Simultaneous Retrieval of Atmospheric and Aquatic Parameters in Turbid waters

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Main challenges: The Black Pixel Approximation does not hold over turbid water - how do we separate out the atmospheric contribution? How do we remove ambiguities in the retrieval and quantify errors?

Answer: Adopt an algorithm for **simultaneous Retrieval of Aerosol Properties and Marine Constituents** that:

1) uses a linearized, coupled RT-model as our forward model
2) uses a continuum set of aerosol models
3) incorporate available data from longer wavelength channels
4) uses state-of-the-art inversion techniques available for linearized models

The New Linearized coupled RT model -- CAO-LDISORT:

1) is an extension of the CAO-DISORT (Coupled Atmosphere Ocean DIScrete Ordinate Radiative Transfer) model.
2) has pseudo-spherical capability for the atmosphere
3) is fully linearizable: techniques for inversion of linear problems can be applied. e.g.:
 a) clear water (ocean) bio-optical model: express input optical properties in terms of chlorophyll concentration, C
 b) linearization of bio-optical model enables derivatives of TOA radiance (weighting functions) w.r.t. parameters to be retrieved
4) calculates TOA radiances, aerosol and chlorophyll weighting functions (Wfs)
5) WFs identify broadly orthogonal trends; easily enough sensitivity to retrieve the two parameters

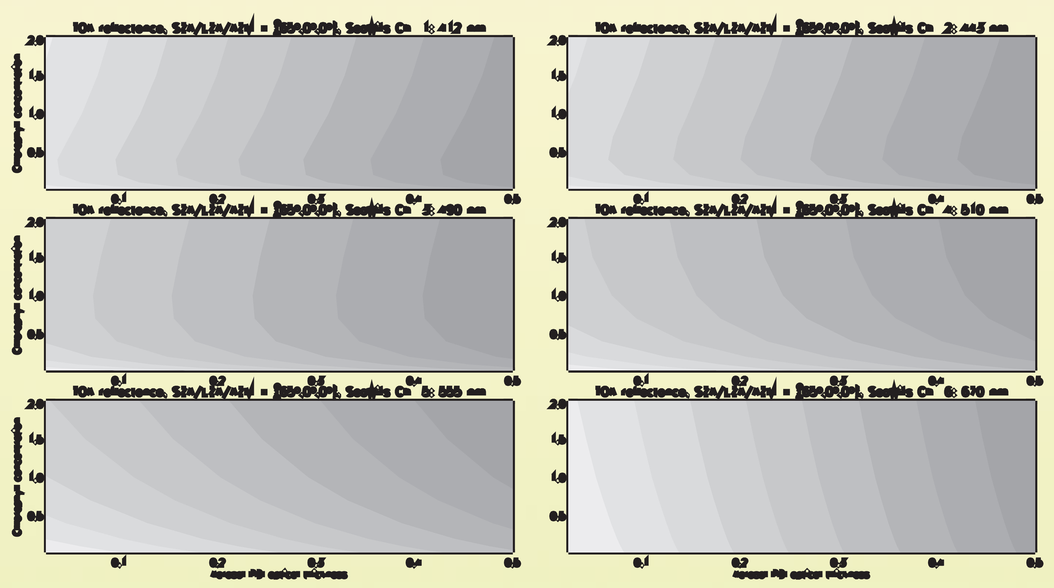


Fig.1 TOA radiance: 6-channel SeaWiFS simulation at 412, 443, 490, 510, 555, and 670 nm using CAO-LDISORT

