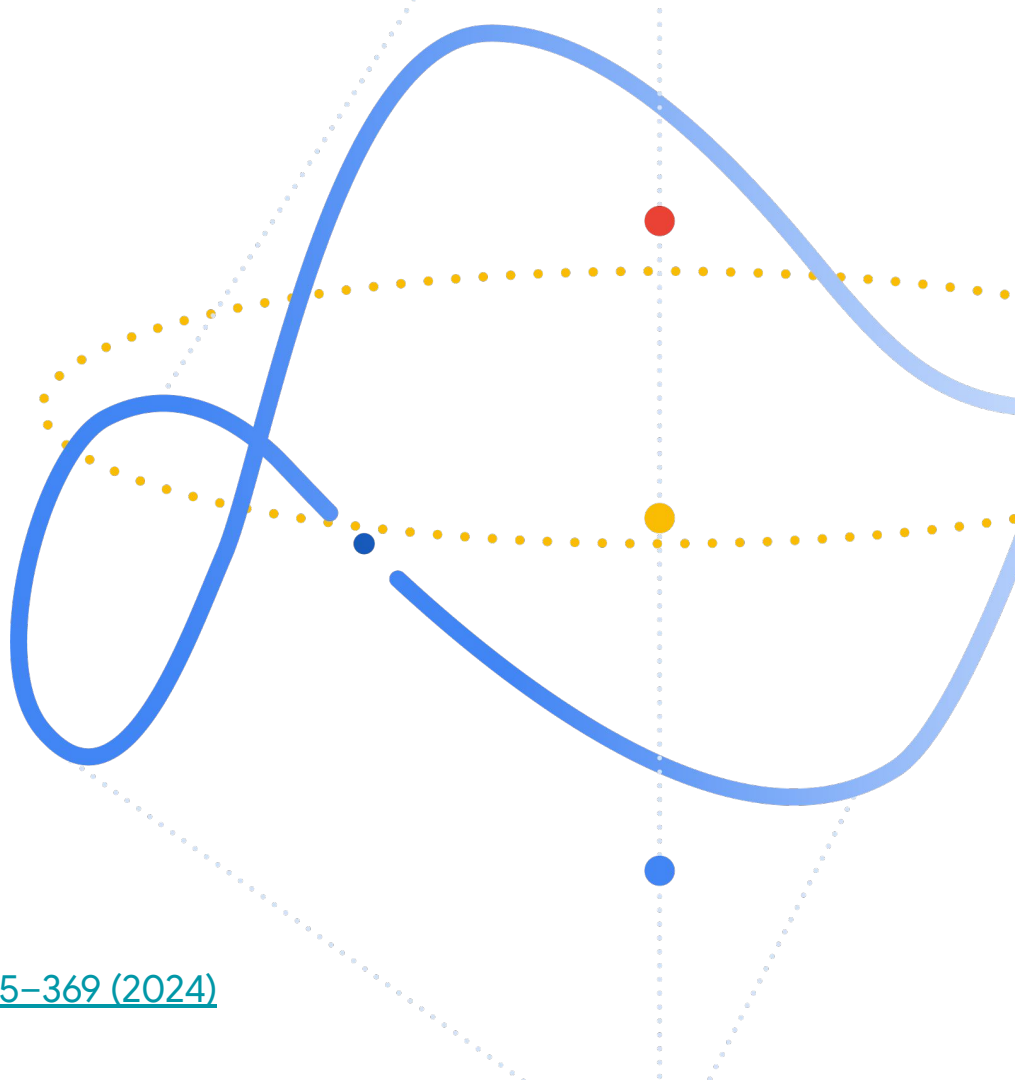


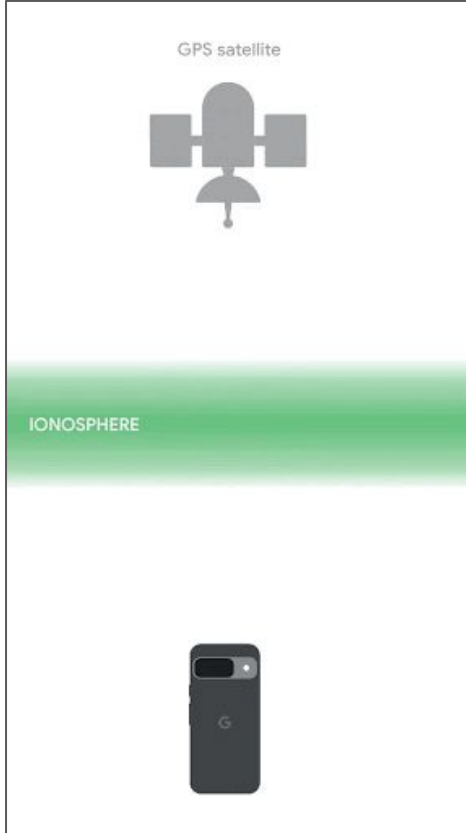
Mapping the ionosphere with millions of phones

