Improvement of the GLI ocean color algorithm and monitoring of the trend in the east Asian aerosol characteristics

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in collaboration with

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at GLI Workshop, Tsukuba, Japan
January 30, 2007

Works done so far…

- worked on the GLI standard ocean color atmospheric correction
  - Algorithm implementation/tuning
    - Iterative procedure for "turbid case 2 waters"
    - Absorptive aerosol correction: empirical algorithm for "V2 GLI" processing
    - Refinement of QC flags incl. cloud screening
    - Sun-glitter masking/correction
  - Validation
  - Level-3 product evaluation

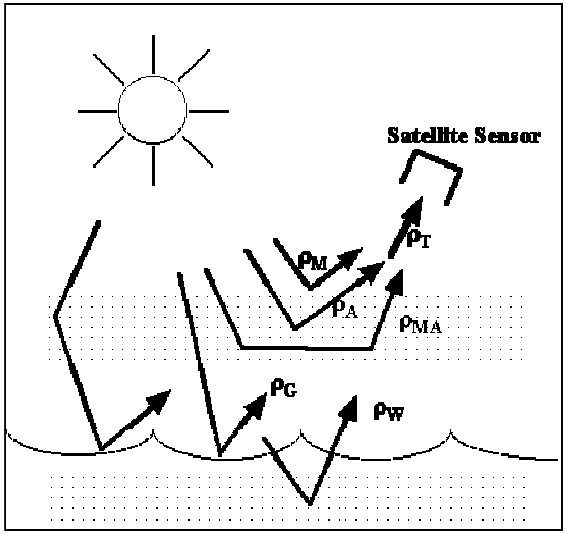
Works this year

- FY'06: Further efforts towards "future"
  - Absorptive aerosol correction
  - Sun-glitter correction/evaluation
- FY'06: Application studies
  - Atmospheric correction over coastal waters - use of SWIR bands, and "red tide" observation
  - "Trend in East Asian aerosols"

    A trial for "climate record"

GLI atmospheric correction

$$\rho_T(\lambda) = \rho_M(\lambda) + \rho_A(\lambda) + \rho_{MA}(\lambda) + T(\lambda)\rho_G(\lambda) + t(\lambda)\rho_{WC}(\lambda) + t(\lambda)\rho_W(\lambda)$$



ρ_T : **Satellite observed reflectance**

ρ_M : **Reflectance due to gas molecules**

ρ_A : **Reflectance due to aerosol particles**

ρ_{MA} : **Reflectance due to molecule-aerosol interact.**

ρ_G : **Reflectance due to sunglint**

ρ_{WC} : **Reflectance due to whitcap**

ρ_W : **Reflectance of water body (our target!)**

t : Diffuse transmittance between sea-surface and satellite

T : Direct transmittance between sea-surface and satellite

Reflectance in atmospheric correction

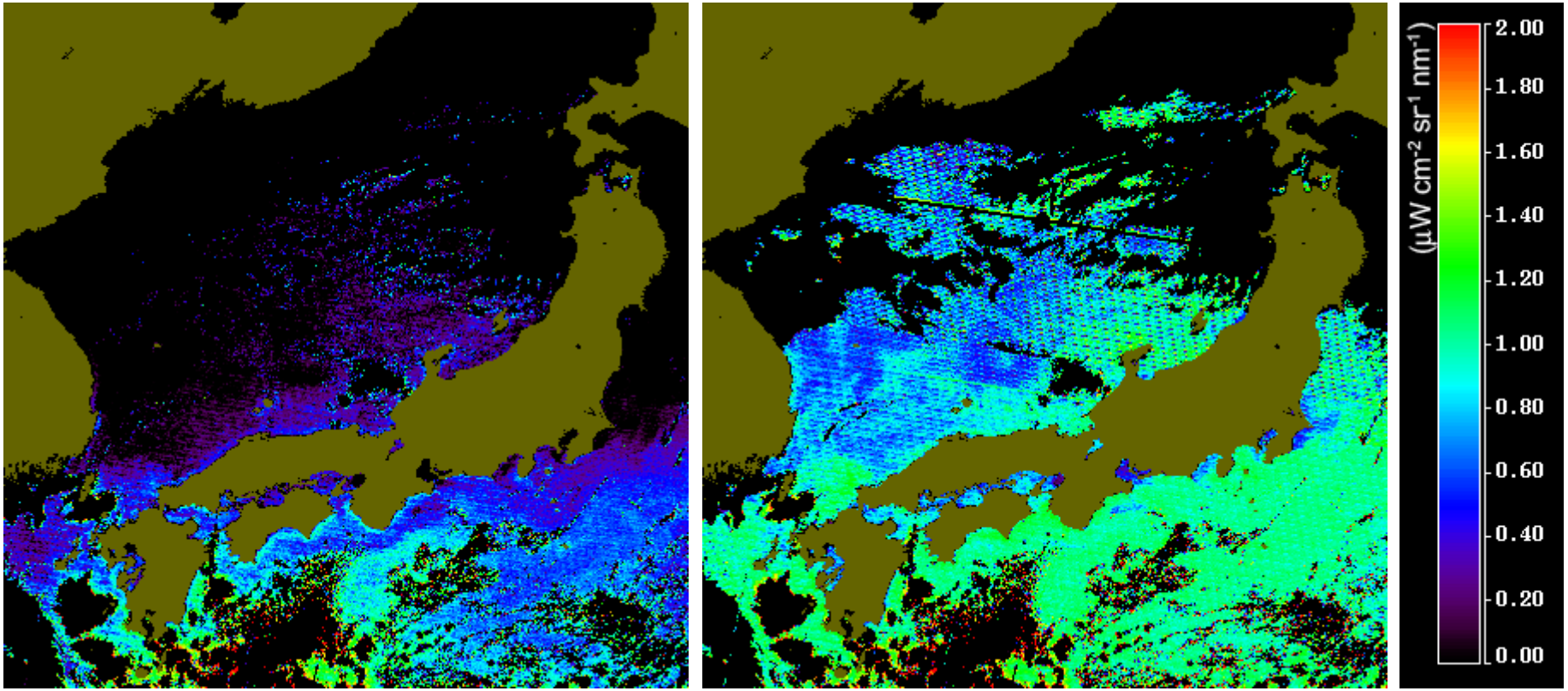
$$\rho \equiv \frac{\pi \cdot L}{F_0 \cdot \cos\theta_0}$$

Features and difficulties

- **Algorithm fairly established for "case 1" ocean waters**
- **Difficulties**
  - **Over "turbid case 2" coastal waters**
    - **Needs to work with "in-water model"**
  - **Under "absorptive aerosol"** → **Important to SGLI**
    - **Needs new aerosol models & schemes**
- **Current V2 algorithm features…**
  - **In-water optical models to estimate water reflectance $\rho_W(\lambda)$**
  - **Neural network to predict chl-a, SS, and CDOM concentrations**
  - **Use of 380 nm band to estimate the aerosol "absorption"**

