EUFAR FP7

N6SP - Standards and Protocols

EGADS Algorithm Handbook

Version 0.5.0

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Contents

Chapter 1

Introduction

This document contains descriptions of algorithms contained in the EGADS toolbox. Within each algorithm description is the following:

- **Algorithm Name** – name of algorithm as implemented in EGADS .
- **Category** – general category of algorithm. Algorithm can be found in this subdirectory in EGADS .
- **Summary** – short description of what the algorithm does.
- **Inputs** – expected inputs to algorithm. This field includes expected units, and data type of input.
- **Outputs** – outputs produced by algorithm.
- **Formula** – description of formulas or methods behind the algorithm.
- **Source** – person, institution or entity who provided the algorithm.
- **References** – any references to literature, journals or documents with more information on the current algorithm

To aid in algorithm usage and discovery, there is a general naming scheme for EGADS algorithms. Generally, algorithm names are composed as follows:

`{measurement}_{context/detail/instrument}_{source}`

So, for example, an algorithm provided by CNRM to calculate the density of dry air would be named `density_dry_air_cnrm`.

Part I

Atmospheric

Chapter 2

Thermodynamics

2.1 Pressure altitude

Algorithm name: altitude_pressure_cnrm

Category: Thermodynamics

Summary: Calculates pressure altitude using virtual temperature.

Inputs:

T_v	Vector	Virtual temperature [K or °C]
P_s	Vector	Static pressure [hPa]
$P_{surface}$	Coeff	Surface pressure [hPa]
R_a/g	Coeff	Gas constant of air over acceleration of gravity

Outputs:

Alt_p	Vector	Pressure altitude [m]

Formula:

$$Alt_p = \frac{R_a}{g} T_v \log\left(\frac{P_{surface}}{P_s}\right)$$

Source: CNRM/GMEI/TRAMM

References:

2.2 Density of dry air

Algorithm name: density_dry_air_cnrm

Category: Thermodynamics

Summary: Calculates density of dry air given static temperature and pressure.

Inputs:

P_s	Vector	Static pressure [hPa]
T_s	Vector	Static temperature [K or °C]

Outputs:

ρ	Vector	Density of dry air [kg/m^3]

Formula:

$$\rho = \frac{100P_s}{R_a T_s}$$

with $R_a = 287.05$ J kg$^-1$ K$^-1$

Density of humid air can be calculated using this same algorithm by using virtual temperature instead of static temperature.

Source: CNRM/GMEI/TRAMM

References: Equation d'état d'un gaz parfait, Triplet-Roche [7], page 34.

2.3 Relative humidity from capacitive probe

Algorithm name: hum_rel_capacitive_cnrm

Category: Thermodynamics

Summary: Calculates relative humidity using the measured frequency from a capacitive probe.

Inputs:

$Ucapf$	Vector	Output frequency of the capacitive probe [Hz]
T_s	Vector	Static temperature [K]
P_s	Vector	Static pressure [hPa]
ΔP	Vector	Dynamic pressure [hPa]
C_t	Coeff.	Temperature correction coefficient [%°C]
F_{min}	Coeff.	Minimal acceptable frequency [Hz]
C_0	Coeff.	0th degree calibration coefficient
C_1	Coeff.	1st degree calibration coefficient
C_2	Coeff.	2nd degree calibration coefficient

Outputs:

H_u	Vector	Relative humidity [%]

Formula: If $Ucapf \leq F_{min}$ then $Ucapf = F_{min}$

$$H_u = \frac{P_s}{P_s + \Delta P}\left[C_0 + C_1 Ucapf + C_2 Ucapf^2 + C_t(T_s - 20)\right]$$

with T_s in $°C$.

Source: CNRM/GMEI/TRAMM

References: CAM note on humidity instrument measurements. [1]

2.4 Pressure and angle of incidence

Algorithm name: pressure_angle_incidence_cnrm

Category: Thermodynamics

Summary: Calculates static pressure and dynamic pressure by correction of static error. Angle of attack and sideslip are calculated from the horizontal and vertical differential pressures.

Inputs:

P_{sr}	Vector	Raw static pressure [hPa]
ΔP_r	Vector	Raw dynamic pressure [hPa]
ΔP_h	Vector	Horizontal differential pressure [hPa]
ΔP_v	Vector	Vertical differential pressure [hPa]
C_α	Coeff.[2]	Angle of attack calibration coefficients
C_β	Coeff.[2]	Slip calibration coefficients
$C_{errstat}$	Coeff.[4]	Static error coefficients

Outputs:

P_s	Vector	Static Pressure [hPa]
ΔP	Vector	Dynamic pressure corrected with static error [hPa]
α	Vector	Angle of attack [rad]
β	Vector	Sideslip [rad]

Formula: If $\Delta P_r > 25$hPa:

$$Errstat = C_{errstat}[0] + C_{errstat}[1]\Delta P_r + C_{errstat}[2]\Delta P_r^2 + C_{errstat}[3]\Delta P_r^3$$

otherwise:

$$\begin{aligned} Errstat &= \frac{\Delta P_r}{25}\text{ Errstat @ 25 hPa} \\ P_s &= P_{sr} - Errstat \\ \Delta P &= \Delta P_r + Errstat \\ \alpha &= C_\alpha[0] + C_\alpha[1]\frac{\Delta P_v}{\Delta P} \\ \beta &= C_\beta[0] + C_\beta[1]\frac{\Delta P_h}{\Delta P} \end{aligned} \tag{2.1}$$

Source: CNRM/GMEI/TRAMM

References:

2.5 Potential Temperature

Algorithm name: temp_potential_cnrm

Category: Thermodynamics

Summary: Calculates potential temperature.

