INTERFERENCE MITIGATION IN PASSIVE MICROWAVE RADIOMETRY

Application to Airborne C-Band Imagery

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Background

- The effective microwave dielectric constant of bare soil is modified by its volumetric moisture content (VSM) within the top ~0.5-3 cm:

  <5% ➔ very dry ~40% ➔ saturated

  A signature of ~140K is available for 5-40% VSM change at L-band (1400-1427 MHz).

- C- or X-band systems (~6-10 GHz) are more practical from an antenna size standpoint, but exhibit greater sensitivity to vegetation cover & surface roughness. Nonetheless, C-band sensitivity to surface soil moisture is ~1/2 that available from L-band, viz:

  5-40% VSM ➔ ~60K change at 6.9 GHz H-pol

- AMSR-E on NASA EOS Aqua spacecraft (~July 2001) will have a conically-scanned 6.925 GHz channel (V&H) with 75 x 43 km footprint. NPOESS CMIS will also, but of slightly differing size.

…Background (cont'd)

However:

- Anthropogenic emission in key microwave bands (L, C, X, Ku, Ka) increasingly threatens the ability to conduct environmental remote sensing for either research or operations.
- Only small amounts of interfering power are necessary to corrupt environmental data. Worst case is for interference power levels that are indistinguishable from thermal emission, i.e.,

$$\delta P_{INT} \sim k\delta TB \quad \text{with} \quad \sim 0.1 < T < \sim 10\ K$$

- Persistent undetected interference can be expected to have adverse impacts on microwave radiometer-based climate records, weather forecasts, and nowcast products.
- Radio band allocations are critical, but even primary allocations are no guarantee of long-term immunity.

Essential Interference Mitigation Techniques

1) **Subband diversity** – Anthropogenic interference often narrowband (~a few to hundreds of MHz) WRT radiometric bands.

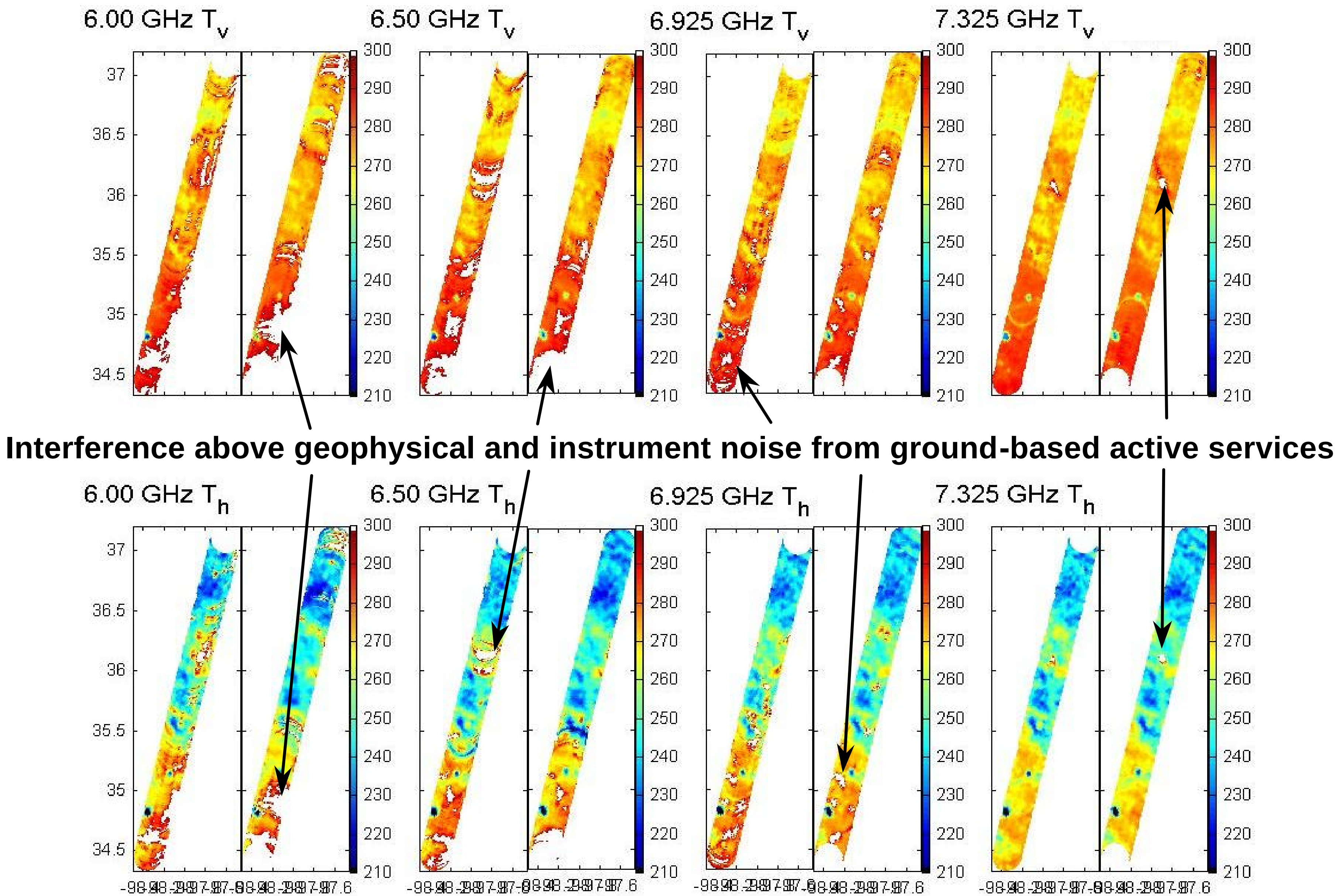
2) **Polarization diversity** – Geophysical v-h difference often predictable to within a few K, while v-h interference deviations are often larger

