

# **Vicarious calibration of Ocean-Colour Sensors in the Red and Near Infrared**

**Robert Frouin**

*Scripps Institution of Oceanography, La Jolla, California*

IOCCG Calibration Workshop  
30 October 2004, Fremantle, Australia

# The SeaWiFS onboard calibration

- A reference panel

Problem: how to monitor the aging of the panel in the space environment?

- Inter-temporal calibration using the Moon

Changes in radiometric sensitivity have been quantified satisfactorily, i.e., within a fraction of 1% (Barnes et al., 1999)

# The level-2 vicarious calibration

- Principle

Radiometric sensitivity is adjusted so that water-leaving radiance estimates agree best with data from MOBY

- Assumption

Standard maritime aerosol model

- Limitation

Case-1 ocean (open ocean) calibration

No calibration in the red and near IR

# Radiometric Calibration in the red and near infrared

---

*Formulation of the signal*

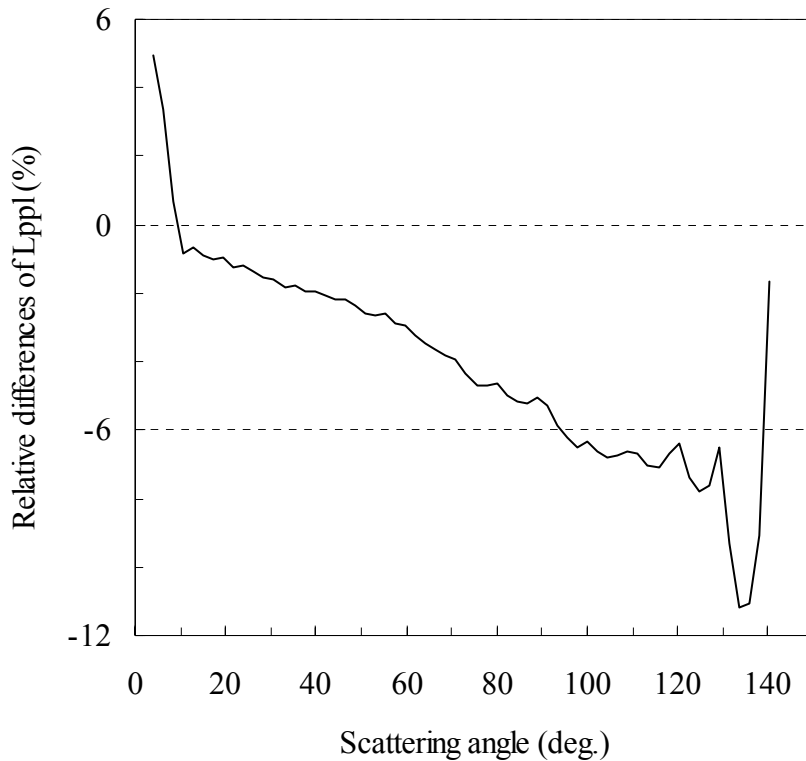
$$L_{toa} = [L_{atm} + T * L_g + t * (L_w + L_{wc})] T_g$$

# How to estimate $L_{atm}$ ?

- A Rayleigh-like calibration?
- An improved aerosol model!

# Using an inversed aerosol model

Simulations of  $L_{atm}$  using the aerosol parameters derived by the Dubovik and King method: Relative differences between simulations and measurements



Inversed aerosol models are not accurate enough to retrieve  $L_{atm}$  in back-scattering

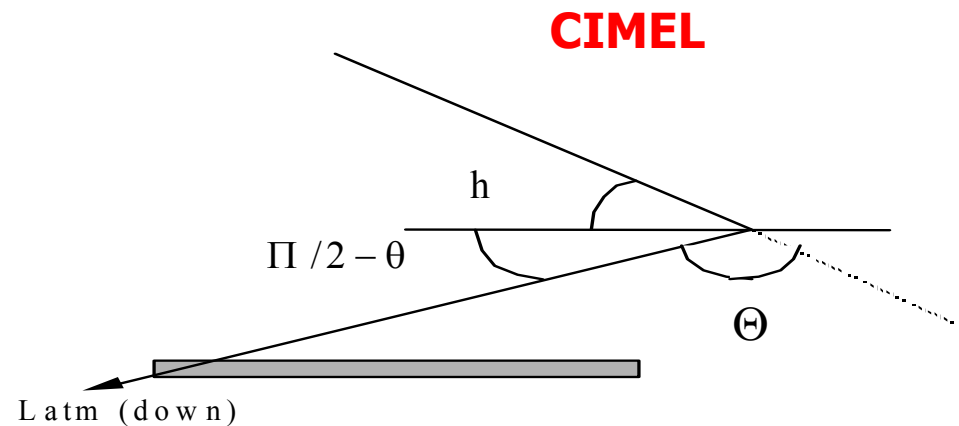
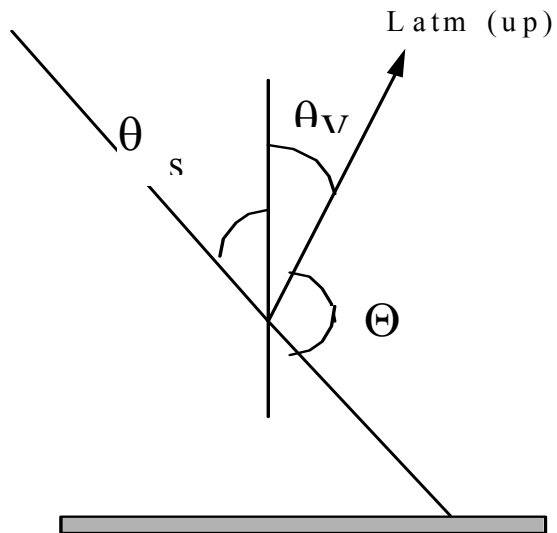
# Atmospheric path radiance