Empirical absorptive aerosol correction for V2 GLI data processing

- **Normalized water-leaving radiance at 412nm band**

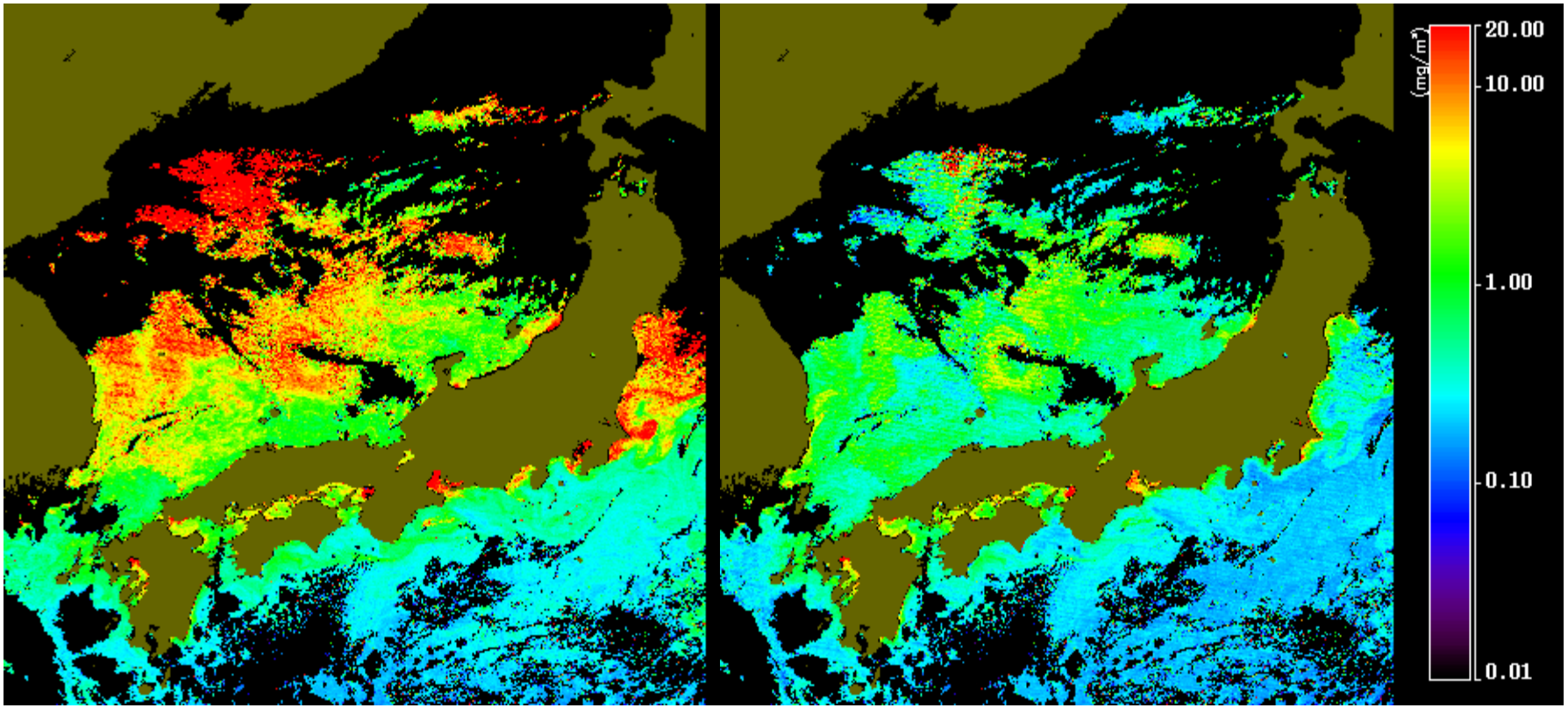


Before correction **After correction**

GLI 2003/4/17

Empirical absorptive aerosol correction for V2 GLI data processing

- **Chlorophyll *a* concentration estimate**

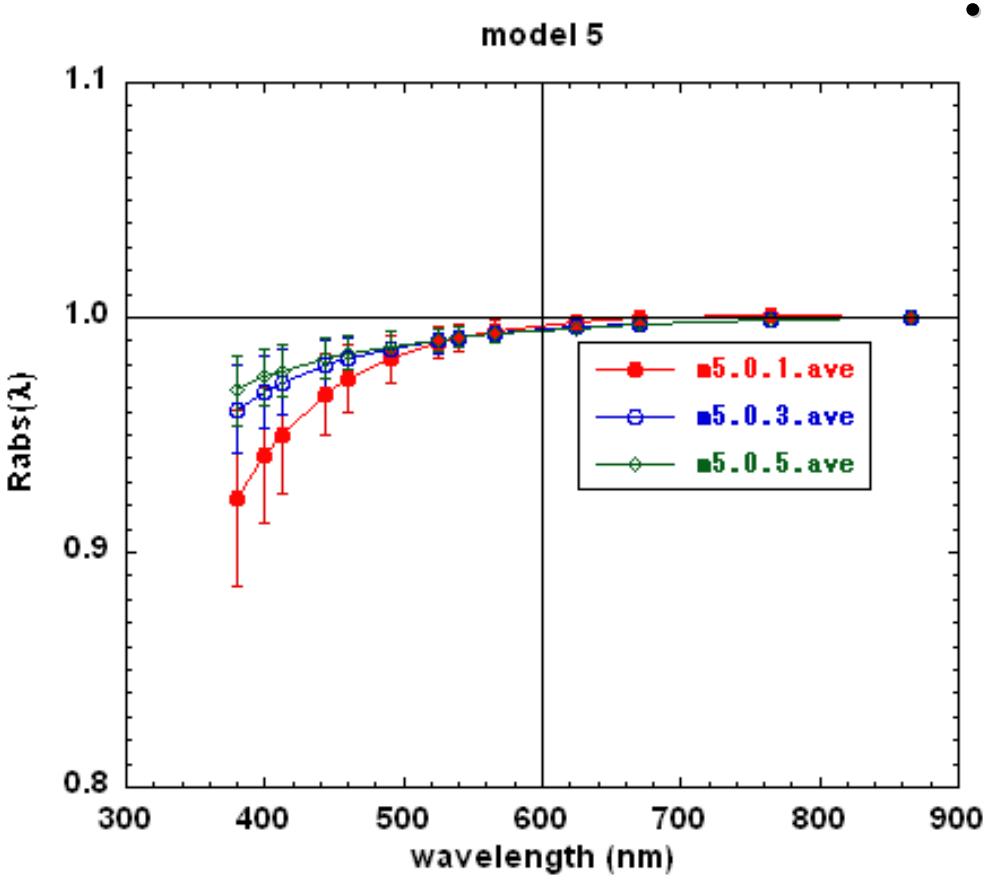


Before correction **After correction**

GLI 2003/4/17

Current version algorithm to appear in *J. Oceanogr.*

Radiative Transfer Simulation on Absorptive Aerosol

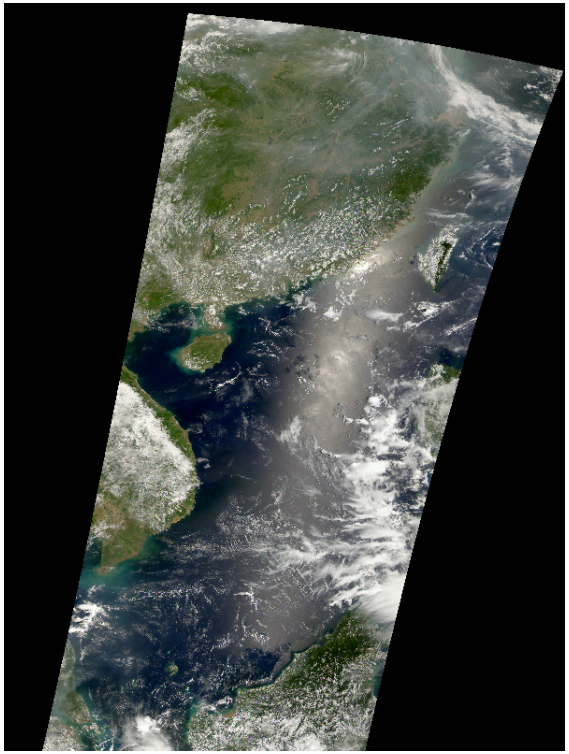


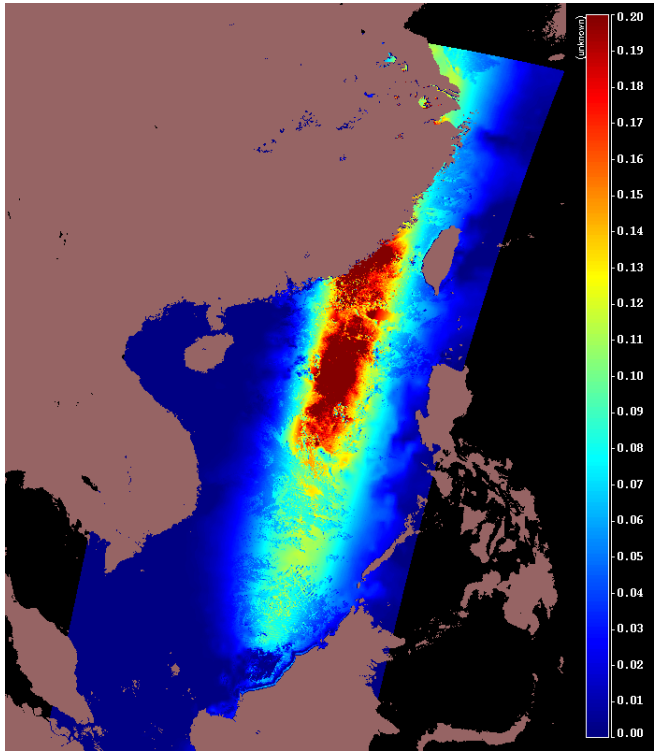
- **Effect is larger in short wave visible**
- **Magnitude dependent**
  - **on Mixture ratio of absorptive aerosol**
  - **on Path length**
  - **on Scan geometry**
  - **on Vertical distribution**

