



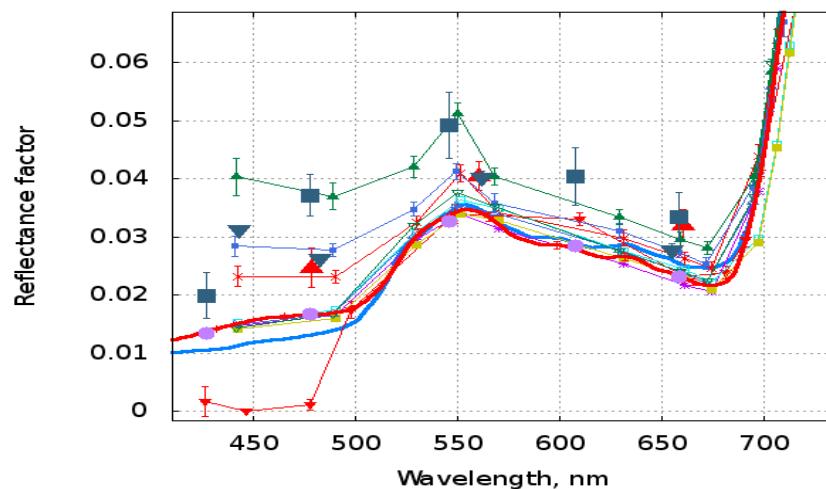
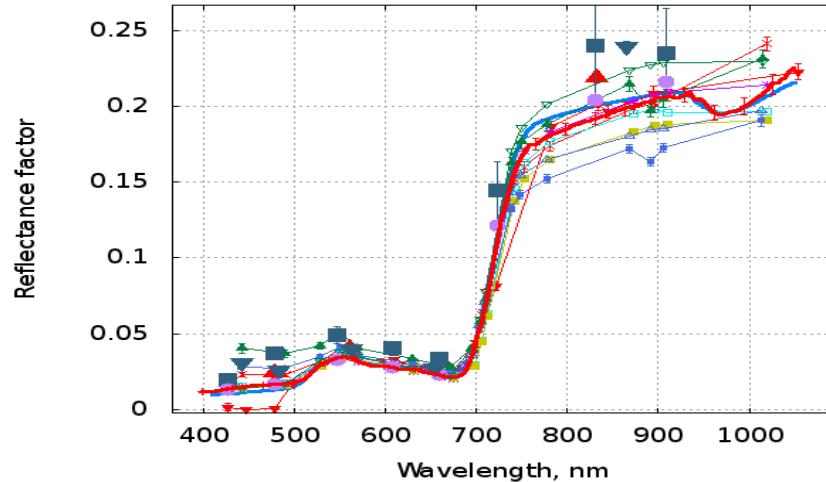
WorldView-2 calibration experiment at Järvselja

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Juhan Ross Legacy Symposium
25 August 2017, Tõravere

BRF of the pine stand

FRT — blue line
 CHRIS2005 — red x
 Hyperion05 — red inverted triangle
 ETM+2005 — red triangle
 UAV2007 — magenta asterisk
 UAV2008 — cyan square
 UAV2009 — yellow square
 CHRIS2010 — blue circle
 UAV2010 — blue triangle
 CHRIS2011 — green triangle
 UAV2011 — green inverted triangle
 WV2_2013 — black square
 UAV2013 — purple circle
 OLI2013 — dark blue inverted triangle
 UAV2007 — red line

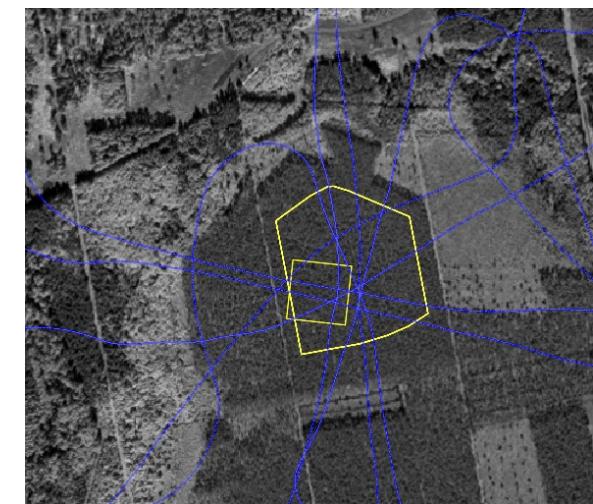


Standard parameters:

