

Distributed observations of ionospheric irregularities and scintillation using low-cost GNSS-based monitors

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Acknowledgments:

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1. JRO, Peru, 2. IAE, Brazil, 3. UFCG, Brazil, 4. UTD, 5. ERAU, 6. MIT Haystack,
7. University of Scranton, 8. UIUC, 9. USU.

Introduction

- *Deploying most commercial sensors* for ground-observations of the upper atmosphere *are difficult and costly*.
- At UTD, we have been working on *low-cost, easy-to-deploy and easy-to-maintain sensors* for ionospheric observations and educational initiatives.
- Here, we will present *results related to the development of these sensors and their application to observations of ionospheric behavior and irregularities* that are relevant to studies targeting equatorial to mid latitudes.

Outline

1. Description of ScintPi monitors
2. Examples of deployments, observations, and performance
3. Concluding remarks

1. ScintPi

- ScintPi is a series of scintillation and TEC monitors developed at UT Dallas.
- The sensors were developed using off-the-shelf GNSS receivers and single-board computers (Raspberry Pi).



1. ScintPi

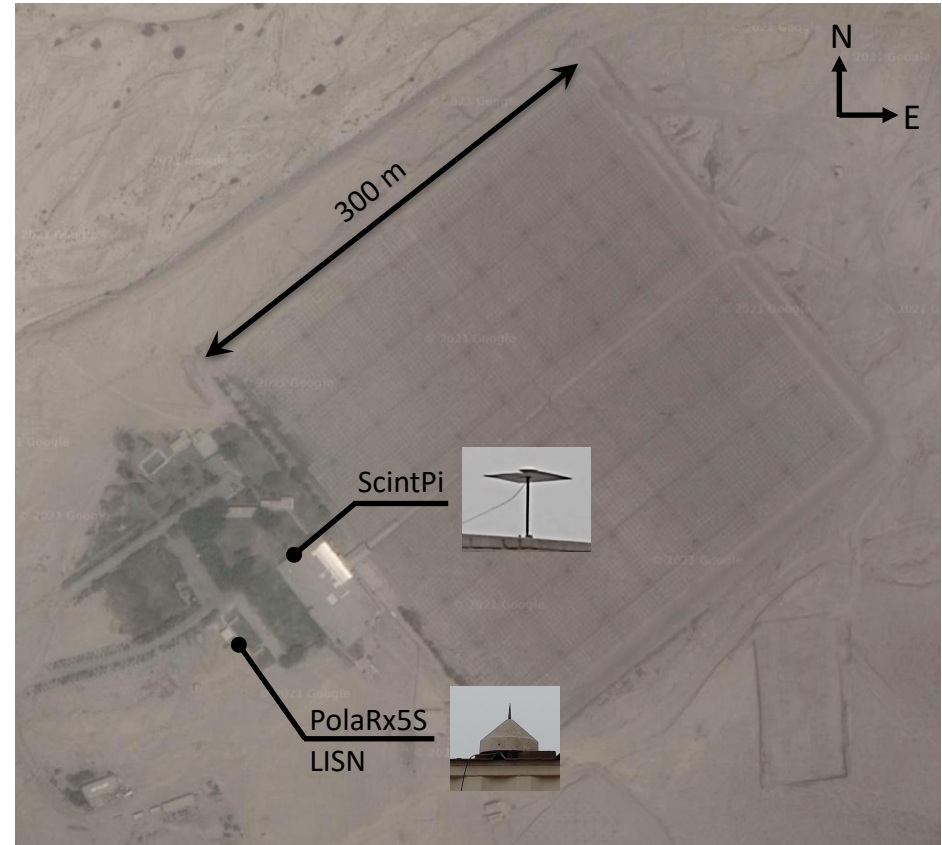
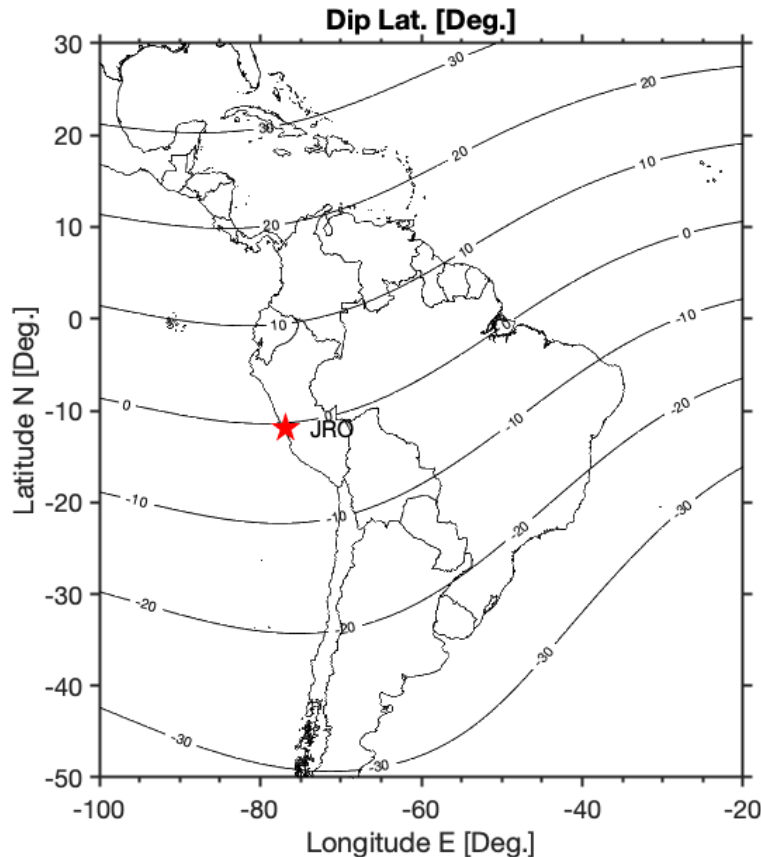
- ScintPi is a series of scintillation and TEC monitors developed at UT Dallas.
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- | | | |
|--|-----------------------------|-----------------------------|
| ■ GPS-only | ■ Multi-GNSS | ■ Multi-GNSS |
| ■ Single frequency | ■ Single frequency | ■ Dual-frequency |
| ■ Amplitude | ■ Amplitude | ■ Amplitude |
| ■ ≤ 10 Hz update rates | ■ ≤ 25 Hz update rates | ■ Phase |
| ■ utdallas.edu/~fabiano | | ■ ≤ 25 Hz update rates |

