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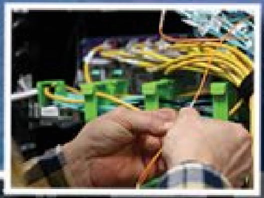

TPU from Atmospheric Correction of Landsat 8 OLI Imagery

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KBR, contractor to the U.S. Geological Survey (USGS)
Earth Resources Observations and Science (EROS) Center, Sioux Falls, SD 57198, USA.
Work performed under USGS Contract [G15PCXXXXX].

U.S. Department of the Interior
U.S. Geological Survey

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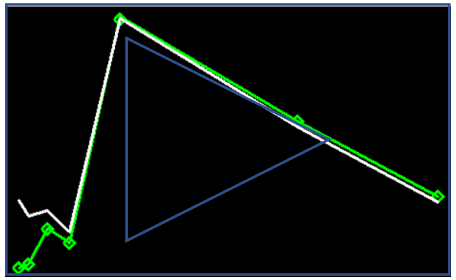
Total Propagated Uncertainty due to Atmospheric Correction of Landsat 8 OLI Imagery

TPU

$$J \cdot \Sigma \cdot J^T$$

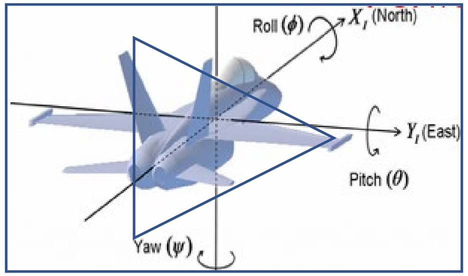
Atmospheric Correction



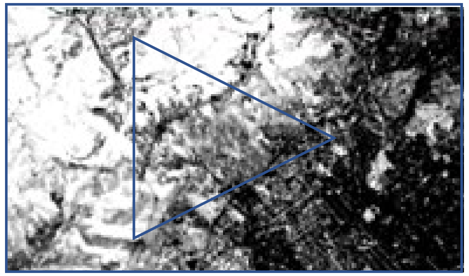
TPU gov. Eq. ATCOR

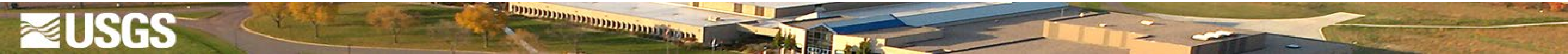
$$\left(\sigma_{\rho_i}\right)^2 = \left(\frac{\partial \rho_i}{\partial \tau_a}\sigma_{\tau_a}\right)^2$$

Lidar TPU (position data)



TPU example (NDVI)





TPU, Uncertainty Chain

Radiance, or TOAR → SR (ATCOR) → ARD or harmonization (resampling, etc) → Derived products (LCMAP, etc)

Sat. Imagery (OLI)

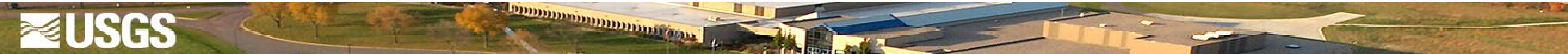
SAR, Lidar data

x → σ_x

y → σ_y

z → σ_z

ρ_{B1}, ρ_{B2}, ρ_R, ρ_G, ρ_{NIR}, ρ_{SW1}, ρ_{SW2} → $\sigma_{\rho_{B1}}$, $\sigma_{\rho_{B2}}$, σ_{ρ_G}, σ_{ρ_R}, $\sigma_{\rho_{NIR}}$, $\sigma_{\rho_{SW1}}$, $\sigma_{\rho_{SW2}}$



Each and every pixel ?

Each and every point ?

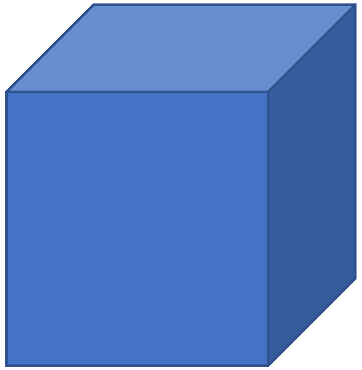
NAVY & NOAA (sonar & lidar)

FIDUCEO (satellite imagery)

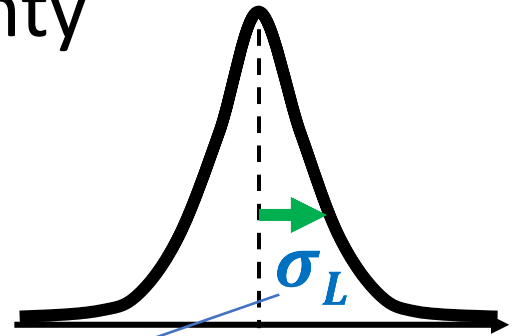
FIDUCEO is funded by the Horizon 2020 Framework Programme of the European Union.

Fidelity and uncertainty in climate data records from Earth Observations

Total Propagation of uncertainty



$V = L^3 \longrightarrow \Delta V = \frac{dV}{dL}\Delta L$



Repeated length measurement

$$\sigma_V = 3L^2 \cdot \sigma_L$$

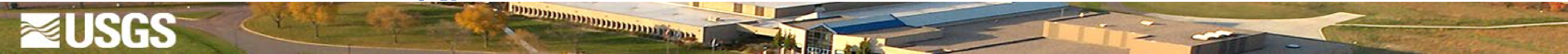
volume uncertainty ← Propagates through (vol) Equation ← Length uncertainty

Total uncertainty due to ATCOR ← Propagates through ATCOR Equation ← Multiple uncertainty sources from Atmosphere (aerosol, O_3, H_2O, P, SZA, VZA,…)

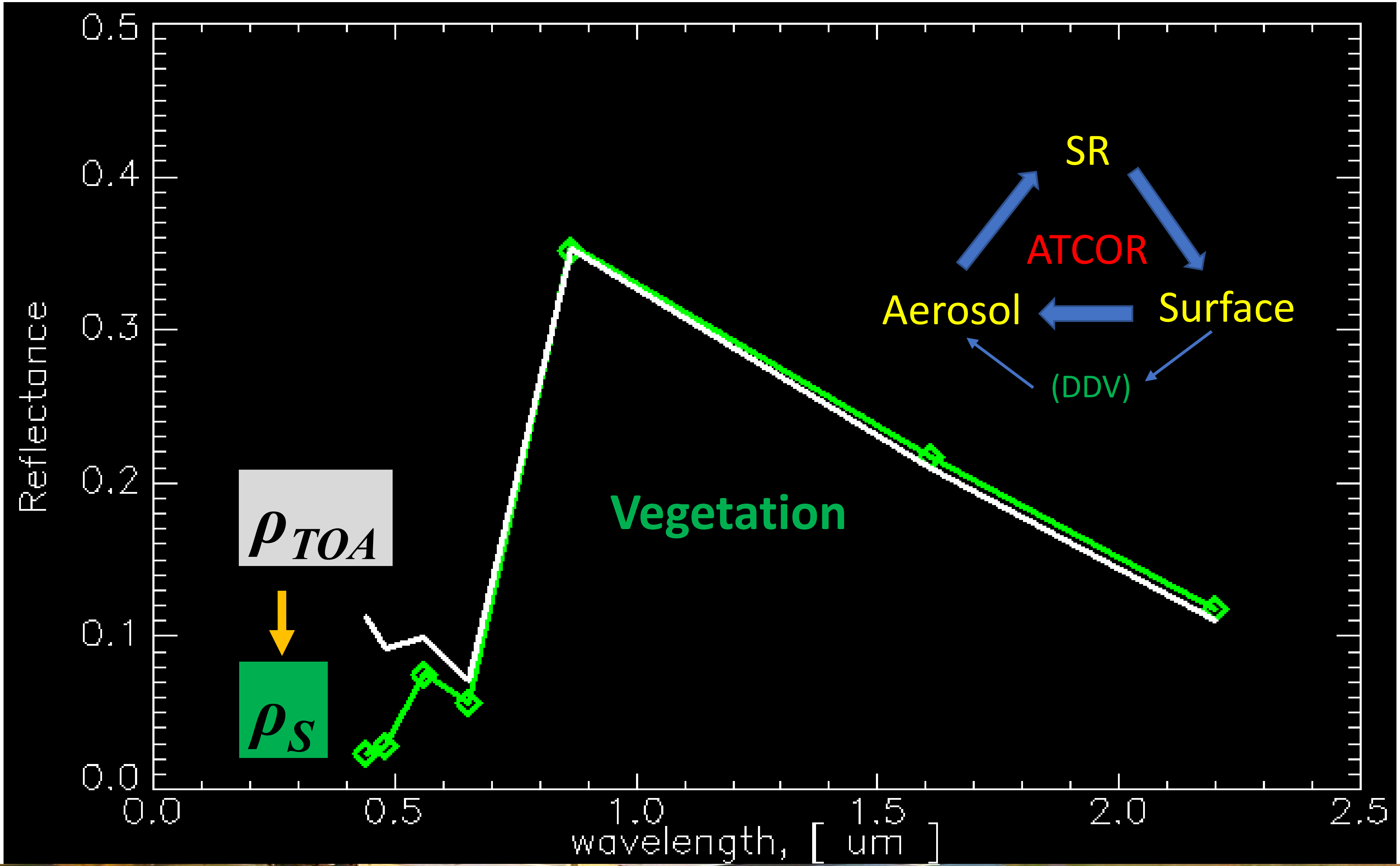
L8 OLI $\begin{matrix}\sigma_{\rho_{B1}} \\ \sigma_{\rho_{B2}} \\ \sigma_{\rho_G} \\ \sigma_{\rho_R}\end{matrix} = TPU = J \cdot \Sigma \cdot J^T$

