SUBPIXEL VARIABILITY AND QUALITY ASSESSMENT OF SATELLITE SEA SURFACE TEMPERATURE DATA USING A NOVEL HIGH RESOLUTION MULTISTAGE SPECTRAL INTERPOLATION TECHNIQUE

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INTRODUCTION

A new powerful global interpolation technique yielding an interpolant in functional form has been developed with multiple potential applications to the generation and analysis of satellite-derived SST products. While directly relevant to the traditional application of gap filling for construction of blended gap-filled analyses, the technique has additional novel applications to the quality assessment of satellite SST retrievals and quantitative estimation of spatial variability on different scales. Use in addressing these problems could provide important guidance not readily available through other currently available methods.

TRIGONOMETRIC INTERPOLATION METHODOLOGY

The technique is based on the construction of a trigonometric interpolating function that fits the input satellite retrievals within a limited spatial wavenumber domain, providing adequate resolution in regions of larger data gaps and the highest possible resolution in regions with sufficient data density. This resulting interpolant provides a functional representation of the underlying physical SST field that can be evaluated anywhere within the domain over which it was derived. Importantly, moments of the interpolating function can be calculated accurately and efficiently, enabling estimation of the mean and variance of the field over desired sub-regions. In this application, our choice of functional form was trigonometric polynomials to assure speed of computation by using the FFT or the USFFT. The theoretical basis for the methodology was developed by The Numericus Group, LLC.

The basic functional form is given by the real-valued trigonometric polynomial:

$$I(x,y) = \sum_{|k|\le K, |l|\le L} c_{kl}\, e^{2\pi i k a x + 2\pi i l b y}$$

for some coefficients c_{kl}, positive integers K and L, and positive (scaling) constants a and b.

The approach employs multiple stages to build the function I as follows:

- We first approximate the data using a low degree L_o by solving the weighted linear squares problem:

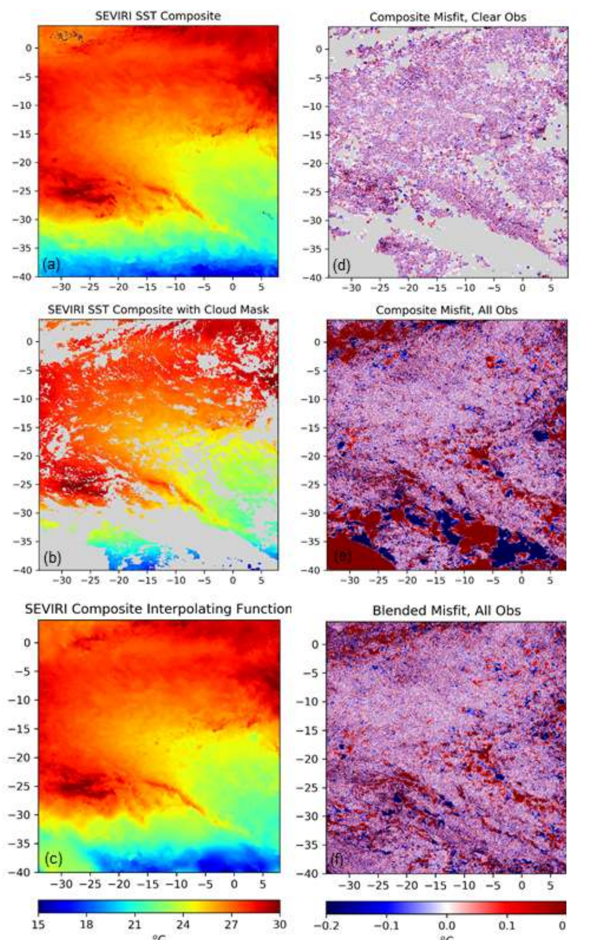
$$\sum_{|k,l|\le L_0} c^0_{kl}\, e^{2\pi i k a x_n + 2\pi i l b y_n} = t_n$$

- With these coefficients we build the trigonometric polynomial:

$$I_0(x,y) = \sum_{|k,l|\le L_0} c^0_{kl}\, e^{2\pi i k a x + 2\pi i l b y}$$

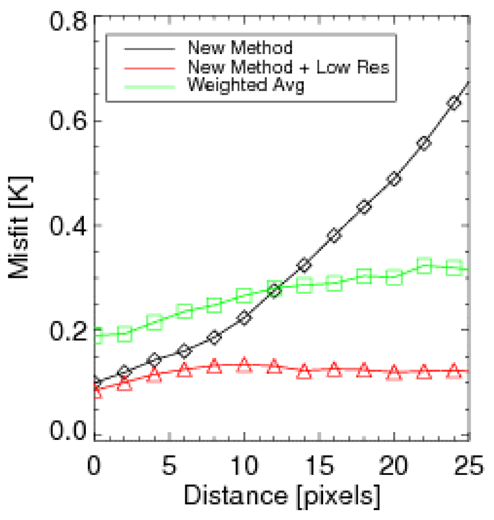
- We continue in this manner partially filling existing gaps and increasing the degree of the trigonometric polynomial.

