

Over Ocean Aerosol Data Assimilation Using Operational MODIS Aerosol Products

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Background

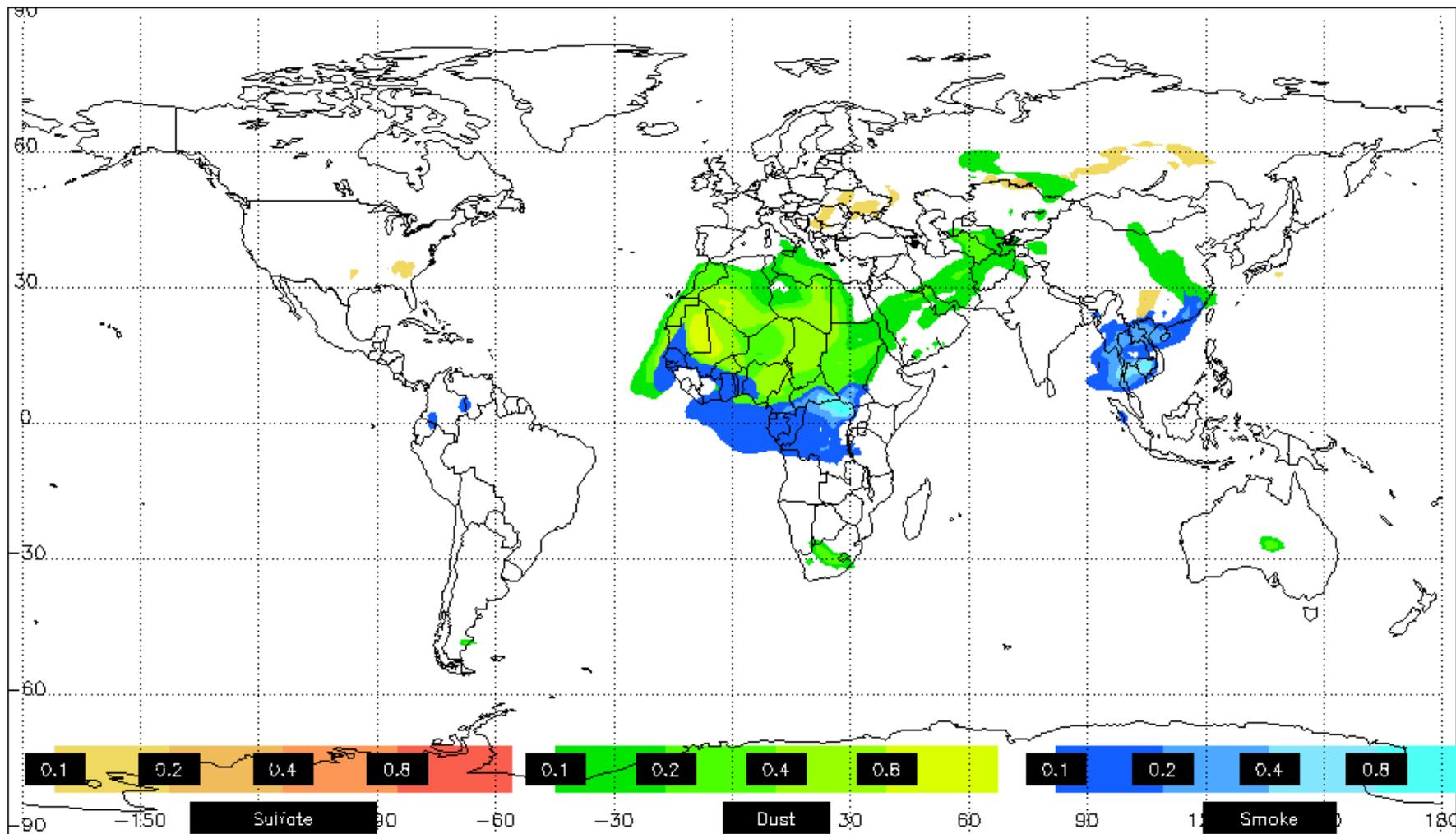


NRL aerosol data assimilation system includes:

- NRL Aerosol Analysis and Prediction System (NAAPS), the world's only truly operational global aerosol model.
- Newly derived Level 3 aerosol optical thickness (AOT) product based on NRTPE MODIS level II data stream.
- NRL Atmospheric Variational Data Assimilation System (NAVDAS)

NRL Aerosol Analysis and Prediction System (NAAPS)

