Merging SMAP and CYGNSS observations to create a downscaled soil moisture product

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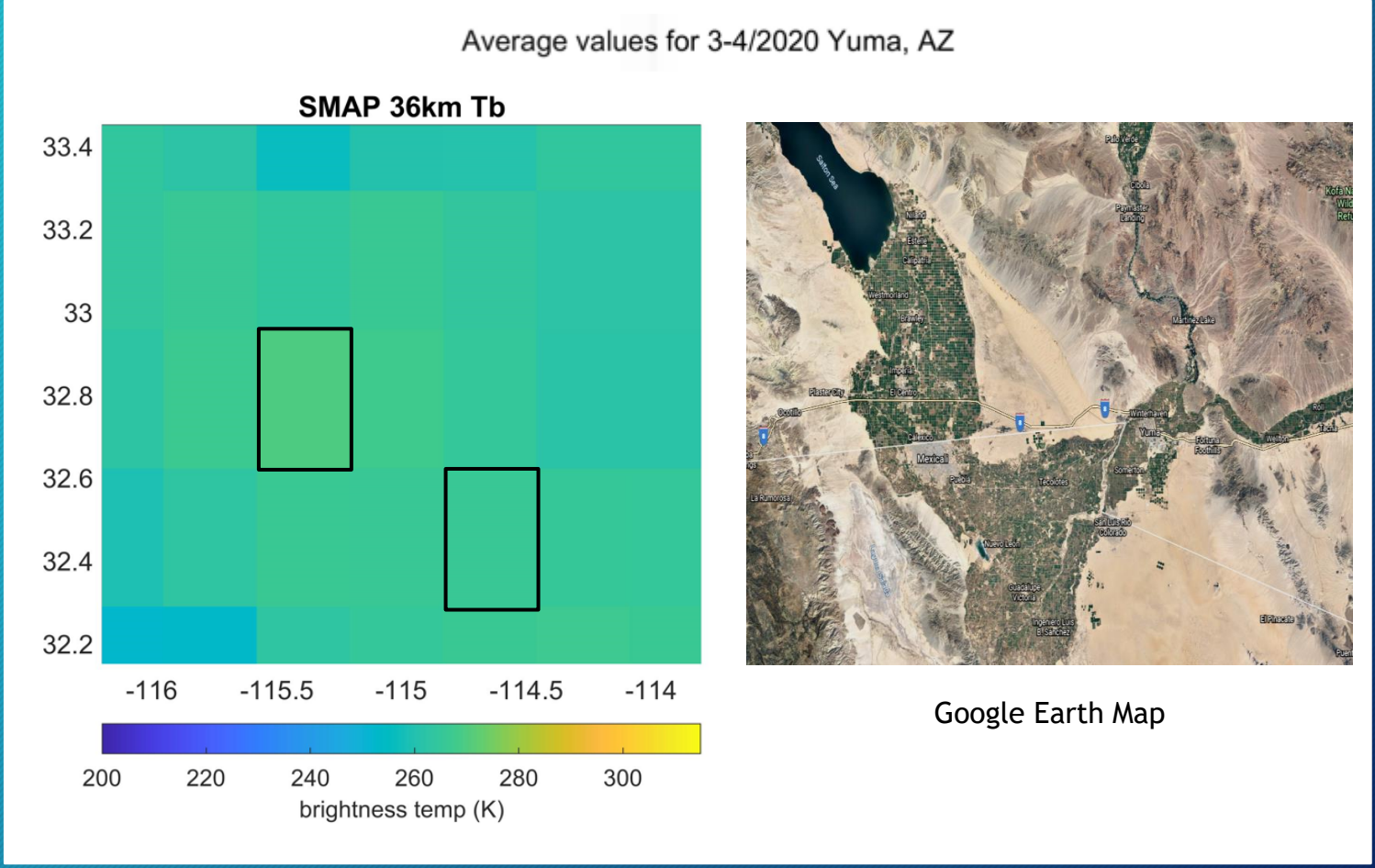
Motivation

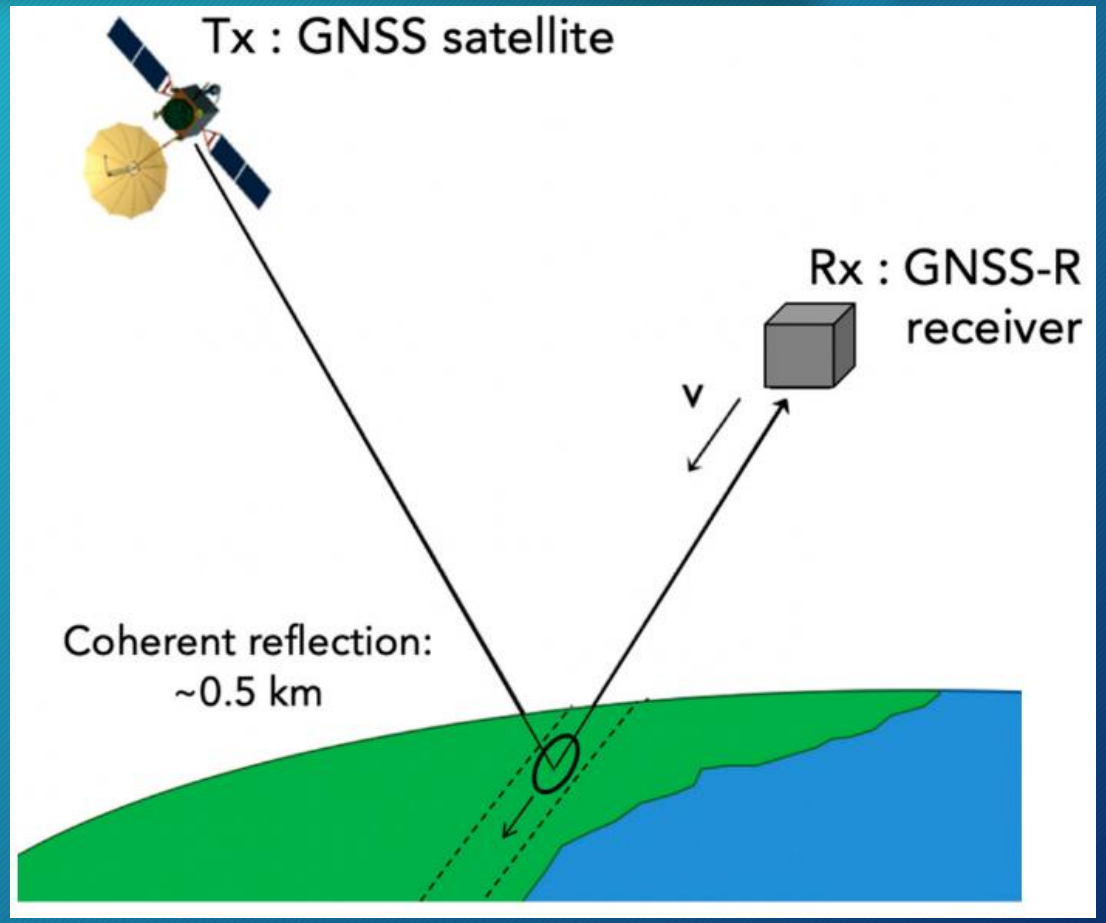
- SMAP's original plan included a downscaled soil moisture product using SMAP radar
- **Our goal:** combine coarse scale SMAP brightness temperatures and fine scale CYGNSS reflectivities to develop a downscaled soil moisture product



Google Earth Map

Cyclone Global Navigation Satellite System (CYGNSS)

- 8 CYGNSS observatories with L-band bistatic radar receivers
- Each observatory can measure 4 GPS signals at a time

