ENVIRONMENTAL REMOTE SENSING AND GIS FOR LAND SURFACES

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This paper aims to give an overview of the main research tasks conducted by the Hydrology Remote Sensing Laboratory (HRSL) and its contributions to conquer the societal challenges that our society is facing. The research areas of the HRSL include applications of advanced airborne and space borne remote sensing to key environmental issues and land surface processes, such as hydrological cycles, urban heat island, eco-environmental vulnerability assessment, as well as natural hazards. To fulfil the needs for completing the abovementioned tasks, there is a need to integrate multiple sensors to take data covering a variety of scales for physical measures, such as multispectral, hyperspectral, microwave, thermal, as well as LiDAR sensors with incorporating geographical information systems. Various approaches of data processing and image analysis are then adopted to extract information for subsequent entry to statistical or physical models to monitor spatiotemporal properties and trends of the environmental issues and land surface processes. In addition, the HRSL utilizes GNSS radio occultation (RO) remote sensing data to advance their processing schemes and study earth's atmosphere and ionosphere for assisting the improvement of weather forecast and space weather prediction. Examples of utilizing earth observations and remote sensing for conquering societal challenges are addressed. They include a wide spectrum of general environmental problems concerned by the citizens and governments all over the world, such as post-earthquake disaster assessment, typhoon-to-typhoon interactions, identification of dangerous glacial lakes, land subsidence monitoring and revealing its influential factors, modelling of hydrological process components (evapotranspiration, surface energy fluxes, and soil moisture), flood mapping, eco-environmental vulnerability, drought, snow falls… etc..

Keywords: Land surface parameters, eco-environmental vulnerability, remote sensing; natural hazards

INTRODUCTION

Global warming is a topic not only concerned by the scientific communities, but also by the government and people all over the world as it is frequently considered to be the cause of the intensified natural hazards in recent decades, especially under the circumstance that the scientists are incapable of predicting or monitoring it. Nevertheless, it is been found that, statistically speaking, both climate and land-use have been contributing to increase the contribution of short duration floods to the increase in the number of flooded locations, and, thus, interaction arises, determining land-use dynamics to couple with climatic changes influencing the flood aggressiveness simultaneously (Sofia et al. 2017). The importance of understanding the land surface processes and the improvement of its monitoring cannot be overstressed. Furthermore, as suggested by Sofia et al. (2017), an effective disaster management clearly requires an integrated approach to land planning and supervision given the fact that it is impossible to control the climatic trend. Therefore, there is a need to classify the level of eco-environmental vulnerability for the follow-up management and practice implemented by the authority.

In this paper, we intend to provide a glance of the outcomes of our major research topics, including the land-air interaction (land surface processes (LSP) models, remote sensing of surface variables (land surface fluxes, soil moisture, evapotranspiration), monitoring and assessment of post-natural disaster events (typhoons and earthquakes), and eco-environmental vulnerability assessment (EVA) with emphasis on the description of the EVA.

A GLANCE ON OUR RESEARCH OUTCOMES

Liou and England (1996, 1998a,b) and Liou *et al*. (1998, 1999a, 2001a) presented a series of land surface process/Radio brightness (LSP/R) models that simulate the interactions of land surface and air, and their radiometric signatures by considering the biophysical characteristics of the land surfaces with or without occurrence of soil freezing and thawing. Such biophysically-based LSP/R models are specifically important to improve our knowledge how the land and air interact, and helpful to construct the scenarios of a variety of land-air interactions for the land surface type of our interest. Subsequently, retrievals of land surface parameters including soil moisture and vegetation biomass by using neural networks were investigated (Liou et al. 1999b, 2001b, Liu et al., 2002) as well as estimates of the land surface fluxes, including sensible heat, latent heat, and evapotranspiration, by other data processing schemes (Chang et al. 2010, 2013; Wang et al. 2010; Cheng et al. 2014; Liou and Kar, 2014; Wang et al. 2016). Figure 1 shows schematic diagram of the global mean annual energy balance (W/m2) of the Earth (adopted from Liou and Kar 2014).