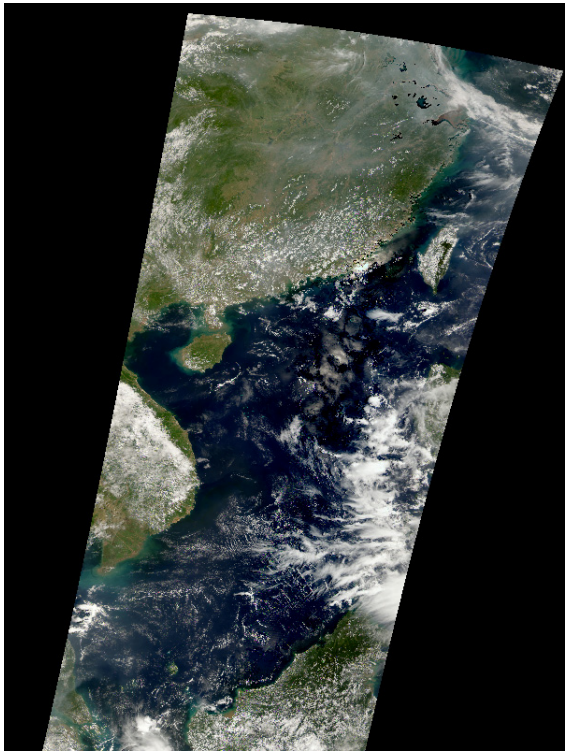
[FY'06] RTS ongoing with model-predicted aerosol vertical profiles

GLI Level 2 Sunglint Correction

- **SeaWinds-derived wind speed used for correction (25 km spatial resolution)**
- **Based on Cox and Munk (1954) isotropic model for wave slope probability distribution**

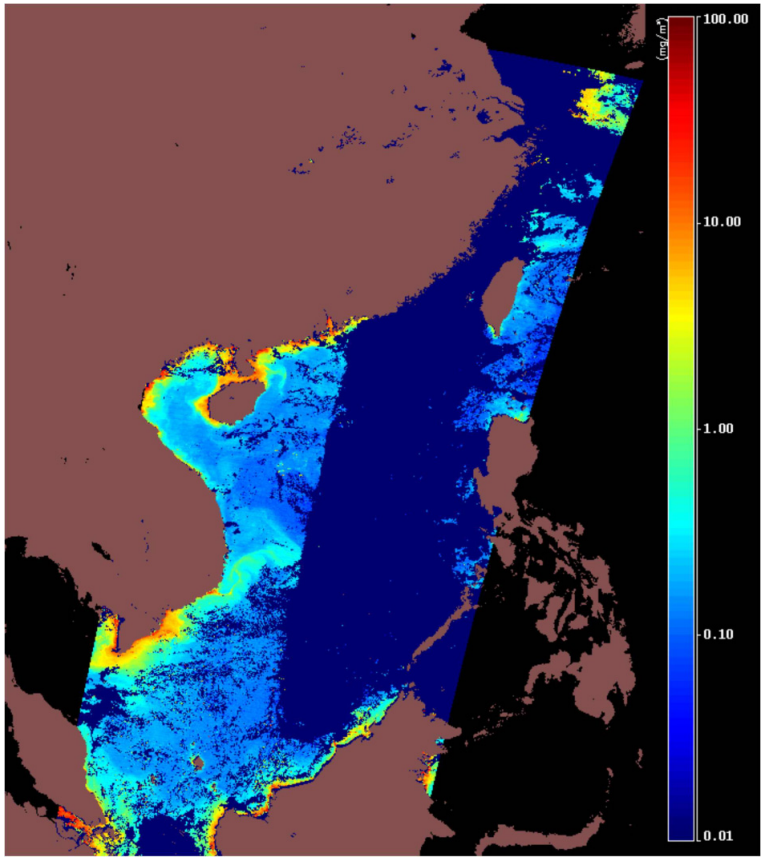




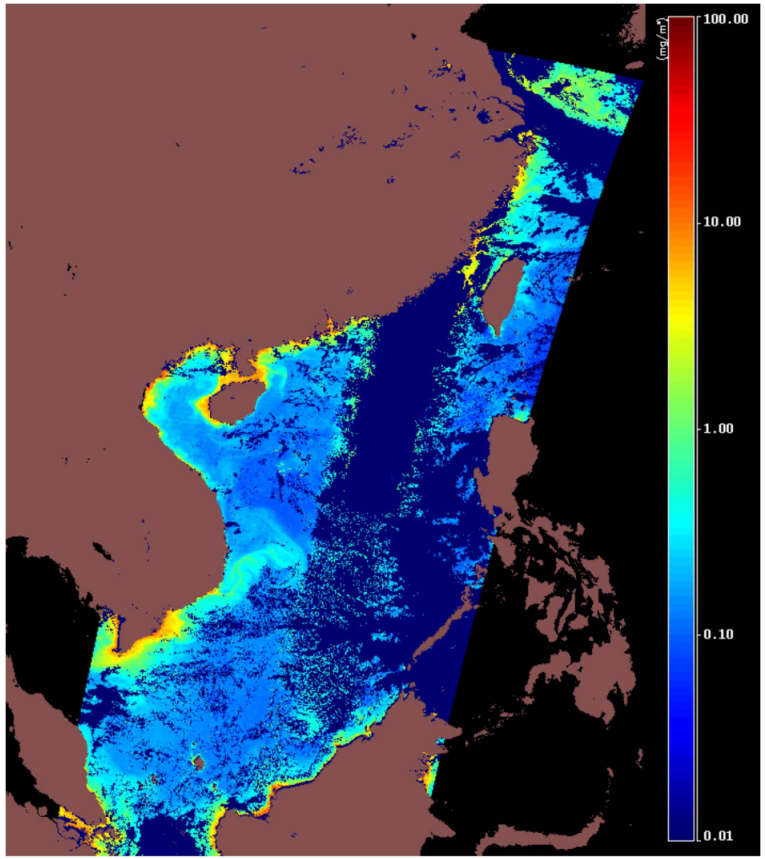


Original image | **Predicted sunglint intensity** | **Corrected image**

Comparison of Chlorophyll-a imagery: version 1 and 2 sunglitter masking/correction



Ver.1 algorithm with JMA-OA



Ver.2 algorithm with SeaWinds

Sun-glitter evaluation: ongoing refinement in FY'06

- **Paper submitted on "sun-glitter reflectance evaluation" for wind-direction independent model**
  - **Based on the analysis of 750 GLI L1B FR scenes with SeaWinds/SeaWiFS L3 data set**

- **[FY'06] Re-analysis of the GLI L2AOA and SeaWinds data set ongoing for wind-direction dependent model.**