3) **Polarimetric detection** – Anthropogenic interference is often highly polarized in 3^{rd} or 4^{th} Stokes parameter while most natural surfaces are either predictably polarized or mostly unpolarized.

4) **Azimuthal diversity** – Many natural surfaces are predictably isotropic whereas interference is highly isotropic (applicable to conical scanning).

Calibrated (uncorrected) Imagery

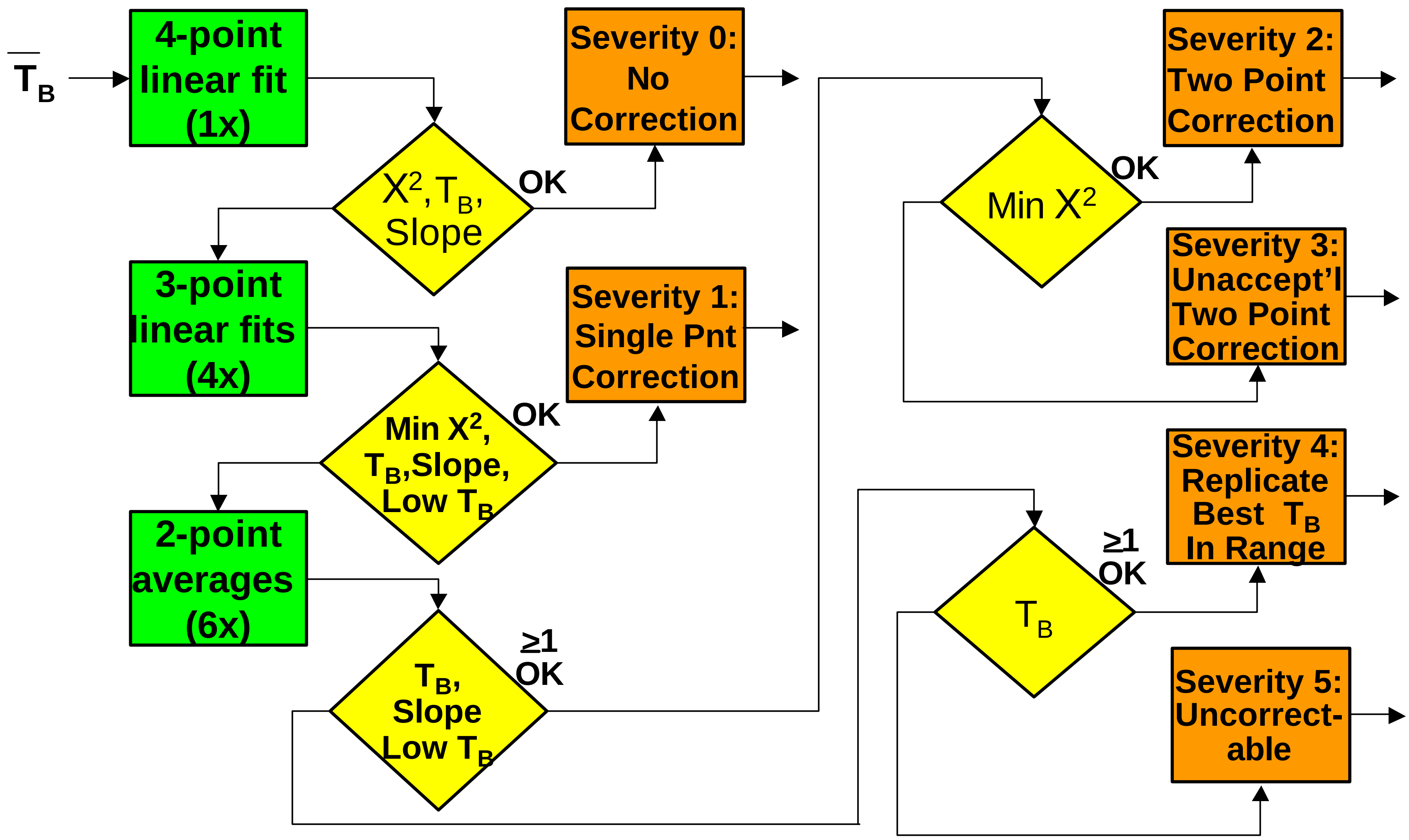
PSR/C SGP99 7/14/99 – Oklahoma – SN 0049



