Analysis of ATMS and AMSU Striping Noise from Their Earth Scene Observations

Zhengkun Qin[1], Xiaolei Zou[1], Fuzhong Weng[2]

1. Center for data assimilation in research and applications Nanjing University of Information Science & Technology, China
2. National Environmental Satellite, Data & Information Service, National Oceanic and Atmsopheric Administration, Washington, DC, USA

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Outline

- ATMS Striping Phenomena
- Striping analysis based on PCA and EEMD
- Striping noise of water vapor channels
- Striping analysis of Maneuver data
- Summary

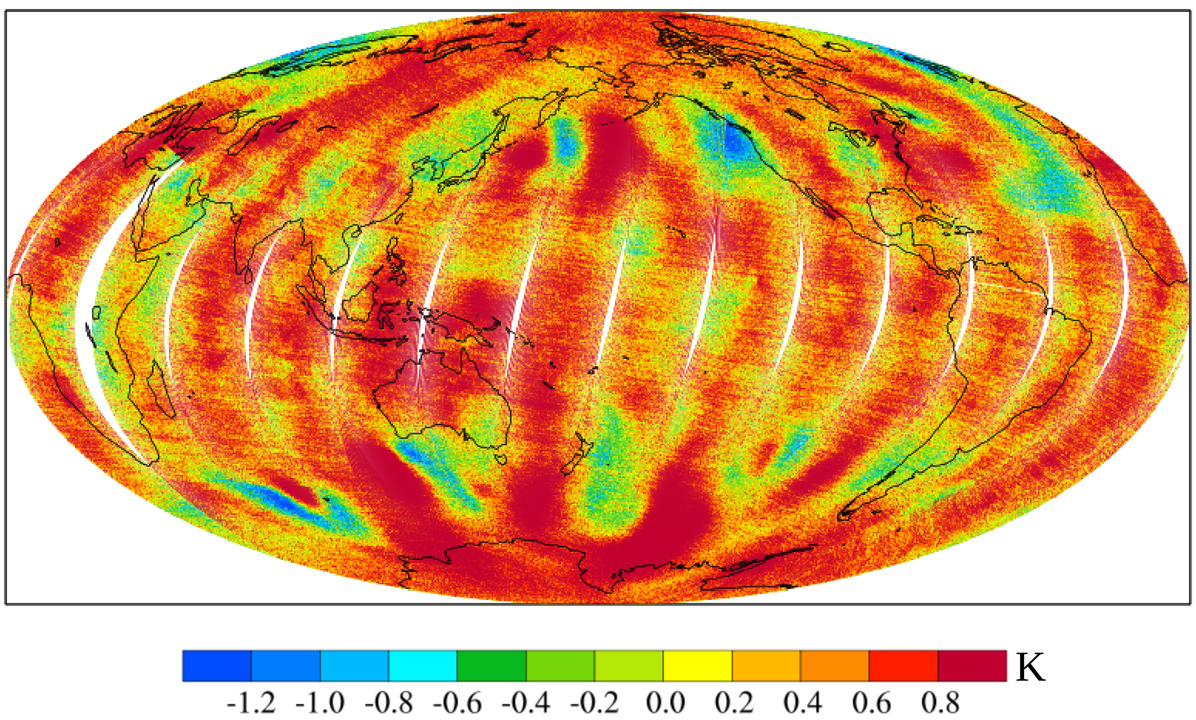
Suomi NPP ATMS Striping

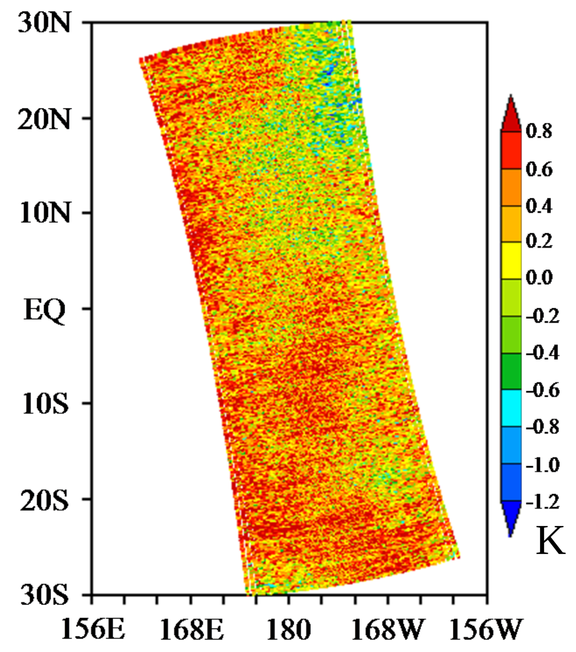
It was first identified by NWP user community through the global distribution of the bias (O-B) between ATMS observations and simulations. Unlike AMSU-A, ATMS O-B displays a distinct O-B irregularity in its along-track direction. NWP users refer this irregularity as striping brightness temperatures or radiances.

Global Distribution of ATMS Ch10 O-B

February 24, 2012

Obvious Stripping noise can be found in the O-B figure of Ch10



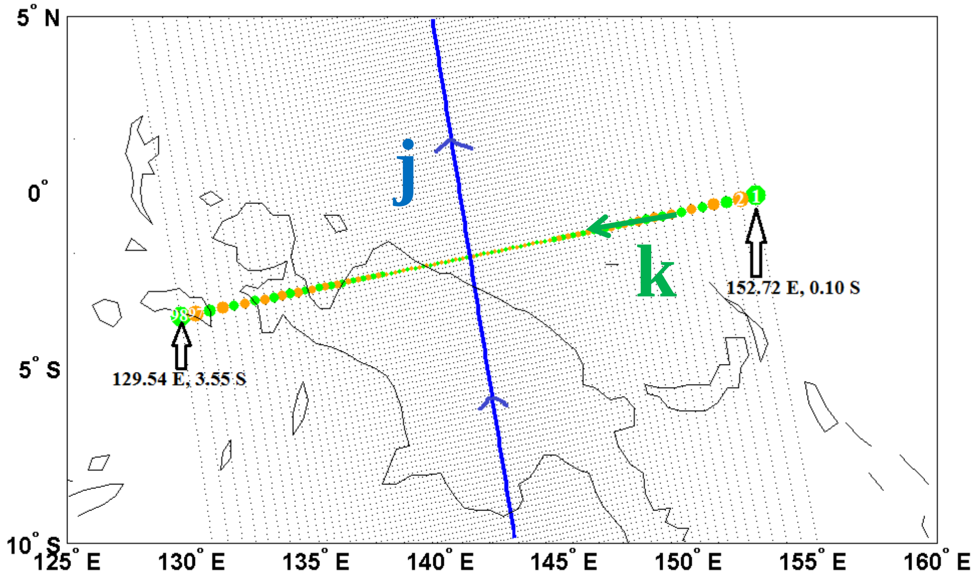


Principle Component Analysis (PCA)

Data Matrix: $A_{96\times N} = \begin{pmatrix} TB_{1,1} & \cdots & TB_{1,N} \\ \vdots & \ddots & \vdots \\ TB_{96,1} & \cdots & TB_{96,N} \end{pmatrix}$

$TB_{k,j}$: Brightness temperature at the kth FOV and the jth scanline

k=1,2,…,96; j=1,2,…,N



Principle Component Analysis (PCA)

The covariance matrix: $\mathbf{S} = \mathbf{A}\mathbf{A}^T$

$$\mathbf{S}\vec{e}_i = \lambda_i \vec{e}_i$$

$$\begin{pmatrix} \vec{u}_1 & \vec{u}_2 & \cdots & \vec{u}_{96} \end{pmatrix}^T = \mathbf{E}^T \mathbf{A}$$

$$\vec{e}_i = \begin{pmatrix} e_{1,i} & e_{2,i} & \cdots & e_{96,i} \end{pmatrix}$$

: the principle component (PC) for the i*th* mode.

