U.S. NAVAL RESEARCH LABORATORY

Tafkaa Atmospheric Correction Algorithm

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ACIX Meeting, Washington DC

This work has been presented previously in this form; the formatting has been changed.
NRL/OP/7230—07-0646

Outline

Atmospheric Correction Using Tafkaa

Short Summary

- Algorithm
- Lookup table information
- Versions and upgrades

Example

- Full geometry using airborne HSI

Fraser Algorithm

$$L_t = L_0(\lambda;\ \theta,\ \phi;\ \theta_0,\ \phi_0;\ z_{sen},\ z_{sfc}\ ;\ \tau_a) +$$
$$L_{sfc}(\lambda;\ \theta,\ \phi;\ \theta_0,\ \phi_0;\ z_{sen},\ z_{sfc}\ ;\tau_a;\ W)\ t(\lambda;\ \theta;\ z_{sen},\ z_{sfc}\ ;\tau_a) +$$
$$L_w(\lambda;\ \theta,\ \phi;\ \theta_0,\ \phi_0;\ W;\ C)\ t'(\lambda;\ \theta;\ z_{sen},\ z_{sfc}\ ;\ \tau_a)$$

L_t	=	measured radiance
L_0	=	path radiance (i.e., atmospheric scattering)
L_{sfc}	=	direct and diffuse radiance reflected off ocean surface
L_w	=	water (or ground) leaving radiance
t	=	diffuse + direct upward transmission
t'	=	diffuse upward transmission
τ_a	=	aerosol optical properties
W	=	wind speed
C	=	water column and bottom constituents
$\theta,\ \phi$	=	view zenith and azimuth angles
$\theta_0,\ \phi_0$	=	solar zenith and azimuth angles
$z_{sen}\ ,\ z_{sfc}$	=	sensor and surface altitudes

Tafkaa: an Atmospheric Correction Algorithm

- Over optically shallow and case-II waters, *Tafkaa* assumes L_W = 0 at λ>0.865 μm to determine aerosol properties; otherwise the aerosol properties must be provided or determined in some other manner.

- Tafkaa calculates the absorptive components due to atmospheric gasses, but needs to be provided tables for the contributions due to aerosols and Rayleigh scattering.

- Aerosol Lookup-table (modified Ahmad & Fraser) calculations include
  - All orders of scattering & components of polarization
  - Rough ocean surface formalism & effects of foam
  - Absorption and scattering by gas and aerosol
  - ~330 million entries for a variety of view & solar geometries, aerosol models, lower boundaries, sensor altitudes

Look-up Table Dimensions

Properties of Tables

- 14 wavelengths (λ = 0.39 to 2.25 μm)
- 4 lower boundary conditions: a rough ocean surface at 3 wind speeds (2, 6, and 10 m/s), and a Lambertian with 0 reflectance, all at sea-level
- 10 aerosol optical depths at 0.55 mm (from τ = 0.0 to 2.0)
- 5 aerosol models at 5 relative humidities (RH=50, 70, 80, 90, 98%)
  - Urban 99.9875% small continental/ 0.0125% soot-like
  - Tropospheric 100% small continental/ 0% large oceanic
  - Coastal-a 99.8% / 0.2%
  - Coastal 99.5% / 0.5%
  - Maritime 99.0% / 1.0%
- 9 solar zenith angles (θ_0)
- 17 relative azimuth angles (ϕ - ϕ_0)
- 17 view zenith angles (θ)
- Calculated at the top of the atmosphere and 9 sensor altitudes (z_{sen} = 0.0 to 22.0 km)
- There are ~330 million elements in the reflectance tables
- Several much smaller tables are also calculated and used

Versions & Upgrades

Multispectral Version

- Modules for different multi-spectral sensors
- Full solar and view geometry at each pixel
- Wind speed and ozone may vary at each pixel

