The New Angular & Spectral Kernel Model for BRDF and Albedo Retrieval

Authors : Sihan Liu[1] Qiang Liu[1], Qinhuo Liu[1], Xiaowen Li[1,2] ,Qing Xiao[1] ,Xiaozhou Xin[1]

1: State Key Laboratory of Institute of Remote Sensing Applications, CAS

2: School of geography and remote sensing science, Beijing normal university

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Outline

1. Introduction ASK BRDF Model
2. Albedo Retrieval
3. Validation
4. Discussion

Introduction

- BRDF
  - Bidirectional Reflectance Distribution Function
  - Describe how the reflectance depends on incident & reflected angles
- Albedo
  - Ratio of upwilling to downwilling radiation
  - Details the total shortwave energy input into the biosphere and has a key influence on surface energy budget

Introduction

- Kernel-driven BRDF Model

AMBRALS

$$R(\theta_i,\theta_v,\phi,\lambda) = f_{iso}(\lambda) + f_{geo}(\lambda)k_{geo}(\theta_i,\theta_v,\phi) + f_{vol}(\lambda)k_{vol}(\theta_i,\theta_v,\phi)$$

$k_{geo}(\theta_i,\theta_v,\phi)$: geo-optical kernel
$k_{vol}(\theta_i,\theta_v,\phi)$: volumetric kernel
} Incident & viewing geometry

$f_{iso}(\lambda)$ $f_{geo}(\lambda)$ $f_{vol}(\lambda)$: kernel coefficients - spectral dependent

•Schaaf, C., Gao, F., Strahler, A., Lucht, W., Li, X (2002). First operational BRDF, albedo and nadir reflectance products from MODIS. Remote Sensing of Environment, 83, 135-148
•Strahler, A. H., Wanner, W., Schaaf, C., Li, X., et al. (1999). MODIS BRDF/albedo product: ATBD, Version 5.0, April, 1999.

ASK Model – strategy

- The surface is divided into two parts which are respectively described with geo-optical & volumetric kernel

- The component spectra are put into kernels as prior knowledge

$$R(\theta_i,\theta_v,\phi,\lambda)=a_1R_{geo}(\theta_i,\theta_v,\phi,\lambda)+a_2R_{\mathrm{vol}}(\theta_i,\theta_v,\phi,\lambda)$$

rearrange

a1、a2： : area proportion

$R_{geo}(\theta_i,\theta_v,\phi,\lambda)$ $R_{\mathrm{vol}}(\theta_i,\theta_v,\phi,\lambda)$ ： function of wave and angles

$$R(\theta_i,\theta_v,\phi,\lambda)=c_0K_0(\theta_i,\theta_v,\phi,\lambda)+c_1K_1(\theta_i,\theta_v,\phi,\lambda)+c_2K_2(\theta_i,\theta_v,\phi,\lambda)+\cdots$$

Multi-angle & Multi-spectral Kernel

Spectral Independent kernel coefficients

Linear combination

ASK Model –Model1 –basic form

$$R(\theta_i,\theta_v,\phi,\lambda)=c_0K_0(\theta_i,\theta_v,\phi,\lambda)+c_1K_g(\theta_i,\theta_v,\phi,\lambda)+c_2K_v(\theta_i,\theta_v,\phi,\lambda)$$

$K_0 \quad K_g \quad K_v$: describe lambert , geo-optical , volume scattering part

c_0, c_1, c_2 : kernel coefficients related to the canopy structure

$$K_0(\lambda)=\frac{\rho_g}{\pi}$$

$$K_g(\theta_i,\theta_v,\phi,\lambda)=\rho_g\cdot k_{geo}^{g}+\frac{2}{3}\rho_c\cdot k_{geo}^{c}-\rho_g+\frac{2}{3}\rho_c$$

$$K_v(\theta_i,\theta_v,\phi,\lambda)=b\cdot(\frac{2\rho_c}{3\pi^2}k_{vol}^{\rho}+\frac{2\tau_c}{3\pi^2}k_{vol}^{t}+\frac{\rho_c}{3\pi}-\frac{\rho_g}{\pi})$$

$$c_0 = a_1 + a_2$$

$$c_1 = a_1 \cdot nr^2$$

$$c_2 = a_2 \cdot F$$

ρ_g, ρ_c, τ_c : component spectra put into kernels

Snyder, W.C. , Zhengming Wan, BRDF models to predict spectral reflectance and emissivity in thethermal infrared, IEEE Transactions on Geoscience and remote Sensing, 1998