INITIAL DEMONSTRATION



The basic capabilities and limitations of the technique are demonstrated through an initial application to an SST composite image derived from SEVIRI retrievals from 4-11 February 2009.

- A cloud mask is simulated based on the 1500 UTC SEVIRI scene on 8 February
- The interpolating function is constructed based on the clear observations only
- The "misfit" is computed as the difference between the interpolating function and the original observations
- Misfit is displayed as a function of position and distance to nearest observation

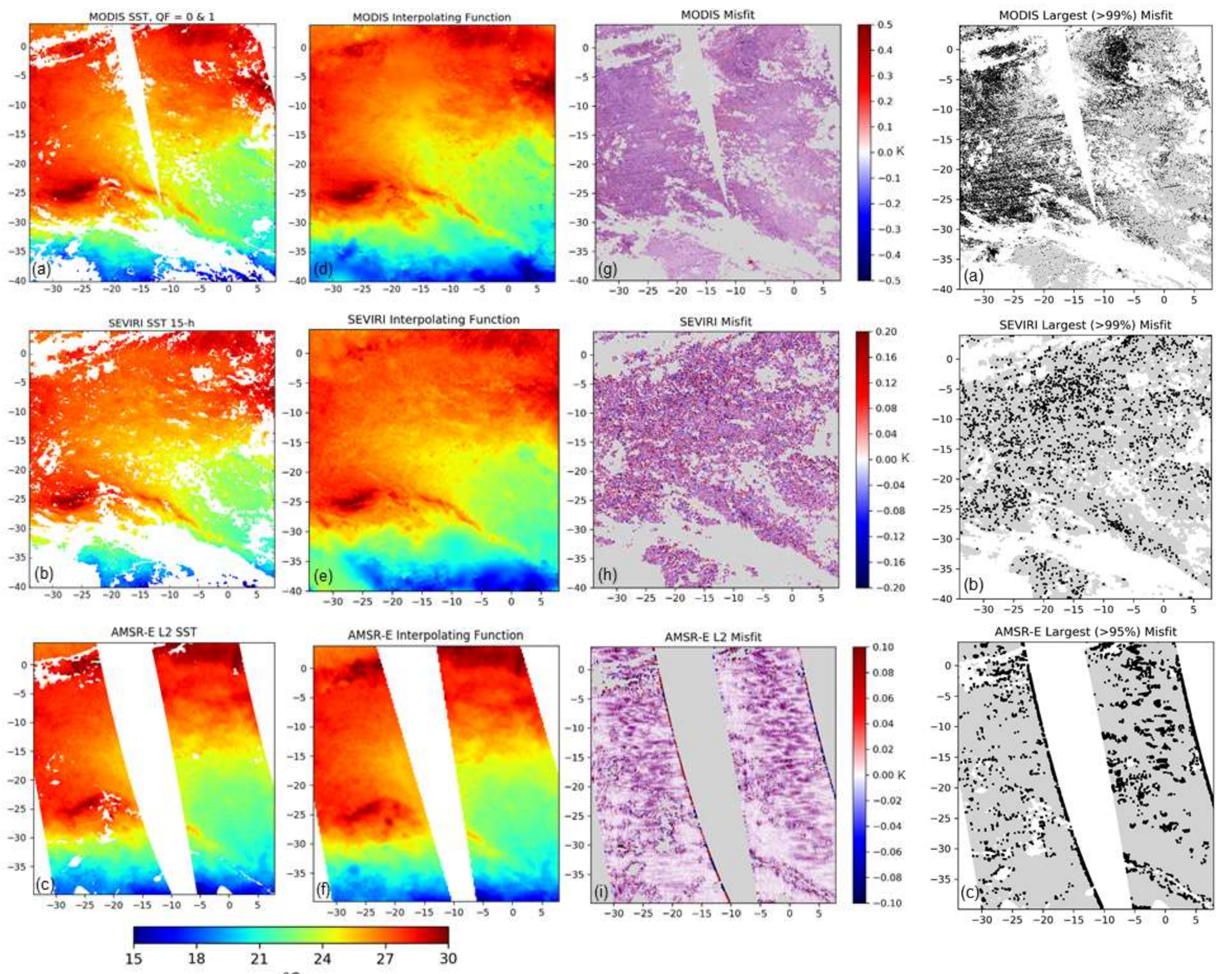


Key Results:

- The misfit is small at observed clear points
- Gaps of up to ~10 pixels can be filled with 0.2 K accuracy based on input of the clear data only
- Performance within larger gaps can be significantly increased by adding simulated lower resolution observations at the cloudy points when the interpolating function is generated
- Performance of a simple weighted average approach is shown for comparison

APPLICATION TO SCENE QUALITY ASSESSMENT

The utility of the technique for helping to assess the quality of the data used to build the interpolating function and identify potential artifacts in the input data is demonstrated through application to SST retrievals from MODIS, SEVIRI, and AMSR-E obtained over the southern Atlantic Ocean on 8 February 2009. Interpolating functions were generated from the available retrievals and the resulting functional values compared against the original retrievals. The patterns suggested by the largest misfit values are quite different for the different sensors suggesting that the differences may be associated with the underlying data.



MODIS

- Misfit shows stripes consistent with individual sensor scan lines and residual scan striping
- Coherent misfit left of scan center at the top of the scene correlates with scan geometry and could be instrumental

SEVIRI

- Large misfit in the regions of maximum diurnal warming could be associated with the interpolator over-smoothing across the sharp gradients
- Pattern otherwise random

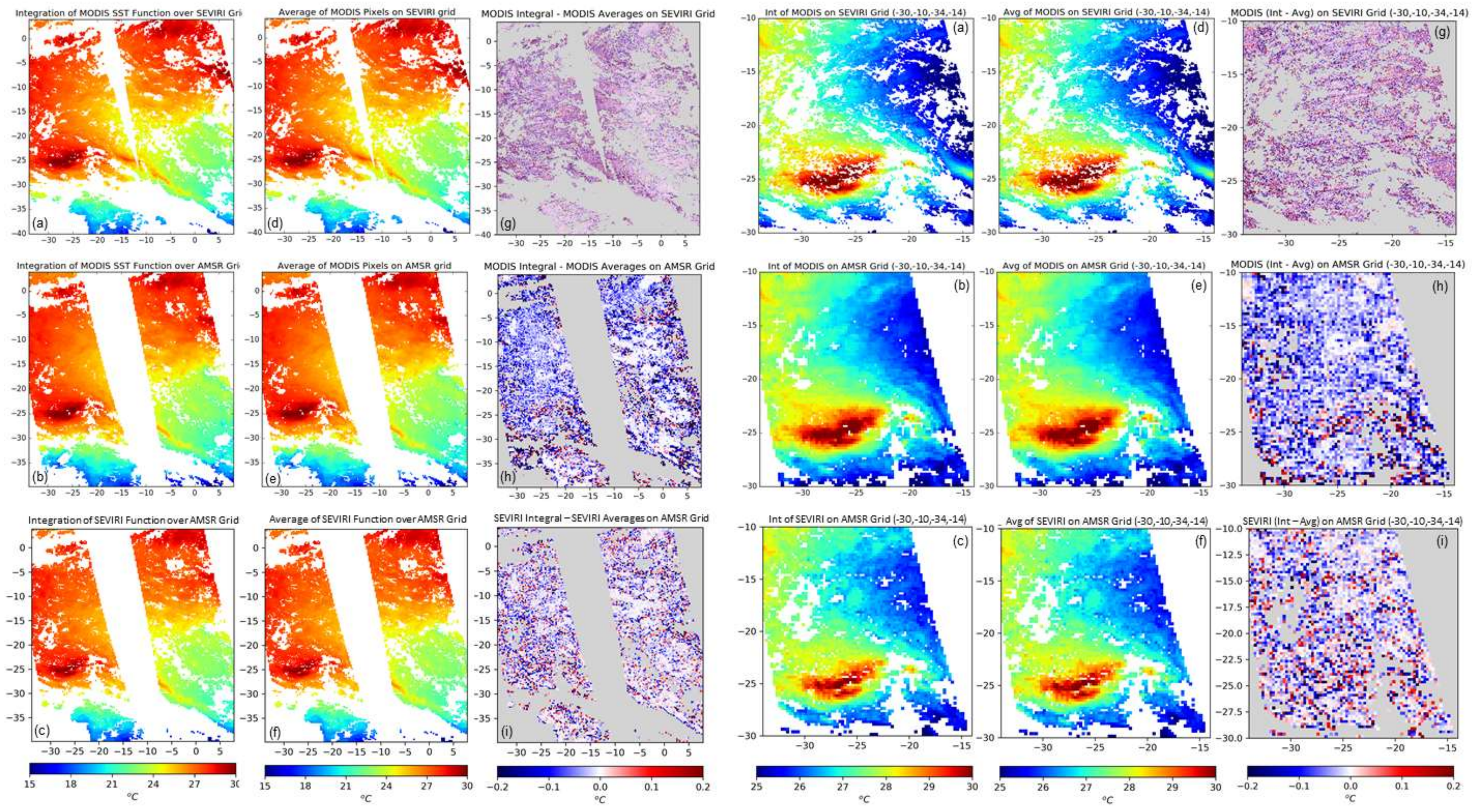
AMSR-E

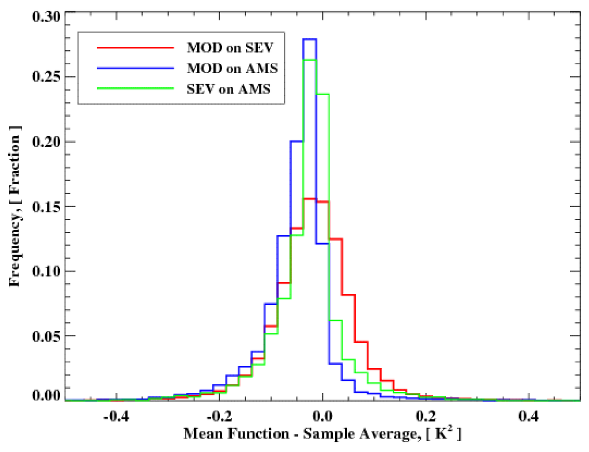
- Suggestion of residual "halos" around screened regions
- Known anomalies at the outermost spots on the right of the scan are identified

APPLICATION TO SUB-PIXEL SST VARIABILITY

A second novel application is to use the interpolating function to explore subpixel variability within satellite products of differing spatial resolution. Accurately quantifying the true variability is challenging in practice and the interpolating functions can provide physically consistent values throughout coarser footprints of arbitrary size. The first and second moments of the interpolating functions yield estimates of the mean SST and its variance, respectively, over selected footprints. We are particularly interested in using the second central moment of the function to estimate the variance of the field. This approach is demonstrated using the different resolutions of the MODIS (1 km), SEVIRI (5 km), and AMSR-E (25 km) scenes examined previously.

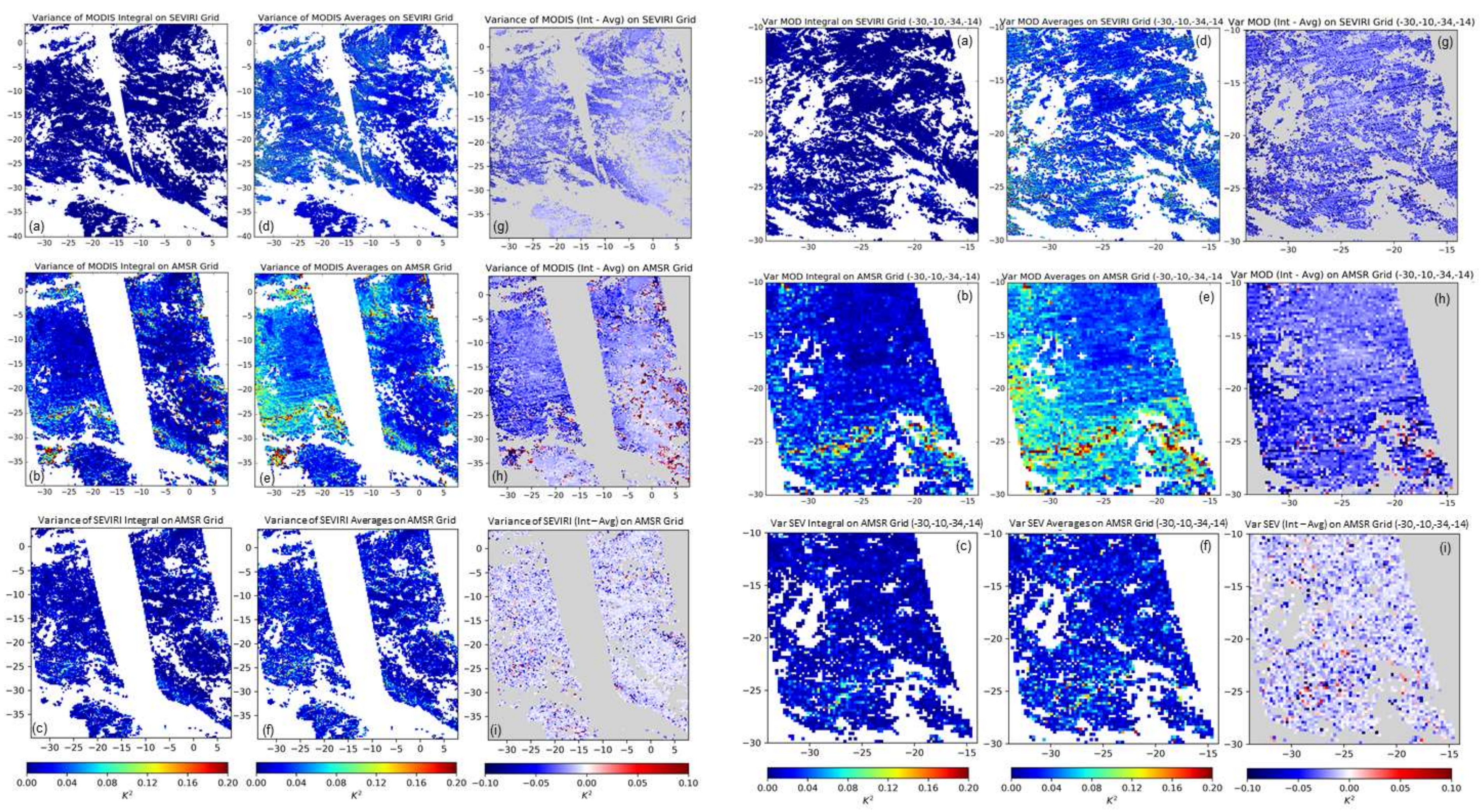
First moment: We first verified that the integral of the interpolant over a selected footprint accurately represents the mean SST over that region.

