Seasonal aerosol trends from satellite measurements over H.E.S.S.

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Intervenant : Dr. RISTORI, Pablo

Lidar Division – UNIDEF-CEILAP (CITEDEF-CONICET)

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Outline

- Motivation: Aerosol research with remote sensing instrumentation.
- Optical depth fundamentals
- Aerosol Optical Depth (AOD) retrievals from ground and from space
- MISR Data Levels and data retrieval
- Dataset Analysis (MISR)
- Conclusions

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Motivation

- The Lidar Division research is oriented to study the atmosphere (aerosols, trace gases, dynamics and radiative transfer) by means of active (Lidar) and passive (sun-photometers, DOAS, radiometers, mw-radiometers) and its impact in the society and the ecosystems
- Active and passive remote sensing of aerosols is one of the main activities of the group
- These measurements are frequently combined with satellite measurements and lagrangian models to identify the source and the regional impact of local measurements
- One of the most important aerosol events in Buenos Aires is the biomass burning transport in spring

Motivation #2

- Recent conversations in CTA Meetings with Max-Planck-Institut für Kernphysik (Joachim Hahn, Raquel de los Reyes) and the Laboratoire Univers et Particules de Montpellier (Georges Vasileiadis) showed exciting possibilities to combine our skills in aerosol science with LUPM expertise in lidar at H.E.S.S. and current MPI research in retrieving transparency coefficients

- NOTE: Joachim Hahn's presentation will complete this one in terms of transparency coefficient time series and MISR retrievals

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Optical Depth (Fundamentals)

- We can estimate the terrestrial incomming flux as a function of the extraterrestrial flux using the Beer-Lambdert-Bouguer law as:

$$T(\lambda) = \exp\left[-\tau(\lambda)/\cos\theta\right]$$

were $\tau(\lambda) = \tau_{Rayleigh}(\lambda) + \tau_{abs}(\lambda) + \tau_{aerosol}(\lambda)$

- Ozone Absorption limits the transmission below 300 nanometers.

Optical Depth (Fundamentals)

- and $$\tau_{Rayleigh}(\lambda) = \frac{p}{1013.25hPa} 0.00877\lambda^{-4.05}$$

  Dutton et al. (1994),

- Then at sea level

  Optical Depth(545nm) = 0.1 (Transmission = 90%)

  Optical Depth(300nm) = 1.2 (Transmission = 30%)

Aerosol Optical Properties (Fundamentals)

- Aerosol Optical Depth (AOD) cannot be calculated It depends on aerosol properties as size distribution, refraction index, shape etc.
- A simple estimation of the AOD wavelength dependency is the Angstrom law

$$\tau_{Aer}(\lambda) = \tau_{Aer}(\lambda_0)\left(\frac{\lambda}{\lambda_0}\right)^{A}$$

A depends on the aerosol microphysical properties and normally has ranges between [-2 … 0]

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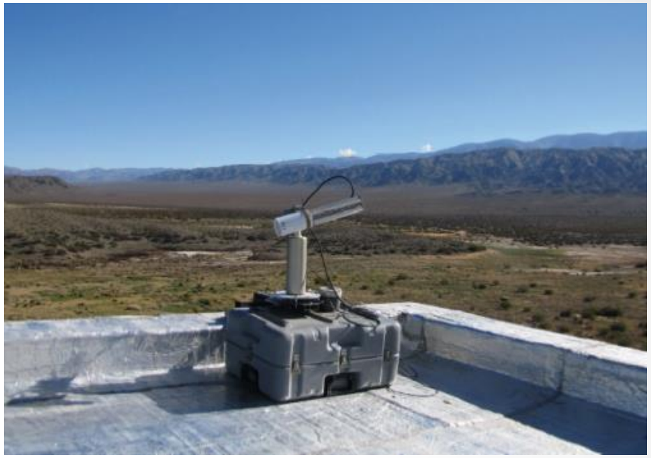
Aerosol Optical Properties Retrieval

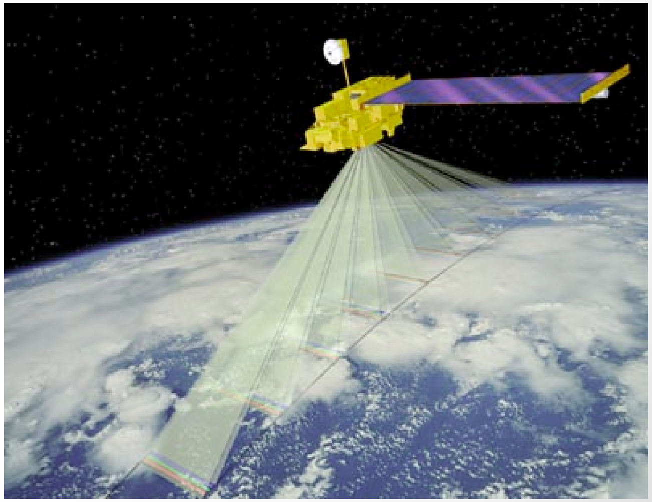
Ground-Based Instruments:

- Better accuracy
- Simpler calculations
- Single location
- Almost continuous observation



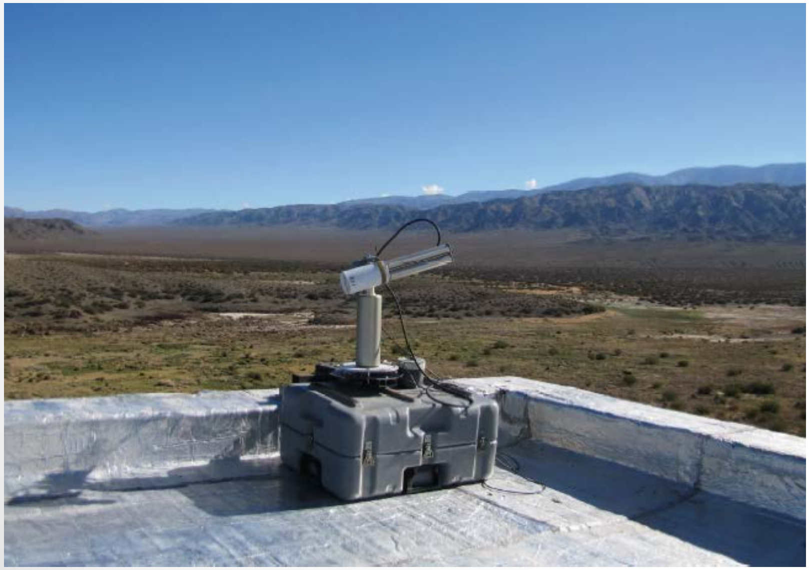
Satellite-Borne instruments

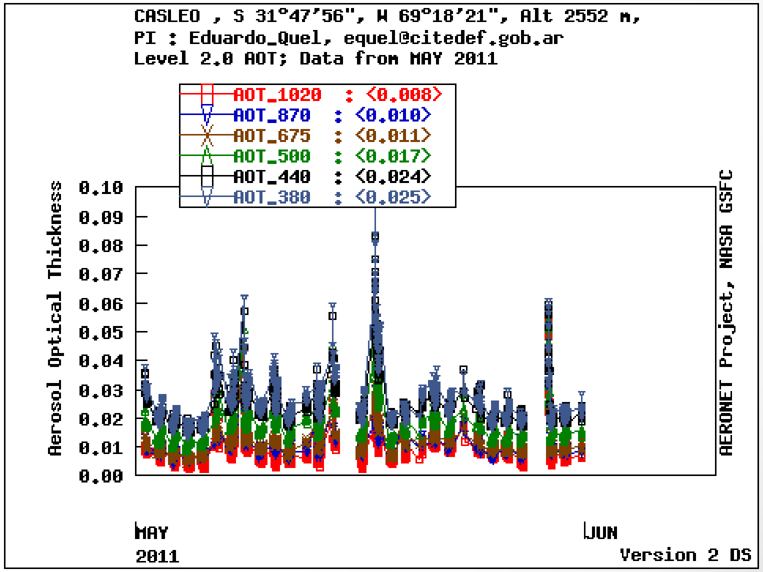
- Complex calculations
- Global(Regional) observations
- Lower accuracy
- Limited number of measurements per day



