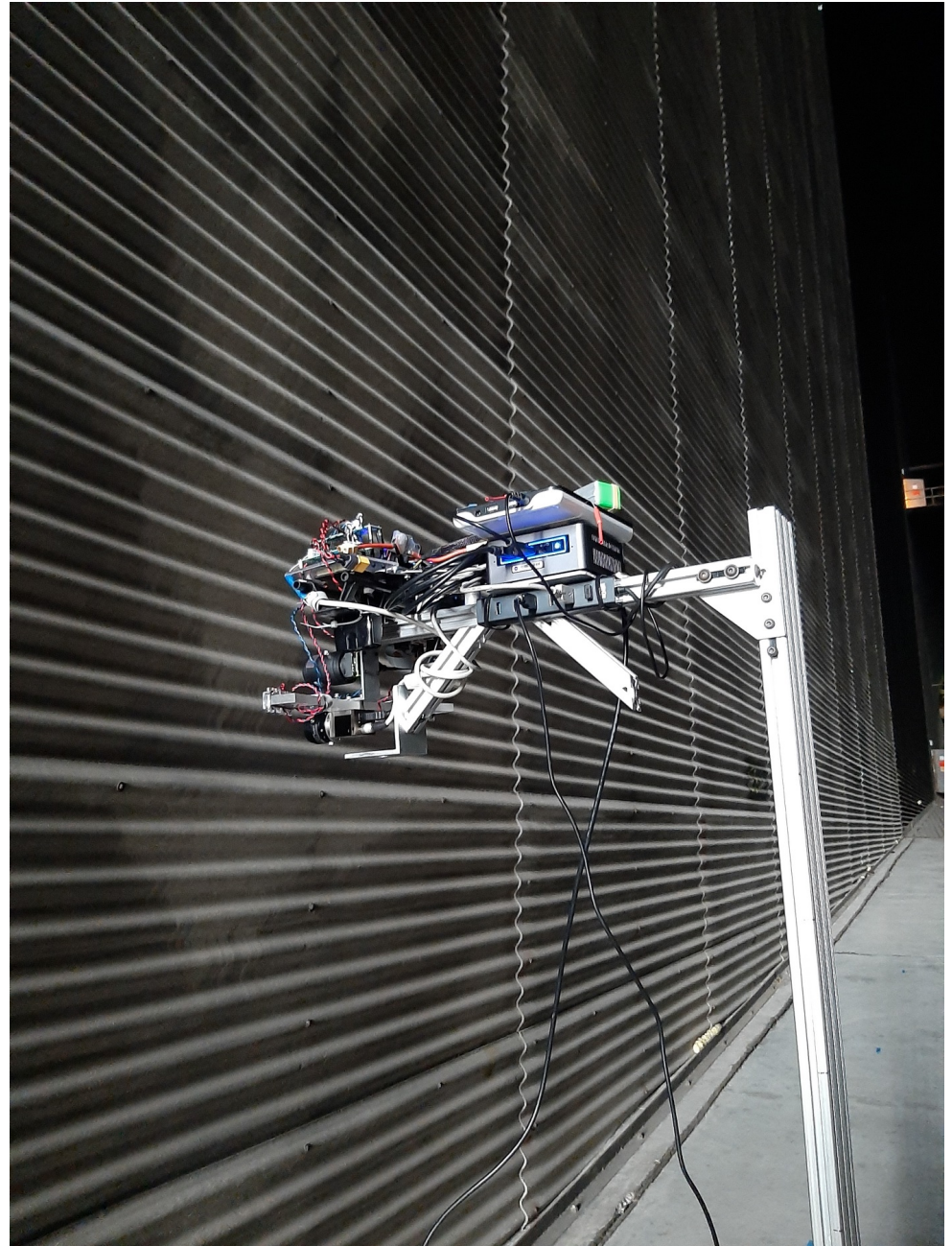


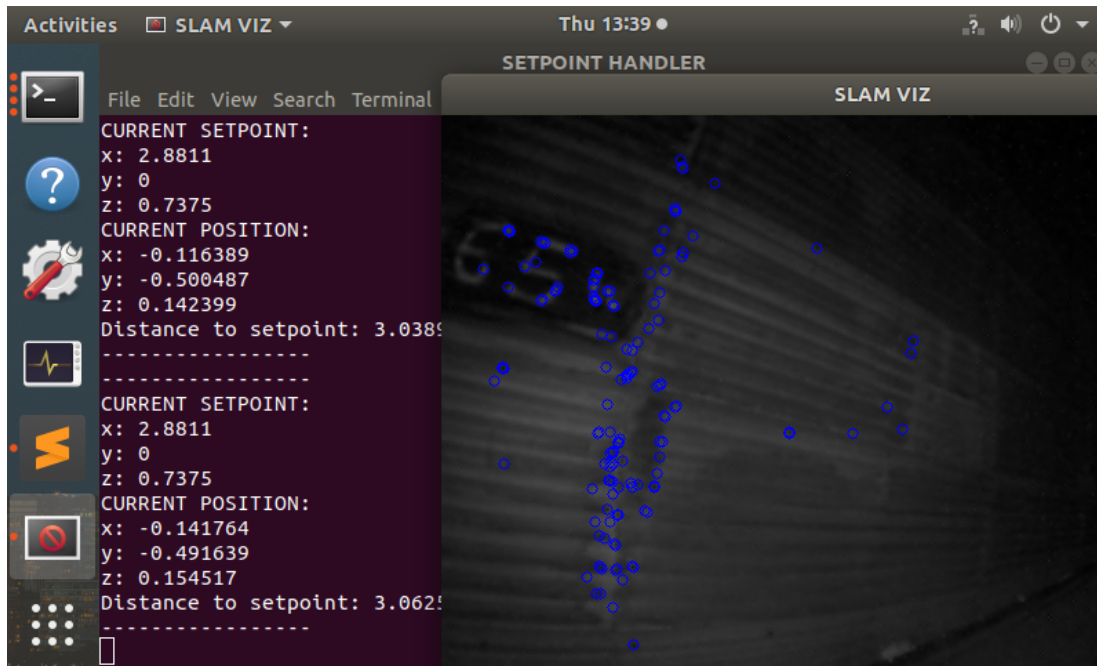
ORB-SLAM2 in the real world

- Issues:
 - Home coordinate frame is set arbitrarily upon initialization
 - True scale cannot be determined with only one camera, and is thus also arbitrary (monocular vs. stereo vision)
 - Therefore all pose coordinates are relative to fully arbitrary basis
- Solutions:
 - Learn quaternions
 - Use IMU data to rotate SLAM attitude into an gravity-down reference frame
 - Use distance sensor data to scale SLAM position into meters

Prototype and Data Collection

- Initially developed system on handheld prototype using aluminum extrusion
- Prototype platform allowed incremental testing of each component and software module
- Mounted onto cart and taken into NFAC for testing and data collection

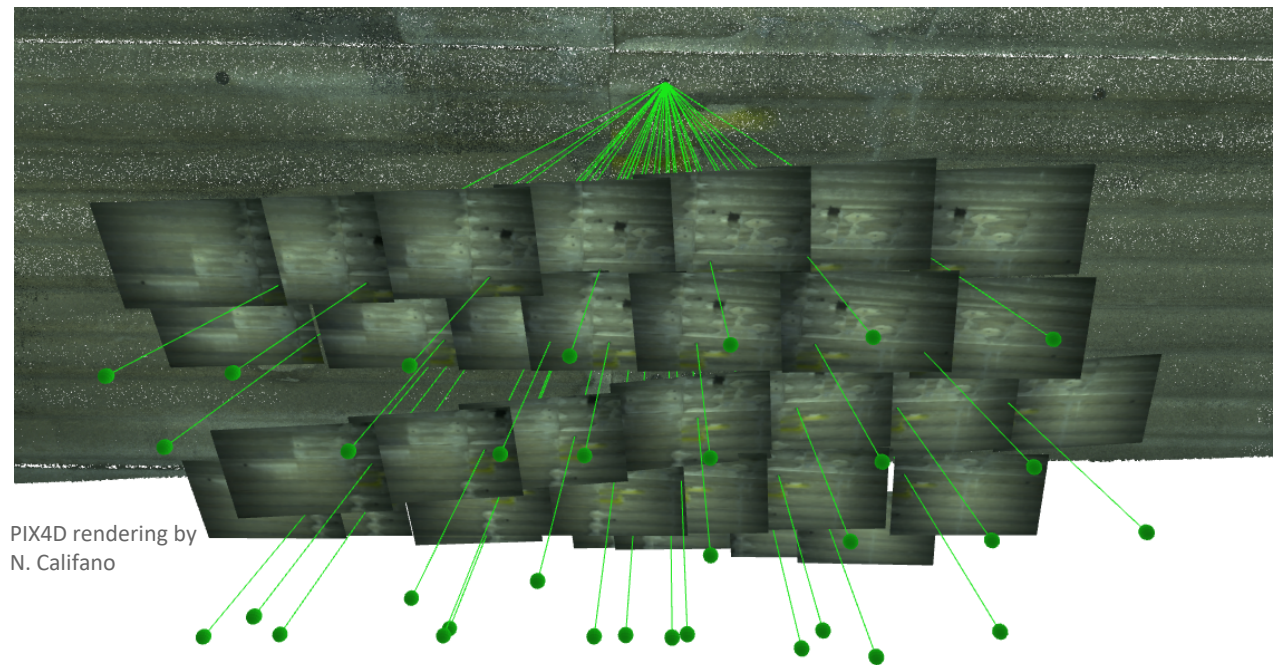




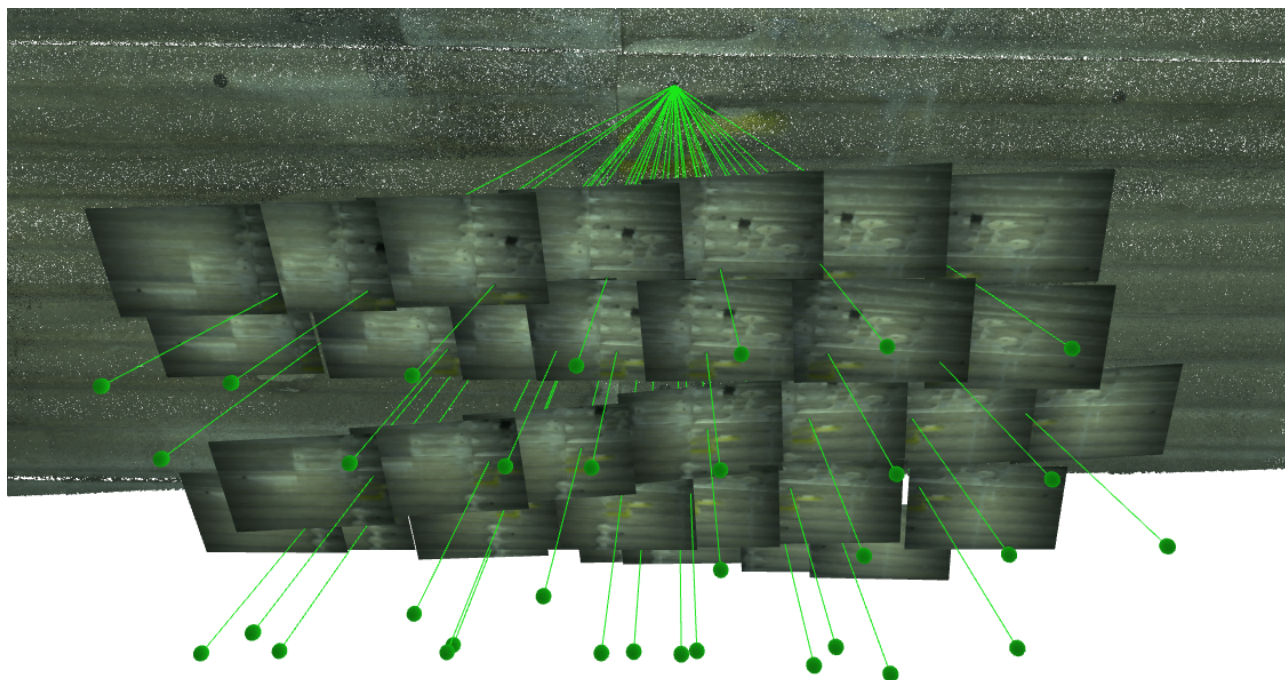
Setpoint handler in action (NFAC)



Images taken at regular(ish) spacing



PIX4D rendering by
N. Califano



PIX4D dense point cloud rendering by N. Califano

Flight Testing

- Began flight testing to tune the controllers and determine any issues with the system
- Found some vibrational issues during manual testing
- Future tests will further tune the controllers and start working with the payload
- Currently on hold

Conclusions & Future Work

- Work performed during this internship developed a UAV payload platform suitable for collecting data for building inspection while demonstrating a localization solution and its viability in the target environment
- There exist many other applications for this type of automation
- The team generated a new dataset within the NFAC for analysis, which showed strong results
- Future work for this project includes:
 - Continuation of flight testing
 - Fine-tuning of the orb-slam conversion algorithms or exploring other localization solutions, as well as improving position filtering within px4
 - Flight missions within the NFAC

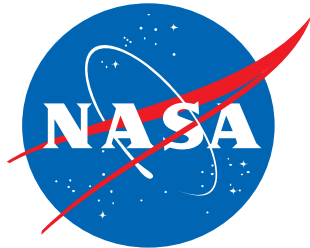
Personal Impact

- This project served as a strong foundation and the culmination of my graduate career as a student of robotics and control
- Explored and utilized the full range of topics relevant to the implementation of an autonomous and usage of topics such as ROS, OpenCV, UAV controls, and attitude estimation
- I learned many professional engineering skills including best practices, electrical workmanship, effective troubleshooting, and professional communication
- There was a lot of difficulty, but a lot of meaningful growth, connections, lessons, and fun

Acknowledgments

With infinite thanks to:

- David Murakami, Nick Califano, Rabi Mehta, and everyone else at the Fluid Mechanics Laboratory
- Saba Hussain and Zeal Panchal (USRA)
- Gabriel Elkaim (UCSC)
- Christopher Seruge and Nick Cramer (Code T)

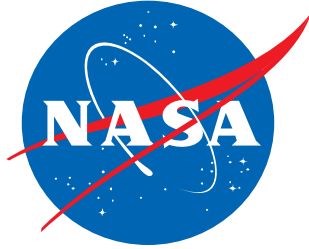


UC SANTA CRUZ

Thanks for your time!

Questions?





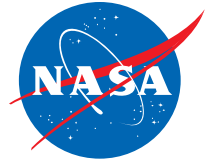
Backup Slides

Setpoint Comparisons

- Generate setpoint stream using simple python script. Spacing is determined by calculations by Nick Califano to achieve, eg, 25 pictures per fastener dependent on lens/resolution characteristics
- Use Pixhawk's position controllers to fly to the setpoint
- Snap picture at each setpoint, then move on

ORB-SLAM2 in the real world

- Attitude solution: generate a correction factor using Inertial Measurement Unit (IMU) and apply it to incoming SLAM measurements to rotate them into a gravity-down frame
 - Using quaternion magic
 - Rotate position measurements by the same correction
- Scaling solution: use onboard distance sensors to scale position to an absolute scale by moving a set distance and recording deltas
 - Multiply all incoming position measurements by this scale factor
- Final result: SLAM measurements are processed into true-scaled, gravity-oriented pose readings. Last step of processing allows for 'homing' the system



System-wide Safety Assurance in Aeronautics : Deep-Reinforcement Learning for Anomalies Detection

Saehong Park

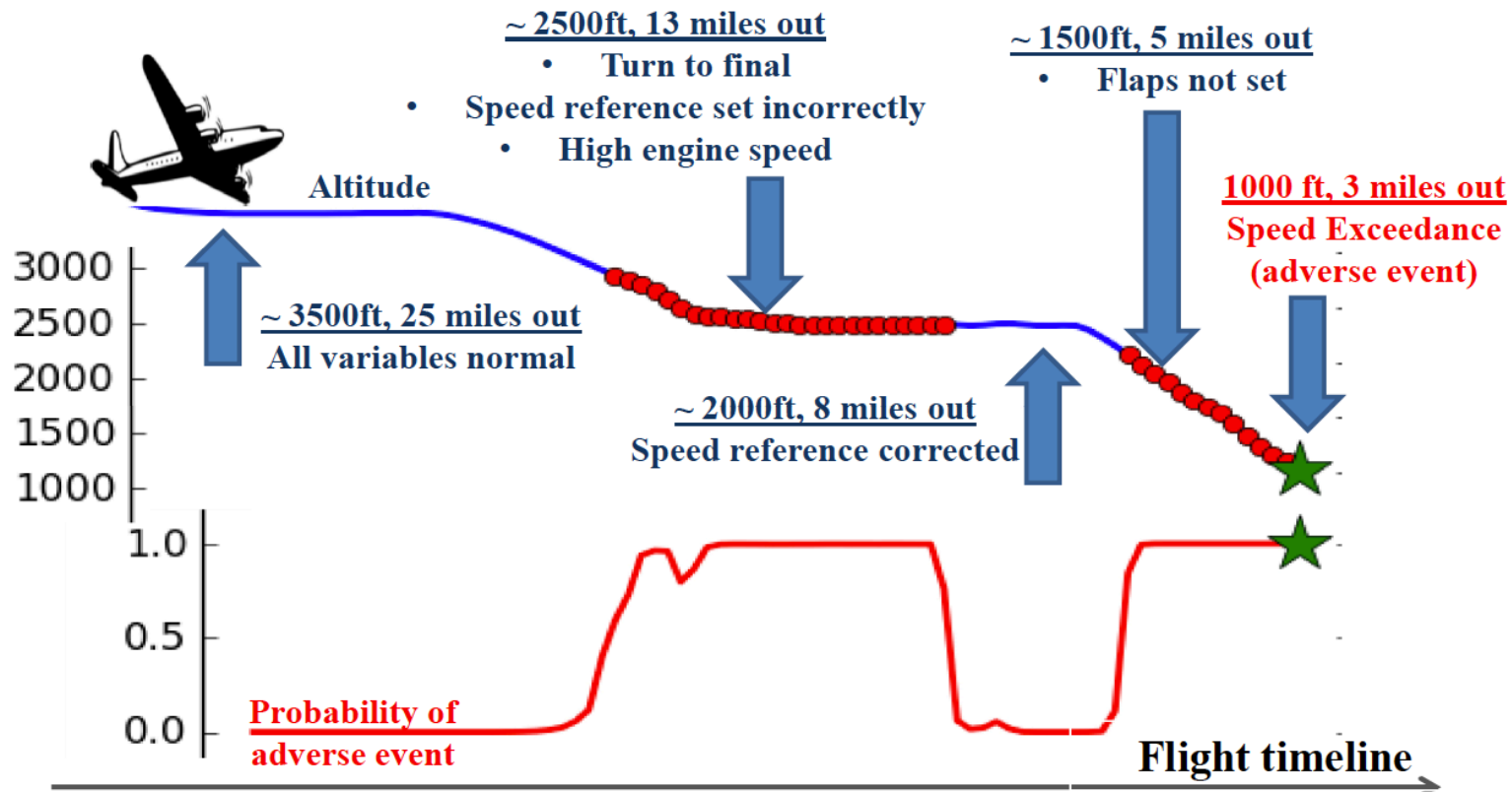
University of California, Berkeley

Mentor : Dr. Milad Memarzadeh, ARC-T / Datamining

Summer 2020

Introduction

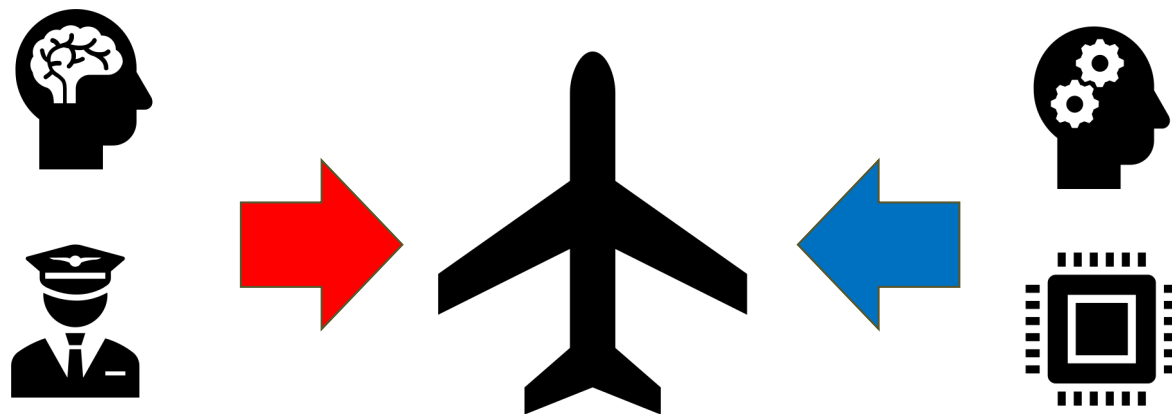
- Aviation safety is critical aspect in the aerospace industry
- Identifying precursors for anomalies would decrease the fatal incident



[Ref.] V. Janakiraman, Explaining Aviation Safety Incidents Using Deep Temporal Multiple Instance Learning KDD 2018

Background of Project / Literature Review

- This project is to leverage a deep reinforcement learning techniques to identify precursors for operationally significant anomalies
 - We specifically focus on the anomaly during take-off, i.e., Airspeed drop
- The data is recorded as high-dimensional time-series of Flight's Operational Quality Assurance (FOQA) data.

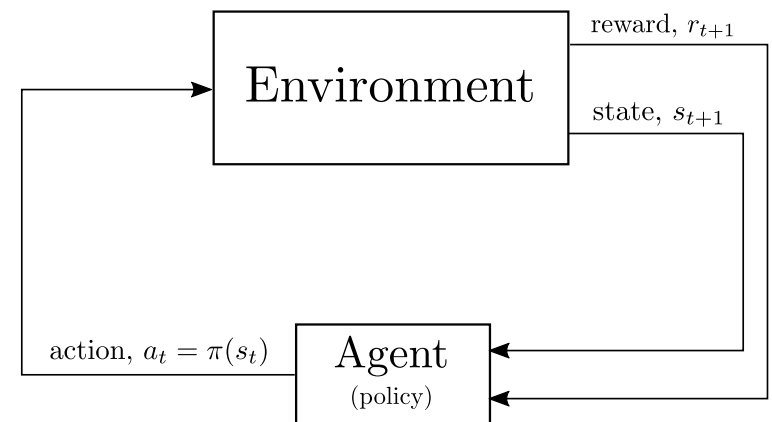
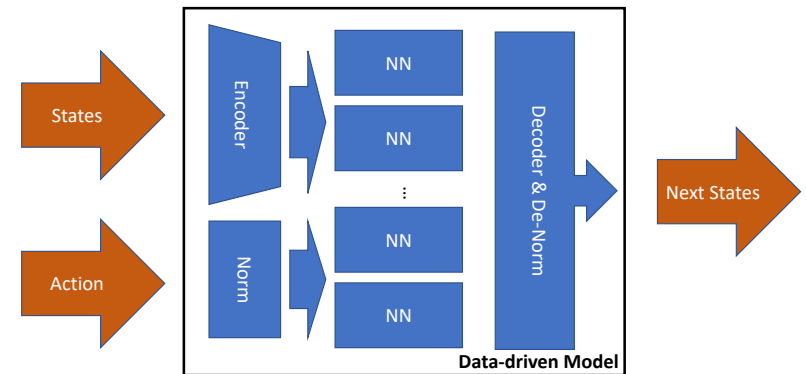


Research Questions

- Can we build a data-driven model from the amount of data?
 - What kind of model should we design?
 - What types of model representation?
- Can reinforcement learning approach provide an assurance in Aeronautics?
 - How to design reward to train the agent properly?
 - How does it link to design a precursor?

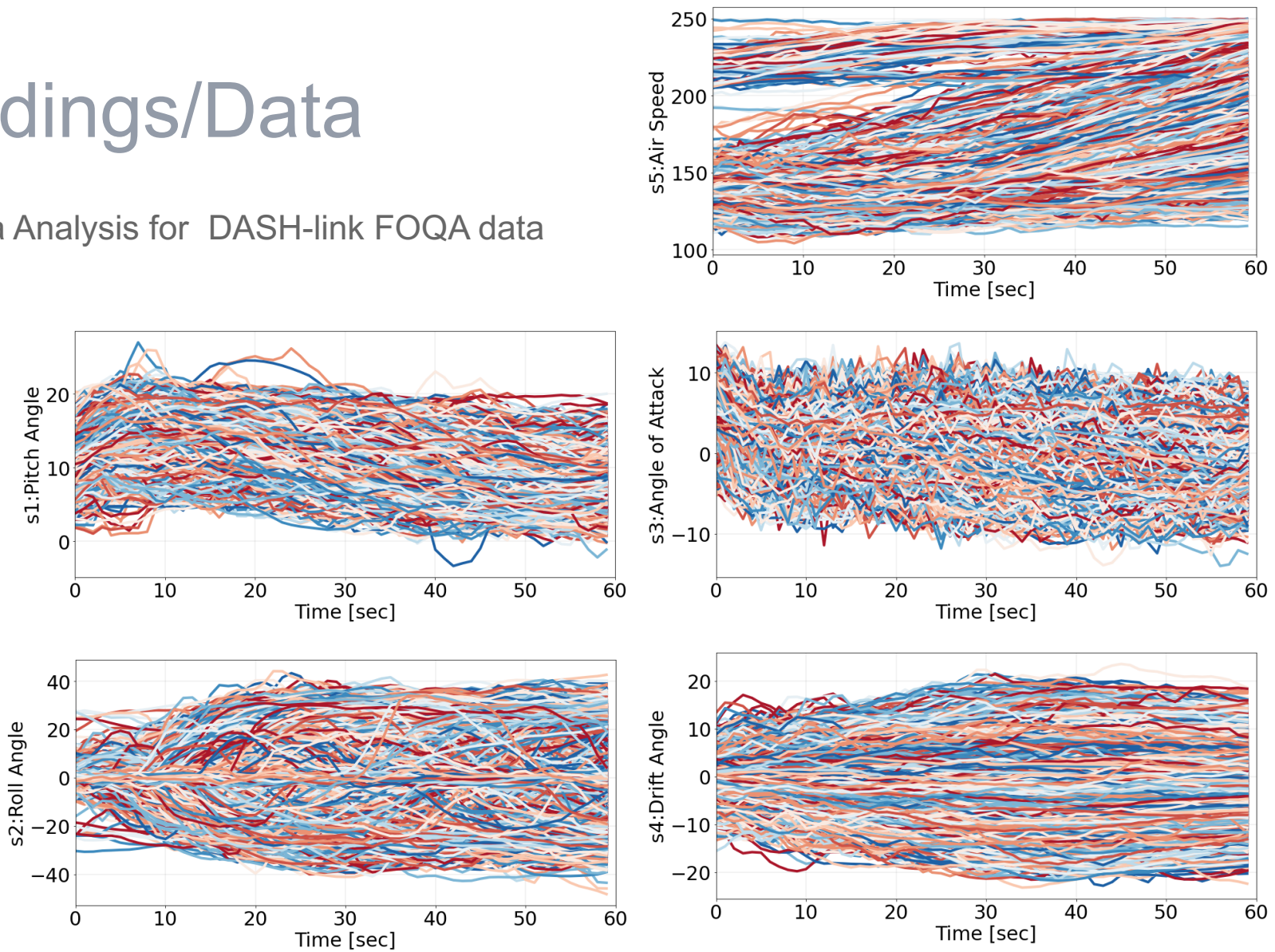
Methods

- Develop data-driven model
 - Define state-space model
 - Train the model with DASH-link data
 - Validate the prediction performance
- Reinforcement Learning
 - Train the agent in order to avoid the anomalies
 - Use Agent as a precursor for anomalies



Findings/Data

- Data Analysis for DASH-link FOQA data



Findings/Data

- Data-driven Flight Simulator (DFS)

DASH GYM

In this tutorial, we show how Data-driven Anomaly Detection Simulator (DADS) is working on the Gym environment.

```
In [11]: import numpy as np
import logz
import gym
import gym_dash
import pandas as pd
import ipdb

# Load simulator
env = gym.make("dash-v0")

print("Action space is discrete?:", env.discrete)
print("Size of states: {}".format(env.observation_space))
print("Size of actions: {}".format(env.action_space))

# Initialize the states with time-series data
example_data_name = './all_drop_DF/658200206070849.csv'
example_data = pd.read_csv(example_data_name)
init_states = env.reset(example_data_name)
```

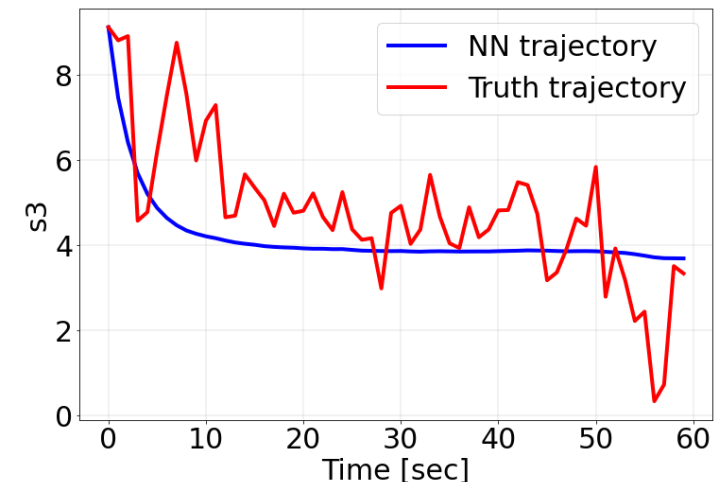
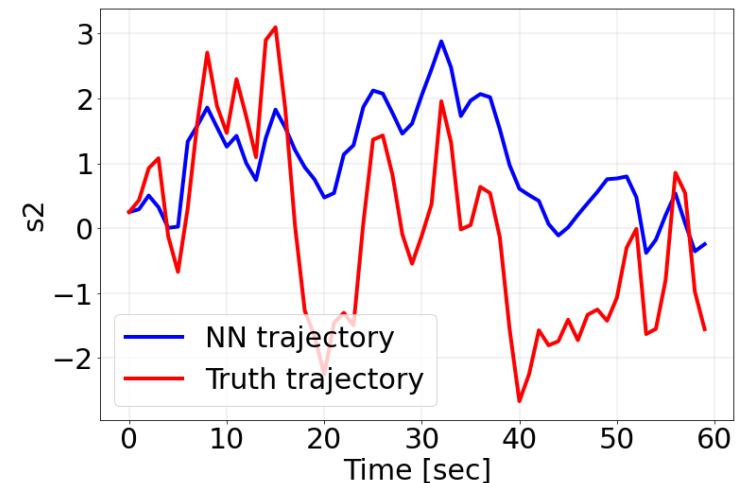
```
Action space is discrete?: False
Size of states: Box(5,)
Size of actions: Box(37,)
```

```
/home/saehong/miniconda3/envs/shp_1/lib/python3.6/site-packages/gym/logger.py:30: UserWarning: WARN: Box bound pre
cision lowered by casting to float32
warnings.warn(colorize('%s: %s'%( 'WARN', msg % args), 'yellow'))
```

```
In [12]: def extract_state_action_from_csv(data):

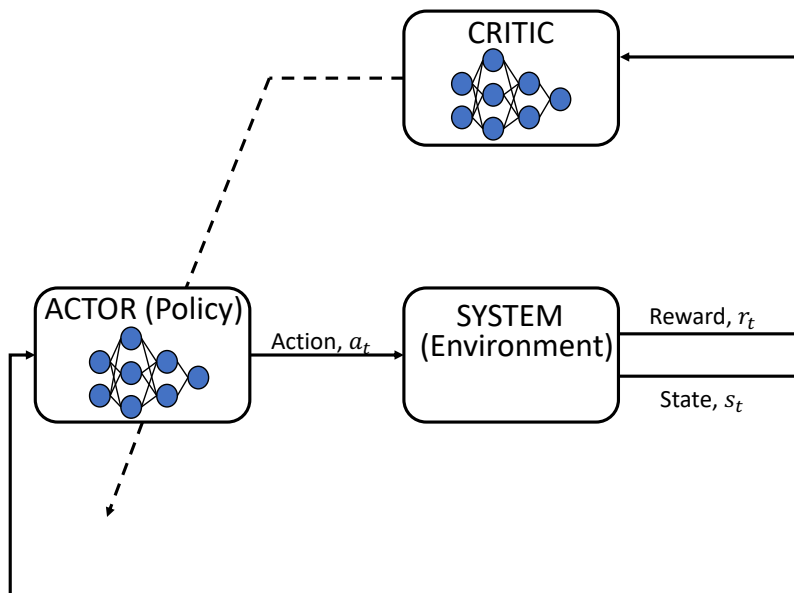
# States
s1 = data['PITCH ANGLE LSP'].tolist()
s2 = data['ROLL ANGLE LSP'].tolist()
s3 = data['CORRECTED ANGLE OF ATTACK'].tolist()
s4 = data['DRIFT ANGLE'].tolist()
s5 = data['COMPUTED AIRSPEED LSP'].tolist()

# Actions
a1 = data['AILERON POSITION LH'].tolist()
a2 = data['AILERON POSITION RH'].tolist()
a3 = data['ELEVATOR POSITION LEFT'].tolist()
a4 = data['ELEVATOR POSITION RIGHT'].tolist()
a5 = data['RUDDER POSITION'].tolist()
a6 = data['T.E. FLAP POSITION'].tolist()
a7 = data['N1 COMMAND LSP'].tolist()
a8 = data['N2 COMMAND LSP'].tolist()
```



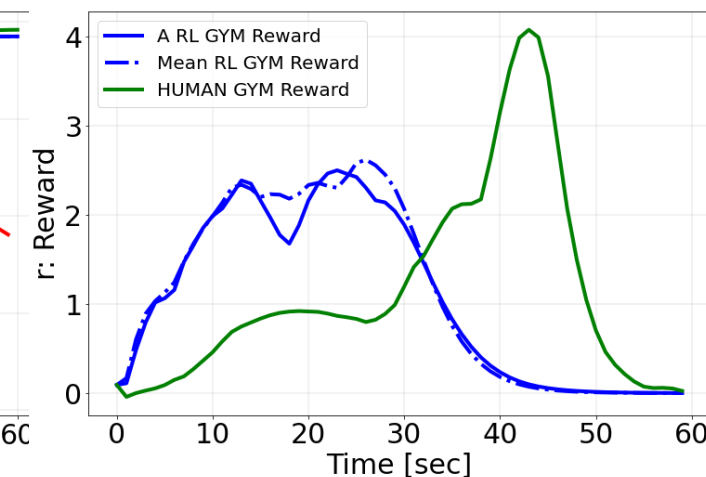
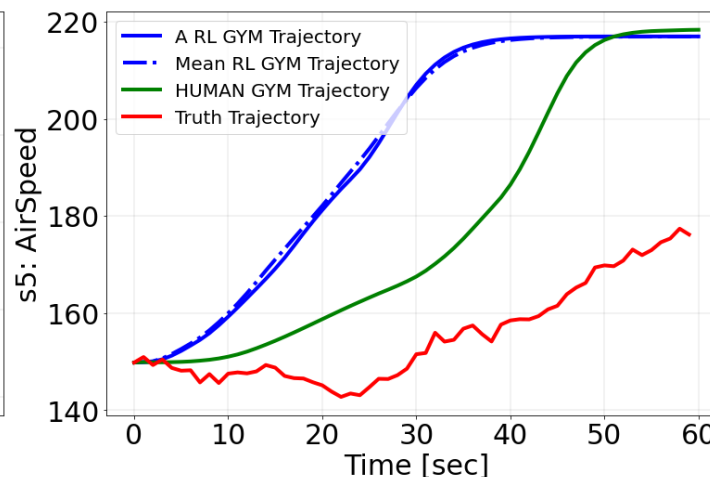
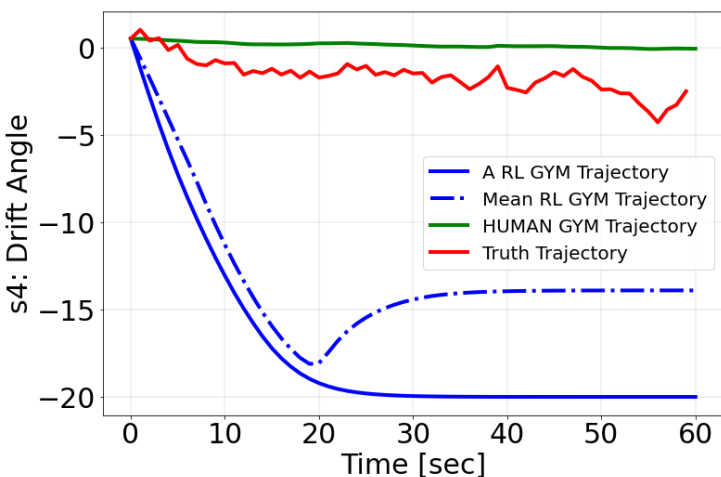
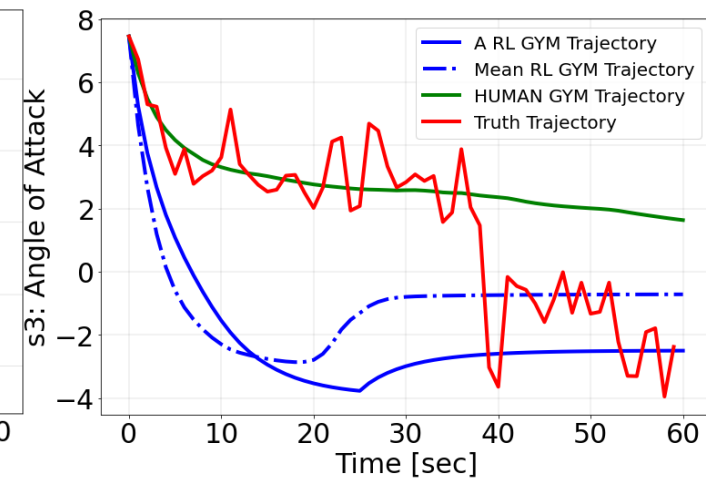
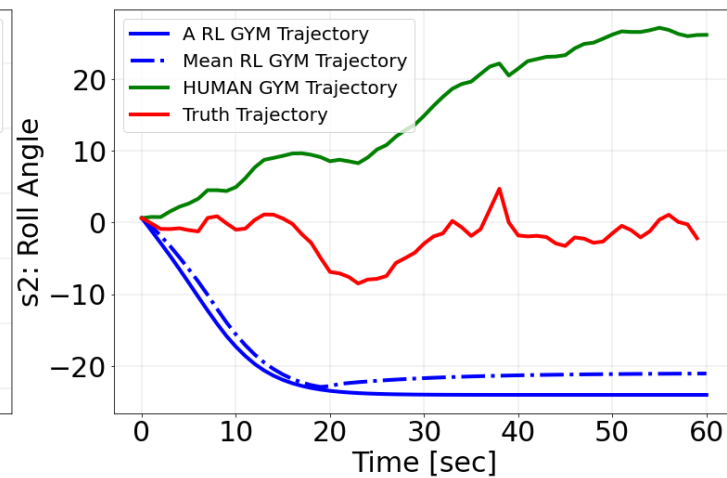
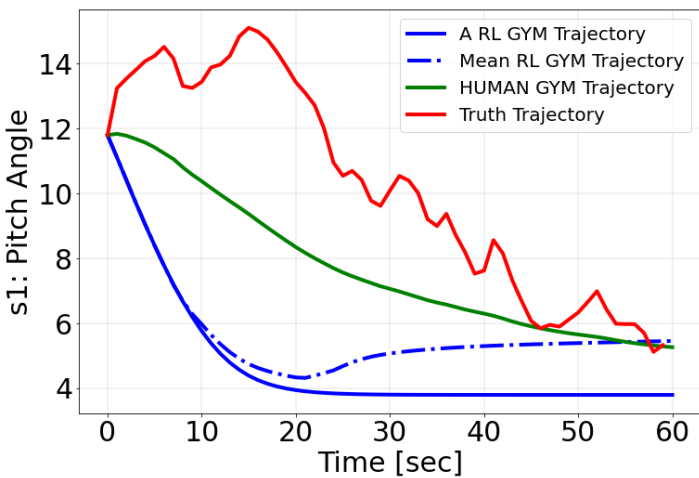
Findings/Data

- Reinforcement Learning
 - Actor-Critic Approach



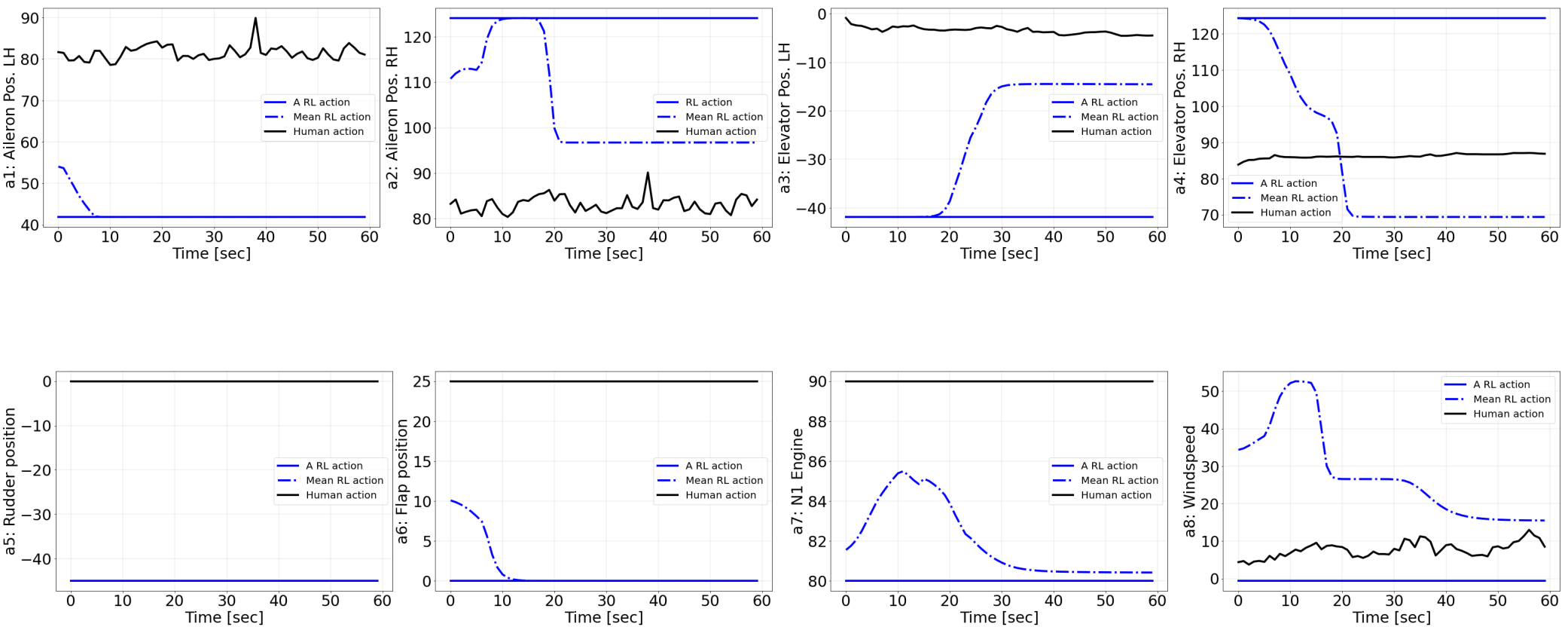
Findings/Data

- Design a precursor



Findings/Data

- Design a precursor



Discussion/Conclusions

- Construct a data-driven model from a large amount of time-series data
- Build a simulator to test RL algorithms
- Train agents to avoid the anomaly and use their actions to design a precursor
- Validate the proposed framework for NASA DASH-link data

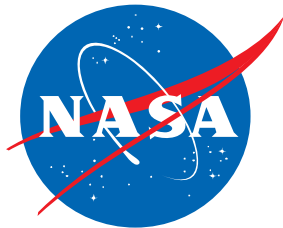
Future Research & Implications

- Improve the simulator in terms of long-term prediction
 - Hybridize the first principle and data-driven model
 - Explore the NN architectures for data-driven model, i.e., recurrent neural network
 - Investigate the noise/disturbance for FOQA data
- Develop RL+Precursor algorithms
 - Combine the long-term prediction and RL-guidance to develop a precursor

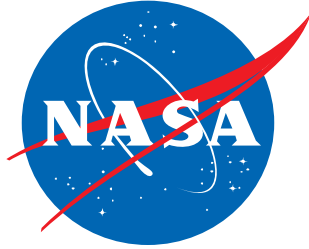
Acknowledgments

I would like to thank:

- My mentors Dr. Milad Memarzadeh (USRA) and Bryan Matthew (Code TI)
- NAMS R&D Student Program: Saba Hussain (Program Manager) and Zeal Panchal (Program Coordinator)



Berkeley
UNIVERSITY OF CALIFORNIA



Design of a Search and Rescue Drone for the US Coast Guard

Felipe Borja¹, Brendon Botchway², Ian Burwell³, Marcos Figueroa⁴, Amol Garg⁵, Jacob Halaweh⁶, Christopher Townsend⁷, Natalie Urieva⁸

¹Virginia Tech, ²University of the District of Columbia, ³Northeastern University, ⁴California State University – Bakersfield,

⁵Cornell University, ⁶Santa Rosa Junior College, ⁷Florida International University, ⁸Cal Poly Pomona

Abstract

Reliably sourced Small Unmanned Aerial System (sUAS) platforms provide unmatched versatility and utility in research and practical applications. Our project goal was to research and design an sUAS for use in U.S. Coast Guard (USCG) Search-and-Rescue (SAR) missions. The sUAS design had to meet USCG criteria on system capabilities and mission parameters. It also had to comply with strict USCG sourcing guidelines. We divided our system into its constituent subsystems and worked on them in subteams. The subteams were: Chassis, Propulsion, Control, Ground Station, and Camera/Payload. Each subsystem was thoroughly researched and designed throughout the course of the summer. This project will continue in the Fall with the goal of physically prototyping all sUAS subsystems to refine them into a mass-producible aircraft for the USCG mission toolbox.

Chassis

- Requirements:** Robust construction, bright (visible) color, beacon and navigation lights, must enclose and protect all avionics, resilient to minor accidents.
- Design Choice:** Custom carbon fiber chassis.
- Characteristics:**
 - Folding design minimizes storage space when sUAS not in use.
 - Sensor mounts and avionics casings made from 3D printed ABS plastic.
 - Extraneous hardware components machined from aluminum.
- Waterproofing:** Foam enclosure and conformal coating on electronic components.

