The upcoming OMPS/LP mission

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5th Limb Workshop
Helsinki, Finland
Nov 16-19th, 2009

The upcoming OMPS/LP mission

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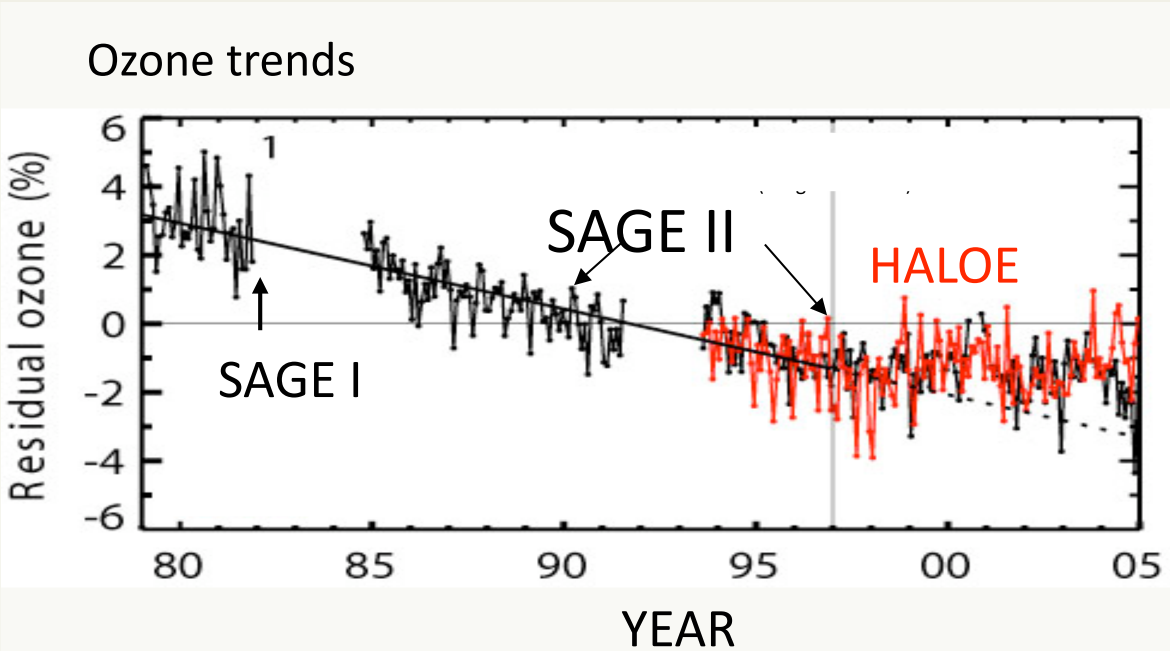
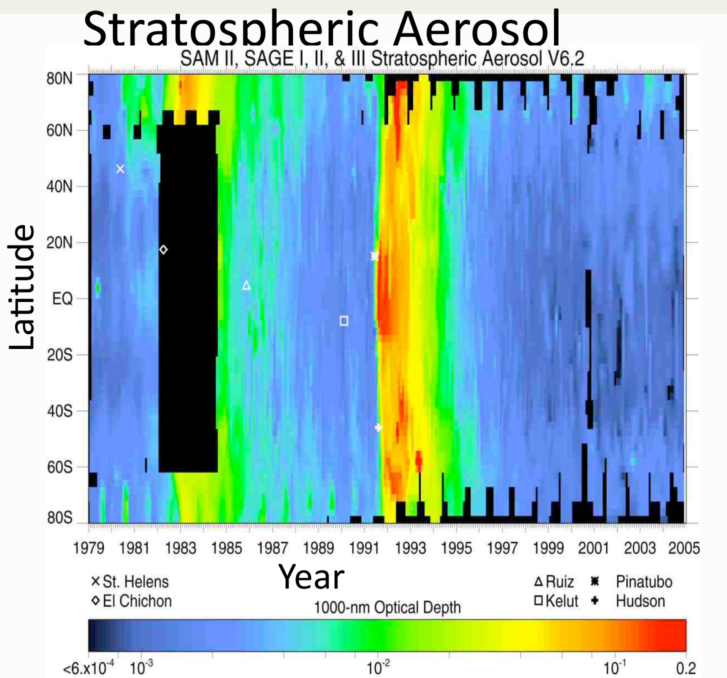
The Ozone Mapping Profiler Suite

- **Mission goal**
  - To continue US commitment to monitor global **ozone**: horizontal and vertical distribution within the Earth's atmosphere. Continue TOMS/OMI/SBUV/SAGE
  - Secondary products: stratospheric aerosol, cloud top, NO_2(?), BrO (??)





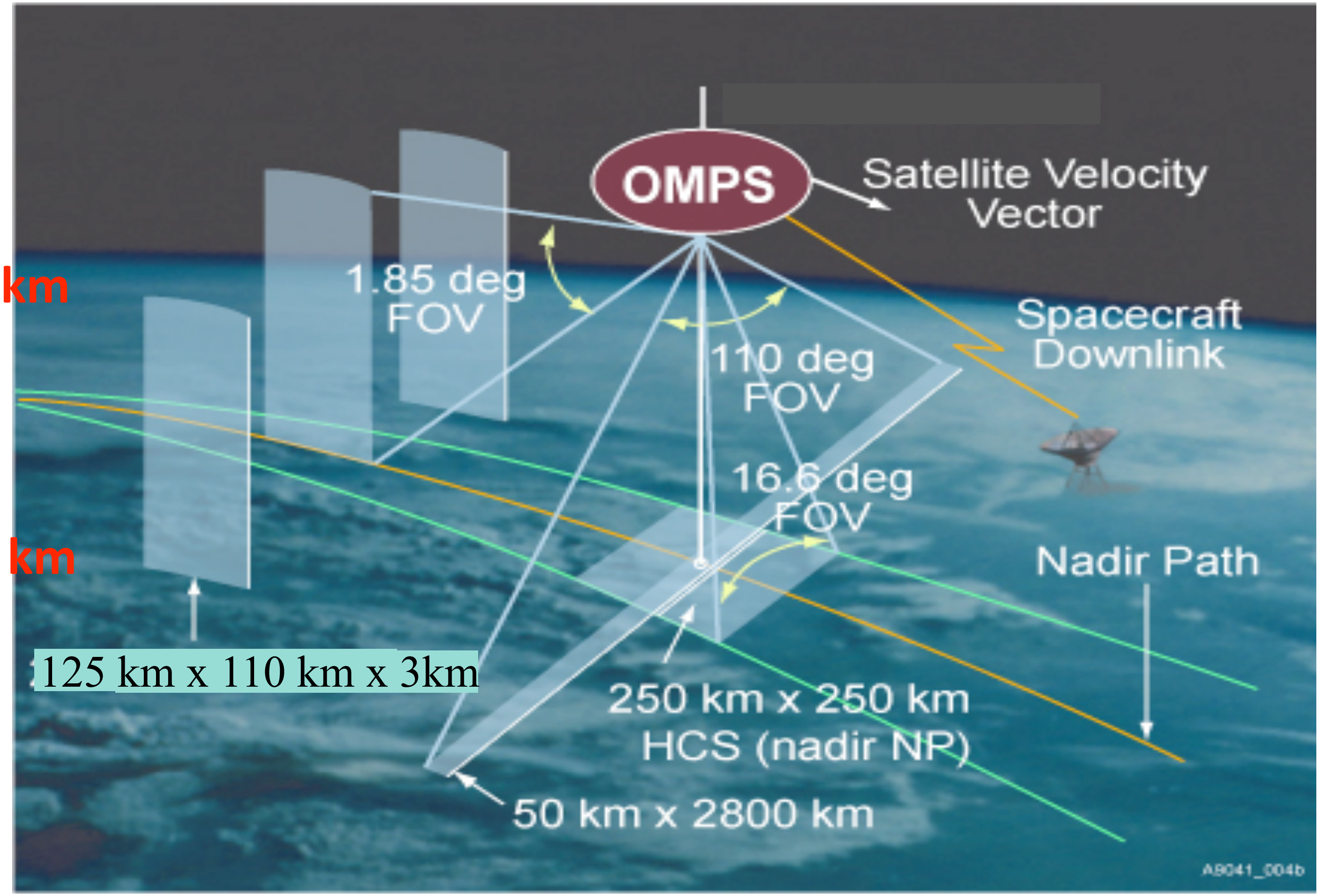
From L. Thomason LaRC

NPOESS Preparatory Project (NPP)

National Polar-orbiting Operational Environmental Satellite System

Sun-synchronous
Altitude of 825 km
13:30 ascending orbit
Spring 2011 launch

- **NPP is joint mission between IPO (NOAA / NASA / DoD) and NASA**
  - Conceived as "bridge" mission for NASA, risk reduction for IPO
  - Presently, much more of an operational aspect due to delays
- **5 sensors:**
  - **VIIRS (MODIS)**
  - **CrIS (AIRS)**
  - **ATMS (AMSU)**
  - **OMPS (OMI, SOLSE-LORE)**
  - **CERES**



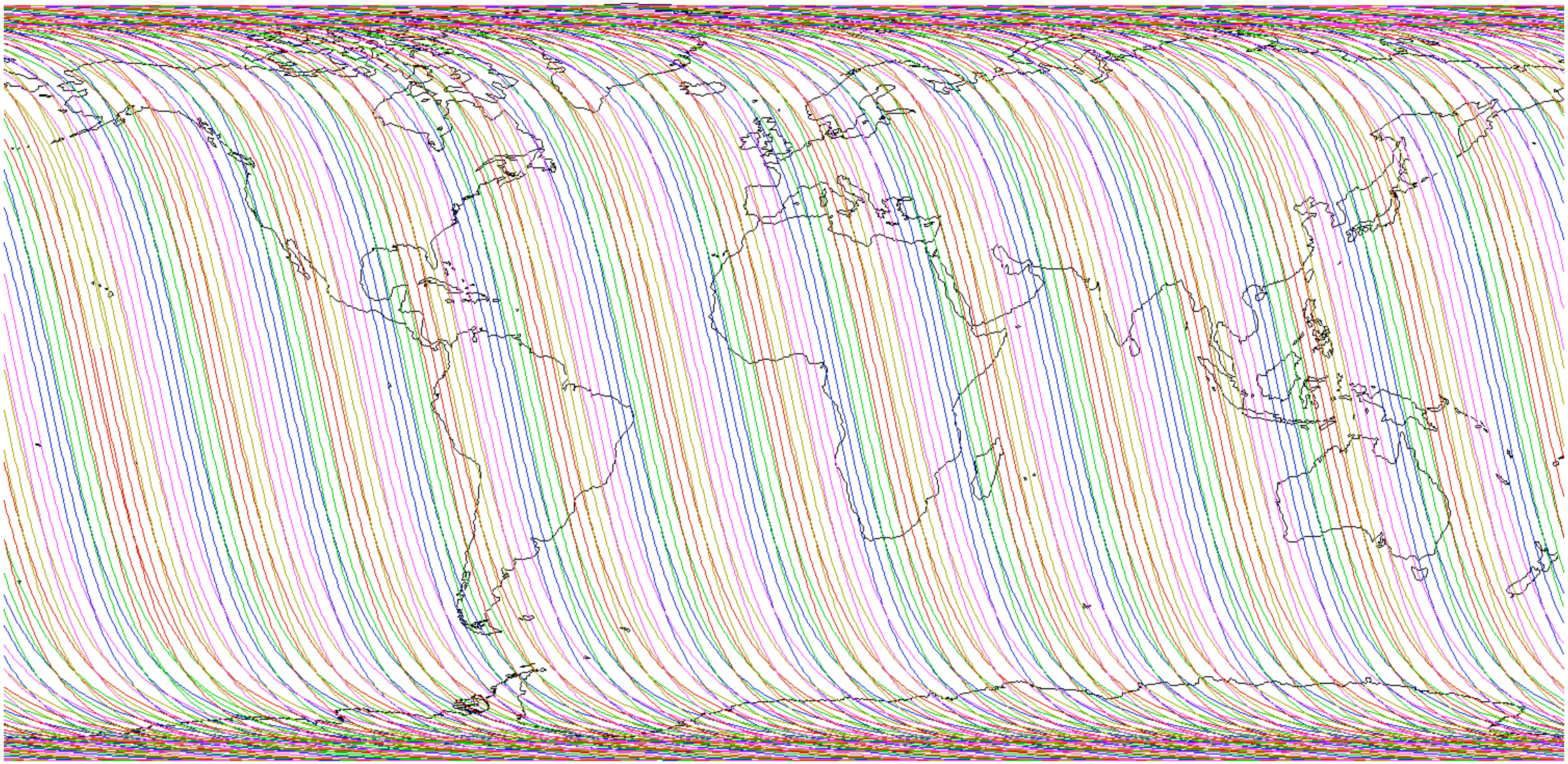
Designed and built by Ball Aerospace

OMPS specifications

	Nadir Total column	Nadir profiler	Limb profiler
Heritage	TOMS, OMI	SBUV, OMI	SOLSE/LORE, OSIRIS, SCIAMACHY, SAGE III
Spectral Range	300 - 380 nm	250 – 310 nm	290-920 nm
Spectral FWHM	1.0 nm	1.19 nm	1.5 - 40 nm (prism)
Field of Regard	110 x 0.3 deg	16.7 x 0.3 deg	500kmx125kmx110km
CCD pixel Field Of View (FWHM)			Elevation: 1.3-1.5 km Azimuth: 3 km
Revisit time (days)	1	2	4
Cell Size: Horizontal Vertical	50kmx50 km at Nadir	250 kmx250km 5 km	125kmx250km (3 slits) 1 km
Accuracy	15 DU or better	7% (at 1 mb)	10% (15 - 60 km) 20% (UTLS)
Precision	3 DU+0.5% or better	10% (at 30 mb)	3% (15-50 km) 10% (UTLS, 50-60km)
Long-term Stability	1% over 7 years	2% over 7 years	2% over 7 years

