ATMS Optimal Striping Filters

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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

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.

PCA Decomposition for ATMS Channel 10

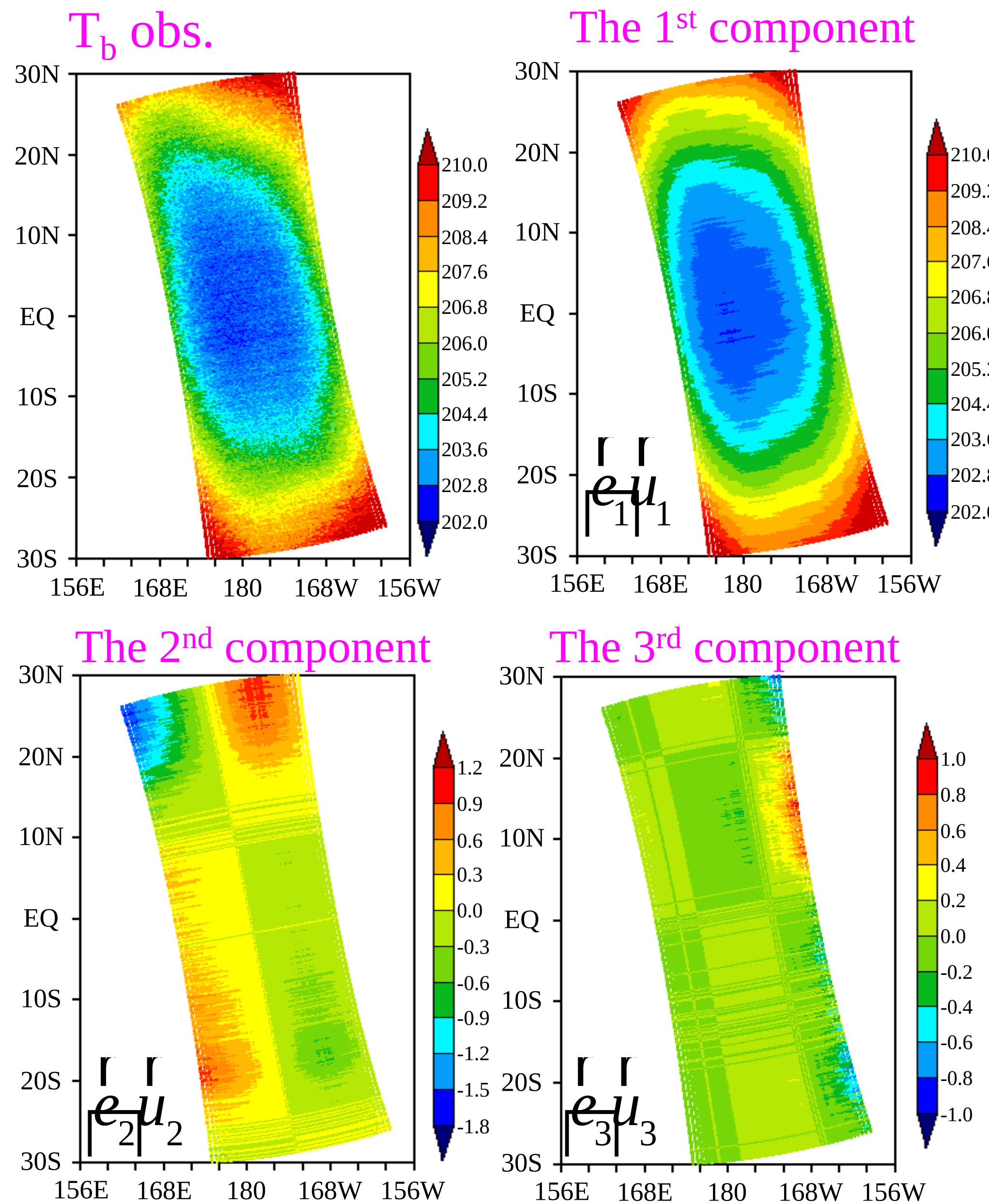
The ATMS data can then be expressed as in PCA:

$$\mathbf{A} = \sum_{j=1}^{96} \vec{e}_j \vec{u}_j$$

PC mode PC coefficient

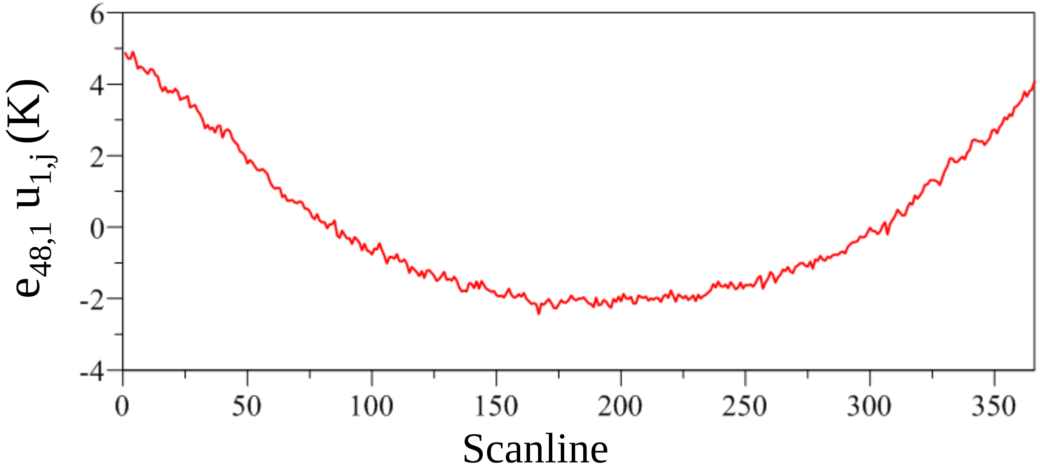
$$\mathbf{A} = \begin{pmatrix} TB_{1,1} & TB_{1,2} & \cdots & TB_{1,j} & \cdots & TB_{1,K} \\ TB_{2,1} & TB_{2,2} & \cdots & TB_{2,j} & \cdots & TB_{2,K} \\ \vdots & & \ddots & & & \\ TB_{k,1} & & & TB_{k,j} & & TB_{k,K} \\ \vdots & & & & \ddots & \\ TB_{96,1} & & & & & TB_{96,K} \end{pmatrix}$$

