IPID4all Doctorate Research Exchange with University of Oldenburg
Feedback report

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Exchange topic

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Solar Radiation Variability and Forecasting

Introduction

I have been working as a Ph.D. candidate in the Indian Institute of Technology (IIT) Mandi, Himachal Pradesh-India, led by Prof. Dr. Anil K Sao and Prof. Dr. Ankit Bansal, since August 2012. The main objective of this research is to develop and improve the accuracy of solar resource estimation and forecasting models using satellite-derived multi-channel data and hybrid models based on Autoregressive Integrated Moving Average (ARIMA), Artificial Neural Networks (ANN) and Kalman Filter (KF) for spatiotemporal predictions. Special attention is given to various weather events occurring over India, such as dust storm, western disturbance, and fog events as shown in figure 1. The effective methodologies and respective inputs considered for accurate forecast are highly dependent on the time horizons.
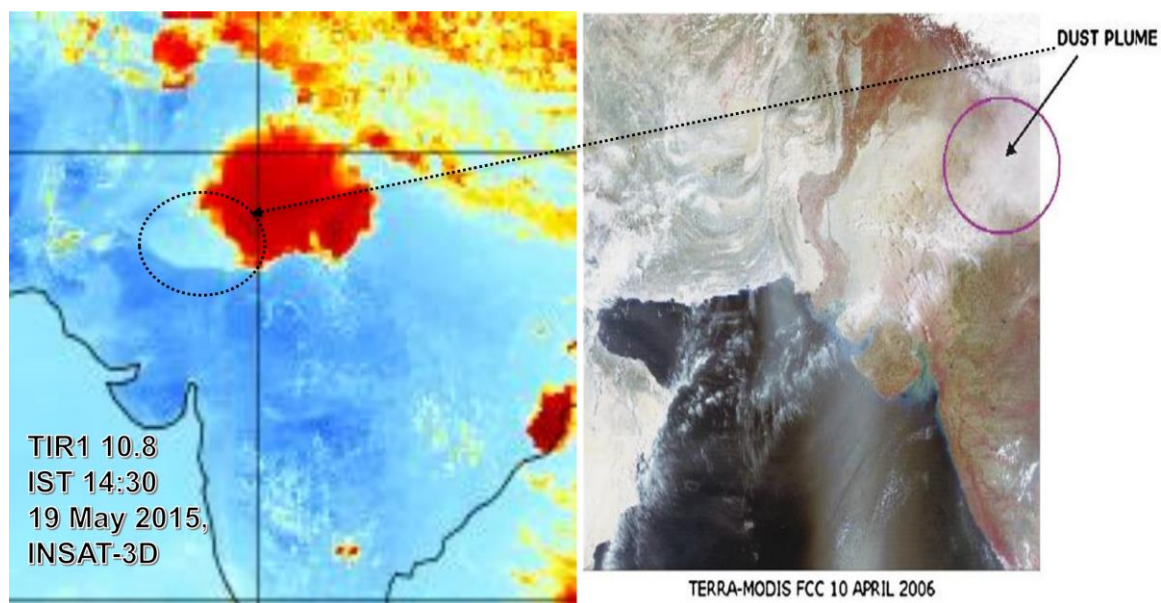

Figure 1 Dust event over Indian region

The images obtained from the satellite have multiple features (ocean, desert, land etc.) that need to be extracted with image segmentation. The segmentation divide (clusters) the data based on colors scheme, the user has to define the number of clusters based on the desired feature from imager. There are a number of clustering methods available, but we employed k-mean clustering due to its simplicity and less computational requirement. To relate the GHI with the clear sky irradiation, an all-day index (ADI) with fog, dust and cloud effects is introduced. This All-day index is derived from various features of the spectral band data from the satellite such as VIS, BTD_{30}, BTD_{12}, IDDI, and RAT_{30}. The BTD_{31} is the difference between MIR (central wavelength 3 microns) and TIR-1 (central wavelength 10 microns) band for night time cloud index, similarly for others BTDs. The normalized index is in the range -0.2 to 1.2 to maintain the desired index limit for day and night.