From downward to upward

**Satellite**

$\theta_s$

$\theta_v$



First order correction: airmass

# Derivation of phase function from sky radiance measurements

---

## 1- Correct for multiple scattering:

$$f = \left( \frac{L(1)}{L} \right)_{theo} \approx \left( \frac{L(1)}{L} \right)_{mes}$$

*SOS Code*

## 2- Primary scattering approximation :

$$P(\Theta) = 4L_{mes}^{(1)} \exp\left(\frac{\tau}{\mu}\right) \left[ 1 - \exp\left(-\tau\left(\frac{1}{\mu_o} - \frac{1}{\mu}\right)\right) \right]^{-1} \left[ \frac{\mu_o}{\mu - \mu_o} \right]^{-1}$$

$$P(\Theta) = \frac{\omega a \tau a P_a(\Theta) + \tau_r P_r(\Theta)}{\tau a + \tau_r}$$

# Multiple scattering correction

---

## *Successive orders of scattering code*

### Input :

- Total optical thickness  $\tau$
- Single scattering albedo  $\omega$  times phase matrix  **$M$**

### Hypothesis :

- Homogeneous atmosphere  $\rightarrow H_a = H_r = 3$  km
- Cox and Munk for wave slope distribution

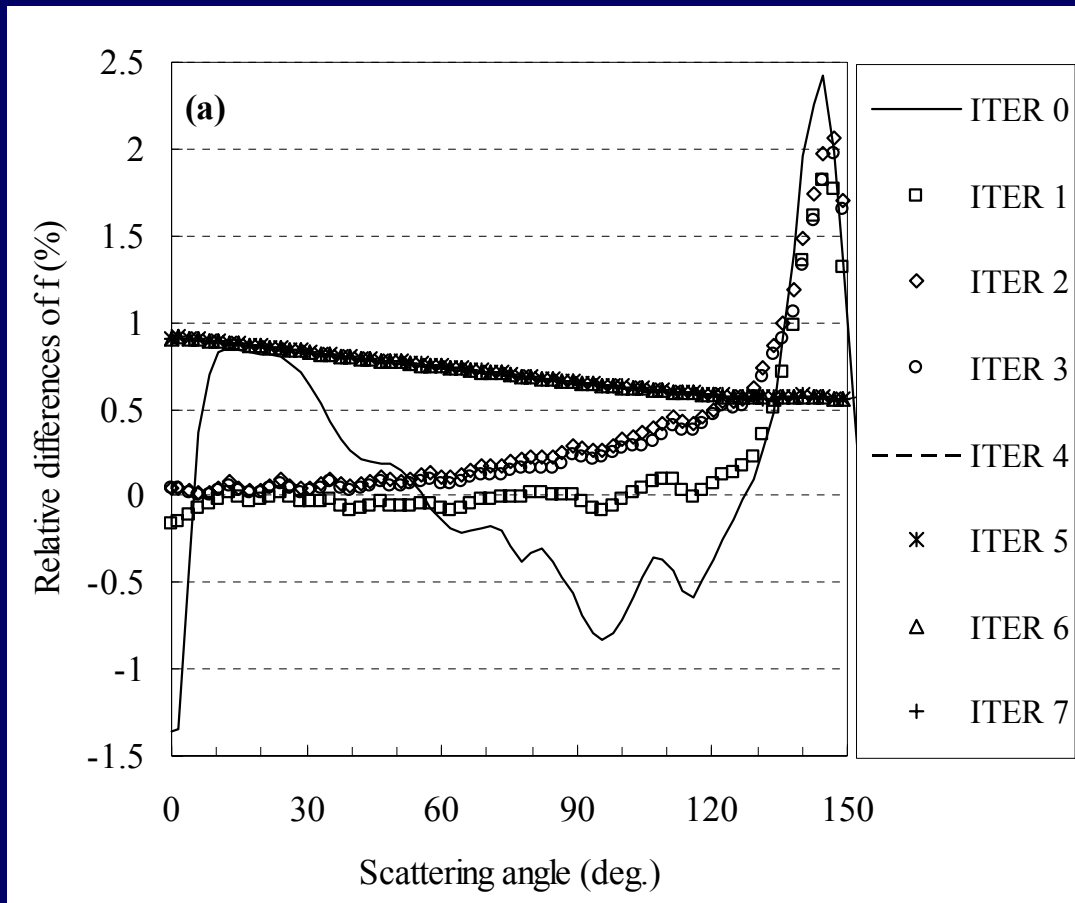
# Iterative retrieval of $f$

---

- Order zero: Junge law
- Order  $n$ : phase function at order  $n-1$
- Convergence on  $f$