Inputs:

T_s	Vector	Static temperature [K or ∘C]
P_s	Vector	Static pressure [hPa]
R_a/c_{pa}	Coeff.	Gas constant of air divided by specific heat of air at constant pressure

Outputs:

θ	Vector	Potential temperature [same unit as T_s]

Formula:

$$\theta = T_s \left(\frac{1000}{P_s} \right)^{R_a/c_{pa}}$$

Source: CNRM/GMEI/TRAMM

References: Triplet-Roche [7].

2.6 Equivalent Potential Temperature

Algorithm name: temp_potential_equiv_cnrm

Category: Thermodynamics

Summary: Calculates equivalent potential temperature of air. The equivalent potential temperature is the temperature a parcel of air would reach if all water vapor in the parcel condensed, and the parcel was brought adiabatially to 1000 hPa.

Inputs:

T_s	Vector	Static temperature [K or ◦C]
θ	Vector	Potential temperature [K or ◦C]
r	Vector	Vater vapor mixing ratio [g/kg]
c_{pa}	Coeff.	Specific heat of dry air at constant pressure

Outputs:

θ_e	Vector	Equivalent potential temperature [same units as T_s]

Formula:

$$\theta_e = \theta \left(1 + r \frac{L}{c_{pa} T_s} \right)$$

where $L = 3136.17 - 2.34 T_s$ (for T_s in K)

Source: CNRM/GMEI/TRAMM

References: From the CAM routine which is identical to the algorithm P. Durand cited in the formula book created for PYREX.

2.7 Static Temperature

Algorithm name: temp_static_cnrm

Category: Thermodynamics

Summary: Calculates static temperature of the air from total temperature. This method applies to probe types such as the Rosemount.

Inputs:

T_t	Vector	Measured total temperature [K]
ΔP	Vector	Dynamic pressure [hPa]
P_s	Vector	Static pressure [hPa]
r_f	Coeff.	Probe recovery coefficient
R_a/c_{pa}	Coeff.	Gas constant of air divided by specific heat of air at constant pressure

Outputs:

T_s	Vector	Static temperature [K]

Formula:

$$T_s = \frac{T_t}{1 + r_f \left(\left(1 + \frac{\Delta P}{P_s}\right)^{R_a/c_{pa}} - 1 \right)}$$

Source: CNRM/GMEI/TRAMM

References:

2.8 Virtual Temperature

Algorithm name: temp_virtual_cnrm

Category: Thermodynamics

Summary: Calculates the virtual temperature of air.

Inputs:

T_s	Vector	Static temperature [K or ∘C]
r	Vector	Water vapor mixing ratio [g/kg]

Outputs:

T_v	Vector	Virtual temperature [same units as T_s]

Formula:

$$T_v = T_s \frac{1 + (R_v/R_a)r}{1 + r}$$

where $R_v/R_a = 1.608$

Source: CNRM/GMEI/TRAMM

References: Triplet-Roche [7], page 56.

2.9 Mach number

Algorithm name: velocity_mach_raf

Category: Thermodynamics

Summary: Calculates the mach number based on dynamic and static pressure.

Inputs:		
ΔP	Vector	Dynamic pressure [hPa]
P_s	Vector	Static pressure [hPa]

Outputs:		
M	Vector	Mach number

Formula:

$$M = \sqrt{\frac{2}{\gamma - 1}\left[\left(\frac{\Delta P}{P_s} + 1\right)^{\frac{\gamma-1}{\gamma}} - 1\right]}$$

Source: NCAR-EOL

References: NCAR-RAF Bulletin #23 [5]

2.10 True air speed

Algorithm name: velocity_tas_cnrm

Category: Thermodynamics

Summary: Calculates true air speed based on static pressure, static temperature and dynamic pressure using the Barré-St Venant formula.

Inputs:

T_s	Vector	Static temperature [K]
ΔP	Vector	Dynamic pressure [hPa]
P_s	Vector	Static pressure [hPa]
c_{pa}	Coeff.	Specific heat of air at constant pressure (for dry air 1004 J K^{-1} kg^{-1})
R_a/c_{pa}	Coeff.	Gas constant of air divided by specific heat of air at constant pressure

Outputs:

V_t	Vector	True air speed [m/s]

Formula:

$$V_t^2 = 2c_{pa}T_s \left[\left(1 + \frac{\Delta P}{P_s} \right)^{R_a/c_{pa}} - 1 \right]$$

Source: CNRM/GMEI/TRAMM

References: NCAR-RAF Bulletin #23 [5], *Méchanique des fluides*, Candel [2]

2.11 True air speed

Algorithm name: velocity_tas_raf

Category: Thermodynamics

Summary: Calculates true air speed based on Mach number, measured temperature and thermometer recovery factor. Typical values of the themometer recovery factor range from 0.75-0.9 for platinum wire ratiometer (flush bulb type) thermometers, and around 1.0 for TAT type thermometers.

