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Re-evaluation of Suomi NPP ATMS Destriping Algorithm for Surface-Sensitive Channels

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Outline

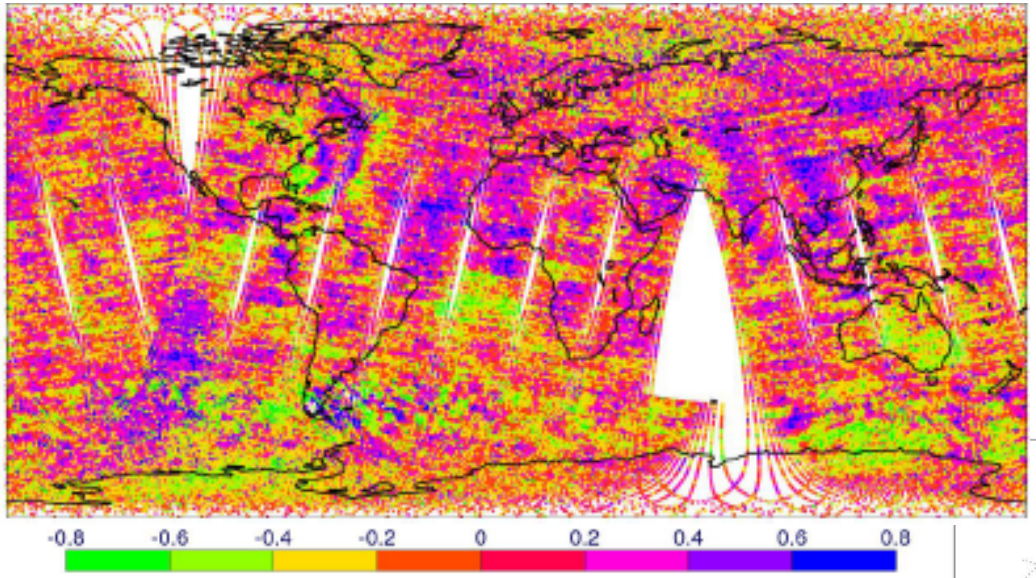
- A Recollection of ATMS Striping Noise
- Two Striping Noise Mitigation (SNM) Algorithms
  - — SDR data of ATMS sounding channels
  - — Pitch-over maneuver data of all ATMS channels
- Challenges for Surface-Sensitive Channels
  - — Artifacts are generated by the SNM when scanlines are aligned with coastal lines and edges of heavy precipitation
- Sensitivity Study
  - — Large jumps of TB are aligned with scanelines
  - — Large jumps of TB are aligned in along-track direction
- A potential solution
- Conclusions and Suggestions

A Recollection of ATMS Striping Noise

- SNPP ATMS upper air sounding channels display clear striping noise in NWP model O-B fields (Bormann et al., 2013), which caused discomfort for NWP users who didn't see this in AMSU-A — Finding
- Striping noise are also seen in prelaunch TVAC data and pitch maneuver data. They are characterized by a constant and random variation in ATMS's cross-track and along-track directions, respectively — Confirmed
- An innovative destriping algorithm was developed to eliminate the striping noise in ATMS brightness temperature observations (Qin et al., 2013) — Solution
- At the CGMS 19th International TOVS Study Conference (ITSC) held on Jeju Island, South Korea, March 26-April 1, 2014, NWP users requested the ATMS CalVal team to develop an operational algorithm for an elimination of the striping noise in ATMS radiance measurements — Requirement
- An operational destriping algorithm was developed that for an elimination of the striping noise in ATMS radiance measurements (Ma and Zou, 2015) — Solution
- ATMS CalVal team provided 45 days of ATMS de-striped data for EMC, ECMWF and other NWP centers to test the impacts of striping noise on ATMS data assimilation for NWP — Action

Striping Noise Found in Global O-B Fields for ATMS Temperature Sounding Channels

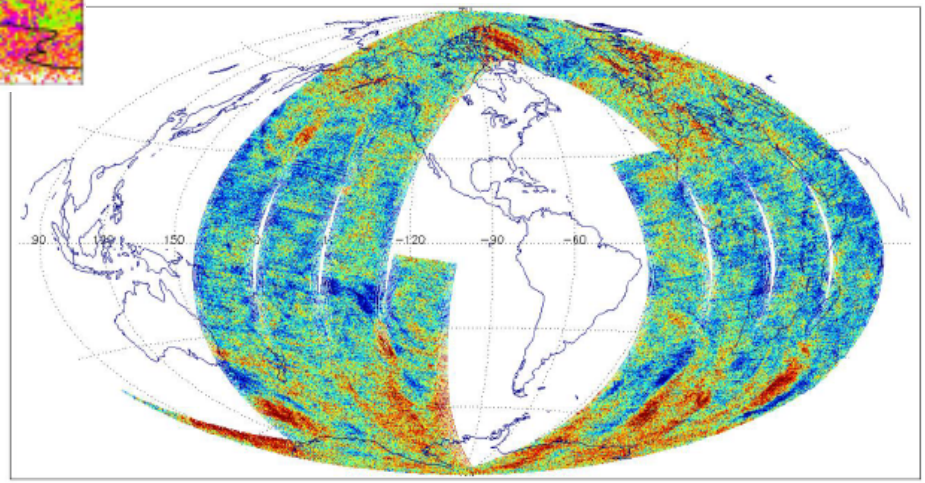
ATMS channel 12 (25 hPa) on 24 February 2012



(Bormann et al, 2013, ECMWF)

User Complains !

ATMS channel 8 (250 hPa)



(Swadley et al, NRL)

(2) The Success of the Striping Noise Mitigation

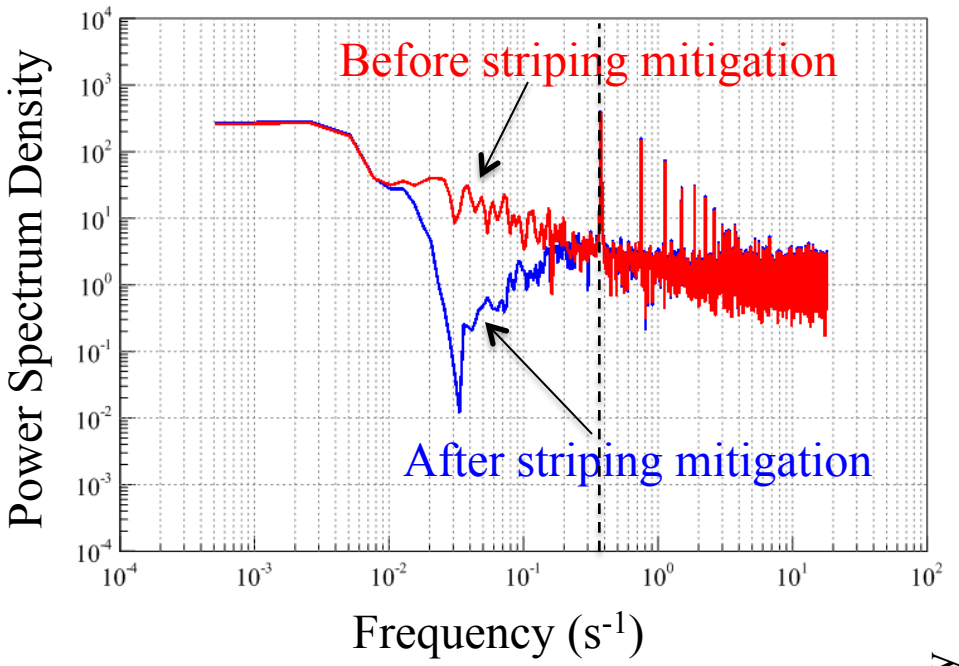
- SDR data of ATMS Temperature Sounding Channels
- Pitch-over Maneuver Data of All ATMS Channels

Qin, Z., X. Zou and F. Weng, 2013: Analysis of ATMS and AMSU striping noise from their earth scene observations. *J. Geophy. Res.*, **118**, 13,214-13,229.

