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Nasrin Nasrollahi

Improving Infrared-Based Precipitation Retrieval Algorithms Using Multi-Spectral Satellite Imagery

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Nasrin Nasrollahi

Improving Infrared-Based Precipitation Retrieval Algorithms Using Multi-Spectral Satellite Imagery

"Doctoral Thesis accepted by University of California, Irvine, USA"

Dissertation

Submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy in Civil Engineering

by

Nasrin Nasrollahi

Dissertation Committee:
Professor Soroosh Sorooshian, Chair
Professor Kuo-lin Hsu
Professor Brett Sanders
Professor Russell Detwiler
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Nasrin Nasrollahi
University of California, Irvine
Irvine
California
USA

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To
Amir, my husband and my best friend
My Dad and Mom who shaped me into who I am
My sisters for their never ending love and
The joy of my life, Kian
Without their constantly support, encouragement and love, this dissertation would not have been possible.

Supervisor's Foreword

There is nothing more gratifying for a Professor than being asked to prepare a preface for the dissertation research of his student whose work is of the caliber worthy of being published in the Springer Theses Series. The dissertation research of Ms. Nasrin Nasrollahi at the University of California, Irvine exemplifies the best one can hope for from a doctoral student.

In a nutshell, her research dealt with the issue of how best one can use technological advances in observation systems and measure one of the key components of the global hydrologic cycle, namely precipitation, with the accuracy useful for various applications. The technology in this case is the availability of a variety of advanced instruments (infrared based channels, passive and active microwave radars, etc.) aboard a number of classes of environmental satellite systems (Geo Stationary, Polar Orbiting). Dr. Nasrollahi's contribution, which is the subject of this publication, is the integration of information from these multiple satellite sensors and multiple channels into the current precipitation estimation algorithms. In her work, she takes advantage of the recent NASA satellite CLOUDSAT which observes clouds and precipitation in high resolution and infuses that information into the current algorithms in order to eliminate some of the errors in existing data. In addition, she employs some of the recent machine-learning techniques to extract relevant information from large quantities of satellite data. Nasrin's final algorithm leads to a significant reduction in false rain signals, hence improving the quality of satellite-based estimates of precipitation.

One may ask "why is this important?" The answer lies in the fact that information about rainfall has become most important for two primary reasons. The first one is that changes in precipitation at the global scale hold clues about climate change with respect to its impact on the elements of the hydrologic cycle. Therefore having comprehensive estimates of precipitation in time and space covering the entire globe can give evidence about the shifting patterns of rainfall and how extreme events are changing. The second of course is how we as humans experience precipitation (rain and/or snow) in our daily lives. This could be simply knowing tomorrow's weather report i.e. if your area is getting rain or not or if you are going to expect flooding in your region. Such information about precipitation is therefore crucial for a range of applications such as dealing with hazards or improving the science and understanding the changes in the hydrologic cycle. Nasrin's dissertation is a research work contributing to this body of knowledge.

Department of Civil & Environmental Engineering, University of California, Irvine, CA, USA
7/31/2014

Soroosh Sorooshian

Preface

The Moderate Resolution Imaging Spectro-radiometer (MODIS) instrument aboard the NASA Earth Observing System (EOS) Aqua and Terra platform with 36 spectral bands provides valuable information about cloud microphysical characteristics and therefore precipitation retrievals. Additionally, CloudSat, selected as a NASA Earth Sciences Systems Pathfinder (ESSP) satellite mission, is equipped with a 94 GHz radar that can detect the occurrence of surface rainfall. The CloudSat radar flies in formation with Aqua with only an average of 60 s delay. The availability of surface rain occurrence based on CloudSat observation together with the multi-spectral capabilities of MODIS makes it possible to create a training data set to distinguish false rain areas based on their radiances in satellite precipitation products (e.g. Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN). The brightness temperature of 6 MODIS water vapor and infrared channels are used in this study along with surface rain information from CloudSat to train an Artificial Neural Network model for no-rain recognition. The results suggest a significant improvement in detecting non-precipitating areas and reducing false identification of precipitation.

The second approach to identifying no-rain regions, developed in this study, is to find the areas covered with non-precipitating clouds. The cloud type data available from CloudSat is used as a target value to train an artificial neural network model to identify non-precipitating clouds such as cirrus and altostratus. Application of the trained model on two case studies investigated in this research, show significant improvements in near real-time PERSIANN rain estimations.

In addition, a cloud type classification algorithm was developed to classify clouds into seven different classes (cumulus (Cu), stratocumulus (Sc), altocumulus (Ac), altostratus (As), nimbostratus (Ns), high cloud and deep convective cloud). The classification model uses a self organizing features map to classify clouds based on multi-spectral MODIS data and CloudSat cloud types. The result of the classification model shows acceptable results for summertime. The winter season cloud classification is challenging due to dominance of low and middle level clouds. A better cloud classification algorithm for wintertime is achievable using active radar data and is beyond the capabilities of currently available remotely sensed multi-spectral information.