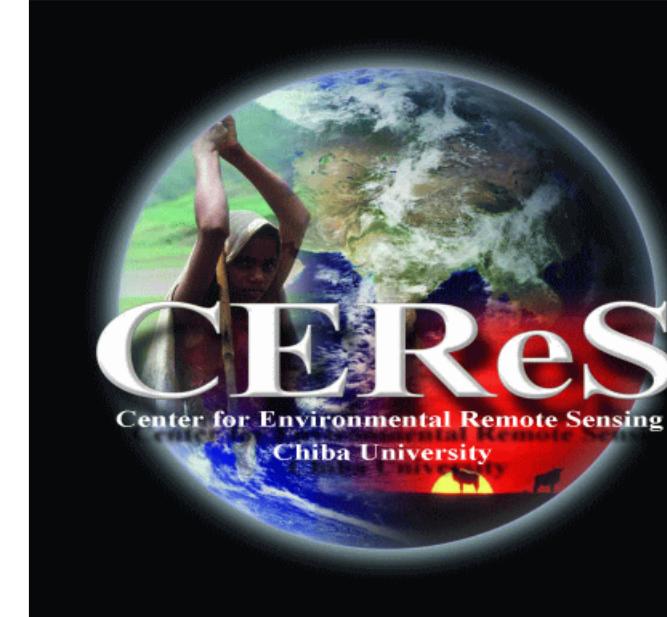


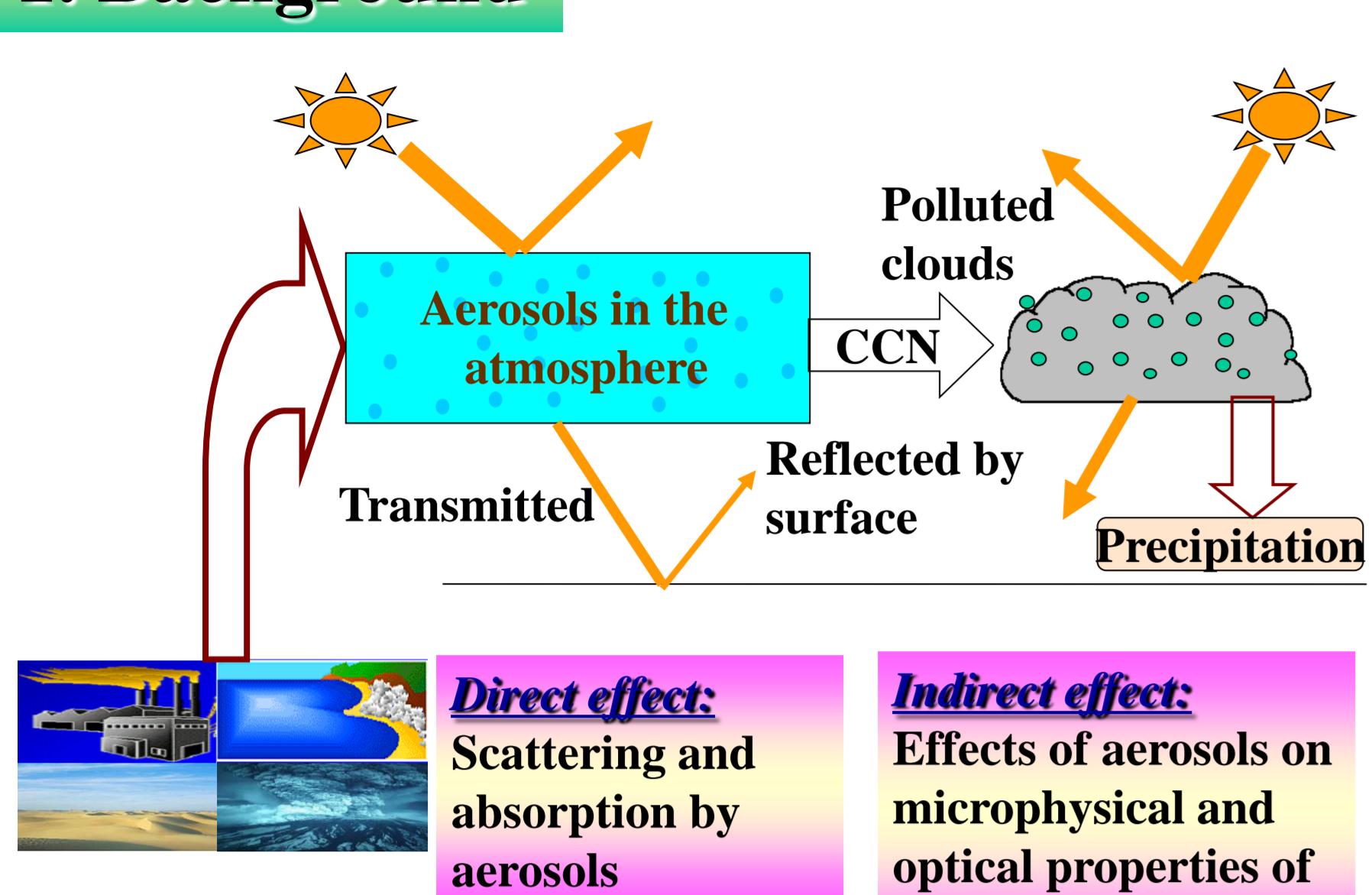
Use of spectral irradiances measured at the surface of SKYNET sites to study aerosol optical properties and aerosol direct effects