Mass 68 kg, Power 108 W, Data rate 165 kbps, Sensor Size 35 x 54 x 56 cm

OMPS/LP spatial coverage

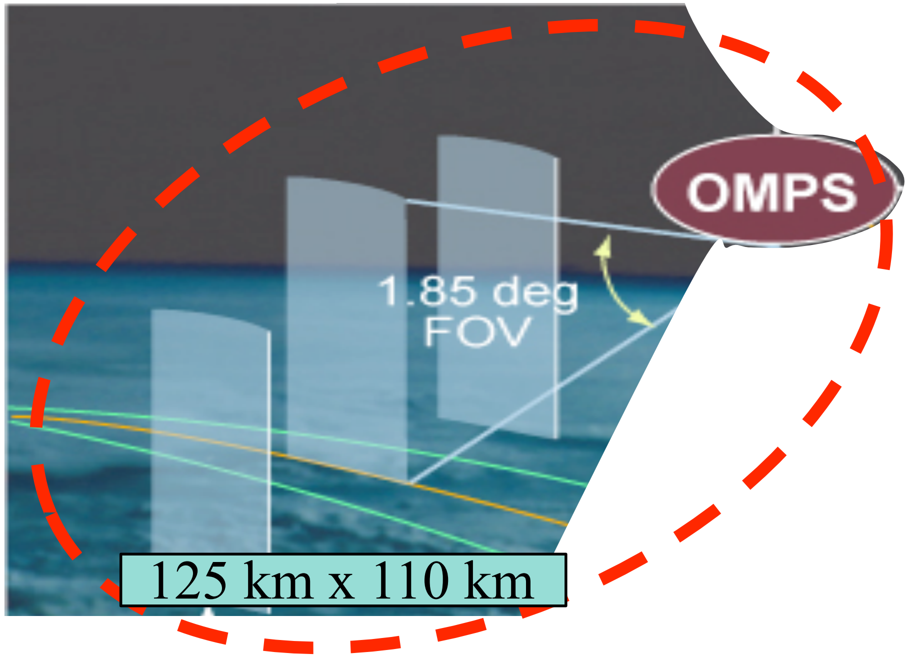


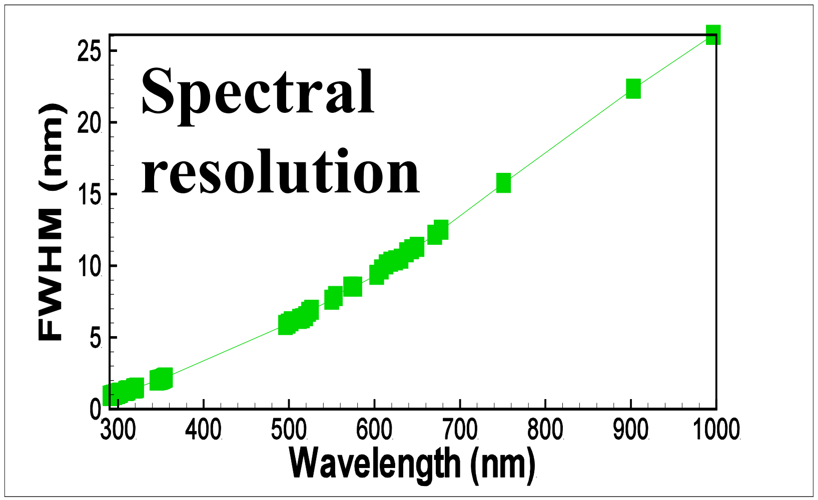
Geo-locations of tangent point (TH=25km) over 5 days period.

Day 1 Day 2 Day 3 Day 4 Day 5

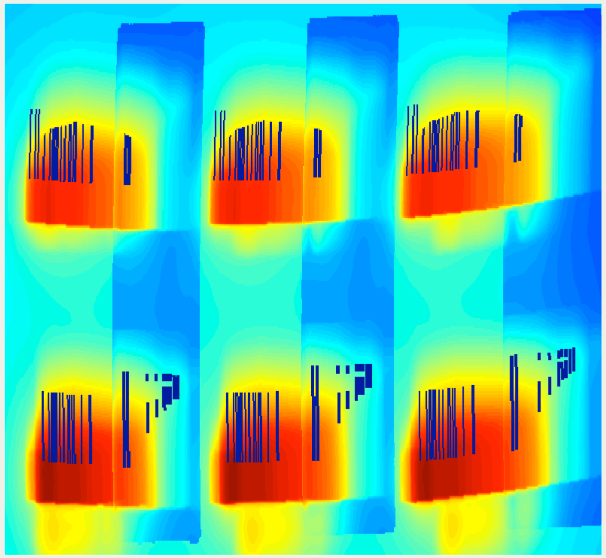
Tracks are shown for the 3 slits.

OMPS Limb Profiler description (1)





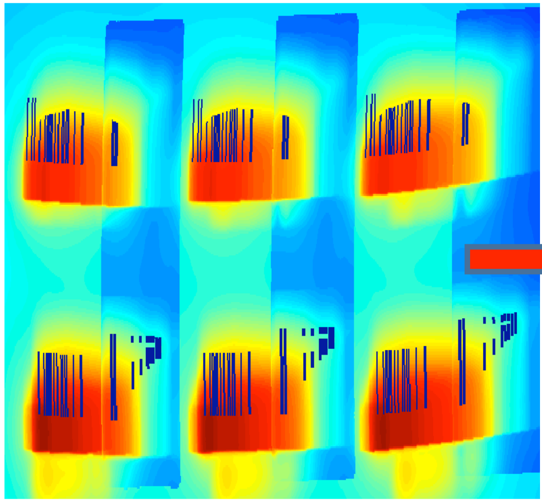
- **Specifically designed for ozone retrieval:**
  Spectral dispersion uses a prism, with highest spectral resolution in Hartley/Huggins (1nm) and lower in Chappuis (10nm)
- **Uses 4 separate gains** to contend with high dynamic range across FOV
- **All gains, all slits imaged onto a single CCD array focal plane**
- **Only download a fraction of CCD array,** due to downlink rate limitations



OMPS Limb Profiler description (2)

LG

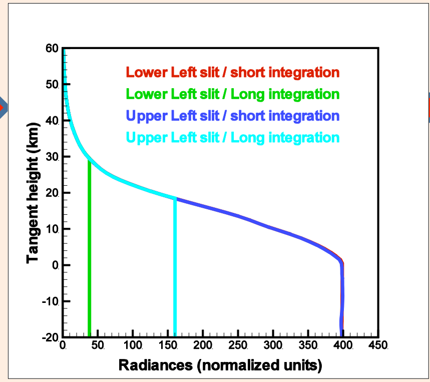
HG



2 gains, 2 integr, Sample Table, Straylight

Level 1 products:

Calibrated, height registered, geolocated, straylight removed radiance profiles



Level 2 products:

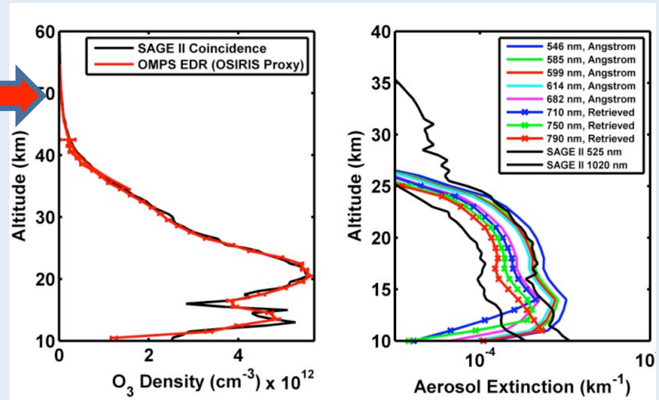
Ozone profile

Aerosol profile

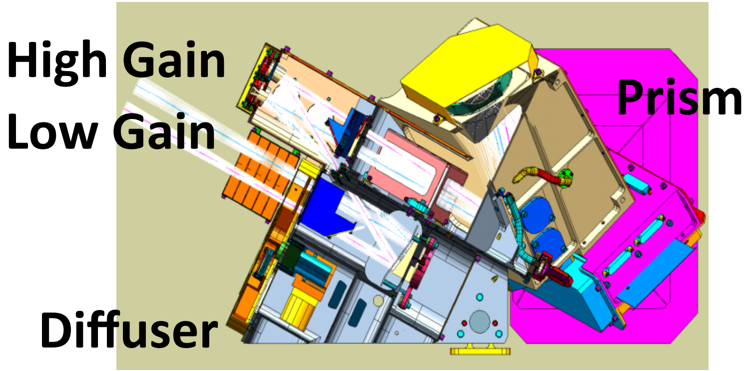
Aerosol size (1 moment)

Cloud top height

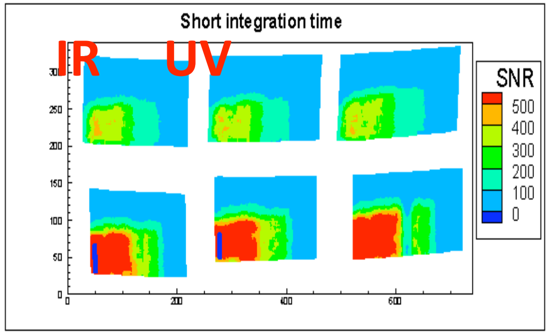
Effective surface albedo

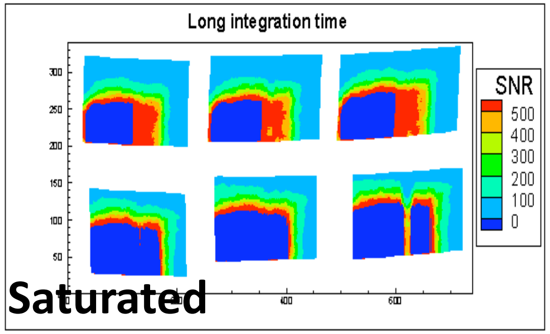


Sensor characterization



- **Laboratory measurements**
  - Spectral and angular registrations
  - Spectral bandpasses, angular FOV
  - Absolute radiometric coefficients (radiance, irradiance)
  - PSFs (straylight)
  - Linearity
  - Goniometry (effect of diffuser incidence angle)

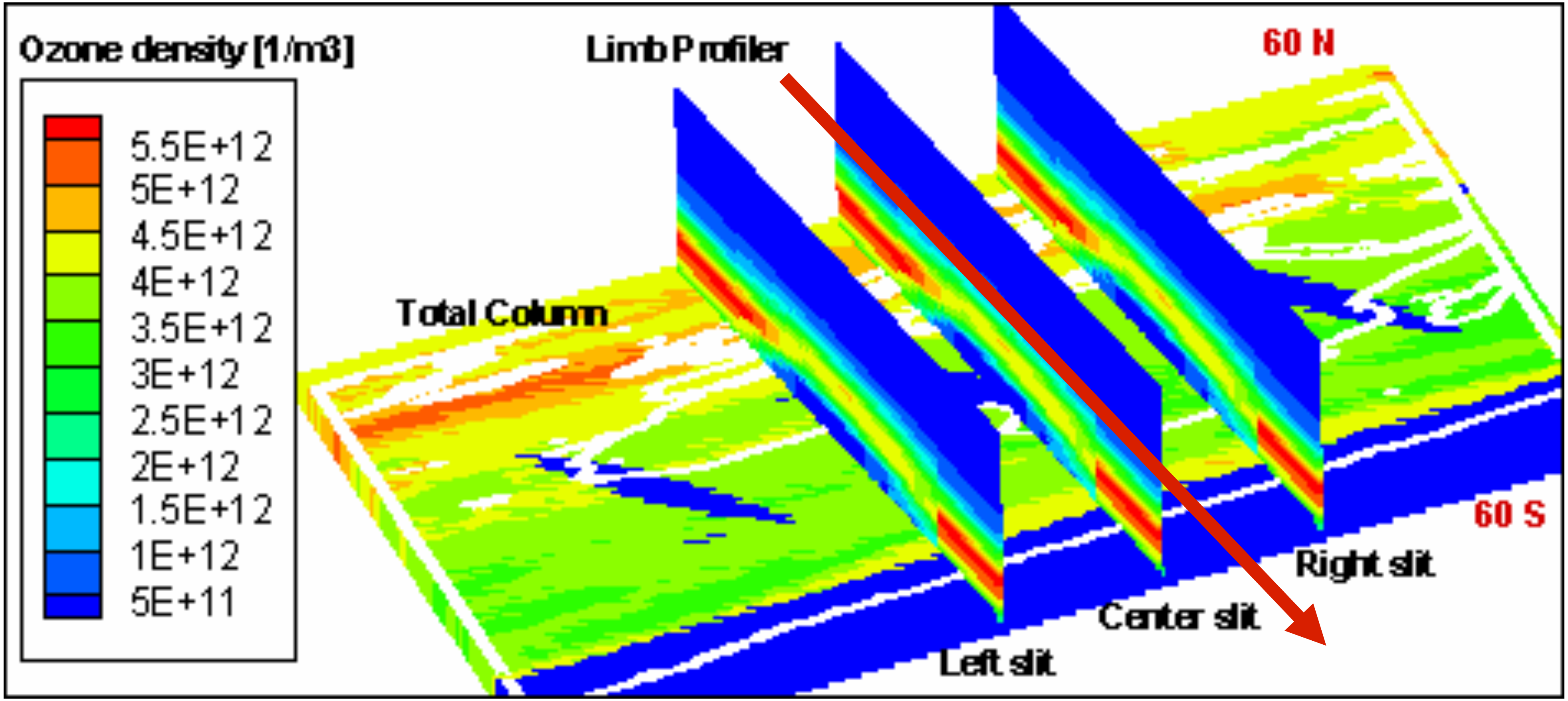




- **On-orbit calibration (solar diffuser)**
  - Weekly irradiance: wavelength calibration
  - Dark current on dark side

- **Instrument model**
  - To be used during operations to do troubleshooting
  - To be used to generate synthetic data