ASK Model – Advantage

- With spectral information adding into kernels, the model inversion process can make use of multi-angular and multi-spectral information together

- Provide a much more convenient algorithm for albedo retrieval

ASK Model –Improvement

- Multi-scattering correction

$$R_{multi} = \frac{1-\sqrt{1-\omega}}{1+2\cos(\theta_i)\sqrt{1-\omega}}$$ --Hapke(1981)

- Variation in soil spectra considered

$$\rho_g(\alpha,\lambda) = \rho_g(0,\lambda)\cdot\exp(-k_g(\lambda)\cdot\alpha)$$

$k_g(\lambda)$: the reflectance attenuation factor in the spectral band λ due to the soil moisture α

ASK Model –Model2 –advanced form

- Final Model

$$R(\theta_i,\theta_v,\phi,\lambda)=c_1\cdot k_1(\theta_i,\theta_v,\phi,\lambda)+c_2\cdot k_2(\theta_i,\theta_v,\phi,\lambda)+c_3\cdot k_3(\theta_i,\theta_v,\phi,\lambda)$$
$$+c_4\cdot k_4(\theta_i,\theta_v,\phi,\lambda)+c_5\cdot k_5(\theta_i,\theta_v,\phi,\lambda)$$

$$k1=\frac{\rho_g(\alpha_0,\ \lambda)}{\pi}$$
$$k2=-\frac{k_g(\lambda)\cdot\rho_g(\alpha_0,\ \lambda)}{\pi}$$
$$k3=(k_{geo}^{g}-1)\cdot\rho_g(\alpha_0,\ \lambda)+\frac{2}{3}\rho_c\cdot(k_{geo}^{c}+1)$$
$$k4=-(k_{geo}^{g}-1)\cdot k_g(\lambda)\cdot\rho_g(\alpha_0,\ \lambda)$$
$$k5=(\frac{2\rho_c}{3\pi^2}k_{vol}^{\rho}+\frac{2\tau_c}{3\pi^2}k_{vol}^{\tau}+\frac{\rho_c}{3\pi}+\frac{1-\sqrt{1-\omega}}{\pi(1+2\cos(\theta_i)\sqrt{1-\omega})}$$

$$c1=a_1+a_2\cdot\exp(-bF)$$
$$c2=(\alpha\text{-}\alpha_0)\cdot(a_1+a_2\cdot\exp(-bF))$$
$$c3=a_1\cdot nr^2$$
$$c4=(\alpha\text{-}\alpha_0)\cdot a_1\cdot nr^2$$
$$c5=a_2\cdot(1-\exp(-bF))$$

ASK Model – Coefficients inversion

- Kernel Coefficients' Inversion
  - Derived from fitting modeled to observed BRF
  - Least-Square Solution
    - m angles & n bands
    - m*n equations $\geqslant$ 5 variables
  - Advantage
    - Joint-Inversion: Coupling the Multi-spectral & Multi-angle information
    - Feasible when the angular observations is limited