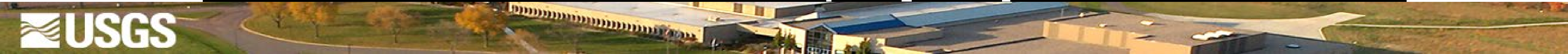
(1)Define ATCOR equation

(2)Derive Jacobian

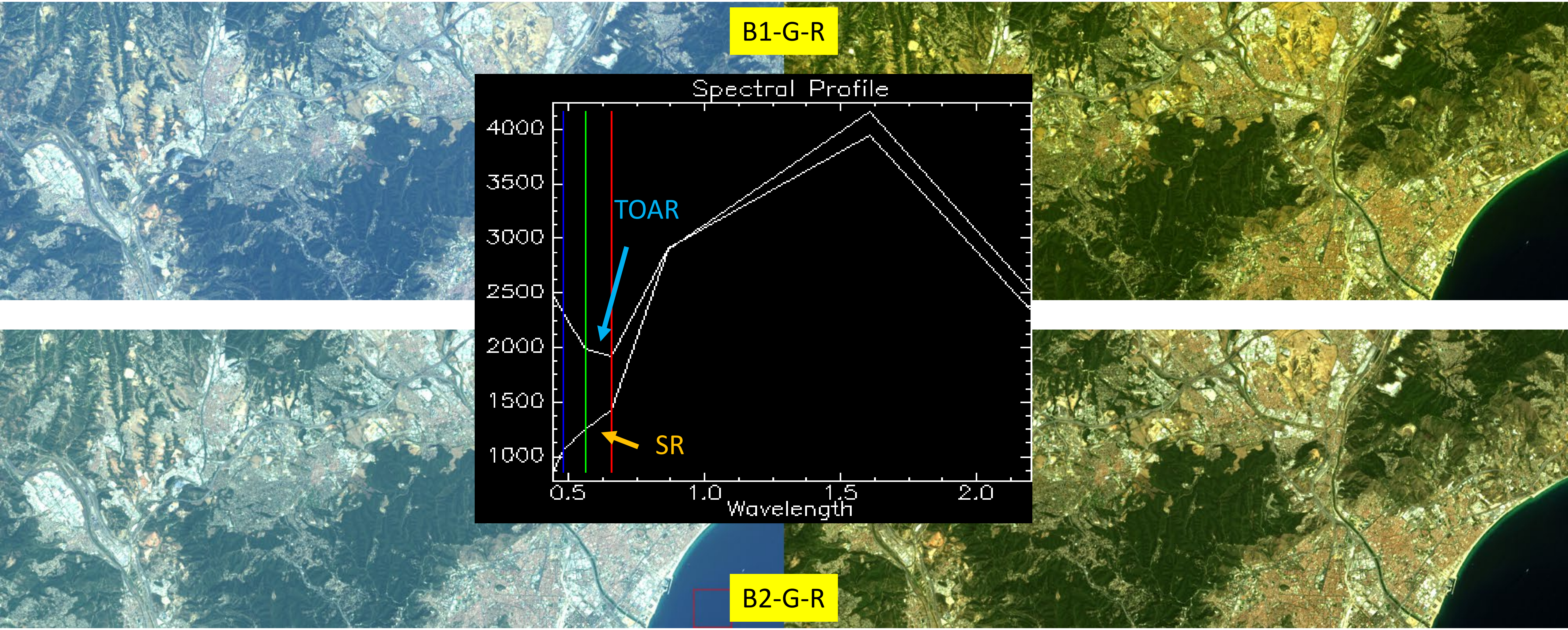


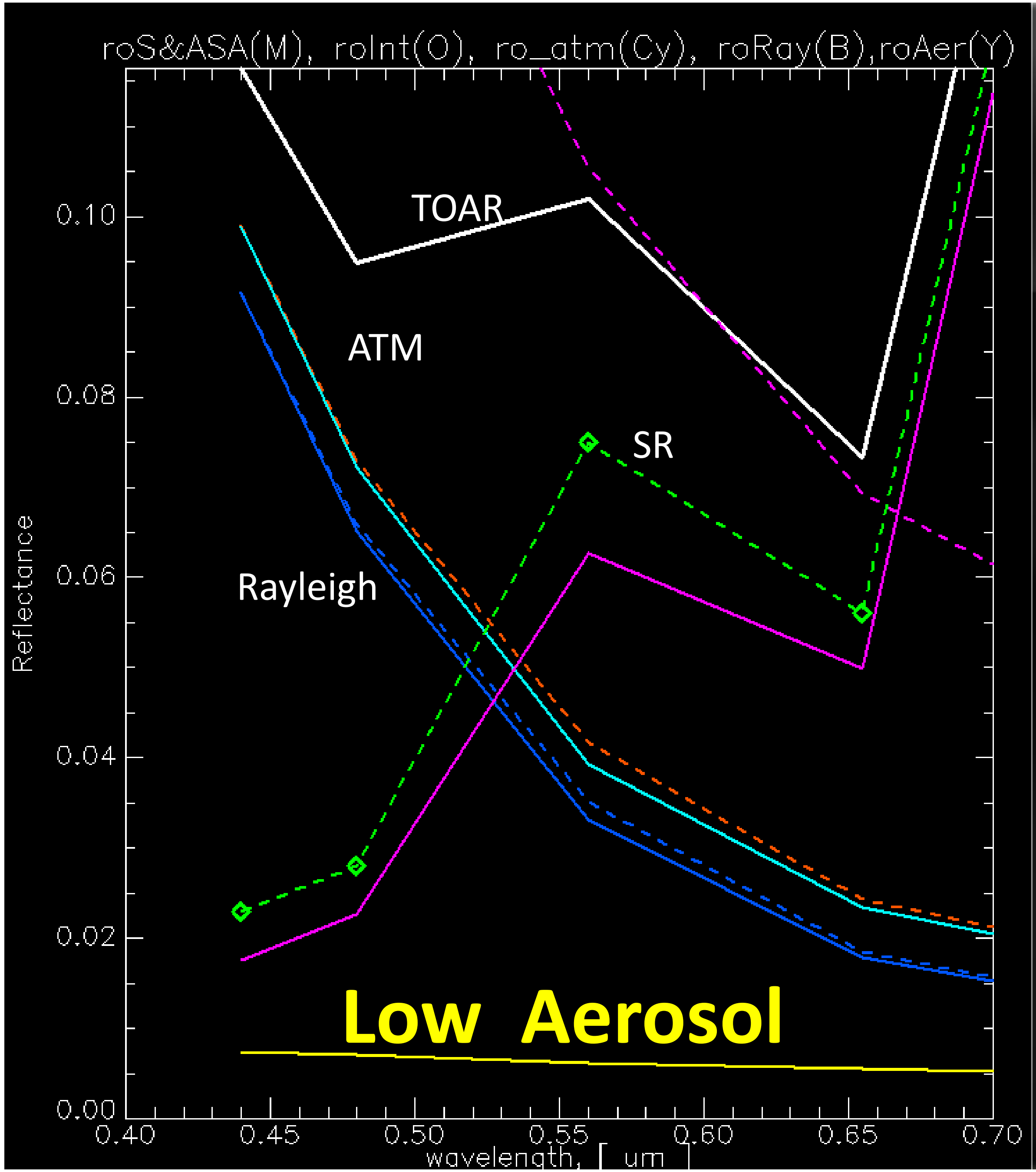
Atmospheric Correction

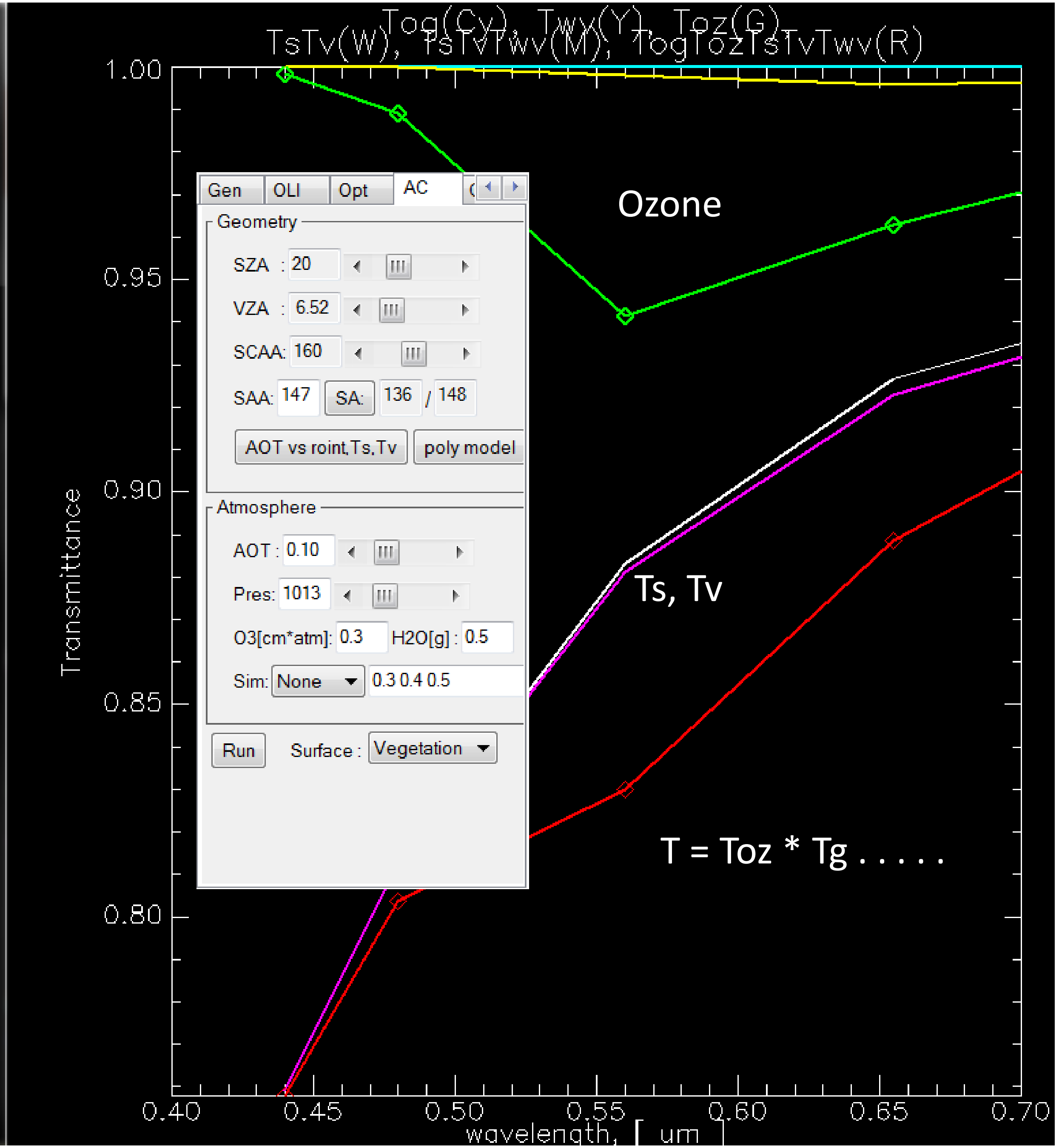




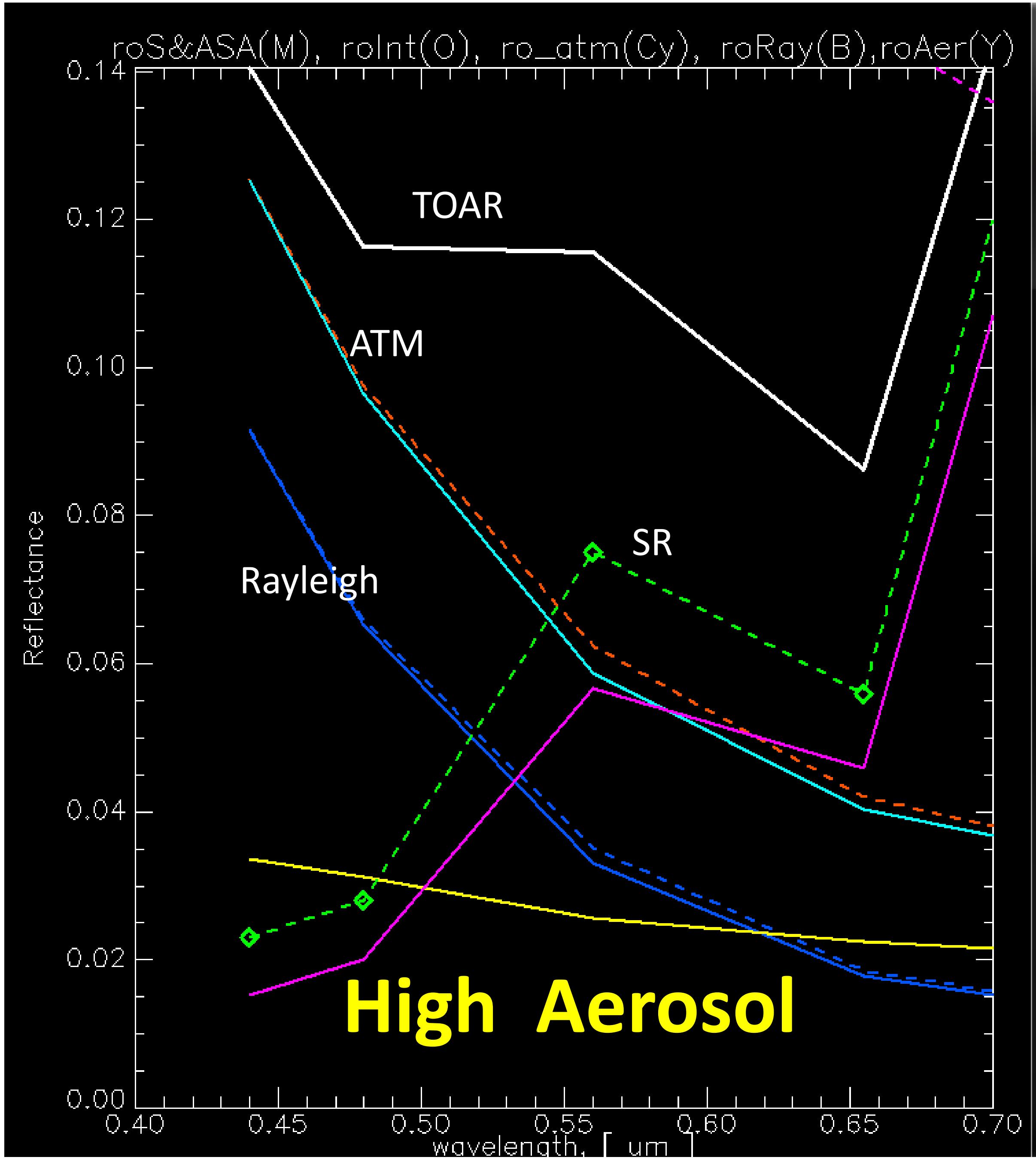
TOAR → Atmospheric Correction → SR

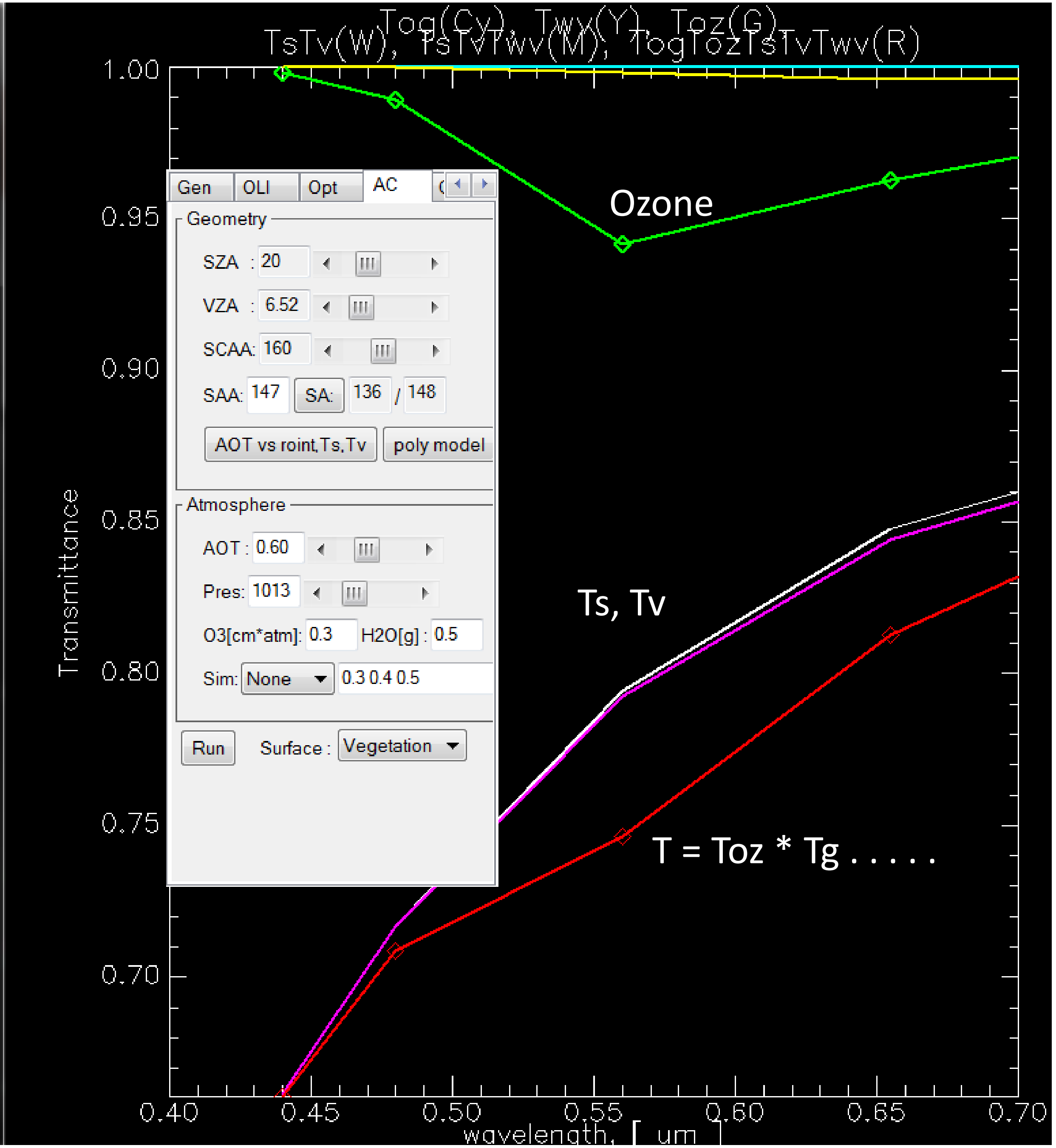



roS&ASA(M), roInt(O), ro_atm(Cy), roRay(B),roAer(Y)
Reflectance
0.10
0.08
0.06
0.04
0.02
0.00
0.40
0.45
0.50
0.55
0.60
0.65
0.70
wavelength, [um]
TOAR
ATM
SR
Rayleigh
Low Aerosol