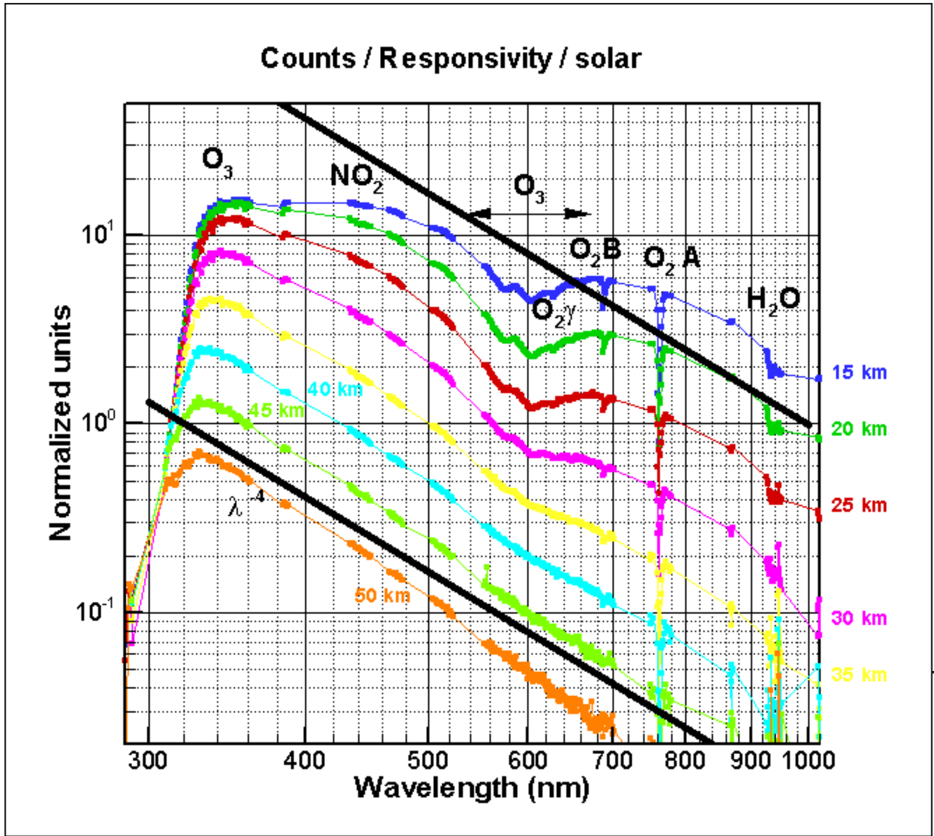
Generic output (one per orbit, 14 times a day)



Similar curtain files for aerosol, aerosol size, cloud top, effective surface albedo

Will be posted on NASA website, with latency of a few days (aka TOMS). HDF formatted files

Retrieval algorithm main concepts



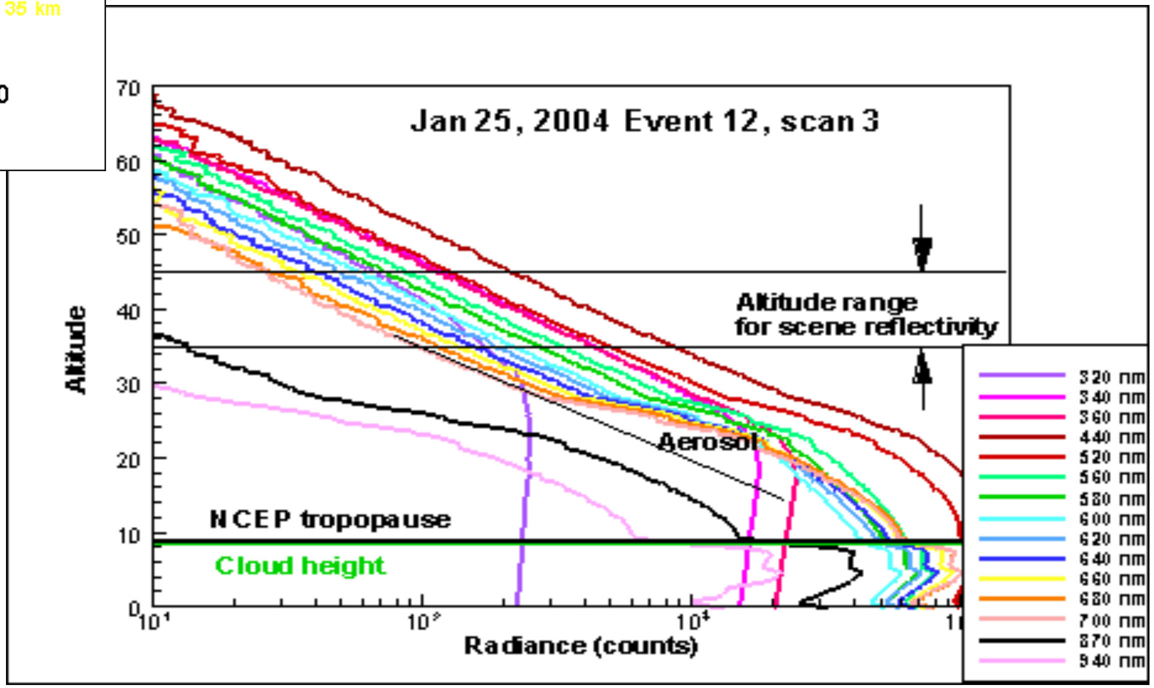
Ozone retrieval:

- contrast highly absorbing channels with weaker absorbing channels (pairs in UV, triplets in Chappuis)
- I_0 reference

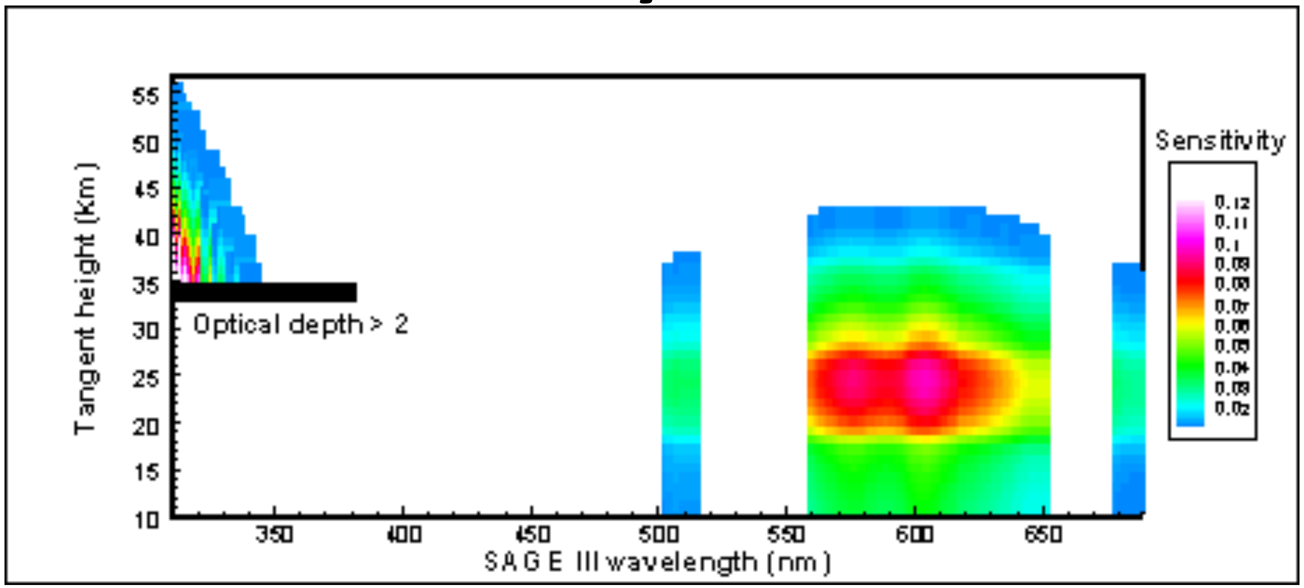
•**Clouds:** jumps in radiance profiles

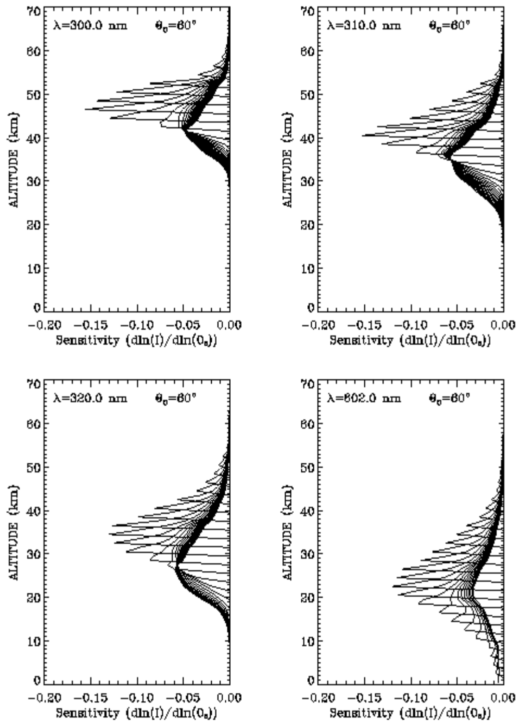
•**Aerosol:** non absorbing channels

•**Albedo:** matching data and model in 35-45 km

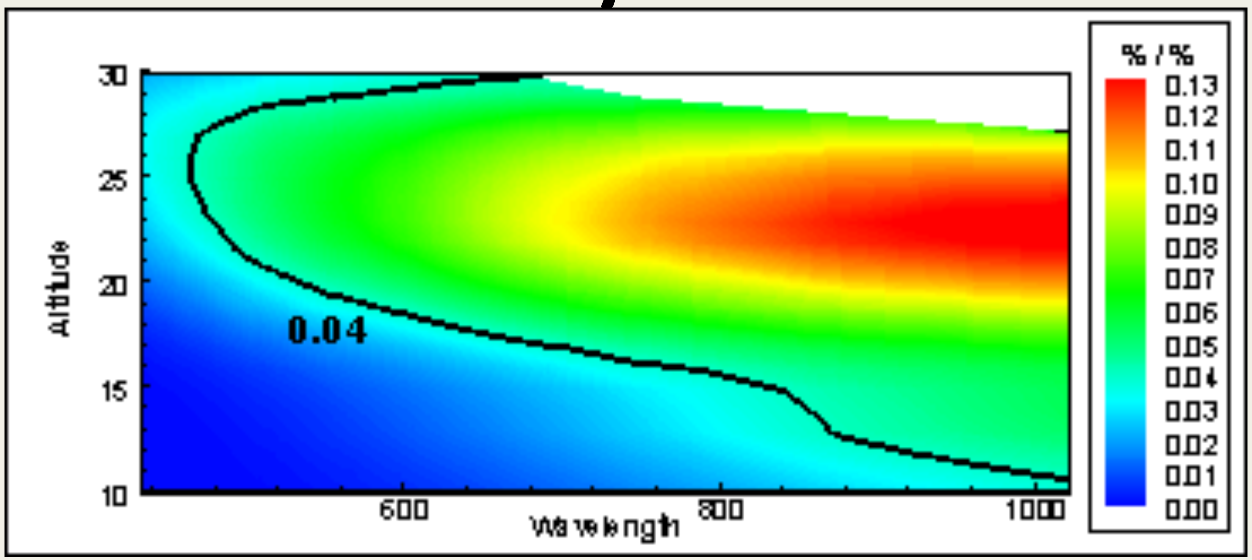


Sensitivity to ozone

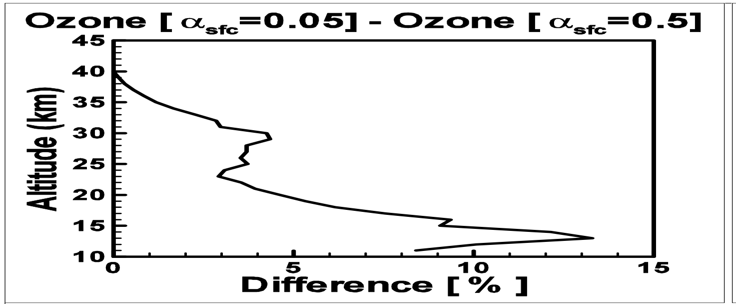


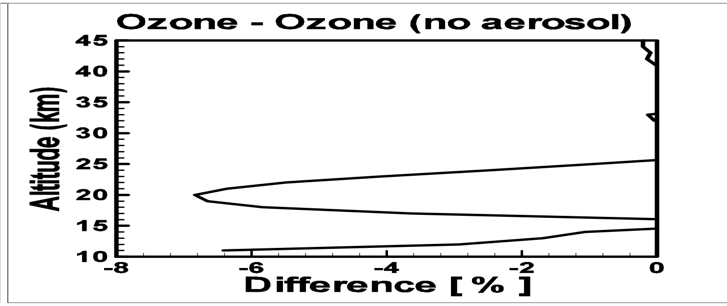


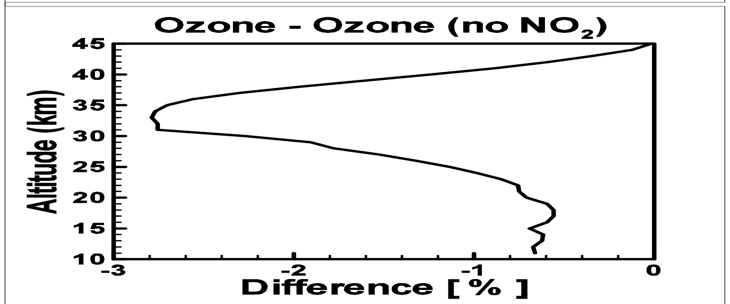
Sensitivity to aerosol

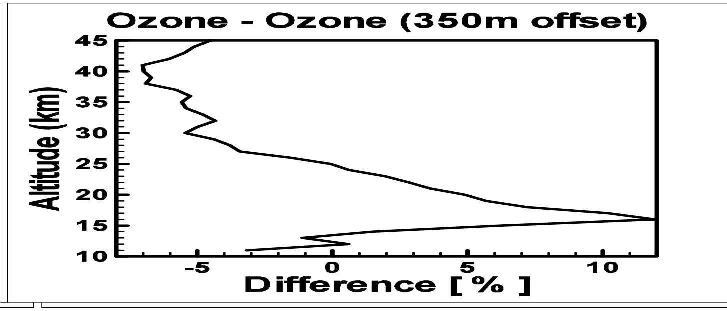


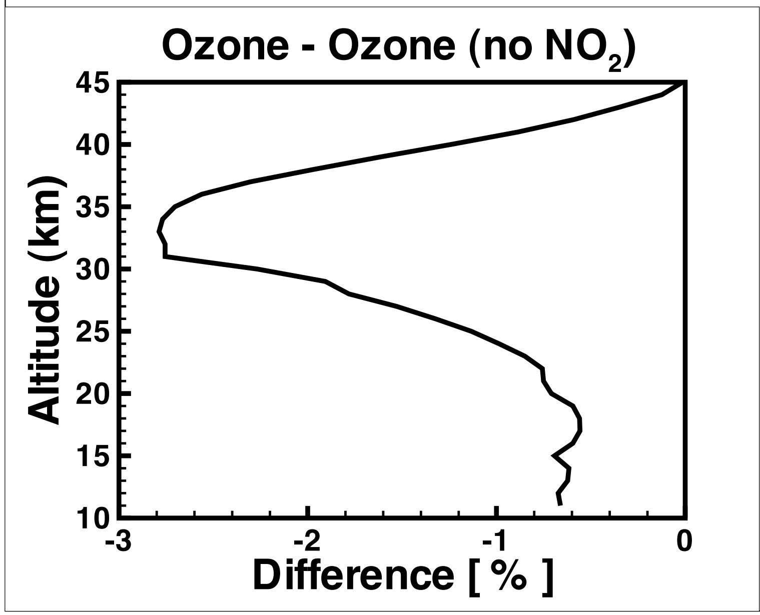
Sensitivity of ozone retrievals to surface reflectance, aerosol, NO_2, TH registration