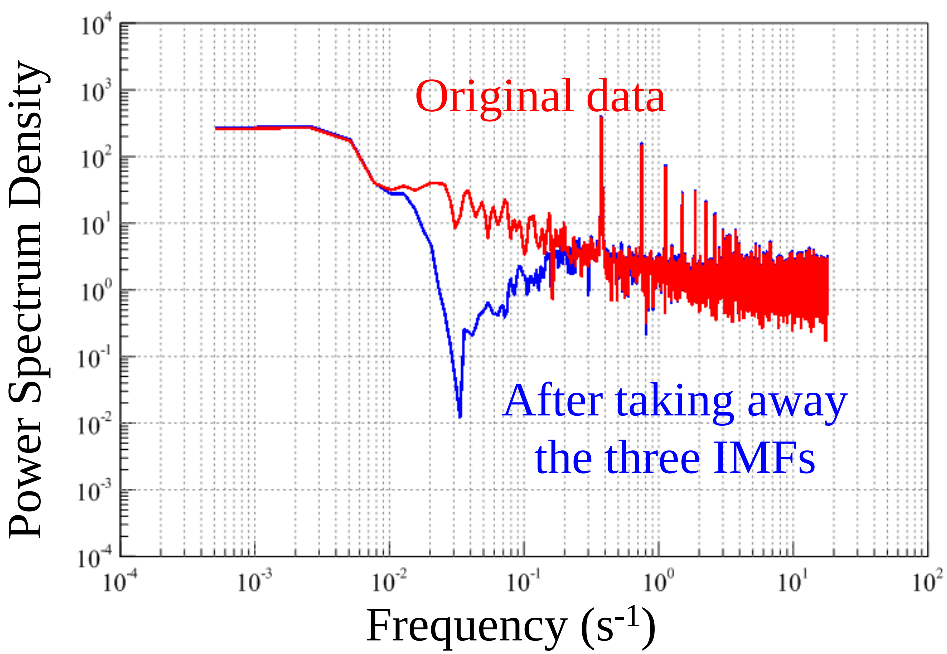
K -total number of scanlines



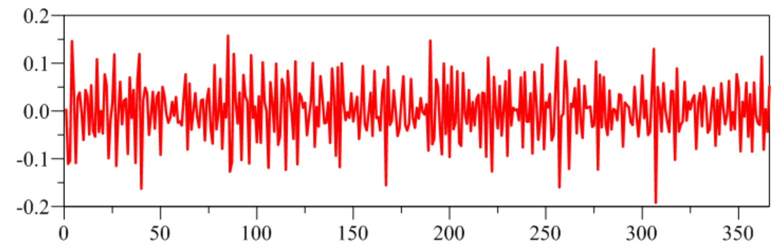
The First Three IMFs of ATMS Ch10 Obs.

The 1st PC Component at Nadir

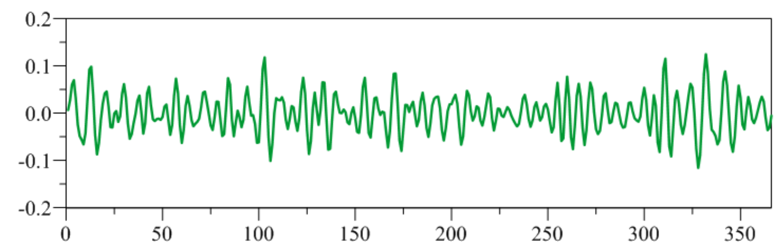




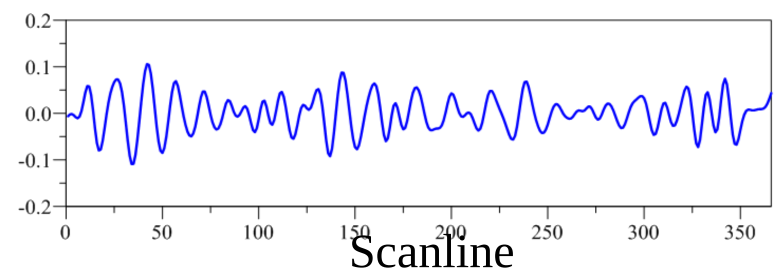
The 1st IMF



The 2nd IMF



The 3rd IMF



The Optimal Striping Filters: Mathematical Formula

The first PC coefficient

$$\{u_{1,k}\}\ (k = 1,2,\ldots,K)$$

$$\begin{cases} \min_{\alpha_n} J = \min \sum_{k=1}^{K} \left(\sum_{n=-N}^{N} \alpha_n u_{1,k+n} - \bar{u}_{1,k}^{eemd} \right)^2 \\ \sum_{n=-N}^{N} \alpha_n = 1, \quad \alpha_n = \alpha_{-n} \end{cases}$$