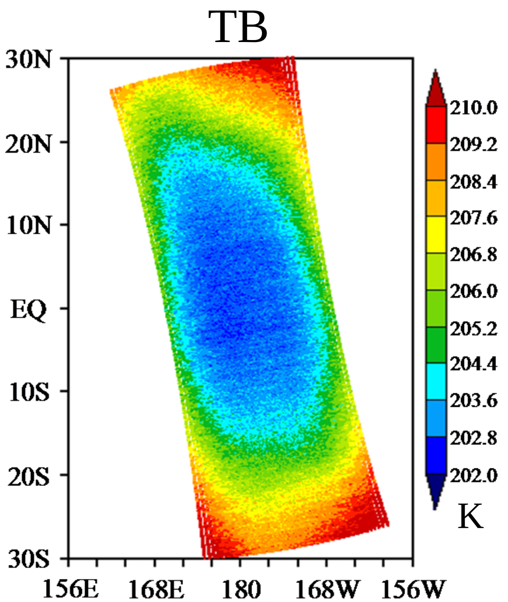
$$\vec{u}_i = \begin{pmatrix} u_{i,1} & u_{i,2} & \cdots & u_{i,N} \end{pmatrix}$$

: the PC coefficient for the i*th* mode.

The ATMS data can be then expressed as:

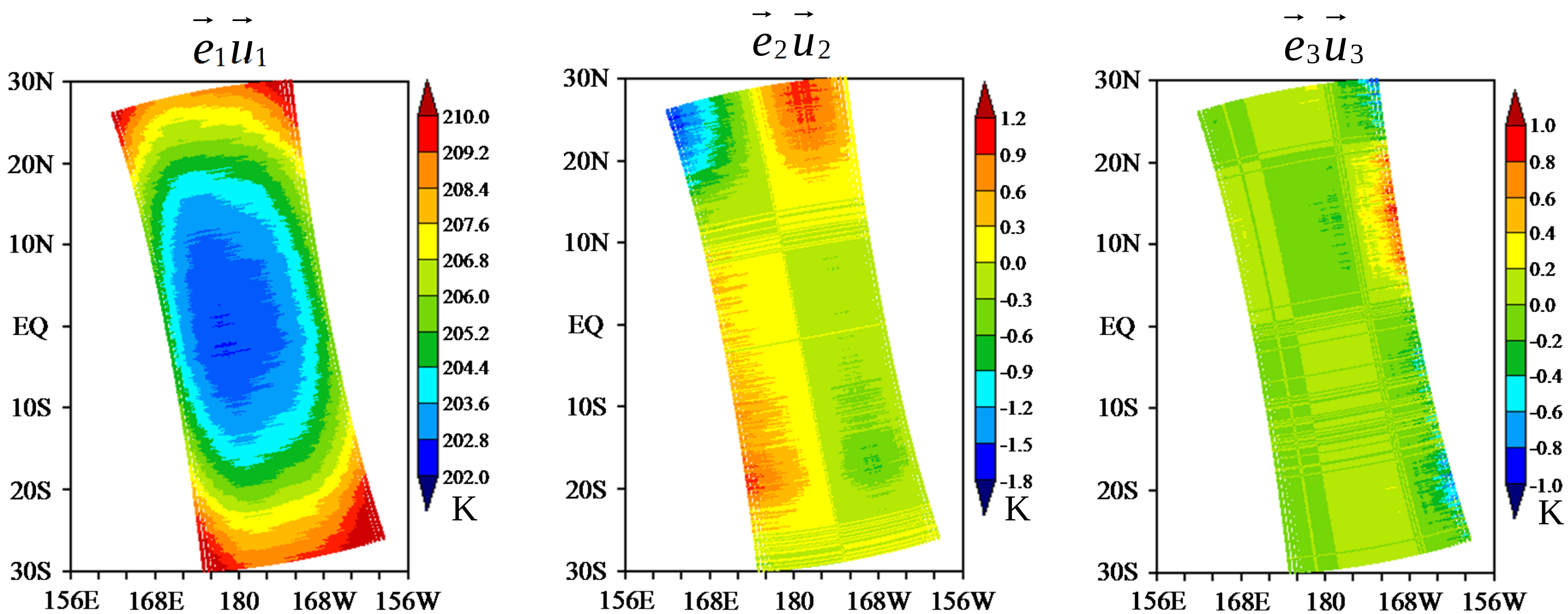
$$\mathbf{A} = \sum_{i=1}^{96} \vec{e}_i \vec{u}_i$$

PCA modes of TB for ATMS Ch10

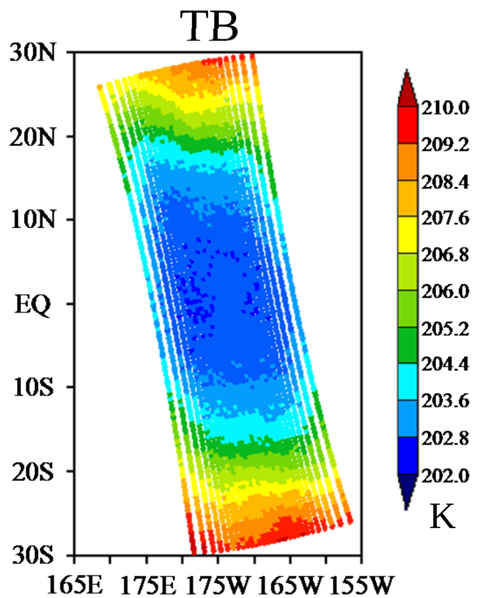


Scan angle dependence of the brightness temperature

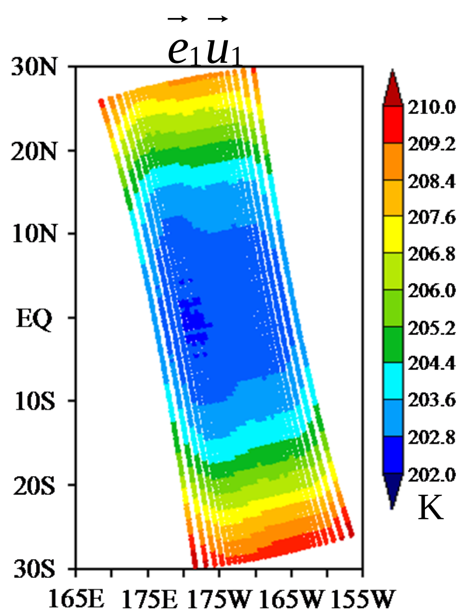
Variations same for all FOVs are tend to appear in the 1st mode

