Image Compression in Local Helioseismology

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Abstract: Several upcoming helioseismology space missions, such as e.g., Solar Orbiter, are going to be very limited in telemetry and will have to perform extensive data compression. In particular, it will probably be necessary to implement lossy methods, which involve a trade-off between the compression efficiency and artifacts caused by the compression. Here we focus on two of the most basic measurements: time-distance helioseismology of supergranulation flows at disk center and time-distance helioseismology of near-surface differential rotation. All of the compression methods that we tested (quantization, JPEG compression, and smoothing and subsampling) allow us to probe these flows using Dopplergrams with a file size of less than a bit per pixel. In both cases, JPEG compression is the best method tested. For supergranulation flows, the compression efficiency can be increased by applying JPEG compression on 2 x 2 subsampled data.

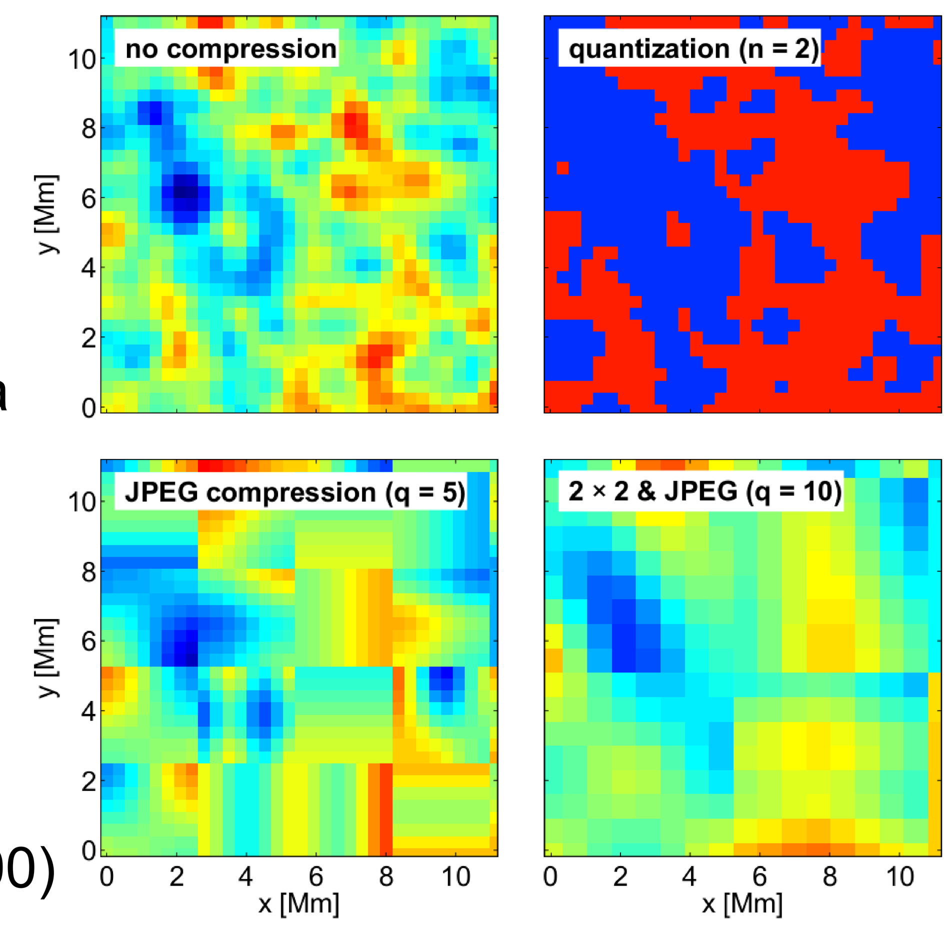
Compression Methods

Quantization:
1. Reduce number of bits/pixel
2. Apply lossless Huffman compression [1]

=> Reduced precision of data

JPEG Compression [4]:
1. Discrete cosine transform on 8 x 8 pixel blocks
2. Truncate DCT coefficients depending on quality factor q (between 0 and 100)
3. Huffman compression of coefficients