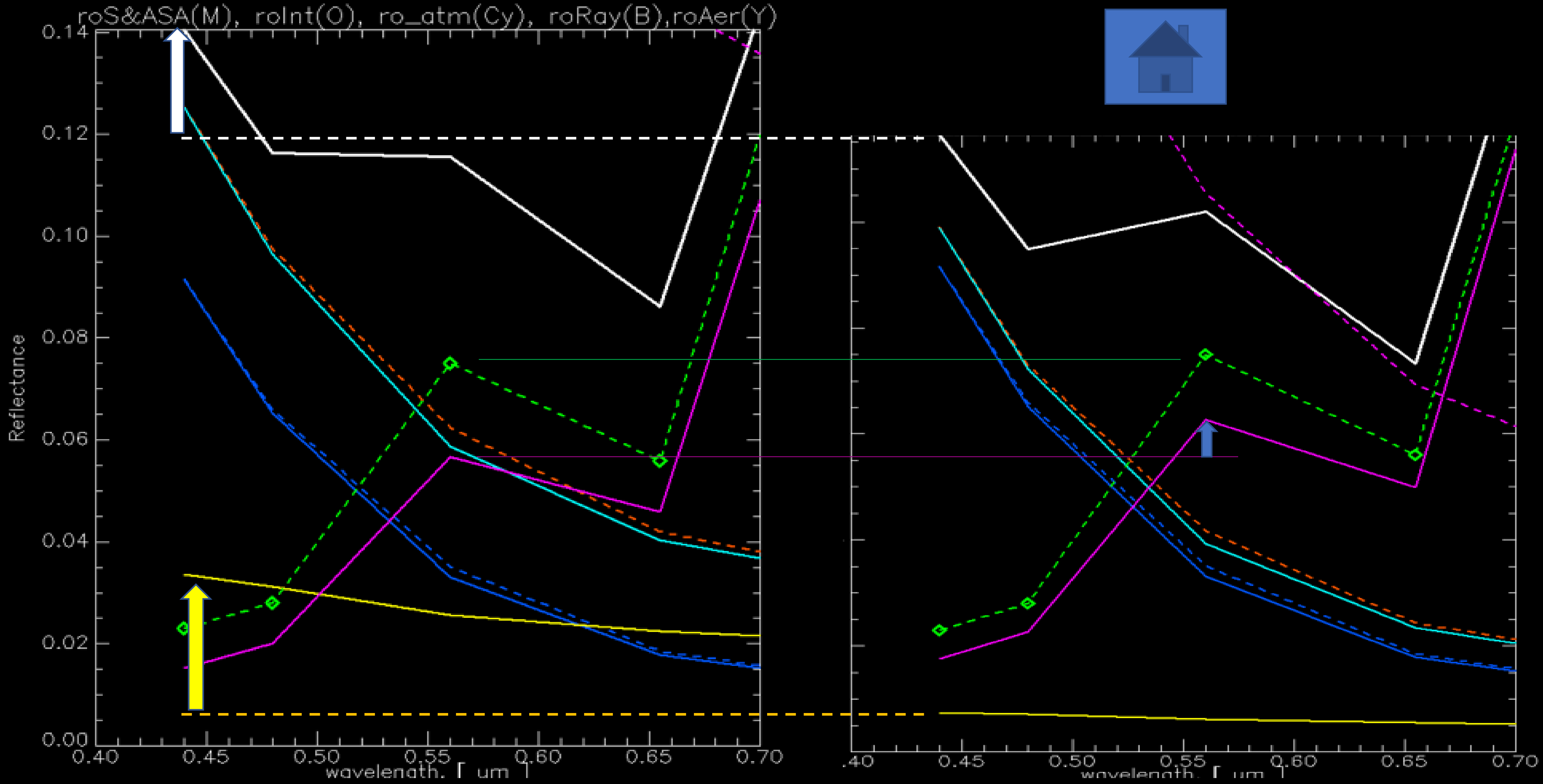

Tog(Cy), Twv(Y), Toz(G),
TsTv(W), TsTvTwv(M), TogTozTsTvTwv(R)
Transmittance
1.00
0.95
0.90
0.85
0.80
0.40
0.45
0.50
0.55
0.60
0.65
0.70
wavelength, [um]
Ozone
Ts, Tv
T = Toz * Tg . . . . .
Gen
OLI
Opt
AC
Geometry
SZA : 20
VZA : 6.52
SCAA: 160
SAA: 147
SA: 136 / 148
AOT vs roint,Ts,Tv
poly model
Atmosphere
AOT : 0.10
Pres: 1013
O3[cm*atm]: 0.3
H2O[g] : 0.5
Sim: None
0.3 0.4 0.5
Run
Surface : Vegetation

USGS


roS&ASA(M), roInt(O), ro_atm(Cy), roRay(B),roAer(Y)
TOAR
ATM
SR
Rayleigh
High Aerosol
Reflectance
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.40
0.45
0.50
0.55
0.60
0.65
0.70
wavelength, [um]


Tog(Cy), Twv(Y), Toz(G)
TsTv(W), TsTvTwv(M), TogTozTsTvTwv(R)
Transmittance
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.40
0.45
0.50
0.55
0.60
0.65
0.70
wavelength, [um]
Ozone
Ts, Tv
T = Toz * Tg . . . . .
Gen
OLI
Opt
AC
Geometry
SZA : 20
VZA : 6.52
SCAA: 160
SAA: 147
SA: 136 / 148
AOT vs roint,Ts,Tv
poly model
Atmosphere
AOT : 0.60
Pres: 1013
O3[cm*atm]: 0.3
H2O[g] : 0.5
Sim: None
0.3 0.4 0.5
Run
Surface : Vegetation

USGS



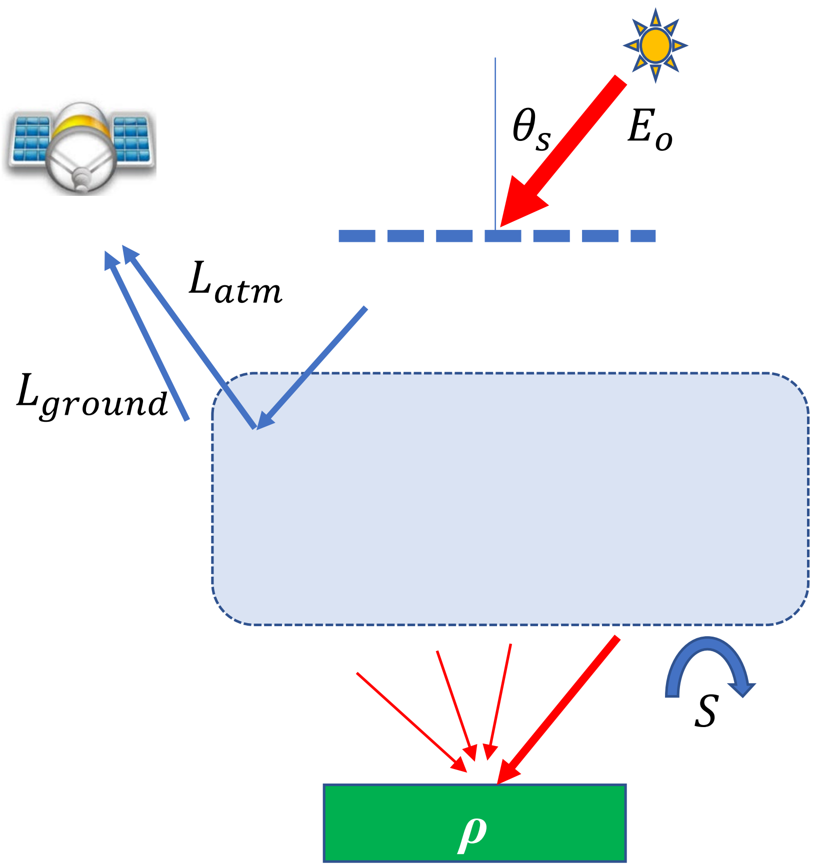
roS&ASA(M), roInt(O), ro_atm(Cy), roRay(B),roAer(Y)
Reflectance
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.40
0.45
0.50
0.55
0.60
0.65
0.70
wavelength, [um]

USGS

Governing Eq.

$$L_{TOA} = L_{atm} + L_{ground}$$

$$\frac{\rho}{\pi} E_d \cdot \left(e^{-\tau/\mu_v} + t_d(\theta_v)\right)$$



$$L_{TOA} = L_{atm} + \frac{\rho}{\pi} \mu_s E_o \cdot \left(e^{-\tau/\mu_s} + t_d(\theta_s)\right) \frac{1}{1 - \rho S} \left(e^{-\tau/\mu_v} + t_d(\theta_v)\right)$$

$$L_{TOA} = L_{atm} + \frac{\rho}{\pi} \mu_s E_o \cdot T_s \frac{1}{1 - \rho S} T_v$$

$$\frac{\pi}{\mu_s E_o} \times$$

$$\rho_{TOA} = \rho_{atm} + \frac{\rho T_s T_v}{1 - \rho S}$$

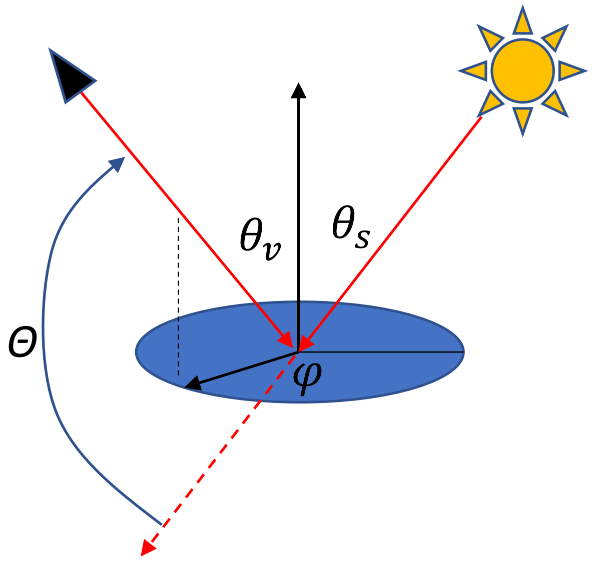
$$\rho_{TOA} = T_g^{og} T_g^{oz} T_g^{cwv} \left[\rho_{atm} + \frac{\rho T_s T_v}{1 - \rho S} \right]$$

$$E_d = \mu_s E_o \cdot \left(e^{-\tau/\mu_s} + t_d(\theta_s)\right) \frac{1}{1 - \rho S}$$

total downwelling irradiance

$$\rho_{TOA} = T_g^{og} T_g^{oz} T_g^{cwv} \left[\{(\rho_{atm}^{int} - \rho_{Ray}) \cdot T_{g,Half}^{cwv} + \rho_{Ray}\}/T_g^{cwv} + \frac{\rho T_s T_v}{1 - \rho S} \right]$$

6S modification (Coupling: Abs-Scat interaction)



$\cos\Theta = -\cos\theta_s\cos\theta_v - \cos\varphi\,\sin\theta_s\sin\theta_v$

$= -\mu_s\mu_v - \cos\varphi\,\sqrt{1-\mu_s\mu_s}\sqrt{1-\mu_v\mu_v}$

scattering angle

$$\boldsymbol{\rho_i = f(\rho_{TOA\_i}, \lambda_i; \tau_a, P, U_{oz}, U_{wv}, \theta_s, \theta_s, \varphi)}$$

SR

$\boldsymbol{\sigma_{\theta_s}, \sigma_{\theta_v}, \sigma_{\varphi}} \sim 0$

$$\boldsymbol{\rho_i = f(\rho_{TOA\_i}, \lambda_i; \tau_a, P, U_{oz}, U_{wv})}$$

$$\boldsymbol{TPU = J \cdot \Sigma \cdot J^T}$$

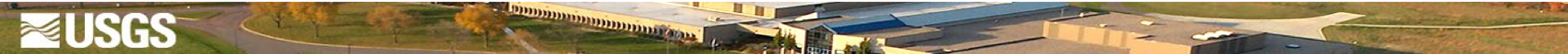
$$\begin{bmatrix} \sigma_{\rho_1} \\ \vdots \\ \sigma_{\rho_N} \end{bmatrix} = \begin{bmatrix} \frac{\partial \rho_1}{\partial \tau_a} & \cdots & \frac{\partial \rho_1}{\partial U_{wv}} \\ \vdots & \ddots & \vdots \\ \frac{\partial \rho_N}{\partial \tau_a} & \cdots & \frac{\partial \rho_N}{\partial U_{wv}} \end{bmatrix} \left[\begin{bmatrix} \sigma^2_{\tau_a} & \cdots & \sigma_{U_{wv}}\sigma_{\tau_a} \\ \vdots & \ddots & \vdots \\ \sigma_{\tau_a}\sigma_{U_{wv}} & \cdots & \sigma^2_{U_{wv}} \end{bmatrix} \right] \begin{bmatrix} \frac{\partial \rho_1}{\partial \tau_a} & \cdots & \frac{\partial \rho_N}{\partial \tau_a} \\ \vdots & \ddots & \vdots \\ \frac{\partial \rho_1}{\partial U_{wv}} & \cdots & \frac{\partial \rho_N}{\partial U_{wv}} \end{bmatrix}$$

Assuming negligible covariances

$$(\sigma_{\rho_i})^2 = \left(\frac{\partial \rho_i}{\partial \tau_a}\sigma_{\tau_a}\right)^2 + \left(\frac{\partial \rho_i}{\partial P}\sigma_P\right)^2 + \left(\frac{\partial \rho_i}{\partial U_{oz}}\sigma_{U_{oz}}\right)^2 + \left(\frac{\partial \rho_i}{\partial U_{wv}}\sigma_{U_{wv}}\right)^2$$

TPU after ATCOR	ATCOR TPU	Before-ATCOR TPU (Rad.Corr. Etc)

$$(\sigma_{\rho_i})^2 <= (\sigma_{\rho_i})^2 + (\sigma_{TOA\_i})^2$$



Surface reflectance Equation (← Atmospheric Correction)

$$\rho = \frac{\frac{\rho_{TOA}}{T_g} - \rho_{atm}^{int}}{T_s T_v + \left(\frac{\rho_{TOA}}{T_g} - \rho_{atm}^{int}\right) \cdot S}, T_g = T_g^{og} T_g^{oz} T_g^{cwv}$$