SZA = 40°

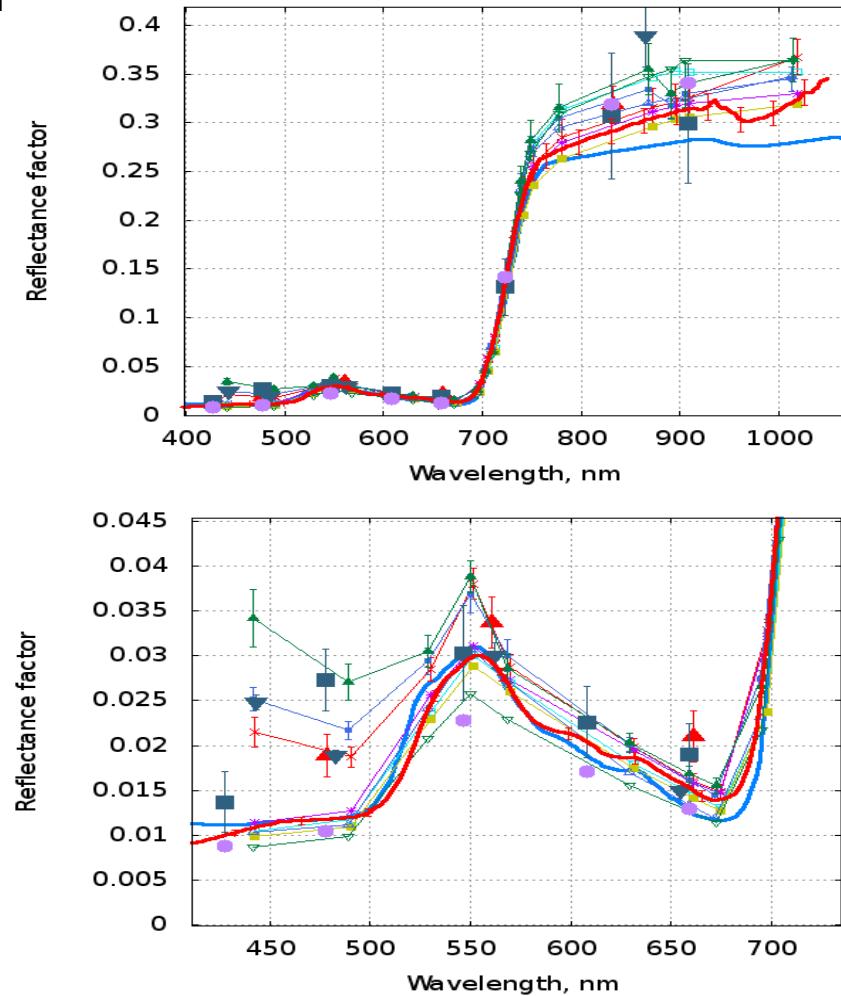
VZA = 0°

$\tau_{550} = 0.12$



BRF of the birch stand

FRT — blue line
CHRIS2005 — red line with 'x'
Hyperion05 — red line with inverted triangle
ETM+2005 — red line with triangle
UAV2007 — magenta line with asterisk
UAV2008 — cyan line with square
UAV2009 — yellow line with square
CHRIS2010 — blue line with circle
UAV2010 — blue line with triangle
CHRIS2011 — green line with triangle
UAV2011 — green line with inverted triangle
WV2_2013 — black line with square
UAV2013 — purple line with circle
OLI2013 — black line with inverted triangle
UAV2007 — red line

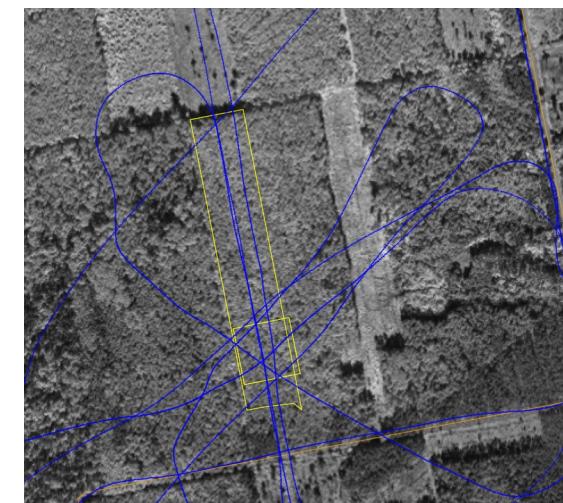


Standard parameters:

SZA = 40°

VZA = 0°

$\tau_{550} = 0.12$



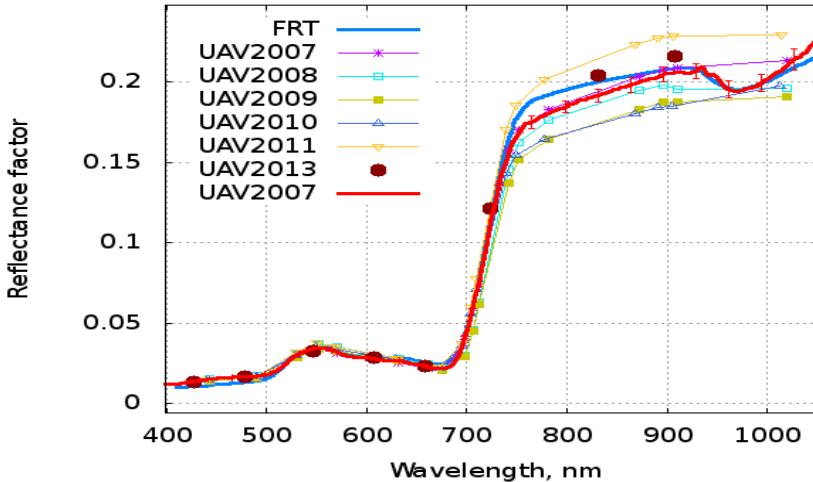
UAVSpec measurements

Standard parameters:

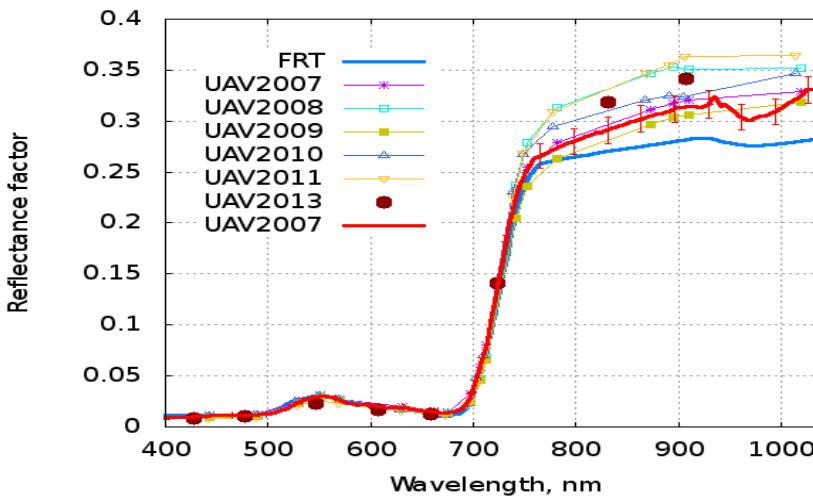
$$\text{SZA} = 40^\circ$$

$$\text{VZA} = 0^\circ$$

$$\tau_{550} = 0.12$$



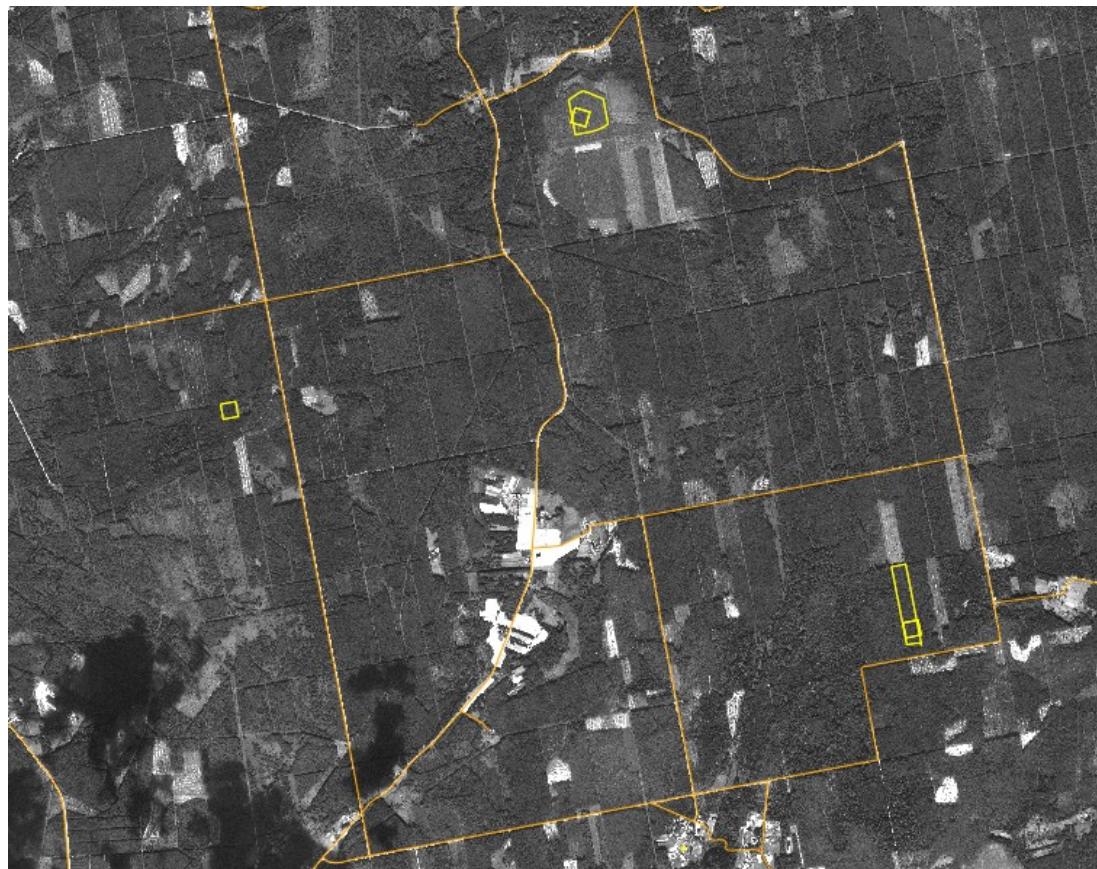
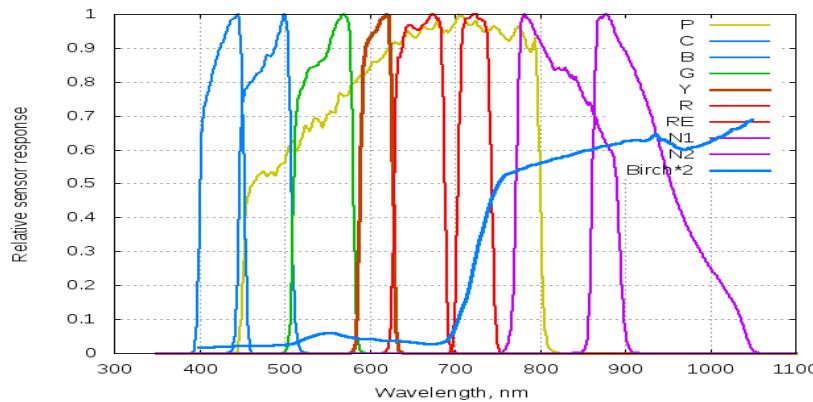
Pine stand



Birch stand

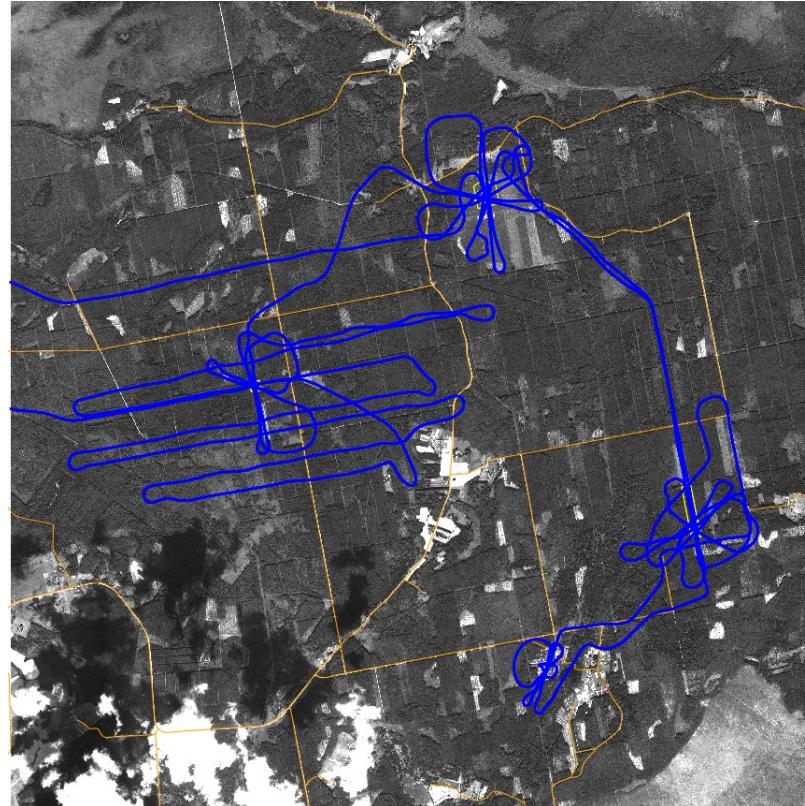
WorldView-2 acquired Järvselja test site on 29 July 2013

Spectral bands		pixel size
Coastal	400–450 nm	2 m
Blue	450–510 nm	
Green	510–580 nm	
Yellow	585–625 nm	
Red	630–690 nm	
Red Edge	705–745 nm	
NIR-1	770–895 nm	
NIR-2	860–1040 nm	
Panchromatic:	450–800 nm	0.5 m