2. Deployments and observations

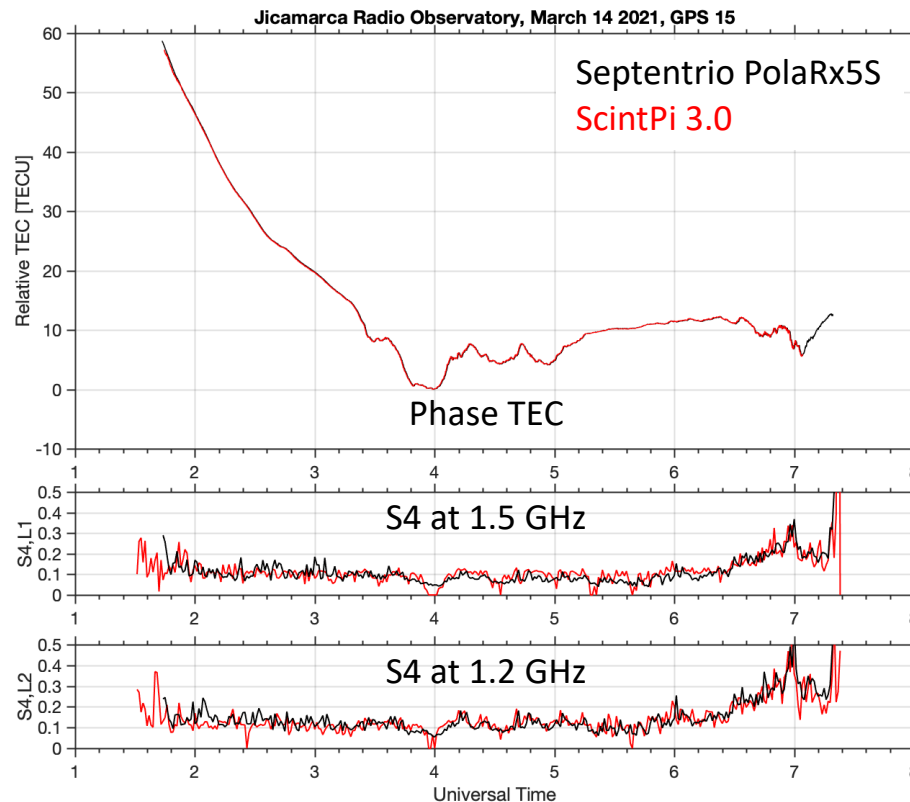
- Deployment at Jicamarca near the magnetic equator



- ScintPi 2.0 and 3.0 used the same inexpensive (~\$150.00) GNSS antenna

2. Deployments and observations

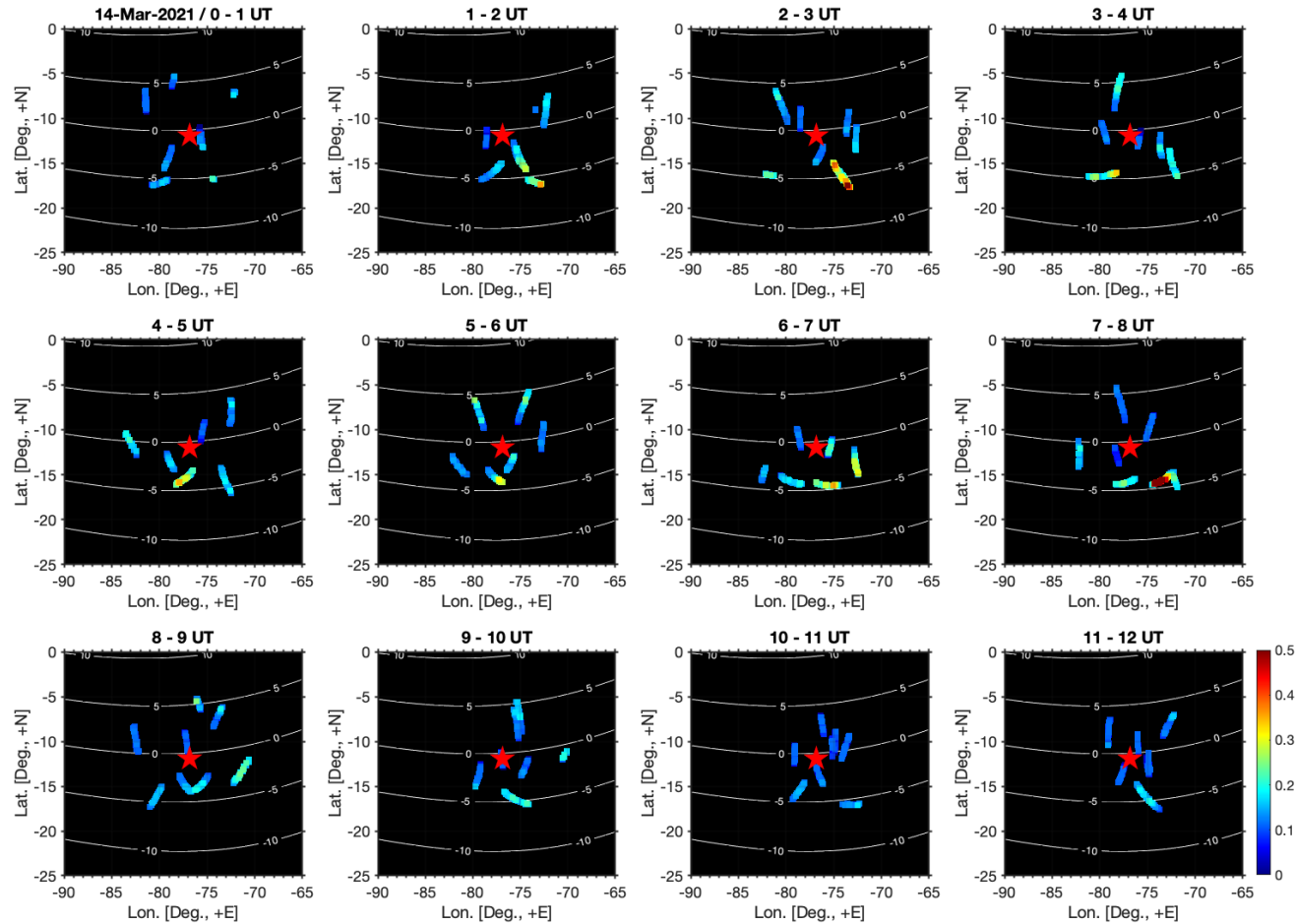
- Performance of ScintPi 3.0: *TEC and Scintillation*