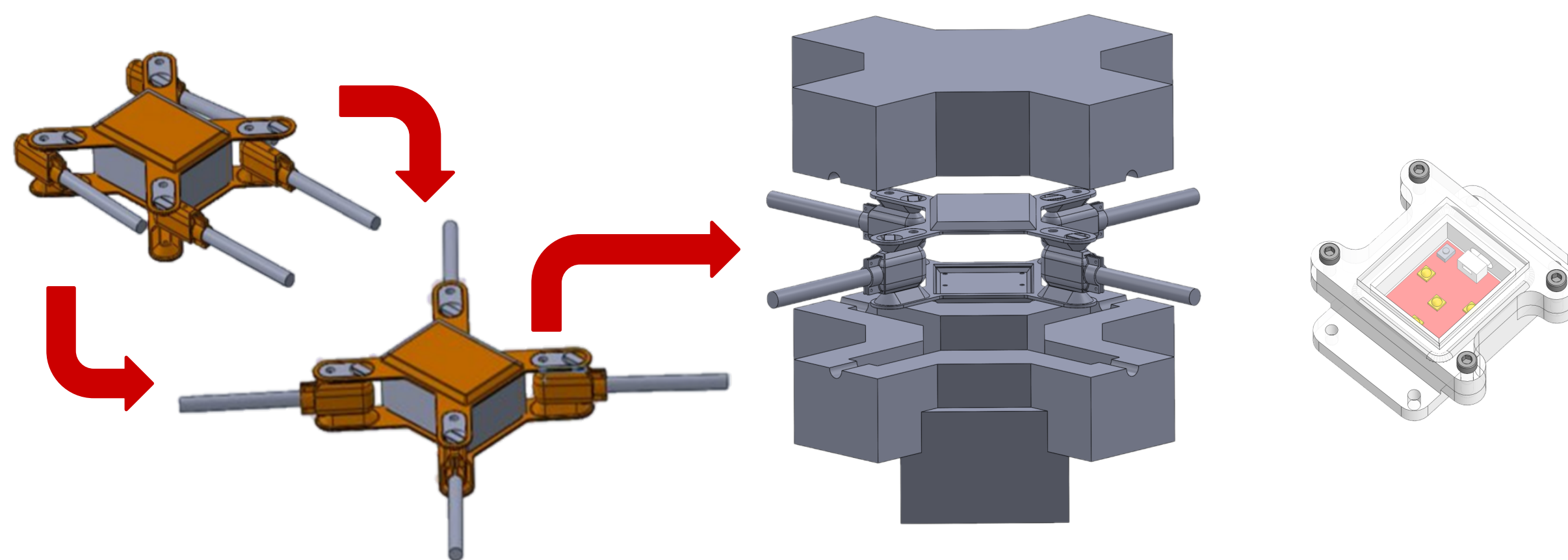


Figure 1: Chassis components. (Left) Arms lock outwards for deployment. (Center) Foam enclosure provides waterproofing and mild impact resistance. (Right) Beacon and navigation lights enclosed in custom waterproof housings and fastener to chassis exterior.

Propulsion

- Requirements:** 40-minute flight time in ideal conditions, operable in 30-knot wind conditions, ability to carry 5-lb payload.
- Design Choice:** Quadrotor configuration with 18" propellers.
- Characteristics:**
 - T-Motor MN5006 motors (300 RPM).
 - 18650 Lithium Ion Cells (24-count).
- Prototyping and Testing:** The propulsion system was developed based on theoretical calculations done in eCalc motor simulation software and thus requires physical testing.

Control

- Requirements:** Semi-autonomous sUAS capabilities, digital signal transmission, NDAA compliance.
- Design Choice:** Auterion Skynode Flight Controller.
- Characteristics:**
 - Provides complete control over a sUAS, utilizing the PX4 Enterprise firmware.
 - NDAA compliant. Government version manufactured in the U.S.
 - Provides all-in-one complete control solution and fleet management.

Ground Station

- Requirements:** Easily pilotable from a moving and rocking boat, detachable screen, ability to input search coordinates.
- Design Choice:** Custom all-in-one ground control unit.
- Characteristics:**
 - 8" Touchscreen monitor.
 - Digital video transmission.
 - First Person View (FPV) video display.

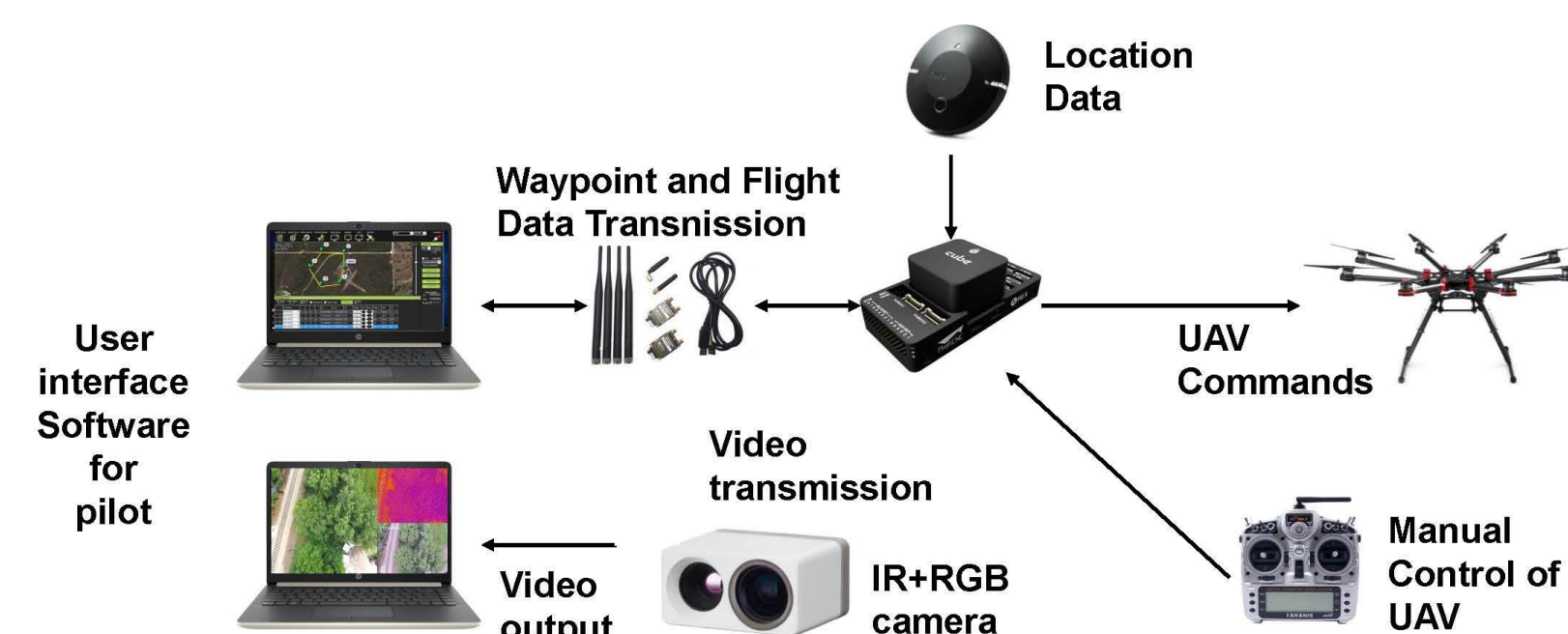
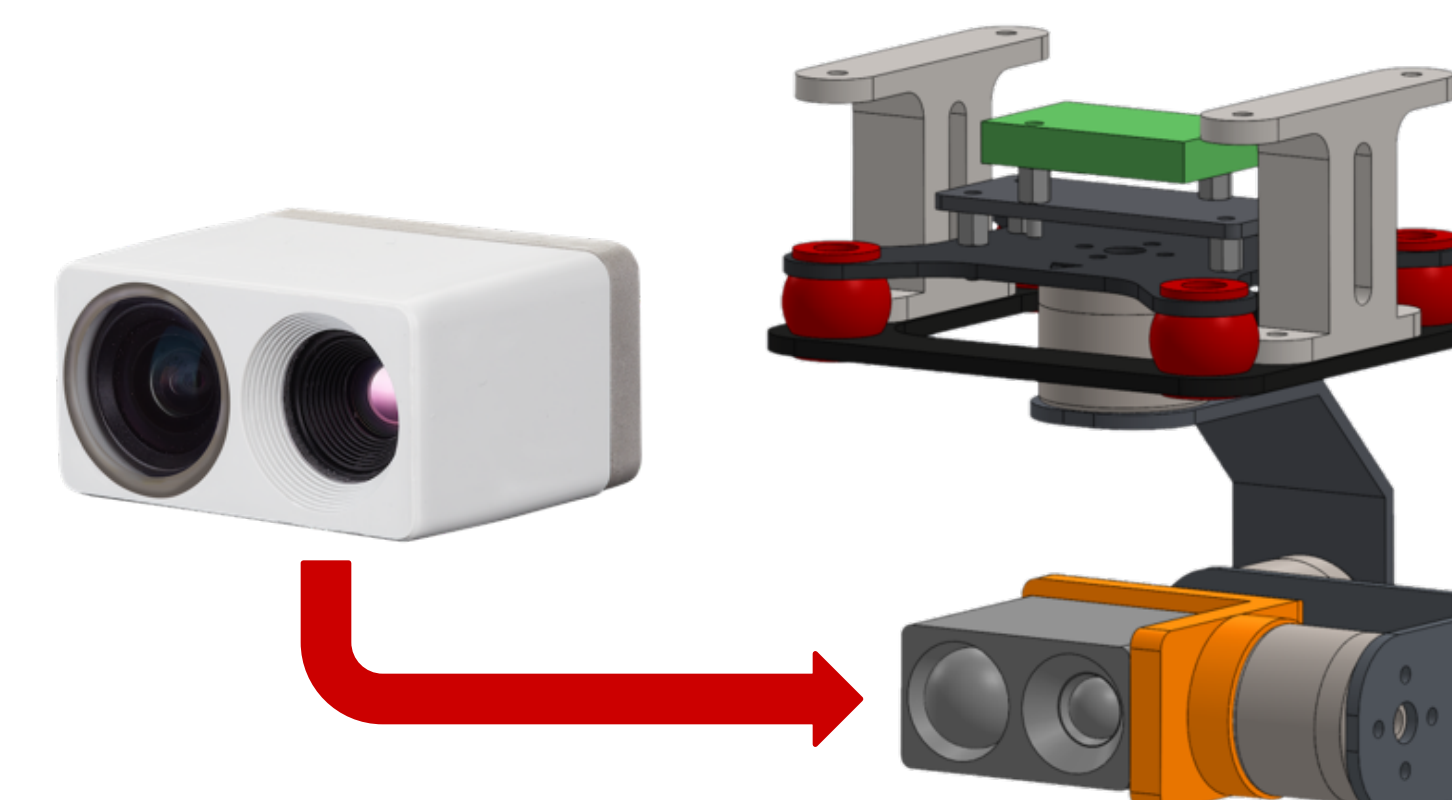


Figure 2: Flow diagram for subsystem communications and overall sUAS control.

Camera

- Camera Requirements:** 4K RGB Camera, IR Camera for identifying people in water, weatherproof construction, stable footage.
- Design Choice:** FLIR Hadron mounted on custom gimbal.
- Camera Characteristics:**
 - 2-in-1 RGB/IR: Allows for sensor image integration.
 - 4K+ RGB Camera, 320 x 256 IR Camera.
 - Requires use of Raspberry Pi Zero companion computer.
- Gimbal Characteristics:**
 - 3-axis gimbal provides full range of camera stabilization and actuation.
 - Costs around \$300 which is competitive to non-Chinese off-the-shelf models.
 - Carbon fiber and machined aluminum frame is sturdy and lightweight.

Figure 3: A FLIR Hadron 2-in-1 RGB/IR camera will be mounted on a custom 3-axis gimbal to the bottom of the sUAS chassis. Vibration dampers isolate the camera and gimbal from high-frequency vibrations affecting the rest of the sUAS. Actuation along roll, pitch, and yaw axes stabilizes video feed and allows for manual control of camera orientation.



Payload

- Requirements:** Accurately drop Type-5 Personal Flotation Device (PFD) and waterproof two-way radio to a person awaiting rescue in the water below the sUAS.
- Design Choice:** Spiral hook mechanism actuated by a waterproof servo.
- Characteristics:**
 - Payloads hang on spiral hook until electrical actuation at moment of release.
 - Minimal torque required since mechanical load close to servo's axis of rotation.



Figure 4: Payload components. (Left) Two-way radio and Type-5 PFD are deployed in rescue operations via (Right) servo-actuated spiral hook mechanism

Sourcing

Our system was originally intended to be built solely with U.S. sourced parts and 3D-printing. The USCG changed this sourcing requirement after initial trade-space exploration yielded a substantial lack of US-manufactured sUAS parts (most notably motors, servos, and gimbal controllers). Our current sourcing criteria allow parts that comply with the National Defense Authorization Act (NDAA) and USCG procurement guidelines. Our sUAS design is fully compliant with these conditions.

Conclusion & Next Steps

Project Impact:

- Our design is a powerful new tool in the USCG's search-and-rescue toolbox.
- Increased operational flexibility will save lives.
- Reliable supply chain reduces U.S. reliance on foreign parts.
- Low-cost solution makes our design easily sourced.
- Work on sourcing transferrable to other sUAS applications (i.e. NASA, DOE, etc.).

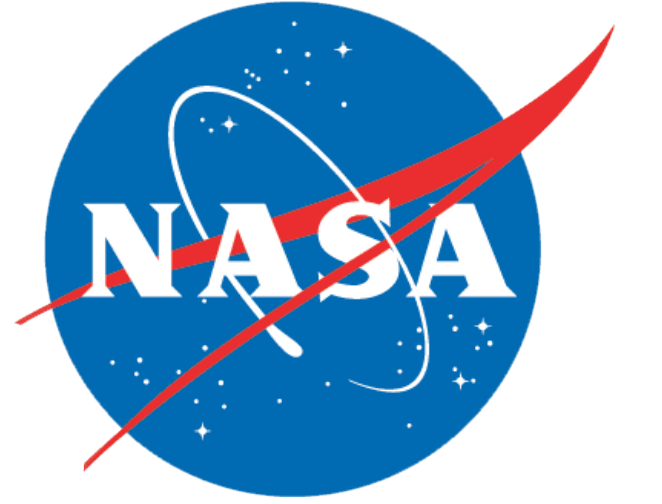
Future work for this project includes:

- Physical prototyping of several of the subsystems to refine their design.
- Fine-tuning of physical components to ensure a well-balanced sUAS.
- Final production and electronics integration of complete sUAS prototype.
- Test flights with the USCG to analyze mission performance.

Acknowledgements

Special thanks to:

Commander Paul Miller (USCG), Ensign Sarah Levesque (USCG), Dr. Parimal Kopardekar (NASA/NARI), Chris Clark (NARI), Dr. David Murakami (NASA), Jonathan La Plain (NASA), Dr. David Bell (USRA), Saba Hussain (USRA), Zeal Panchal (USRA) For their valuable contributions of time, guidance, and mentorship.



Predicting Flight Delays with Supervised Machine Learning

Eric Chen¹, Milad Memarzadeh², and Tyler Ngo²

1 University of California, Los Angeles; 2 Universities Space Research Association

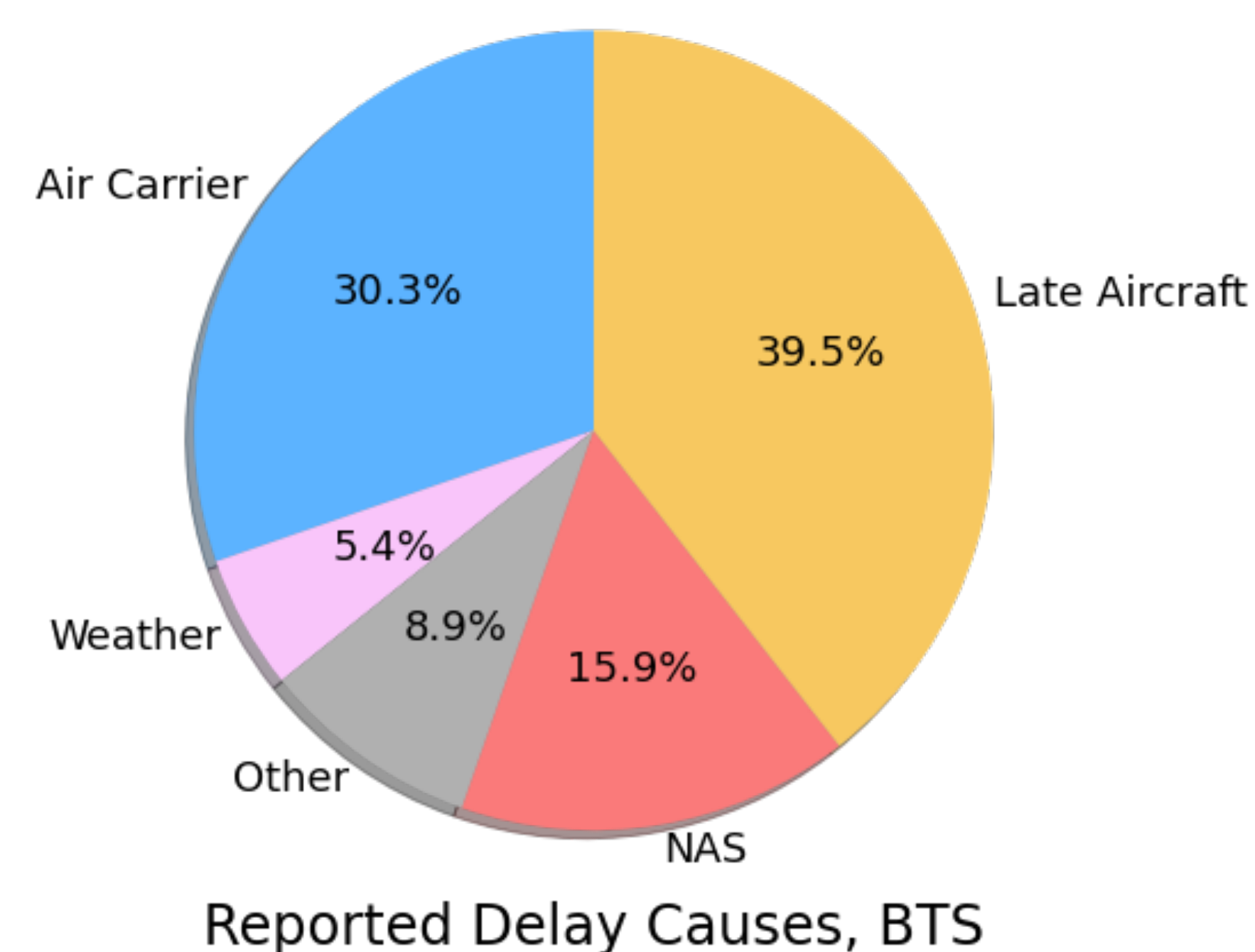
Abstract

Flight delays cost passengers and air carriers money and time. An accurate delay prediction model would reduce the harmful effects of flight delay by enabling improved planning and awareness. The goal of this project is to train supervised machine learning models to predict departure delay and to determine the accuracy of each model.

Data

Overview:

A total of 65 continuous and categorical data features were extracted from the US Bureau of Transportation and NOAA Local Weather datasets from April 2019.



Model Selection:

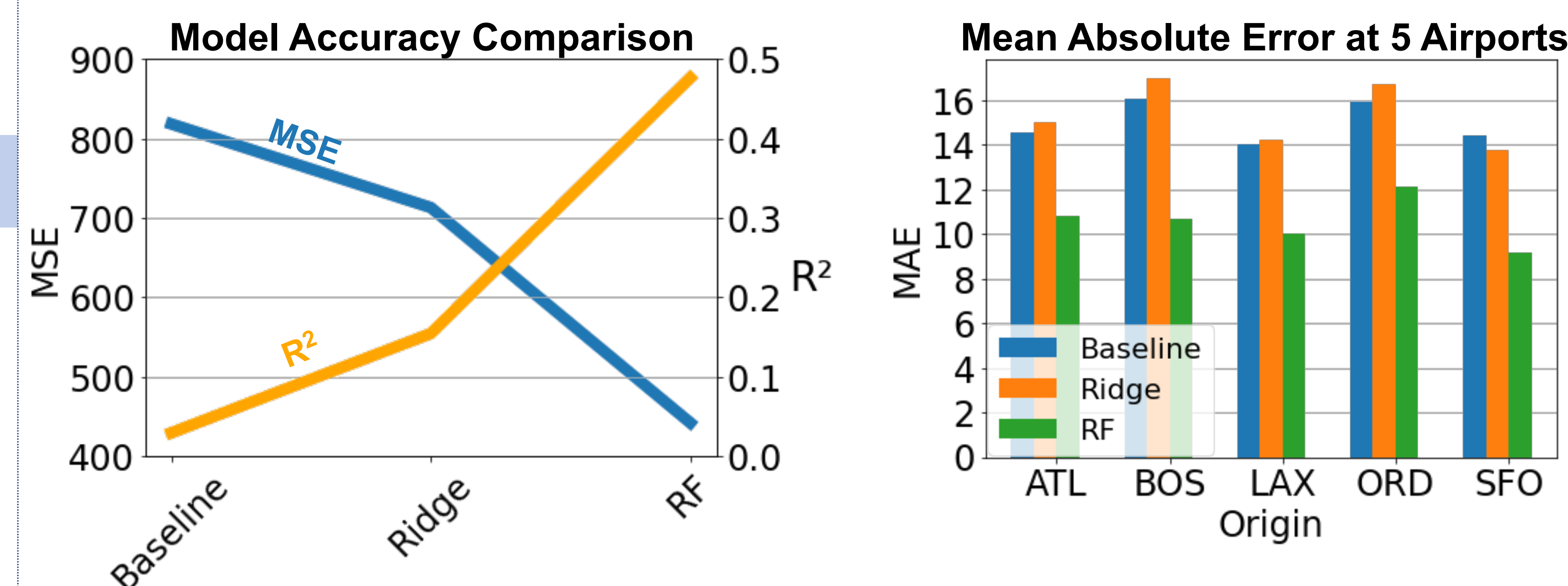
1. Data normalization and missing value imputation
2. Split into 80% training and validation, 20% testing
3. 5-fold, cross-validated hyperparameter optimization

Assumptions:

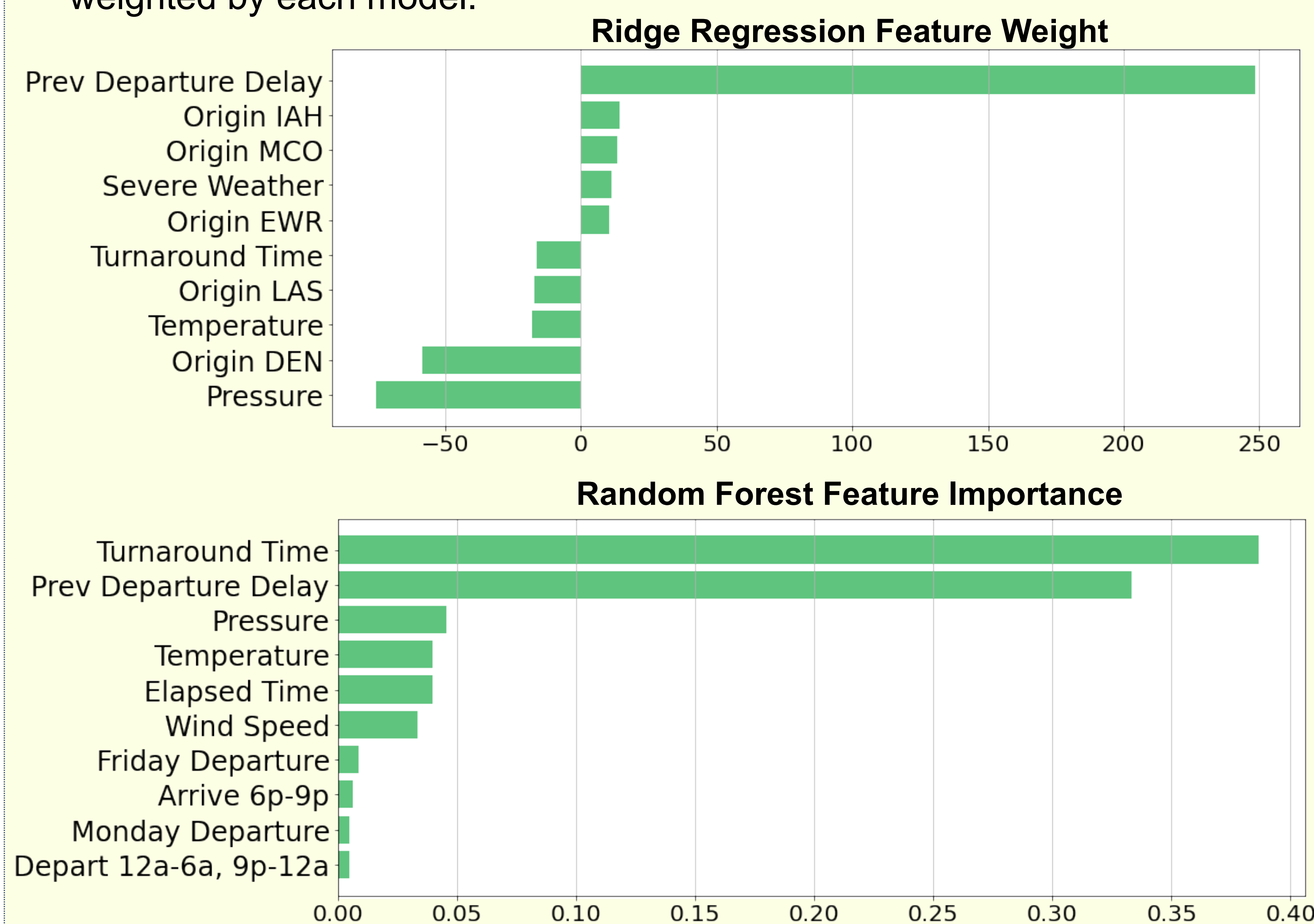
- Flights with over 200 minutes of delay filtered out
- Flights involving an airport with less than 10,000 flights in the dataset filtered out

Results

Various linear and non-linear models were tested. Figures below show results for one linear model (**ridge regression**), one non-linear model (**random forest regression**), and a **naïve baseline model** which predicts each flight's delay to be the average delay at its origin airport in the preceding hour.



Feature importance plots reveal which features are most heavily weighted by each model.



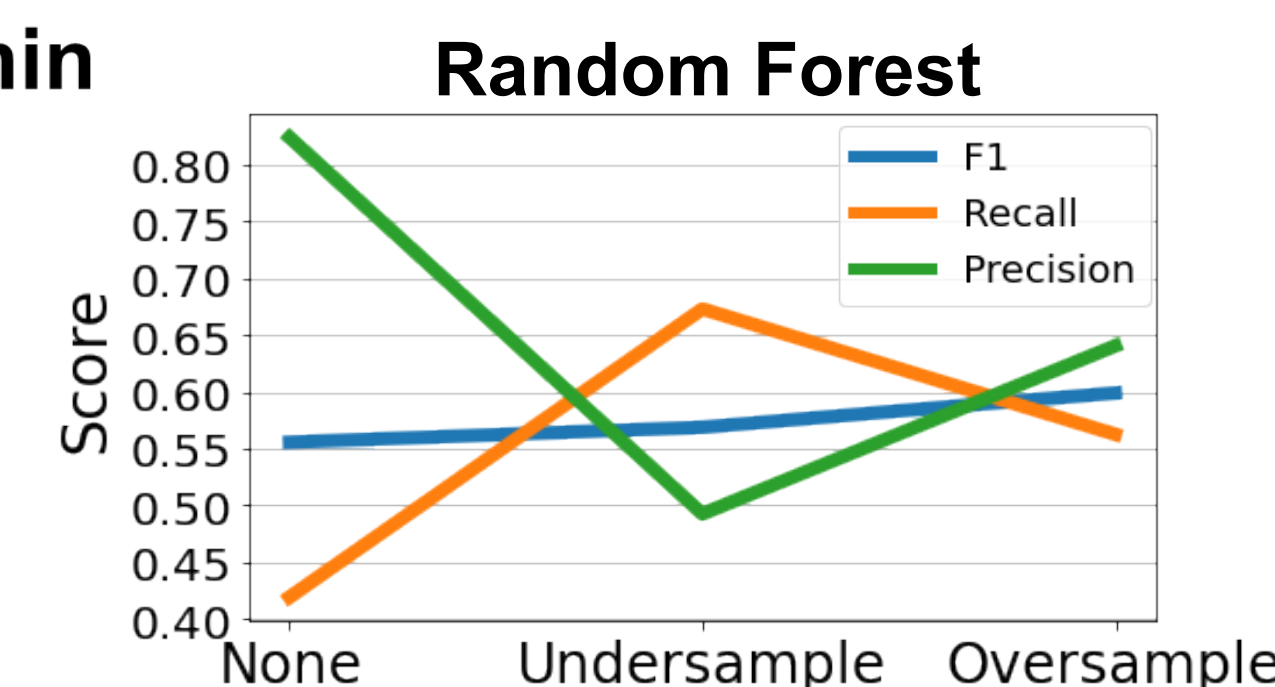
Delay Classification

Positive Class: Delay > 15 min

$$\text{Precision} = \frac{TP}{TP+FP}$$

$$\text{Recall} = \frac{TP}{TP+FN}$$

$$F1 = \frac{2 * \text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}$$



Conclusions

The **random forest regression** model achieved:

- Mean absolute error = 10.8 min
- $R^2 = 0.48$
- 46% reduction in MSE compared to baseline

Key features: turnaround time, previous flight departure delay.

The **random forest classification** model with random over-sampling achieved:

- $F1 = 0.60$

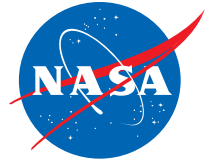
Future Improvements

- Use deep neural networks to capture complex non-linear relationships
- Gather more data including features like "aircraft arrival acceptance rate"

Impact

- Spark new questions and ideas for flight delay prediction
- Adopted for Aviation Data Science Course
- Improved Python coding and readability
- Learned highly-applicable data science and machine learning techniques

Thank you so much to my mentors Milad Memarzadeh and Tyler Ngo, to the NAMS Student R&D program's Saba Hussain, Zeal Panchal, and to Dr. David Bell for this awesome opportunity.



Improving randomized benchmarking for quantum computers

Jahan Claes

University of Illinois, Urbana-Champaign

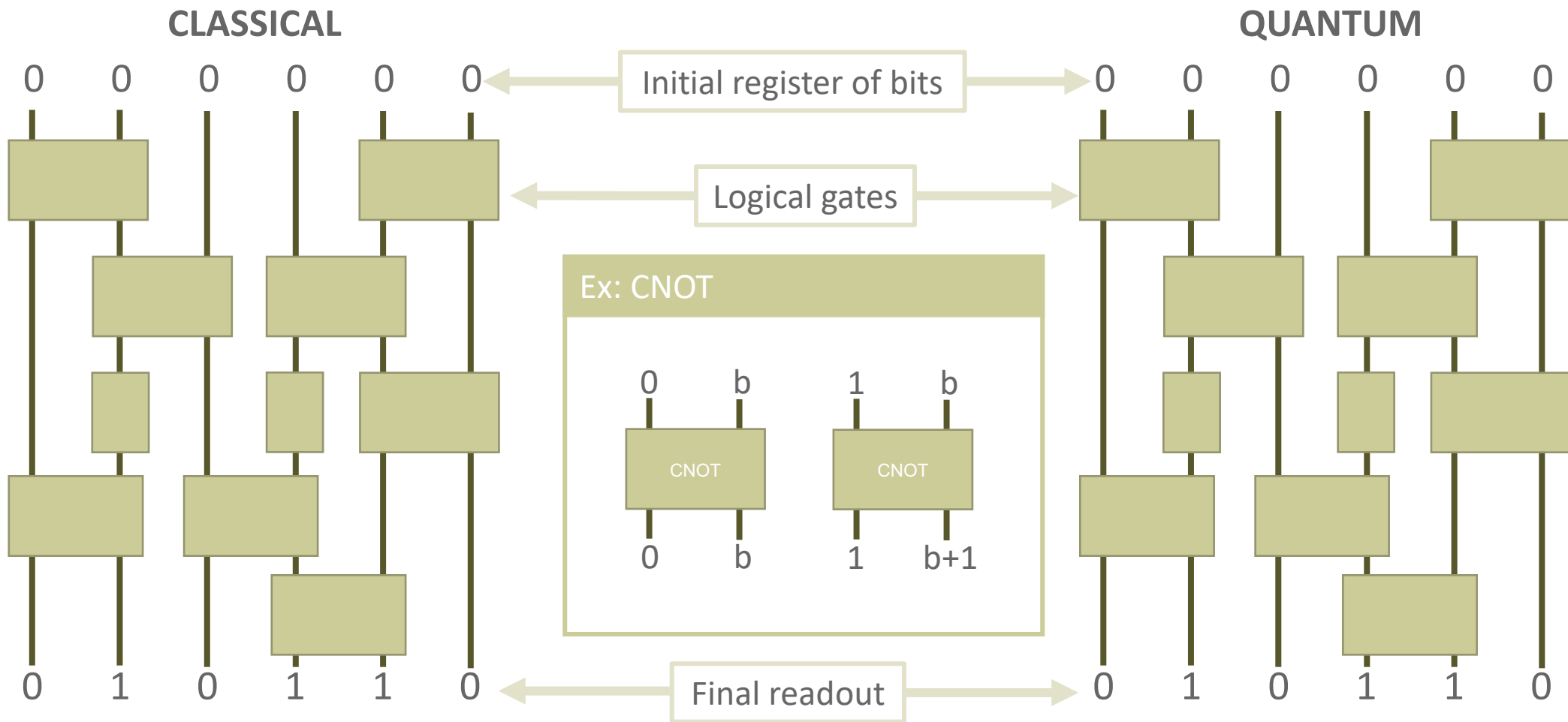
Zhihui Wang, QuAIL group

Summer 2020

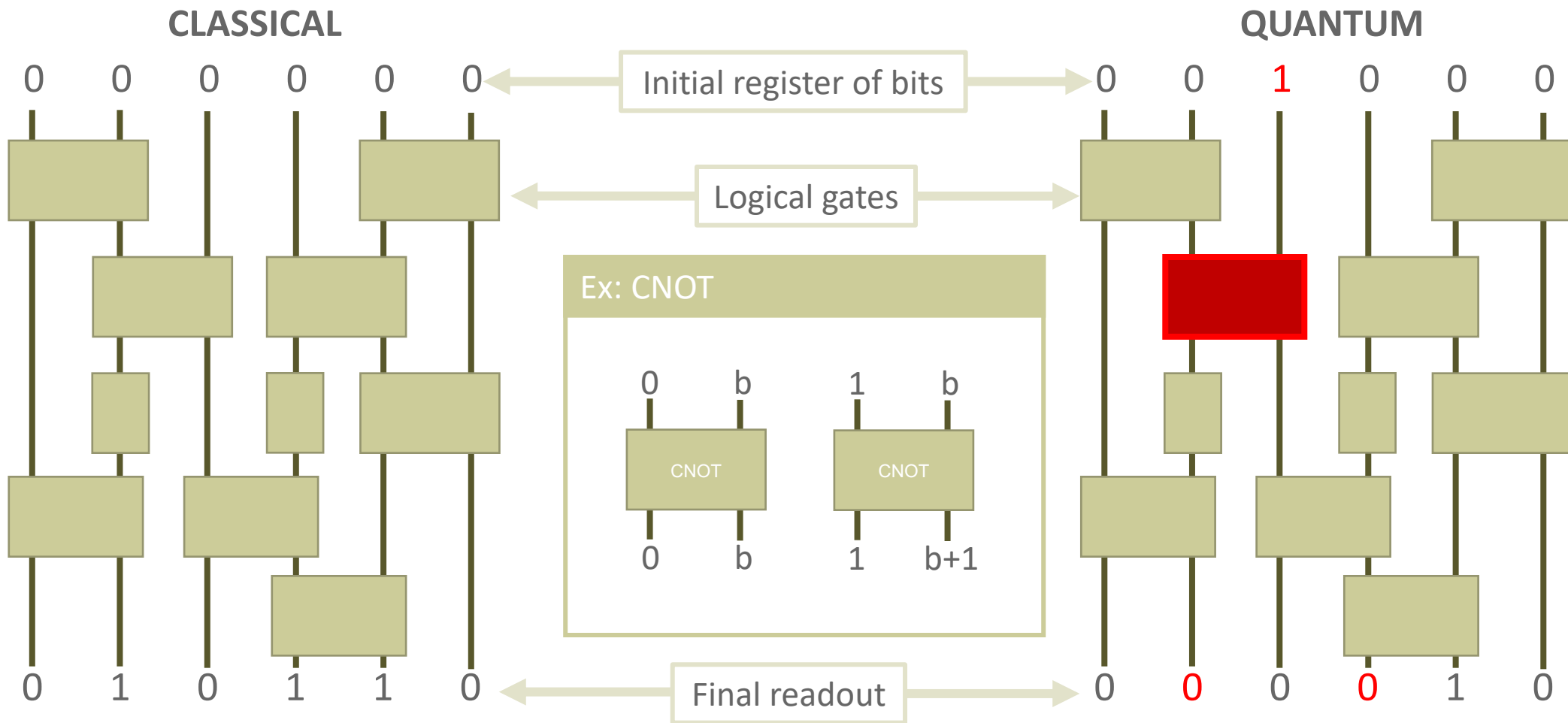


UNIVERSITY OF
ILLINOIS
URBANA-CHAMPAIGN

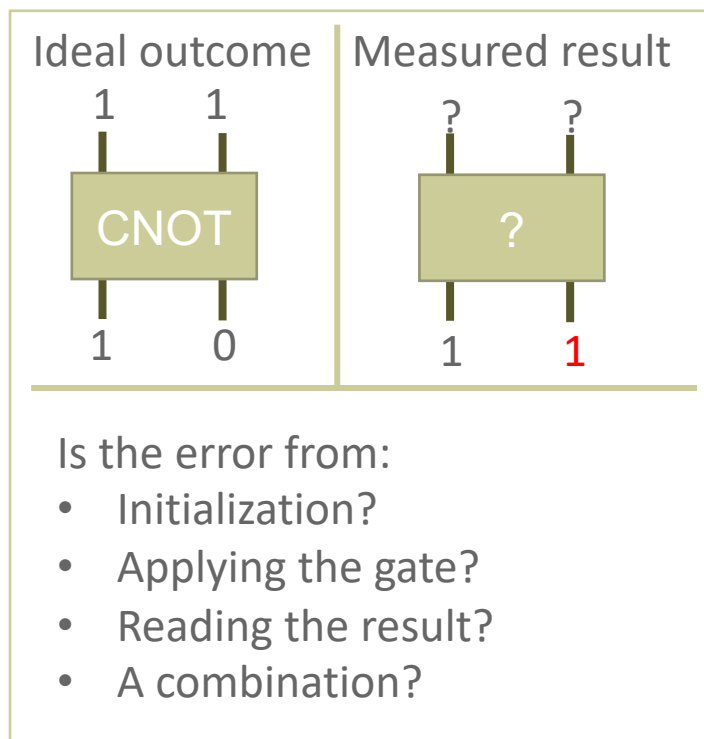
Introduction: What is a computer?



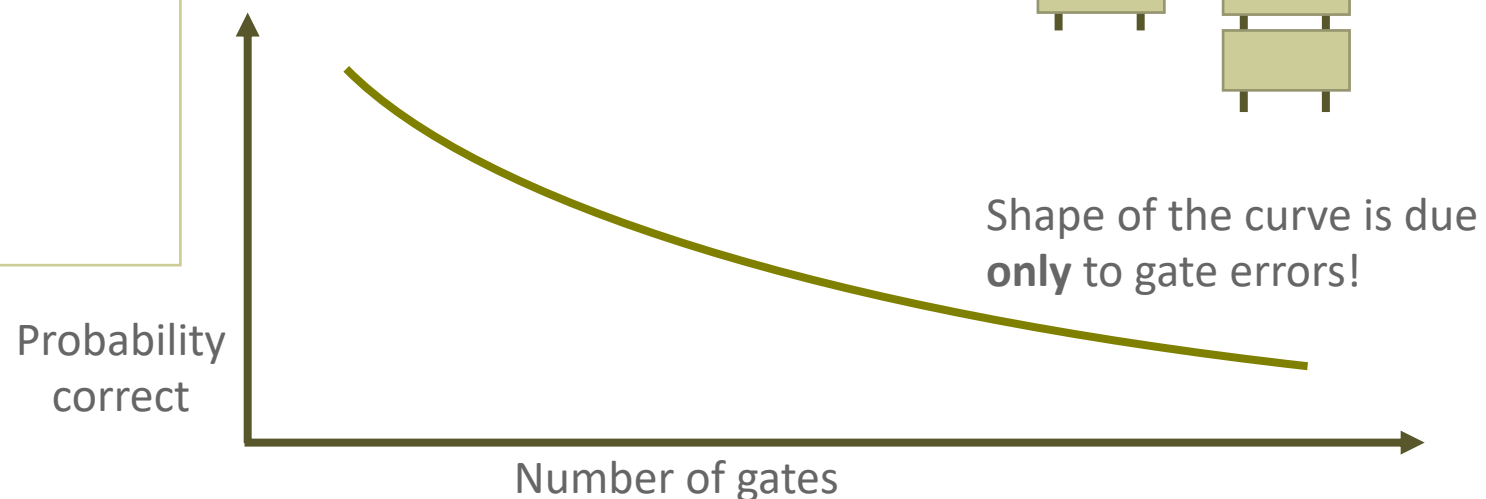
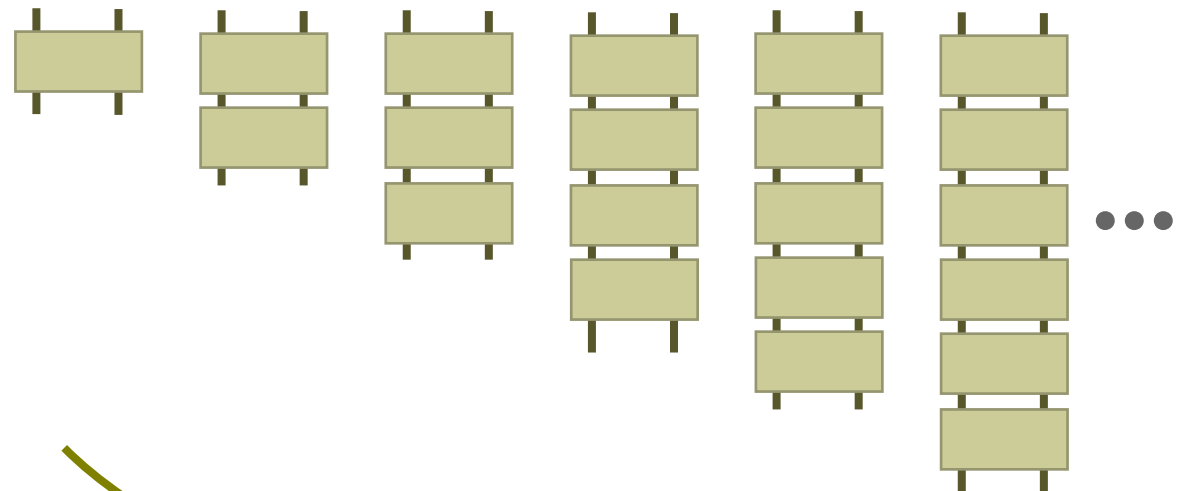
Introduction: Quantum computers have **errors**



Introduction: How to determine just the gate errors?

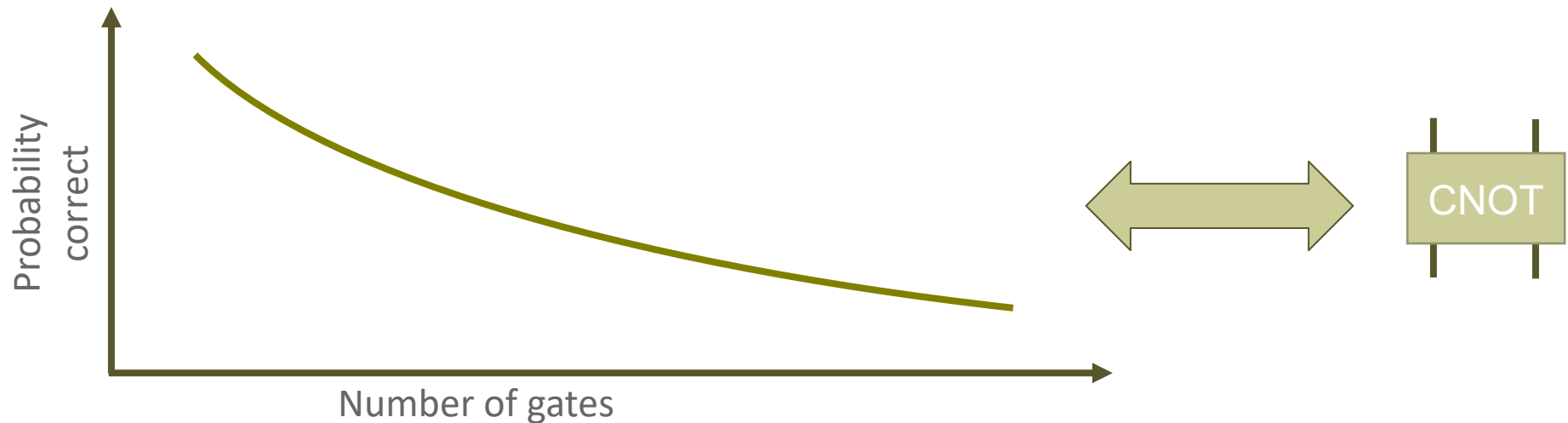


Solution: Consider longer sequences!