ASK Model – Albedo Retrieval

- Angular integration of kernels

$$h_k(\theta_i,\lambda) = \frac{1}{\pi}\int_0^{2\pi}\int_0^{\frac{\pi}{2}}[K_k(\theta_i,\theta_v,\psi,\lambda)]\sin\theta_v\cos\theta_v d\theta_v d\psi$$

$$H_k(\lambda) = 2\int_0^{\frac{\pi}{2}} h_k(\theta_i,\lambda)\sin\theta_i\cos\theta_i d\theta_i$$

spectral kernel integration

f_k →

$$\alpha_{b\lambda}(\theta_i) = \sum_k f_k h_k(\theta_i,\lambda)$$

$$\alpha_{w\lambda} = \sum_k f_k H_k(\lambda)$$

spectral albedo

- Spectral integration of kernels

$$\tilde{h}_k(\theta_i) = \int_{\lambda_1}^{\lambda_2} c_\lambda h_k(\theta_i,\lambda)d\lambda$$

$$\tilde{H}_k = \int_{\lambda_1}^{\lambda_2} c_\lambda H_k(\lambda)d\lambda$$

broad band kernel integration

f_k →

$$\tilde{\alpha}_b(\theta_i) = \sum_k f_k \tilde{h}_k(\theta_i)$$

$$\tilde{\alpha}_w = \sum_k f_k \tilde{H}_k$$

broad band albedo

Validation

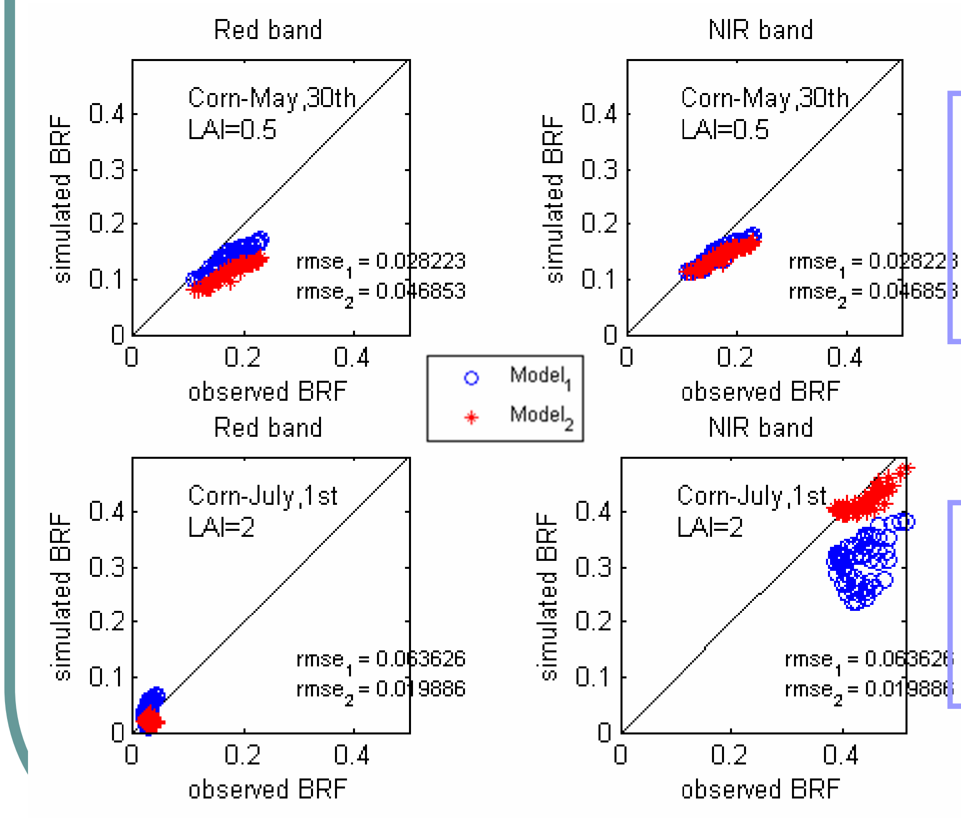
- Data description
- BRDF fitting ability
  - Fitting field-measured BRDF
  - Fitting satellite observed BRDF
- Retrieved Albedo Validation
  - Values from field measurement
  - MODIS1B & CHRIS & Field-measured Data