- **Plan to complete the work to publish in FY'07**

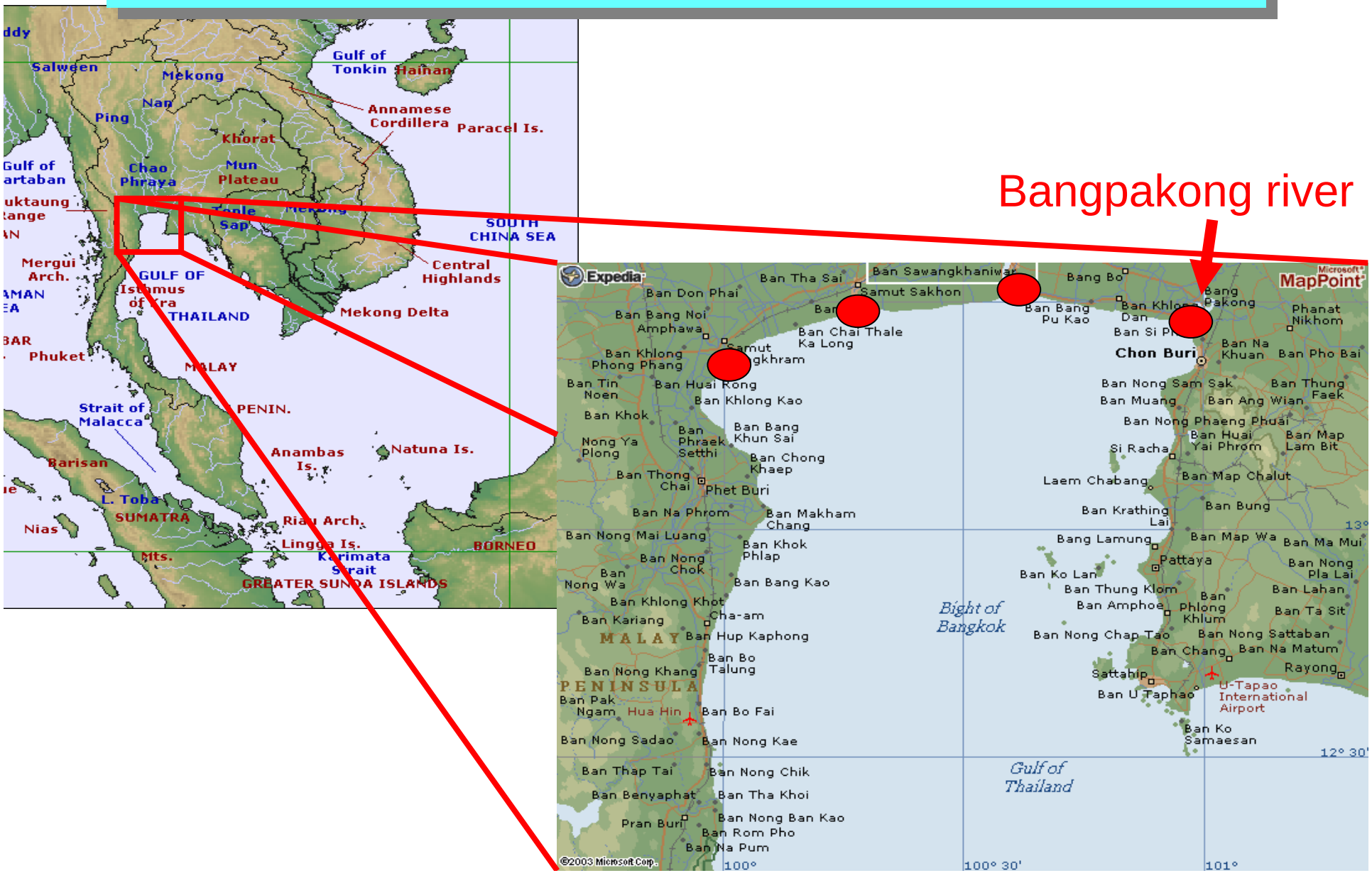
Evaluation of AC over coastal waters

- **Study area**
  - **Bangpakong river estuary - "Turbid case 2"**
    - **The suspended matter is dominant.**
    - **To evaluate AC with SWIR bands?**
  - **Yellow Sea**
  - **Ise Bay**
    - **Red tide**
    - **To see possibility of identifying "dominant species"**

MODIS specs

Primary Use	Band	Bandwidth	Spectral Radiance	Required SNR
Land/Cloud/Aerosols	1	620 - 670	21.8	128
Boundaries	2	841 - 876	24.7	201
Land/Cloud/Aerosols	3	459 - 479	35.3	243
Properties	4	545 - 565	29	228
	5	1230 - 1250	5.4	74
	6	1628 - 1652	7.3	275
	7	2105 - 2155	1	110
Ocean Color/	8	405 - 420	44.9	880
Phytoplankton/	9	438 - 448	41.9	838
Biogeochemistry	10	483 - 493	32.1	802
	11	526 - 536	27.9	754
	12	546 - 556	21	750
	13	662 - 672	9.5	910
	14	673 - 683	8.7	1087
	15	743 - 753	10.2	586
	16	862 - 877	6.2	516
Atmospheric	17	890 - 920	10	167
Water Vapor	18	931 - 941	3.6	57
	19	915 - 965	15	250