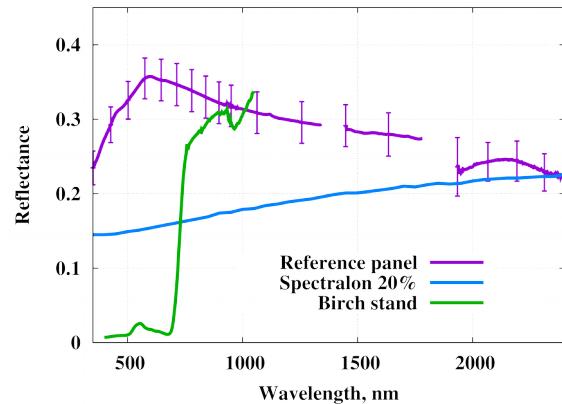
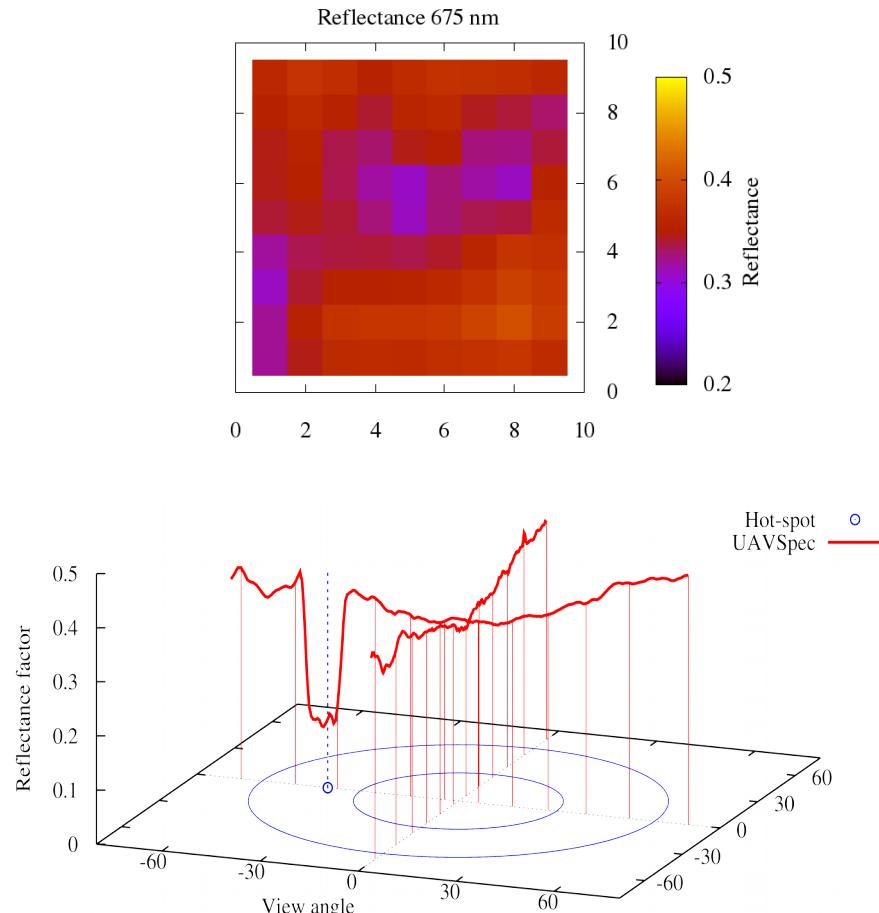


Supporting measurements at Järvselja on 29 July 2013

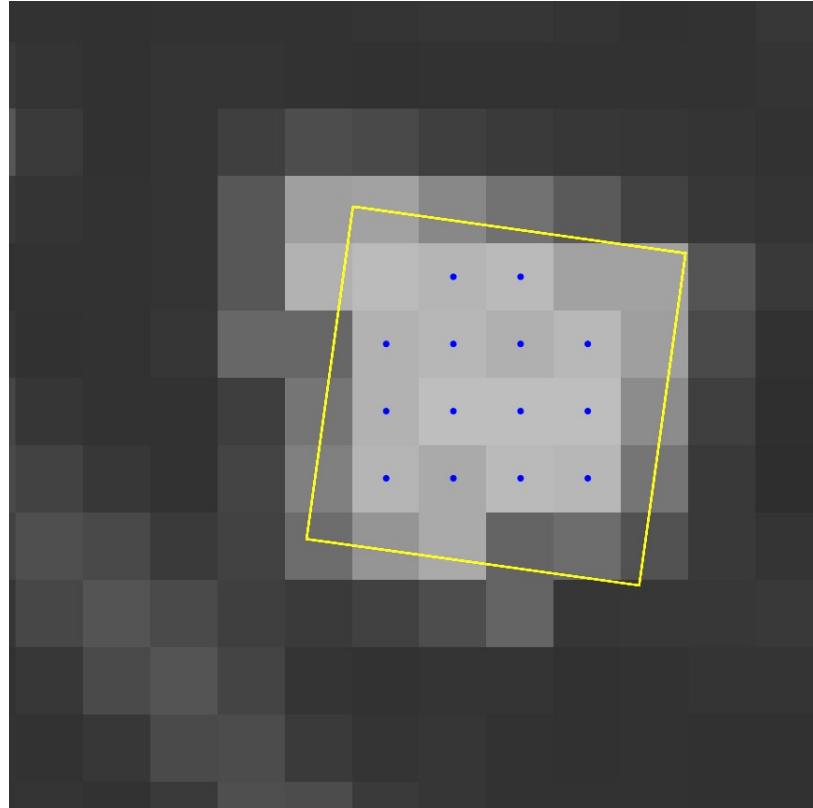
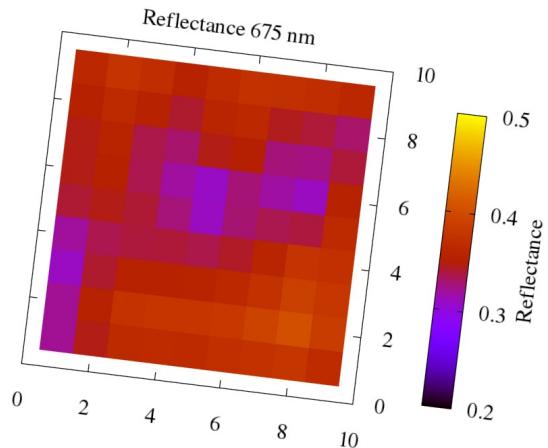
- Cimel – aerosol, H₂O, O₃
- SpectraVista – vis-NIR Q_λ, D_λ
- hemispherical sky images
- UAVSpec3 – forest reflectance
in WV2 bands



