Comparison of ATMS Striping Noise between NOAA-20 and S-NPP and Noise Impact on Warm Core Retrieval of Typhoon Jelawat (2018)

Xiaoxu Tian and Xiaolei Zou

Earth System Science Interdisciplinary Center

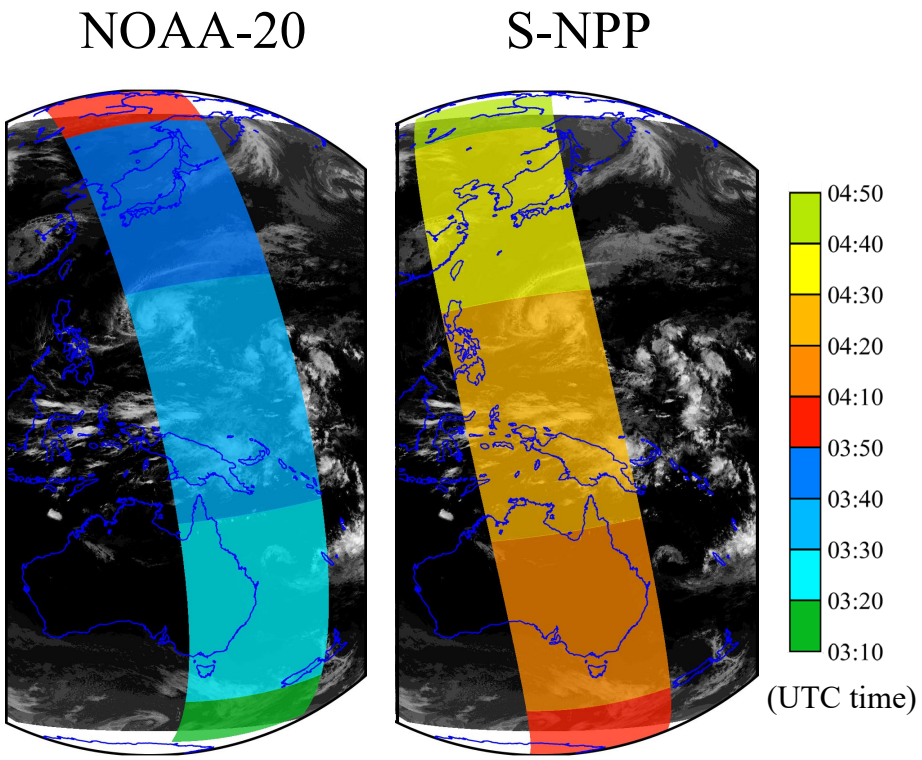
University of Maryland

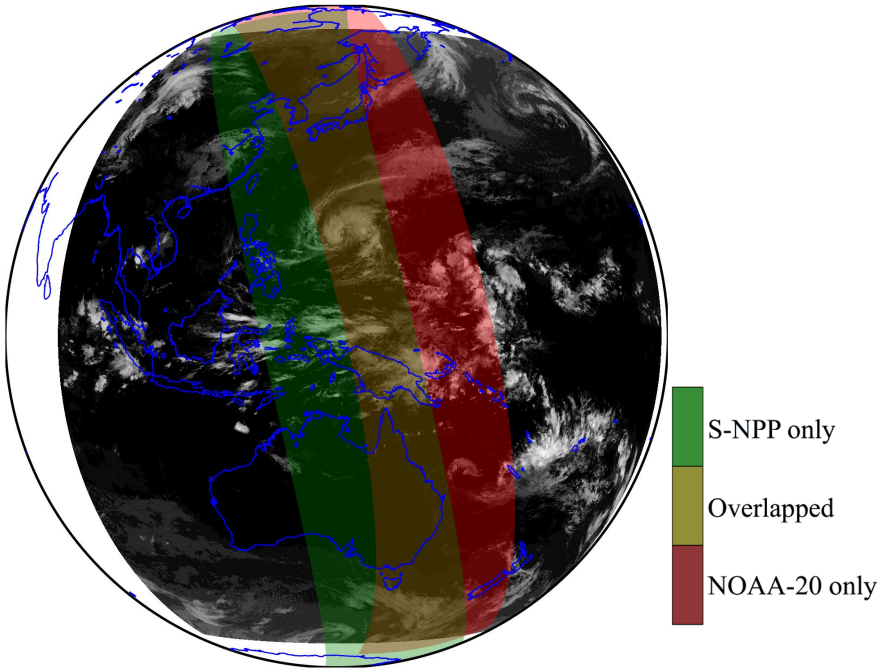
2019 CISESS November 12, 2019

Outline

- Characteristic orbital difference between NOAA-20 and S-NPP
- Comparisons of the detected striping noise in NOAA-20 and S-NPP ATMS
- ATMS-retrieved 3D structural evolution of Typhoon Jelawat (2018)
- Summary and conclusions