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1. Background



The roles of aerosols and clouds on regional and global climate change are still not clearly understood

Aerosols in the Asian region

- The Asian aerosol sources are unlike those in Europe and North America: much more coal and biomass are burned adding more absorbing soot and organic aerosols to the atmosphere.
 - The rapid industrialization of the Asian countries further causes the amounts of anthropogenic aerosols such as soot, sulfate, nitrate, organic matters to increase.
 - East Asia is also one of the important sources of dust aerosol, which further adds complexity.
 - The amounts of aerosols in the atmosphere of the East Asia are predicted to further increase in the future.
- It is well known that the East Asian aerosols can have impacts on climate system, but the major question of how are they linked with climate system still remains unanswered.

SKYNET network

• SKYNET is an observation network to study aerosol, cloud, and radiation interaction in the atmosphere.

For detail, visit <http://atmos.cr.chiba-u.ac.jp/>

• Major instruments for aerosol observation

Sky radiometer

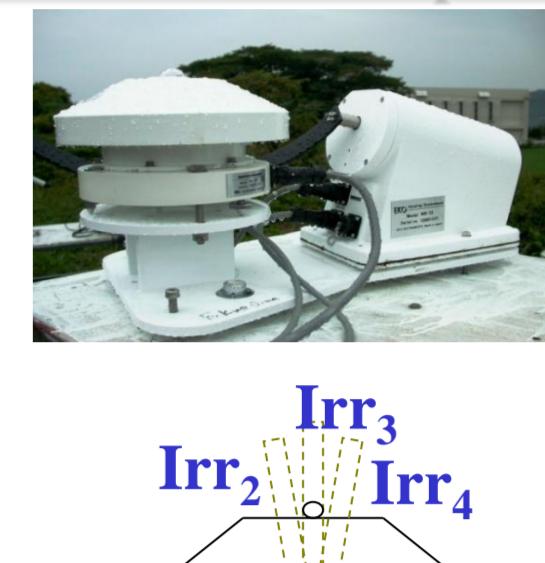


Manufacturer PREDE Co. Ltd., Japan

Data analysis software Skyrad.pack (Nakajima et al., 1996)

Cloud screening software CSSR (Khari and Takamura, 2009)

Shadow band attached spectroradiometer



Manufacturer EKO Co. Ltd., Japan

Data analysis software MS700analysis (Khari et al., 2011)

Irr₁Irr₂Irr₃Irr₄

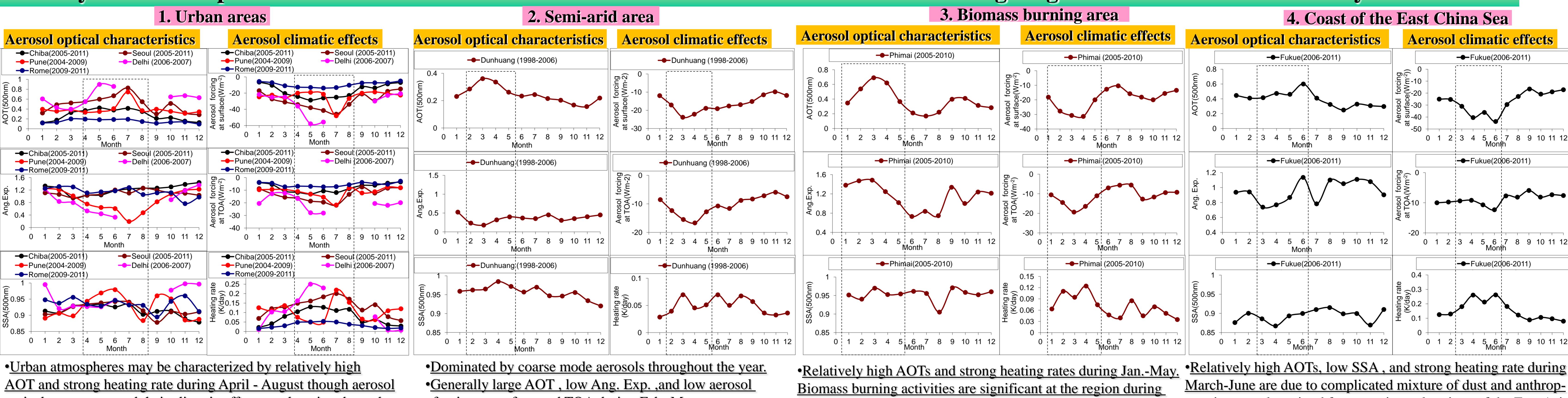
Sky radiometer is being operated at more than 50 sites around the world

