EGADS Algorithm Handbook

EUFAR FP7

N6SP - Standards and Protocols

Last Updated: November 10, 2010

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, there is a general naming scheme for EGADS algorithms. Generally, algorithm names are composed as follows: `{general calculation}_{specific calculation}_{` So, for example, an algorithm provided by CNRM to calculate the density of dry air would be named `density_dry_air_cnrm`.

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:

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

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 [?], 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: H. Bellec and G. Duverneuil. Appareils de mesure de l'hygrométrie sur le Merlin IV. Note de Centre 9, Météo-France CNRM/CAM, July 1996.

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 [**?**].

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 [?], page 56.

2.9 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:

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

Source: CNRM/GMEI/TRAMM

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

2.10 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 [?]

Chapter 3

Microphysics

3.1 Mean diameter

Algorithm name: mean_diameter_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 – http://www.eol.ucar.edu/raf/Bulletins/bulletin24.html

3.2 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 – http://www.eol.ucar.edu/raf/Bulletins/bulletin24.html

3.3 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 – http://www.eol.ucar.edu/raf/Bulletins/bulletin24.html

3.4 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:

$$DOF_i = \frac{6R_i^2}{\lambda} \qquad (3.2)$$

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

$$X = 1...N$$

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 – http://www.eol.ucar.edu/raf/Bulletins/bulletin24.html

3.5 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 – http://www.eol.ucar.edu/raf/Bulletins/bulletin24.html

3.6 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 – http://www.eol.ucar.edu/raf/Bulletins/bulletin24.html

Index