Elaborazione di dati iperspettrali per applicazioni di telerilevamento

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*** CNR-IEIIT

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Nicola Acito – Ricercatore – **Accademia Navale**

Stefania Matteoli – Ricercatore – **CNR IEIIT**

Introduction

Data Domain

Information Domain

Processing

- Radiometric calibration
- Spectral calibration
- Geo-rectification

- Atmospheric compensation
- Temperature/emissivity separation

L0
- Raw data (Digital Numbers)

Spectral discrimination
- Anomaly Detection
- Image Segmentation

L1
- radiance data
- geo-coded image

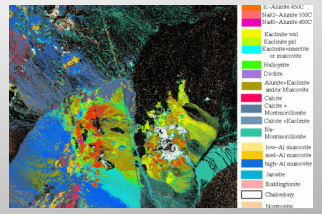
Spectral and spatial information
- Data Fusion
- Context analysis
- Change detection (multi-temporal)

L2
- reflectance data
- spectral emissivity
- temperature

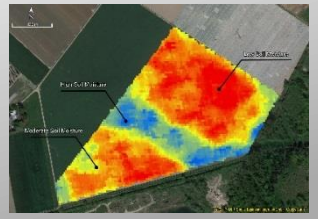
Spectral analysis
- Material identification
- Classification
- Bio-Physical parameters estimation