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

The filtered first PC coefficient

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

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

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

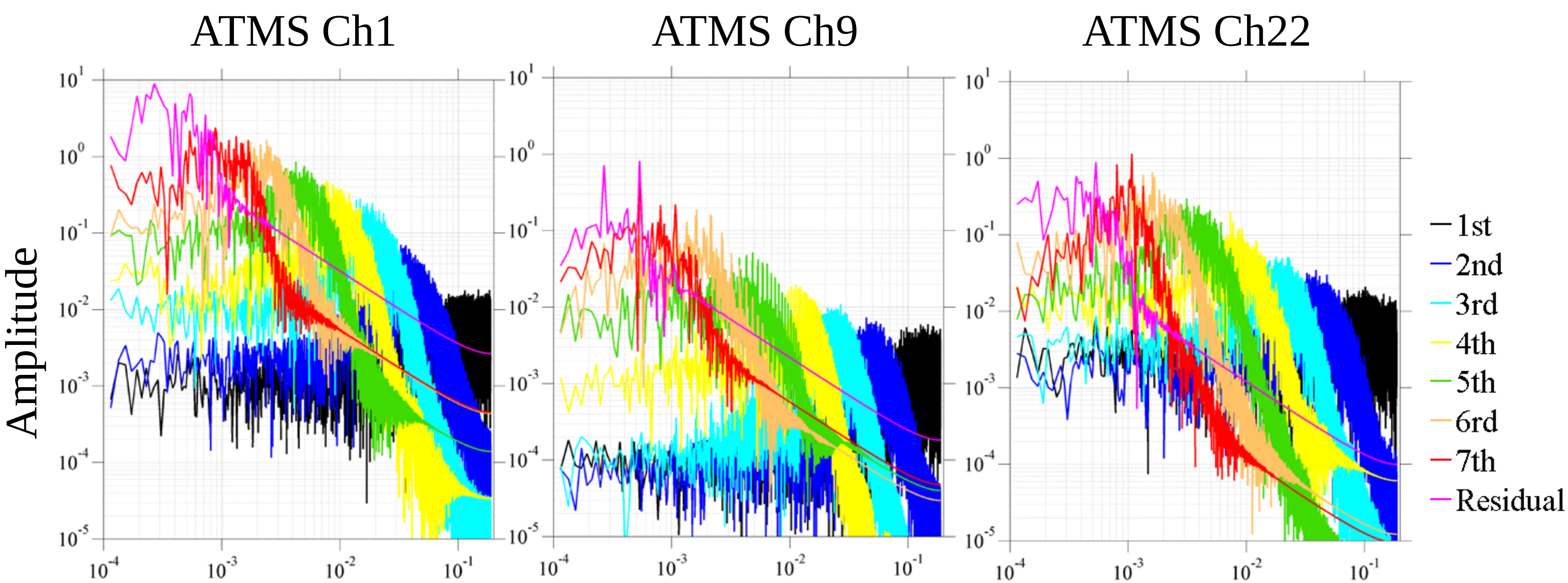
$$\bar{C}_m = r_m C_m, \; f = \frac{m}{K\Delta t}, \Delta t = \frac{8}{3} s$$

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

$i = 1,2,\ldots,96$ represents scan position

$k = 1,2,\ldots,K$ represents scan line

Power Spectrum Density of the First Seven IMFs and Residuals of ATMS Brightness Temperatures

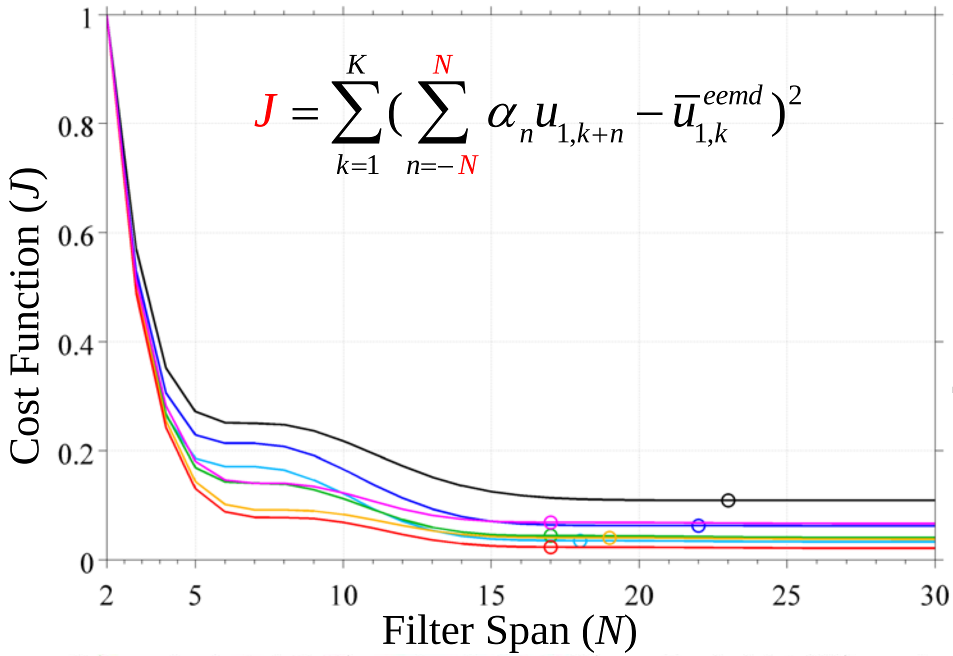


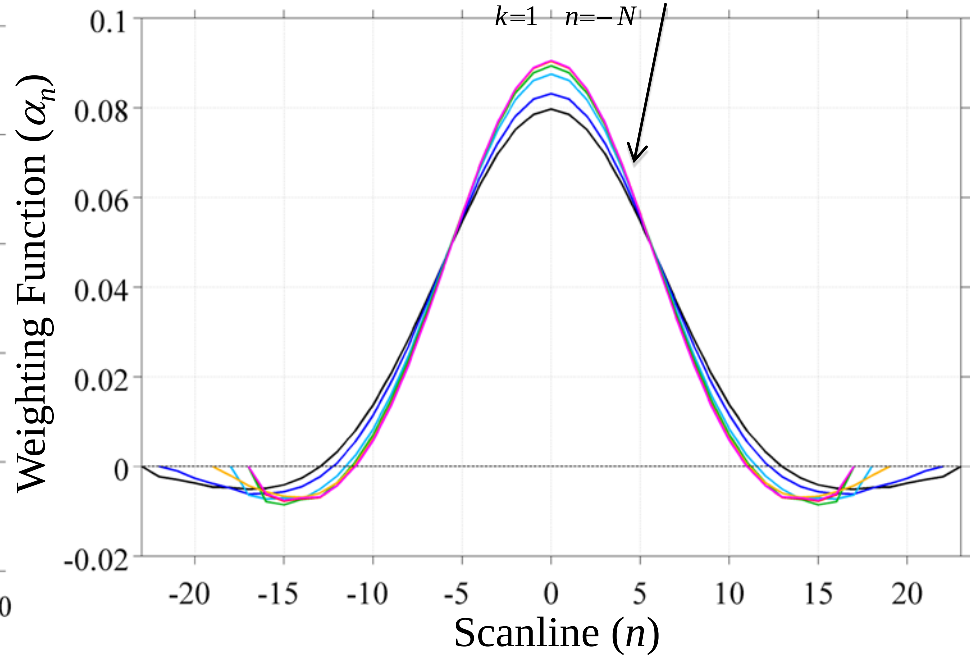
Decision:

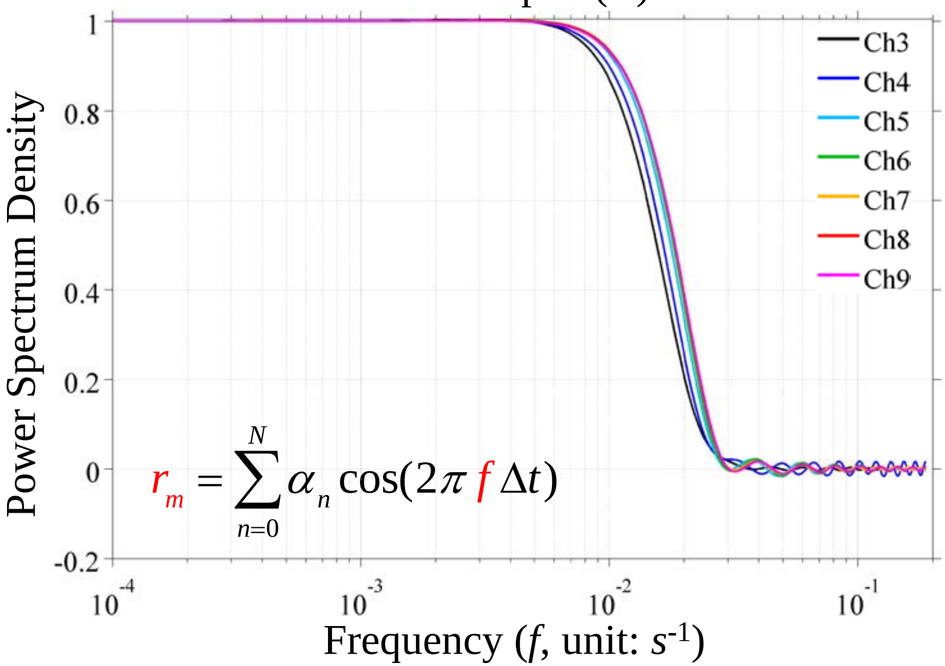
The total number of IMFs removed are two for channels 1-2 and three for channels 3-22.

The Optimal Striping Filters: Numerical Results

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



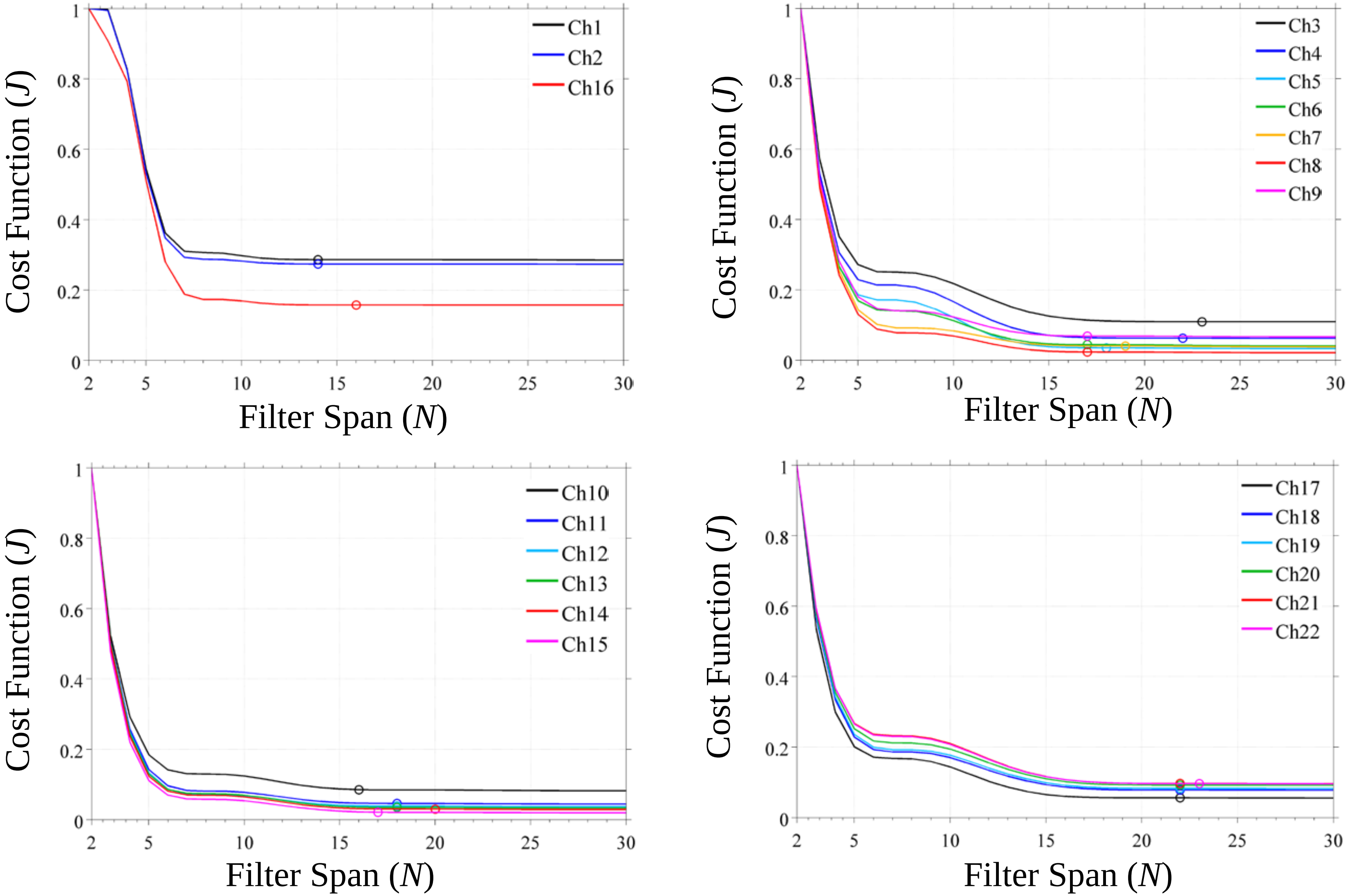




This is a set of optimal filters for ATMS radiances designed to smooth out the striping noise but not to alter lower frequency weather signals.