Validation -Data Source

- Field-measured dataset – Heihe Experiment
  - during May, 2008 – July, 2008
  - corn, wheat, semi-desert, bulrush
- MODIS – Heihe Experiment
  - Mod43 Albedo Product
    - 16days period - day153
  - Mod09 Daily Surface Reflectance Product
    - Day 146-161 16days period
    - Day 151-154 4days period
  - Modos1B Raw data
    - Atmospheric & Geometric Correction processed
    - 4days period
- CHRIS – Heihe Experiment
  - 18bands * 4angles Resolution：17.3m
  - Date: June 4th,2008
- PARASOL data – Global
  - POLDER-3/PARASOL BRDF dataset

Validation-- Fitting field-measured BRDF

BRDF inversion -for pure pixel



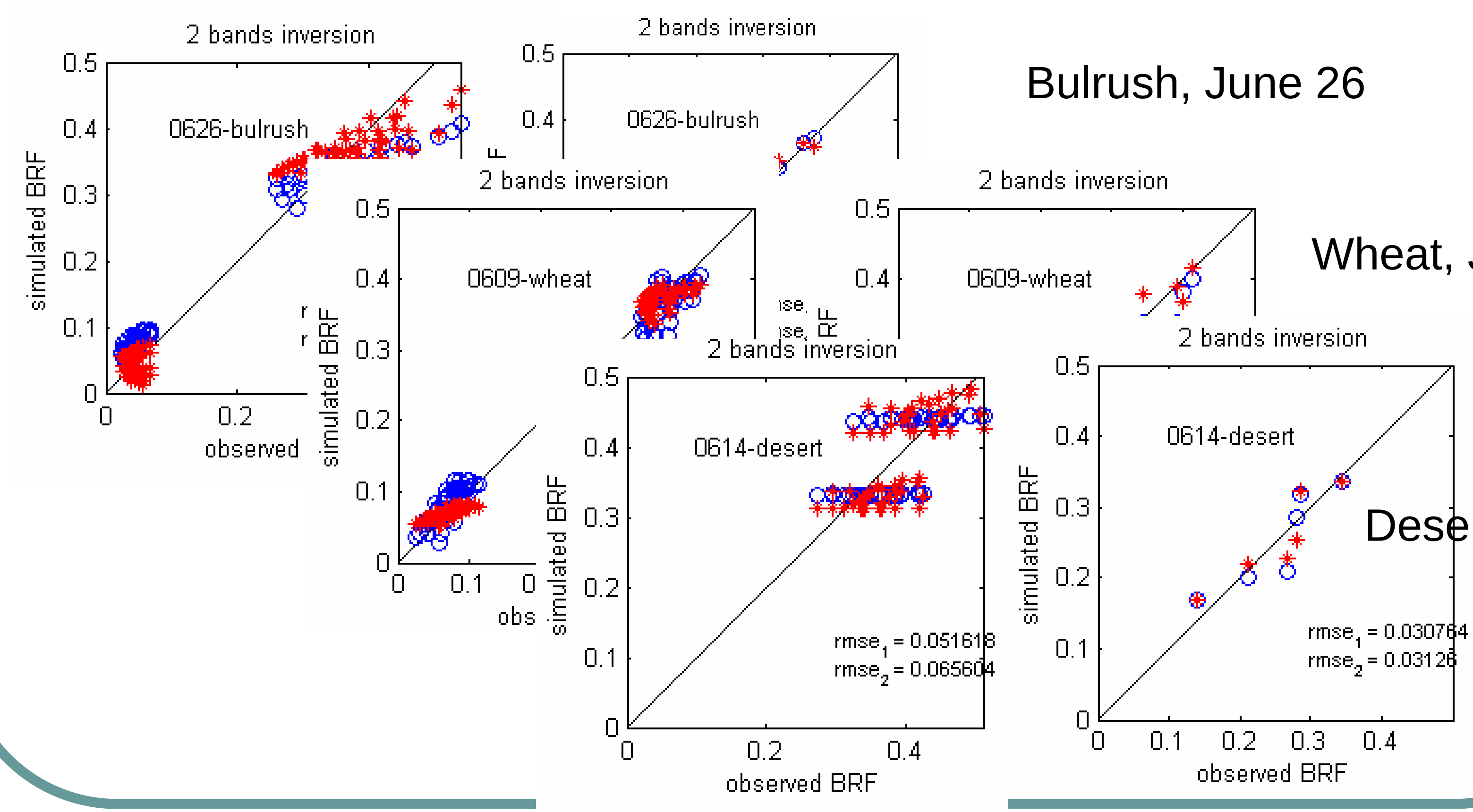
- **Field-measured multi-angular BRF dataset**
- Corn May,30th & Corn July,1st
- zenith 5° interval in four different view planes
- Corresponding to MODIS's first 7 bands