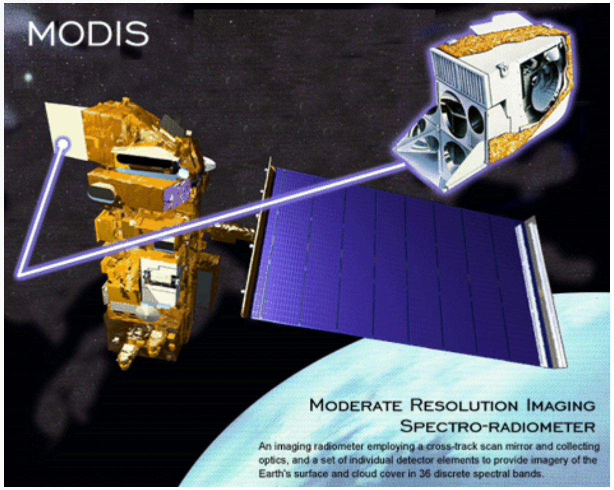
Aerosol Optical Properties (Ground-Based Observations)

AERONET is a ground base remote sensing aerosol monitoring network created by NASA to support NASA, CNES and NASDA Earths satellite systems based on weather resistant sun and sky scanning radiometers and a standardized calibration and data processing protocol with freely available observation. Its main goal was to obtain an accurate knowledge of the spatial and temporal aerosol extent of aerosol concentration and properties for assessing their influence on remote sensed data





MODIS Instrument in TERRA and AQUA




```
Orbit:       705 km,
             10:30 a.m. descending node (Terra)
              1:30 p.m. ascending  node (Aqua),
             sun-synchronous, near-polar,
circular

Scan Rate:    20.3 rpm, cross track
Swath:        2330 km (cross track)
                10 km (along track at nadir)

Telescope:    17.78 cm diameter.
Size:         1.0 x 1.6 x 1.0 m
Weight:       228.7 kg
Power:        162.5 W (single orbit average)
Quantization:12 bits
Resolution:    250 m (bands 1-2)
               500 m (bands 3-7)
              1000 m (bands 8-36)
```

Primary Use	Band	Bandwidth[1]	Spectral Radiance[2]	Required SNR[3]
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128
	2	841 - 876	24.7	201
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243
	4	545 - 565	29.0	228
	5	1230 - 1250	5.4	74
	6	1628 - 1652	7.3	275
	7	2105 - 2155	1.0	110
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	44.9	880
	9	438 - 448	41.9	838
	10	483 - 493	32.1	802
	11	526 - 536	27.9	754
	12	546 - 556	21.0	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 Water Vapor	17	890 - 920	10.0	167
	18	931 - 941	3.6	57
	19	915 - 965	15.0	250
Primary Use	**Band**	**Bandwidth[1]**	**Spectral Radiance[2]**	**Required NE[delta]T(K)[4]**
Surface/Cloud Temperature	20	3.660 - 3.840	0.45(300K)	0.05
	21	3.929 - 3.989	2.38(335K)	2.00
	22	3.929 - 3.989	0.67(300K)	0.07
	23	4.020 - 4.080	0.79(300K)	0.07
Atmospheric Temperature	24	4.433 - 4.498	0.17(250K)	0.25
	25	4.482 - 4.549	0.59(275K)	0.25
Cirrus Clouds Water Vapor	26	1.360 - 1.390	6.00	150(SNR)
	27	6.535 - 6.895	1.16(240K)	0.25
	28	7.175 - 7.475	2.18(250K)	0.25
Cloud Properties	29	8.400 - 8.700	9.58(300K)	0.05
Ozone	30	9.580 - 9.880	3.69(250K)	0.25
Surface/Cloud Temperature	31	10.780 - 11.280	9.55(300K)	0.05
	32	11.770 - 12.270	8.94(300K)	0.05
Cloud Top Altitude	33	13.185 - 13.485	4.52(260K)	0.25
	34	13.485 - 13.785	3.76(250K)	0.25
	35	13.785 - 14.085	3.11(240K)	0.25
	36	14.085 - 14.385	2.08(220K)	0.35

[1] Bands 1 to 19 are in nm; Bands 20 to 36 are in µm
[2] Spectral Radiance values are (W/m^2 -µm-sr)
[3] SNR = Signal-to-noise ratio
[4] NE(delta)T = Noise-equivalent temperature difference

