ATMS Optimal Striping Filters

X. Zou\textsuperscript{1}, Y. Ma\textsuperscript{1} and F. Weng\textsuperscript{2}

\textsuperscript{1}Department of EOAS, Florida State University
\textsuperscript{2}Center for Satellite Applications and Research, NOAA

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Outline

• ATMS TDR/SDR Striping Issues
• User Complains
• Requirements for Characterization and Correction
• AMSU-A/MHS/AMSU-B
• ATMS Striping (TVAC, Pitchover Data, Earth Scene ...)
• De-striping Methodology
• Optimal Striping Filters for Radiances
• Optimal Striping Filters for Calibration Counts

The ATMS data can then be expressed as in PCA:

$$ A = \sum_{j=1}^{96} \mathbf{r}_e \mathbf{r}_u \mathbf{j} $$

PC mode  PC coefficient

$$ A = \begin{bmatrix}
TB_{1,1} & TB_{1,2} & \cdots & TB_{1,j} & \cdots & TB_{1,K} \\
TB_{2,1} & TB_{2,2} & \cdots & TB_{2,j} & \cdots & TB_{2,K} \\
\vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\
TB_{k,1} & TB_{k,2} & \cdots & TB_{k,j} & \cdots & TB_{k,K} \\
\vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\
TB_{96,1} & TB_{96,2} & \cdots & \cdots & \cdots & TB_{96,K}
\end{bmatrix}_{M \times K} $$

- $M$ - total number of scanlines
- $K$ - total number of scanlines
The First Three IMFs of ATMS Ch10 Obs.

The 1st IMF

The 2nd IMF

The 3rd IMF

The 1st PC Component at Nadir

Original data

After taking away the three IMFs

Power Spectrum Density

Frequency (s⁻¹)
The Optimal Striping Filters: Mathematical Formula

The first PC coefficient

\[ \{u_{1,k}\}_{k=1,2,L,K} \]

The filtered first PC coefficient

\[ \bar{u}_{1,k} = \sum_{n=-N}^{N} \alpha_n u_{1,k+n}, \quad \alpha_n = \alpha_{-n} \]

\[ u_{1,k} = \sum_{m=0}^{K-1} C_m e^{-i\frac{2\pi mk}{K}} \]

\[ \bar{u}_{1,k} = \sum_{m=0}^{K-1} \bar{C}_m e^{-i\frac{2\pi mk}{K}} \]

\[ r_m = \sum_{n=0}^{N} \alpha_n \cos(2\pi f \Delta t) \]

\[ \bar{C}_m = r_m \bar{C}_m, \quad f = \frac{m}{K\Delta t}, \quad \Delta t = \frac{8}{3} s \]

\[ \min_{\alpha_n} J = \min \sum_{k=1}^{K} \left( \sum_{n=-N}^{N} \alpha_n u_{1,k+n} - \bar{u}_{1,k}^{eemd} \right)^2 \]

\[ \sum_{n=-N}^{N} \alpha_n = 1, \quad \alpha_n = \alpha_{-n} \]

where

\[ \bar{u}_{k,1}^{eemd} = u_{k,1} - \sum_{m=1}^{L} IMF_m(k) \]

\[ T_{\text{destriping}}^{b,k,i} = e_{1,i} \sum_{n=-N}^{N} \alpha_n u_{1,k+n} + \sum_{j=2}^{96} e_{j,i} u_{j,k} \]

where

\[ r \neq 1,2,L,96 \quad \text{represents scan position} \]

\[ r \neq 1,2,L,K \quad K \text{ represents scan line} \]
Power Spectrum Density of the First Seven IMFs and Residuals of ATMS Brightness Temperatures

The total number of IMFs removed are two for channels 1-2 and three for channels 3-22.

Decision:
The Optimal Striping Filters: Numerical Results

This is a set of optimal filters for ATMS radiances designed to smooth out the striping noise but not to alter lower frequency weather signals.

Cost Function ($J$)

$$J = \sum_{k=1}^{K} \left( \sum_{n=-N}^{N} \alpha_n u_{1,k+n} - \bar{u}_{1,k}^{eemd} \right)^2$$

Filter Span ($N$)

Power Spectrum Density

$$r_m = \sum_{n=0}^{N} \alpha_n \cos(2\pi f \Delta t)$$

Frequency ($f$, unit: s$^{-1}$)
Variation of Cost Function $J$ with Filter Span

$$J = \sum_{k=1}^{K} \left( \sum_{n=-N}^{N} \alpha_n u_{1,k+n} - \bar{u}_{1,k}^{eemd} \right)^2$$
Optimal Weighting Coefficients

\[ J = \sum_{k=1}^{K} \left( \sum_{n=-N}^{N} \alpha_n u_{1,k+n} - \overline{u}_{1,k}^{eemd} \right)^2 \]
Response Functions of the Optimal Striping Filters

\[ r_m = \sum_{n=0}^{N} \alpha_n \cos(2\pi f \Delta t) \]

Power Spectrum Density vs. Frequency (\( f, \) unit: \( s^{-1} \))
Striping noise Spectrum removed by the optimal striping filters

Global O-B Spectrum with and without Applying the Optimal Striping Filter
Global O-B Distributions of ATMS Channel 8

Before

After

Before minus After

Striping noise
Pitch-Over Maneuver Data with and without Optimal Filtering

ATMS Channel 1

ATMS Channel 9
Striping Index (SI)

\[ SI = \frac{V_{\text{along}}}{V_{\text{cross}}} \]

Along-track variance

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

Cross-track variance

\[ V_{\text{cross}} = \frac{1}{M} \sum_{k=1}^{M} \left( \frac{1}{N} \sum_{j=1}^{N} \left( T_b(k, j) - \frac{1}{N} \sum_{j=1}^{N} T_b(k, j) \right)^2 \right) \]
Striping Index (SI) of Pitch-Over Maneuver Data

Variance of down-track (VDT), variance of cross-track (VCT), and striping index (SI) before (red) and after (blue) applying the optimal striping filter.

SI is significantly reduced to one for ATMS all channels.
Summary

• Twenty two optimal striping filters are developed for 22 ATMS channels

• Two months of de-striping ATMS data are being produced for NWP impact test
Future Plan

Similar optimal striping filters will be developed for calibration counts, and impact of striping noise on NEDT will be quantified.