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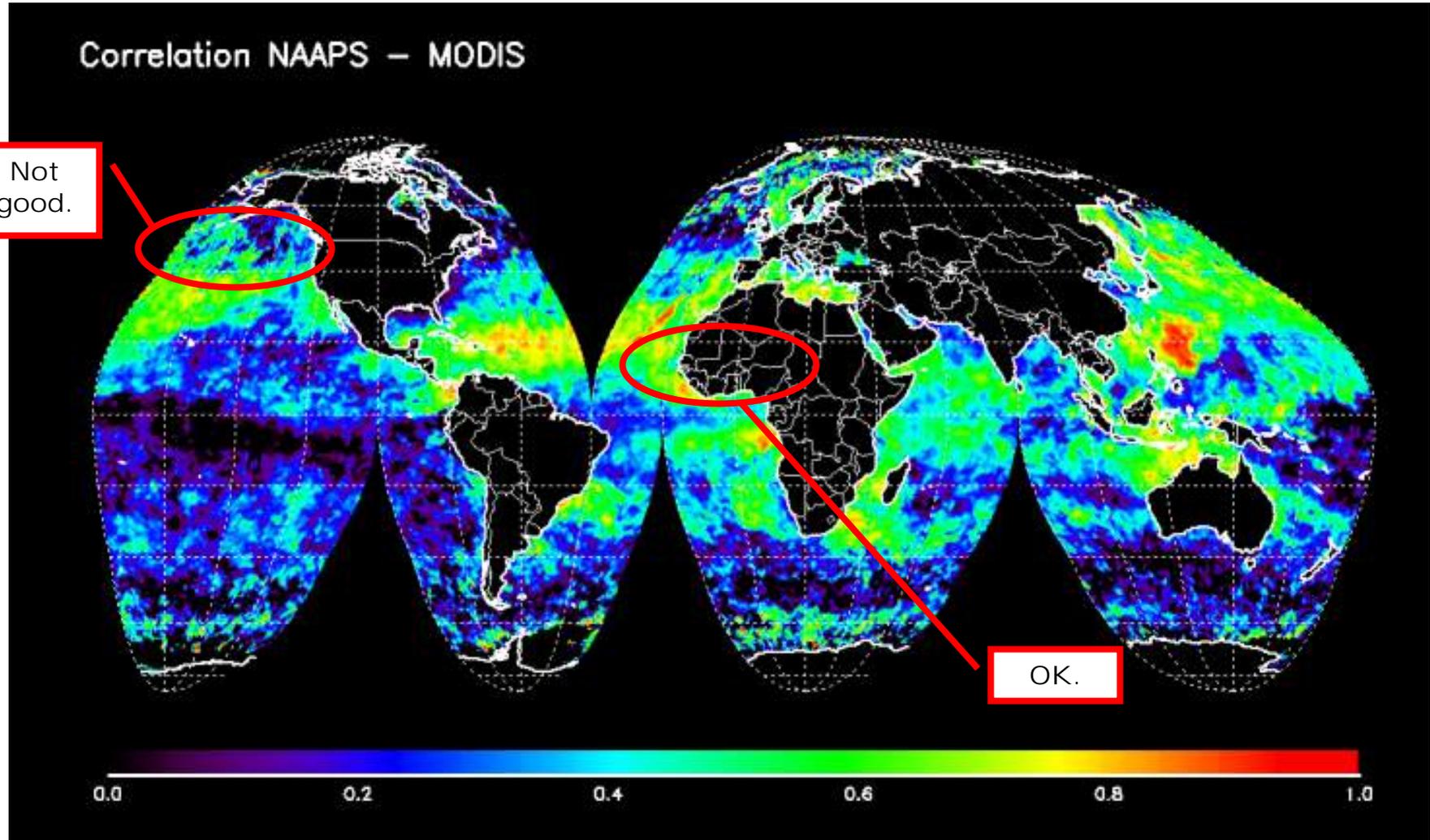


Sulfate AOT

Dust AOT

Smoke AOT

The really big picture: Correlation



This is a global map of 6 hour NAAPS/MODIS correlations. This is a good indicator of what to expect from NAAPS in the realm of timing. However, if we have the magnitude wrong, this won't show it.

Understanding your data source

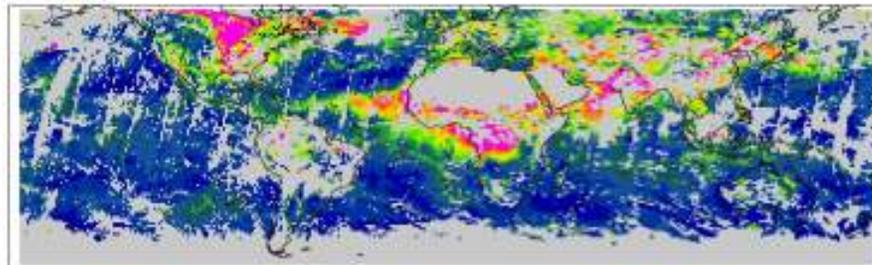


- MODIS level II aerosol optical thickness (AOT) is best suitable for near real-time aerosol data assimilation.

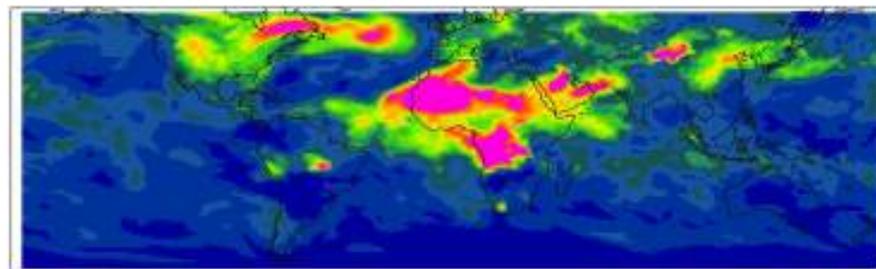
- However, MODIS satellite data have uncertainties, especially in the regions with cirrus clouds, coastal waters and complicated land features.

- An objective analysis of MODIS data is necessary to estimate the true benefits and uncertainties of MODIS data before implementing them into aerosol analysis-forecast applications.

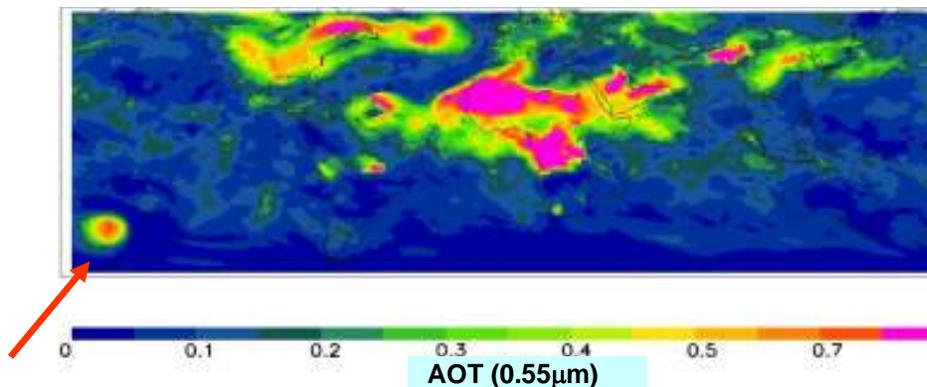
MOD04 (v4) three day composite (July 17-19, 2004)



Five day assimilation run from July 15, 00:00UTC to July 19, 18:00UTC, 2005.