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Feedback report

Now, to forecast the GHI values over India in the presence of dust, cloud, and fog, a hybrid model is employed. This model tracks and projects the various features derived from satellite images forward in time. It implements the following steps: In the first step, the resolution of the image is reduced to decrease the computation time and memory. This is done through decomposition using wavelet transform (WT); in the second step, the features such as cloud and dust are tracked in space using the Kalman Filter (KF); in the third step, the tracking model is combined with a time series model ARMA /ANN to construct a hybrid forecast model and improve the accuracy of the forecast as compared to simple tracking model. The ANN network is trained with an Ensemble Kalman Filter (EKF) to update the weights. Finally, the wavelet transform is applied to reconstruct the image at the original resolution and recover radiation map. The IMD network data all over India of every 10-minute is used for validation of estimated GHI over 32 stations.

Research Undertaken

My goal was to build model that work on the fog, dust and cloud effect on solar radiation considering both spatial and temporal resolution. The Oldenburg research team already work on the cloud phenomena and forecast. The prediction of radiation for a few hours in advance is based on satellite images. These contain information about the weather-dependent uncertainties and the prediction reliability. Statistical methods are used to improve radiation forecasts models. I would like to incorporate the dust and fog section into the solar radiation modeling with help of Oldenburg team. The major contribution during Oldenburg was as follows: The development and application of Heliosat model considering the dust and fog event; the data preparation and consideration of major technical point while radiation estimation in case of INSAT-3D data; the comparison and valuation of estimated data with Meteosat and ground measurements; Also make some major correction on Heliosat model for new event like dust and fog ceases.

Personal Experience

Germany is a great place, and Germans are a wonderful people. I was absolutely comfortable talking to any person there or visiting any place I wanted. Many Germans know India, and in my experience, bear respect and warmth for Indians. The ones that I met during my stay were all very open-minded and well-travelled. They opened their homes for me, introduced me to their families and took me out to great places. Europe in general and Germany in particular, has a rich and long history. Plus, Germans have an unusual fondness for museums. As an Indian, it is a pleasure to understand German history and compare and contrast it with Indian history. Coming from India, the German language can initially be a problem, especially in small German towns where few speak English. However, while learning German, being an Indian helps. German is not only of Indo-European origin (like English), but it has also managed to retain a remarkable similarity to many modern Indian languages (unlike English). The German grammar is very similar to Sanskrit grammar, and many German words sound very close to their counterparts in languages such as Marathi, Hindi, and Bengali. Another big change is the Nature. In Germany, you are always in public-transport range to a lovely, dense, Hansel-and-Gretel forest. Plus, German forests have extremely well-marked walking and biking trails, and they are almost empty of dangerous predators. So exploring wilderness is easy and very pleasant. Some utilities (like electricity, water, and gas) effectively cost less in Germany than in India. (Also, there is no water shortage in Germany.) Some other utilities (like phone, Internet, public transport) can carry higher effective cost. There are few organized Indian communities in Germany. Therefore, compared to Indian expats in, say, US or UK, there are fewer opportunities to meet fellow Indians. (I know of Indians who have quit their job in Germany and left for home because they felt lonely here.)

IPID4all Doctorate Research Exchange with University of Oldenburg
Feedback report

Conclusions

I had a successful exchange period in the department of physics at University of Oldenburg. I achieved the primary goals of getting acquainted with the Heliosat model of the radiation estimation and able to work with its measurement data and identified the steps needed to be taken to process it to produce useful data sets. This will make it easier to get started once compare with INSAT-3D and Meteosat that will help me with my Ph.D. research. On top of these comparisons, we were able to establish a research plan for an interesting methodology (modified Heliosat) for radiation forecast based on Indian atmospheric aspect particularly on the duct and fog. On a personal level, I strengthened the relationship with Oldenburg physics department and got to know many friendly and intelligent people, who helped me to find my way in Germany, inspired me scientifically and contributed positively to my overall social experience.

Outlook

As mentioned before, a research plan was established and this implies that I will keep close contact with the researchers at Oldenburg to progress with our ideas. This research can lead to either a conference poster or presentation, and most preferably also a journal paper. Oldenburg physics department will be involved in research related to my Ph.D. topic in the future, where the collaboration with Dr. Annette Hammer will be maintained.

The exchange strengthened the relationship between IIT Mandi and University of Oldenburg and my experience could be the first of several exchanges of students in both ways. Especially considering that these institutes are leading in the field of solar radiation and measurements, both with their own contributions, large benefits of the combined knowledge could be gained in different collaboration projects. The IPID4all organisation provides a convenient programme that makes it possible to plan future Ph.D./Postdoc exchanges, both incoming and outgoing.

Acknowledgments