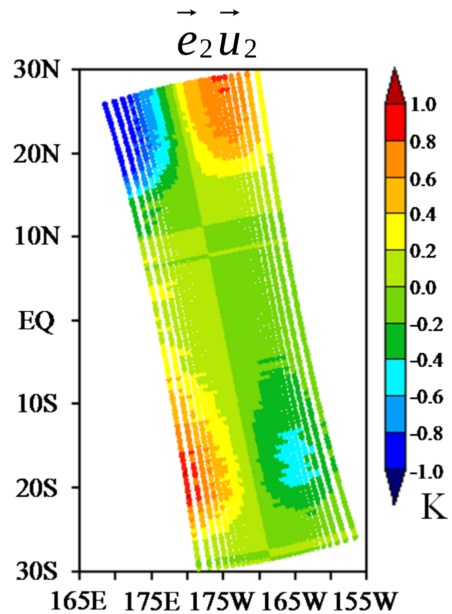


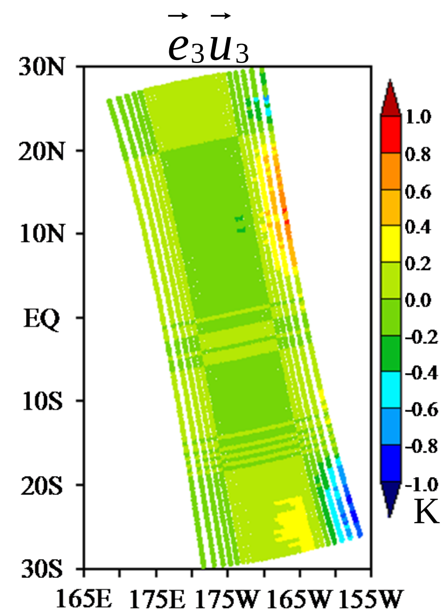
PCA modes of TB for NOAA-18 AMSU-A Ch9



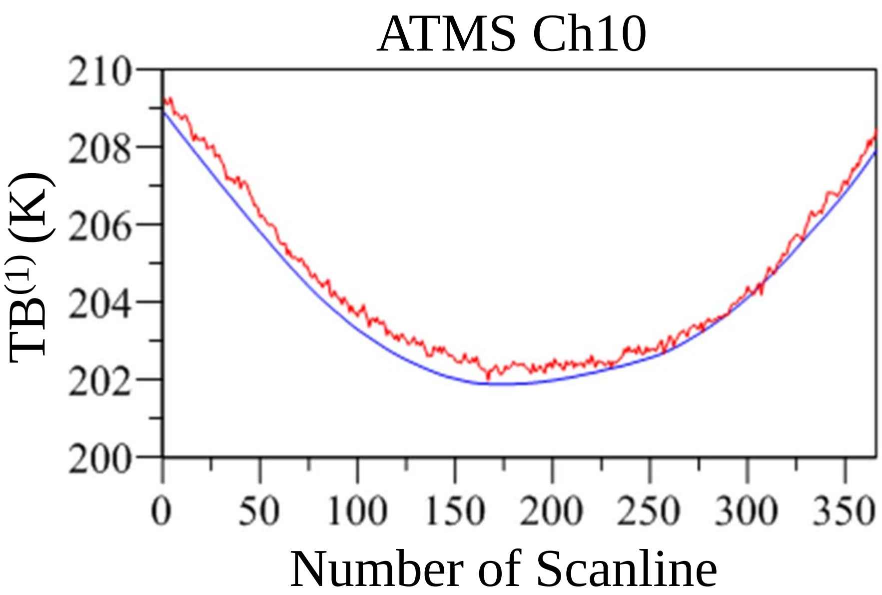
Same features as ATMS Ch10, but the first mode is more smooth.







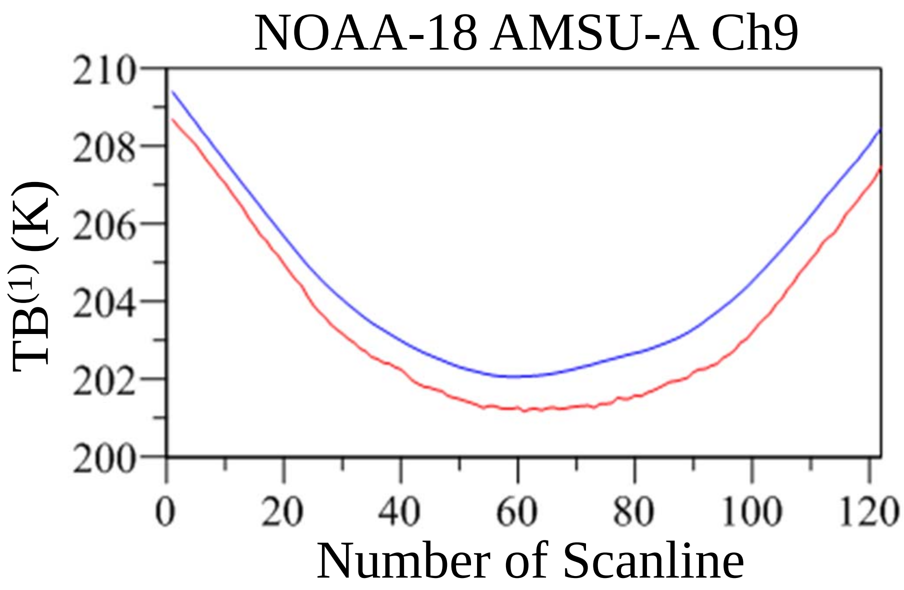
Brightness Temperature at nadir



$$TB^{nadir} = e_{48,1}\vec{u}_i$$

Observation

Simulation



Obvious oscillations can be found in ATMS, but not in AMSU-A

EEMD Method

Raw data

$$R_0(t) = T_b(t)$$

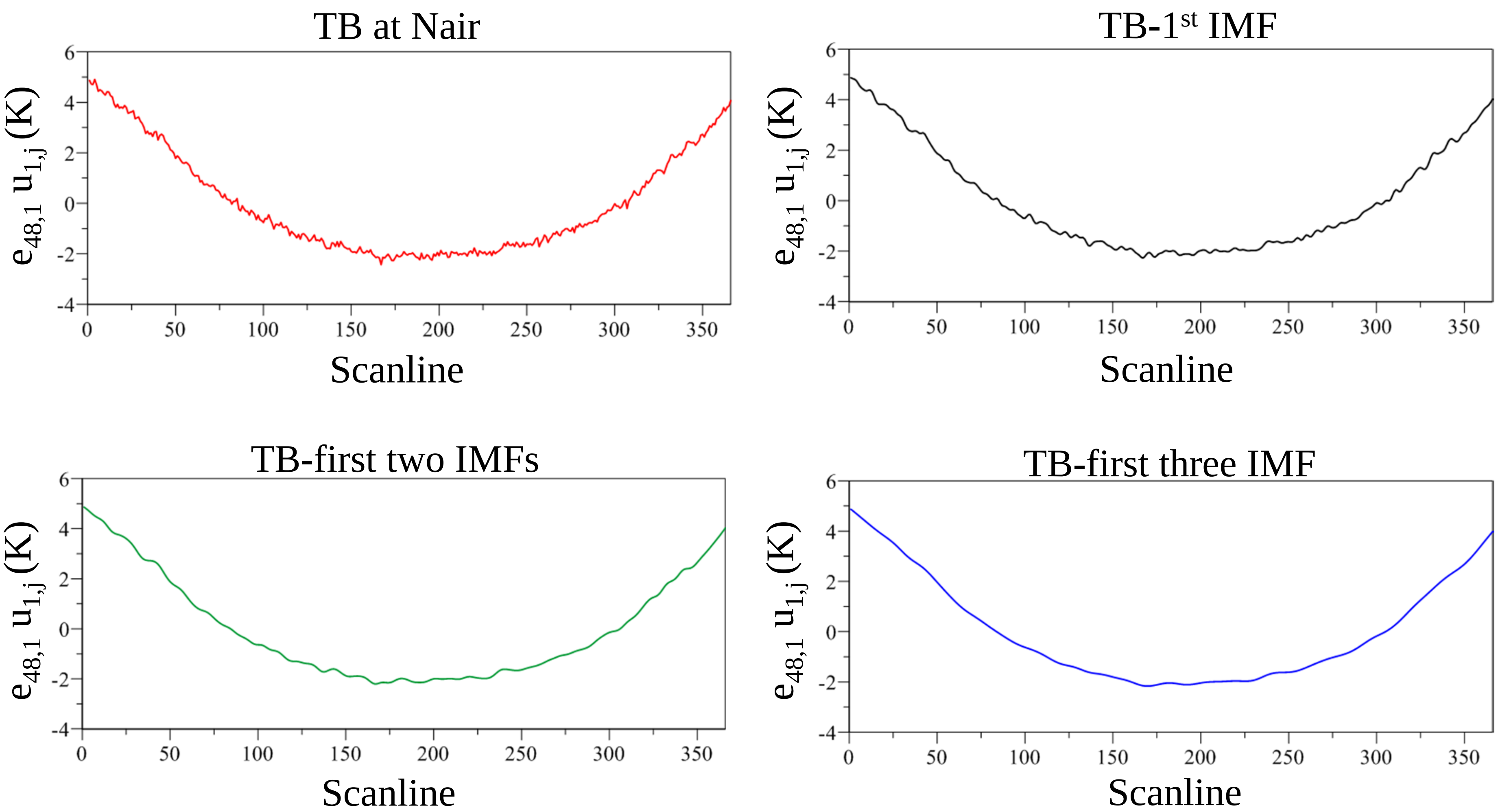
$C_{n-1} \leftarrow$ Intrinsic Mode Function (IMFs)
Mean of the envelopes of $R_{n\text{-}1}$