Hyperspectral Version

- Wind speed and ozone constant over scene (user input)
  - Ozone can be chosen with from climatological model
- Support for different view and/or solar geometry methods
  - Constant over scene
  - Line by line variation for solar geometry, sample by sample for view geometry
  - Full geometry at each pixel
    - View Geometry changes as sensor pitches, rolls, and heading changes (important for airborne observations)
    - Many sensors have a persistent forward or backward pitch of several degrees based on their mounting and typical flight platform profile
    - Roll of several degrees is typical on low-altitude flights
    - If scene can be georectified, then view geometry is available
    - Allows application to mosaicked scenes obtained over large time as long as mosaicked versions of the view & solar geometry are available
  - Ability to use spectral response functions (not just band center and fwhm)

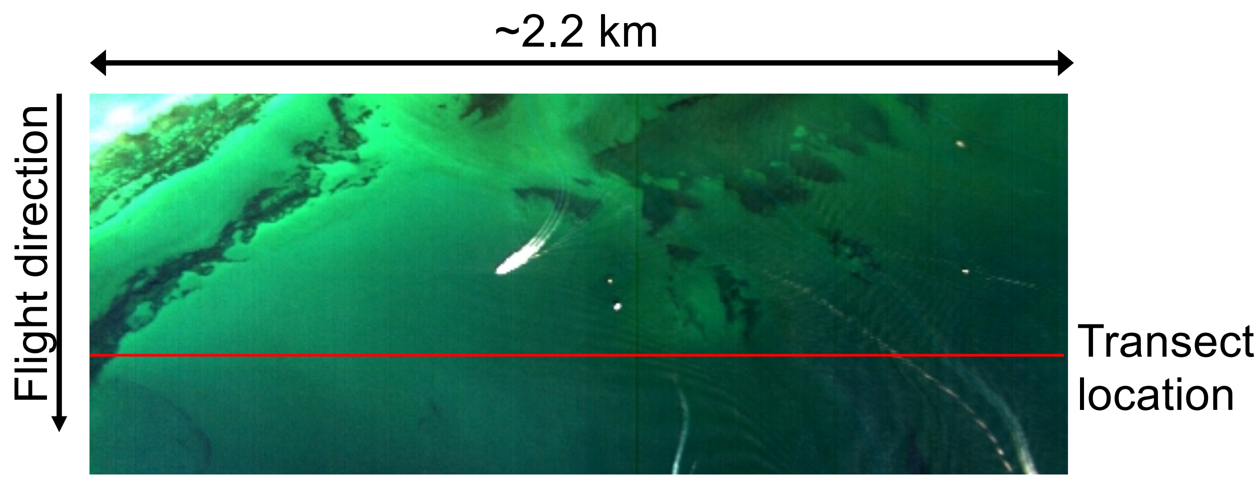
Example

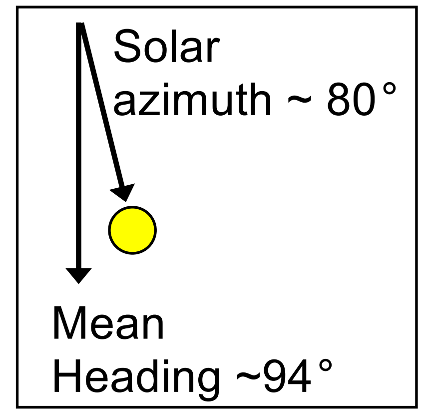
NRL-PHILLS1

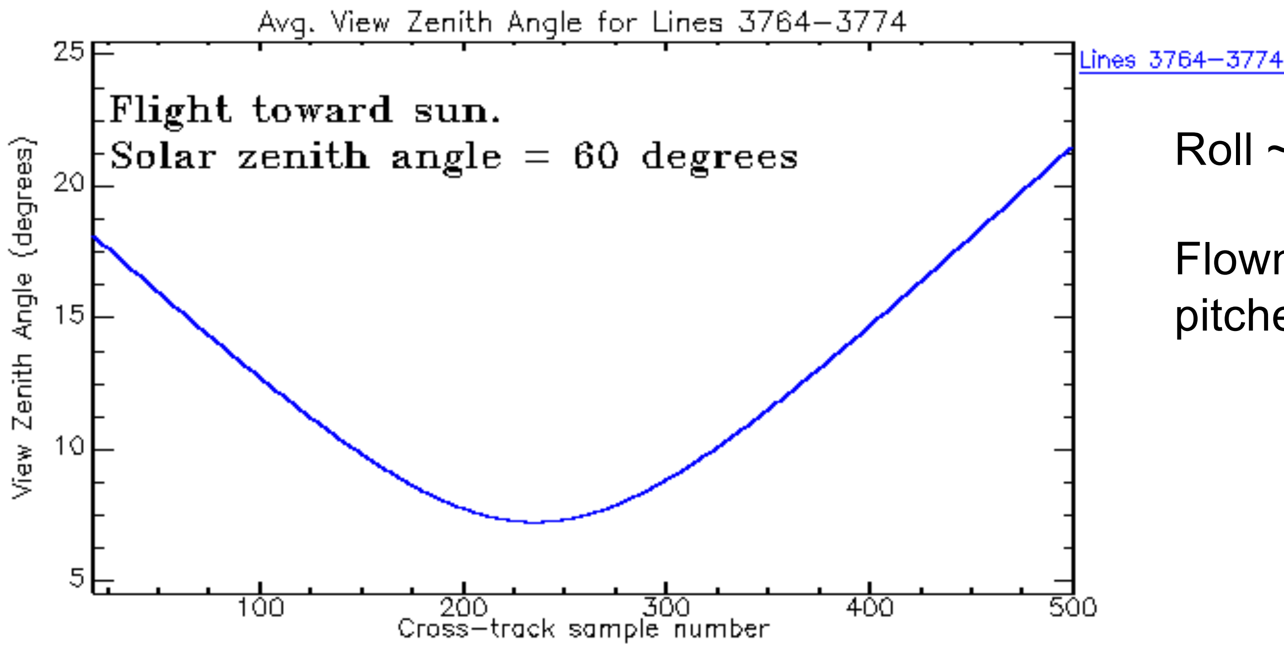
Metadata

- Ocean off the entrance of the Indian River Lagoon, Florida, USA
- 2004 July 15, at 13:00 GMT
- Solar Zenith Angle = 60°, Solar Azimuth Angle = 80°
- Flight heading was approximately toward the sun
- GPS/INS data available to determine full geometry
- Data shown below is binned by 2 along track, cross-track, and spectrally
- For more information about the data please refer to “Hyperspectral imaging of an inter-coastal waterway,” J. H. Bowles, S. J. Maness, W. Chen, C. O. Davis, T. F. Donato, D. B. Gillis, D. Korwan, G. Lamela, M. J. Montes, W. J. Rhea, W. A. Snyder. Proc. SPIE Vol. 5983, *Remote Sensing for Environmental Monitoring, GIS Applications, and Geology V*; Manfred Ehlers, Ulrich Michel, Eds.; Publication Date: Oct 2005

