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# A Bayesian Model to Study Spatio-Temporal Variability of Latent Heat Flux and Its Trend

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## Abstract

This paper talks about two models. First model is presented to study space-time variability of latent heat flux, where latent heat flux has been decomposed into three periodic terms, spatio-temporal process term, long term trend and a term due to covariates. And the second model is presented to characterize the long term trend and its possible causes. For both the models Bayesian approach was adopted. The method presented is particularly useful for characterizing environmental spatio-temporal processes variability. The model parameters were sampled using a Markov chain Monte Carlo simulation technique. The models were used for studying latent heat flux components in the Indian Ocean for the period of January 1985 to April 2010. The results showed that in LHF variability, dominant factors were annual variability, spatio-temporal variability and variability due to covariates. Further it has been found that the long term positive trend of LHF is dominated by the increase in wind speed. In some regions of Indian Ocean, increase in sea surface temperature has also been the cause for increase in LHF.

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## 1. Introduction

Transfer of heat between sea surface and lower atmosphere through latent heat is a key driving force of the atmospheric circulation. The latent heat flux (LHF) is a source of energy for intra tropical convergence zone. There exists a strong relationship between precipitation and latent heat flux ([1]). Study on global warming

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infers that slightly more increase in atmospheric temperature can trigger unmanageable climate variability ([9]). Much of the heat is stored in the ocean which will be released to the atmosphere in coming time ([10]). Much of the heat released by ocean will be in the form of latent heat flux. Increased wind speed together with the increased heat content of ocean has made study of latent heat flux more important.

Earlier studies on LHF variability mainly concentrated on variability on different time scales ([4,7,12]). Some study has been done on relationship between climate parameters and latent heat flux ([2-3]). More recently there are studies on latent heat flux trend. Study on latent heat flux trend is done by [16] and the positive trend in LHF is associated with sea surface temperature (SST) increase. Study done by [8] on decadal-scale trend based on four types of data sets, associated the positive trend of LHF to increase in wind speed trend. Study of LHF on different time scales was done by [12] in the Indian Ocean. Their study shows that net heat flux has positive trend and since latent heat flux is the main contributor, the trend must be associated with latent heat flux positive anomaly. They showed that wind speed has a positive trend since 1960 and specific humidity difference also has a positive trend from 1970. Therefore, they concluded that LHF positive trend is due to wind speed and specific humidity difference. Study of latent heat flux trend over the southern Ocean is done by [15].

The focus of this paper is to model the relationship of LHF with wind speed and sea surface temperature (SST). The relationship will be used to estimate the proportion of contributions by wind speed and SST for the increase in LHF. To extract the trend component and to model LHF, Bayesian hierarchical spatio-temporal modeling approach was used. Bayesian hierarchical method (BHM) is a space time model technique, in which we first define model parameter and hyper parameters and their prior statistical distributions. Bayes theorem can be used to calculate posterior distribution for model parameters. Using the posterior distribution, model parameter samples can be simulated. These samples are then used for analysis of the spatio-temporal process. For the purpose of this study objectively analyzed (OA) heat flux data was used. More information about OA air-sea heat flux data set can be found in [16]. The OA LHF data used in the study is downloaded from Indian national centre for ocean information services (INCOIS) Hyderabad, India website with spatial resolution  $1^\circ \times 1^\circ$ .

## 2. Model

This section describes two models, one describes the latent heat flux and the other describes the trend in latent heat flux. For the purpose of study, the Indian Ocean is divided into 8 regions as in [12]. Table 1 describes regions in the Indian Ocean.

Table 1. Regions of Indian Ocean as in [12]

Region id	Region
1	Arabian sea
2	Bay of Bengal
3	South China sea
4	South of region 1 and north of 5°S latitude
5	South of region 2 and north of 5°S latitude
6	South of region 3 and north of 5°S latitude
7	South of region 4, 5, 6 and north of 20°S latitude
8	South of region 7 and north of 40°S latitude

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