Application domain

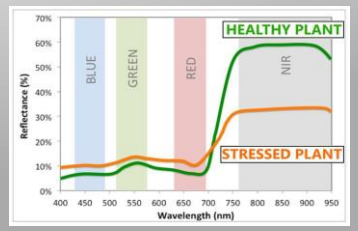
Mineralogy



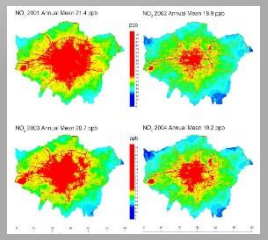
Precision Farming



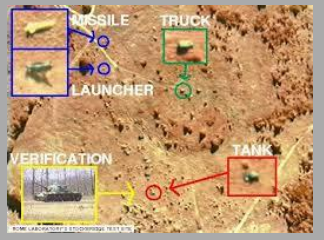
Vegetation health



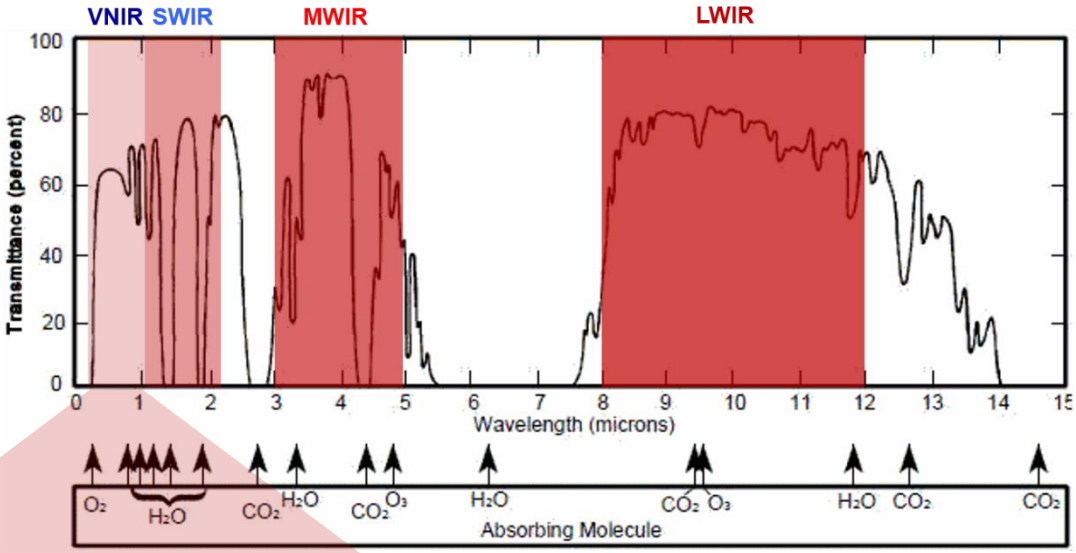
Pollution analysis

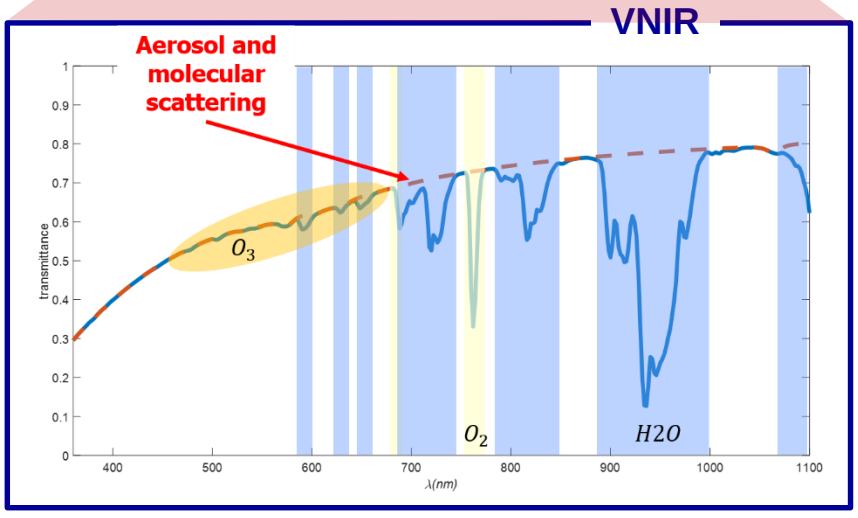


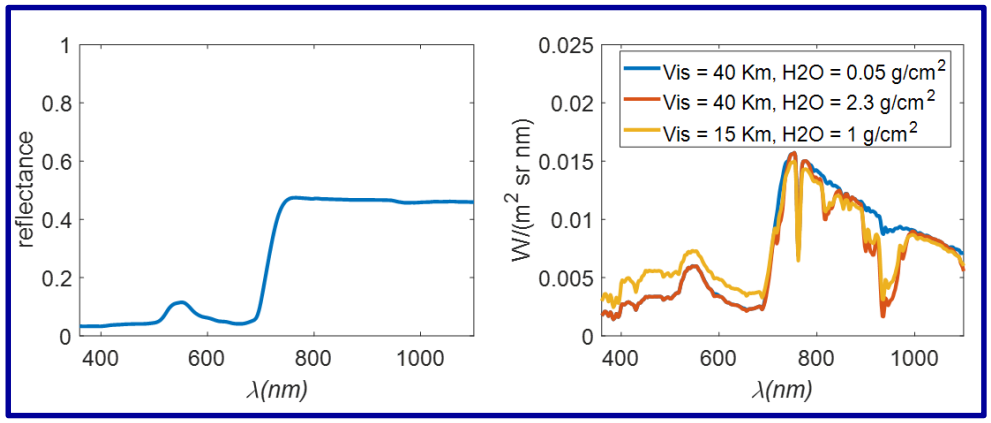
Defence & Security



Atmoshperic effects







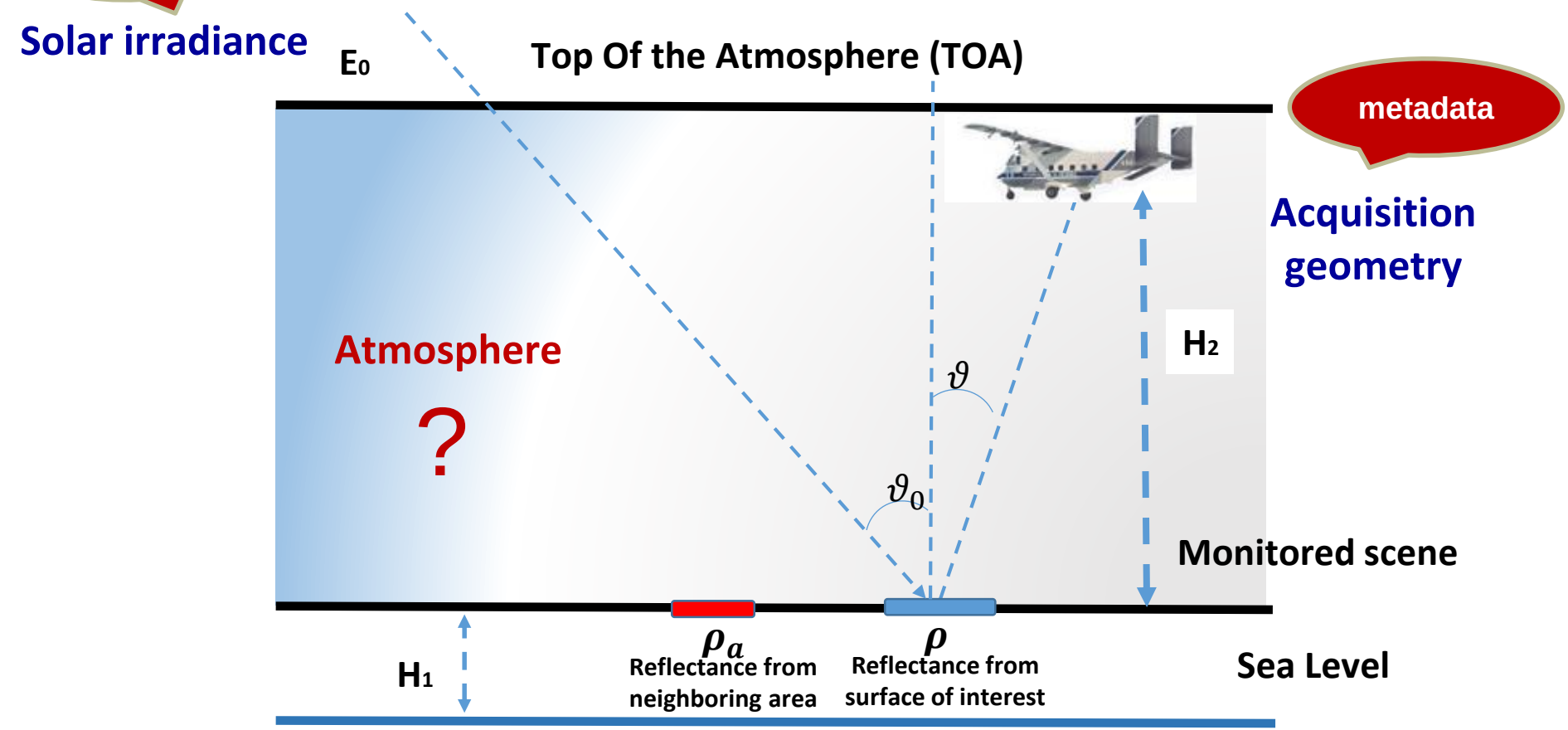
Atmoshperic effects

Atmosphere

- Spatially variant
- Temporally variant
- Hardly predictable

metadata

Solar irradiance

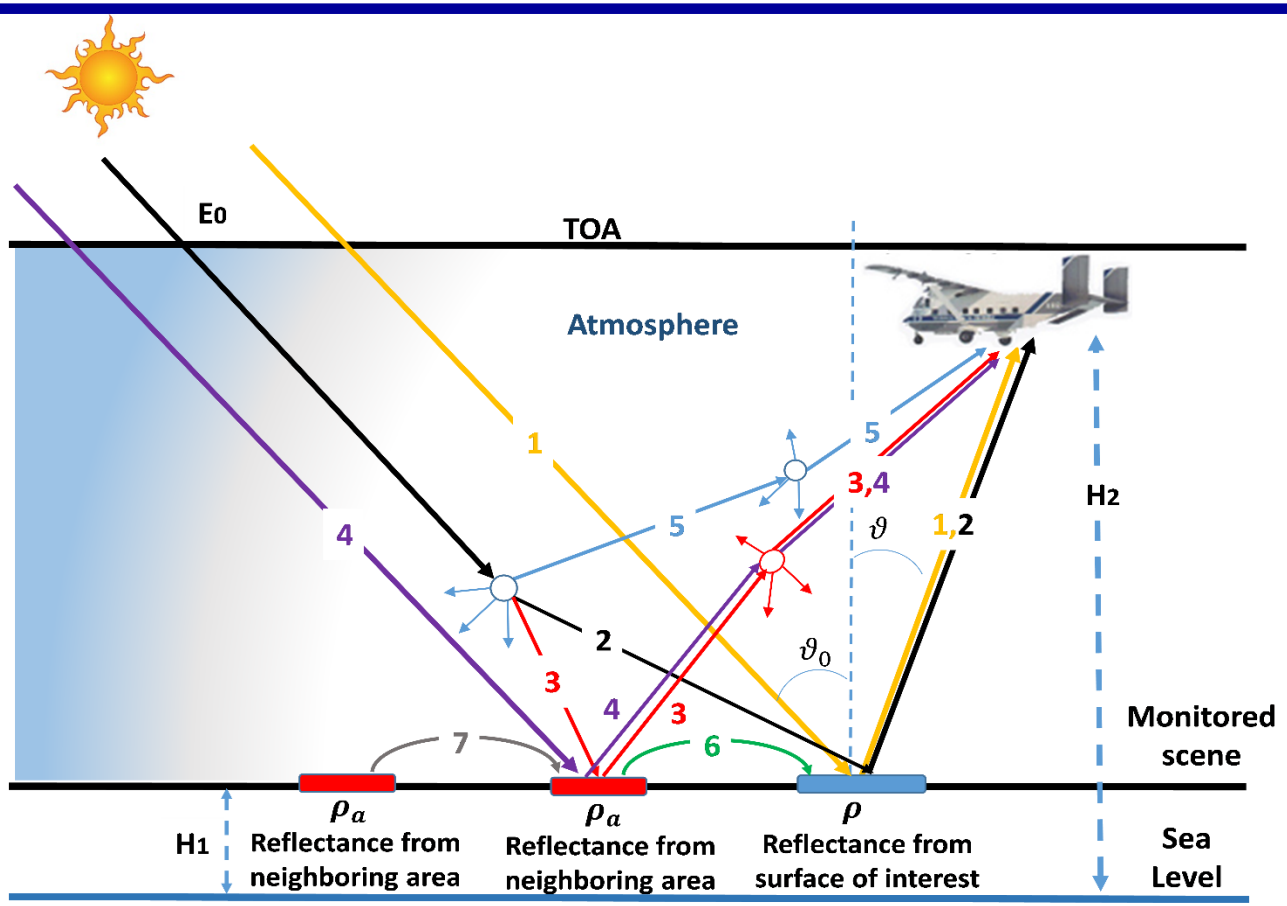


Radiative Transfer Model (RTM)

$$L(\lambda) = E_0(\lambda) \cdot \cos(\vartheta) \cdot \frac{\rho^*(\lambda)}{\pi}$$

$$\rho^*(\lambda) = \left[\tau_1(\lambda) + \tau_2(\lambda)\right] \cdot \frac{\rho(\lambda)}{1 - S(\lambda) \cdot \rho_a(\lambda)} + B(\lambda) \cdot \frac{\rho_a(\lambda)}{1 - S(\lambda) \cdot \rho_a(\lambda)} + L^*_{atm}(\lambda)$$

VNIR

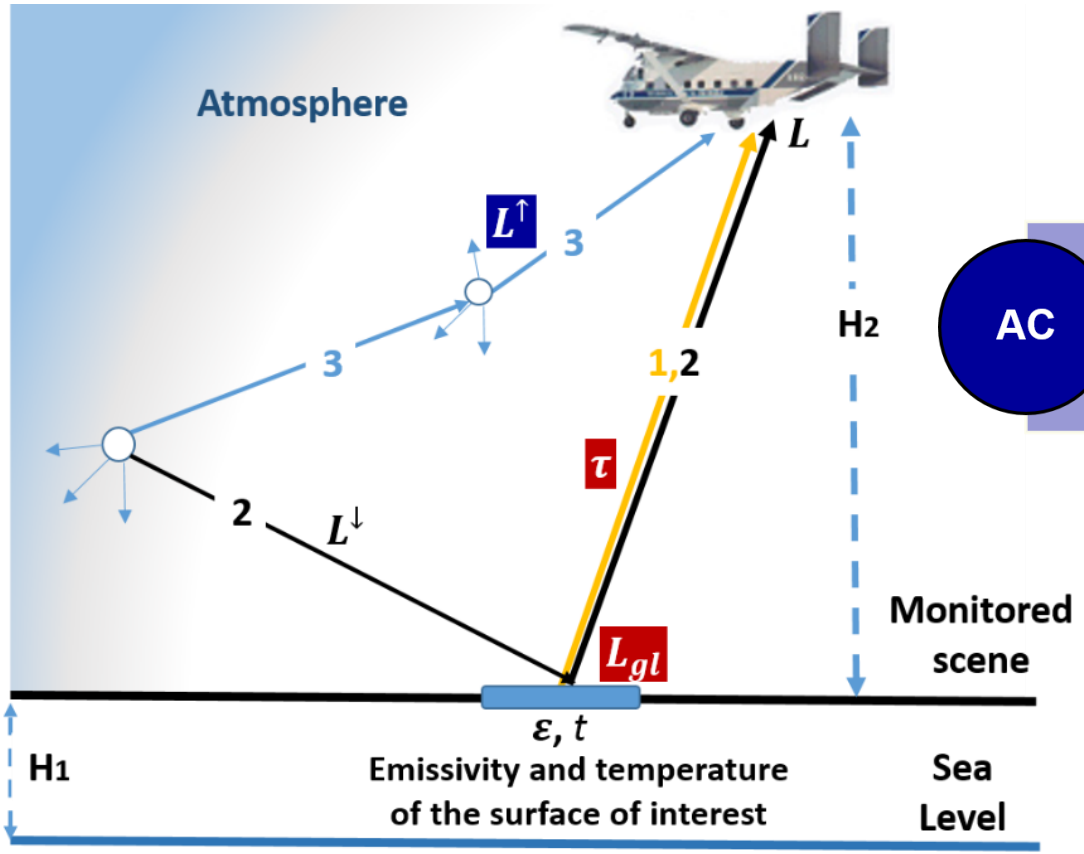


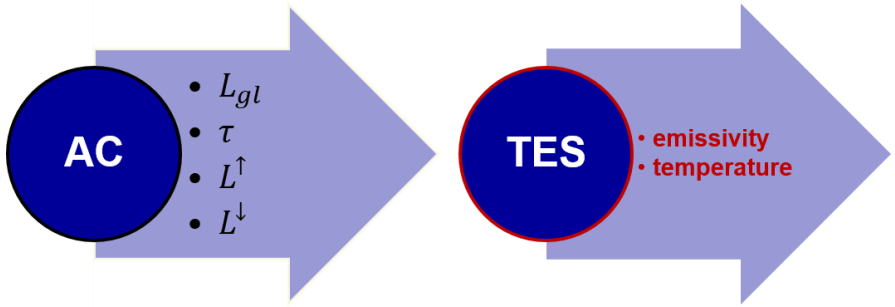
Radiative Transfer Model (RTM)