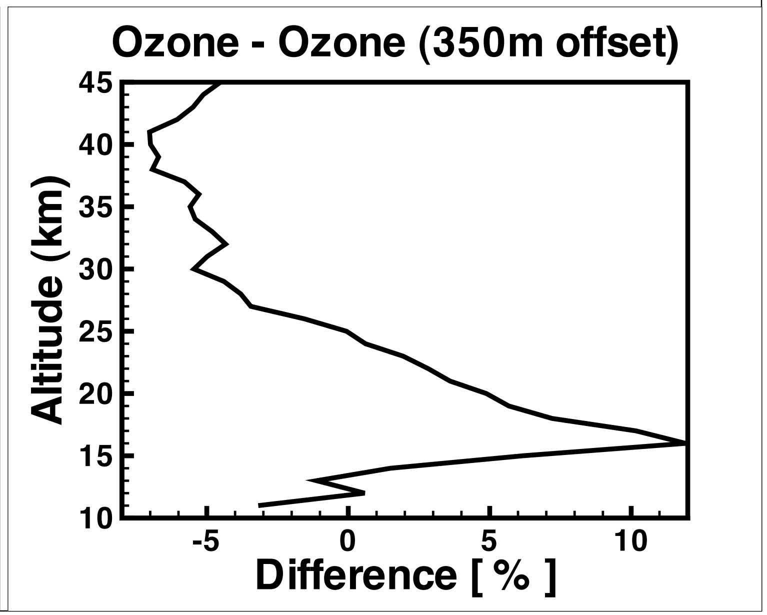




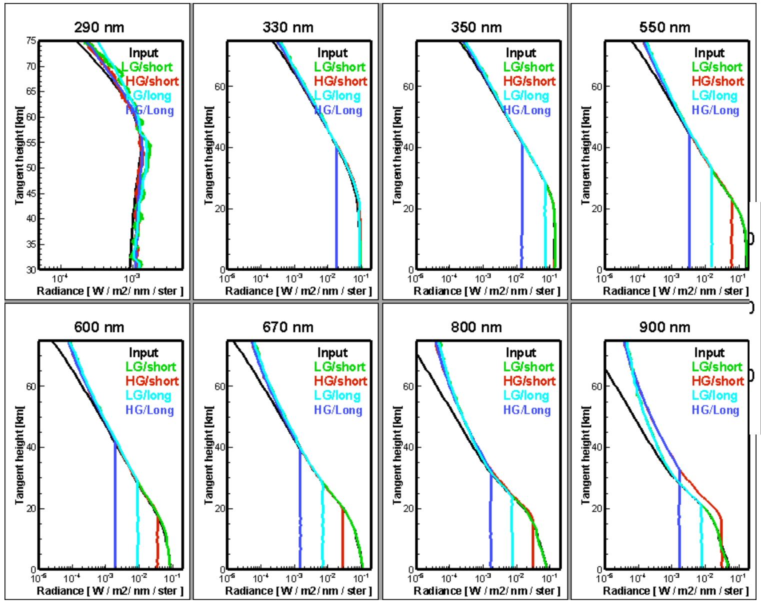




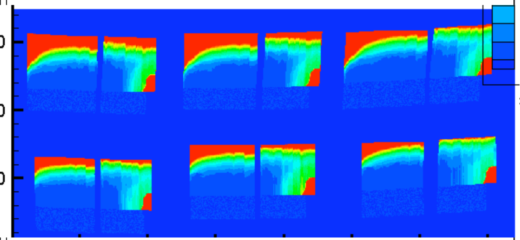


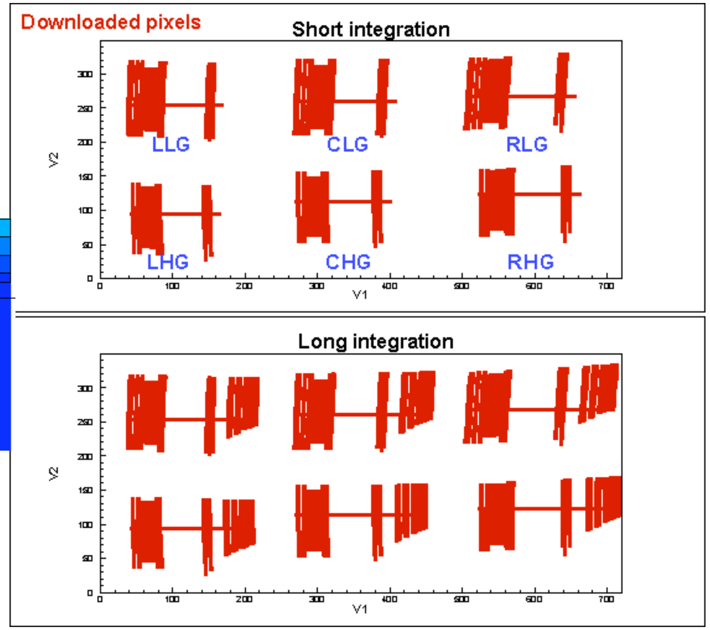


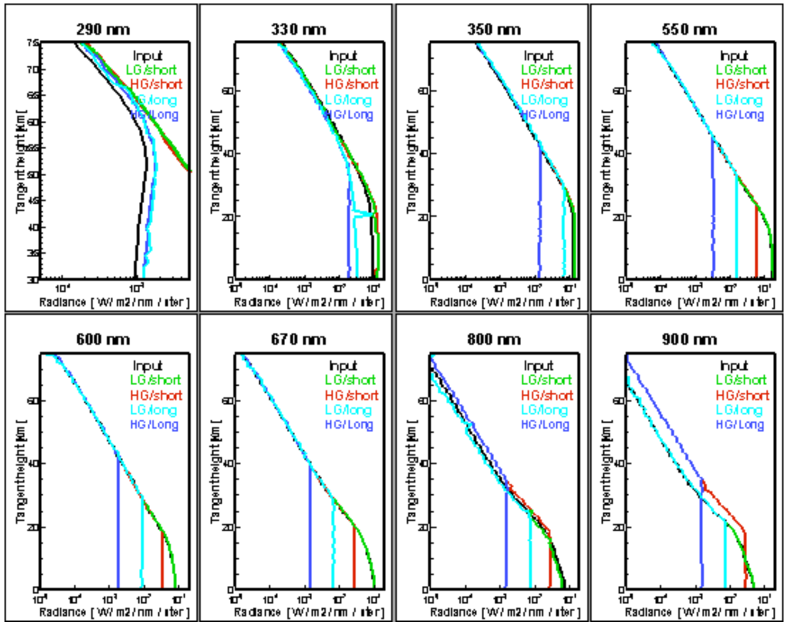
Straylight

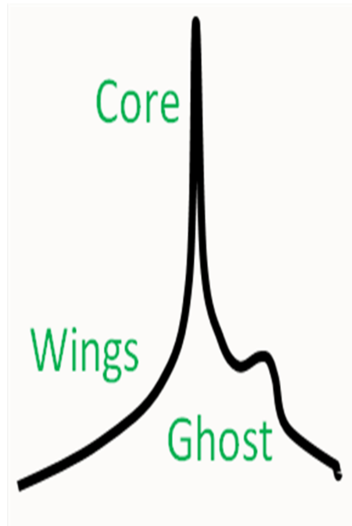


Straylight (red=30%)



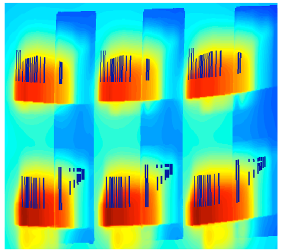




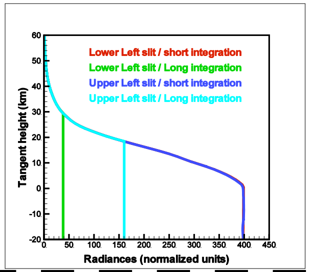


Retrieval algorithms

- **Mainstream**



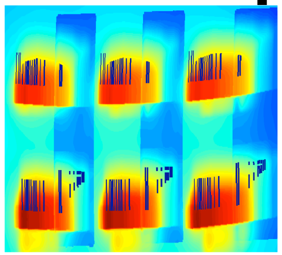
Preprocessing



Retrieval

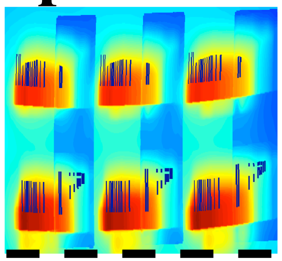
MART

- **Direct Optimal Estimation**

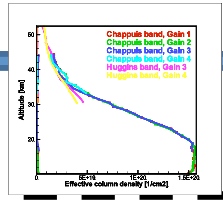


Retrieval

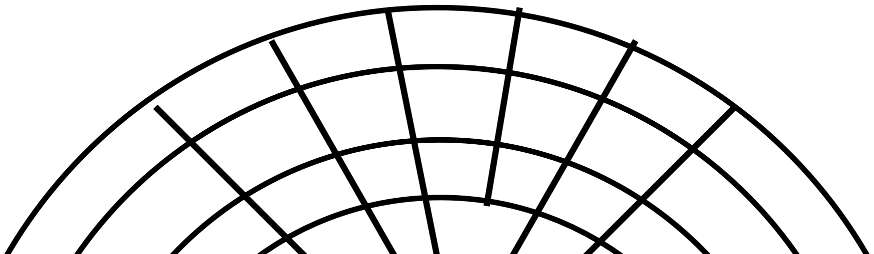
- **Spectral fitting**



Retrieval



- **Two dimensional retrieval**



Ozone profile
(trop-60km)

Aerosol extinction
profile
(15-35km)

Aerosol size
(1 moment)

Cloud Top height

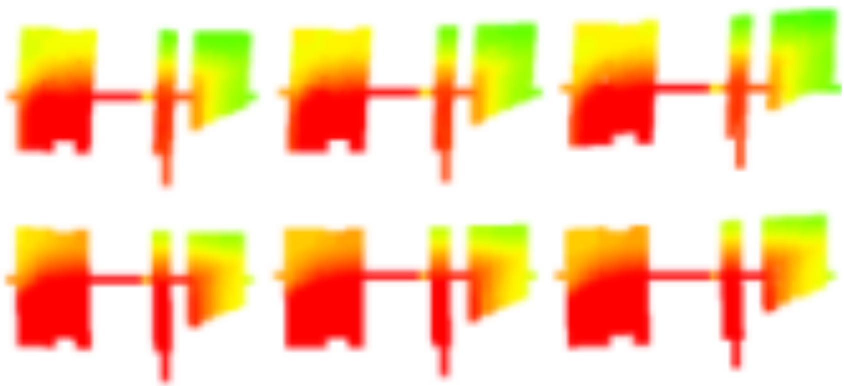
Effective scene
albedo

Troposphere
Vortex

Forward modeling and instrument model

- **Forward models**
  1. University of Arizona Gauss Seidel Radiative Transfer model : spherical SS, MS along tangent point vertical
  2. VLIDORT (Discrete ordinates): same SS as above, MS source term
  3. SASKTRAN: pending

- **Instrument model**
  1. To simulate main functions of instrument (radiance to counts, projection [λ,TH] into CCD array coordinates, noise, straylight, smear, dark current,…)
  2. To generate synthetic CCD array focal planes to be used for module and end-to-end testing



