National Aeronautics and Space Administration

Spatio-Temporal Super-Resolution for Geostationary Microwave Observing System Simulation Experiments (OSSE)

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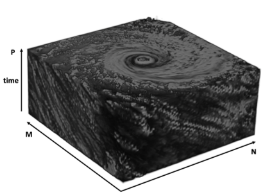
Program: Spontaneous Concept

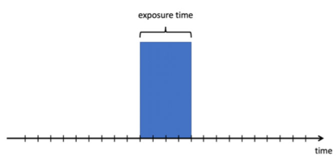
Project Objective:

The objective of this proposal was to develop a spatio-temporal resolution enhancement methodology that deconvolves the image sequence from spatial distortion and temporal blur. A blurred sequence of observations is assumed to have been generated by convolution of a physical scene with a spatio-temporal convolution kernel whose two-dimensional spatial component is the microwave instrument's point spread function and whose one-dimensional temporal component is the rectangular kernel with sensor exposure time as its support. The resolution enhancement was to be performed in the space-time domain, as opposed to solving deconvolution problem observation by observation.

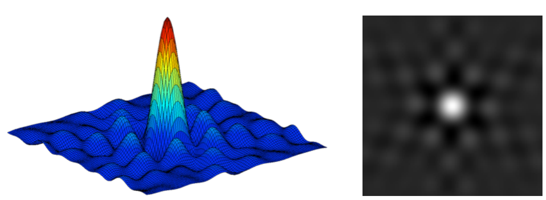
FY19 Results:



Space-Time Volume

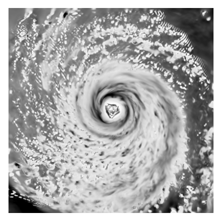


Temporal rectangular kernel with sensor exposure time as its support

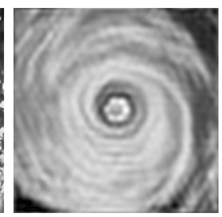


The Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR) point spread function (PSF). A characteristic of an aperture synthesis system is that the PSF is a 2-dimensional sinc-like function, showing positive and negative excursions, that produces ringing at sharp edges and other transitions in the observed field.

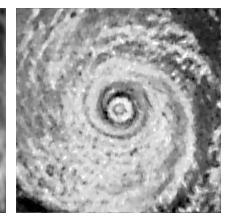
Spatio-Temporal Resolution Enhancement



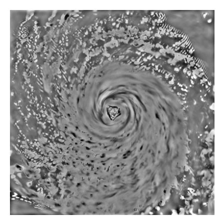
(a) Clean unknown (simulated) frame



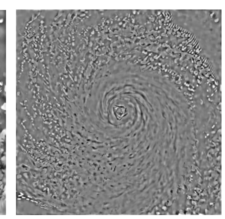
(b) Spatio-temporally blurred and noisy frame



(c) Reconstructed frame



(d) Error before reconstruction



(e) Error after reconstruction

Spatio-temporal resolution enhancement of a simulated 150 GHz hurricane image sequence. Original sequence in (a), is convolved in (b) with spatio-temporal convolution kernel whose two-dimensional spatial component is the GeoSTAR kernel and whose one-dimensional temporal component is the temporal rectangular function. (c) Spatio-temporal enhancement reconstruction result. (d) Error between clean frame and blurry frame. (e) Error between clean frame and reconstruction result.

Benefits to NASA and JPL (or significance of results):

The recent Earth Science Decadal Survey (DS) calls for new observations of atmospheric wind, storm processes, and boundary layer processes. Critical regions within dynamic weather systems are commonly either (1) obscured by clouds and rain, where microwave (MW) sounders have a large advantage over other sensors, or (2) rapidly evolving, where geostationary sensors have a large advantage over low-orbiting satellites. GeoSTAR is a geostationary sounder concept that has been developed at JPL that can provide many of the observations identified in the DS. GeoSTAR is currently at TRL 6 and is ready for space implementation. It measures 3-D fields of temperature, water vapor, clouds, precipitation and wind in a large area below the host satellite. While the spatial and temporal resolutions that can be achieved with GeoSTAR are on the order of 25 km and 15 minutes, more measurement objectives can be met with 10-15 km and 5-10 minutes. The spatio-temporal oversampling that GeoSTAR produces lends itself to digital resolution enhancement techniques. We have previously developed (and published) methodologies to enhance spatial resolution and temporal resolution separately, but not both at the same time. That was the focus of this work. With such a methodology, the value of the GeoSTAR observations would be greatly enhanced, and key portions of the DS goals can be addressed with such an observatory – in conjunction with other sensors as the DS envisions. The proposed work is therefore central to both JPL and NASA goals and objectives for the next decade and beyond.

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