LWIR

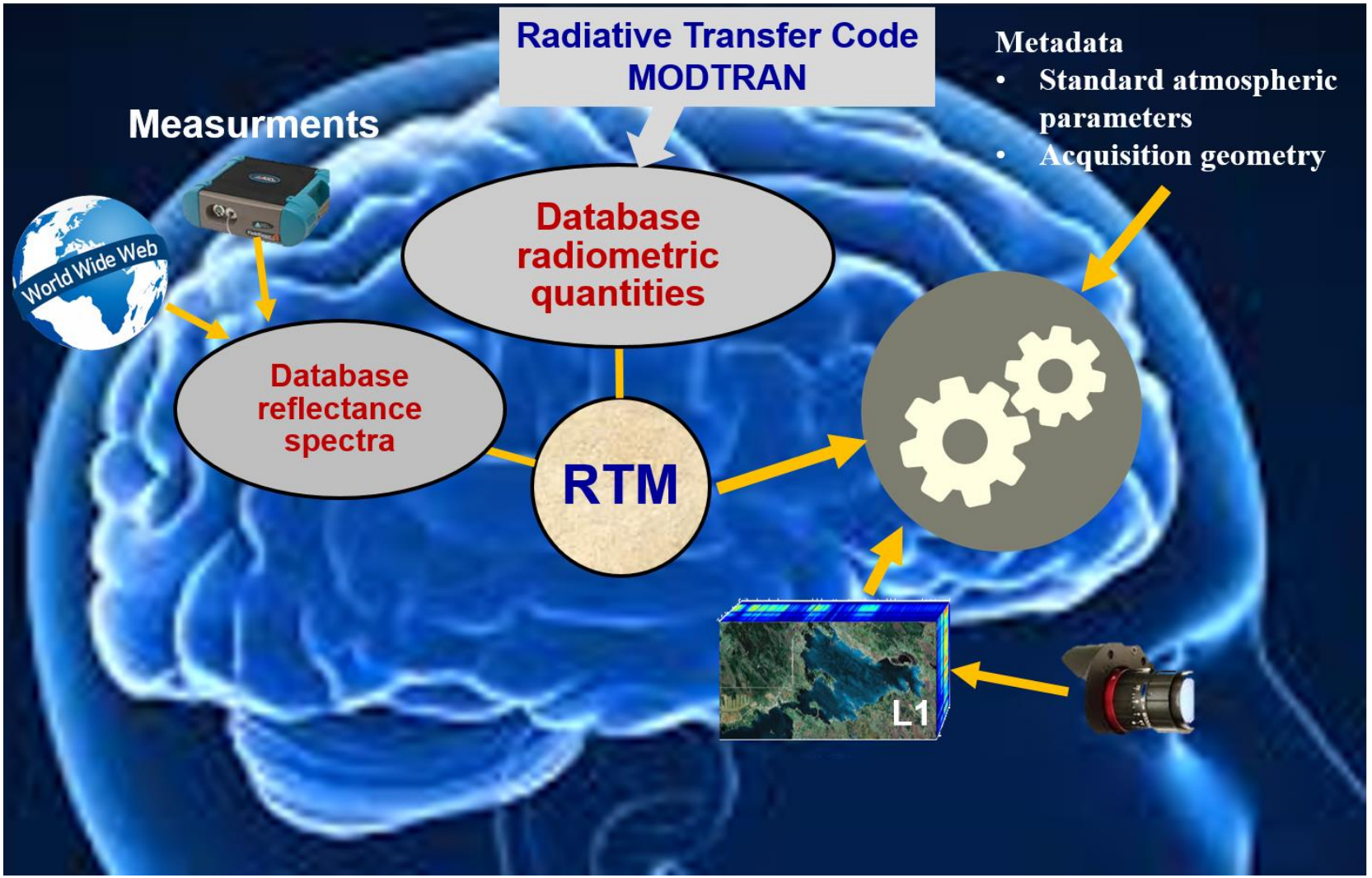
$$L(\lambda) = \tau(\lambda) \cdot L_{gl}(\lambda) + L^{\uparrow}(\lambda)$$

$$L_{gl}(\lambda) = \varepsilon(\lambda) \cdot L_{BB}(\lambda, t) + \left[1 - \varepsilon(\lambda)\right] \cdot L^{\downarrow}(\lambda)$$