Inputs:

T_r	Vector	Measured temperature [K]
M	Vector	Mach number
e	Coeff.	thermometer recovery factor

Outputs:

V_t	Vector	True air speed [m/s]

Formula:

$$V_t = \sqrt{\frac{R\gamma T_r M^2}{1 + 0.5(\gamma - 1)eM^2}}$$

where the recovery factor e can be determined for a thermometer by comparing its measured temperature with the actual total and static temperature.

$$e \equiv \frac{T_r - T_s}{T_t - T_s}$$

Source: NCAR-EOL

References: NCAR-RAF Bulletin #23 [5]

2.12 Longitudinal true airspeed

Algorithm name: velocity_tas_longitudinal_cnrm

Category: Thermodynamics

Summary: Calculates the true air speed along the longitudinal axis of the aircraft.

Inputs:

V_t	Vector	True air speed [m/s]
α	Vector	Angle of attack [rad]
β	Vector	Sideslip angle [rad]

Outputs:

V_{tx}	Vector	Longitudinal true air speed [m/s]

Formula:

$$V_{tx} = \frac{V_t}{\sqrt{1 + \tan^2\alpha + \tan^2\beta}}$$

Source: CNRM/GMEI/TRAMM

References: NCAR-RAF Bulletin #23 [5]

Chapter 3

Microphysics

3.1 Effective diameter

Algorithm name: diameter_effective_dmt

Category: Microphysics

Summary: Calculates effective diameter of a size distribution. In general, this definition is only meaningful for water clouds, and another form must be used when in ice clouds.

Inputs:

c_i	Array[time, bins]	Number concentration of hydrometeors in size category i [cm^{-3}]
d_i	Vector[bins]	Average diameter in size category i [μm]

Outputs:

R_e	Vector[time]	Effective diameter [μm]

Formula:

$$D_e = \frac{\sum\limits_{i=1}^{m} c_i d_i^3}{\sum\limits_{i=1}^{m} c_i d_i^2}$$

Source:

References: "Data Analysis User's Guide Chapter I: Single Particle Light Scattering," Droplet Measurement Technologies, 30. [3]

3.2 Mean diameter

Algorithm name: diameter_mean_raf

Category: Microphysics

Summary: Calculates the arithmetic average of all particle diameters given in a particle size distribution.

Inputs:

n_i	Array[time, bins]	Number of particles in each channel i
d_i	Vector[bins]	Channel i size [μm]

Outputs:

$\bar{D}$	Vector[time]	Mean diameter [μm]

Formula:

$$\bar{D} = \frac{\sum_i n_i d_i}{N_t}$$

where N_t is the total number of particles.

Source: NCAR-RAF

References: NCAR-RAF Bulletin No. 24. [6]

3.3 Median Volume Diameter

Algorithm name: diameter_median_volume_dmt

Category: Microphysics

Summary: Calculates the median volume diameter given a size distribution. The median volume diameter is the size of droplet below which 50% of the total water volume resides.

Inputs:

c_i	Array[time, bins]	Number concentration of hydrometeors in size category i [cm^{-3}]
d_i	Vector[bins]	Average diameter of size category i [μm]
ρ_i	Vector[bins],Optional	Density of hydrometeor in size category i [g cm^{-3}]. Default is $\rho_w = 1.0$ g $cm^{-}3$

Outputs:

D_{mvd}	Vector[time]	Median volume diameter [μm]

Formula: Step 1: Compute liquid water content

$$W = \frac{\pi \rho_w}{6} \sum_{i=1}^{m} c_i d_i^3$$

Step 2: Beginning at the first size channel, calculate the accumulated mass $S_n = w_1 + w_2 + ...w_n$ where w_1 is the mass of water in channel 1, and w_n is the channel where the accumulated mass is greater than or equal to $0.5W$, i.e. greater than or equal to 50% of the total LWC.

Step 3: Compute the median volume diameter, D_{mvd} by interpolating linearly between the channels that bracket where the accumulated mass exceeded the total LWC:

$$D_{mvd} = D_{n-1} + (0.5 - S_{n-1}/S_n)(D_n - D_{n-1})$$

Source:

References: "Data Analysis User's Guide Chapter I: Single Particle Light Scattering," Droplet Measurement Technologies, 33. [3]

3.4 Extinction Coefficient

Algorithm name: extinction_coeff_dmt

Category: Microphysics

Summary: Calculates extinction coefficient given a particle size distribution.

Inputs:

c_i	Array[time, bins]	Number conentration of hydrometeors in size category i [cm^{-3}]
d_i	Vector[bins]	Average diameter of size category i [μm]
Q_e	Vector[bins],Optional	Extinction efficiency; default is $Q_e = 2$

Outputs:

B_e	Vector[time]	Extinction coefficient [km^{-1}]

Formula:

$$B_e = \frac{\pi}{4} \sum_{i=1}^{m} Q_e c_i d_i^2$$

Source:

References: “Data Analysis User’s Guide Chapter I: Single Particle Light Scattering,“ Droplet Measurement Technologies, 30. [3]

3.5 Mass Concentration

Algorithm name: mass_conc_dmt

Category: Microphysics

Summary: Calculates mass concentration given a size distribution. Can be used to calculate liquid or ice water content depending on the types of hydrometeors being sampled.

Inputs:

c_i	Array[time, bins]	Number concentration of hydrometeors in size category i [cm^{-3}]
d_i	Vector[bins]	Average diameter of size category i [μm]
s_i	Array[time, bins]	Shape factor of the hydrometeor of size category i to account for asphericity
ρ_i	Vector[time, bins]	Density of the hydrometeor in size category i [g cm^{-3}]

Outputs:

M	Vector[time]	Mass concentration [g cm^{-3}]

Formula:

$$M = \frac{\pi}{6} \sum_{i=1}^{m} s_i \rho_i c_i d_i^3$$

Source:

References: "Data Analysis User's Guide Chapter I: Single Particle Light Scattering," Droplet Measurement Technologies, 30. [3]

3.6 Total Number Concentration (DMT)

Algorithm name: number_conc_total_dmt

Category: Microphysics

Summary: Calculation of total number concentration given distribution of particle counts from a particle sampling probe.