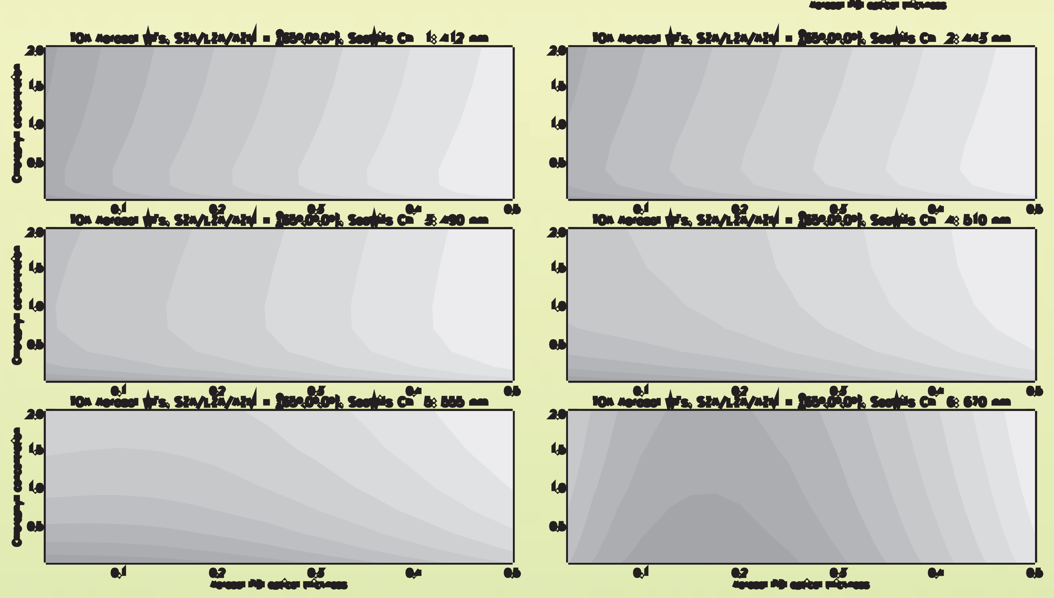


Fig.2 TOA Aerosol optical depth Jacobians: 6-channel SeaWiFS