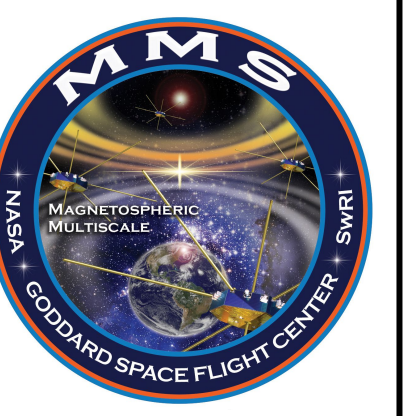




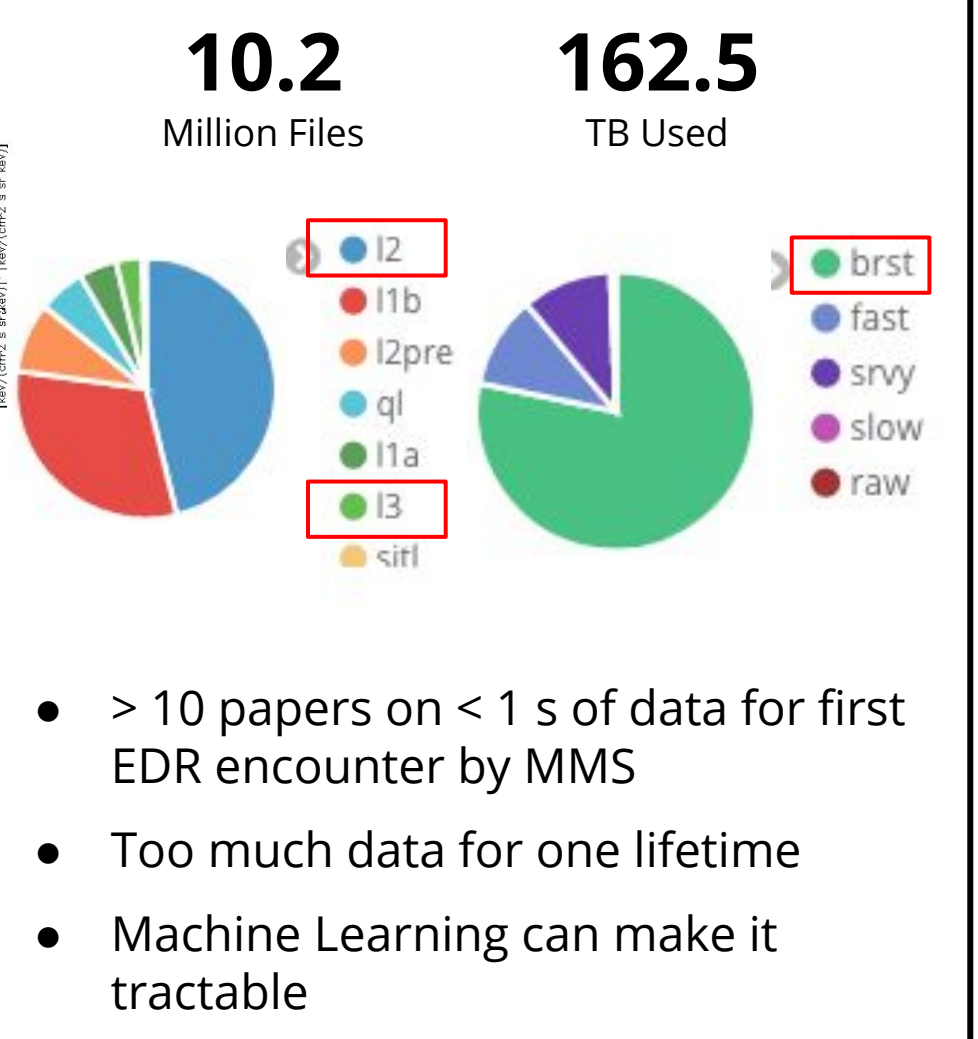
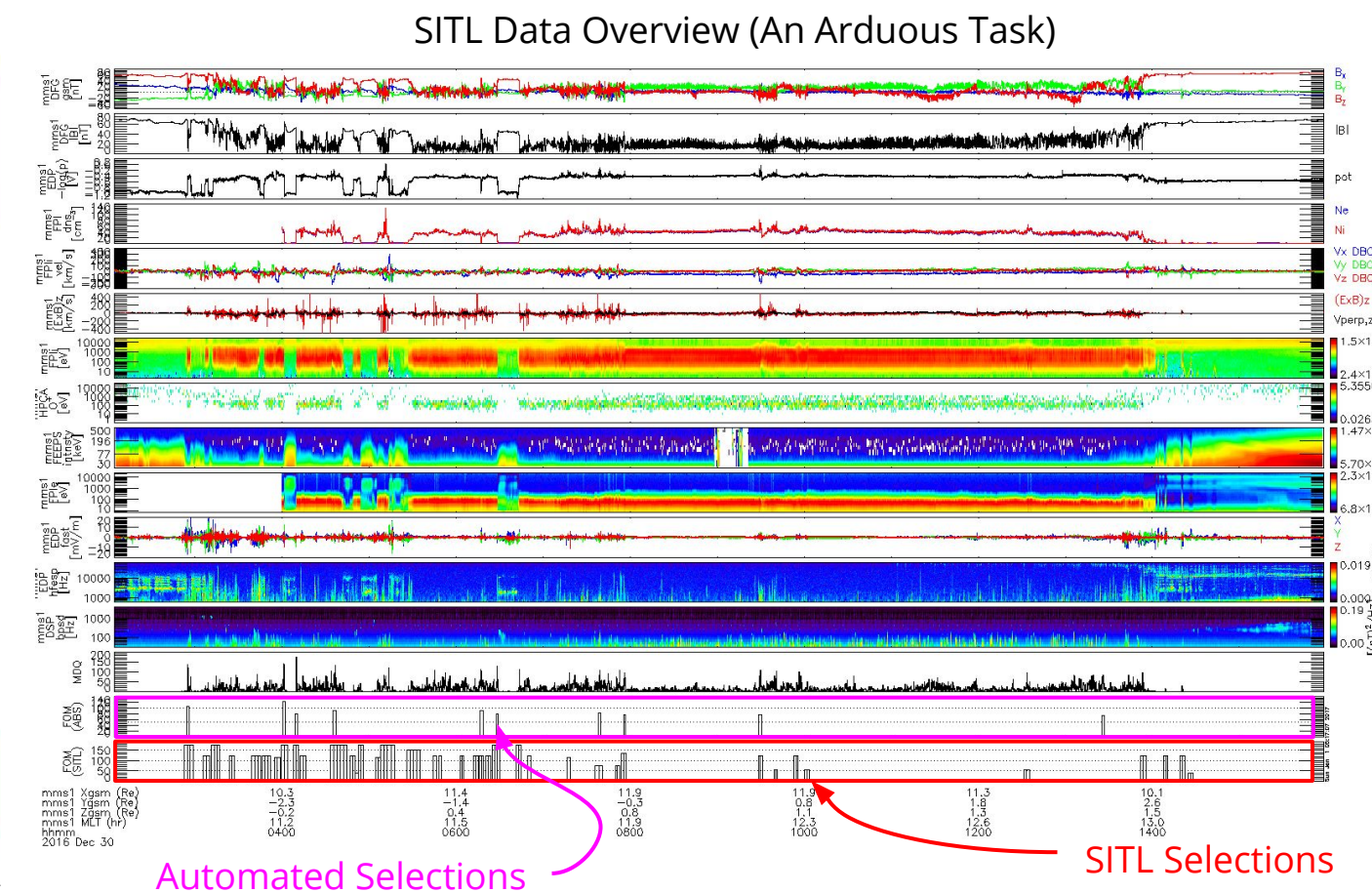