$$R_n(t) = R_{n-1}(t) - C_{n-1}$$

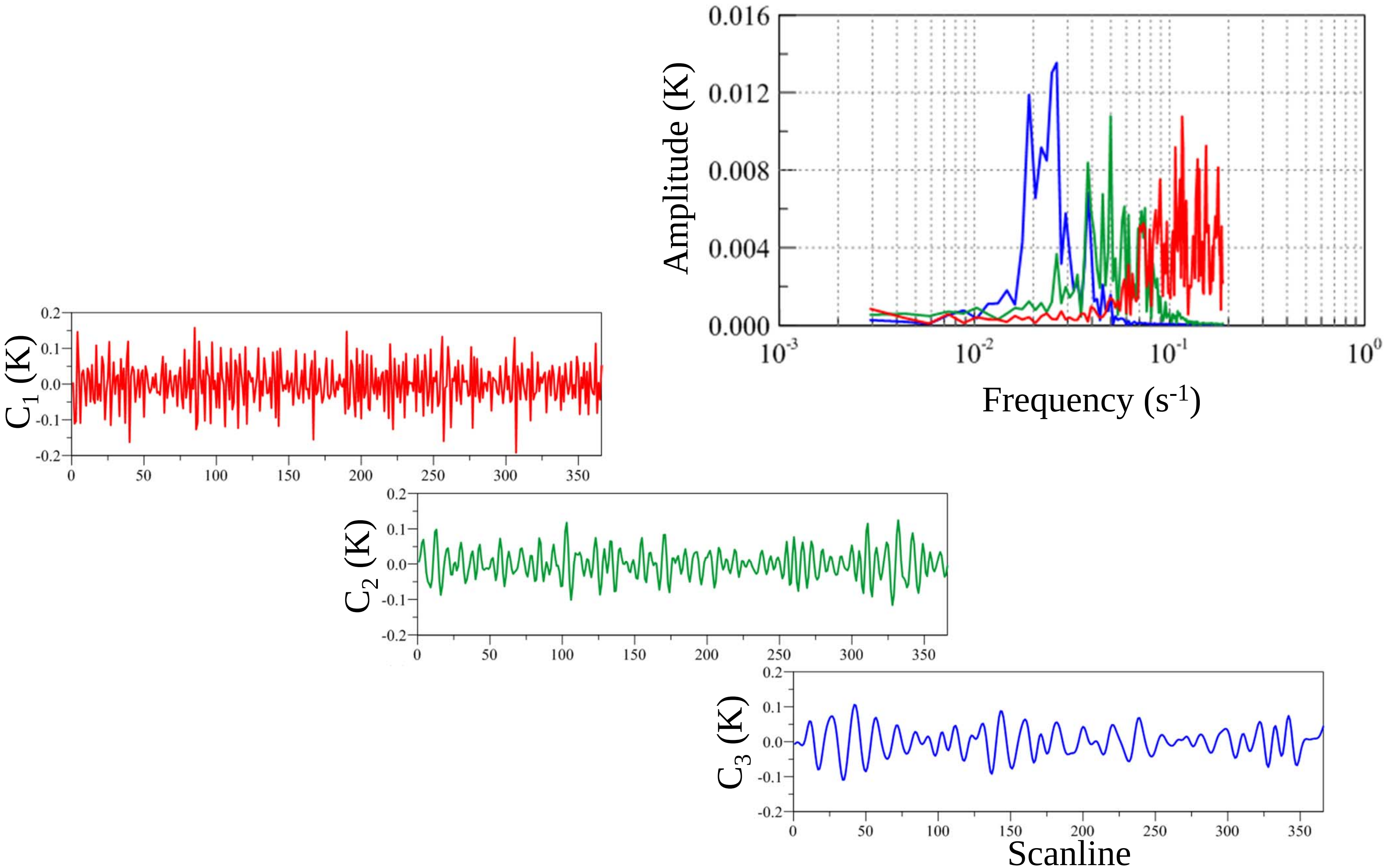
$$T_b(t) = \sum_{j=1}^{n} C_j(t) + R_n(t)$$

Huang and Wu (2008) and Wu and Huang (2009)

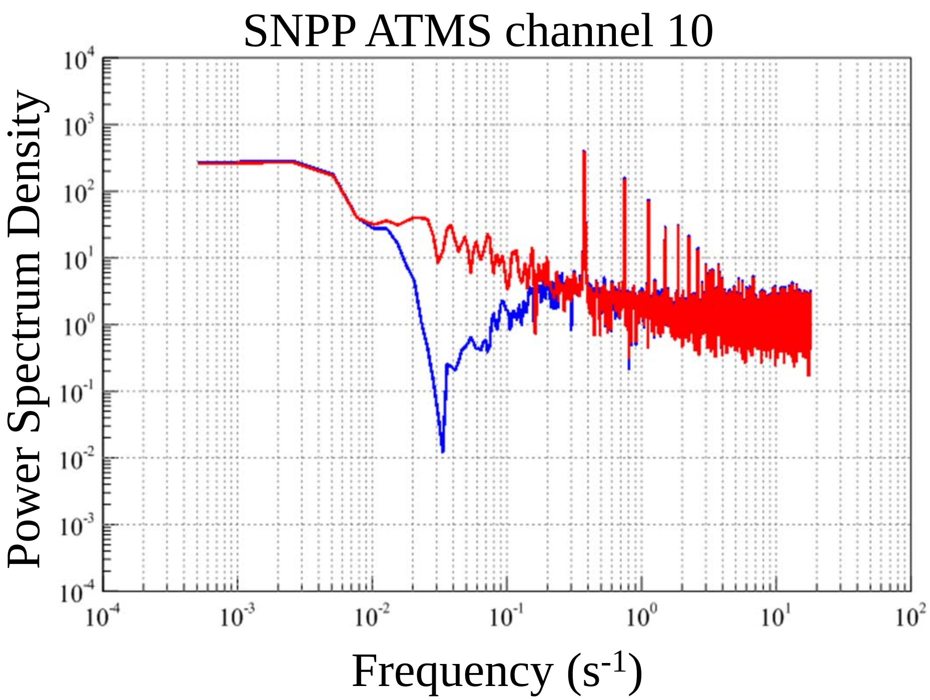
Brightness temperature for the first PCA mode at nadir