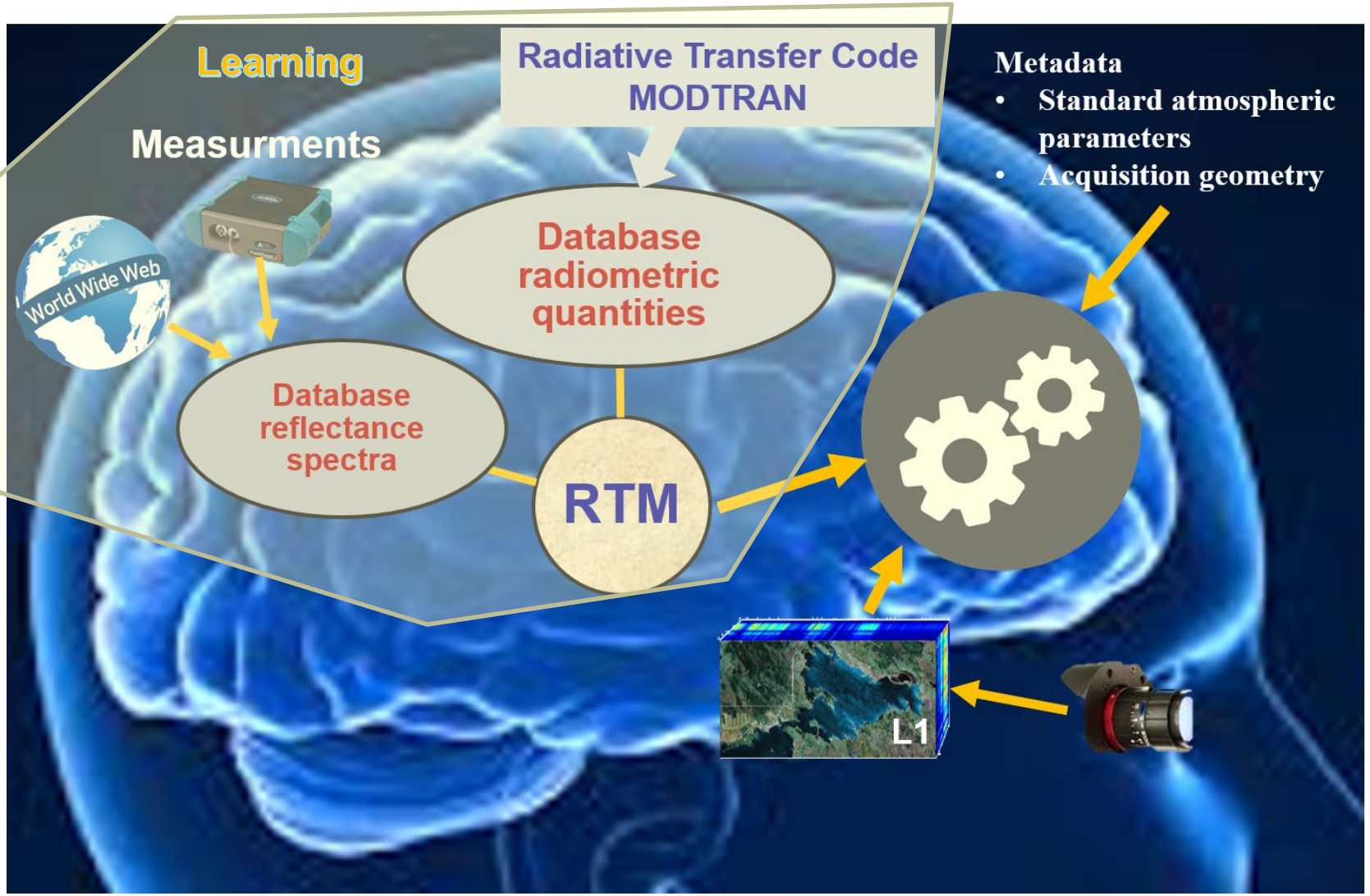




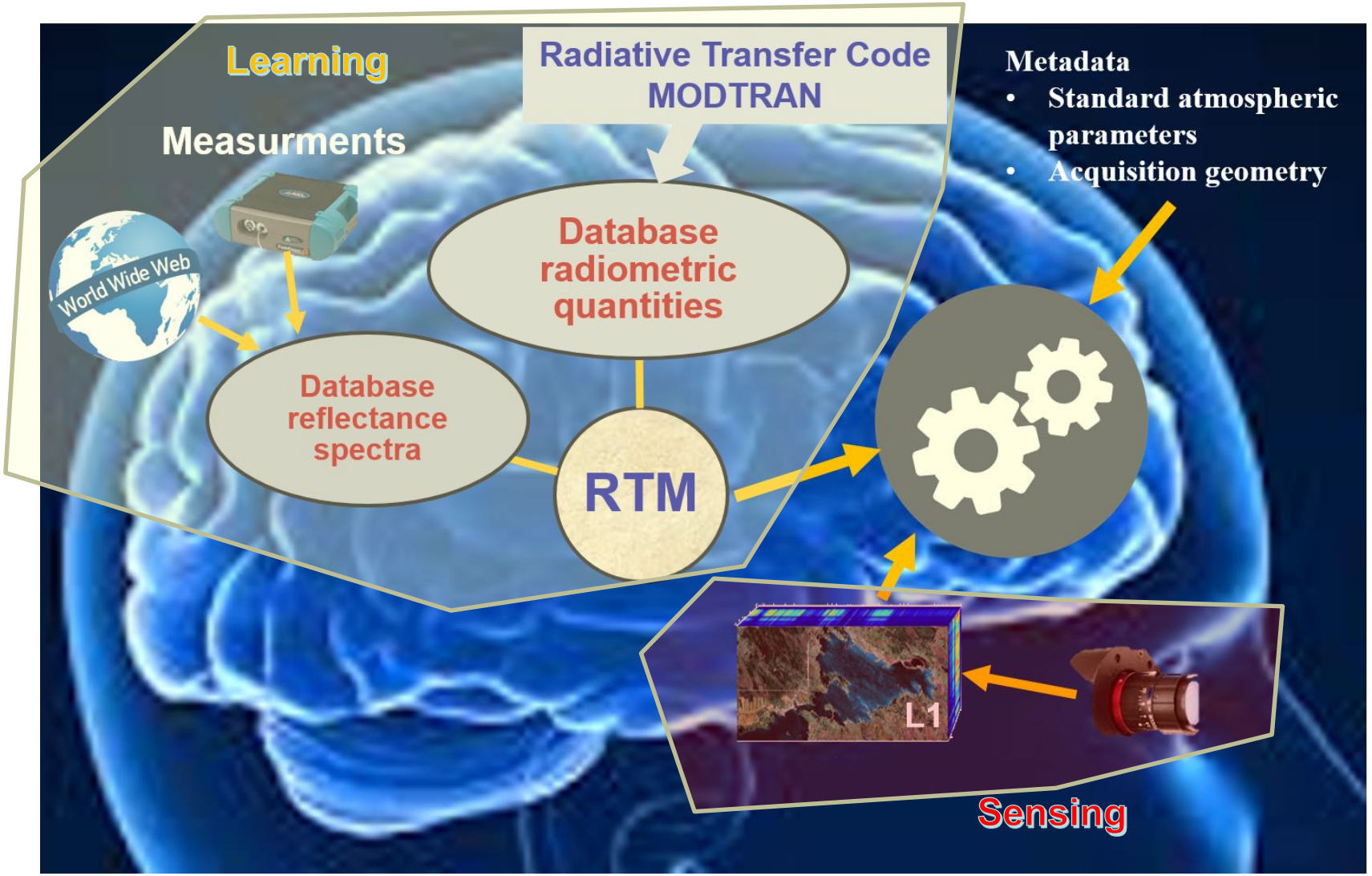
Autonomous Atmospheric Compensation



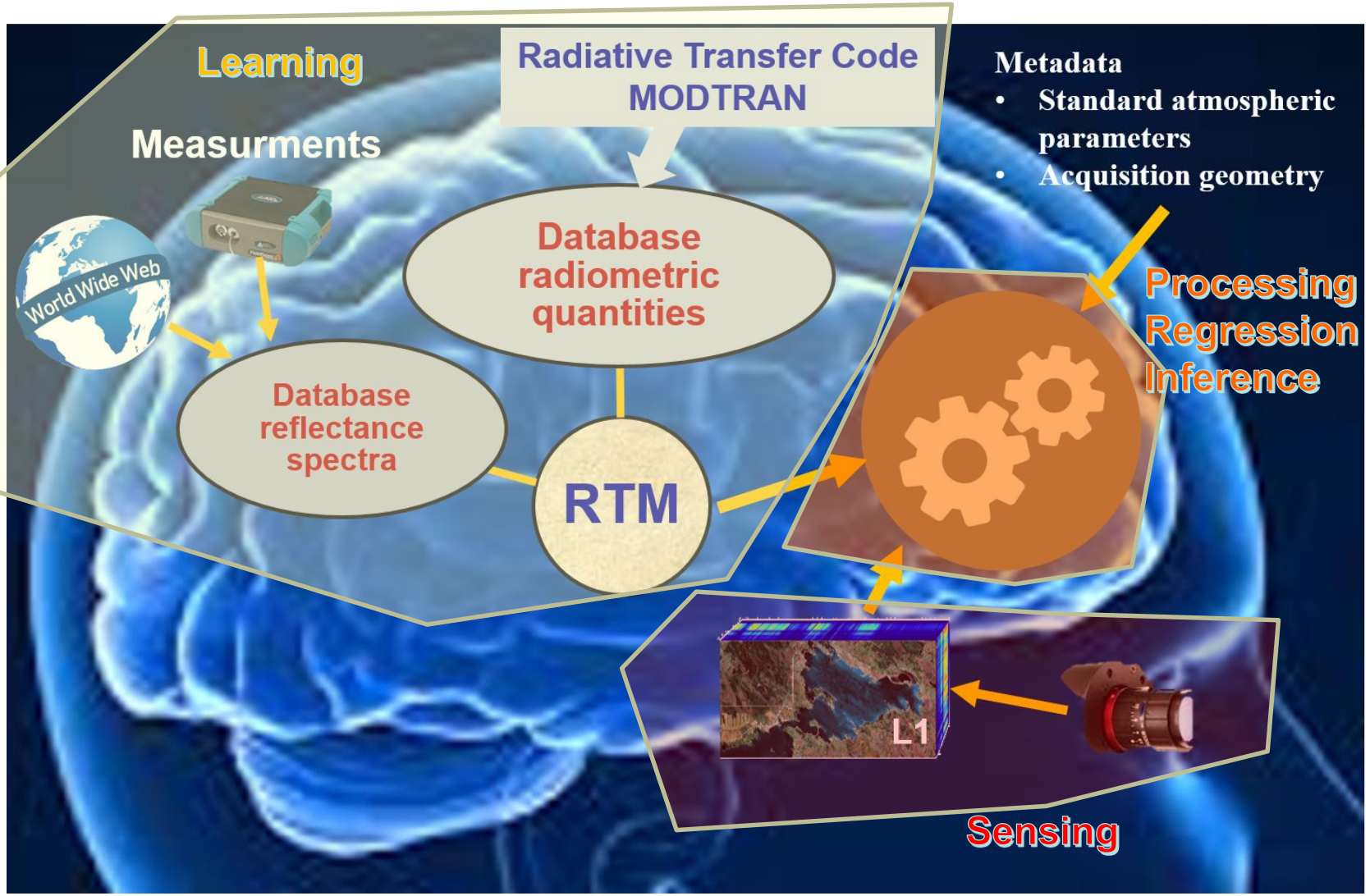
Autonomous Atmospheric Compensation



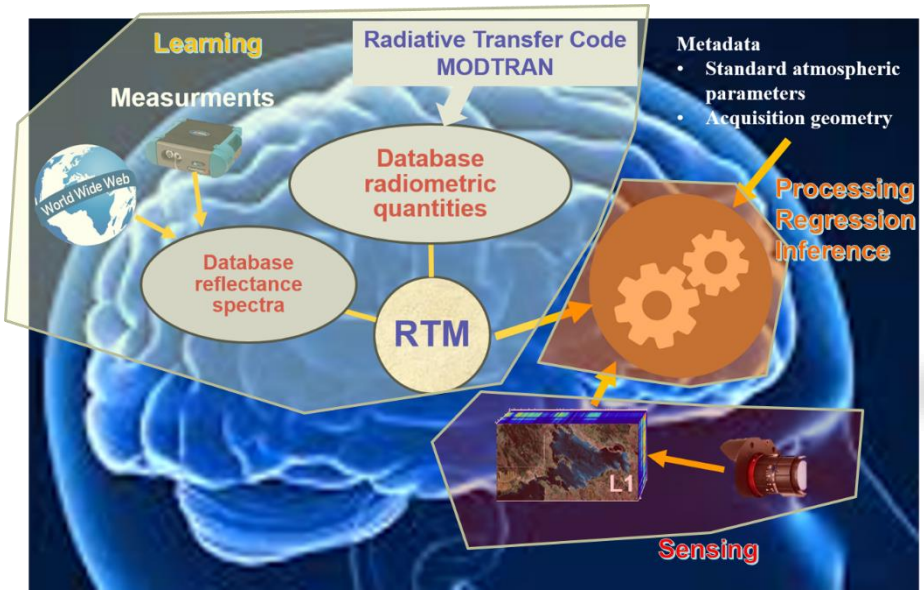
Autonomous Atmospheric Compensation

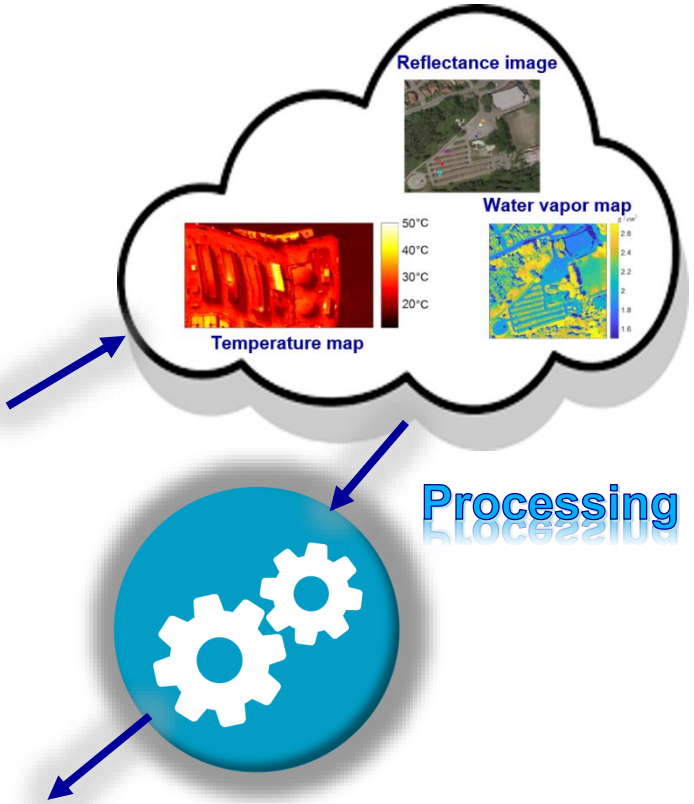


Autonomous Atmospheric Compensation



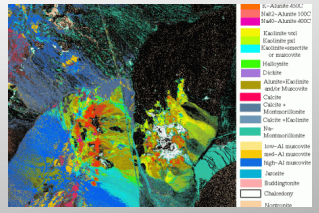
Autonomous Hyperspectral System



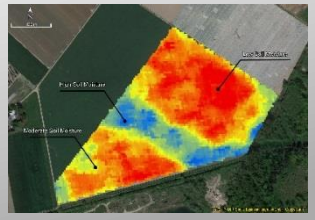


Application domain

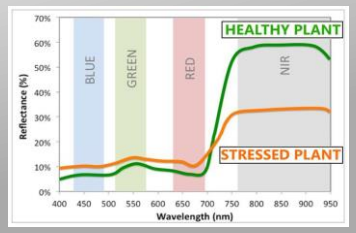
Mineralogy



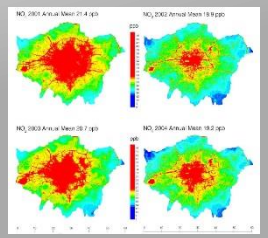
Precision Farming



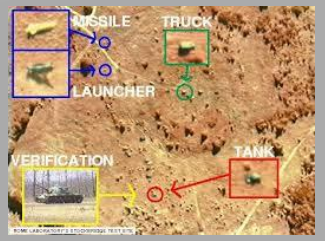
Vegetation health



Pollution analysis



Defence & Security



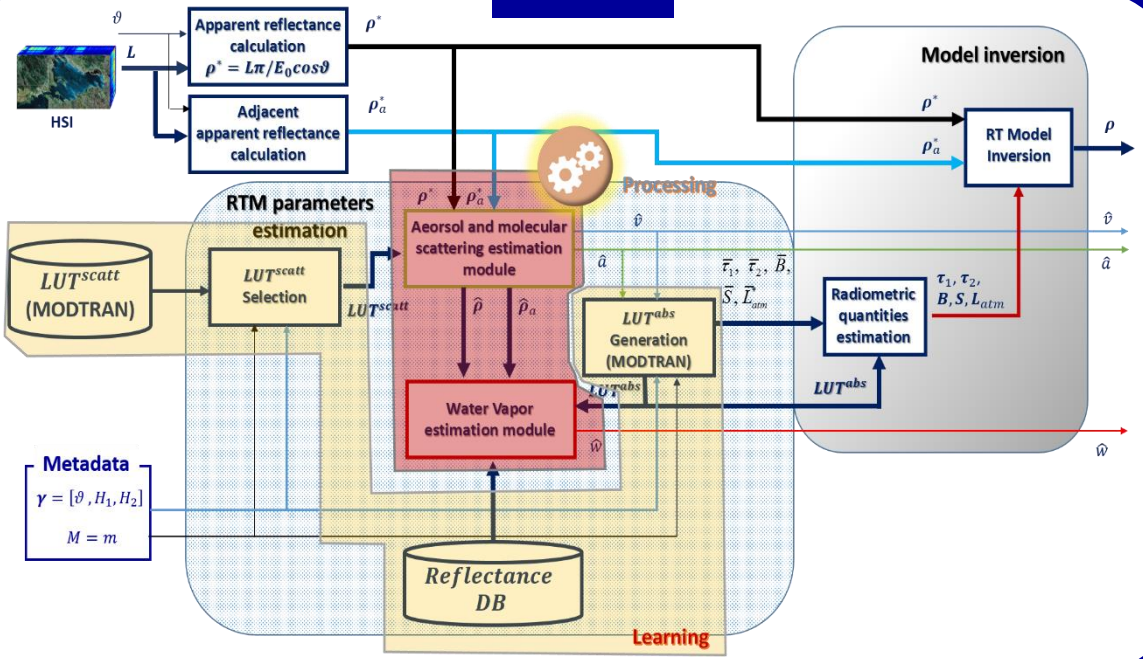
Unsupervised Atmospheric Compensation for Hyperspectral images (UAC4Hyper-VNIR)

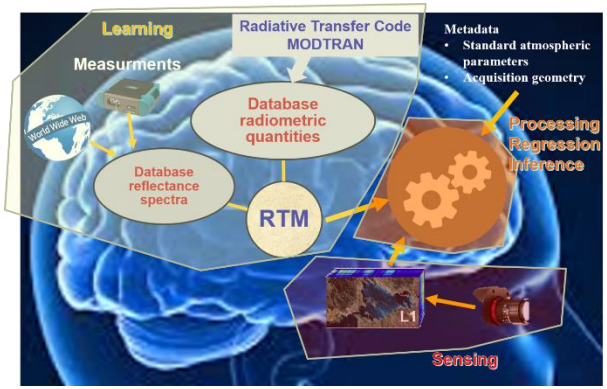
$$L(\lambda) = E_0(\lambda)\cdot\cos(\vartheta)\cdot\frac{\rho^*(\lambda)}{\pi}$$

$$\rho^*(\lambda) = \left[\tau_1(\lambda)+\tau_2(\lambda)\right]\cdot\frac{\rho(\lambda)}{1-S(\lambda)\cdot\rho_a(\lambda)} + B(\lambda)\cdot\frac{\rho_a(\lambda)}{1-S(\lambda)\cdot\rho_a(\lambda)} + L^*_{atm}(\lambda)$$

VNIR

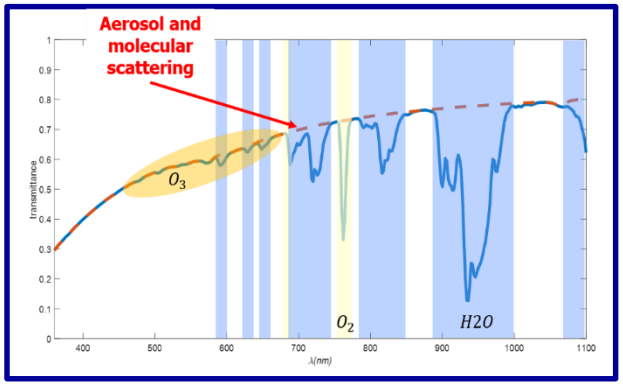
VNIR





Outputs

- Scaled (or normalized) spectral reflectance for each image pixel (no BRDF)