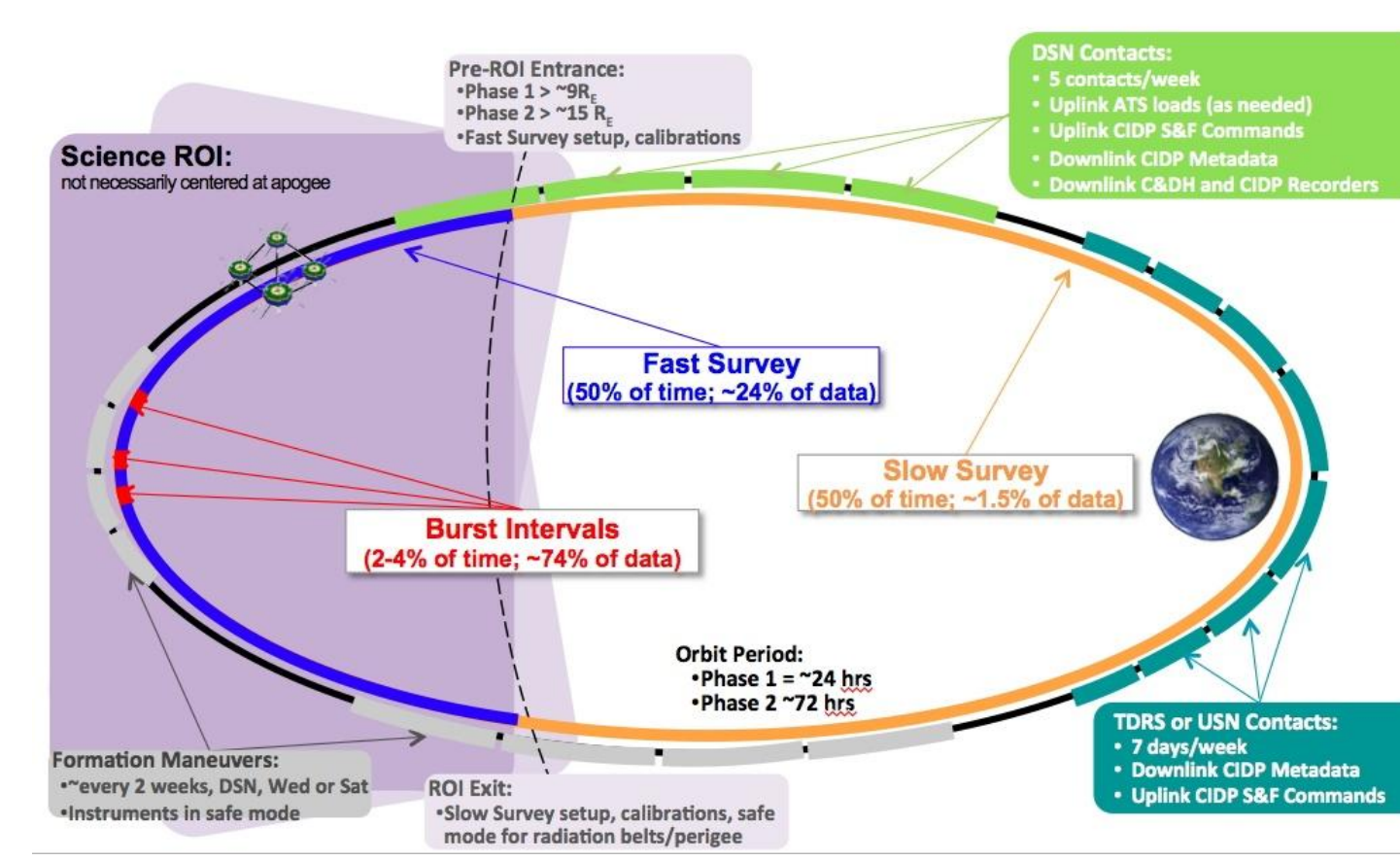
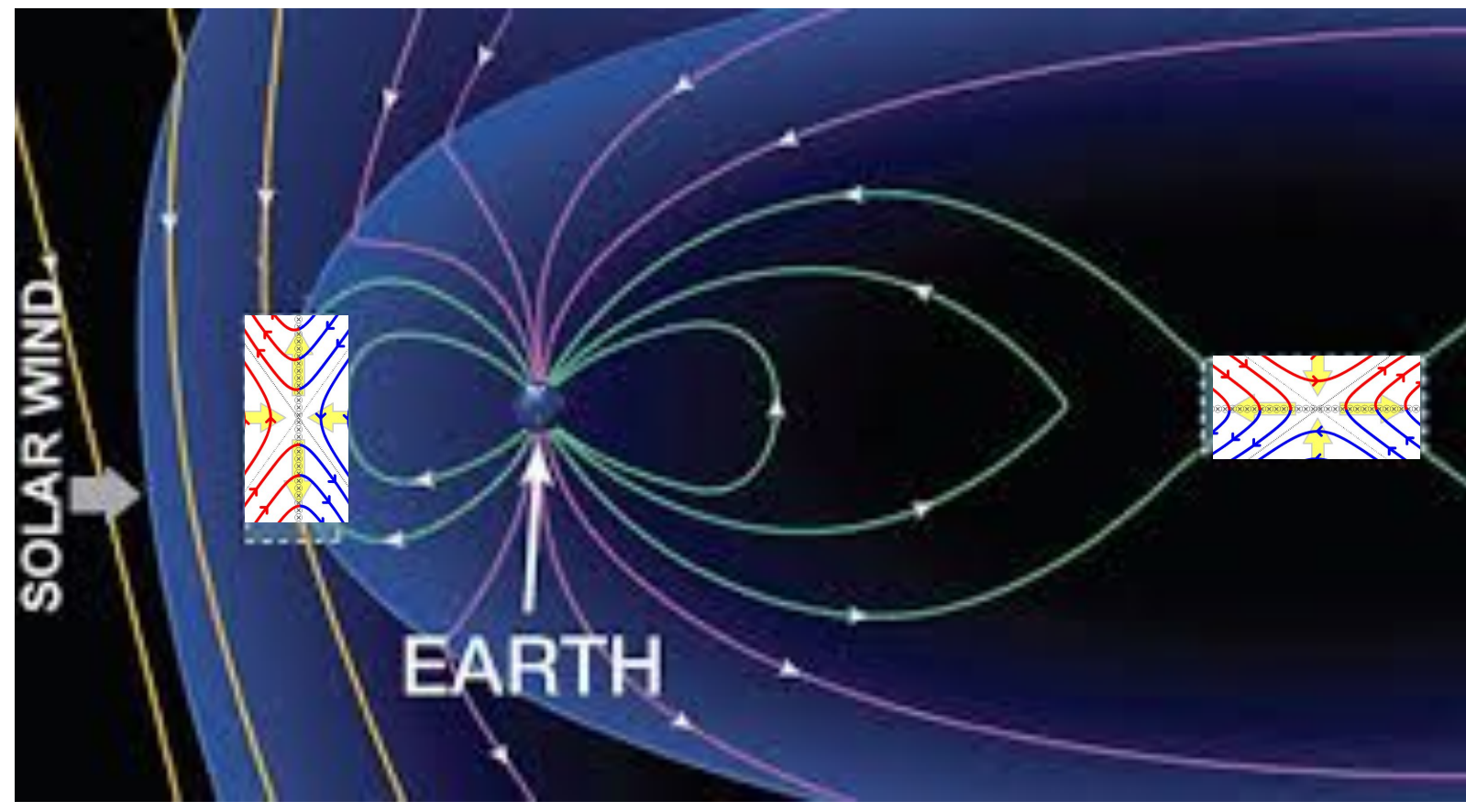
# Automated magnetopause detection to facilitate diffusion region studies with MMS