Basic Spectral Algorithm

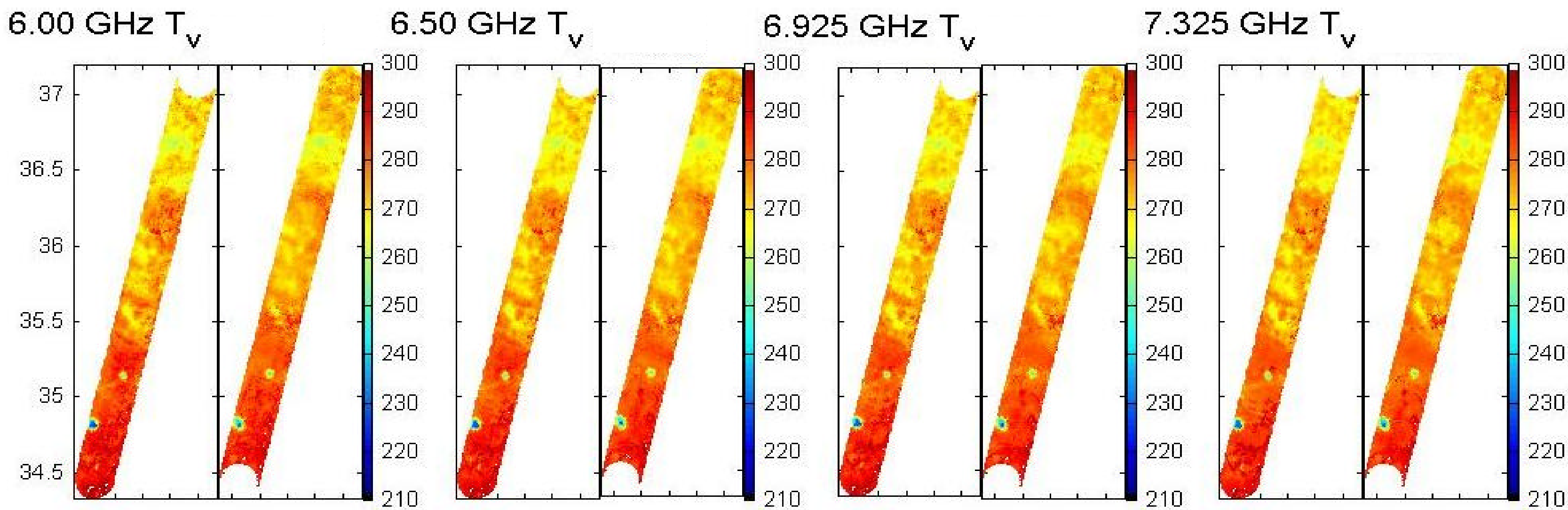
- Perform linear spectral fit (M=2 DOF) for N spectral subbands.
- Check for $\xi^2 < N-M$, M=2 (“good” fit).
- If not “good”, perform linear fits using all permutations of N-1 subbands, then check all ξ^2 values. Select N-1 subbands with smallest ξ^2. Replace missing subband with fit.
- Repeat above until either “good” fit obtained or N=2. If N=2 use average across two remaining spectral subbands.
- Also incorporate spectral slope and subband brightness thresholding.

