Session C

Poster Example

(This example was assembled by the Takeda Foundation using materials provided by Dennis Dye, who is an award winner in 2002.)

The Takeda Techno Entrepreneurship Award 2003

Technical Subject

New Tools and Methods for Monitoring Photosynthetically Active Radiation and its Role in Crop Production and the Terrestrial Carbon Cycle

Corresponding Applicant / Position, Affiliation

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Purpose & Contribution to Human Well-Being

Purpose:

Our research will introduce new tools and methods to advance current knowledge and understanding of how changing atmospheric conditions affect ecosystem functioning at regional and global scales. Of key importance to human societies is the potential influence of increased aerosols and/or cloudiness on photosynthesis, crop yields and the terrestrial carbon cycle (Figures 1, 2 and 3). For example, recent research suggests that extensive aerosols from industrial air pollution may significantly reduce annual crop yields in China as a result of increased optical depths and decreased solar radiation at the surface [1]. On the other hand, other studies indicate that the increased diffuse radiation associated with aerosols and clouds will enhance photosynthesis and plant productivity [2]. Current understanding of this phenomenon is poor.

Our key scientific questions are, *1) What is the magnitude and spatial extent of the aerosol influence on PAR in Asia and globally? 2)How does it affect the productivity of natural vegetation and crops?*

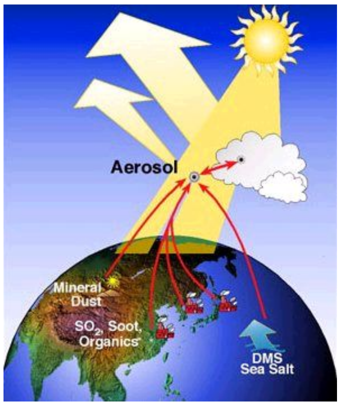

Fig.1 Effect of aerosols on solar radiation at the Earth's surface.

Three main objectives:

a) develop, test and apply a **new satellite-based method** for estimating and monitoring Photosynthetically Active Radiation and its (PAR) on a global basis, with separate consideration to direct and diffuse PAR,
b) assess **the effects of aerosols and clouds** on global distribution and dynamics of PAR,
c) assess the influence of variations in PAR caused by aerosols and clouds on the **productivity of terrestrial vegetation** and **ecosystem-atmosphere carbon exchange**

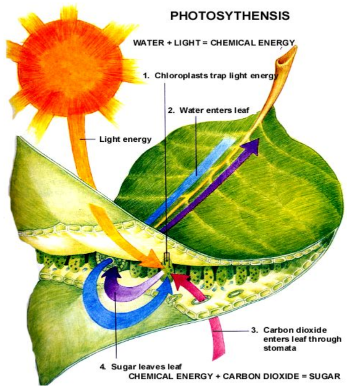

Fig.2 Illustration of photosynthesis at the leaf level.

Expected results and the time expected to be achieved:

* New global, **satellite-based data set on direct & diffuse PAR** to support ecosystem process modeling & carbon cycle studies. **(3 years)**
* **New Asian network of surface PAR sensors** to support studies of atmosphere-PAR-ecosystem interactions. **(7 years)**

Contribution to human well-being:

* Improved understanding of how human-induced atmospheric change affects natural and agricultural systems.
* New data & understanding will support informed decision-making on regulation of atmospheric aerosol pollution, and strategies for adaptation to (or mitigation of) negative impacts on agriculture & natural ecosystems.

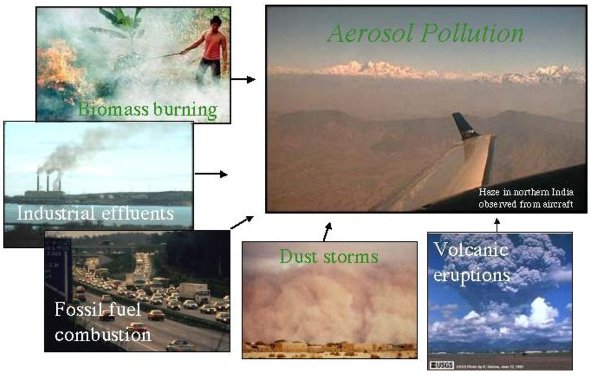

Fig.3 Origin of the aerosol pollution in the air.