Matthew R. Argall<sup>1</sup> (matthew.argall@unh.edu), S. Piatt<sup>1</sup>, C. Small<sup>1</sup>, M. Petrik<sup>1</sup>, K. Larson<sup>2</sup>, K. Kokkonen<sup>2</sup>, J. Barnum<sup>2</sup>, F. D. Wilder<sup>2</sup>, M. Oka<sup>3</sup>, R. E. Ergun<sup>2</sup>, T.-D. Phan<sup>3</sup>, B. L. Giles<sup>4</sup>, R. B. Torbert<sup>1,5</sup>, J. L. Burch<sup>5</sup>, W. R. Paterson<sup>4</sup>

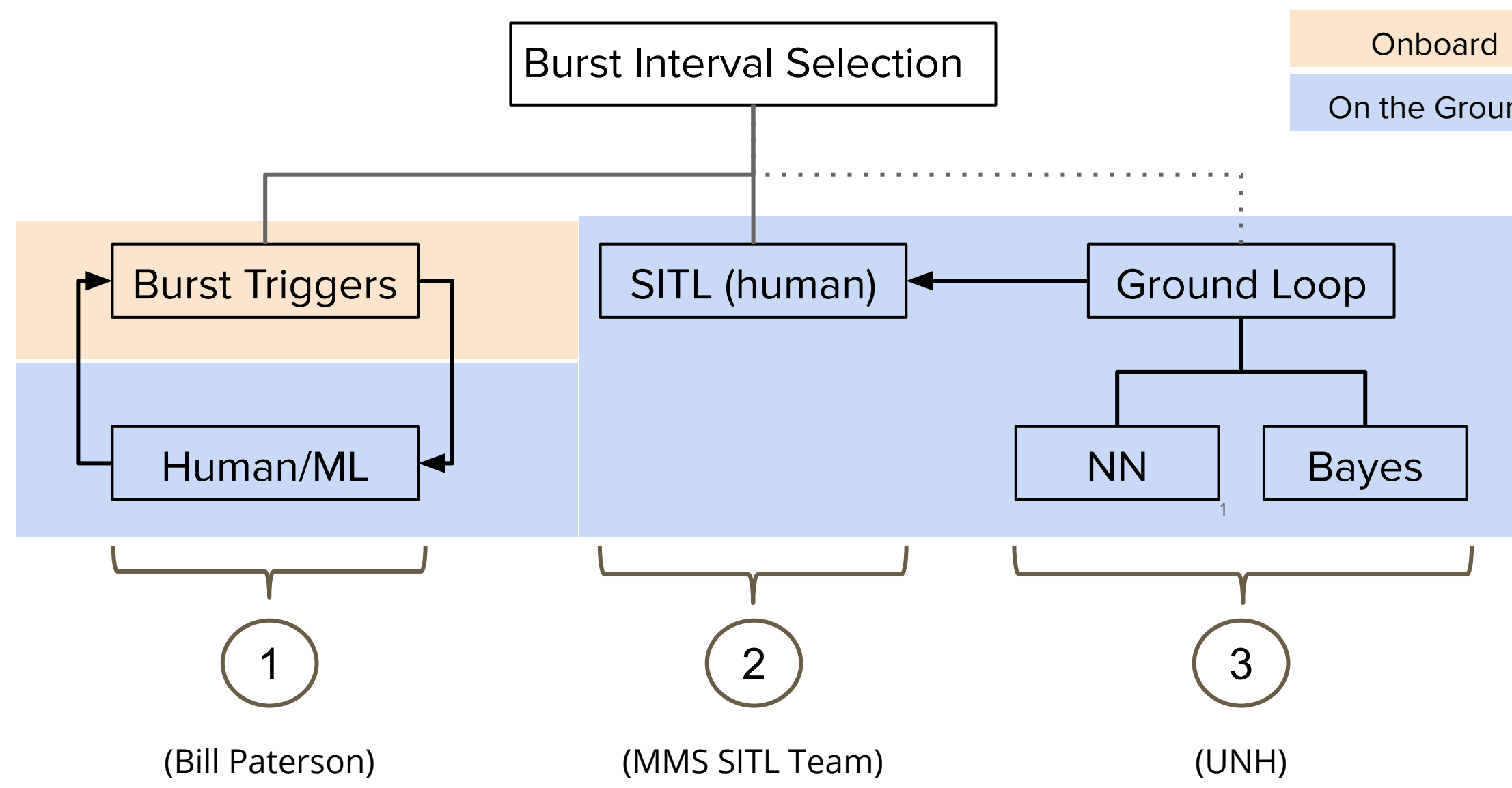
<sup>1</sup>University of New Hampshire, Durham, NH, USA, <sup>2</sup>Laboratory of Atmospheric and Space Physics, Boulder, CO, USA, <sup>3</sup>University of California at Berkeley, Berkeley, CA, USA, <sup>4</sup>Goddard Space Flight Center, Greenbelt, MD, USA, <sup>5</sup>Southwest Research Institute, San Antonio, TX, USA