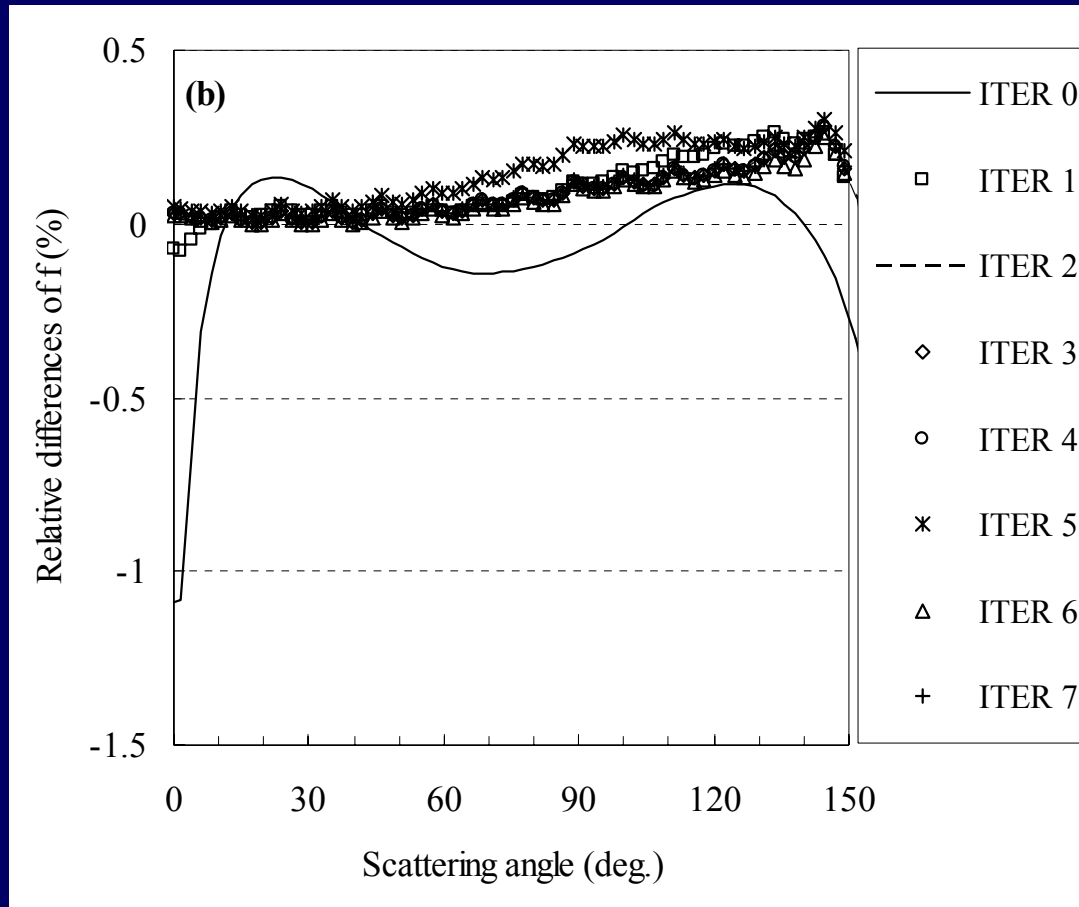
# Example of $f$ retrieval

M90  
 $V=23$  km



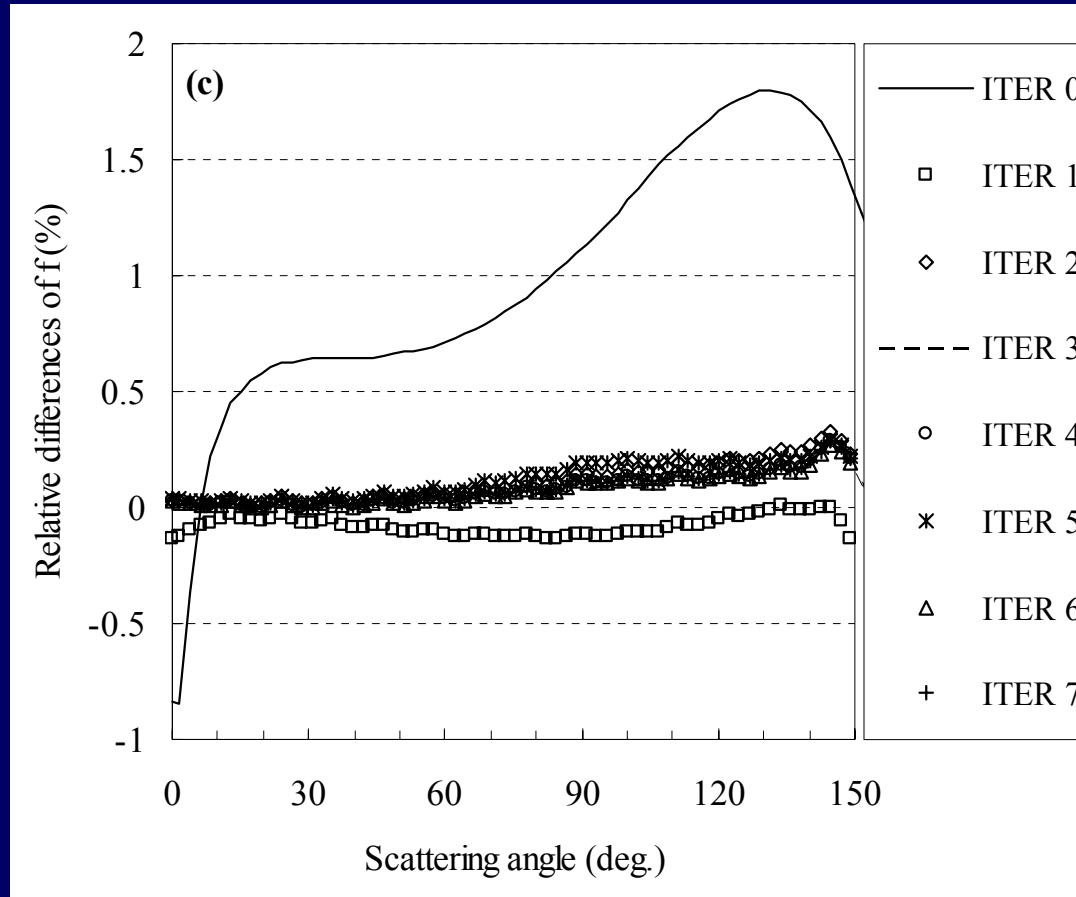
# Example of $f$ retrieval (cont. 1)