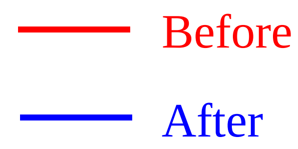


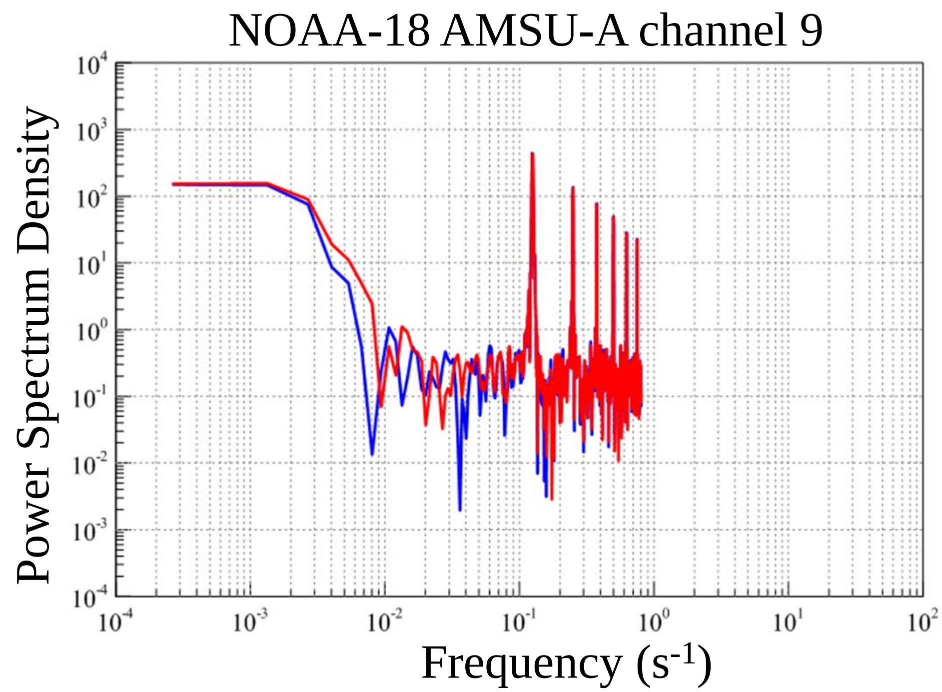
Power Spectral of the first three IMFs



Power spectral density distributions







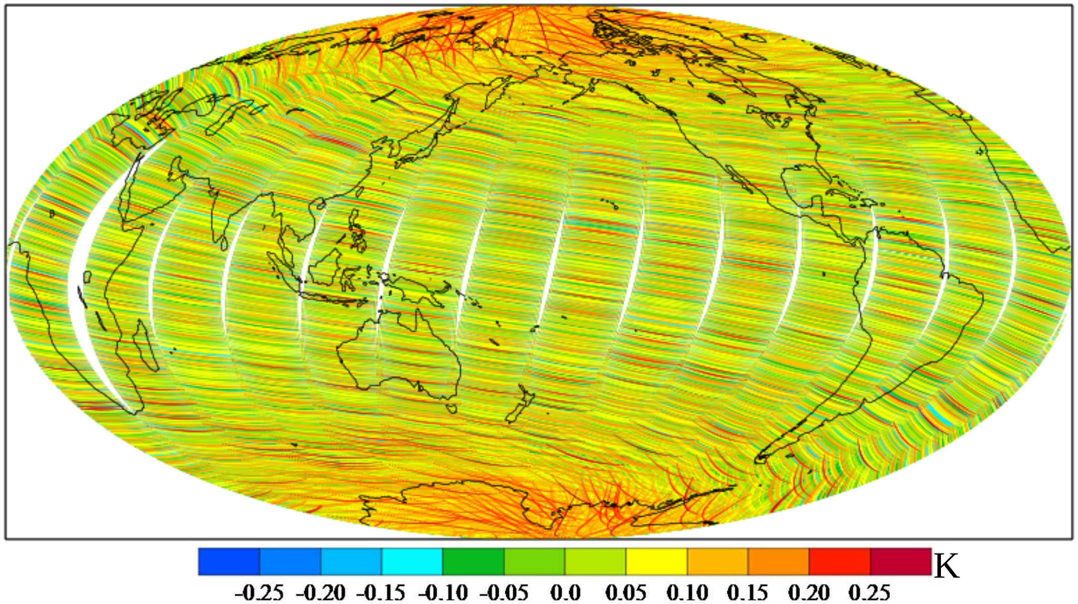
Power spectral is modified after striping noise removed for ATMS, but there are just a little differences for AMSU-A before and after EEMD smoothing.

