# Enhancing Autonomous Satellite Communication Systems with Weather-Aware Scheduling and Reconfiguration

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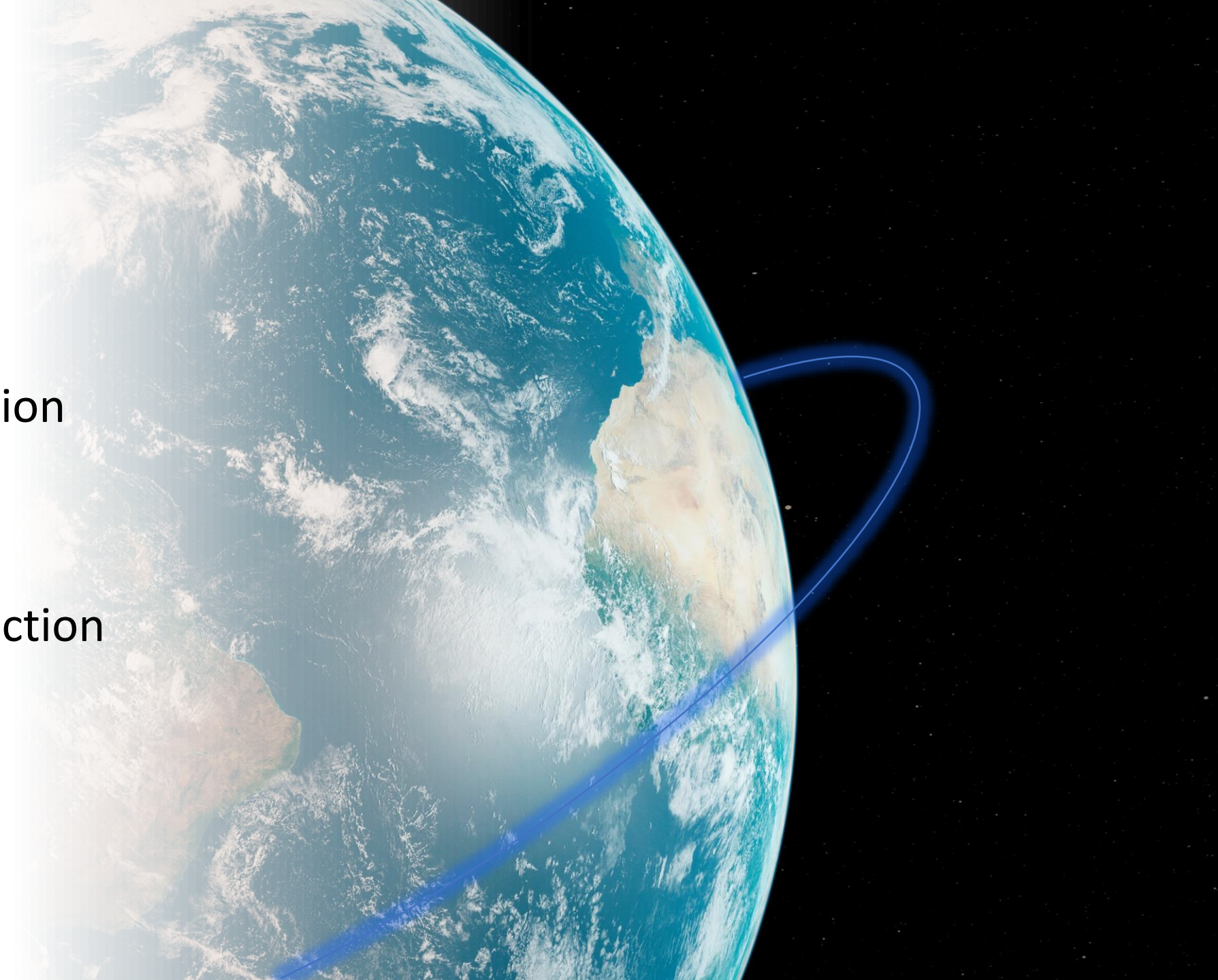
# Overview

- Objective
- Site Characterization
- NIMBUS CONOPS
- Nowcasting
- Link Quality Prediction
- Backtesting
- Results