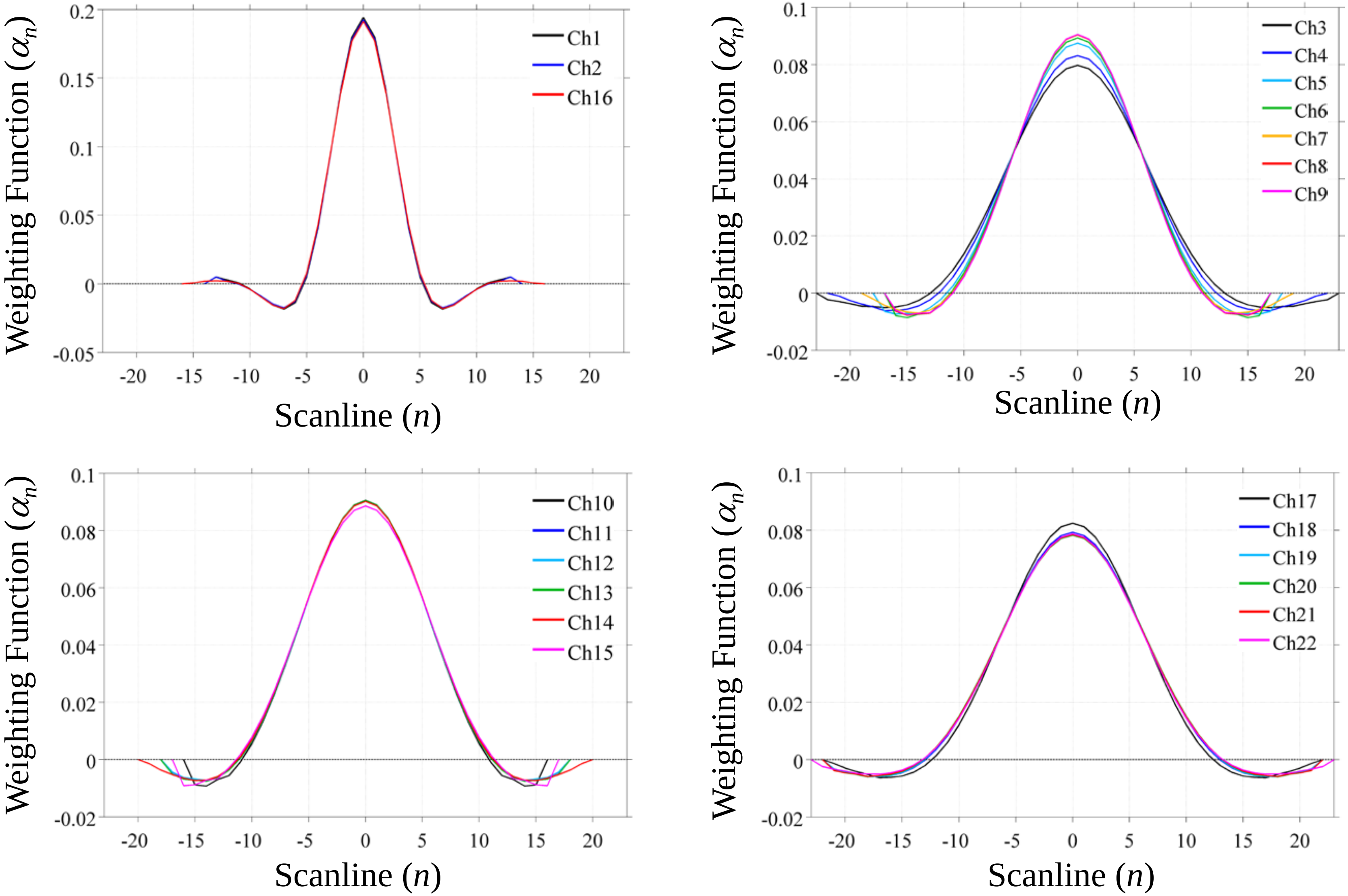
Variation of Cost Function *J* with Filter Span