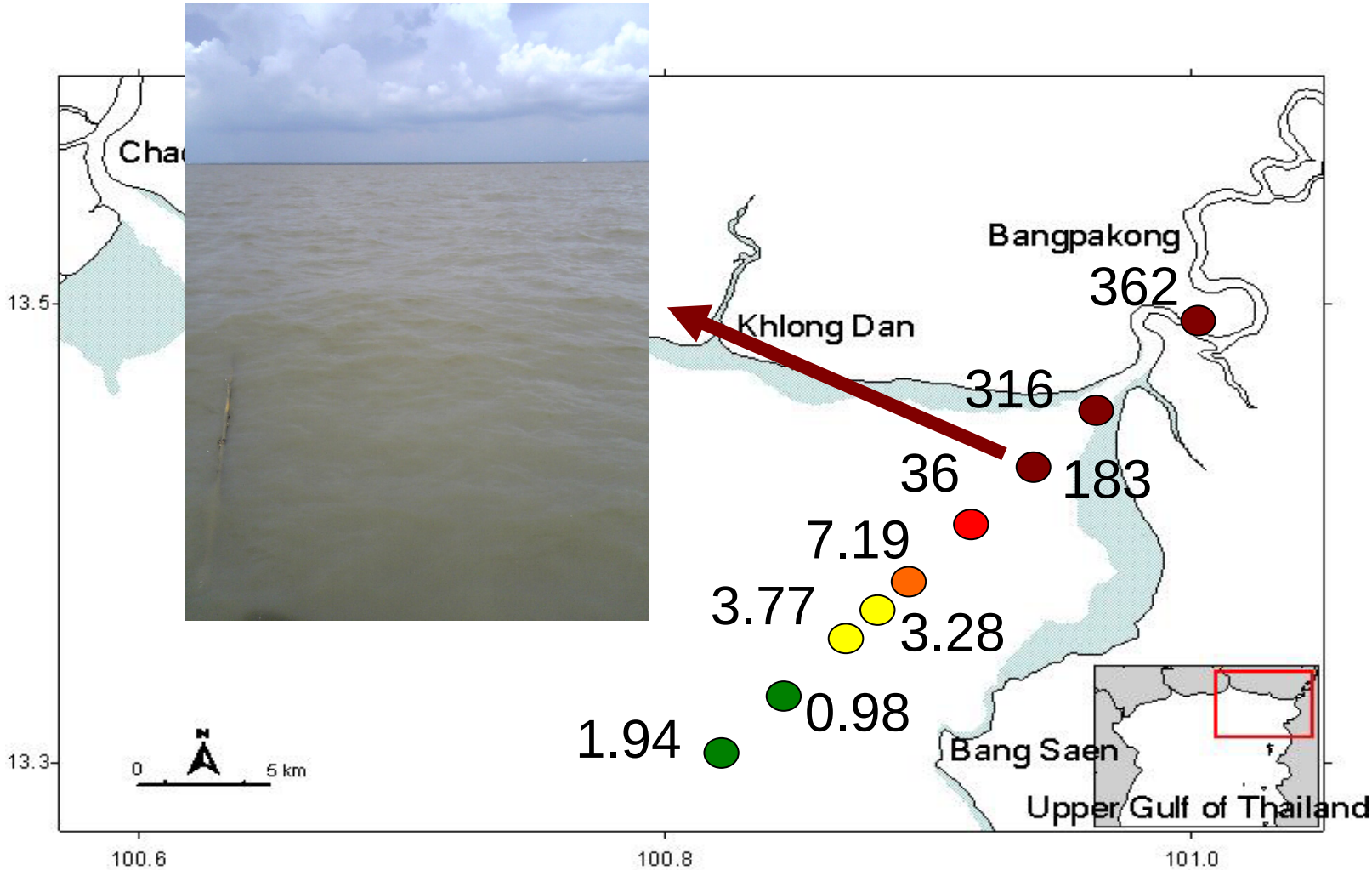
Upper Gulf of Thailand



In situ observation

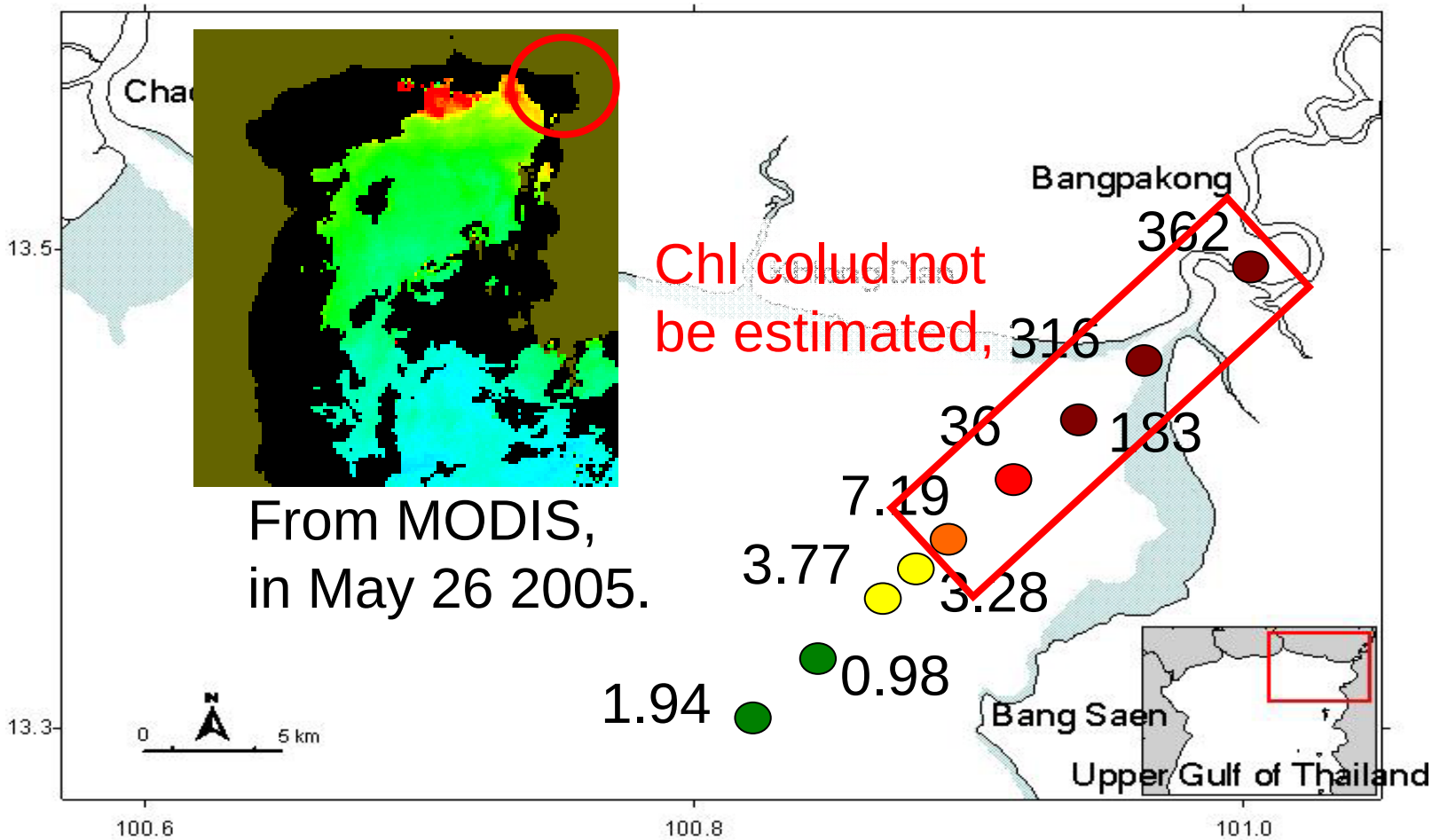
- **May 23-27 in 2005**
- **Measured parameters**
  - **Chlorophyll-a concentration**
  - **Total suspended matter concentration**
  - **Water-leaving radiance by Radiometer (TriOS optical sensors)**

Total Suspended matter concentration (g/m^3)

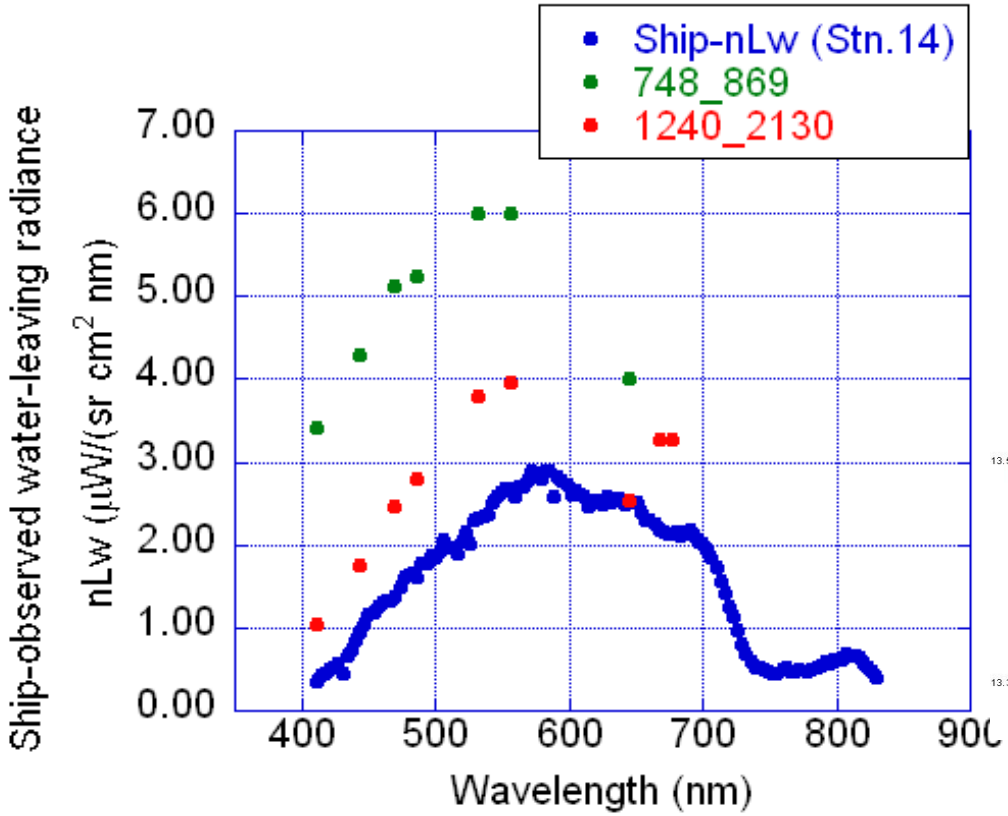


May 23-27 in 2005

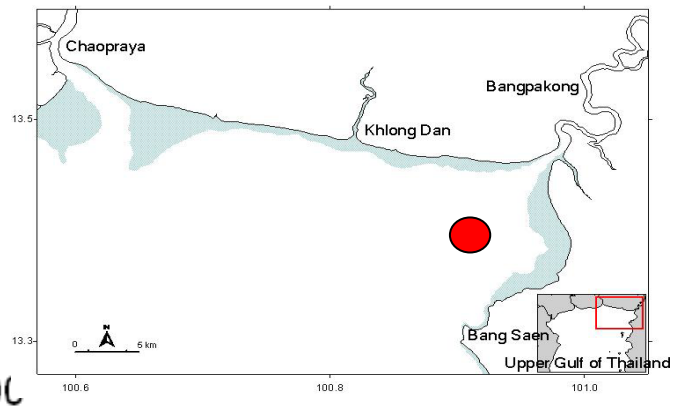
Ship-observed total suspended solid (g/m^3)