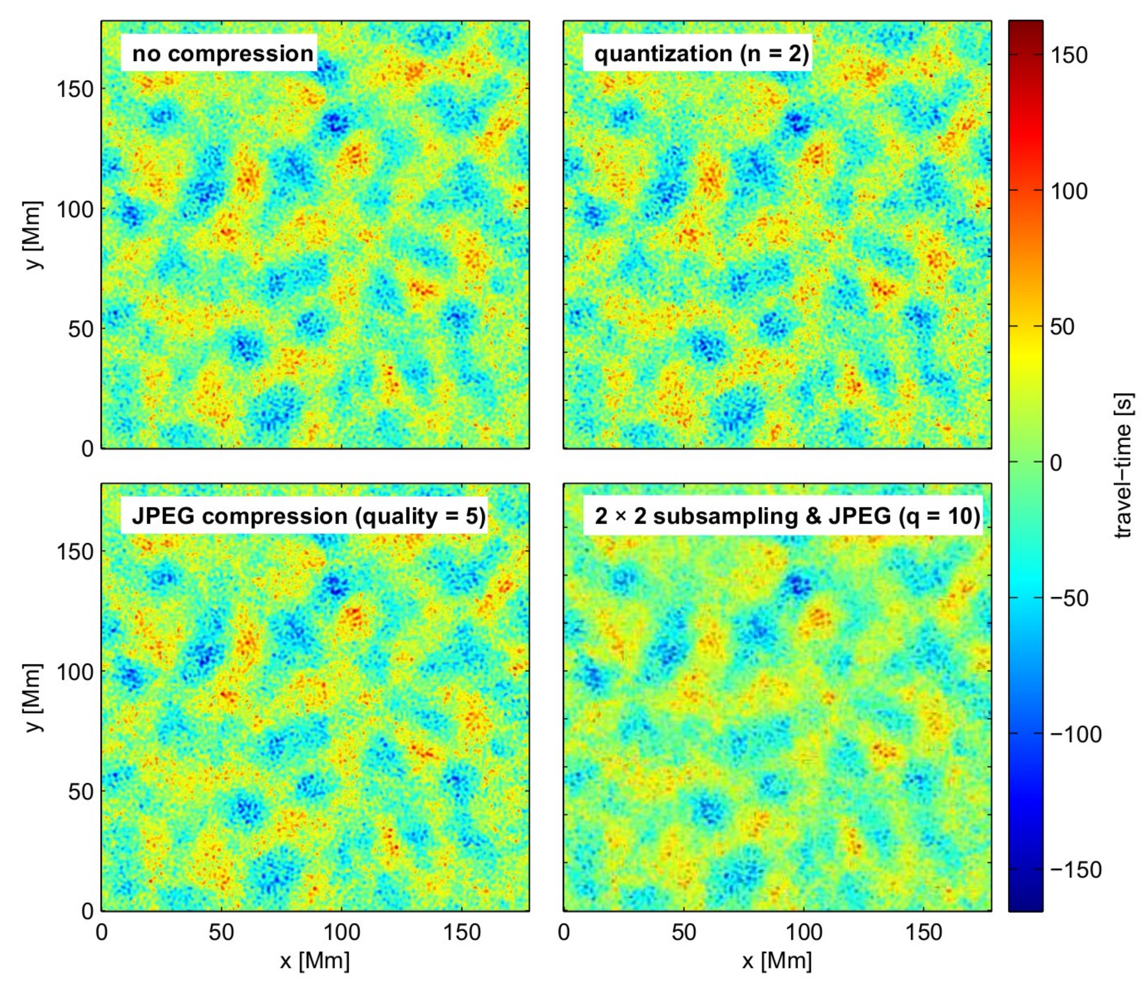
=> Loss of information about small spatial scales