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



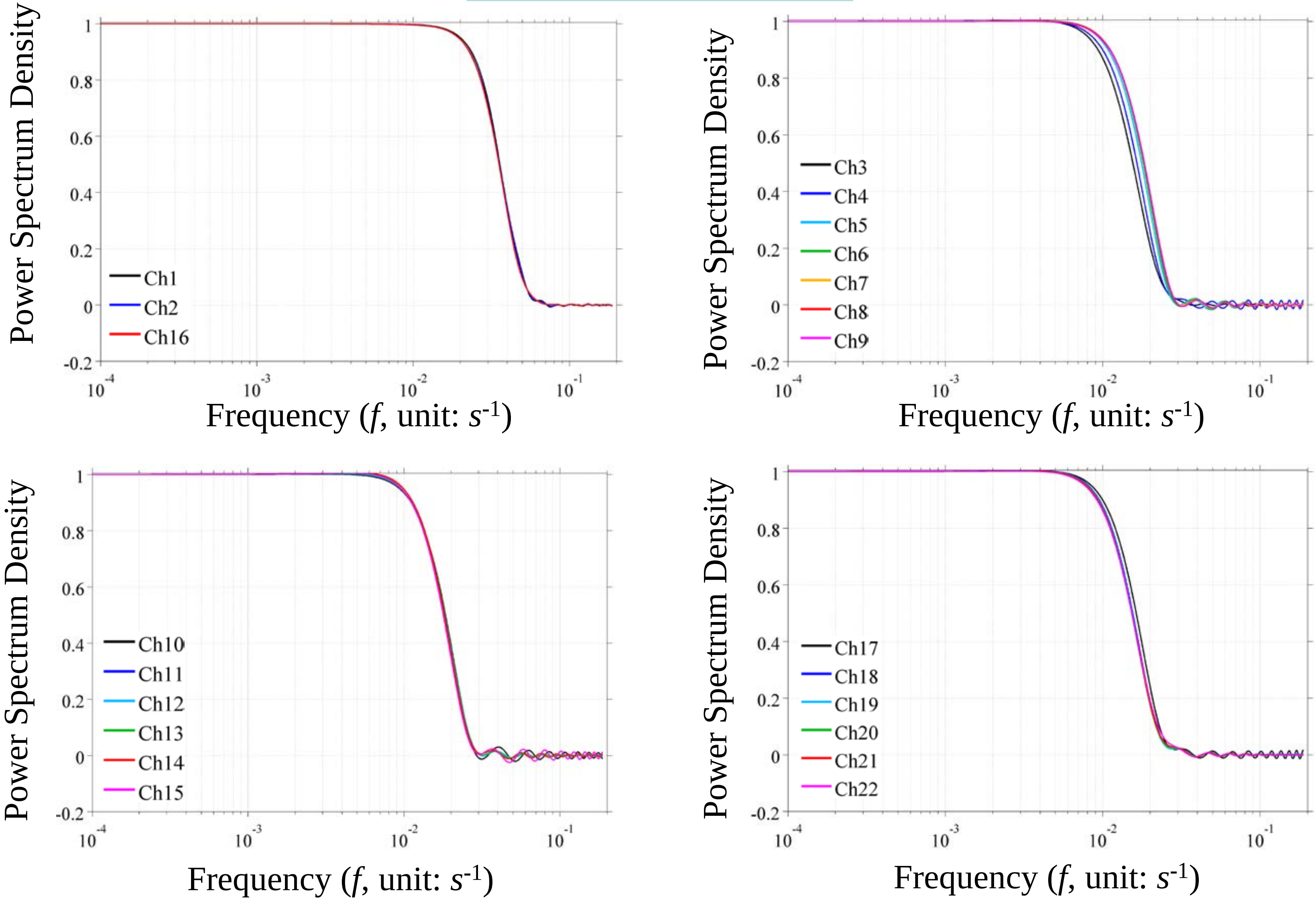
Optimal Weighting Coefficients

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

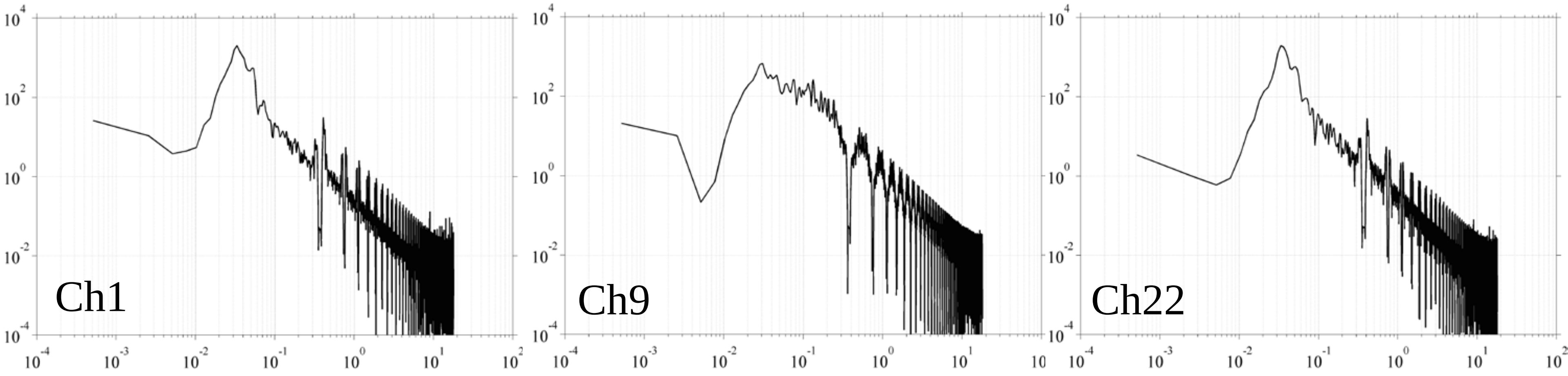


Response Functions of the Optimal Striping Filters

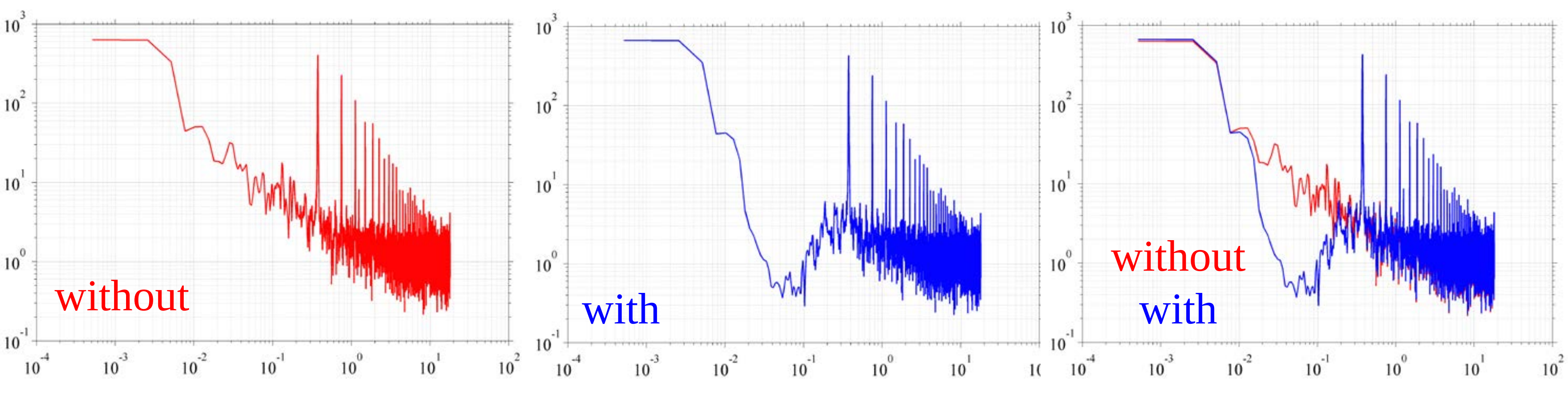
$$r_m = \sum_{n=0}^{N} \alpha_n \cos(2\pi f \Delta t)$$