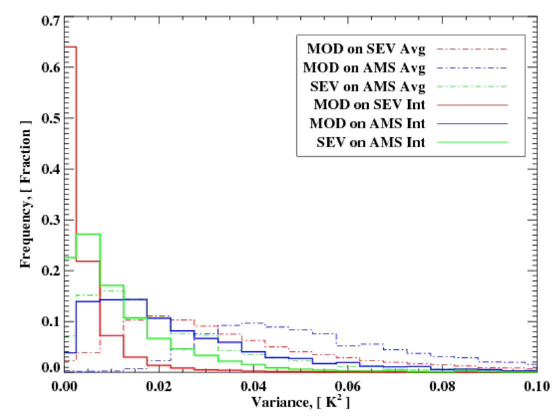




- The integral of the interpolating function derived from a higher resolution sensor evaluated over a coarser resolution footprint was compared against direct arithmetic averages of all the available higher resolution observations within the same domain
- The integrals agree very well with the data averages suggesting that the interpolating function can accurately simulate a coarser resolution observation and capture the variability within coarser sensor footprints
- Small negative biases suggest that the interpolating functions might project slightly cooler SST values into regions with missing observations

Second moment: The ability of the second moment of the interpolating function to characterize the variability within coarser resolution pixel was explored next. Explicit variances obtained from the second moment were compared with direct computations of the sample variance for corresponding higher resolution retrievals within the same domain.





- The variance estimates agree in pattern but are reduced for the interpolator
- The interpolator provides a lower bound on the spatial variability and perhaps an improved estimate in regions where observations are noisy
- Within open ocean regions, variability of 1-km-resolution observations on grids of both 5- and 25-km found to be ~0.07 K
- In regions of sharper gradients, the variability within 25-km resolution grids increased to as much as 0.4 K for sampling at 1-km resolution
- The variability of 1-km observations on a 25-km-resolution grid is about 2.4 times greater than that on a 5-km-resolution grid

CONCLUSIONS

- **A novel interpolating technique yielding an interpolant in functional form has been developed with multiple potential applications to the generation and analysis of satellite-derived SST products.**
- **Comparison of the functional form of the interpolant with the retrievals upon which it was derived can be employed as part of an operational processing scheme to help flag suspect retrievals for additional quality assessment.**
- **Indications of residual scan striping and "halos" surrounding screened regions were provided by the technique.**
- **Direct comparisons between moments of the interpolating functions and the observations used in their derivation show the technique can accurately represent areal averages and quantify spatial variability in the underlying physical SST field.**
- **Application of the technique provided new insight into the spatial SST variability as a function of sampling resolution.**
- **Future work will compare the method's performance and explore its application to multi-sensor SST analysis generation.**