Global distribution of Stripping noise

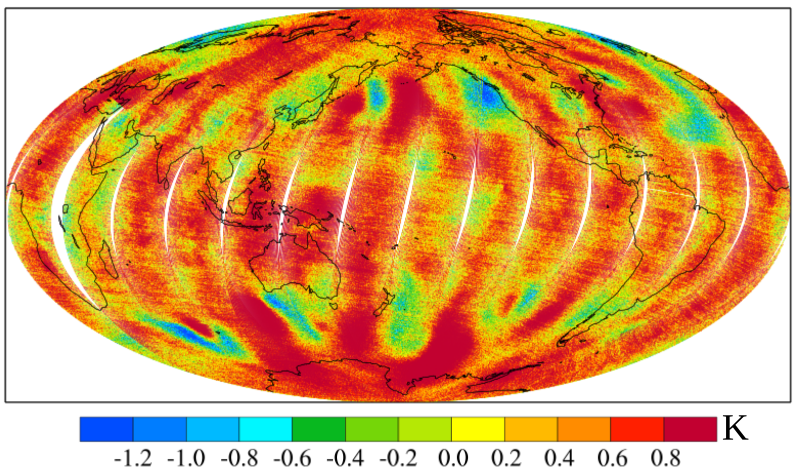
Before-After

Of O-B for

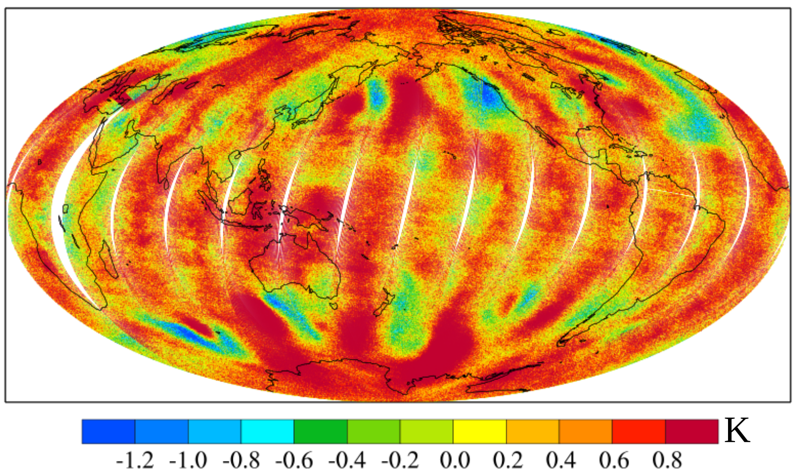
ATMS Ch10



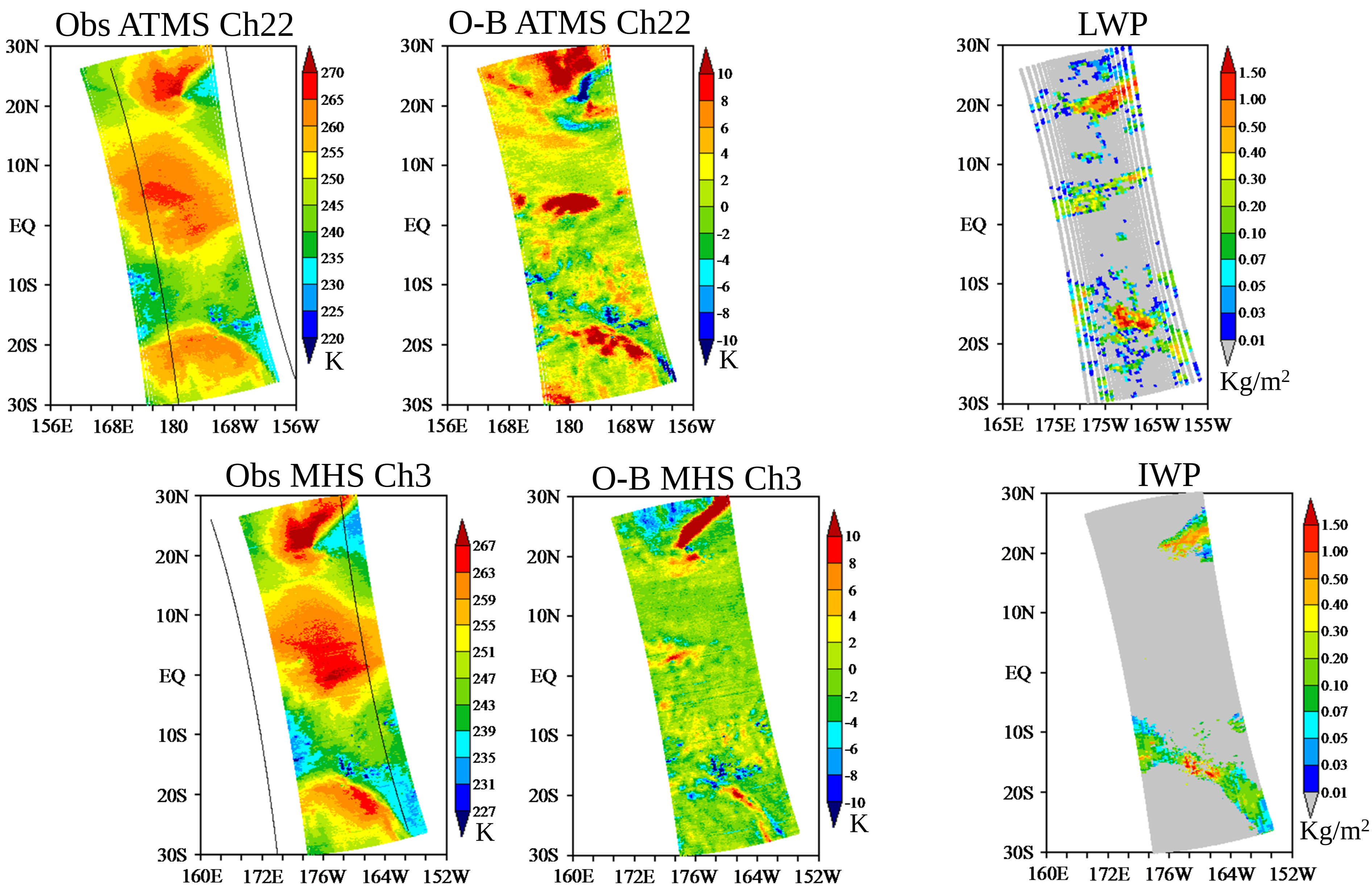
Before



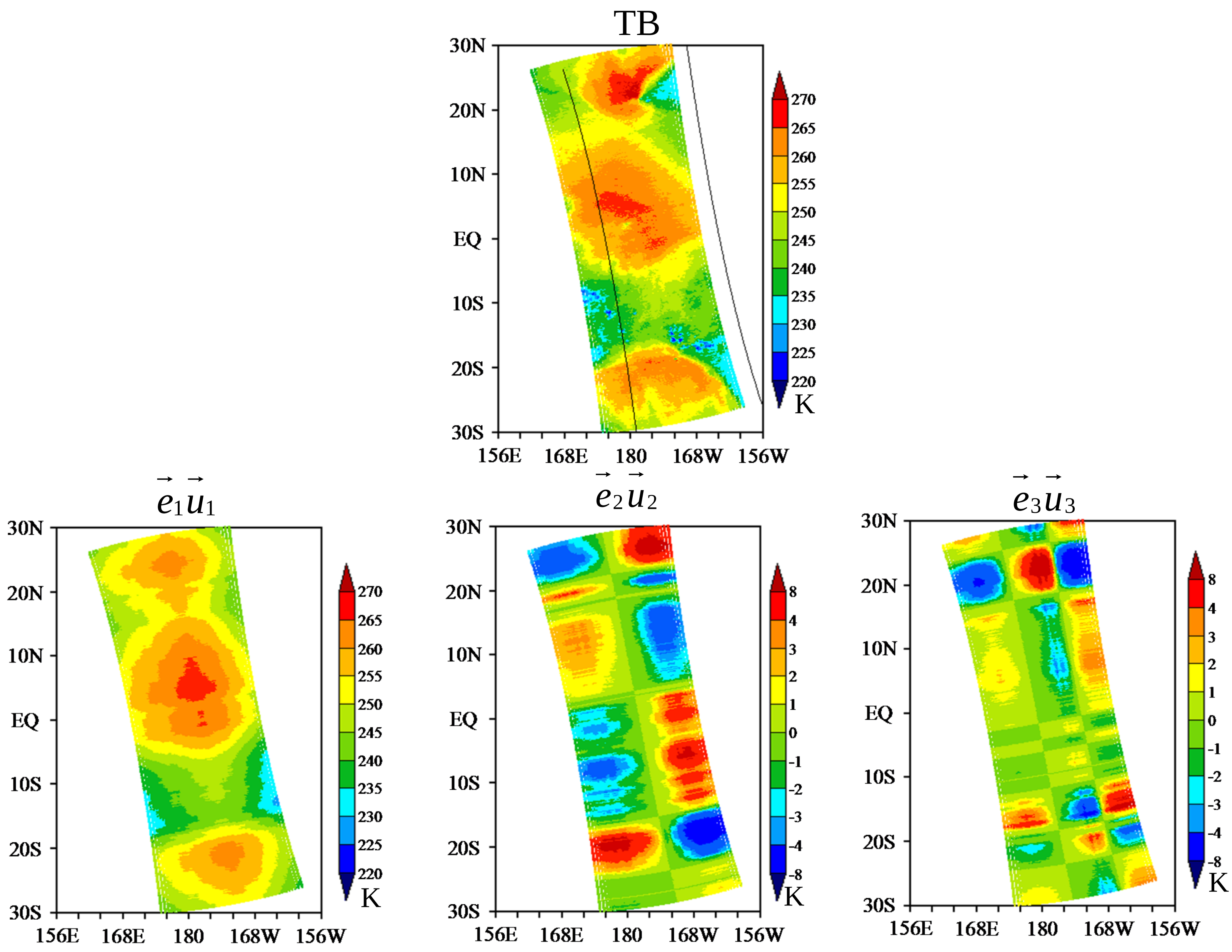
After



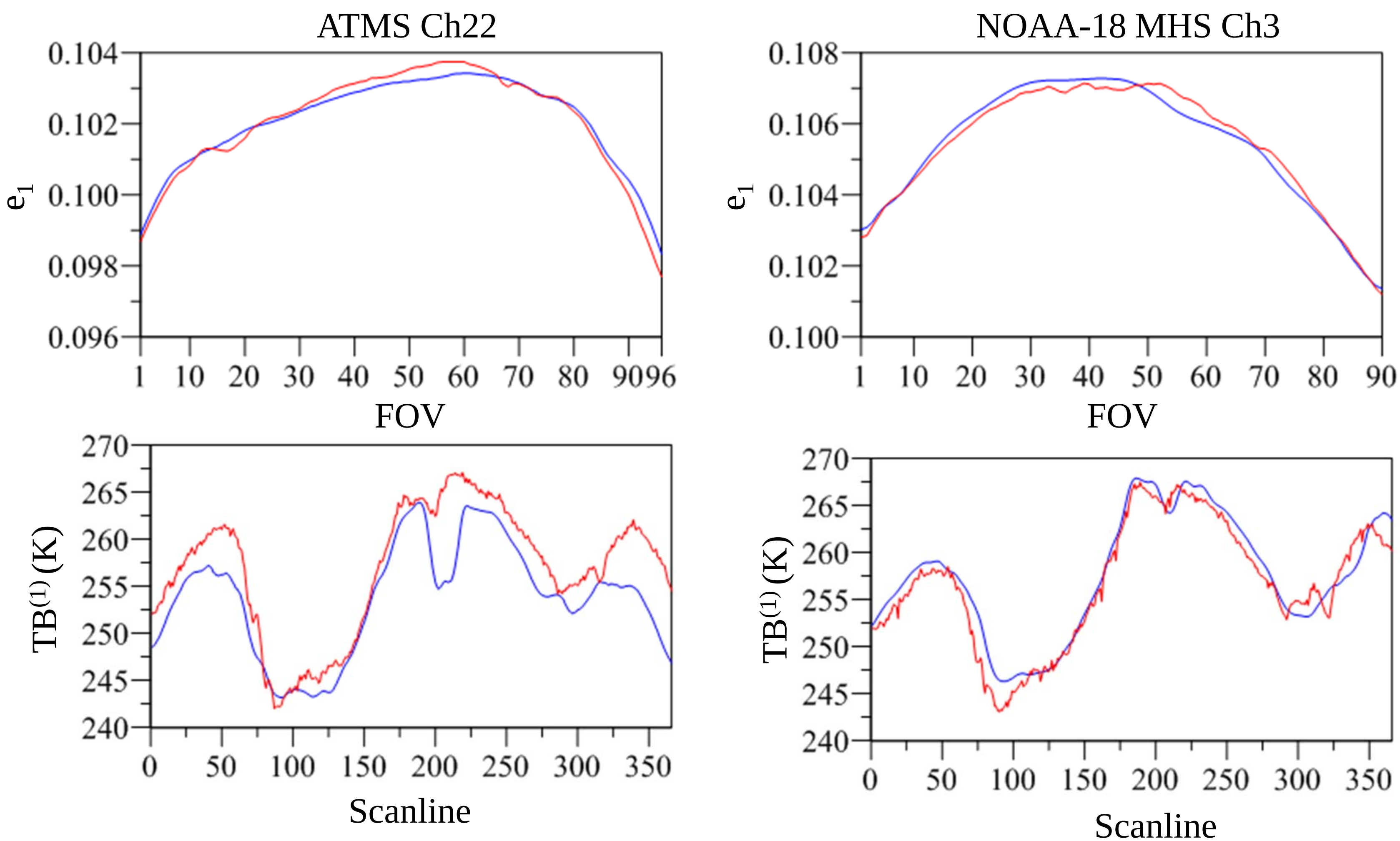
Obs and O-B of the TB



PCA modes of TB for ATMS Ch22



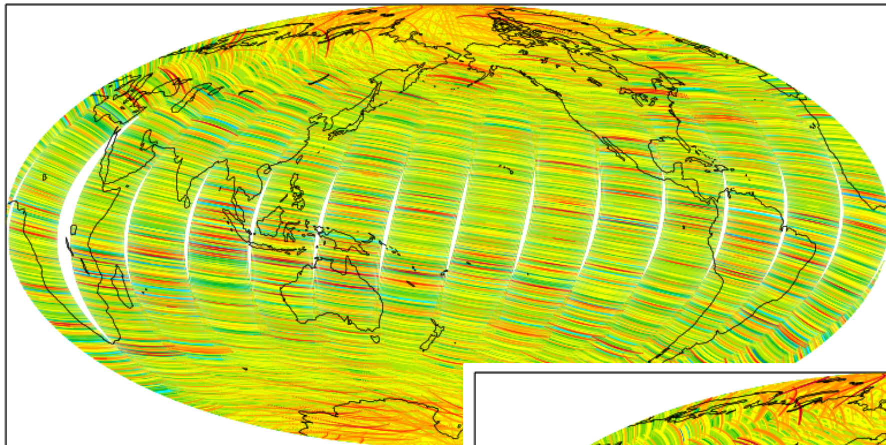
Eigenvector and TB at nadir



