Interpolating Calibration Data on the Sphere with Information Field Theory

Conceptual Advances in Deep Learning for Research on Universe and Matter

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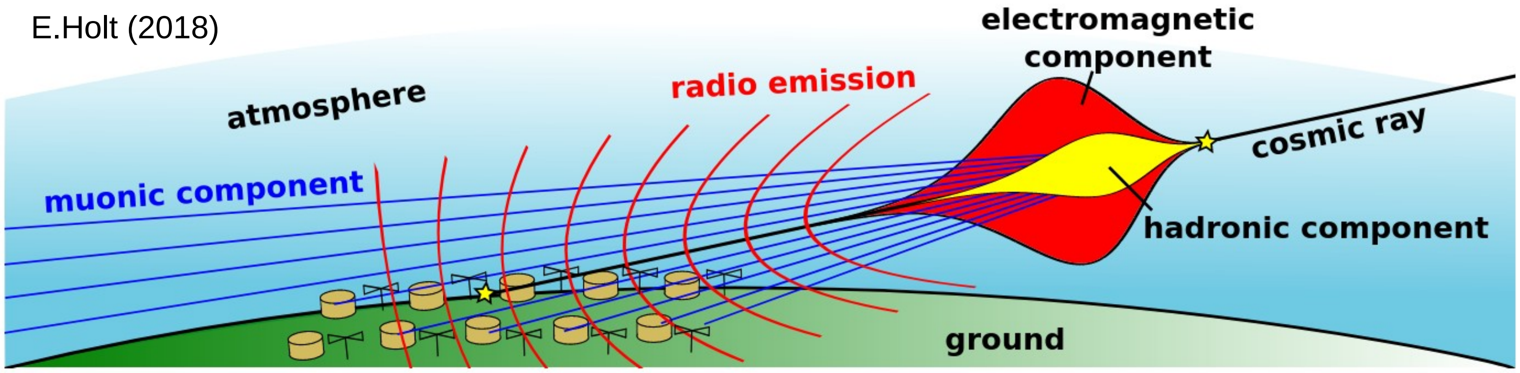
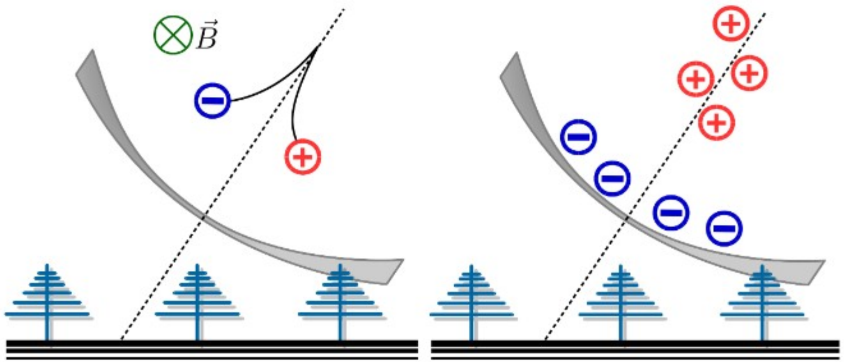
Radio Emissions from Extensive Air Showers