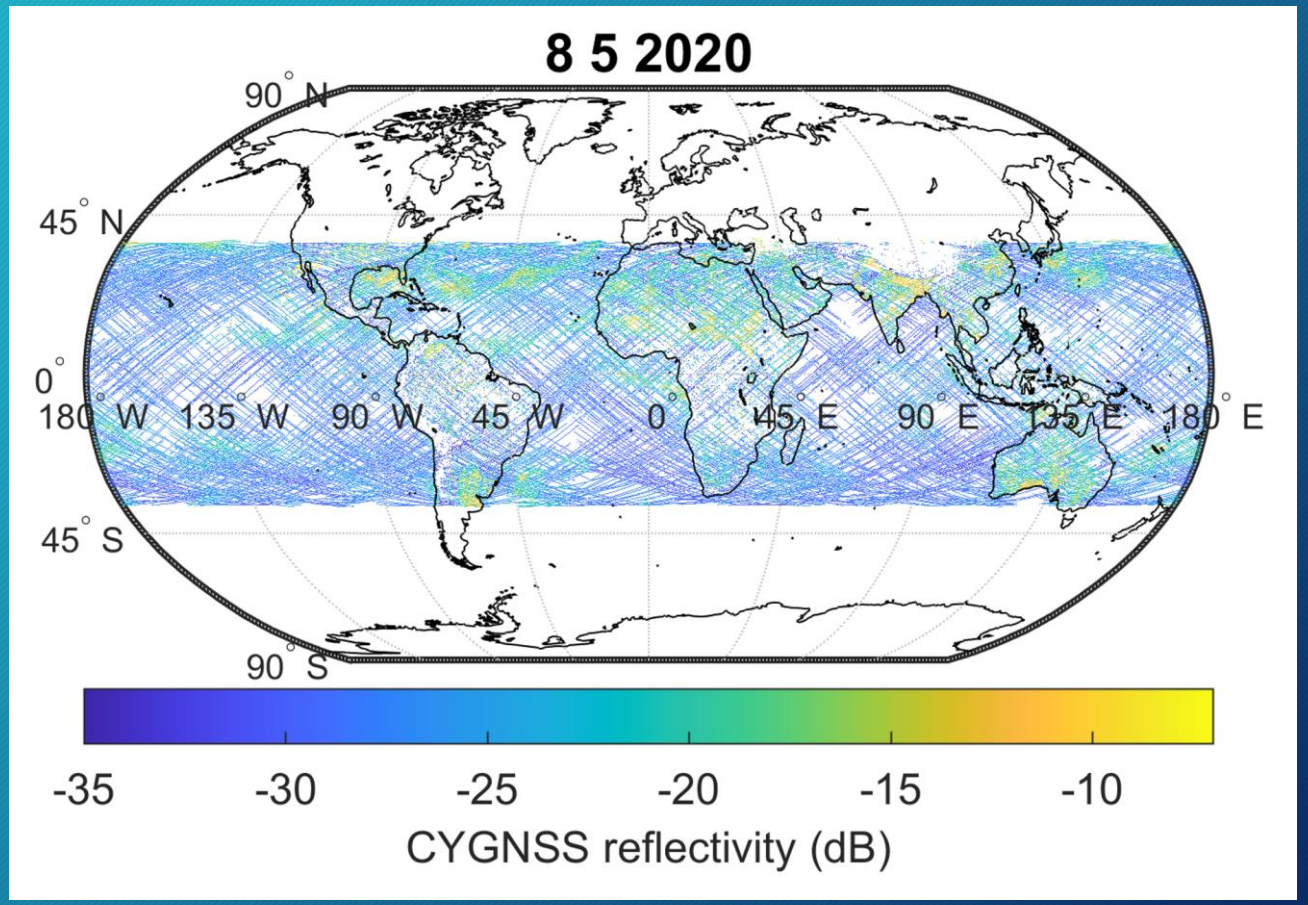


Chew & Small (2020)

(Ruf et al., 2012; Chew & Small, 2018)

CYGNSS data

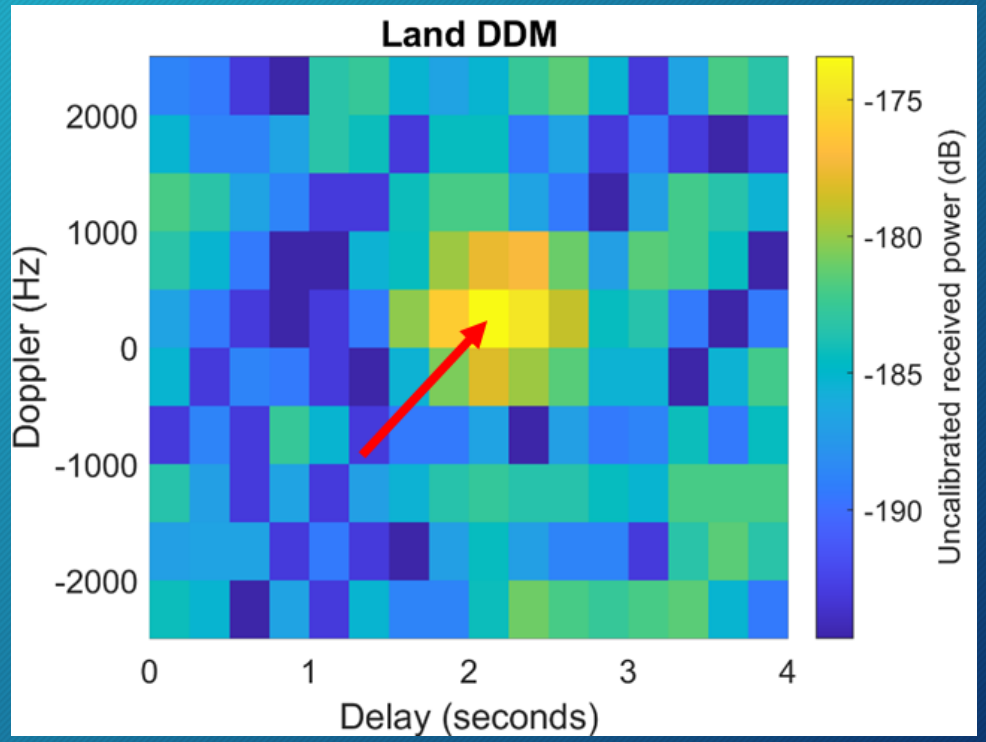
- Low inclination, low Earth orbits
  - ± 38º latitude
- Minimum spatial footprints over land of ~3.5x0.5km
- Global repeat period of ~8-14 days at 3km resolution



(Ruf et al., 2012; Chew & Small, 2018, 2020; Chew, 2021)

CYGNSS data

- Original data are Delay Doppler Maps (DDMs)
- Peak power signal from each DDM (specular point) is located and converted to dB
- Approximate reflectivity is calculated using the bistatic radar equation



Brightness Temp (Tb) algorithm

$$Tb_{v,M} = Tb_{v,C} + \{\beta \times [\Gamma_M - \Gamma_C]\}$$

Adapted for CYGNSS data from original SMAP radiometer/radar downscaling algorithm

Brightness Temp (Tb) algorithm

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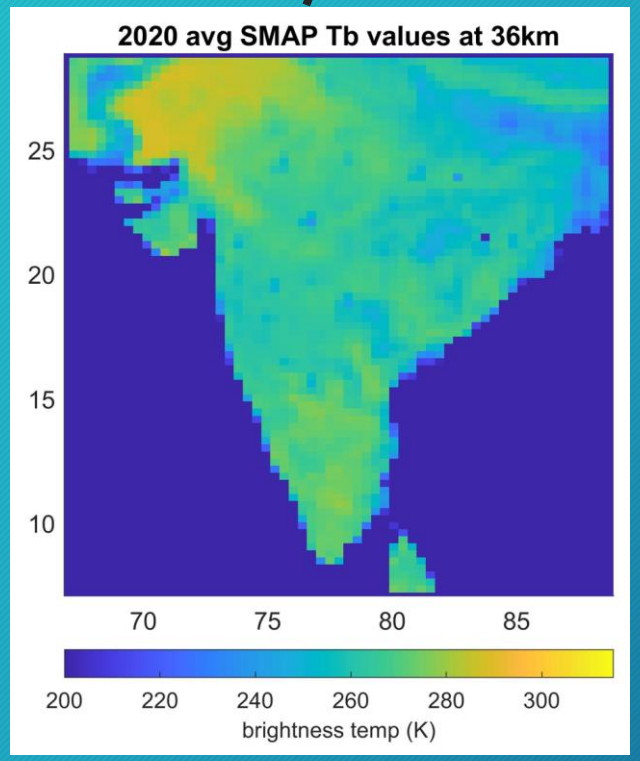