Example of an erroneous retrieval is being used over southern hemisphere.

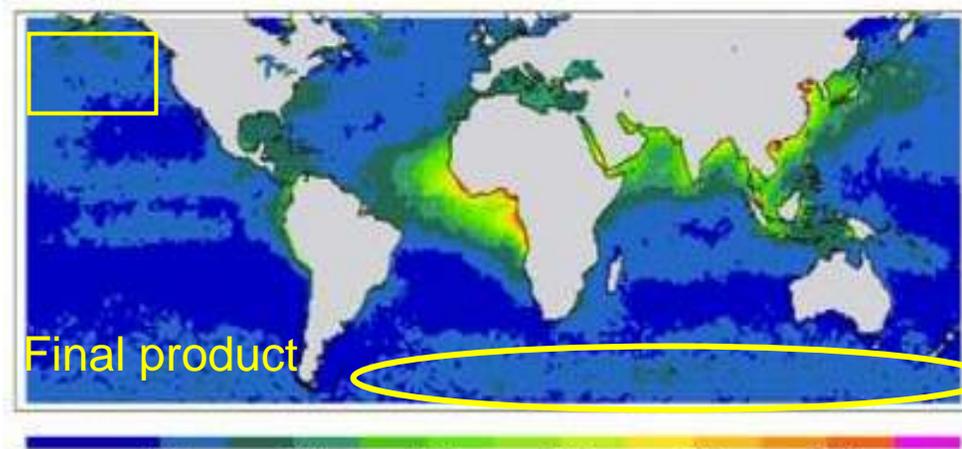
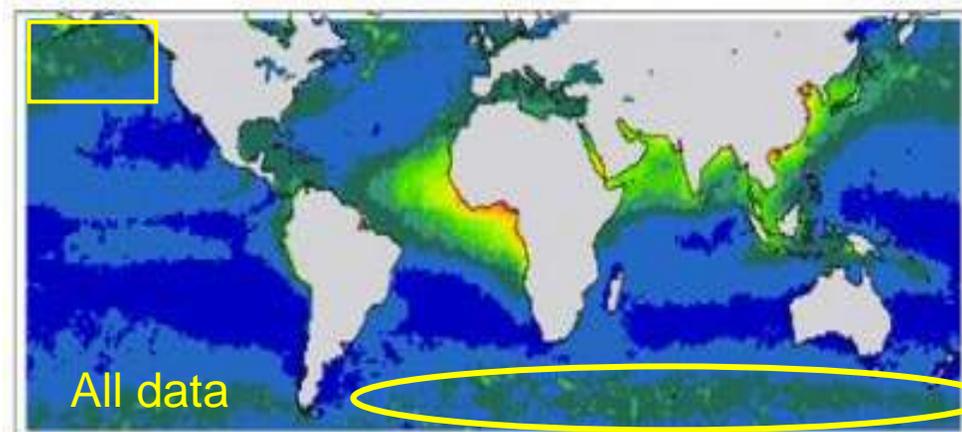


Near real time QA and Aggregation on Level 3 Assimilated Data

Zhang and Reid [2006]



- We begin with NRTPE MOD04 AOT data. Shown is 2004 annual average.
- QA: Data are screened using spatial tests and thresholds. Empirical corrections are made based on satellite and NOGAPS environmental data.
- End result, more than 50% correction in southern oceans and Asian outflow to the north Pacific. 15-20% reduction in error globally.
- Working on putting the data on line for public access.



0.1 0.2 0.3 0.4 0.5 0.7

MODIS Optical Thickness

Aerosol Data Assimilation (DA) Flow Chart

Background
(Convert to 2-D)

Near real time MODIS
level II AOT
QA, QC, error statistics

NAVDAS

New 2-D AOT field

2-D AOT to 3-D mass
concentration (MC)

Run NAAPS

3-D MC to 2-D AOT, new
background

Near real time MODIS
level II AOT
QA, QC, error statistics

Time = T

Time = T + 6 hour

NAVDAS

New 2-D AOT field

Forecast

12z

06z

00z

Assimilation

Mass concentration (3D) and AOT (2D) conversion

- **MODIS provides aerosol optical thickness (AOT) values in a 2-D format.**
- **NAAPS produces 3-D aerosol mass concentration.**
- **Need H operator to convert NAAPS mass concentration into column integrated AOT values for four major aerosol species (Sulfate, Dust, Sea Salt, and Smoke).**
- **Mass concentration is related to AOT using pre-built mass extinction efficiency LUTs.**
- **Aerosol hydroscopic growth is included.**

NAAPS 3-D Aerosol climatology (Vertical partitioning, adjoint of observation operator H)

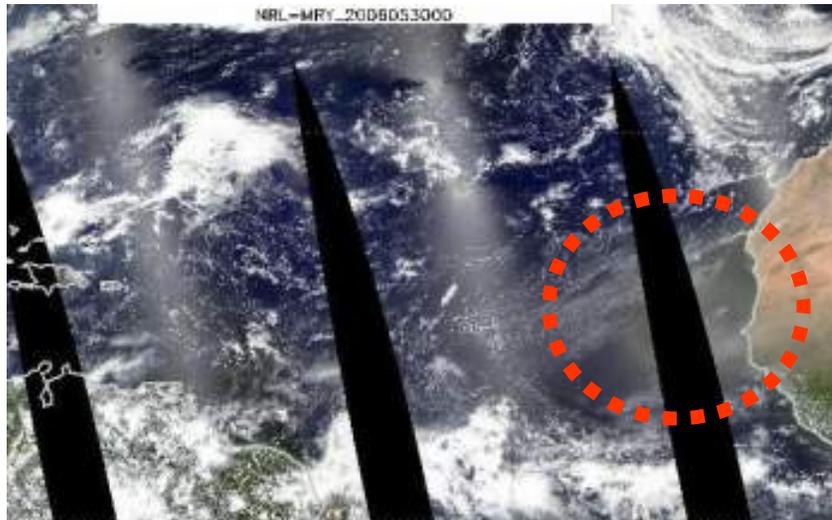
- Created from NAAPS data of 2004-2006
- For three aerosol species (dust, smoke, and sulfate)
- For four seasons