Ma Y. and X. Zou, 2015: Striping noise mitigation in ATMS brightness temperatures and its impact on cloud LWP retrievals. *J. Geophy. Res.*, **120**, 6634-6653.

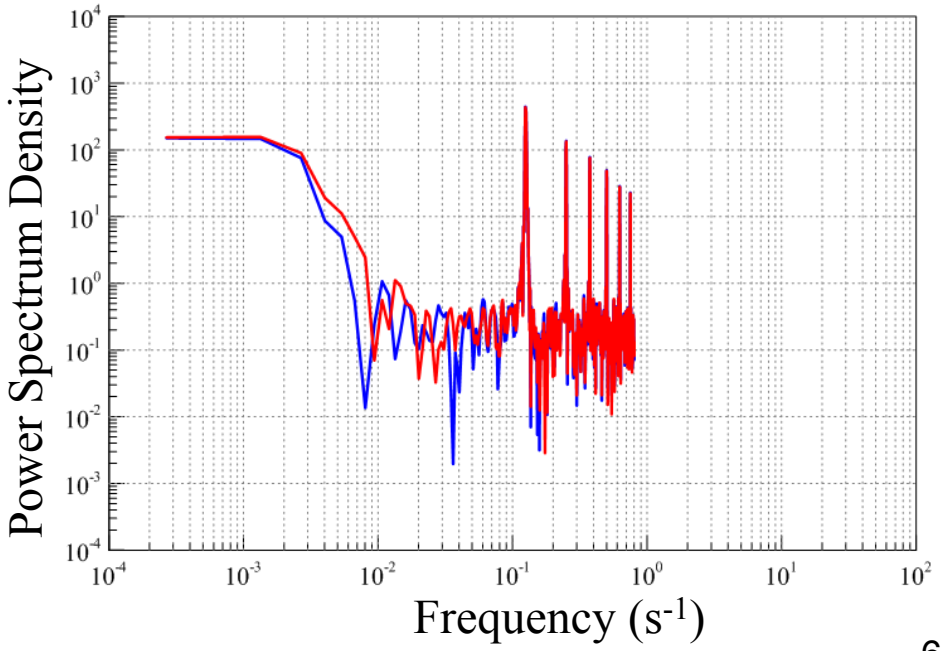
Power Spectral Density Distributions of Global O-B Fields

SNPP ATMS channel 10

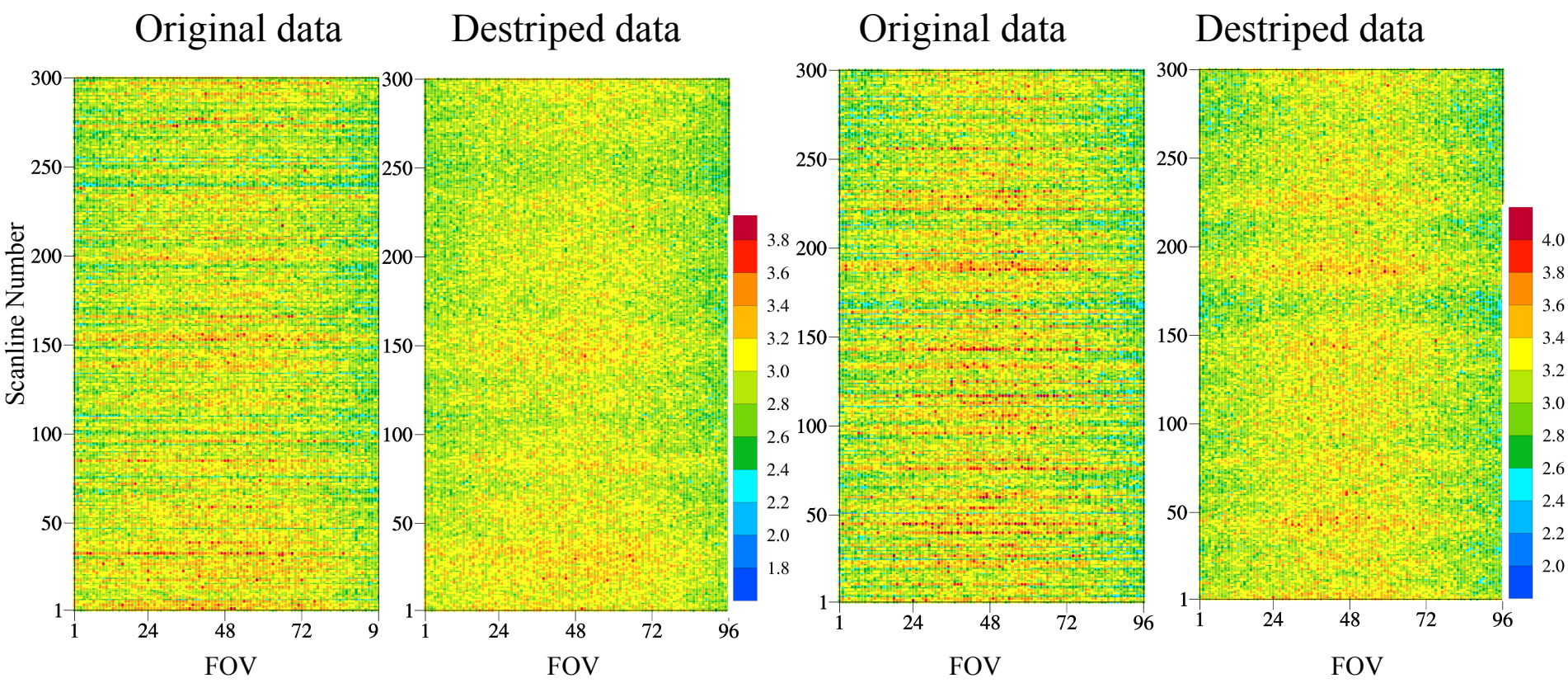


The ATMS power spectrum is significantly modified within frequency range 10^{-2} -0.375 s^{-1} by removing striping noise.

