LOSSLESS COMPRESSION STUDIES FOR NOAA'S FUTURE GOES ADVANCED SOUNDERS

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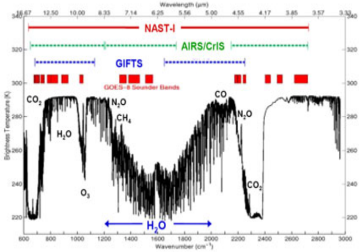
1. INTRODUCTION

➢To support future GOES data compression studies, we investigate various 2D and 3D lossless compression methods using the grating-type Atmospheric Infrared Sounder (AIRS) data and the . National Polar-orbiting Operational Environmental Satellite System (NPOESS) Airborne Sounder Testbed-Interferometer (NAST-I) data.

➢These data compression techniques are applicable for future GOES sounder data rebroadcast.

➢We show that an **average lossless compression ratios of 3.33** and **5.10** are achievable for the AIRS grating data and the NAST-I interferometer data, respectively.

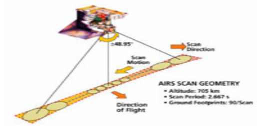


2. ULTRASPECTRAL DATA FOR LOSSLESS COMPRESSION STUDIES

• **Test Data from AIRS (*Grating Spectrometer Type Sounder Sensor*)**

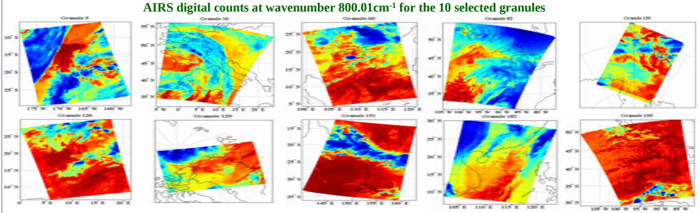
10 selected AIRS digital counts granules on March 2, 2004

Granule 9	00:53:31 UTC	-12 H	(Pacific Ocean, Daytime)
Granule 16	01:35:31 UTC	+2 H	(Europe, Nighttime)
Granule 60	05:59:31 UTC	+7 H	(Asia, Daytime)
Granule 82	08:11:31 UTC	-5 H	(North America, Nighttime)
Granule 120	11:59:31 UTC	-10 H	(Antarctica, Nighttime)
Granule 126	12:35:31 UTC	-0 H	(Africa, Daytime)
Granule 129	12:53:31 UTC	-2 H	(Arctic, Daytime)
Granule 151	15:05:31 UTC	+11 H	(Australia, Nighttime)
Granule 182	18:11:31 UTC	+8 H	(Asia, Nighttime)
Granule 193	19:17:31 UTC	-7 H	(North America, Daytime)



• Each granule consists of 135 scan lines containing 90 cross-track footprints per scan line.
• Publicly available via anonymous ftp (ftp://ftp.ssec.wisc.edu/pub/bormin/Count)

AIRS digital counts at wavenumber 800.01cm⁻¹ for the 10 selected granules



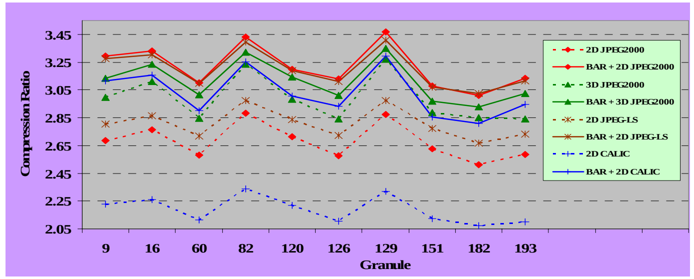
• **Test Data from NAST-I (*FTS Type Sounder Sensor*)**

➢ NAST-I flight instrument specifications
- Aircraft platform
- Spectral Resolution: 0.25 cm-1
- Spectral Range:
  - Longwave: 645 - 1300 cm -1
  - Midwave: 1290 - 2000 cm-1
  - Shortwave: 1980 - 2700 cm-1
- Spatial Resolution: 2.6 km field of view @ 20 km altitude
- Scan Width +/- 48o
- Number of Elements/Scan Line:13 earth spots

➢ NAST-I Interferogram Data Format
- Longwave, midwave, and shortwave interferograms stored separately.
- Test dataset has two scenes:
  Scene 1.Winter case off the East Coast of the U.S
  Scene 2. Summer case off the Coast of Italy (ADREIX)
- Each scene has 100 scan lines each containing 15 views (2 blackbody views + 13 earth views)
- Each longwave, midwave, and shortwave interferogram has 3957 points
- Real and imaginary parts of interferogram data stored separately

3. CIMSS-DEVELOPED DATA PREPROCESSING SCHEME

➢ CIMSS's **Bias-Adjusted Reordering (BAR) data preprocessing scheme** ***(Huang et al. 2004)*** improves the performance of state-of-the-art compression methods (2D CALIC, 2D JPEG-LS, 2D JPEG2000 (Part 1), 3D JPEG2000 (Part 2))



➢ Comparison of the **Bias-Adjusted Reordering (BAR) data preprocessing scheme** with the **Minimum Spanning Tree (MST) Reordering** for context-based and context-free arithmetic coding ***(Huang et al. 2006)***

Granule	9	16	60	82	120	126	129	151	182	193	Average
MST+Context-free AC	2.57	2.73	2.42	2.75	2.58	2.44	2.73	2.34	2.35	2.49	**2.54**
BAR+Context-free AC	2.44	2.58	2.30	2.60	2.44	2.32	2.59	2.22	2.24	2.36	**2.41**
MST+Context-based AC	2.76	2.76	2.62	2.68	2.68	2.64	2.75	2.63	2.58	2.64	**2.67**
BAR+Context-based AC	2.68	2.80	2.66	2.81	2.61	2.63	2.83	2.64	2.60	2.64	**2.69**