With solid knowledge of the properties and physics of the land surface processes, and mature image processing skills, our research team applies the remote sensing and GIS techniques to a wide spectrum of applications associated with natural or manmade hydrological or geological hazards or extremes. For examples, (1) thermal dynamics and interaction mechanisms of typhoon, typhoon-typhoon, and super-typhoons are studied (Chane Ming et al. 2014; Liu et al. 2015; Liou et al. 2016; Lee et al. 2017). An innovative interpretation on the distance to define the typhoon to typhoon is given. Generalized empirical formulas of threshold distance with computational efficiency to characterize cyclone–cyclone interactions are proposed for its practical use in operationally numerical models. Figure 2 shows the tracks of typhoons Haiyan (2013) and Hagupit (2014) and cold fronts with geography indicated in the background as described in Lee et al. (2017). Pressures of the two typhoons were given along the tracks. Supertyphoons were formed very closed as easily observed near the lowest pressures 895 and 905 hPa for Haiyan (2013) and Hagupit (2014), respectively; (2) Drought signatures in Mongolia and USA are investigated

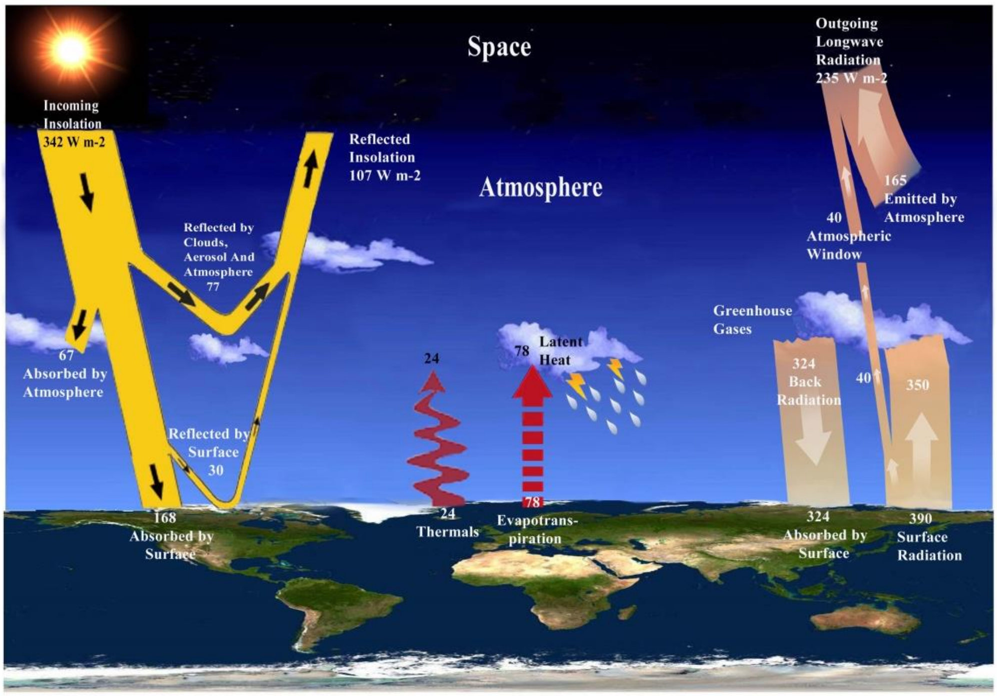

Figure 1. Schematic diagram of the global mean annual energy balance (W/m^2) of the Earth (Adopted from Liou and Kar 2014).

(Cheng et al. 2015; Dorjsuren et al. 2016). A new drought index consisting of Bowen ratio is invented; (3) Other disasters, including flood mapping (Phuong and Liou 2015), assessment of post-earthquake loss damages (Liou et al. 2010, 2012), identification of dangerous glacial lakes (Che et al. 2014), and land subsidence (Hsu et al. 2015); And, (4) a framework to classify the zones of eco-environmental vulnerability for environmental management and protection is presented by incorporating satellite data and in-situ measurements (Nguyen et al. 2016). For easier implementation of the framework, it is improved to simply use the Landsat data (Liou et al. 2017).