Background error analysis

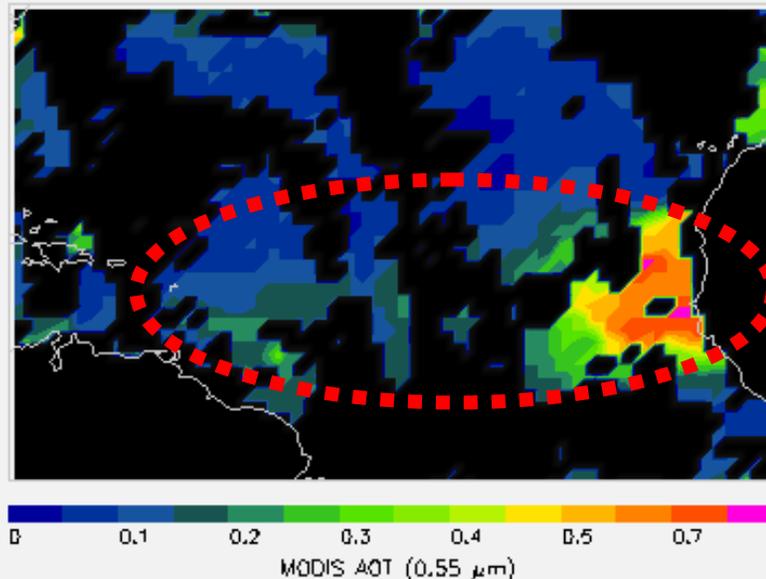
- Estimated from collocated NAAPS and AERONET data from 2006
- RMS of background error variance
 - $0.2 \pm 0.4\tau$ (no assimilation)
 - $0.15 \pm 0.25\tau$ (with assimilation, over ocean only)

Results (case study)

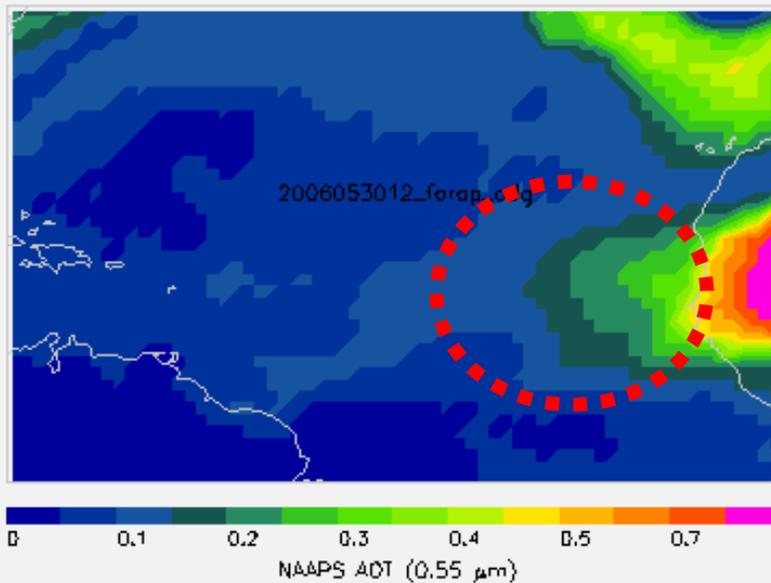
MODIS Level 1B RGB composite for May 30, 2006