Characteristic Orbital Difference between NOAA-20 and S-NPP



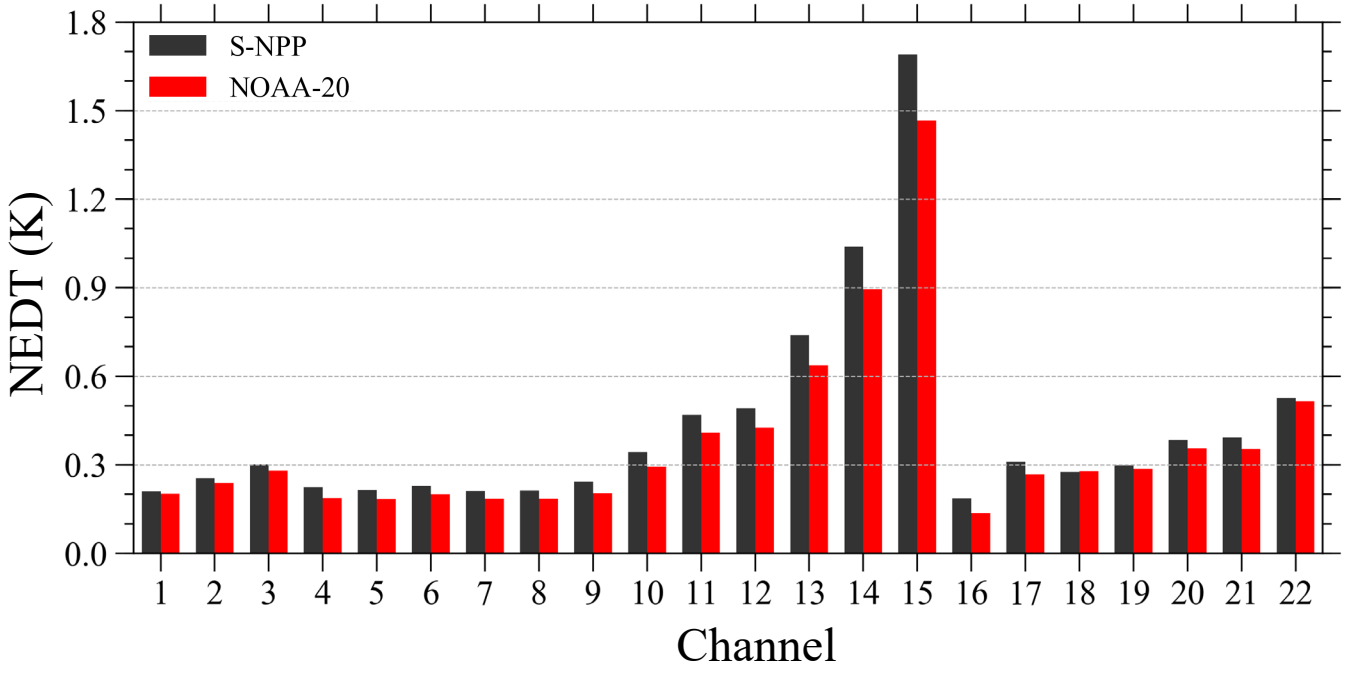


At 0400 UTC July 8, 2018
NOAA-20 is at the North Pole
S-NPP is at the South Pole

The two neighboring swaths of NOAA-20 and S-NPP has a considerable overlapping area.

NOAA-20 is ahead of S-NPP by a half orbit.

NOAA-20 and S-NPP ATMS Instrument Features



- The NEDTs are calculated with the Allan deviation formula reported in Tian et al (2015).
- The instrument noise of the ATMS on NOAA-20 is lower than that of the ATMS onboard S-NPP

Striping Noise Mitigation Algorithm

1. Form ATMS data matrix

$$\mathbf{A} = \begin{pmatrix} T_b^{obs}(1,1) & \cdots & T_b^{obs}(1,96) \\ \vdots & \ddots & \vdots \\ T_b^{obs}(M,1) & \cdots & T_b^{obs}(M,96) \end{pmatrix}$$