Reference panel at Järvselja, 2013



Reference panel in the WV2 image



Atmospheric correction of the WV-2 images using 6S and LUT

SZA = 39.6°

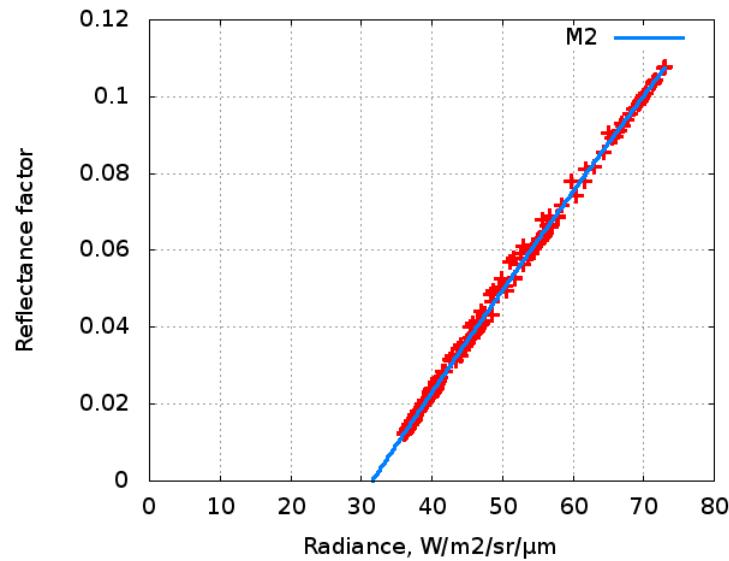
VZA = 19.4°

SZA-VZA = 152.5°

H₂O: 1.91 cm

O₃: 314 DU

τ_{550} = 0.12



Atmospheric correction of the WV-2 images using 6S and LUT

SZA = 39.6°

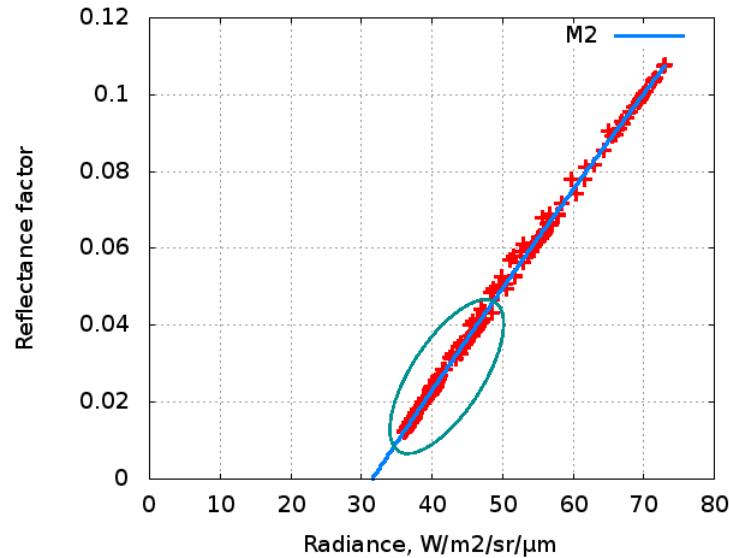
VZA = 19.4°

SZA-VZA = 152.5°

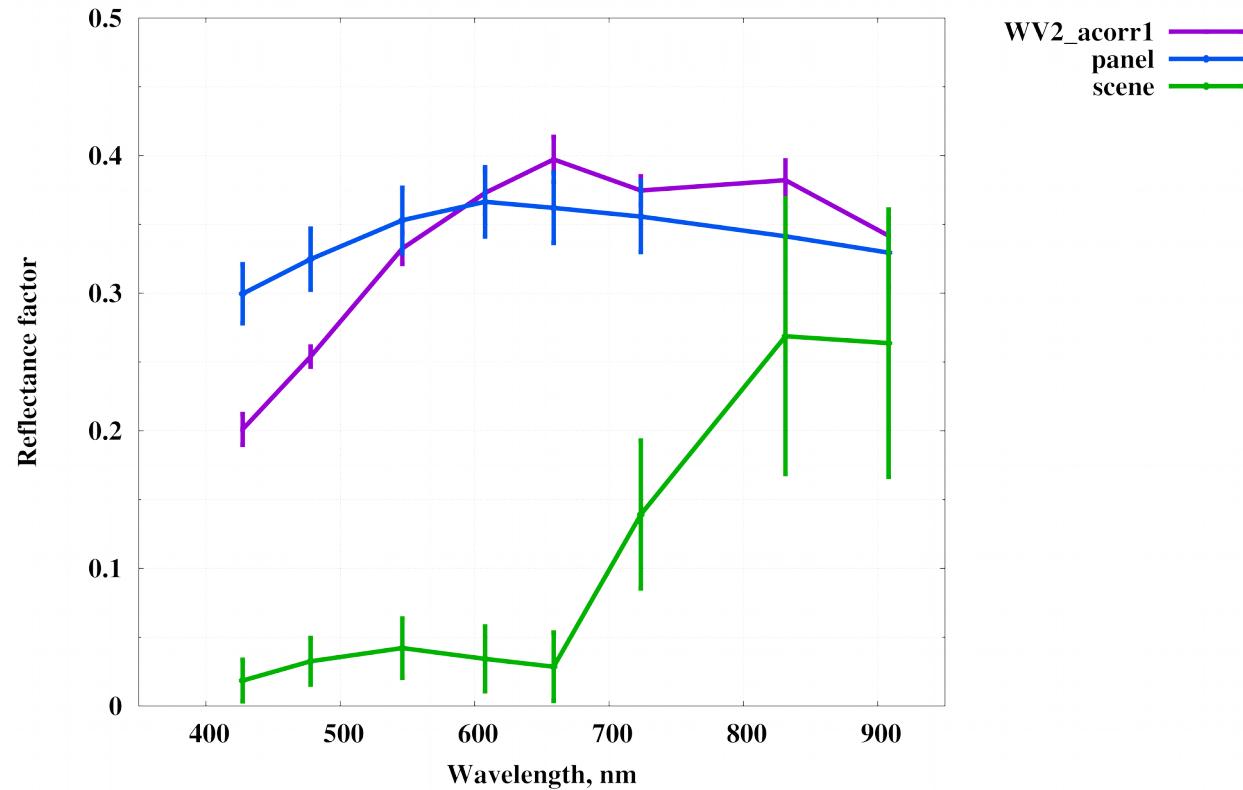
H₂O: 1.91 cm

O₃: 314 DU

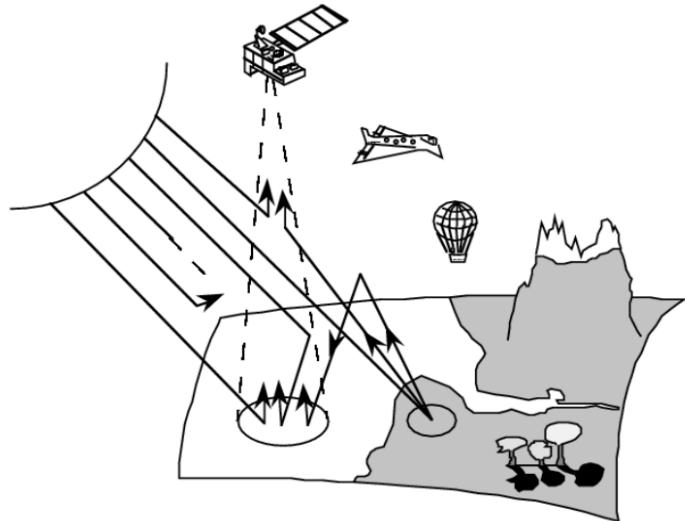
τ_{550} = 0.12



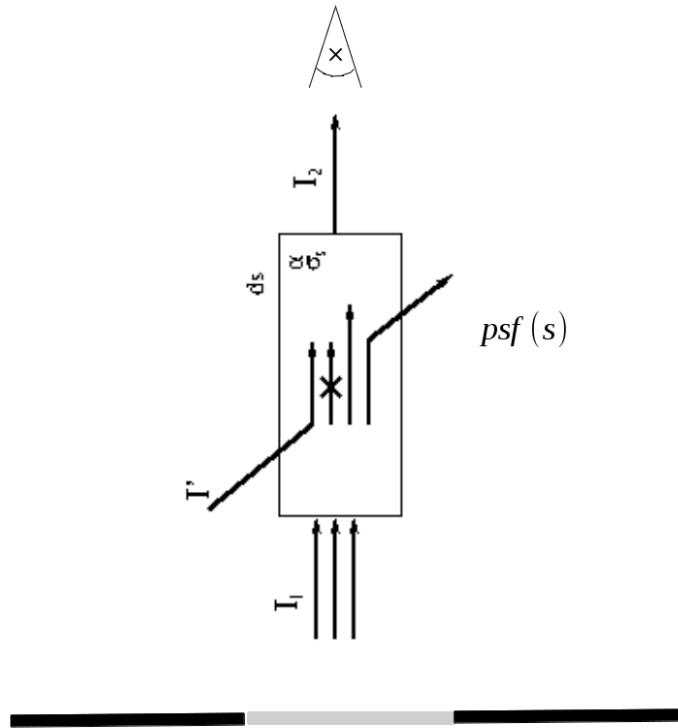
Reference panel in WV2 images



Adjacency effects