- Column water vapor concentration map (per-pixel)

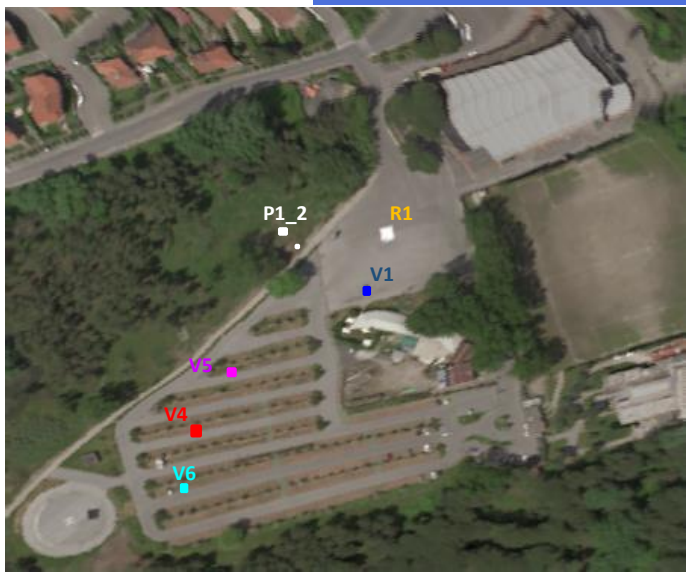


Limitations

- Flat terrain assumption ← Digital Elevation Model (DEM)
- Clear sky condition ← Clouds model in RTM???
- No real-time ← SW optimization
- No BRDF ← BRDF model in RTM???
- No shadow compensation

UAC4Hyper-VNIR: experimental results

Viareggio 2013 Trial



Sensor

CHARACTERISTICS	VNIR SIM.GA
IMAGING	Pushbroom
SPECTRAL RANGE [nm]	400 - 1000
SPECTRAL SAMPLING [nm]	≈ 1.2
# SPECTRAL BANDS	512
# SPATIAL PIXELS	1024
FOCAL LENGTH [mm]	24.0
NOMINAL IFOV [mrad]	0.499
FIELD OF VIEW (FOV) [deg]	± 15

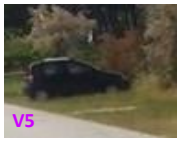
TgTs Description

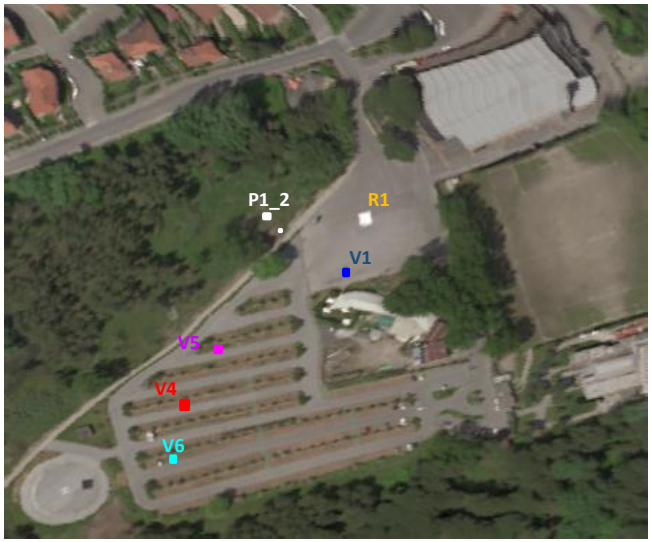
OBJECT	DESCRIPTION
V1	Light blue vehicle
V3	Green vehicle
V4	White vehicle covered with red tarp
V5	Purple vehicle
V6	Black vehicle covered with green tarp
P1_2	Green panel
P2	Bright green panel
R1	White reference calibration tarp
DA	Dark Asphalt
BA	Bright Asphalt

Metadata

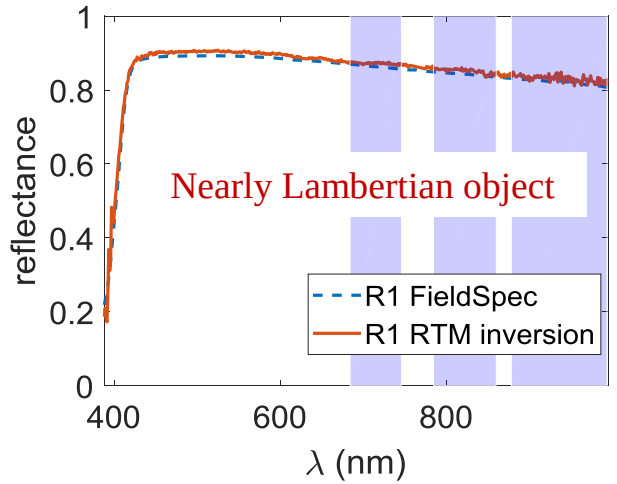
CHARACTERISTICS	D2F22H2
DAY	May 9 2013
TIME (GMT – hours:minutes)	12.38
Sensor altitude H_2 [Km]	1.24
LATITUDE	43° 51′ 25″ N
LONGITUDE	10° 14′ 51″ E
Terrain elevation H_1 [Km]	~0 (sea level)
SKY CONDITIONS	clear
# SAMPLES	450
# LINES	375
# BANDS (after binning)	256
SPECTRAL RANGE	VNIR
RADIANCE UNITS	$W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$