simulation using CAO-LDISORT

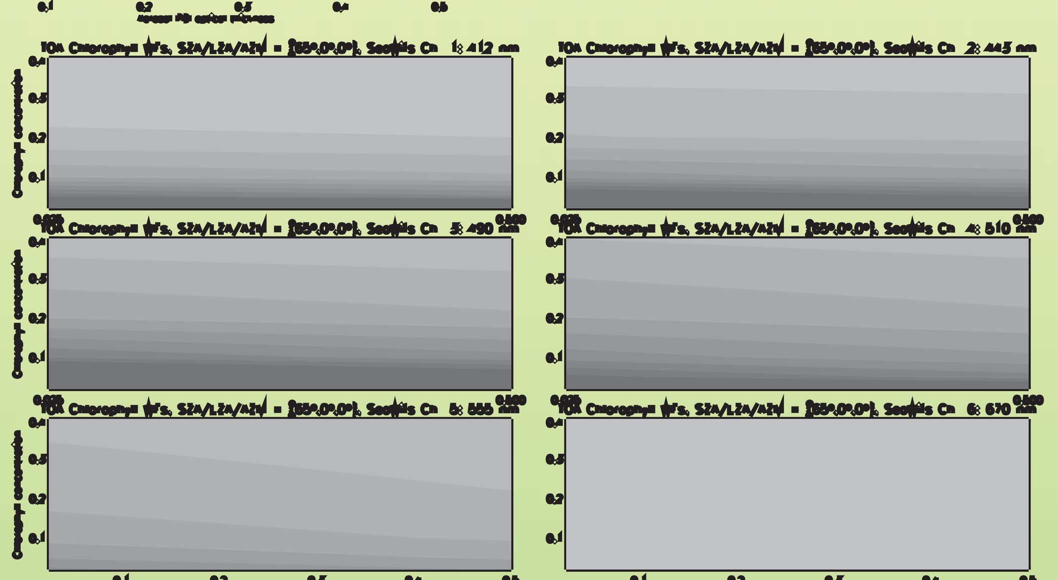
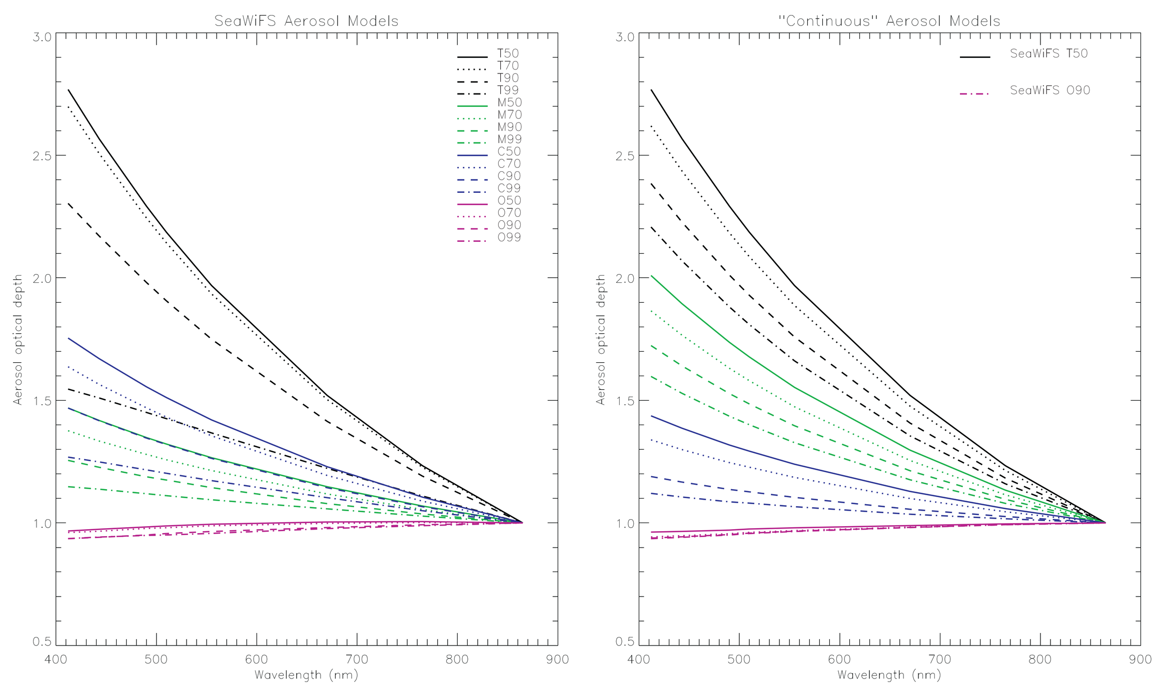