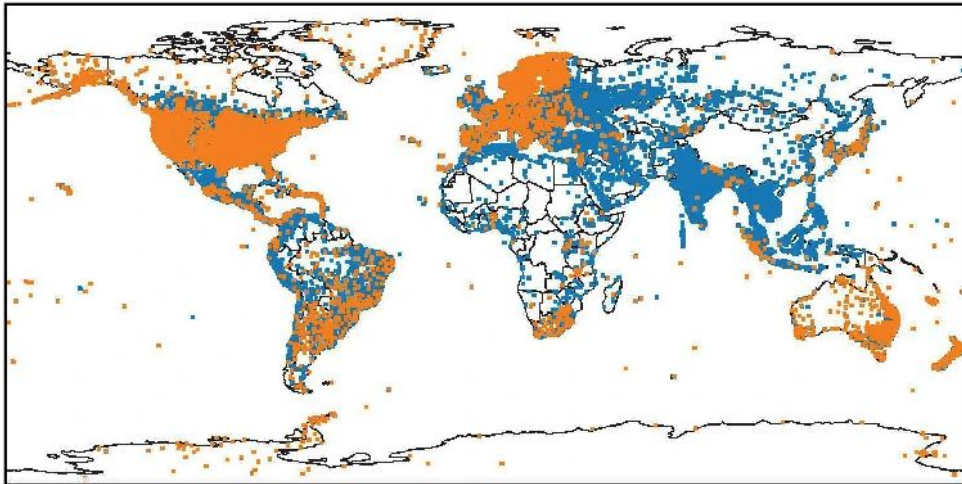
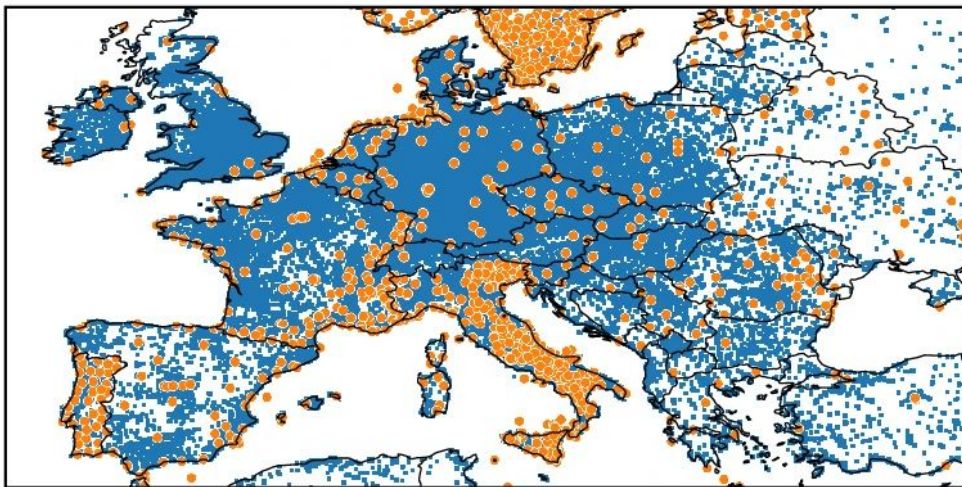
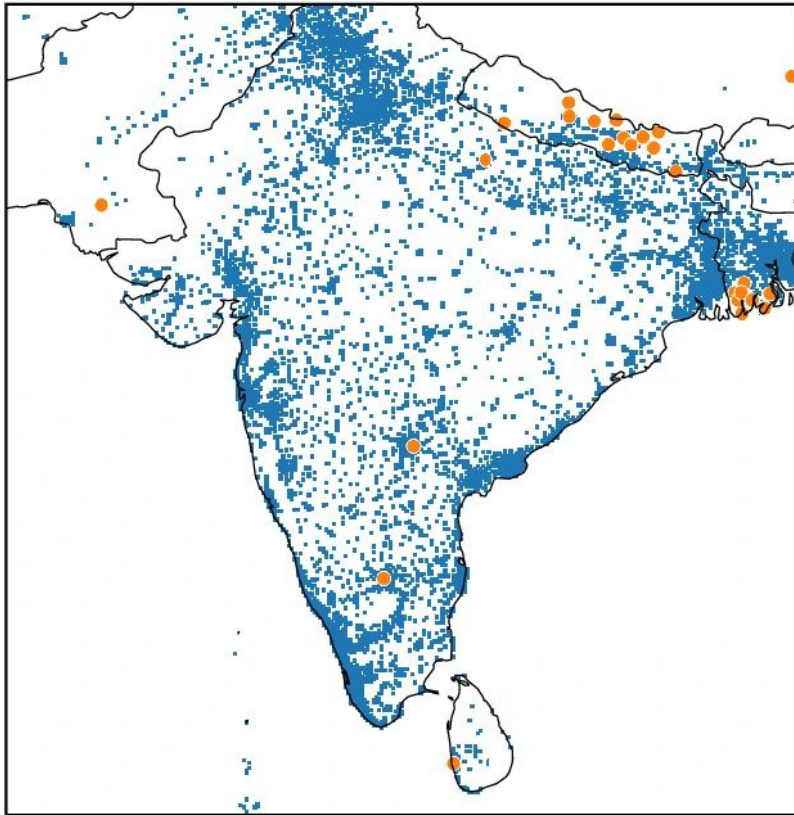
Jamie Smith
Anton Kast
Anton Geraschenko
Y. Jade Morton
Michael P. Brenner
Frank van Diggelen
Brian P. Williams

[Nature Article \(open access\) Volume 635, pages 365–369 \(2024\)](#)