UAC4Hyper-VNIR: experimental results

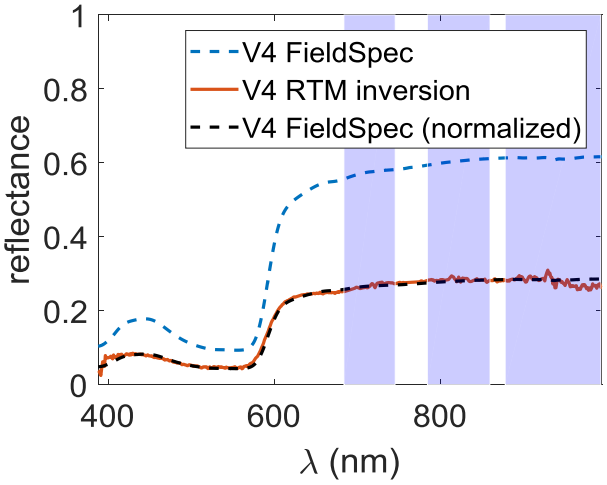




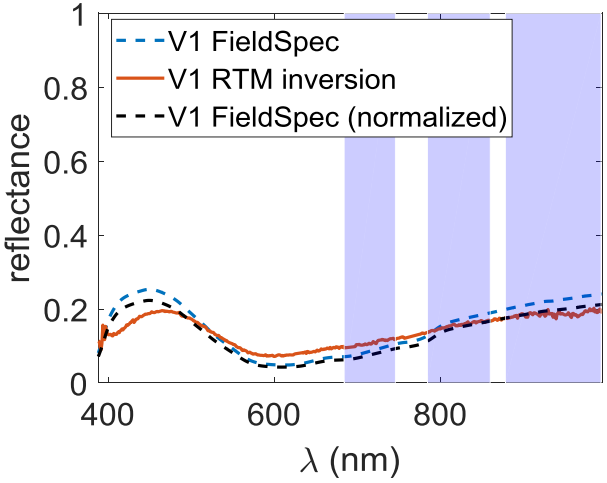
White reference calibration tarp



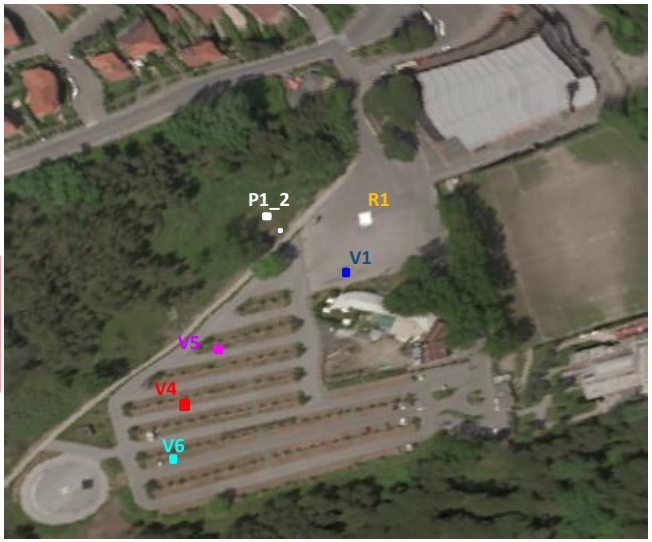
White vehicle covered by red tarp

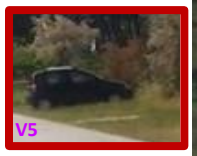


Light blue vehicle

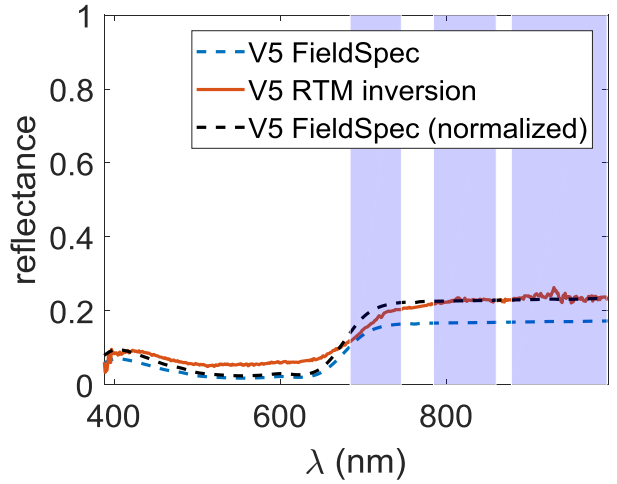


UAC4Hyper-VNIR: experimental results

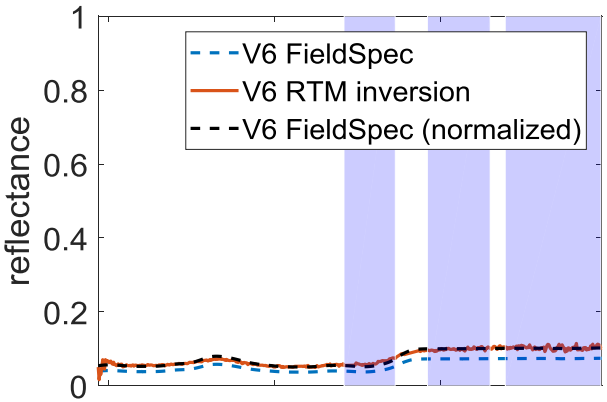




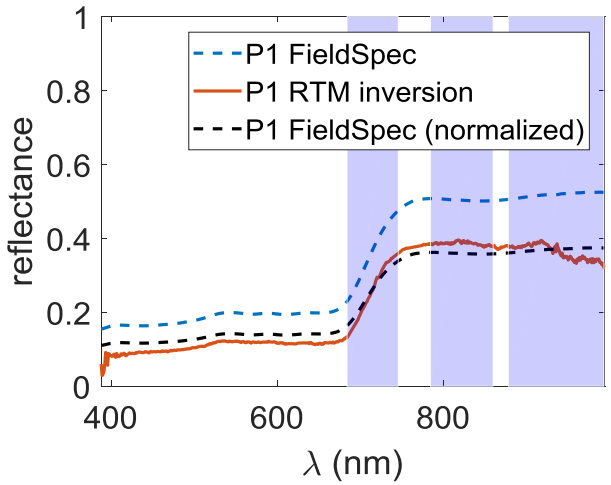
Purple vehicle



Black vehicle covered by green tarp

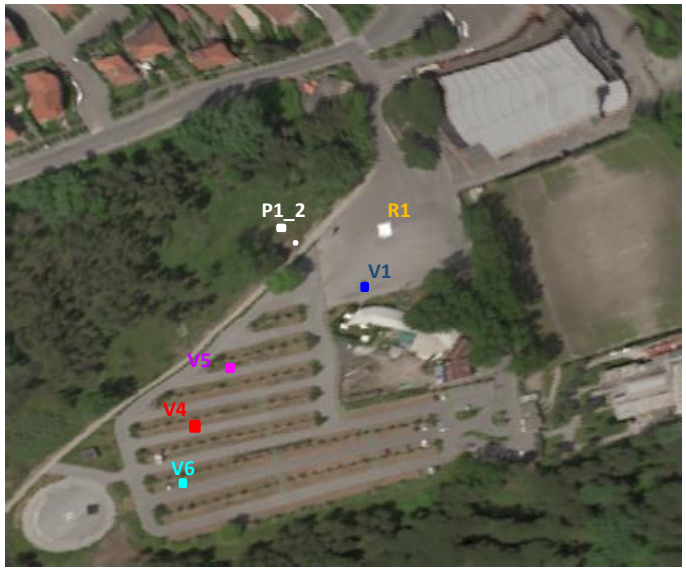


Green Panel

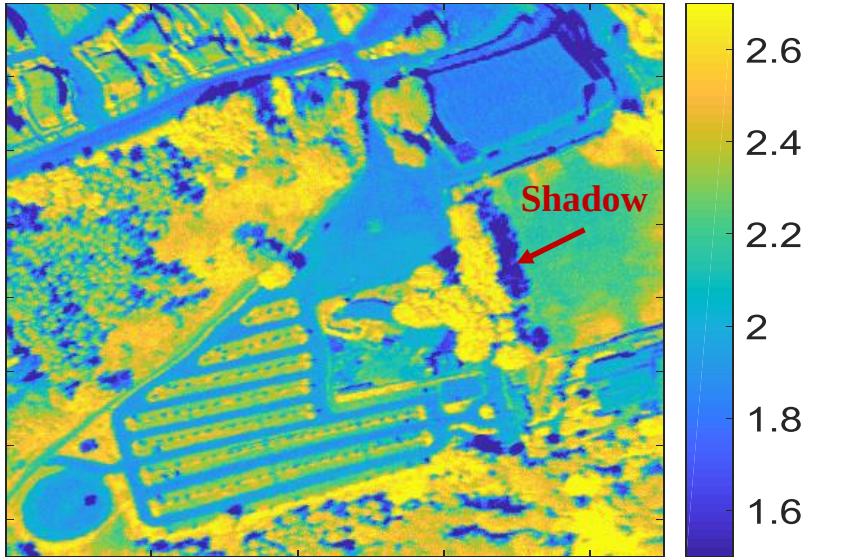


UAC4Hyper-VNIR: experimental results

Original Image (RGB)