ECO-ENVIRONMENTAL VULNERABILITY ASSESSMENT

It has been recognized that eco-environmental vulnerability assessment is crucial for environmental and resource management. The knowledge about zoning EVA becomes even more important with the increased frequency of extreme events possibly associated with anthropogenic stresses.

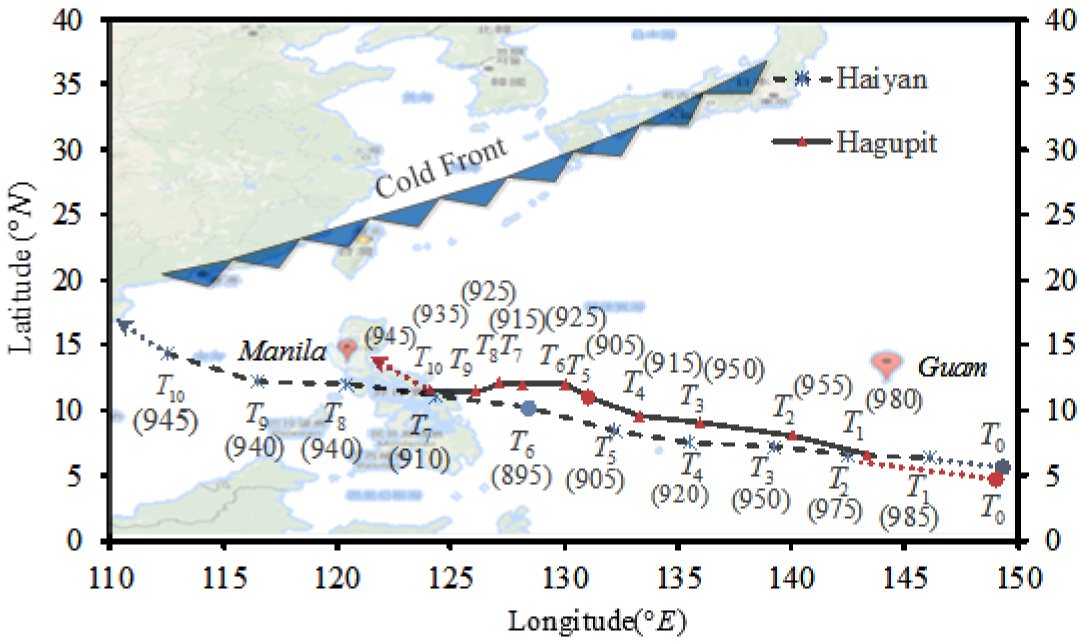

Figure 2. Tracks of typhoons Haiyan (2013) and Hagupit (2014) and cold fronts with geography indicated in the background. Supertyphoons were formed very closed as easily observed near the lowest pressures 895 and 905 hPa for Haiyan (2013) and Hagupit (2014), respectively. (Adopted from Lee et al. 2017)

In our study (Nguyen et al., 2016), an assessment framework was proposed to evaluate the eco-environmental vulnerability in the Thua Thien - Hue Province, Vietnam, with involvement of 16 variables including those extracted from Landsat 8 OLI, digital maps, and *in situ* measurements. In the view of long-term environmental monitoring, two concerning issues remain in the concept of eco-environmental vulnerability assessment: (1) some indices were generated from *in situ* measured data, especially meteorological indices such as precipitation, which have certain limited capabilities of reflecting spatial variation of eco-environmental vulnerability due to insufficient spatial resolutions; and (2) applicability of previous framework was limited by resolution of station measurement and interpolation technique applied.

Liou et al. (2017) intended to further apply Landsat data to monitor eco-environmental vulnerability by proposing an improved framework based on our previous version (Nguyen et al., 2016). The improved framework is more suitable for long-term eco-environmental monitoring by improving the illustration of spatial and temporal variability of eco-environmental vulnerability using time series of Landsat data to retrieve variables for detecting changes in surface characteristics affecting regional eco-environment as depicted in Figure 3. This is aiming to resolve difficulties in obtaining long-term in situ eco-environmental measurements. The impacts and trends of land use and land cover (LULC) on environmental vulnerability for the past 25 years were assessed as an example to demonstrate how the remote sensing data can be used to support planners to obtain objective measurements and comparative context.