Background of Project / Literature Review

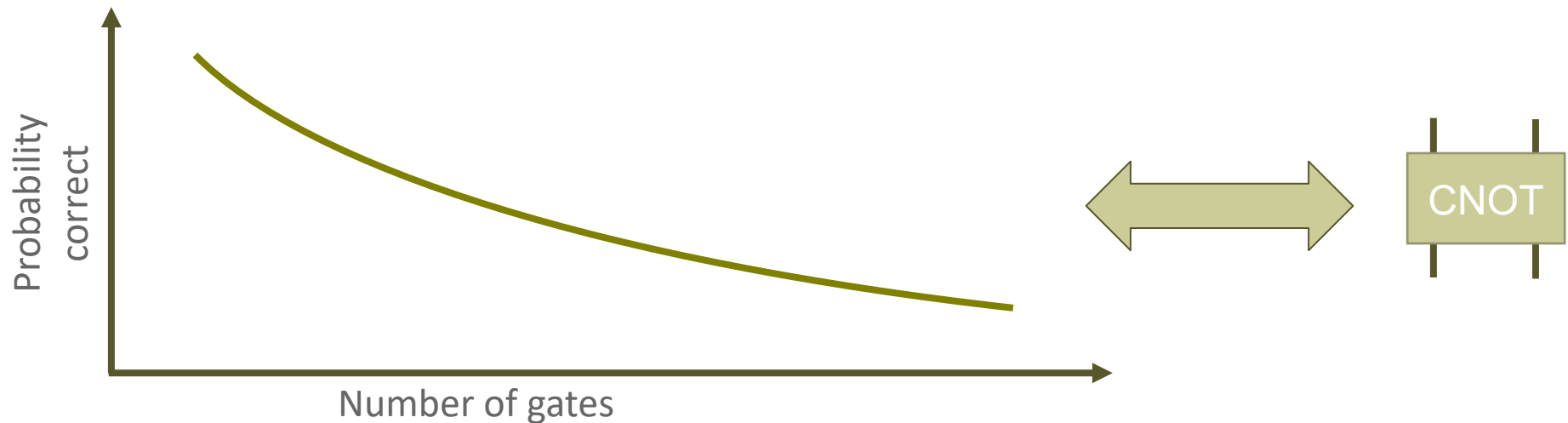
- Methods to relate the shape of the probability curve to the gate error are called **Randomized Benchmarking** [1-4]



- Randomized benchmarking only works for **certain groups of gates**, but work is being done to extend it to other groups[5-9].

Research Questions

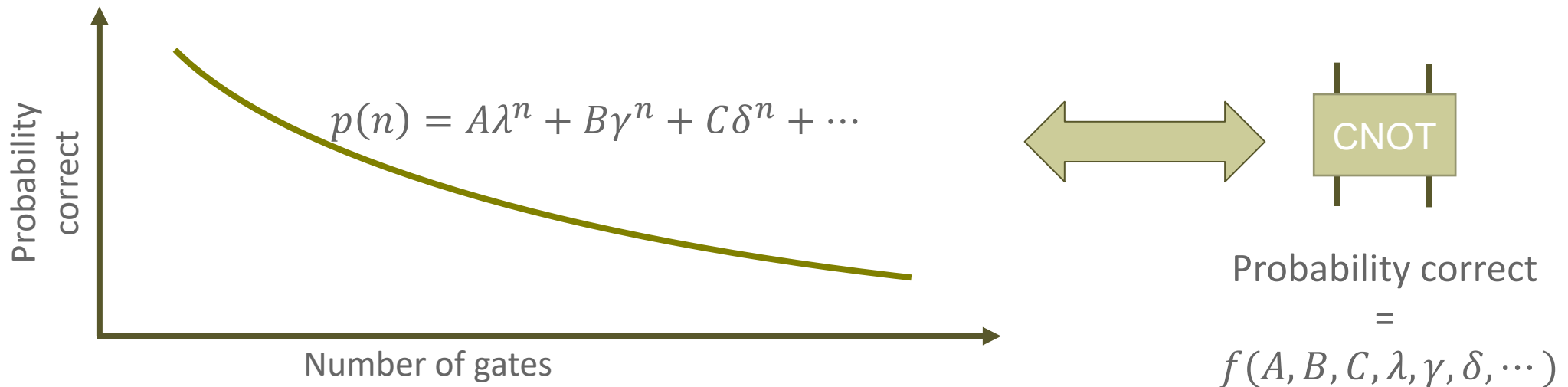
- Is there a way to relate the shape of the probability curve to gate errors for arbitrary groups of gates?



- When is this relation useful? What additional gates can be characterized with this method?

Methods

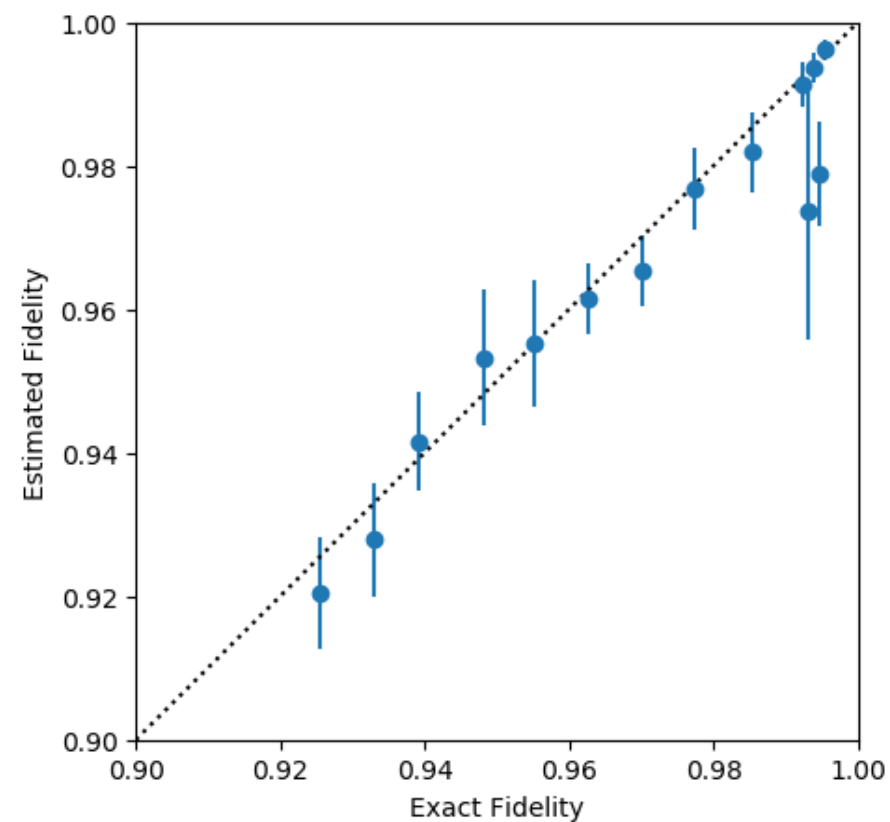
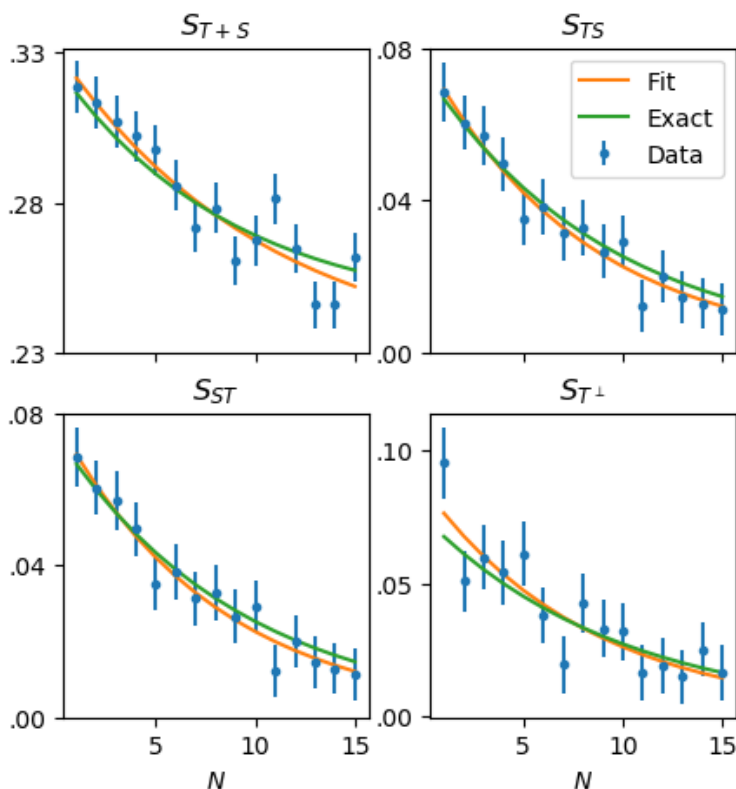
- Generalize the representation theory method developed in [9] to find functional forms for the probability decay curve



- Find specific groups where the number of parameters $A, B, C, \lambda, \gamma, \delta, \dots$ is small enough to be experimentally determined
- Perform simulations of a quantum computation to verify the method

Findings/Data: Preliminary example

- Honeywell recently studied a group of gates that could not be benchmarked by traditional methods [11]
- Using our method, we can determine their gate errors



Discussion/Conclusions/Future Work

- We have developed a method for benchmarking arbitrary groups
- We are currently studying examples of groups that have not been previously benchmarked, but where our method is feasible
- Future work involves expanding the number of examples and exploring the robustness of the method

Lessons Learned

- Learned about the state-of-the-art for benchmarking quantum computers
- Learned about error models for quantum computing
- Learned about the quantum computing research community
- Developed code for modelling quantum computers

Acknowledgments

Thank you to my mentor, Dr. Zhihui Wang, for advice, direction and encouragement.

Thank you to the head of the QuAIL group, Dr. Eleanor Rieffel, for organizing the research program and taking a personal interest in this work

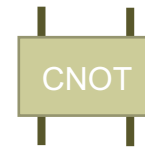
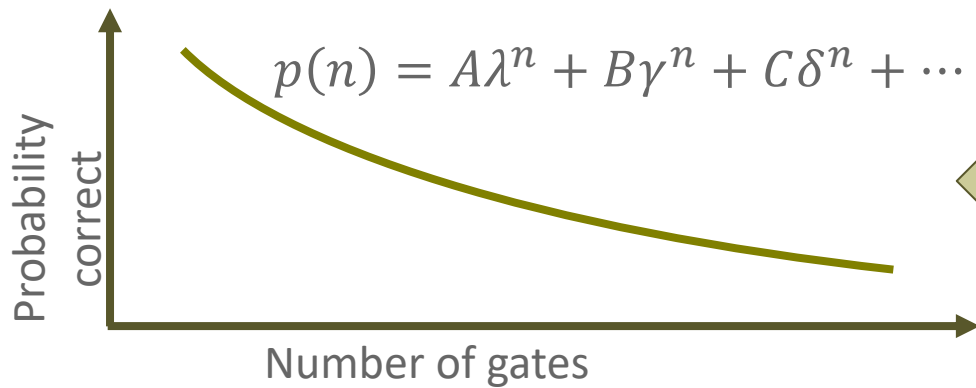
Thank you to Dr. Jeffrey Marshall for bringing me to the program and helping me choose a project

Thank you to everyone at NASA QuAIL for their questions and conversations

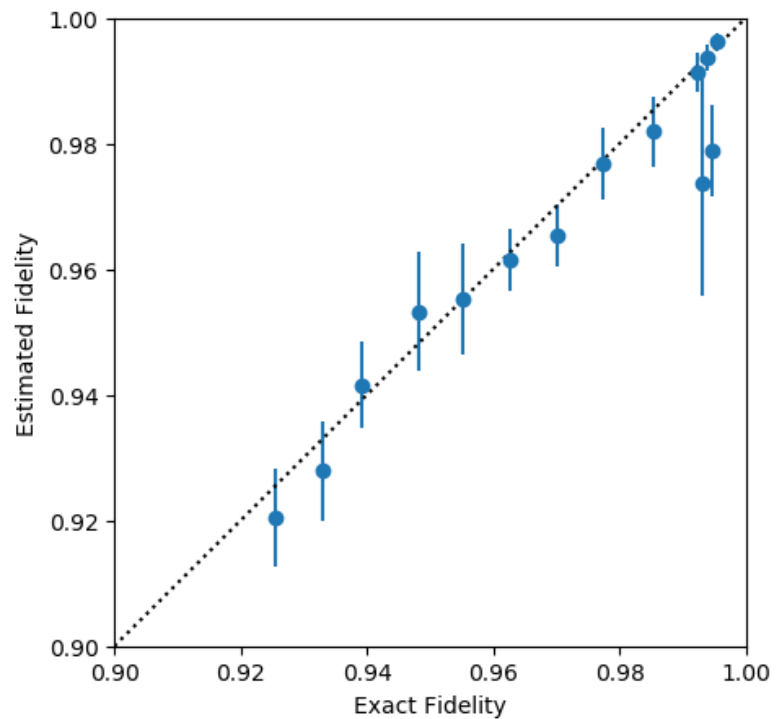
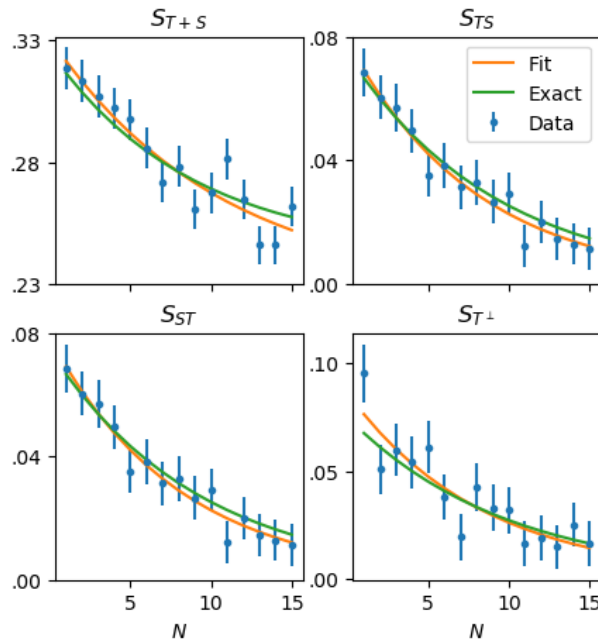
References

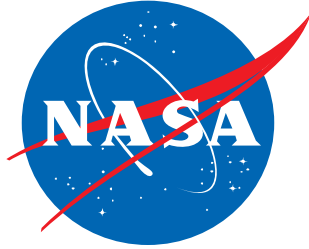
1. J. Emerson, R. Alicki, and K. Życzkowski, Scalable noise estimation with random unitary operators, *Journal of Optics B: Quantum and Semiclassical Optics* 7, S347(2005).
2. E. Knill, D. Leibfried, R. Reichle, J. Britton, R. B. Blakestad, J. D. Jost, C. Langer, R. Ozeri, S. Seidelin, and D. J. Wineland, Randomized benchmarking of quantum gates, *Physical Review A* 77, 012307 (2008).
3. E. Magesan, J. M. Gambetta, and J. Emerson, Scalable and robust randomized benchmarking of quantum processes, *Physical Review Letters* 106, 180504 (2011).
4. E. Magesan, J. M. Gambetta, and J. Emerson, Characterizing quantum gates via randomized benchmarking, *Physical Review A* 85, 042311 (2012).
5. A. Carignan-Dugas, J. J. Wallman, and J. Emerson, Characterizing universal gate sets via dihedral benchmarking, *Physical Review A* 92, 060302 (2015).
6. A. W. Cross, E. Magesan, L. S. Bishop, J. A. Smolin, and J. M. Gambetta, Scalable randomised benchmarking of non-Clifford gates, *npj Quantum Information* 2, 1 (2016).
7. W. G. Brown and B. Eastin, Randomized benchmarking with restricted gate sets, *Physical Review A* 97, 062323 (2018)
8. D. S. Franca and A. Hashagen, Approximate randomized benchmarking for finite groups, *Journal of Physics A: Mathematical and Theoretical* 51, 395302 (2018).
9. J. Helsen, X. Xue, L. M. Vandersypen, and S. Wehner, A new class of efficient randomized benchmarking protocols, *npj Quantum Information* 5, 1 (2019).
10. C. Baldwin, B. Bjork, J. Gaebler, D. Hayes, and D. Stack, Subspace benchmarking high-fidelity entangling operations with trapped ions, *Physical Review Research* 2, 013317 (2020).

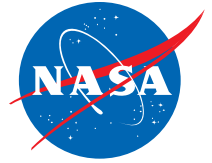
Questions?



Probability correct
=
 $f(A, B, C, \lambda, \gamma, \delta, \dots)$







A Machine Learning Approach to Predicting Urban Noise via Satellite Imagery

Emily Deardorff

San Diego State University

Dr. Meytar Sorek-Hamer, Environmental Analytics Group

Summer 2020

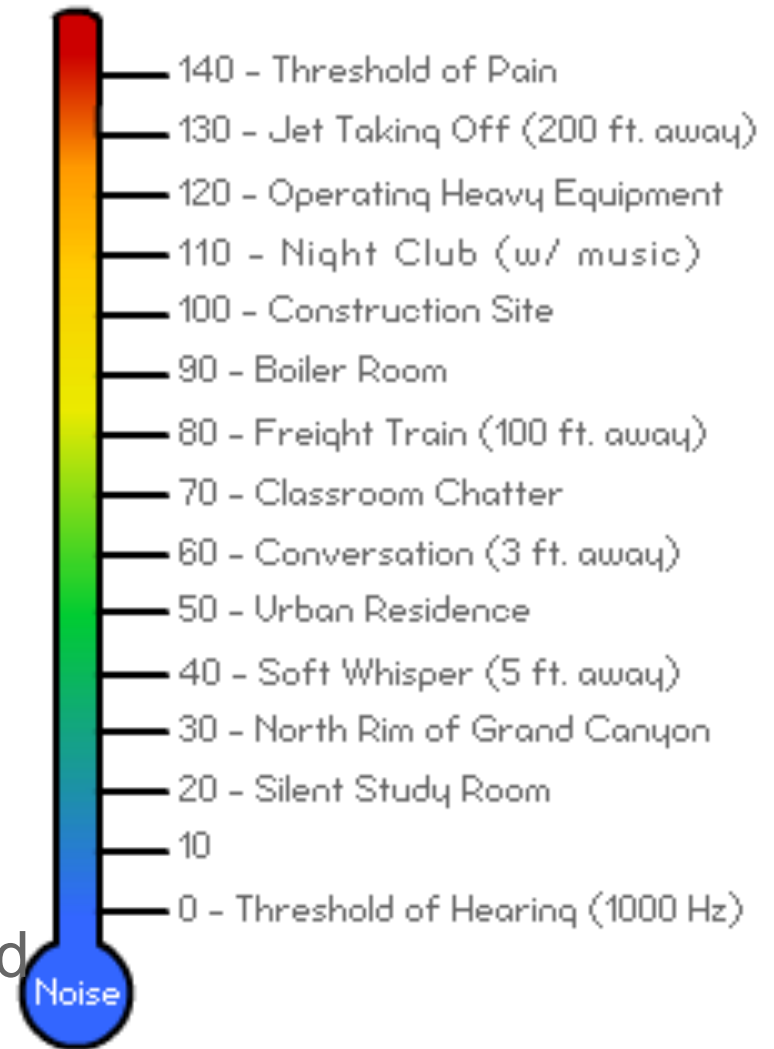


Goals for Noise Model

- **Feasibility:** Is it possible to predict urban noise levels with a satellite imagery model?
- **Accuracy:** Does the model predict urban noise with reasonable accuracy?
- **Transferability:** Can the model predict well on multiple cities? Can it predict accurately on unseen cities?

Quantifying Noise

- **dB – Decibels**, a logarithmic measurement of sound pressure intensity
- **dB(A) – A-weighted Decibels**, weighted according to how loud they sound to the human ear
- **70 dBA** is the **U.S. D.O.T.** noise abatement criteria
- **40 dB** (at night) is the lowest observed adverse effect (via W.H.O.)



Measuring Noise

- **L_{eq}** – sound level averaged over time, usually measured in dB or dB(A)
- **LDEN** – time-weighted noise level, an average of L_{eq} over the 24-hour period, with a 5dB(A) penalty for evening noise and a 10dB(A) penalty for nighttime noise



Current State of Noise Modeling

- Highly detailed urban noise models are available (with large data requirements)
- Land use regression noise modeling
- City block-scale physical noise models

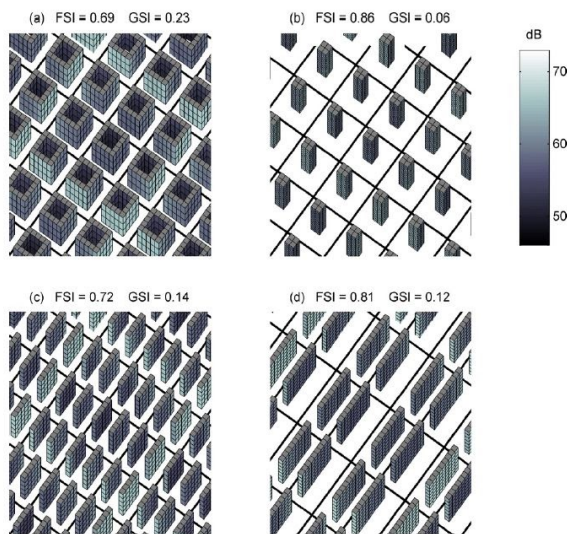
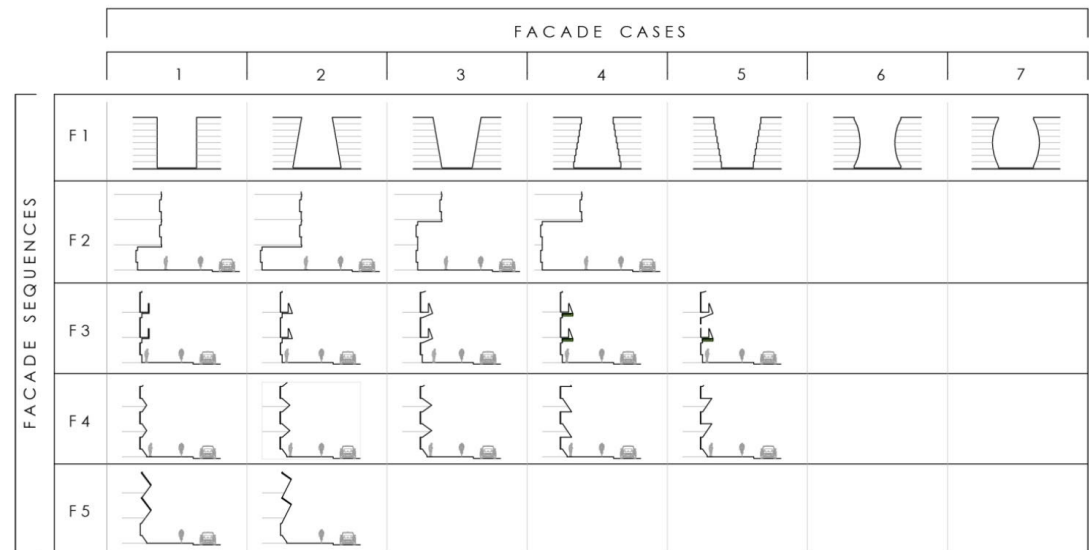


Fig. 12. Four urban fabrics with calculated facade sound levels: (a) blocks with sides of 5 building units and 3 floors, (b) blocks with sides of 2 building units and 15 floors, (c) double strips with lengths of 5 building units and 5 floors, and (d) single strips with lengths of 9 building units and 7 floors.



Factors Affecting Urban Noise:



Sound
Creation



Sound Propagation



Noise
Perception

Factors Affecting Urban Noise:



Sound
Creation



Sound Propagation



Noise
Perception

Traffic

Industry

Trains and airplanes

Wildlife

Wind and rain

Water and Topography

Building size and shape

Impervious surfaces and
roadways

Soft surfaces (vegetation, soil)

Urban density

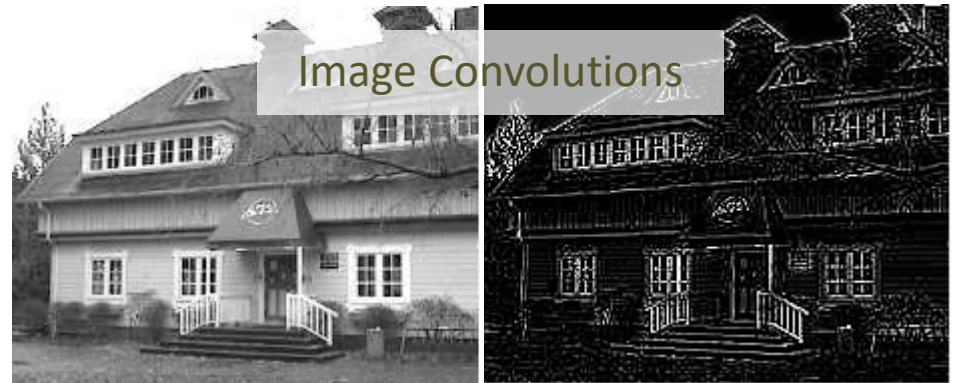
Time of day

Sound sensitivity

Detecting Relevant Factors via Satellite Imagery

Object Detection via CNN (Shape Characteristics)

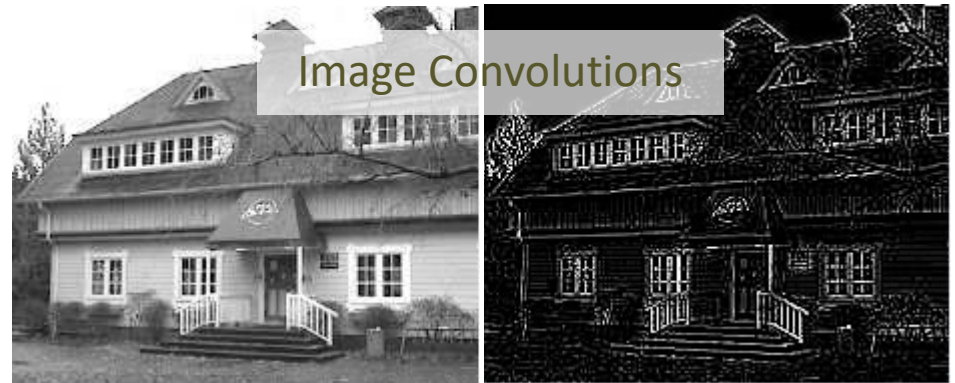
- Buildings and building shadows
- Impervious surfaces and roadways
- Vegetation and soft surfaces
- Noise barriers, highway buffers



Detecting Relevant Factors via Satellite Imagery

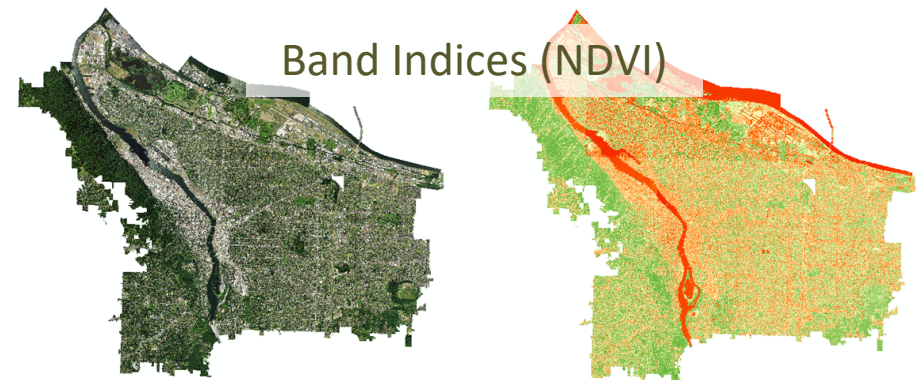
Object Detection via CNN (Shape Characteristics)

- Buildings and building shadows
- Impervious surfaces and roadways
- Vegetation and soft surfaces
- Noise barriers, highway buffers



Multiband Characteristics

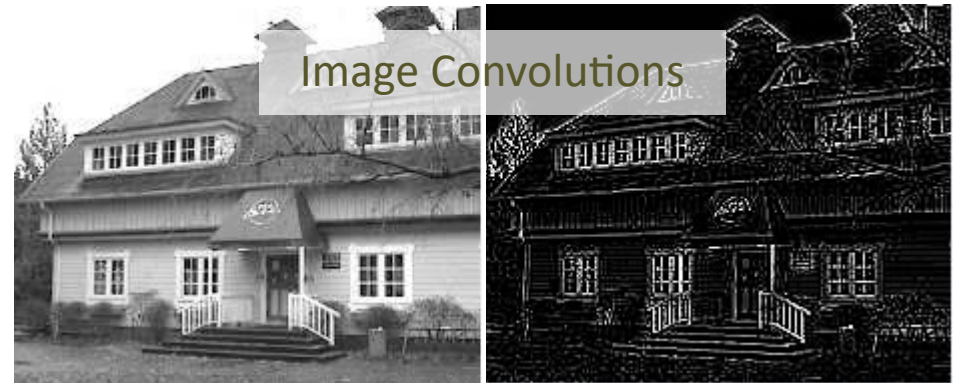
- Vegetation health or greenness
- Soil and impervious surfaces detection
- Shadow detection



Detecting Relevant Factors via Satellite Imagery

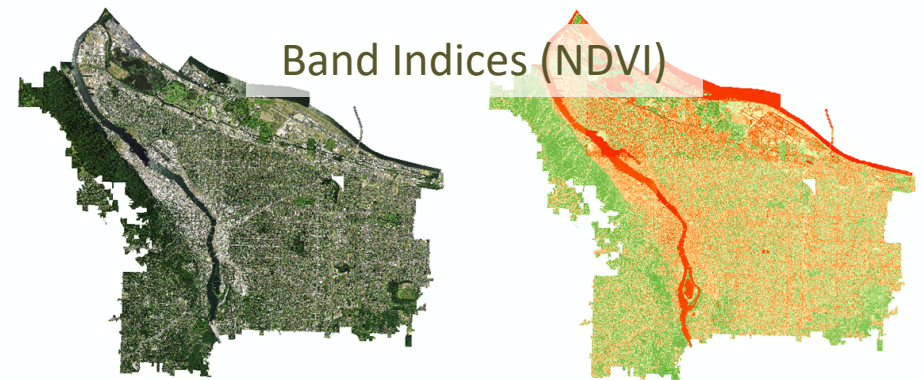
Object Detection via CNN (Shape Characteristics)

- Buildings and building shadows
- Impervious surfaces and roadways
- Vegetation and soft surfaces
- Noise barriers, highway buffers



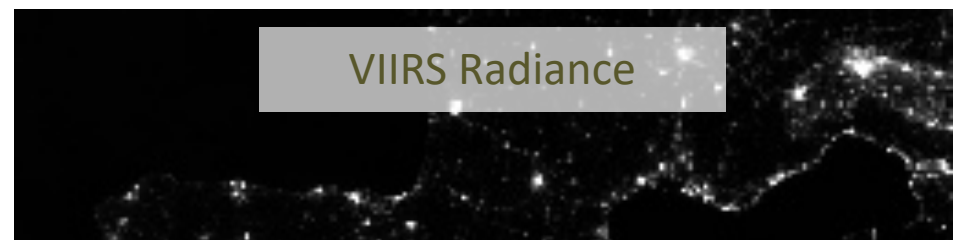
Multiband Characteristics

- Vegetation health or greenness
- Soil and impervious surfaces detection
- Shadow detection



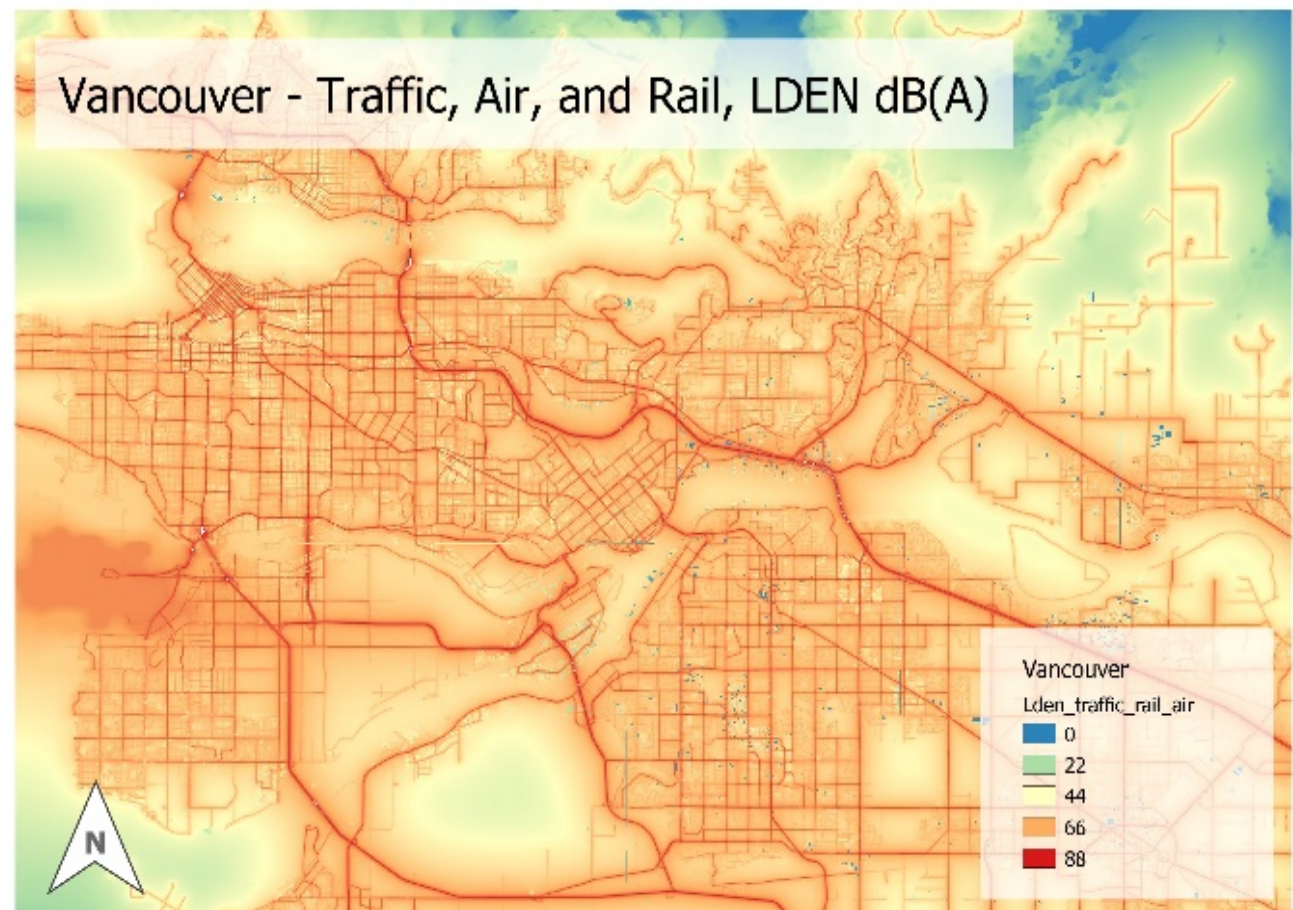
Ancillary Data

- VIIRS nighttime radiance imagery



Target Data - Vancouver

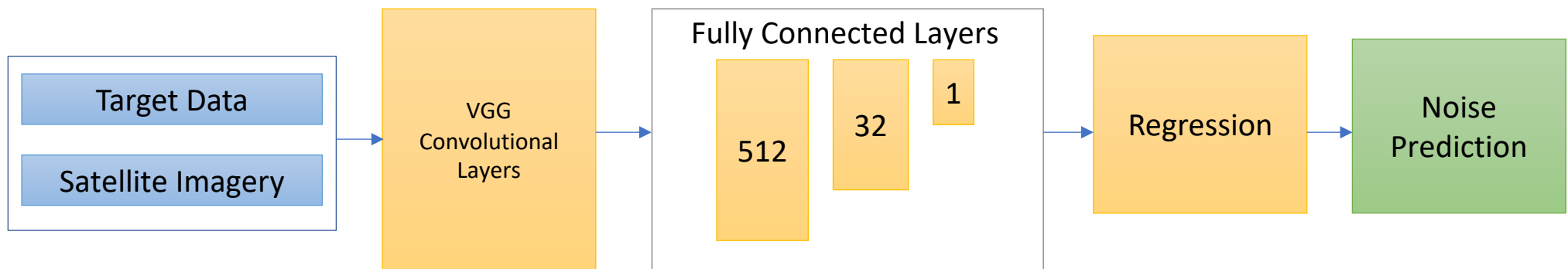
- Incorporates roads, traffic volume, aircraft flight paths, train data, topography, building shapes, etc.
- 2010 annual estimate, LDEN
- Two modeled data products:
 - Traffic only
 - Traffic, air, and rail



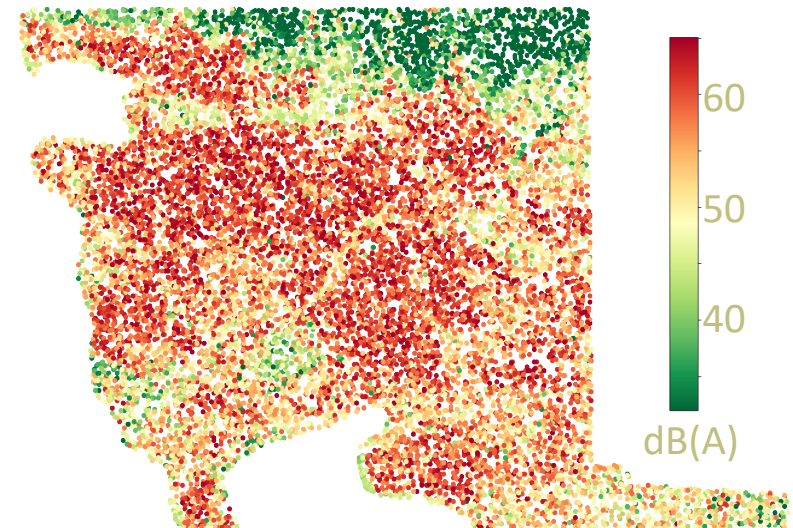
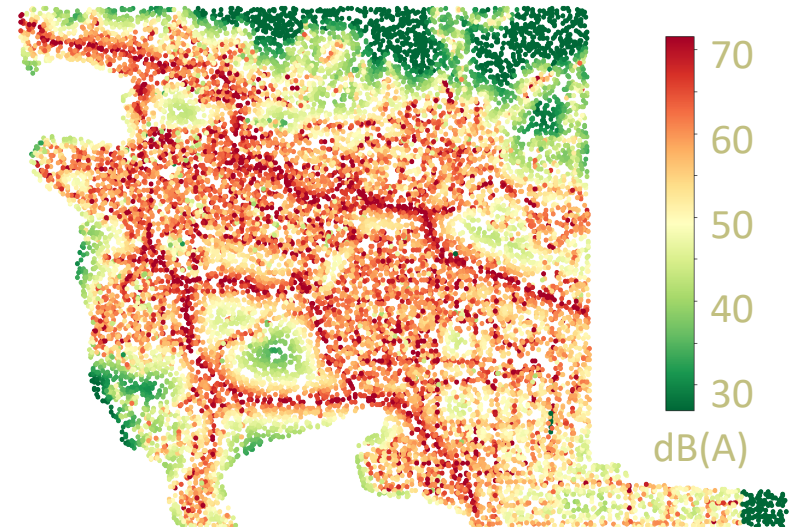
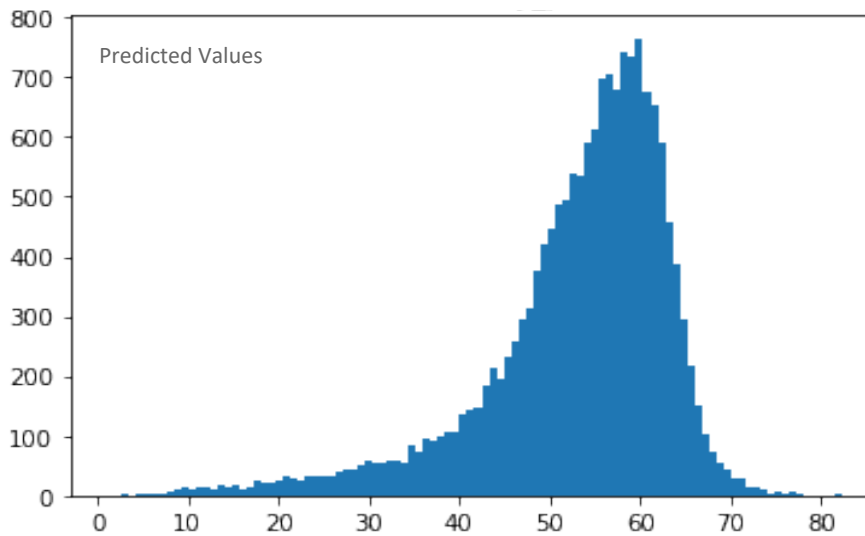
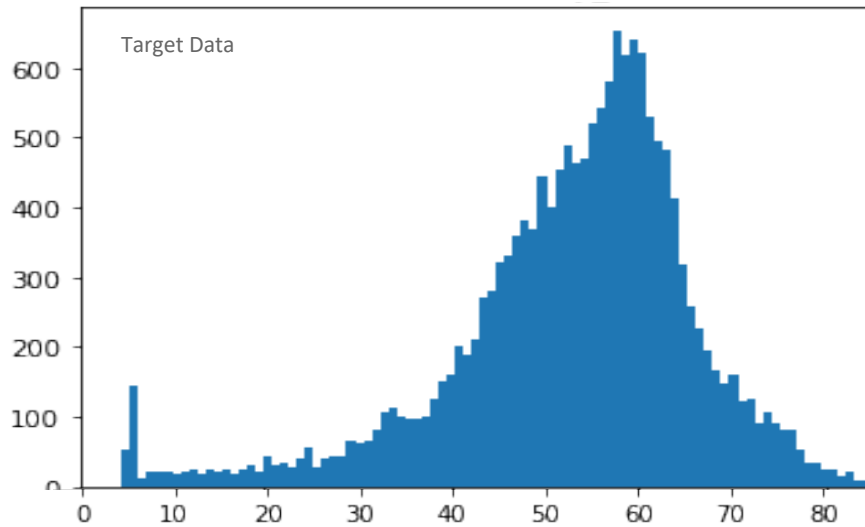
Baseline Noise Model (Model 1)

- **Study Year:** 2010
- **Location:** Vancouver, BC
- **Input Imagery:** 2.5m resolution WorldView
- **Patch Size:** 100m x 100m (40 pixels)

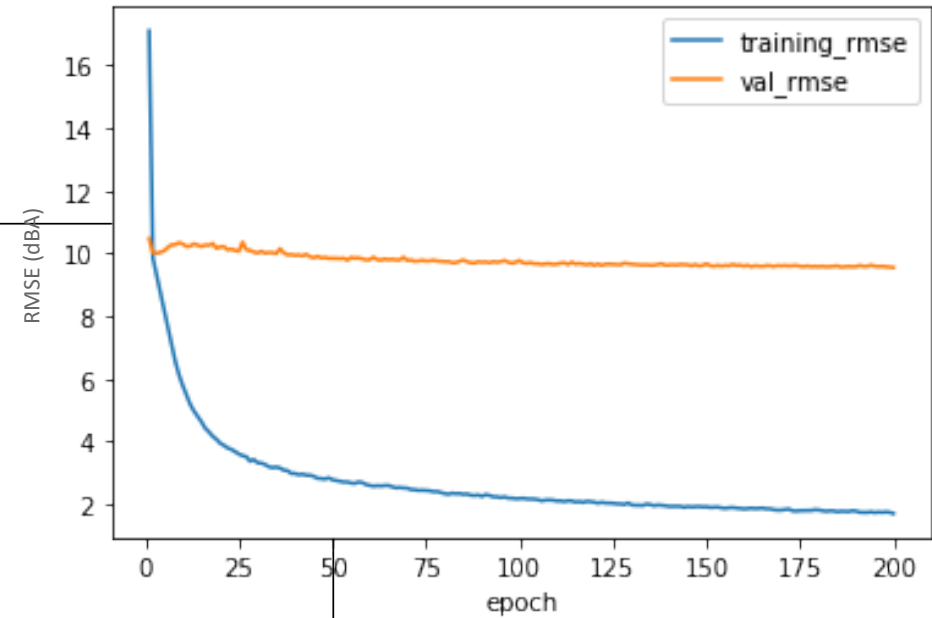
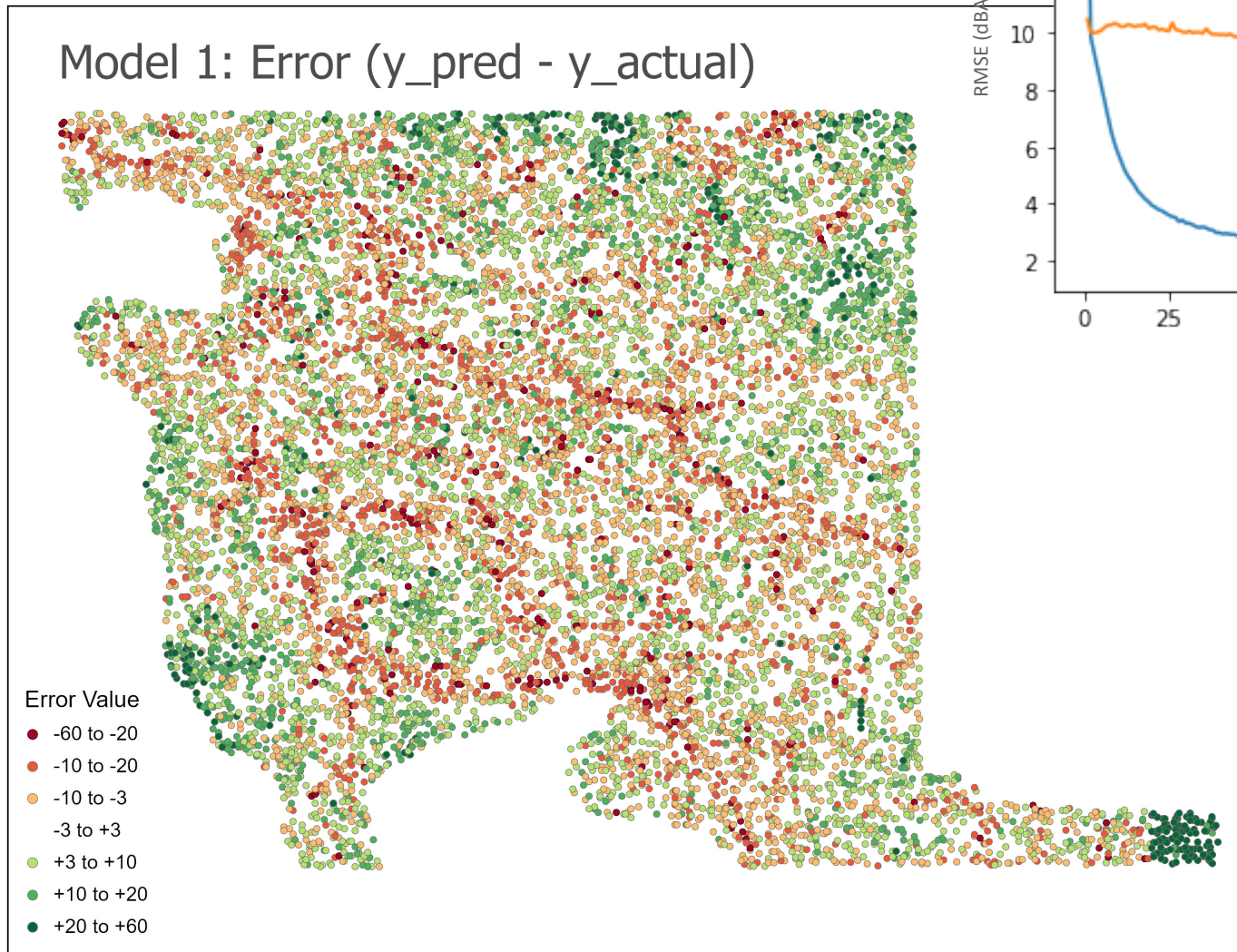
- **Architecture:**
 - VGG pretrained weights
 - Fully connected layers: 512, 32, 1