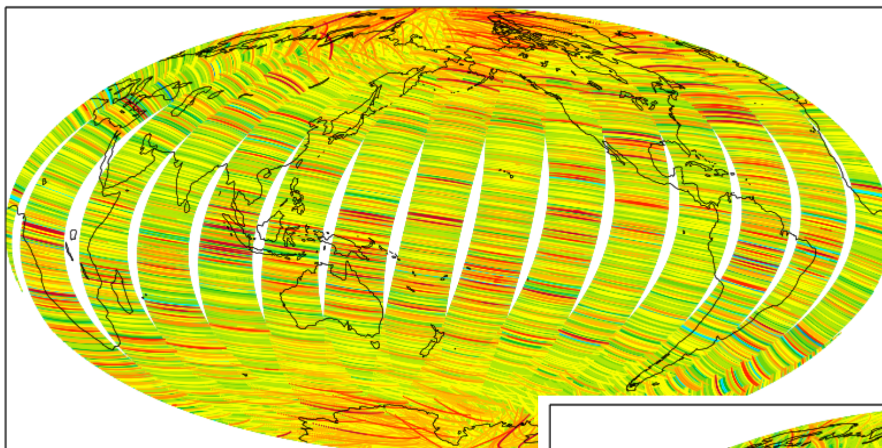
Striping noise can be found in both ATMS Ch22 and NOAA-18 MHS Ch3

Global distribution of stripping noise

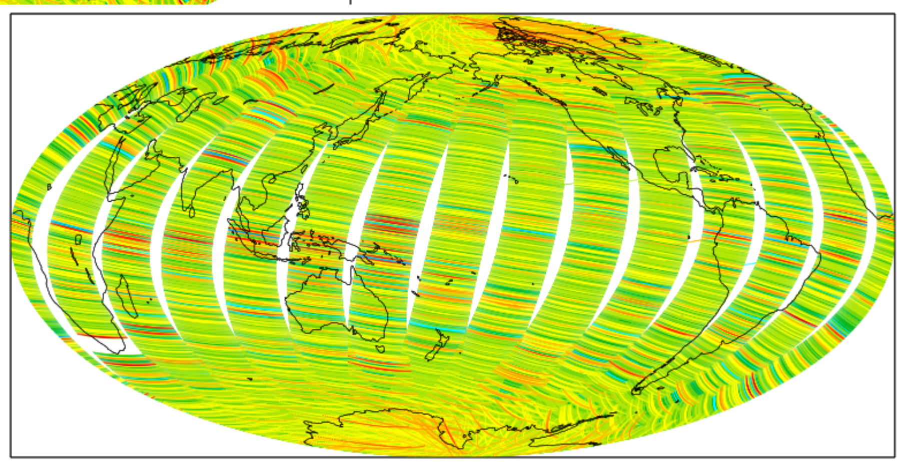
SNPP ATMS Ch 22



NOAA-18 MHS Ch3

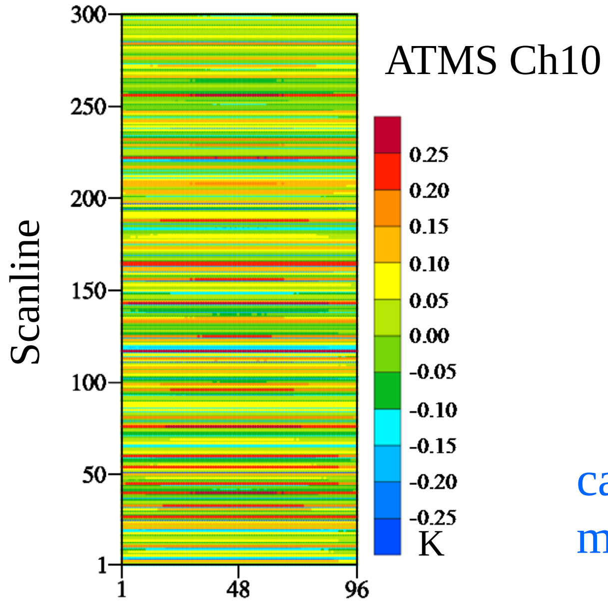


NOAA-16 AMSU-B Ch3

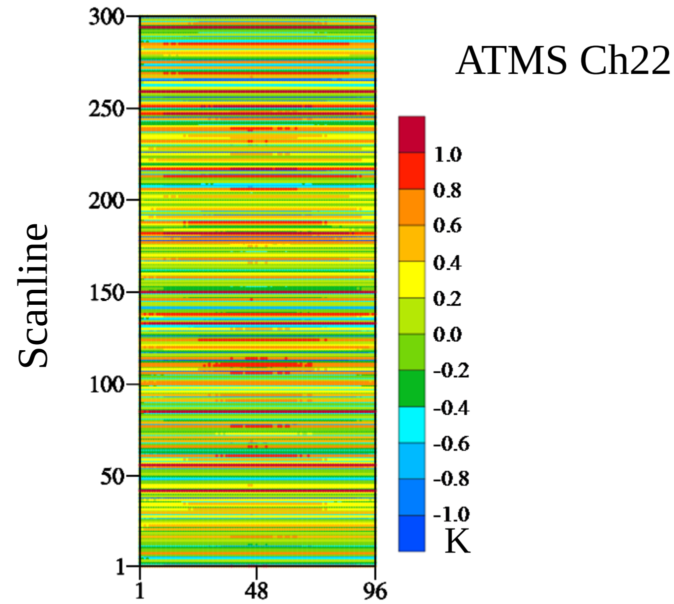


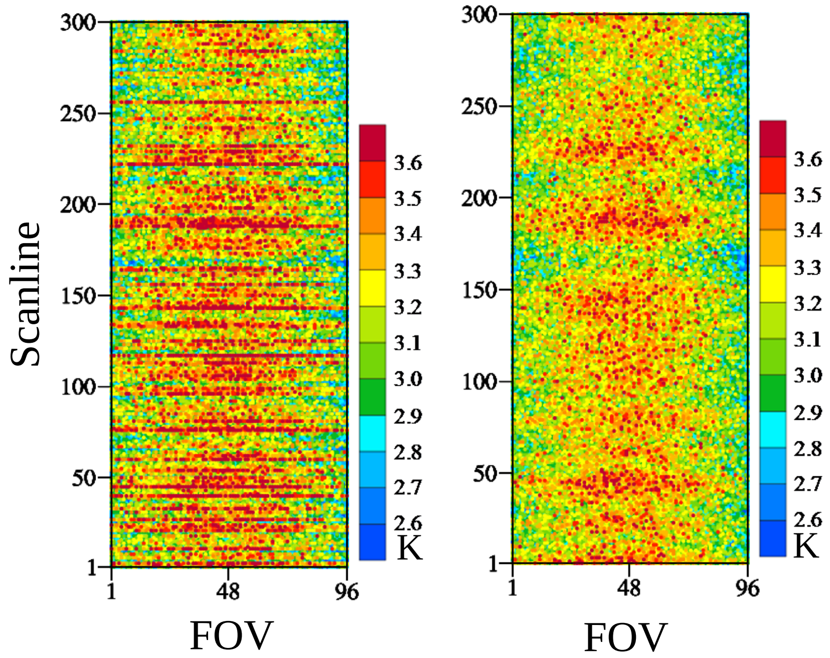
Stripping noises are stronger in ATMS and MHS, but weaker in AMSU-B.

