The effect of the surface BRDF on the measurement of tropospheric NO_2 from a geostationary orbit

Katsuyuki Noguchi(1,2), Andreas Richter(2), John P. Burrows(2), Hitoshi Irie(3) and Kazuyuki Kita(4)

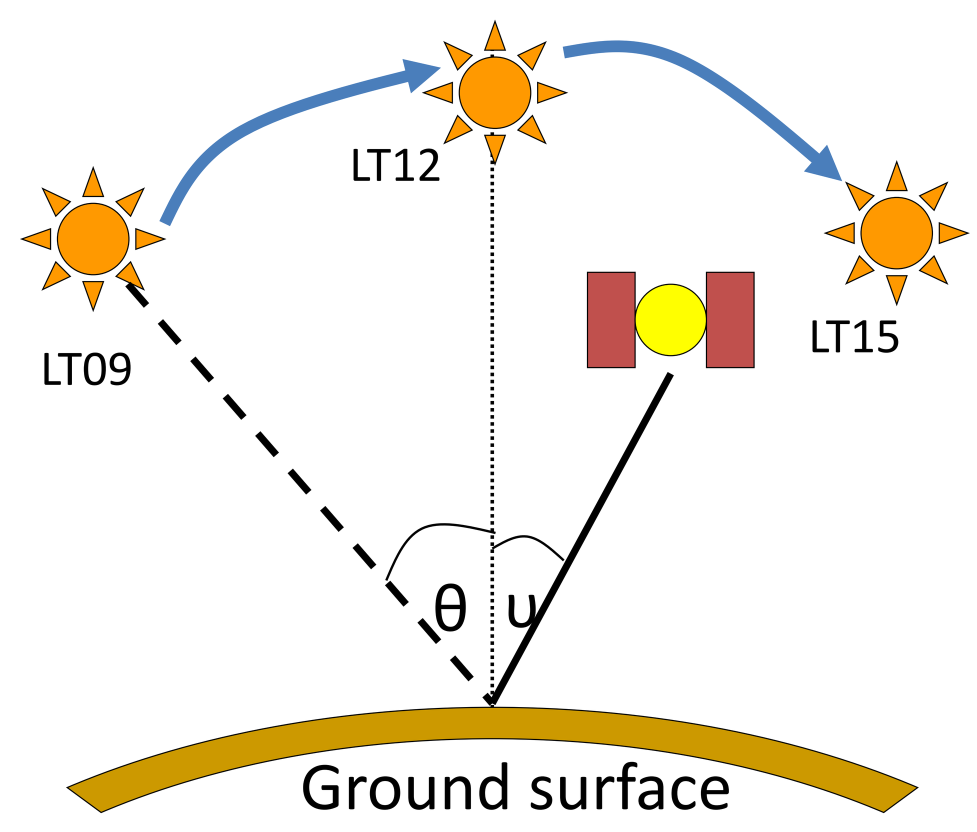
1) Nara Women's University, Nara, Japan 2) University of Bremen, Bremen, Germany 3) Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan 4) Faculty of Science, Ibaraki University, Mito, Japan

Abstract

BRDF (Bidirectional Reflectance Distribution Function) is the dependency of the surface reflectance on incident and outgoing directions. It was shown that the surface BRDF affects the retrieval of the tropospheric NO_2 with sun-synchronous low Earth orbit (LEO) satellites [Zhou et al., 2010], as line-of-sight angles largely change in the sun-synchronous LEO measurements. On the other hand, measurements from a geostationary orbit (GEO) have a large change in solar zenith angles. BRDF can also affect GEO measurements of the tropospheric NO_2. In the present study, we have investigated the influence of BRDF on the tropospheric NO_2 retrieval from GEO by using the MODIS BRDF product released by NASA. The diurnal change of reflectance over Tokyo is up to 33% in summer and 38% in winter respectively, and those change affects the air mass factor in the retrieval of tropospheric NO_2 as well.