Fig.3 TOA Chlorophyll concentration Jacobians: 6-channel SeaWiFS simulation using CAO-LDISORT

"Discrete" versus "Continuous" Aerosol Models:

MODIS and SeaWiFS employs a "Discrete" Set of Aerosol Models:
- tropospheric, coastal, maritime and oceanic aerosol types
- allowed to grow with different relative humidities (50%, 70%, 90% and 99%)
- 16 models total

We use a "Continuous" Set of Aerosol Models in our CAO-DISORT algorithm:
- start with a combination of a small particle model and a large particle model: small particle model: Tropospheric-50, large particle model: Oceanic-90
- let the ratio of one aerosol model to the other vary continuously as needed



Left: Extrapolation of aerosol optical depth from the NIR into visible. (Left panel: The discrete MODIS/SeaWiFS aerosol models. Right panel: our continuous aerosol model representation.)
The continuous model representation provide a better "coverage" of the aerosol optical properties-space.

The Advantage of Continuously Varying Aerosol Model Representation:

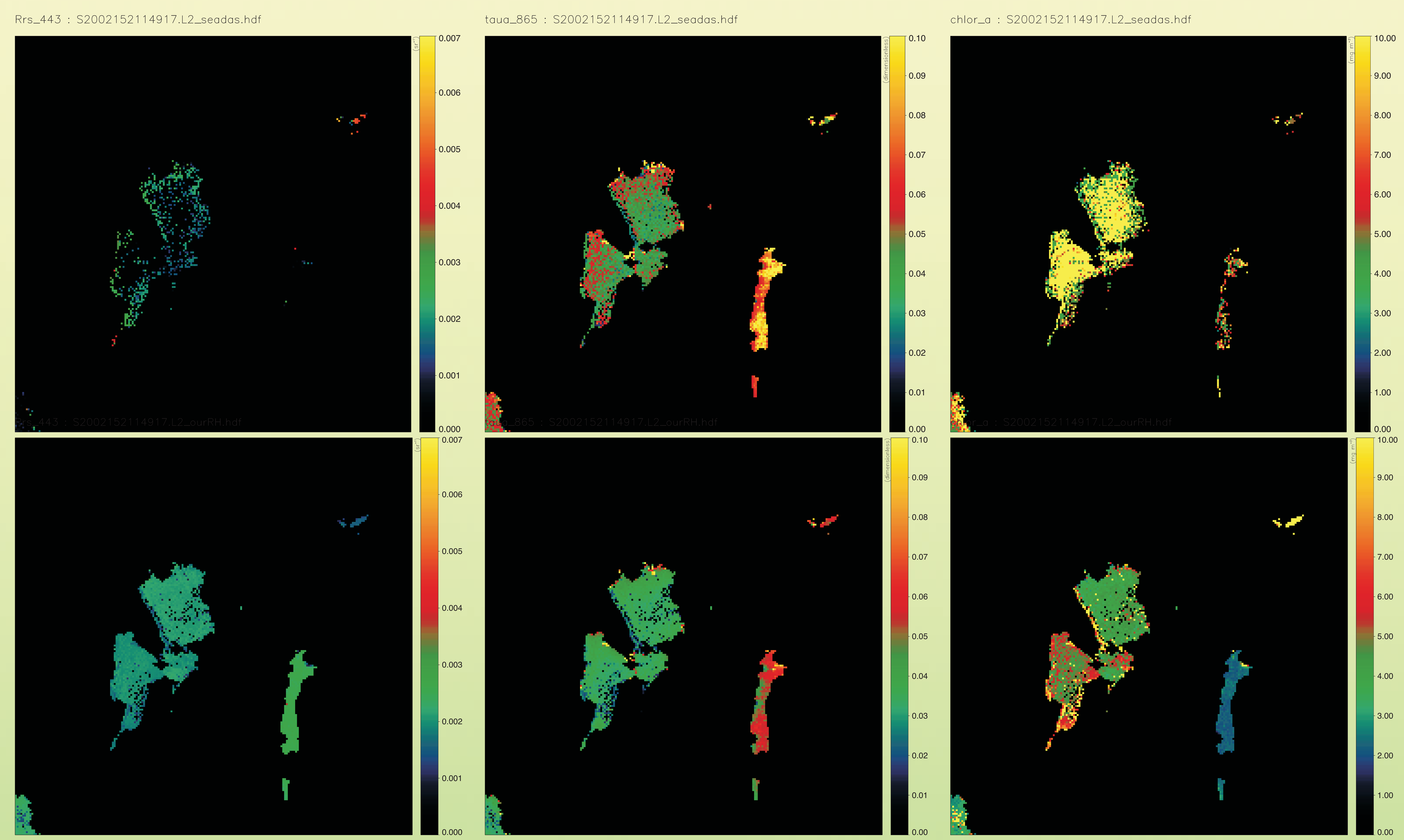
1) All candidate models are bi-modal and the fraction of large versus small aerosols can be retrieved
2) Enables fast and accurate computation of Jacobians using a linearized radiative transfer code for the coupled atmosphere-ocean system (CAO-LDISORT)
3) Enables use of state-of-the-art iterative inversion methods such as optimal estimation theory based on Bayes' theorem.