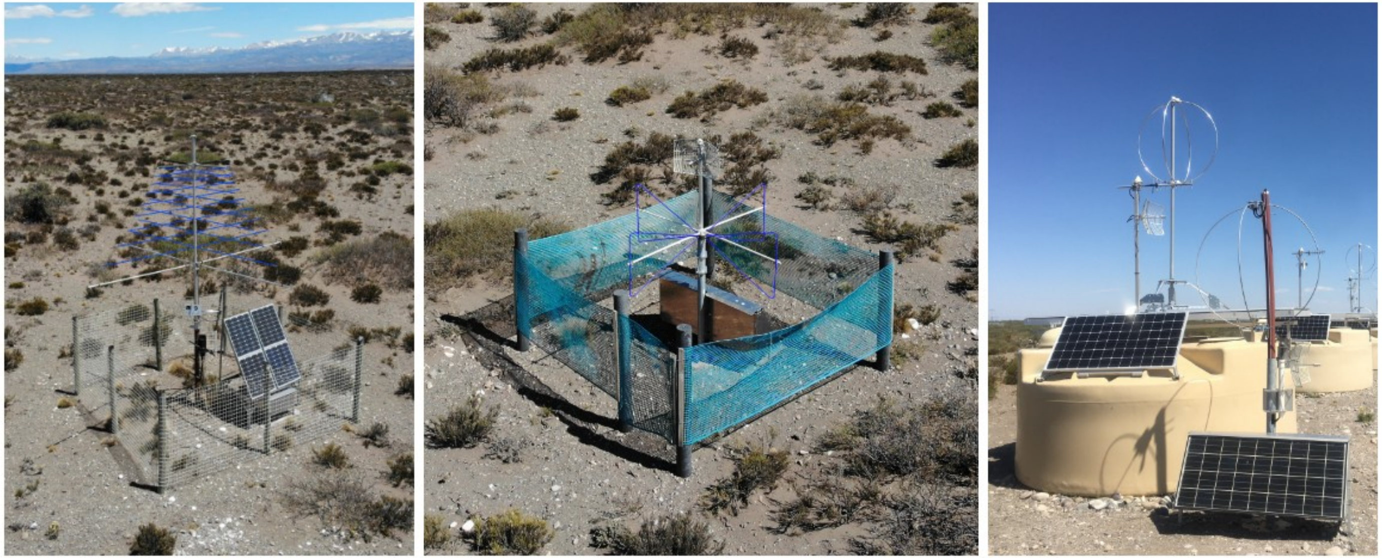
E.Holt (2018)

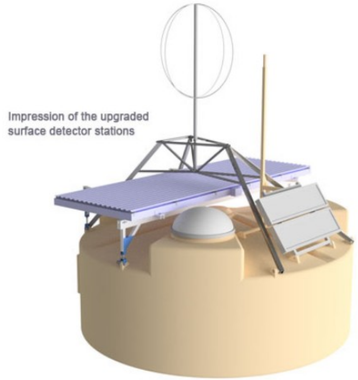




C. Glaser (2017)

Detecting Radio Emissions on Ground





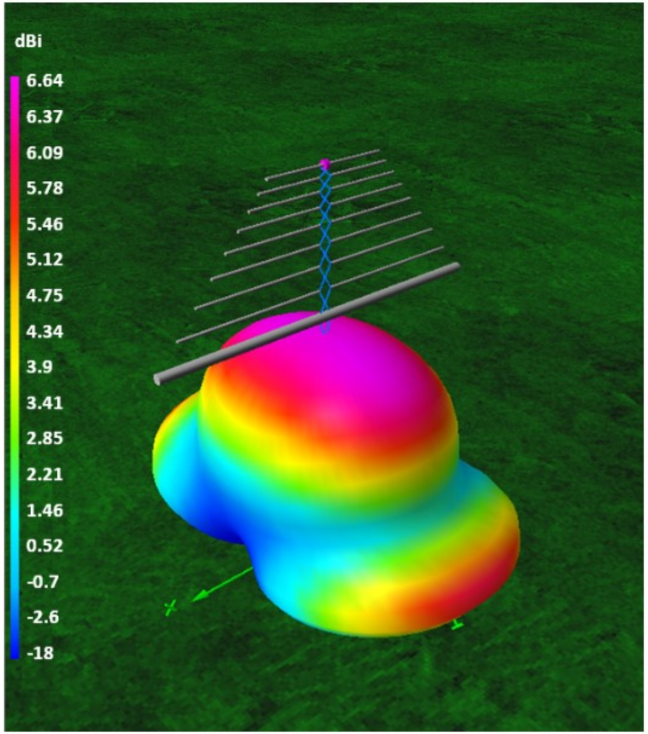
F. Schlüter (2022)

https://www.auger.org/observatory/augerprime

Antenna Patterns

$$\mathcal{U}(\theta, \phi, f) = \vec{H}(\theta, \phi, f) \cdot \vec{\mathcal{E}}(f)$$