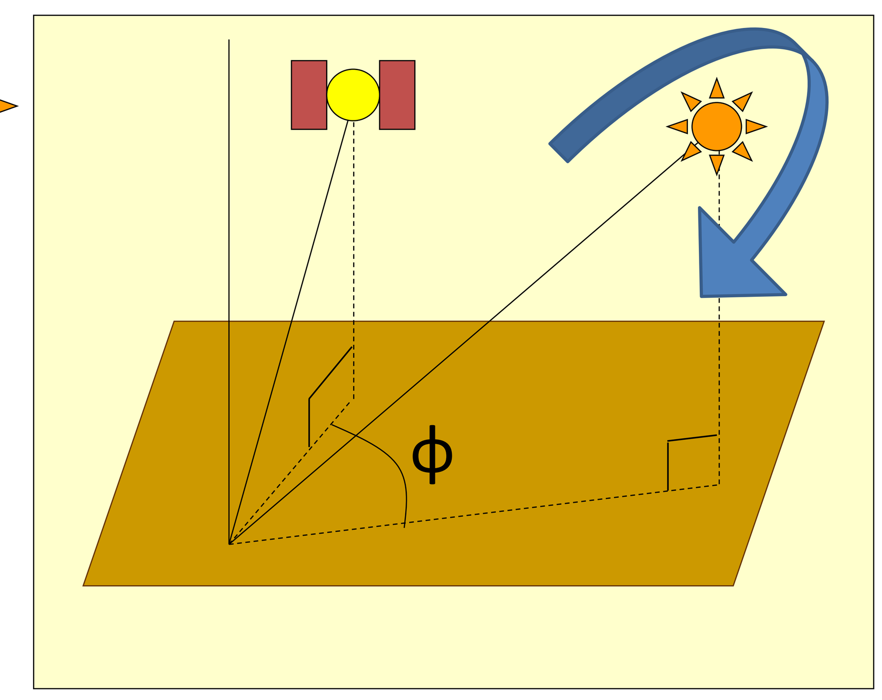
Effect of BRDF on DOAS measurements from GEO

- Bidirectional Reflectance Distribution Function:
  Dependency of surface reflectance on the directions of incoming and outgoing lights
- Most of tropospheric NO_2 DOAS retrievals on low Earth orbits (LEO) assumed an ideal Lambertian (isotropic) reflector for the surface
- However, real measurements have the variations of solar zenith angle, viewing zenith angle and relative azimuth angle
- The effect not negligible (e.g., Zhou et al. [2010])
- In a geostationary orbit (GEO) measurement, not viewing angle but solar zenith angle and relative azimuth angle change.



υ: satellite's viewing zenith angle (VZA), ϕ: relative azimuth angle (RAZ), θ : solar zenith angle (SZA)

SZA and RAZ diurnally changes through measurements



- We estimated the variations of the surface reflectance by using MODIS-based data, and we investigated the effect of the diurnal variation of the reflectance on air mass factor (AMF) in GEO measurements.

How to estimate BRDF? – RossThick-LiSparseReciprocal model (adopted by MODIS data processing)

Semi-empirical kernel-driven model which uses combination of:

- Isotropic reflection (1)
- Volume scattering effect (K_{vol})
- Surface scattering and geometric shadow casting effect (K_{geo})

$$BRDF(\vartheta, \upsilon, \varphi, \lambda) = f_{iso}(\lambda) + f_{vol}(\lambda) K_{vol}(\vartheta, \upsilon, \varphi) + f_{geo}(\lambda) K_{geo}(\vartheta, \upsilon, \varphi)$$

Three parameters (f_{iso}, f_{vol}, f_{geo}) are estimated by the surface reflectance obtained by MODIS (459-479nm, channel 3).