Model 1 – Initial Results

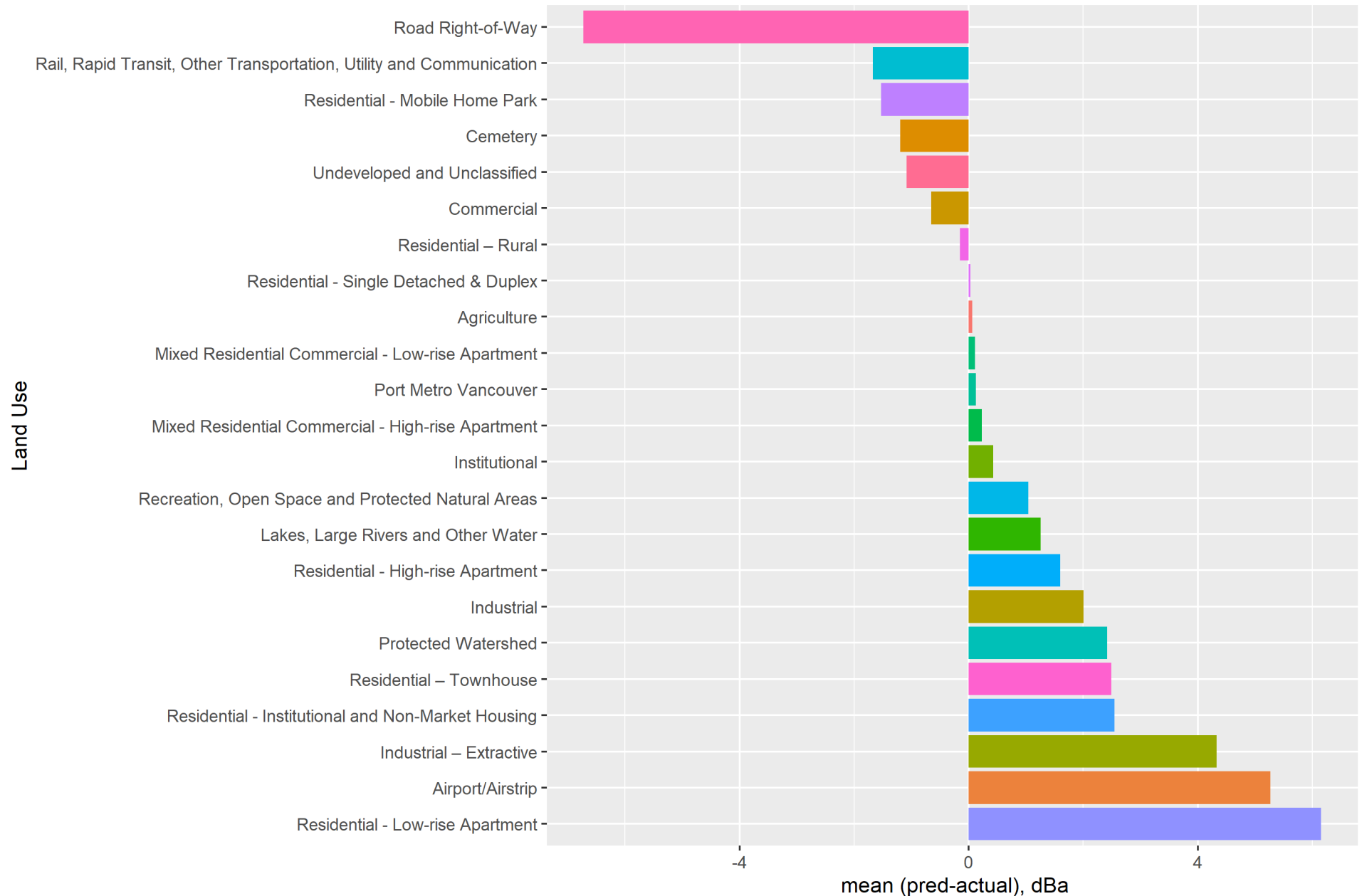


Model 1 – Initial Results



Model 1 – Error by Land Type

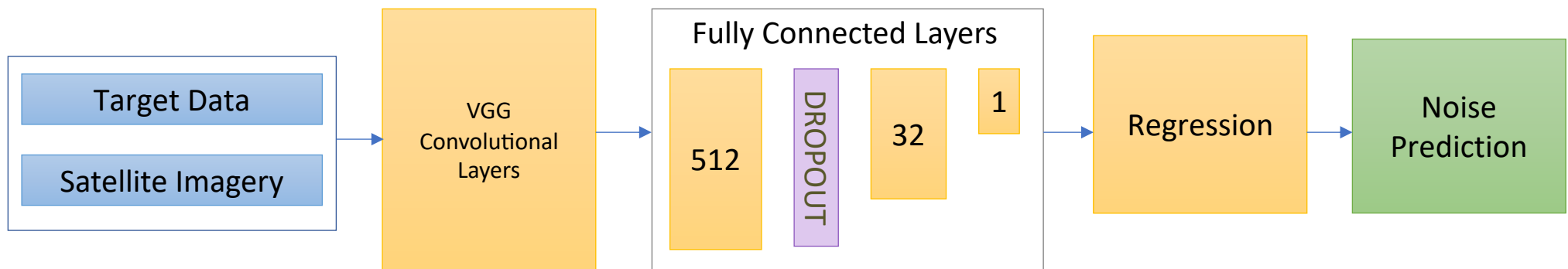
2011 Generalized Land Use Classification



Dropout Noise Model (Model 2)

- **Study Year:** 2010
- **Location:** Vancouver, BC
- **Input Imagery:** 2.5m resolution WorldView
- **Patch Size:** 100m x 100m (40 pixels)

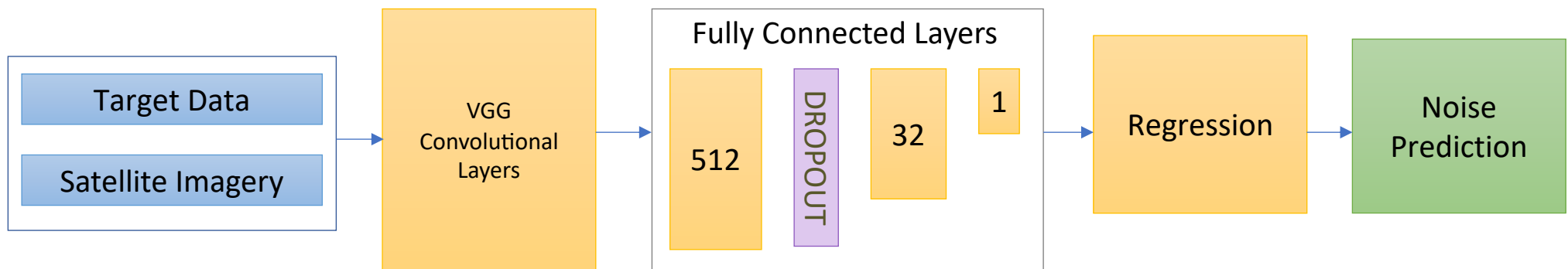
- **Architecture:**
 - VGG pretrained weights
 - Fully connected layers: 512, 32, 1
 - **Dropout included**



High-Res Noise Model (Model 3)

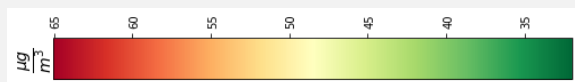
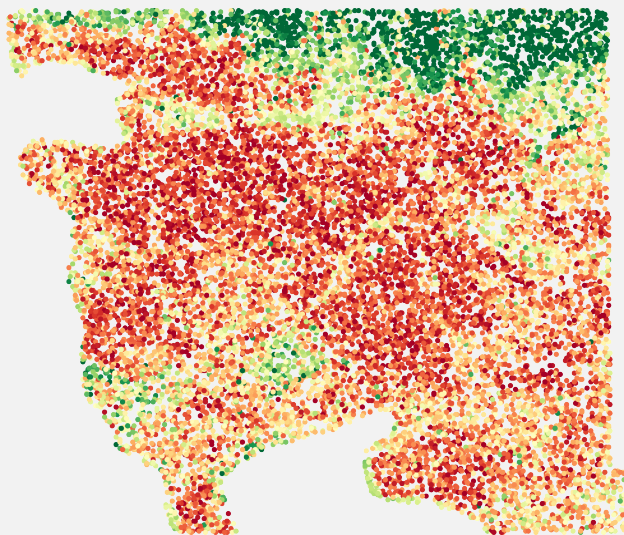
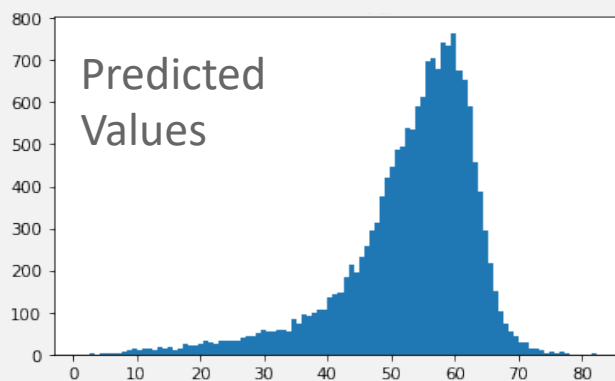
- **Study Year:** 2010
- **Location:** Vancouver, BC
- **Input Imagery:** **0.5m** resolution WorldView
- **Patch Size:** 100m x 100m (**200 pixels**)

- **Architecture:**
 - VGG pretrained weights
 - Fully connected layers: 512, 32, 1
 - Dropout included

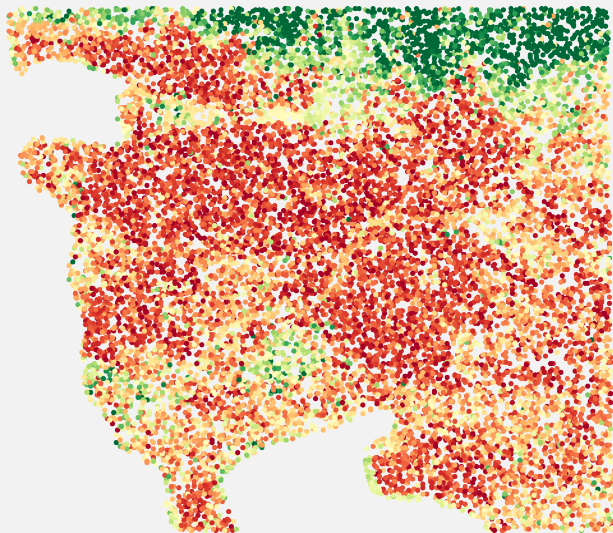
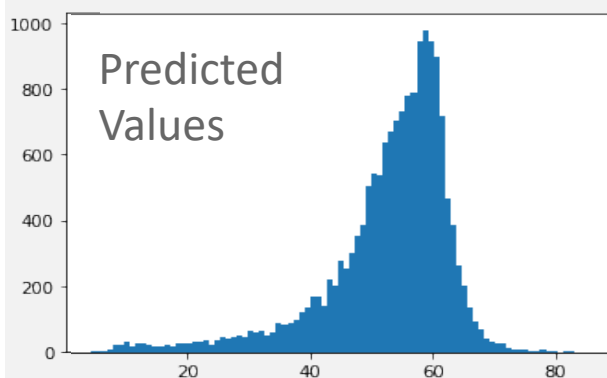


Output Comparison

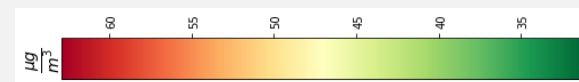
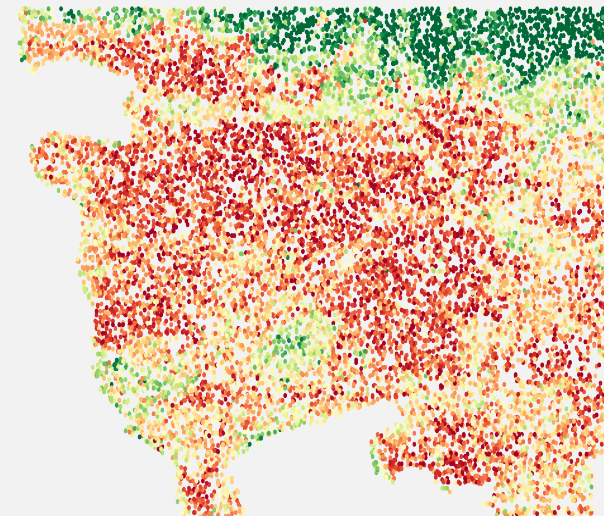
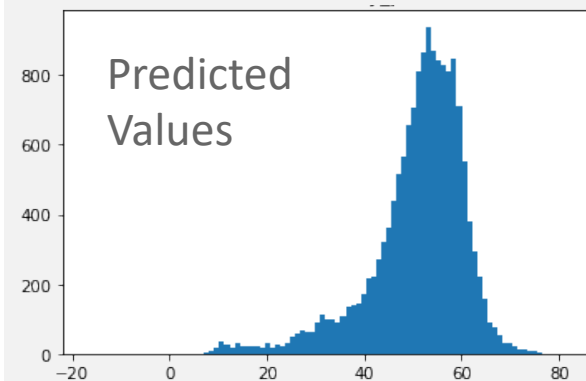
Model 1



Model 2



Model 3



Implications

- Imagery and CNNs is a feasible noise prediction method
- However, additional spatial context is needed

Future Work

- Incorporate ancillary data, such as VIIRS Night Light
- Use a pretrained SpaceNet network for land use segmentation
- Saliency mapping to examine what features the model picks out



Acknowledgments

Advisor: Dr. Meytar Sorek-Hamer (USRA)

Michael von Pohle, Adwait Sahasarabojanee, Violet Lingenfelter, Ata Akbari

Asanjan, Esra Suel

Zeal Panchal and Saba Hussain (USRA)

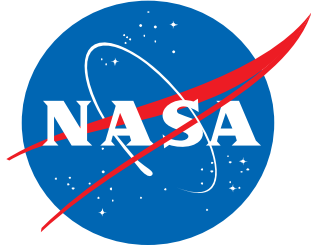
Dr. Nikunj Oza (NASA), ARC Data Sciences Group

References

- Gan, W.Q., McLean, K., Brauer, M., Chiarello, S.A., & Davies, H.W. (2012) Modeling population exposure to community noise and air pollution in a large metropolitan area. *Environmental Research*(116), 6-11.
- Gulliver, J., Morley, D., Vienneau, D., Fabbri, F., Bell, M., Goodman, P., Beevers, S., Dajnak, D., Kelly, F.J., & Fecht, D. Development of an open-source road traffic noise model for exposure assessment. *Environmental Modelling & Software*(74), 183-193.
- Sanchez, G., Van Renterghem, T., & Botteldooren, D. The effect of street canyon design on traffic noise exposure along roads. *Building and Environment*(97). 96-110.
- Magrini, A., & Lisot, A. (2016) A simplified model to evaluate noise reduction interventions in the urban environment. *Building Acoustics*(23), 36-46.
- Mennitt, D., Sherrill, K., & Fristrup, K. A geospatial model of ambient sound pressure levels in the contiguous united states. *Journal of the Acoustical Society of America*(135). 2746-2764.

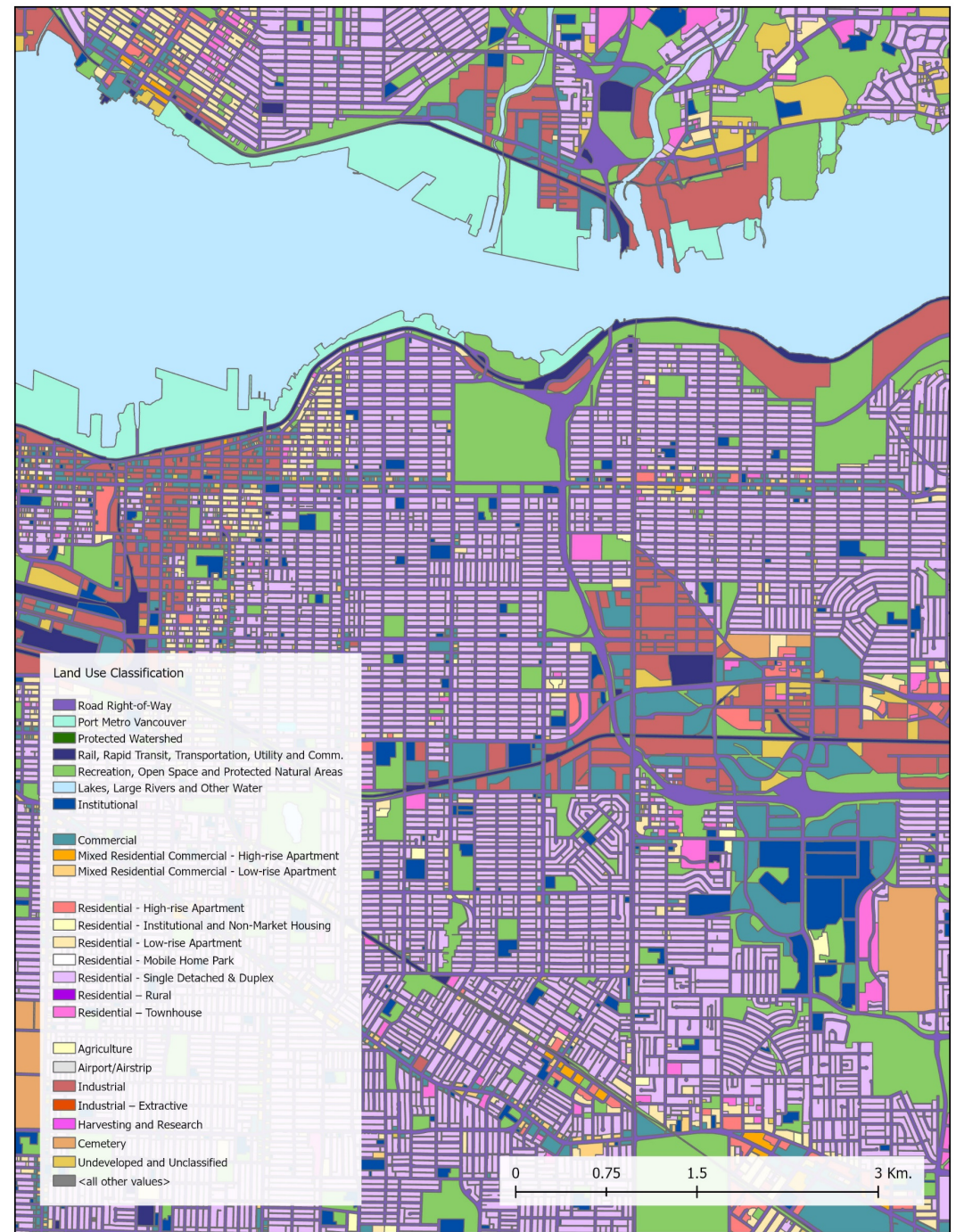
Questions?



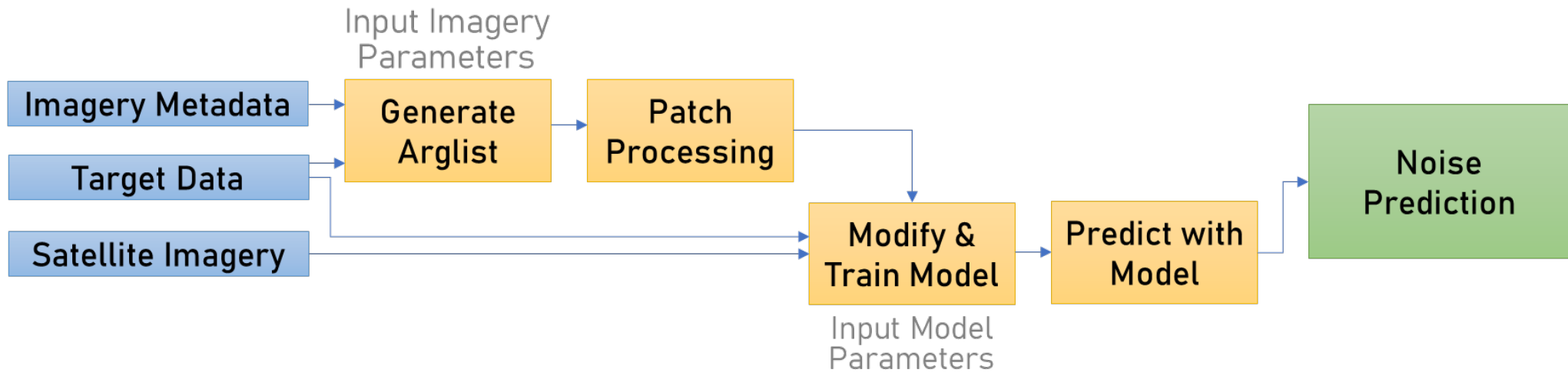


2011 Generalized Land Use Classification

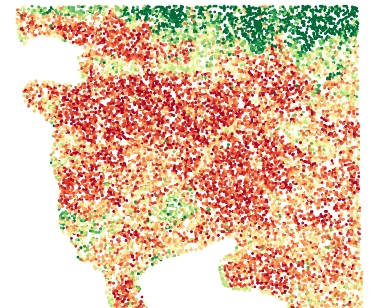
“Metro Vancouver’s 2011 Generalized Land Use map was compiled using a consistent interpretation of all available information. Every effort was made to depict land use activities accurately and consistently across all of the region’s municipalities. Land use classifications were assigned at the municipal cadaster geography wherein each cadaster lot was assigned one single land use classification. Exceptions to this rule occurred in instances where cadaster lots clearly have more than one discrete land use activity which did not fit into one single classification thus requiring the cadaster lot to be split to accommodate multiple land use polygons (e.g. school property – where buildings were classified as ‘institutional’ and playing fields as ‘recreational’).”



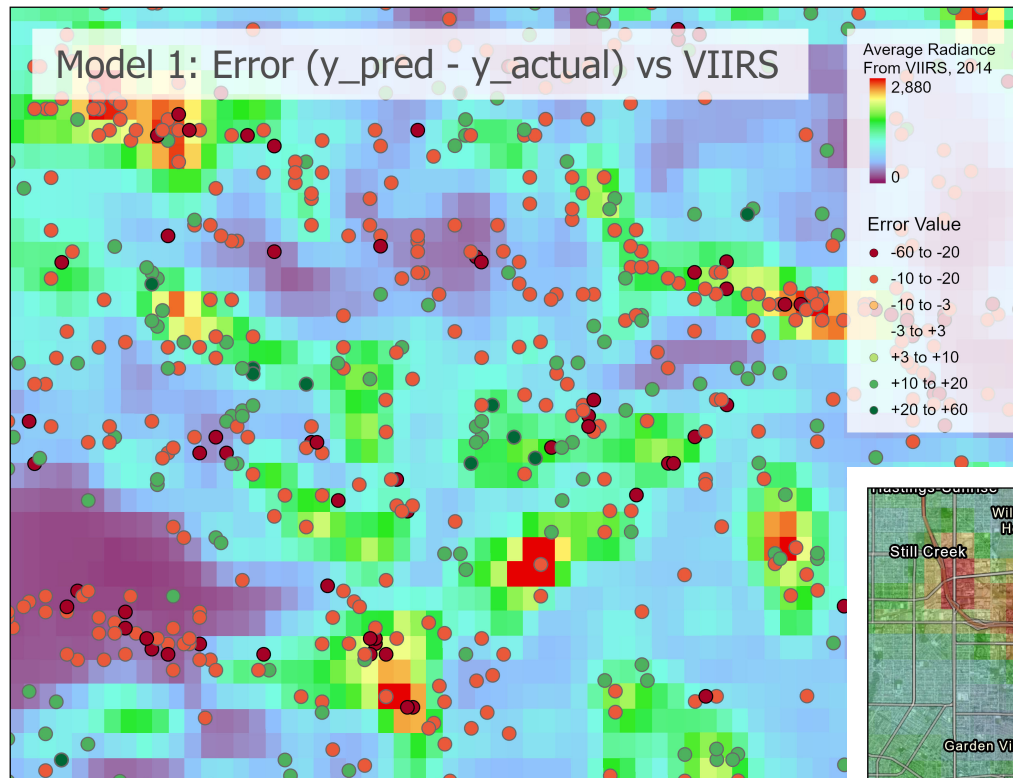
Model Workflow



	A	B	C	D
1	lon	lat	value	
2	-123.274	49.37354	0.386608	
3	-123.272	49.37354	0.330052	
4	-123.271	49.37354	0.085471	
5	-122.891	49.37354	0.001065	
6	-122.889	49.37354	0.034955	
7	-122.873	49.37354	0.03389	
8	-122.871	49.37354	0.00221	

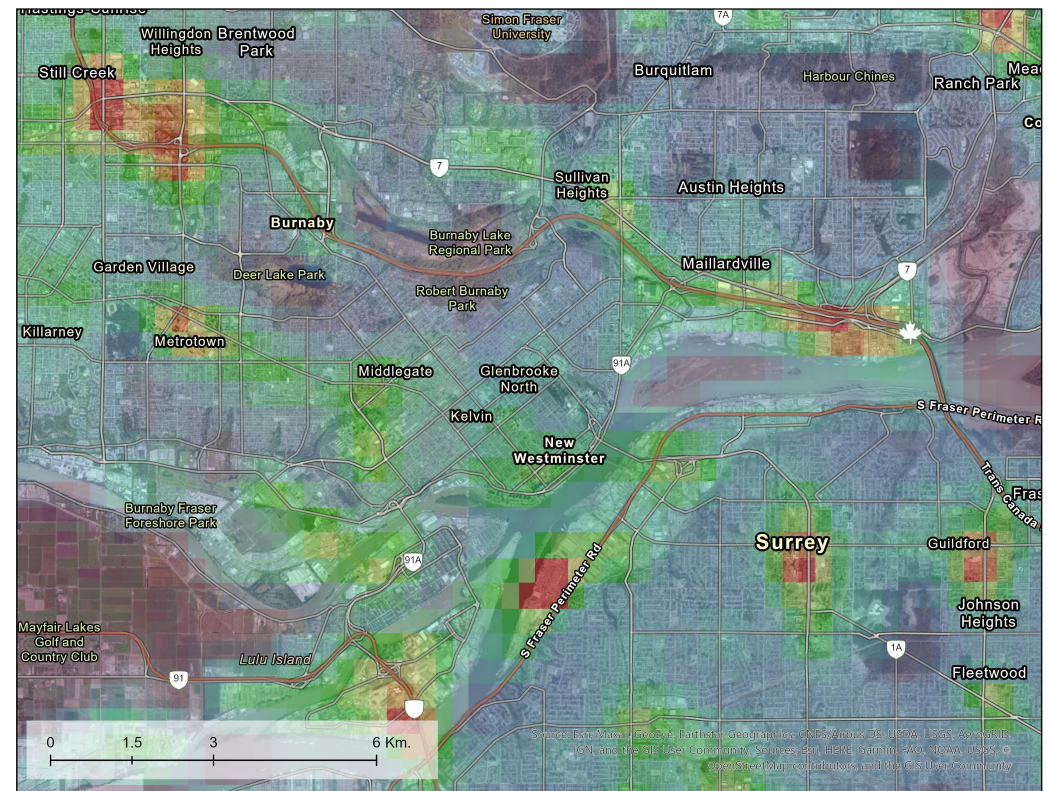


Model 1 – Initial Results: Relationship with Night Light



under-estimating noise

over-estimating noise



Advanced Urban Air Mobility

Mitigating Unforeseen Risk via Preserving Trajectory Flexibility

Fanruiqi Zeng¹, Dr. Husni R. Idris²

¹Georgia Institution of Technology, ²NASA Ames Research Center

MAIN RESULTS

MOTIVATION

In order to handle the expected increase in air traffic, the next generation of transportation system will transform from a centralized architecture to a more distributed version. In this architecture, aircraft gains more authority in determining their routes rather than following “freeways” specified by ground based-control centers.

In a decentralized scheme, each agent will gain a higher degree of autonomy in mitigating **foreseen** disturbances. Our research focuses on developing a trajectory-oriented approach to routing a vehicle in highly dense and congestive traffic so that the vehicle can reach its destination in the most flexible way while mitigating **unforeseen** risk.

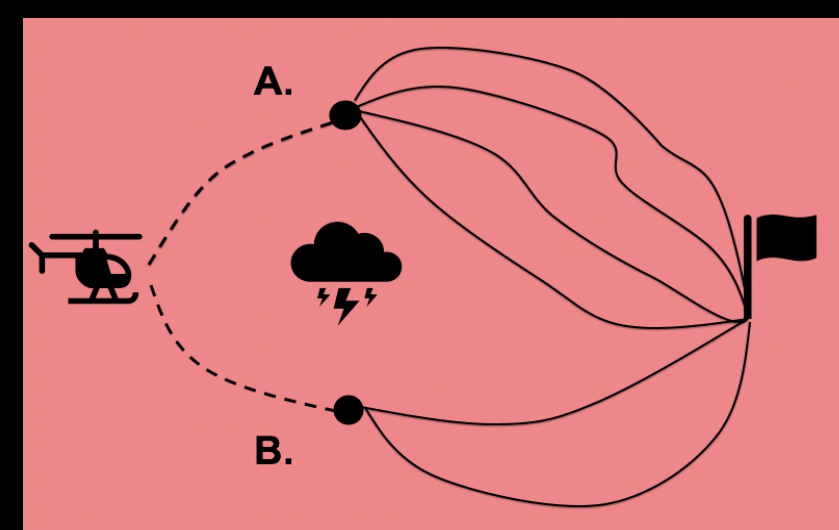


Fig.1 Flexibility Ideation.

“Be over prepared so that you won’t under perform.”

BACKGROUND

The **Trajectory Flexibility Metric** is defined as an aircraft’s ability to abide by all constraints imposed on it while mitigating its exposure to risks that results in violation of these constraints.[1]

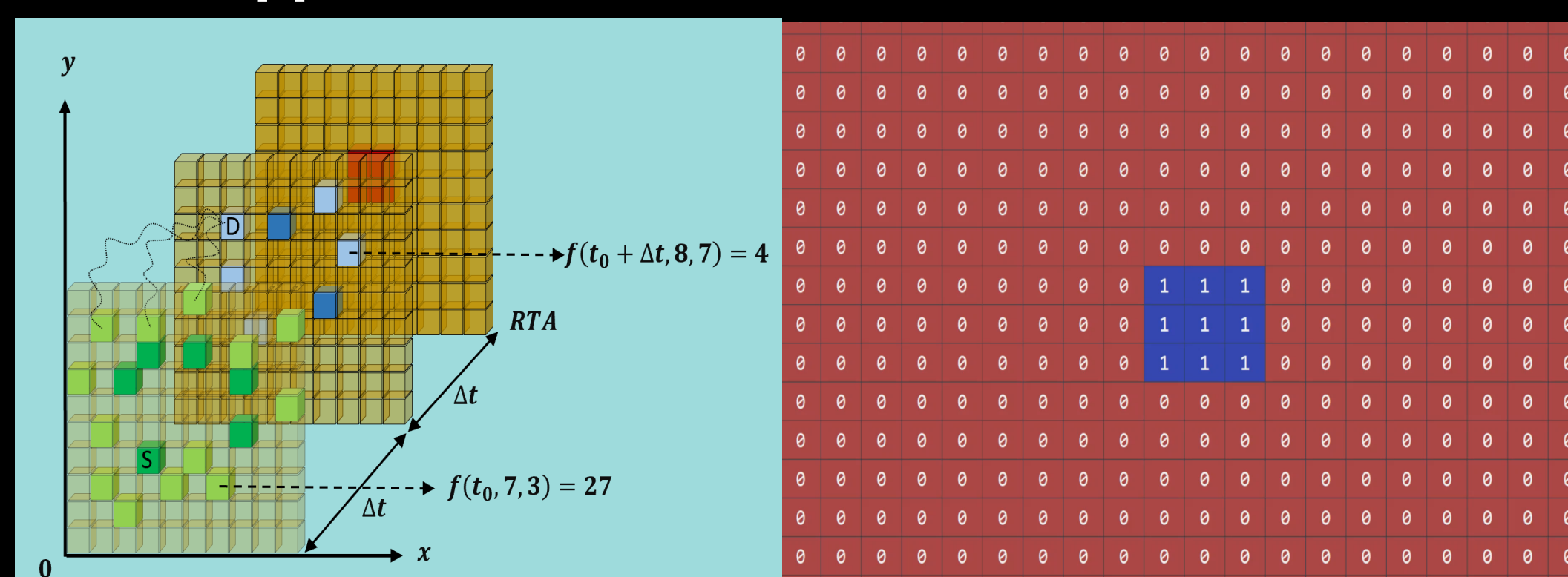


Fig.2 Computation of flexibility metrics.

Trajectory Planning Algorithms

- $V_t(x_t, y_t)$ The minimum cost of proceeding from $cell(x_t, y_t)$ at t .
- $g_t(x_t, y_t, x_{t+1}, y_{t+1}) = 1$ If $cell(x_{t+1}, y_{t+1})$ is reachable from $cell(x_t, y_t)$ at t .

$$V_t(x_t, y_t) = \text{Min}(V_{t+1}(x_{t+1}, y_{t+1}) + \text{interest})$$

$$x_{t+1}, y_{t+1}: g_t(.) = 1$$

→ **Maximum Flexibility:** $-f(x_t, y_t, x_{t+1}, y_{t+1})$

→ **Shortest Path:** $\text{distance}(x_t, y_t, x_{t+1}, y_{t+1})$

www.nasa.gov

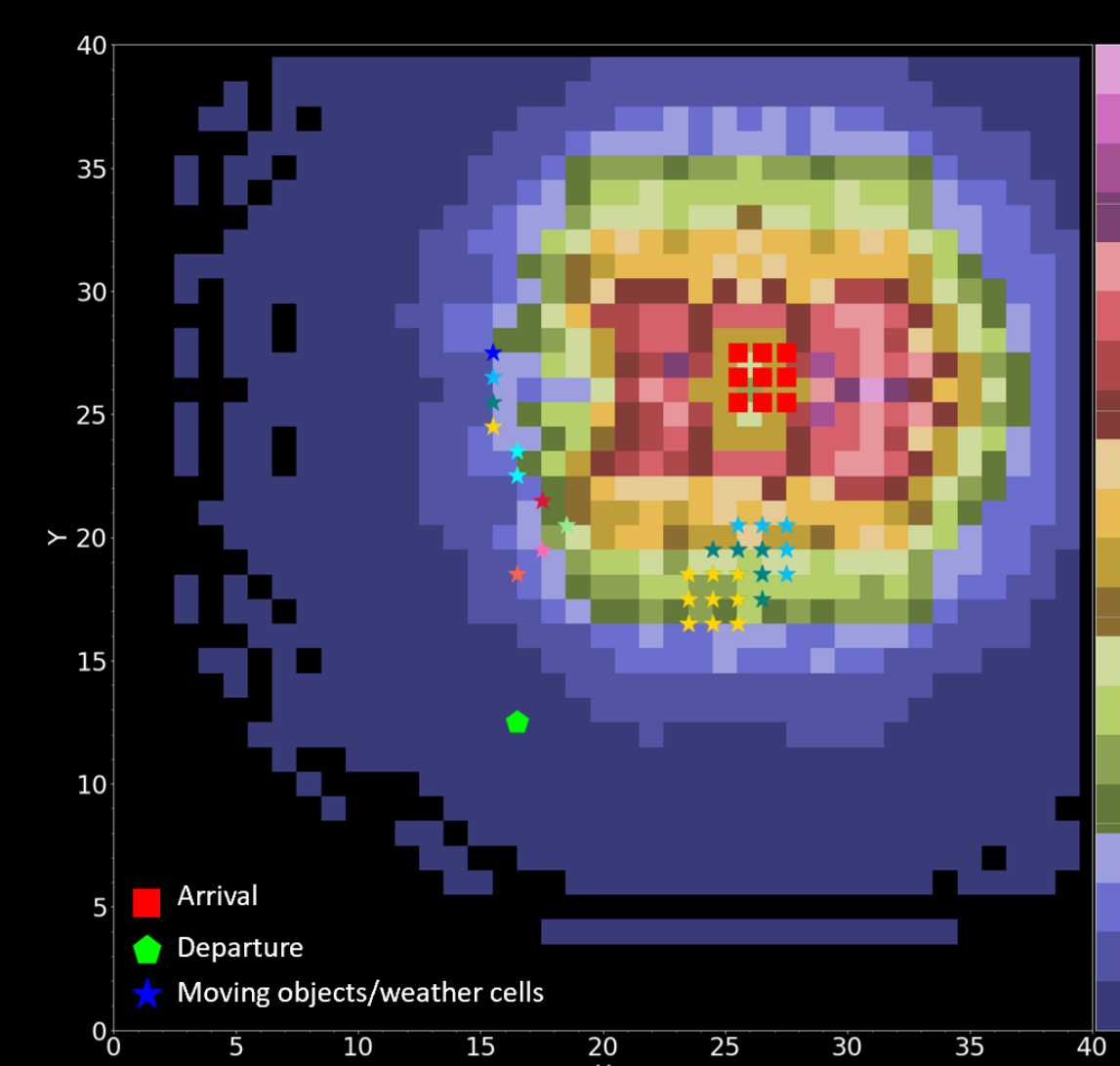


Fig.7 Block Map - Seen events.

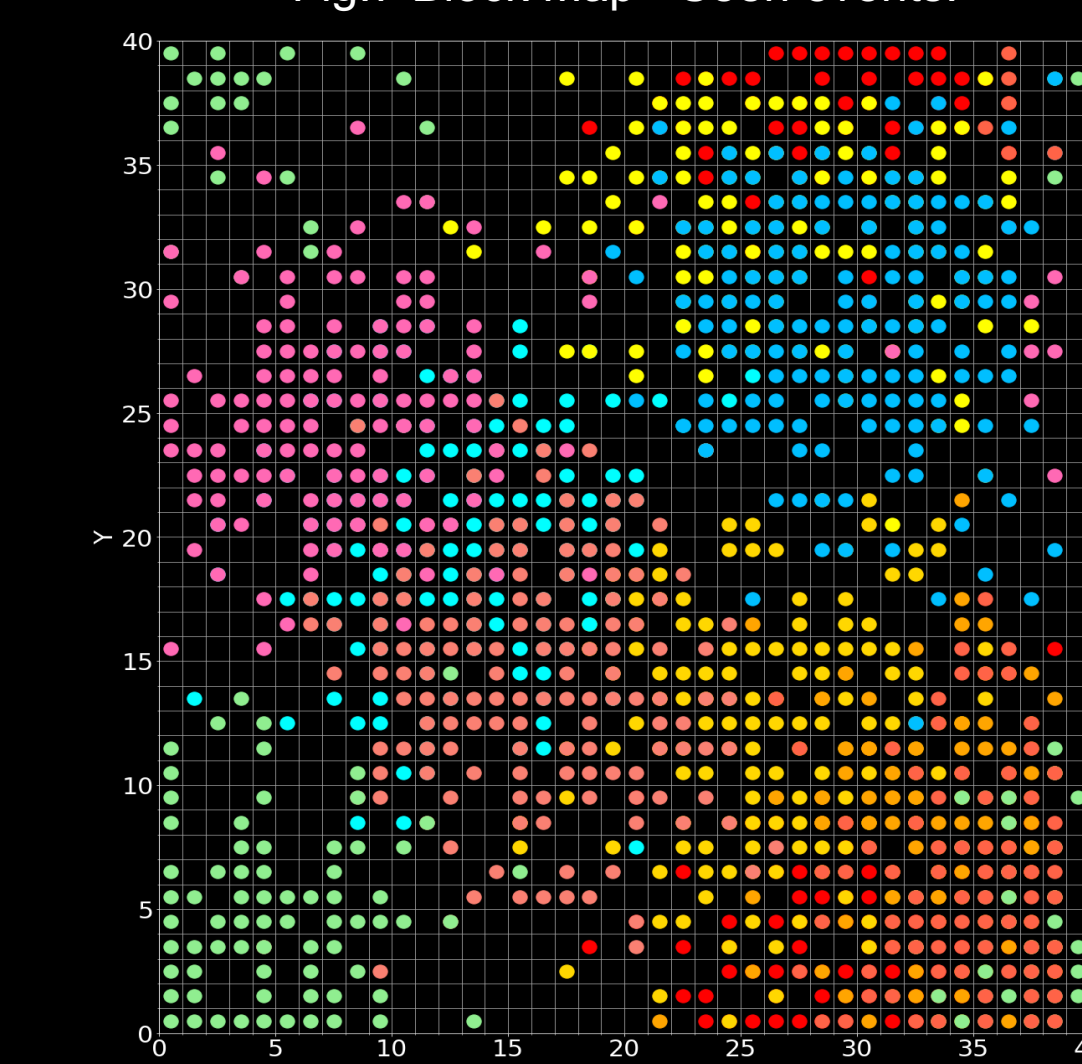


Fig.4 Risk Map - Unforeseen risky events.

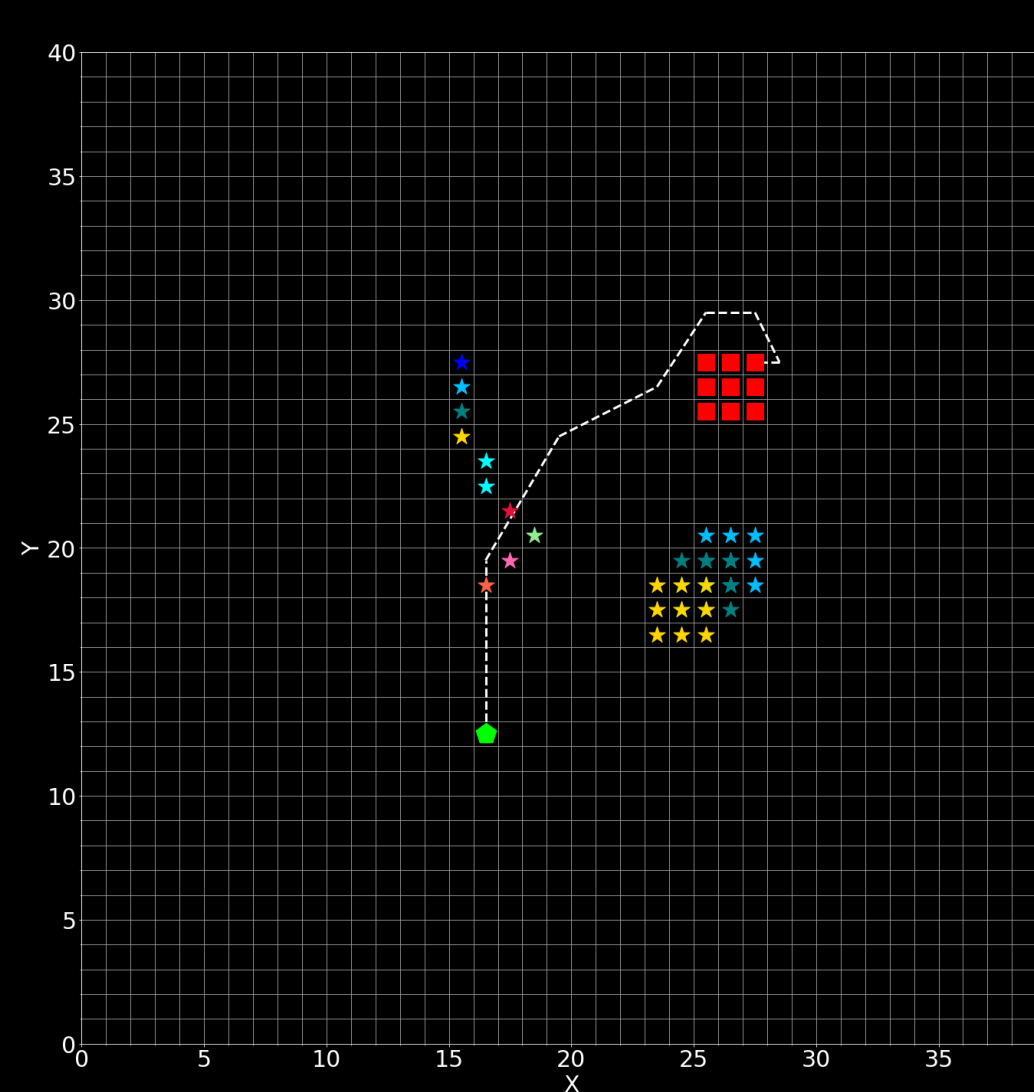


Fig.5 Successful mission.

