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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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

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

\( \rho_T \): Satellite observed reflectance
\( \rho_M \): Reflectance due to gas molecules
\( \rho_A \): Reflectance due to aerosol particles
\( \rho_{MA} \): Reflectance due to molecule-aerosol interact.
\( \rho_G \): Reflectance due to sunglint
\( \rho_{WC} \): Reflectance due to whitcap
\( \rho_W \): 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”
    - 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”

*Important to SGLI*
Empirical absorptive aerosol correction for V2 GLI data processing

- Normalized water-leaving radiance at 412nm band
Empirical absorptive aerosol correction for V2 GLI data processing

- Chlorophyll $a$ concentration estimate

Before correction

After correction

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
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

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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/m³)

From MODIS, in May 26 2005.

Chl could not be estimated.
Comparison water-leaving radiance

CHL
5.008 mg/m³
TSS
36 g/m³
Comparison water-leaving radiance

CHL
5.226mg/m³

TSS
3.28g/m³
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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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

- 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) \( \tau_A(490\text{nm}) \)
  - Angstrom exponent \( \alpha \)
  - derived from 765 and 865 nm band data
- Cloud mask: Local variance in \( \rho_A(865) \) in add. to simple threshold \( (\tau_A(490) = 2.5) \)
- 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 $\tau_A (490\text{nm})$ and $\alpha (765\text{nm}, 865\text{nm})$ 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
    - Access 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-derived AOT (single scene)
SeaWiFS vs. MODIS-derived Ang. Exp. (v.1)

SeaWiFS $\alpha_{\tau}(490, 865\text{nm})$
SeaWiFS vs. MODIS-derived Ang. Exp. (v.2)

\[ \alpha_\rho < \frac{\rho_A(765)}{\rho_A(865)} \]
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”