NOAA-18 AMSU-A channel 9

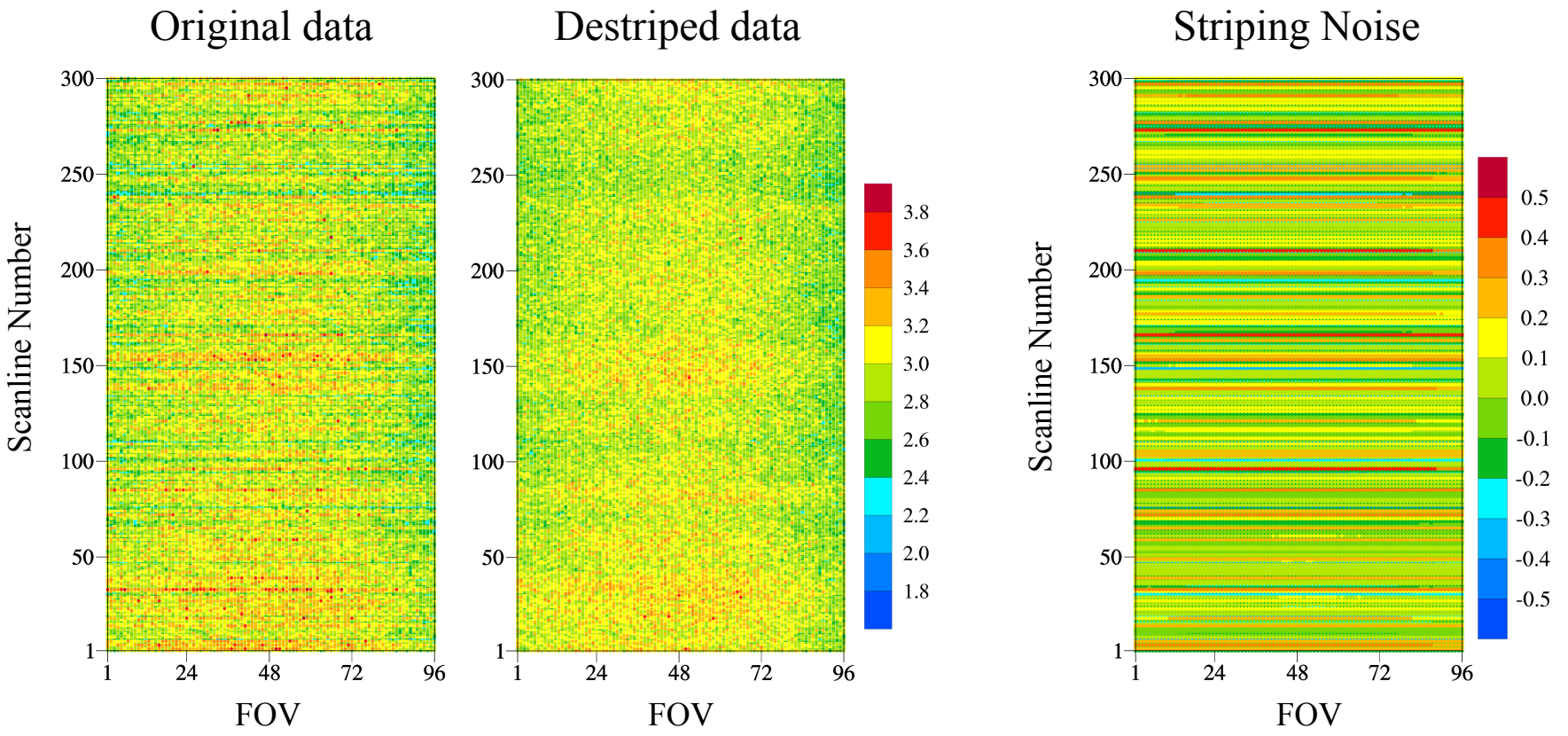


Striping Noise Mitigation for Pitch-Over Maneuver Data



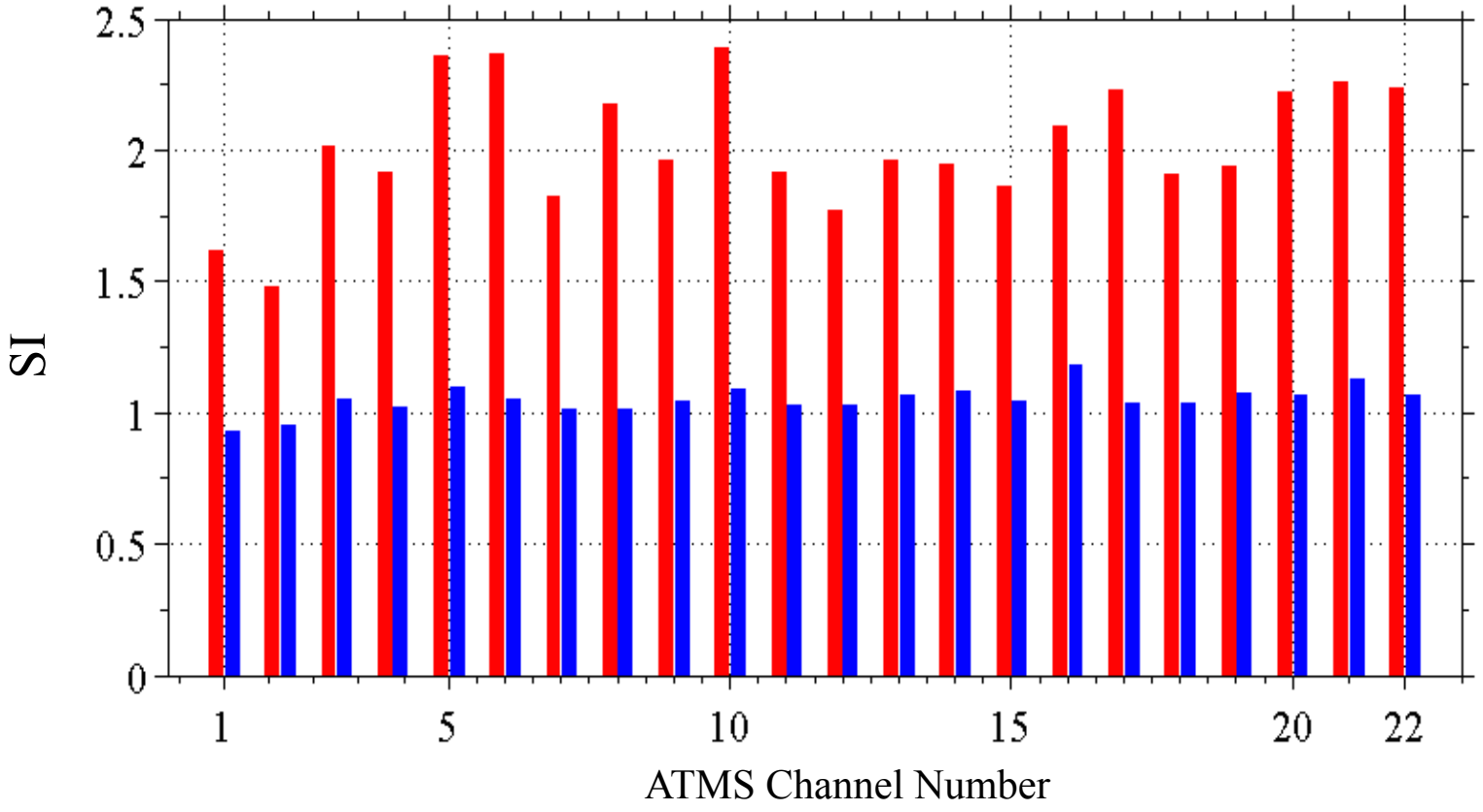
- Striping noise are visible in pitch-over maneuver data of all channels
- Striping noise are successfully eliminated by the mitigation algorithm

Striping Noise for Channel 3 Pitch-Over Maneuver Data



- The striping noise are less than 0.5 K and greater than -0.5 K
- The striping noise vary randomly in the along-track direction

Striping Index: $SI = \frac{\sigma^2_{along-track}}{\sigma^2_{cross-track}}$



- SIs for pitch-over maneuver data are greater than one
- SIs for destriped pitch-over maneuver data are around one

(3) Problems Encountered by Striping Noise Mitigation for ATMS Surface-Sensitive Channels

— Artefacts in the destriped dataset were found for surface-sensitive channels and reported by ECMWF

— The problems occurred for scanlines that are aligned with coastal curves and edges of heavy precipitation

ECMWF Finding:

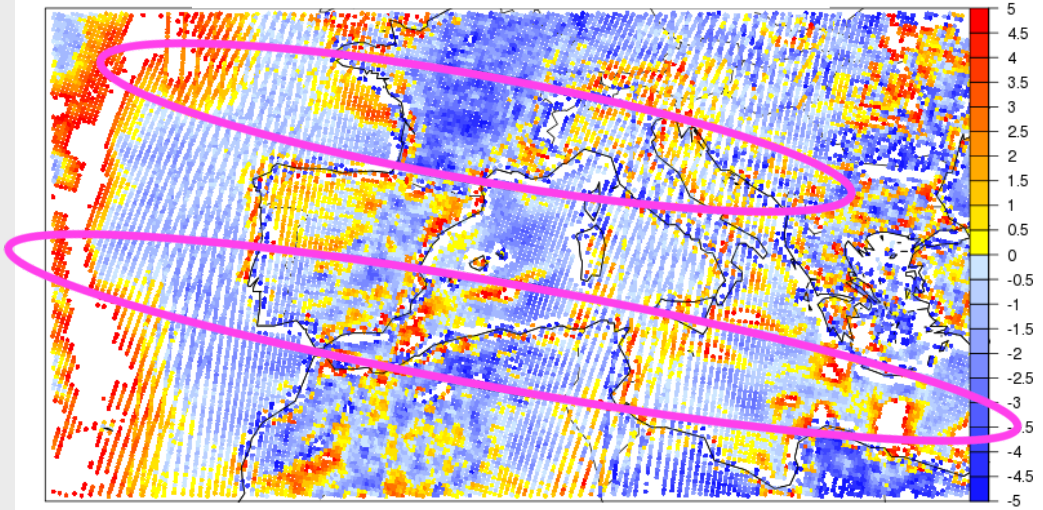
Artefacts Are Found in ATMS Destriped Dataset for Window Channels!