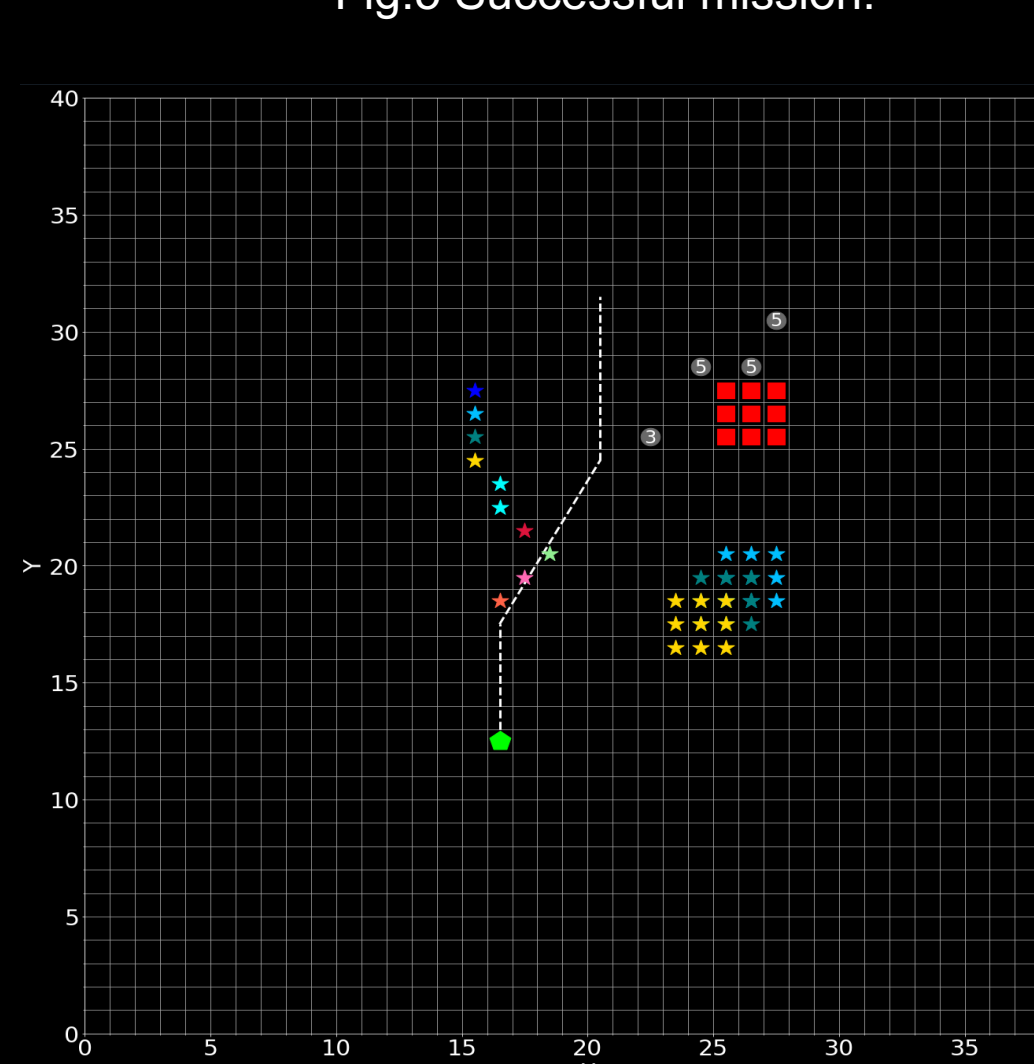


Fig.8 Failed mission.

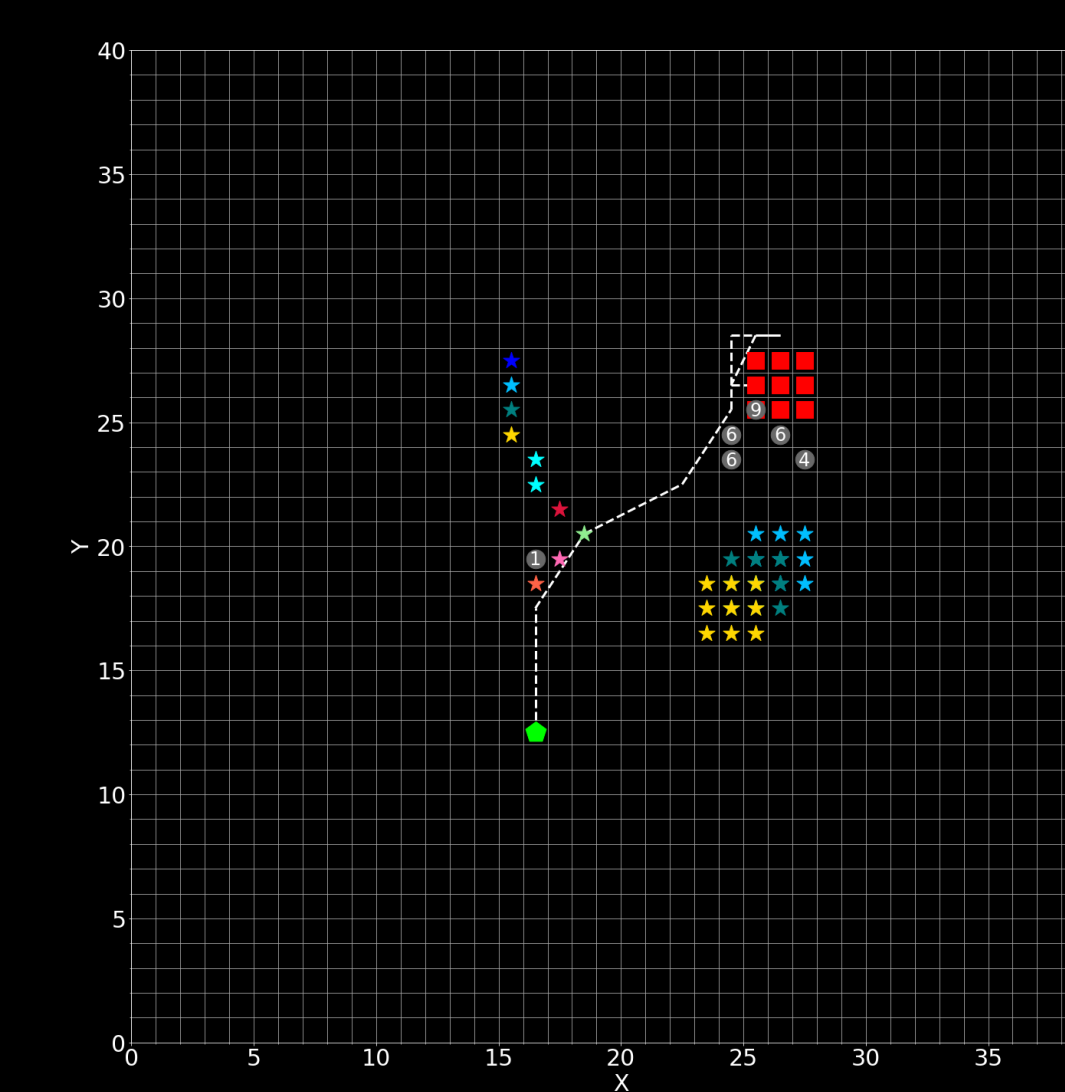


Fig.6 Successful mission.

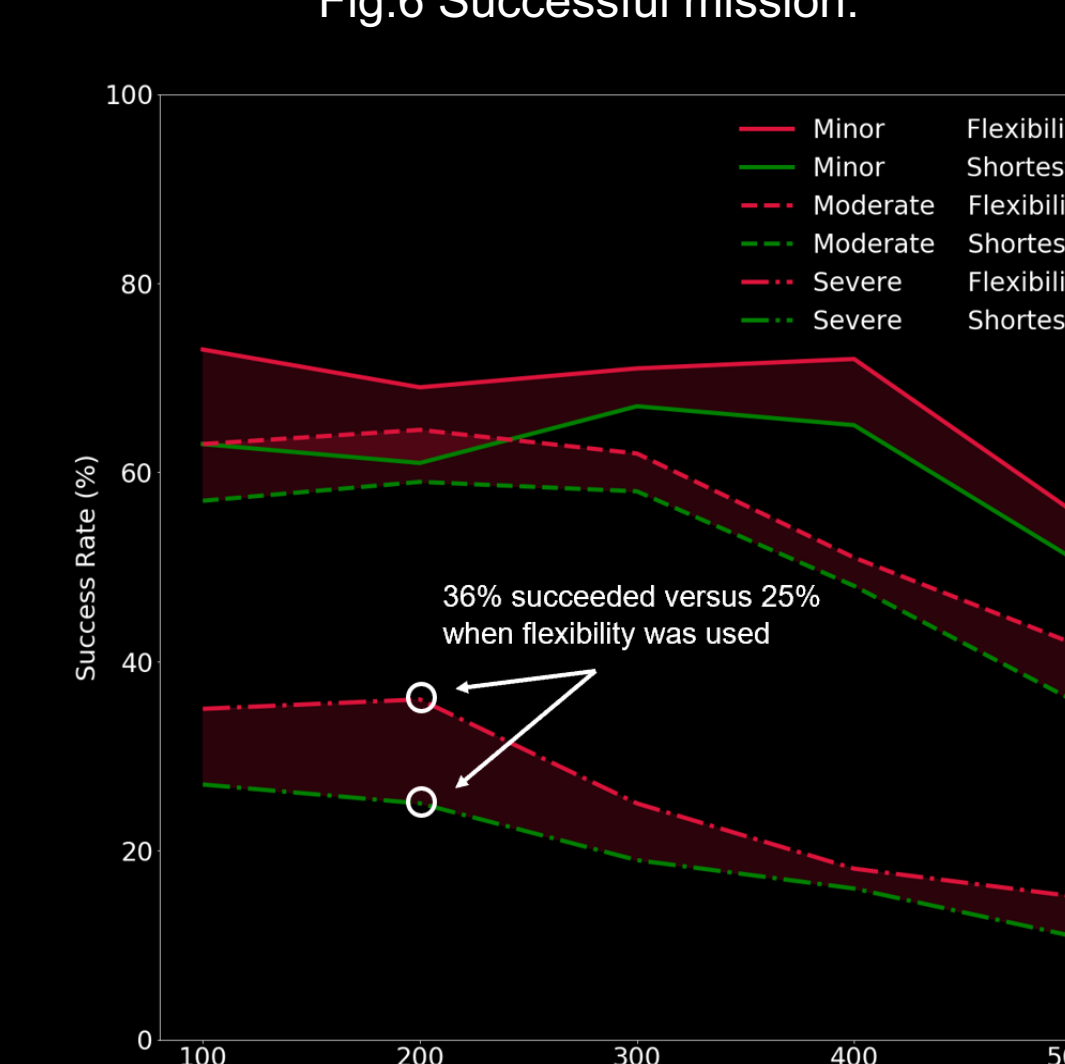


Fig.9 Comparison of mission success rate.

ALGORITHM

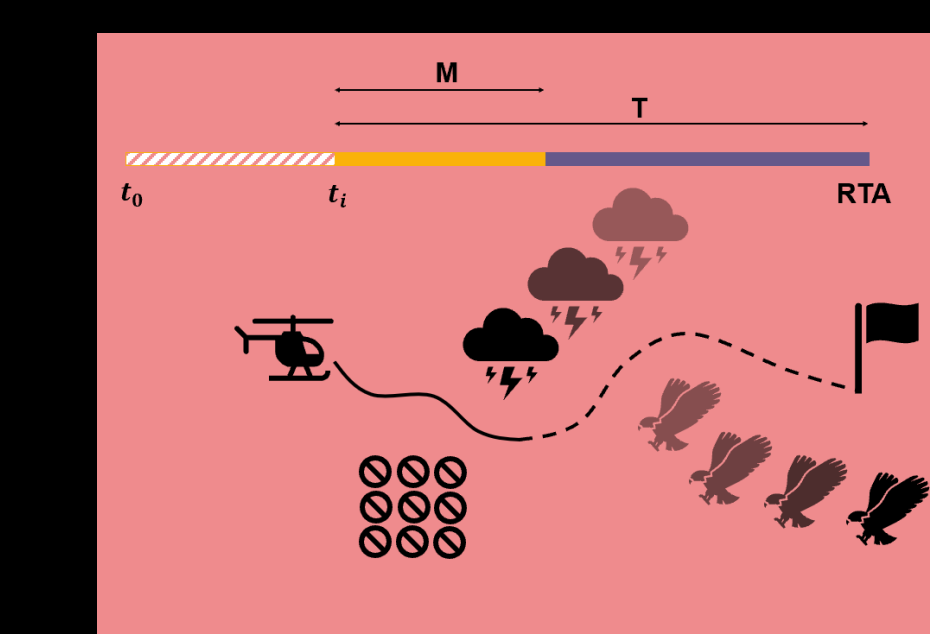


Fig.3 Key modules in algorithm design.

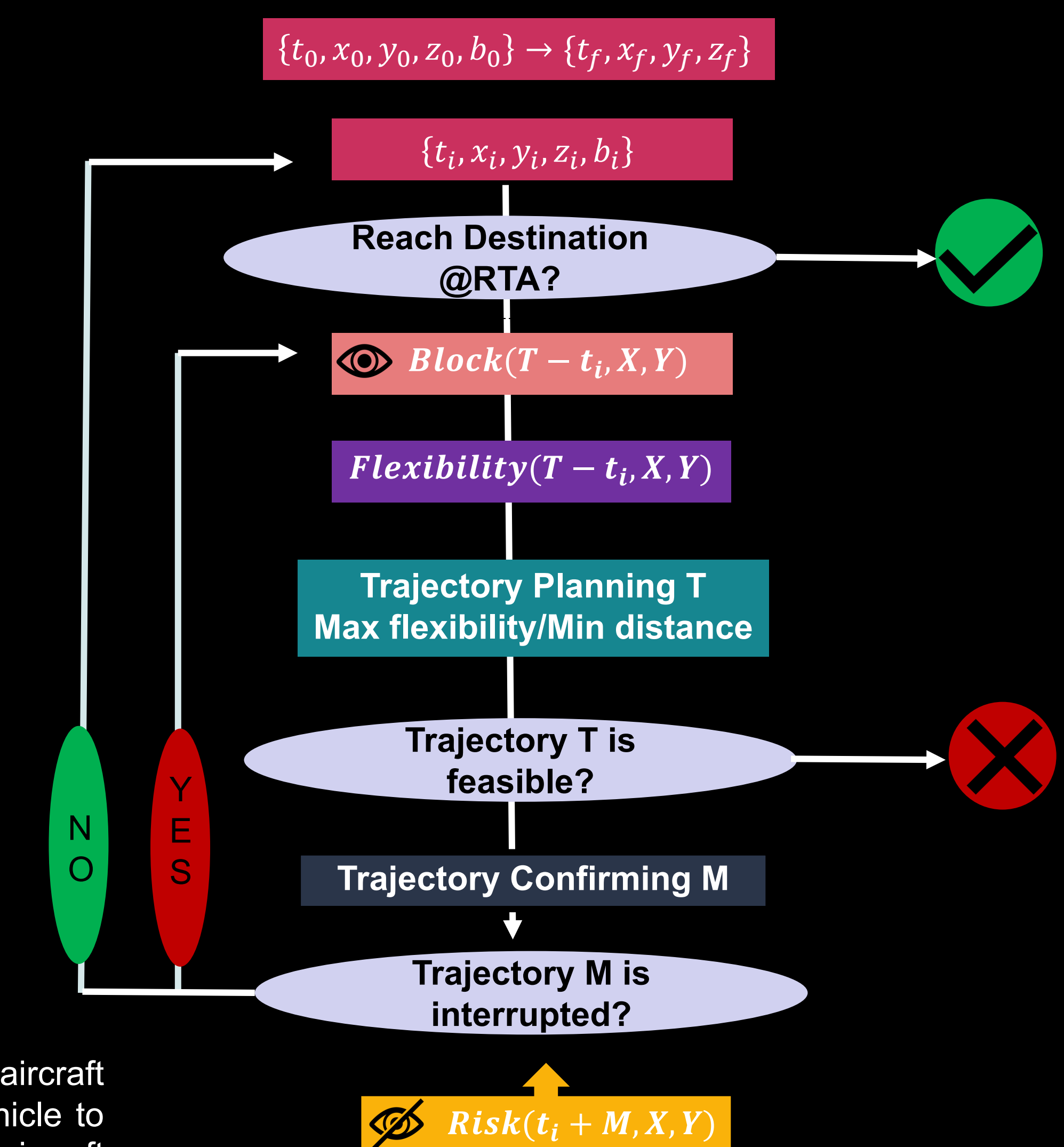


Fig.10 Unforeseen risk mitigation experiment set up.

DISCUSSION

• Conclusion

Given an airspace associated with certain congestion levels and unforeseen disruptive events, if an aircraft makes routing decisions by maximizing trajectory flexibility metrics, there is a higher chance for the vehicle to complete the mission. However, if an aircraft makes route decisions based on minimizing distance, the aircraft may run into situations where there are no feasible trajectories to choose from, resulting in a lower success rate.

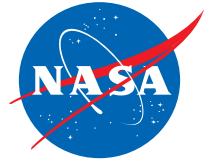
• Reflection

- The current definition of flexibility metric is restricted by discrete choices of vehicle headings and speeds. Once additional degrees of freedom introduced, for example alternative landing sites, the flexibility metric should be defined and estimated in a new way to account for a more complex solution space.
- How do we compare the flexibility metrics of two different aircrafts with different maneuverability?
- From an algorithmic viewpoint, even though an aircraft only takes M steps per planning horizon, preserving the T-M trajectories with a certain confidence level may further facilitate air traffic coordination.

[1] Idris, Husni, Nola Shen, and David Wing. "Complexity management using metrics for trajectory flexibility preservation and constraint minimization." In 11th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference, p. 6809. 2011.

THANKS

The author thanks her mentor **Dr. Husni R. Idris** for his unconditional support during this project. **Zeal Panchal**, **Saba Hussain** for their effort in coordinating this symposium event as well as **USRA** and **NASA** for providing the opportunity to work on this project.



Erosional Studies of Mars Using Digital Terrain Models

Natalie Glines

University of California, Santa Cruz

Mentor Dr. Virginia Gulick, SETI Institute / ARC SST

Summer 2020

Introduction

- Water and the search for evidence of life/conditions of life on Mars has been a major driver of NASA's Missions to Mars.
- Mars in the past had abundant surface water, evidenced by its valley networks, outflow channels, paleolakes and oceans. Most recently, glaciofluvial channels and gullies.
- Where has the surface water gone today?
Subsurface reservoirs, Surface near the poles, Atmosphere.

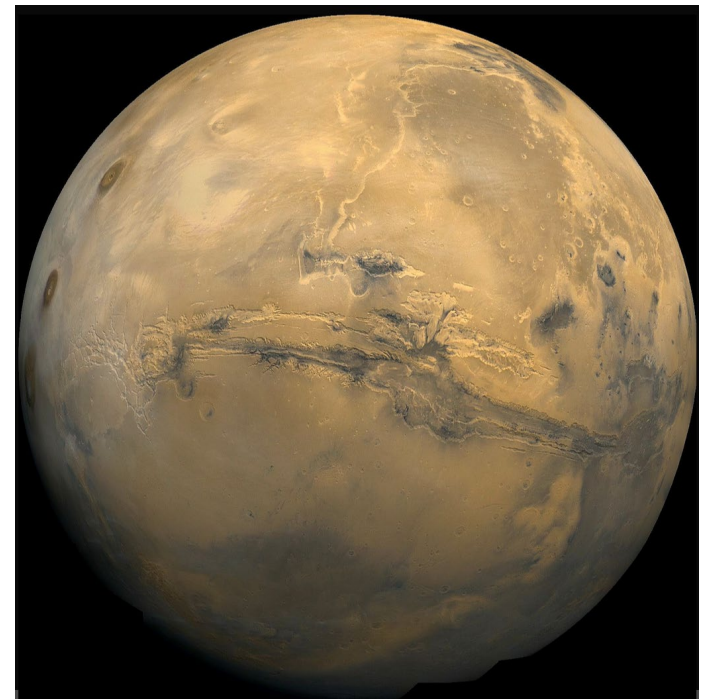


Image: Cornell SPIF / Google Earth

MARS QUICK FACTS

FOR MORE INFO, VISIT:
MARS.NASA.GOV

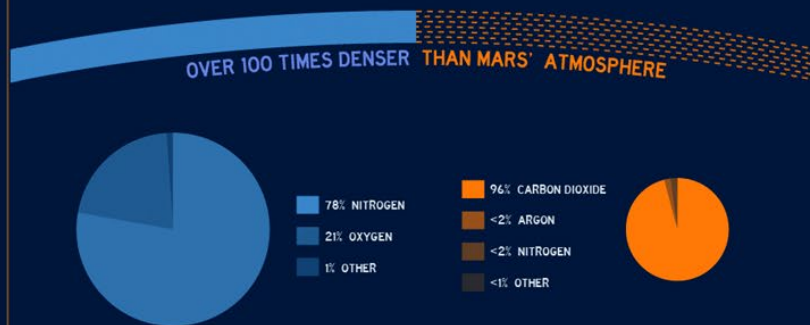
TEMPERATURE

[approximate average and high/low ranges]



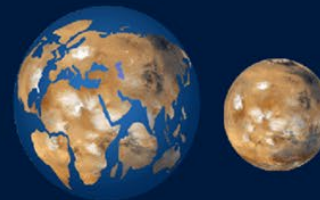
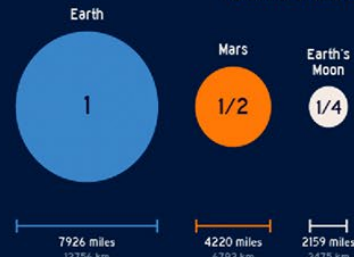
ATMOSPHERE

[characteristics and approximate composition]



SIZE

[equatorial diameter]



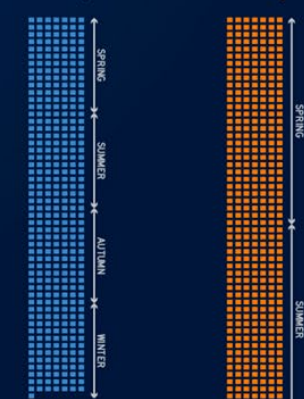
The land area of Earth is similar to that of Mars.

YEAR

[approximately]

365
Earth Days

687
Earth Days



TILT / SEASONS

[approximate tilt]

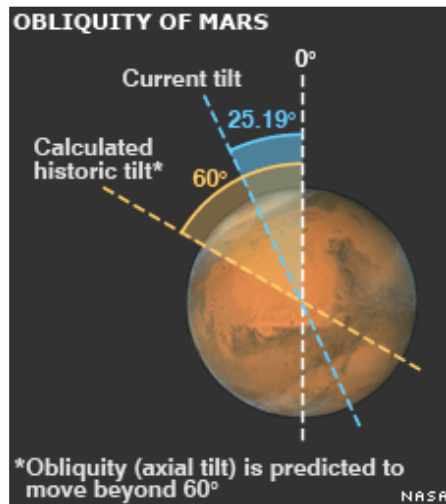


[Northern hemisphere seasons shown]

Image: Mars.NASA.gov

Background of Project / Literature Review

Obliquity Past & Present



"the transport and redistribution of water between ground ice, surface ice, and atmospheric reservoirs appears to be largely sensitive to orbital parameters. ... during periods of high obliquity ($>40^\circ$), large quantities of polar ice could be sublimated and transported away to the tropical regions where it becomes stable (Jakosky and Carr, 1985, Jakosky et al., 1995). ... It is remarkable that the present value of the obliquity of Mars ($\sim 25.19^\circ$) is very far from its mean value..." [$\sim 37.62^\circ$] "This suggests that the present dry and cold martian climate is probably not representative of the past current environmental conditions."

– Laskar et al., 2004

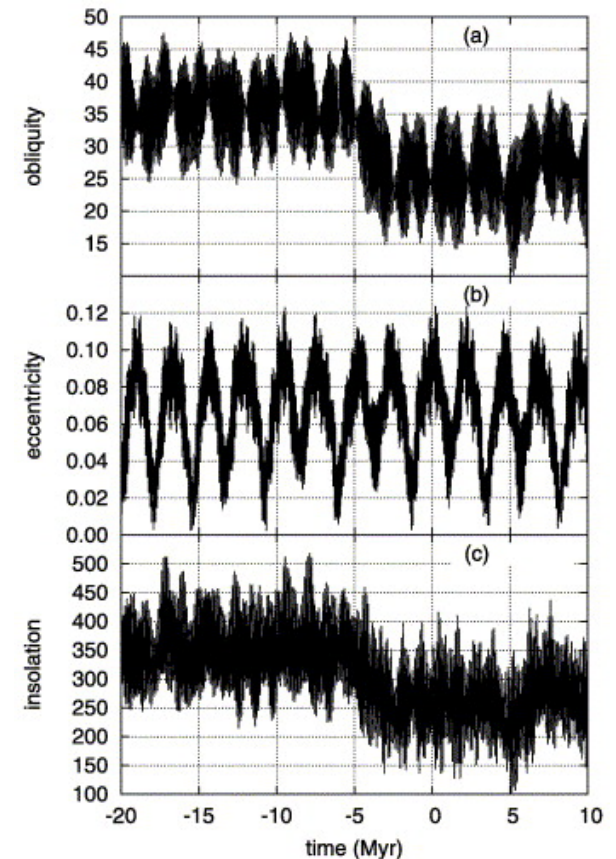
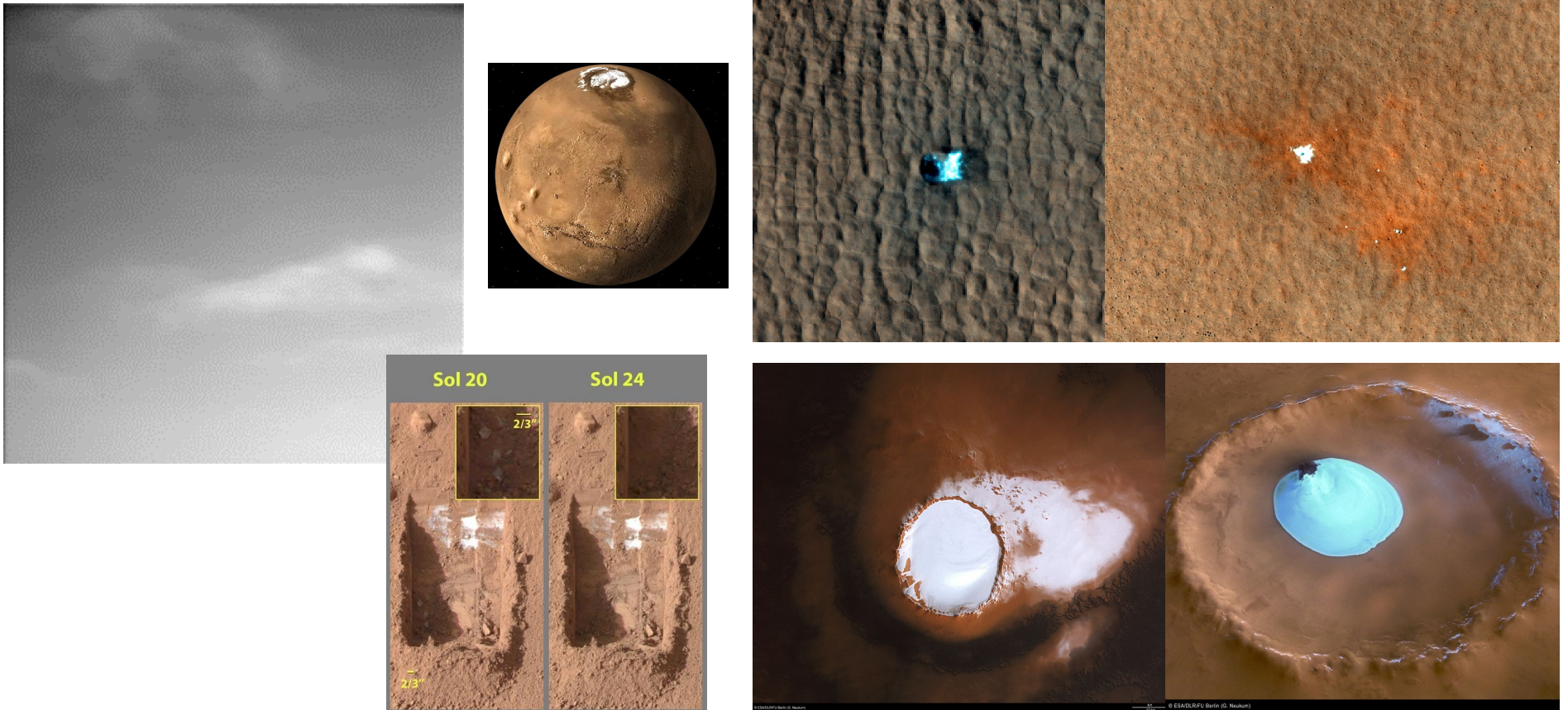


Image: NASA Obliquity Diagram, NASA/JPL/Brown U., Laskar et al., 2004.

Background of Project / Literature Review

Water on Mars Today



Images: Clouds moving over Phoenix landing site (by the Surface Stereo Imager on sol 94), Aug 29, 2008 (NASA/JPL-Caltech/UA/TexasA&M); Phoenix sublimation NASA/JPL; Mars north polar ice USGS; HiRISE fresh impact into water ice NASA/JPL-Caltech/UA/Arizona; HRSC 30km diameter & 35km diameter craters, ESA/DLR/FR Berlin (G. Neukum).

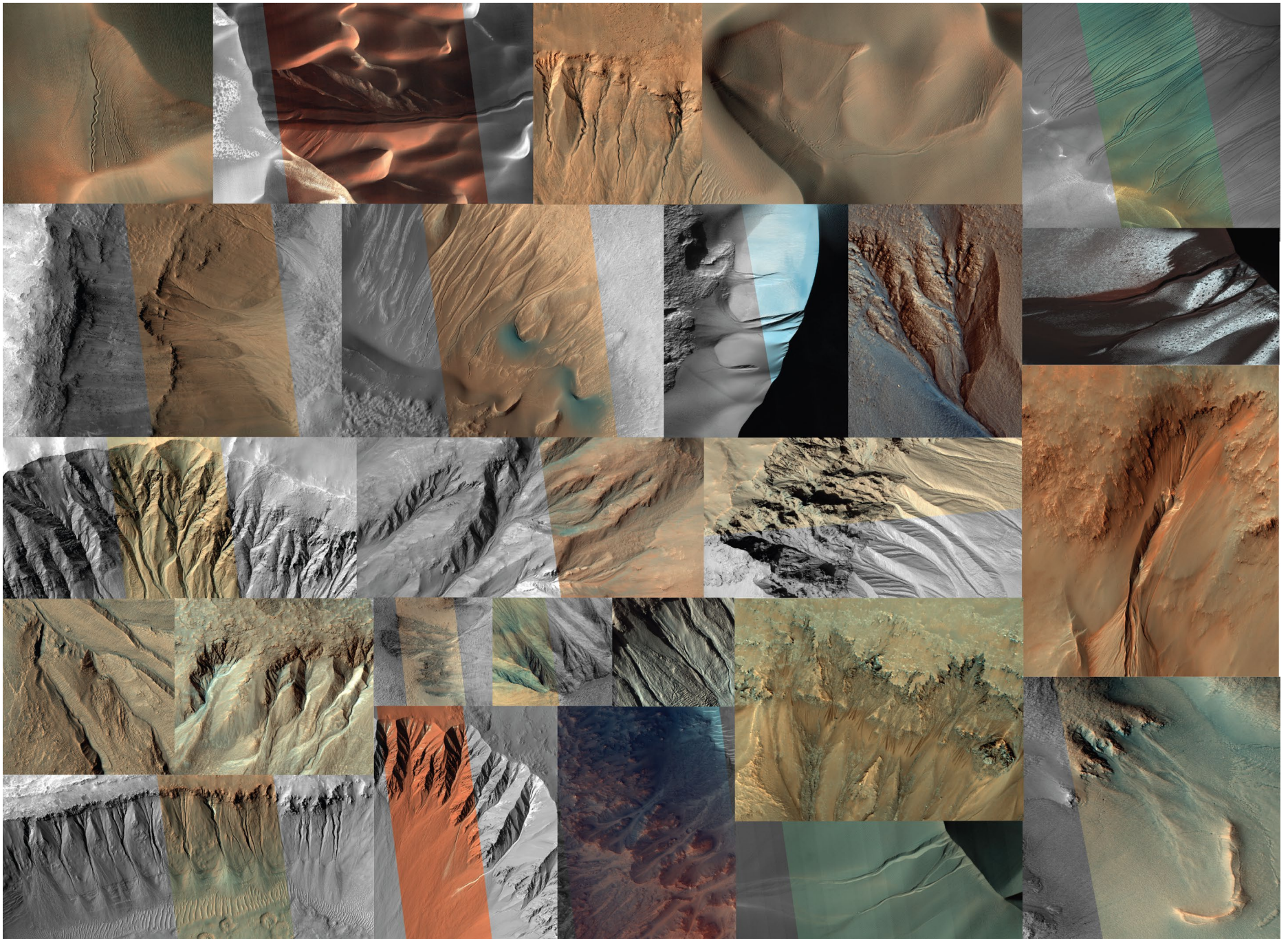


Image: NASA HiRISE Merged RGB's

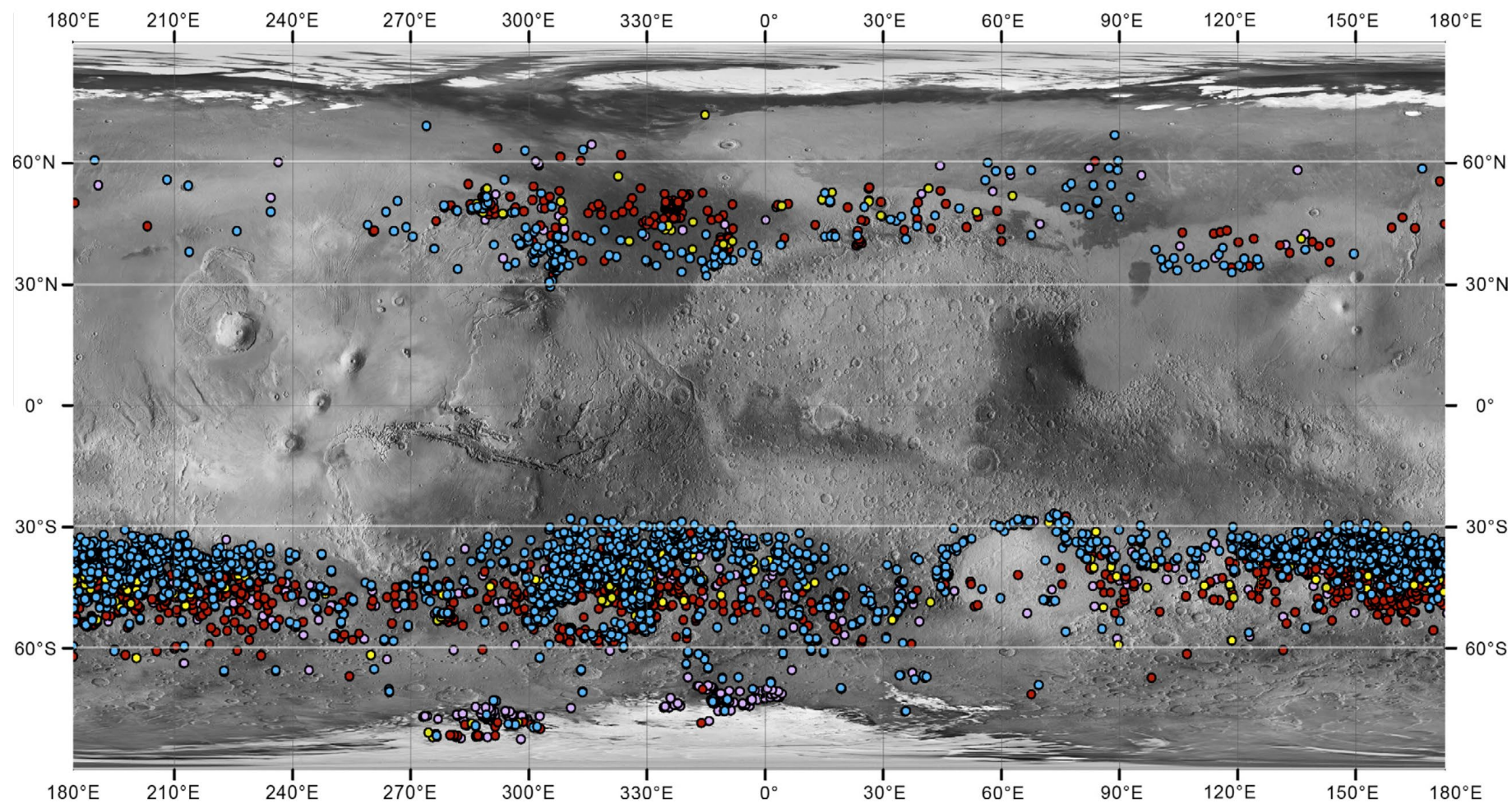


Image: : Harrison et al., 2015 "Global documentation of gullies ..." Icarus.

Background of Project

- Gully Database
- Bamberg Crater (39.71N, 356.9E)

Dichotomy Boundary

Gullies on its central peak/pit

Phyllosilicates (Gross 2012)

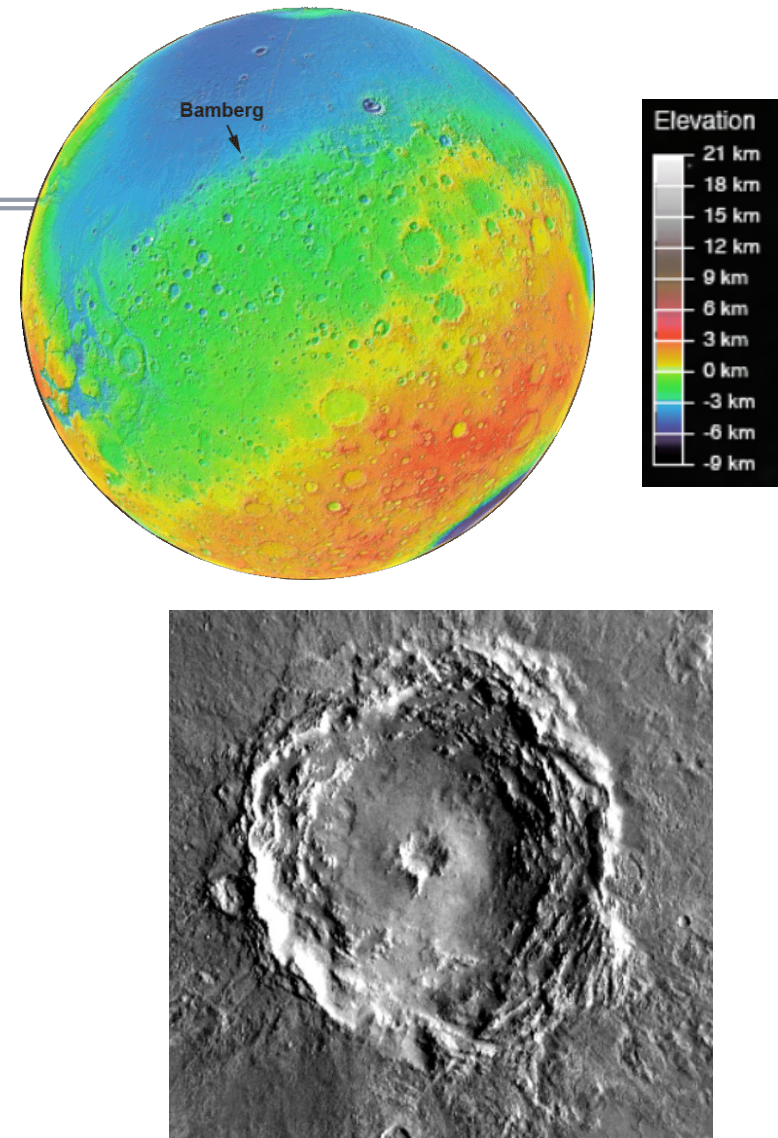


Image: : Google Earth; THEMIS composite in JMARS

Research Questions

1. Is/Was there water in Bamberg? Would it be 'stable' at the surface today or in the past?
2. How are gullies in Bamberg different/similar to other gullies we've studied?
3. How was the setting shaped over time?

Overarching questions:

What processes form gullies on Mars? Can we determine key process based on gully morphometry/morphology? Can we identify global gully trends? Where is the water?

Methods

- Gully Data: ArcGIS, ENVI (HiRISE Imagery/DTM)

Diagram Drainages

Study Erosion/Deposition

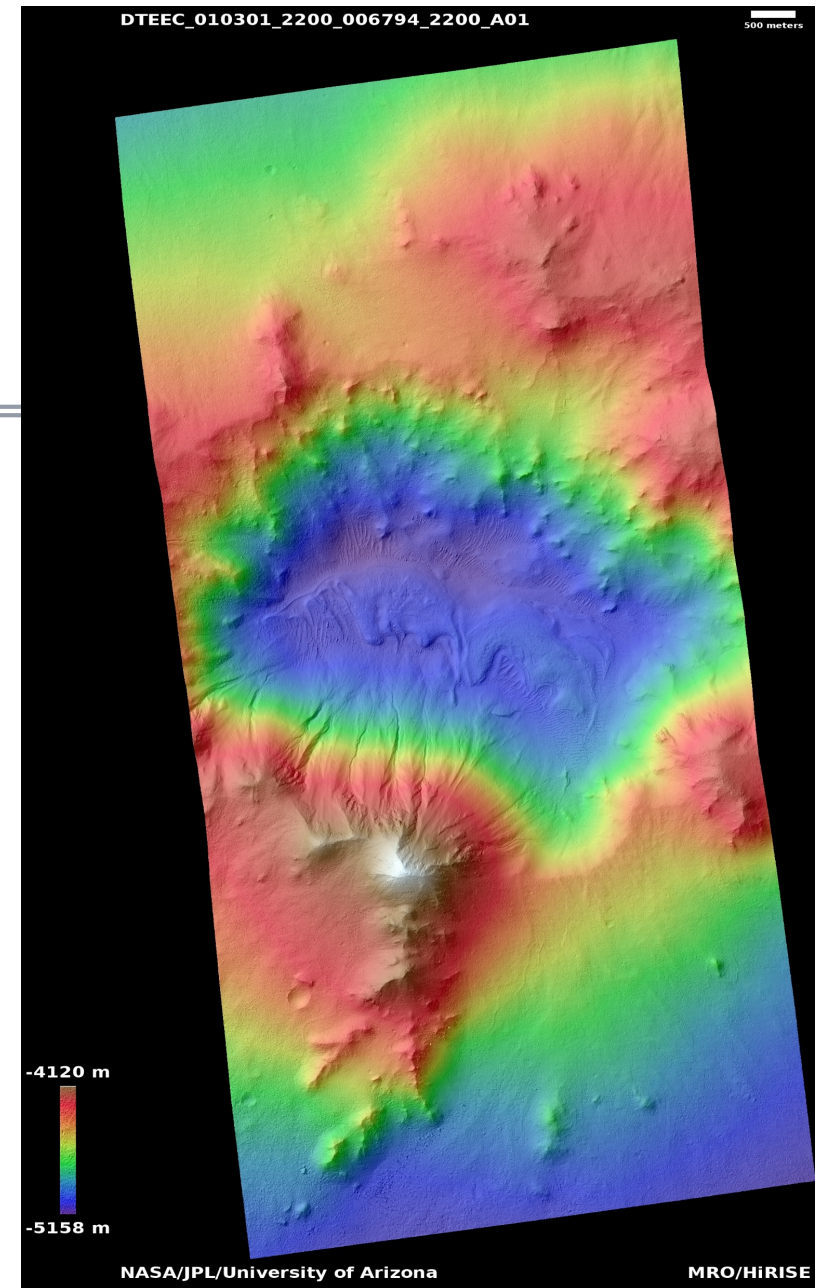
Measure Morphometries

- Site Data: JMARS (TES, THEMIS)

Acquire Pressure/Temperature data

Quality control

Record, Analyze Values



product_id	rationale_desc	left_observation_id	right_observation_id
DTEEC_010301_2200_006794_2200_A01	Gullies within central pit of Bamberg Crater	PSP_010301_2200	PSP_006794_2200

Methods

- Gully Data: ArcGIS, ENVI (HiRISE Imagery/DTM)

Diagram Drainages

Study Erosion/Deposition

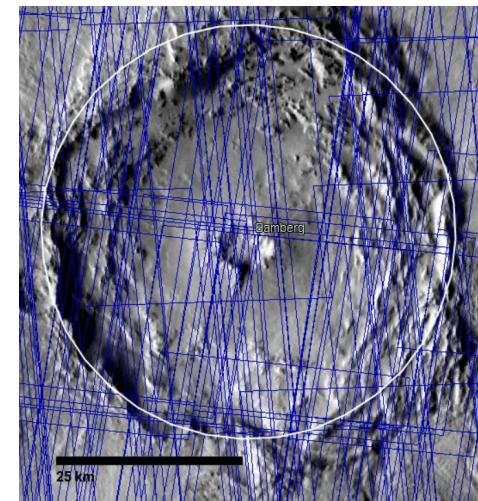
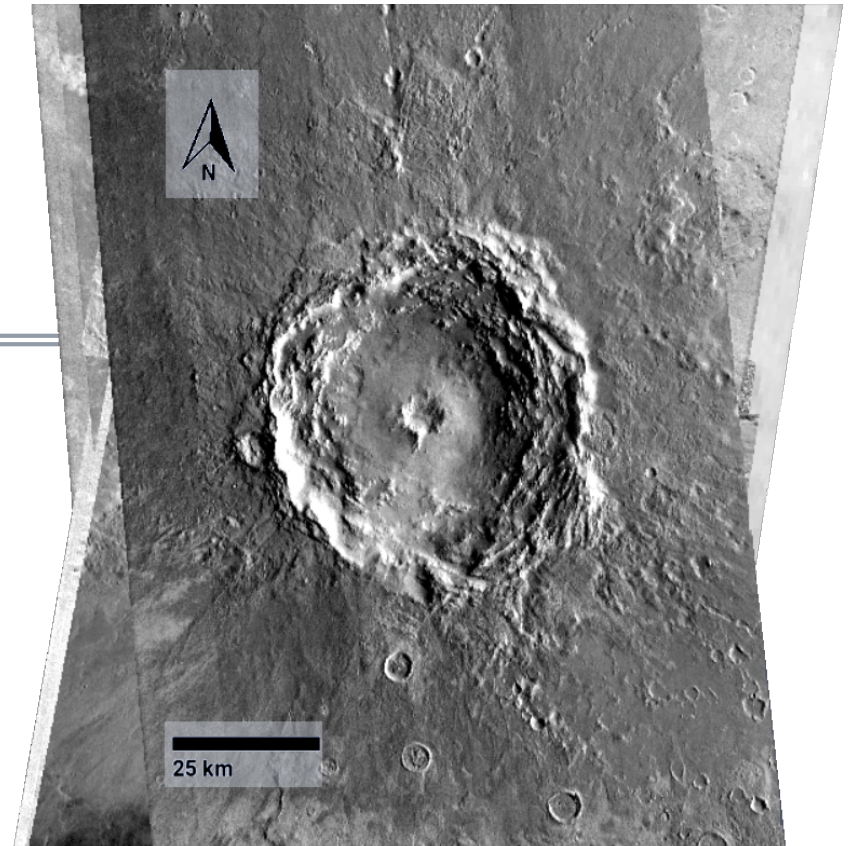
Measure Morphometries

- Site Data: JMARS (TES, THEMIS)