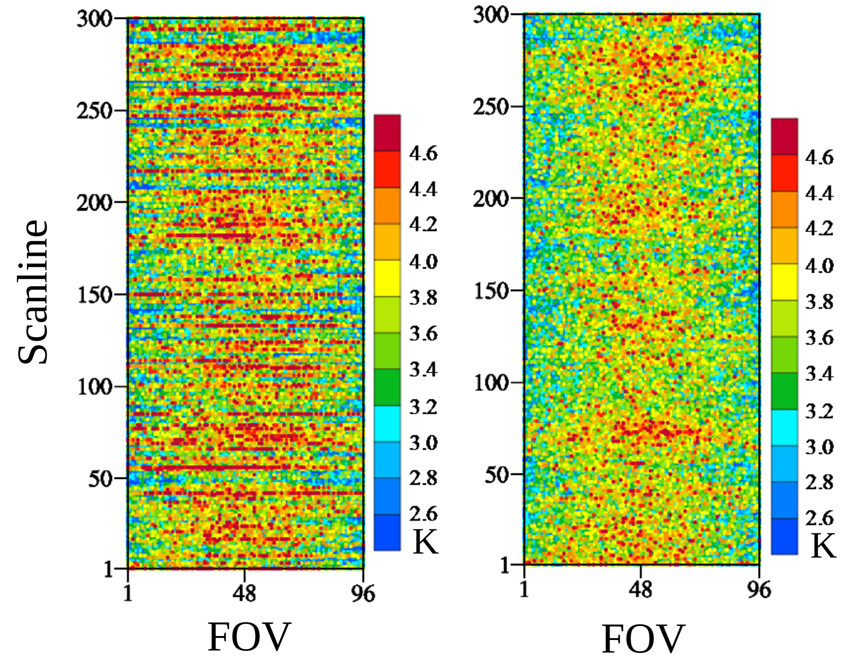
Striping noise of maneuver TB



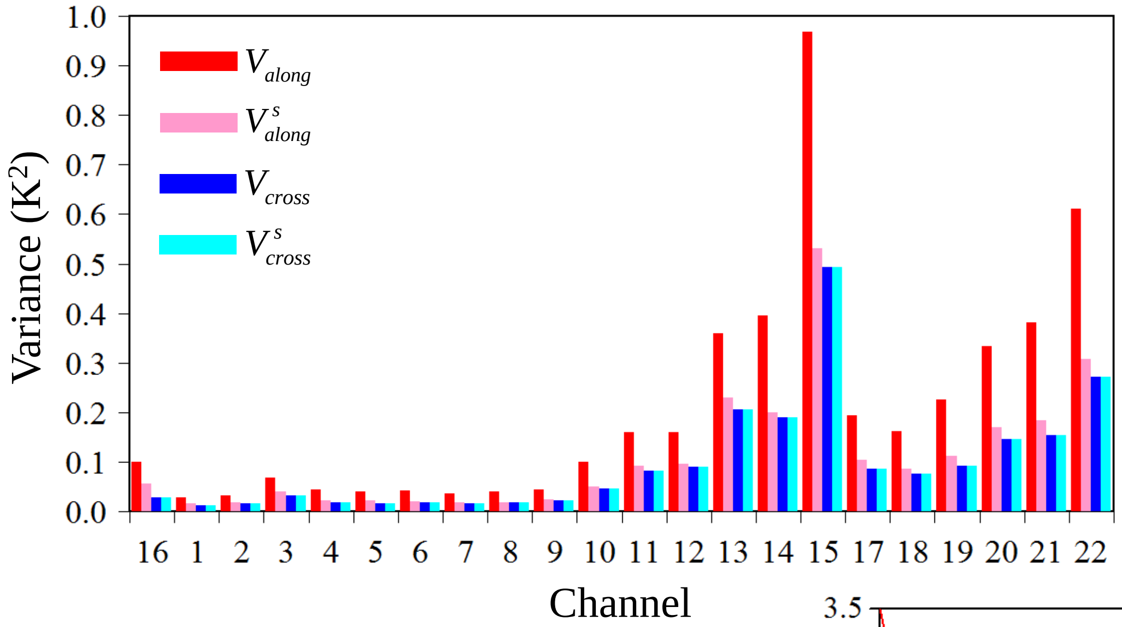
Stripping noise can be removed in maneuver data also.







Striping Index (SI) of maneuver TB



$$V_{along} = \frac{1}{N}\sum_{j=1}^{N}\left(\frac{1}{M}\sum_{k=1}^{M}\left(T_b(k,j) - \frac{1}{M}\sum_{k=1}^{M}T_b(k,j)\right)^2\right)$$

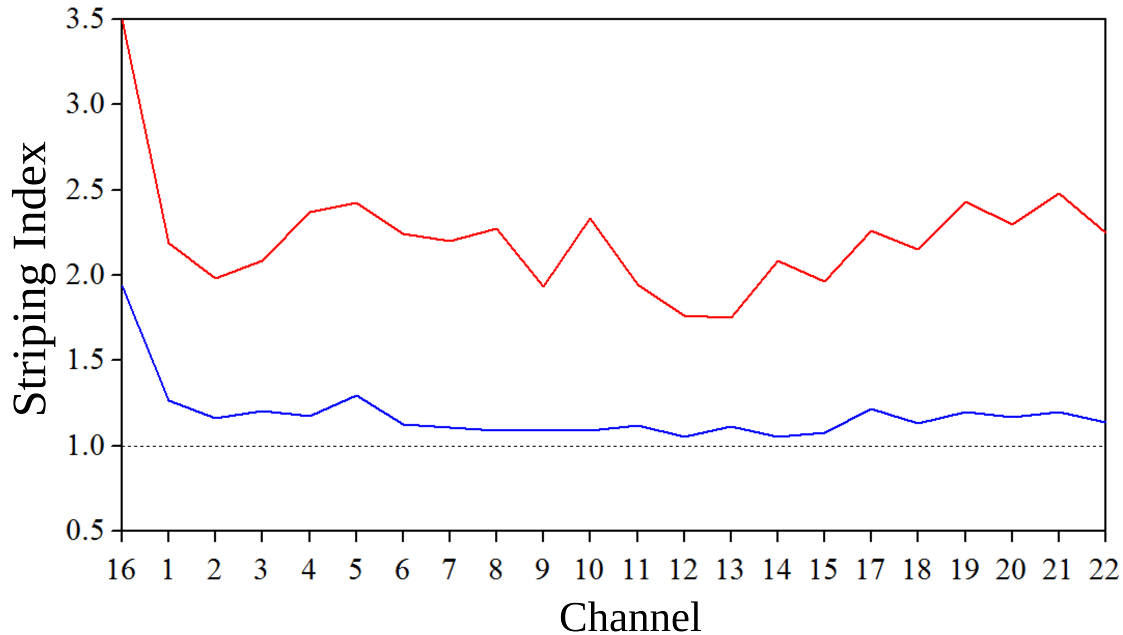
$$V_{cross} = \frac{1}{M}\sum_{k=1}^{M}\left(\frac{1}{N}\sum_{j=1}^{N}\left(T_b(k,j) - \frac{1}{N}\sum_{j=1}^{N}T_b(k,j)\right)^2\right)$$

$$SI = \frac{V_{along}}{V_{cross}}$$

along-track variance V_{along}

cross-track variance V_{cross}

Stripping Index (SI) is reduced to close to one. It shows that our method can removed stripping noise reasonably.



Summary

- For tempearture channels, ATMS's striping noise is much stronger than AMSU-A
- For water vapor channels, both ATMS and MHS (AMSU-B) have striping noise
- Method based on PCA and EEMD can filter the striping noise obviously and flexibly
- Root-cause and more accurate filters need further investigation

Thank you !

Questions ?