Water vapor map

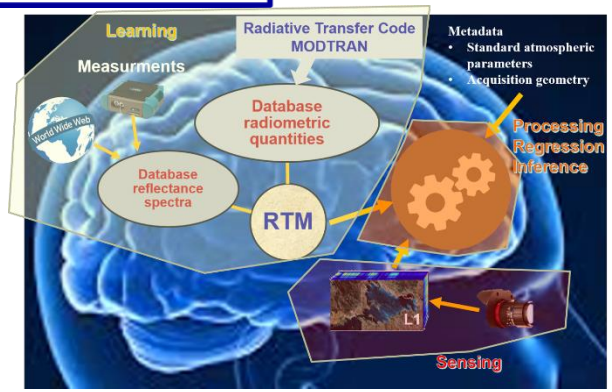


Coupled Subspace based Atmospheric Compensation algorithm (CSAC) and Subspace Based Temperature/Emissivity Separation algorithm (SBTES)

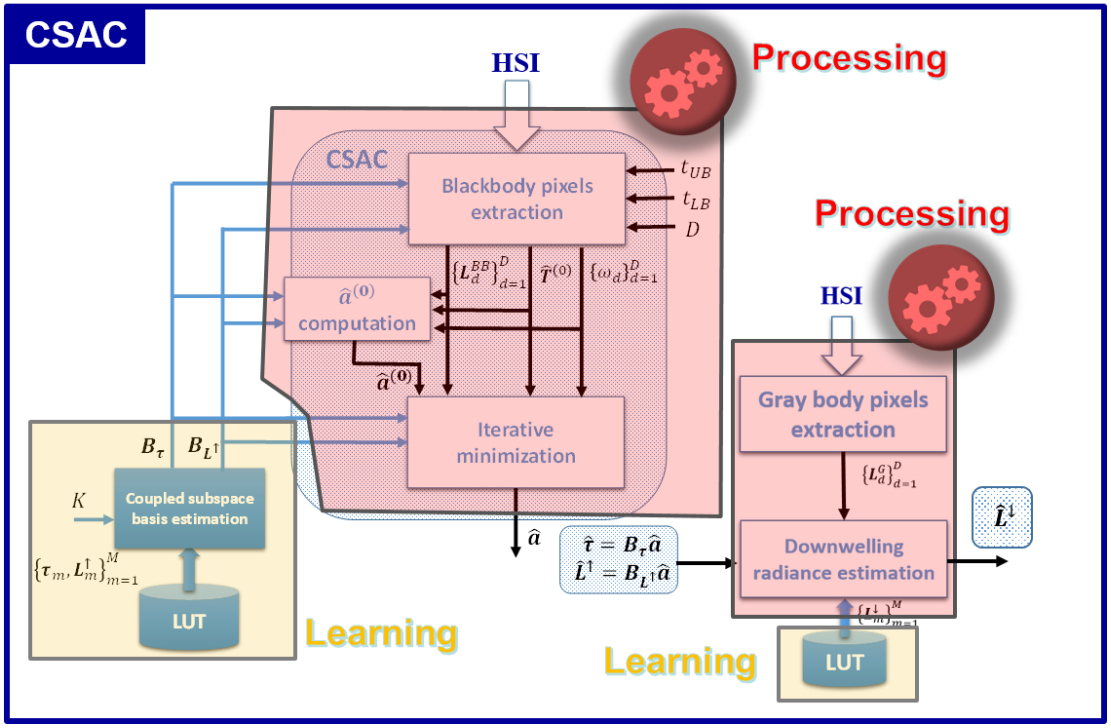
LWIR

$$L(\lambda) = \tau(\lambda) \cdot L_{gl}(\lambda) + L^{\uparrow}(\lambda)$$

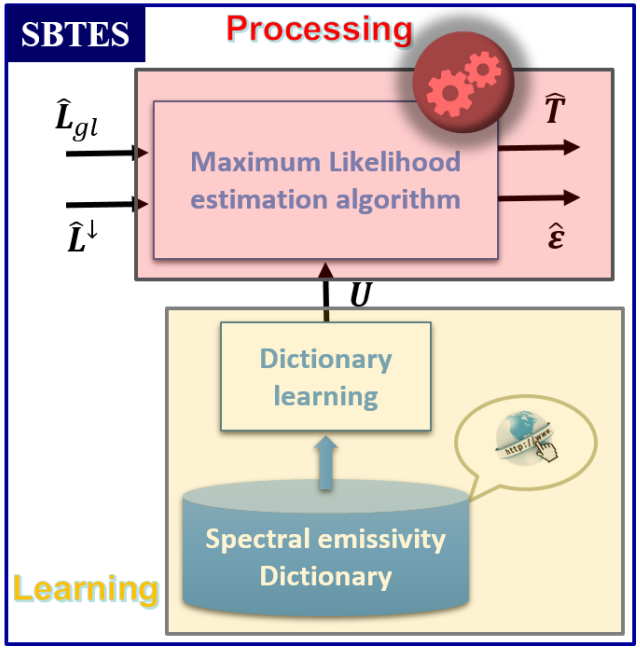
$$L_{gl}(\lambda) = \varepsilon(\lambda) \cdot L_{BB}(\lambda, t) + \left[1 - \varepsilon(\lambda)\right] \cdot L^{\downarrow}(\lambda)$$



CSAC



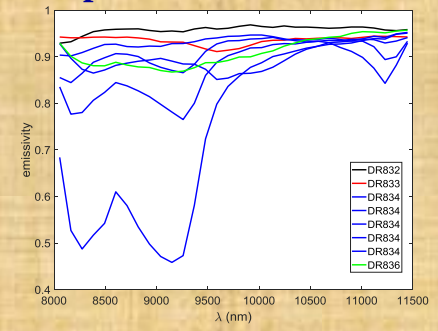
SBTES



CSAC+SBTES: experimental results

Ground Truth

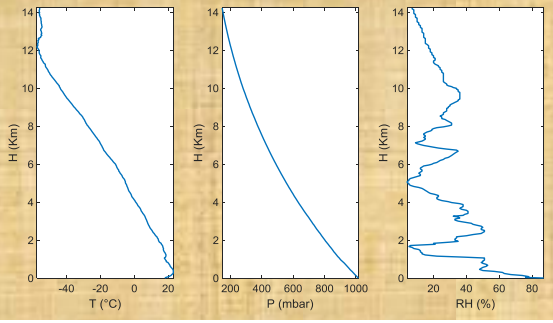
Spectral emissivities

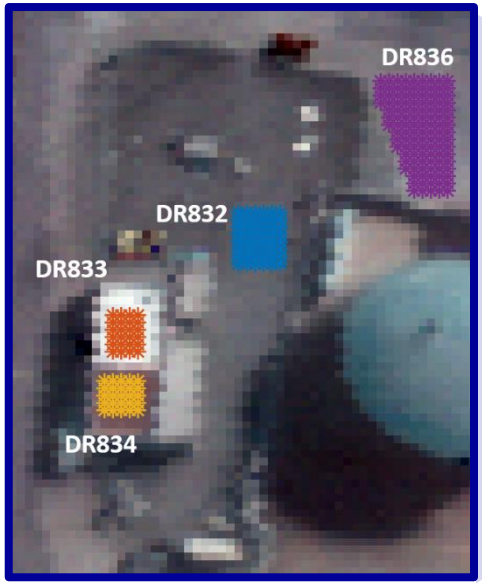


Temperatures

TGT name	Temperature (°C)
DR833	38.2
DR834	25.7
DR836	28.7
DR832	NA

Radiosonde data





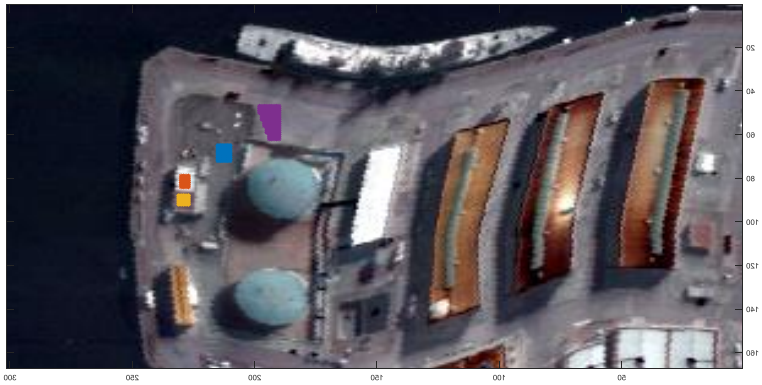
Sensor

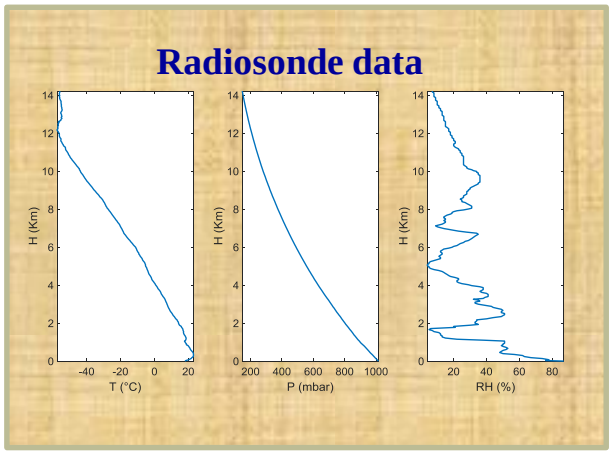
CHARACTERISTICS	TASI-600
IMAGING	Pushbroom
SPECTRAL RANGE [μm]	8-11.5
SPECTRAL SAMPLING [μm]	0.1
#SPECTRAL BANDS	32
FWHM [μm]	0.1095