Acquire Pressure/Temperature data

Quality control

Record, Analyze Values



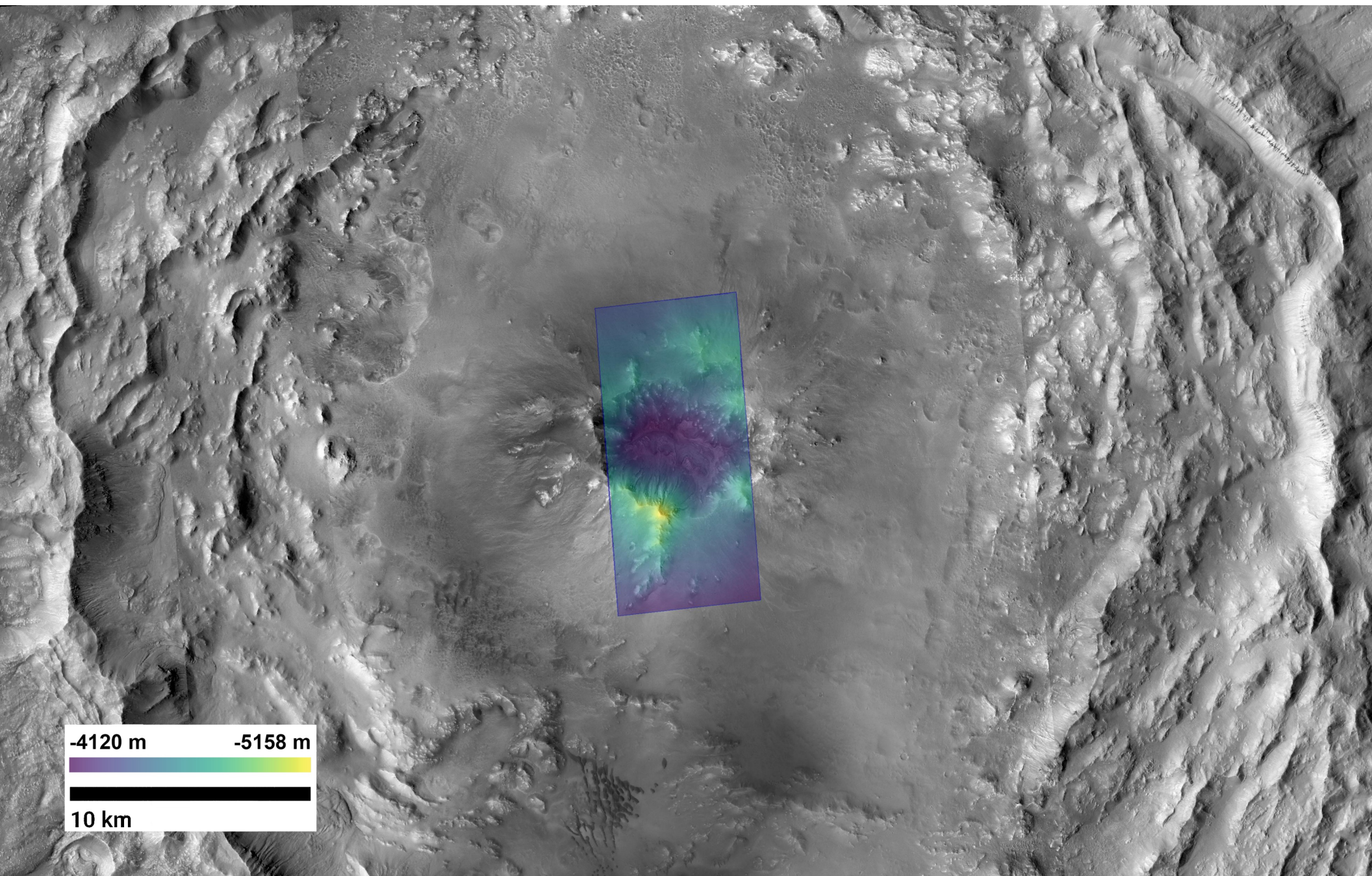


Image: HiRISE DTM colorized elevation over CTX images, in JMARS

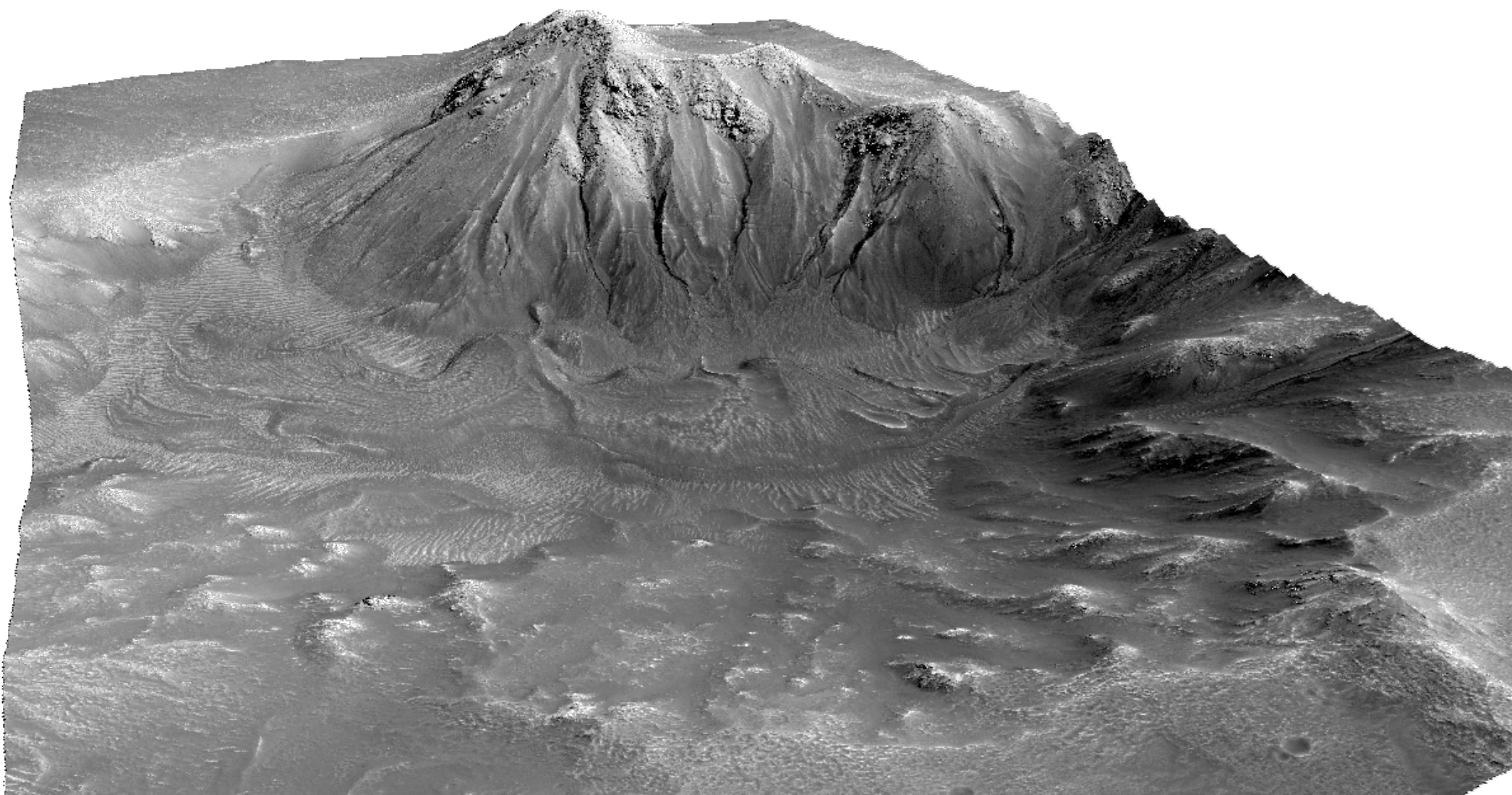


Image: Perspective View of Bamberg's Central Peak / Pit Gullies

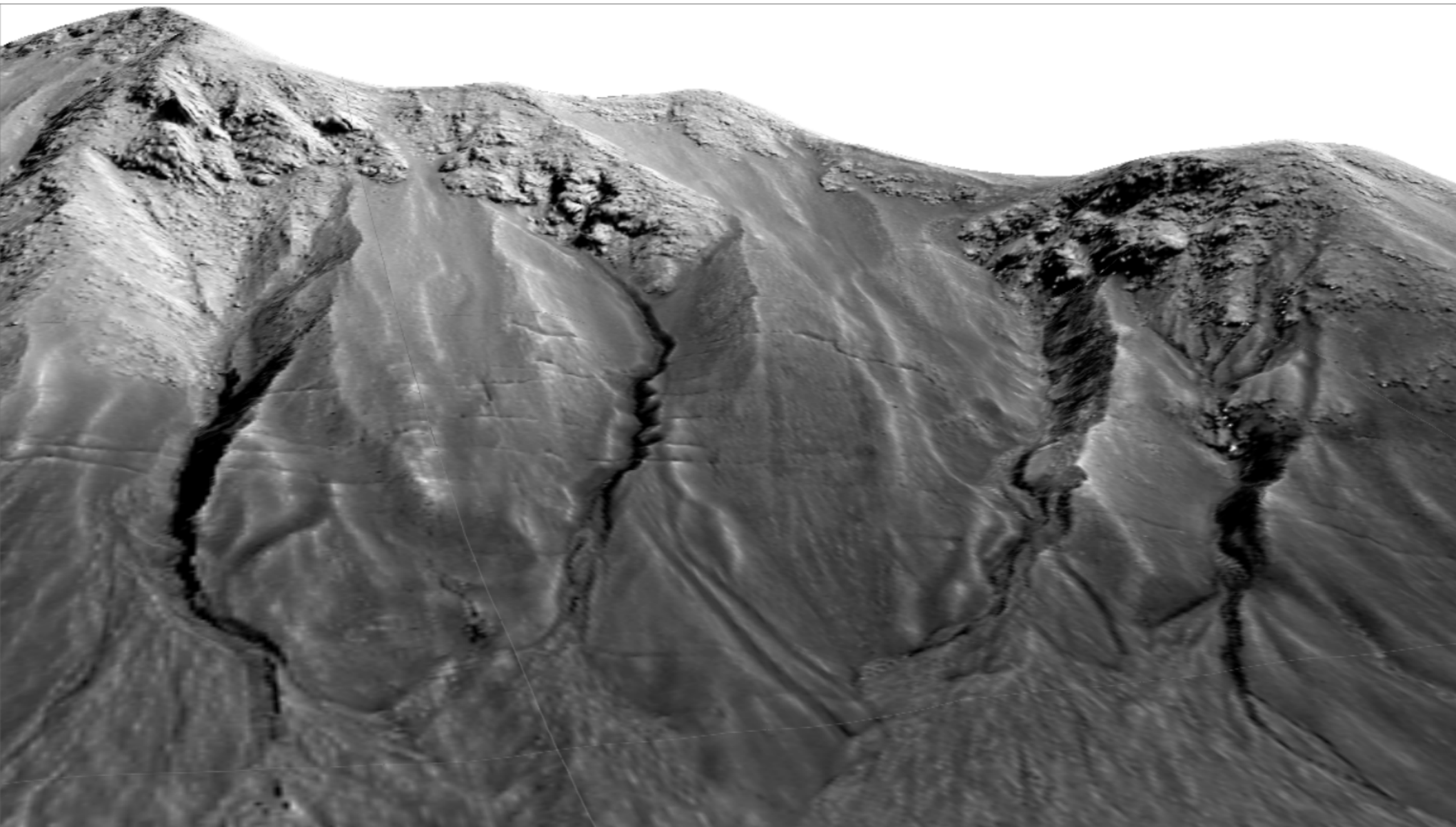


Image: Perspective View of Bamberg's Central Peak / Pit Gullies

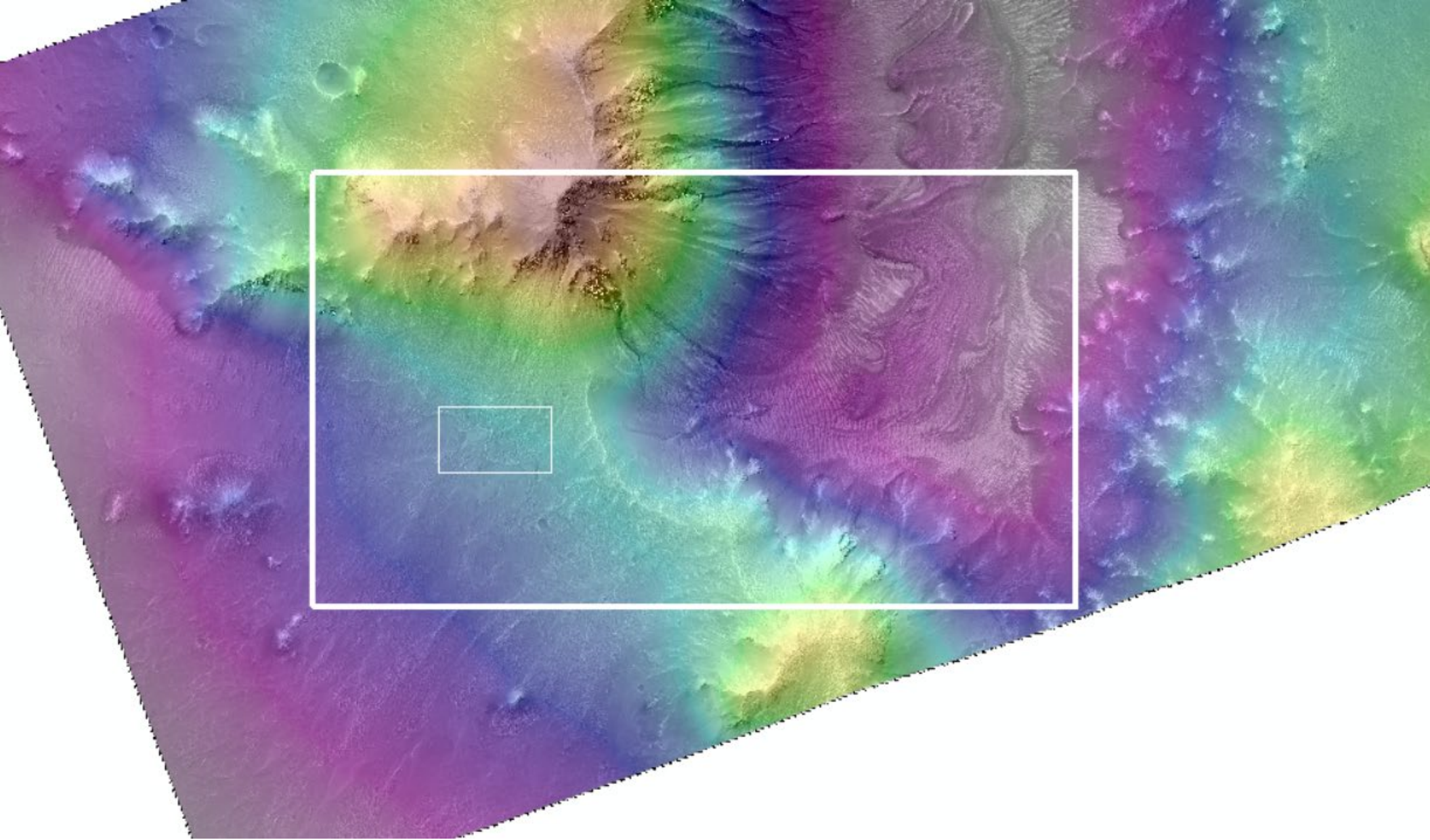


Image: Inset View

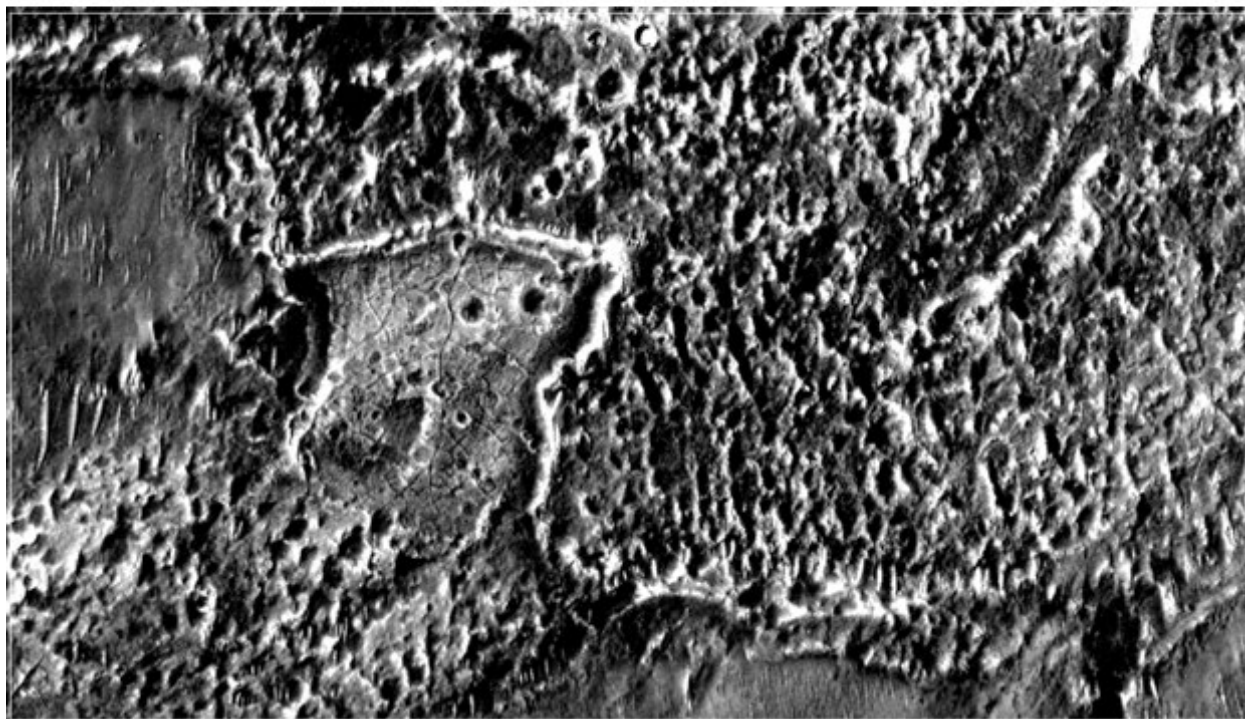
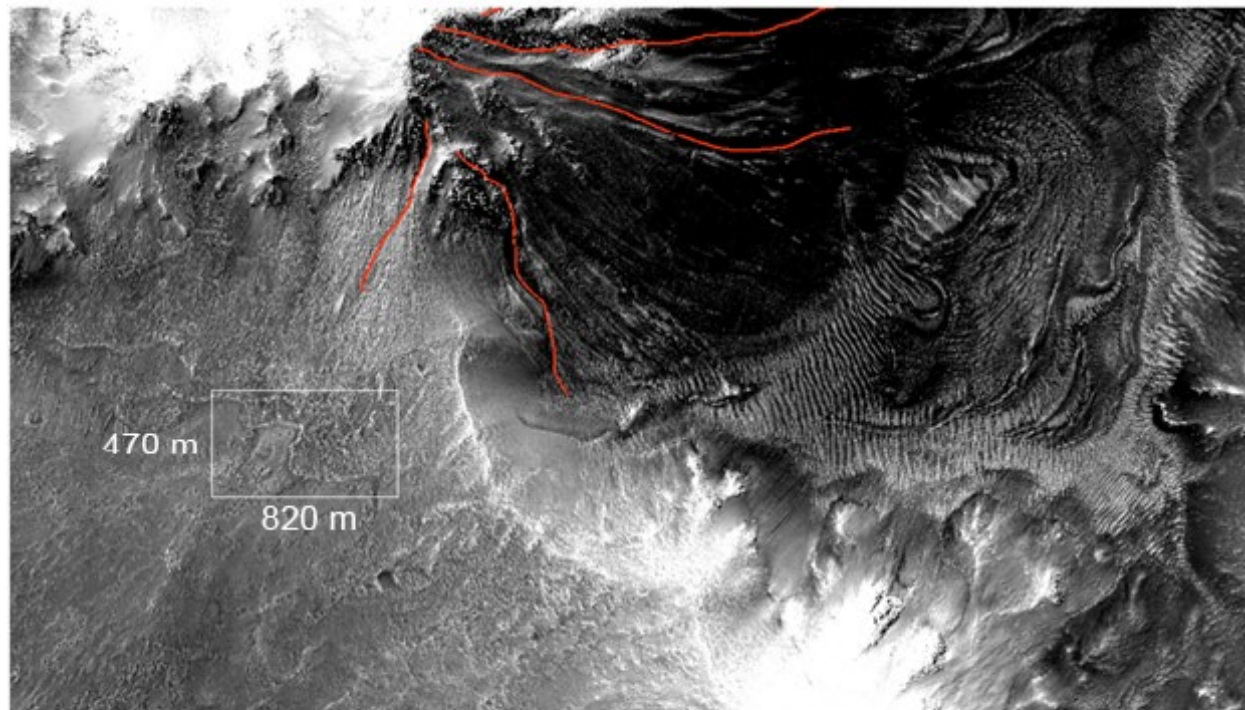


Image: Inset View

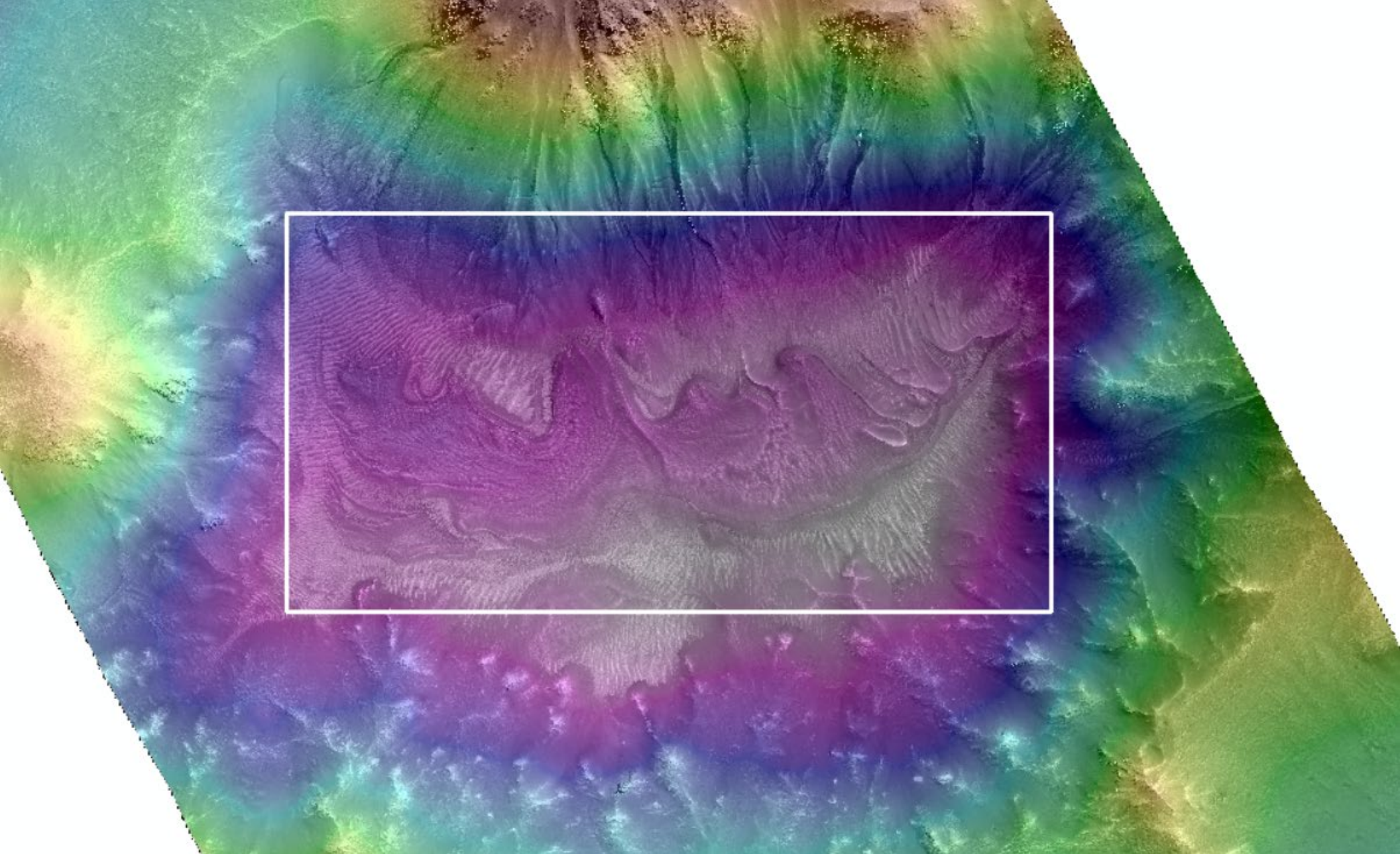
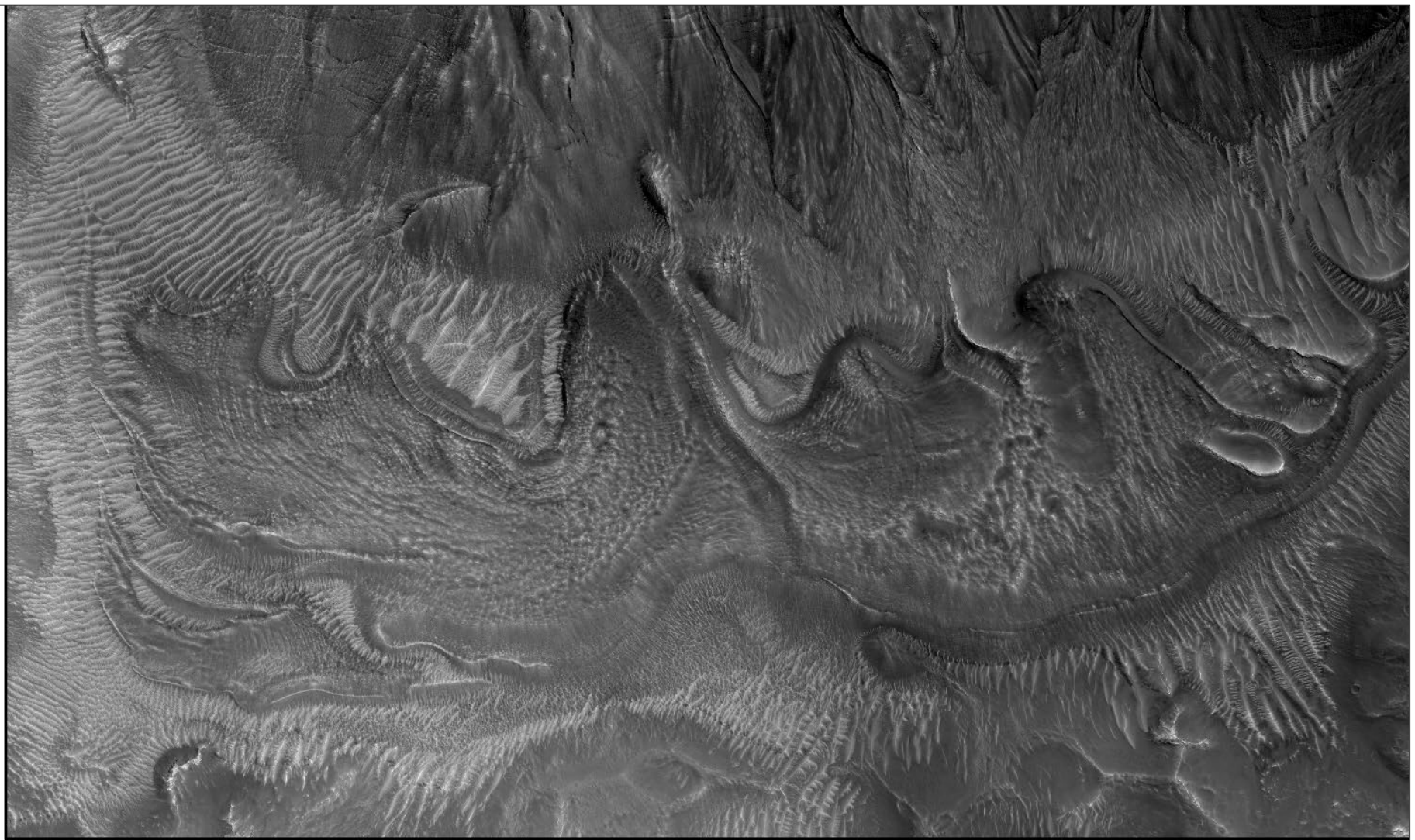


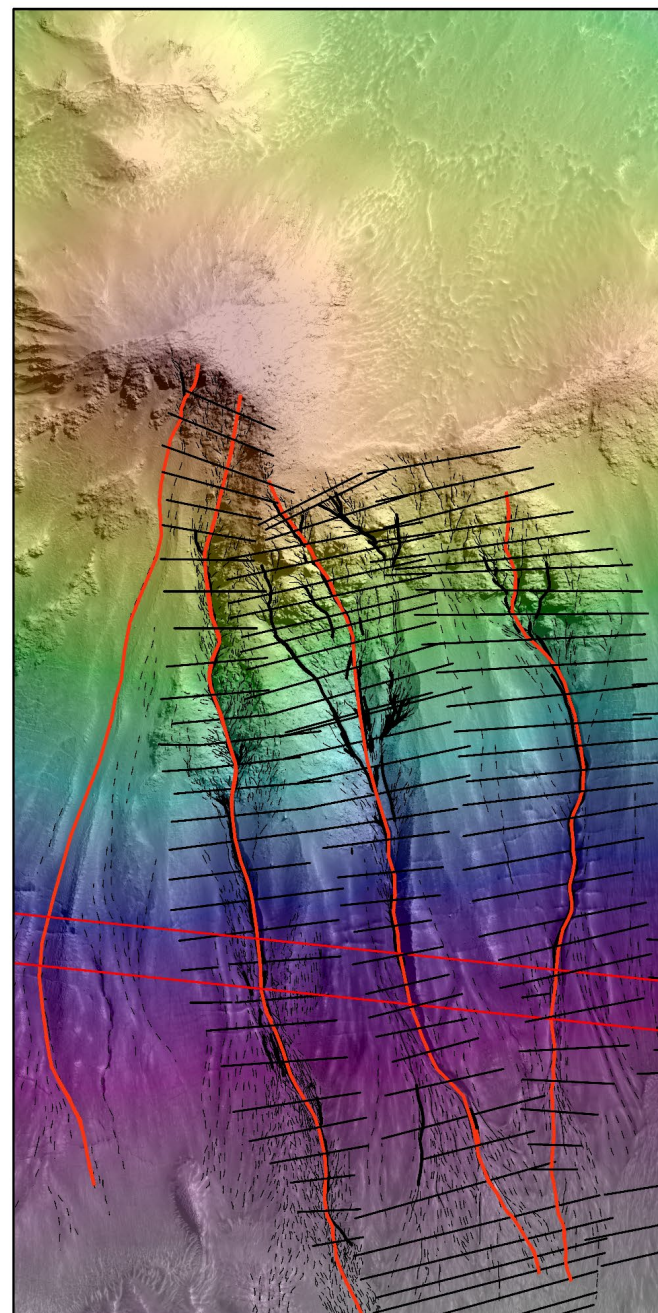
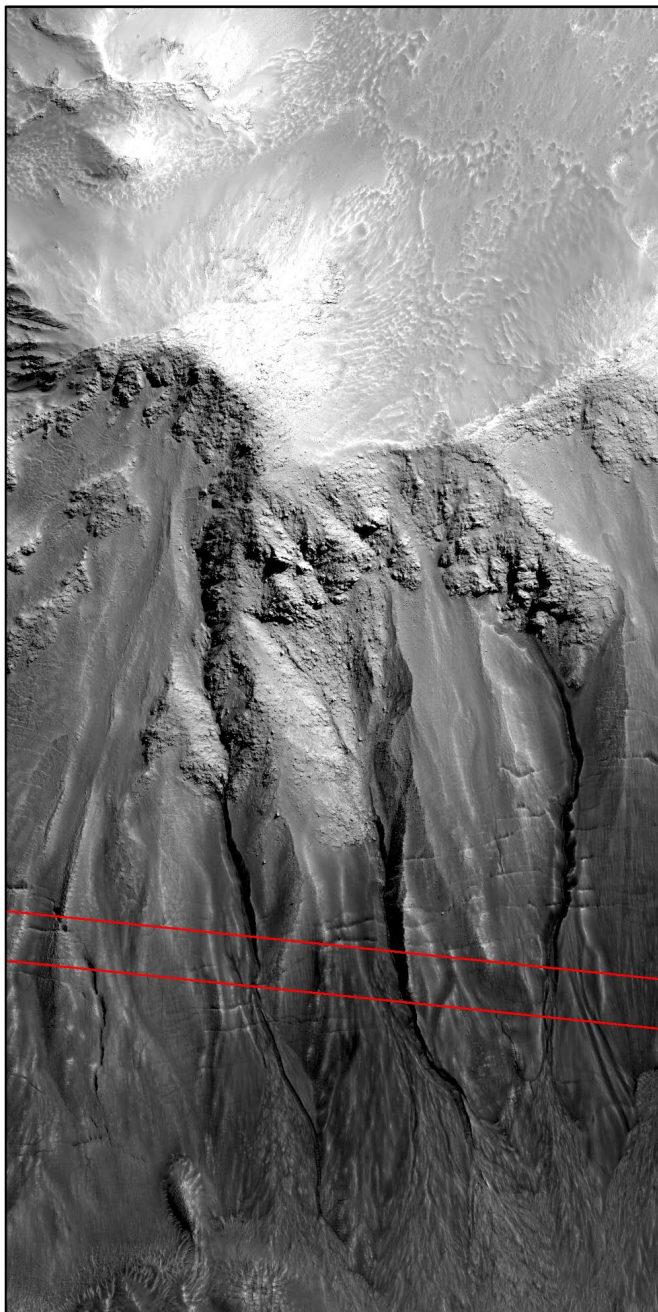
Image: Inset View



550

Meters

Image: Inset View



DTEEC_010301_2200_006794_2200_A01.IMG

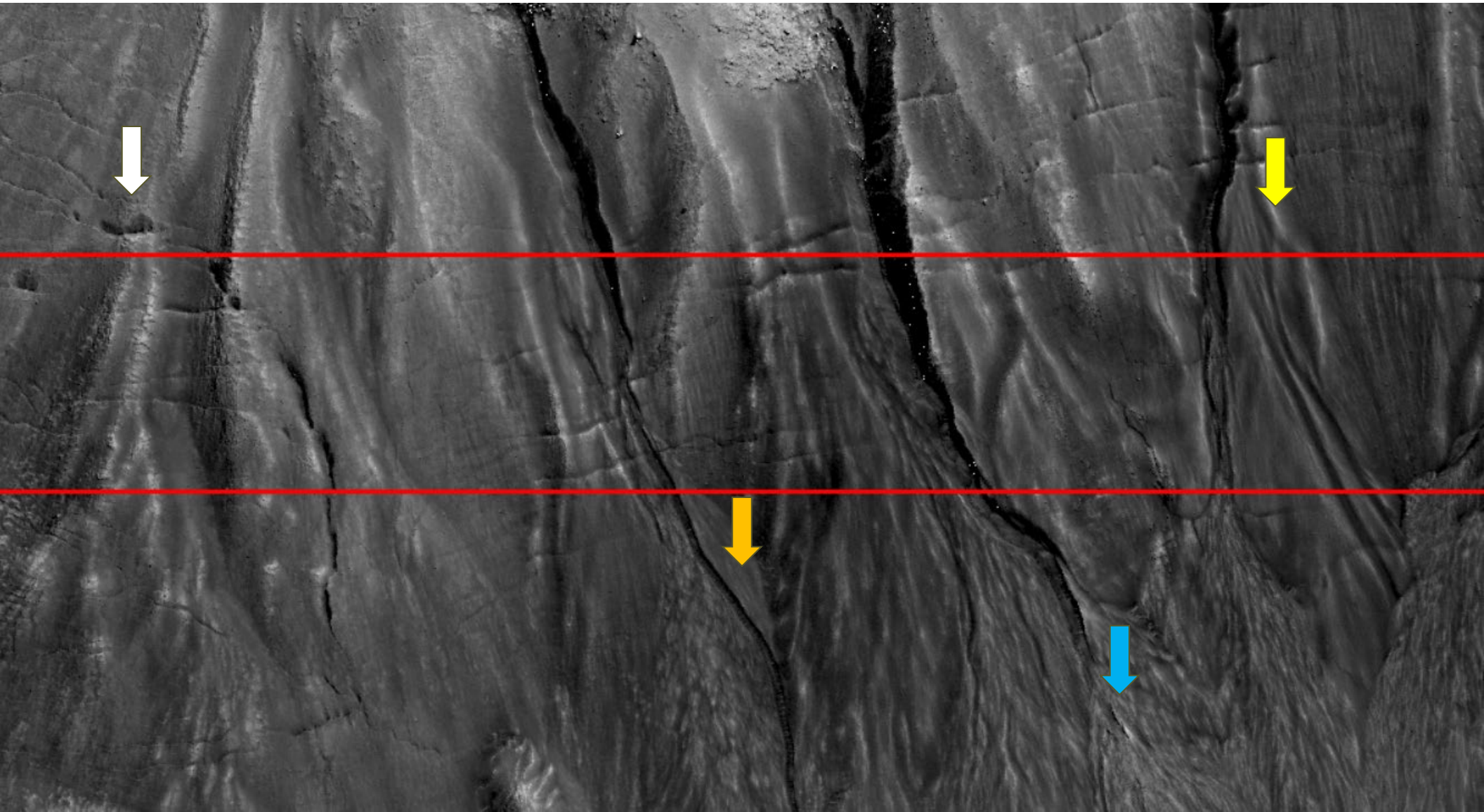
Value

High : -4121.63

Low : -5079.15

500

Meters



Data – Bamberg Peak Gullies

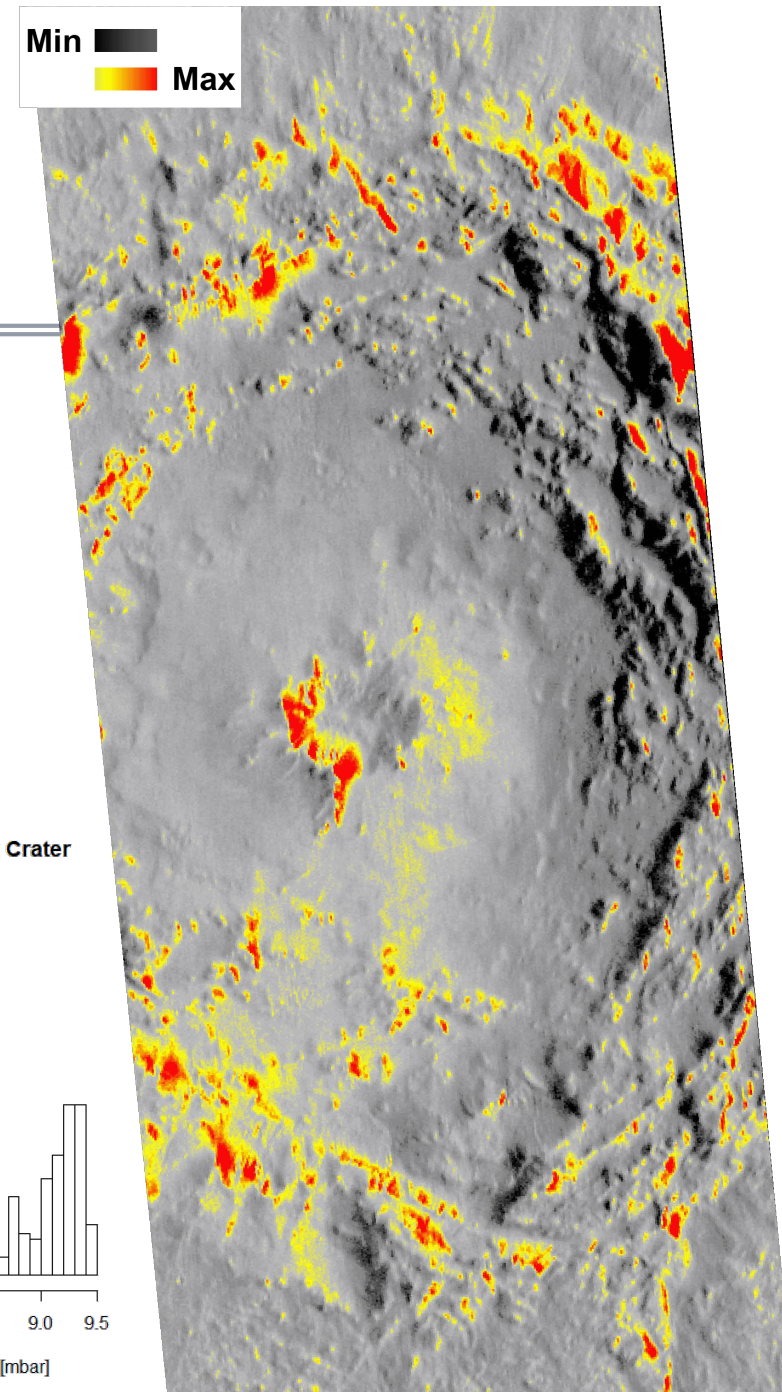
Gully Morphometry	Values
Length [km, avg]	1.8
Incision [m]	10
Overall Slope [deg]	21
Alcove Slope [deg]	31
Apex Slope [deg]	15
Channel Slope [deg]	12

Temperature

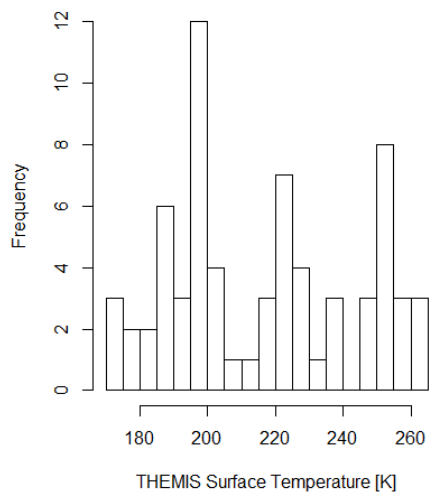
Data	MIN K	MED K	MAX K	IQR
THEMIS	171	216	262	44
TES	219	271	279	7

(623 TES data points; 39 individual days)

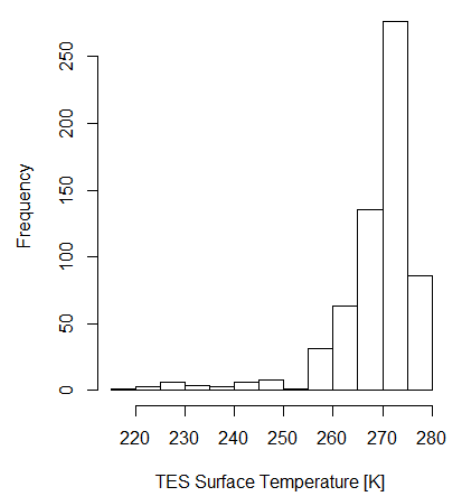
(75 THEMIS of acceptable quality)



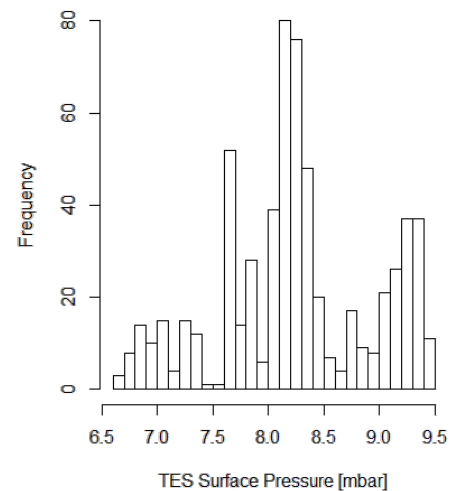
Max THEMIS Temperatures, Bamberg Crat



TES Temperatures, Bamberg Crater



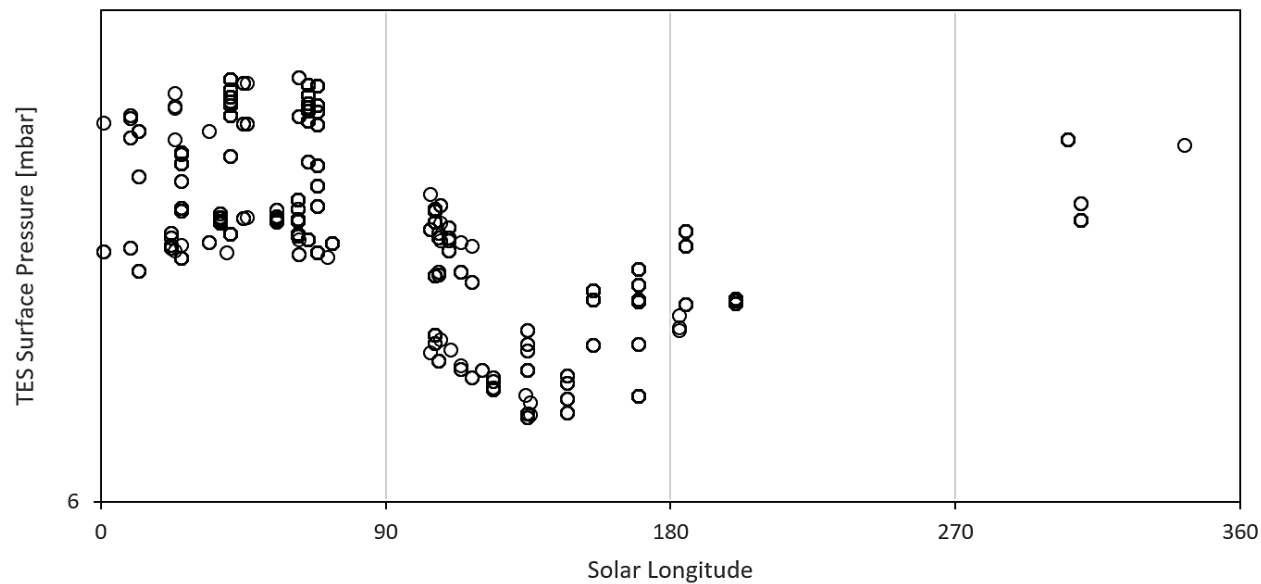
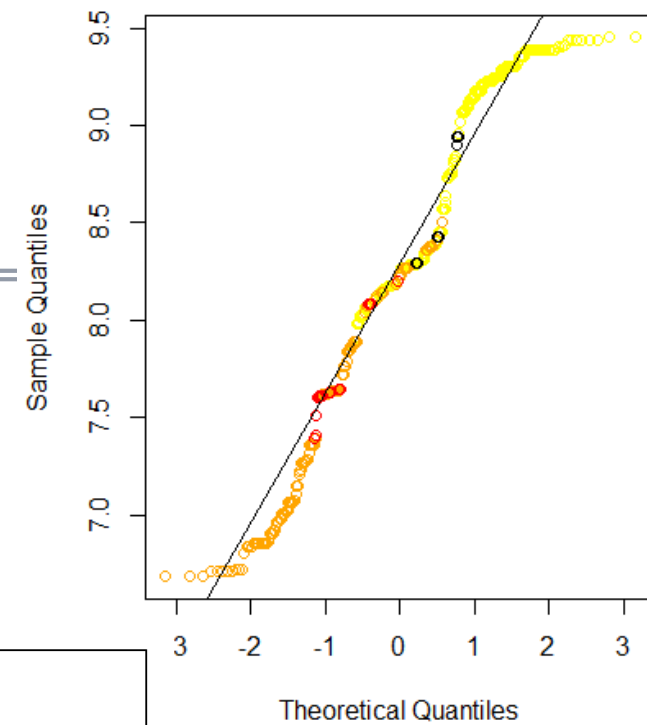
Pressure, Bamberg Crater