Recently installed at 4 SKYNET sites within Japan

2. Purposes of this study

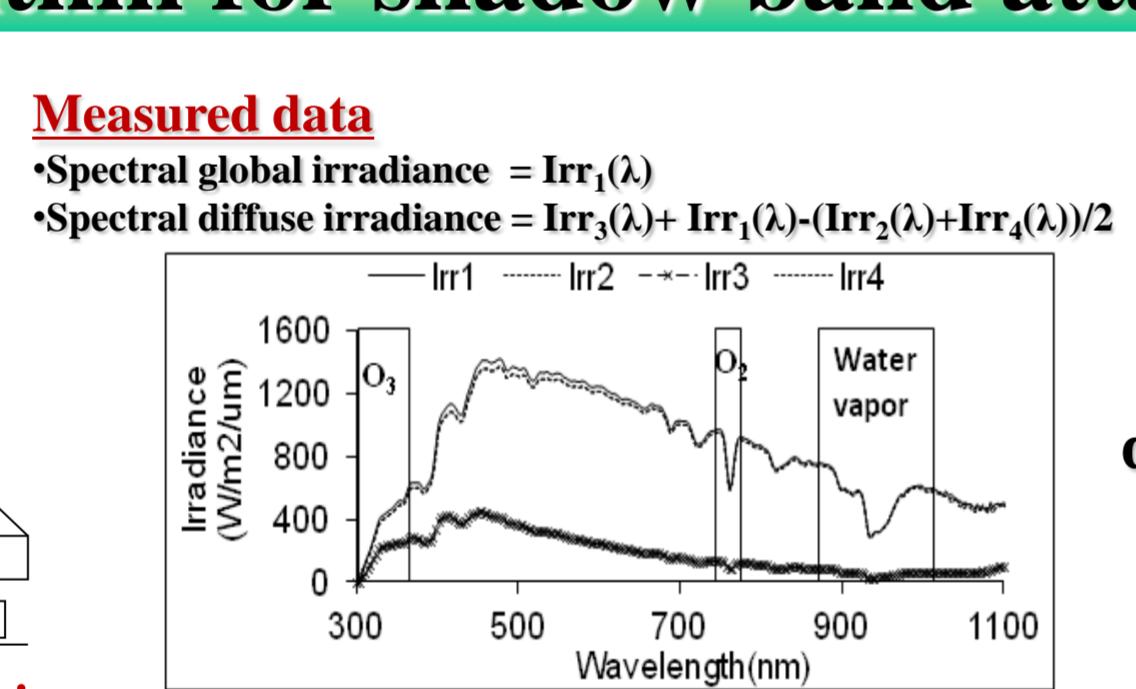
- Study the optical characteristics of the aerosols and their climatic effects at some important SKYNET sites using long term observation data of sky radiometer, which is a key instrument of SKYNET network.
- Develop a data analysis tool (algorithm) for newly installed observation system (shadow band attached spectroradiometer) at some SKYNET sites.

3. Study of aerosol optical characteristics and their climatic effects at some SKYNET sites using long term observation data of sky radiometer



4. Development of an algorithm for shadow band attached spectroradiometer of SKYNET network

Instrumentation



Major problem

Unlike sky radiometer, shadow band attached spectroradiometer measures spectral direct and diffuse irradiance using horizontal surface detector