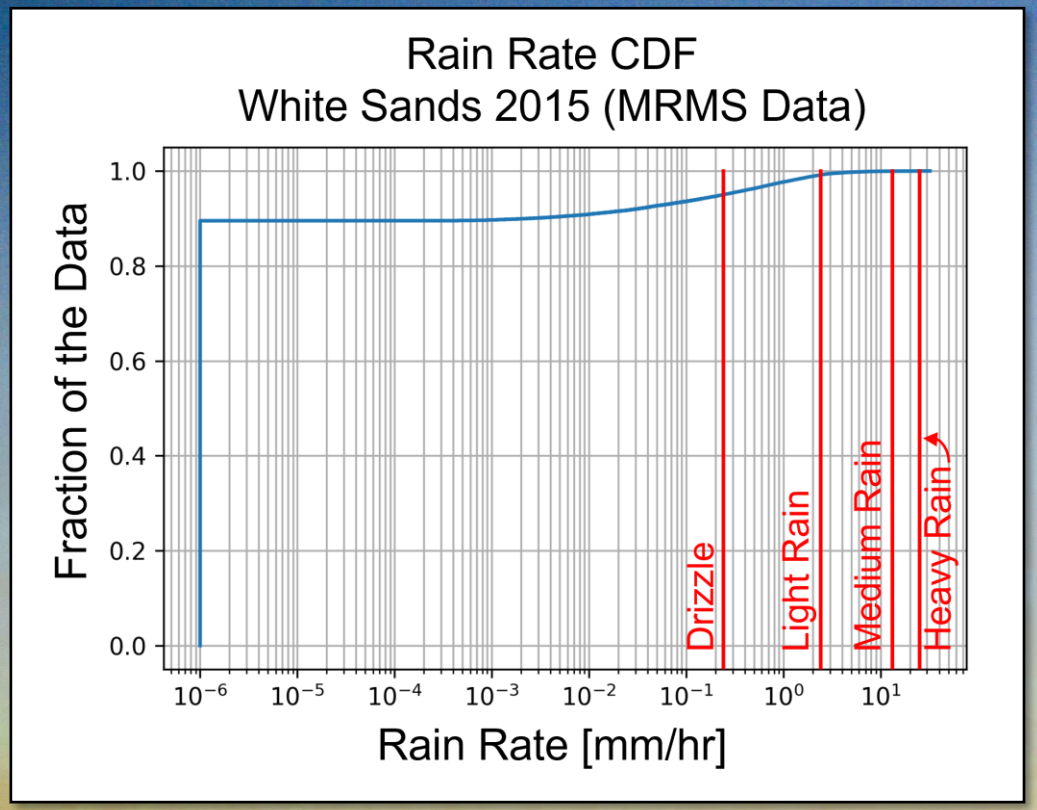
# Objective Statement

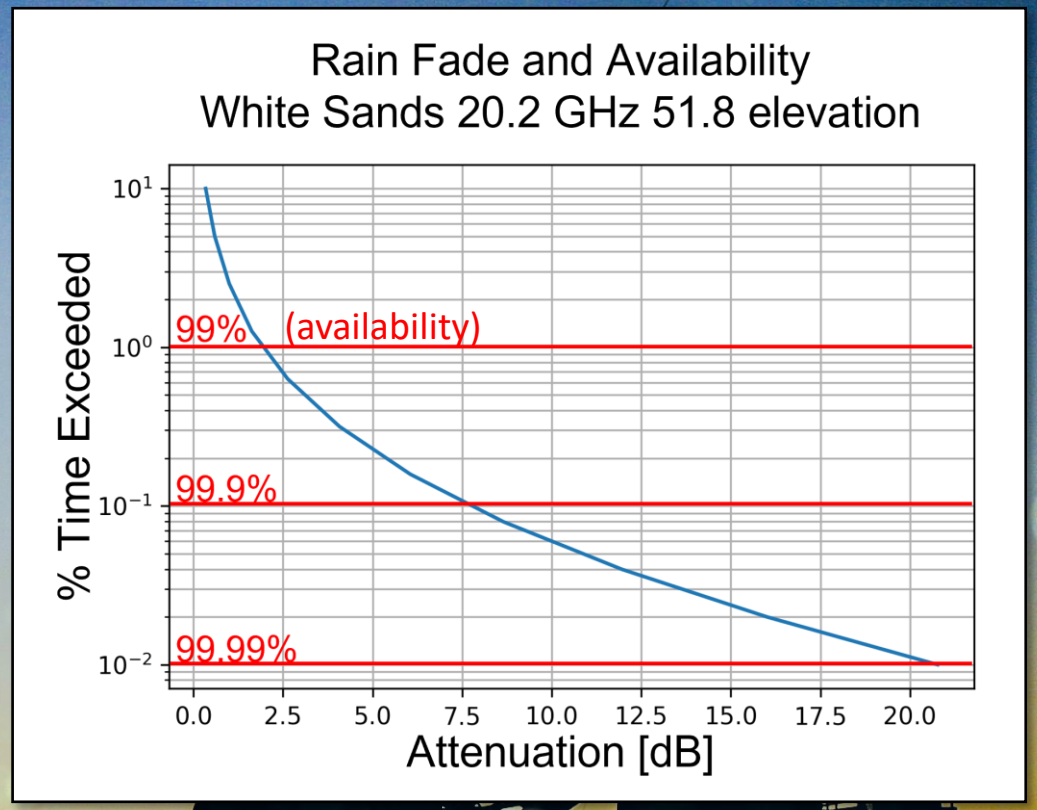
Use
**recent weather information**
to
**improve link budget estimates**

and