- For dense canopy, model_2 shows a distinct preference
- In sparse condition, two models' performance are similar.

Validation

BRDF inversion – In-situ measurement & MODIS1B with 4days period

(Left) (Right)



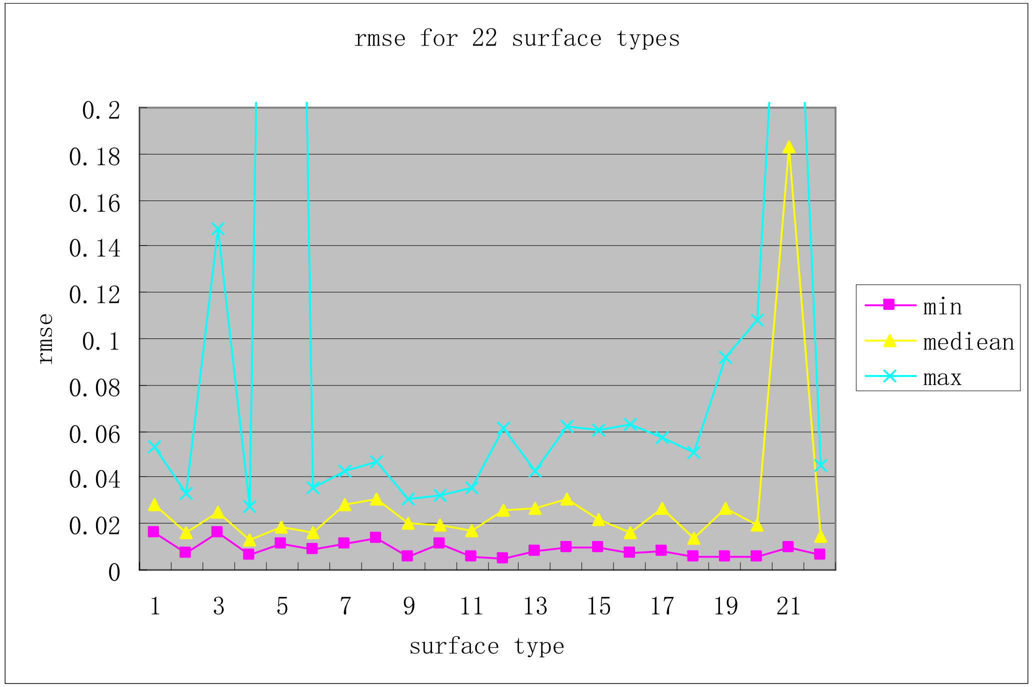
Bulrush, June 26

Wheat, June 26

Desert, June 14

Validation

- BRDF Inversion – Mixed pixel
  - POLDER-3/PARASOL BRDF dataset
  - RMSE Statistic for Model Inversion --- Maximum , Median, Minimum Value



•22 kinds of surface cover
•For each surface cover, observations from different locations around the earth are included.