Inputs:

c_i	Array[time,bins]	Number concentration of hydrometeors in size category i [cm^{-3}]

Outputs:

N	Vector[time]	Total number concentration [cm^{-3}]

Formula:

$$N = \sum_{i=1}^{m} c_i$$

Source:

References: "Data Analysis User's Guide Chapter I: Single Particle Light Scattering," Droplet Measurement Technologies, 30. [3]

3.7 Total Number Concentration

Algorithm name: number_conc_total_raf

Category: Microphysics

Summary: Calculation of total number concentration for a particle probe.

Inputs:

n_i	Array	Number of particles in each channel i
SV	Array	Sample volume [m^3]

Outputs:

N_t	Vector	Total number concentration [m^{-3}]

Formula:

$$N_t = \frac{\sum_i n_i}{SV}$$

Source: NCAR-RAF

References: NCAR-RAF Bulletin No. 24. [6]

3.8 Sample area for imaging probes

Algorithm name: sample_area_oap_all_in_raf

Category: Microphysics

Summary: Calculation of 'all in' sample area size for OAP probes such as the 2DC, 2DP, CIP, etc. This sample area varies by number of shadowed diodes. This routine calculates a sample area per bin.

Inputs:

λ	Coeff.	Laser wavelength [nm]
D_{arms}	Coeff.	Distance between probe arm tips [mm]
dD	Coeff.	Diode diameter [μm]
M	Coeff.	Probe magnification factor
N	Coeff.	Number of diodes in array

Outputs:

SA	Vector	Sample area [m^2]

Formula:

$$\begin{aligned} DOF_i &= \frac{6R_i^2}{\lambda} \\ R_i &= i\frac{dD}{2} \\ X &= 1...N \end{aligned} \tag{3.1}$$

where DOF must be less than D_{arms}. The parameter i ranges from 1 to N.

$$ESW_i = \frac{dD(N - X_i - 1)}{M}$$

A value for ESW_i (effective sample width) is calculated for each X.

$$SA_i = (DOF_i)(ESW_i)$$

Source: NCAR-RAF

References: NCAR-RAF Bulletin No. 24. [6]

3.9 Sample area for imaging probes

Algorithm name: sample_area_oap_center_in_raf

Category: Microphysics

Summary: Calculation of 'center in' sample area size for OAP probes such as the 2DC, 2DP, CIP, etc. This sample area varies by number of shadowed diodes. This routine is intended to calculate a sample area per bin.

Inputs:

λ	Coeff.	Laser wavelength [nm]
D_{arms}	Coeff.	Distance between probe arm tips [mm]
dD	Coeff.	Diode diameter [μm]
M	Coeff.	Probe magnification factor
N	Coeff.	Number of diodes in array

Outputs:

SA	Vector	Sample area [m^2]

Formula:

$$DOF_i = \frac{6R_i^2}{\lambda} \tag{3.2}$$

$$R_i = X\frac{dD}{2}$$

$$X = 1...N$$

where DOF must be less than D_{arms}. The parameter i ranges from 1 to N.

$$ESW = NdD$$

$$SA_i = (DOF_i)(ESW)$$

Source: NCAR-RAF

References: NCAR-RAF Bulletin No. 24. [6]

3.10 Sample area for scattering probes

Algorithm name: sample_area_scattering_raf

Category: Microphysics

Summary: Calculation of sample area for scattering probes such as the FSSP, CAS, etc.

Inputs:

DOF	Coeff.	Depth of field [m]
BD	Coeff.	Beam diameter [m]

Outputs:

SA	Coeff.	Sample area [m^2]

Formula:

$$SA = (DOF)(BD)$$

Source: NCAR-RAF

References: NCAR-RAF Bulletin No. 24. [6]

3.11 Sample Volume

Algorithm name: sample_volume_general_raf

Category: Microphysics

Summary: Calculates sample volume for microphysics probes (1D, 2D, FSSP, etc).

Inputs:

V_t	Vector	True air speed [m/s]
SA	Coeff.	Sample area of probe [m^2]
t_s	Coeff.	Sample rate [s]

Outputs:

SV	Vector	Sample volume [m^3]

Formula:

$$SV = V_t t_s SA$$

Source: NCAR-RAF

References: NCAR-RAF Bulletin No. 24. [6]

3.12 Surface Area Concentration

Algorithm name: surface_area_conc_dmt

Category: Microphysics

Summary: Calculation of surface area concentration given size distribution from particle probe.

Inputs:

c_i	Array[time, bins]	Number concentration of hydrometeors in size category i [cm^{-3}]
d_i	Vector[bins]	Average diameter of size category i [μm]
s_i	Array[time, bins]	Shape factor of hydrometeor in size category i, to account for asphericity

Outputs:

S	Vector[time]	Surface area concentration [$\mu\text{m}^2\ \text{cm}^{-3}$]

Formula:

$$S = \pi \sum_{i=1}^{m} s_i c_i d_i^2$$

Source:

References: "Data Analysis User's Guide Chapter I: Single Particle Light Scattering," Droplet Measurement Technologies, 30. [3]

Chapter 4

Corrections

4.1 Simple correction of spikes

Algorithm name: correction_spike_simple_cnrm

Category: Corrections

Summary: Detection of spikes which exceed a specified threshold. The detected value is replaced with the mean of the surrounding values.