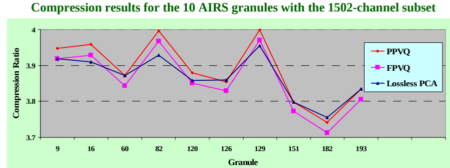
4. CIMSS-DEVELOPED NEW LOSSLESS COMPRESSION METHODS

➢ **Lossless PCA** ***(Huang et al. 2004)***

➢ **Predictive Partitioned Vector Quantization (PPVQ)** ***(Huang et al. 2004)***

➢ **Fast Precomputed Vector Quantization (FPVQ) with optimal bit allocation** ***(Huang et al. 2005)***

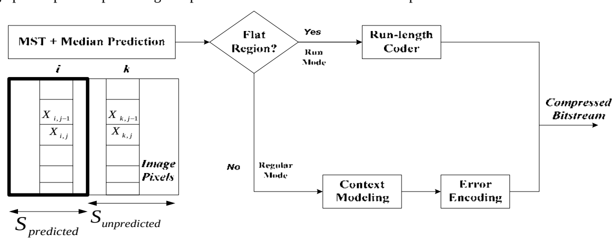
Compression results for the 10 AIRS granules with the 1502-channel subset



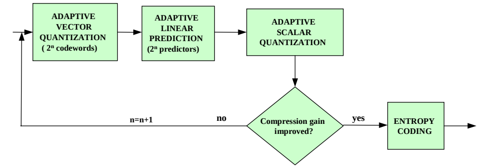
➢ **Lossless Multiwavelet Compression (MWT)** ***(Huang et al. 2006)***: Utilizes an integer version of the multiwavelet transform to obtain lossless compression for ultraspectral sounder data.

➢ **Prediction-based Lower Triangular Transform (PLT)** ***(Huang et al. 2006)***: PLT features the same decorrelation and coding gain properties as PCA/KLT, but with lower complexity (i.e. less CPU time).

➢ **MST-embedded JPEG-LS** ***(Huang et al. 2006)***: Embeds the minimum spanning tree algorithm in JPEG-LS for finding optimal pairs of predicting and predicted channels that minimize the prediction errors.



➢ **Adaptive VQ-based Linear Predition (AVQLP)** ***(Huang et al. 2006)***: The AVQLP method consists of four steps: adaptive vector quantization (VQ), adaptive linear prediction, adaptive scalar quantization (SQ), and entropy coding, as shown below.



5. COMPRESSION RESULTS

➢ **Results for AIRS grating data with 10 complete granules (NOT the lower-noise 1501-channel subset.)**

Granule	9	16	60	82	120	126	129	151	182	193	Avg.
JPEG2000 with BAR	2.73	2.8	2.62	2.87	2.74	2.63	2.88	2.64	2.57	2.64	**2.71**
MWT with BAR	2.65	2.71	2.52	2.76	2.65	2.54	2.8	2.5	2.46	2.54	**2.61**
CALIC with BAR	2.44	2.51	2.33	2.61	2.46	2.35	2.64	2.38	2.31	2.38	**2.44**
JPEG-LS with BAR	2.77	2.82	2.67	2.87	2.76	2.68	2.87	2.67	2.63	2.69	**2.74**
MST with JPEG-LS	2.84	2.9	2.75	2.94	2.84	2.75	2.94	2.73	2.69	2.77	**2.82**
Lossless PCA	3.19	3.19	3.18	3.2	3.16	3.17	3.22	3.14	3.1	3.16	**3.17**
OOMP	3.21	3.3	2.78	3.1	3.26	2.81	2.81	2.79	2.74	3.33	**3.01**
PLT	3.03	3.08	2.97	3.08	3.02	2.95	3.09	2.93	2.88	2.98	**3.00**
PVQ	2.23	2.25	2.01	2.37	2.13	2.07	2.38	2.03	1.96	2.04	**2.15**
DPVQ	2.85	2.88	2.75	2.94	2.8	2.76	2.91	2.73	2.64	2.73	**2.80**
PPVQ	3.35	3.36	3.3	3.39	3.31	3.29	3.38	3.26	3.22	3.27	**3.31**
FPVQ	3.35	3.36	3.3	3.38	3.31	3.29	3.38	3.26	3.22	3.28	**3.31**
AVQLP	3.35	3.37	3.33	3.4	3.32	3.32	3.42	3.26	3.21	3.29	**3.33**

➢ **Results for Michelson interferometer data with 2 scenes.**

	JPEG2000 with BAR	2D CALIC with BAR	2D JPEG-LS with BAR	Lossless PCA	PPVQ
Scene 1 (Winter US East Coast)	4.35	3.98	4.13	4.87	4.48
Scene 2 (Summer Italy Coast)	4.55	4.05	4.3	5.32	4.82
Average	**4.45**	**4.02**	**4.22**	**5.10**	**4.65**

6. SUMMARY

➢ CIMSS's BAR data preprocessing scheme significantly improves the compression ratios of such state-of-the-art compression methods as 2D JPEG2000 (Part 1), 3D JPEG2000 (Part 2), 2D CALIC, and 2D JPEG-LS

➢ After applying the BAR preprocessing scheme, the standard state-of-the-art compression methods perform almost equally well !!

➢ BAR has been shown to be more effective than MST with context-based arithmetic coding.

➢ New CIMSS-developed compression methods (Lossless PCA, PPVQ, FPVQ, PLT, MWT, OOMP, MST-embedded JPEG-LS, and AVQLP) show better results on ultraspectral sounder data than standard compression methods, achieving average lossless compression ratios of 3.33 and 5.10 for grating and interferometer data respectively.

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