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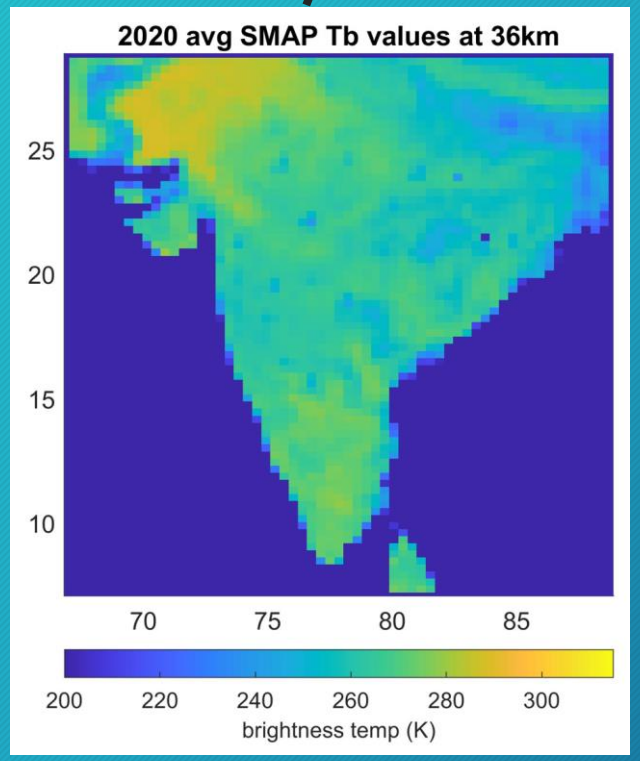
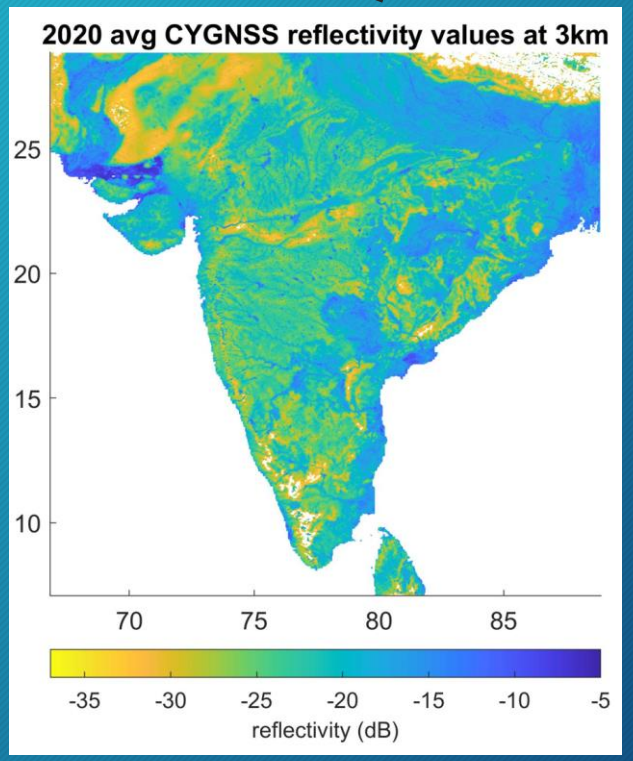
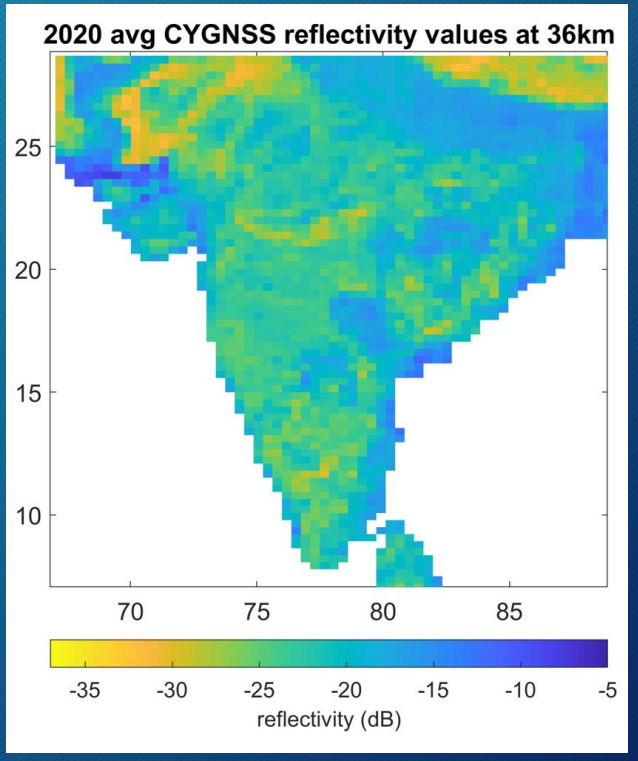






Brightness Temp (Tb) algorithm

-2.763 K/dB

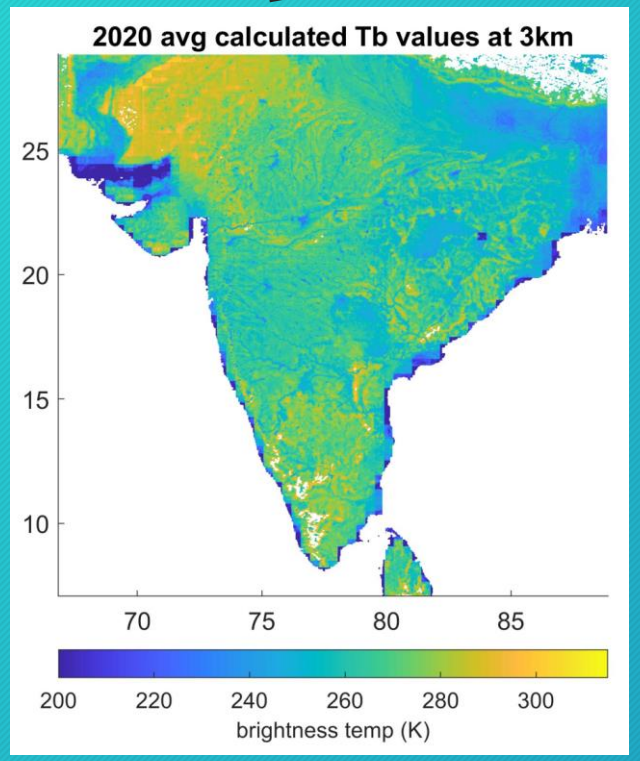
$$Tb_{v,M} = Tb_{v,C} + \{\beta \times [\Gamma_M - \Gamma_C]\}$$

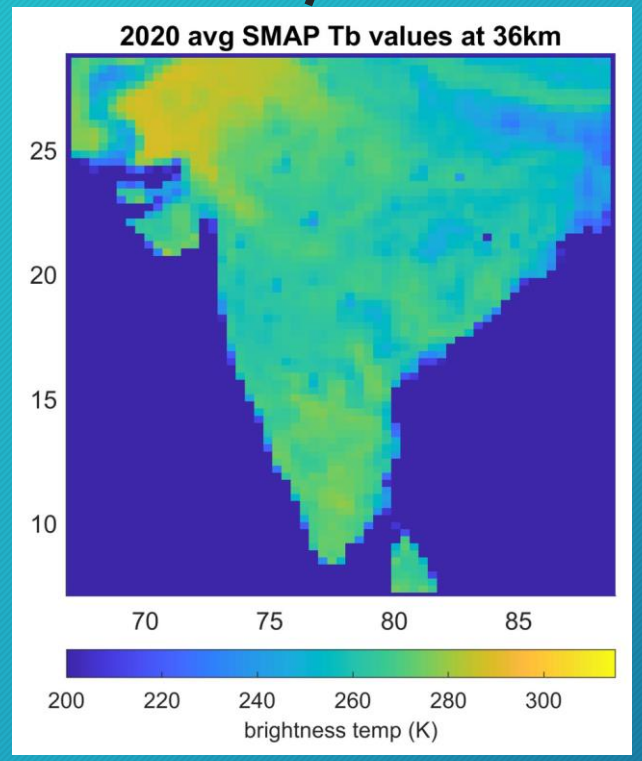
- β (slope) is the linear relationship between SMAP Tb and CYGNSS reflectivity
- Median for India: -2.763 K/dB