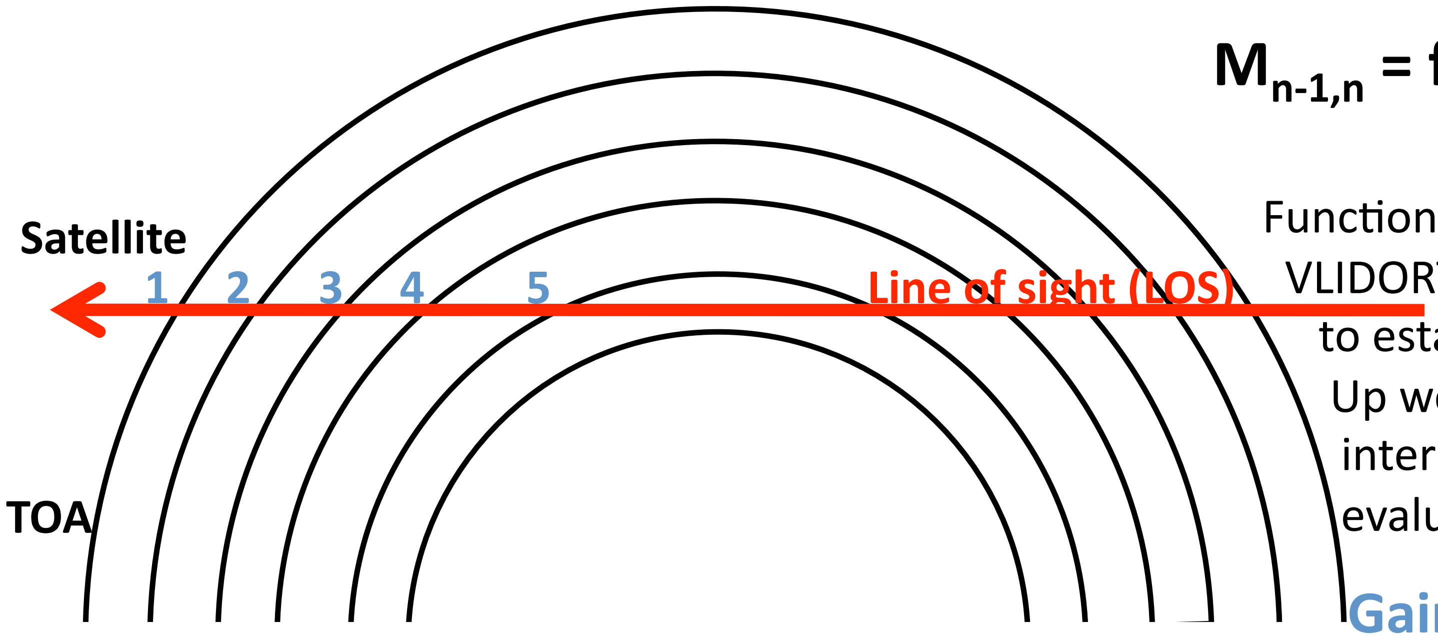
VLIDORT as alternate RT model

VLIDORT (version 2.4RT) is a pseudo-spherical vector RT discrete ordinate model (typically 8 discrete ordinates). Plane-parallel scattering

- **Integrate Source Function along Line of sight:**

  $I_1 = I_2.T_{12} + S_{12} + M_{12}, \; I_2 = I_3.T_{23} + S_{23} + M_{23}$
- T_{12} **= Transmittance along LOS segment from point 2 to point 1.**
- S_{12} **= Single scatter source term, segment 2-->1. (SS, no surface contribution).**
- M_{12} **= multiple scatter source term, segment 2-->1. (Surface included).**
- $T_{n-1,n}$ **and** $S_{n-1,n}$ **unchanged: Fully linearized (profile Jacobians)**
- $M_{n-1,n}$ **to be provided by VLIDORT**

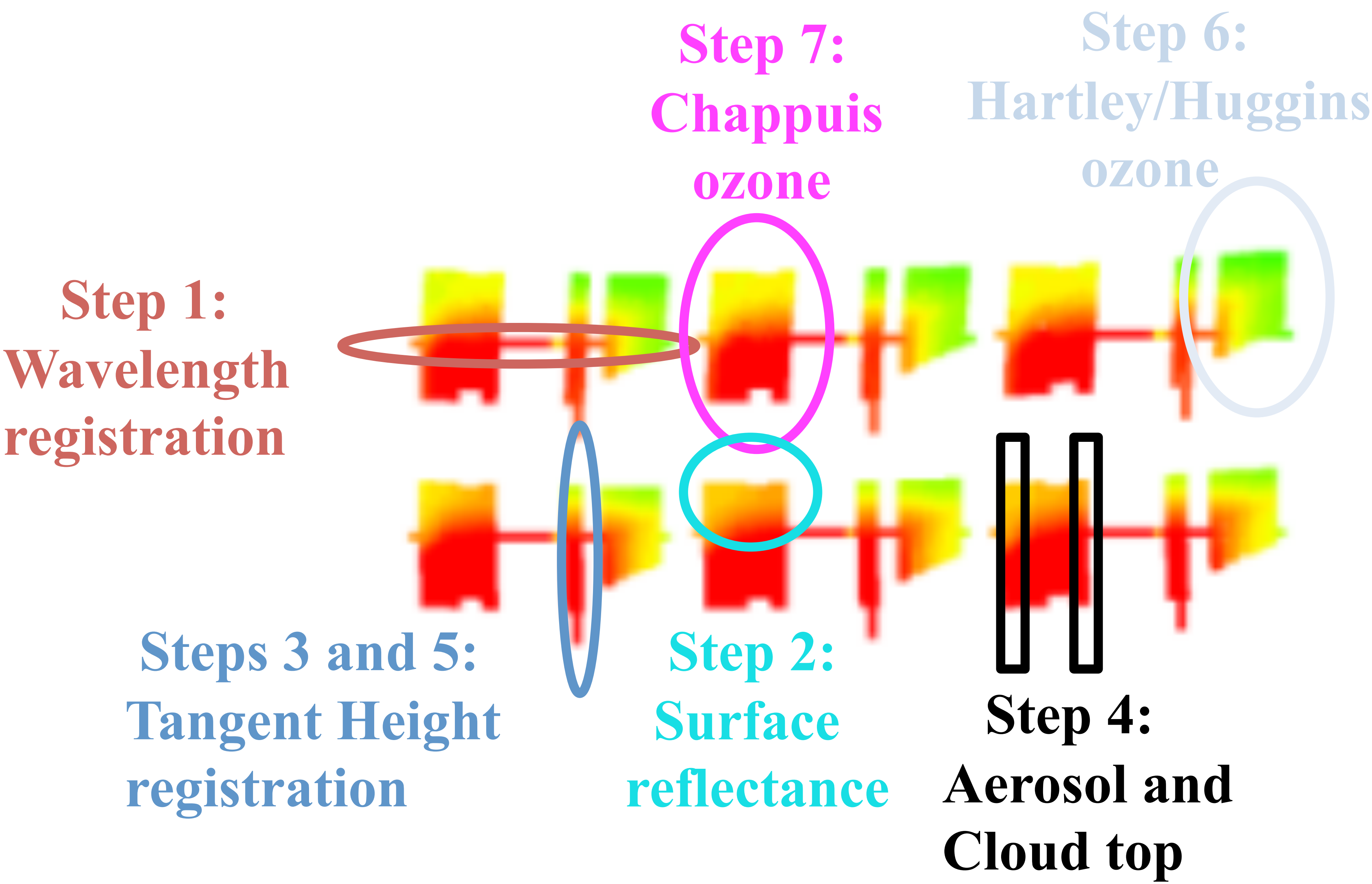
$$M_{n-1,n} = f(SZA_n, Az_n, Vert_n, s_n)$$



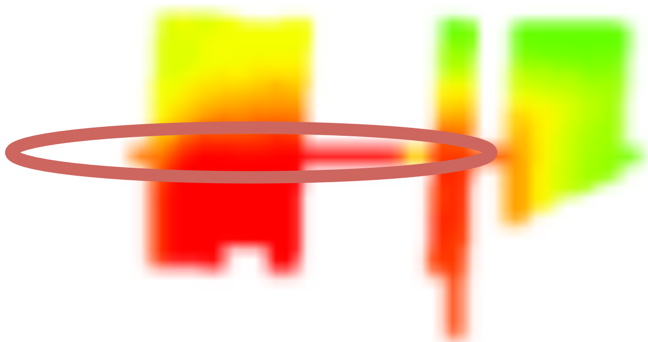
Function **f** is determined by running VLIDORT at a series of node points to establish 2 LUTs (Down and Up welling). Trilinear interpolation is then used to evaluate **f** for each LOS segment

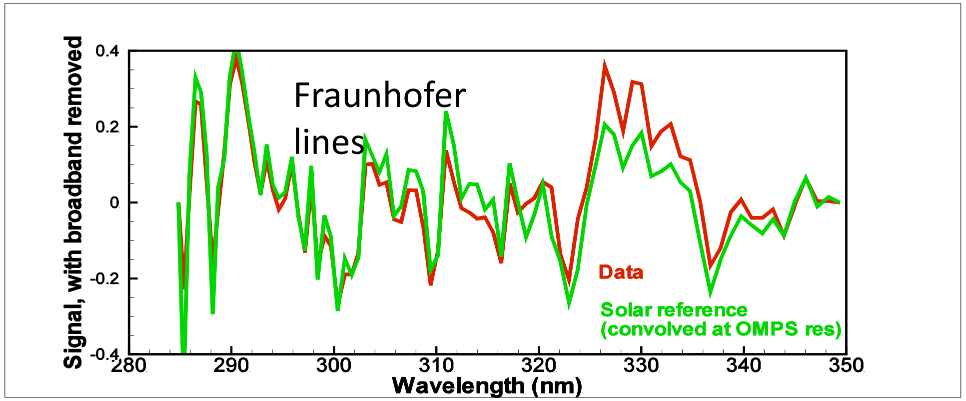
Gain: Speed and accuracy

Retrieval = 7 successive steps:



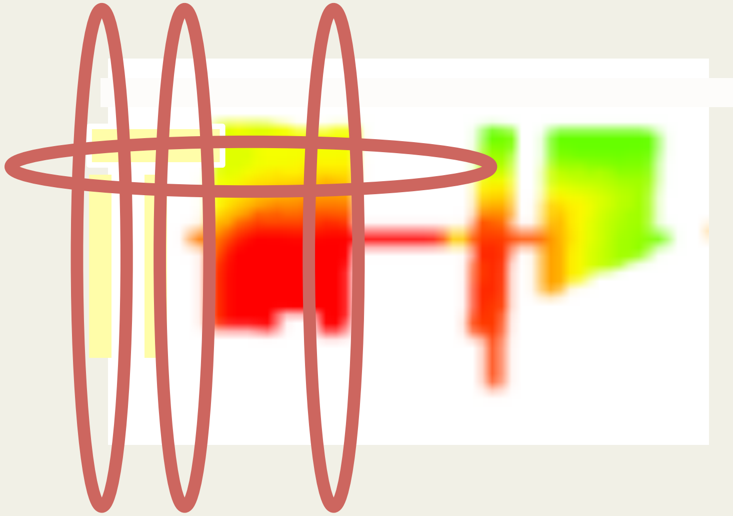
Step 1: Wavelength registration:





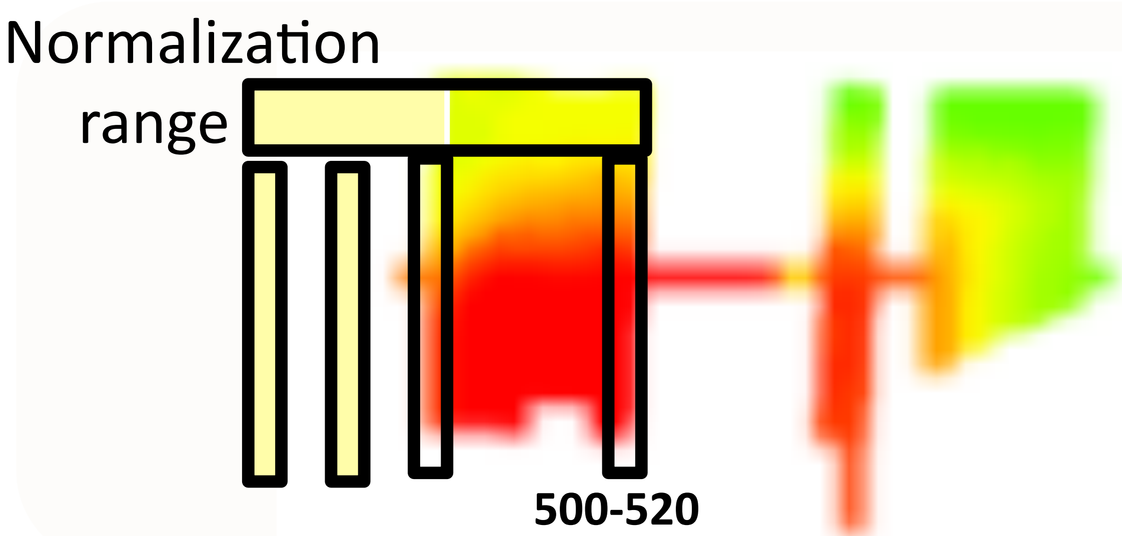
Compare location of solar Fraunhofer lines data vs model, along a CCD pixel row

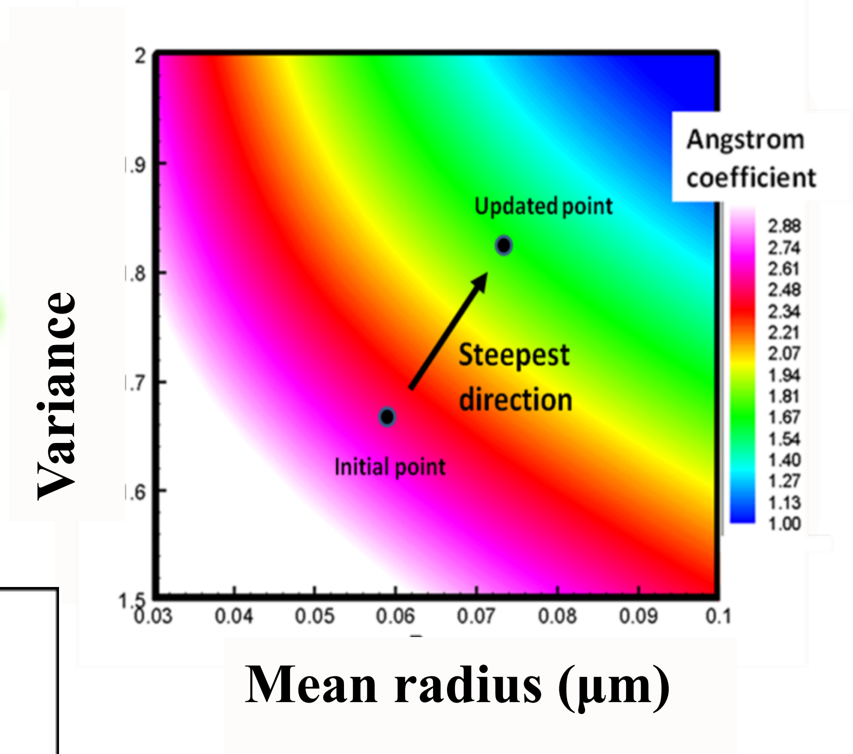
Step 2: Surface reflectance and Cloud top height