Basic Spectral Algorithm

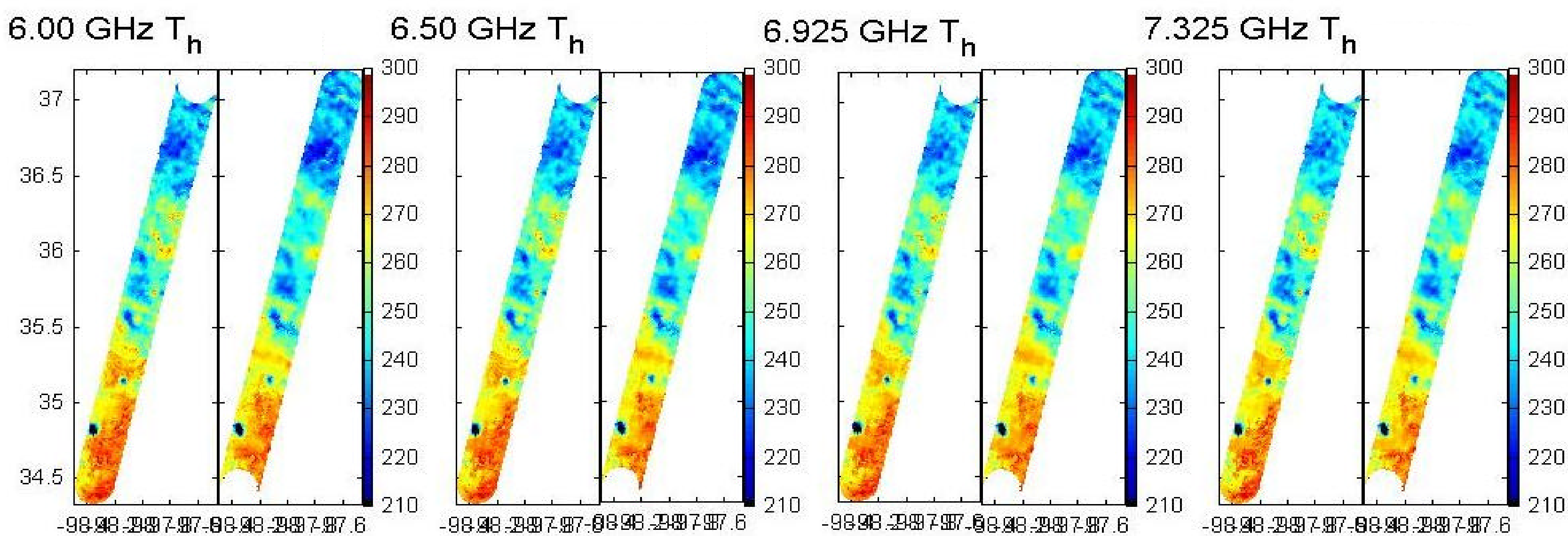


Interference-Corrected Imagery

PSR/C SGP99 7/14/99 - Oklahoma – SN 0049