2. Solve for eigenvalues/eigenvectors of the covariance matrix

$$\mathbf{A}\mathbf{A}^T\vec{e}_i = \lambda\vec{e}_i$$

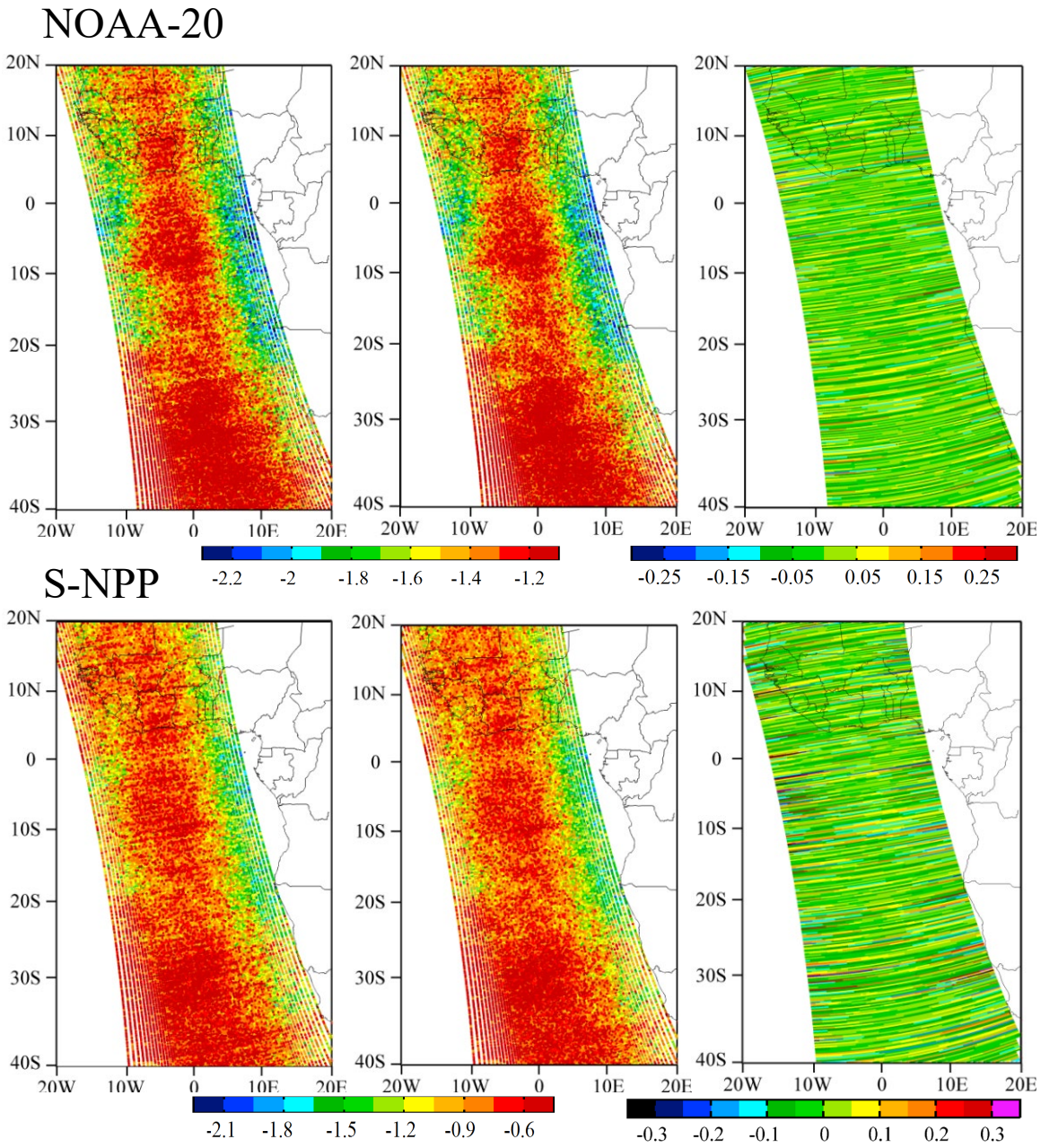
3. Mapping ATMS measurements in PC modes

$$\mathbf{A} = \sum_{i=1}^{96}\mathbf{P}_i = \sum_{i=1}^{96}\vec{e}_i\vec{u}_i, \text{ where } \vec{u}_i = \vec{e}_i\mathbf{A}$$