This algorithm does not apply well to variables that are naturally discontinuous.

Inputs:

X	Vector	Parameter for analysis
S_0	Coeff	Spike detection threshold (same units as X, and must be positive)

Outputs:

X_c	Vector	Parameter with corrections applied

Formula: The ith term is considered a spike if:

$$\|X[i] - X[i-1]\| > S_0 \tag{4.1}$$

$$\|X[i] - X[i+1]\| > S_0 \tag{4.2}$$

$$(X[i] - X[i-1])(X[i] - X[i+1]) > 0 \tag{4.3}$$

with

$$X_c[i] = \frac{X[i+1] + X[i-1]}{2}$$

Otherwise, $X_c[i] = X[i]$

Source: CNRM/GMEI/TRAMM

References:

Part II

Hyperspectral

Chapter 5

Biophysics

5.1 NDVI

Algorithm name: biophys_indices (NDVI is one index calculated within the overall program)

Category: Biophysics - broad band VIS

Summary: Calculation of Normalised Difference Vegetation index (NDVI)

Inputs: Multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 671nm and 864nm.

Outputs: Single band with NDVI values

Formula:

$$NDVI = \frac{R_{864} - R_{671}}{R_{864} + R_{671}}$$

Source: DLR-DFD

References: Rouse, J. W., Haas, R. H., Schell, J. A. and Deering, J. A. (1973). Monitoring vegetation systems in the great plains with erts. In: Proceedings of the Third Symposium on Significant Results Obtained with ERTS Vol. 1, p. 309317

5.2 RVI

Algorithm name: biophys_indices (RVI is one index calculated within the overall program)

Category: Biophysics - broad band VIS

Summary: Calculation of Ratio Vegetation index (RVI)

Inputs: Multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 671nm and 864nm.

Outputs: Single band with RVI values

Formula:

$$RVI = \frac{R_{864}}{R_{671}}$$

Source: DLR-DFD

References: Pearson, R. L., and L. D. Miller, 1972, Remote mapping of standing crop biomass for estimation of the productivity of the short-grass Prairie, Pawnee National Grassland, Colorado: 8th international symposium on remote sensing of environment, p. 1357-1381

5.3 MCARI

Algorithm name: biophys_indices (MCARI is one index calculated within the overall program)

Category: Biophysics - narrow band chlorophyll indices

Summary: Calculation of Modified Chlorophyll absorption in Reflectance Index (MCARI)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 550nm, 670nm and 701nm.

Outputs: Single band with MCARI values

Formula:

$$MCARI = ((R_{701} - R_{670}) - 0.2 * (R_{701} - R_{550})) * \frac{R_{701}}{R_{670}}$$

Source: DLR-DFD

References: Daughtry, C.S.T., Walthall, C.L., Kim, M.S., Brown de Colstoun, E., McMurtrey, J.E. III (2000): Estimating corn leaf chlorophyll concentration from leaf and canopy reflectance. In: Remote Sensing of Environment, 74, p.229-239.

5.4 LCI

Algorithm name: biophys_indices (LCI is one index calculated within the overall program)

Category: Biophysics - narrow band chlorophyll indices

Summary: Calculation of Leaf Chlorophyll Index (LCI)

Inputs: Multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 710nm and 850nm.

Outputs: Single band with LCI values

Formula:

$$LCI = \frac{R_{850} - R_{710}}{R_{850} + R_{710}}$$

Source: DLR-DFD

References:

5.5 SR705

Algorithm name: biophys_indices (SR705 is one index calculated within the overall program)

Category: Biophysics - narrow band chlorophyll indices

Summary: Calculation of Chlorophyll-Index SR705 // Linear regression

Inputs: Multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 705nm and 750nm.

Outputs: Single band with SR705 values

Formula:

$$SR705 = \frac{R_{750}}{R_{705}}$$

Source: DLR-DFD

References: Sims, D.A., Gamon, J.A., 2002, Relationships between leaf pigment content and spectral reflectance across a wide range of species, leaf structures and developmental stages. In: Remote Sensing of Environment, p. 337-354

5.6 mND705

Algorithm name: biophys_indices (mND705 is one index calculated within the overall program)

Category: Biophysics - narrow band chlorophyll indices

Summary: Calculation of Chlorophyll-Index mND705 // hyperbolic regression

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 445nm, 705nm and 750nm.

Outputs: Single band with mND705 values

Formula:

$$mND705 = \frac{R_{750} - R_{705}}{R_{750} + R_{705} - 2R_{445}}$$

Source: DLR-DFD

References: Sims, D.A., Gamon, J.A. (2002): Relationships between leaf pigment content and spectral reflectance across a wide range of species, leaf structures and developmental stages. In: Remote Sensing of Environment, 81, p.337-354.

5.7 GI

Algorithm name: biophys_indices (GI is one index calculated within the overall program)

Category: Biophysics - narrow band chlorophyll indices

Summary: Calculation of Greenness Index (GI)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 549nm and 671nm.