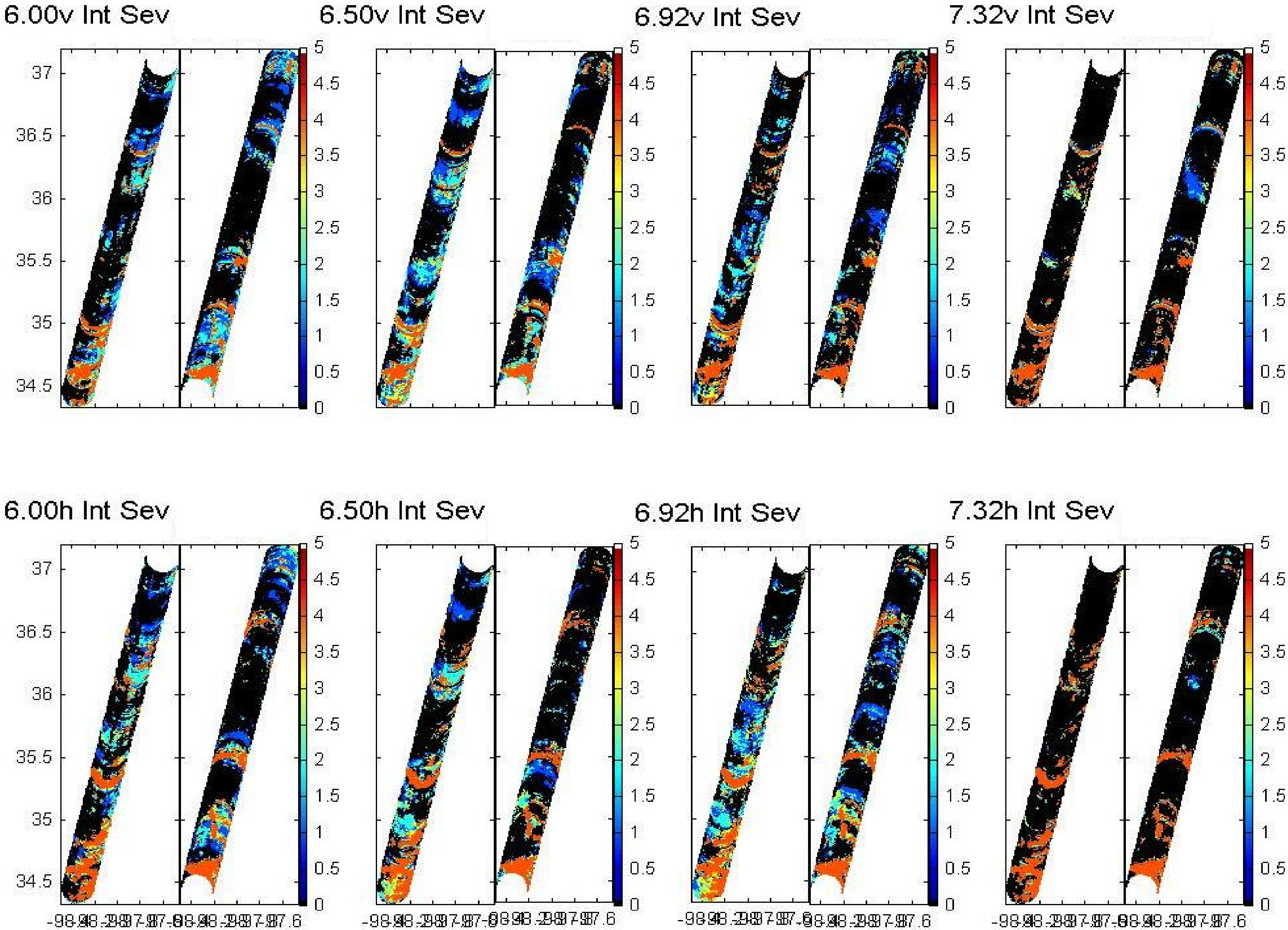


Interference mostly removed for purposes of soil moisture measurement.