SR

$$(\sigma_{\rho_i})^2 = \left(\frac{\partial \rho_i}{\partial \tau_a}\sigma_{\tau_a}\right)^2 + \left(\frac{\partial \rho_i}{\partial P}\sigma_P\right)^2 + \left(\frac{\partial \rho_i}{\partial U_{oz}}\sigma_{U_{oz}}\right)^2 + \left(\frac{\partial \rho_i}{\partial U_{wv}}\sigma_{U_{wv}}\right)^2 + \cdots$$

0 0 0

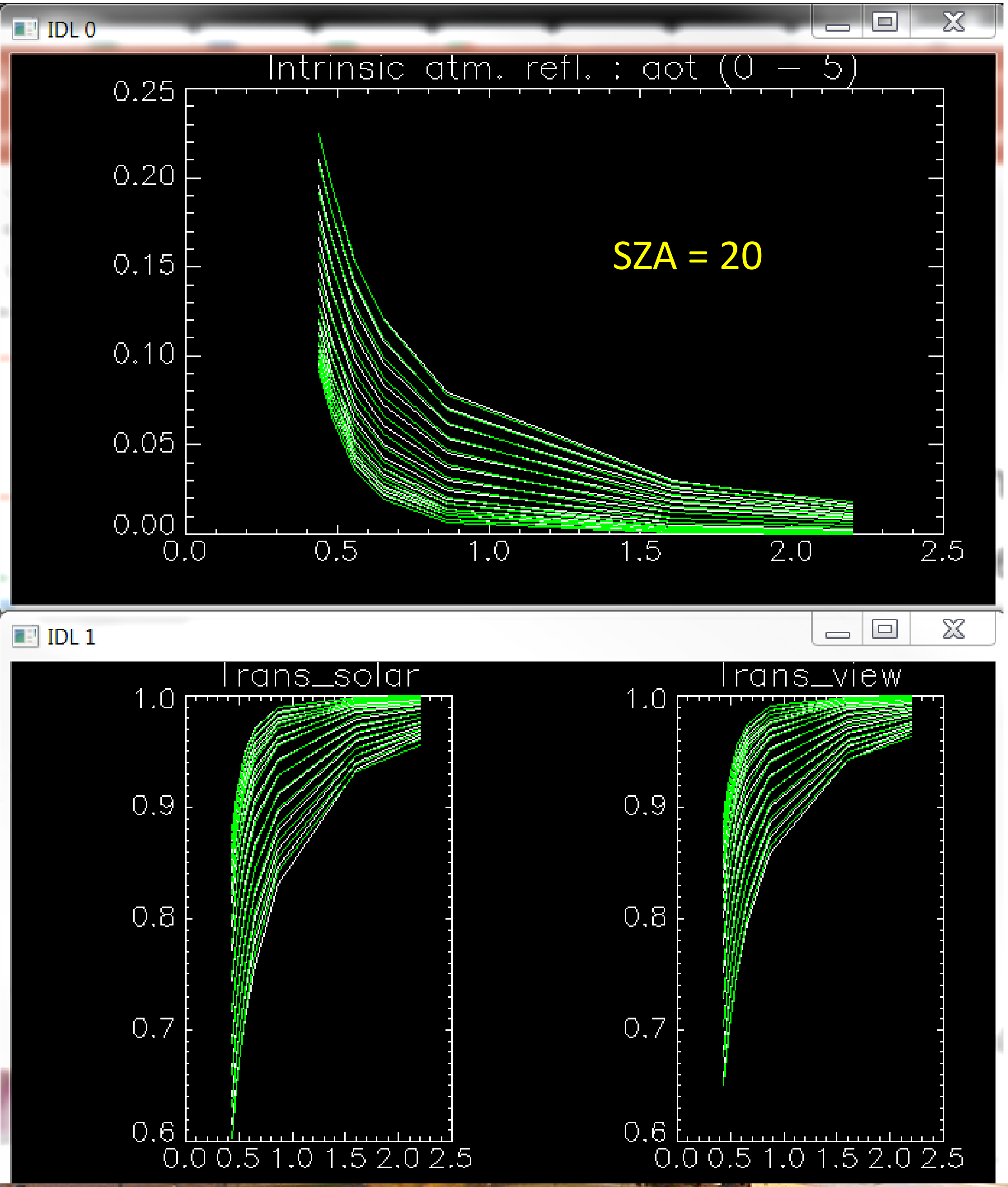
τ_a terms : $F(\tau_a)$

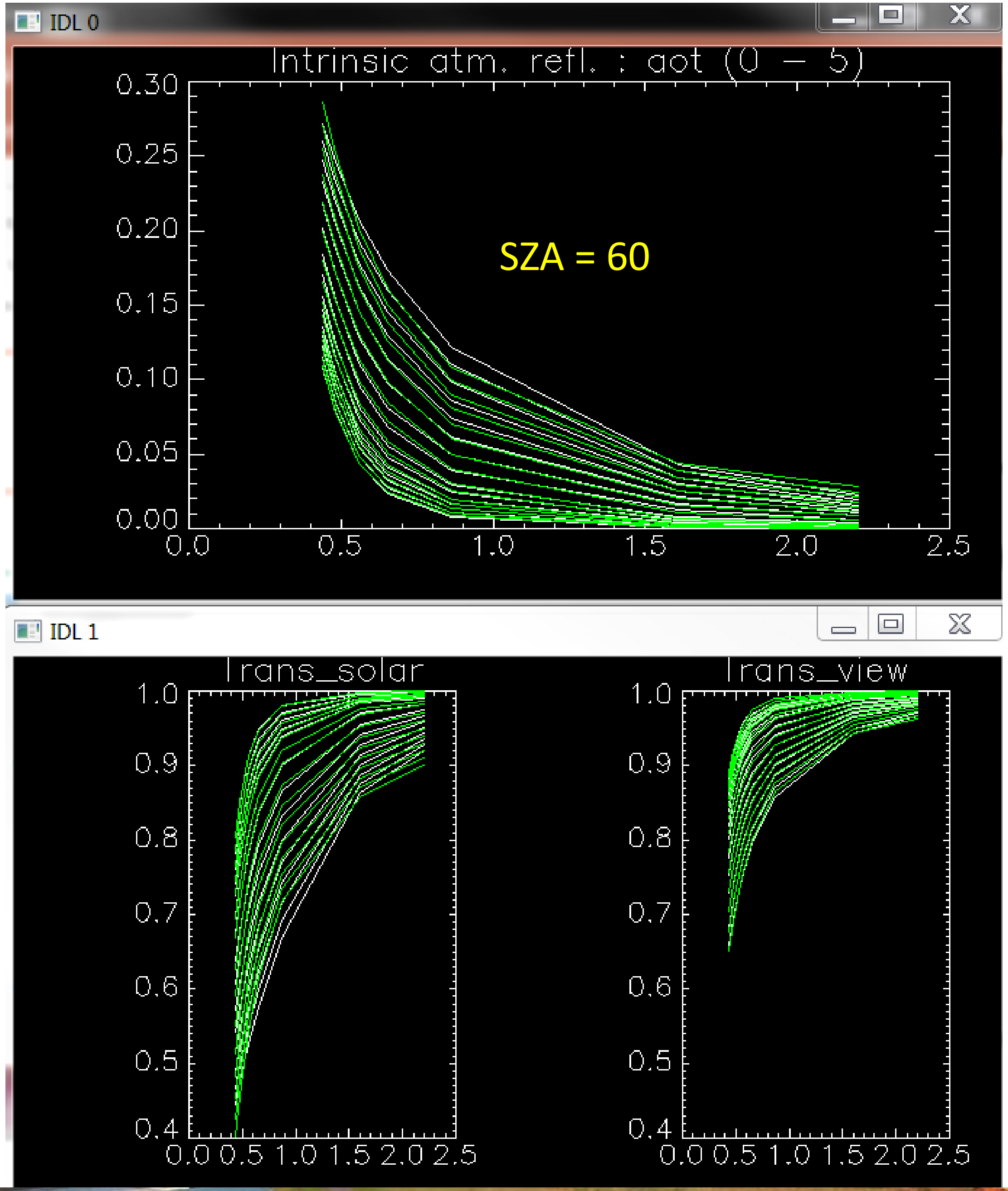
$$\frac{\partial \rho}{\partial \tau_a} = \frac{-\frac{\partial \rho_{atm}^{int}}{\partial \tau_a}\left[T_s T_v + \left(\frac{\rho_{TOA}}{T_g} - \rho_{atm}^{int}\right) S\right] - \left(\frac{\rho_{TOA}}{T_g} - \rho_{atm}^{int}\right)\left[\frac{\partial T_s}{\partial \tau_a} T_v + \frac{\partial T_v}{\partial \tau_a} T_s + \left(\frac{\rho_{TOA}}{T_g}\right)\frac{\partial S}{\partial \tau_a} - \left(\frac{\partial \rho_{atm}^{int}}{\partial \tau_a} S + \rho_{atm}^{int}\frac{\partial S}{\partial \tau_a}\right)\right]}{\left[T_s T_v + \left(\frac{\rho_{TOA}}{T_g} - \rho_{atm}^{int}\right) S\right]^2}$$

τ_a derivative terms : $\partial F(\tau_a)/\partial \tau_a$

$T_s \sim f(\lambda; P, \tau_a, \theta_s)$ $S \sim f(\lambda; P, \tau_a)$

$T_v \sim f(\lambda; P, \tau_a, \theta_v)$ $\rho_{atm}^{int} \sim f(\lambda; P, \tau_a, \Theta)$


IDL 0
Intrinsic atm. refl. : aot (0 – 5)
SZA = 20
0.25
0.20
0.15
0.10
0.05
0.00
0.0 0.5 1.0 1.5 2.0 2.5
IDL 1
Trans_solar
Trans_view
1.0
0.9
0.8
0.7
0.6
0.0 0.5 1.0 1.5 2.0 2.5


IDL 0
Intrinsic atm. refl. : aot (0 – 5)
SZA = 60
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0 0.5 1.0 1.5 2.0 2.5
IDL 1
Trans_solar
Trans_view
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.0 0.5 1.0 1.5 2.0 2.5

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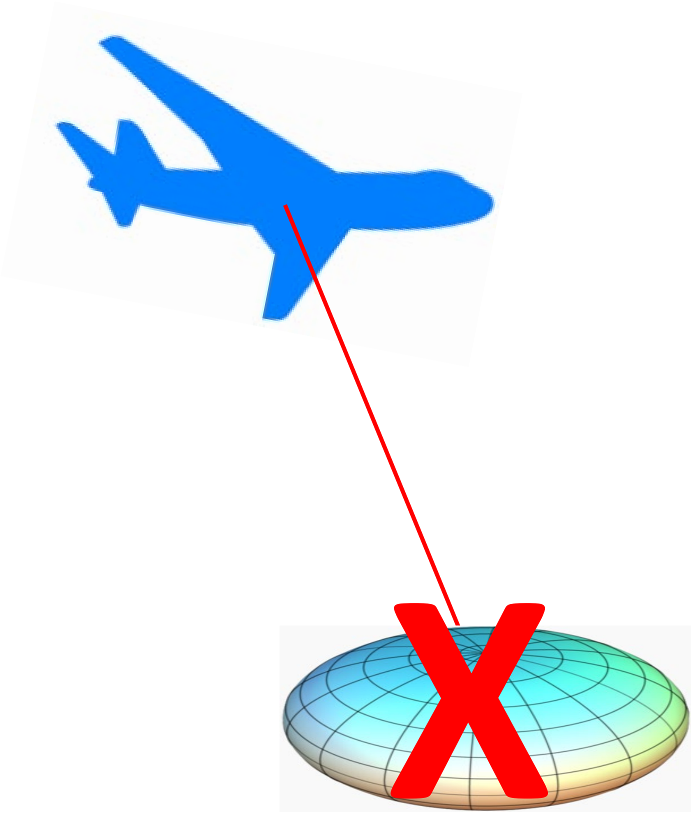
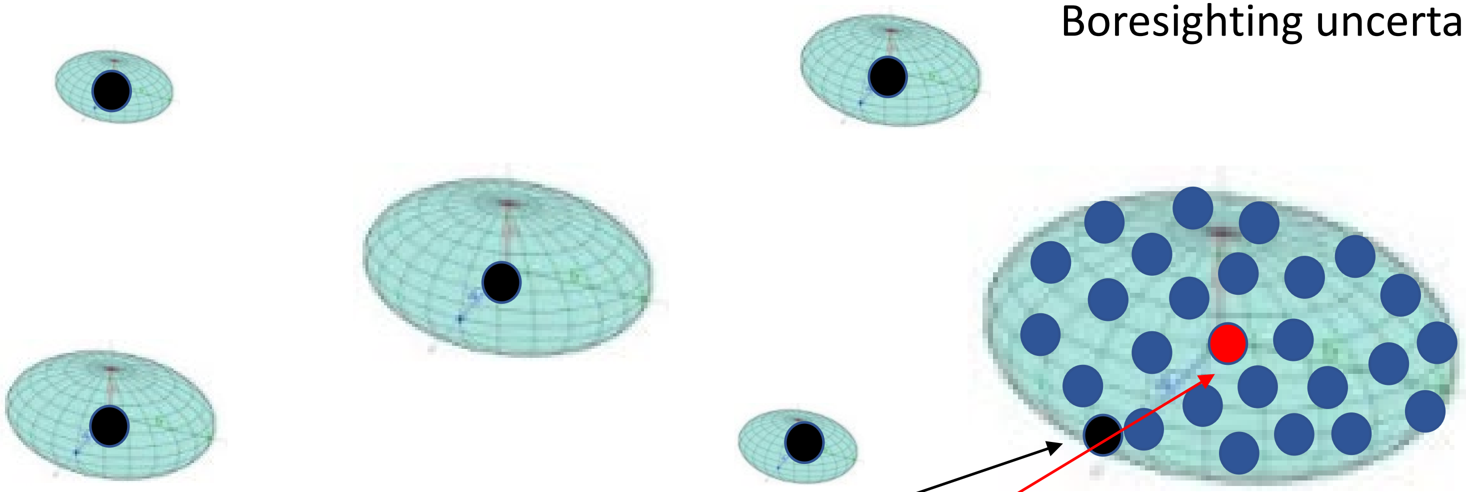
measurement uncertainty ← GNSS position uncertainty
IMU orientation uncertainty
Ranging uncertainty
Scanner uncertainty
Boresighting uncertainty