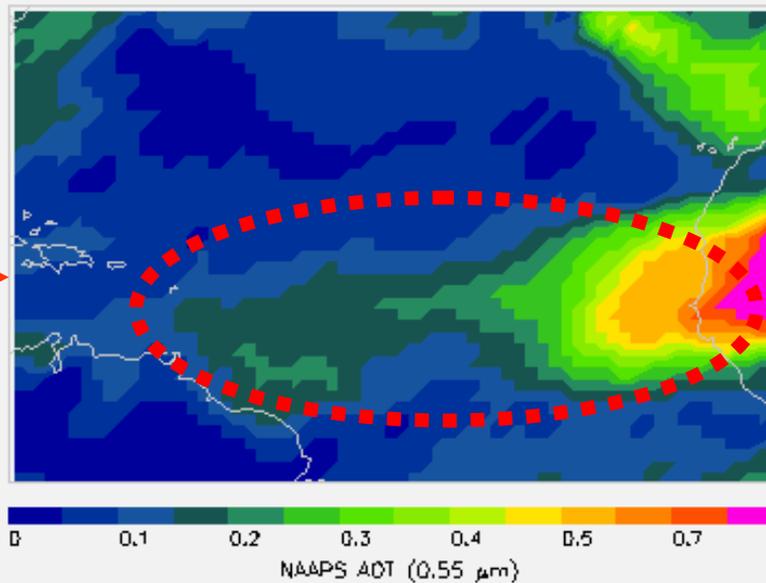
MODIS retrieved AOT for May 30, 2006



NAAPS AOT (no assimilation, forecast) for 12Z, May 30, 2006

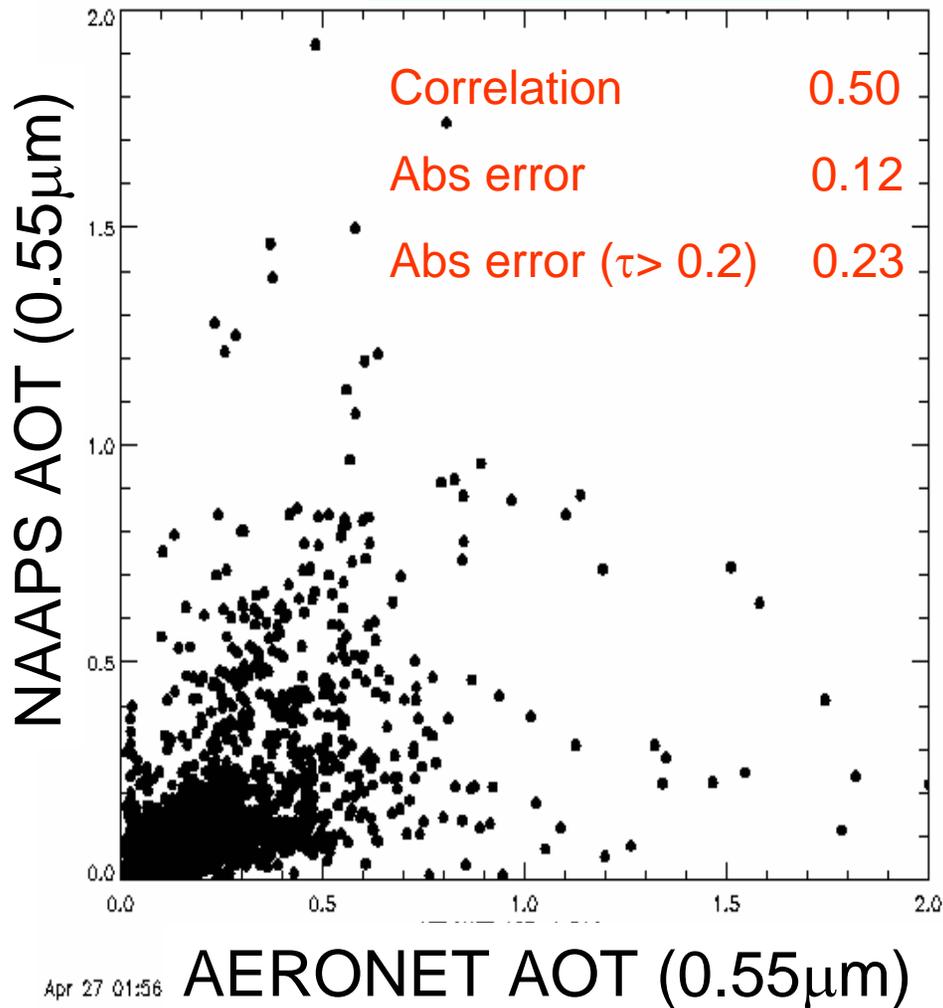


NAAPS AOT analysis with 5 month data assimilation