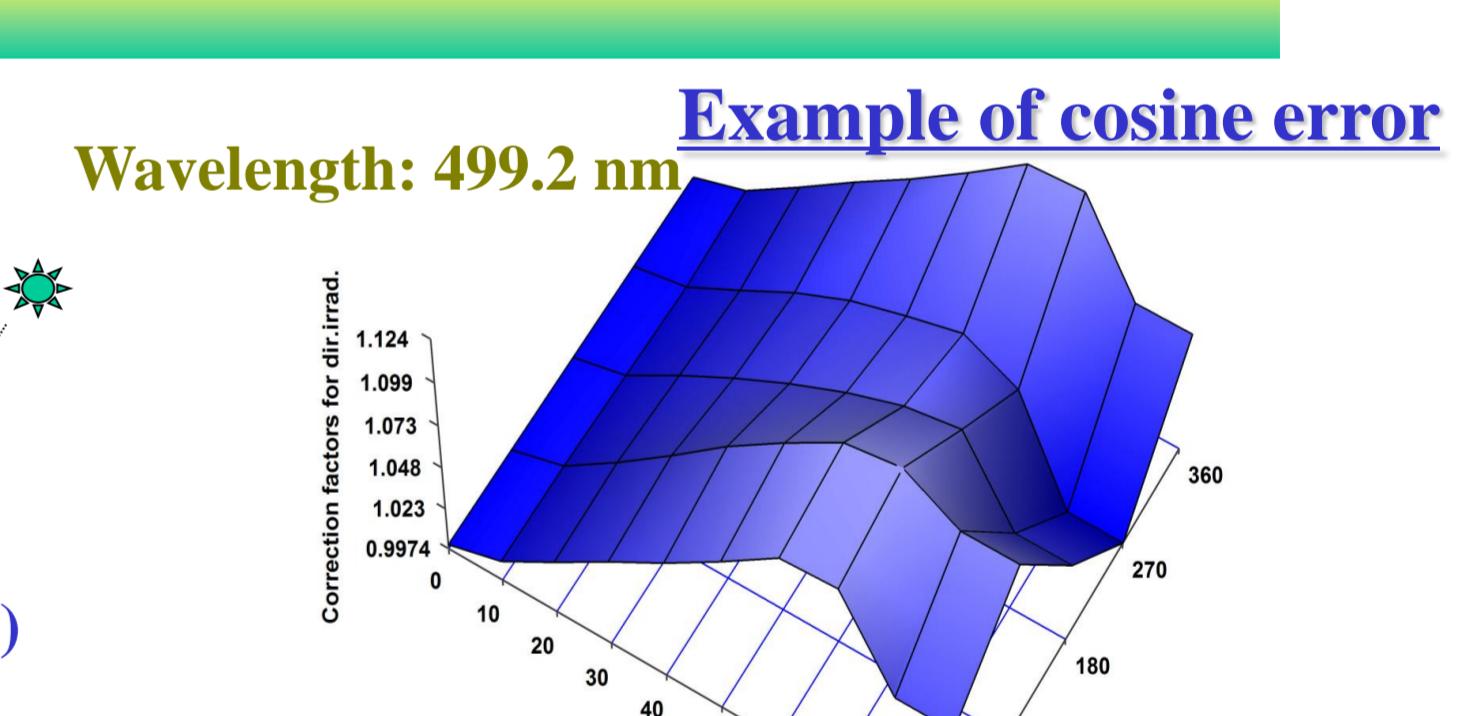
Such radiometer suffers from cosine error

What is cosine error?

1. For ideal Lambertian surface
 $Irr(0) = Irr(0=0) \cdot \cos(\theta)$

2. During actual measurement
 $Irr(0) \neq Irr(0=0) \cdot \cos(\theta)$

$$\text{3. Cosine error} = \frac{Irr(0)}{Irr(0=0) \cdot \cos(\theta)}$$



Retrievals of aerosol optical thickness (AOT) and single scattering albedo (SSA)

• For AOT retrieval

$$\text{Direct irradiance (Corrected)} = \text{Direct irradiance (Measured)} * \text{Correction factor (Direct)}$$

Can be measured at the laboratory

AOT

• For SSA retrieval

$$\text{Diffuse irradiance (Corrected)} = \text{Direct irradiance (Measured)} * \text{Correction factor (Diffuse)}$$

Cannot be measured at the laboratory

SSA

Depends on aerosol parameters, atmospheric condition, etc.

Procedure to retrieve SSA

Calculate diffuse irradiance using different SSA values until the modeled diffuse irradiance becomes equal to directly measured value

Radiation propagating from direction of zenith angle θ and azimuth angle ϕ for incident light from direction of zenith angle θ_0 and azimuth angle ϕ_0

$$D_{obs} = \int_0^{2\pi} \int_0^{\pi/2} I^d(\theta, \phi; \theta_0, \phi_0) \sin \theta \cos \theta d\theta d\phi$$

Correction factor for direct irradiance for zenith angle θ and azimuth angle ϕ

Integration over full domains of zenith and azimuth angles

Division of (1) by (2) at fine grid points defined by zenith and azimuth angle intervals of 0.5° and 1° over full domains of zenith and azimuth angles

5 values for 5 pre defined ϕ

5 files for 5 pre defined ϕ

Integration over full domains of zenith and azimuth angles

Division of (1) by (2) at fine grid points defined by zenith and azimuth angle intervals of 0.5° and 1° over full domains of zenith and azimuth angles