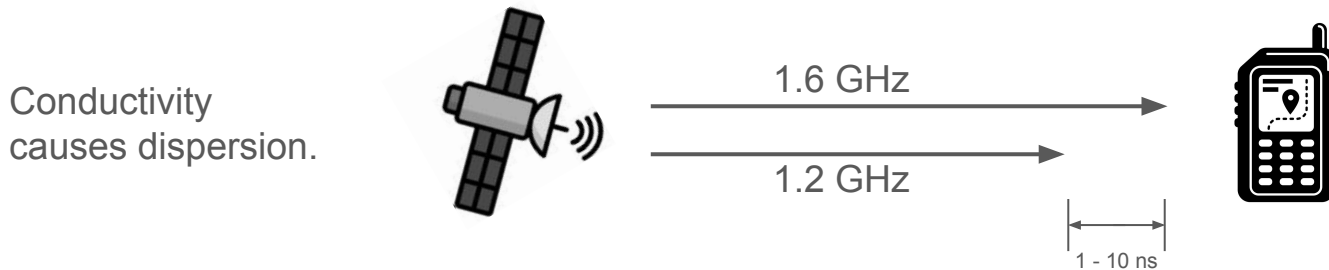
The relative signal delay between two frequencies provides a measurement of the Ionosphere.



a**b****c**

- Location with phone measurements
- Location with station measurements

What kind of sensitivity are we talking about?



Common resolution of ionosphere maps: 1 TECU

1 TECU: 0.14 ns difference in arrival time (at 1.6 GHz)

Resolution of Android Raw GNSS API: 1 ns

Noise: +/- 100 TECU

Receiver systematic error: **0 - 18,000 TECU**

Relevant carrier frequencies on Android
(GPS, Galileo, BeiDou)*

1.575 GHz ~ 19 cm (L1, E1, B1C)

1.176 GHz ~ 26 cm (L5, E5a, B2a)

* The Russian GLONASS constellation is never observed at multiple frequencies concurrently on Android.