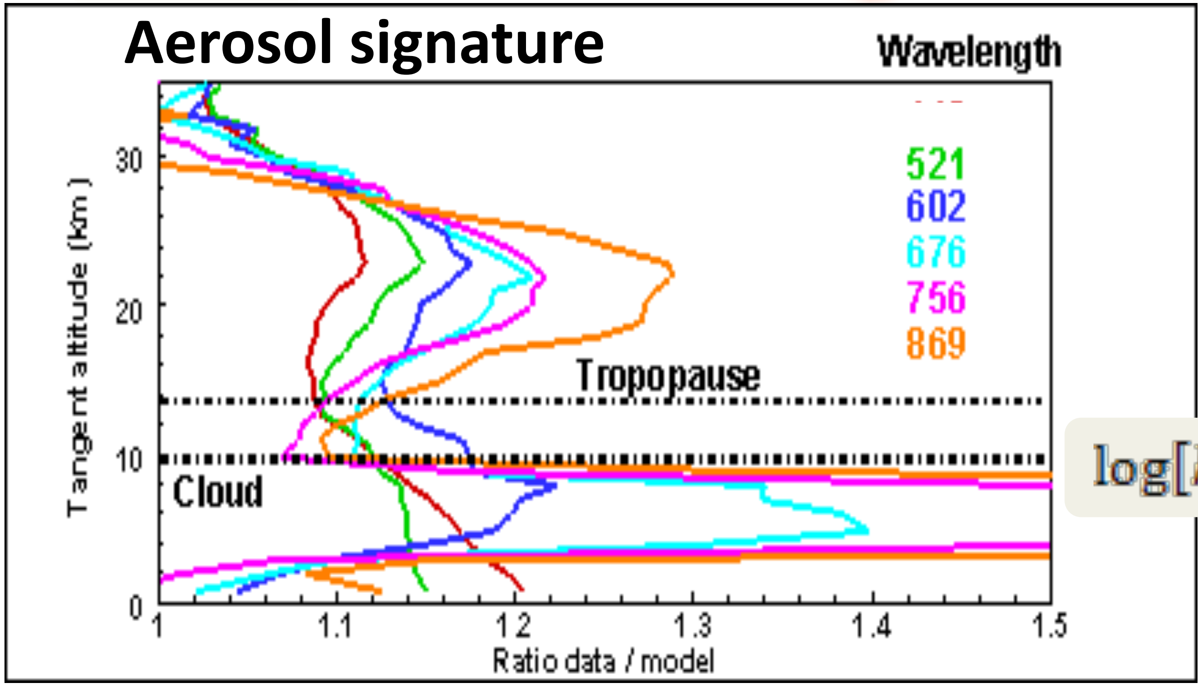


- Compare measured radiance and modeled radiance in the TH range: 35-45 km
- Identify radiance profile sudden increases at long wavelengths

Step 4: Aerosol retrieval: extinction + 1 moment of size distribution







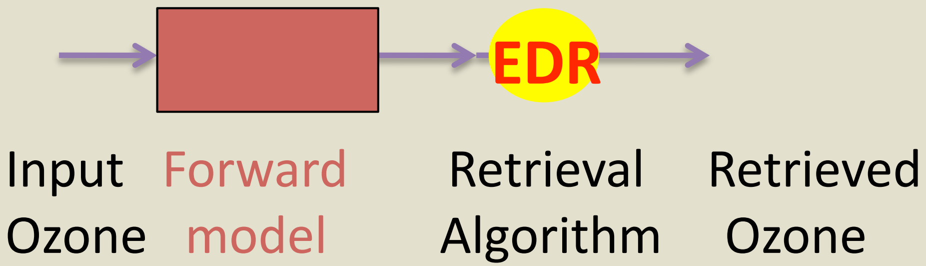
Alternative:

$$\log[k(\lambda, H)] = a(H) . \log(\lambda) + b(H)$$

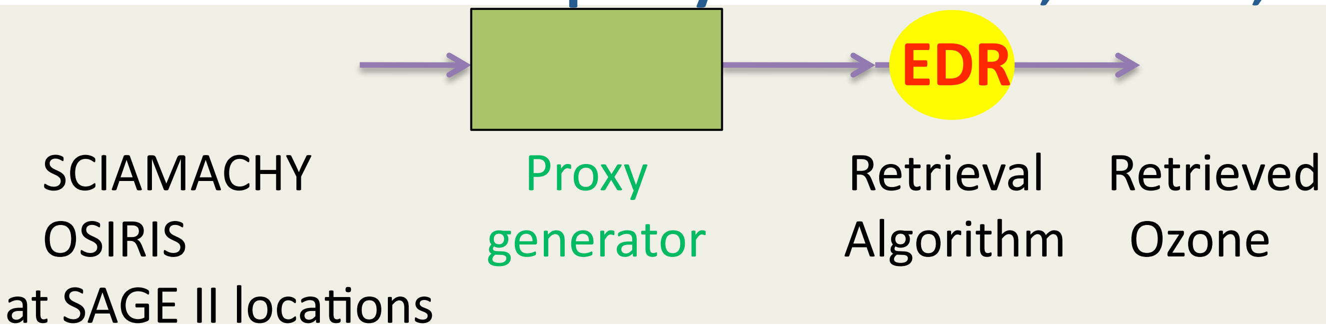
Testing concepts

One step at a time

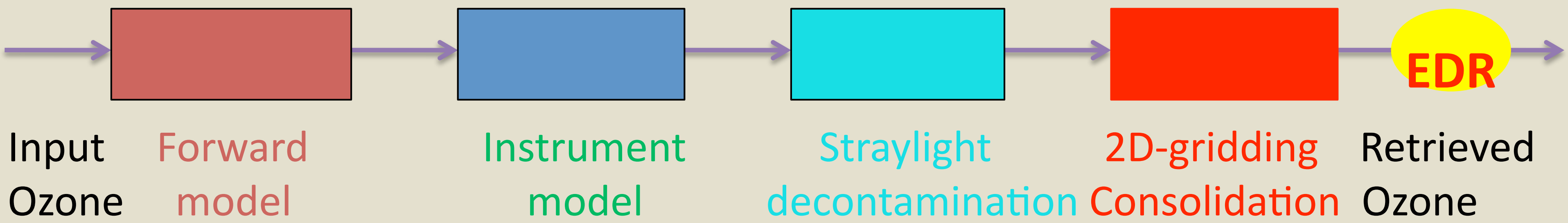
1. Test forward model vs inversion in a controlled environment: synthetic data



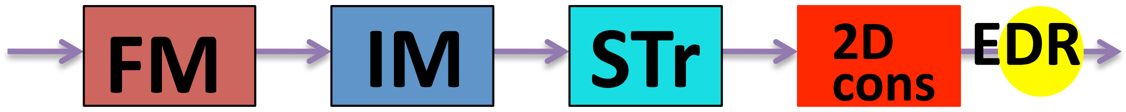
2. Test Inversion with real data proxy: SAGE III LS, OSIRIS, SCIAMACHY

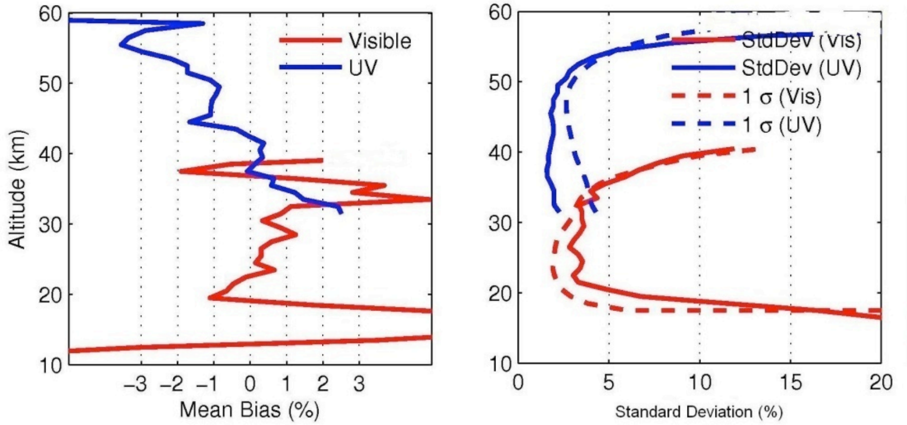


3. Test instrument effects

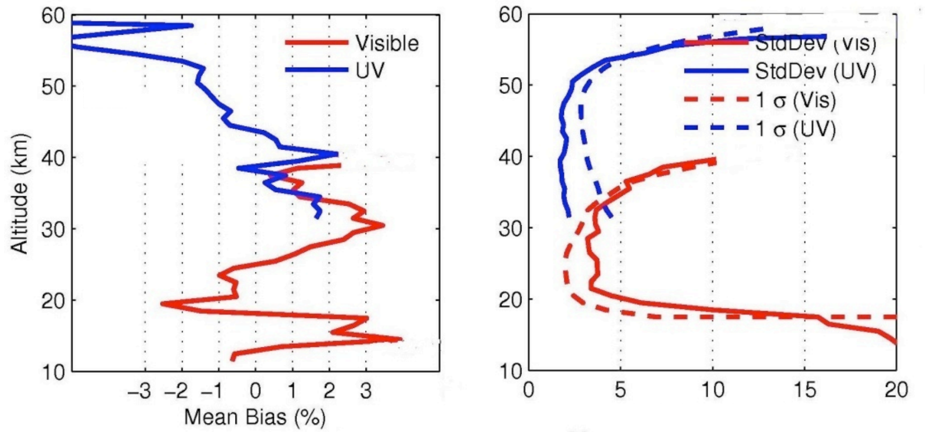


End to End testing



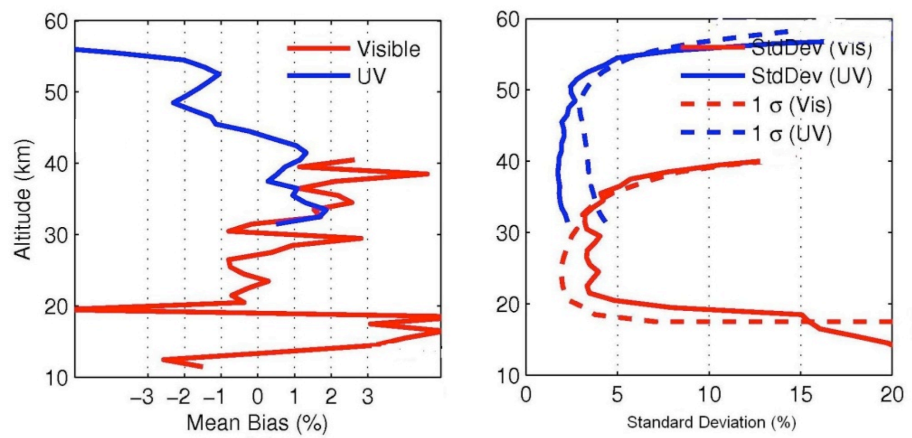


Slit 1

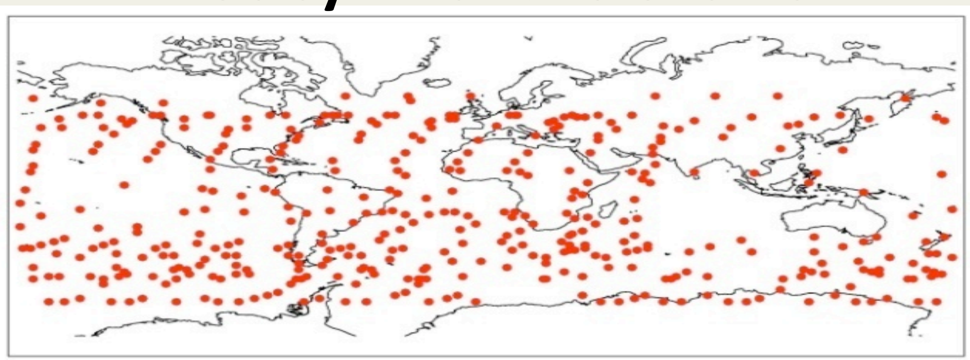


Slit 2

Slit 3



450 synthetic LS events



Conclusion

- **Launch is approaching: Spring 2011**
- **Numerical tools have been developed and are being tested and upgraded and tested and fine-tuned and tested…**
- **Codes are being integrated into operational stream** (Processing speed = real time on couple of 16 processors PCs for raw to ozone / aerosol / cloud products)
- **Alternatives are being implemented to be ready by launch time**
- **Looking forward to real data…**

Back up slides

Advanced Microwave Sounding Unit

Total Precipitable Water (mm)
Rain Rate (mm/hr)
Brightness Temperature (K)
Cloud Liquid Water (mm)
Sea Ice
Snow Cover

Atmospheric Infrared Sounder

Air and surface temperature
Water vapor
Cloud properties
Ozone, carbon monoxide, carbon dioxide, and methane.

