Appendix A. Proposal Format

HICO Data User's Proposal

Title of Proposal: A hyperspectral atmospheric correction algorithm to retrieve water-leaving radiance signal from HICO data

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Abstract/project summary

Through this proposal, we intend to develop an atmospheric correction algorithm to retrieve accurate water-leaving radiance signal from hyperspectral remote sensing data provided by HICO. It is considered as the main radiometric entity from which various coastal oceanic products are derived. However, the current atmospheric correction algorithms developed for processing typical ocean color sensor data (such as MODIS-Aqua, SeaWiFS, MERIS etc.) are multispectral in nature and limited to the clear oceanic waters. These algorithms do not produce appreciable results for optically more complex waters falling in following categories: (1) Water features covered by intense aerosols (absorbing as well as non-absorbing), (2) Dense phytoplankton blooms dominated waters, (3) Waters containing high particulate matter (suspended sediments) and dissolved substances (CDOM), and (4) Waters bearing all above stated properties together (i.e. Case 2 waters). These problems define the limitation of satellite generated products owing to lesser accuracy to coastal applications. Therefore, in this project we desire to develop an efficient atmospheric correction algorithm to

retrieve the water-leaving radiance signal from HICO data. The new algorithm will render accurate estimates of water-leaving radiance which can be subsequently used in many bio-optical algorithms for quantitative assessments of coastal ocean water constituents needed for the various applications and coastal management activities.

1. Statement of work/project description

HICO is the first spaceborne imaging spectrometer designed to sample the coastal ocean. HICO samples selected coastal regions at approximately 90m Ground Sample Distance (GSD) with full spectral coverage (400 to 900 nm sampled at 5.7 nm interval), and signal-to-noise ratio sufficiently high to resolve the complexity of the coastal ocean (HICO Report). In order to make HICO imagery offer unrivaled utility in monitoring and quantifying the components of ecologically important coastal water features, we need to determine accurately the water leaving radiance from HICO data. For the accurate retrieval of water leaving radiance, a precise atmospheric correction is essential. Many atmospheric correction algorithms, with their own advantages and limitations have been developed. A number of researchers including Bailley et al. (2010), Ruddick et al. (2000), Siegel et al. (2000), Wang and Shi (2007) have tried to improve the pre-existing atmospheric correction algorithms. The results are quite convincing in case of clear waters, but are highly deteriorated in coastal oceanic waters and bloom-dominated waters due to high radiance reflected by various water components (like algal blooms and suspended sediments). Algorithms by Shanmugam (2012) and Shanmugam et al. (2013) produce good results in turbid and algal bloom dominated waters, but are not able to fully remove the aerosol effects (mainly in the NIR bands) in the presence of intense aerosols. Further, these algorithms are multispectral in nature, and cannot be directly applied to HICO data.

The presence of aerosol degrades the performance of the atmospheric correction algorithms, thus its addressal becomes of utmost importance as it varies randomly in time and space. The atmospheric correction algorithm developed for sensors such as SeaWiFS and MODIS assumes water leaving radiance (L_w) to be negligible in the near infrared bands centred at 765nm and 865 nm for SeaWiFS (748nm and 869 nm for MODIS) and to extrapolate the radiances to the visible spectrum considering them as aerosol induced radiance (Gordon and Wang, 1994). Also, response in NIR band changes with the increased radiance due to turbidity and algal blooms, which is interpreted as aerosol radiance and hence a correction is required to estimate correct amount of aerosol radiance.

The extrapolation technique is inevitably less precise in calculating the aerosol radiance in the visible spectrum. Therefore, a new extrapolation technique will be developed in this research work, which will use the corrected near infrared (NIR) band aerosol radiance. The performance of existing algorithms can be used as a leverage to develop a new atmospheric correction algorithm suitable for processing hyperspectral data from HICO.

The proposed regions for the HICO data acquisition are the Arabian Sea and Palk Bay (Bay of Bengal) which are considered to be optically more complex waters (Fig. 1), where current atmospheric correction algorithms breakdown due to the enhanced radiances.

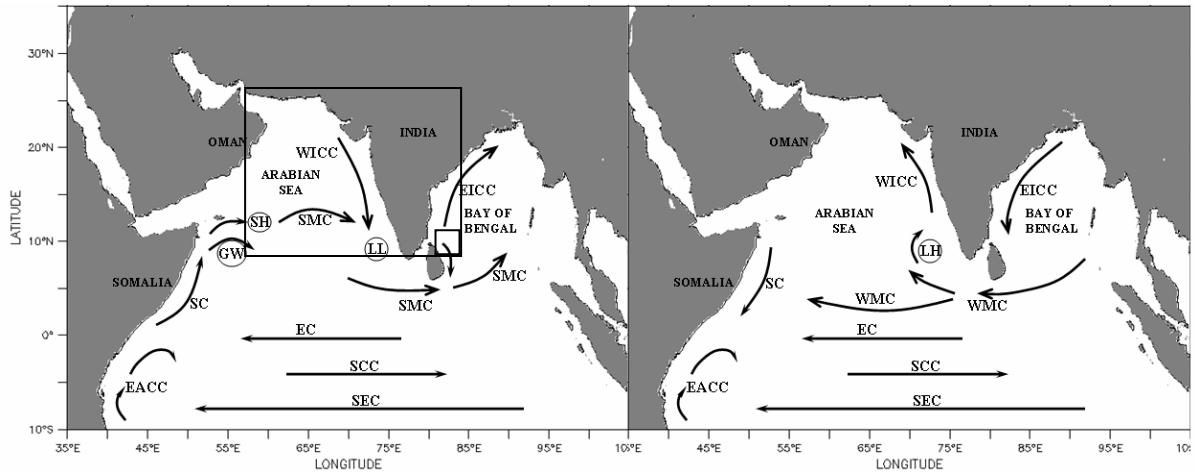

Fig. 1. Study area showing the Arabian Sea (big square area) and Palk Strait (small square area), along with current patterns during summer and winter **(9°-29°N and 55°-80°E).**