- Excellent agreement in S4 and TEC
- Detection of moderate L-Band scintillation in the PM sector

2. Deployments and observations

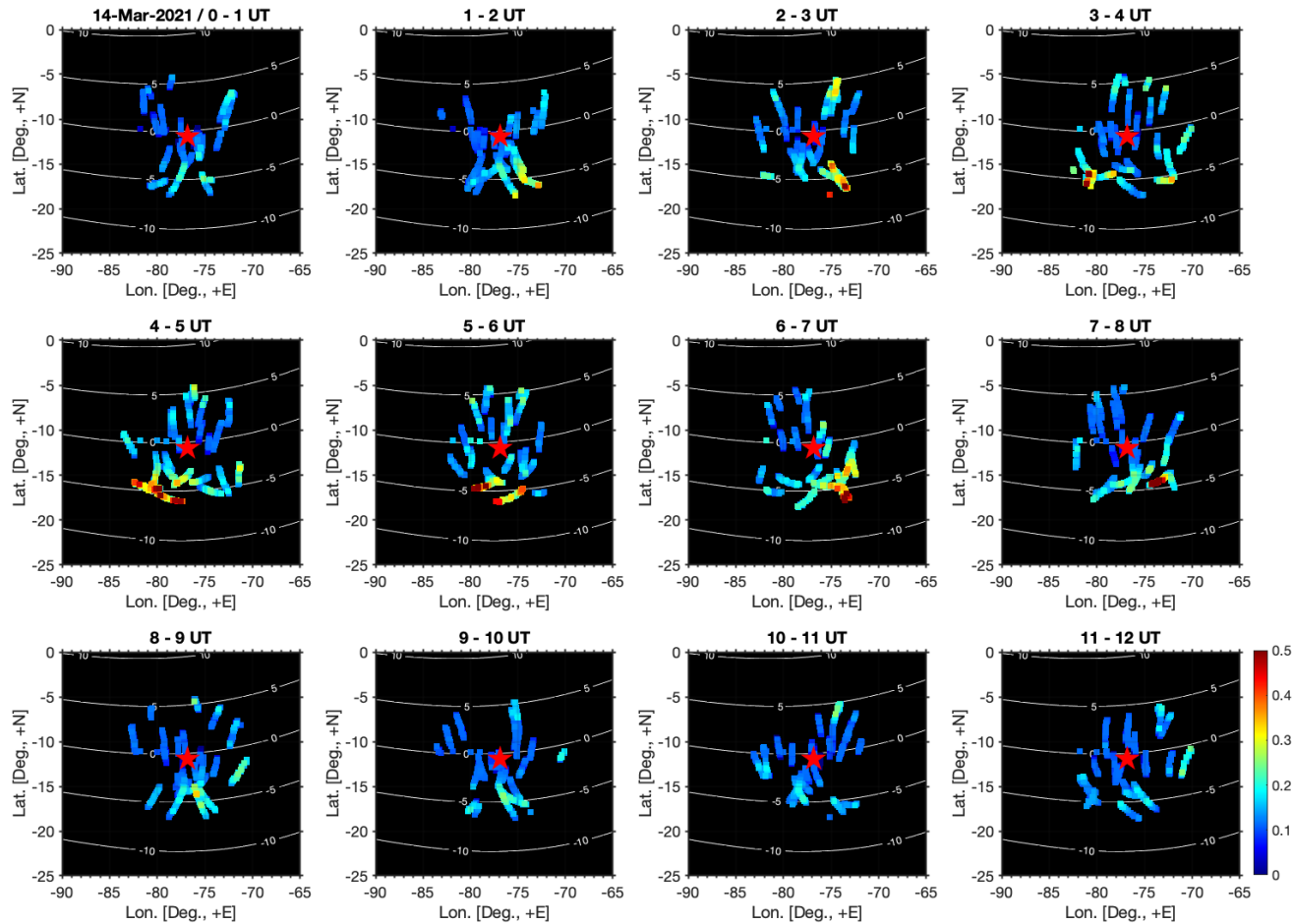
■ Example and benefits of multi-constellation observations