C90  
 $V=23$  km



# Example of $f$ retrieval (cont. 2)

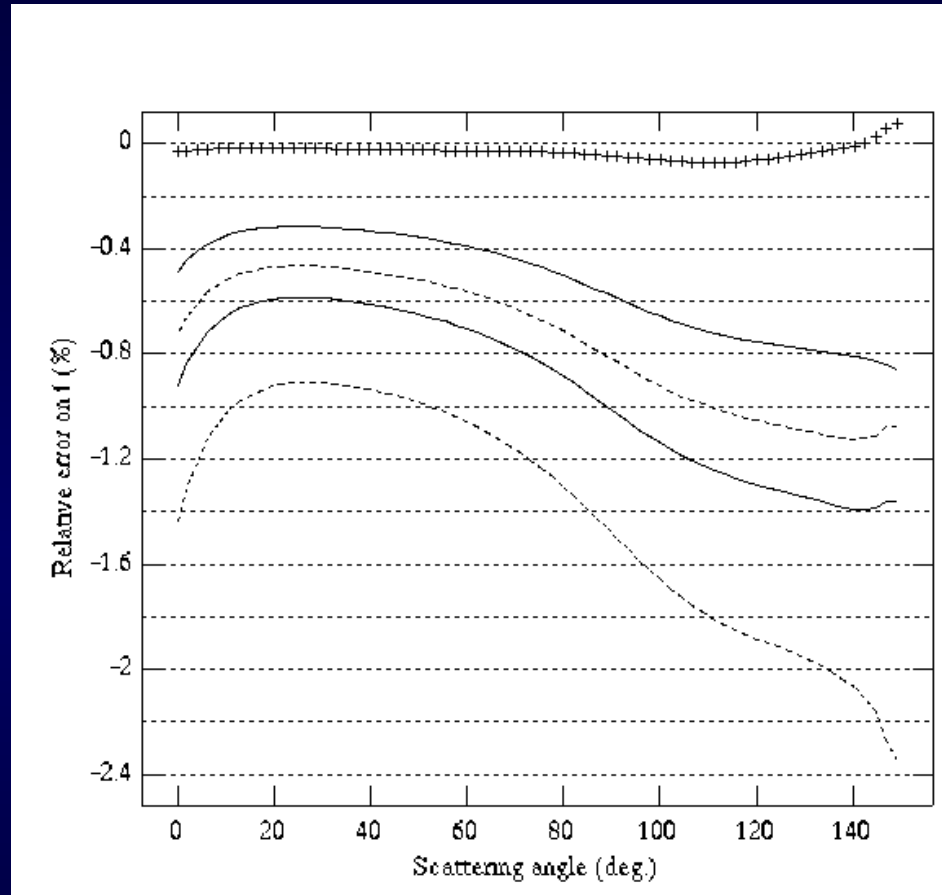
U90  
 $V=23$  km



# Conclusion 1

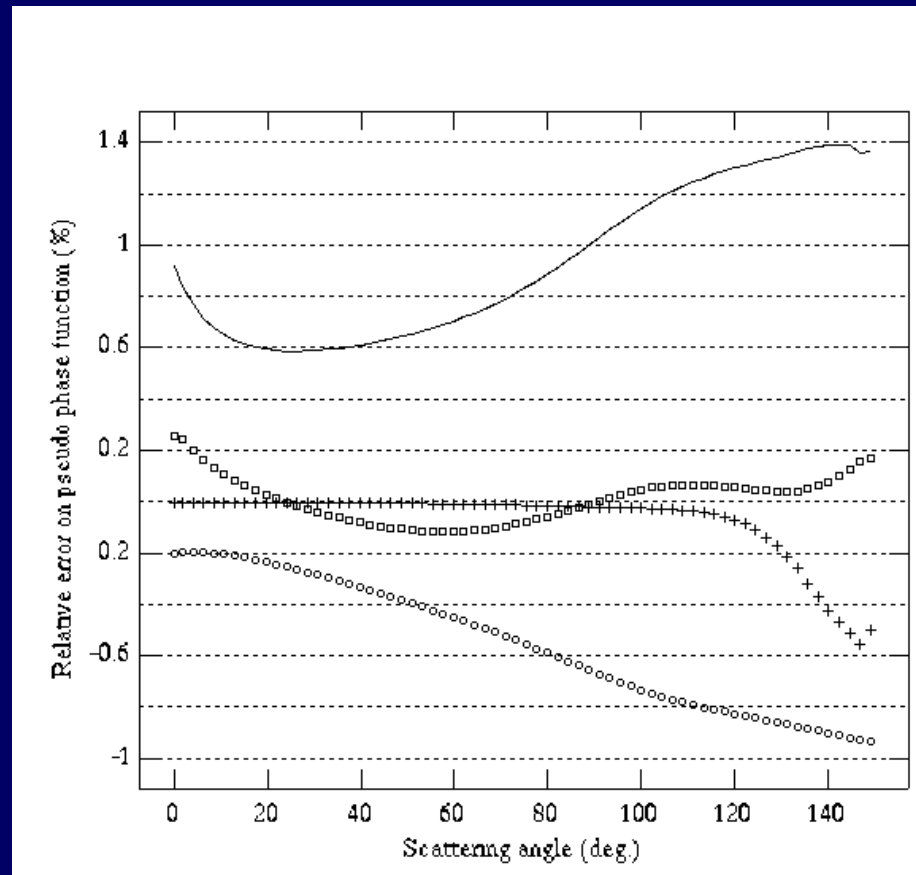
- A fast iterative method to retrieve the phase function from sky measurements
- A simple relationship between satellite and surface atmospheric path radiance

Sea surface roughness errors for the  $f$  corrective factor simulated for the M90 model,  $V=23\text{km}$ .  $\theta_s=75^\circ$ .  $\Delta W=3\text{m/s}$