Moderate Resolution Imaging Spectroradiometer

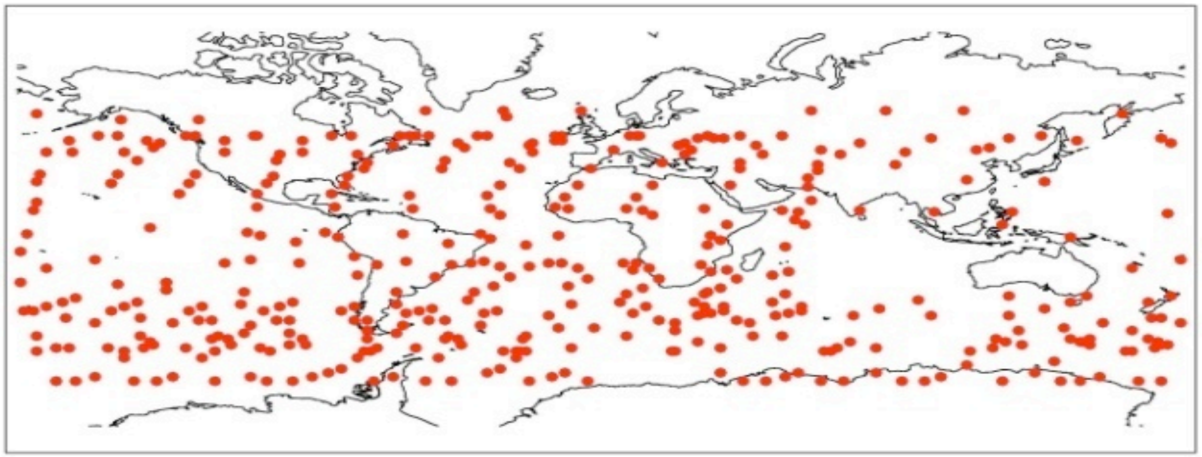
RGB Composite
Cloud Optical Thickness
Cloud Top Pressure
Cloud Effective Radius
Aerosol Optical Depth

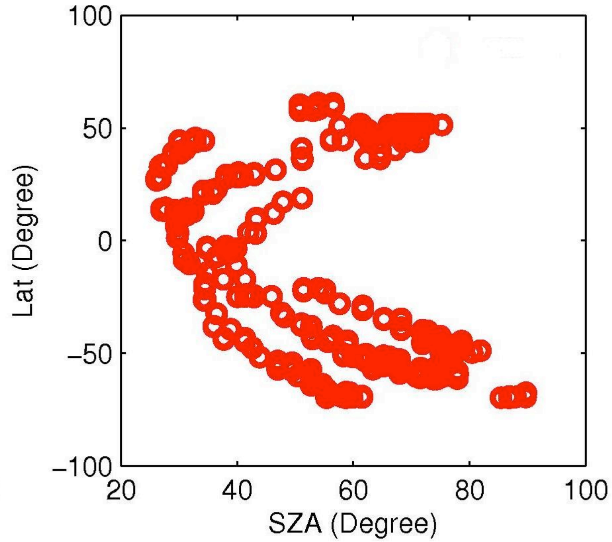
Clouds and the Earth's Radiant Energy System

Solar-reflected and Earth-emitted radiation from the top of the atmosphere to the Earth's surface.

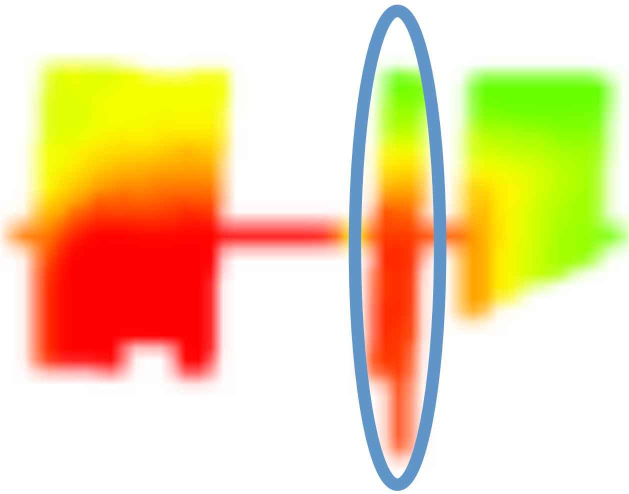
Test data dataset

- 450 co-locations of a SAGE II occultation measurement with a SCIAMACHY limb scattering measurement over a one-year period.
- Forward model run with
  - ozone profile = SAGE II
  - solar view angles = SCIAMACHY
  - surface albedo = 0.15, aerosol = constant = climatology
  - atmosphere Temperature/Pressure = NCEP reanalysis





Steps 3 and 5:Tangent Height registration:



→Base: Use spacecraft state vector and attitude

→Fine tune: Use the RSAS technique with all CCD pixels around 350nm, comparing data vs model (model run with NCEP Temperature/Pressure profiles)

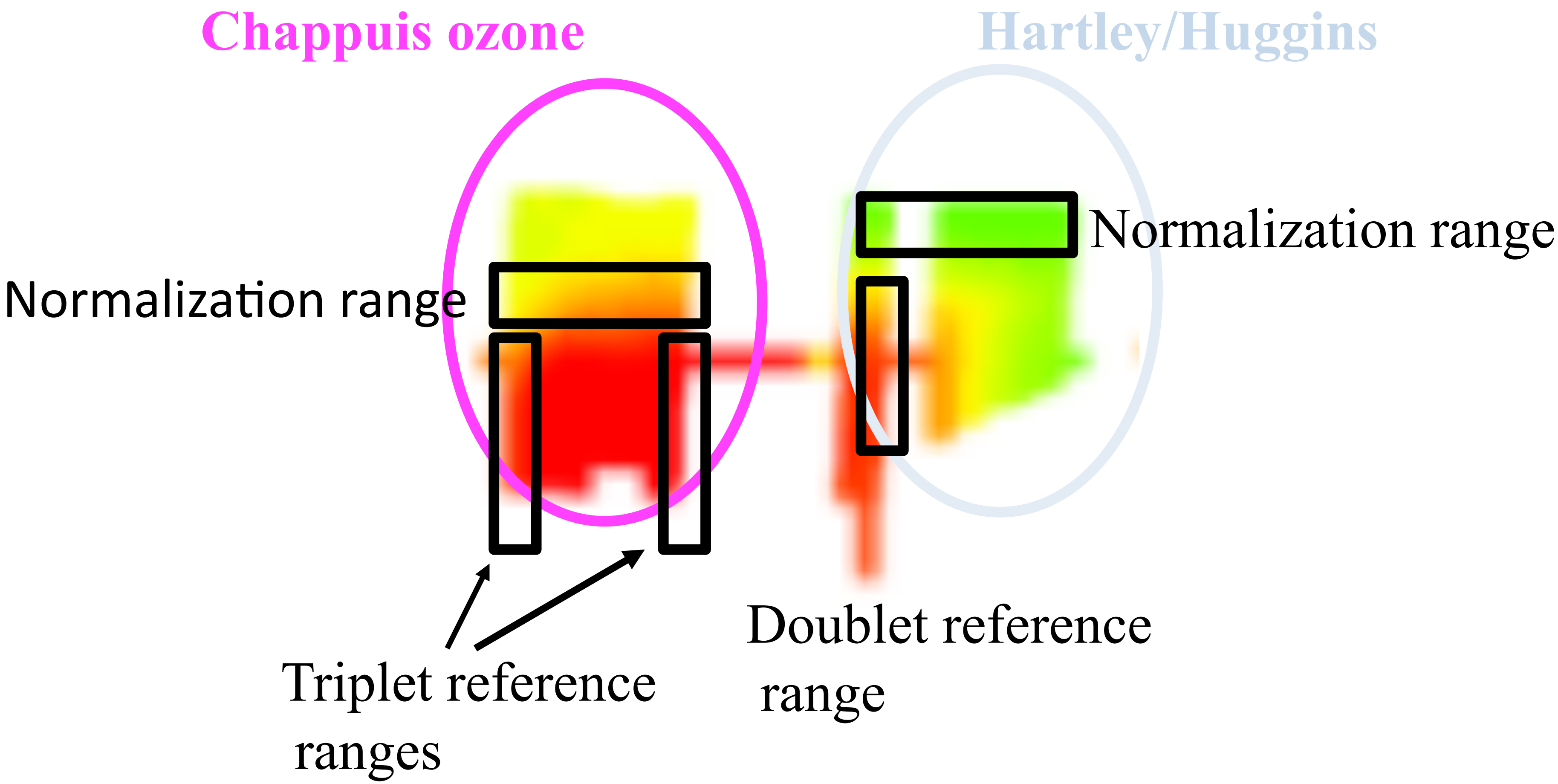
→ Fine tune 2: Extend RSAS to wavelengths up to 500nm

Spectral channels selection for ozone retrieval

Parameters	Values
TH_{NORM} (Doublet)	65 km
$\mathrm{TH}_{\mathrm{NORM}}$ (Triplet)	45 km
Doublet λ_0	355 nm
Triplet λ_L	500 nm
Triplet λ_R	680 nm
Wavelengths used in UV (nm)	289.3 289.8 290.3 290.9 291.4 292.0 293.1 293.6 294.2 294.7 295.2 295.8 296.5 297.0 297.6 298.2 298.8 299.4 300.0 300.6 301.2 301.8 302.4 303.0 308.9 309.5 310.1 310.8 311.6 318.0 318.7 319.4 320.2 320.9 321.7
Wavelengths used in visible (nm)	522.8 526.3 549.9 554.3 572.1 576.9 602.5 608.1 613.4 619.624.8 630.9 637.4 643.4 649.7