Hyperspectral water-leaving radiance retrieved from HICO data will be very useful for quantitative assessments of various water constituents of the coastal oceanic waters. It can be used for classification of major algal blooms that occur in these regions. Hyperspectral inversion techniques can be applied to the retrieved water-leaving radiance data for deriving IOPs (inherent optical properties) in these waters. Some of the far reaching impacts are given as below :

1) The accurate prediction and evaluation of chl-a and absorption coefficient models and identification of the major size classes of the phytoplanktons size class would not only assist us but also other research communities in developing the subsequent stages of the co-related models.
2) The evolution of the precise atmospheric correction algorithm would help to develop our understanding of ocean dynamics along with the factors that affects the water quality and ecosystem.
3) Better way to identify the grounds of fisheries and other marine species which would help to predict the growth of fishing economy and yield better outcomes in the field of pharmacology.
4) Help us understand the correlation between carbon cycle and ocean environment.
5) Hyperspectral satellite imagery can be properly classified on the basis of culture and growth that represents the particular class of phytoplankton and its kin.

2. Biographical sketch and available facilities

Dr P Shanmugam**,** PhD in Ocean Colour Remote Sensing and Digital Image Processing and a distinguished personality in the Ocean Optics Community who has worked with eminent Researchers across the globe. He is also an active member of Optical Societies, IOCCG (Ocean Colour Coordinating Group), IACG (International Atmospheric Correction Group) and various others Organizations. He has worked on various aspects of Technology Transfer Tools which has provided Ocean Optics an inter-rope ability to various other disciplines of Engineering and its sub-streams. He has published over 45 papers in International Journals, and has attended various worldwide conferences addressing the issues related to Oceanography, Hydrologic and Ocean Optics. He has numerous Internationally acclaimed papers and manuscripts to his credits which includes the following topics:

- Radiative Transfer Modelling
- Underwater imaging
- Algorithm Development and Modelling
- Satellite oceanography
- Coastal and marine hazards
- Coastal zone management

His Research team is highly skilled and dedicated to explore new paradigms in the realm of Ocean Colour Remote Sensing. The team has performed pioneer research in the field of Ocean Optics, Ocean Colour Remote Sensing, and Marine Geo-informatics with an unparalleled efforts and devotion. Each member has his/her own area of expertise and possesses excellent co-ordination during the task. The team consists of 9 members (one Faculty + eight Research Scholars) headed and guided by Dr. P. Shanmugam (Associate Professor, Department of Ocean Engineering, IIT Madras)

The team has also carried out Cruise Programs under his supervision in the recent years. This included the on-board in-situ measurements and conducting ship-board experiments in coastal waters around India, specifically in and around Bay of Bengal (highly turbid waters off Point Calimere) and Arabian Sea. Being a member of KORDI (Korea Oceanic Research and Development Institute), he has been an integral part of various Korean Research Projects and has played a pivotal role in Strengthening collaborative research and capacity building with Korean Institute of Seoul (South Korea).

The above stated roles, incontestably defines his professional capability and strength to be one of the most potential Researcher in the field of Ocean Optics and Ocean Colour Remote Sensing.

The available facilities include many workstation computers equipped with SeaDAS, Hydrolight, and ENVI-IDL softwares. We have also developed computer codes and entirely modified the already existing SeaDAS code for processing satellite ocean color data.

We have also acquired the large data sets from MODIS-Aqua, SeaWiFS and OCM2 sensors.

Since we have regular cruise programs to collect in-situ profiling data in coastal oceanic waters of the Arabian Sea and Bay of Bengal, we would like to use these data for calibration and validation activities.

In addition, we have enough funding resources to do this work and enough research scholars to support the research activities related to this work. Our funding will also allow attending and presenting results arising out of this proposal.

3. Output and deliverables

It is manifested that the completion of the project would impart numerous benefits and tactical advantages as outlined below:

(1) One of most common demand of the Research Community is to seek more comprehensive and precise Atmospheric Correction Algorithm, that can be applied with certainty to eliminate the errors in the data acquired from the Satellite. In our project, we aim to develop enhanced version of the Algorithm which would be a reappraisal to the previous ones meeting the demands of the user.
(2) Worldwide Publications on Ocean Colour Remote Sensing.
(3) Transfer of relevant data required for development and subsequent evaluation of Bio-optical models.
(4) Development of the atmospheric correction code.
(5) Strengthening of the relationship during the working period which would help us in building and expanding our collaborative Research Programs in the near future.
(6) Capacity building and capacity development aimed to solve the challenges of the project with broad view to understand the developmental needs of the project.
(7) To enhance the capability of implementation of the methodology and techniques which would catapult the work to next level of Research.

The project also incorporates the main idea of study and analysis the available field (in-situ) measured data which are acquired through external collaborative projects (or in other terms as a part of another project plans/ programs).

4. References

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