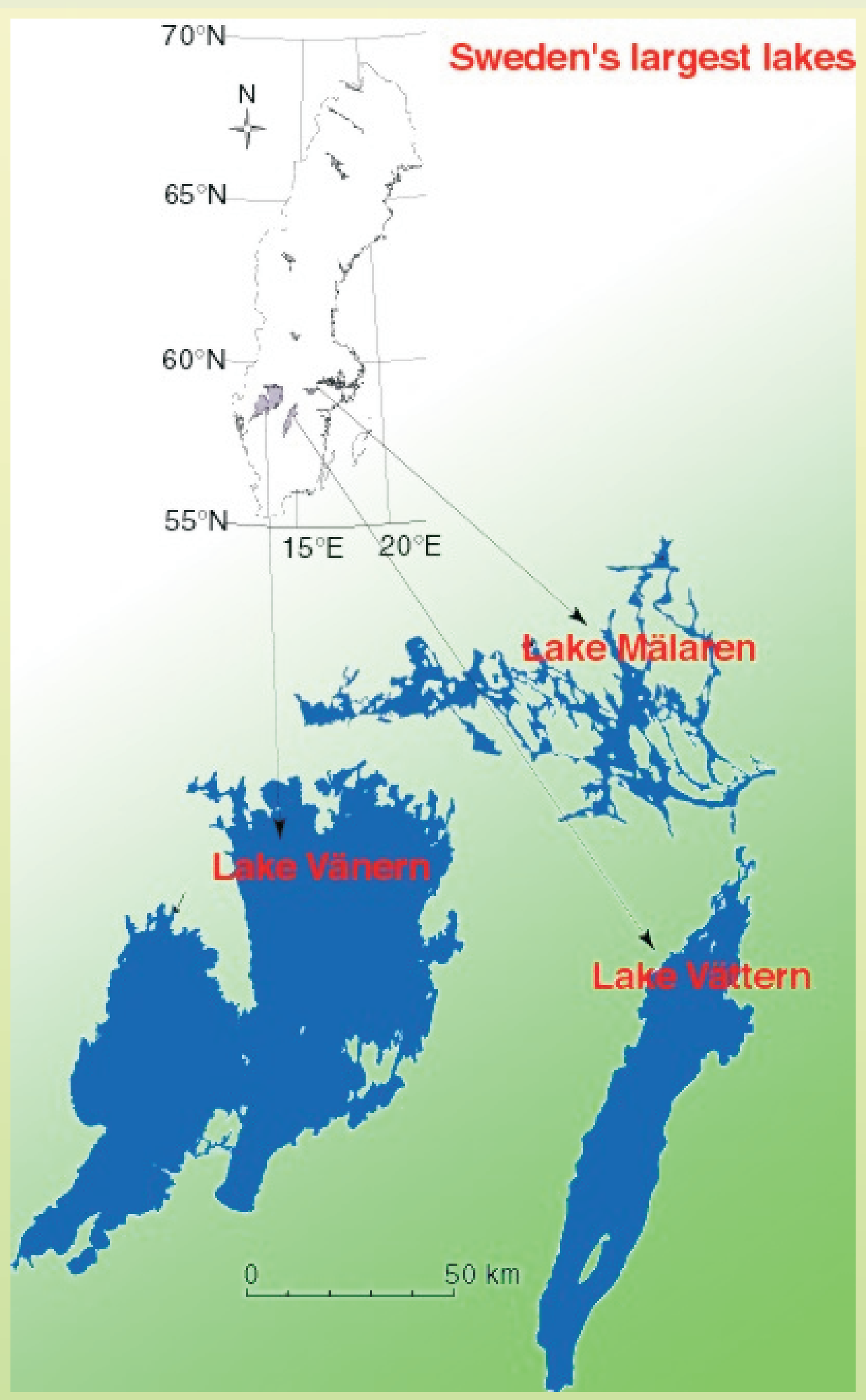
Use of Longer Wavelength Channels Available on Multi- and Hyperspectral Sensors:

Compared to most ocean color instruments (e.g. SeaWiFS), MODIS has channles at longer wavelengths (1.24, 1.64, and 2.13 um) that are useful for atmospheric correction, because:
1) at the longer wavelengths even very turbid water has negligible reflectance due to the shallow penetration depth (the BPA holds),
2) yet these channels are sensitive to aerosol properties, and
3) they be used to easily discriminate land and cloud areas at the same time.

Summary:

- We have developed a linearized radiative transfer code for the coupled atmosphere-ocean system (CAO-LDISORT)
- Using an aerosol representation that can be varied in a continuous manner rather than one based on a "discrete" set of fixed models, the CAO-LDISORT forward model allows for fast and accurate computation of Jacobians that are required for inversion schemes yielding simultaneous retrieval of:
 1) Aerosol optical properties that are accurate and reliable with known error budgets.
 2) Marine parameters and water-leaving radiances that are accurate and reliable with known error budgets.
- We have demonstrated that with longer wavelength channels (such as 1.24 and 1.64 um available on MODIS) we can
 1) better discriminate water from land and clouds (i.e. the BPA holds)
 2) solve problems with aerosol retrievals and atmospheric correction over turbid waters including shallow or highly sediment-loaded water.





Above: The "continuum" aerosol model algorithm applied to retrievals in Swedish lakes compared with results from SeaWiFS. The SeaWiFS algorithm performs poorly for this particular case (negative water-leaving reflectances). Our algorithm yields reasonable retrieval for both chlorophyll concentration and aerosol optical depth

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