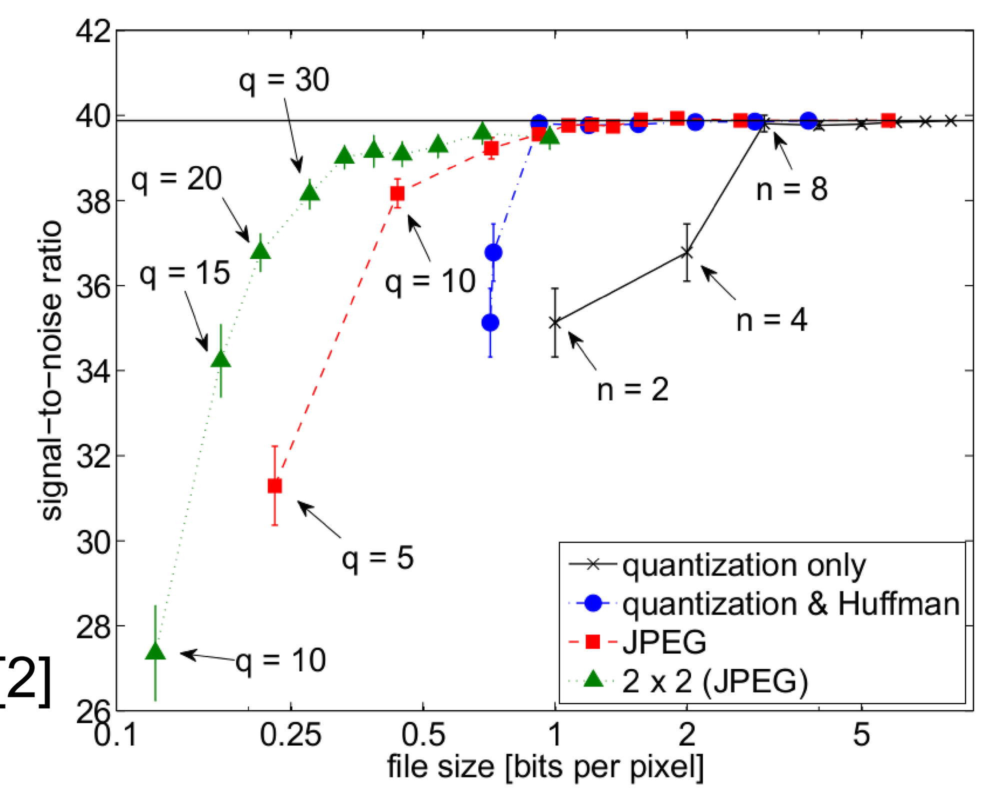
2 x 2 Subsampling & JPEG Compression:
1. Convolve data with Gaussian (σ = 0.4 pixels)
2. Apply 2 x 2 subsampling
3. JPEG compression

Influence on Supergranulation Travel-Times

- Input data: 20 HMI Doppler datacubes with T = 8h, 178 x 178 Mm at disk center
- F-mode, point-to-annulus geometry (annulus size 13.2 Mm), t_{oi}
- Sensitive to horizontal divergence of supergranulation flows
- Almost no influence of compression



- Compression adds noise
- Noise not correlated with travel-times
- High signal-to-noise ratio (@ ell = 120) down to 0.5 bits/pixel
- 2 x 2 subsampling & JPEG best method tested
- For more information see [2]