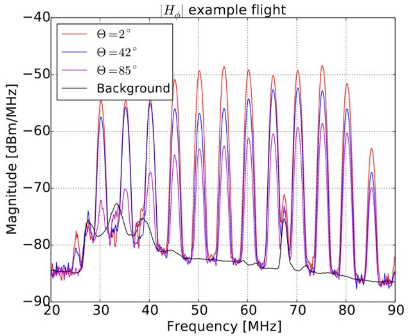
$$|H_k(\theta, \phi, f)| = \sqrt{\frac{4\pi Z_R}{Z_0}} R \sqrt{\frac{P_{r,k}(\theta, \phi, f)}{P_t(f) G_{abs,t}(f)}}$$



R. Krause (2018)

Determining Antenna Patterns: Directional Calibration

- Probe far field region: Use a drone to get there
- Emit a known signal from various directions
  - Comb generator
  - Biconical antenna
  - Antenna allows for different polarizations
- Batteries for 4 flights of 20 minutes



R. Krause (2018)

Determining Antenna Patterns: Directional Calibration

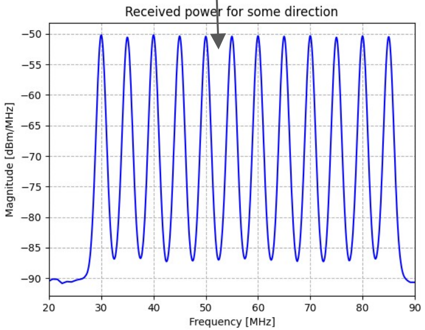
- Emission position:
  - Drone is stabilized via GPS
  - Secondary GPS: Allows ~cm accuracy on position
- Gimbal mounted antenna
  - 3-axis adjustments
  - Active stabilization, “decoupling” from drone orientation
  - Active aiming of emission at ground antenna

Challenging evaluation

- Finite amount of time
  - Can only probe finite number of directions
- Current setup: Comb spectrum
  - Frequency gaps!
- Uncertainties on measurements
  - Received power
  - Fluctuations on drone position

→ How to get in-between values?

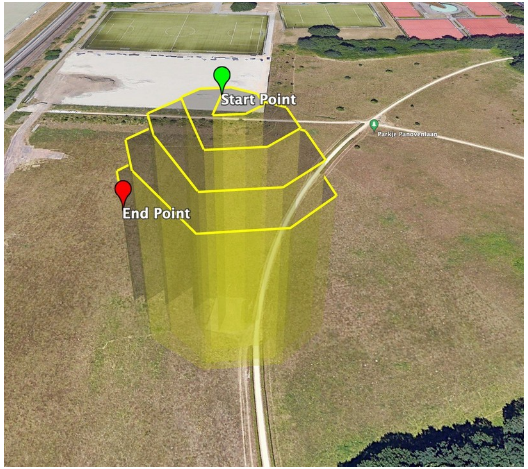
What about here?

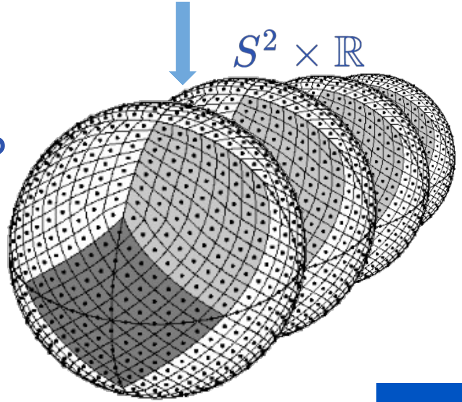


Interpolation on S²×R

- Antenna pattern has structure
  - Expected range of values (e.g. informed by simulations)
  - Certain expected smoothness
  - Local correlation between values
- Direction degree of freedom: Sphere
  - Hard to interpolate on
  - Symmetries, no projection, etc.
- Spectral degree of freedom: R
- How to use information of both domains at the same time?