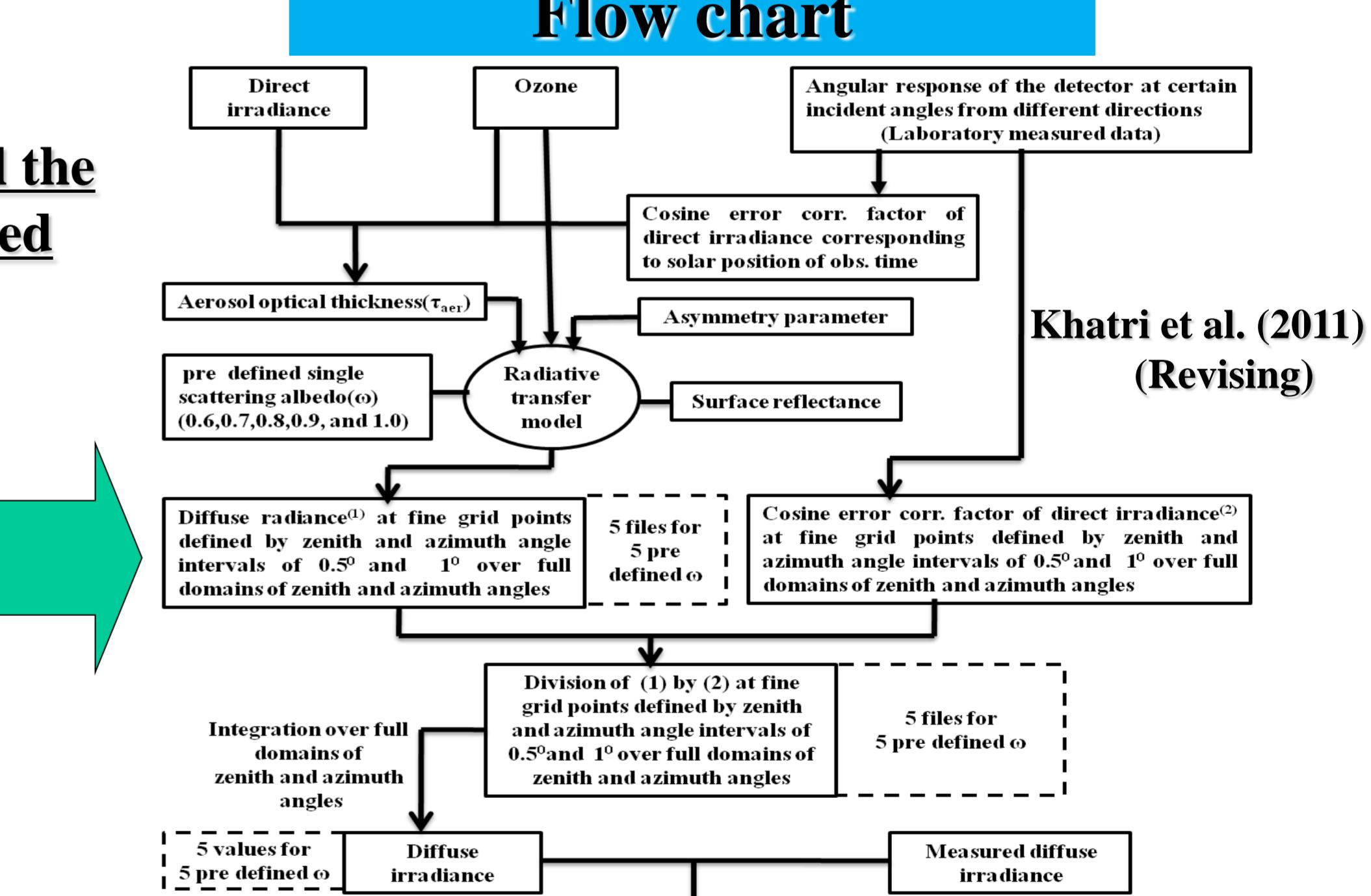
5 values for 5 pre defined ϕ

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Measured diffuse irradiance

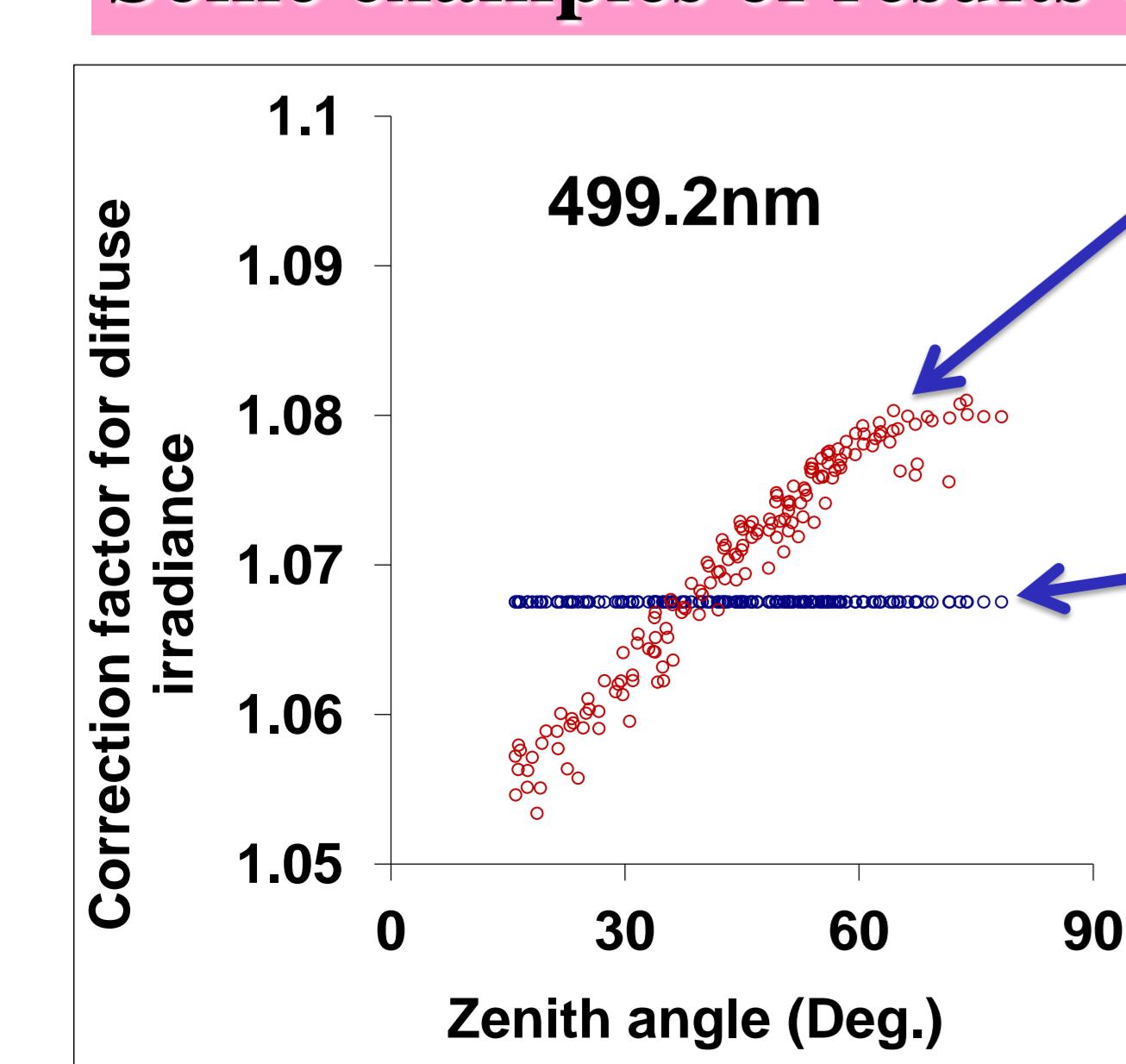
Interpolation/Extrapolation

Flow chart