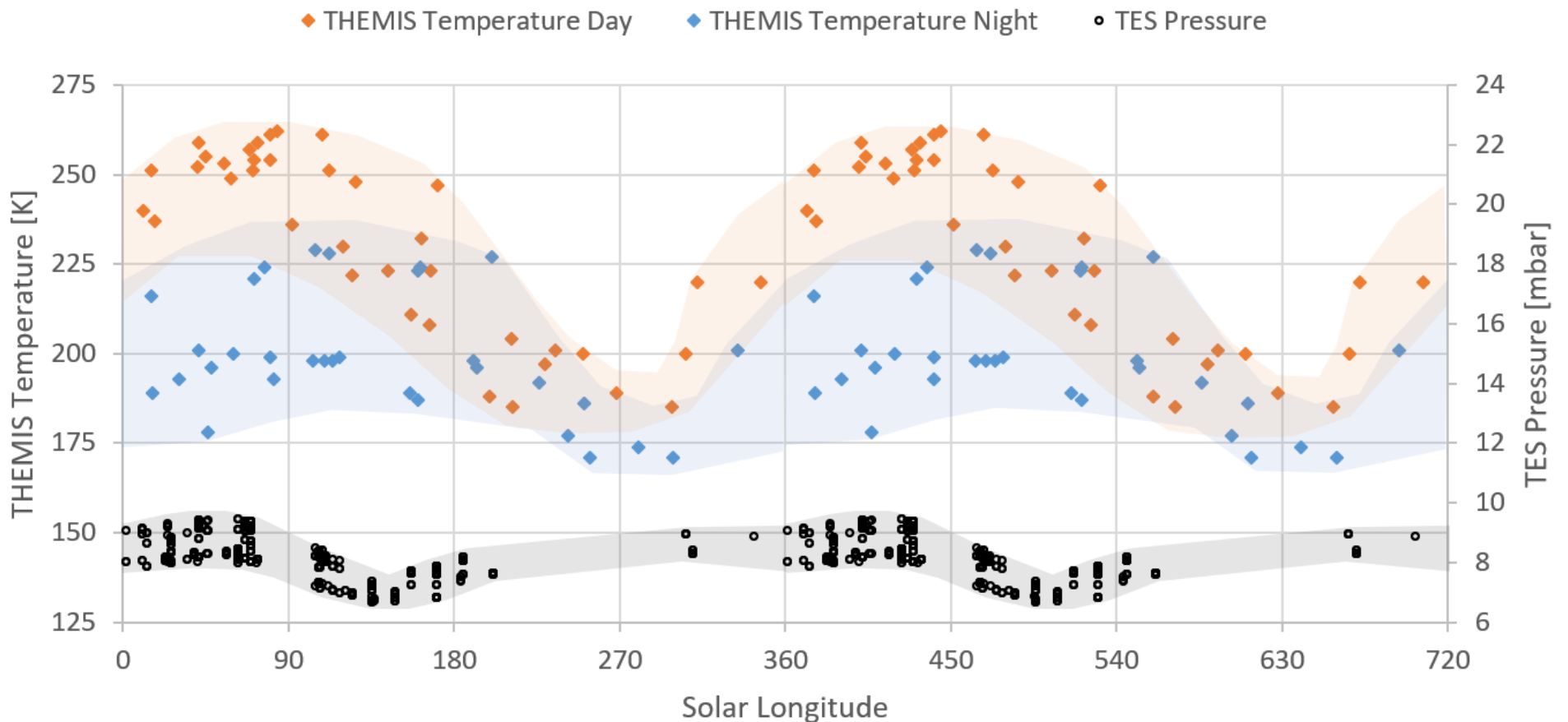
Pressure

Data	MIN mbar	MAX mbar
TES	6.7	9.45

Pressure by Season Q-Q Plot

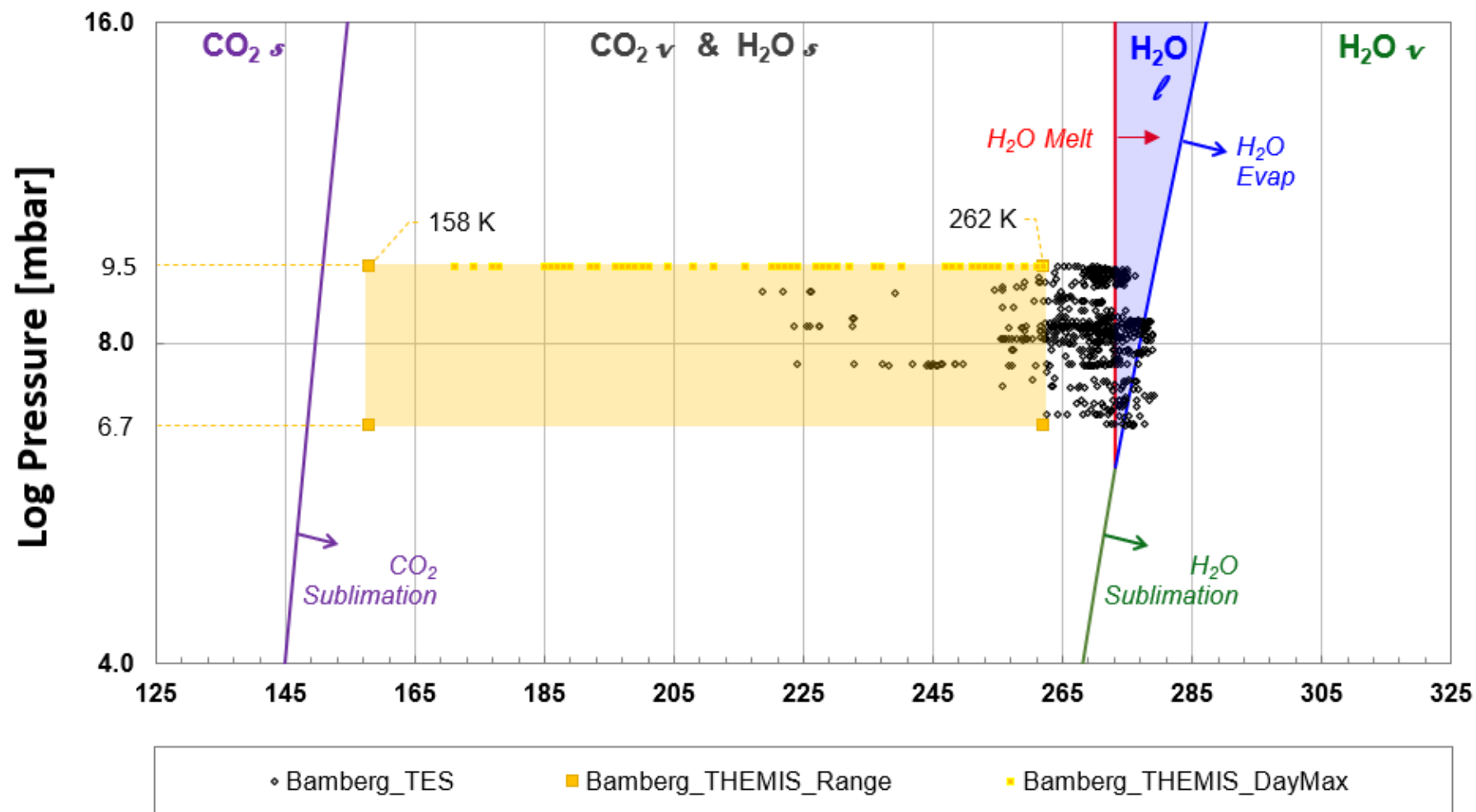


Seasonal Temperature & Pressure



Bamberg Crater: Present-Day State of H₂O and CO₂

Temperature (K)



Data – Bamberg Crater

Bamberg Crater	Values
Elevation [km]	~ -4.2
Max Surface Pressure [mbar]	9.45 (623 TES data points; 39 individual days)
Max Surface Temperature [K]	270 (75 THEMIS of acceptable quality)

Discussion/Conclusions

- Surface Pressure in Bamberg today [max ~9.5mbar] is above that of water's triple point [~6.1mbar].
- Peak temperatures here [262K THEMIS / 279K TES] could enable temporary surface meltwater flows before evaporation, infiltration, and freezing.
- Surface temperatures & pressures vary on Mars largely due to changes in obliquity. In the present-day, we see that Bamberg temperature varies ~100K & pressure varies ~3mbar.
- Bamberg Crater has been modified by surface ice and its meltwater. Terrain textures indicate much ice has been lost at the surface, yet an abundance of water remains accessible as ice in the subsurface, and in the moraine-like arcuate ridges below the gullies.
- We propose meltwater is the leading process behind the formation of Bamberg's gullies, and that the gullies could have formed recently in the Late Amazonian. Some of this meltwater is preserved within the gully aprons it infiltrated.

Future Research & Implications

- Gully Database & Statistics

Which factors contribute to the formation of various gullies, and which are most important?

How does water play a role?

Identify global gully trends.

Crater Gullies: Asimov, Bunnik, Corozal, Moni, Palikir, **Bamberg, Selevac, Dunkassa, Istok, Triolet, Galap, Unnamed Craters in Sirenum Fossae, Noachis Terra, Arabia Terra.**

Megadune Gullies: Matara, Kaiser megadunes

Central Peak Gullies: Lyot and Hale.

High Lat gullies: [refer to Rowan Huang's Summer abstract].

Acknowledgments

THANK YOU to my mentor, Dr. Gulick, and to the NIFS program for this opportunity.

THANK YOU to the HiRISE Instrument Team for providing the terrain models and imagery integral to this project.



References

HiRISE Image Credits: NASA/JPL-Caltech/USGS/U.Arizona

Software Credits: JMARS, ArcGIS

All Other Image Credits: Cornell SPIF, Google Earth, NASA, JPL, Brown University, Caltech, University of Arizona, Texas A&M, ESA/DLR/FR Berlin.

Laskar et al., 2004 “Long term evolution and chaotic diffusion of the insolation quantities of Mars” *Icarus* 170, 343-364.

Harrison et al., 2015 “Global documentation of gullies with the Mars Reconnaissance Orbiter Context Camera and implications for their formation” *Icarus* 252, 236-254.

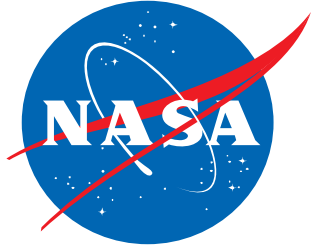
Hynek et al., 2010 “Updated global map of Martian valley networks and implications for climate and hydrologic processes” *JGR: Planets* 115, E9.

Gross 2012, LPSC Abstract #2356.

Numerous works by Dr. Gulick and Team 2013 – Present.

Questions

Thank you!



MORPHOLOGIC AND SLOPE STUDIES OF CRATER GULLIES IN THE HIGH-NORTHERN LATITUDES OF MARS

R.I. Huang¹, V.C. Gulick^{2,3}, N.H. Glines^{3,4}

¹Brigham Young University, ²NASA Ames Research Center, ³SETI Institute, ⁴University of California -- Santa Clara

National Aeronautics and Space Administration



Abstract

Gullies on Mars are usually defined by a source alcove and a single channel that shallows into a debris apron. This holds true for many of gullies, especially those in southern latitudes. However, several gullies in northern high-latitudes ($>50^\circ$ N) show complex forms with more than one prominent channel. Initial detailed morphometric analysis of two northern high-latitude sites was established in a previous study. This study expands on that work in addition to conducting the same analysis on another northern high-latitude site. Morphometric comparison of these gully morphologies and their spatially associated landforms can give insight to different gully forming processes and provide clues to past environmental conditions in the Martian northern hemisphere.

Introduction

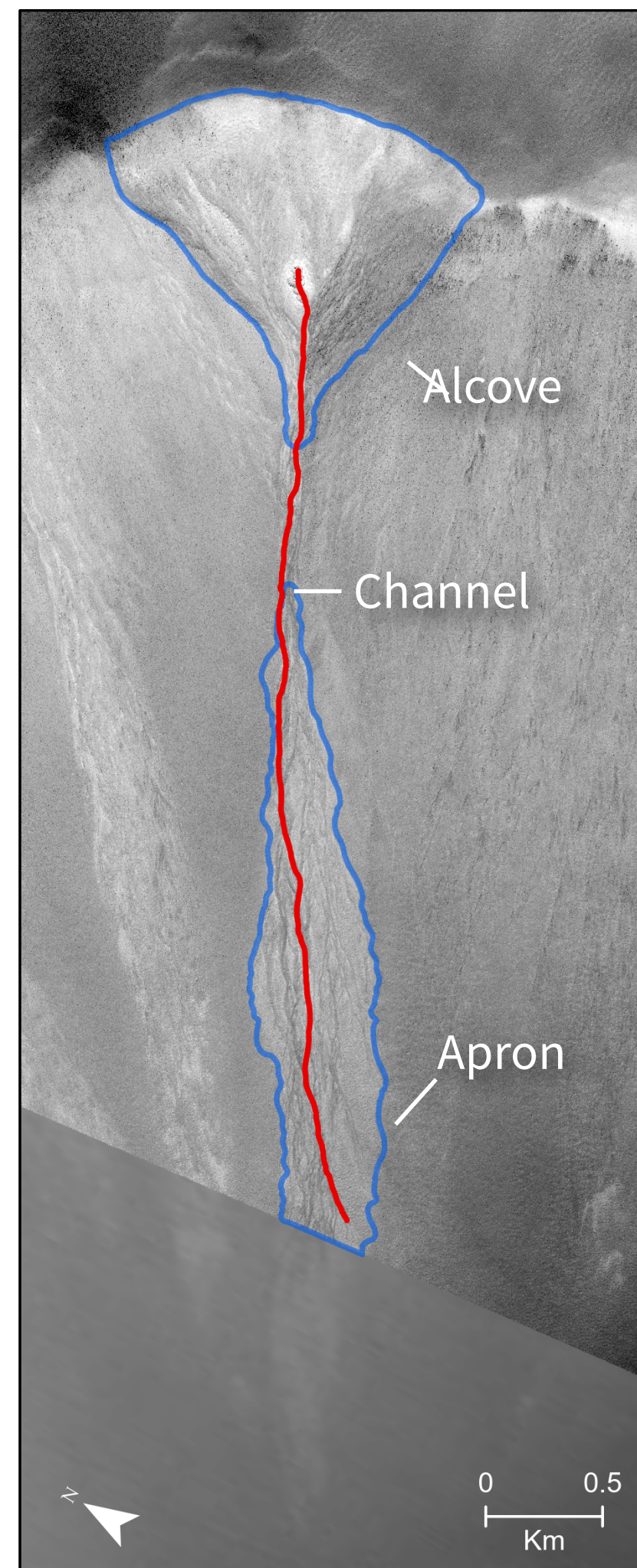


Fig. 1: CTX image of one gully of interest overlain by HiRISE orthoimage PSP_008141_2440. Here, its apron and alcove margins have been defined in blue as well as its CSL (center stream line) in red

Gullies on Mars are usually defined by three parts (Fig. 1): The alcove, the channel, and the apron. They are commonly found on crater walls, but can also form on dunes, central crater peaks, mesas, mountains or montes, and valley systems on Mars. In this study, we are focusing on crater-wall gullies.

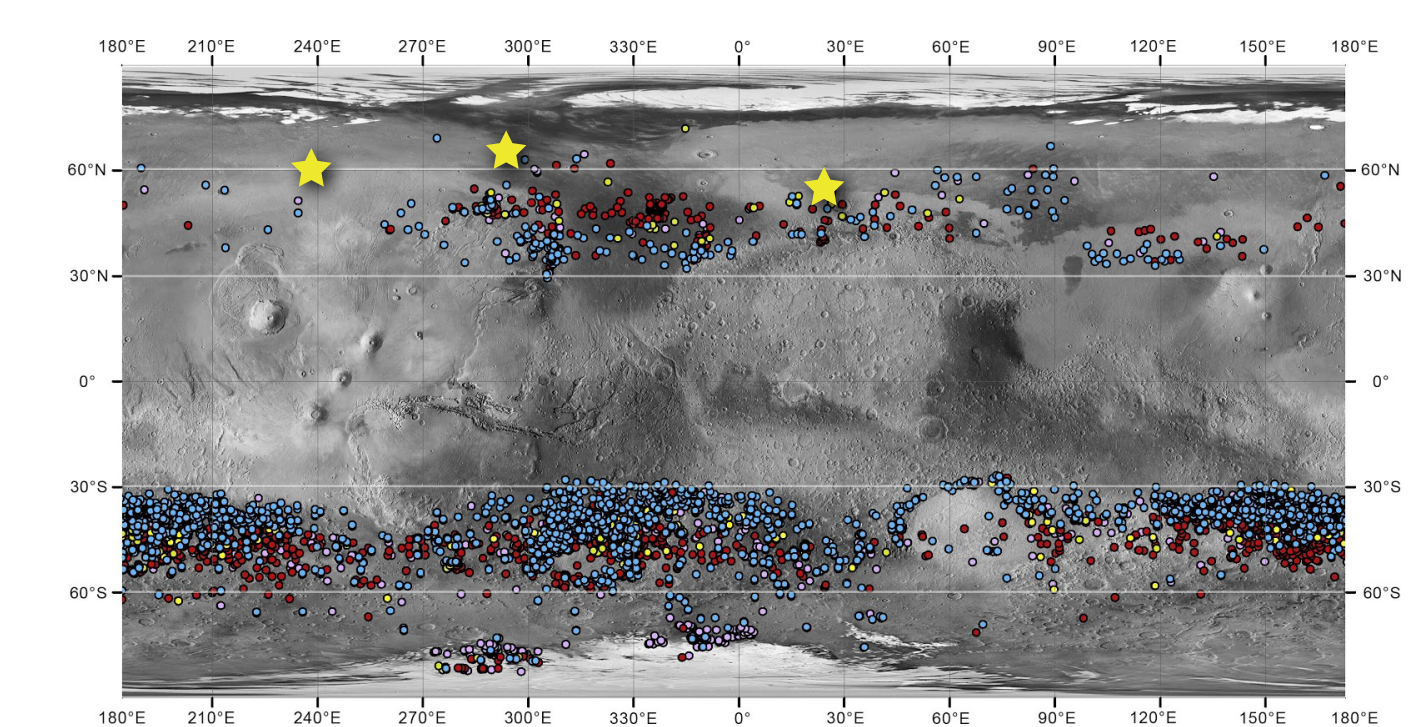


Fig. 2: Harrison global map of gullied landforms (Harrison et al, 2015, Icarus). The craters studied in this project are starred to highlight the scarcity and high latitude of the study areas.

While most gullies are found in the mid-latitudes of Mars, especially those in the southern hemisphere (Fig. 2), this study concentrates on those in northern high latitudes. It is an entirely different environment at lower elevations with different rock types and processes shaping the landscape.

Crater NE of Tantalus Fossae Crater 1: 63.8° N 292.3° E

This crater is located to the northeast of Tantalus Fossae. It is ~ 16.3 km in diameter and contains numerous poorly developed gullies on its eastern and western interior slopes. One exceptional gully displays a braided morphology in which deep channels incise the entire thin, light-toned apron (Fig. 3). This morphology may be due to unconsolidated sediment composing the crater slopes. At the deepest part of its alcove is an intriguing, elongated 12-m high mound, which is eroded along its downslope trend. We interpret this to be a dust-covered snowpack (Fig. 4). This gully has a gentle overall slope of $\sim 11.91^\circ$.

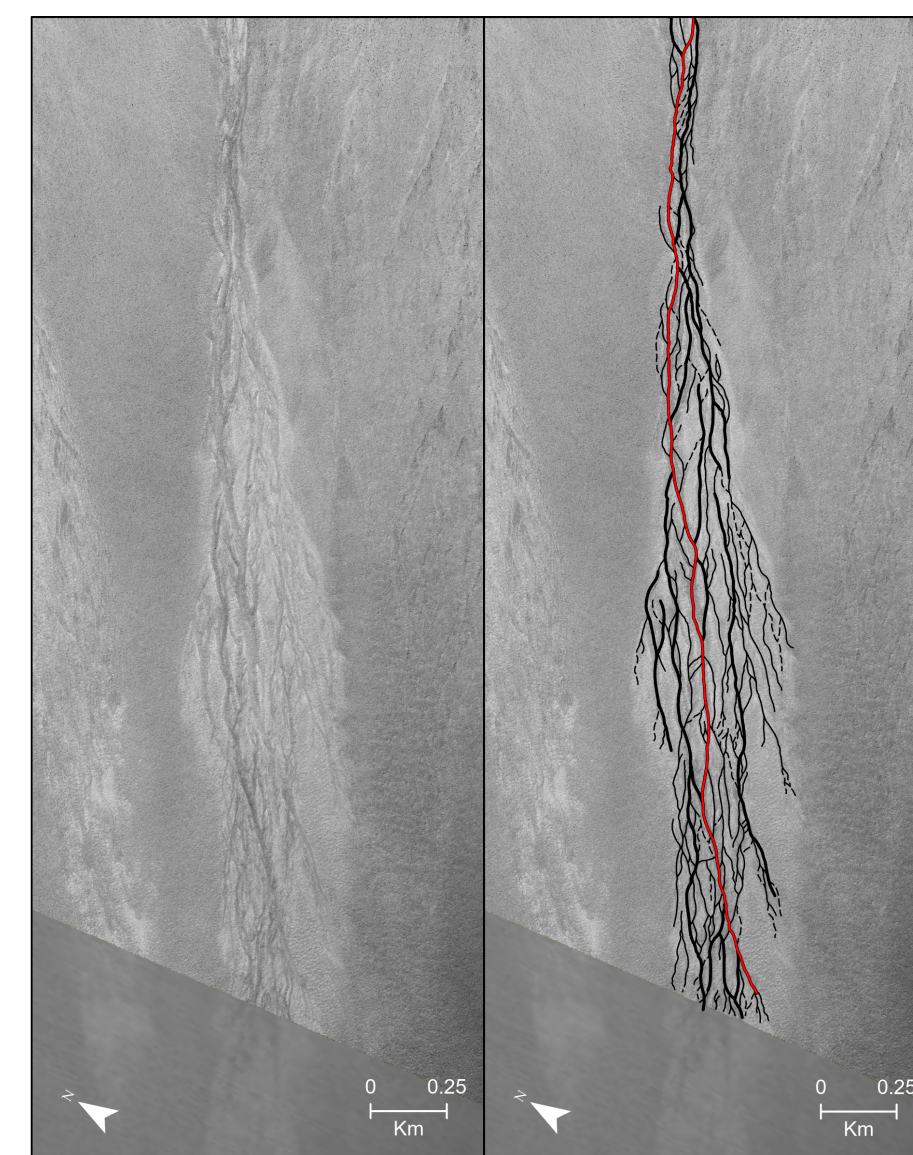


Fig. 3: Side-by-side comparison of the apron of the gully of interest (left) and interpreted channels (right). Note the bright nature of it (perhaps due to icy composition or recent deposition) as well as the complexity of the networked channels, not unlike a terrestrial braided stream. The center stream line (deepest and most continuous channel, highlighted in red) appears to anastomose and change, suggesting multiple episodes of erosion.

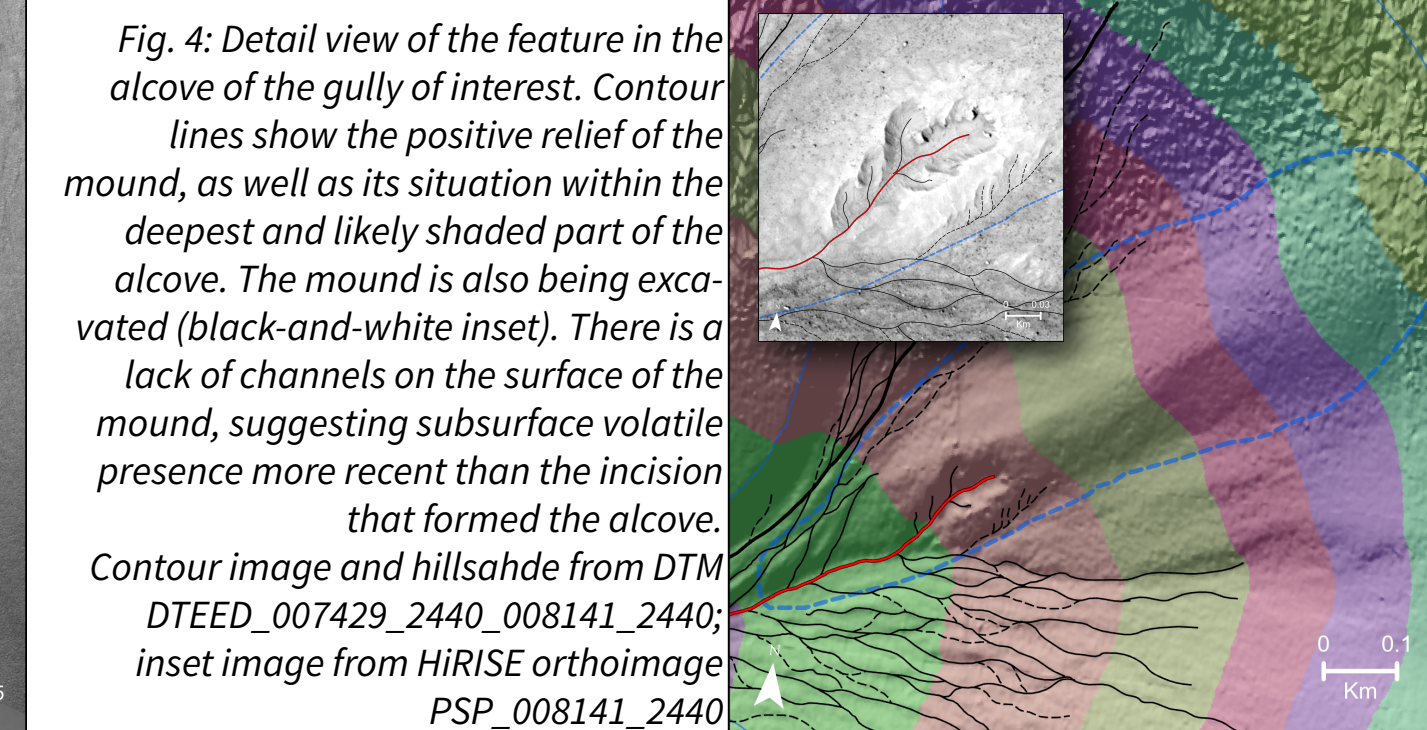


Fig. 4: Detail view of the feature in the alcove of the gully of interest. Contour lines show the positive relief of the mound, as well as its situation within the deepest and likely shaded part of the alcove. The mound is also being excavated (black-and-white inset). There is a lack of channels on the surface of the mound, suggesting subsurface volatile presence more recent than the incision that formed the alcove. Contour image and hillshade from DTM DTEED_007429_2440_008141_2440; inset image from HiRISE orthoimage PSP_008141_2440

Crater in N Lyot Ejecta Crater 2: 53.6° N 26.3° E

This crater is ~ 4.5 km across, and is located on Lyot Crater's ejecta blanket. While all its slopes contain gullies (Fig. 5), only two have distinct aprons. The first has several indistinct channel-like forms on its thick apron. Its alcove shows escarpments suggesting episodic flow (Fig. 6). The latter consists of several gullies merging into a lobate apron. Pitted features on the apron's surface (Fig. 7), consistent with sublimation processes, suggest high-volatile subsurface volumes within the crater. These gullies are possibly more recent with overall slopes of 23.055° and 23.195° respectively.

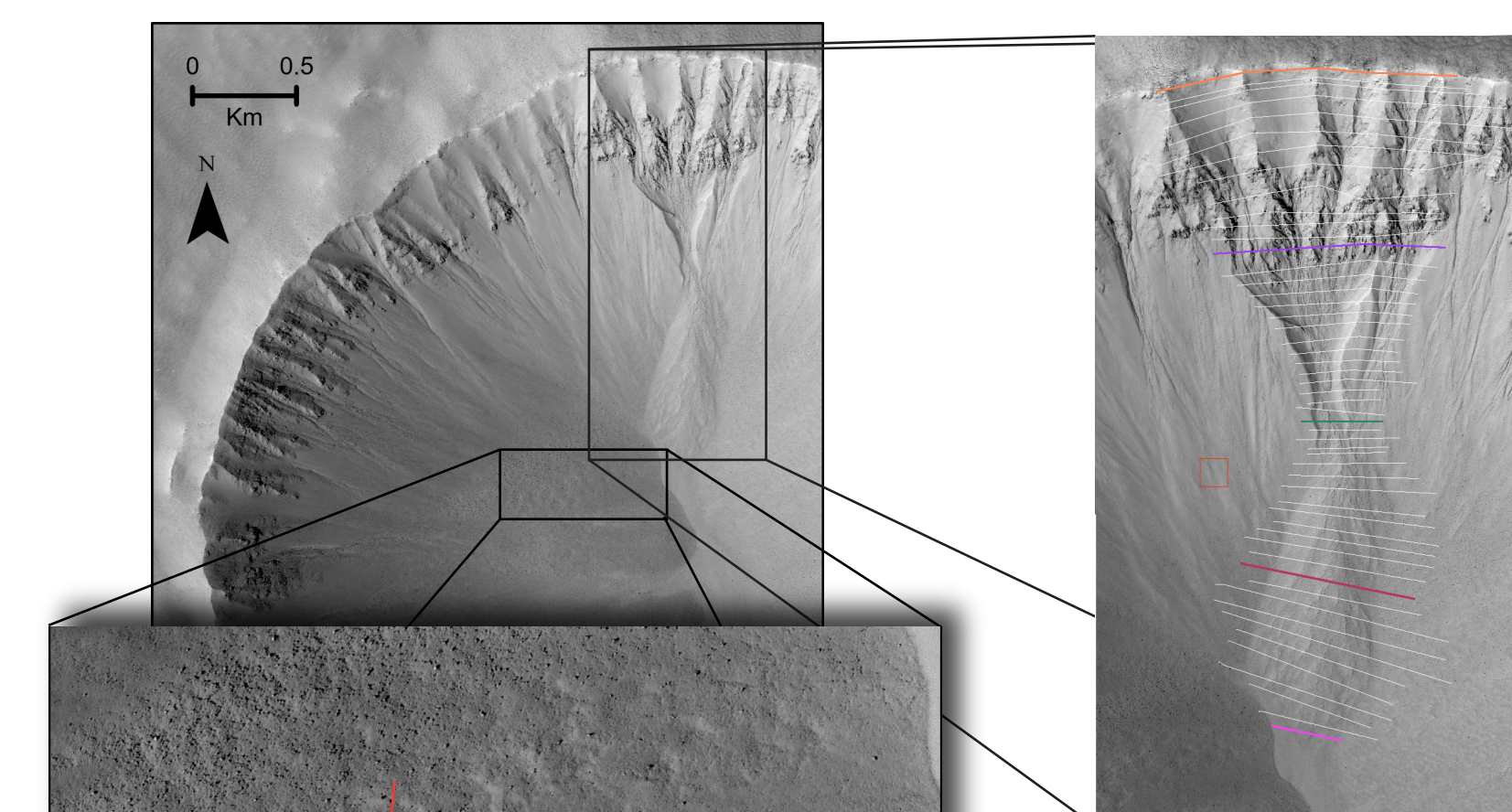


Figure 6: The most well-developed gully on the northern rim of the crater. This image shows the transect method, which is used to determine the volume of material removed from the alcove and deposited in the apron. On the right, profiles of selected transects show the vertical expression of the formation. Note the scalloped appearance of the embankment on the left. This suggests multiple episodes of erosion. It also has a thick apron with possible inverted channels. Image from HiRISE orthoimages ESP_027231_2340 and ESP_019438_2340

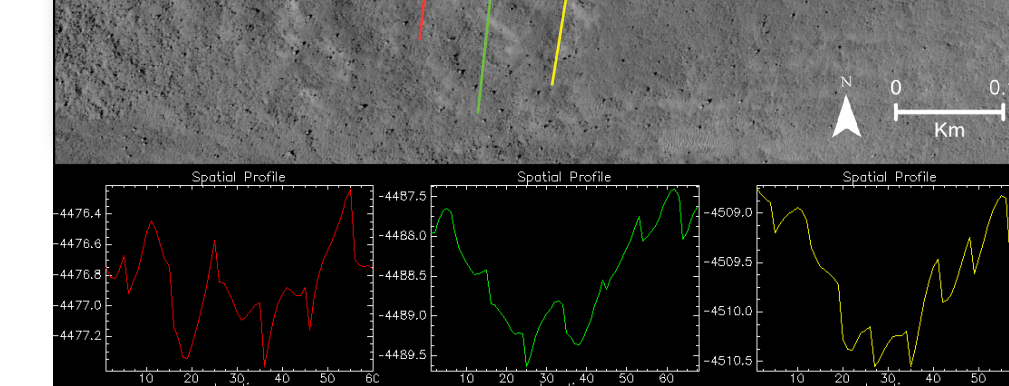


Figure 7: Image of pits on the apron of a gully on the west side of the crater. An average diameter of the pits is about 50 meters. These show the pits have an average depth of about 1.4 m. These pits resemble sublimation pits, the presence of which would suggest an original volatile content of the apron has been lost. Image from HiRISE orthoimages ESP_027231_2340 and ESP_019438_2340

Crater NE of Arcadia Dorsa Crater 3: 60.20° N 236.27° E

This crater is our new site. It is 3.13 km in diameter with a unique micro-environment likely due to differing insolation (Fig. 8). Its NW slope is devoid of gullies, although there are a series of lobate features pointing downslope, suggesting frost creep or gelifluction (Fig. 8b). All other slopes, especially the NE and SW, contain gullies with somewhat deeply incised channels. These gullies form laterally extensive tributary systems (Fig. 8a). While most gullies in this crater have poor--if any--aprons, there are several bright, discrete aprons on the N and E slopes (Fig. 8r). Gully alcoves form in the heavily degraded, crenulated crater rim.

Images from HiRISE orthoimages ESP_027065_2405 and ESP_026564_2405_

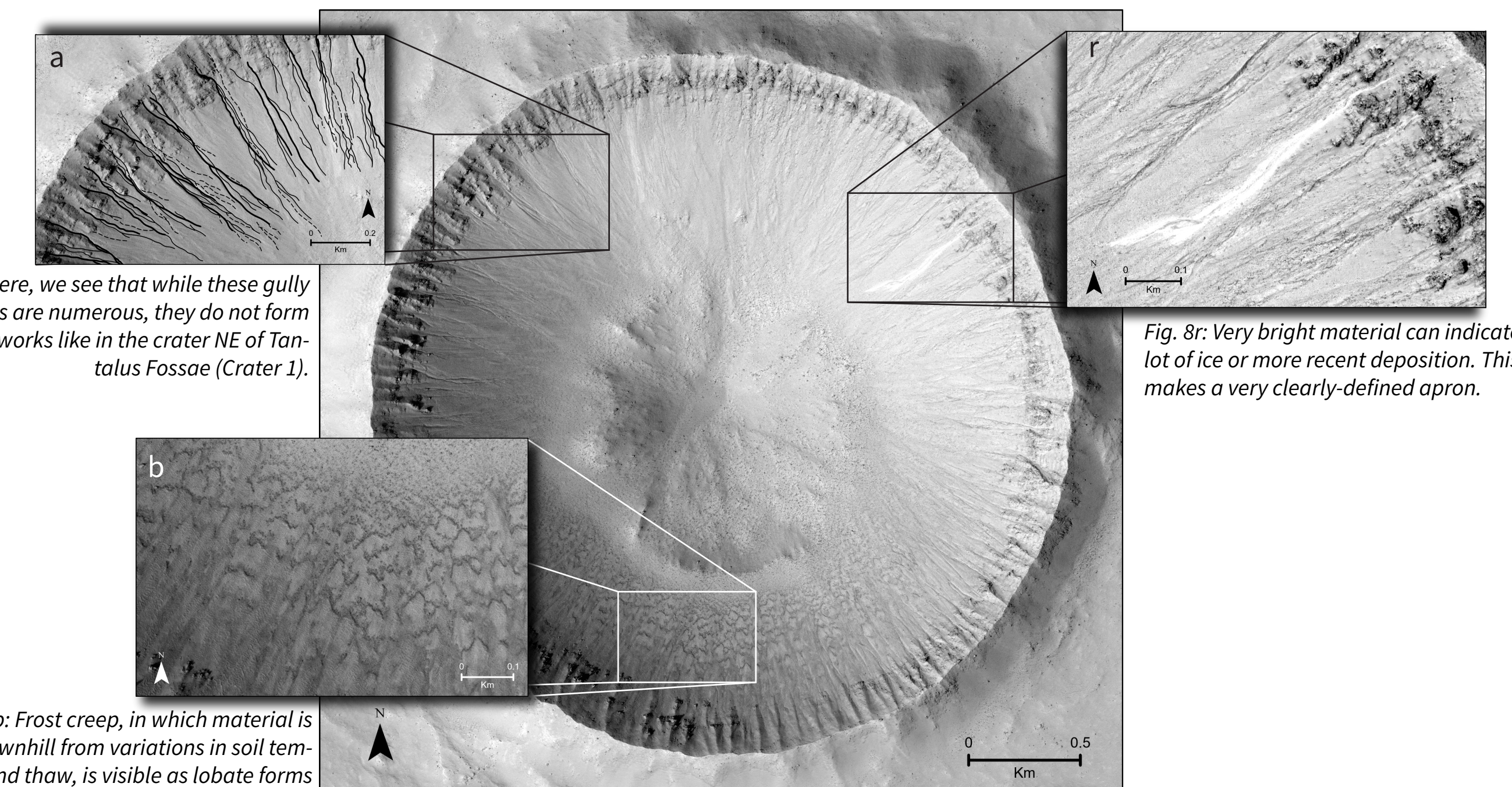


Fig. 8a: Here, we see that while these gully channels are numerous, they do not form complex networks like in the crater NE of Tantalus Fossae (Crater 1).

Fig. 8b: Frost creep, in which material is heaved downhill from variations in soil temperature and thaw, is visible as lobate forms

Fig. 8r: Very bright material can indicate a lot of ice or more recent deposition. This makes a very clearly-defined apron.

Slope Analysis

The slope of a gully can be indicative of the gully's age as well as the process that formed the gully. Preliminary results show that the Crater 1 gully has an alcove slope $\sim 16^\circ$ and apex slope $\sim 11^\circ$, while the two Crater 2 gullies studied have higher alcove slopes ($\sim 30^\circ$ and 27°) and apex slopes (20° and 20°).

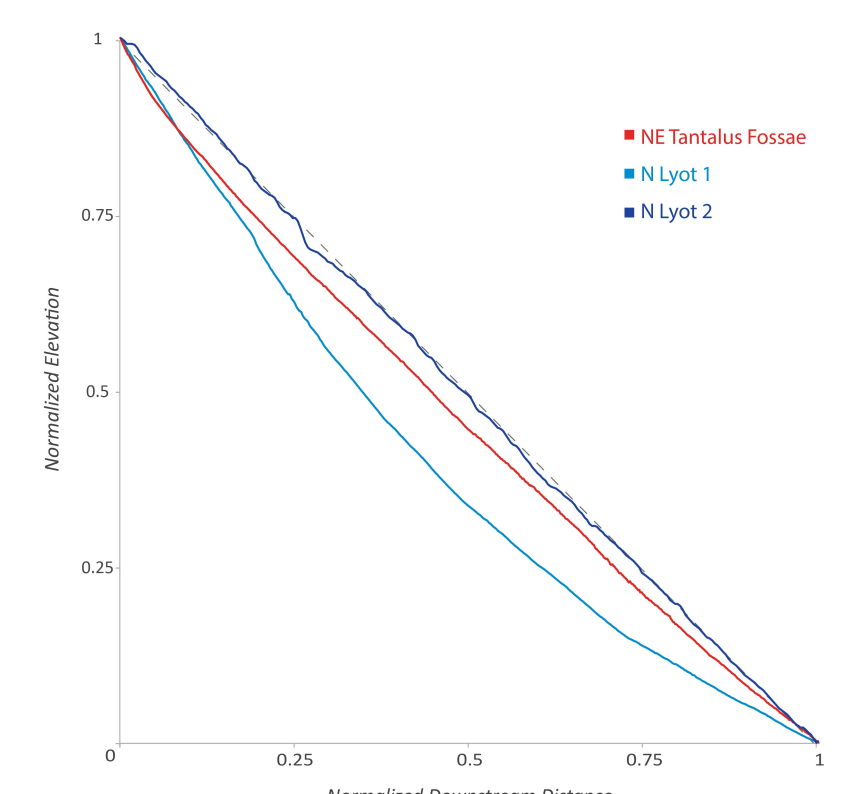


Fig. 9: Normalized gully center stream line profiles. Straighter profiles, such as N Lyot 2, have more dry flow character, while more concave profiles such as N Lyot 1 are associated with fluidized flow.

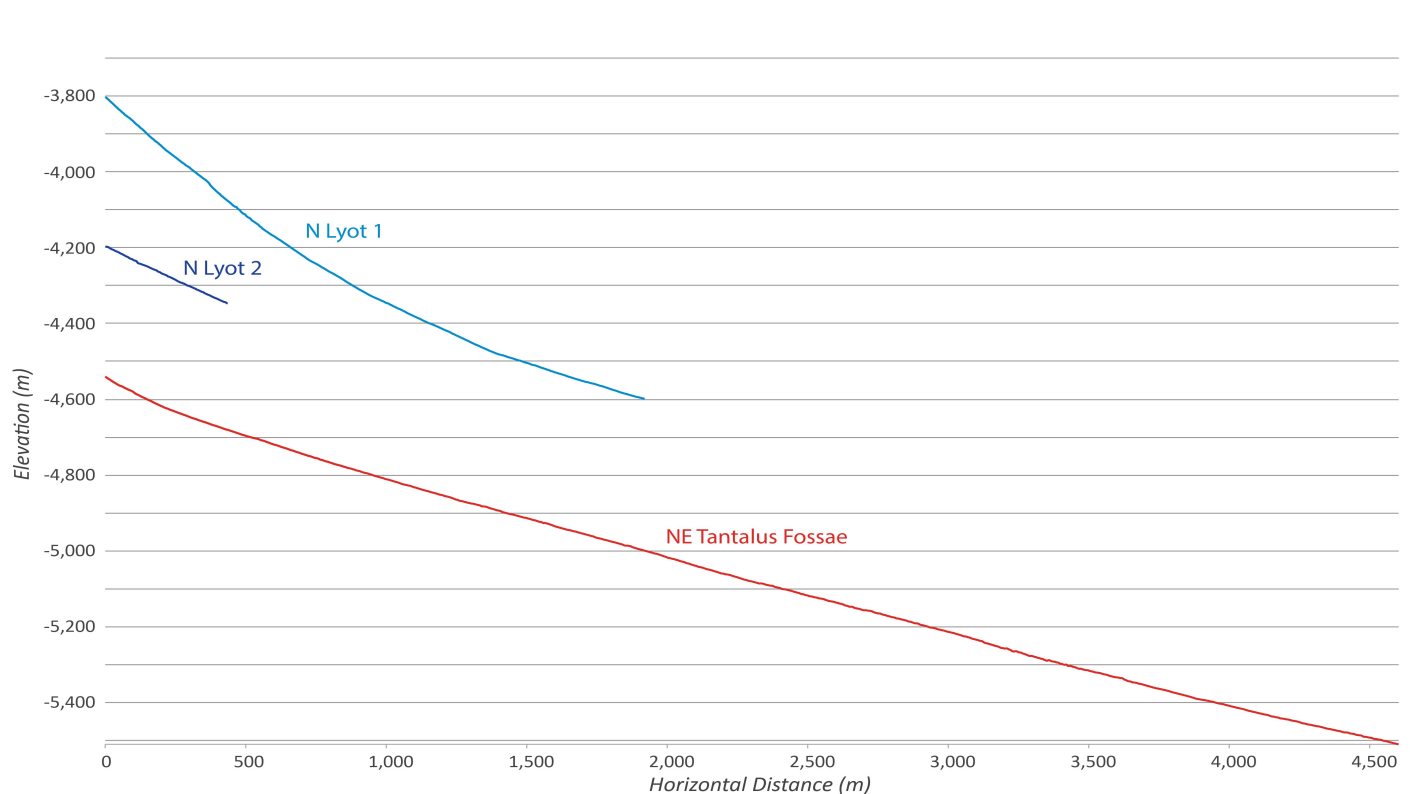


Fig. 10: Gully center stream profiles placed corresponding to their respective elevation with accurate center stream lengths. This is helpful in comparing gully environment based on elevation as well as the length of the center stream lines.

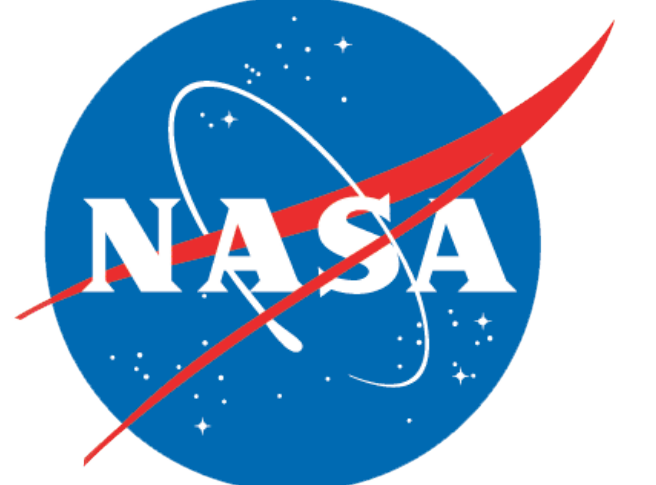
Conclusion

We have mapped these gully systems and have delineated their drainage basin areas. Currently, we are analyzing their detailed morphologies, slopes, and morphometrics to compare these systems with other Martian gully systems. Based on its channel morphology and the slope analysis, fluid flow is a likely emplacement mechanism for this gully. The crater 2 gullies are more uncertain, and their origin may be more clearly determined using ENVI transects and volumetric analysis. Crater 3 results are forthcoming, as future work involves detailed analysis of volumes, drainage and slope for this site.

www.nasa.gov

Acknowledgements

Funding provided by the 2019 SETI REU for RH, 2020 NASA ARC Summer internship for NH and RH, and MRO HiRISE for VG



Aviation Data Science Course Development

Ang Li¹, Banavar Sridhar²

¹University of California, Berkeley, ²Universities Space Research Association

Introduction

UC Berkeley and USRA are collaborating to develop the course “Aviation Data Science” to be taught in the Fall 2020 semester at UC Berkeley. The internship is to support the development of the course curriculum. Prof. Mark Hansen at UC Berkeley will be the responsible faculty for the course. Dr. Banavar Sridhar will be the lead instructor. The course has been listed on the official Berkeley course catalog website shown in Figure 1.