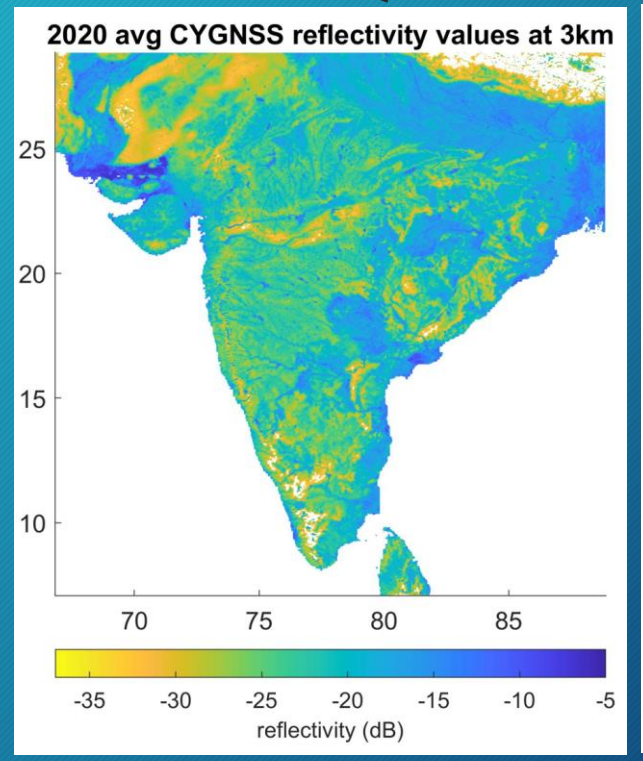
Brightness Temp (Tb) algorithm

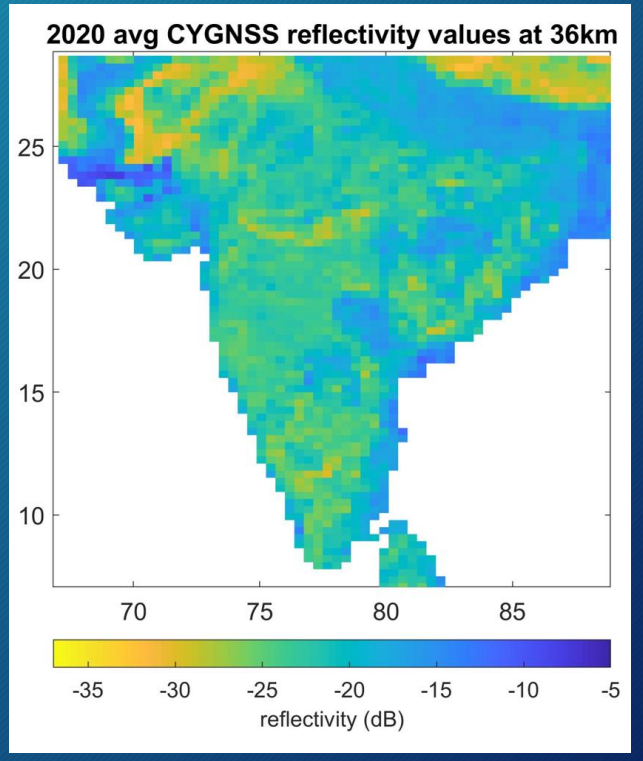
-2.763 K/dB

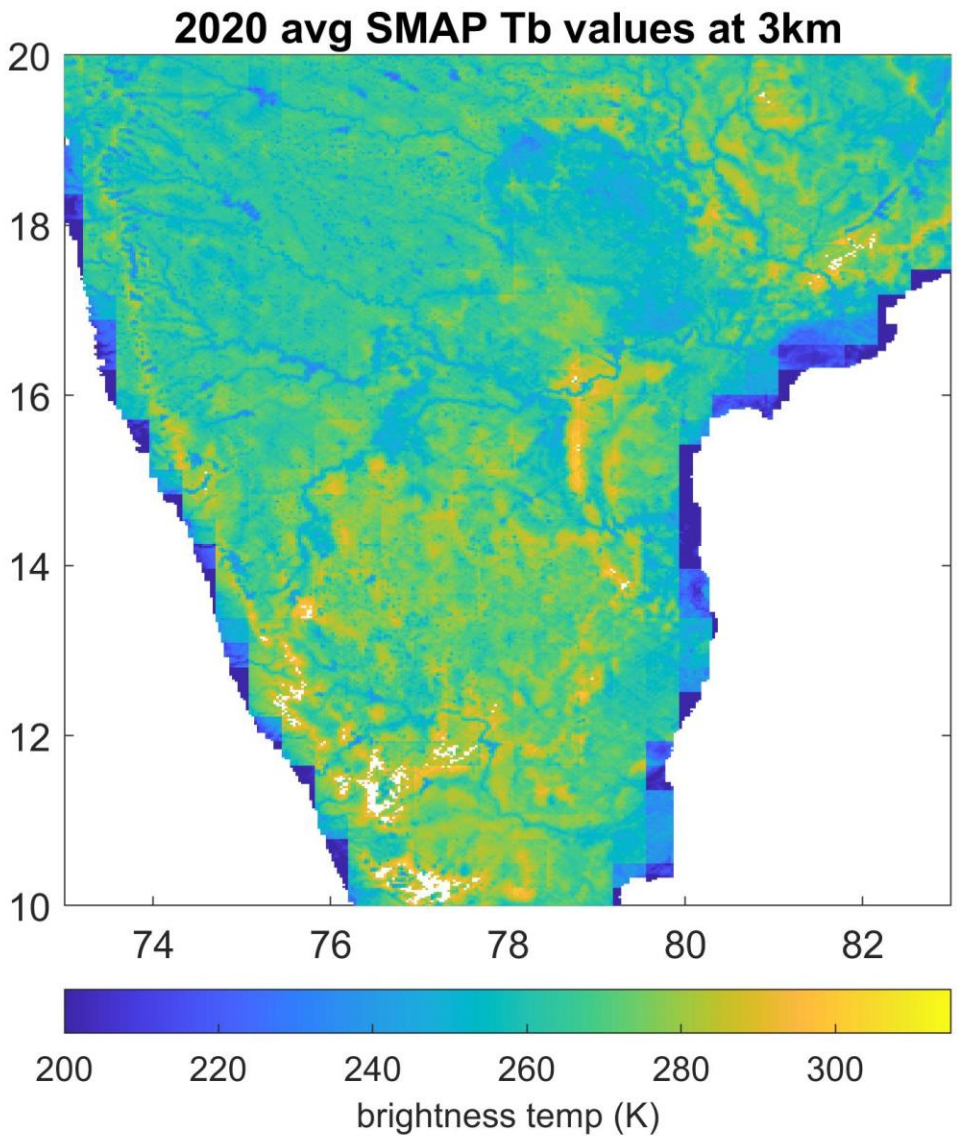
$$Tb_{v,M} = Tb_{v,C} + \{\beta \times [\Gamma_M - \Gamma_C]\}$$










2020 avg SMAP Tb values at 3km
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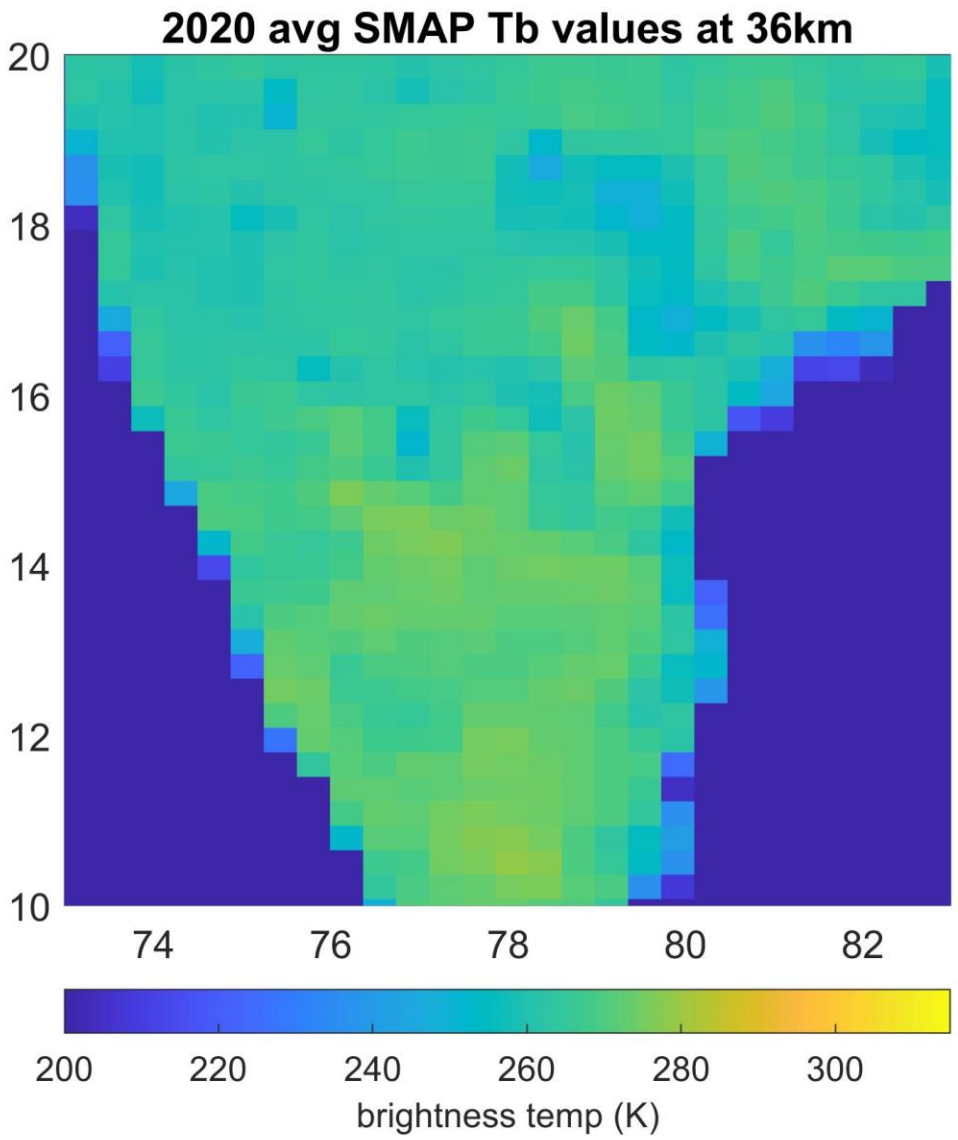
brightness temp (K)