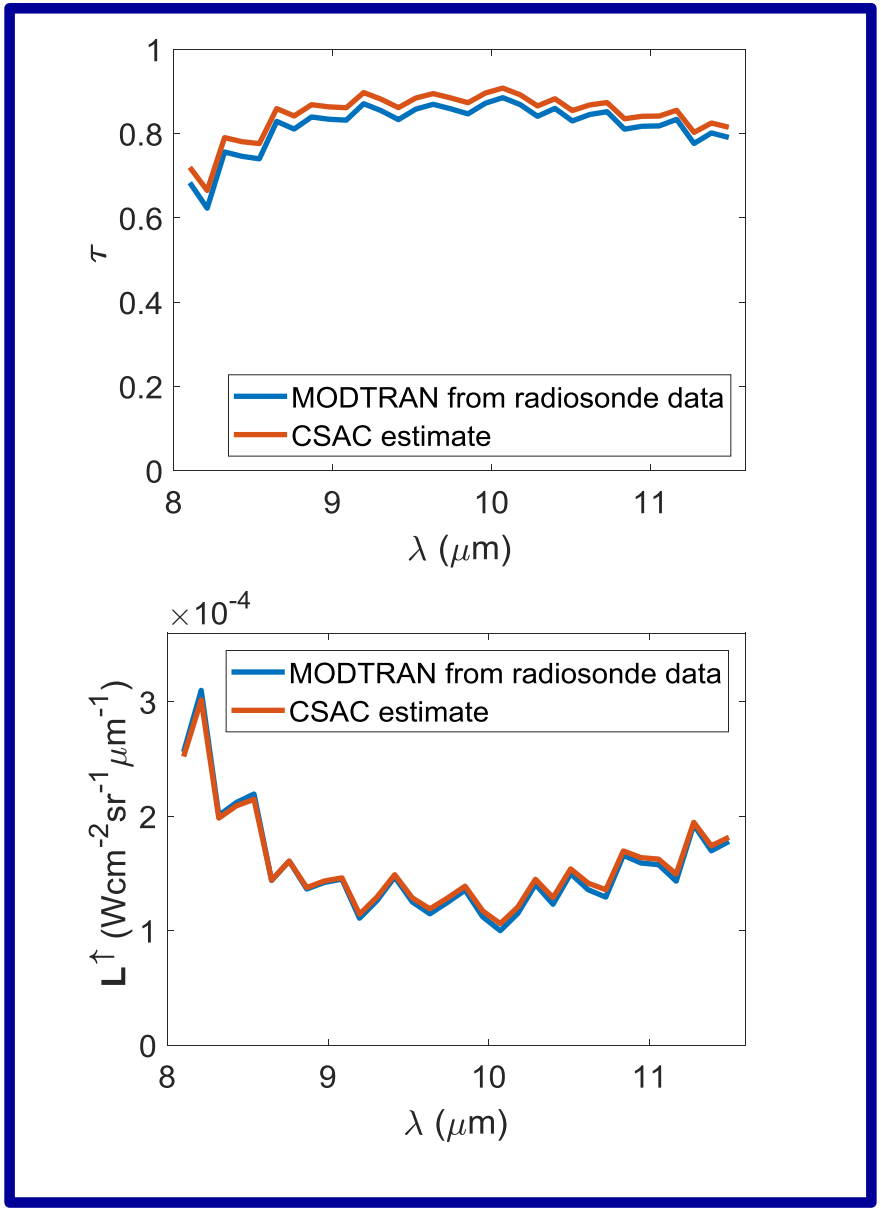
Metadata

CHARACTERISTICS	Morning
DAY	June 27 2011
TIME (GMT – hours:minutes)	7.35
Sensor altitude H_2 [Km]	0.850
LATITUDE	51° 19′ 83″ N
LONGITUDE	3° 11′ 52″ E
Terrain elevation H_1 [Km]	~0 (sea level)
SKY CONDITIONS	clear
# SAMPLES	160
# LINES	300
# BANDS (after binning)	32
SPECTRAL RANGE	LWIR
RADIANCE UNITS	$W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$

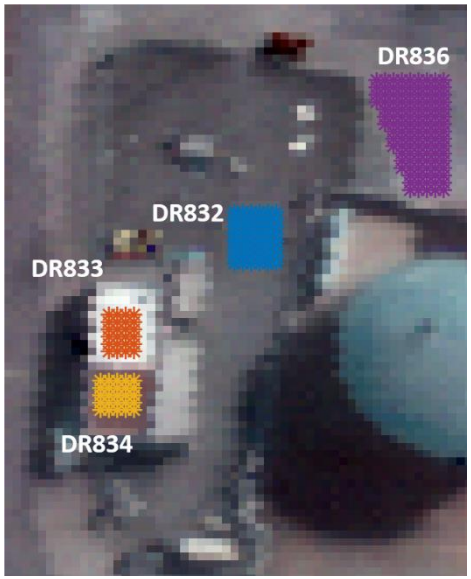
CSAC+SBTES: experimental results



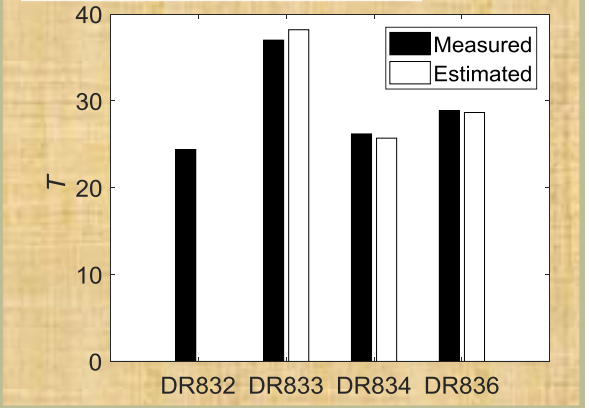


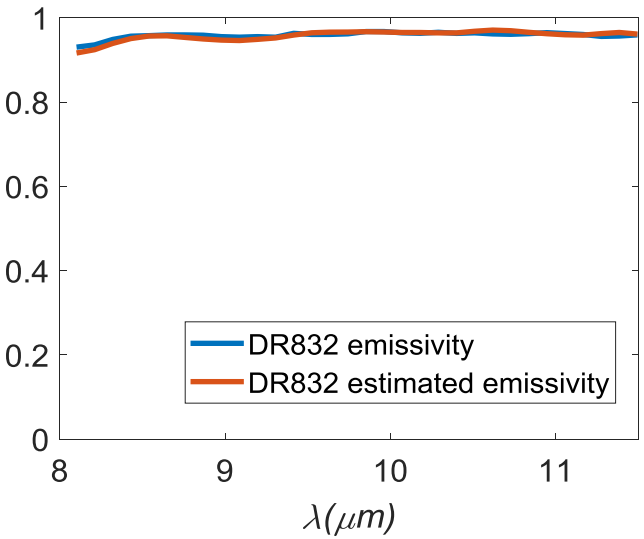


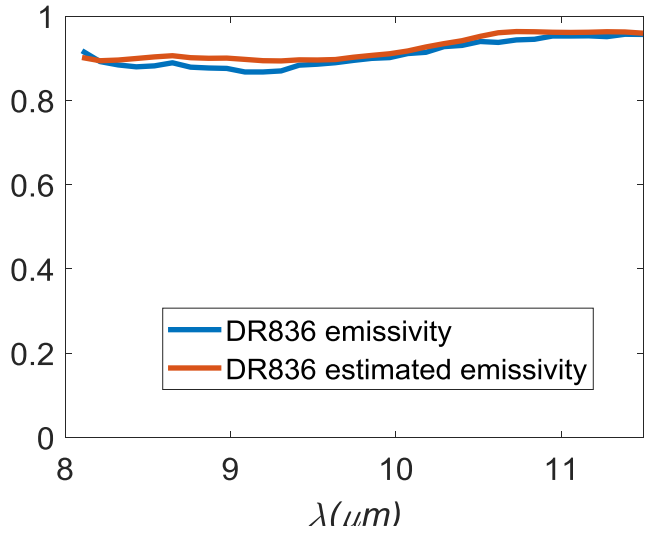
CSAC+SBTES: experimental results

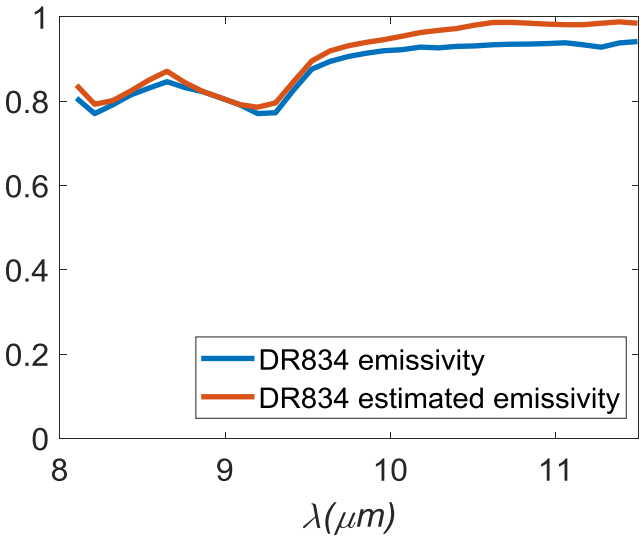


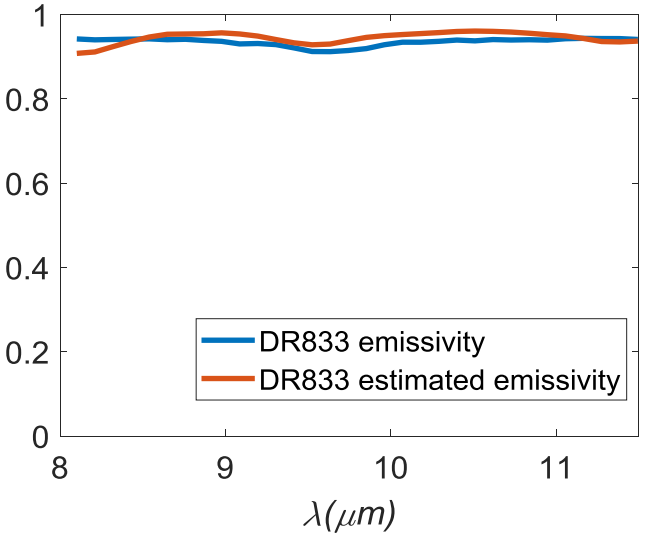
TGT name	Temperature (°C)
DR833	38.2
DR834	25.7
DR836	28.7
DR832	NA











CSAC+SBTES: experimental results

Temperature Map