Use a
**control plane**
to coordinate
**date rate reconfiguration**

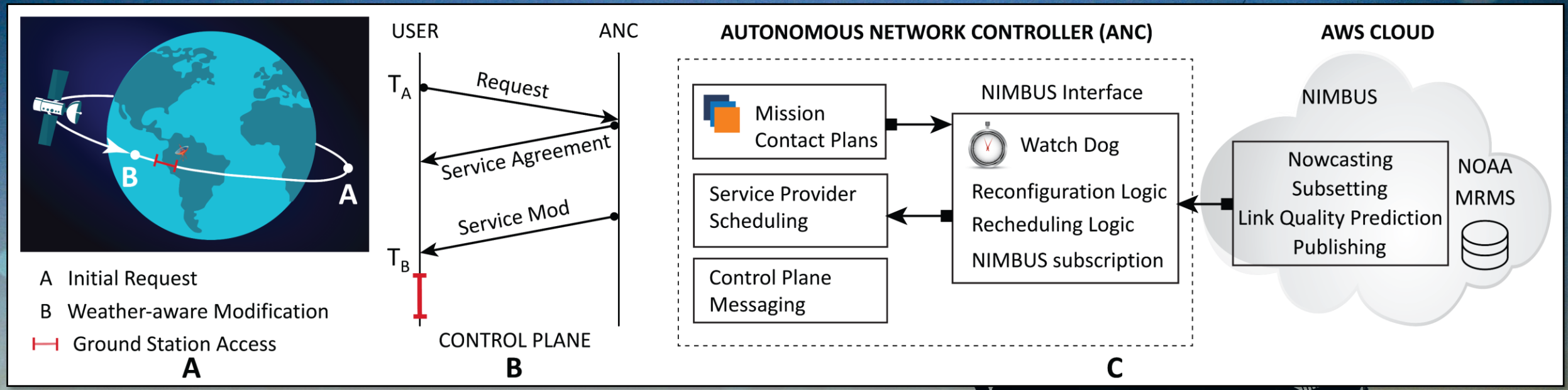
# Site Characterization - Atmospheric Atten.