An evaluation of the destriped dataset at ECMWF lead to the following conclusions:

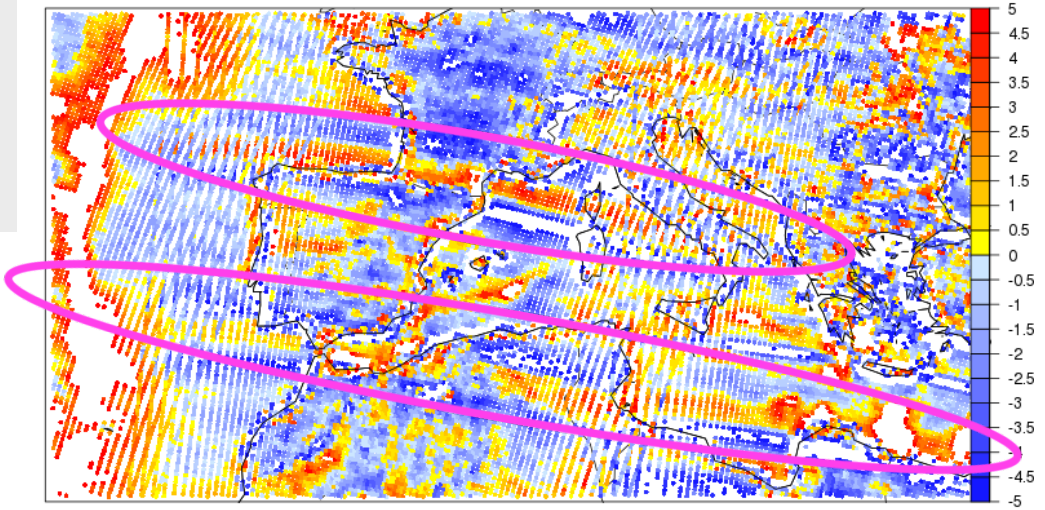
- Destriped dataset appears to reduce the striping for temperature-sounding channels
- Evidence of artefacts for window channels and lower humidity sounding channels in regions where there are sharp contrasts of Tb (e.g., terrain, cloud) that are aligned with ATMS scanlines
- The benefits of striping noise removal through post-processing are therefore not clear
- The striping noise should be avoided at source, i.e., at the instrument design level

The content on this slide comes from the talk by Dr. Heather Lawrence at "NOAA Worksop on JPSS Life-Cycle Data Reprocessing to Advance Weather and Climate Applications. May 17-18, 2016. ESSIC, College Park, MD.

$O\text{-}B^{clear\text{-}sky}$ (ATMS Channel 3)



$O^{destriped}\text{-}B^{clear\text{-}sky}$ (ATMS Channel 3)