- UT ~ LT + 5
- GPS

2. Deployments and observations

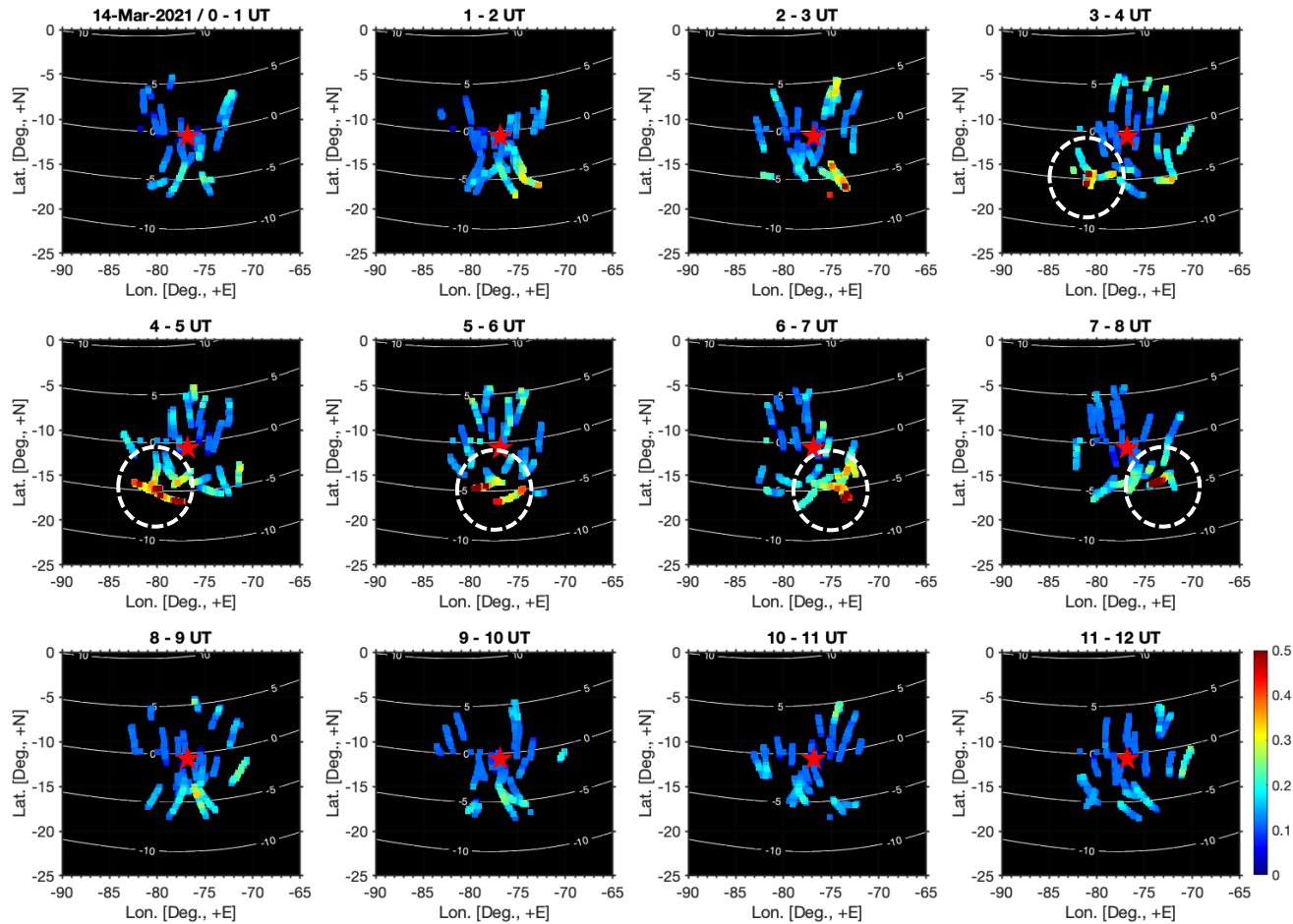
■ Example and benefits of multi-constellation observations



- More measurements, better coverage

2. Deployments and observations

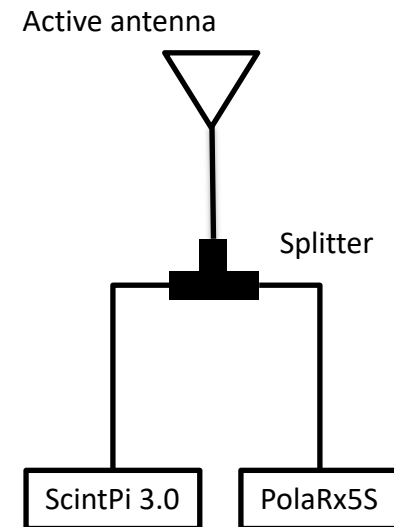
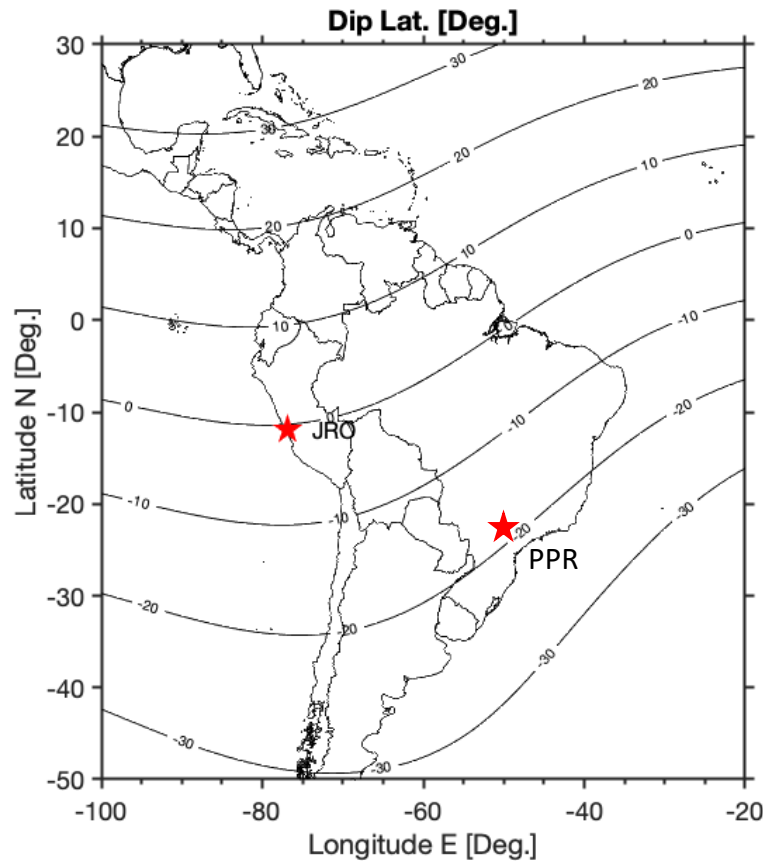
■ Example and benefits of multi-constellation observations