Simultaneous averaging and calibration

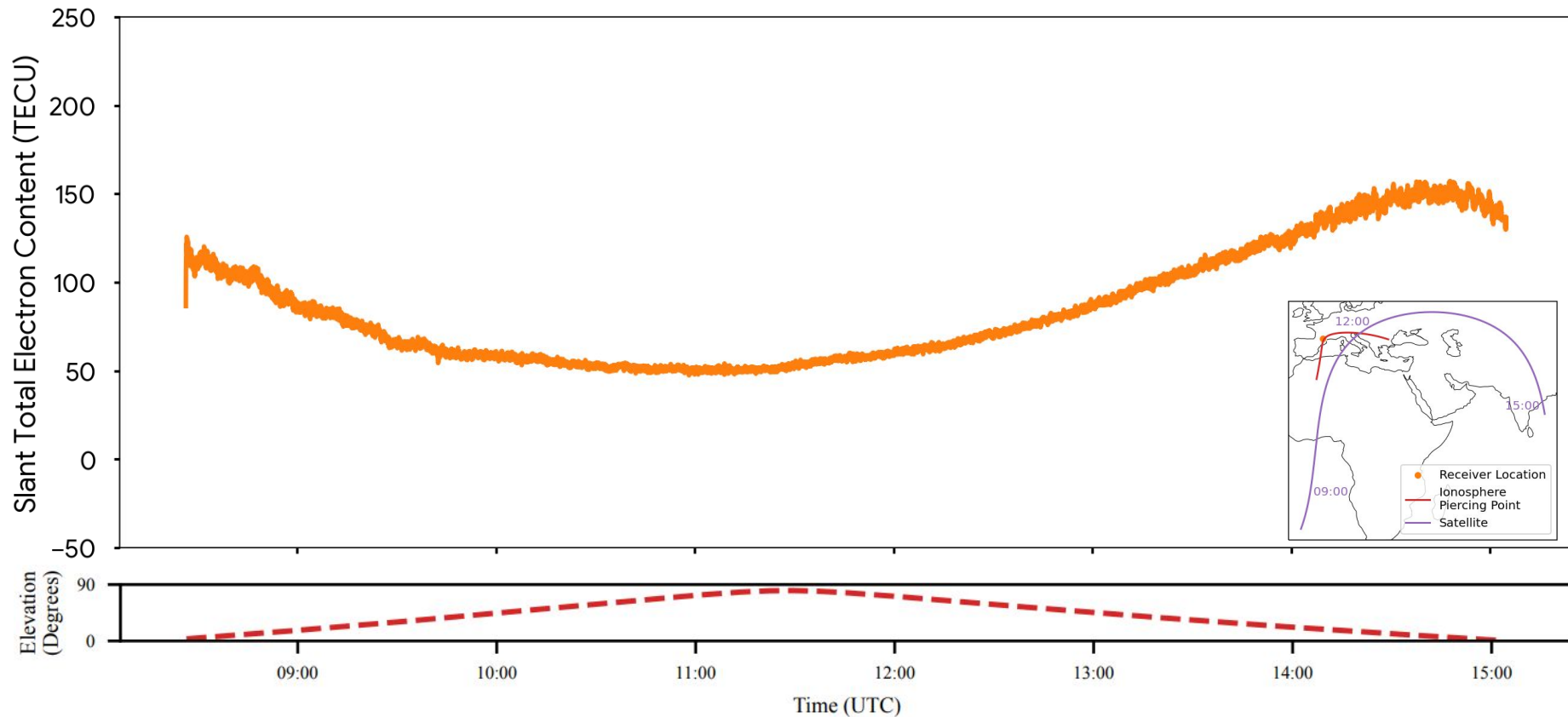
We solve jointly for

- 1) ionosphere VTEC in all regions
- 2) receiver calibration of all phones

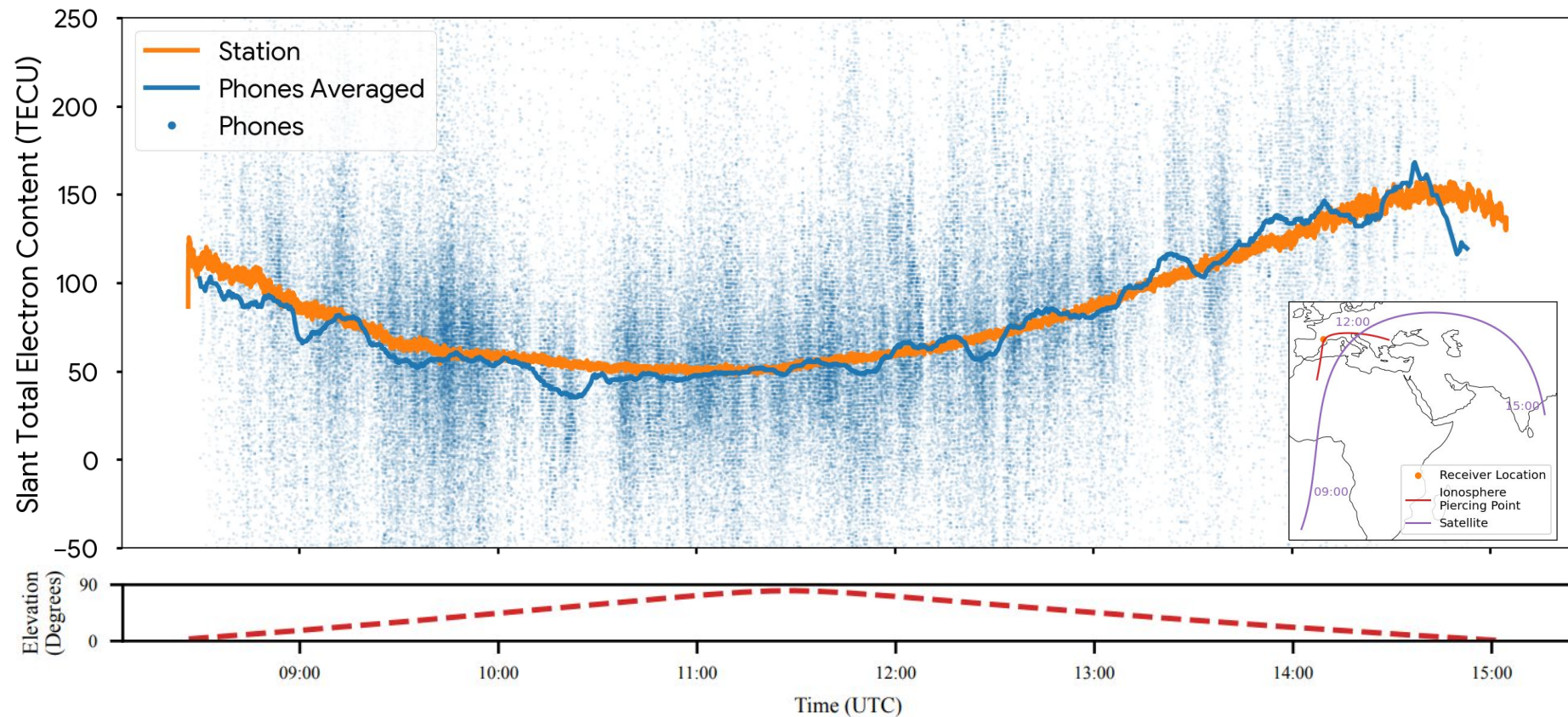
using uncertainty-weighted least-squares.

(thousands of regions) x (millions of receivers)

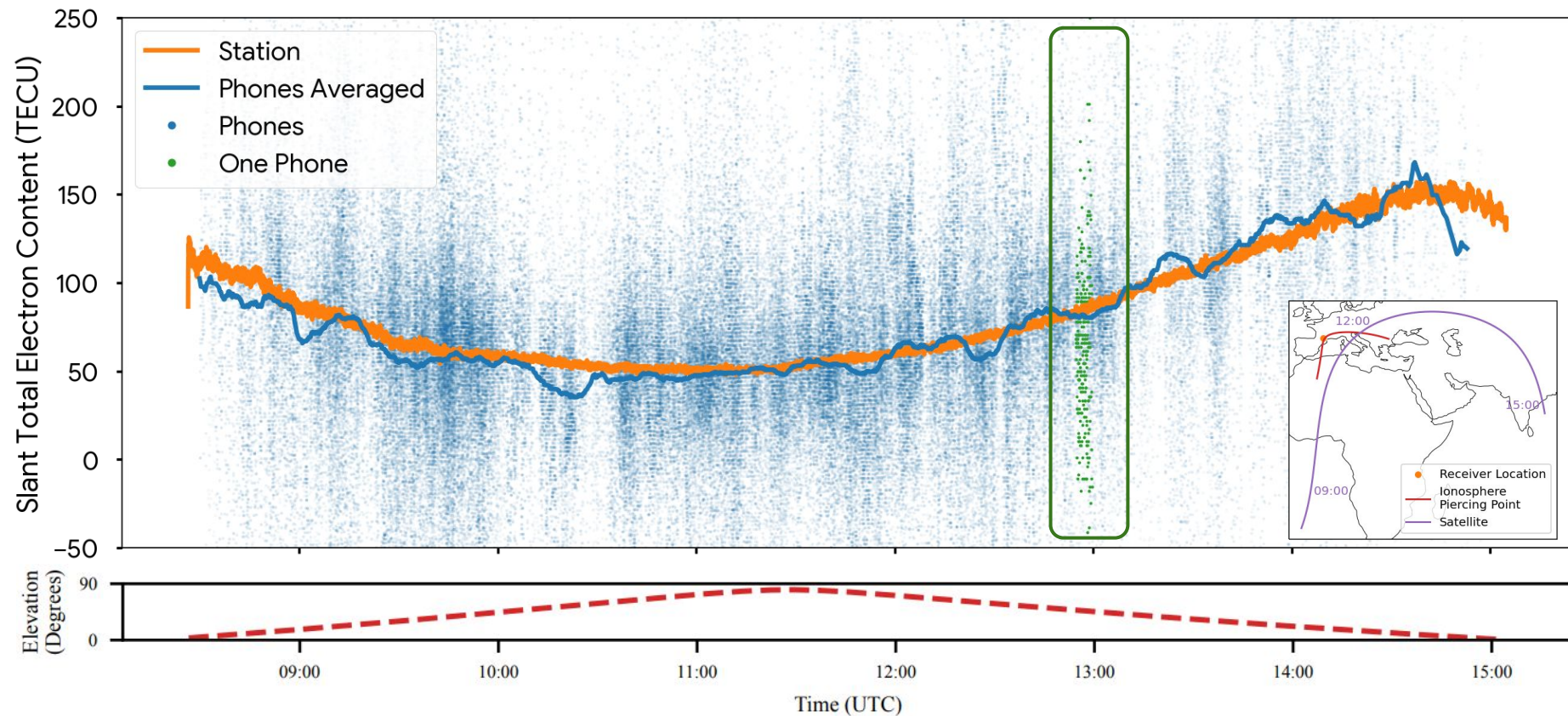
Precise Monitoring Stations vs. Noisy Phones