Striping noise Spectrum removed by the optimal striping filters

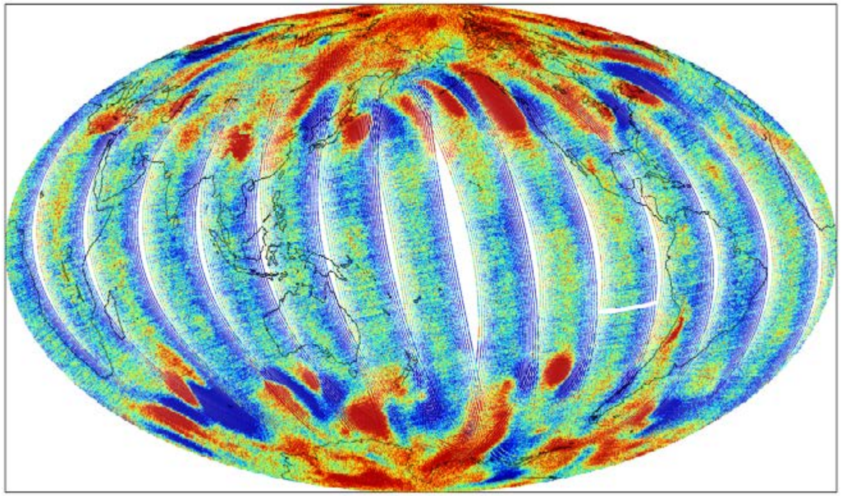


Global O-B Spectrum with and without Applying the Optimal Striping Filter

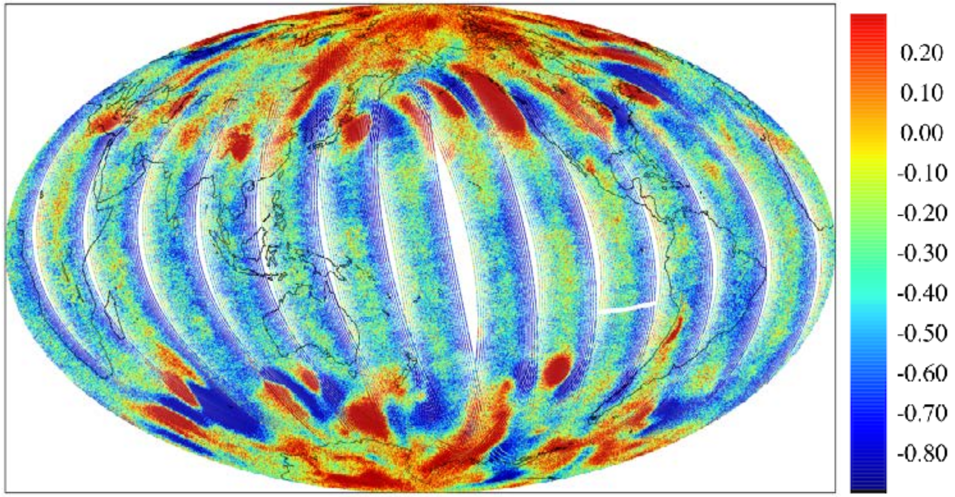


Global O-B Distributions of ATMS Channel 8

Before

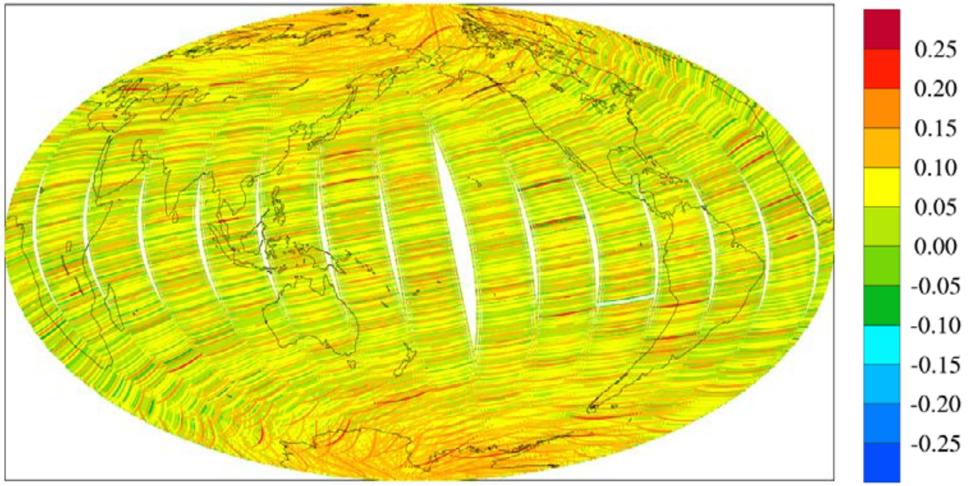


After

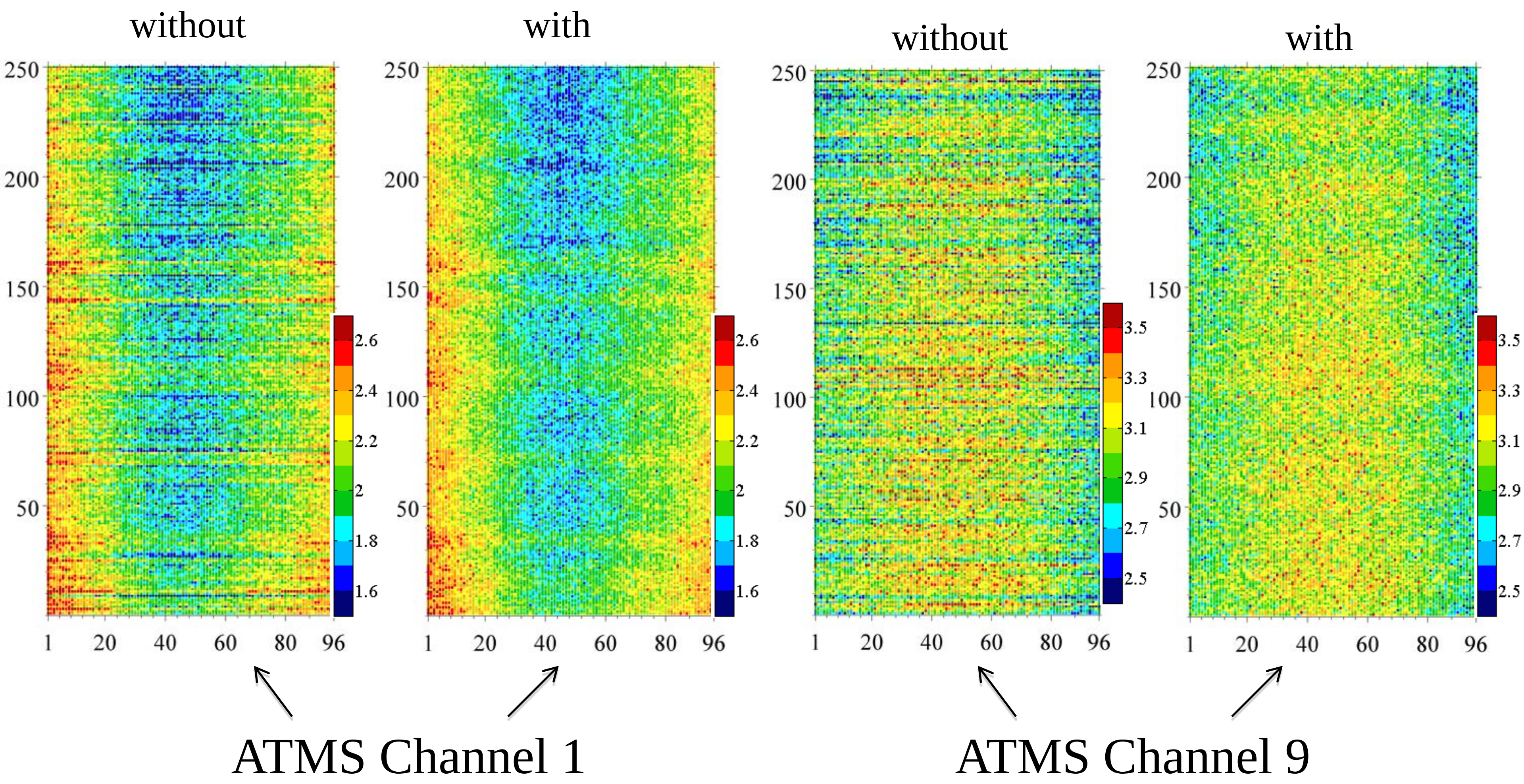


Before minus After