● Patch of scintillation-producing irregularities

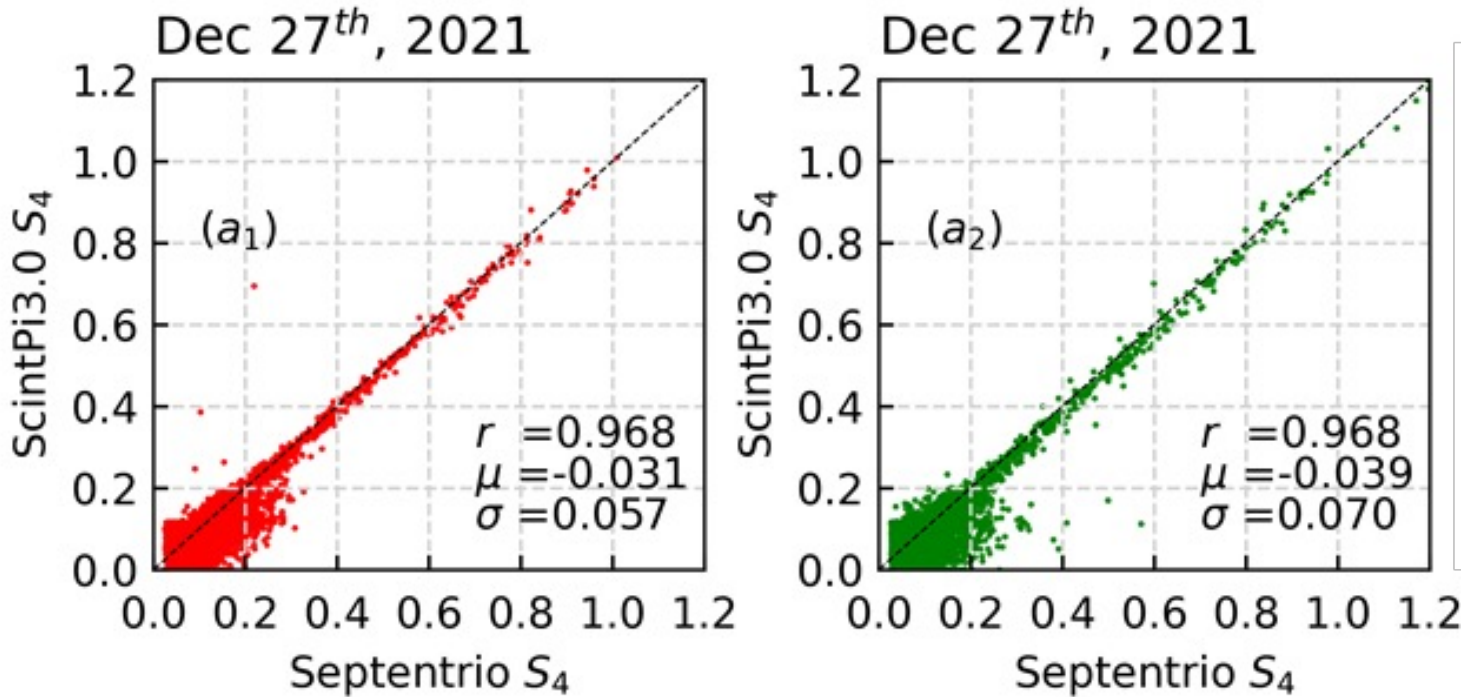
2. Deployments and observations

- Deployment in Presidente Prudente (PPR), Brazil at low latitudes



2. Deployments and observations

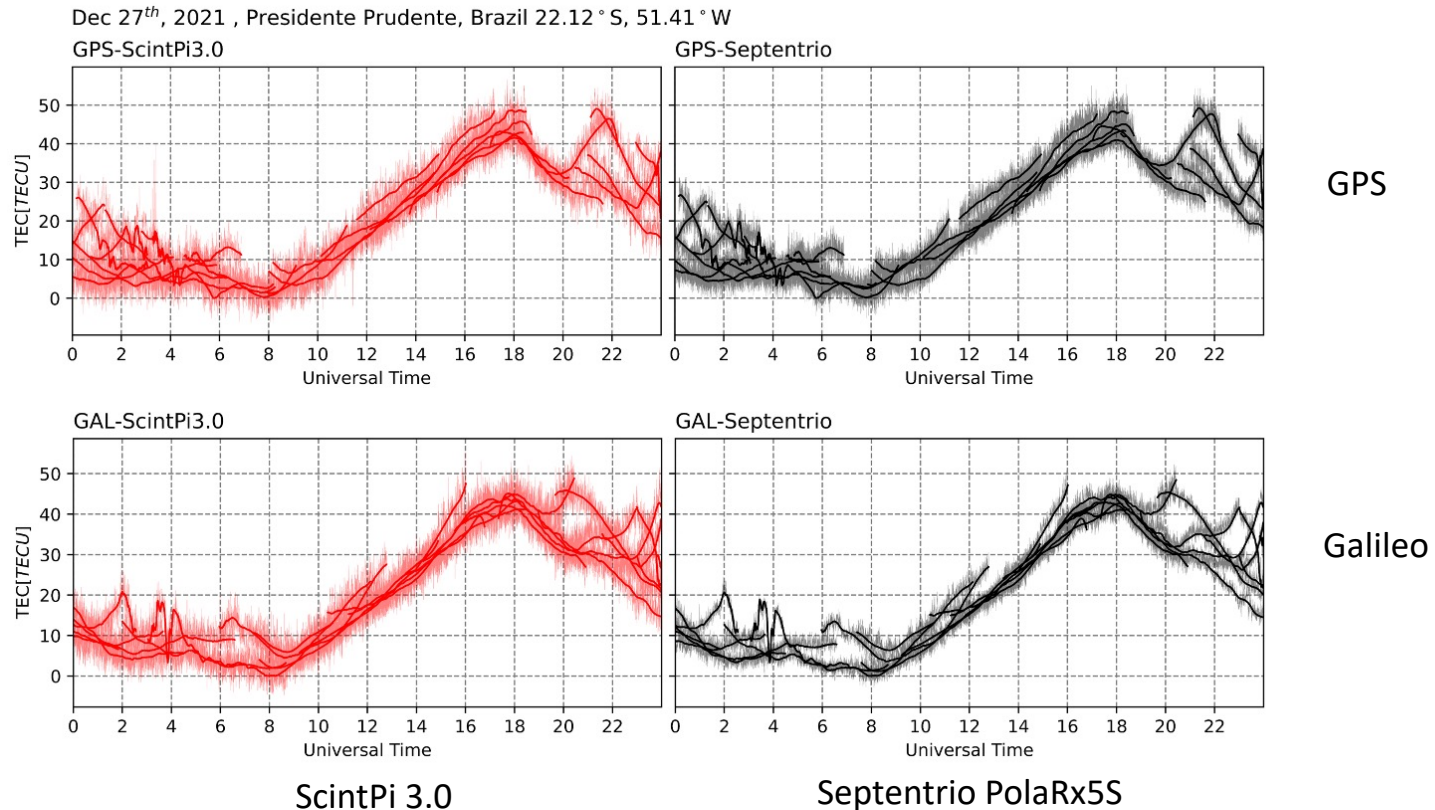