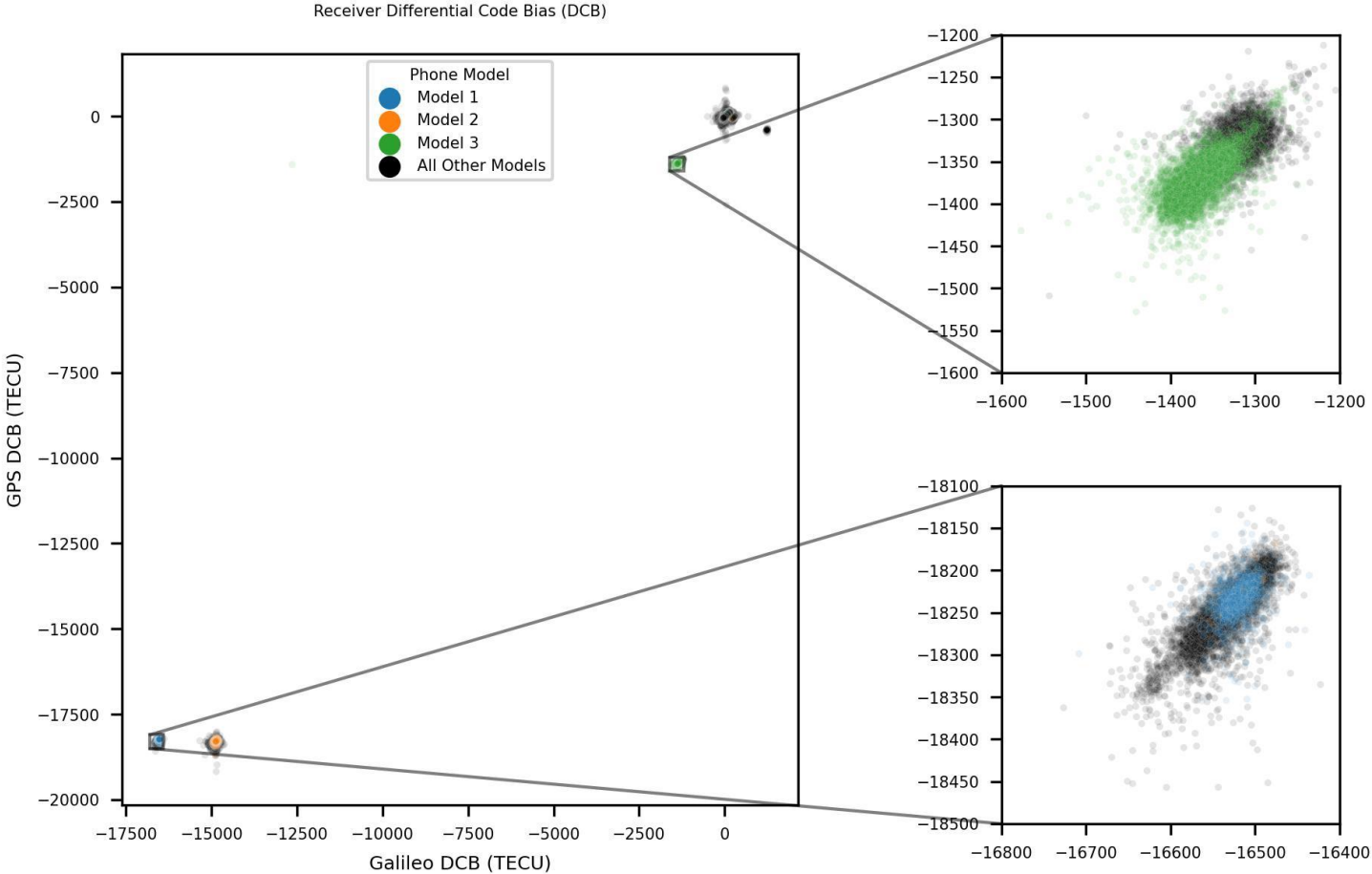
Precise Monitoring Stations vs. Noisy Phones