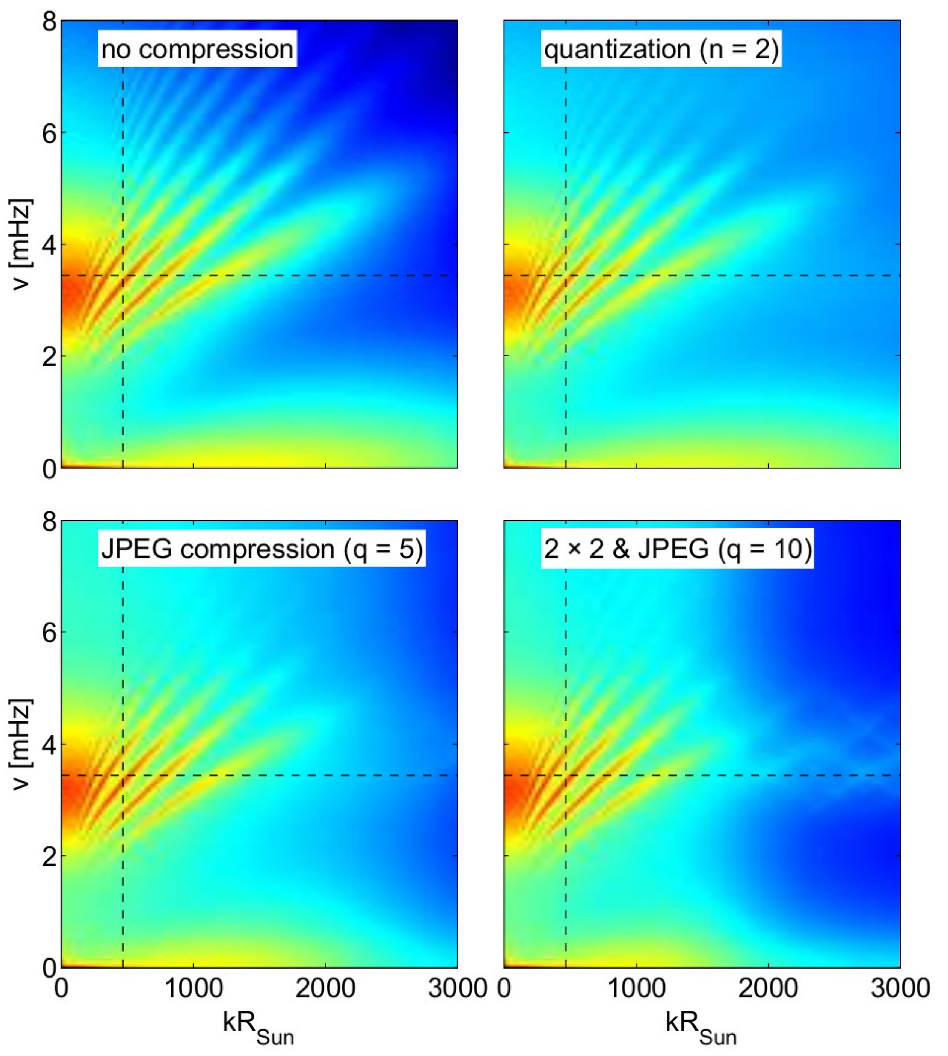


Influence on Helioseismic Power Spectra

- Oscillations clearly visible

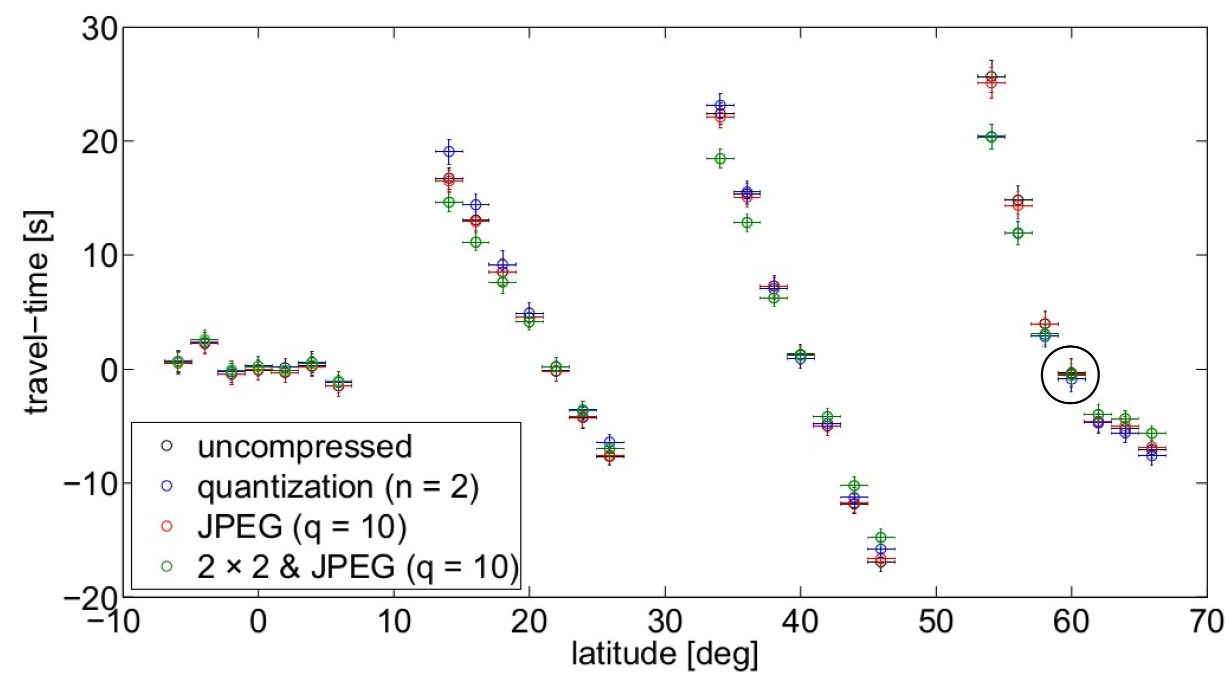
Quantization:
- Almost flat background noise