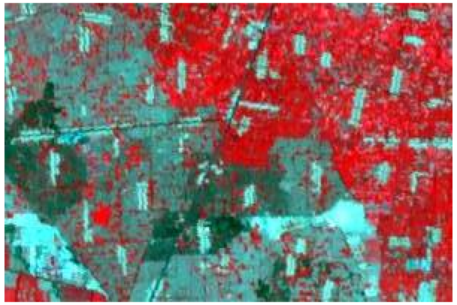
Validation - Albedo

- Albedo Validation
  - The retrievals from field-measured dataset are in good agreement
  - On-board data : difference results derived
  - Scale Mismatch field measurement ⇔ on-board observation

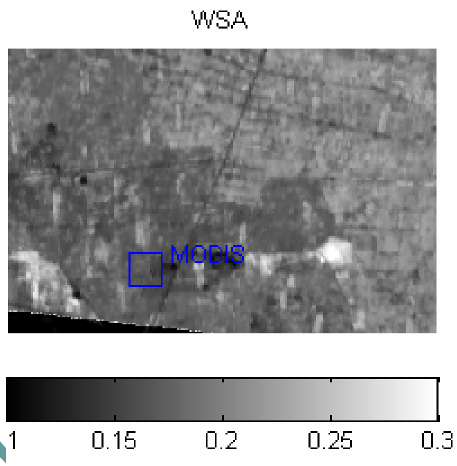
Cover Type		Corn(0530)		Wheat(0609)		Desert(0614)		bulrush (0626)	
Data Source		Field	Modis1B	Field	Modis1B	Field	Modis1B	Field	Modis1B
Model1	Real	0.1690	0.1782	0.1582	0.1860	0.3226	0.2078	0.1468	0.1843
Model2	Real	0.1613	0.1725	0.1441	0.1838	0.2937	0.1824	0.1564	0.1717
Weather Station		0.1683				0.2493		0.1534	
Albedometer		0.1830		0.1434		0.2348			

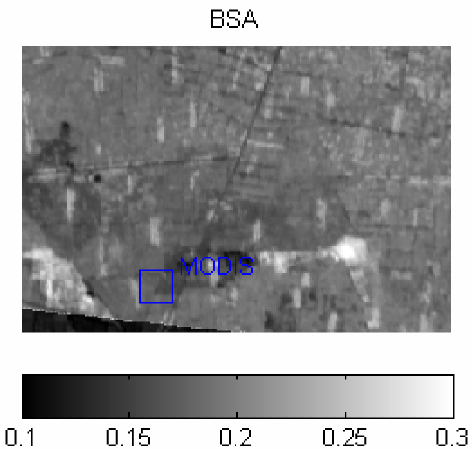
Validation - Albedo

false color image

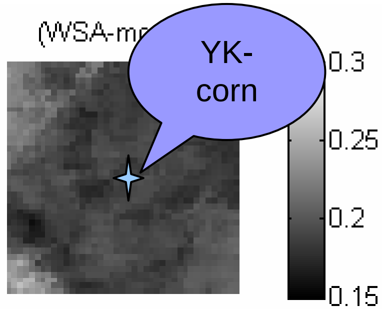


CHRIS
Retrieval

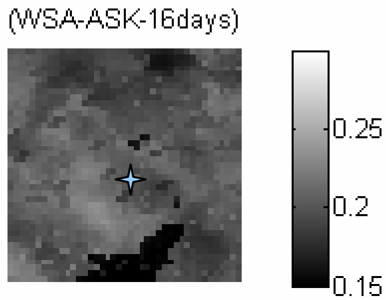




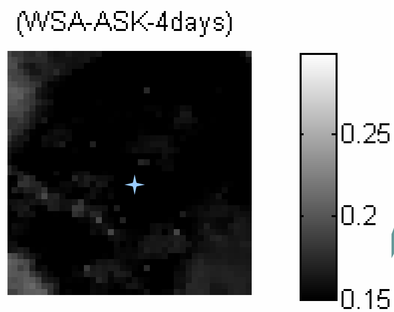
- Modis43 albedo product (day153-168)