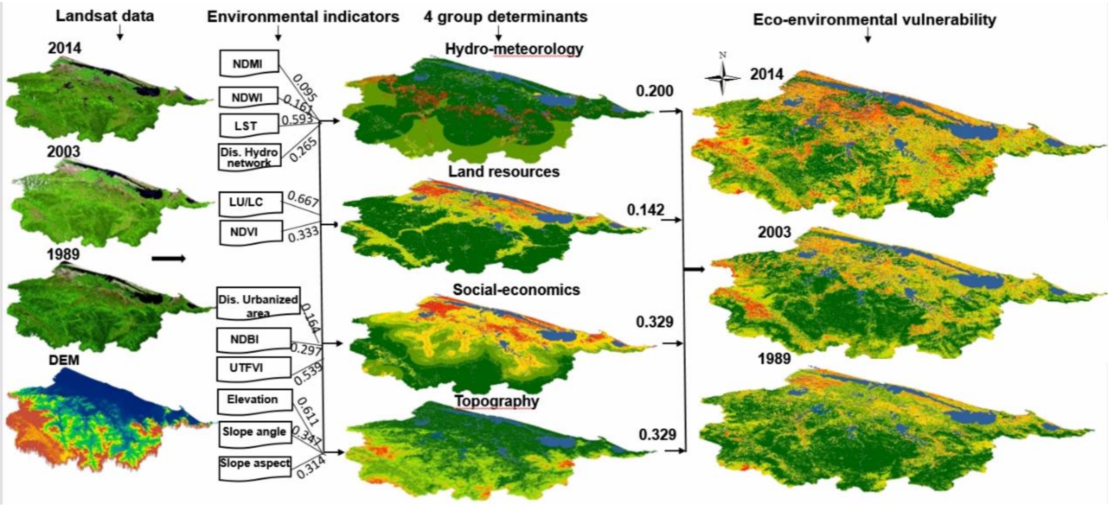

Figure 3. Framework of long-term eco-environmental vulnerability assessment by remote sensing data. (Adopted from Liou et al. 2017)

Liou et al. (2017) assessed the impacts of past anthropogenic processes (mainly LULC) changes on spatial-temporal eco-environmental vulnerability by: (1) evaluating eco-environmental vulnerability changes based on variables retrieved from Landsat TM, ETM, and OLI & TIRS (Thematic Mapper, Enhanced Thematic Mapper, and Operational Land Imager & Thermal Infrared Sensor); and (2) analysing the relationship between land use changes and thermal anomaly by computing correlation coefficient between land surface temperature (LST) and Normalize Difference Built-up Index (NDBI) over the past 25 years (1989-2003-2014).

Results show that time series maps of eco-environmental vulnerability in 1989, 2003, and 2014 in the Thua Thien–Hue Province exhibit an evolving pattern of urban thermal anomalies highly associated with sprawl of developed land and tightly correlated with higher eco-environmental vulnerable levels, namely *medium, heavy*, and *very heavy* over the period of interest. The area percentage of *medium, heavy*, and *very heavy* eco-environmental vulnerable levels was increased with spatial distribution from low to high elevation belts during the same period of time. It supports the ideas that intensification of human activities has amplified the vulnerability of eco-environment in the Thua Thien-Hue Province.

RESULTS AND CONCLUDING REMARKS

This paper presents an overview of the main research tasks conducted by the HRSL and its main contributions. The outcomes include improved knowledge about LSP, retrieval schemes by remote sensing, understanding of typhoons' characteristics, and assessment of manmade and natural hazards/disasters, and proposing an EVA framework. Each outcome has its specific significance. The main purpose of reviewing the previous outcomes is to disclose their usefulness and value so that they can be implemented for the corresponding works.

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