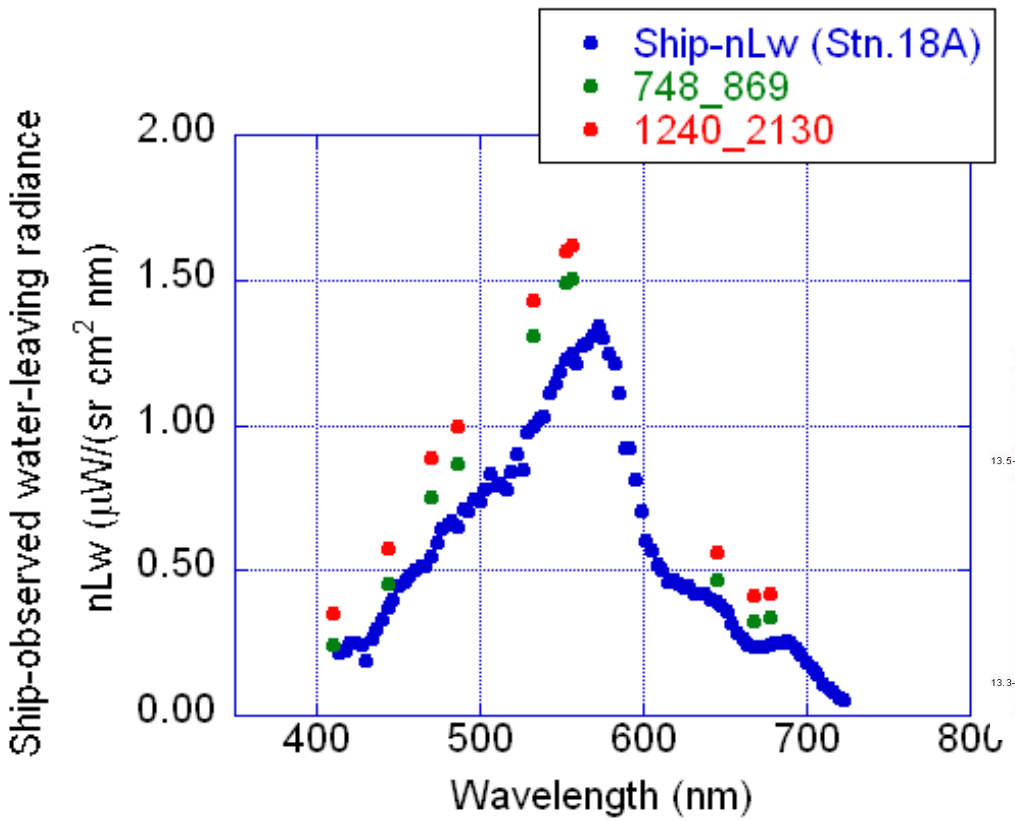
Comparison water-leaving radiance



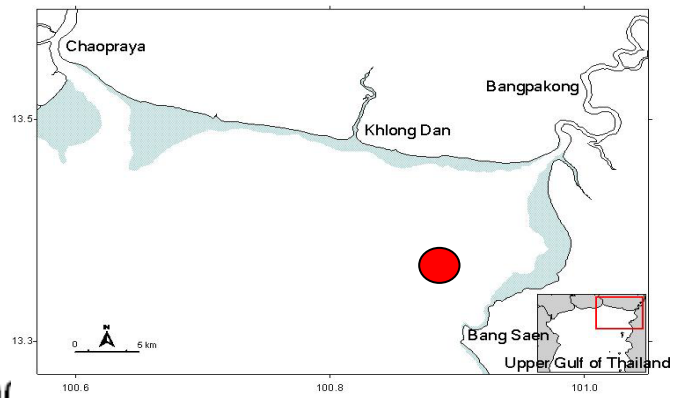
CHL
5.008mg/m^3
TSS
36g/m^3



Comparison water-leaving radiance



CHL
5.226mg/m^3
TSS
3.28g/m^3



AC with SWIR bands

- **AC with SWIR band combination useful over "highly turbid waters" if high S/N achieved**

Concluding Remarks for AC part

- **Towards further improvement on ocean color AC [FY'06 activities]**
  1. **Absorptive aerosol correction**
     - **RT simulations ongoing…**
  2. **Sun glitter evaluation model**
     - **Reanalysis on the global GLI L2AOA data with SeaWinds data**
  3. **Atmospheric correction over "coastal waters"**
     - **Confirmed usefulness of SWIR bands over "Turbid Case II" waters**
     - **Showed possibility of identifying "dominant Akashio species"**
- **Future plans**
  - **Fix the "absorptive aerosol correction" to evaluate the performance**
  - **Discuss/collaborate on "AC for coastal waters"**
- **Suggestion/proposal**
  - **Need "precision" in-water optical model to predict $\rho_W(\lambda)$) spectrum possibly using "Monte Carlo"?**

Increasing trends of sub-micron aerosol particles over East Asian waters observed in 1998-2004 by Sea Wide Field-of View Sensor (SeaWiFS)

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[b] *Department of Physics, Ocean University of China, China*

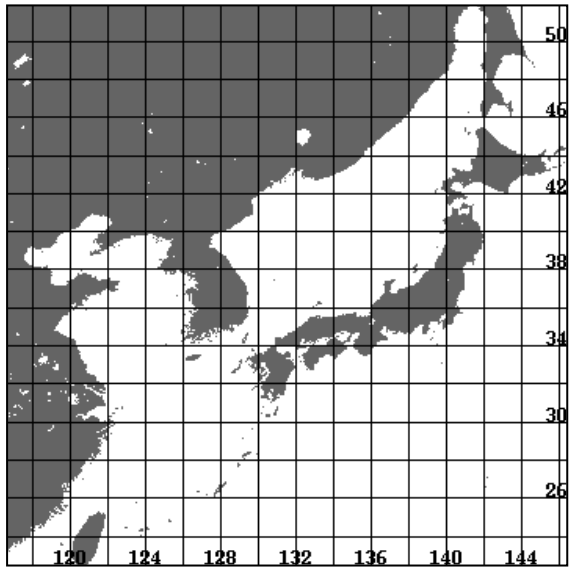
January 30, 2007

Motivation of the Study

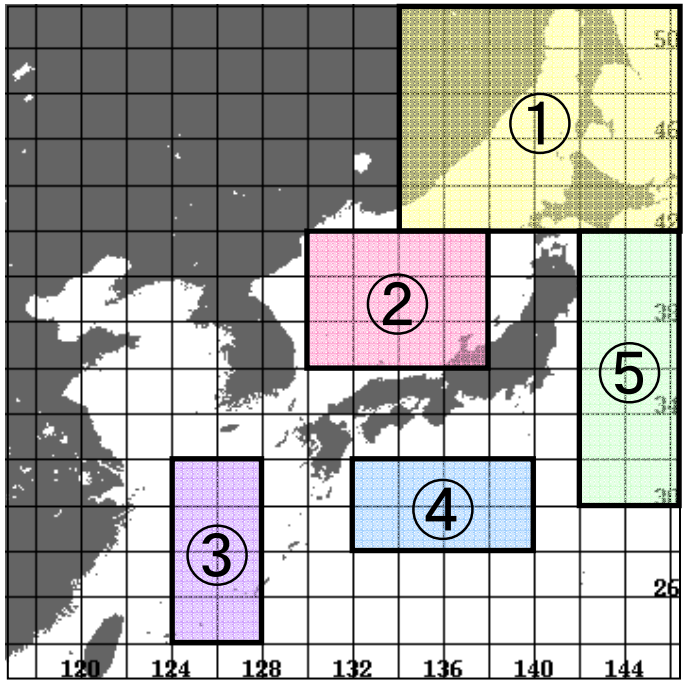
1. Observation of aerosol characteristics and its spatial variability is important
   - in terms of evaluating its effect on climate change
   - Even more important in East Asia
2. Can satellite observation measure the inter-annual variability in characteristics of aerosol?
   Candidate satellite sensors:
   - NOAA/AVHRR
   - TERRA/MODIS and AQUA/MODIS
3. SeaWiFS data set may provide a view for a potential change in aerosol characteristics
   - Over 1998-2004
   - With well-calibrated sensor

Analysis of SeaWiFS East Asian data set

- About 7500 scenes of SeaWiFS GAC L1A analyzed to cover Jan. 1998 - Dec. 2004.
- Over adjacent seas of Japan (22.4-51.9° N, 116.6-146.5° E)
- SeaDAS (ver.4.8) used to produce
  - Aerosol Optical Thickness (AOT) τ_A(490nm)
  - Angstrom exponent α
  - derived from 765 and 865 nm band data
- Cloud mask: Local variance in ρ_A(865) in add. to simple threshold (τ_A(490) = 2.5)
- Daily composites averaged monthly