Note: Performance goal is 30-40% better than required

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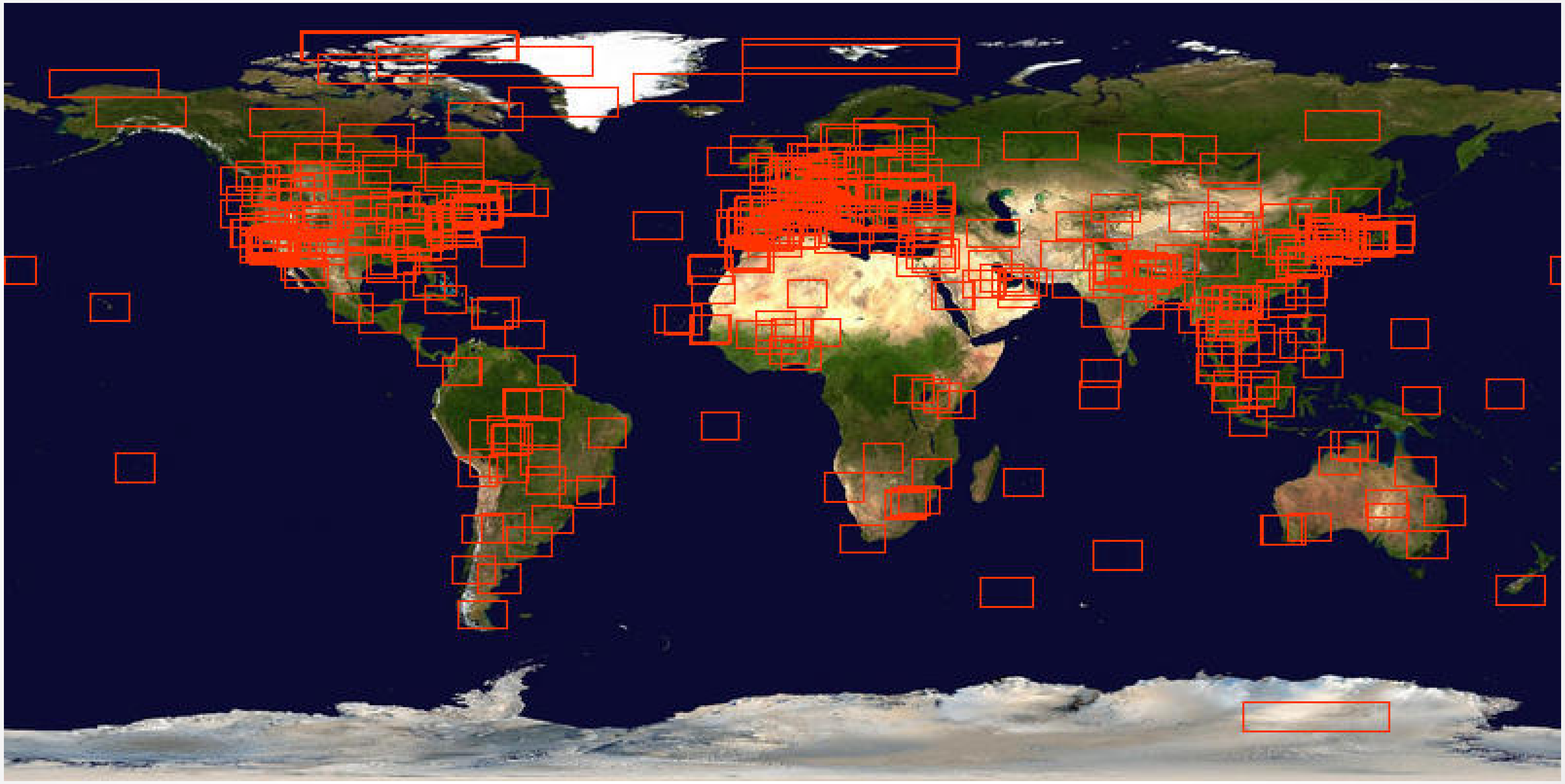
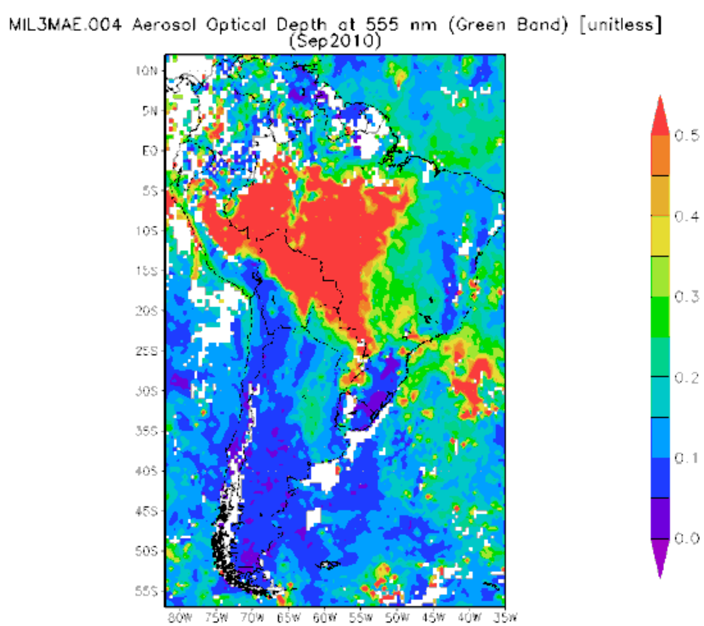
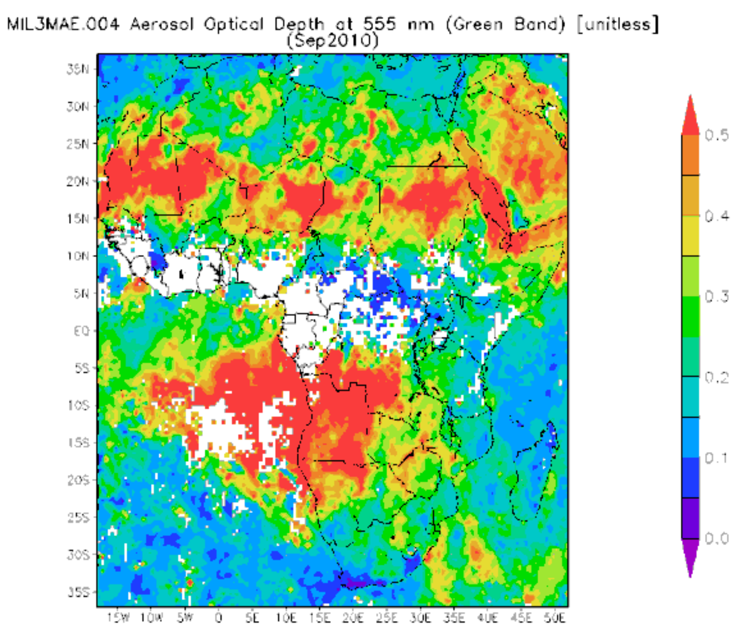
MODIS Rapid Response for AERONET SITES



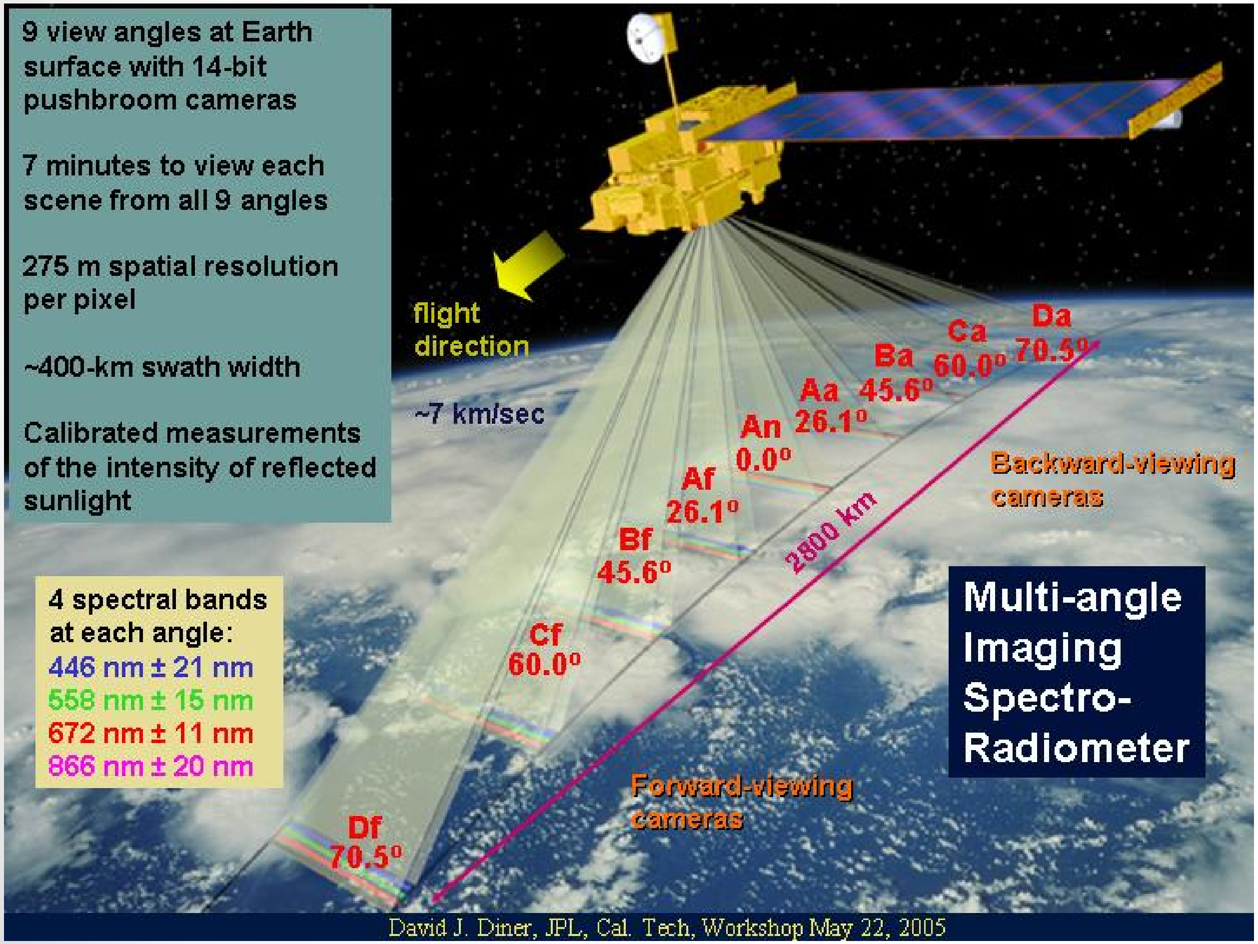
Aerosol Optical Properties (MODIS Satellite Observations)