Outputs: Single band with GI values

Formula:

$$GI = \frac{R_{671}}{R_{549}}$$

Source: DLR-DFD

References: Zarco Tejada , P.J., Berjon, A., Lopez Lozano, R., Miller, J.R., Martin, P., Cachorro, V., Gonzalez, M.R., de Frutos, A. (2005): Assessing vineyard condition with hyperspectral indices: Leaf and canopy reflectance simulation in a row-structured discontinuous canopy. In: remote Sensing of Environment, 99, p.271 287

5.8 PRI

Algorithm name: biophys_indices (PRI is one index calculated within the overall program)

Category: Biophysics - narrow band chlorophyll indices

Summary: Calculation of Photochemical Reflectance Index (PRI), also Carotenoid/chlorophyll

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 529nm and 569nm.

Outputs: Single band with PRI values

Formula:

$$PRI = \frac{R_{529} - R_{569}}{R_{529} + R_{569}}$$

Source: DLR-DFD

References: Sims, D.A., Gamon, J.A. (2002): Relationships between leaf pigment content and spectral reflectance across a wide range of species, leaf structures and developmental stages. In: Remote Sensing of Environment, 81, p.337-354.

5.9 REIP

Algorithm name: biophys_indices (REIP is one index calculated within the overall program)

Category: Biophysics - red edge parametrisation

Summary: Calculation of red edge infliction point (REIP), method 1

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 671nm, 701nm, 740nm and 780nm.

Outputs: Single band with REIP values

Formula:

$$REIP = 700 + 40 * \frac{0.5 * (R_{671} + R_{780}) - R_{701}}{R_{740} - R_{701}}$$

Source: DLR-DFD

References: Guyot, G., Baret, F. and Major, D. J. (1988). High spectral resolution: determination of spectral shifts between the red and the near infrared. In: International Archives of Photogrammetry and Remote Sensing 11, p. 750760

5.10 DGVI1

Algorithm name: biophys_indices (DGVI1 is one index calculated within the overall program)

Category: Biophysics - red edge parametrisation

Summary: Calculation of Derivative-based Green Vegetation Index (DGVI). Surface under curve of first derivative between 626nm and 795nm.

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 626nm and 795nm.

Outputs: Single band with DGVI1 values

Formula:

$$DGVI1 = \int_{\lambda_1=626nm}^{\lambda_2=795nm} \mid \frac{d\rho}{d\lambda} \mid d\lambda$$

Source: DLR-DFD

References: Elvidge, C.D., Chen, Z.(1995): Comparison of Broad-Band and Narrow-Band Red and Near-Infrared Vegetation indices. In: Remote Sensing of Environment, 54, p.38-48.

5.11 DGVI2

Algorithm name: biophys_indices (DGVI2 is one index calculated within the overall program)

Category: Biophysics - red edge parametrisation

Summary: Calculation of Derivative-based Green Vegetation Index (DGVI). Surface under curve of second derivative between 626nm and 795nm.

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 626nm and 795nm.

Outputs: Single band with DGVI2 values

Formula:

$$DGVI2 = \int_{\lambda_1=626nm}^{\lambda_2=795nm} \mid \frac{d\rho}{d^2\lambda} \mid d\lambda$$

Source: DLR-DFD

References: Elvidge, C.D., Chen, Z.(1995): Comparison of Broad-Band and Narrow-Band Red and Near-Infrared Vegetation indices. In: Remote Sensing of Environment, 54, p.38-48.

5.12 NDNI

Algorithm name: biophys_indices (NDNI is one index calculated within the overall program)

Category: Biophysics - dry vegetation (stress) indices

Summary: Calculation of Normalized Difference Nitrogen Index (NDNI)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 1510nm and 1680nm.

Outputs: Single band with NDNI values

Formula:

$$NDNI = \frac{log\frac{1}{R_{1510}} - log\frac{1}{R_{1680}}}{log\frac{1}{R_{1510}} + log\frac{1}{R_{1680}}}$$

Source: DLR-DFD

References: Serrano, L., Penuelas, J., Ustin, L.S. (2002): Remote sensing of nitrogen and lignin in Mediterranean vegetaion from AVIRIS data: Decomposing biochemical from structural signals. In: Remote Sensing of Environment, 81, p.355-364

5.13 NDLI

Algorithm name: biophys_indices (NDLI is one index calculated within the overall program)

Category: Biophysics - dry vegetation (stress) indices

Summary: Calculation of Normalized Difference Lignin Index (NDLI)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 1754nm and 1680nm.

Outputs: Single band with NDLI values

Formula:

$$NDLI = \frac{log\frac{1}{R_{1754}} - log\frac{1}{R_{1680}}}{log\frac{1}{R_{1754}} + log\frac{1}{R_{1680}}}$$

Source: DLR-DFD

References: Serrano, L., Penuelas, J., Ustin, L.S. (2002): Remote sensing of nitrogen and lignin in Mediterranean vegetaion from AVIRIS data: Decomposing biochemical from structural signals. In: Remote Sensing of Environment, 81, p.355-364

5.14 CAI

Algorithm name: biophys_indices (CAI is one index calculated within the overall program)

Category: Biophysics - dry vegetation (stress) indices

Summary: Calculation of Cellulose Absorption Index (CAI)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 2000nm, 2100nm and 2200nm.

Outputs: Single band with CAI values

Formula:

$$CAI = 0.5 * (R_{2000} + R_{2200}) - R_{2100}$$

Source: DLR-DFD

References: Nagler, P.L., Daughtry, C.S.T., Goward, S.N. (2000): Plant Litter and Soil Reflectance. In: Remote Sensing of Environment, 71, P.207-215.