(Vermote et al., 1994)



Adjacency effects

Inverse filtering in the 2D Fourier space $g(x,y) = psf(\xi,\eta) \otimes f(u,v)$

Kaufman 1984, 1989, MTF of the atmosphere:

$$mtf(k) = 1 - 0.5 \tau_r (1 - \exp(-2.5 k H_r)) - 0.7 \lambda^{-0.2} \tau_a (1 - \exp(-1.3 k H_a))$$

k — frequency, $1/km$

λ — wavelength

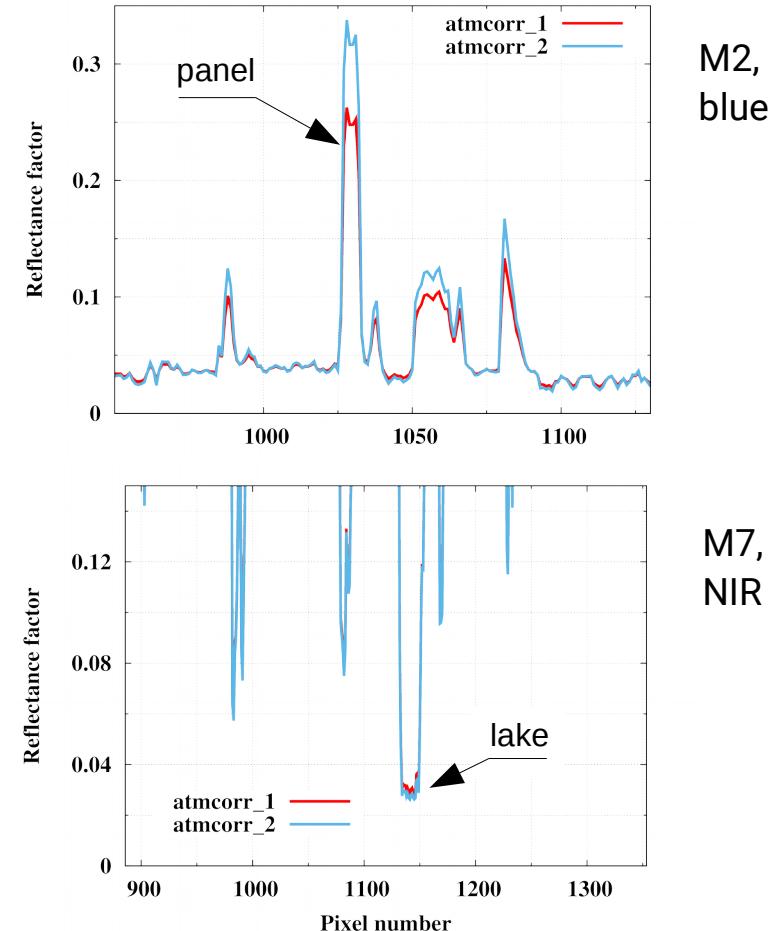
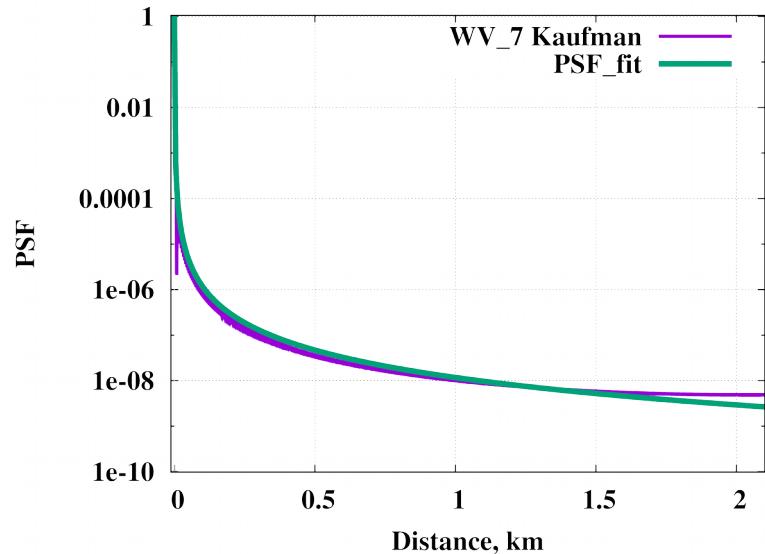
H_r — the scale height of molecules ($\approx 8 km$) τ_r — Rayleigh

H_a — the scale height of aerosol ($\approx 1 km$) τ_a — aerosol

$$\begin{matrix} mtf(k) \\ FFT \end{matrix} \longrightarrow \begin{matrix} psf(s) \end{matrix}$$