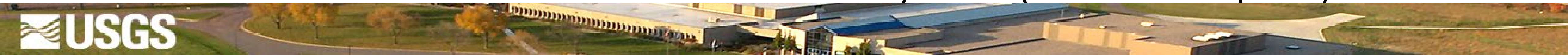
TPU ellipsoid



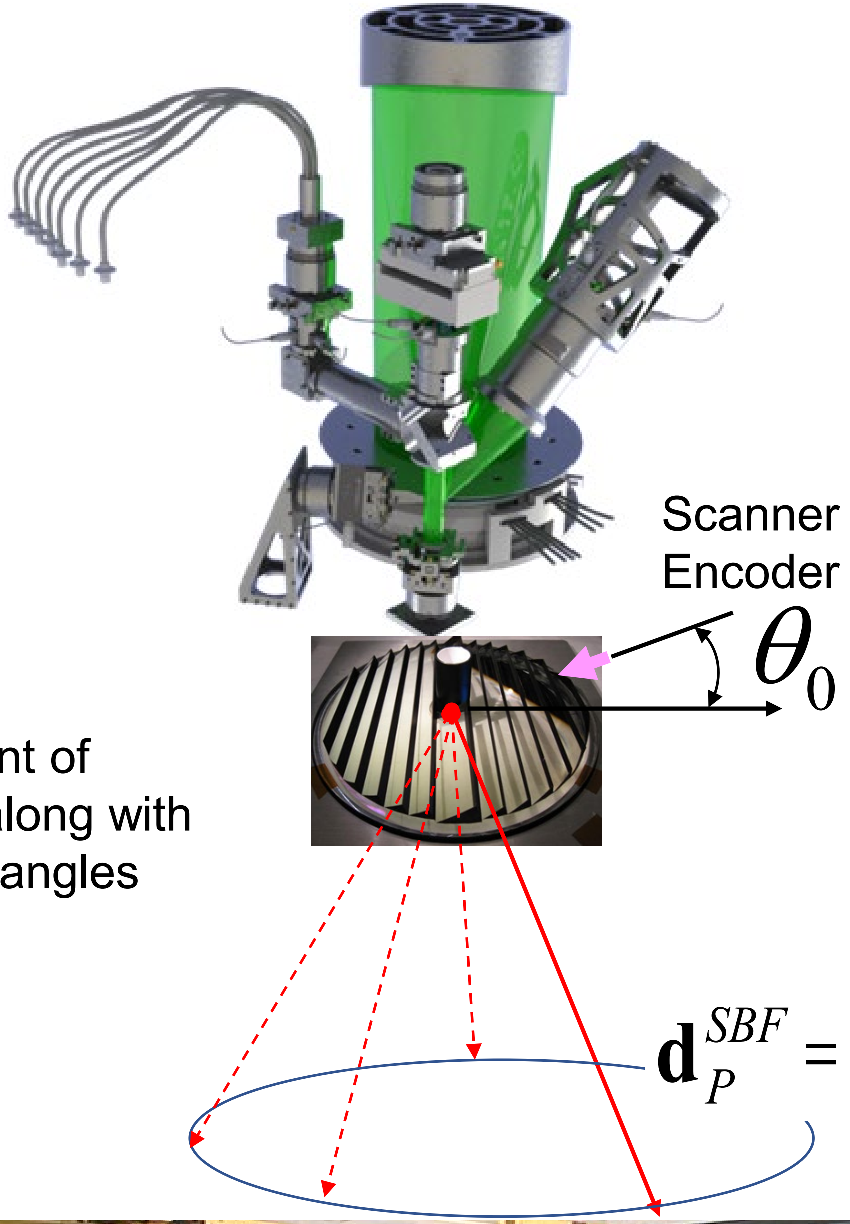
Lidar point : a specific realization based on measurement uncertainty

True point : unknown (exist only in the simulation)

TPU : uncertainty cloud (center : true point)



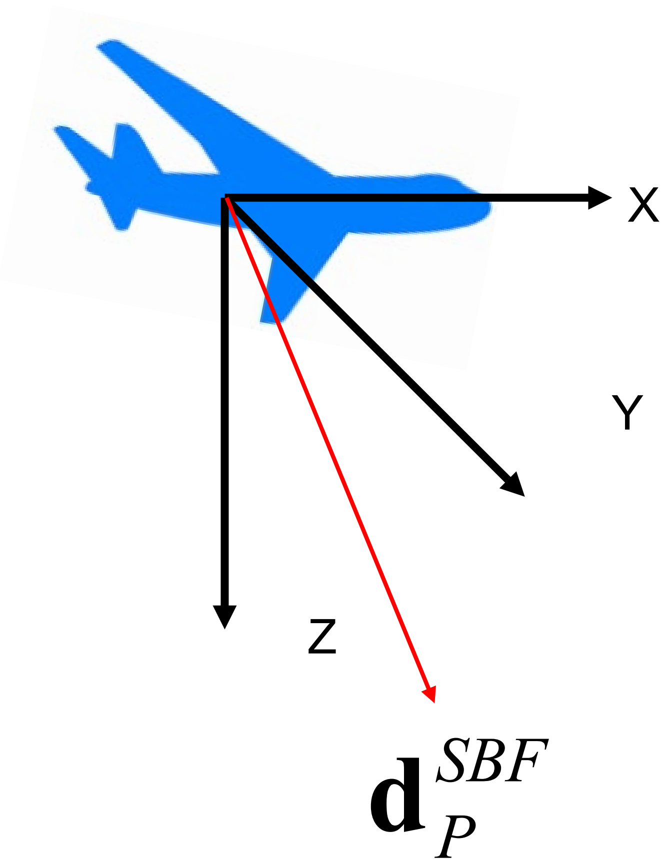
Direct Georeferencing of lidar point

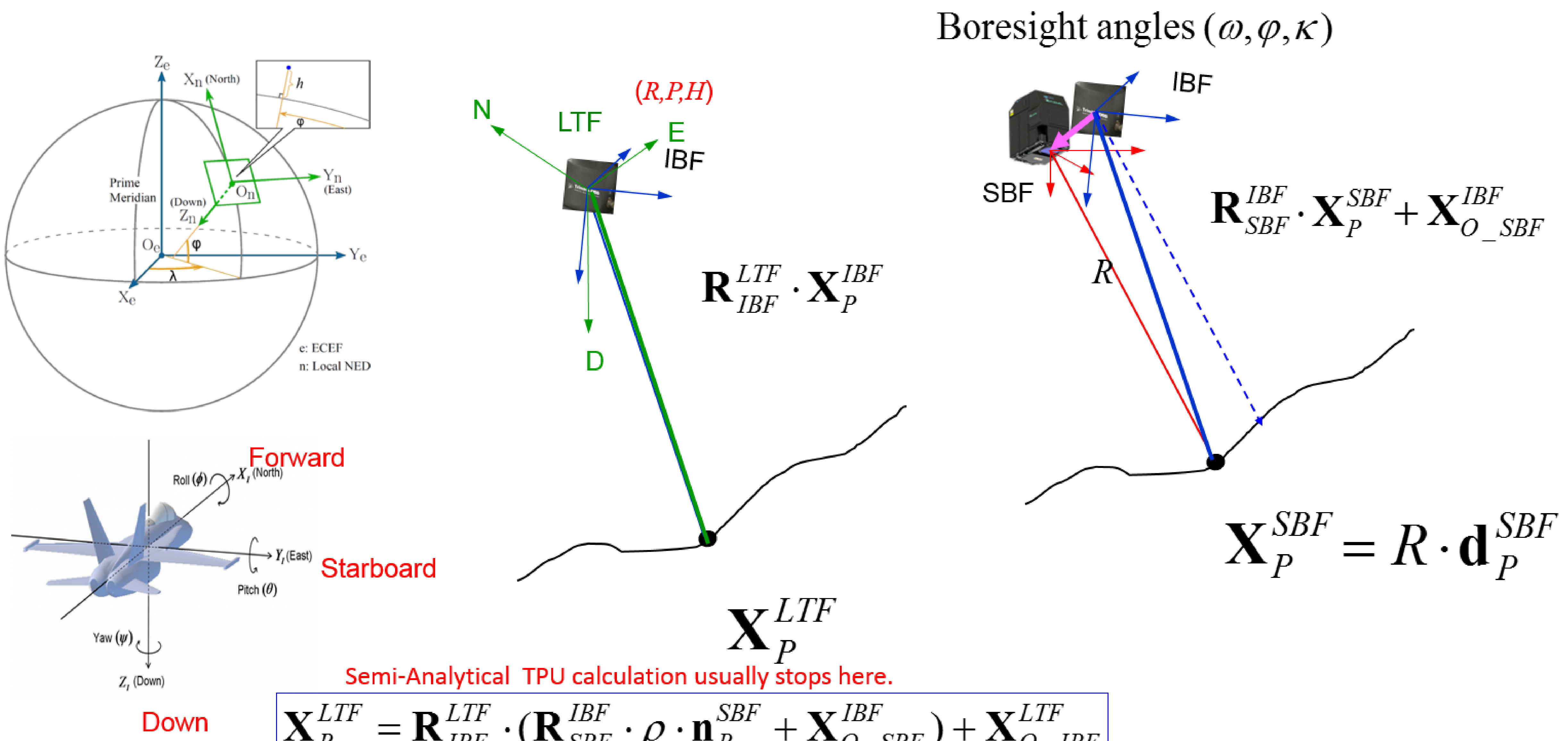


θ_0 : 4-th component of boresighting along with misalignment angles

$$\mathbf{d}_P^{SBF} = f(t, \theta_0)$$

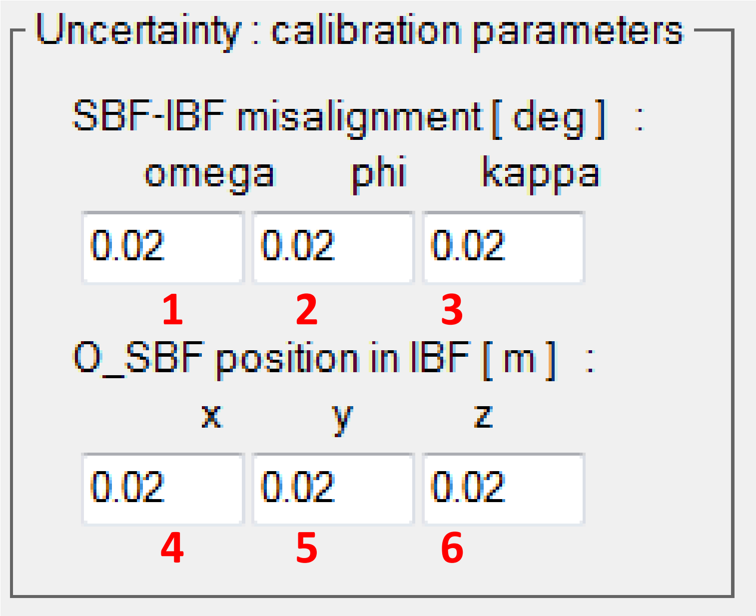
SBF (Sensor Body Frame)



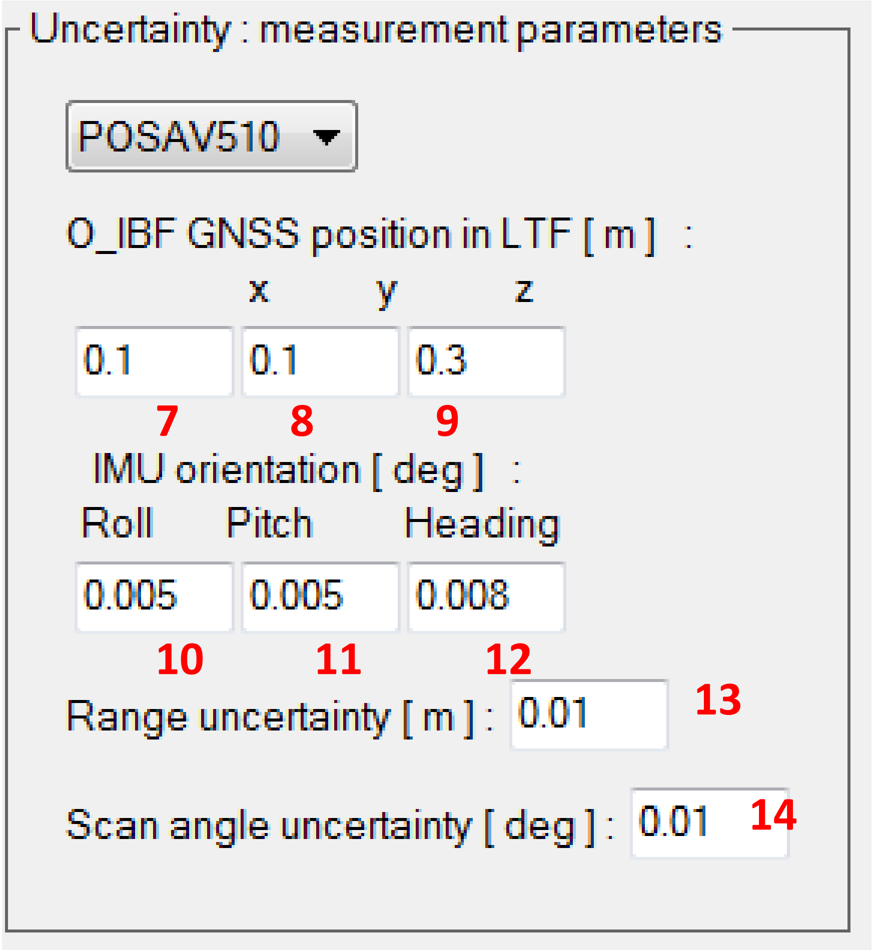


Semi-Analytical TPU calculation usually stops here.

$$\mathbf{X}_P^{LTF} = \mathbf{R}_{IBF}^{LTF} \cdot (\mathbf{R}_{SBF}^{IBF} \cdot \rho \cdot \mathbf{n}_P^{SBF} + \mathbf{X}_{O\_SBF}^{IBF}) + \mathbf{X}_{O\_IBF}^{LTF}$$