Precise Monitoring Stations vs. Noisy Phones

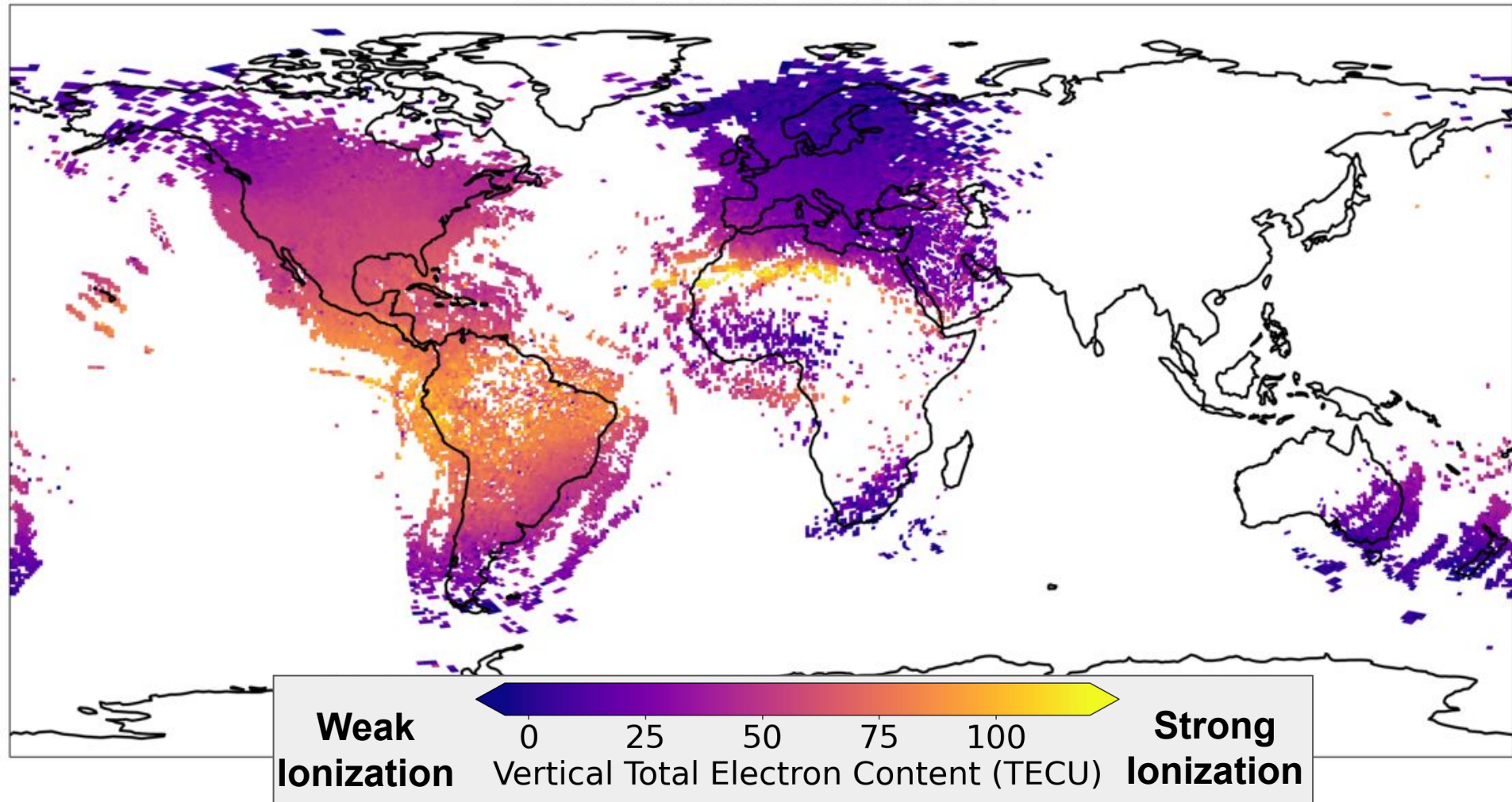


Calibration parameters cluster by phone model.