Example: View Zenith Angle



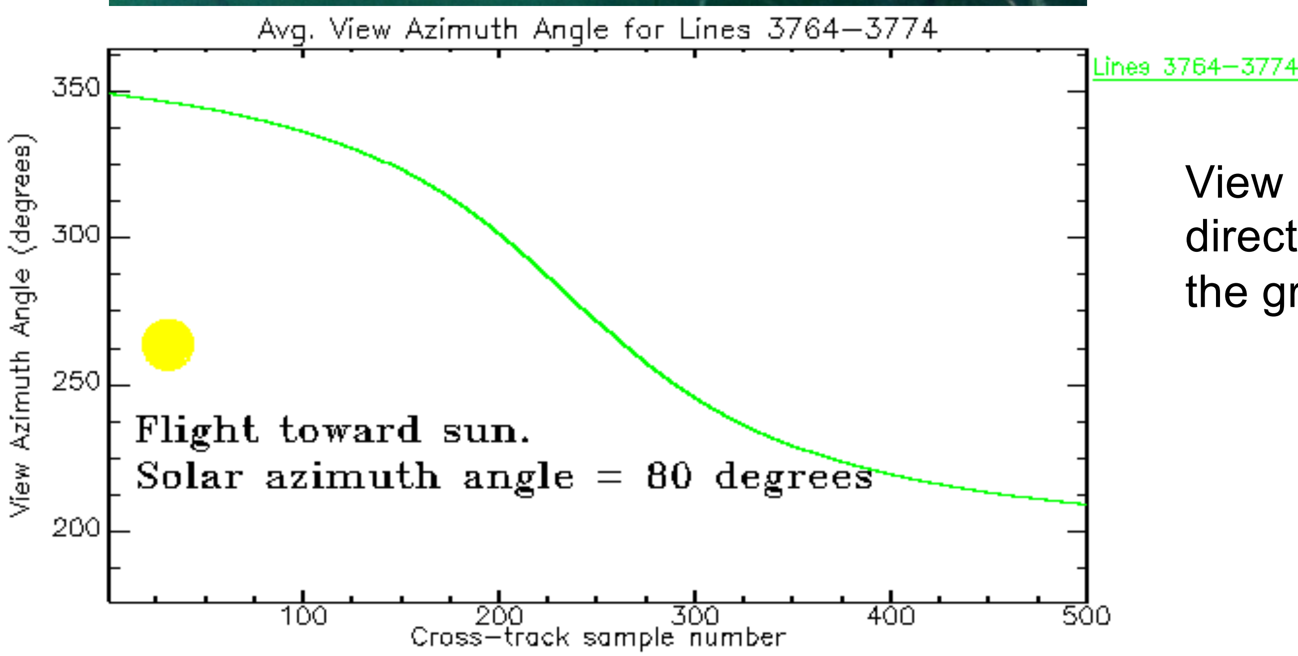


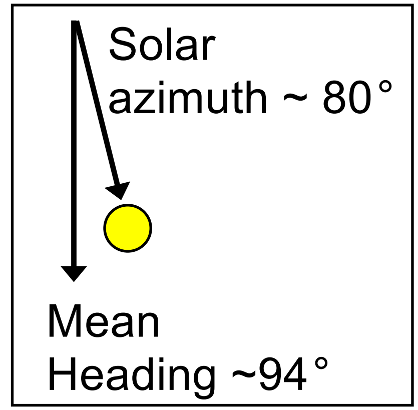


Roll ~3° at this location.

Flown in Antonov, typically pitched *forward* by ~5° – 7°.