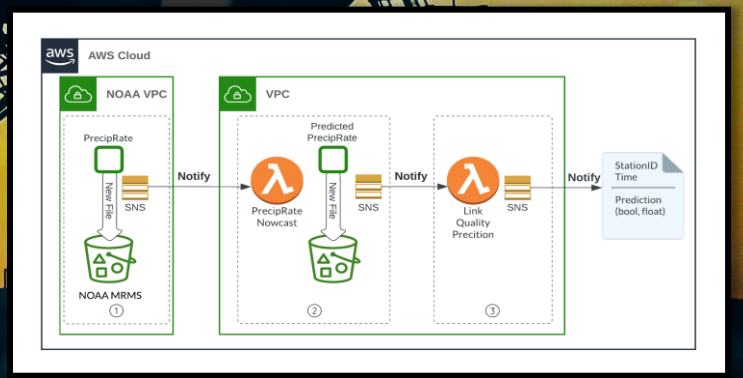

- At Ka-band frequencies, rain fade is the dominant atmospheric attenuation
- System link budgets use long-term availability statistics
- Most of the year, the link is run too conservatively

# NIMBUS Concept-of-Operations




## NIMBUS performs the following core functions:

1) Maintains a subscription to NOAA's MRMS rain rate data stream
2) Produces rain rate Nowcasts
3) Subsets Nowcasts into local regions around relevant ground stations
4) Produces link quality predictions