- Performance of ScintPi 3.0: *Absolute TEC*



- Excellent agreement in S₄
- Linear correlation around 0.97 and RMS error < 0.04

2. Deployments and observations

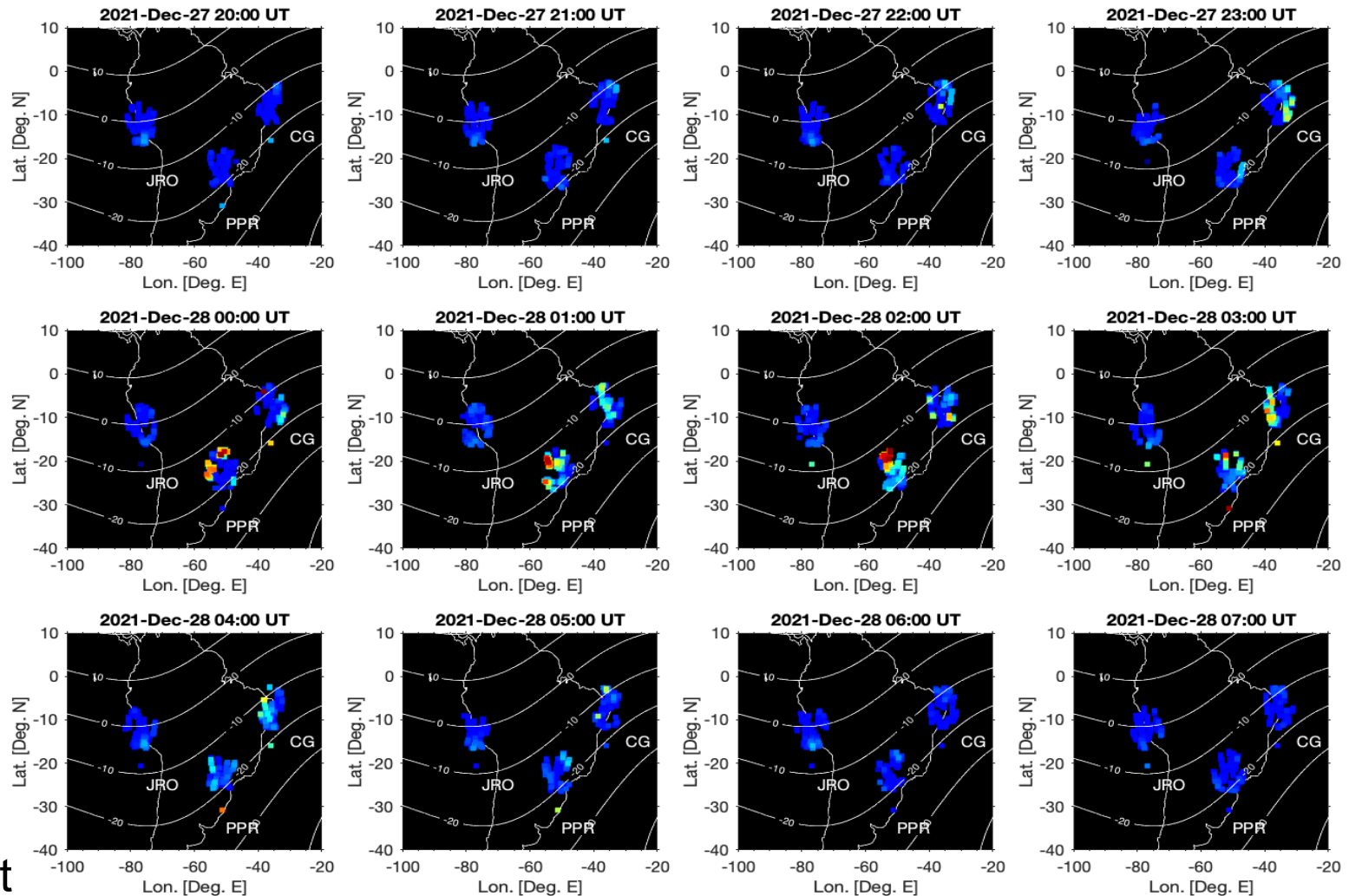
- Performance of ScintPi 3.0: *Absolute vertical TEC*