## Motivation



- Magnetic reconnection drives the flow of energy throughout the magnetosphere
- It is triggered by the microphysics of the Electron Diffusion Region (EDR).
- The Region of Interest (ROI) encompasses locations likely to contain EDRs.
- Only enough telemetry to downlink ~43 minutes of burst data per day
- Burst selections are made primarily by the (human) Scientist in the Loop (SITL)
- Need to automate the selection process
- > 10 papers on < 1 s of data for first EDR encounter by MMS
- Too much data for one lifetime
- Machine Learning can make it tractable

## Automation Options

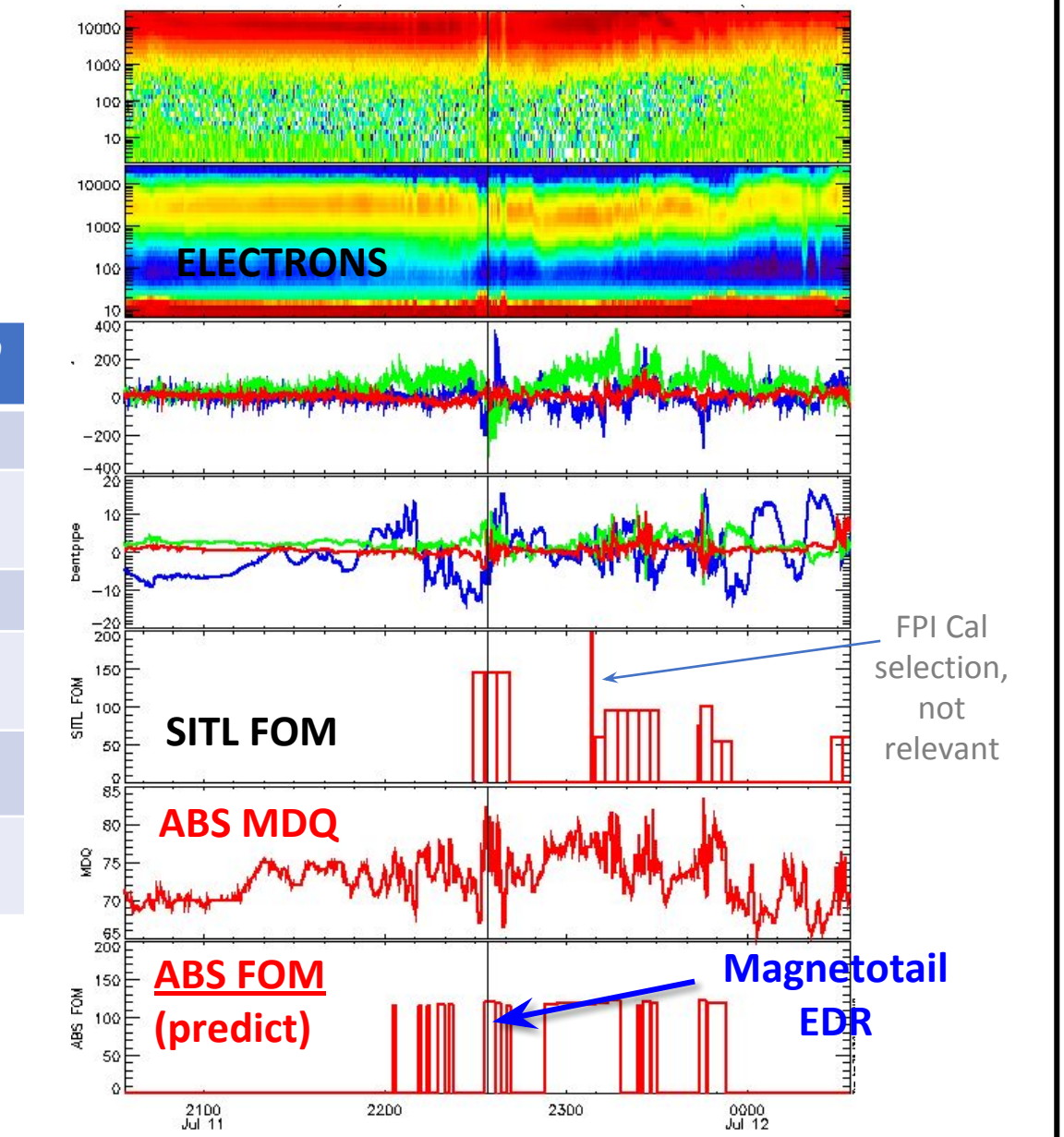


## Burst Triggers

### Equation 1. Cycle Data Quality (CDQ) Calculation

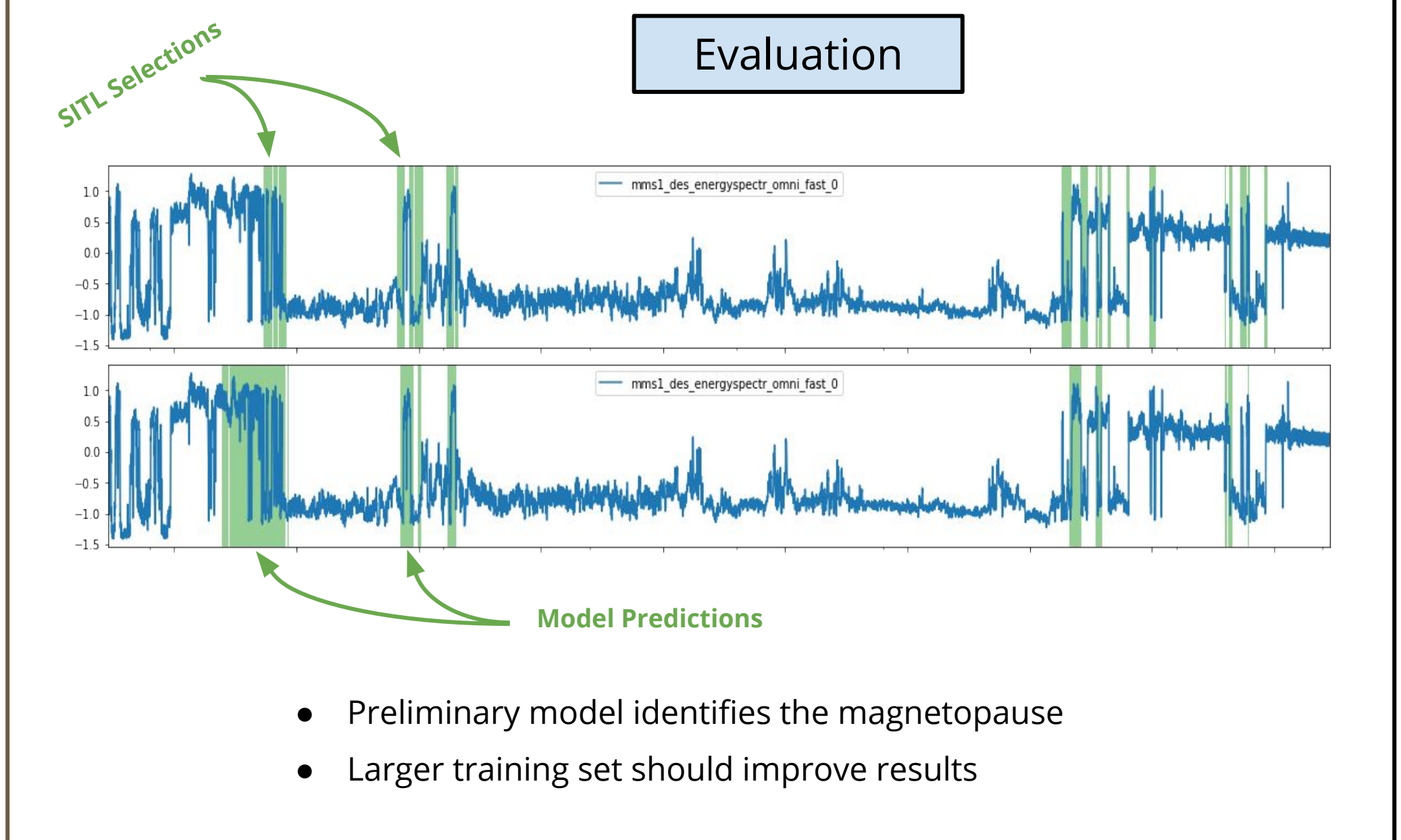
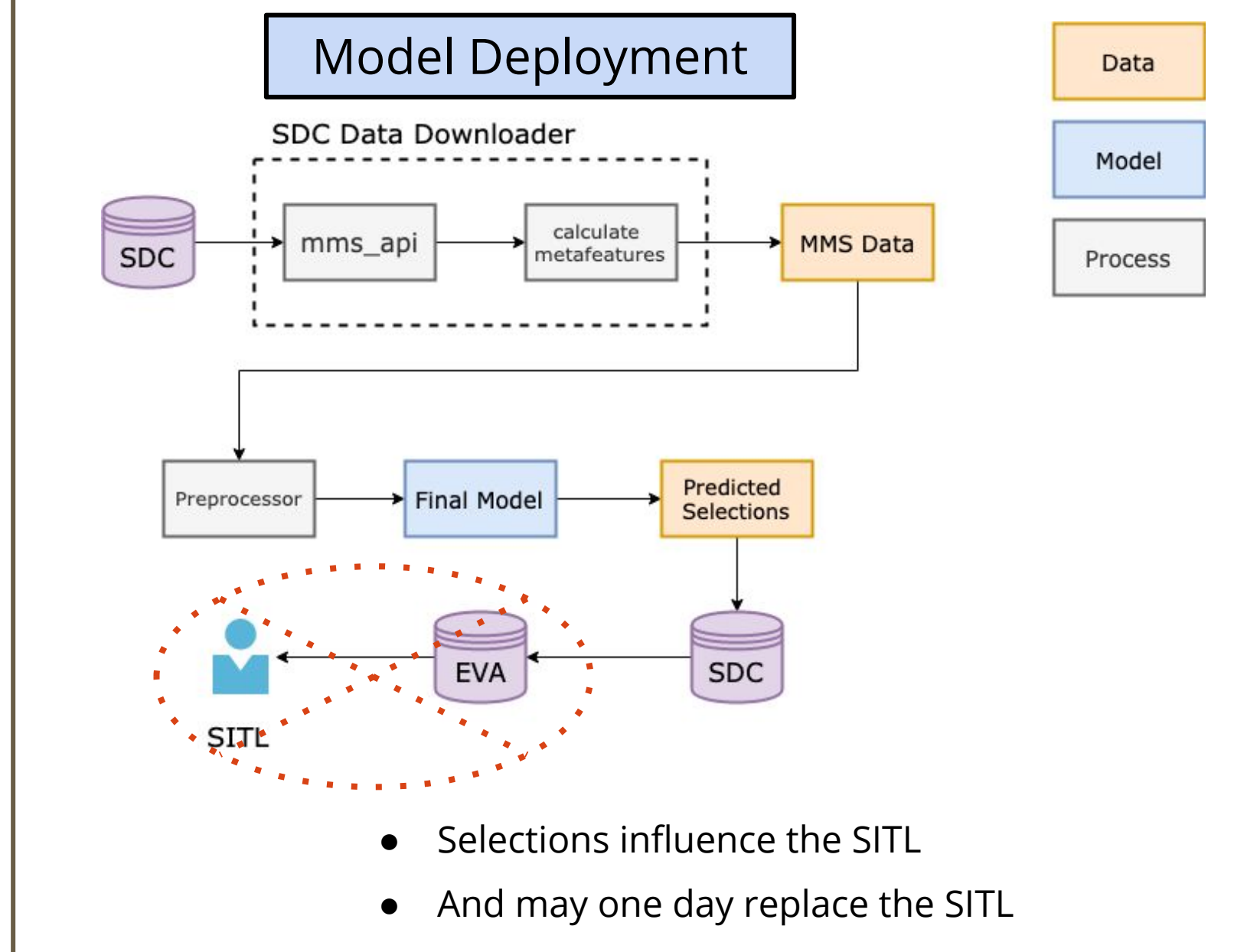
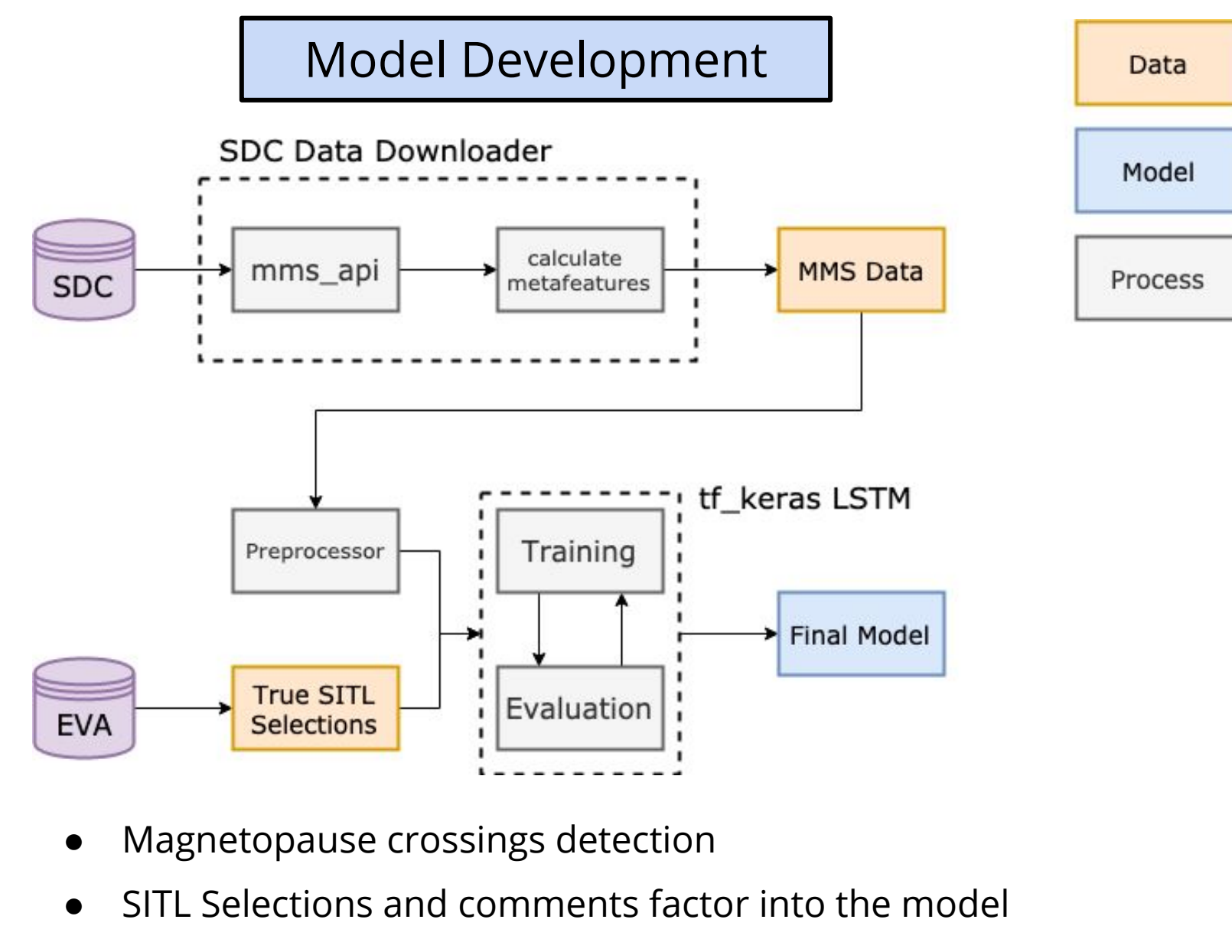
$$CDQ = \sum_{All} [TDN(i) + O(i)] * G(i) / \sum_{All} G(i)$$