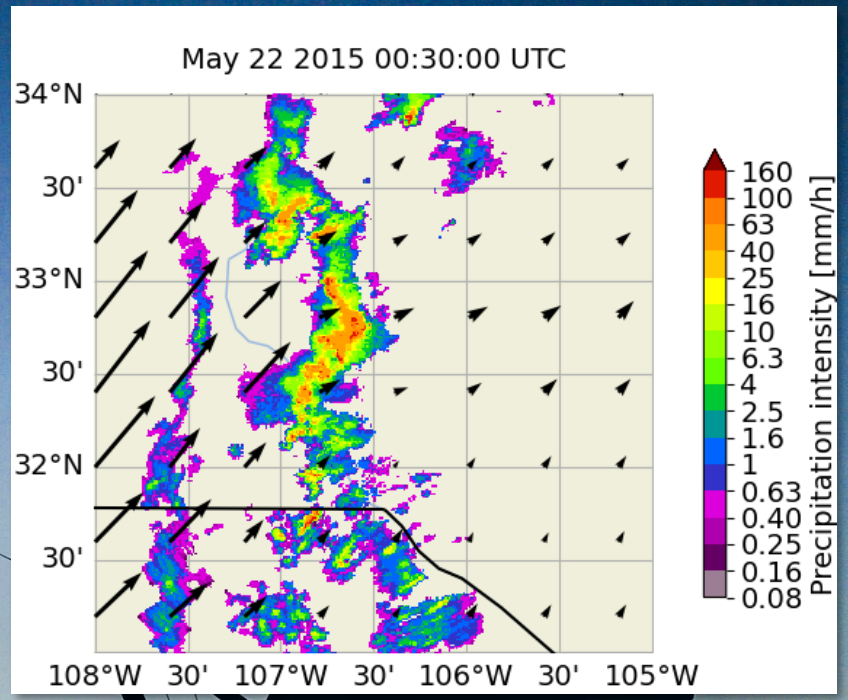
# Nowcasting

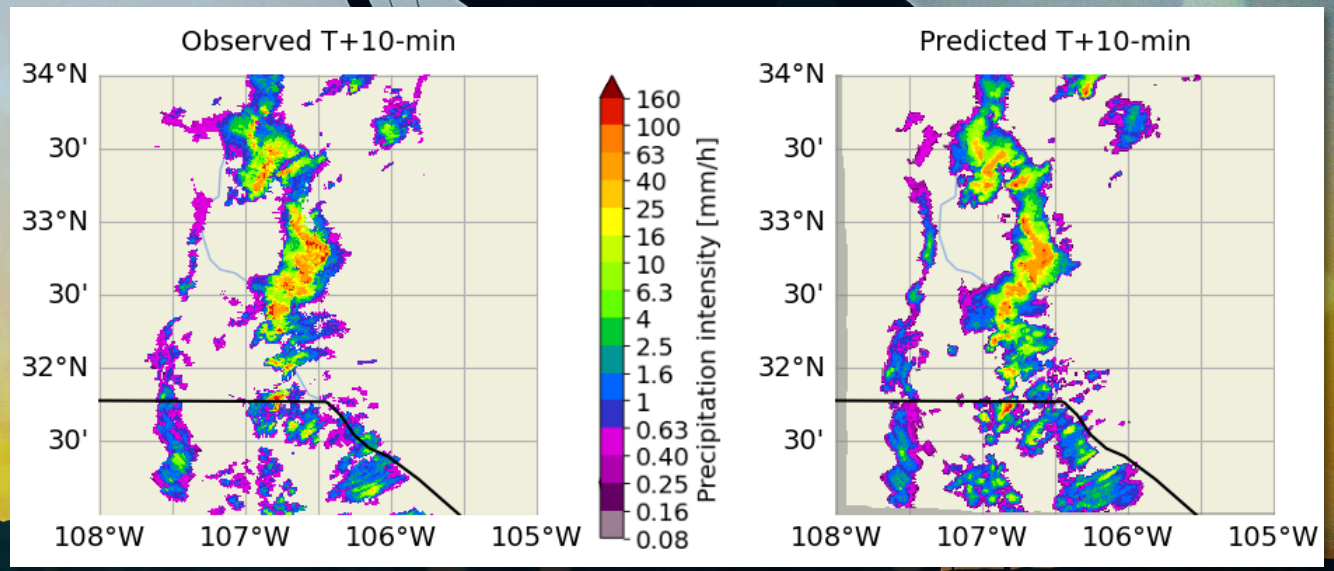
Implemented with the PySTEPs algorithm

Optical flow motion fields (advection)

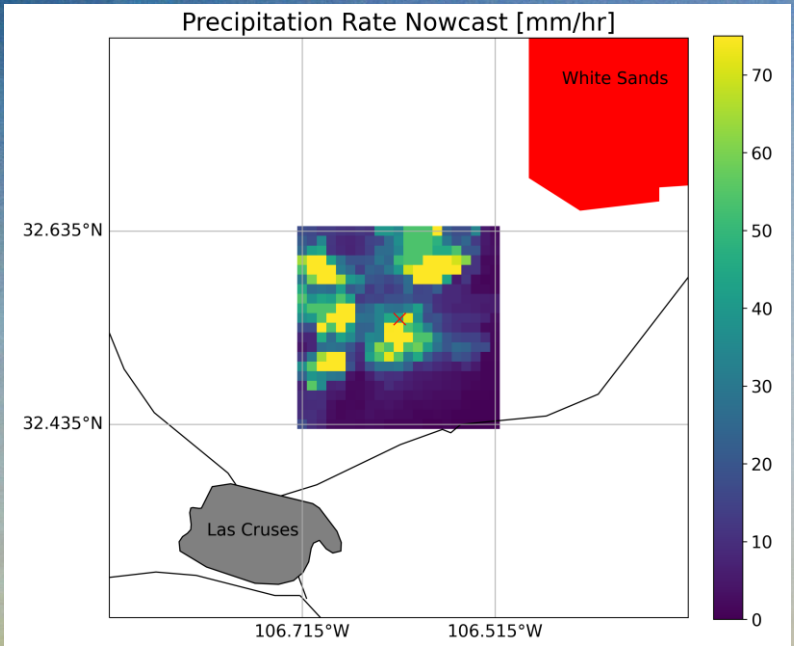
If real-time data is better, why Nowcast?

- NOAA data updates every 2-min
- Some architectures may prohibit last minute reconfiguration
- Advanced warning enables earlier rescheduling opportunities



# Link Quality Prediction




21km x 21km (21 x 21 cells)

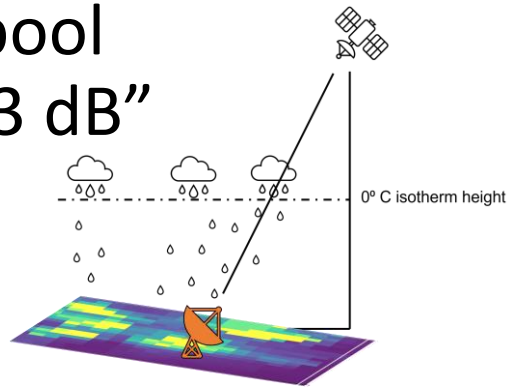
White Sands Ground Site

Observation variable $\hat{r}$ is mean value

**Binary classifier**

Average rain rate over tile is compared against threshold

Classes represent the bool "Link is degraded by > 3 dB"