- Excellent agreement in absolute TEC

2. Deployments and observations

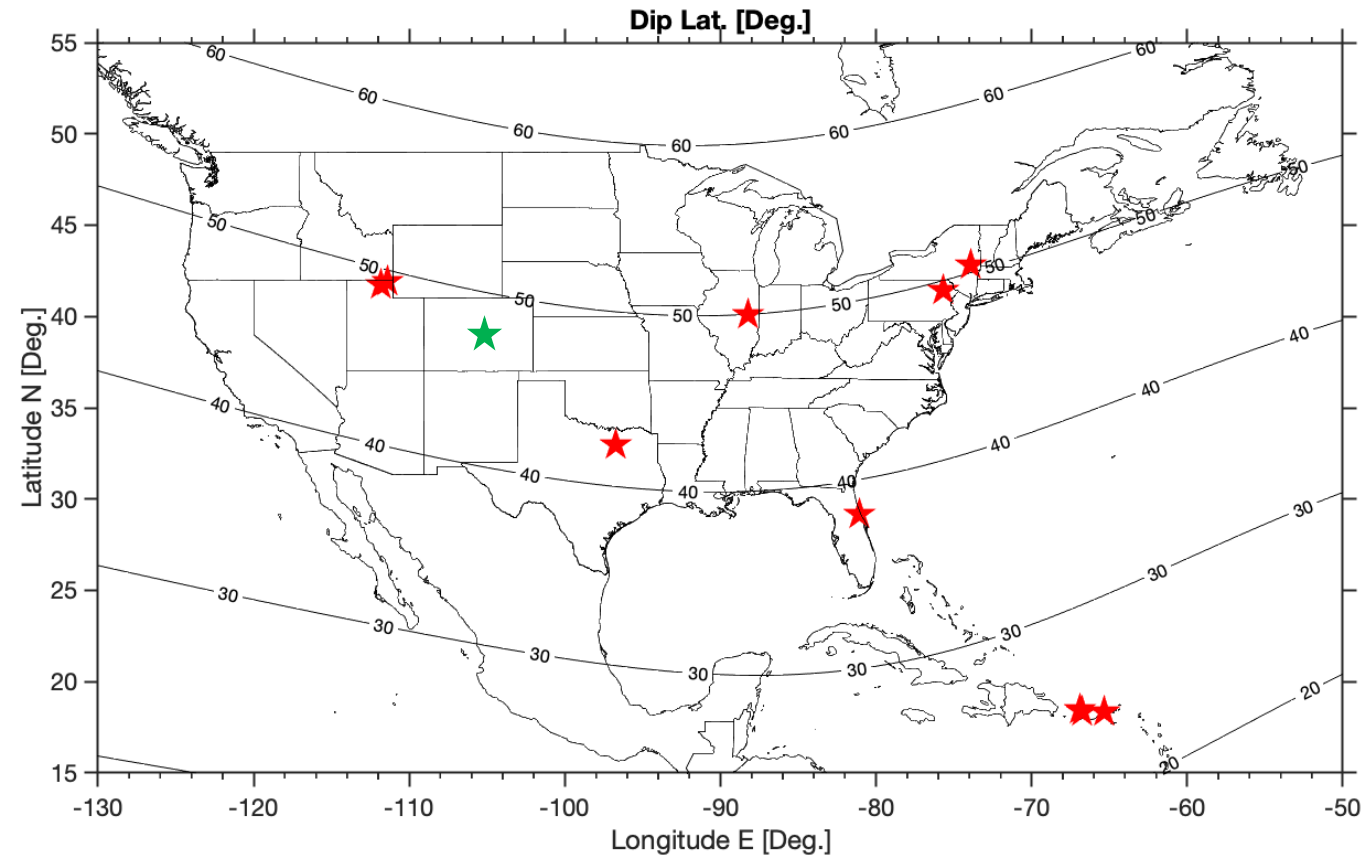
- Example and benefits for distributed observations