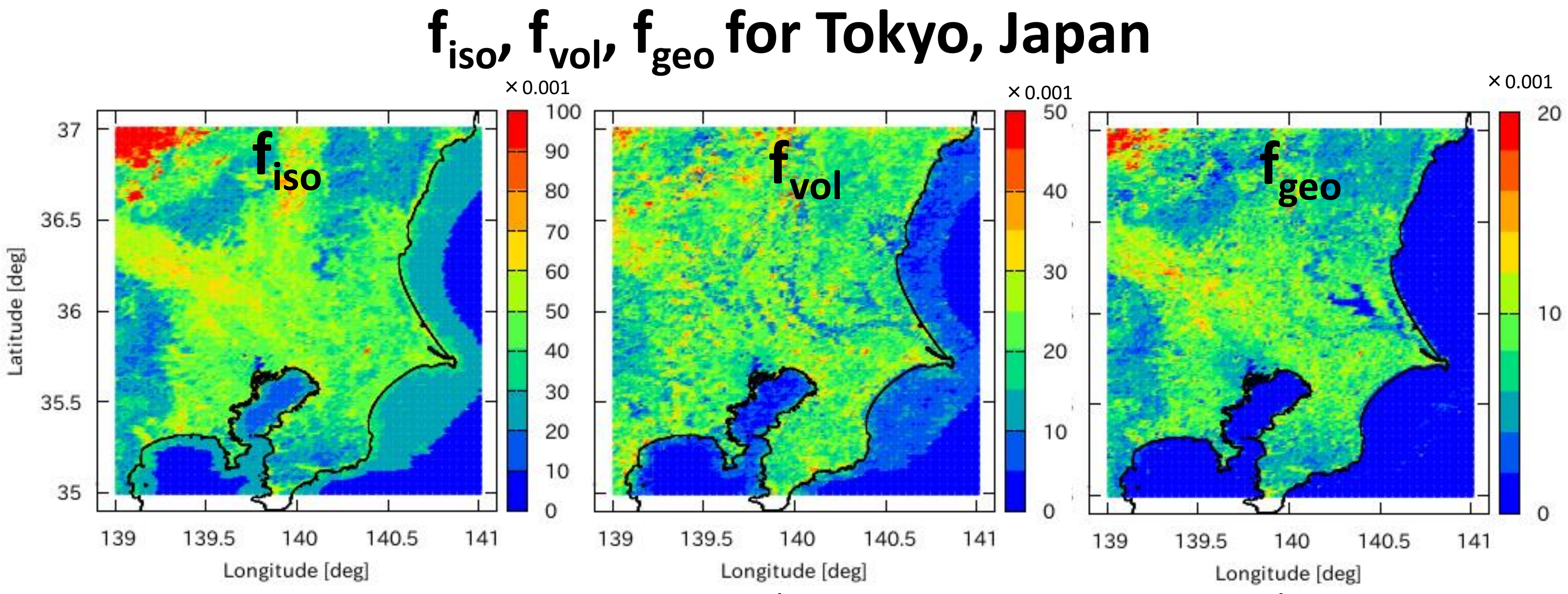
Implementation of surface reflectance into RTM

	Dependency on angles	Implementation into RTM
Lambertian Albedo	No	
Black-Sky Albedo(BSA)	SZA	Input as Lambertian albedo
BRF	SZA, VZA, RAZ	Input as Lambertian albedo
Full BRDF (next task)	*SZA, VZA, RAZ*	*Directly implemented into RTM*

Difference between BRF and full BRDF: BRF can consider only direct sunlight but not diffuse light. In the full BRDF treatment, diffuse light included as well.