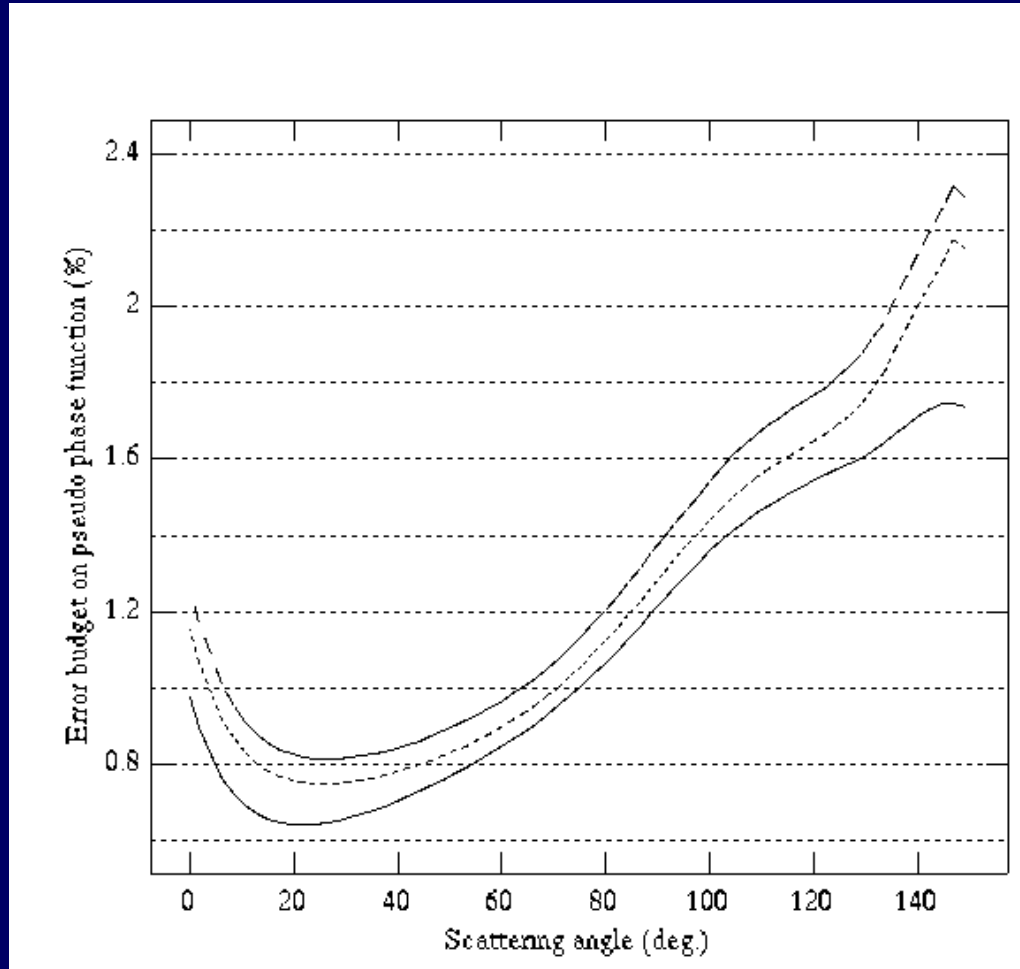
convergence (crosses), upper solid line is the relative difference between  $f(7\text{m/s})$  and  $f(7\text{m/s}+\Delta W)$  [lower, between  $f(7\text{m/s}-\Delta W)$  and  $f(7\text{m/s})$ ], upper dashed line is between  $f(5\text{m/s})$  and  $f(5\text{m/s}+\Delta W)$  (lower, between  $f(5\text{m/s}-\Delta W)$  and  $f(5\text{m/s})$ ].