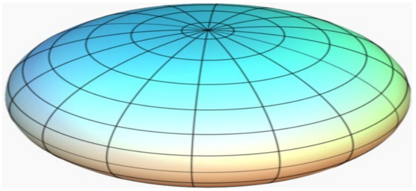
Uncertainty : calibration parameters
SBF-IBF misalignment [deg] :
omega
phi
kappa
0.02
0.02
0.02
1
2
3
O_SBF position in IBF [m] :
x
y
z
0.02
0.02
0.02
4
5
6



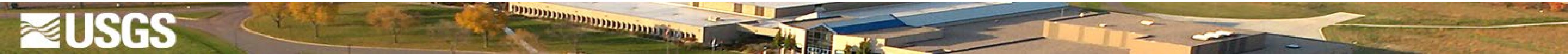
Uncertainty : measurement parameters
POSAV510
O_IBF GNSS position in LTF [m] :
x
y
z
0.1
0.1
0.3
7
8
9
IMU orientation [deg] :
Roll
Pitch
Heading
0.005
0.005
0.008
10
11
12
Range uncertainty [m] :
0.01
13
Scan angle uncertainty [deg] :
0.01
14

$$\begin{bmatrix} \sigma_x^2 & \sigma_x\sigma_y & \sigma_x\sigma_z \\ \sigma_y\sigma_x & \sigma_y^2 & \sigma_y\sigma_z \\ \sigma_z\sigma_x & \sigma_z\sigma_y & \sigma_z^2 \end{bmatrix} = \mathbf{J} \begin{bmatrix} \sigma_{x_0}^2 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & \sigma_\kappa^2 \end{bmatrix} \mathbf{J}^T$$

14 x 14



$$\mathbf{J} = \begin{bmatrix} \frac{\partial x}{\partial x_0} & \frac{\partial x}{\partial y_0} & \frac{\partial x}{\partial z_0} & \frac{\partial x}{\partial x_1} & \frac{\partial x}{\partial y_1} & \frac{\partial x}{\partial z_1} & \frac{\partial x}{\partial \rho} & \frac{\partial x}{\partial \theta} & \frac{\partial x}{\partial R} & \frac{\partial x}{\partial P} & \frac{\partial x}{\partial H} & \frac{\partial x}{\partial \omega} & \frac{\partial x}{\partial \varphi} & \frac{\partial x}{\partial \kappa} \\ \frac{\partial y}{\partial x_0} & \frac{\partial y}{\partial y_0} & \frac{\partial y}{\partial z_0} & \frac{\partial y}{\partial x_1} & \frac{\partial y}{\partial y_1} & \frac{\partial y}{\partial z_1} & \frac{\partial y}{\partial \rho} & \frac{\partial y}{\partial \theta} & \frac{\partial y}{\partial R} & \frac{\partial y}{\partial P} & \frac{\partial y}{\partial H} & \frac{\partial y}{\partial \omega} & \frac{\partial y}{\partial \varphi} & \frac{\partial y}{\partial \kappa} \\ \frac{\partial z}{\partial x_0} & \frac{\partial z}{\partial y_0} & \frac{\partial z}{\partial z_0} & \frac{\partial z}{\partial x_1} & \frac{\partial z}{\partial y_1} & \frac{\partial z}{\partial z_1} & \frac{\partial z}{\partial \rho} & \frac{\partial z}{\partial \theta} & \frac{\partial z}{\partial R} & \frac{\partial z}{\partial P} & \frac{\partial z}{\partial H} & \frac{\partial z}{\partial \omega} & \frac{\partial z}{\partial \varphi} & \frac{\partial z}{\partial \kappa} \end{bmatrix}$$



Compact version of TPU equations

$$\boldsymbol{X}_P^{LTF} = \boldsymbol{R}_{IBF}^{LTF} \cdot \left(\boldsymbol{R}_{SBF}^{IBF} \cdot \rho \cdot \boldsymbol{d}_P^{SBF} + \boldsymbol{X}_{O\_SBF}^{IBF}\right) + \boldsymbol{X}_{O\_IBF}^{LTF}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \boldsymbol{R}_{IBF}^{LTF} \cdot (\boldsymbol{R}_{SBF}^{IBF} \cdot \rho \cdot \boldsymbol{d}_P^{SBF} + \begin{bmatrix} x_0 \\ y_0 \\ z_0 \end{bmatrix}) + \begin{bmatrix} x_1 \\ y_1 \\ z_1 \end{bmatrix}$$

$$\sigma_x^2 = \left(\frac{\partial x}{\partial x_0}\sigma_{x_0}\right)^2 + \left(\frac{\partial x}{\partial y_0}\sigma_{y_0}\right)^2 + \left(\frac{\partial x}{\partial z_0}\sigma_{z_0}\right)^2$$
$$+ \left(\frac{\partial x}{\partial x_1}\sigma_{x_1}\right)^2 + \left(\frac{\partial x}{\partial y_1}\sigma_{y_1}\right)^2 + \left(\frac{\partial x}{\partial z_1}\sigma_{z_1}\right)^2 +$$
$$\left(\frac{\partial x}{\partial \rho}\sigma_{\rho}\right)^2 + \left(\frac{\partial x}{\partial \theta}\sigma_{\theta}\right)^2$$
$$+ \left(\frac{\partial x}{\partial R}\sigma_{R}\right)^2 + \left(\frac{\partial x}{\partial P}\sigma_{P}\right)^2 + \left(\frac{\partial x}{\partial H}\sigma_{H}\right)^2$$
$$+ \left(\frac{\partial x}{\partial \omega}\sigma_{\omega}\right)^2 + \left(\frac{\partial x}{\partial \varphi}\sigma_{\varphi}\right)^2 + \left(\frac{\partial x}{\partial \kappa}\sigma_{\kappa}\right)^2$$

$$\begin{bmatrix} \frac{\partial \boldsymbol{X}_P^{LTF}}{\partial x_0} & \frac{\partial \boldsymbol{X}_P^{LTF}}{\partial y_0} & \frac{\partial \boldsymbol{X}_P^{LTF}}{\partial z_0} \end{bmatrix} = \boldsymbol{R}_{IBF}^{LTF},$$

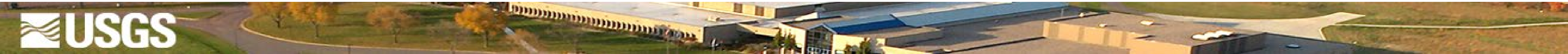
$$\begin{bmatrix} \frac{\partial \boldsymbol{X}_P^{LTF}}{\partial x_1} & \frac{\partial \boldsymbol{X}_P^{LTF}}{\partial y_1} & \frac{\partial \boldsymbol{X}_P^{LTF}}{\partial z_1} \end{bmatrix} = \boldsymbol{I}.$$

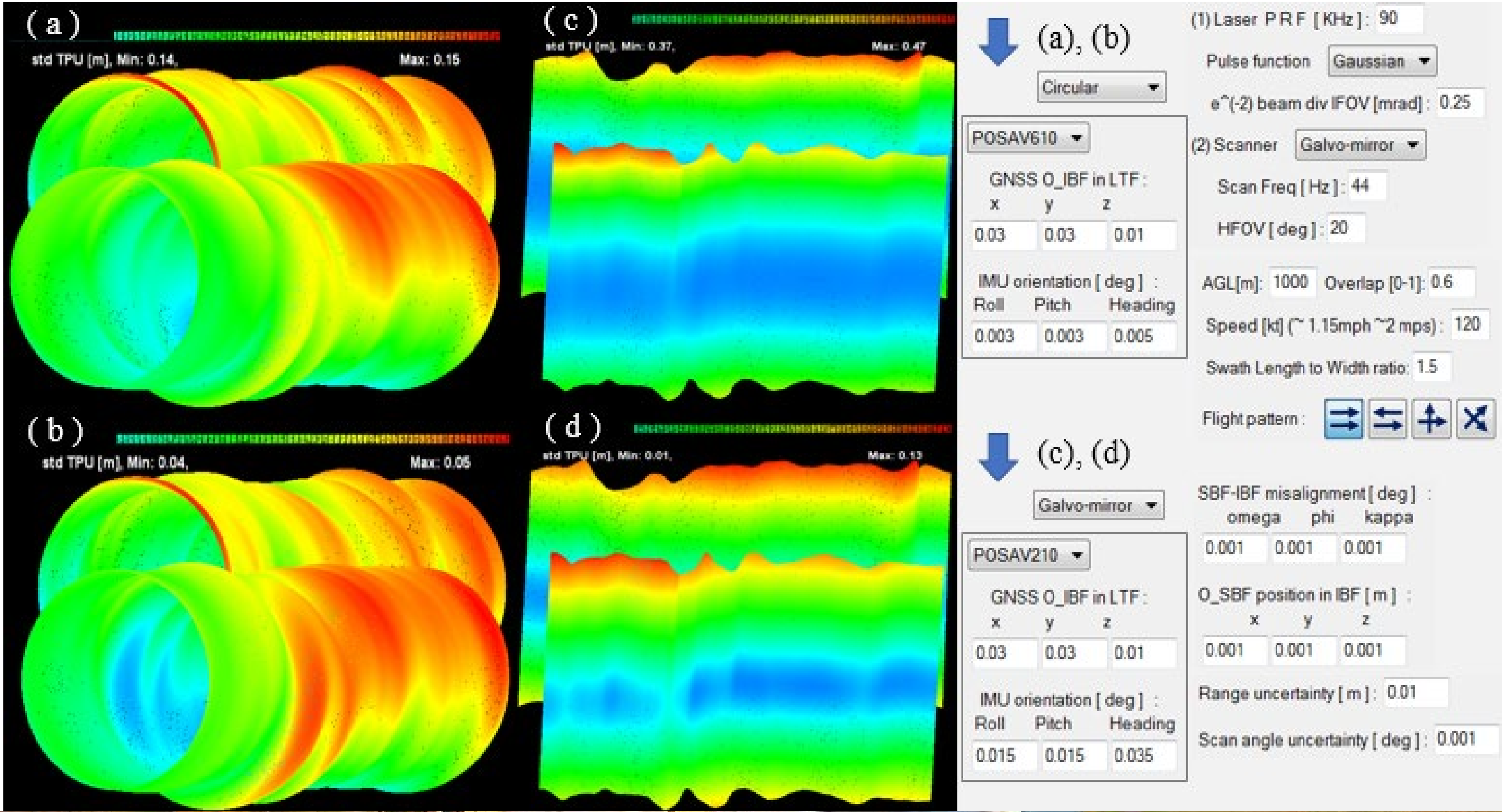
$$\frac{\partial \boldsymbol{X}_P^{LTF}}{\partial \rho} = \boldsymbol{R}_{IBF}^{LTF} \cdot \boldsymbol{R}_{SBF}^{IBF} \cdot \boldsymbol{d}_P^{SBF},$$

$$\frac{\partial \boldsymbol{X}_P^{LTF}}{\partial \theta} = \rho \cdot \boldsymbol{R}_{IBF}^{LTF} \cdot \boldsymbol{R}_{SBF}^{IBF} \cdot \frac{\partial \boldsymbol{d}_P^{SBF}}{\partial \theta}.$$

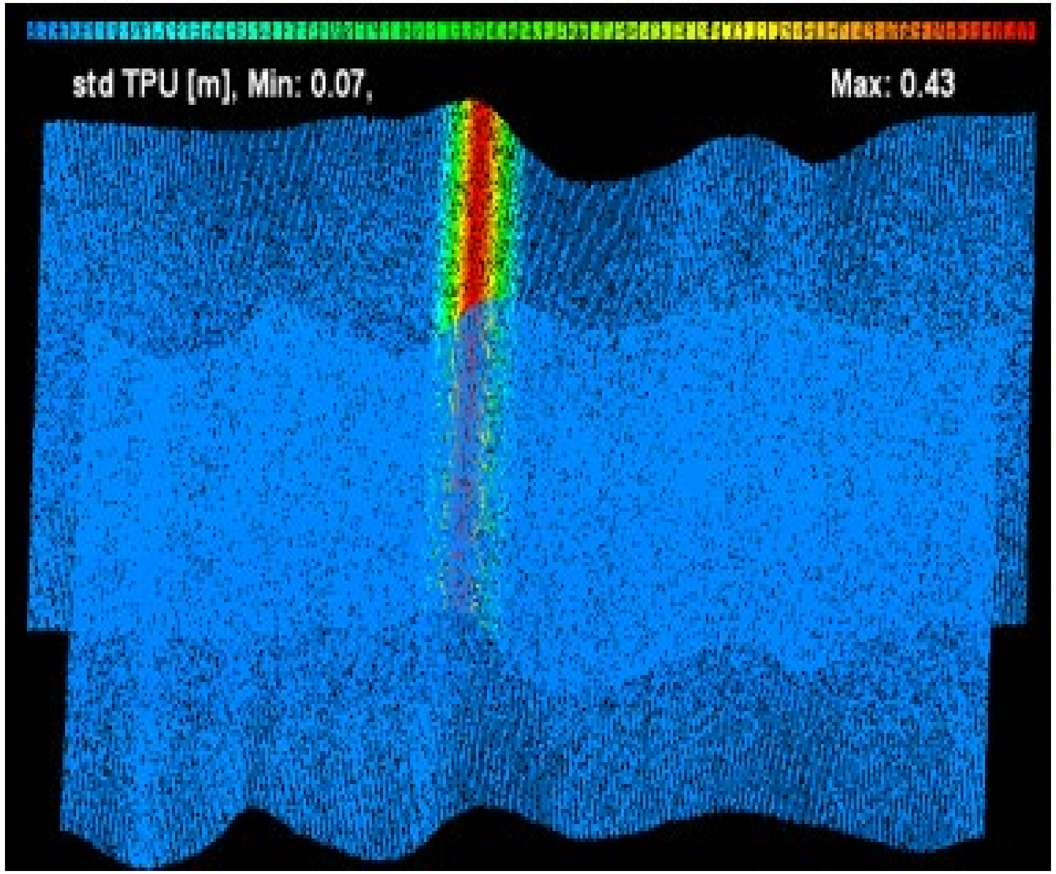
$$\frac{\partial \boldsymbol{X}_P^{LTF}}{\partial \chi} = \rho \cdot \boldsymbol{R}_{IBF}^{LTF} \cdot \frac{\partial \boldsymbol{R}_{SBF}^{IBF}}{\partial \chi} \cdot \boldsymbol{d}_P^{SBF},\ \ (\chi = \omega, \varphi, \kappa)$$