- Lower cost
- Reduced downtime

2. Deployments and observations

- Example and benefits for distributed observations



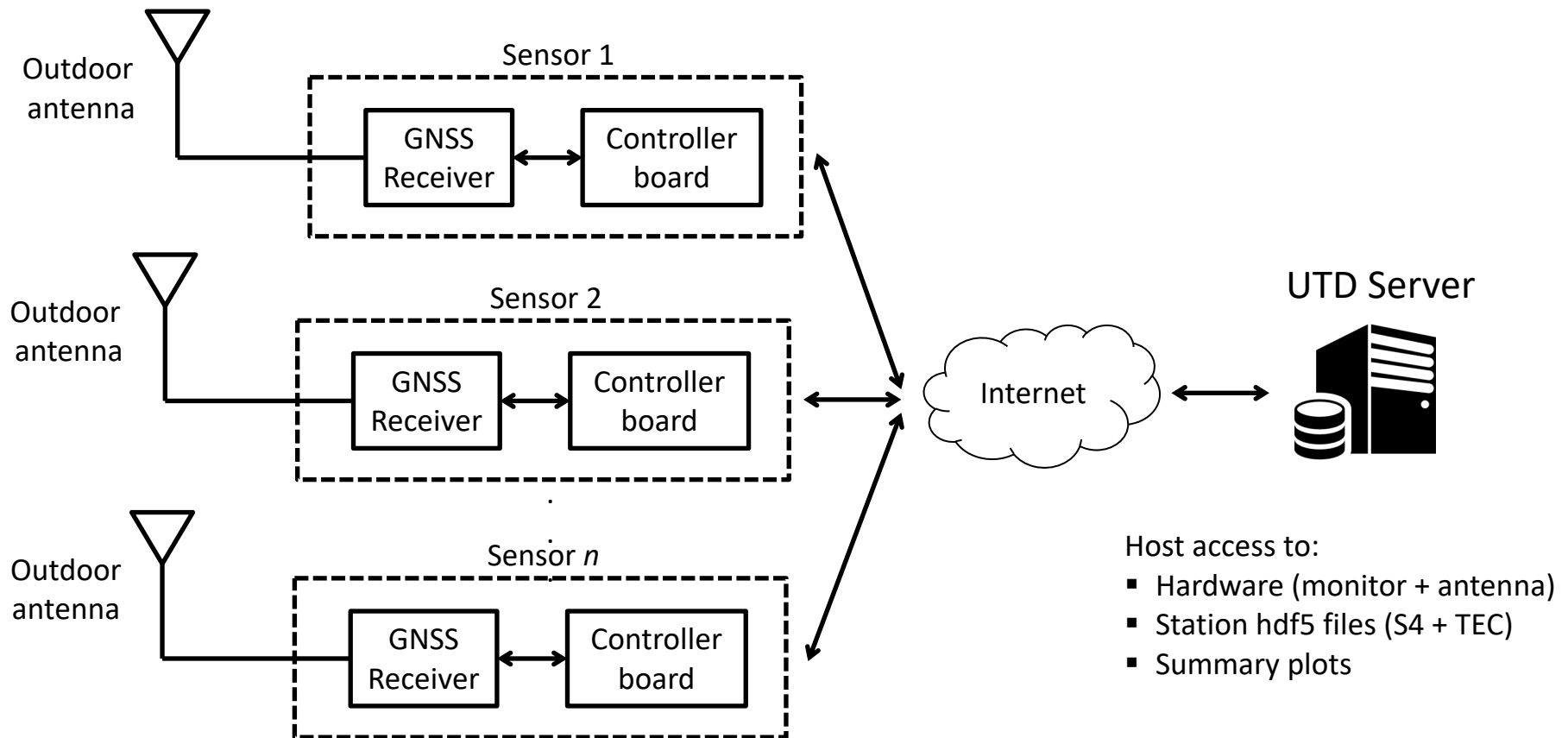
1. UT Dallas
2. Embry-Riddle Aer. Univ.
3. University of Scranton
4. U of I Urbana Champaign
5. Utah State University
6. Bear Lake Observatory
7. Schenectady, NY
8. Arecibo Observatory, PR
9. Quebradilla, PR
10. Culebra, PR

11. DSES

- Lower cost opens up possibilities for new studies

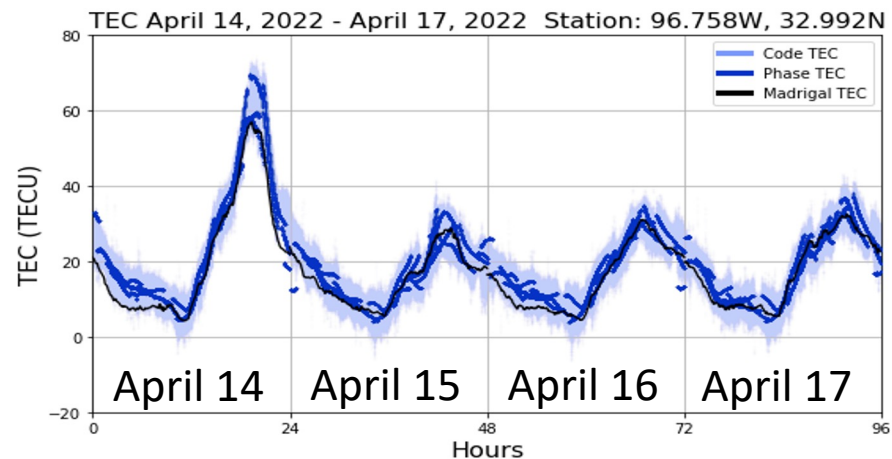
2. Deployments and observations

- We are looking for ScintPi 3.0 hosts in the US
- System available requires power and internet
- It provides automated processing and data management



2. Deployments and observations

- Undergrad student team built a solar-powered ScintPi platform equipped with a cell modem.
- Tests in Dallas show that the system can run continuously without power interruptions, and for at least 9 days with battery only.
- Isaac Wright awarded with NSF graduate fellowship to conduct spaced-receiver scintillation measurements at Jicamarca.



3. Concluding remarks

- We developed a low-cost GNSS-based scintillation and TEC monitor that is easy to deploy and maintain (ScintPi).
- Development was not intended to replace commercial monitors. It can, however, assist in studies that require a large number of distributed sensors.
- ScintPi is also suitable for educational and citizen science projects.
- An autonomous system has been built and tested for deployment at locations where electricity or internet are not available.