Errors for the  $\omega P$  product derived for the M90 model:  
 $V=23\text{km}$ .  $\theta_s = 75^\circ$ .  $W=7\text{m/s}$ .  $\Delta W=-3\text{m/s}$



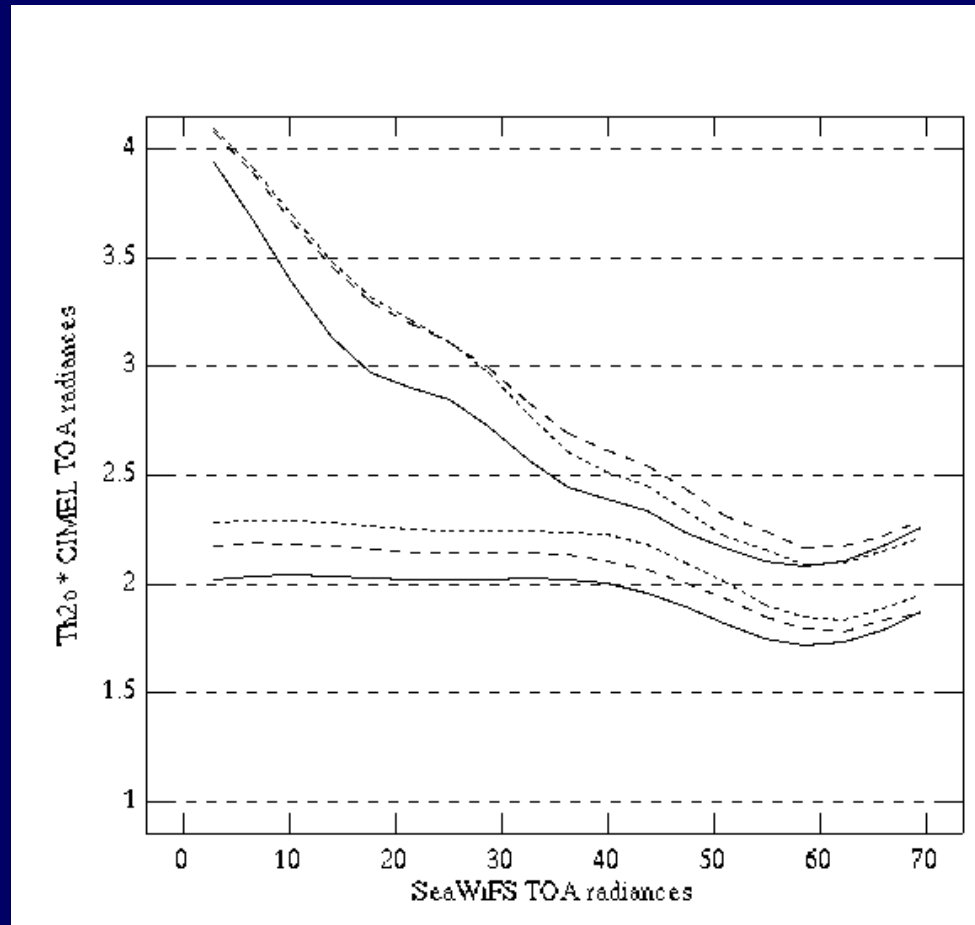
$f$  parameter (solid line), PPL sky radiance calibration (circles),  
Irradiance calibration (squares), extrapolation (crosses)

Error budget on  $\omega P$ :  $V=23\text{km}$ .  $\theta_s = 75^\circ$ .  $W=7\text{m/s}$ .



M90 model (solid line), T90 model (dashed line), U90 model (micro-dashed line)

Error budget on the  $L_{toa}$  simulations:  $V=23\text{km}$ ,  $\theta_s = 30^\circ$  (upper plots) and  $60^\circ$  (lower plots).  $\Delta\varphi=90^\circ$ .