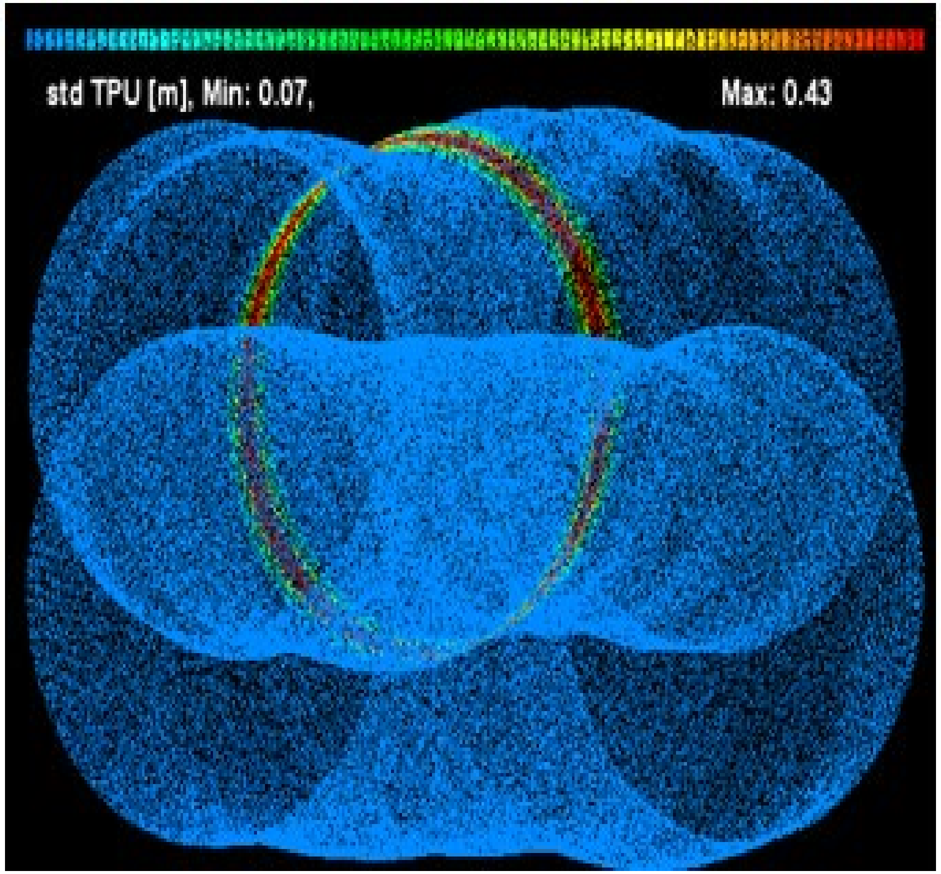
$$\frac{\partial \boldsymbol{X}_P^{LTF}}{\partial \chi} = \rho \cdot \frac{\partial \boldsymbol{R}_{IBF}^{LTF}}{\partial \chi} \cdot \boldsymbol{R}_{SBF}^{IBF} \cdot \boldsymbol{d}_P^{SBF},\ \ (\chi = R, P, H)$$




(a)
std TPU [m], Min: 0.14,
Max: 0.15
(b)
std TPU [m], Min: 0.04,
Max: 0.06
(c)
std TPU [m], Min: 0.37,
Max: 0.47
(d)
std TPU [m], Min: 0.01,
Max: 0.13
(a), (b)
Circular
POSAV610
GNSS O_IBF in LTF :
x y z
0.03 0.03 0.01
IMU orientation [deg] :
Roll Pitch Heading
0.003 0.003 0.005
(c), (d)
Galvo-mirror
POSAV210
GNSS O_IBF in LTF :
x y z
0.03 0.03 0.01
IMU orientation [deg] :
Roll Pitch Heading
0.015 0.015 0.035
(1) Laser P R F [KHz] : 90
Pulse function Gaussian
e^(-2) beam div IFOV [mrad] : 0.25
(2) Scanner Galvo-mirror
Scan Freq [Hz] : 44
HFOV [deg] : 20
AGL[m]: 1000 Overlap [0-1]: 0.6
Speed [kt] (~ 1.15mph ~2 mps) : 120
Swath Length to Width ratio: 1.5
Flight pattern :
SBF-IBF misalignment [deg] :
omega phi kappa
0.001 0.001 0.001
O_SBF position in IBF [m] :
x y z
0.001 0.001 0.001
Range uncertainty [m] : 0.01
Scan angle uncertainty [deg] : 0.001

TPU from a momentary poor PDOP





$$\rho_{toa} = [\rho_{B1}, \ \rho_{B2}, \ \rho_{G}, \ \rho_{R}, \ \rho_{NIR}, \ \rho_{SW1}, \ \rho_{SW2}]^T$$

TPU_NDVI

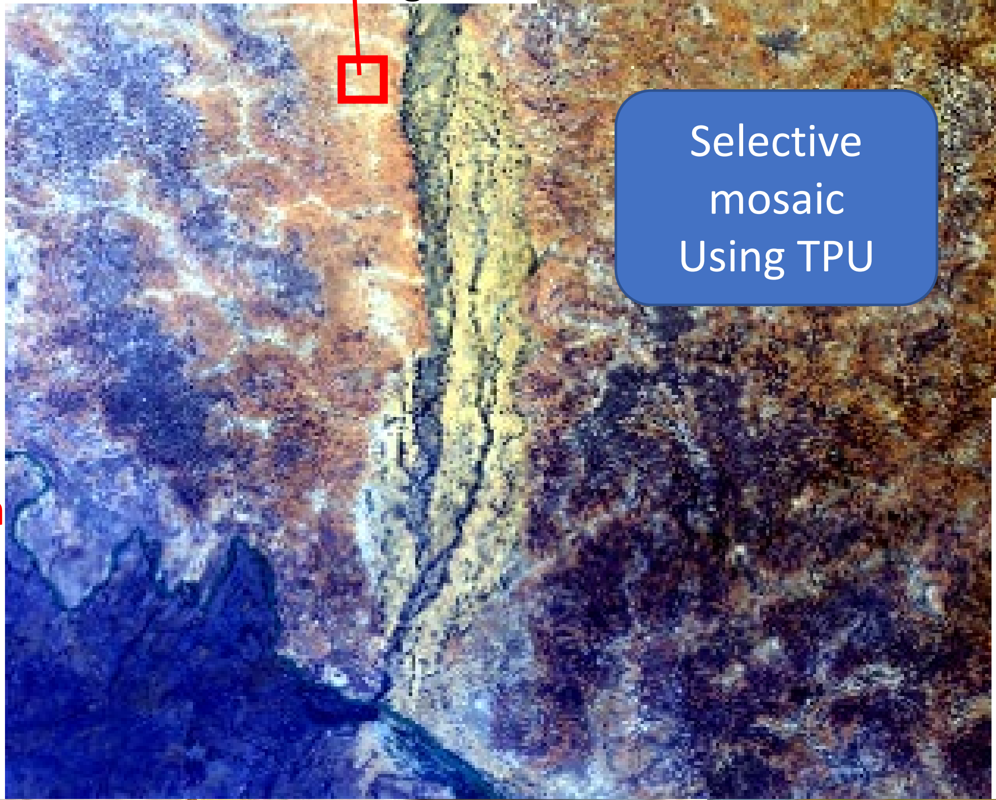
$$\text{NDVI} = \frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R} \qquad \sigma_{\rho_R} \qquad \sigma_{\rho_{NIR}}$$

$\sigma_{NDVI} = ???$

$$(\sigma_{NDVI})^2 = \left(\frac{\partial NDVI}{\partial \rho_R}\Big|_{\rho_R,\rho_{NIR}} \cdot \sigma_{\rho_R}\right)^2 + \left(\frac{\partial NDVI}{\partial \rho_{NIR}}\Big|_{\rho_R,\rho_{NIR}} \cdot \sigma_{\rho_{NIR}}\right)^2$$

Because it is a derivative-based approach,
as long as the scientific application is based on
analytical formula, it is applicable.
However, non-analytical, e.g. decision tree,
categorical outcome, etc