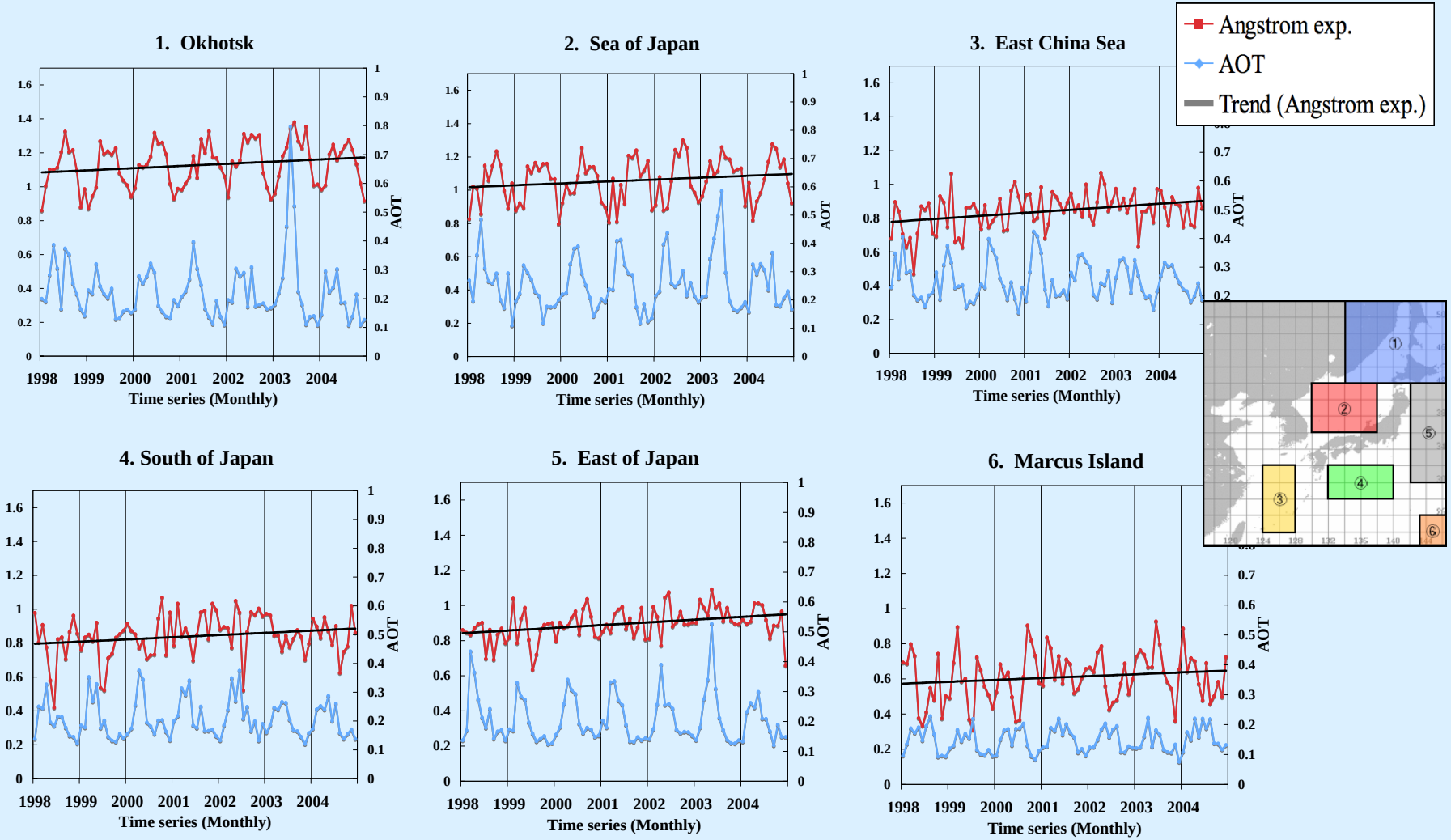


Study sub-areas



1. Okhotsk
2. Sea of Japan
3. East China Sea
4. South of Japan
5. East of Japan

Variabilities in monthly mean τ_A (490nm) and α(765nm, 865nm) over 1998-2004 period



Results so far…

- **Trend over 98-04 period**
  - **No significant increase in AOT**
  - **Angstrom exponent increased by 0.1 in most of the East Asian waters over the 7 years**
    - **Accessed as**
      4-5 % increase in sub-micron fraction (SMF)
      (by conversion formula in *Anderson et al., 2005*)

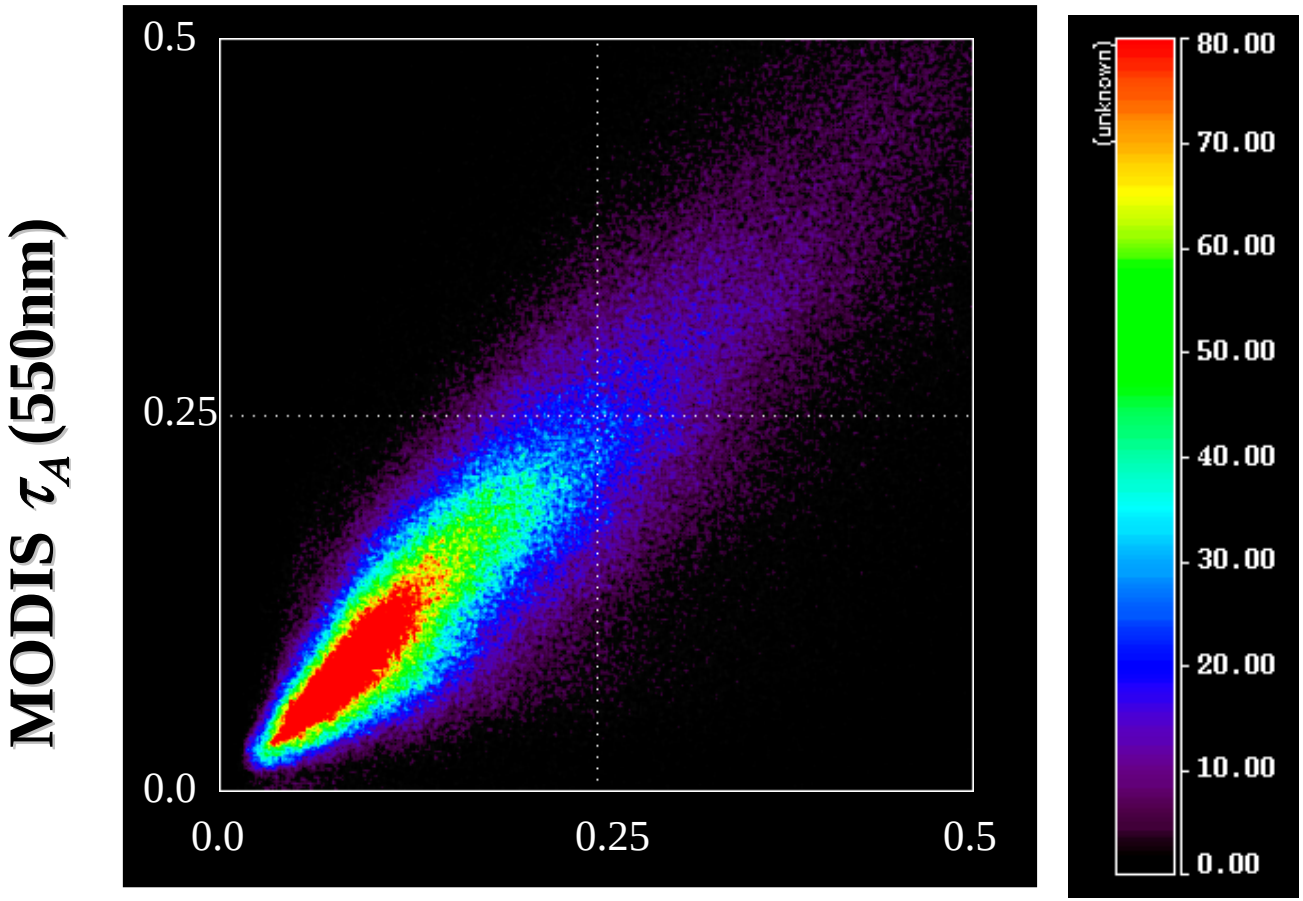
$$SMF = -0.0512\alpha^2 + 0.5089\alpha + 0.02$$