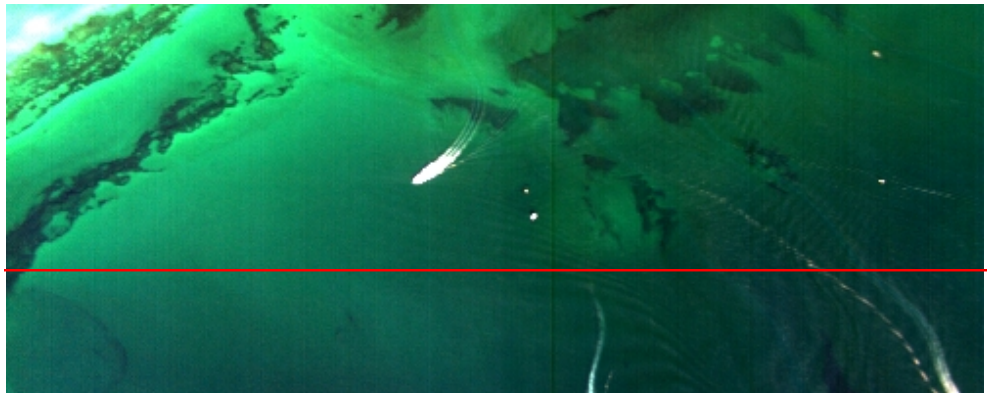
Example: View Azimuth Angle



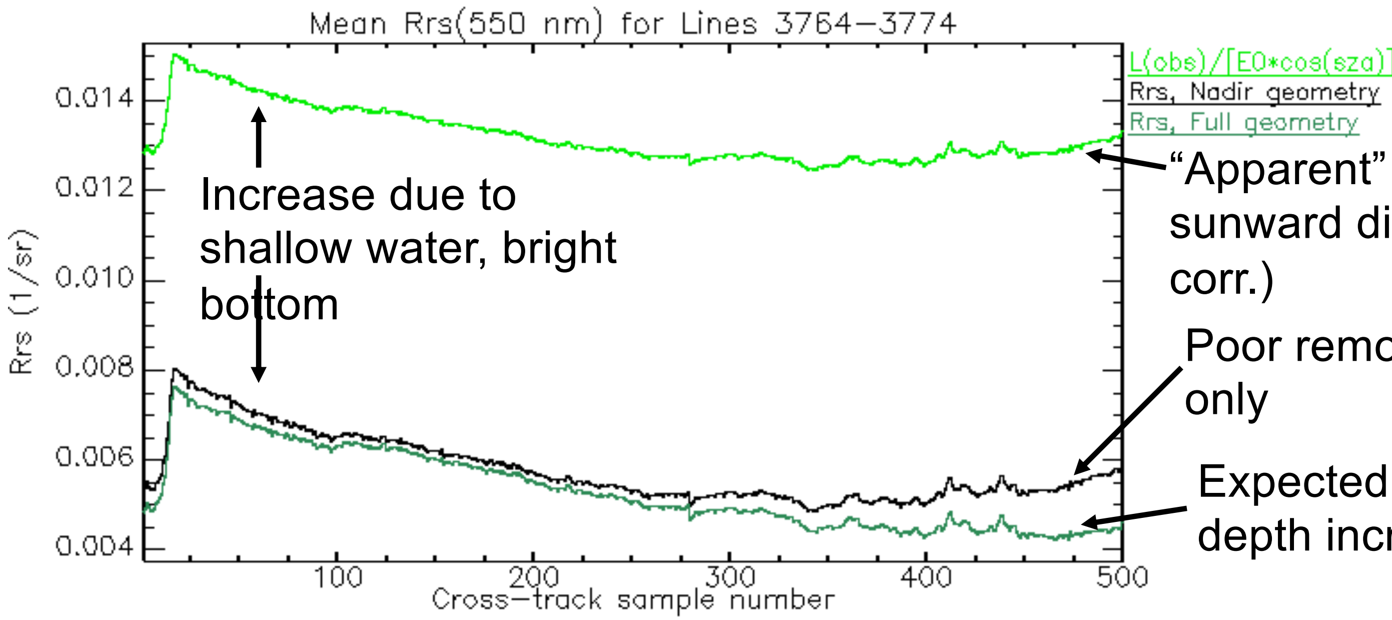


View azimuth is the direction from the point on the ground to the sensor.

Example: Retrieved R_{rs}



Retrieved R_{rs} when including full geometry yields more appropriate values – note difference at right side of transect