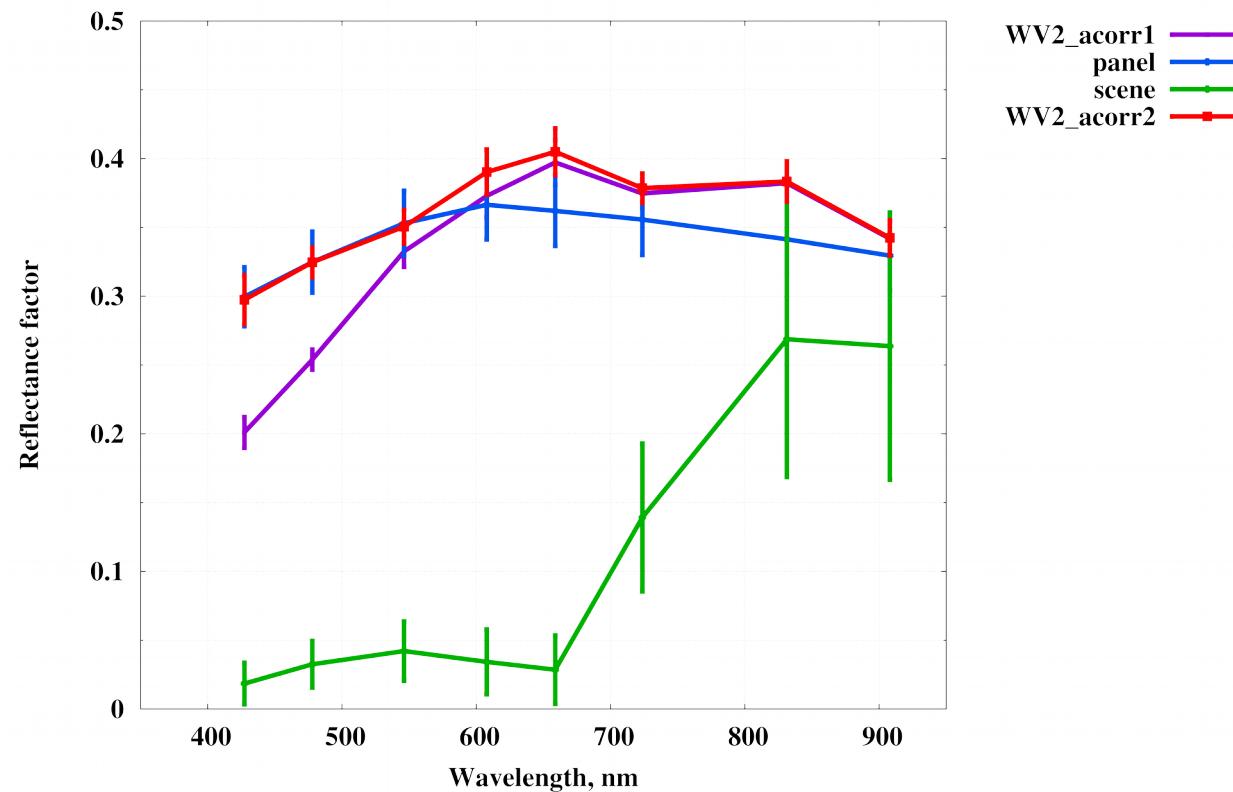
$$psf(s) \approx (a_1 \exp(a_2/(1+s^{a_3})) + b_1 \exp(b_2 s))/(1+s^2)/(a_1 \exp(a_2) + b_1)$$

Adjacency effects, PSF of the atmosphere

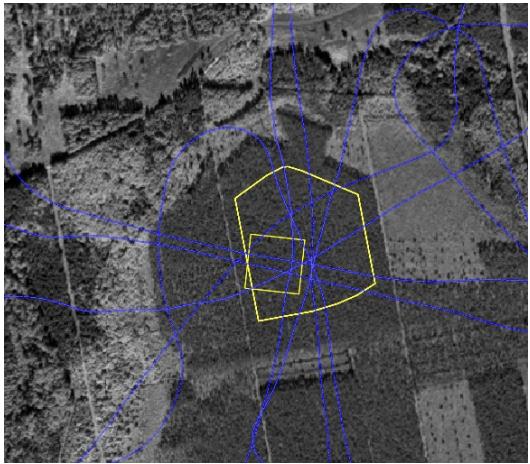


$$psf(s) \approx (a_1 \exp(a_2/(1+s^{a_3})) + b_1 \exp(b_2 s))/(1+s^2)/(a_1 \exp(a_2) + b_1)$$

Adjacency effects, the reference panel



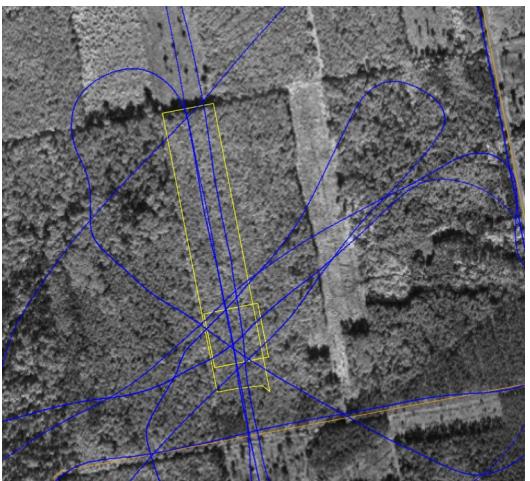
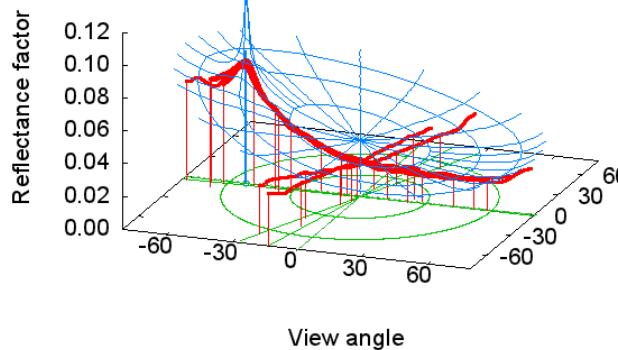
Directional effects, forest stands