Biomass Burning and Saharan dust transport is the most important long range transport event in the Southern Hemisphere. It occurs after the harvesting every year.





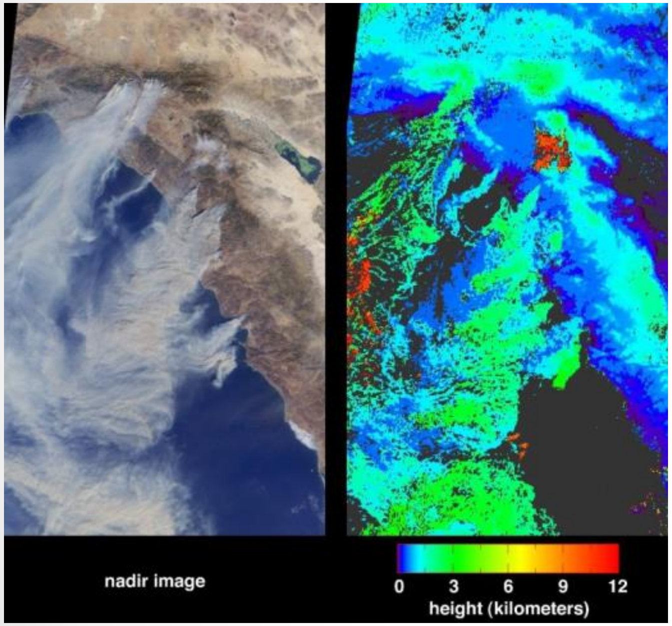
Multi-Angle Imaging Spectral Radiometer (*MISR*)



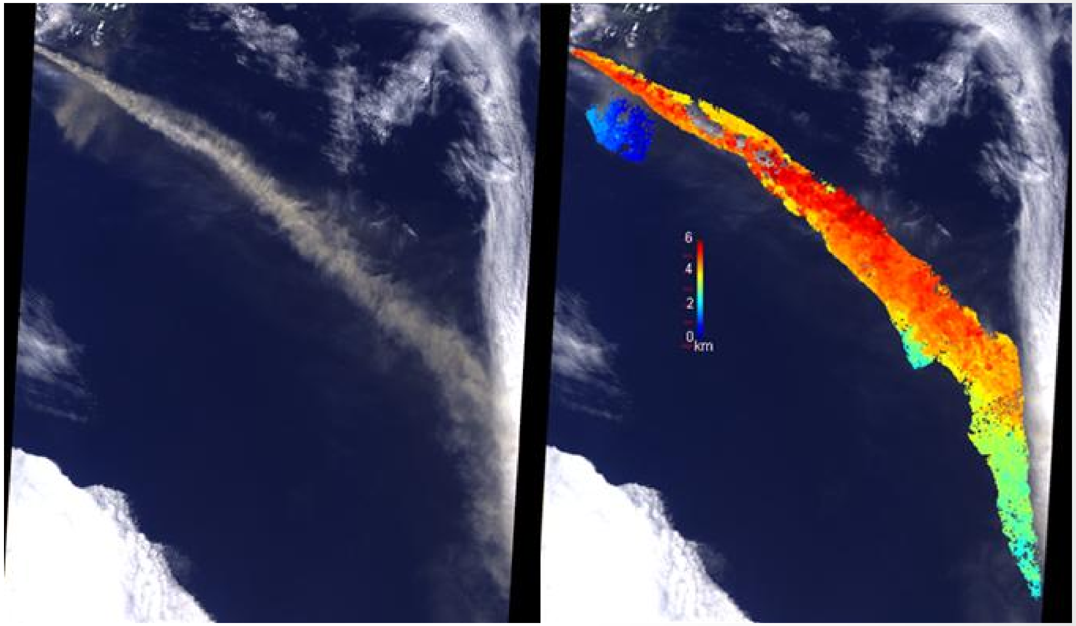
MISR Multi-angle Imaging SpectroRadiometer