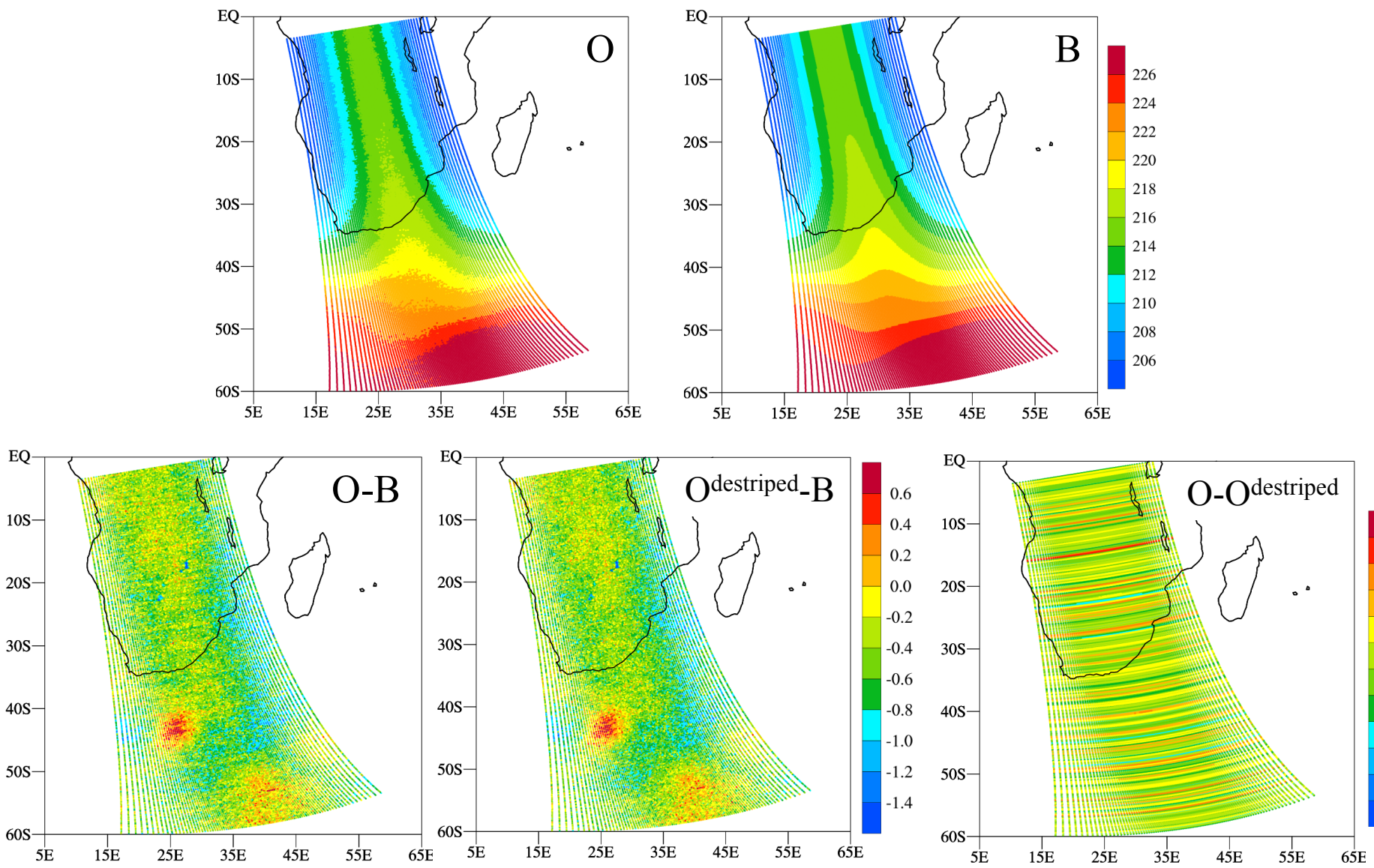


(4) Sensitivity Study

— Large jumps of TB that are aligned with scanelines

— Large jumps of TB that are aligned with a fixed FOV

TB Observations of ATMS Ch9 on 14 June 2016



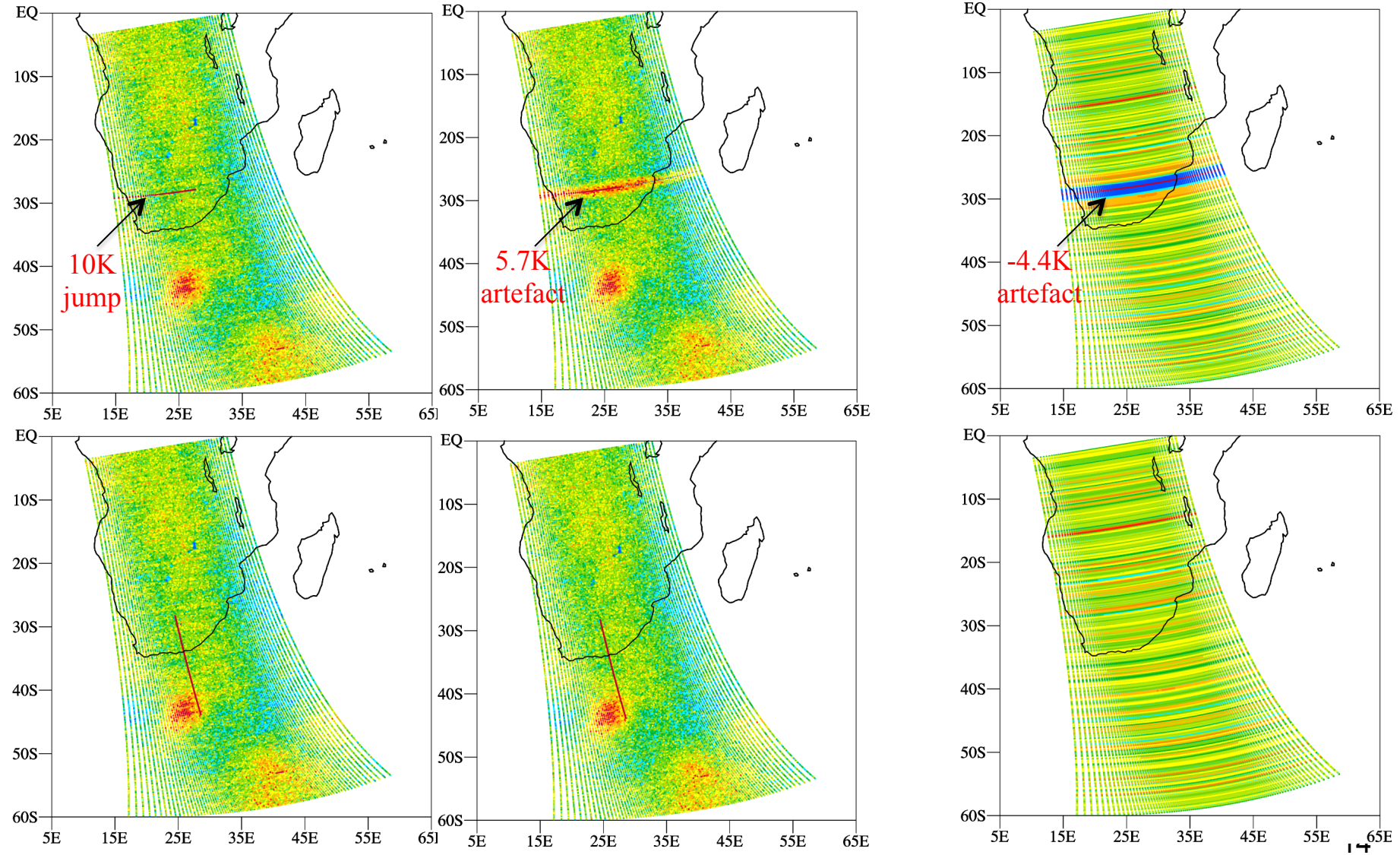
- Striping noise are visible in O and O-B fields
- Striping noise are successfully eliminated by the mitigation algorithm

Impacts of TB Jumps on Striping Noise

O-B (no destriping)

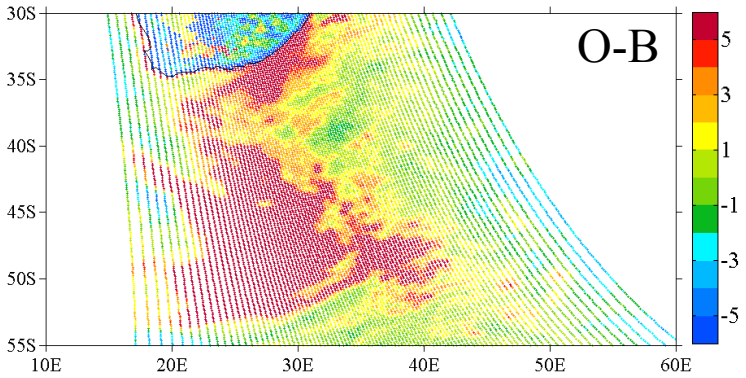
$O^{destriped}$-B (after destriping)

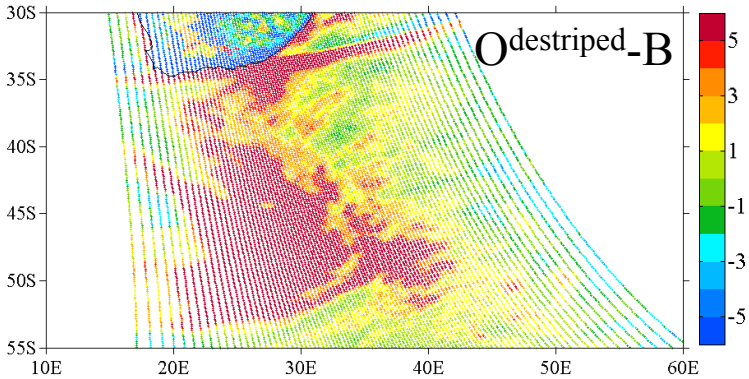
$O-O^{destriped}$, Striping noise

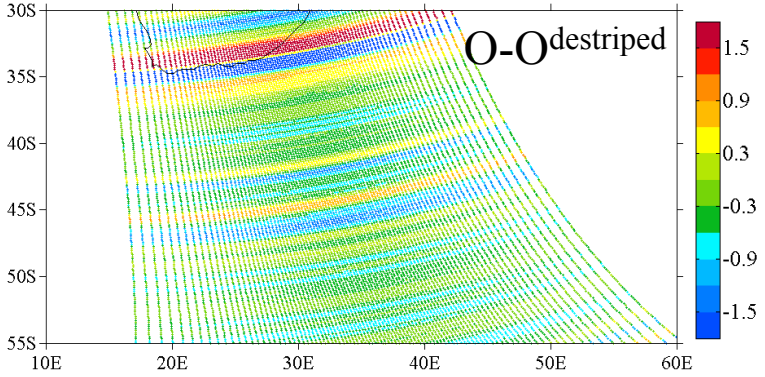


What Happened When TB Experienced a Jump?