2020 avg SMAP Tb values at 36km
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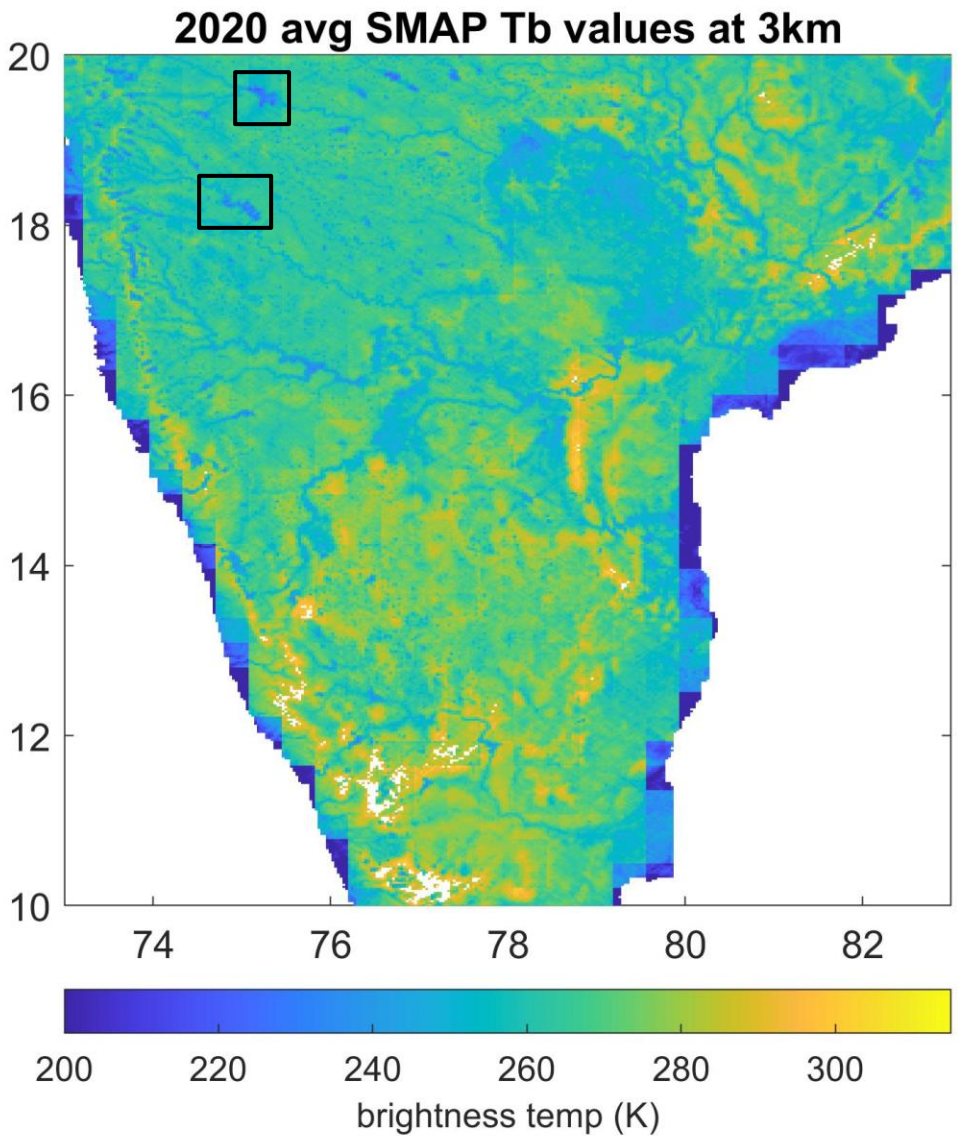
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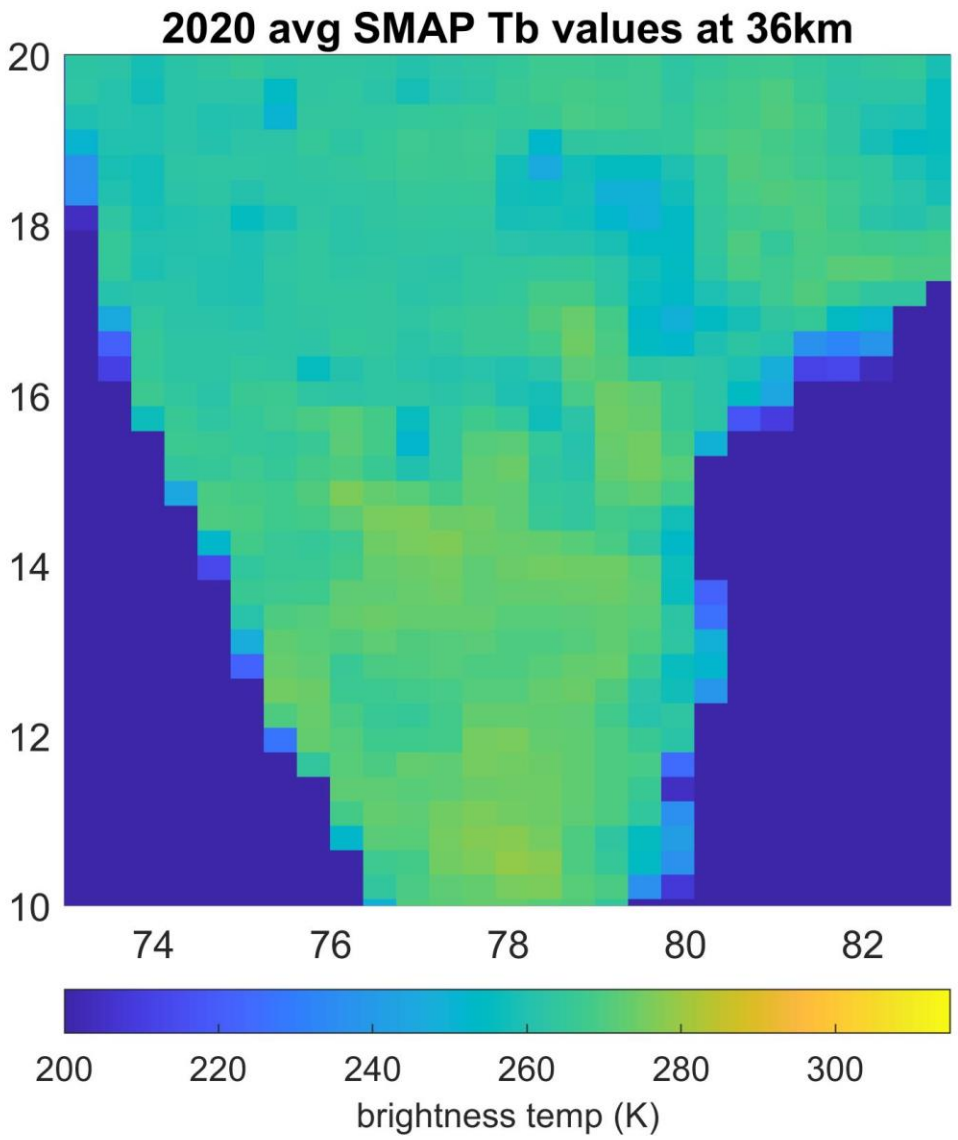
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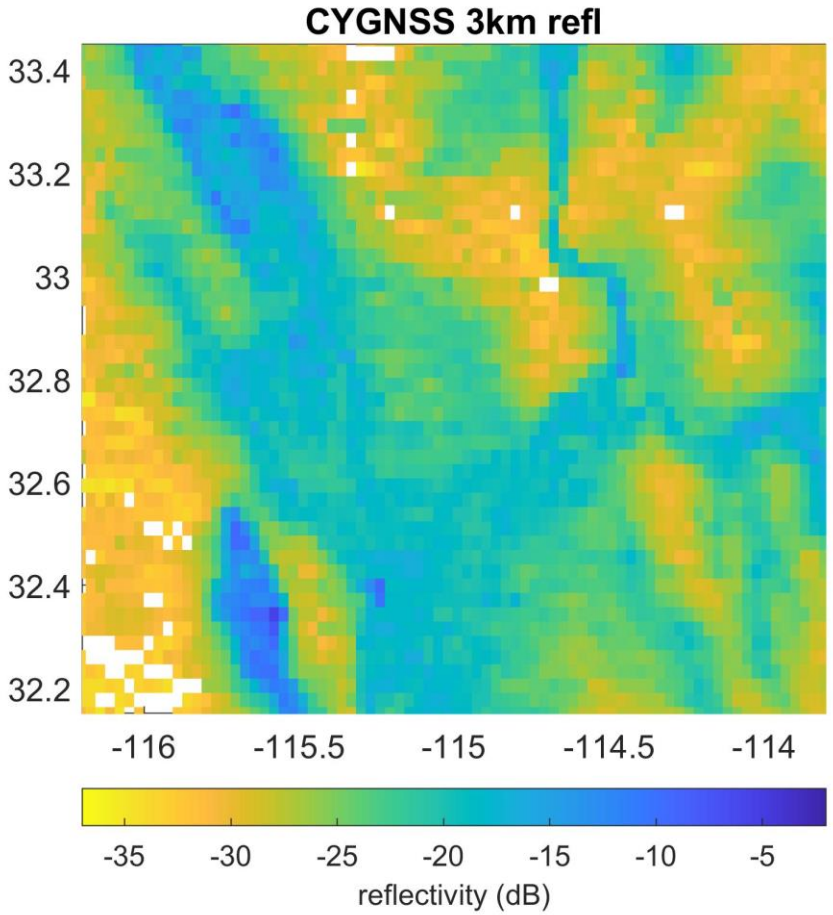
Example results – Yuma, AZ