27.07.2011, SZA = 52 deg, Pine stand

Hot-spot
UAVSpec
FRT

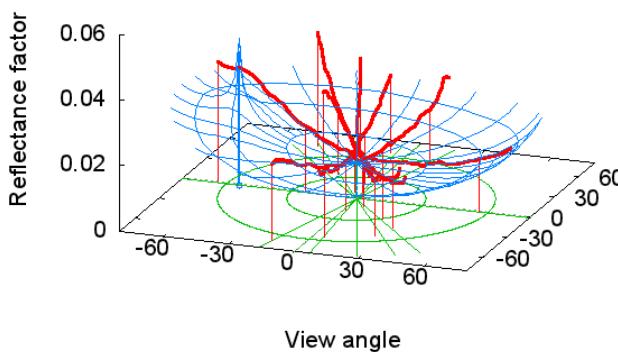
Pine



27.07.2011, SZA = 54 deg, Birch stand

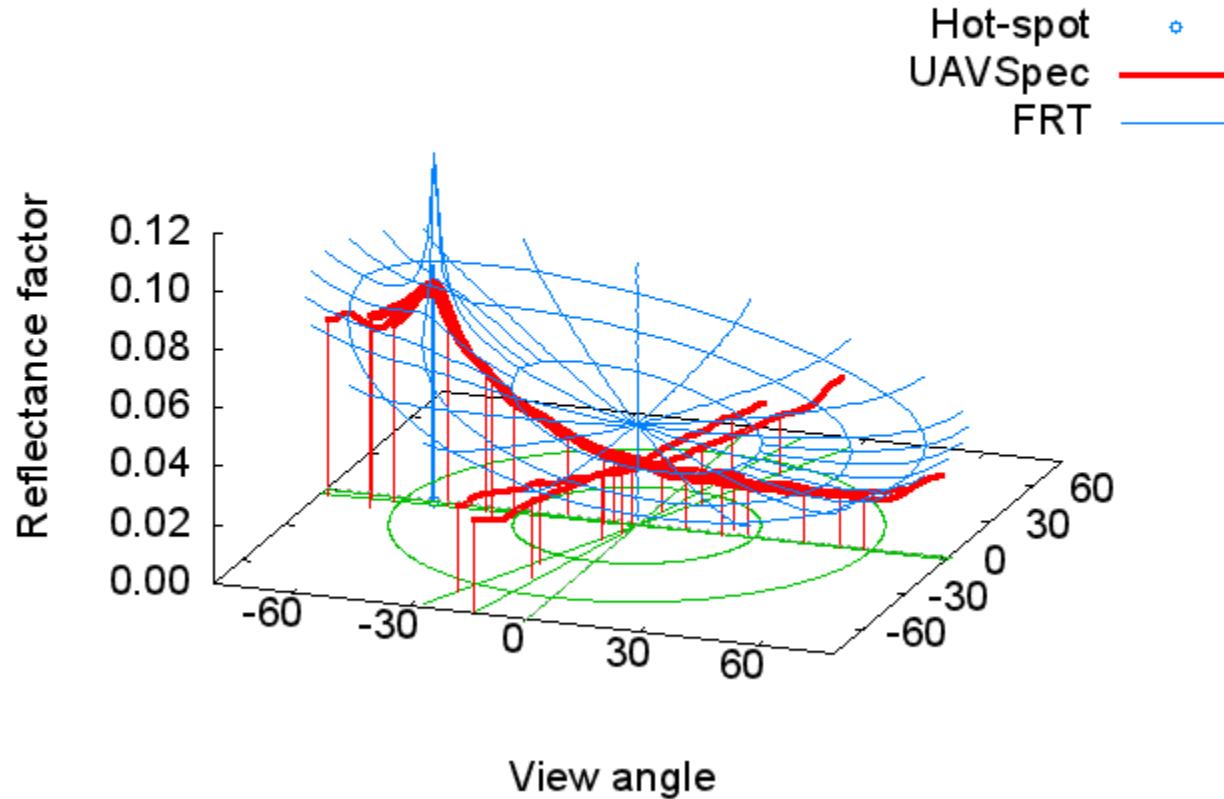
Hot-spot
UAVSpec
FRT

Birch



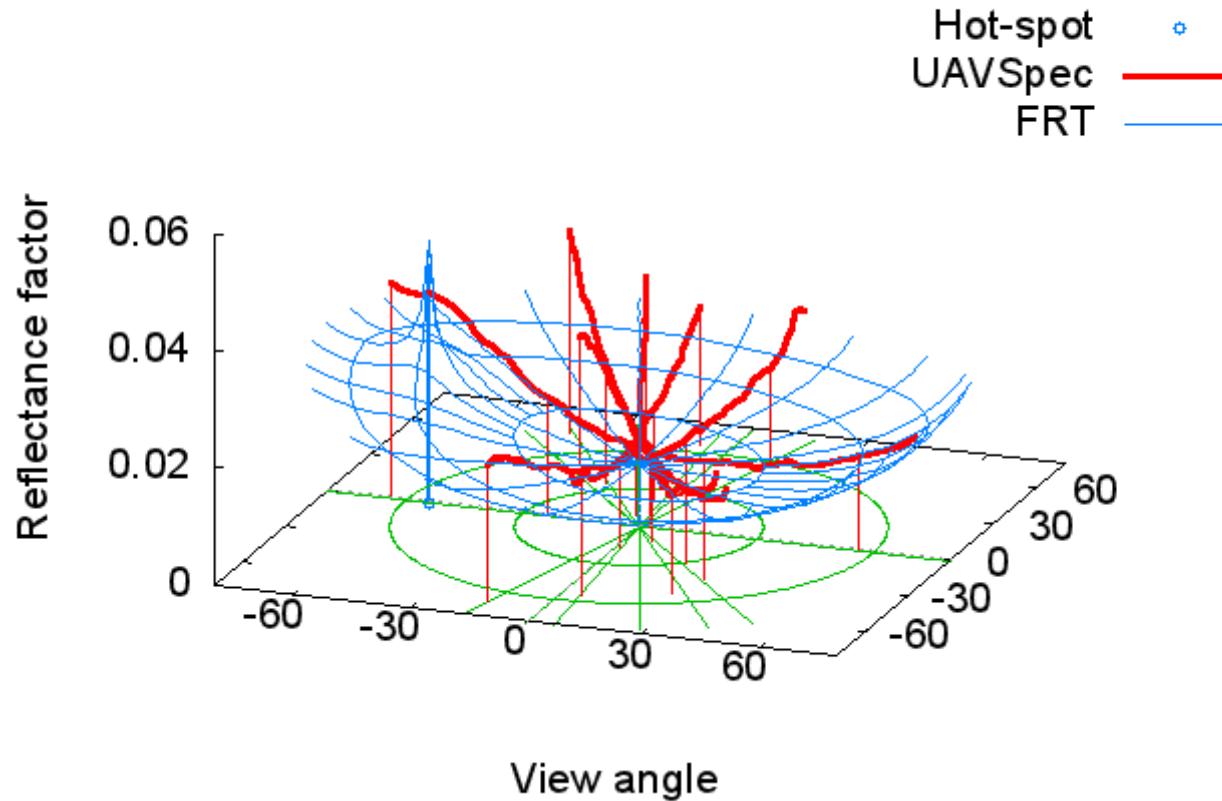
BRF of forest stands

27.07.2011, SZA = 52 deg, Pine stand



BRF of forest stands

27.07.2011, SZA = 54 deg, Birch stand



Summary

Radiometry of satellite remote sensing needs

- reference targets
- detailed optical properties and 3D RT in the atmosphere
 - adjacency correction
 - directional effects

Acknowledgments

- European Space Imaging & DigitalGlobe
- Kaupo Voormansik & AS Regio
- Pakker Avio