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Method / Approach

We will develop a new remote sensing method that combines data on global aerosol and cloud properties from the satellite with an atmospheric radiation transfer model to estimate direct and diffuse PAR irradiance.

Surface measurement data for direct and diffuse PAR are crucial for PAR model calibration and accuracy assessment, however such data are extremely rare. To provide suitable surface PAR data, we will establish a new network of PAR measurement sites throughout the Asian region.

The satellite and surface PAR data will be used to drive an ecosystem process model and quantify the effects of PAR variability (attributed to aerosols and clouds) on photosynthesis and carbon exchange in natural vegetation and crops. Our overall approach is summarized in Figure 4.

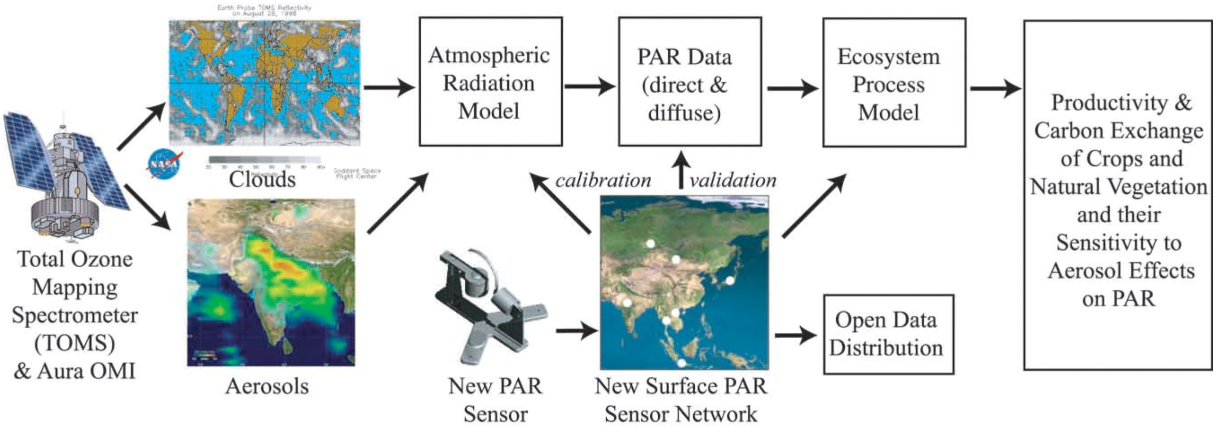

Fig.4 Overview of our project

Satellite Measurements of Clouds

Ultraviolet (UV) reflectivity measurements at 380 nm from the TOMS instrument provide a means to estimate the effect of clouds on the atmospheric transmission of PAR. **The basic technique is described by Eck and Dye [3]** The TOMS reflectivity measurement is used to infer the fraction of the PAR incident at the top of the atmosphere that is backscattered to space by clouds. Because absorption by clouds is negligible in the PAR waveband, the surface-incident PAR can be estimated from knowledge of the PAR at the top of the atmosphere and the TOMS reflectivity. **The Eck and Dye technique was successfully applied and validated on a global basis in earlier work [4].** The proposed research will resolve shortcomings of the Eck and Dye approach by accounting for the effects of aerosols, and by giving separate consideration to direct and diffuse PAR.

Satellite Measurements of Aerosols

Data on global aerosol properties derived from TOMS will be employed in the proposed research. **The theoretical basis for the using Total Ozone Mapping Spectrometer (TOMS) (and future OMI sensor) to detect and monitor aerosols is described by Torres et al. [5]. The technique exploits spectral differences in the UV backscattered radiances to separate aerosol absorption from scattering effects, and to derive values of aerosol optical depth and single-scattering albedo.** The aerosol properties will be incorporated in the atmosphere radiation transfer model to account for aerosol effects on the PAR surface irradiance.