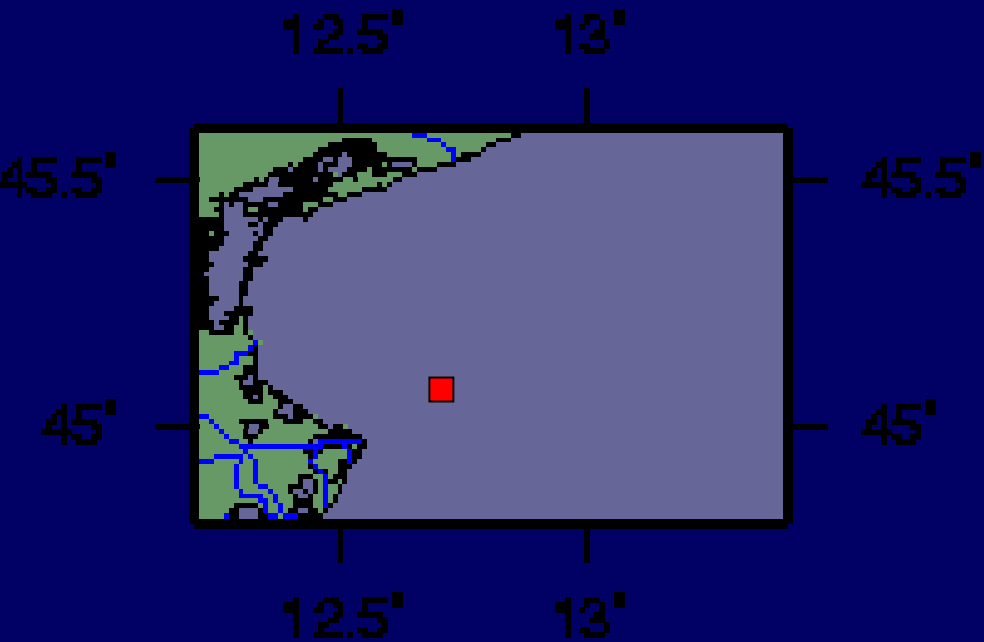


M90 model (solid line), T90 model (dashed line), U90 model (micro-dashed line)

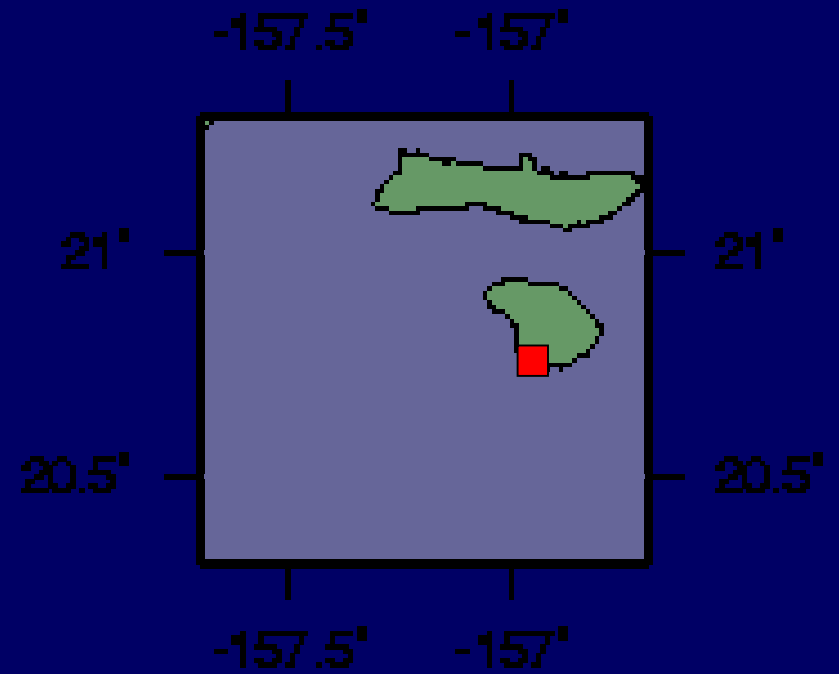
## Conclusion 2

- If the Cimel calibration is within  $\pm 2$  percent accuracy,
- If the wind speed is known within  $\pm 3$  m/s,
- If the correspondence in scattering angle exists between satellite and ground obs.,
- Then, we can achieve a vicarious calibration in the near infrared within  $\pm 2\%$