Average values for 3-4/2020 Yuma, AZ



Google Earth Map

Example results – Yuma, AZ

Salton Sea

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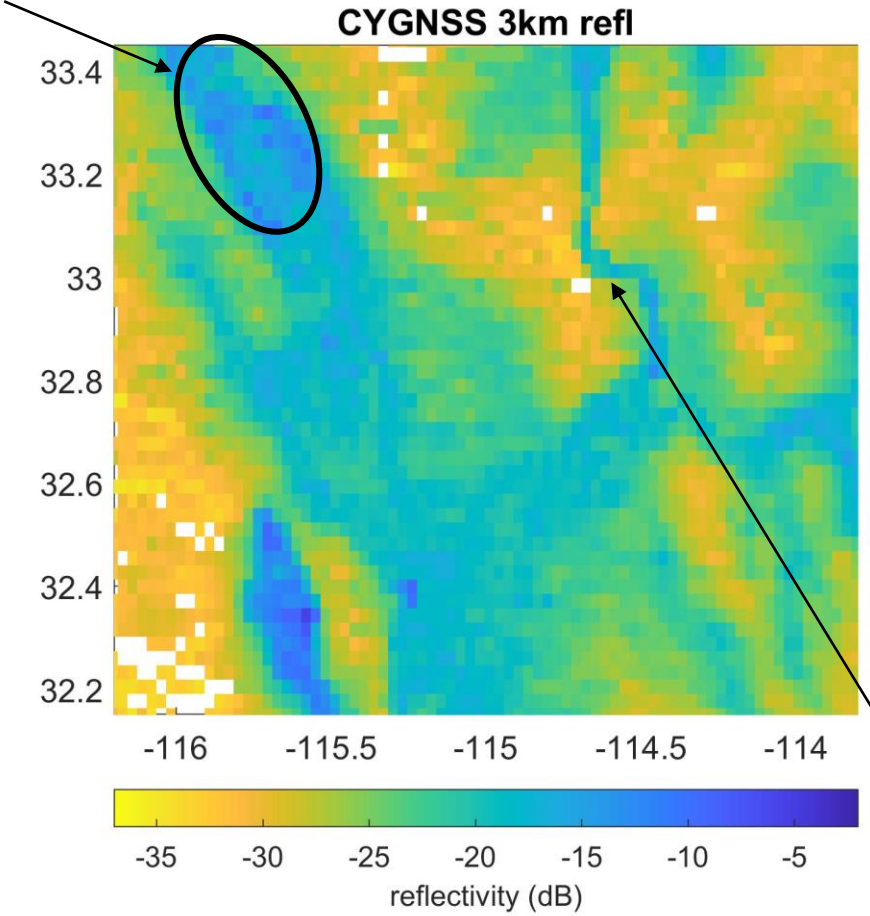

CO River

Google Earth Map

Example results – Yuma, AZ

Irrigated croplands

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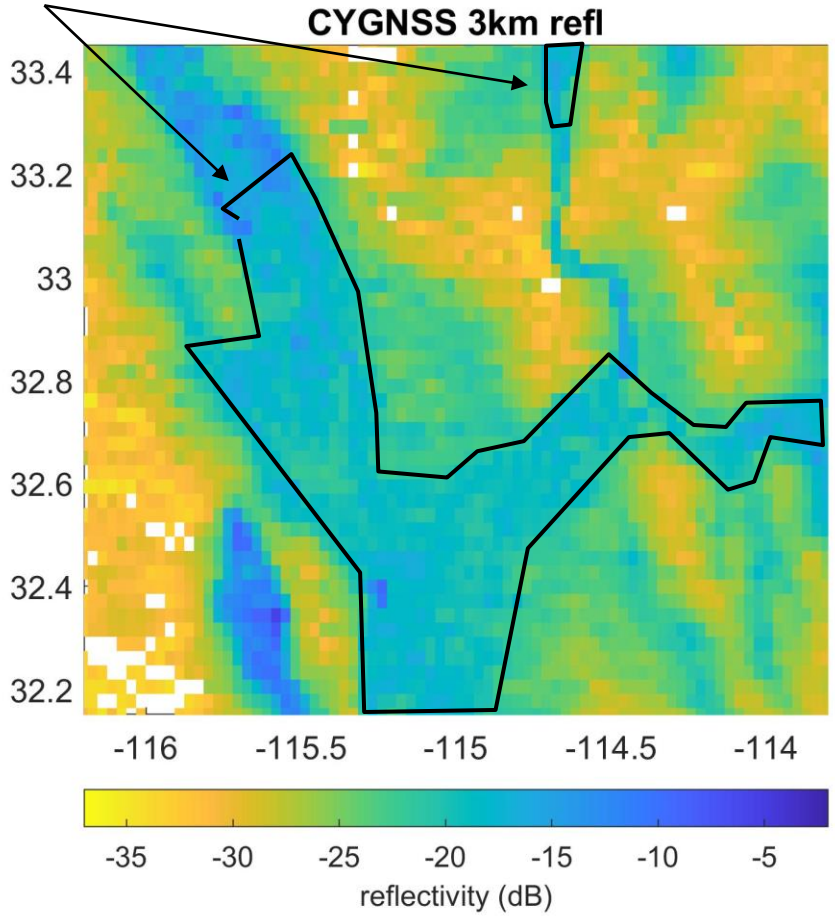

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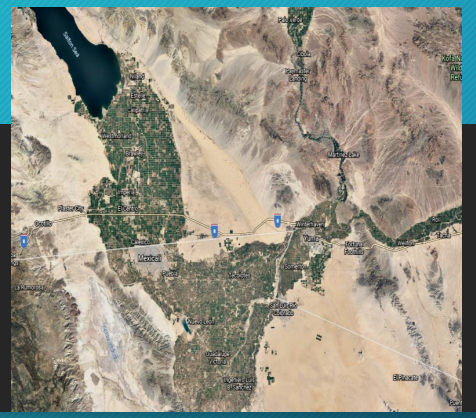

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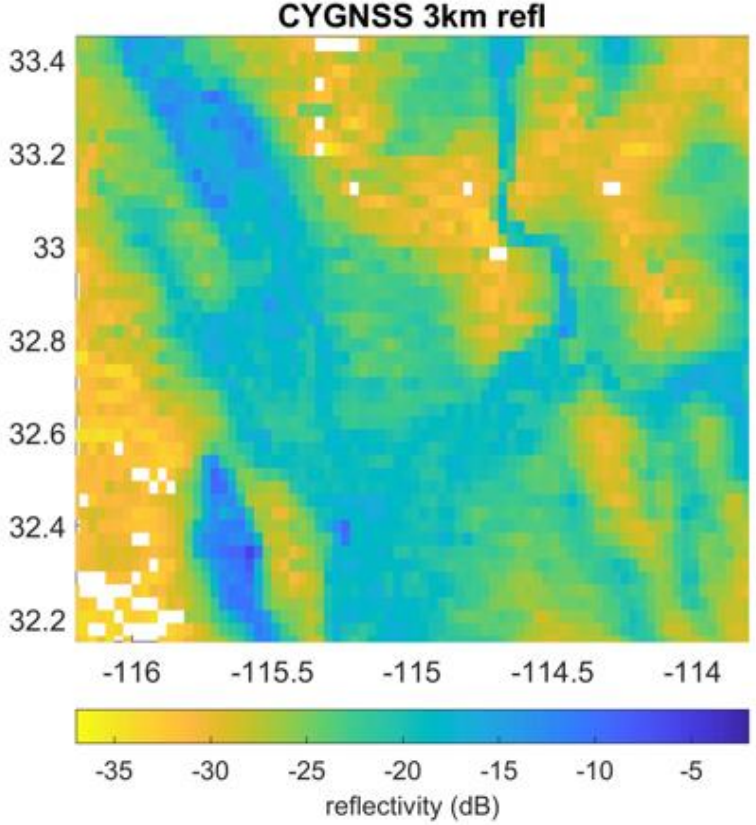