5.15 CSI2

Algorithm name: biophys_indices (CSI2 is one index calculated within the overall program)

Category: Biophysics - dry vegetation (stress) indices

Summary: Calculation of Carter stress index 2 (CSI2)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 695nm and 760nm.

Outputs: Single band with CSI2 values

Formula:

$$CSI2 = \frac{R_{695}}{R_{760}}$$

Source: DLR-DFD

References: Carter et al., 1994/6

5.16 NDWI

Algorithm name: biophys_indices (NDWI is one index calculated within the overall program)

Category: Biophysics - water (stress) indices

Summary: Calculation of Normalized Difference Water Index (NDWI)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 864nm and 1245nm.

Outputs: Single band with NDWI values

Formula:

$$NDWI = \frac{R_{864} - R_{1245}}{R_{864} + R_{1245}}$$

Source: DLR-DFD

References: Gao, Bo-Cai (1996): NDWI A Normalized Difference Water Index for Remote Sensingof Vegetation liquid Water from Space. In: Remote Sensing of Environment, 58, p.257-266

5.17 NDWI_MIR

Algorithm name: biophys_indices (NDWI_MIR is one index calculated within the overall program)

Category: Biophysics - water (stress) indices

Summary: Calculation of Normalized Difference Water Index - Mid Infrared (NDWI_MIR)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 864nm and 2161nm.

Outputs: Single band with NDWI_MIR values

Formula:

$$NDWI\_MIR = \frac{R_{864} - R_{2161}}{R_{864} + R_{2161}}$$

Source: DLR-DFD

References:

5.18 LWVI1

Algorithm name: biophys_indices (LWVI1 is one index calculated within the overall program)

Category: Biophysics - water (stress) indices

Summary: Calculation of Leaf Water Vegetation Index (LWVI-1)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 983nm and 1094nm.

Outputs: Single band with LWVI1 values

Formula:

$$LWVI1 = \frac{R_{1094} - R_{983}}{R_{1094} + R_{983}}$$

Source: DLR-DFD

References: Galvao, L.S., Formaggio, A.R., Tisot, D.A. (2005): Discriminating of sugarcane varieties in Southeastern Brazil with EO-1 Hyperion data. In: Remote Sensing of Environment, 94, p.523-534

5.19 LWVI2

Algorithm name: biophys_indices (LWVI2 is one index calculated within the overall program)

Category: Biophysics - water (stress) indices

Summary: Calculation of Leaf Water Vegetation Index (LWVI-2)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 1094nm and 1205nm.

Outputs: Single band with LWVI2 values

Formula:

$$LWVI2 = \frac{R_{1094} - R_{1205}}{R_{1094} + R_{1205}}$$

Source: DLR-DFD

References: Galvao, L.S., Formaggio, A.R., Tisot, D.A. (2005): Discriminating of sugarcane varaieties in Southeastern Brazil with EO-1 Hyperion data. In: Remote Sensing of Environment, 94, p.523-534

5.20 DWSI5

Algorithm name: biophys_indices (DWSI5 is one index calculated within the overall program)

Category: Biophysics - water (stress) indices

Summary: Calculation of Disease Water Stress Index (DWSI-5)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 549nm, 680nm, 803nm and 1659nm.

Outputs: Single band with DWSI5 values

Formula:

$$DWSI5 = \frac{R_{803} + R_{549}}{R_{1659} + R_{680}}$$

Source: DLR-DFD

References: Apan et al., 2003

5.21 SWIRVI

Algorithm name: biophys_indices (SWIRVI is one index calculated within the overall program)

Category: Biophysics - cover indices

Summary: Calculation SWIR index: green (SWIRVI)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 2090nm, 2210nm and 2280nm.

Outputs: Single band with SWIRVI values

Formula:

$$SWIRVI = 37.72 * (R_{2210} - R_{2090}) + 26.27 * (R_{2280} - R_{2090}) + 0.57$$

Source: DLR-DFD

References: Lobell, D.B., Asner, G.P., Law, B.E., Treuhaft R.N. (2001): Subpixel canopy cover estimation of coniferous forests in Oregon using SWIR imaging spectrometry. In: Journal of geophysical research, 106, p.5151-5160

5.22 SWIRLI

Algorithm name: biophys_indices (SWIRLI is one index calculated within the overall program)

Category: Biophysics - cover indices

Summary: Calculation SWIR index: litter (SWIRLI)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 2090nm, 2210nm and 2280nm.

Outputs: Single band with SWIRLI values

Formula:

$$SWIRLI = 3.87 * (R_{2210} - R_{2090}) - 27.51 * (R_{2280} - R_{2090}) - 0.20$$

Source: DLR-DFD

References: Lobell, D.B., Asner, G.P., Law, B.E., Treuhaft R.N. (2001): Subpixel canopy cover estimation of coniferous forests in Oregon using SWIR imaging spectrometry. In: Journal of geophysical research, 106, p.5151-5160

5.23 SWIRSI

Algorithm name: biophys_indices (SWIRSI is one index calculated within the overall program)

Category: Biophysics - cover indices

Summary: Calculation SWIR index: soil (SWIRSI)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 2090nm, 2210nm and 2280nm.