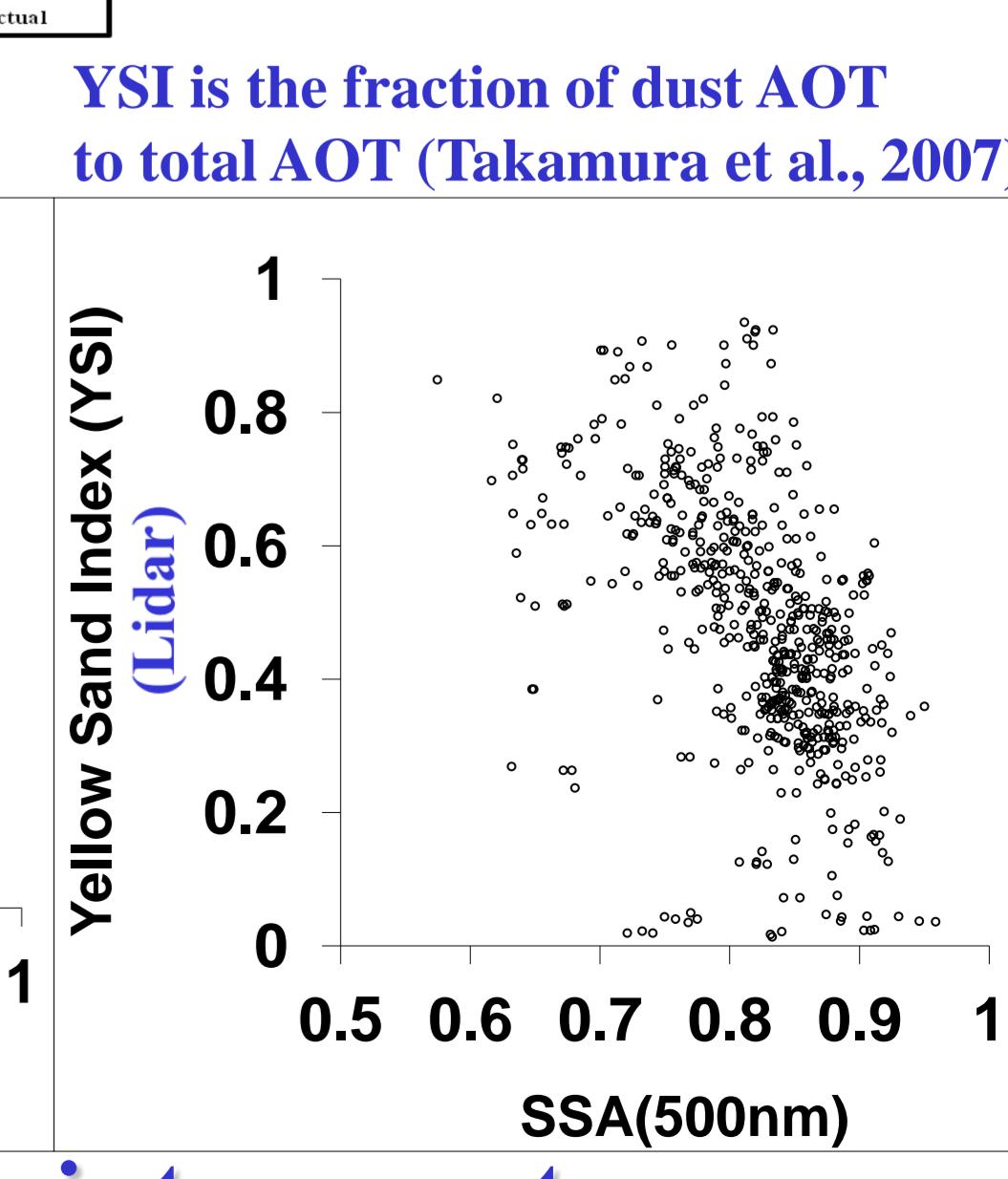
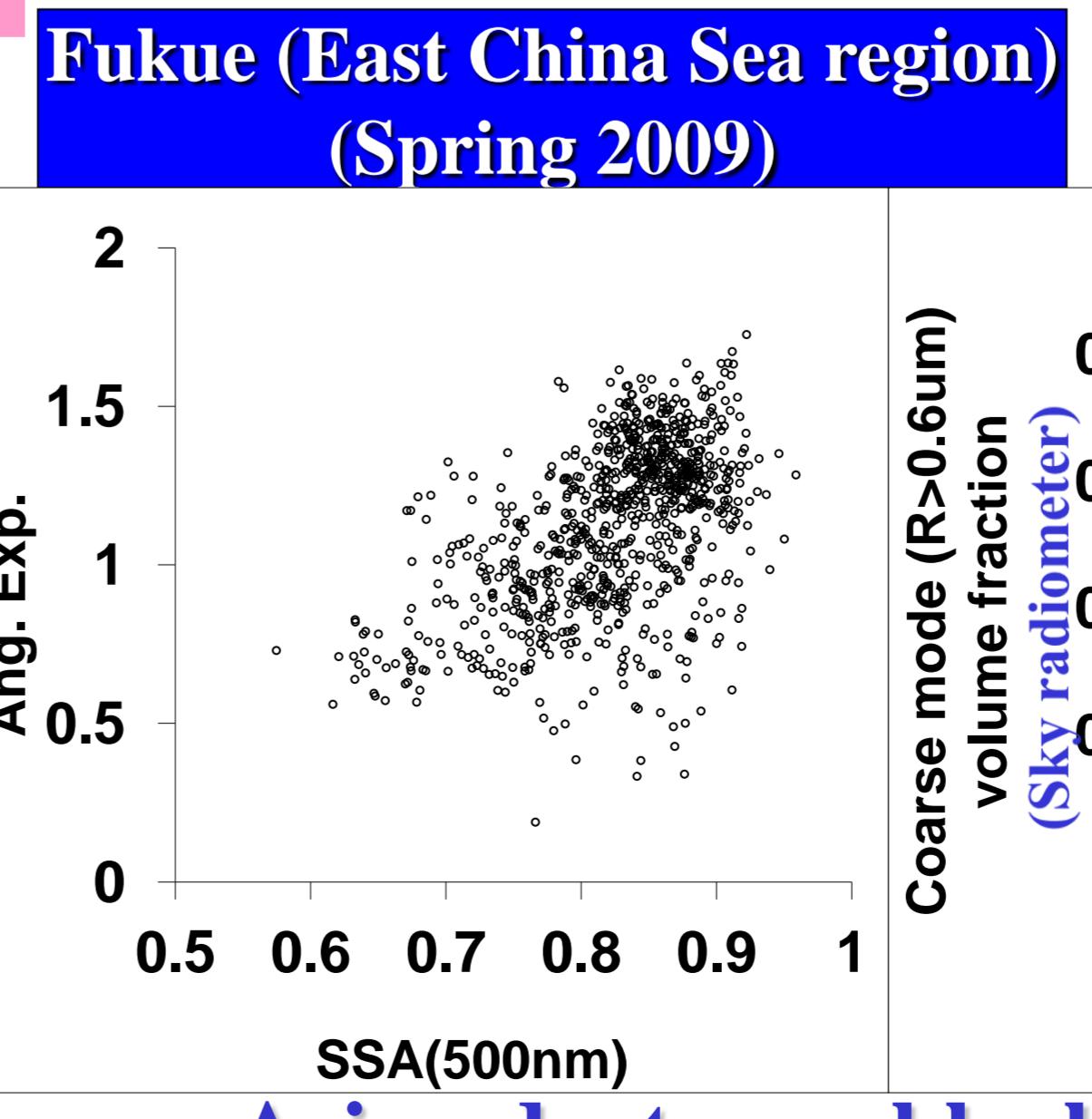
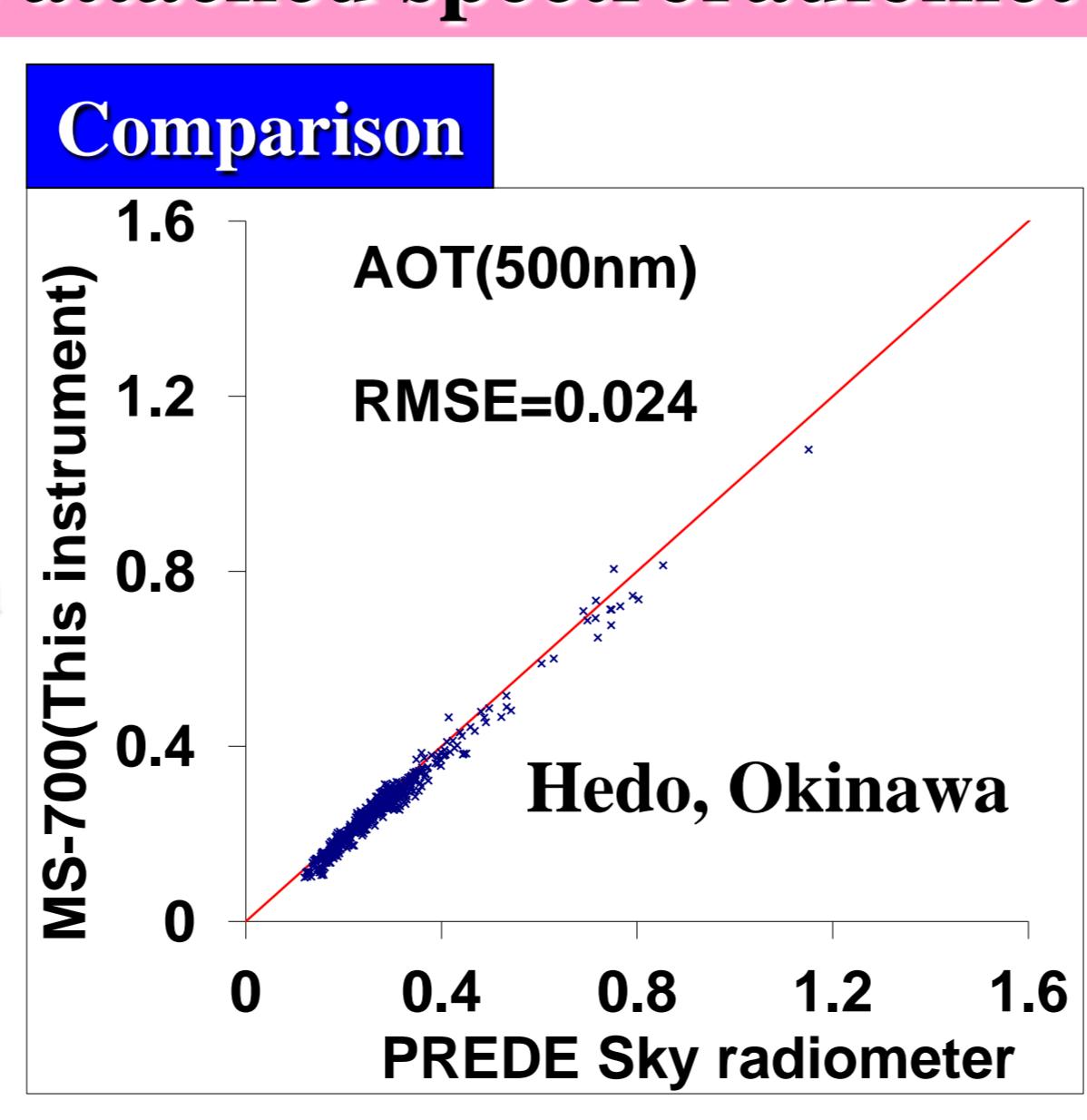
Khatri et al. (2011)
(Revising)

Some examples of results obtained from shadow band attached spectroradiometer



For anisotropic distribution of sky radiance and actual values of aerosol optical parameters (Output from this algorithm)

For assumed isotropic distribution of sky radiance
Cosine error correction factor for diffuse irradiance cannot be measured at the laboratory



5. Acknowledgements

The authors are thankful to Asia-Pacific Network for Global Change Research for providing financial support to attend WCRP open science conference. The authors are also thankful to all collaborators of SKYNET network.