MISR Aerosol Observation Examples

California Fire



Volcanic Plume



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MISR Aerosol Products

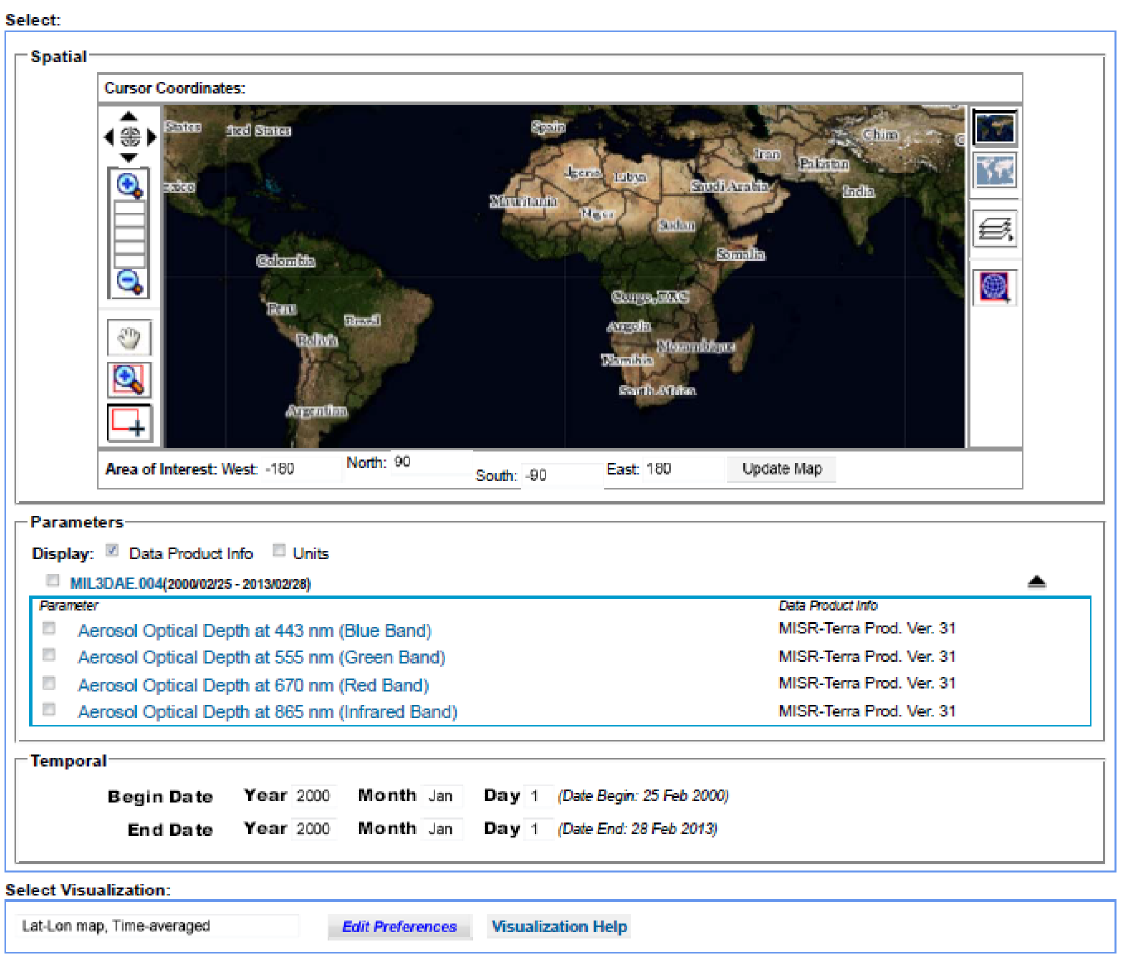
- **Level 1** products are processed and calibrated to remove the instrument effects. The resulting products contain minimal instrument artifacts and are suitable for subsequent scientific derivations. Products are in swaths, derived from a single MISR orbit (360 km wide and 20,000 km long).
- **Level 2** Products are geophysical measurements derived from the Level 1B2 data. TOA/Cloud Products contain measurements of TOA bidirectional reflectance factors, stereoscopically-derived cloud and land (reflecting level) elevation, cloud fraction, cloud texture, and other related parameters. Aerosol/Surface Product includes tropospheric aerosol optical depth; aerosol composition and size; surface directional reflectance factors and bi-hemispherical reflectance; and other related parameters.
- **Level 3** Products are global or regional maps of select parameters from the Level 2 products and associated covariances reported on various geographic grids depending on the data product. Parameters from multiple orbits are combined to make complete Level 3 global maps at daily (D), monthly (M), quarterly (Q), and yearly (Y) time scales and regional maps associated with field campaigns at daily and monthly time scales.

Aerosol Product Retrieval

Level 3 information

From **Giovanni a Web-based application developed by the GES DISC** that provides a simple and intuitive way to visualize, analyze, and access vast amounts of Earth science remote sensing data without having to download the data. Giovanni is an acronym for the **G**ES-DISC (Goddard Earth Sciences Data and Information Services Center) **I**nteractive **O**nline **V**isualization **AN**d a**N**alysis **I**nfrastructure.

http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=MISR_Daily_L3



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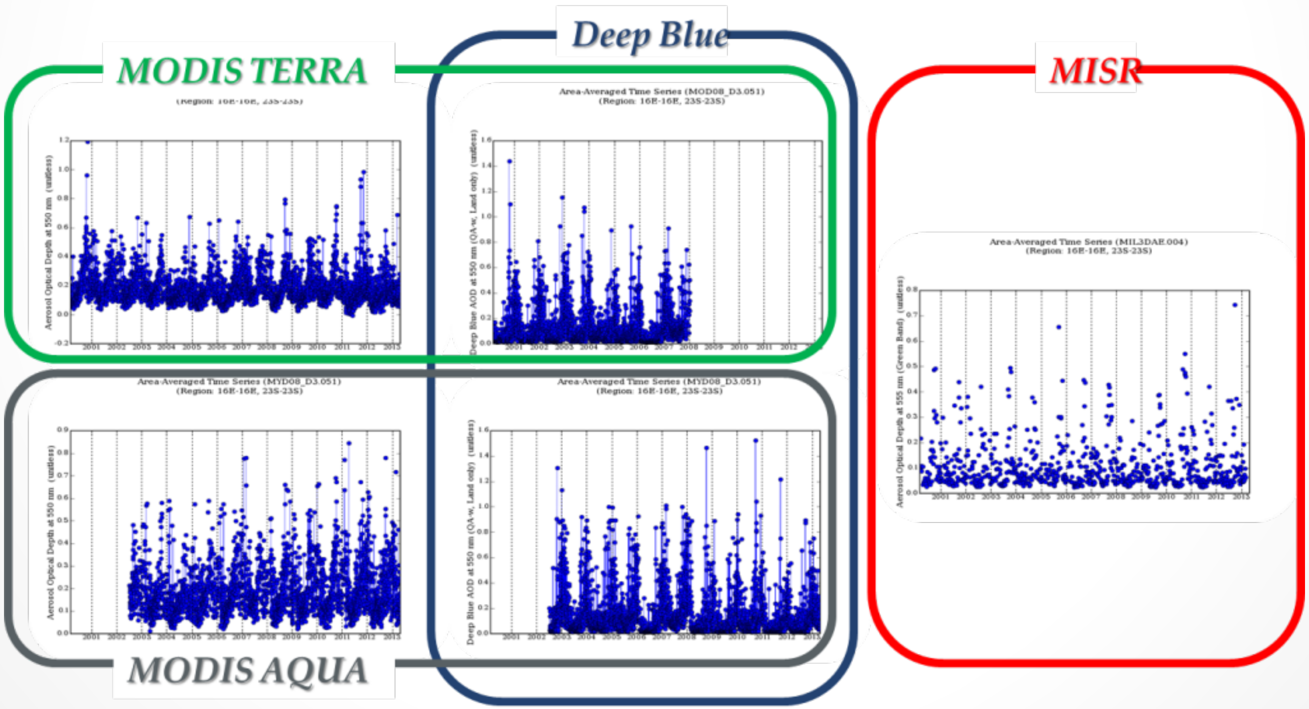
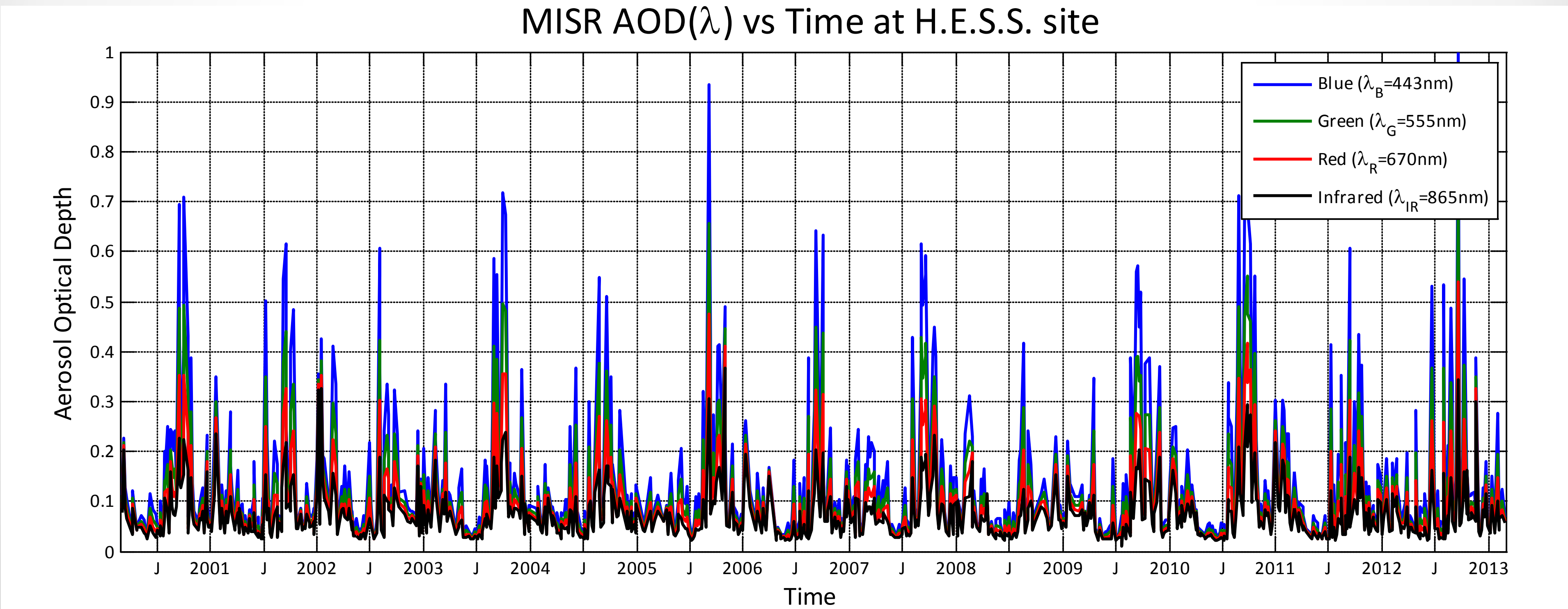
Dataset Analysis