**Attenuation Estimator**

Based on ITU-R P.618-13

Instantaneous rain rate estimated by replacing R0.01 with average rate over tile

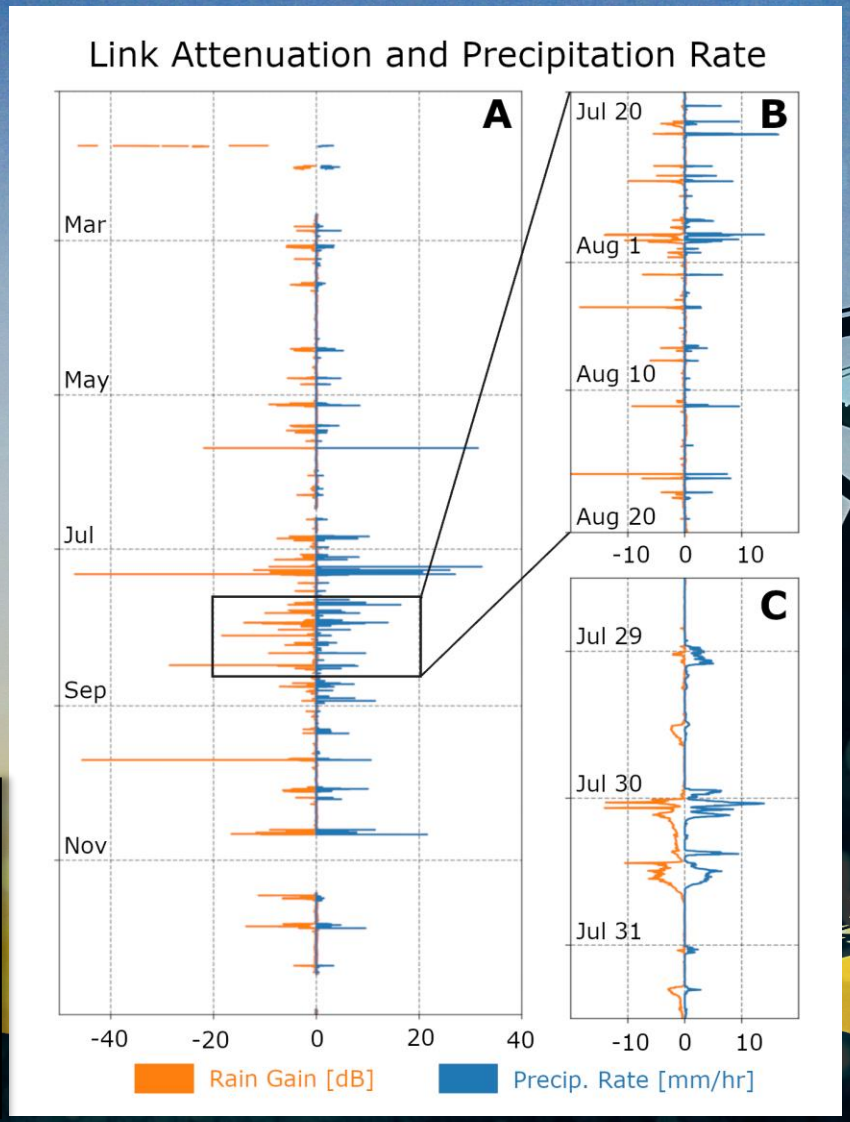
# Backtesting (2015 data)