4. Perform EEMD on the first three PC coefficients

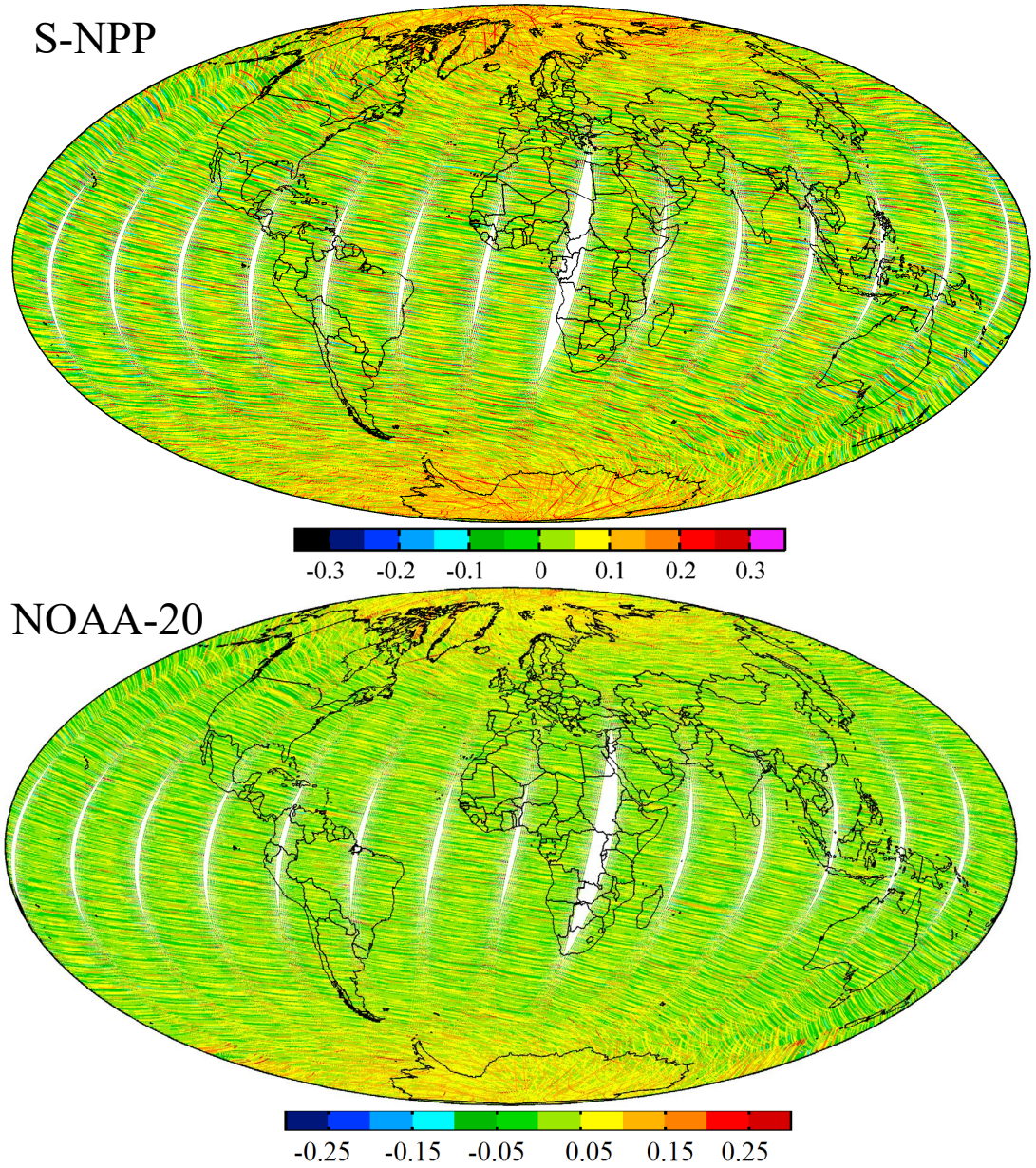
$$\mathbf{A}^{\text{destriped}} = \sum_{i=1}^{3}\mathbf{P}_i^{\text{destriped}} + \sum_{i=4}^{96}\mathbf{P}_i$$

Striping Noise in NOAA-20 and S-NPP ATMS



- The striping patterns can be seen in raw O-B (left) from both satellites
- Results for S-NPP ATMS slightly more obvious than in NOAA-20
- After mitigation, the striping patterns (middle) in observations are effectively removed

Striping Noise at a Global Scale



The magnitudes of striping noise detected from S-NPP ATMS are consistently greater than NOAA-20 ATMS.