Outputs: Single band with SWIRSI values

Formula:

$$SWIRSI = -41.59 * (R_{2210} - R_{2090}) + 1.24 * (R_{2280} - R_{2090}) + 0.64$$

Source: DLR-DFD

References: Lobell, D.B., Asner, G.P., Law, B.E., Treuhaft R.N. (2001): Subpixel canopy cover estimation of coniferous forests in Oregon using SWIR imaging spectrometry. In: Journal of geophysical research, 106, p.5151-5160

5.24 clay_1

Algorithm name: biophys_indices (clay_1 is one index calculated within the overall program)

Category: Biophysics - soil indices

Summary: Calculation of clay ratio (clay_1)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 2136nm, 2195nm and 2240nm.

Outputs: Single band with clay_1 values

Formula:

$$clay\_1 = 0.5 * (R_{2136} + R_{2240}) - R_{2195}$$

Source: DLR-DFD

References:

5.25 iron_1

Algorithm name: biophys_indices (iron_1 is one index calculated within the overall program)

Category: Biophysics - soil indices

Summary: Calculation of iron ratio (iron_1)

Inputs: Narrow band multi- or hyperspectral imagery (ENVI standard image data) including channels close to the wavelengths of 780nm, 920nm and 1245nm.

Outputs: Single band with iron_1 values

Formula:

$$iron\_1 = 0.5 * (R_{780} + R_{1245}) - R_{920}$$

Source: DLR-DFD

References:

Chapter 6

Quality Control

6.1 Check navigation data for inconsistencies

Algorithm name: nav_chk

Category: Quality Control

Summary: Tests navigation file (position and attitude) for inconsistencies and corrects them. The code is based on a HyMap *gps File.

Inputs: *.gps file plus the number of image lines according to the ENVI header of the related image data. The *.gps file is a multi-column ASCII file derived by HyVista Corp. proprietary software, which synchronises times and generates an output which is indexed by scan line number. The table below shows the list of parameters.

Parameters	Example	Description
Line	1	Scan line number
UTC Time	48835.0462/20/5/2004	Time of day in seconds/day/month/year
VME Time	929386852.0	Internal computer tick time in microseconds
IMU Time	2048825953.1	Internal IMU time in microseconds
Latitude	48.03321015	Decimal degrees (positive = north, negative = south)
Longitude	11.28140200	Decimal degrees (positive = east, negative = west)
Altitude	2970.79892155	Meters above MSL
Pitch	0.22235917	Decimal degrees (positive = nose up)
Roll	0.54269902	Decimal degrees (positive = right wing up)
Heading	0.37774316	Decimal degrees (positive = N-E-S direction, negative = N-W-S direction)
True Track	1.00507651	Decimal degrees (0 to 360)
Ground Speed	72.90907700	Meters / second
Sat	5	Number of satellites being received
DGPS	1	DGPS status: 1 = DGPS being received 0 = no DGPS received

Outputs: status file → template+'_status'
If applicable: corrected gps file
backup of original .gps → filename.gps_original

Formula: test & correct the following

- point or colon - separator in .gps =¿ error catched in hymap_read_gps.pro corrected when re-writing the .gps-file anyway

- #lines in image = #lines in gps
  if too many gps-lines: truncate lines at beginning (like Hyvista does)
  if too few gps-lines: adding extrapolated lines at end
- invalid start / end time: calculating average timestep & using last relieable line
- data gaps (indicated by identical time): interpolate info

Source: DLR-DFD

References: EUFAR FP7 - DJ2.2.2 - Quality Layers for VITO, DLR, INTA and PML

6.2 Additional consistency check & QA for navigation data (no correction!)

Algorithm name: nav_const

Category: Quality Control

Summary: Tests navigation file (position and attitude) for consistency. The code is based on a HyMap *gps File.
This check can be performed after nav_chk.pro.

Inputs: *.gps file. The *.gps file is a multi-column ASCII file derived by HyVista Corp. proprietary software, which synchronises times and generates an output which is indexed by scan line number. The table below shows the list of parameters.

Parameters	Example	Description
Line	1	Scan line number
UTC Time	48835.0462/20/5/2004	Time of day in seconds/day/month/year
VME Time	929386852.0	Internal computer tick time in microseconds
IMU Time	2048825953.1	Internal IMU time in microseconds
Latitude	48.03321015	Decimal degrees (positive = north, negative = south)
Longitude	11.28140200	Decimal degrees (positive = east, negative = west)
Altitude	2970.79892155	Meters above MSL
Pitch	0.22235917	Decimal degrees (positive = nose up)
Roll	0.54269902	Decimal degrees (positive = right wing up)
Heading	0.37774316	Decimal degrees (positive = N-E-S direction, negative = N-W-S direction)
True Track	1.00507651	Decimal degrees (0 to 360)
Ground Speed	72.90907700	Meters / second
Sat	5	Number of satellites being received
DGPS	1	DGPS status: 1 = DGPS being received 0 = no DGPS received

Outputs: if (KEYWORD_SET(gps_err_array)) → QC array
otime, lat, lon, alt, pit, rol, heading, track, speed, sat, dgps
Values: 0:OK 1:minor problem 2:major problem
if (KEYWORD_SET(gps_data)) → gps data as array
otime, lat, lon, alt, pit, rol, heading, track, speed, sat, dgps

Formula: test & report the following

- if data range is not plausible

- if change between steps > threshold:
  latlon, alt, pit, rol, heading, track, speed
- uncorrectable errors in:
  time, latlon, alt, pit, rol, heading, track, speed, sat, dgps

Source: DLR-DFD

References: EUFAR FP7 - DJ2.2.2 - Quality Layers for VITO, DLR, INTA and PML

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