White Sands Terminal

Operational Freq. 20.2 GHz

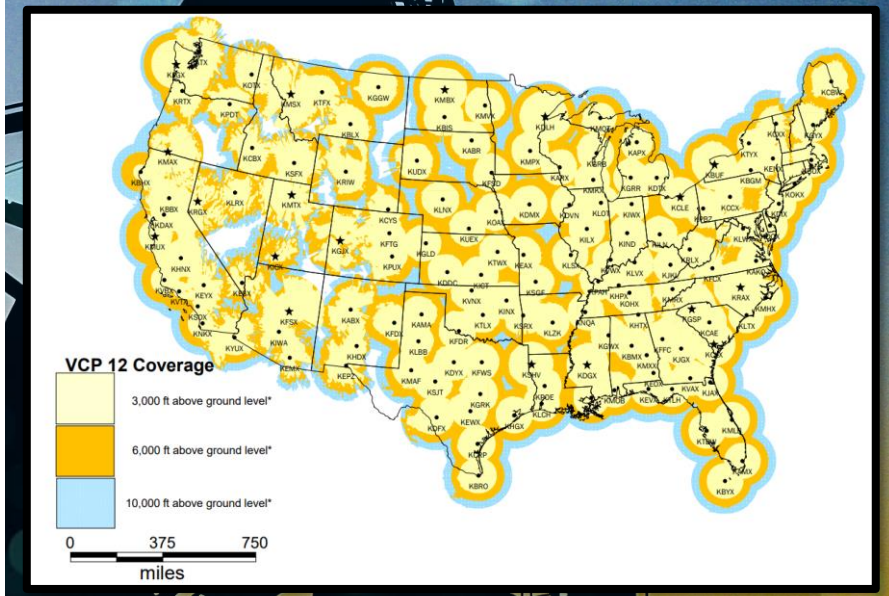
Software-based FFT Receiver

Observing ANIK F2 Beacon




NSSL

NOAA National Severe Storms Laboratory

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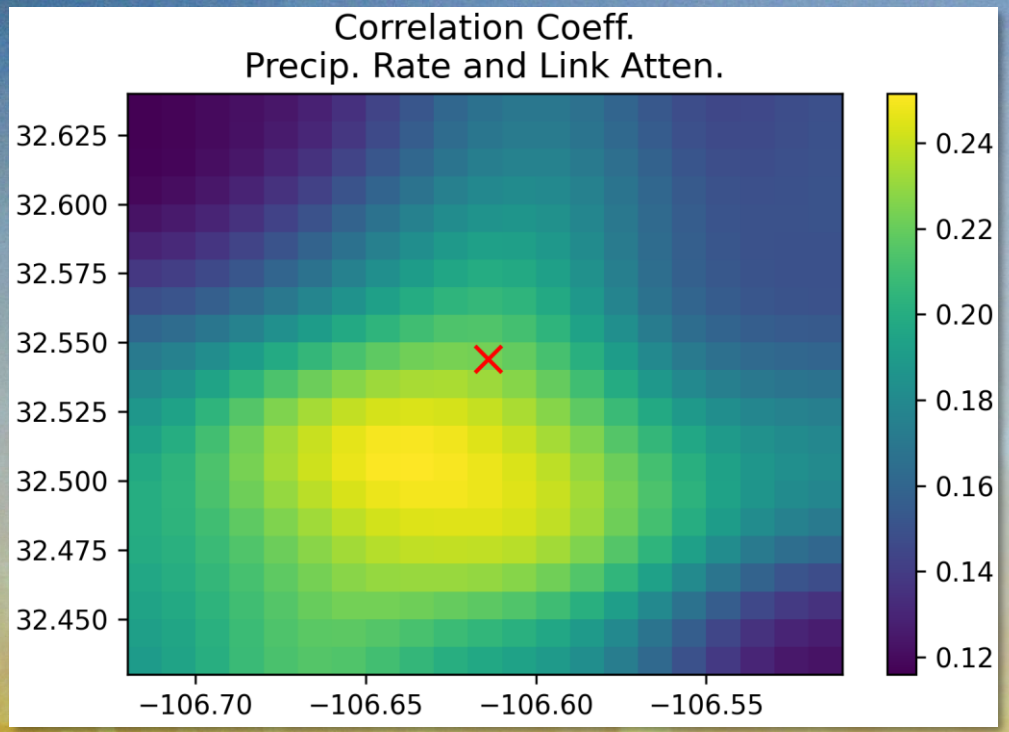
# Results – Spatial Correlations