JPEG Compression:
- Several artificial ridges at high wavenumbers
- Reduction of power from granulation

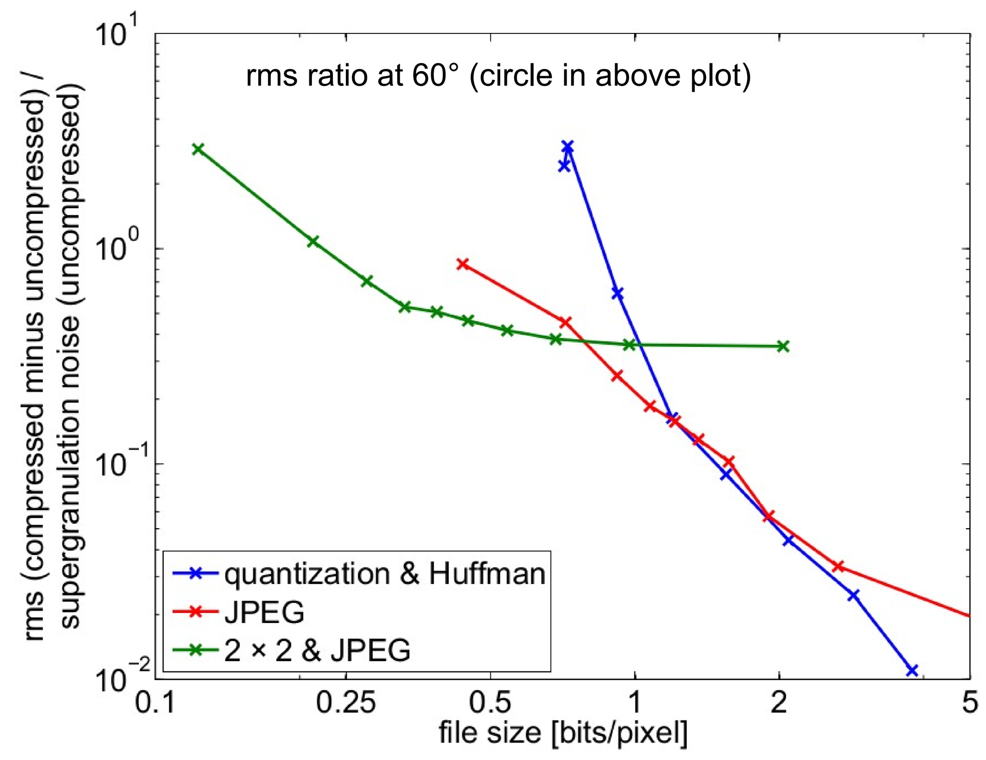


Probing Near-Surface Differential Rotation

Input Data:
- 120 days of tracked and remapped HMI Doppler datacubes (provided by J. Langfellner)
- Size: 178 x 178 Mm (~14 deg), T = 24 h
- 4 latitudes: 0°, 20°, 40°, 60°
- Tracked with Snodgrass (1984) rotation rate at center of cube [3]



- F-mode, EW geometry (annulus size 13.2 Mm)
- Compression reduces amplitudes
- Field-dependence: Quantization significantly worse at north and south edges
- High compression ratios possible
- JPEG best method tested



References:
[1] Huffman, D. A. 1952, Proceedings of the I.R.E., 40, 1098–1102
[2] Löptien, B., Birch, A. C, Gizon, L. & Schou, J. 2014, accepted by A & A
[3] Snodgrass, H. B. 1984, Sol. Phys., 94, 13
[4] Wallace, G. K. 1992, IEEE Transactions on Consumer Electronics, 38, 18