- Several datasets are available for aerosol study
- While MISR has better albedo suppression due to its 9 observation angles, MODIS has more observations due to its bigger swath



Data: MISR AOD Time Series

- Level 3 MISR data displayed for the H.E.S.S. site
  (NOTE: Red and Infrared channels are almost not detected by the PMT camera but can be used for aerosol identification)



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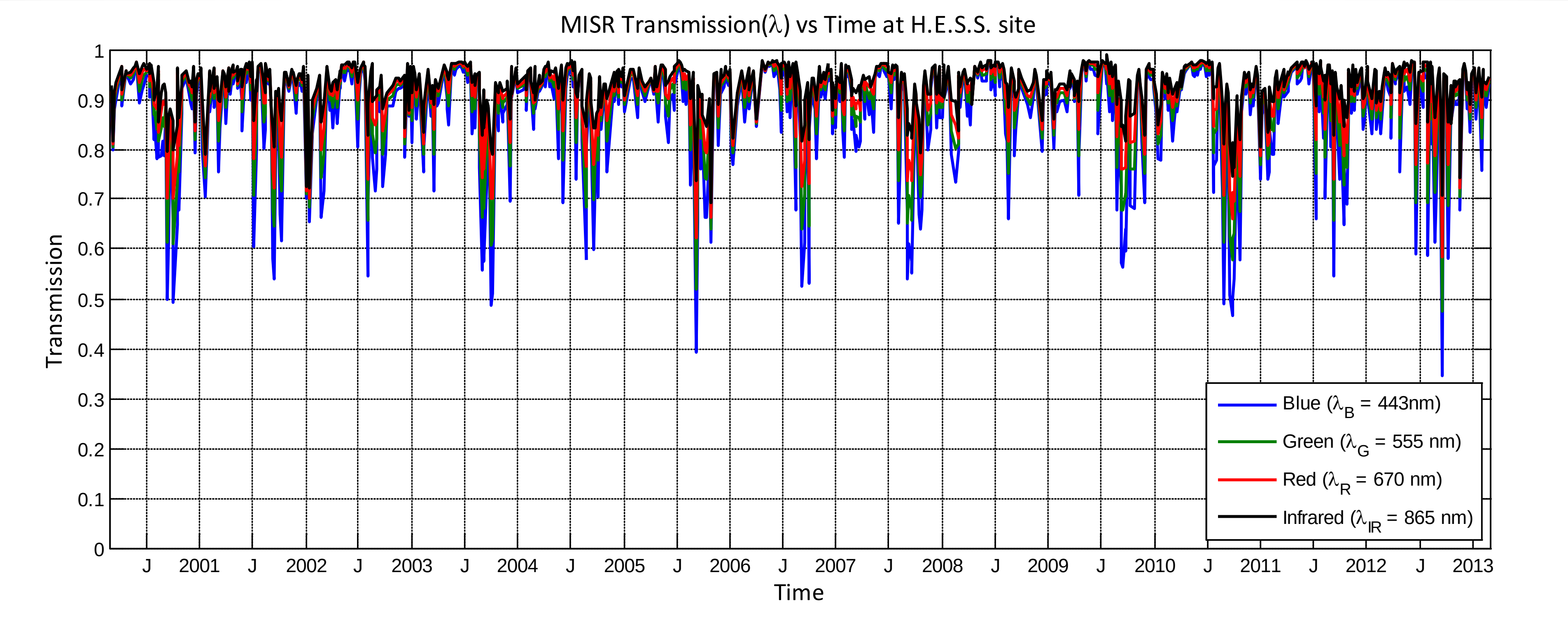
Data: MISR Transmission Time Series

- Level 3 MISR data displayed for the H.E.S.S. site
  (NOTE: Red and Infrared channels are almost not detected by the PMT camera but can be used for aerosol identification)