→ Build field on product space with Nifty

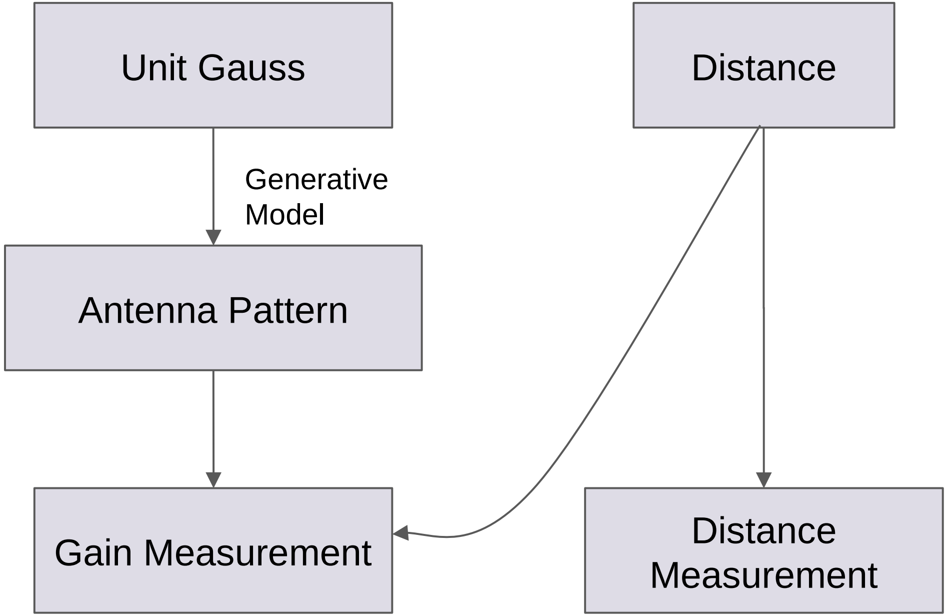




The model

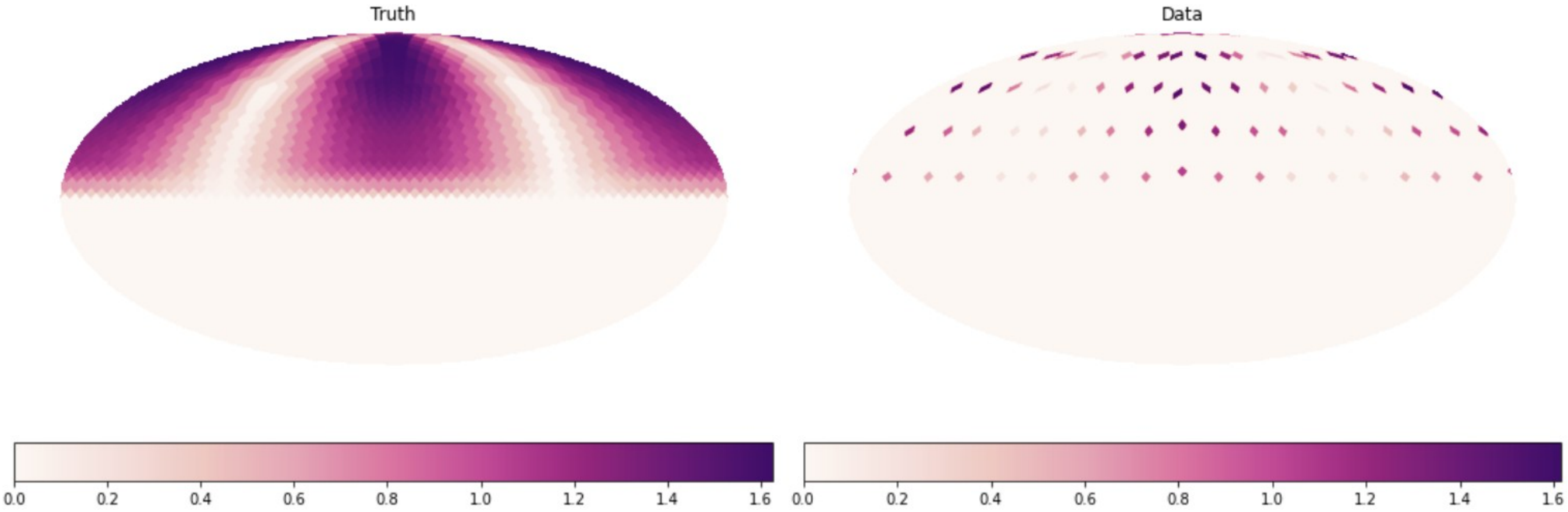
$$|H_k(\theta,\phi,f)| = \sqrt{\frac{4\pi Z_R}{Z_0}}\,R\sqrt{\frac{P_{r,k}(\theta,\phi,f)}{P_t(f)G_{abs,t}(f)}}$$