- **Most likely due to increasing anthropogenic activities?**

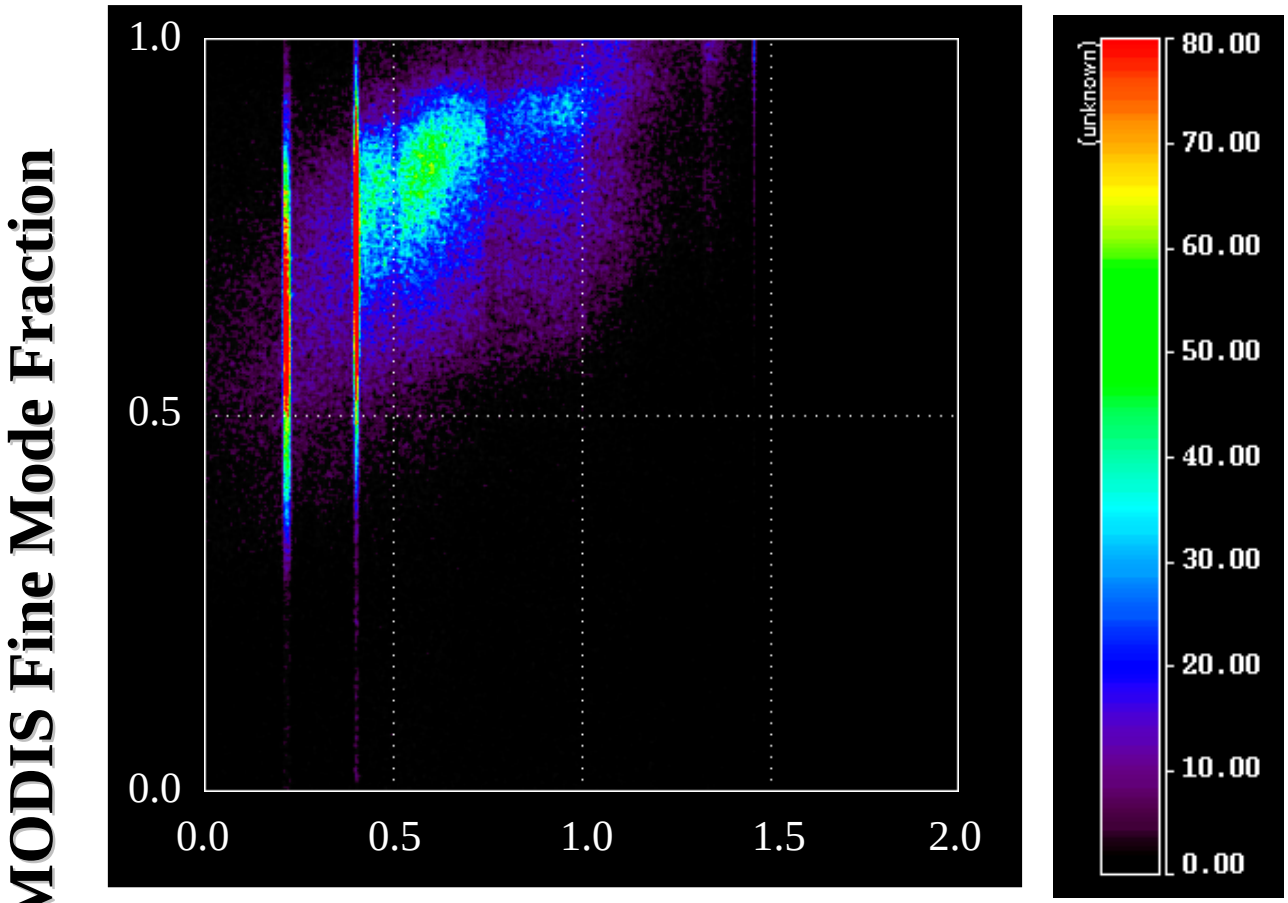
Discussion

- **Calibration reliable?**
  - **Lunar calibration maintained in addition to solar and vicarious calibration**
- **Can compare with ground observation?**
- **How does it compare with MODIS?**

SeaWiFS vs. MODIS-derved AOT (single scene)

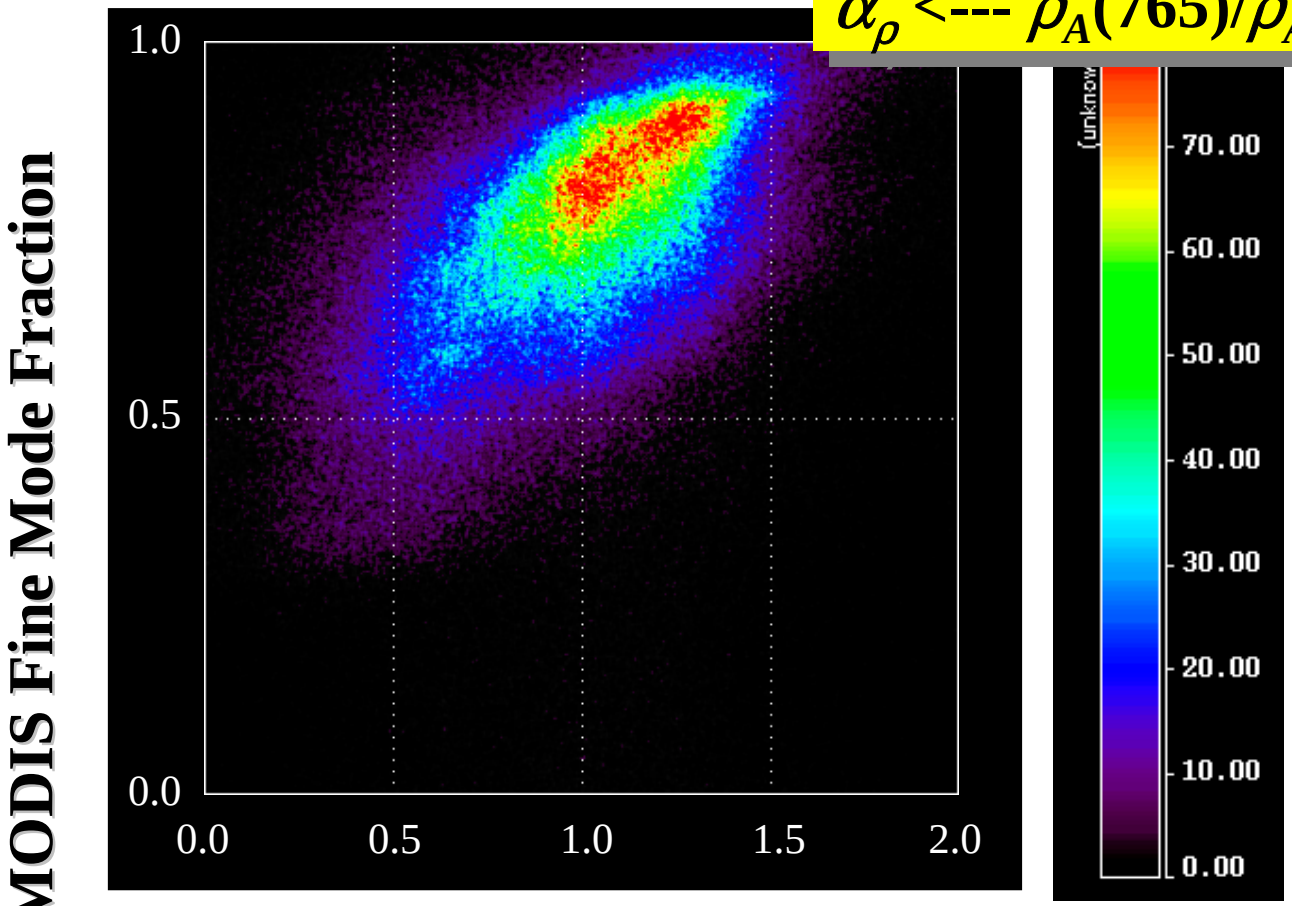


SeaWiFS vs. MODIS-derved Ang. Exp. (v.1)



SeaWiFS vs. MODIS-derved Ang. Exp. (v.2)

α_ρ <--- $\rho_A(765)/\rho_A(865)$



CONCLUSION for “aerosol” part

- **The time series analysis shows the possibility of tracking a “trend” in aerosol characteristics**
- **Lessons:**
  - **Calibration of the satellite sensor is essential/critical**
  - **Aerosol model determination scheme in ocean color AC should be re-evaluated**
- **Future works**
  - **Collaboration: comparison with model prediction/ground measurements**
  - **Absorptive aerosol distribution mapping planned**
    - **Based on some “in-water model”**