Tail ABS Table				Dayside ABS Table (MP019)			
TDN	DESCRIPTION	GAIN	OFFSET	TDN	DESCRIPTION	GAIN, G	OFFSET, O
dB	dBx  +  dBz	1	0	dBz	dBz	2	0
dBz	dBz	2	0	ERMS1	EOMNI, Power Density 10-100 Hz	10	0
1/ B	B inverse	4	30	dB	dBx  +  dBz	2	0
ERMS1	Power density 10-100 Hz	5	0	Var Pe	Electron Pressure, Variance	1	0
Var Ion X Flux	Variance, spinning coords	1	150	Var Ni	Ion Density, Variance	1	0
Var Ion Y Flux	Variance, spinning coords	1	150	Delta Ni	Ion Density, Delta of Mean	1	0



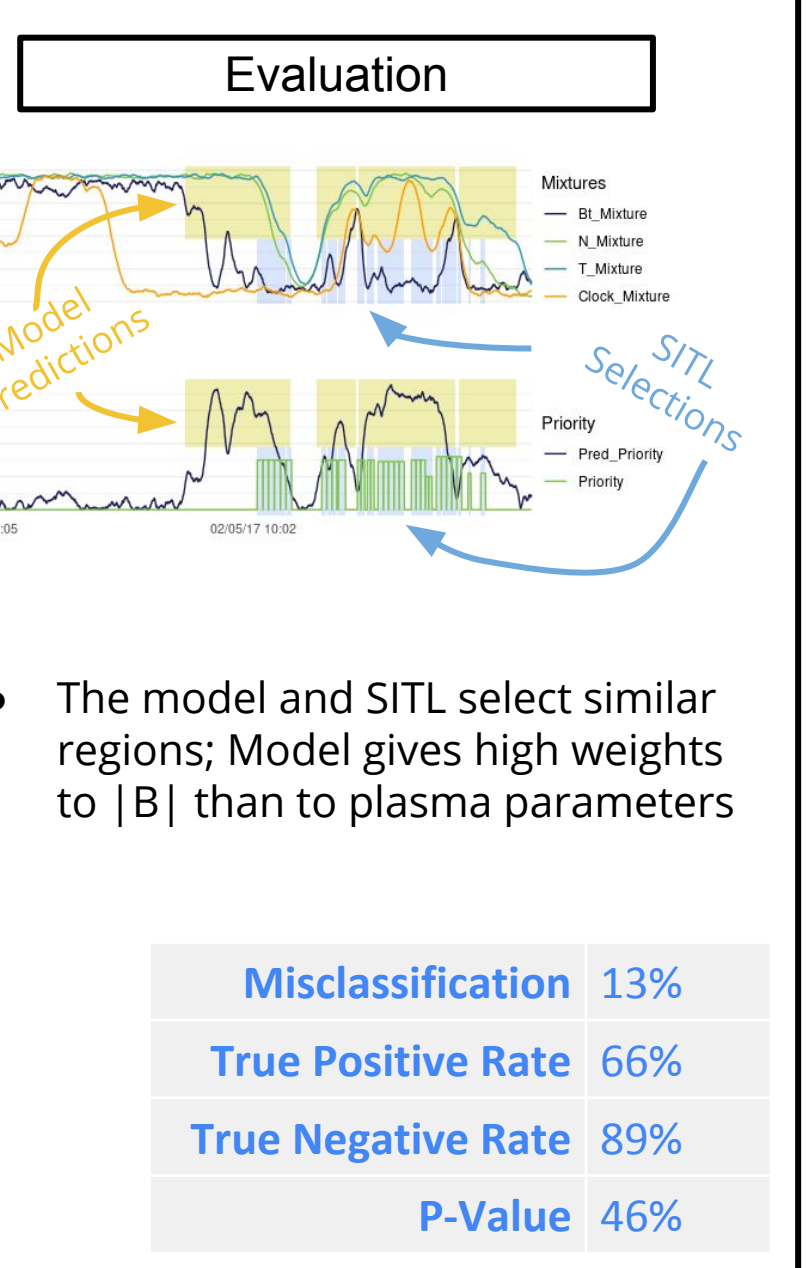
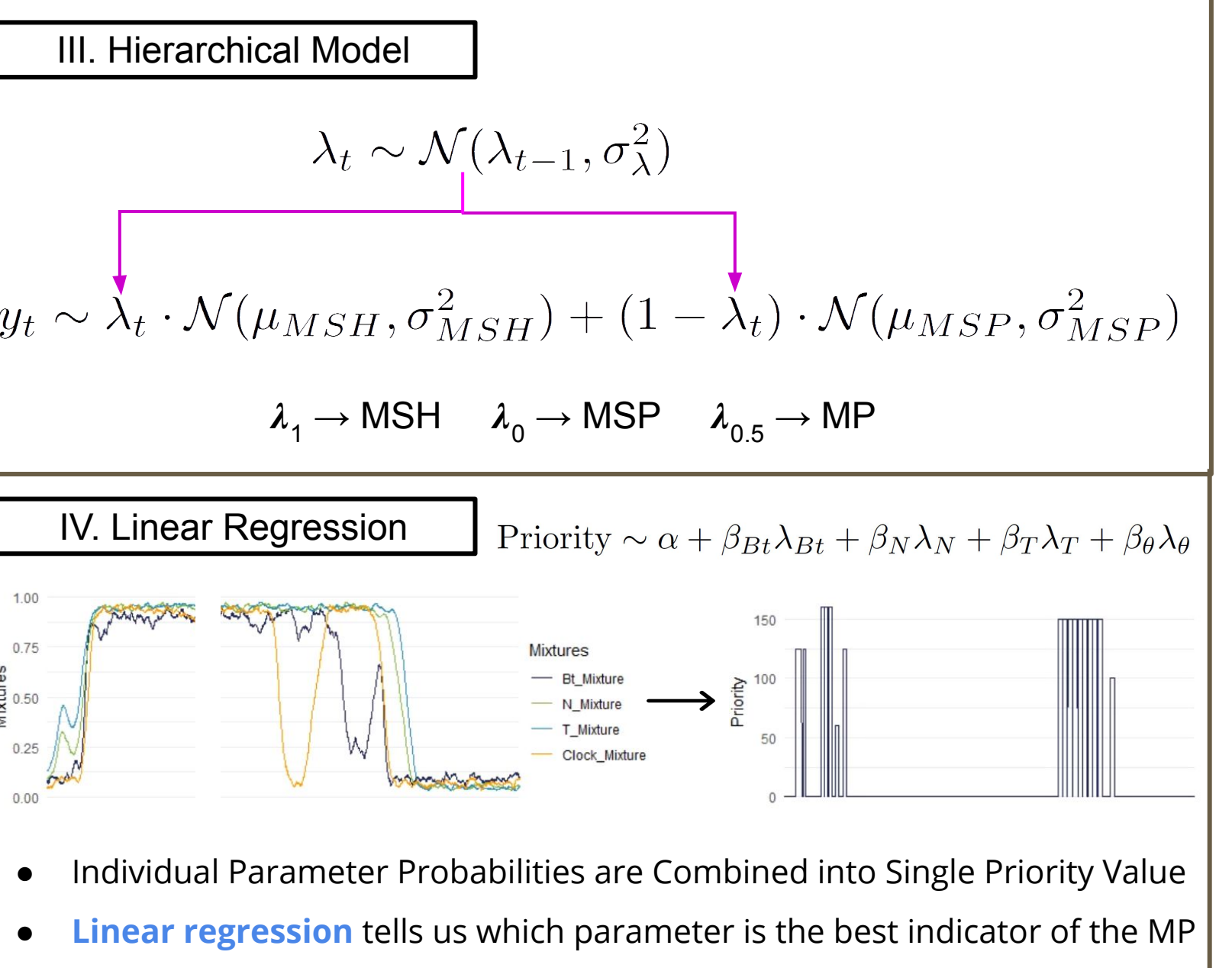
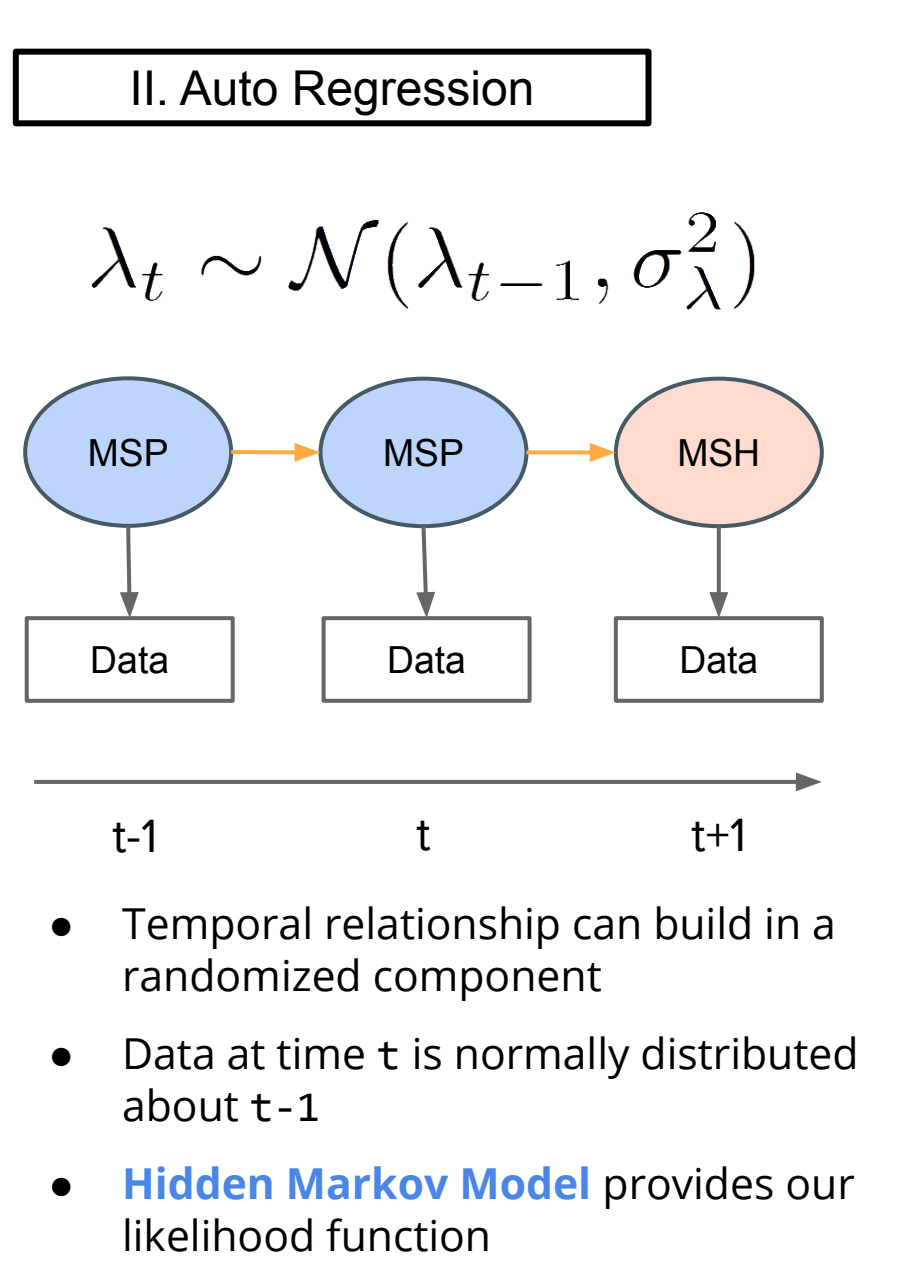
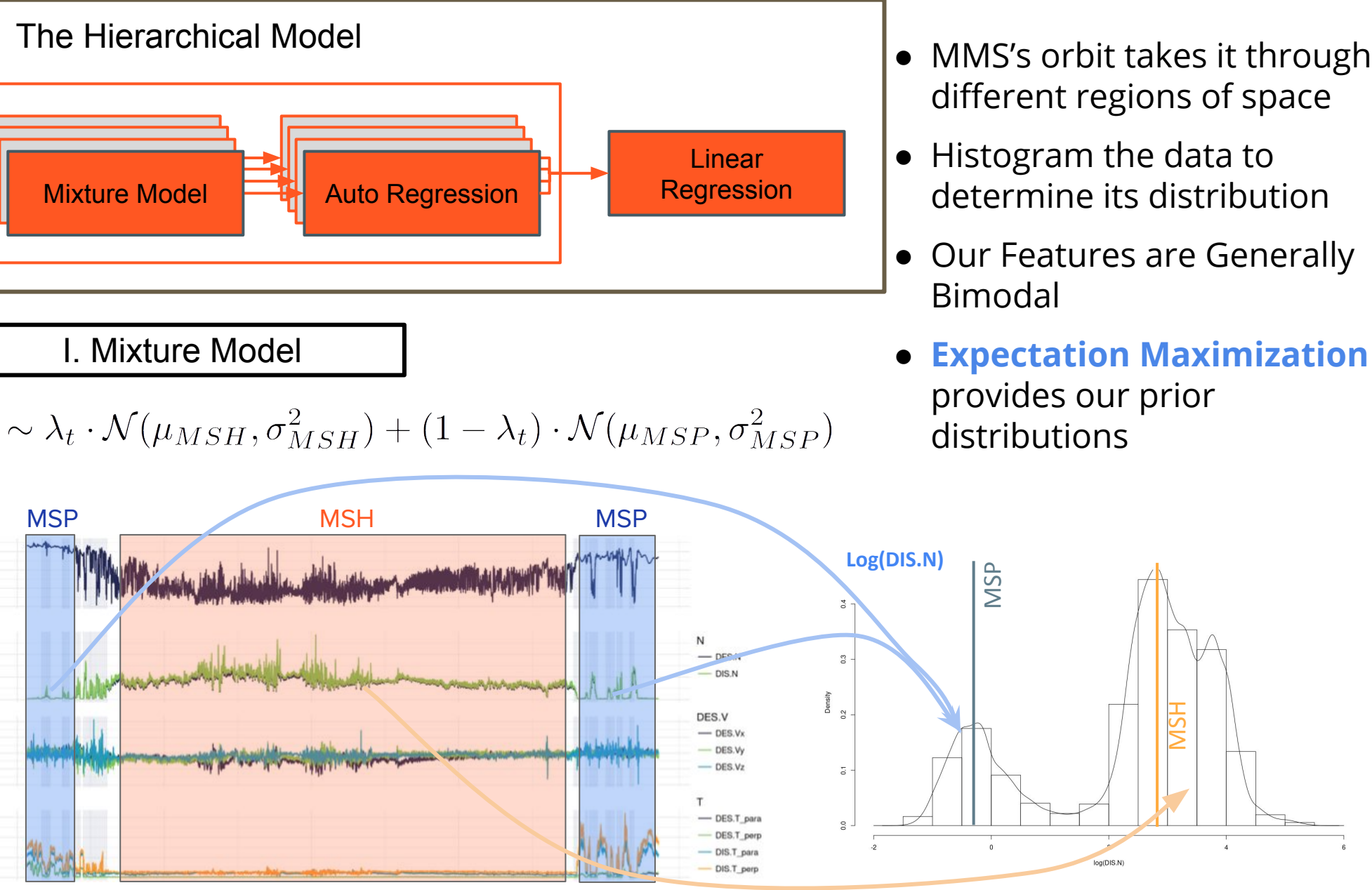
- Tune-able burst trigger tables for each region
- Tail table successfully selects a magnetotail EDR event