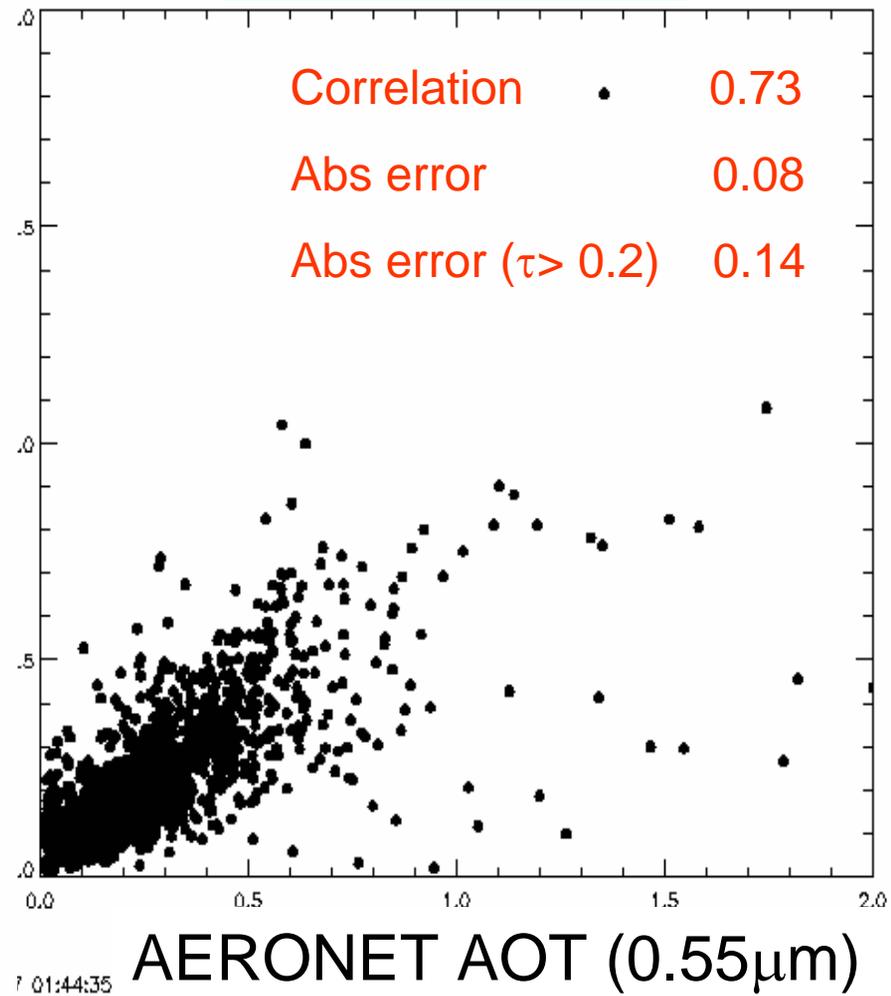


NAAPS vs. AERONET (Coastal sites) 2006-03-01 - 2006-05-31

Natural Run



With NAVDAS

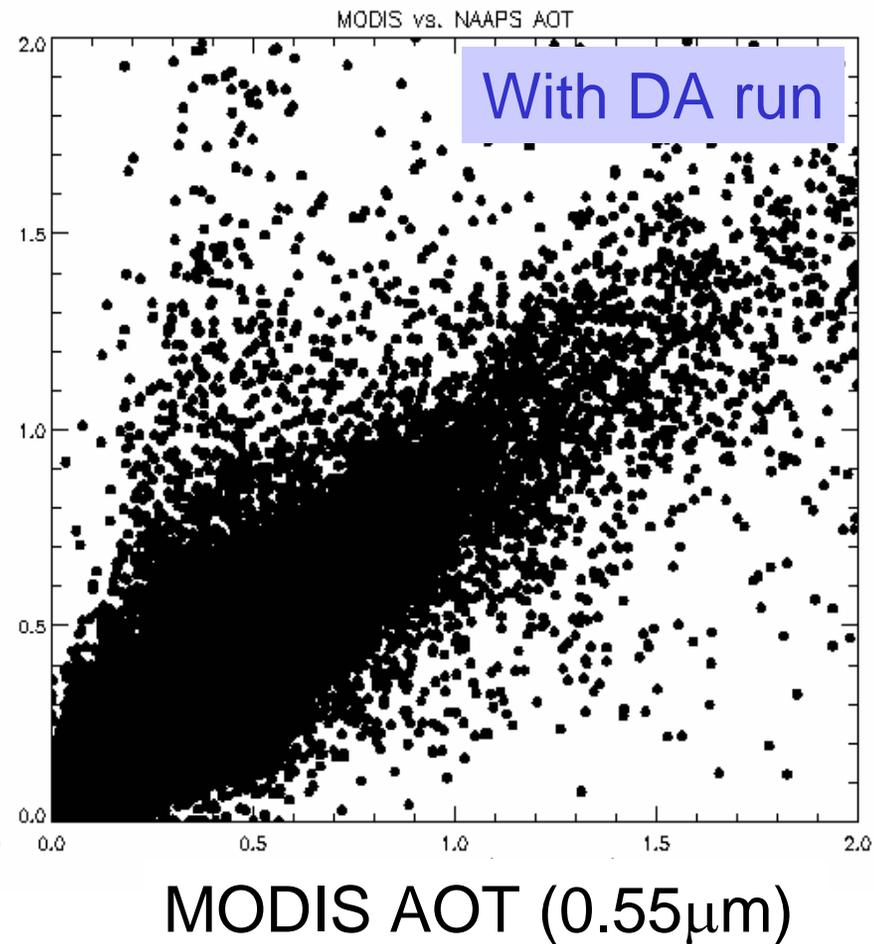
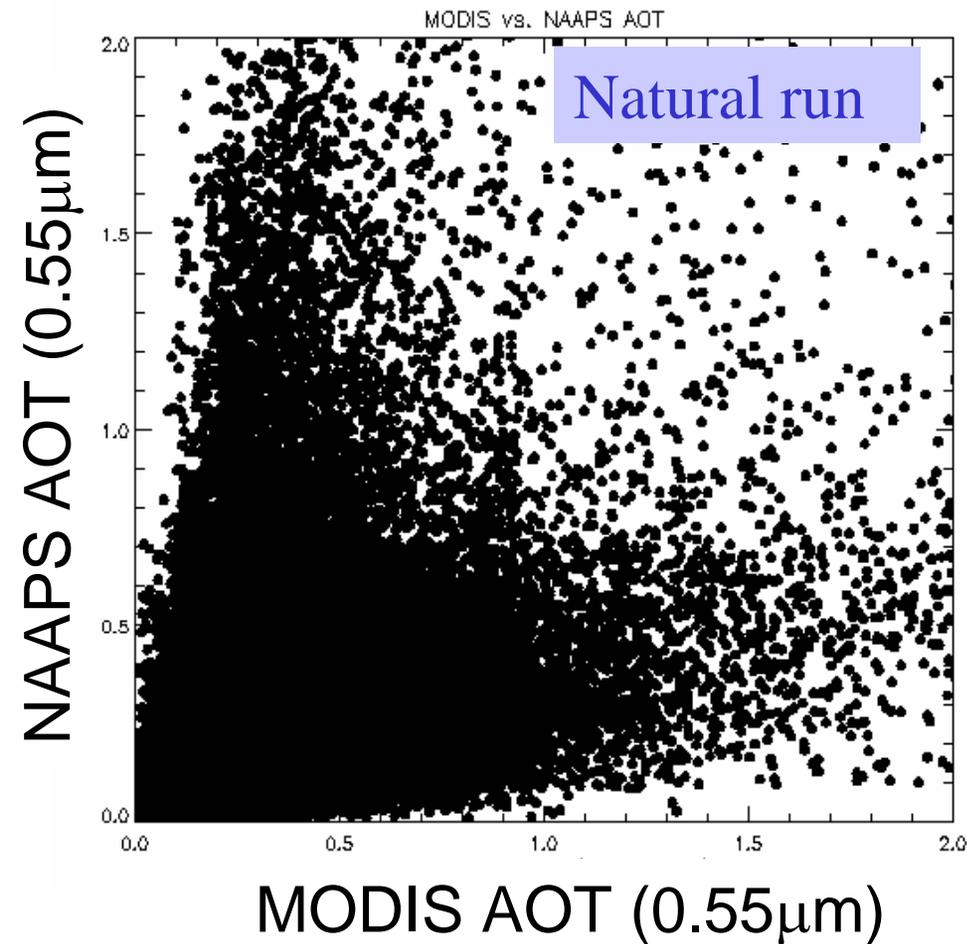


NAAPS vs. MODIS

(over water for 2006-03-01 – 2006-05-31)