Modeling PAR at the Earth's Surface

A modeling approach based on the one described by Eck and Dye [3] will be employed with the TOMS-derived data to estimate direct and diffuse PAR. The model will use the **delta-Eddington approximation to the radiation transfer equation for a plane-parallel, vertically inhomogeneous atmosphere**. A major shortcoming of the application by Eck and Dye [3] was their assumption of standard aerosol conditions. The proposed research will improve upon their work by using the TOMS-derived data to specify the observed aerosol properties, rather than assume standard conditions. Inclusion of the observed aerosol conditions is expected to **significantly improve the accuracy and reliability of the model for global PAR monitoring.** State-of-the art methods to account for 3-D cloud effects on atmospheric radiative transfer of PAR will also be incorporated into the model.

Calibration and Validation with Surface PAR Measurements

Availability of surface measurement data for both direct and diffuse PAR is crucial for model calibration and accuracy assessment. Such PAR data, however, are extremely rare. Meteorological stations that include radiation sensors typically measure only broadband solar radiation, not PAR. The PAR sensors in operation today typically measure global PAR, not its direct and diffuse components. To overcome the absence of suitable PAR data, **a new network of surface PAR measurement sites will be established as part of the proposed research.** The PAR network will consist of six distributed throughout the Asia region*, each representing a distinct radiation/cloud/aerosol regime. When possible, the sites will be located at existing or planned carbon flux measurement sites.

** The sites will be established in Japan, India, Mongolia, Russia, Vietnam and Indonesia through cooperation with local researchers. Including an additional site in Thailand that currently planned by the Frontier Research System for Global Change, the full network will consist of at least seven sites. The network will provide unique data on the dynamics of diffuse and direct PAR under variable aerosol and cloud conditions. The data will be archived and made available online to the general public. In this way, the PAR network will support environmental research even beyond the scope of the project proposed here.*

Assessing the Influence of Aerosols and Clouds on Terrestrial Photosynthesis

The time-series PAR data set produced in the proposed research above will be used to drive an existing model of the terrestrial carbon cycle, **SimCYCLE**. A sensitivity analysis will be performed to quantify the effect of interannual variations in PAR (attributed to aerosols and clouds) on photosynthesis and ecosystem-atmosphere carbon exchange. Agricultural croplands and natural vegetation will be analyzed separately.

References

[1] Chameides, W., *et al.*, 1999. Case study of the efects of atmospheric aerosols and regional haze on agriculture: An opportunity to enhance crop yields in China through emission controls? *Proc. Natl. Acad. Sci.*, 96:13626-13633.

[2] Gu, L., *et al.*, 2002. Advantages of diffuse radiation for terrestrial ecosystem productivity. *J. Geophys. Res.*, 107:10.1029/2001JD001242.

[3] Eck, T., and Dye, D., 1991. Satellite estimation of incident photosynthetically active radiation using ultraviolet reflectance. *Remote Sens. Environ.*, 38:135-146.

[4] Dye, D. and Shibasaki, R., 1995. Intercomparison of global PAR data sets. *Geophys. Res. Lett.*, 22:2013-2016.

[5] Torres, O., *et al.*, 1998. Derivation of aersol optical properties from satellite measurements of backscattered ultraviolet radiation: Theoretical basis. *J. Geophys. Res.*, 103:17,099-17,110.

Answer to the Chair's Questions

Our research will promote the commercial development of a new type of sensor for *in situ* measurement of global and diffuse photosynthetically active radiation (PAR). The SDR-1 Single Detector Rotating Shadowband Radiometer from YES, Inc. is designed to measure UV or broadband shortwave radiation. We will engage the company to develop a PAR-specific version of this instrument. Because such a sensor has not previously been available for PAR, it will provide new opportunities for marketing and sales to researchers worldwide.

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Call for collaboration

We welcome discussion on possible collaboration with researchers with relevant interests and expertise!!

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