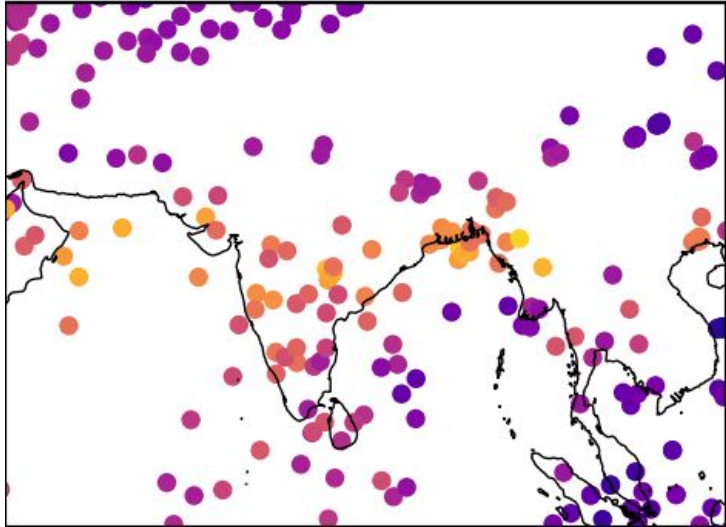
From
Extended
Data Figure 1

2023-10-13 20:00:00

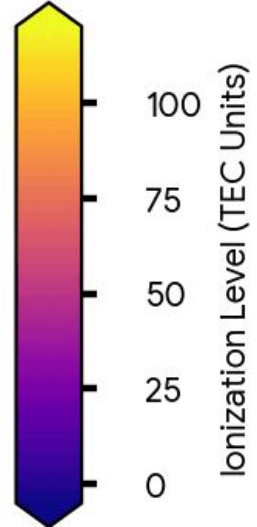
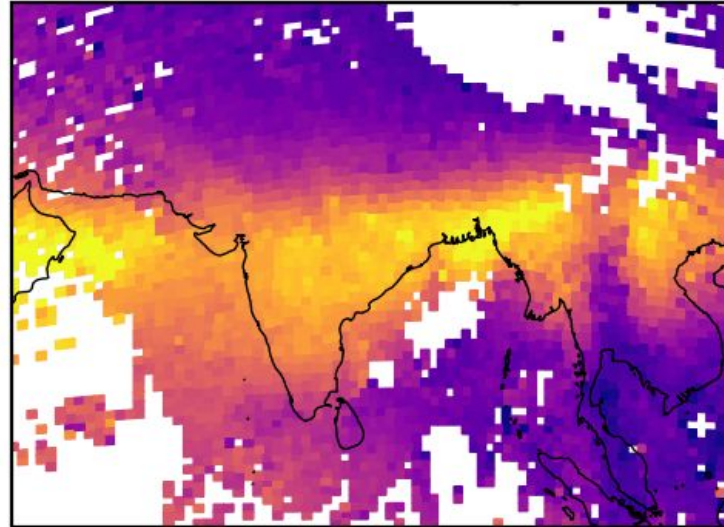