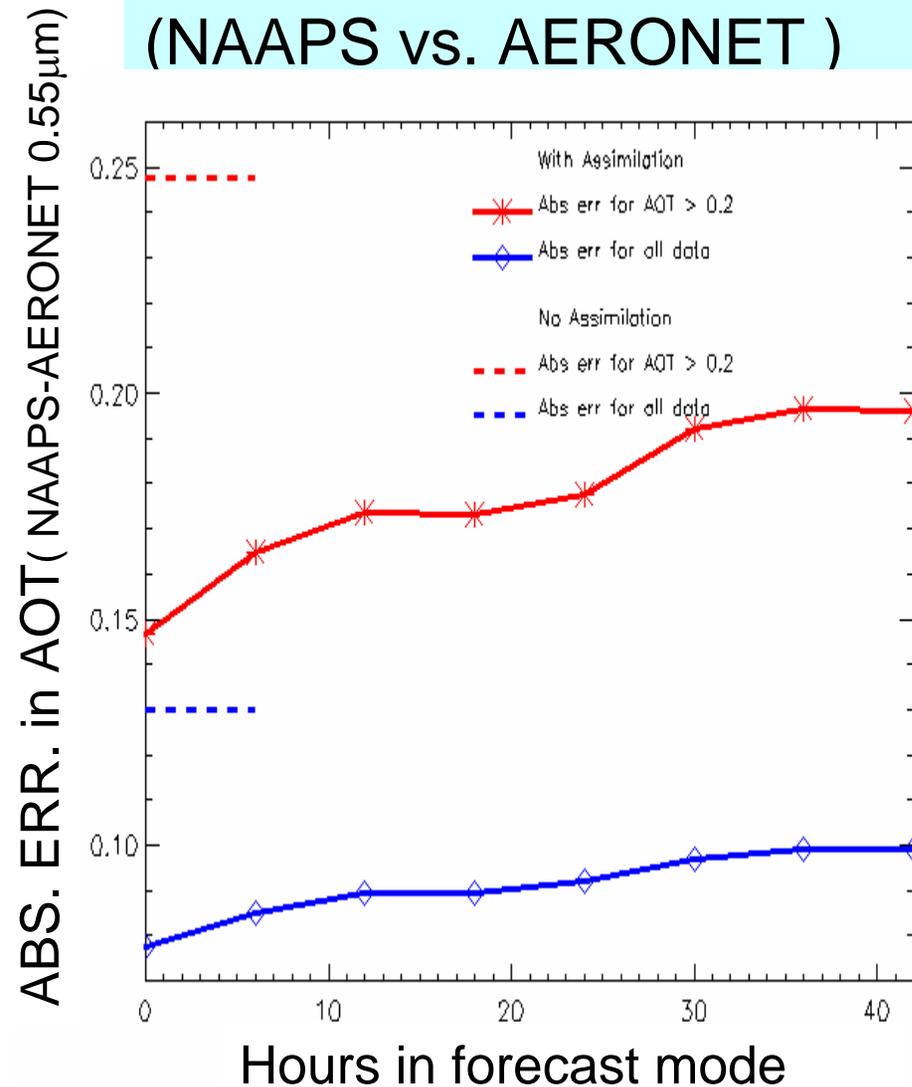
Correlation 0.57
Absolute error 0.07
Absolute error ($\tau > 0.2$) 0.20

Correlation 0.90
Absolute error 0.02
Absolute error ($\tau > 0.2$) 0.05

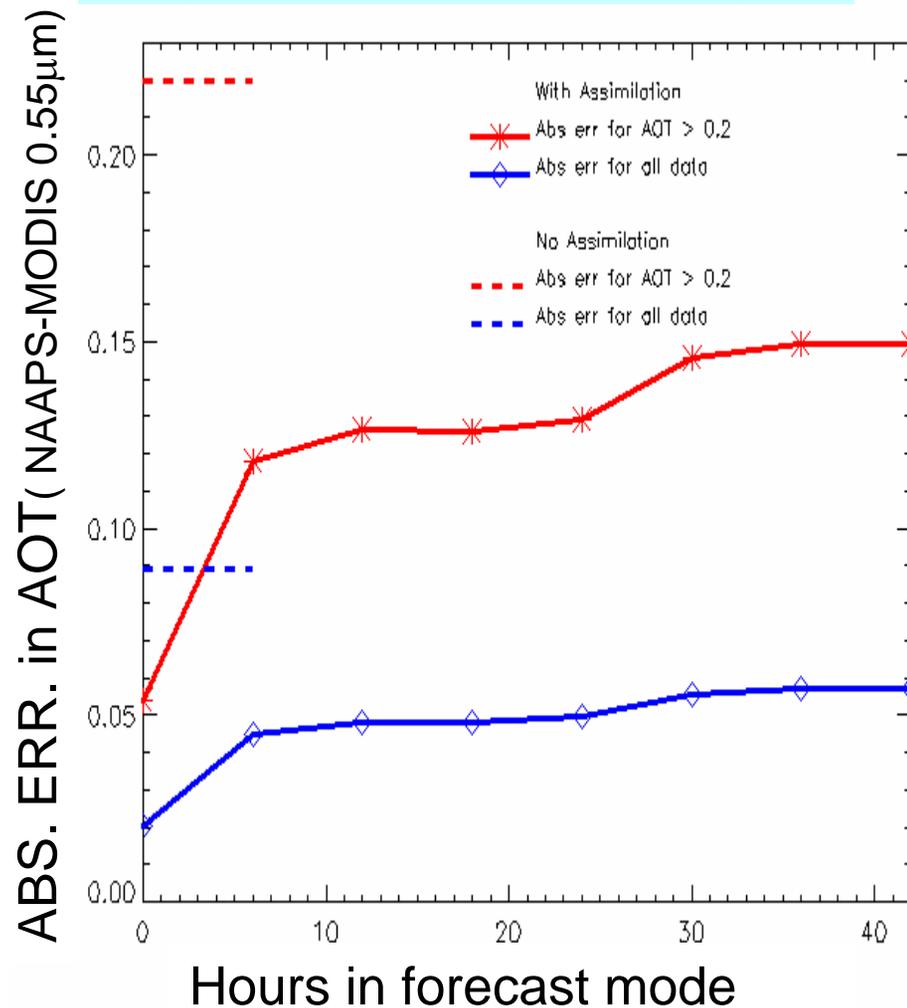


Results for forecast run (6 month run)

Abs. Error for forecast run (NAAPS vs. AERONET)



Abs. Error for forecast run (NAAPS vs. MODIS)



Radiances in the Vicinity of Clouds: The “Twilight Zone?”