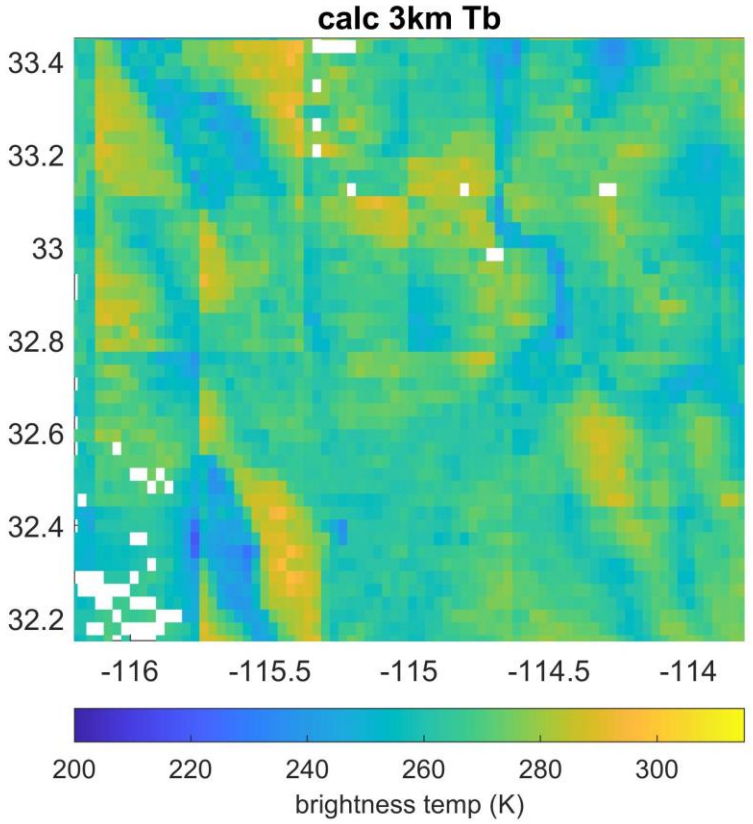

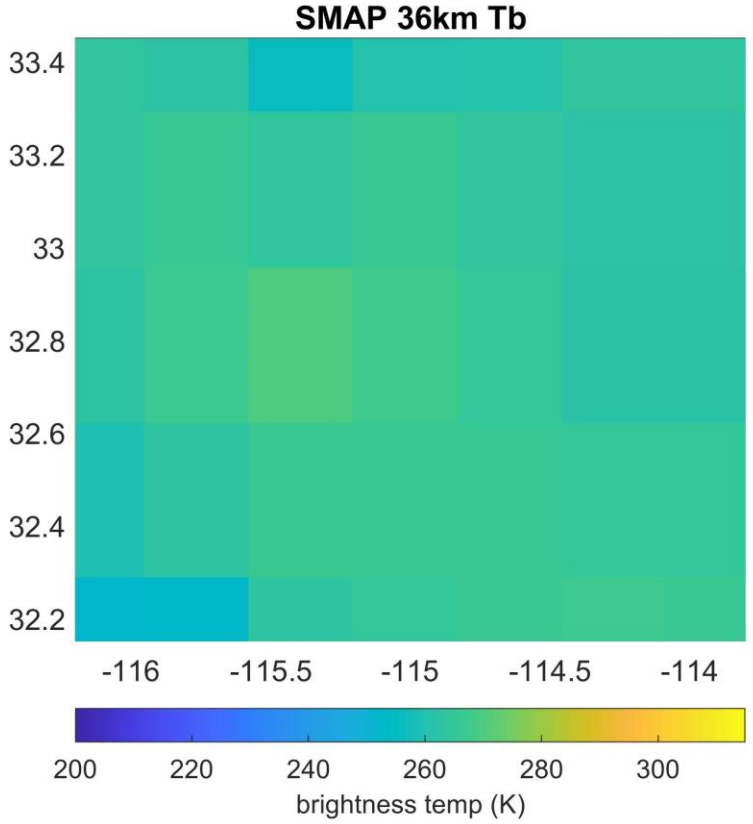

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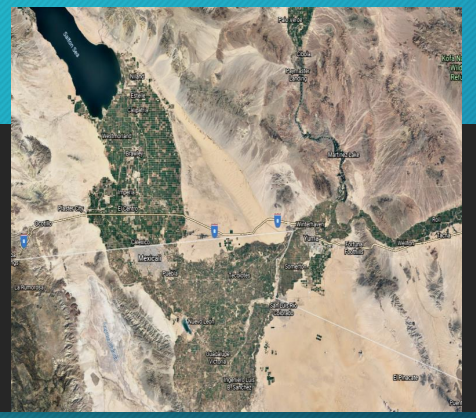

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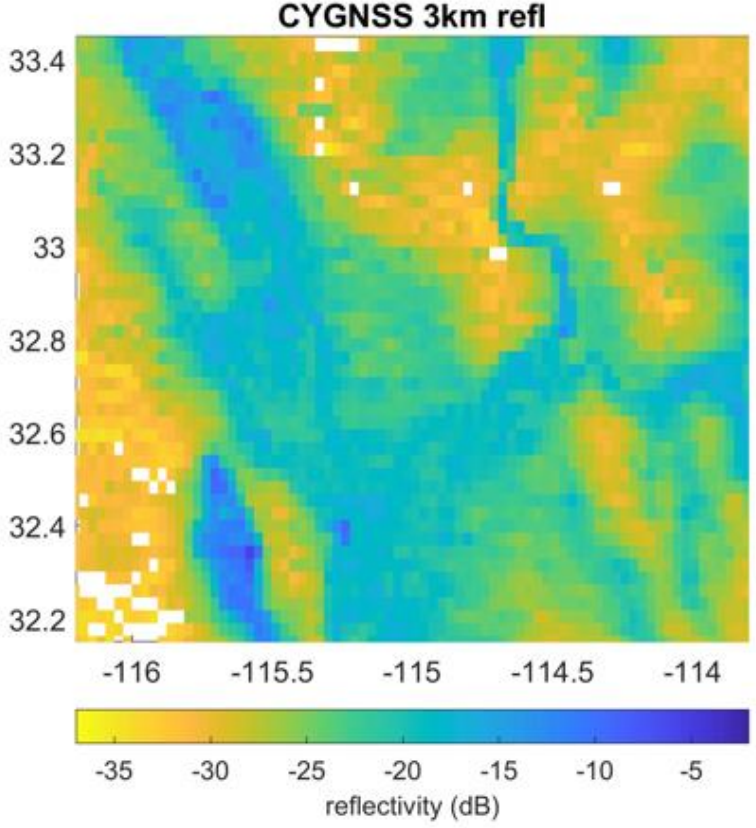

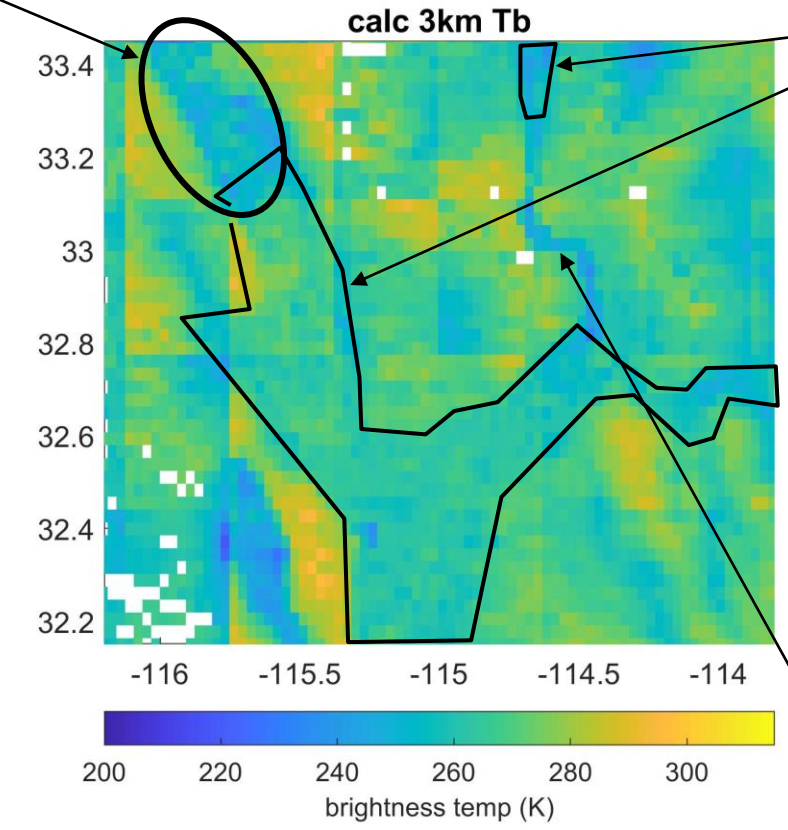

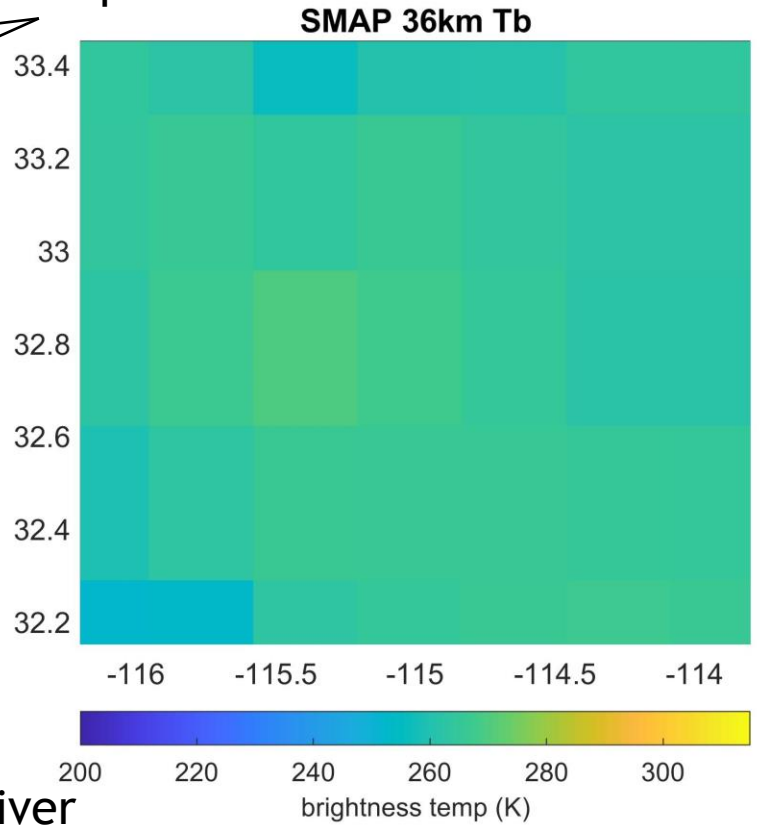

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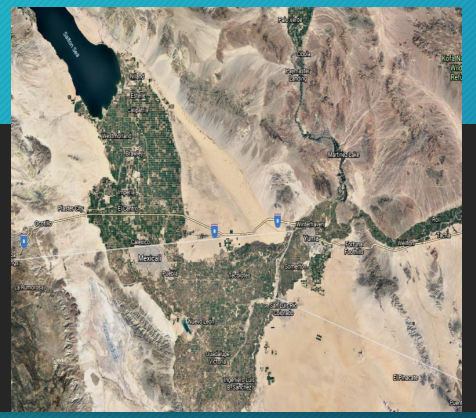