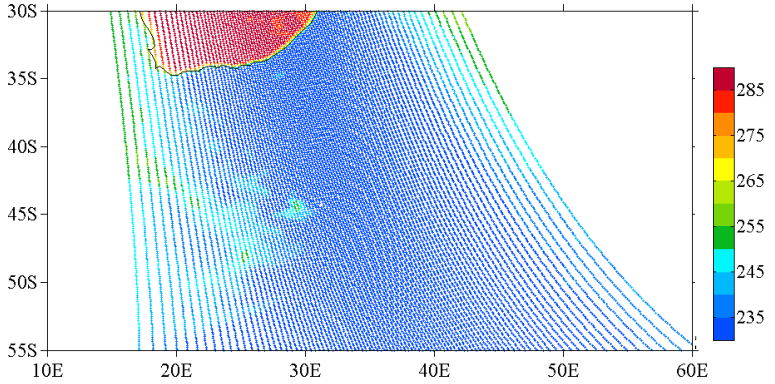
ATMS Channel 3 on January 2, 2013

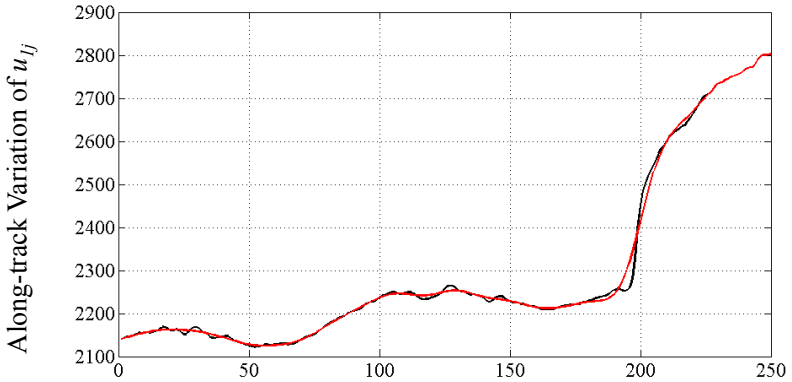


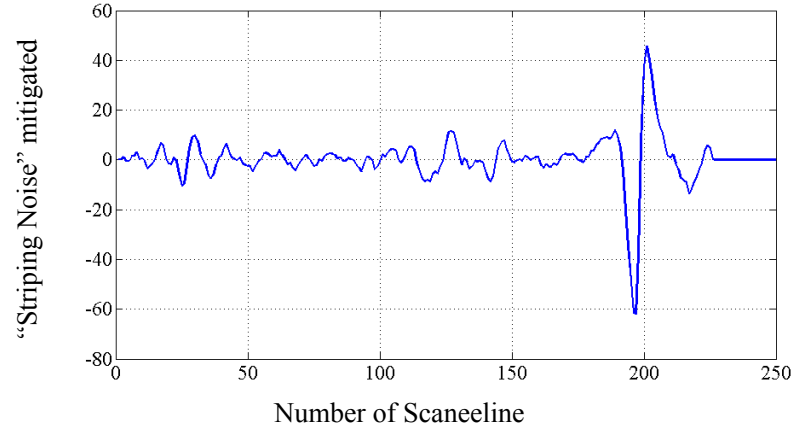




ATMS Observations







Proposed Modification I

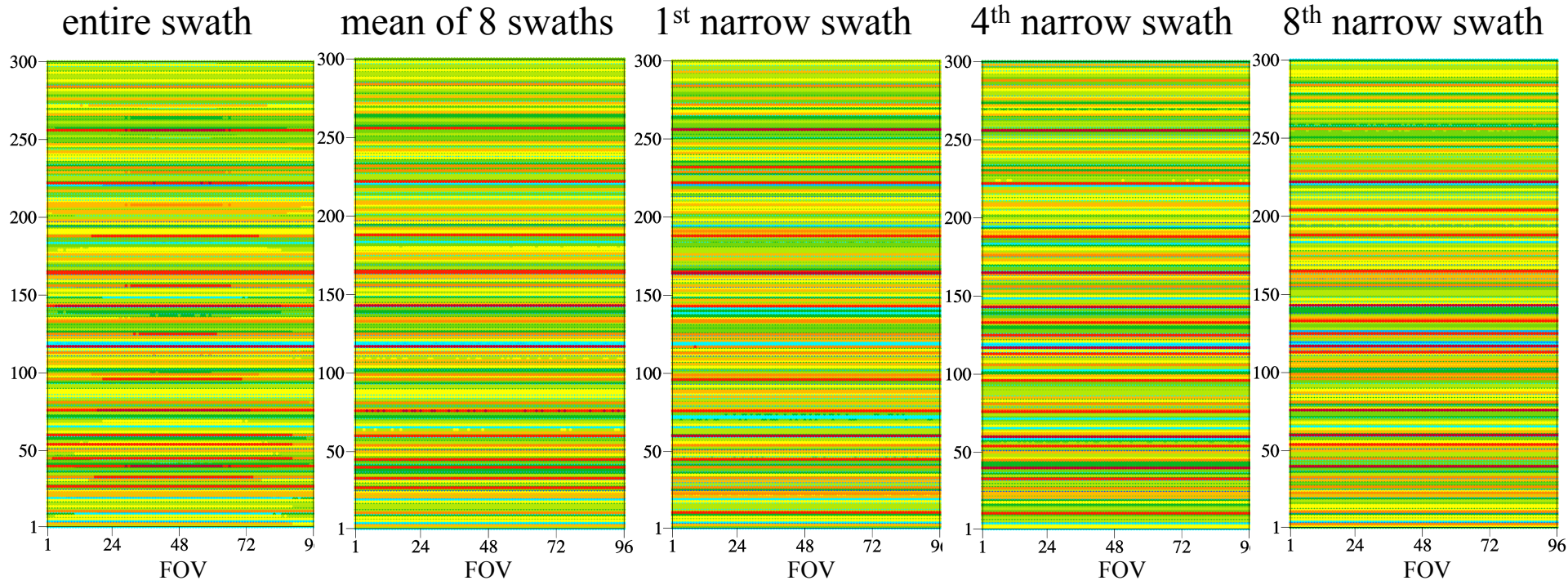
1) An ATMS swath is divided into eight parts. Each narrow swath part consists of 12 continuous FOVs.
2) The striping noise mitigation is applied to each narrow swath.
3) The striping noise of the part with the minimum standard deviation is taken as the striping noise of the entire swath.

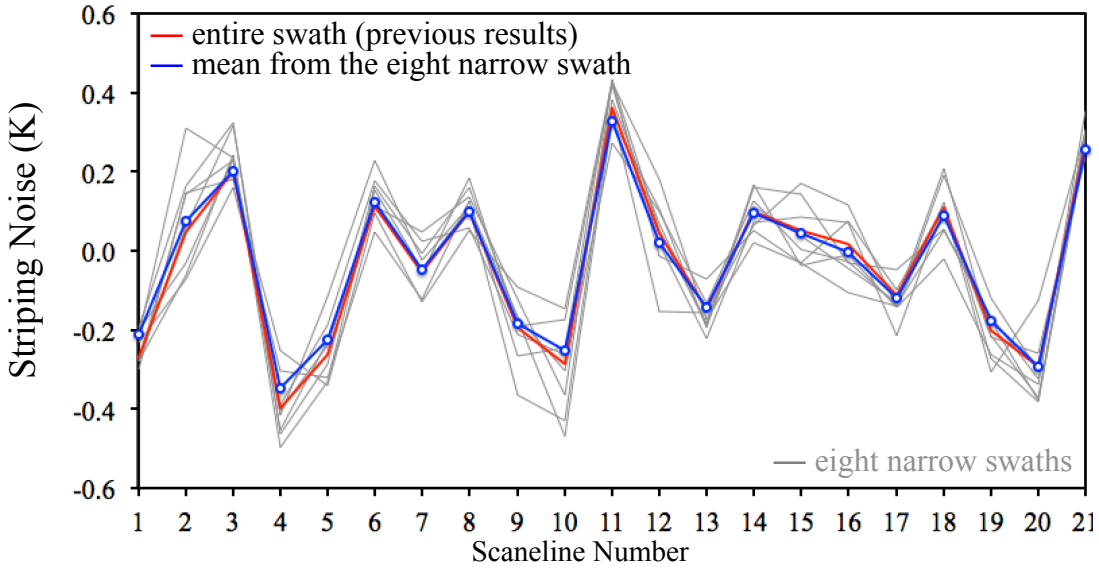
Motivation: Often only a portion of the ATMS scanline is aligned with coastal curves or edges of heavy precipitation.

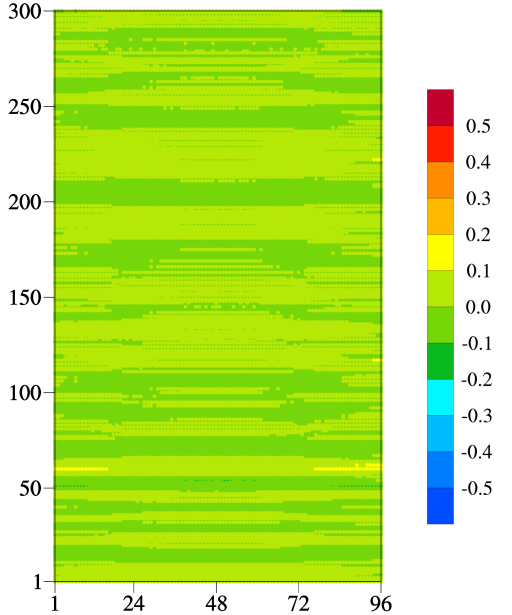
Applications:

- Use pitch-over maneuver data to confirm if the proposed modification works
- Apply the proposed modification to ATMS channel 3 data