Landsat 8 OLI image

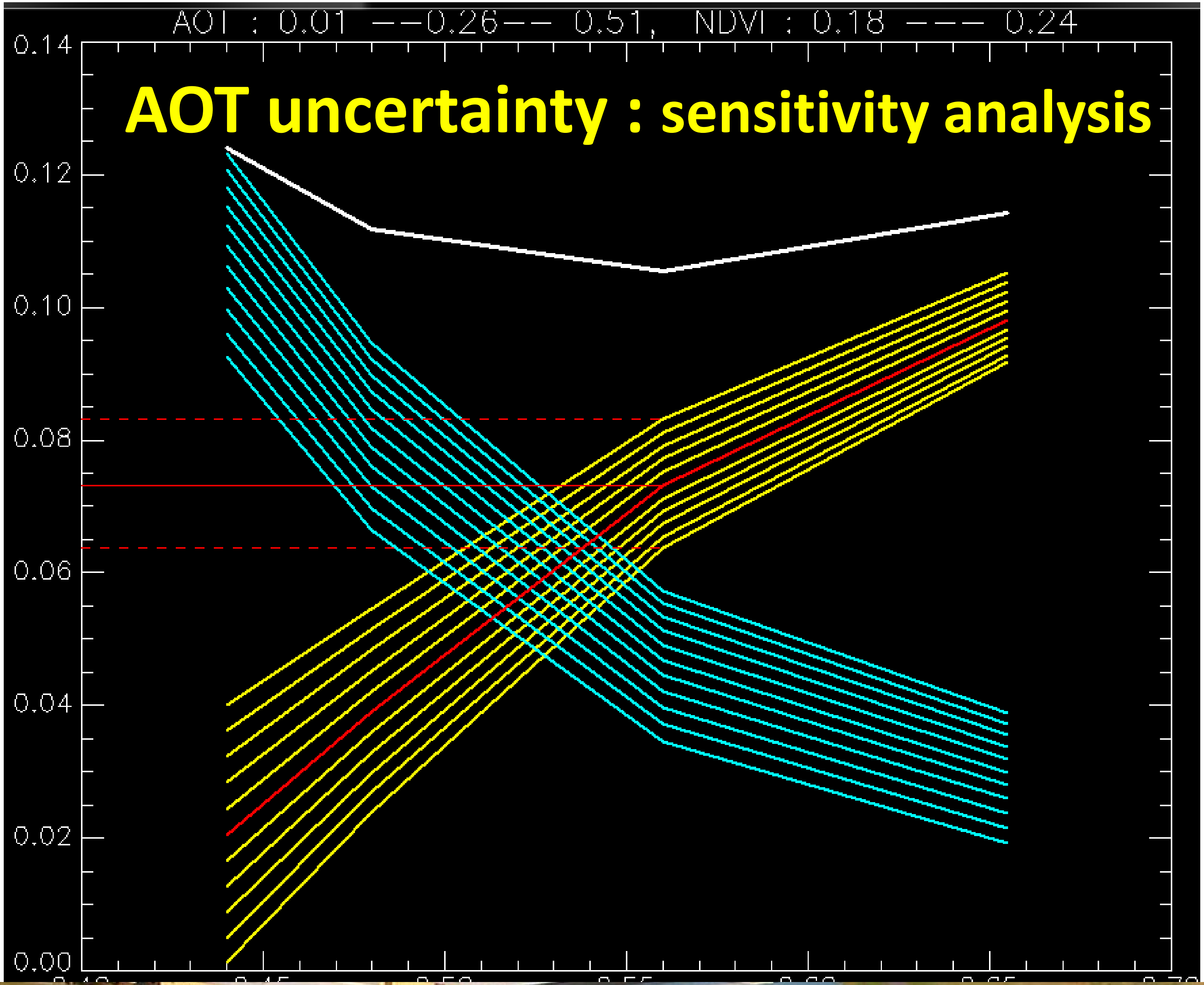


Selective mosaic Using TPU

AOT uncertainty : sensitivity analysis

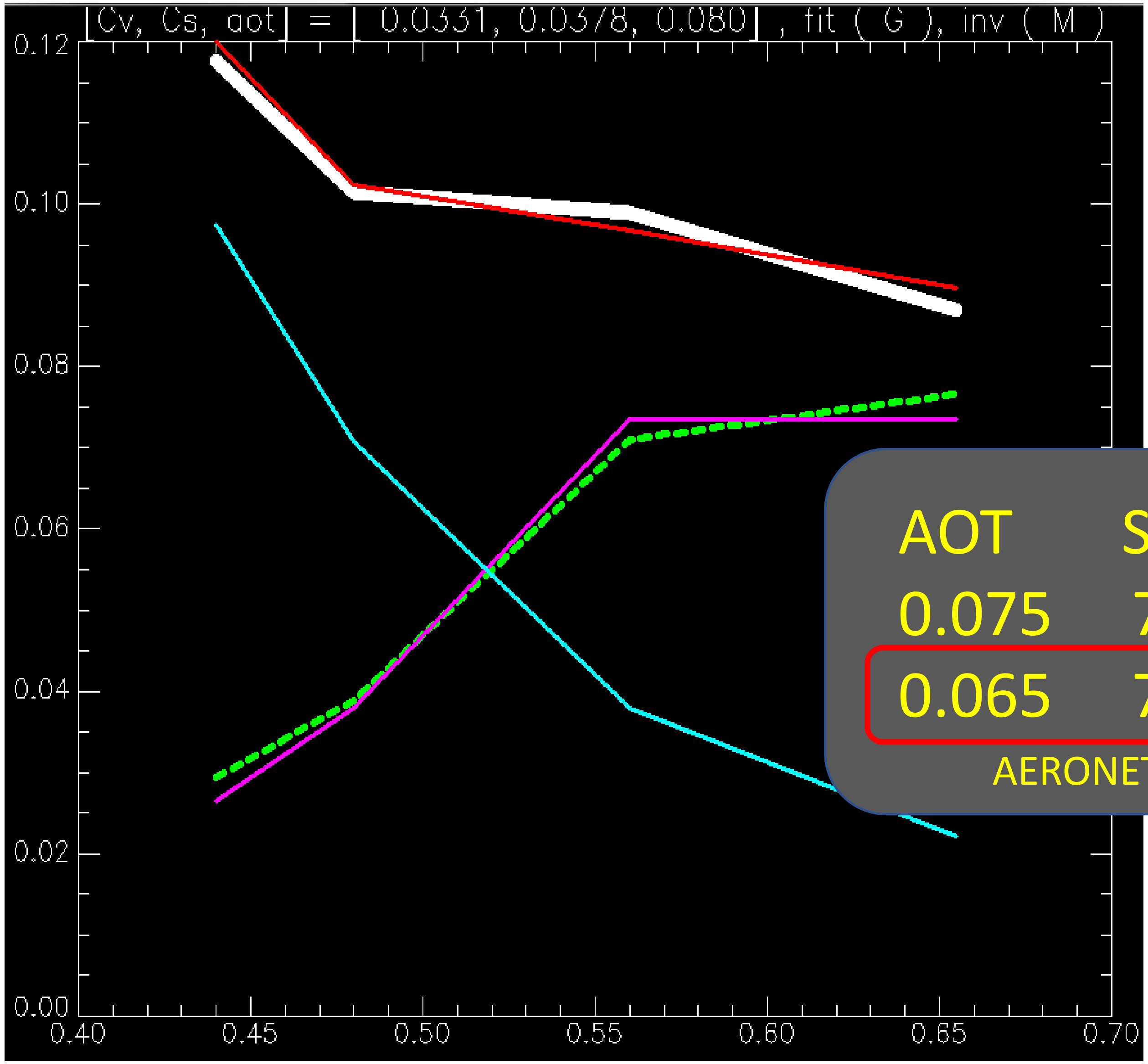
AOT	SR
0.25	7.35 %
0.35	6.95 %

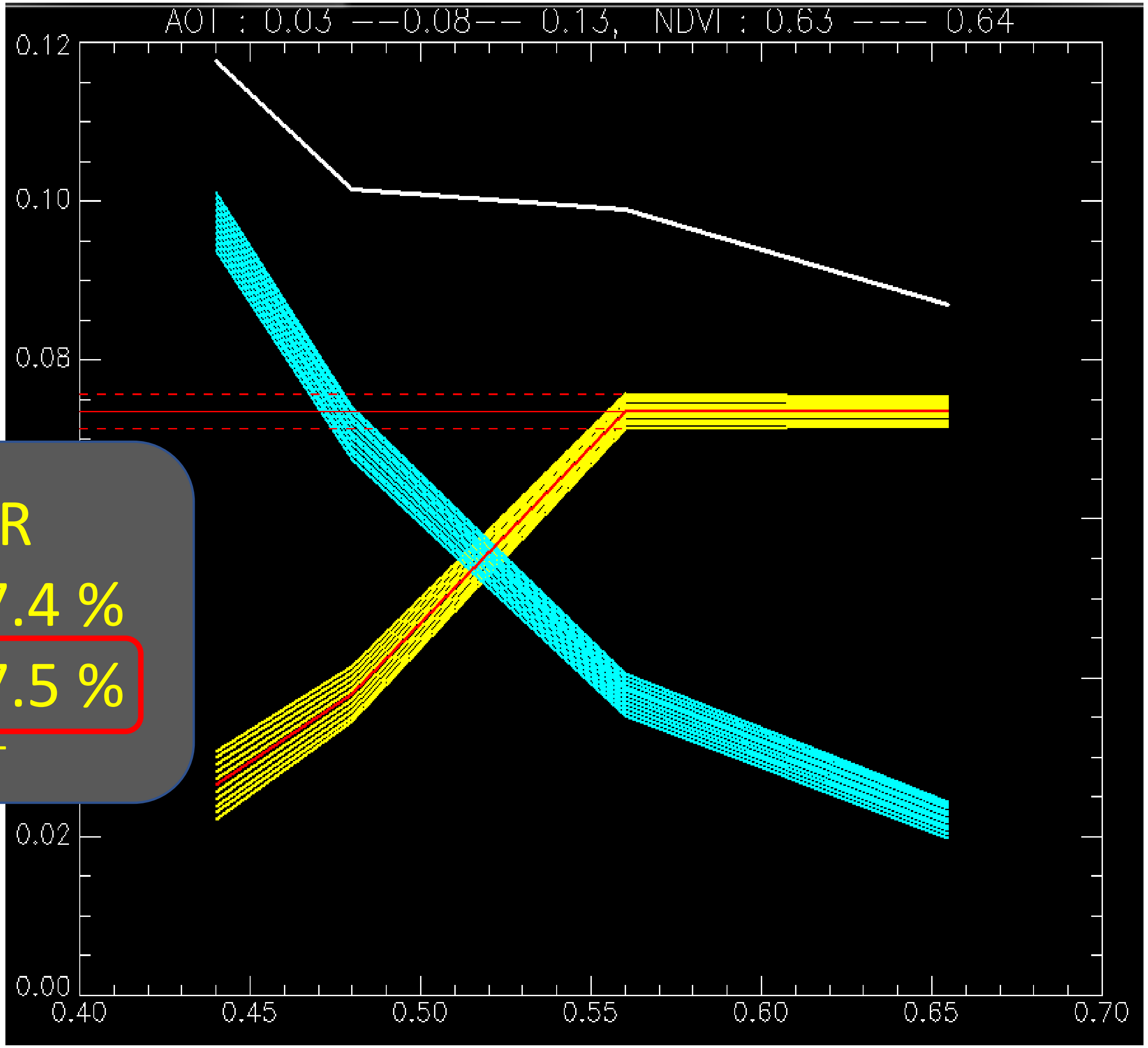
AERONET



USGS

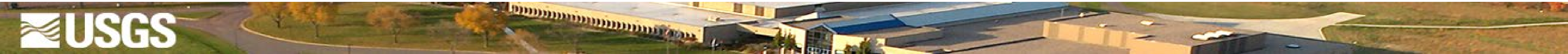
AOT sensitivity on Surface Reflectance

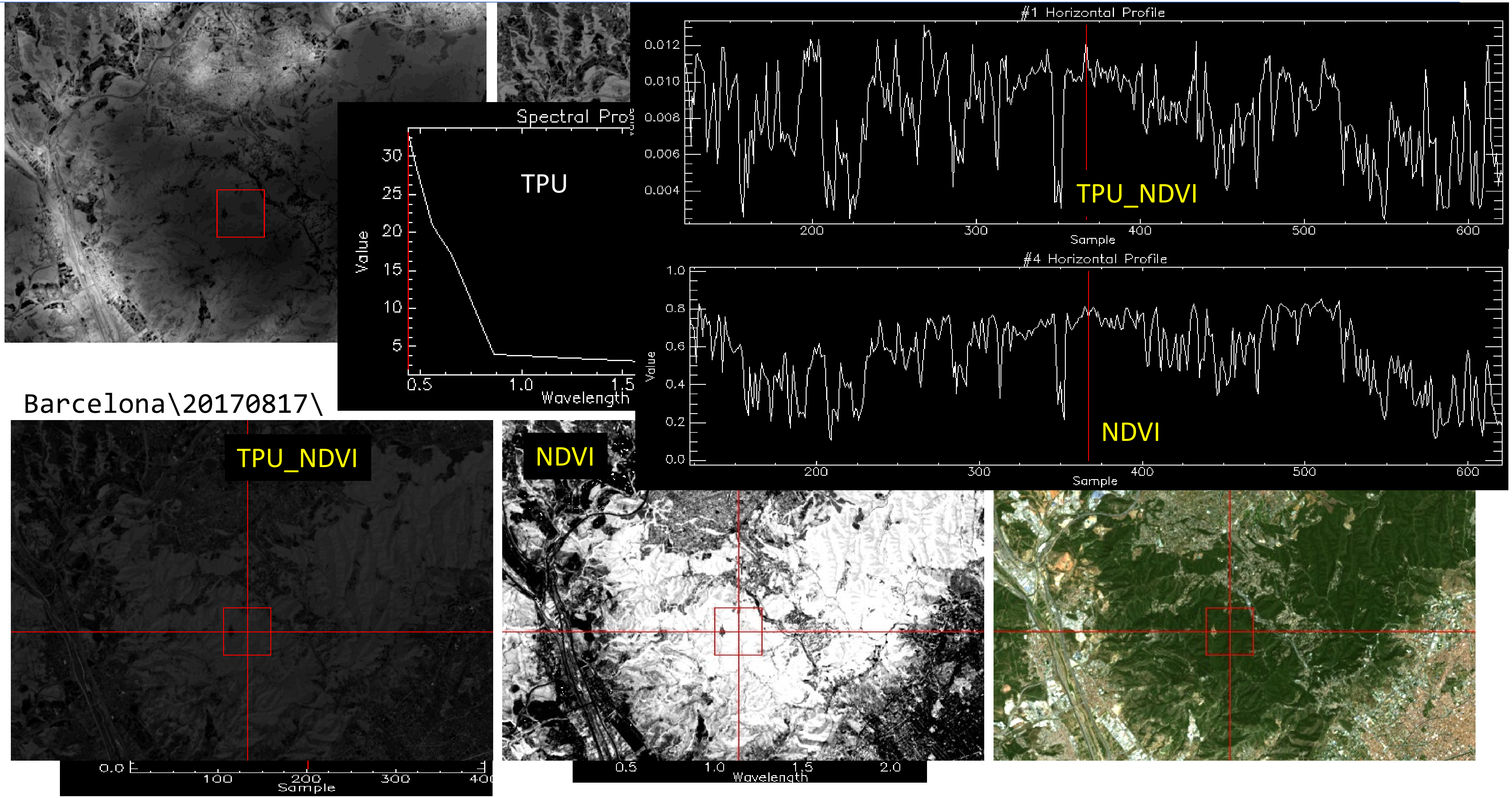


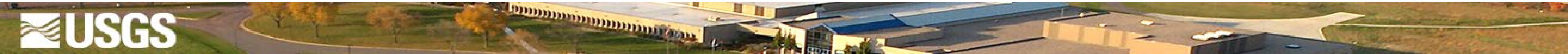


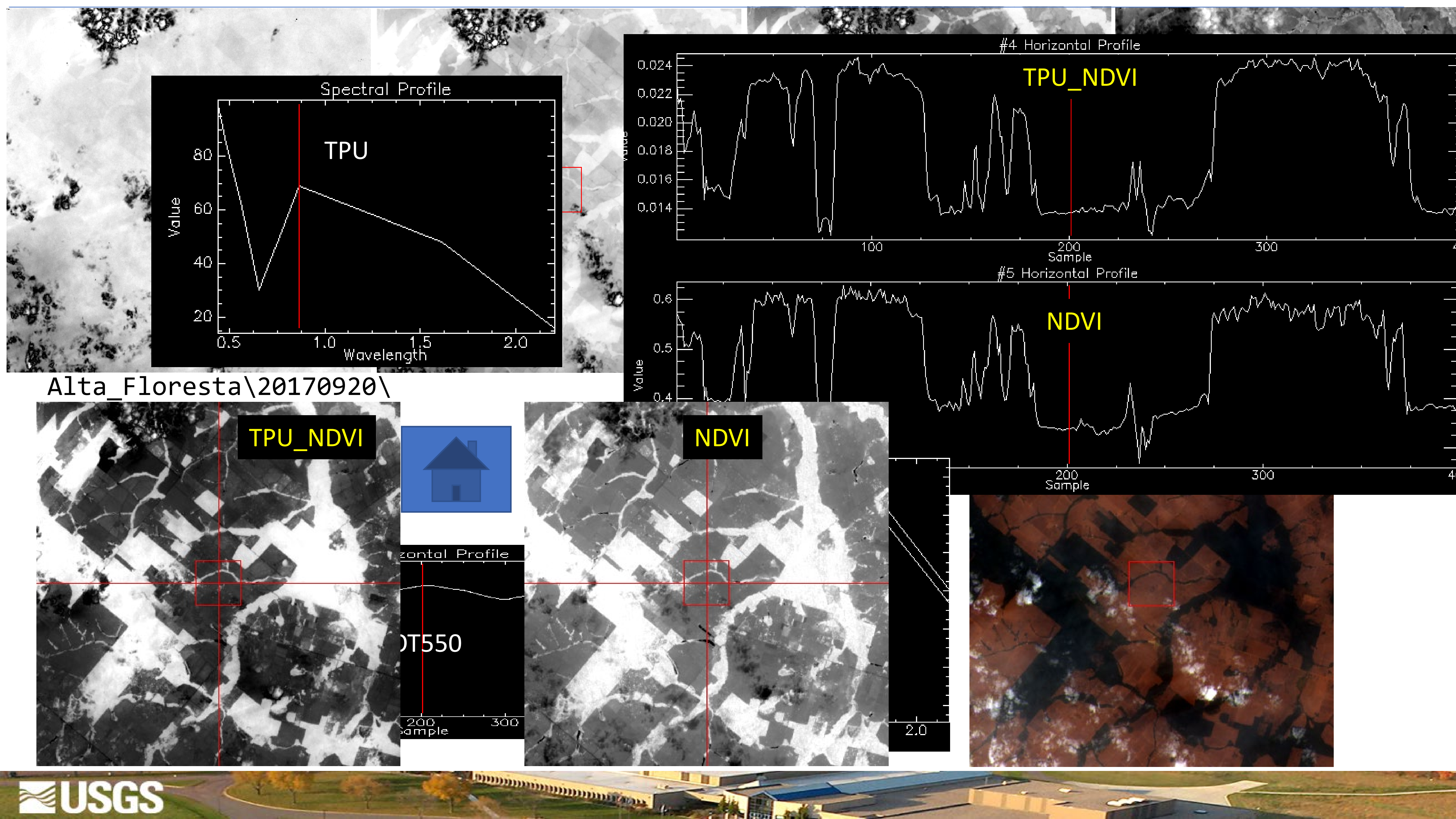
AOT	SR
0.075	7.4 %
0.065	7.5 %

AERONET




Spectral Pro
TPU
Value
Wavelength
#1 Horizontal Profile
TPU_NDVI
Sample
#4 Horizontal Profile
Value
NDVI
Sample
Barcelona\20170817\
TPU_NDVI
NDVI
Sample
Wavelength


USGS


Spectral Profile
TPU
Value
80
60
40
20
0.5
1.0
1.5
2.0
Wavelength
#4 Horizontal Profile
TPU_NDVI
0.024
0.022
0.020
0.018
0.016
0.014
100
200
300
Sample
#5 Horizontal Profile
NDVI
0.6
0.5
0.4
Value
200
300
Sample
Alta_Floresta\20170920\
TPU_NDVI
NDVI
zontal Profile
T550
200
300
ample
2.0
USGS