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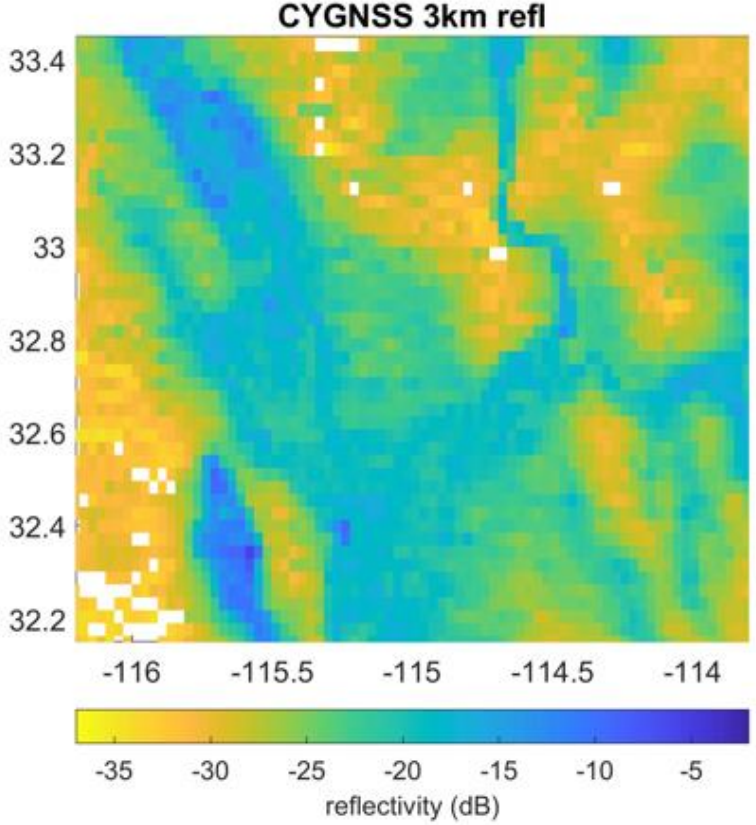
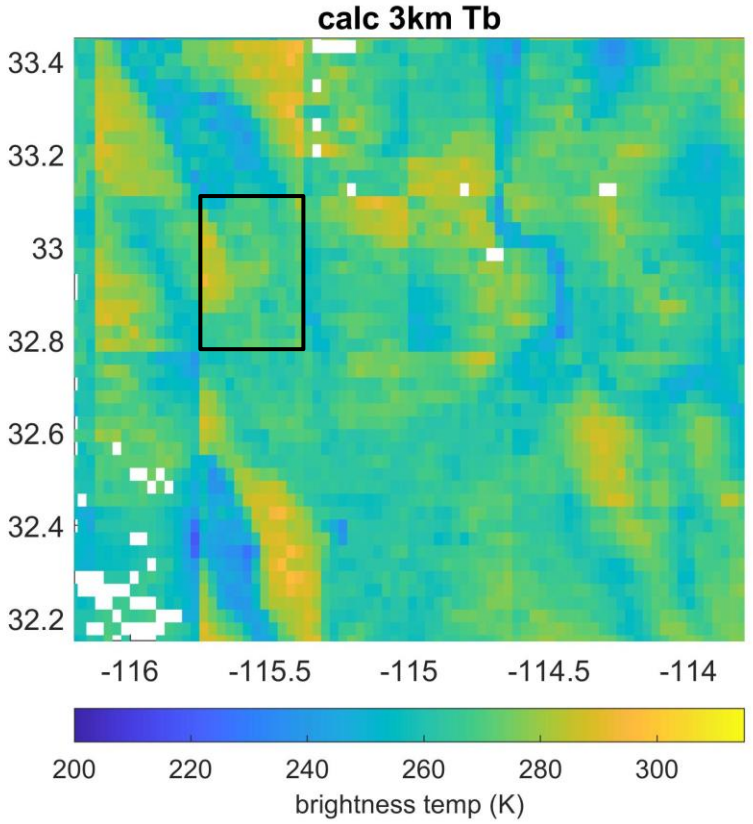
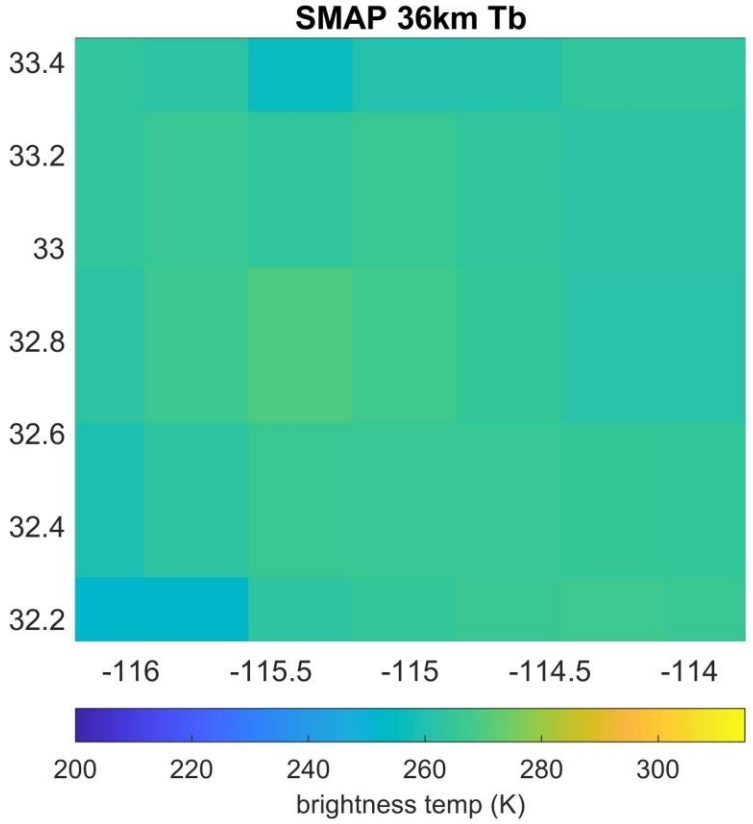
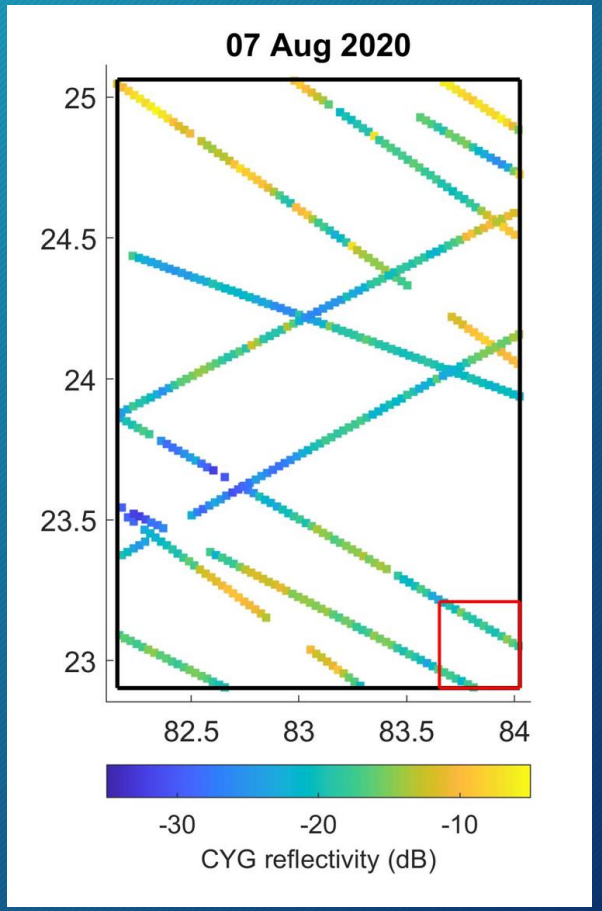






Tb algorithm considerations and complications

1. Calculating β
   - Spatial and temporal variation
2. Edge effect
   - Spatial varying β
3. Sparse daily CYGNSS observations create sparse daily 3km maps
   - Temporal and spatial resolution of final product



SM product

Analyze which SMAP algorithm and ancillary datasets will optimize accuracy of final SM product

References

Chew, C. (2021). Spatial interpolation based on previously-observed behavior: a framework for interpolating spaceborne GNSS-R data from CYGNSS. *Journal of Spatial Science*, 1-14.

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