Striping Noise in Pitch-Over Maneuver Data for Channel 10

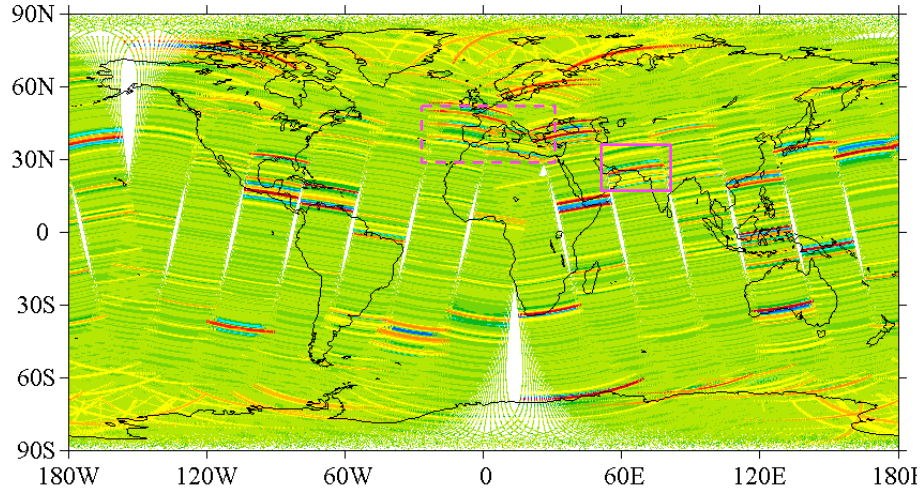




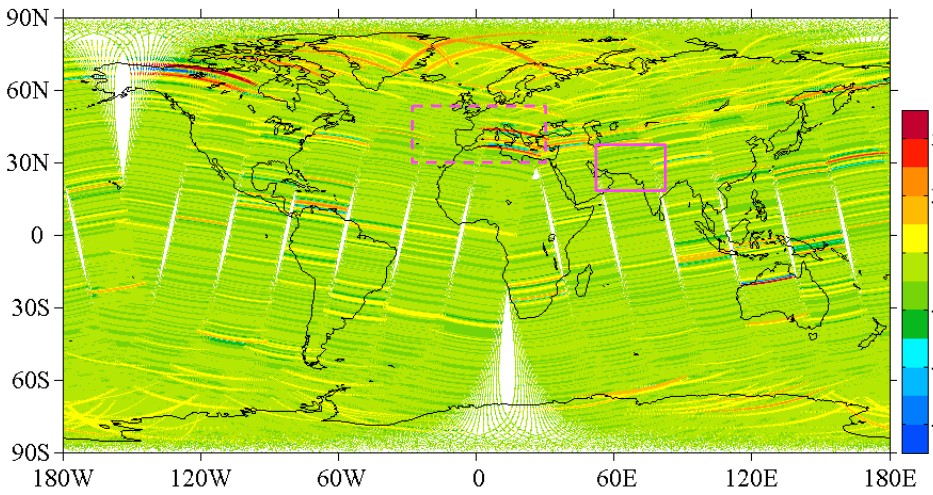


Striping Noise for ATMS Channel 3 on 2 January 2013

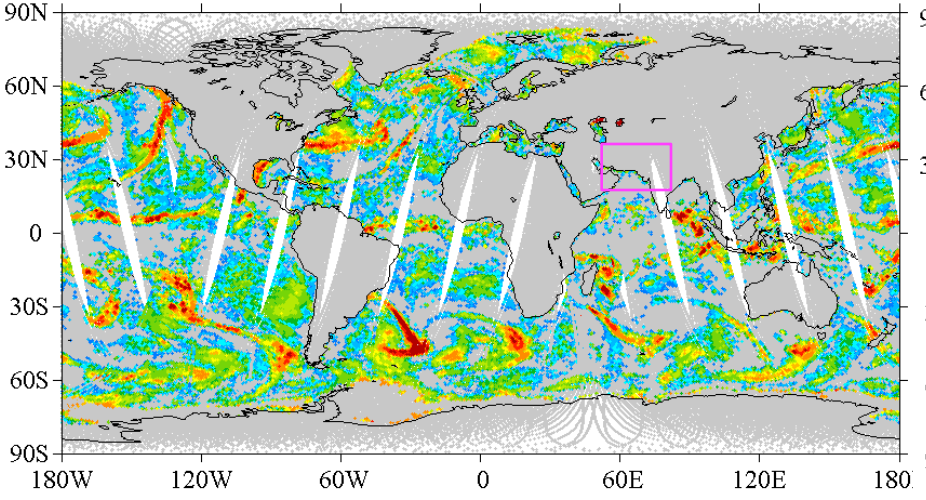
Striping Noise Previously Obtained



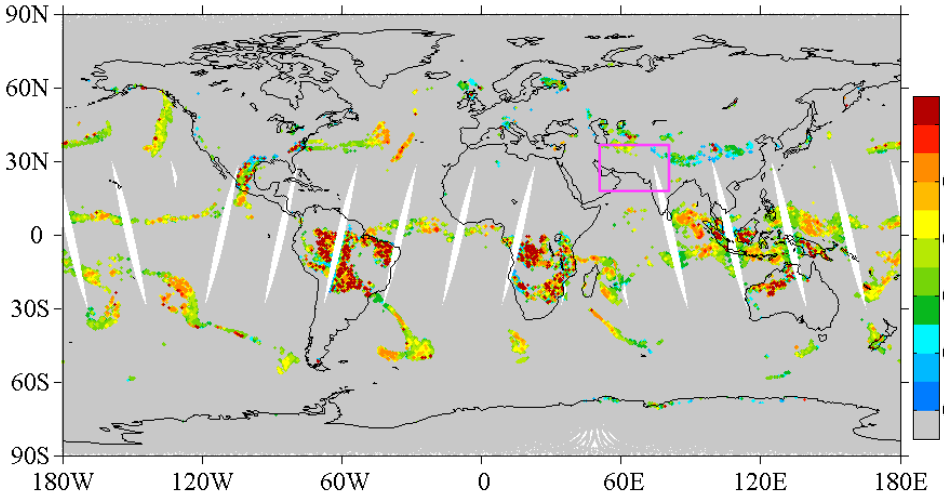
New Results



LWP



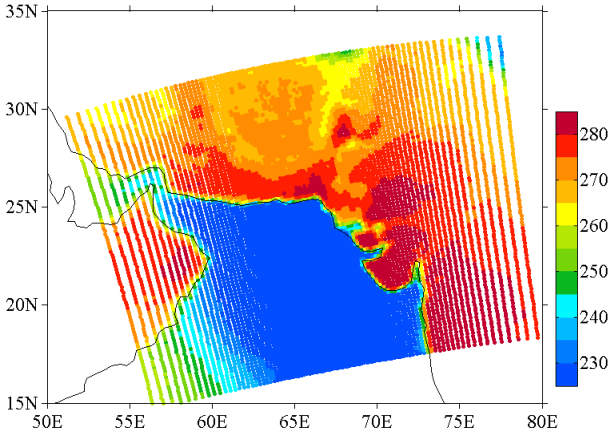
IWP



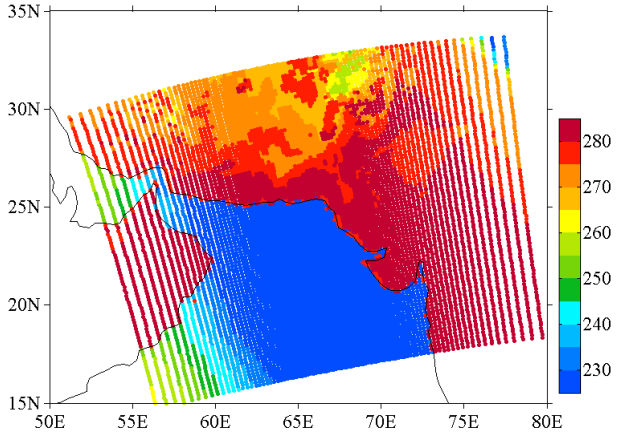
Striping noise of significant magnitudes are mostly eliminated by the proposed modification.