Interference Severity Maps

PSR/C SGP99 7/14/99 - Oklahoma – SN 0049



Spectral Algorithm Statistics

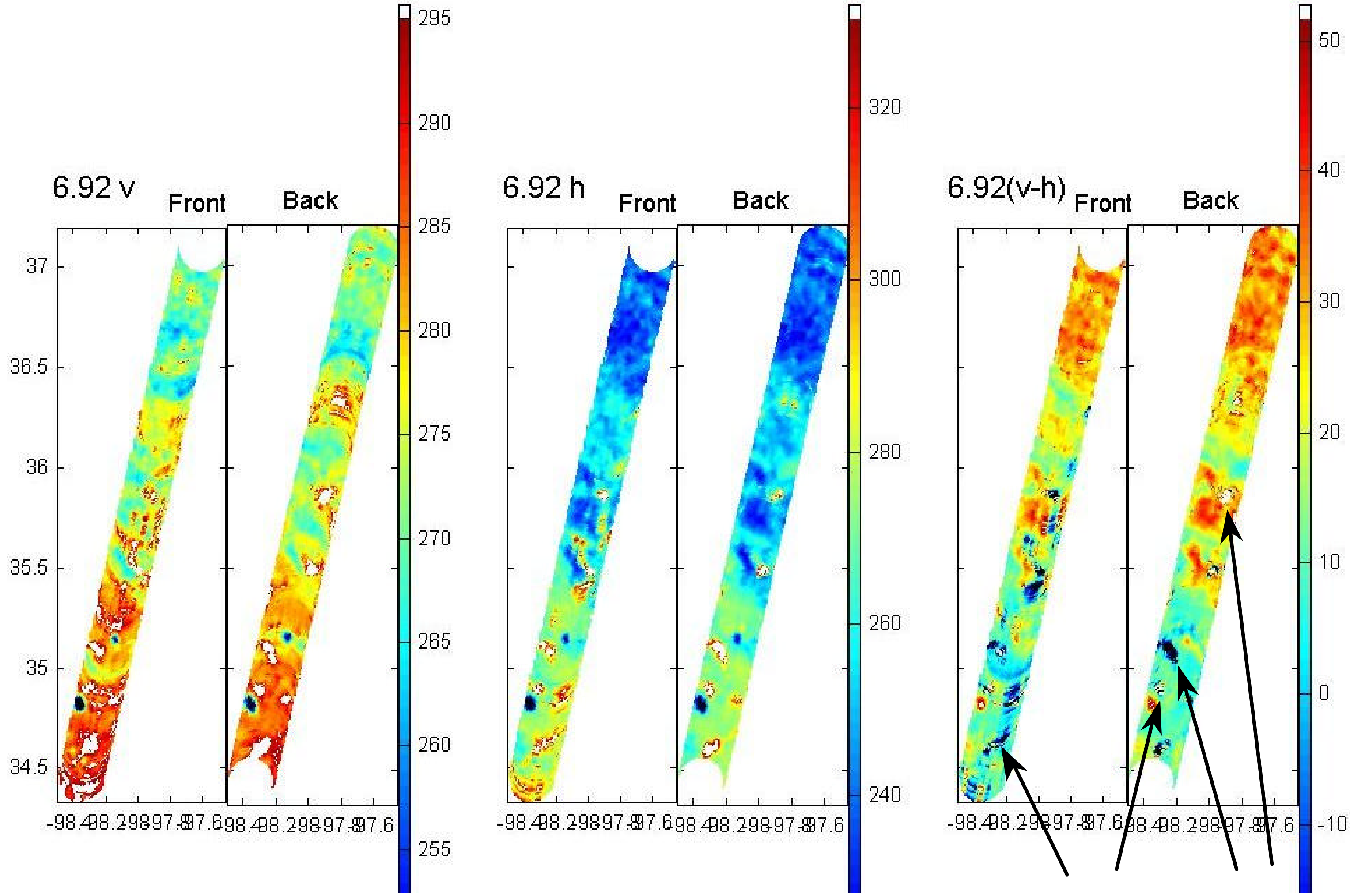
- PSR/C SGP99 data on 7/14/02 over Oklahoma, 76608 pixels
- Tb acceptance range: (v) 190-310 K (h) 130-310 K
- Maximum spectral slope: 7 K/GHz
- Combined geophysical + instrument noise: 2.5K RMS

RF Channel/ Severity (%)	6.00v	6.50v	6.92v	7.32v	6.00h	6.50h	6.92h	7.32h
Level 0	62.1	58.9	58.7	62.0	68.7	54.5	81.8	80.4
Level 1	11.4	10.9	11.6	7.6	6.8	9.9	2.2	0.3
Level 2	12.7	9.8	13.6	9.3	8.6	11.8	1.8	1.4
Level 3	0.5	2.7	2.8	3.5	2.5	6.0	0.9	0.2
Level 4	13.3	17.7	13.3	17.7	13.3	17.7	13.3	17.7
Level 5	0	0	0	0	0	0	0	0

- No correction needed (severity 0): ~27%
- Detected/corrected cases (severity 1-2): ~53%
- Failure rate (severity 3-5): ~21%

Polarization Signature (V-H)
- Sensitivity to Interference -

PSR/C SGP99 7/14/99 - Oklahoma – SN 0049



Interference above geophysical and instrument noise clearly detectable in v-h polarization difference maps.