Hurricane Warm Core Retrievals with Microwave Temperature Sounders

The atmospheric temperature at a specific level *T(p)* is expressed as a weighted linear combination of brightness temperature observations at different channels (Tian and Zou, 2018)

$$T_\theta(p) = C_0(p,\theta) + \sum_{i=i_{1,p}}^{i_{2,p}} Ci(p,\theta) T_{b,\theta}^{obs}(i)$$

$T_\theta(p)$ – atmospheric temperatures

$C_i(p,\theta)$ – regression coefficients trained with ECMWF temperatures

$T_{b,\theta}^{obs}(i)$ – ATMS brightness temperatures at channels 5-15

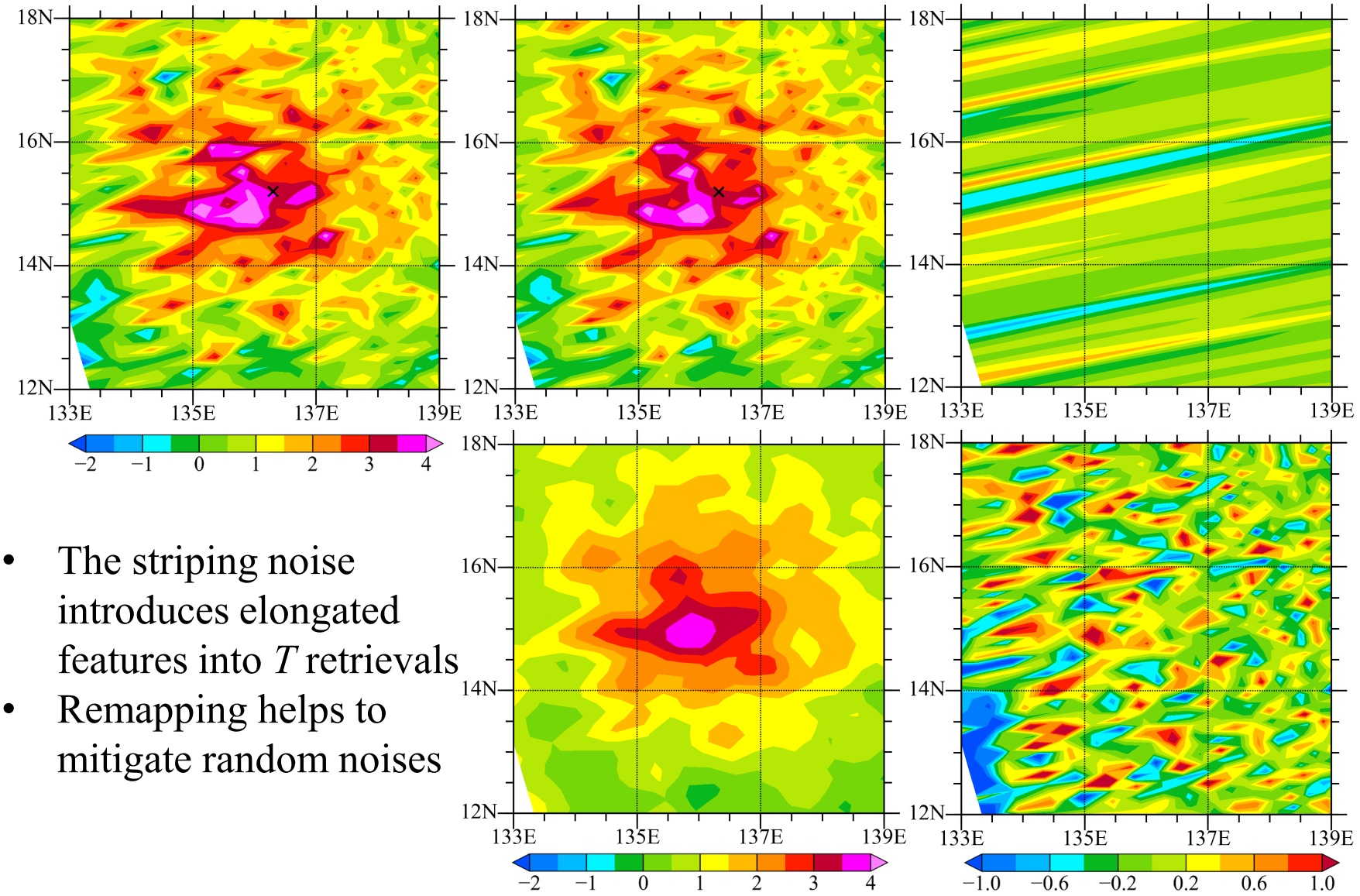
θ – local zenith angle denoting scan positions

Tian, X. and X. Zou, 2016: ATMS and AMSU-A derived warm core structures using a modified retrieval algorithm. *J. Geophy. Res.,* **121**, 12,630-12,646.

Tian, X. and X. Zou, 2018: Polar-orbiting satellite microwave radiometers capturing size and intensity changes of Hurricane Irma and Maria (2017). *J. Atmos. Sci.*, **75**, 2509-2522.