Equatorial plasma bubbles

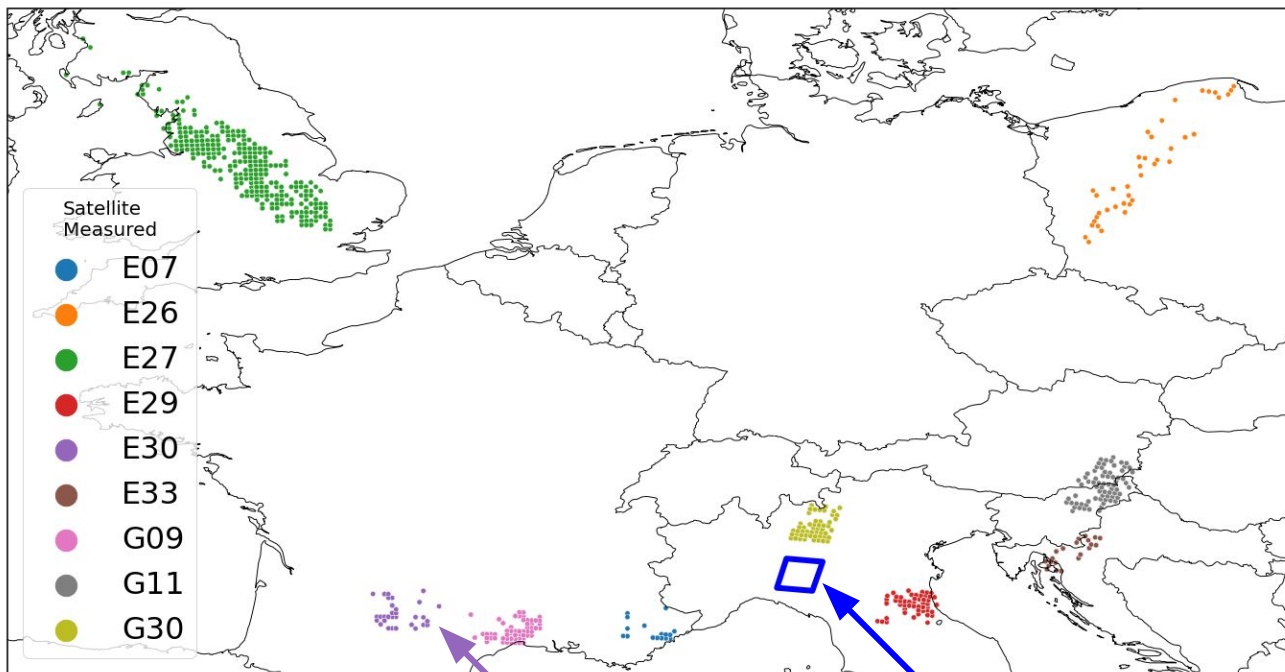
Using Stations



Using Phones

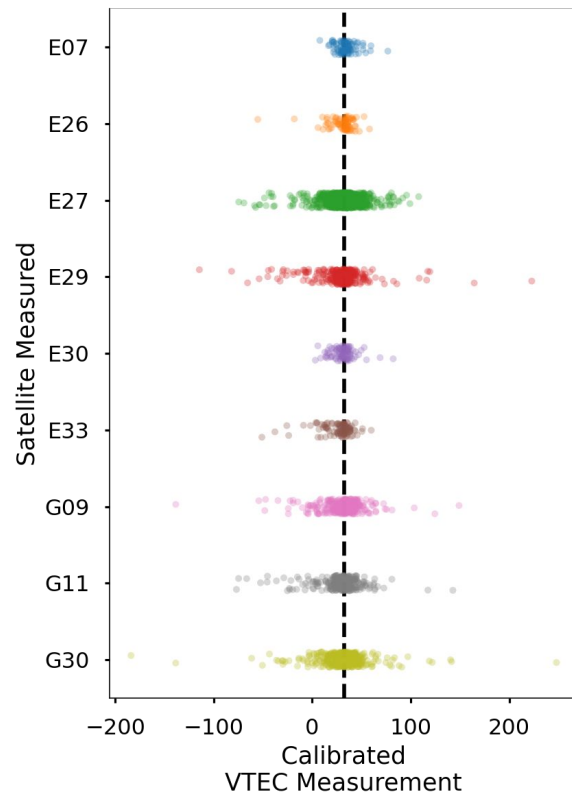
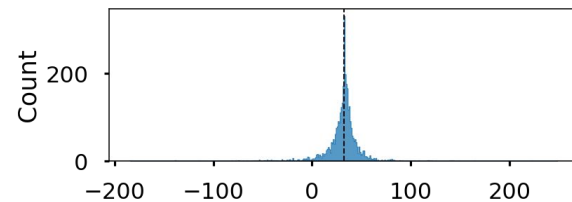


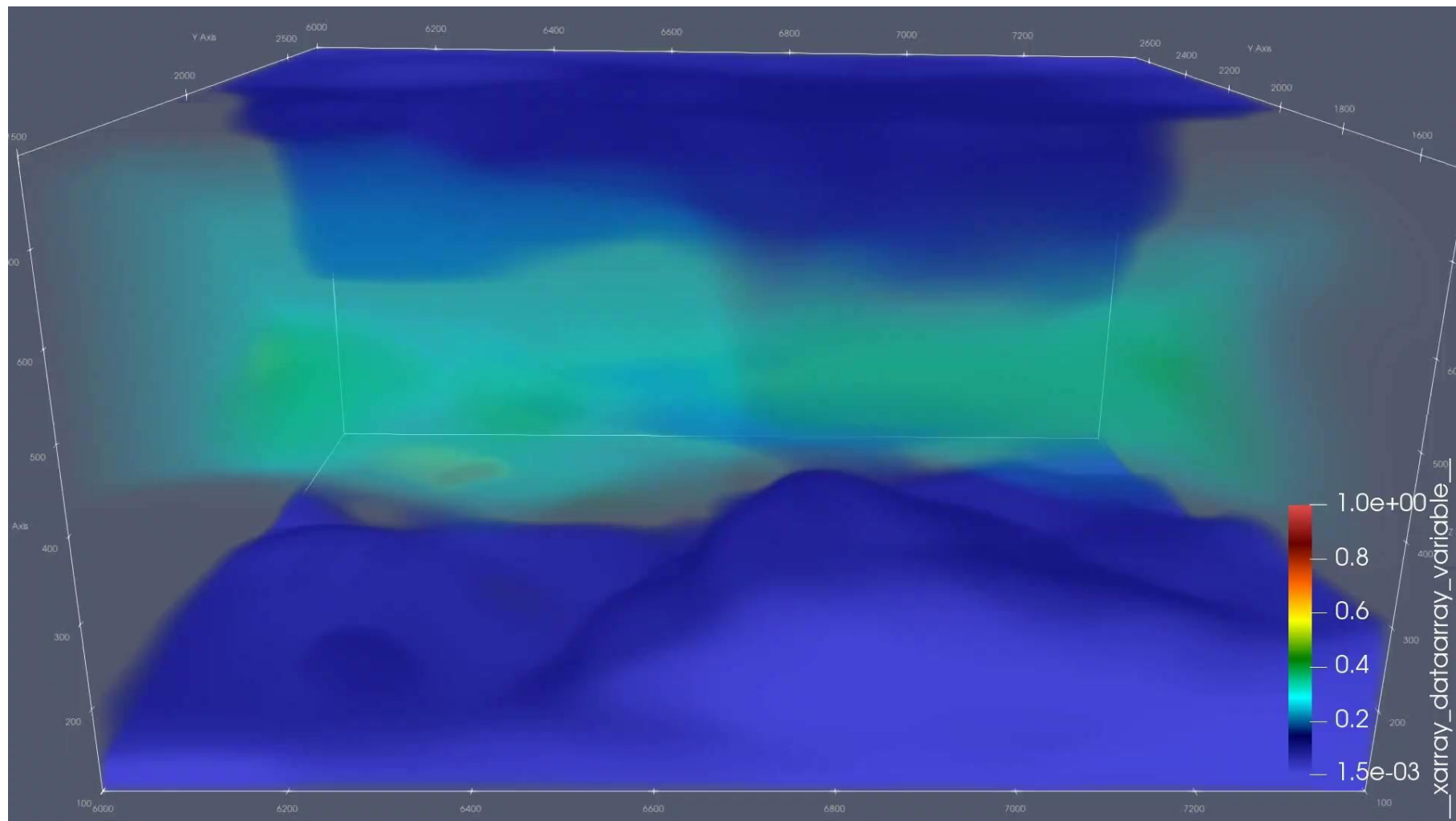
Receivers in many different locations simultaneously measure the same ionosphere region using different satellites. The combination of all the measurements gives the value for the ionosphere region.



Location of receivers measuring the ionosphere region using satellite E30

The ionosphere region measured







Published

Mapping the Ionosphere with ... (Jamie Smith e...)

Published v1.1

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Files

Tabs

Core Files

> metadata	642 B	✓
> environment	682 B	✓
> code	3.6 MB	✓
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iono_notebook.ipynb	3.54 MB	✓
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Results

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iono_notebook.html	3.93 MB

interactive_glo... X