$$P_{\text{receive}}(\theta,\phi,f) = C\frac{|H_k(\theta,\phi,f)|^2}{R^2}$$



Antenna Calibration with IFT

Slice for f = 35MHz



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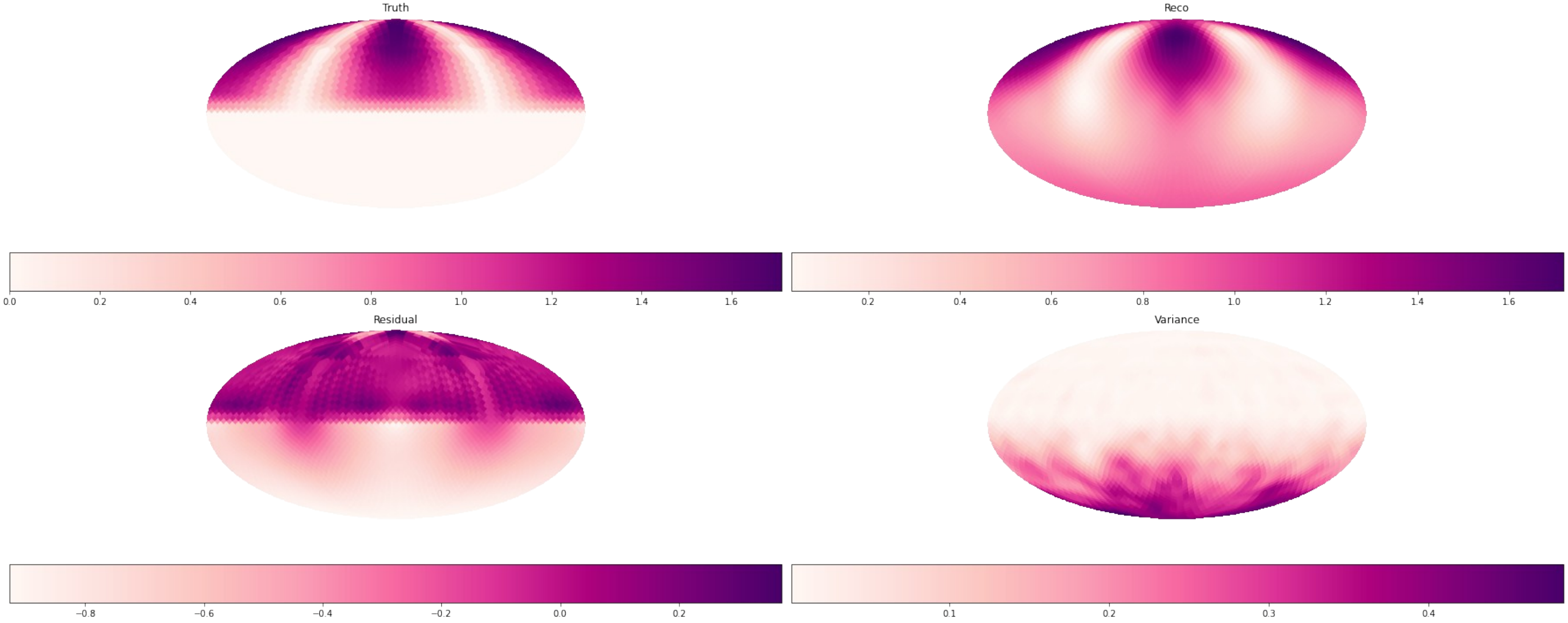