Correlations measured on time aligned data

ANIK F2 Satellite (geostationary)

Orbital Lon. 111.1 W

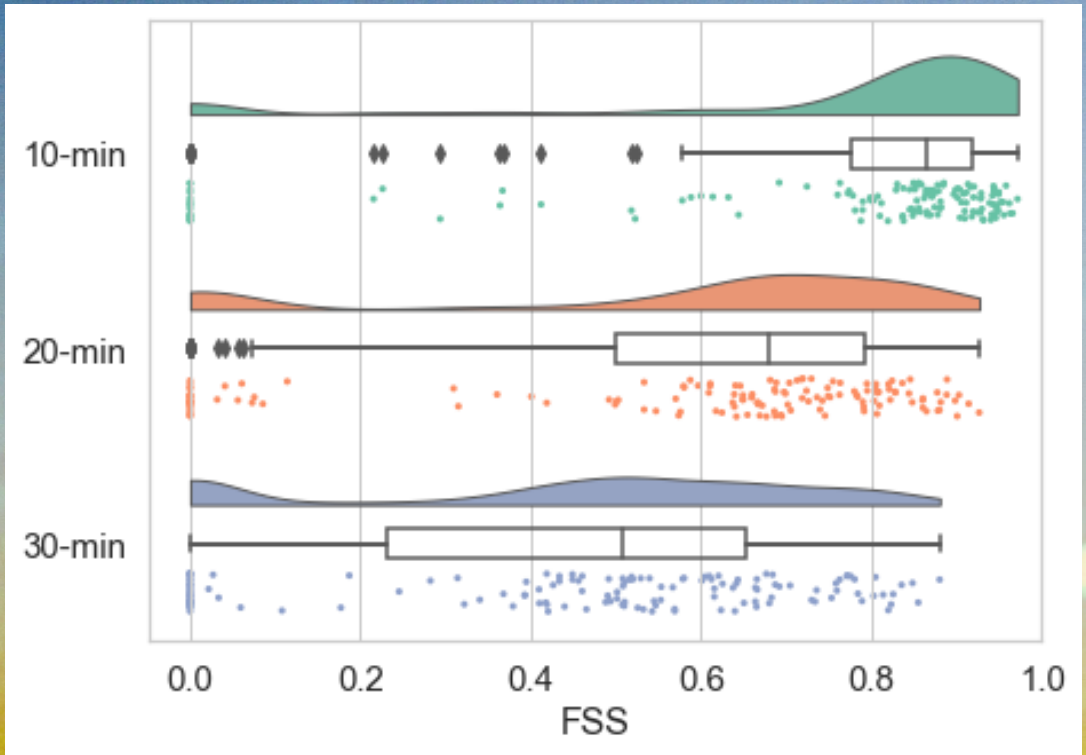
Elevation 51.8 degrees

Azimuth 188 degrees

Correlation focused south of the receiver, as expected due to geostationary satellite

# Results – Independent Nowcast / CQP

Nowcast Fractions Skill Score




21km grid, 1 mm/hr threshold

**Binary Classifier**

Area under the ROC: 92%

For FPR < 5%, choose 0.414 mm/hr

Accuracy over 1-year = 97%

**Attenuation Estimator**

Mean Absolute Error 0.919 dB on frames that contained some rain

# Results – 30-min Nowcast + CQP

Evaluated over a rainy 24-hour period

July 20, 2015 (720 frames)

**Binary Classifier**

Overall accuracy 84%

**Attenuation Estimator**

Mean Absolute Error 1.17 dB

# Conclusions

The NIMBUS algorithm produced 30-minute forecasts of link degradation with 84% accuracy, and predicted rain attenuation with an MAE of 1.17 dB.

These early results provide evidence that link quality prediction could be used to reduce static atmospheric link margins

Closed loop systems, such as adaptive coding and modulation (ACM) would outperform the open loop system presented, but the NIMBUS CONOPs could be used in conjunction with ACM, by predicting pass transfer volumes and through symbol rate control


“Tut, tut, looks like rain”
- Christopher Robins