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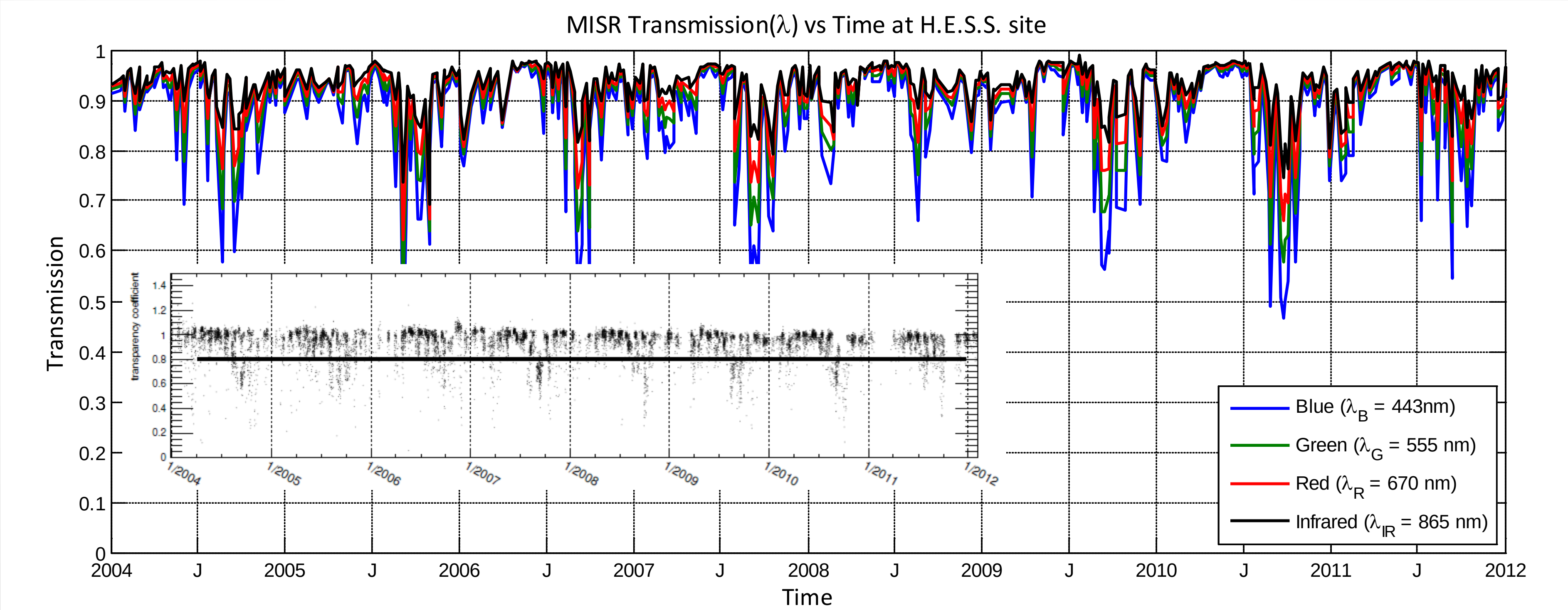

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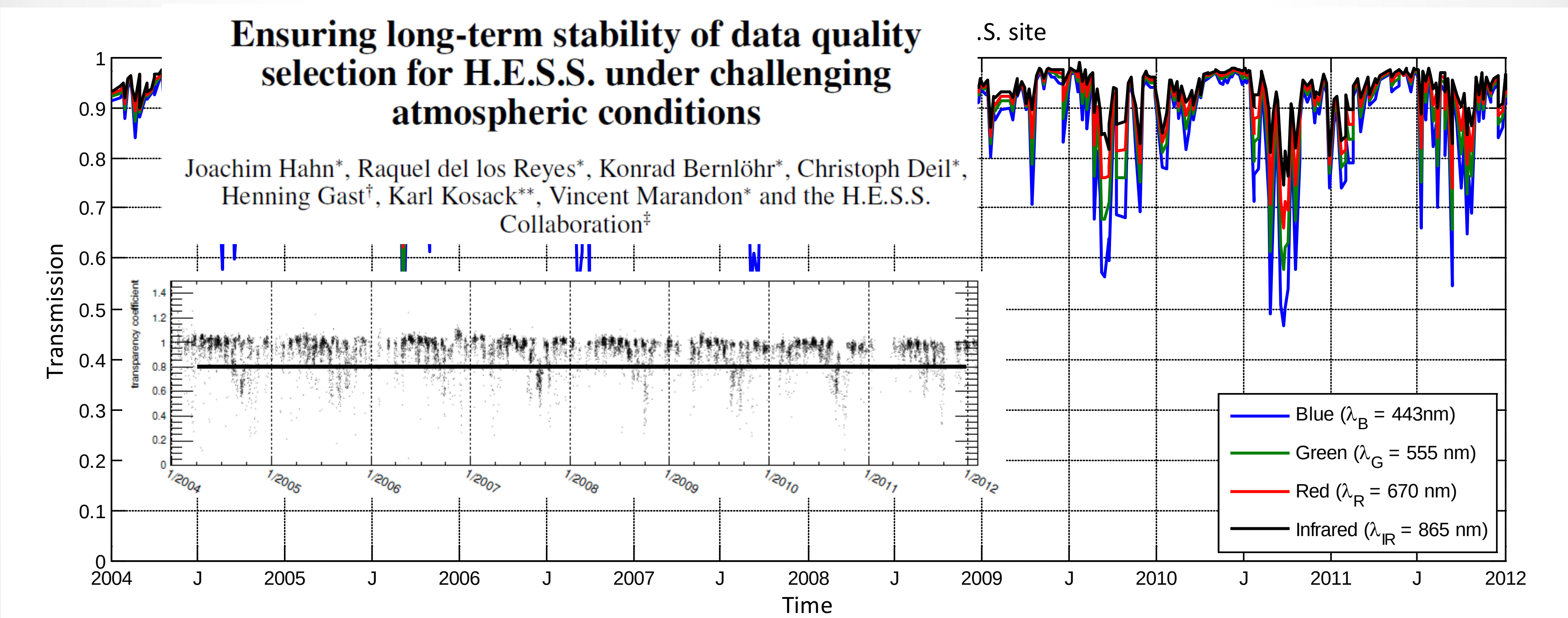

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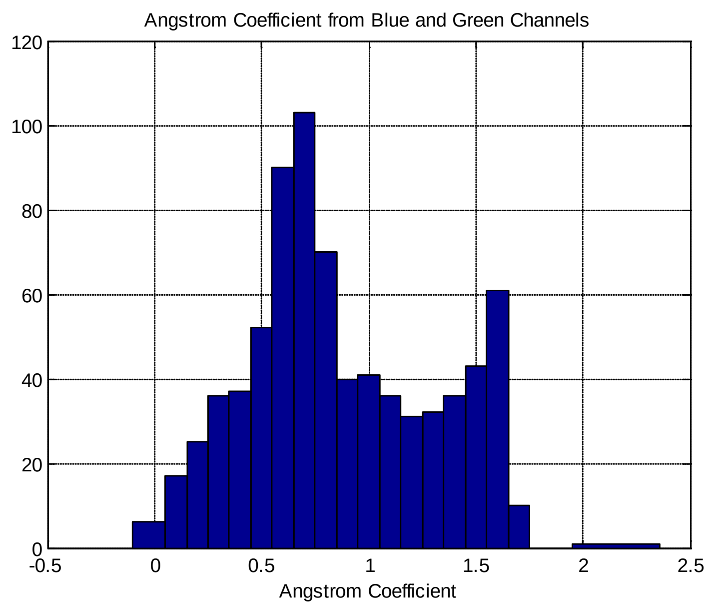
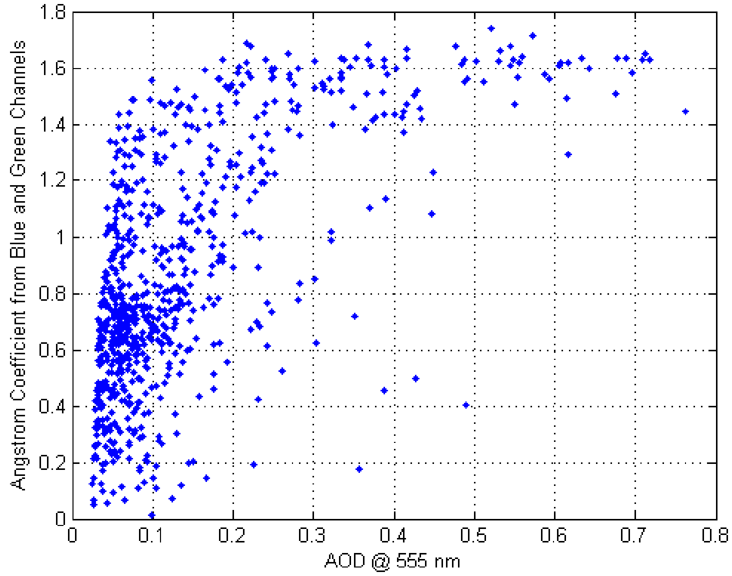
Data: MISR (Blue/Green) Ångström Coefficient