- Modis09 retrieval （day146-161）

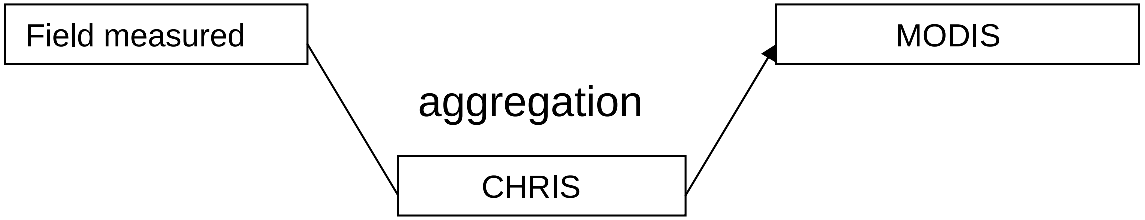


- Modis09 retrieval (day151-154)



Validation - scale transform

- CHRIS 17.3m 58*58→MODIS (1KM)



YK-corn Site	CHRIS point	CHRIS aggregation	MODIS
WSA	0.1515	0.1705	0.1912
BAS	0.1487	0.1734	0.1732
real	0.1491		0.1747
station			0.120441
albedometer			0.146565

YK-wheat Site	CHRIS point	CHRIS aggregation	MODIS
WSA	0.1691	0.1748	0.2003
BAS	0.1663	0.1739	0.1788
real	0.1667		0.1809

Discussion

- Possible error source -- Inaccurate spectra's impact
  - Component spectra as driven variables are given typical values
  - Different surface cover : different values should be given

Analysis based on simulation

- Random noise is added to component spectral ρ_g ρ_c τ_c
- Sensitivity index.

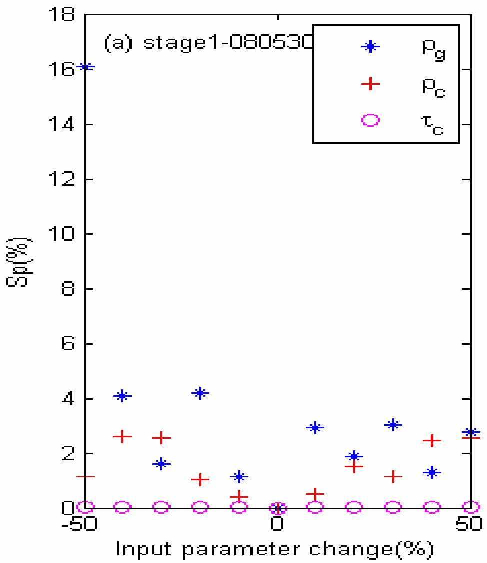
$$S_p = \left(\sum_{1}^{n} \frac{BRDF_{\text{var}} - BRDF_0}{BRDF_0} * 100\%\right) / n$$

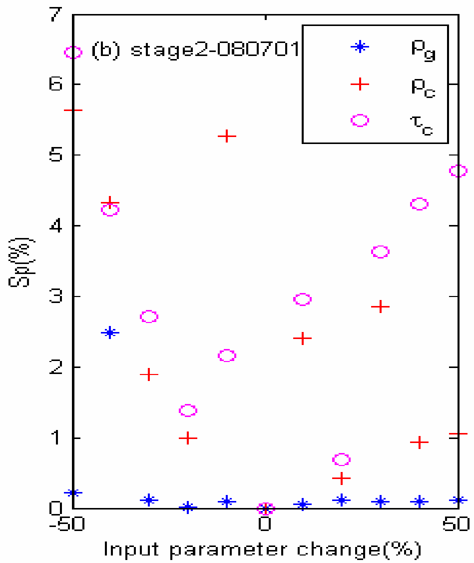
$BRDF_0$ inverted with the standard typical input spectral parameters

$BRDF_{\text{var}}$ random noise added

Discussion

- Results
  - Most numbers are below 10% with the 10%-50% noise added
  - The model remains stable with inaccurate component spectra
  - For global retrieval, different component spectra should be given according to the land surface type





- **Field-measured BRF for corn**
  - Zhangye city, Gansu province
  - data for 2 growth stage
  - May,50th 2008 – July,1st 2008

Thank You !