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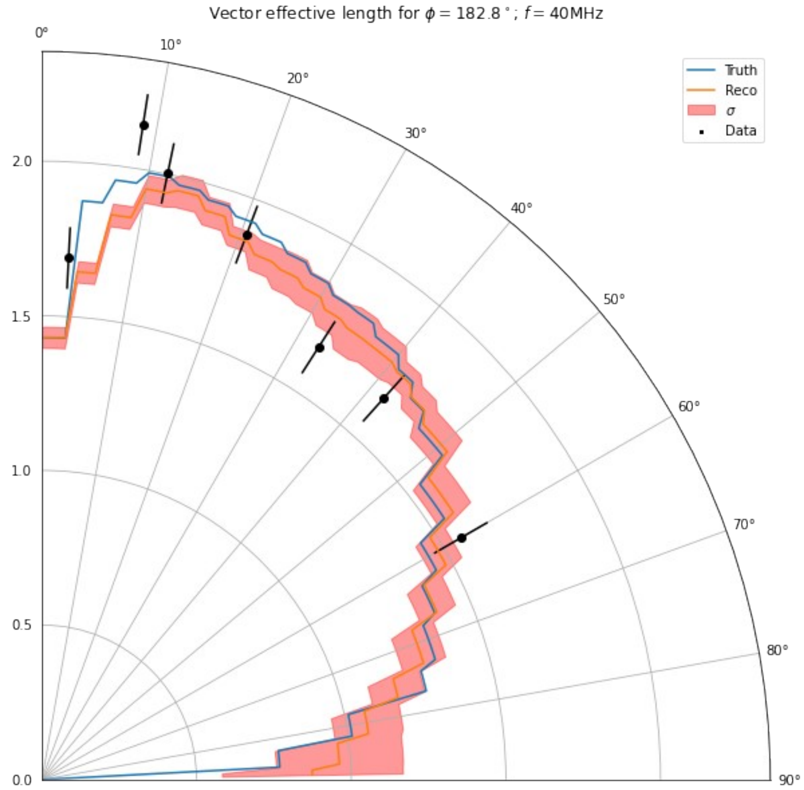

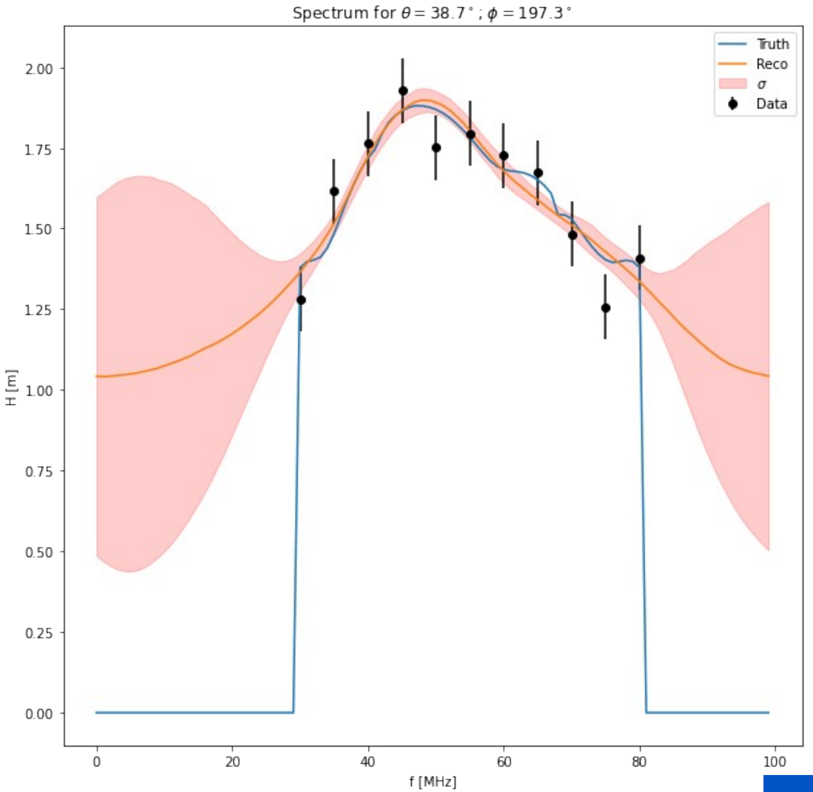

Conclusion

- IFT allows smart interpolation on sphere
- Incorporate uncertainties easily
- Soon: Application on real measurements (both old and new)
- Currently implementing phase reconstruction via pulsed signals
- Building pipeline to directly take in drone data