Applications of the Proposed Modification to Channel 3 Observations

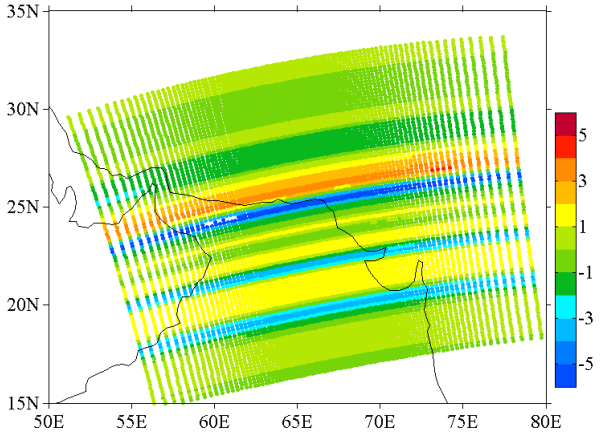
ATMS Observations



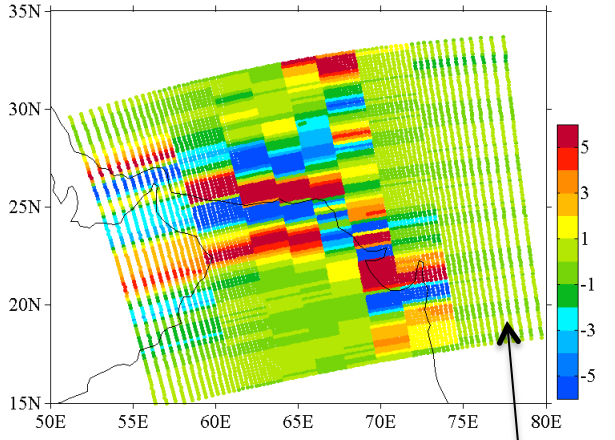
Model Simulation



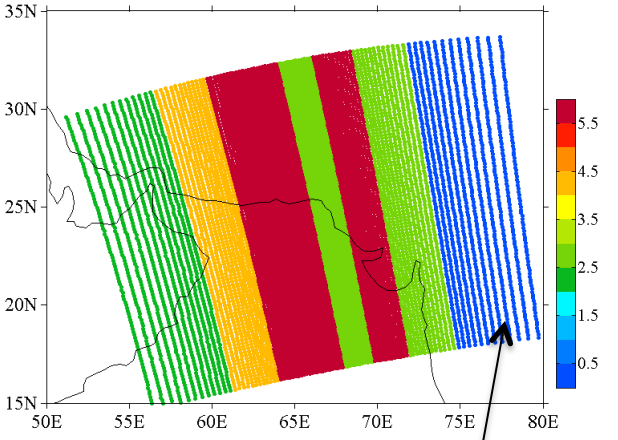
Wrong Striping Noise



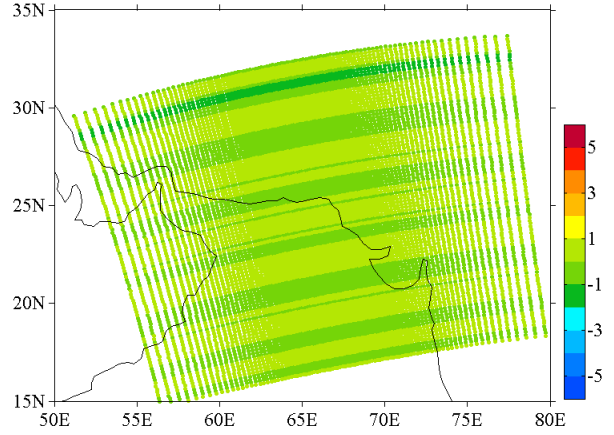
8 Swath Striping Noise



Standard Deviation



New Striping Noise



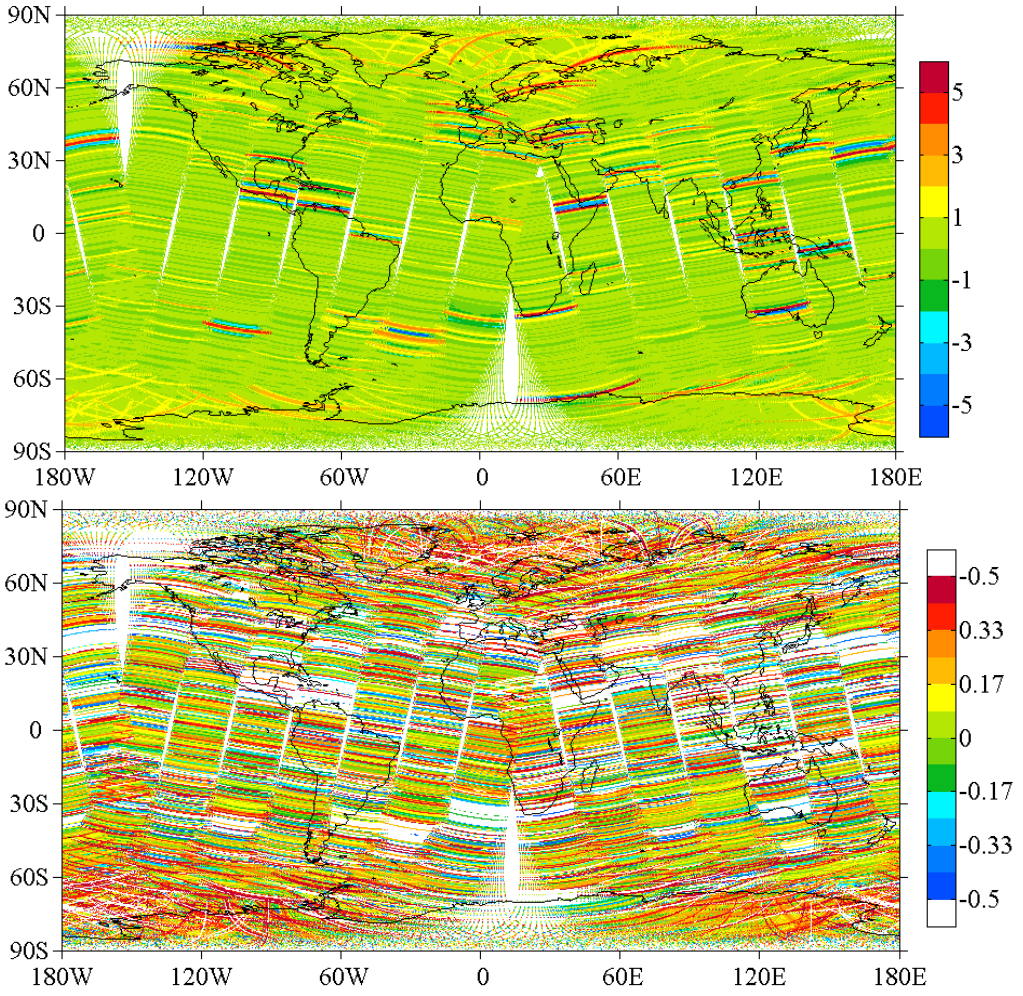
The eighth narrow swath is chosen for striping noise mitigation since it is not affected by a sharp land/ocean contrast and has the smallest standard deviation.

Proposed Modification II

Apply SNM to those scanelines with striping noise being less than 0.5 K.

The "striping noise" in ATMS channel 3 obtained previously

The "striping noise" in ATMS channel 3 obtained by removing those striping noise of magnitudes greater than ±0.5 K



Out of 16300 scanelines, about 6185 (37.9%) have outstanding striping noise.

Summary and Conclusions

- The striping noise mitigation problems found by ECMWF when ATMS channel 3 swaths pass over Europe with complicated land/ocean boundaries were confirmed. Same problems were found in other places over the globe.
- Similar problems of striping noise mitigation were also found over ocean in places with heavy precipitation.
- The causes for the striping noise to be elevated were carefully analyzed by a sensitivity study. It was shown that such problems occur when large jumps of TB are aligned with ATMS scanelines.
- It is suggested that the striping noise mitigation could only be done for those ATMS scanlines for which at least a portion of the scaneline (greater than 1/8) is not aligned with coastal curves or edges of heavy precipitation. Even in this case, a modified implementation of the striping noise mitigation is required to avoid impacts of large jumps in TB for noise mitigation.
- Given the fact that the dynamic ranges of O-B variations are much larger than the striping noise for window channels and lower temperature and humidity sounding channels, striping noise mitigation is not as critical as for upper-level sounding channels and could be avoided.

Acknowledgement

This work was supported by NOAA JPSS Proving Ground Program.