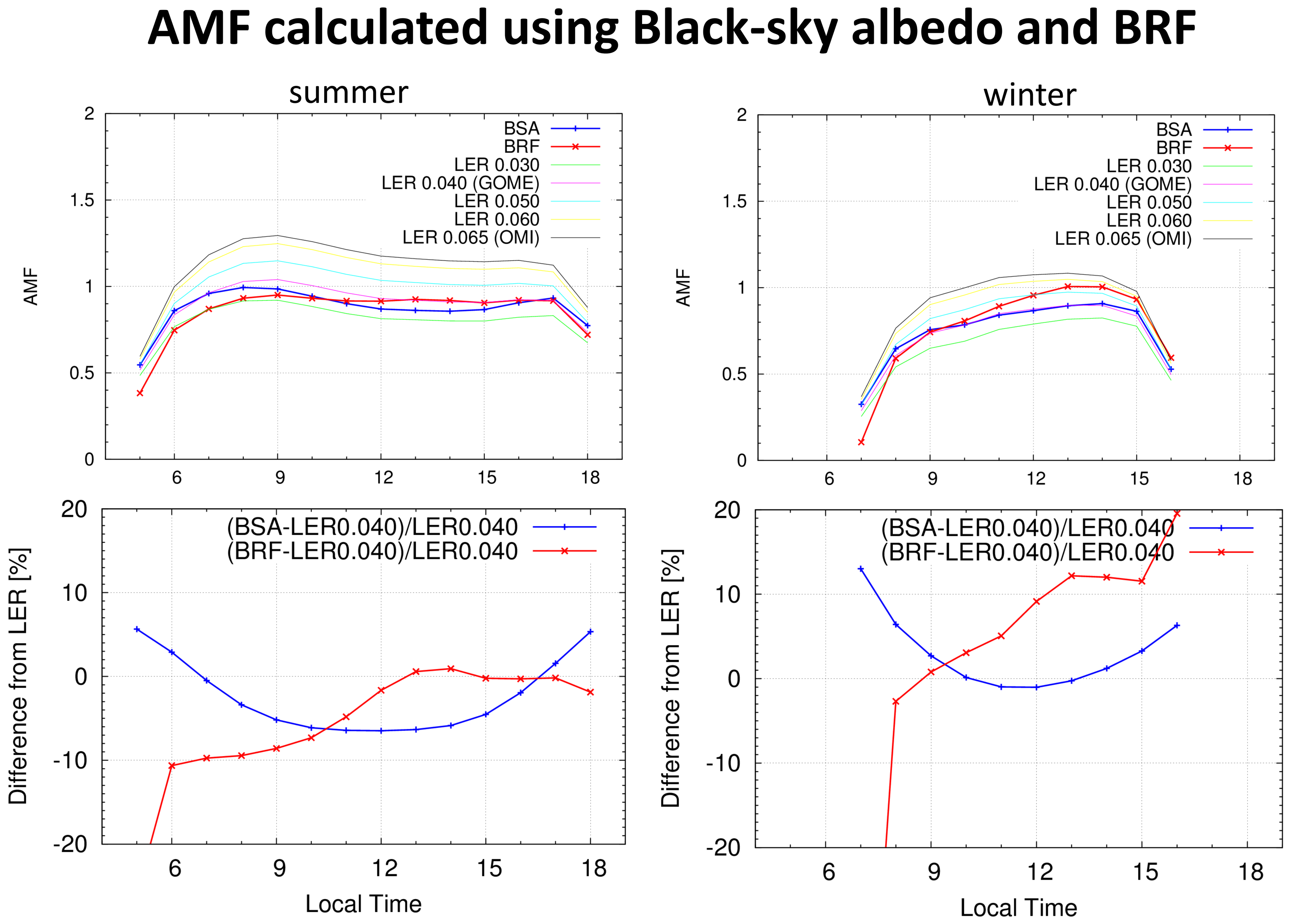
Results

f_{iso}, f_{vol}, f_{geo} for Tokyo, Japan



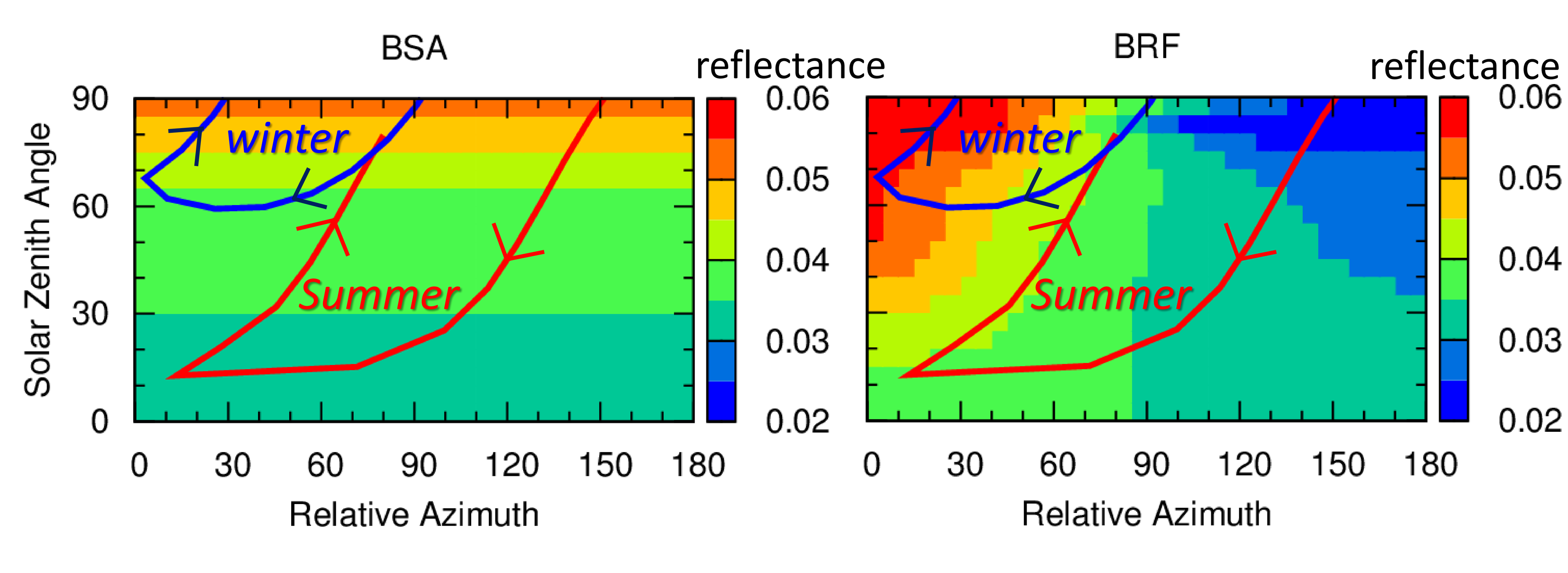
0.044±0.008 0.019±0.005 0.007±0.002

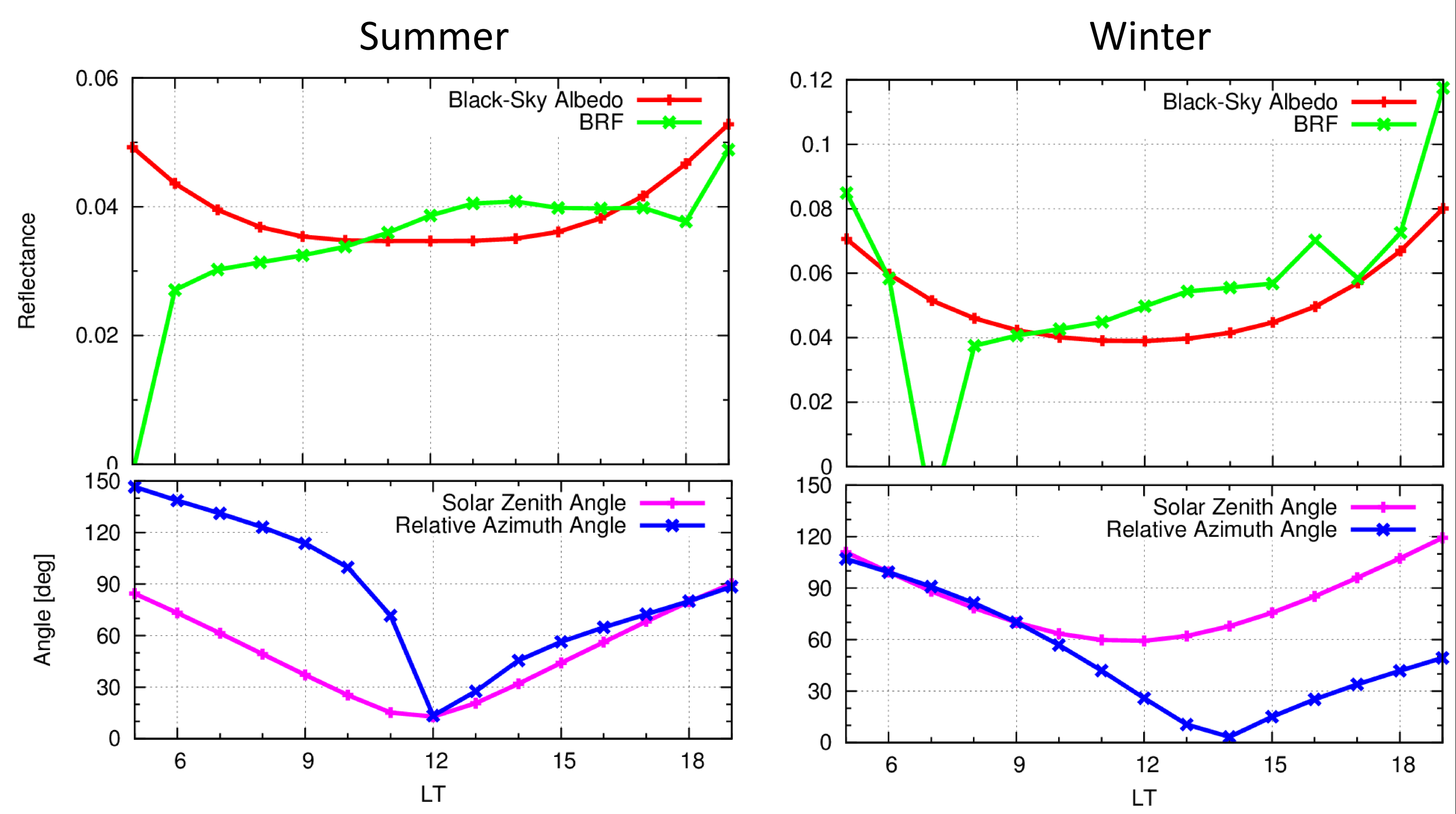
AMF calculated using Black-sky albedo and BRF



AMF differs 10% or more if we use Lambertian albedo instead of BSA/BRF

Angular dependency of BSA and BRF reflectance





	BRF	
Summer: LT07	0.03	+33%
LT17	0.04	

	BRF	
winter: LT09	0.04	38%
LT14	0.055	