Comment on oversampling methods in general

Pertaining to “A physics-based approach to oversample multi-satellite, multi-species observations to a common grid” by K. Sun et al. (https://www.atmos-meas-tech-discuss.net/amt-2018-253/)

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The paper describes a new algorithm to increase spatial coverage and reduce noise at the expense of temporal resolution for satellite datasets. The super Gaussian spatial response function and comparison of tessellation and discretization errors are well described, as well as several target satellite data products.

Main Comment

My comment pertains to the conclusion: “This physical oversampling is applied to OMI NO_2 products and IASI NH_3 products, showing substantially improved visualization of trace gas distribution and local gradients.”, as well as the premise of producing a grid that is significantly finer than the observed satellite pixels. My main argument is that the satellite measurement is the convolution of the spatial response function on the real atmospheric gas distribution, and that performing sensitivity weighted averaging like described does not change that the effective resolution of the product is still limited (to at least some extent, which does not seem to be characterized at all in the existing oversampling literature) by the Level 2 satellite pixel resolutions. Increasing resolution is actually a complex inverse problem to solve for the estimated gas distribution using the lower resolution Level 2 pixels even in the absence of noise.

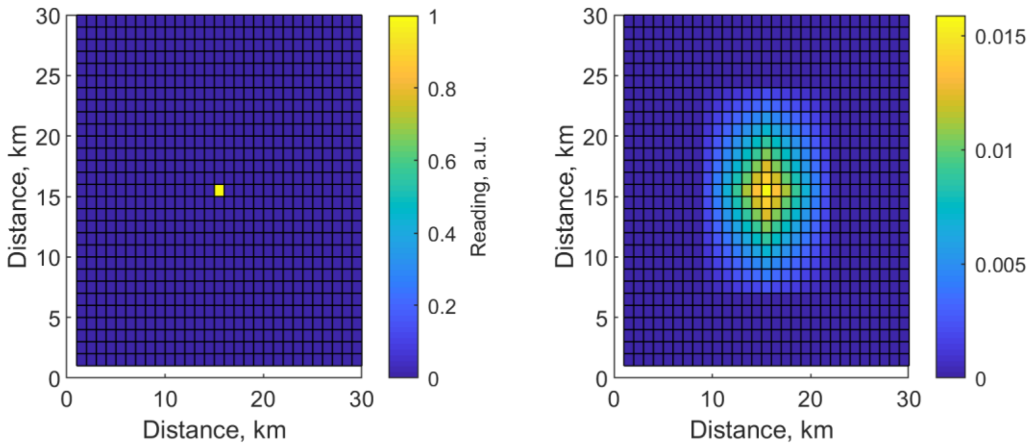
By way of example, the Comment Figure below shows a simulated 1 km by 1 km region of high gas values as ‘oversampled’ if there was a series of 7 km by 9 km pixels each with a 2D boxcar response function. Due to the limited resolving power of the underlying pixels, the result is seen to be spread over a much larger, 13 km by 17 km area. This is a tough test case because the gas distribution is discontinuous, nevertheless the paper shows point sources applications and a very similar pattern (distinct ‘circular blur’) is seen in the observational results (Figs. 8, 9, and 10) at sub-pixel scales.

- If the Comment Figure is interpreted directly, then one would conclude there are gradients around the 1 km by 1 km source, when this is purely an artifact - the algorithm displays far more information than there actually is. For this reason, caution should be used in applications where there are apparent gradients around point sources, which could easily lead to mistaken conclusion about atmospheric transport or decay processes.

- Similarly, if this Comment Figure were used for a high resolution emission inventory, the emission should be proportional to the value at that specific 1 km by 1 km grid cell, which has a source strength here defined as 1. By my calculation, the corresponding oversampled grid cell has a value of only 1/63. The true source value can be retrieved - but only by integrating the whole 13 km by 17 km area which negates the high-resolution.

- One exception where higher-resolution can be used quantitatively is that that the *center* location of a source can be identified below Level 2 pixel resolution (exactly in the ideal case, but noise will of course play a role in real applications).

In summary, besides the application just mentioned, it is unclear whether the much higher-than-pixel resolution output can be justified. In the past literature, Fioletov et al. 2011 (GRL) and Fioletov et al. 2013 (JGR:A) claims ‘detailed “subpixel-resolution” spatial distribution’ is possible and Streets et al. 2013 (Atmos. Environ.) refers to oversampling as achieving “super-resolution”. To what extent is the enhanced resolution (such as 1 km, as proposed in this manuscript) physically real? I suggest adding discussion of the limitations of the approach and caveats in interpreting the results of oversampling. This will strengthen the manuscript and help the community who may use the described algorithm or other similar methods in the future.



Comment Figure. (left) Real distribution of a gas with high concentration in a 1 km x 1 km area; (right) the same distribution, except as measured with a series of rectangular 7 km by 9 km satellite pixel and oversampled at 1 km resolution.

Minor

A point on the nomenclature of oversampling: while the term has been used in some past satellite papers, nevertheless I find it problematic since it is quite different than how it used in signal processing, where there is a well-known and widely used meaning of natively sampling at high resolution and then converting to a lower one. The authors note instead that the presented algorithm is a type of interpolation. I believe that referring to the algorithm as ‘gridding’ rather than ‘oversampling’ is formally correct and gives a much better intuition of what the algorithm actually does.

A minor point - ‘agile’ is also used to describe the algorithm, can a few words be added to clarify what the intended meaning is?