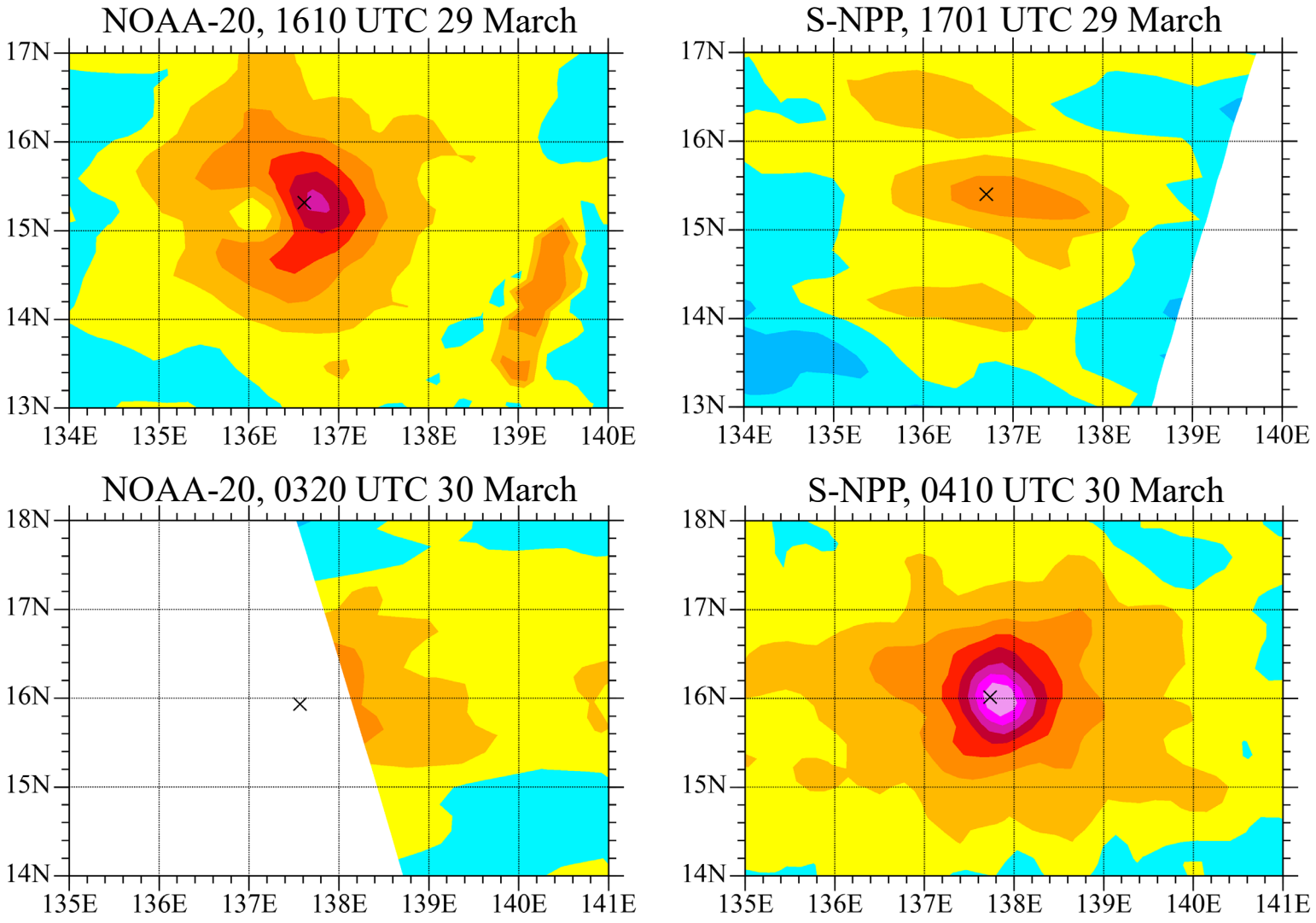
Zou, X. and X. Tian, 2018: Hurricane warm core retrievals from AMSU-A and remapped ATMS measurements with rain contamination eliminated. *J. Geophy. Res.,* **123**, 10,815-10,829.