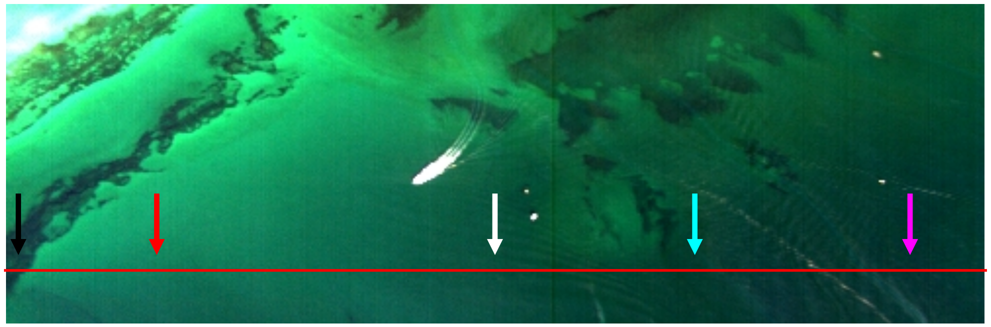


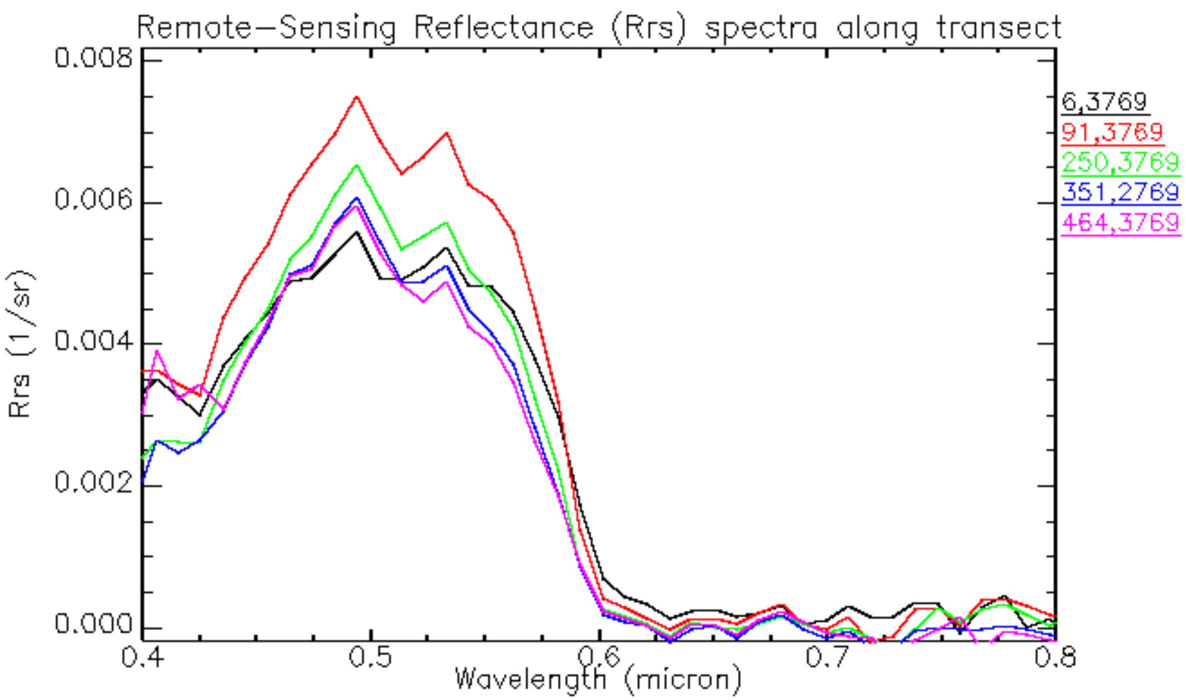
“Apparent” reflectance rises in sunward direction (no atm. corr.)

Poor removal with nadir only

Expected behavior as depth increases

Example: Retrieved R_{rs}





Retrieved R_{rs} spectra along the transect (left to right) are associated with the spectra labeled by coordinates in the key (top to bottom).

Discussion

- Just a single example, but over water, especially with wide field of view sensors, it is necessary to account for the full geometry.
- *Tafkaa* has been modified to do this
- Hyperspectral satellites viewing the same region on the ground will have much smaller range of view zenith angles (angles subtended to image the identical area are ~30 – 100s of times smaller)

References

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