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Use of Cloud-Structure, Advection and Storm Development Information in High Resolution Satellite Precipitation Monitoring

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Many water resources management applications require precipitation products at spatial and temporal resolutions commensurate with the pixel resolution of geostationary data (˜5km and 15 min. respectively). Current multi-platform satellite precipitation algorithms combine geostationary microwave data from low orbiting satellites with geostationary imagery. However, these techniques remain dependent on the physically indirect relationship between geostationary cloud indices and precipitation and at near-pixel resolutions, new approaches are required to move towards operationally useful products. Of equal importance to the generation of the precipitation estimates is the quantification of their associated uncertainty. Such quantification should take account of the mixed discrete/continuous nature of both the probability distribution of precipitation and the structures of the satellite retrieval algorithms.

Current multi-platform satellite precipitation monitoring strategies combine the high spatial and temporal resolutions provided by geostationary imagery with the direct sensitivity to precipitation-related hydrometeors provided by passive and active microwave sensors on low-orbiting platforms. In most of these algorithms, the former data are calibrated against the latter, leading to the local dynamic calibration of a geostationary satellite technique. The availability of microwave satellite data is steadily improving, with sampling times progressively reducing towards the three hour return time envisaged by the proposed GPM mission. Such improvement may make it possible to develop effective near-pixel-resolution satellite algorithms. However, it is becoming clear that deriving a very high resolution (15 minute, 5km or better) rainfall product from 3 hourly microwave data and next-generation geostationary imagery will require a radically different approach to the production of daily precipitation products from geostationary data calibrated using a handful of microwave overpasses.

Current research suggests that further improvements in geostationary precipitation algorithms will require a move away from techniques based on single image pixels or even local groups of pixels to a broader consideration of the spatial and temporal contexts of each pixel location. A number of research groups have looked at the identification and quantitative representation of large-scale cloud structures and the use of this information in precipitation estimation, frequently through the use of neural networks. Others have studied geostationary imagery as a source of information on storm advection. This paper looks at a combined approach in which storm elements are tracked and modelled through their lifecycle. The elements in question may be defined in two different ways, leading to two distinct but related algorithm designs. In the first approach, individual storm “cells” are defined and tracked using a segmentation algorithm. The second approach models precipitation processes within the cells of a rectangular grid that is progressively deformed by advection. These algorithms are being developed using GOES imagery for the continental US combined with NEXRAD ground data that are used both for validation and as a proxy for a possible future 3 hour microwave dataset.

An additional feature of the algorithms being developed is the way in which they quantify uncertainty. The error in a satellite precipitation product is difficult to characterise using the variance of the difference between the estimated field and ground truth. At near-pixel resolutions the most significant satellite retrieval errors are associated either with failures in discrete categorisation processes, such as distinguishing raining and non-raining clouds, or with geolocation errors. These types of error give rise to conditional probability distributions of precipitation that are poorly represented by simple error models. An alternative approach is to include stochastic elements into the satellite retrieval models that yield either pixel-resolution fields of conditional probability distributions for precipitation with respect to the satellite data or ensemble products in which each element represents an equiprobable representation of the precipitation field consistent with the satellite data.