Impact of Striping Noise On Temperature Retrievals



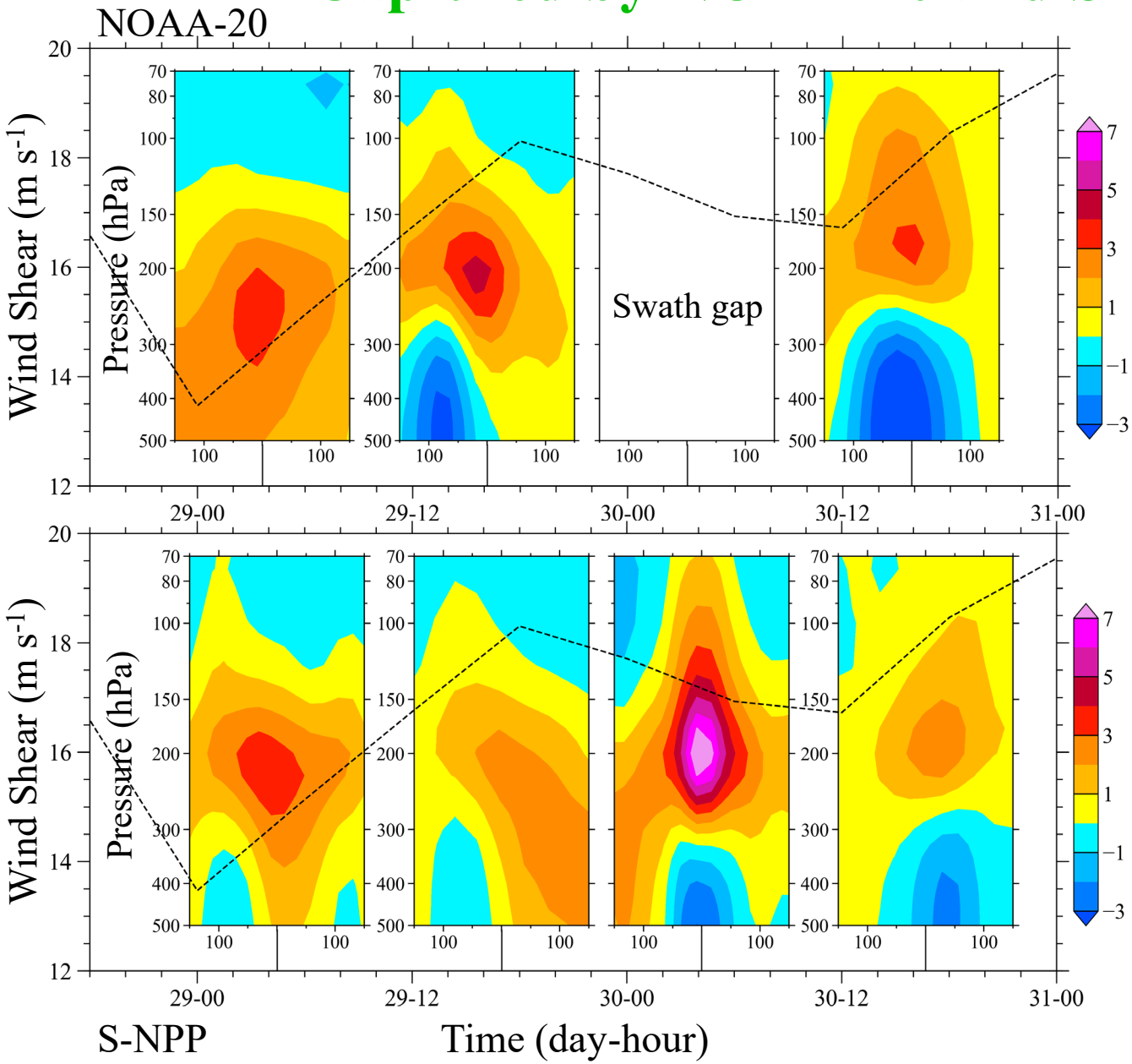
- The striping noise introduces elongated features into *T* retrievals
- Remapping helps to mitigate random noises