- The Angstrom coefficient using the blue and green channels is about 0.5-0.6 for low aerosol loads
- This value rises to 1.4-1.6 for high aerosol loads





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Data MISR AOD distributions in MAY and SEPTEMBER

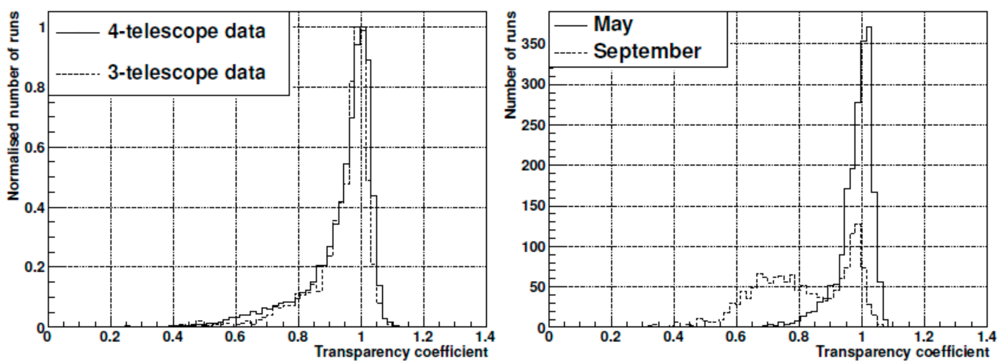
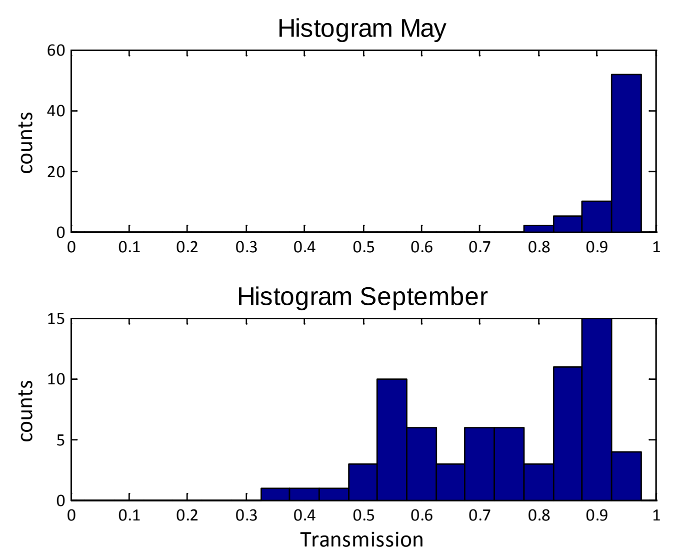


FIGURE 2. Left: Distribution of transparency coefficients for data taken with 3 and 4 telescopes, respectively. Right: Distribution of transparency coefficients for data taken during the May and September months of the last 8 years.

If threshold is set at at Tr = 80%
3% of rejection in May
57% of rejection in September
However low amount of data from MISR observations.



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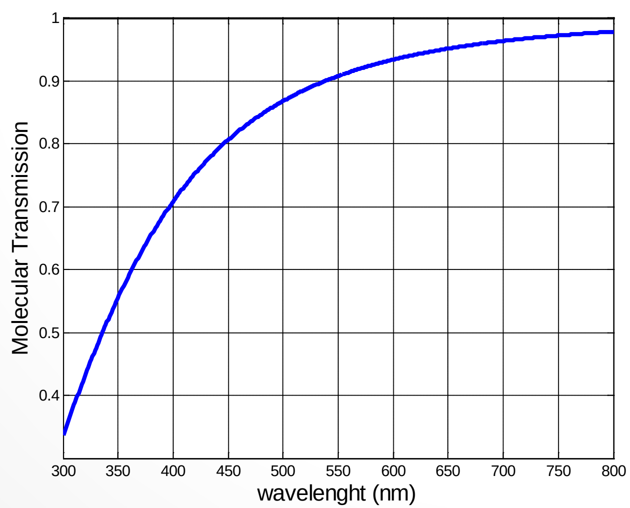
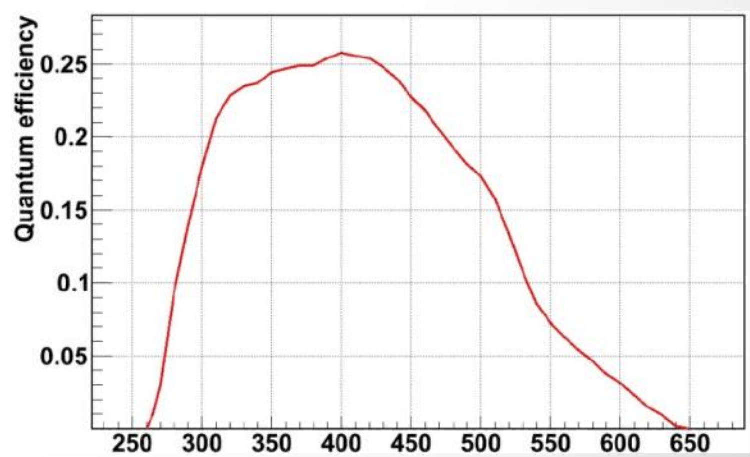
Some other concerns

- Quantum efficiency of the PMTs (Photonis XP2960?)
- Atmospheric transmission (Tr(Green)=1.14xTr(Blue) at ground level)
- Etc…





Conclusions

- As expected from seasonal AOD maps H.E.S.S. observation site experiences high aerosol load during the biomass burning season
- Aerosol intensive properties changes during this period as the aerosol type is different
- Ångström coefficient during high aerosol loads rises from 0.6 – 0.7 (big particles) to 1.4 – 1.6 (dust – smoke)
- Combining this measurements with lidar measurements and model results some of the data influenced by high aerosol loads could be possibly corrected