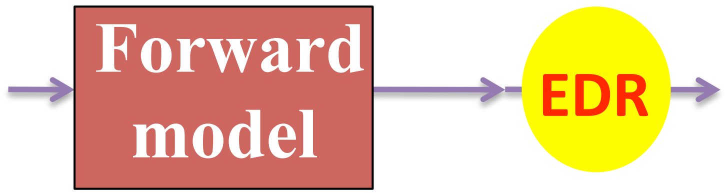
Steps 6 and 7: ozone retrieval

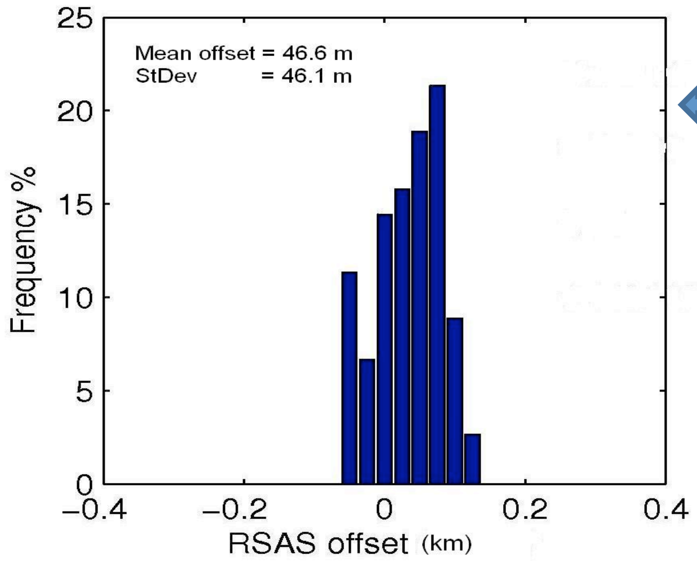
- **Method relies on Doublet/Triplet**



- **Doublet/Triplet measurement vectors used in Optimal Estimation**

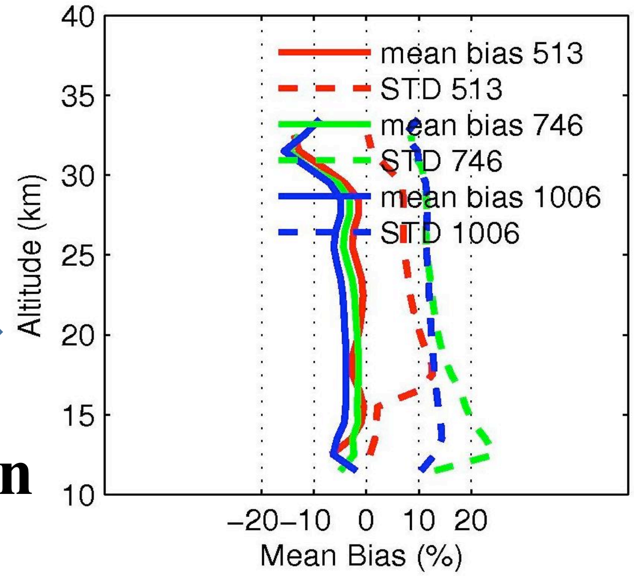
Comparison Retrievals vs Inputs

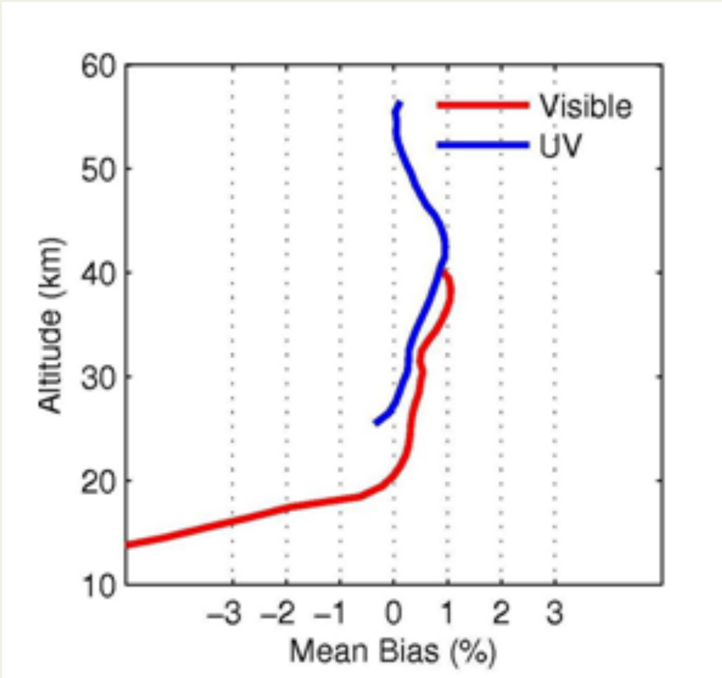




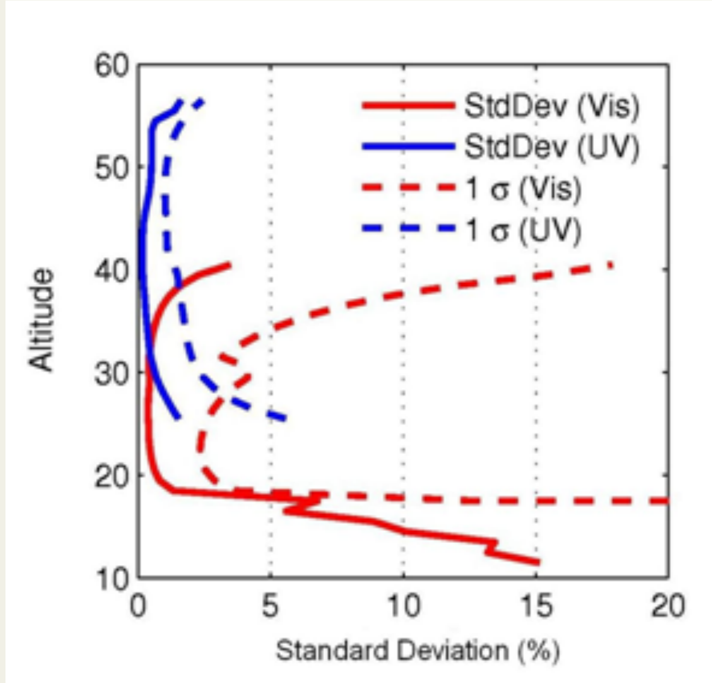
RSAS

Aerosol extinction



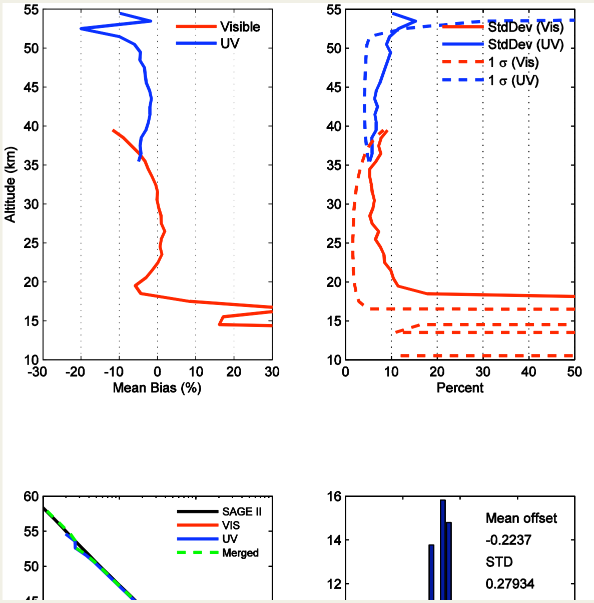


Ozone retrieval

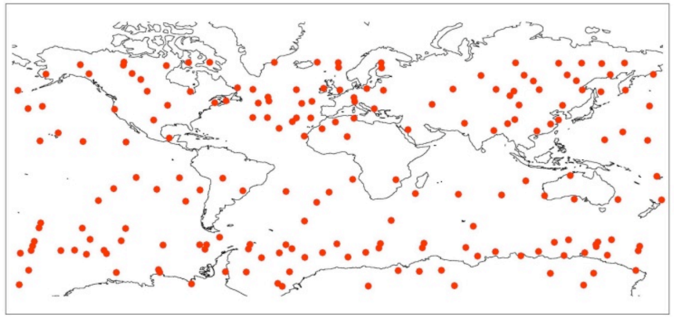


EDR testing with OSIRIS proxy radiances

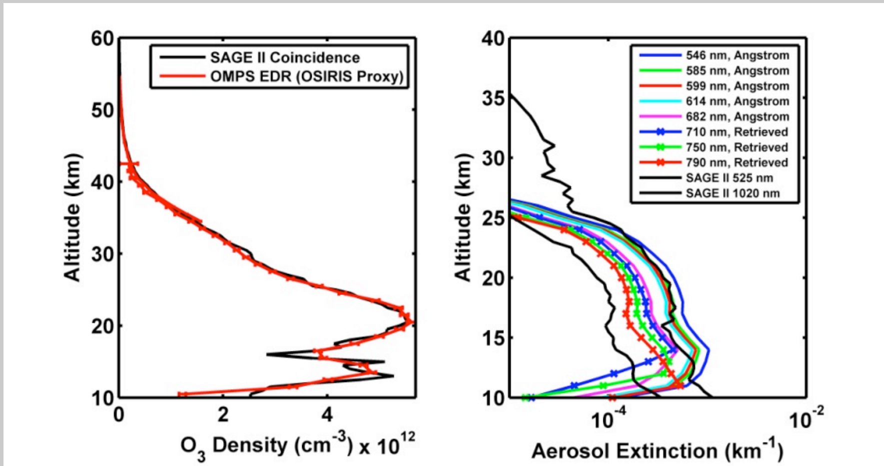
Ozone retrievals



200 LS events close to SAGE II

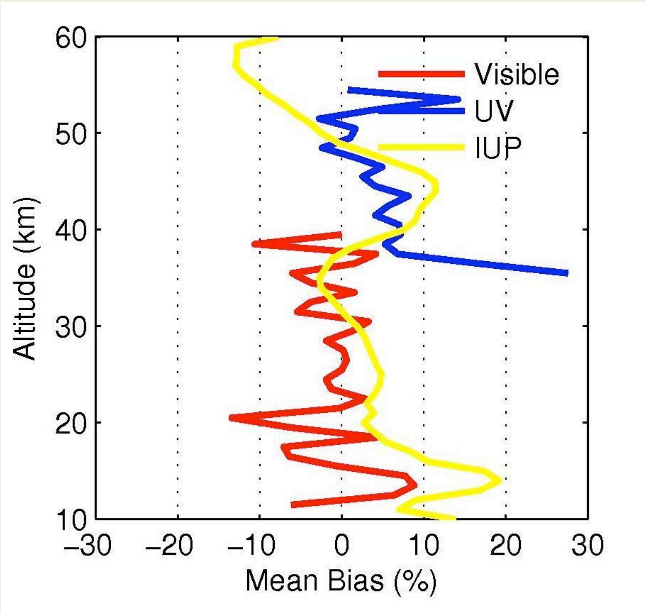


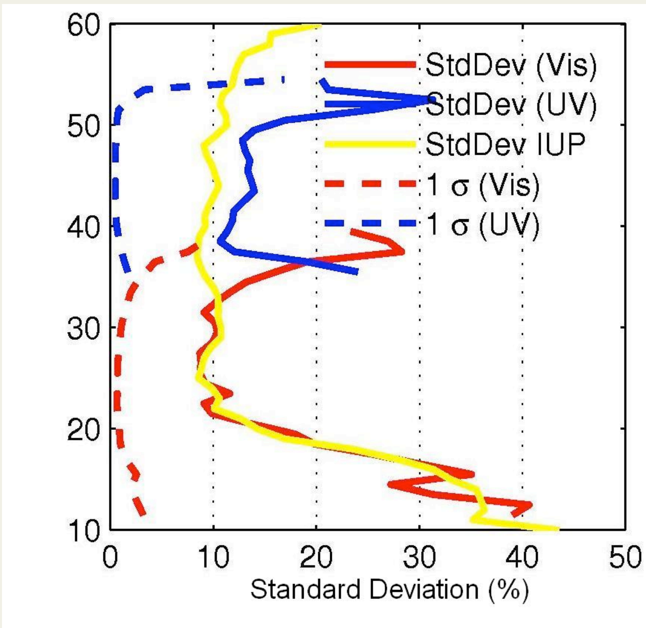
Typical ozone and aerosol retrievals



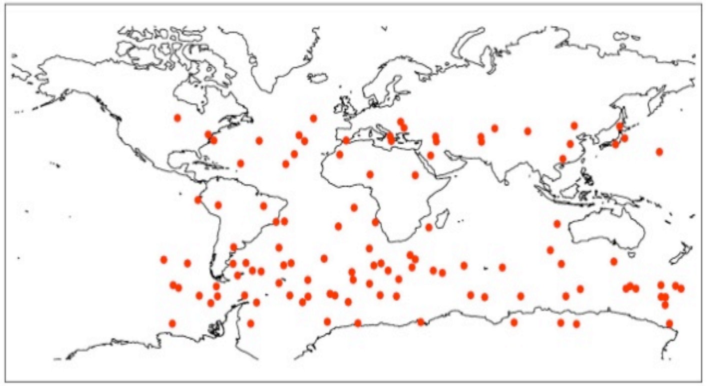
EDR testing with SCIAMACHY proxy radiances

Ozone retrievals

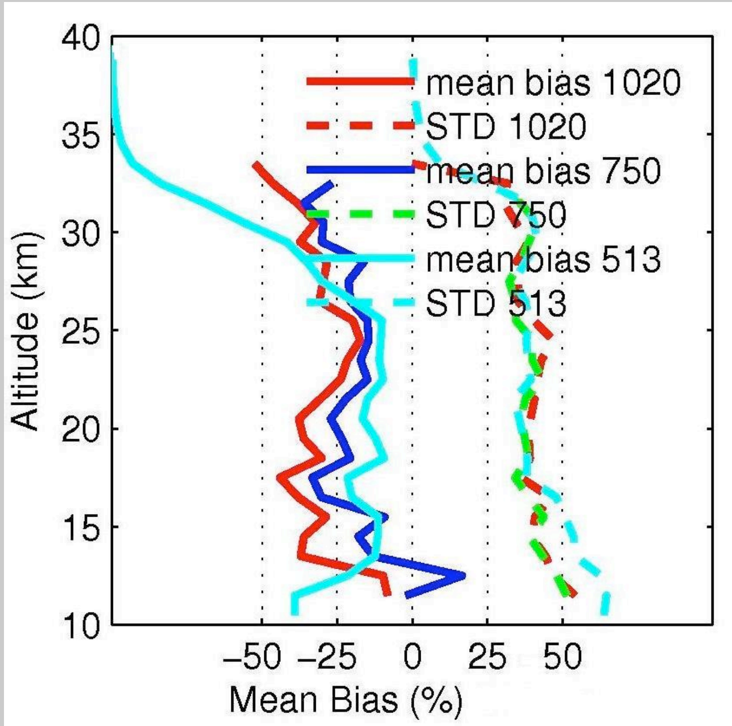




120 LS events close to SAGE II

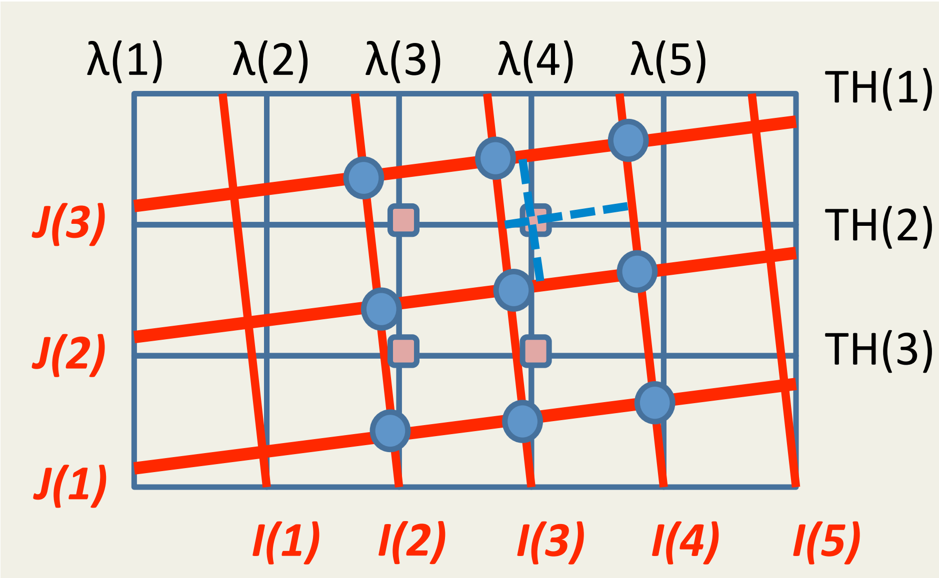


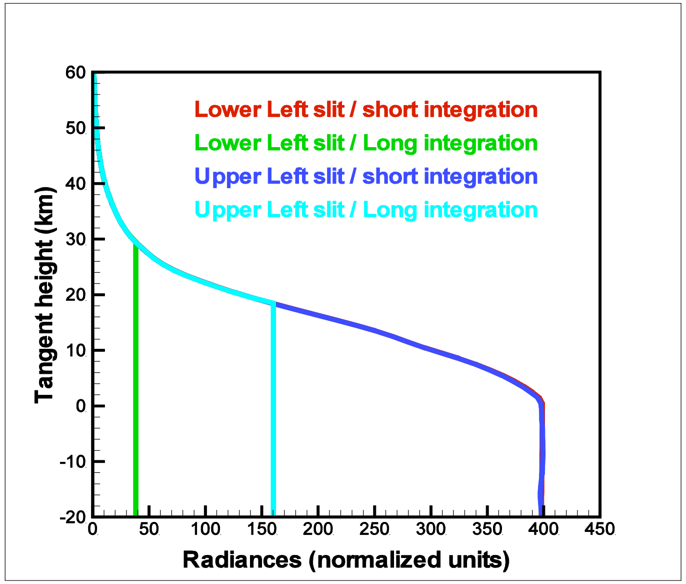
Aerosol retrievals



Three main EDR methods:

1. Mainstream: CCD data, 2D gridding, 4 gain consolidation





2. Direct Optimal Estimation: operate directly on ensemble of CCD pixels

3. Spectral fitting: DOAS on both data and model

Spectral channel selection

Wavelength range (nm)	Altitude range (km)	Useage
290-295	50-60	Ozone
295-300	47-53	Ozone
300-305	43-53	Ozone
305-315	38-45	Ozone
315-325	28-38	Ozone
340-360	whole FOV	RSAS, Straylight
360-500	whole FOV	Straylight
500-520	10-50	Aerosol, albedo
525-675	10-50	Ozone
660-680	10-45	Aerosol, albedo, cloud top
740-750	10-45	Aerosol, albedo, cloud top
840-860	10-45	Aerosol, albedo, cloud top
900-920	10-45	Aerosol, albedo, cloud top
960	10-30	Cloud top
All wavelengths	25, 30	Wavelength registration

Present performance assessment