# The test sites

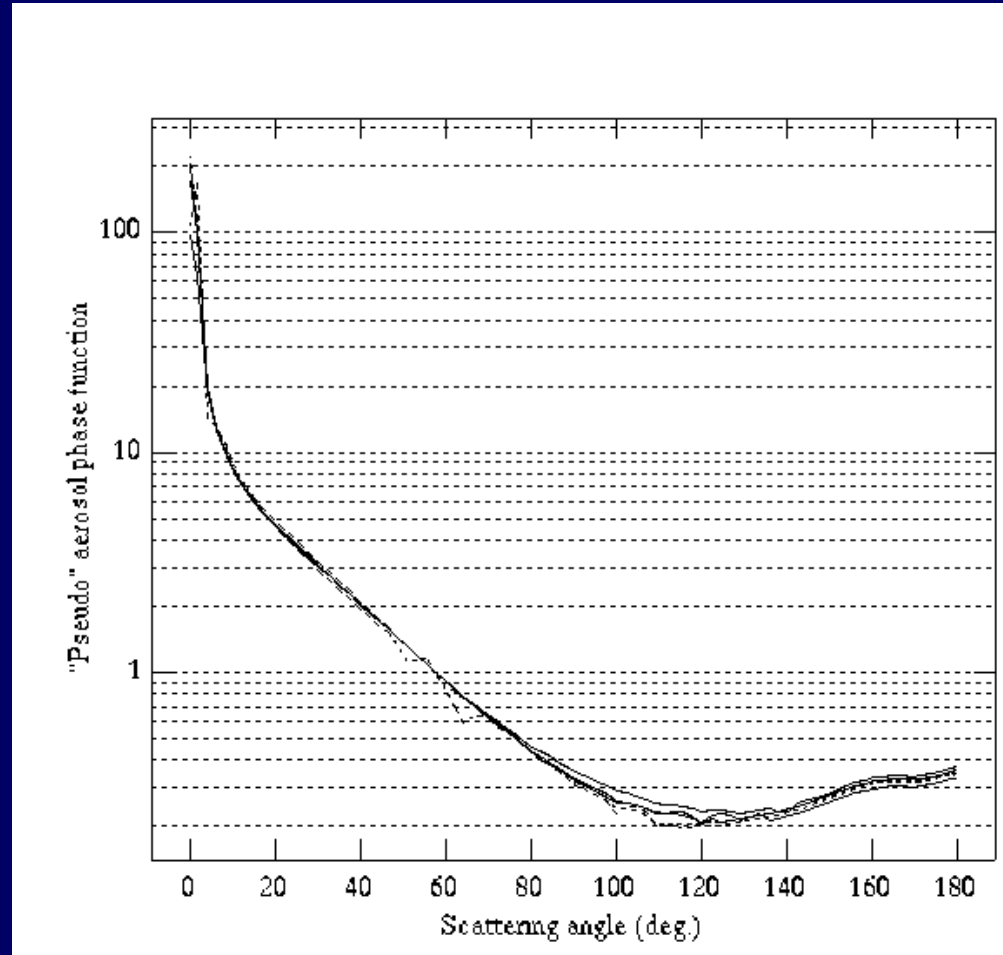


(a) the Venice Platform



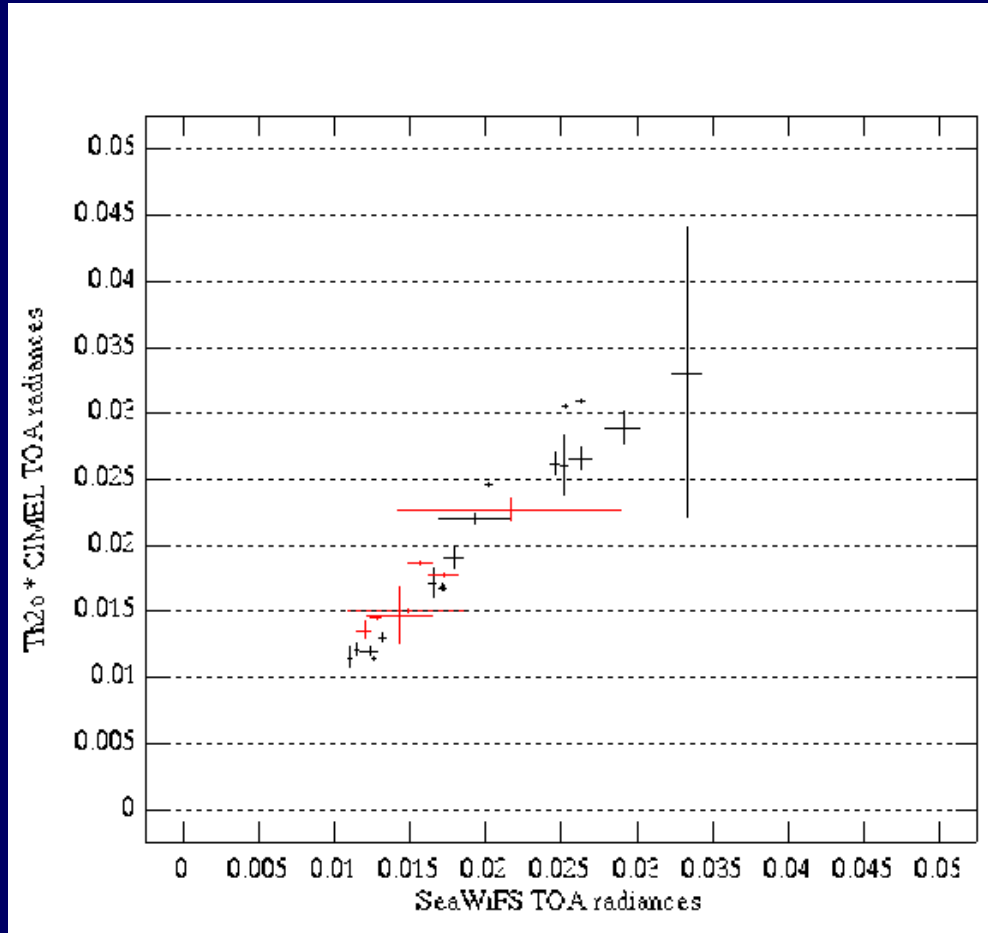
(b) the Lanai station

# Stability of the phase function $\omega P$



5 PPL protocols, 9 June 2000 morning, Venice site

# The SeaWiFS calibration at 865 nm



SeaWiFS  $L_{toa}$  is too low by 6.3% at 865 nm

## Conclusion 3

- Consistent results between the 2 sites
- Findings are confirmed by inter- calibration between sensors
- Dispersion of the calibration points indicate that accuracy is  $\pm 2$  percent

# Perspectives

- Use more data for the 2 sites
- Use more sites
- Do 765 nm and 670 nm calibration
- Do calibration of other sensors

# References

- Gordon, H. R., and T. Zhang, 1996: How well can radiance reflected from the ocean-atmosphere system be predicted from measurements at the surface?. *Appl. Opt.*, 35, 6527-6543.
- Santer, R., and N. Martiny, 2003: Sky radiance measurements for ocean color calibration-validation. *Appl. Opt.*, 42, 896-907.
- Martiny, N., R. Frouin, and R. Santer, 2004: Radiometric calibration of SeaWiFS in the near infrared. *Appl. Opt.*, submitted.