Warm Core at 200 hPa



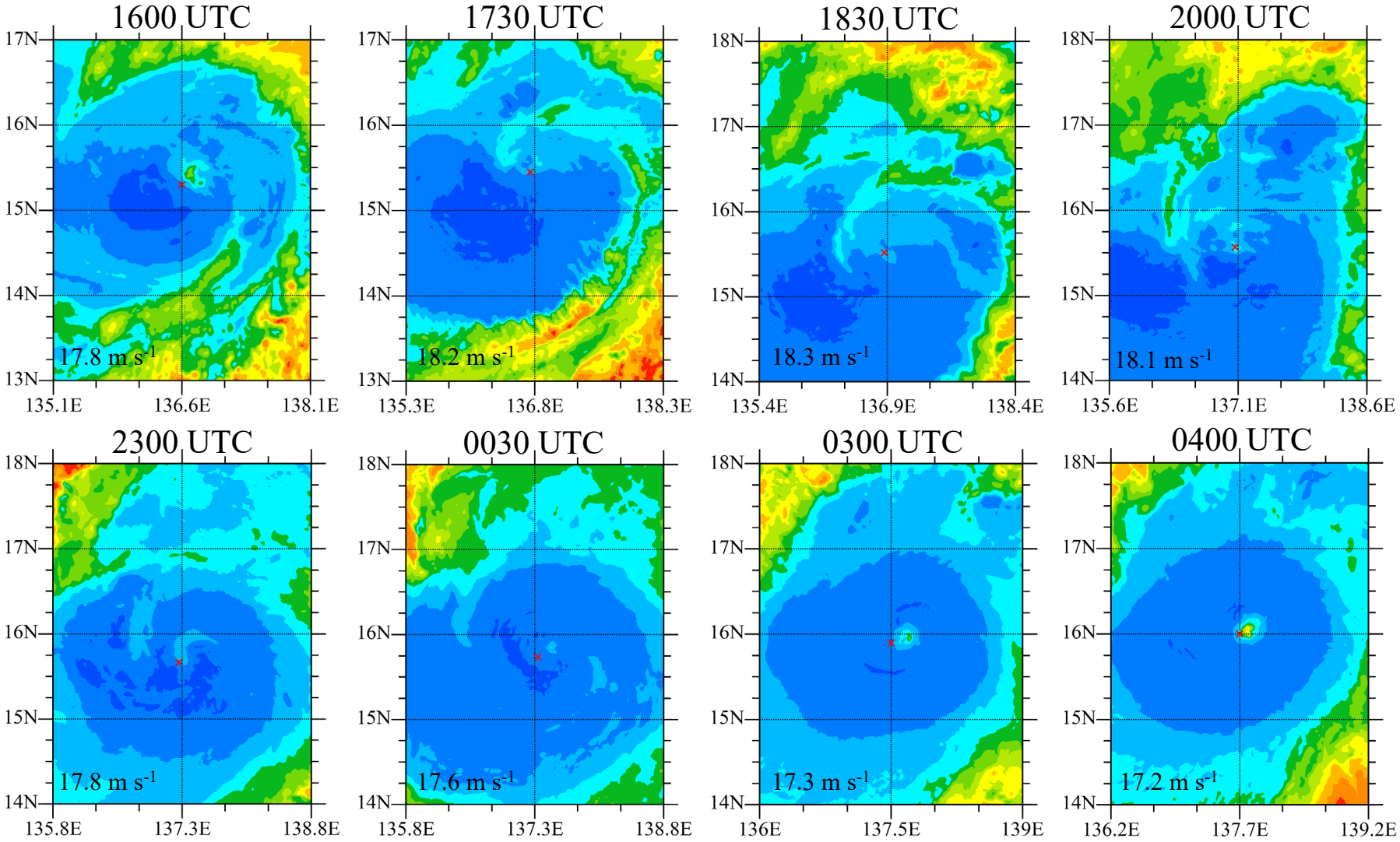
The rapid weakening process during the 50 min from 1610 UTC to 1701 UTC was captured by the back-to-back orbital setup of NOAA-20 and S-NPP

Typhoon Warm Core Evolutions Captured by NOAA-20 and S-NPP



- At 0000 UTC March 29, 2018, Typhoon Jelawat rapidly intensified from a Cat. 1 typhoon to a Cat 4 typhoon
- The storm quickly weakened to Category 1 the same day due to strong vertical wind shear in its vicinity
- These rapid changes were well captured by the NOAA-20 and S-NPP, thanks to the 50-min apart orbital configuration

Typhoon Evolutions Captured by Himawari-8



Brightness temperatures at 10.4 μm from the AHI onboard Himawari-8 with wind shear values at the lower left corner.

Summary and Future Work

- The NOAA-20 satellite shares nearly the same orbit as the S-NPP satellite, flying 50 min ahead of it
- Similar with the NEDTs, the striping noise detected in NOAA-20 is also smaller in magnitudes than those in S-NPP ATMS
- Retrieved temperatures can be affected by nearly 1 K if striping noise is not mitigated beforehand
- Rapid changes may be well captured by the NOAA-20- and S-NPP ATMS-retrieved atmospheric temperature fields, thanks to the 50-min back-to-back orbit setup

Reference

Zou, X., and X. Tian, 2019: Comparison of ATMS Striping Noise Between NOAA-20 and S-NPP and Noise Impact on Warm Core Retrieval of Typhoon Jelawat (2018). *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, **12(7)**, 2504-2512.