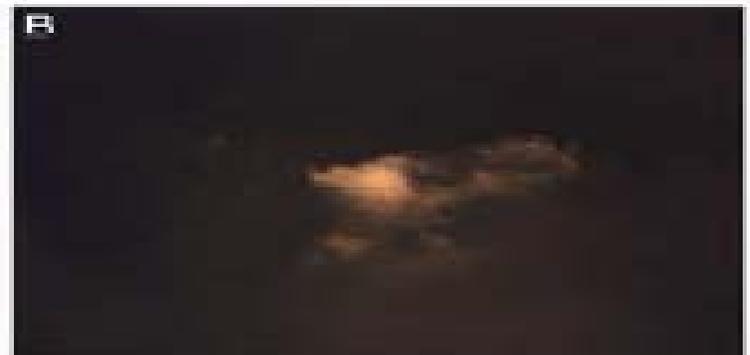


Quality of ADA process is limited by the quality of satellite data.

Ambiguous aerosol features over cloudy regions, physical? Non-physical?

Could introduce ambiguous features in the ADA process.

“Figure 1. An image of a cloud and the “twilight zone” taken from the ground using a digital camera: (a) true color image of an isolated dissipating cumulus cloud; (b) background gradients caused mostly by molecular scattering were removed; and (c) by masking out the obvious cloud pixels the new dynamic range allows to see the extent of the twilight zone and how the clear sky is not so clear”



Over-land AOT Assimilation

Fidelity of MODIS products

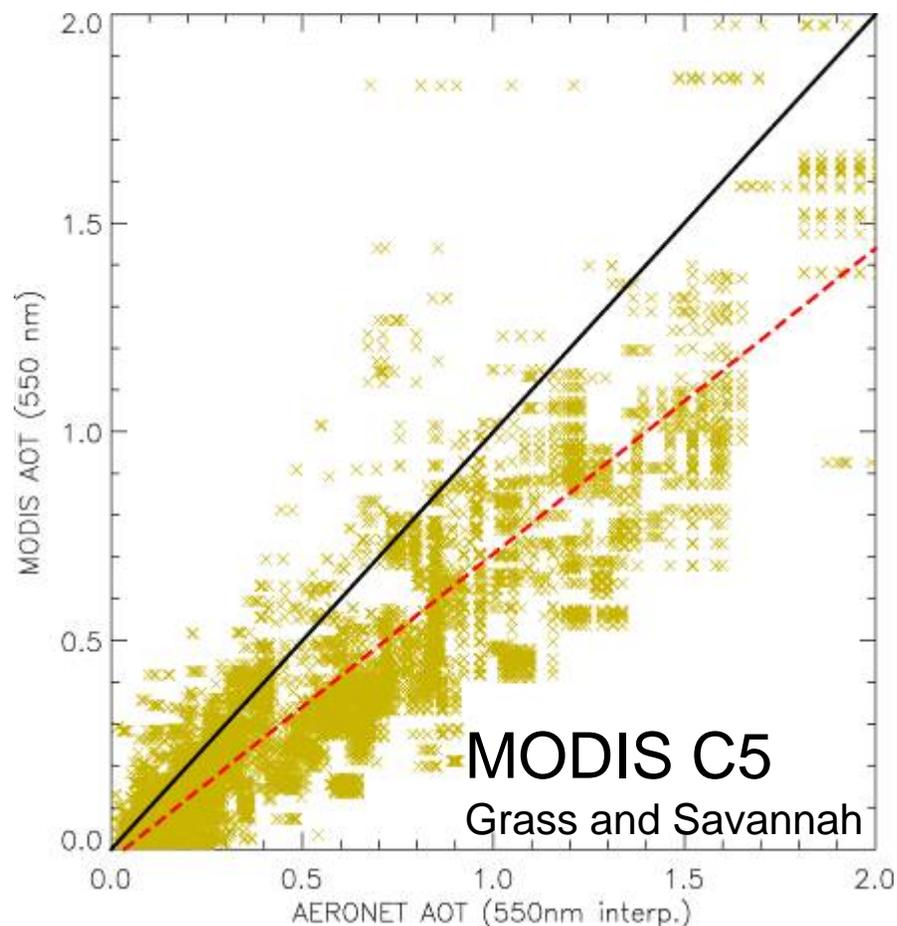


Previous over land data AOT products were too poor in fidelity to even contemplate data assimilation

Recently, MODIS data collect 5 was released which is significantly improved, but still not sufficient for DA.

Biases are mostly related to lower boundary condition or aerosol microphysics.

By end of year, we will have an over land suitable MODIS data postprocessor for over land DA.



Problems and Future Plans

1. Better understanding of true aerosol features from MODIS and future satellites
2. Use innovations from the ADA runs to help identify events that NAAPS misses
3. Run in operational mode
4. QA and QC V5 over water MODIS aerosol product
5. QA and QC MODIS over land aerosol product
6. Over land aerosol data assimilation
7. Included other satellite/ground observations

Summary of Year Two Progress

- 1. Derived new MODIS level 3 aerosol product (QC+QA) from operational level II MODIS aerosol product.**
- 2. Constructed NAAPS 3-D aerosol climatology, conducted background error analysis.**
- 3. Constructed a working version of Aerosol Data Assimilation (ADA) system using over water aerosol optical depth observations from MODIS.**
- 4. Examined aerosol forecast skill. Our studies show that the ADA process improves aerosol forecasting accuracy.**