## Ground Loop 1: Recurrent Neural Network (RNN) with Long Short-Term Memory (LSTM)



- Magnetopause crossings detection
- SITL Selections and comments factor into the model
- Selections influence the SITL
- And may one day replace the SITL
- Preliminary model identifies the magnetopause
- Larger training set should improve results

## Ground Loop 2: Hierarchical Bayesian Model



### Summary

- MMS employs a human Scientist-In-The-Loop (SITL) to select burst data for downlink
  - Time consuming and arduous
  - Consumes mission resources
- Two possible paths to automation:
  - Improve on-board burst triggers
  - Create "ground loops" that use SITL data to make selections
- Two machine learning models have been developed as magnetopause detectors
  - A neural network ground loop is making near real-time selection for SITL review
  - A Hierarchical Bayesian Model
- ML enables more complex mission design
  - Makes large volumes of data tractable
  - Simplifies complex mission operations schemes
- ML is helping MMS select its mission critical data
  - Ground loops can be tailored to specific campaigns or extended mission objectives
  - Neural networks and Bayesian models automate the SITL magnetopause selection process

### Acknowledgements

We would like to thank all of the scientists who have acted as SITL for identifying magnetopause crossings throughout the mission. This was a great help in building the training and test sets. M.R.A. would like to thank M. Bobra for the inspiration and discussions that motivated this work. Funding was provided, in part, by NASA contract NNG04EB99C and grant 80NS55C19K1203

### References

Piatt, S. (2019). Large-Scale Statistical Survey of Magnetopause Reconnection. ArXiv E-Prints, arXiv:1905.11359. Retrieved from <https://arxiv.org/abs/1905.11359>

Argall, M. R., et al. (2019). Machine Learning in Space Physics (Student Invited Tutorial). Abstract presented at the GEM Workshop, Santa Fe, NM, 22-28 June. <https://www.youtube.com/watch?v=3hB5W7EBtSI>