Figure 1 Aviation Data Science on official Berkeley course catalog website

Objectives and Tasks

The objective of this internship is to help develop the course curriculum including following tasks:

- ☐ Identify aviation databases and Machine Learning Techniques for assignments
- ☐ Incorporate NASA data into the course curriculum as case studies
- ☐ Design assignment problems in aviation domain with data science application
- ☐ Design discussion course sessions
- ☐ Design term project and collect example ideas or resources

Course Syllabus

The course will be centered around analyses of a set of aviation data sets and will enable the students to become familiar with data science applications to aviation. The developed curriculum will include extensive content on air traffic management concepts and machine learning techniques. The course syllabus with time schedule for each topic is presented in Figure 2.

Course Syllabus	
Week 1: Fundamentals of air traffic control Simulation of aviation operations	
Week 2: Models of air traffic control (Single aircraft to Global traffic) Introduction to Machine Learning	
Week 3: Aircraft trajectory prediction and optimization Aviation Data Sources	
Week 4 and 5: Conflict detection and resolution: Use of synthetic data to design CD&R algorithms Supervised Machine Learning (Logistic regression, Trees, Feature selection)	
Week 6 and 7: En Route Traffic Management (Dynamic Weather Routing) Supervised Machine Learning (Support Vector Machines)	
Week 8 and 9: Traffic Flow Management (Trajectory grouping and Classification; Delay Modeling) Unsupervised Machine Learning (Clustering, Dimensionality reduction)	
Week 10 and 11: Arrivals Management : Effect of Winds and Aviation Weather) Neural Networks	
Week 12: Airline operations: Fuel example Reinforcement Learning	
Week 13: Aviation Safety Anomaly Detection	
Week 14: Urban Air Mobility	

Figure 2 Course Syllabus

Machine Learning Techniques include regression, trees, clustering, constraint optimization, neural network.

Assignment Design Workflow

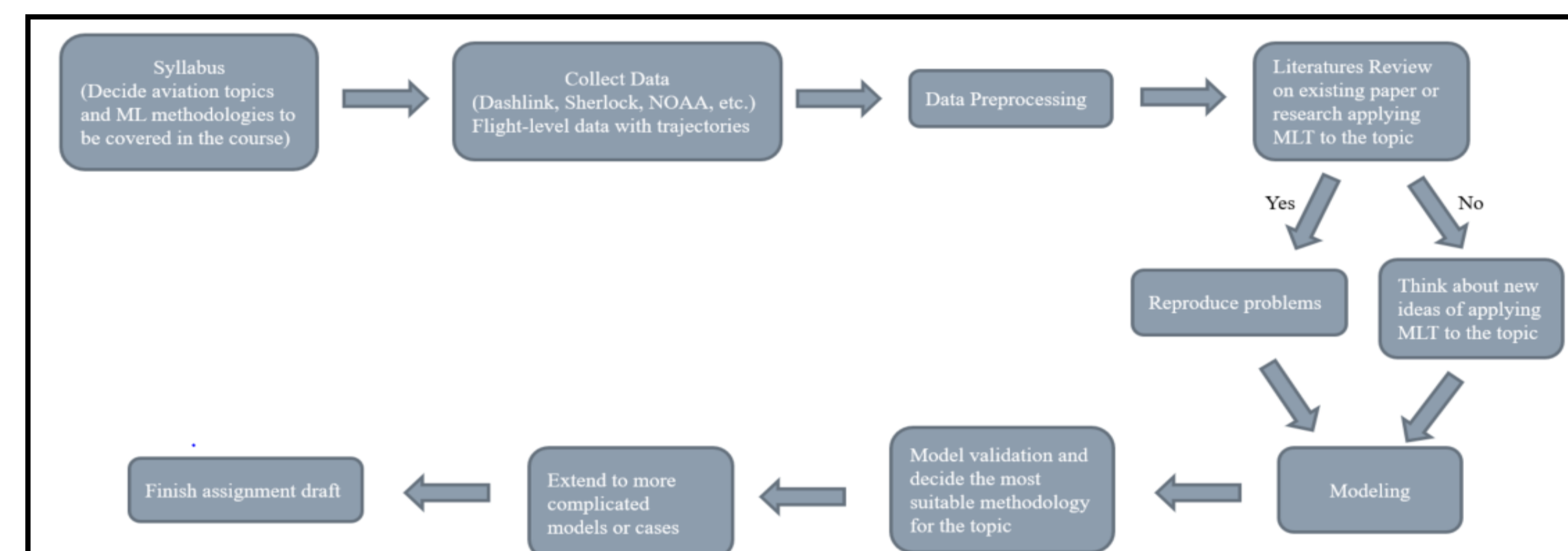


Figure 3 Assignment Design Workflow

The course has five following assignments in total:

- ☐ Use linear regression to analyze features that influence the angle of attack of flight trajectories.
 - ☐ Use logistics regression and decision trees to detect nominal and anomalous flights
 - ☐ Use optimal control to optimize trajectories
 - ☐ Use different clustering algorithms to group flight trajectories of same departure and arrival airport pair
 - ☐ Use Neural Network to predict flight location and trajectories.
- Five assignment sets involve various operational datasets provided by USRA and NASA, including flight-level TBFM trajectory data around ZAU control center from Sherlock database, FOQA data from Dashlink, trajectory data from TFMS.

Course topics include fundamentals of air traffic control, models of aviation operations, aircraft trajectory prediction and optimization, data sources in aviation, overview of data science methods, role of data science in solving problems in aviation operations such as conflict detection and resolution, traffic flow management, arrivals management and surface operations, airline operations, fuel efficiency, global aviation.

Deliverables and Accomplishments

Figure 4 Trajectory Clustering Assignment Set Write-up

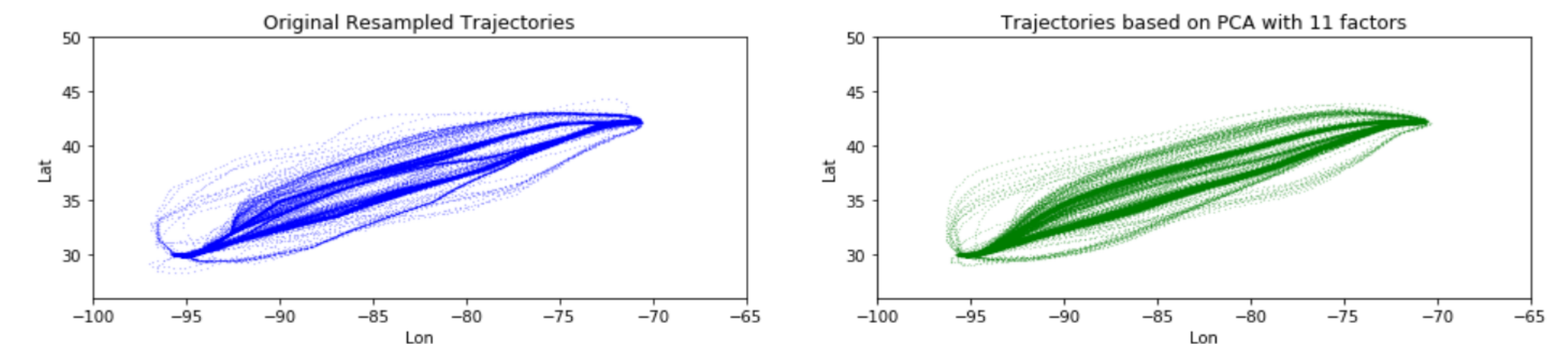


Figure 5 PCA Results Comparison of Flight Trajectories

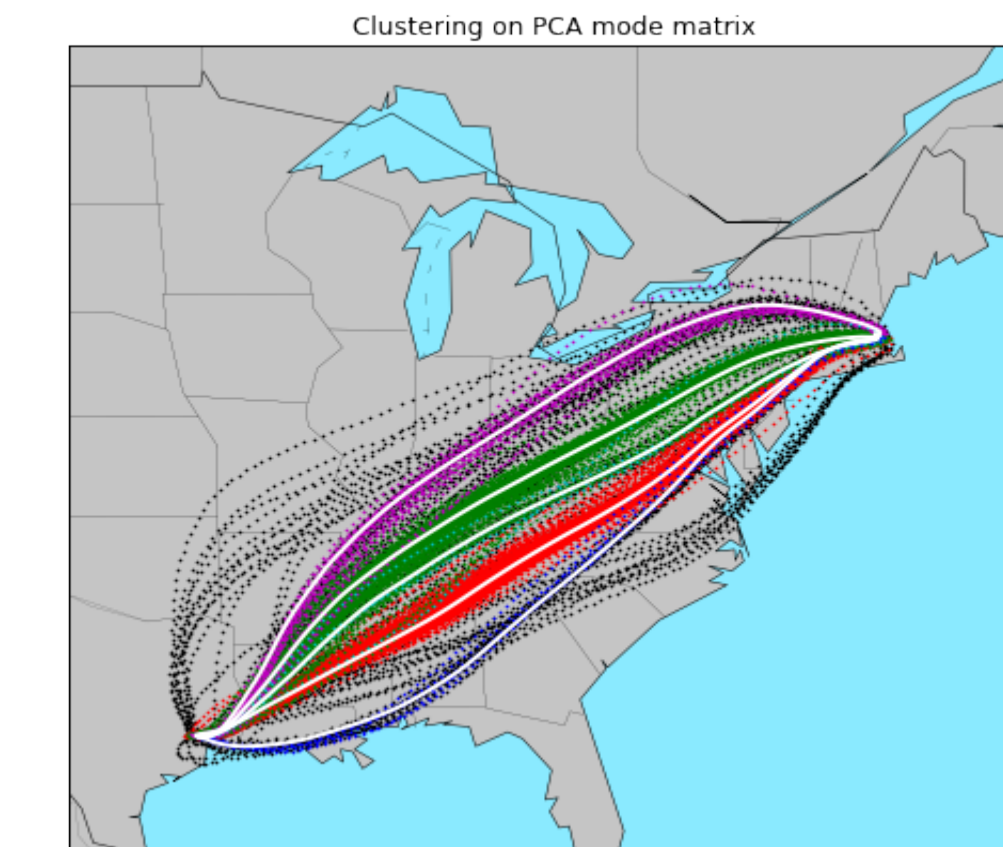


Figure 6 Trajectories Clustering Results

Assignment sets have been developed during the internship. An assignment example of trajectory clustering is presented in Figure 4. It shows the write-up of the assignment including research topics related to homework problems, data descriptions and detailed problems. Figure 5 and Figure 6 present the assignment solution using PCA and DBSCAN clustering algorithms.

Acknowledgement

This course development work acknowledges the excellent guidance of Dr. Banavar Sridhar and Prof. Mark Hansen. The internship and the course are funded and supported by USRA. This work acknowledges the data support from Dr. Milad Memarzadeh

References

- B. Sridhar, “Applications of Machine Learning Techniques to Aviation Operations: Promises and Challenges,” 2020 International Conference AIDA-AT.
Y. Liu, M. Hansen, D. J. Lovell, M. O. Ball, “Predicting Aircraft Trajectory Choice – A Nominal Route Approach,” 2018 ICRAT Conference.



MORPHOLOGIC AND SLOPE STUDIES OF CRATER GULLIES IN THE HIGH-NORTHERN LATITUDES OF MARS

R.I. Huang¹, V.C. Gulick^{2,3}, N.H. Glines^{1,3}

National Aeronautics and Space Administration

¹NASA Ames Research Center Summer internship, ²NASA Ames Research Center, ³SETI Institute

Abstract

Gullies on Mars are usually defined by a source alcove and a single channel that shallows into a debris apron. This holds true for many of gullies, especially those in southern latitudes. However, several gullies in northern high-latitudes ($>50^\circ$ N) show complex forms with more than one prominent channel. Initial detailed morphometric analysis of two northern high-latitude sites was established in a previous study. This study expands on that work in addition to conducting the same analysis on another northern high-latitude site. Morphometric comparison of these gully morphologies and their spatially associated landforms can give insight to different gully forming processes and provide clues to past environmental conditions in the Martian northern hemisphere.

Introduction

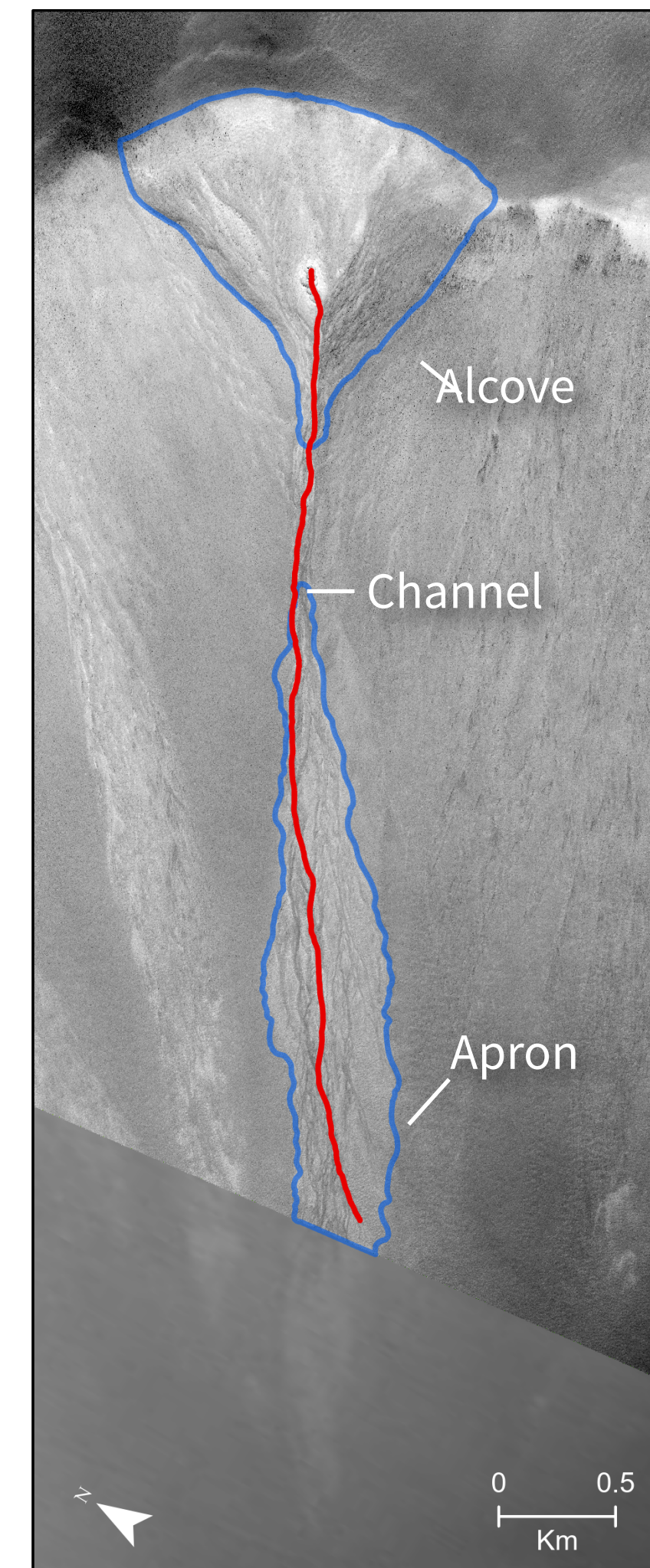


Fig. 1: CTX image of one gully of interest overlain by HiRISE orthoimage PSP_008141_2440. Here, its apron and alcove margins have been defined in blue as well as its CSL (center stream line) in red.

Gullies on Mars are usually defined by three parts (Fig. 1): The alcove, the channel, and the apron. They are commonly found on crater walls, but can also form on dunes, central crater peaks, mesas, mountains or montes, and valley systems on Mars. In this study, we are focusing on crater-wall gullies.

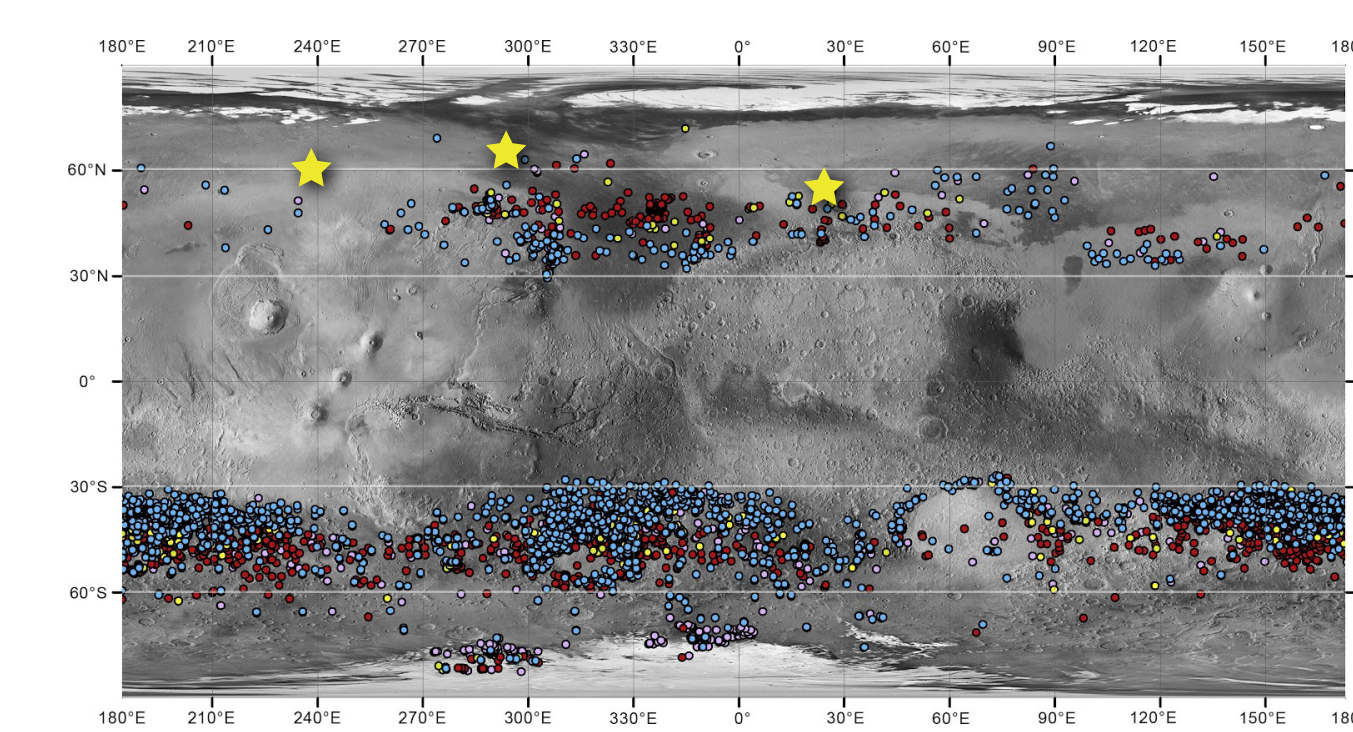


Fig. 2: Harrison global map of gullied landforms (Harrison et al, 2015, Icarus). The craters studied in this project are starred to highlight the scarcity and high latitude of the study areas.

While most gullies are found in the mid-latitudes of Mars, especially those in the southern hemisphere (Fig. 2), this study concentrates on those in northern high latitudes. It is an entirely different environment at lower elevations with different rock types and processes shaping the landscape.

Crater NE of Tantalus Fossae Crater 1: 63.8° N 292.3° E

This crater is located to the northeast of Tantalus Fossae. It is ~ 16.3 km in diameter and contains numerous poorly developed gullies on its eastern and western interior slopes. One exceptional gully displays a braided morphology in which deep channels incise the entire thin, light-toned apron (Fig. 3). This morphology may be due to unconsolidated sediment composing the crater slopes. At the deepest part of its alcove is an intriguing, elongated 12-m high mound, which is eroded along its downslope trend. We interpret this to be a dust-covered snowpack (Fig. 4). This gully has a gentle overall slope of $\sim 11.91^\circ$.

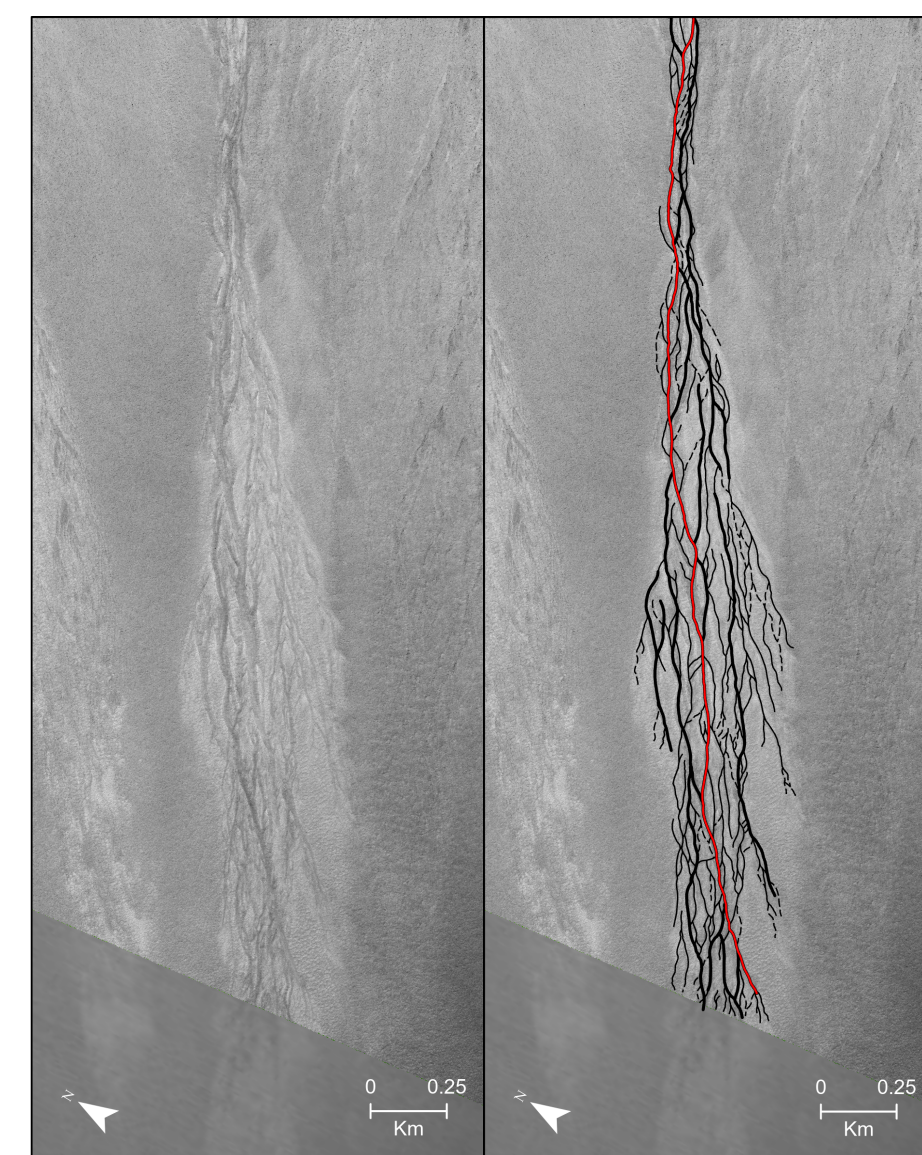


Fig. 3: Side-by-side comparison of the apron of the gully of interest (left) and interpreted channels (right). Note the bright nature of it (perhaps due to icy composition or recent deposition) as well as the complexity of the networked channels, not unlike a terrestrial braided stream. The center stream line (deepest and most continuous channel, highlighted in red) appears to anastomose and change, suggesting multiple episodes of erosion.

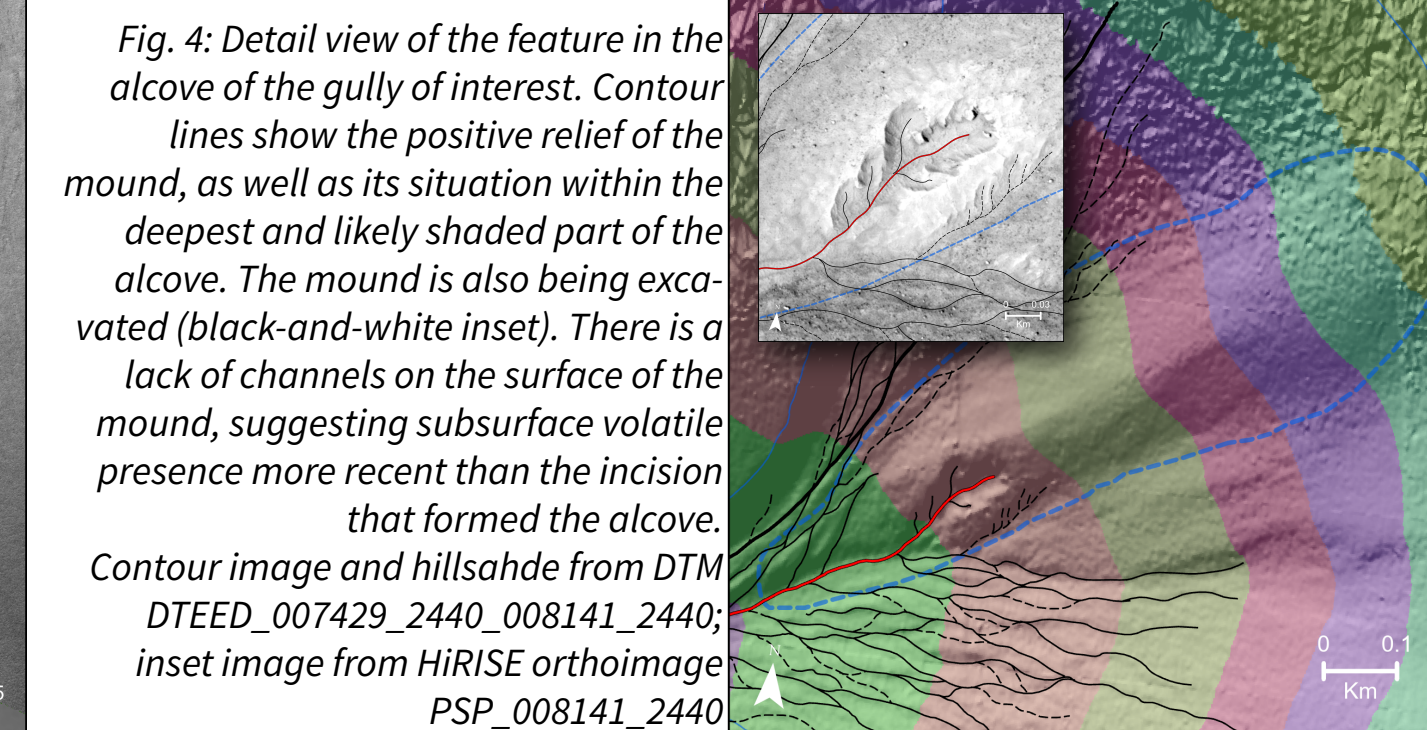


Fig. 4: Detail view of the feature in the alcove of the gully of interest. Contour lines show the positive relief of the mound, as well as its situation within the deepest and likely shaded part of the alcove. The mound is also being excavated (black-and-white inset). There is a lack of channels on the surface of the mound, suggesting subsurface volatile presence more recent than the incision that formed the alcove. Contour image and hillshade from DTM DTEED_007429_2440_008141_2440; inset image from HiRISE orthoimage PSP_008141_2440.

Crater in N Lyot Ejecta Crater 2: 53.6° N 26.3° E

This crater is ~ 4.5 km across, and is located on Lyot Crater's ejecta blanket. While all its slopes contain gullies (Fig. 5), only two have distinct aprons. The first has several indistinct channel-like forms on its thick apron. Its alcove shows escarpments suggesting episodic flow (Fig. 6). The latter consists of several gullies merging into a lobate apron. Pitted features on the apron's surface (Fig. 7), consistent with sublimation processes, suggest high-volatile subsurface volumes within the crater. These gullies are possibly more recent with overall slopes of 23.055° and 23.195° respectively.

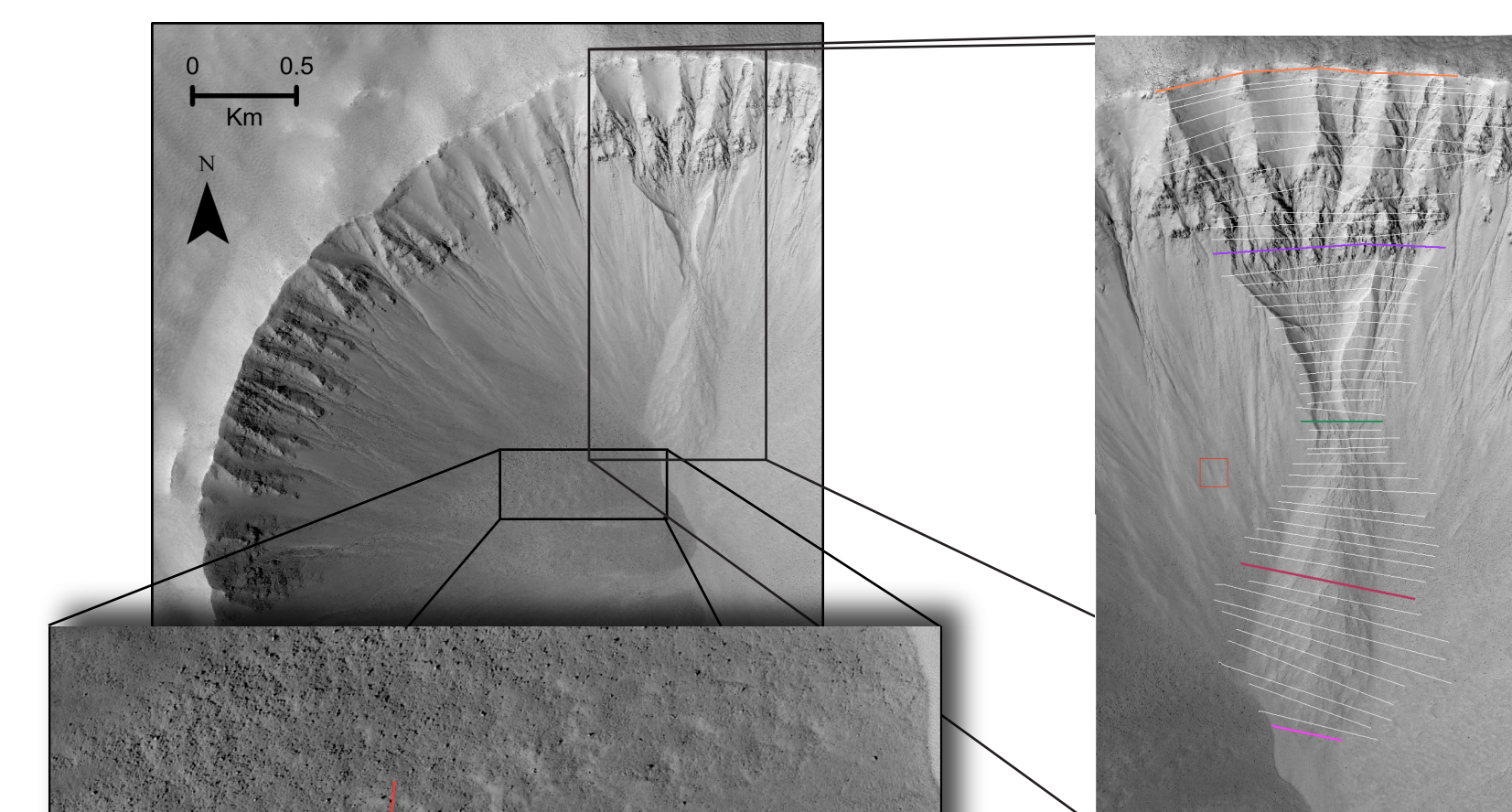


Figure 6: The most well-developed gully on the northern rim of the crater. This image shows the transect method, which is used to determine the volume of material removed from the alcove and deposited in the apron. On the right, profiles of selected transects show the vertical expression of the formation. Note the scalloped appearance of the embankment on the left. This suggests multiple episodes of erosion. It also has a thick apron with possible inverted channels. Image from HiRISE orthoimages ESP_027231_2340 and ESP_019438_2340.

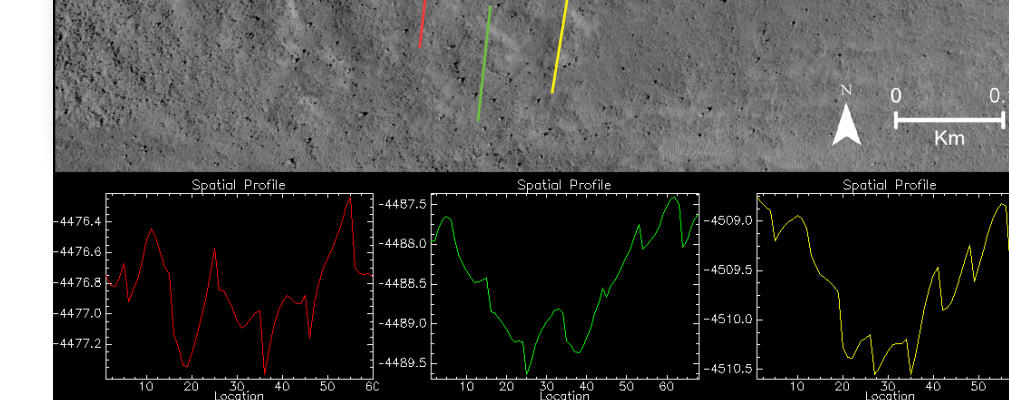


Figure 7: Image of pits on the apron of a gully on the west side of the crater. An average diameter of the pits is about 50 meters. These show the pits have an average depth of about 1.4 m. These pits resemble sublimation pits, the presence of which would suggest an original volatile content of the apron has been lost. Image from HiRISE orthoimages ESP_027231_2340 and ESP_019438_2340.

Crater NE of Arcadia Dorsa Crater 3: 60.20° N 236.27° E

This crater is our new site. It is 3.13 km in diameter with a unique micro-environment likely due to differing insolation (Fig. 8). Its NW slope is devoid of gullies, although there are a series of lobate features pointing downslope, suggesting frost creep or gelifluction (Fig. 8b). All other slopes, especially the NE and SW, contain gullies with somewhat deeply incised channels. These gullies form laterally extensive tributary systems (Fig. 8a). While most gullies in this crater have poor--if any--aprons, there are several bright, discrete aprons on the N and E slopes (Fig. 8r). Gully alcoves form in the heavily degraded, crenulated crater rim.

Images from HiRISE orthoimages ESP_027065_2405 and ESP_026564_2405_.

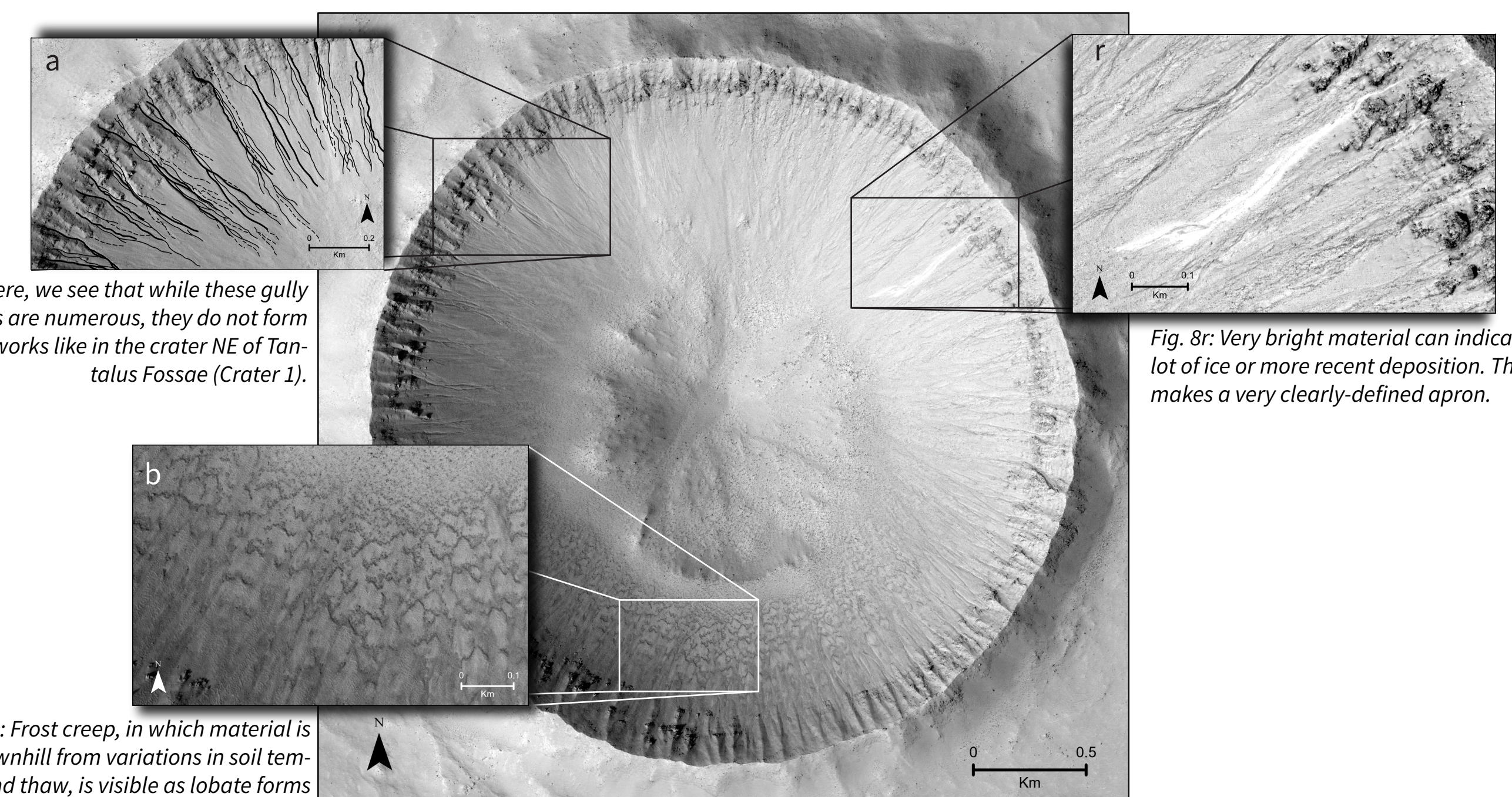


Fig. 8a: Here, we see that while these gully channels are numerous, they do not form complex networks like in the crater NE of Tantalus Fossae (Crater 1).

Fig. 8b: Frost creep, in which material is heaved downhill from variations in soil temperature and thaw, is visible as lobate forms.

Fig. 8r: Very bright material can indicate a lot of ice or more recent deposition. This makes a very clearly-defined apron.

Slope Analysis

The slope of a gully can be indicative of the gully's age as well as the process that formed the gully. Preliminary results show that the Crater 1 gully has an alcove slope $\sim 16^\circ$ and apex slope $\sim 11^\circ$, while the two Crater 2 gullies studied have higher alcove slopes ($\sim 30^\circ$ and 27°) and apex slopes (20° and 20°).

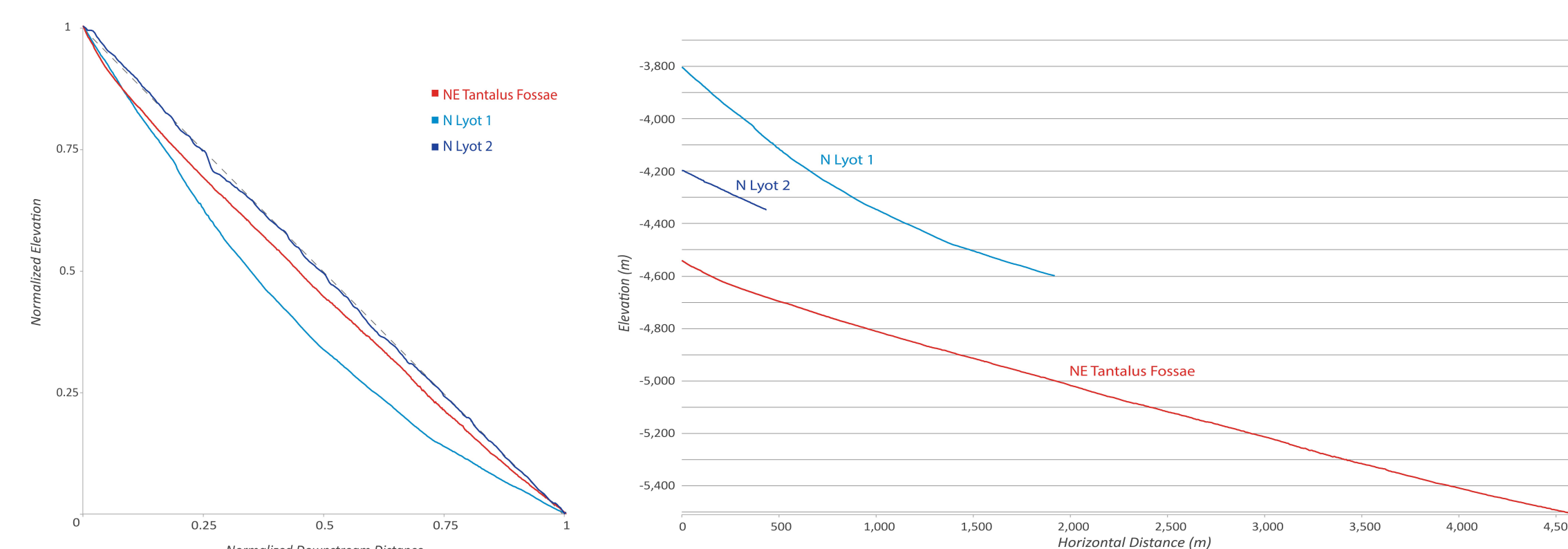


Fig. 9: Normalized gully center stream line profiles. Straighter profiles, such as N Lyot 2, have more dry flow character, while more concave profiles such as N Lyot 1 are associated with fluidized flow.

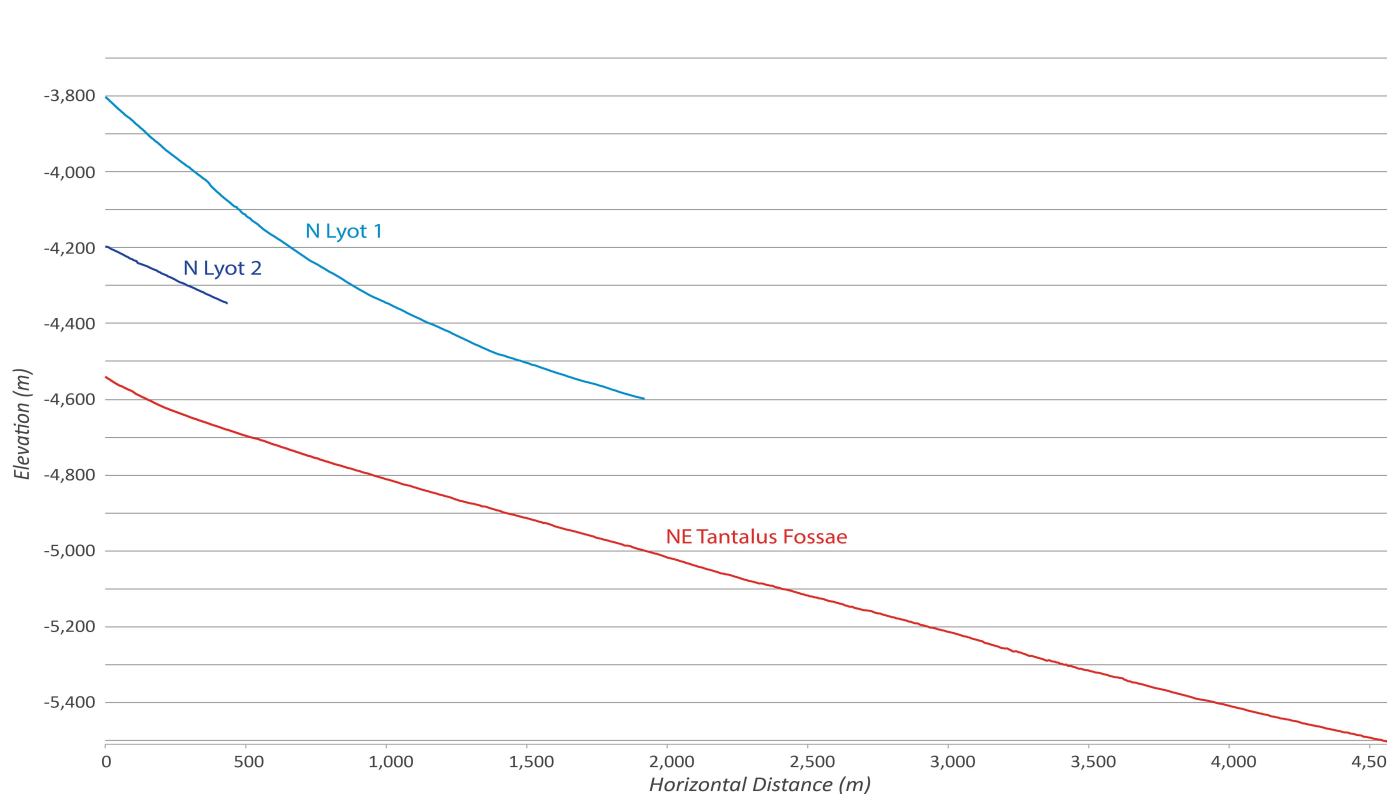


Fig. 10: Gully center stream profiles placed corresponding to their respective elevation with accurate center stream lengths. This is helpful in comparing gully environment based on elevation as well as the length of the center stream lines.

Conclusion

We have mapped these gully systems and have delineated their drainage basin areas. Currently, we are analyzing their detailed morphologies, slopes, and morphometrics to compare these systems with other Martian gully systems. Based on its channel morphology and the slope analysis, fluid flow is a likely emplacement mechanism for this gully. The crater 2 gullies are more uncertain, and their origin may be more clearly determined using ENVI transects and volumetric analysis. Crater 3 results are forthcoming, as future work involves detailed analysis of volumes, drainage and slope for this site.