3rd & 4th Stokes Parameter - Sensitivity to Interference -

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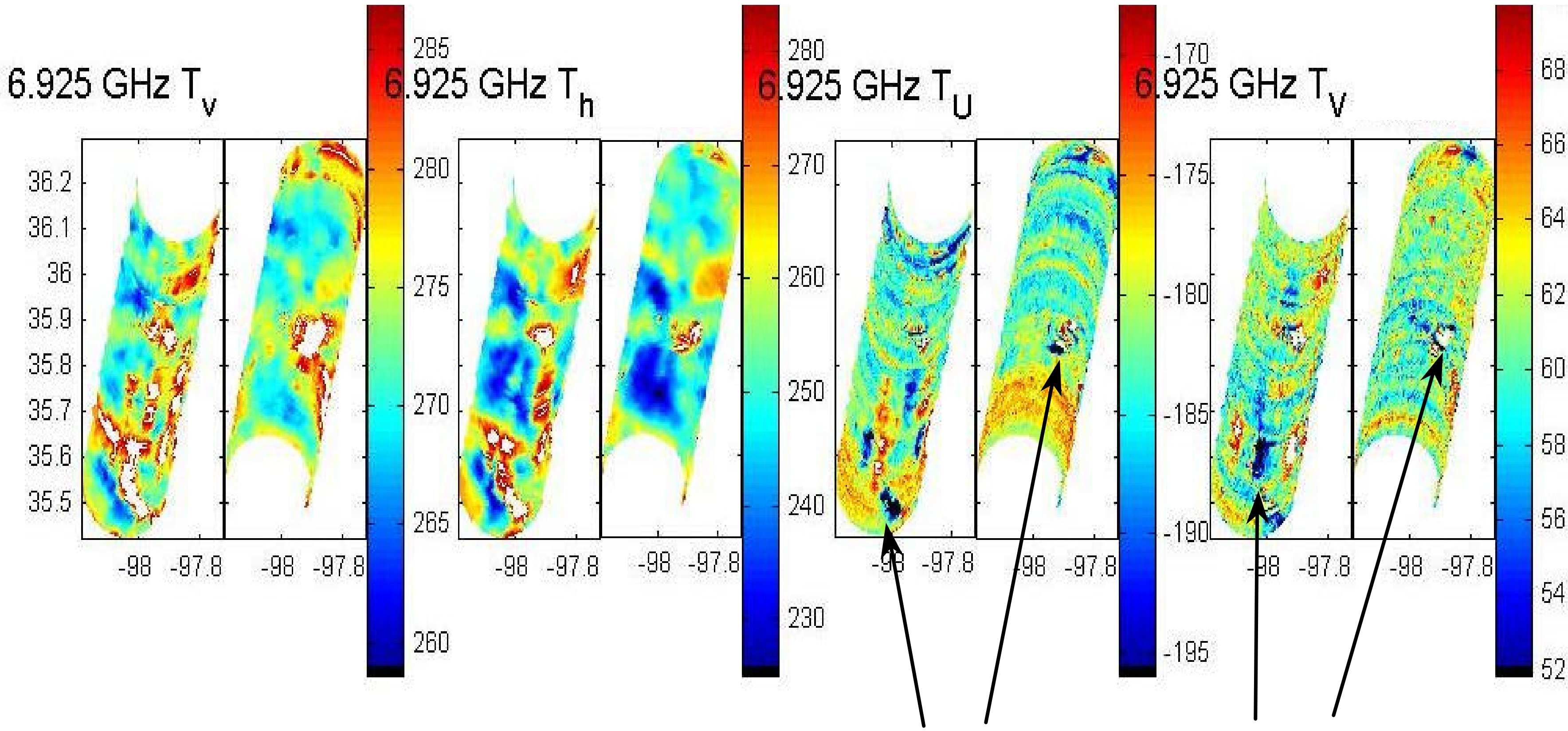

Interference above geophysical and instrument noise clearly detectable in 3rd & 4th Stokes (uncalibrated) channels.

Summary

- Anthropogenic interference in passive microwave imaging systems is a growing problem especially at L, C, X, and Ku bands.
- Effective and relatively inexpensive spectral interference mitigation techniques are possible - but certainly not as desirable as clean protected spectrum.
- Effective spectral and polarization interference mitigation has been demonstrated using airborne C-band imagery with 4 subbands.
- Spatial detection technique is plausible, and algorithms are being developed.