Striping noise



Pitch-Over Maneuver Data with and without Optimal Filtering



Striping Index (SI)

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

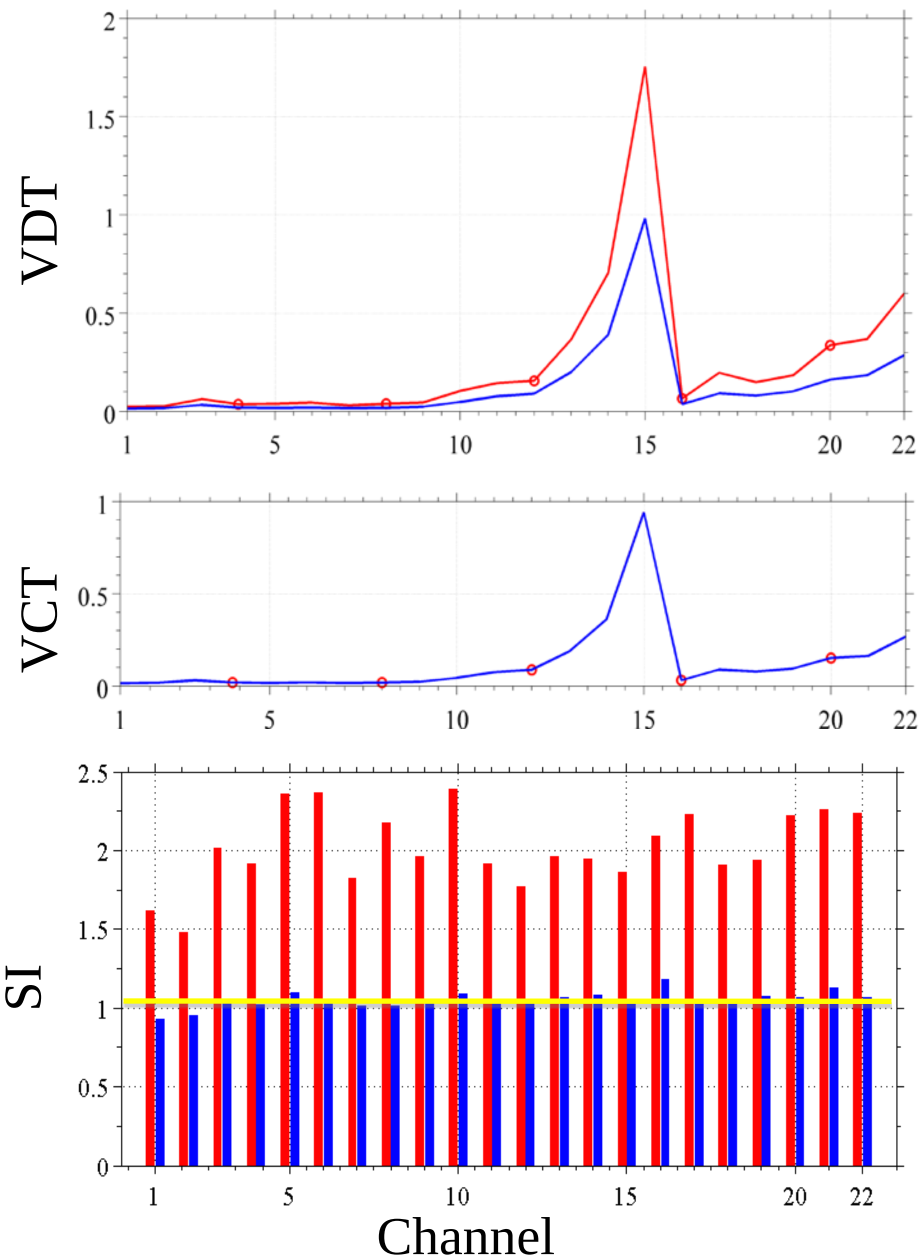
Along-track variance

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

Cross-track variance

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

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.