EGADS Algorithm Handbook

EUFAR FP7

N6SP - Standards and Protocols

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Thermodynamics

3.1 Pressure altitude

Algorithm name: altitude_pressure_cnrm

Summary: Calculates pressure altitude using virtual temperature.

Inputs:

T_v	Vector	Virtual temperature [K or $\circ$ 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:

3.2 Density of dry air

Algorithm name: density_dry_air_cnrm

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.

3.3 Relative humidity from capacitive probe

Algorithm name: hum_rel_capacitive_cnrm

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.

3.4 Pressure and angle of incidence

Algorithm name: pressure_angle_incidence_cnrm

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 $\Delta P_r > 25\text{hPa}$:

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

otherwise:

$$Errstat = \frac{\Delta P_r}{25} Errstat@25hPa P_s = P_{sr} - Errstat \Delta P = \Delta P_r + Errstat \alpha = C_\alpha[0] + C_\alpha[1]\frac{\Delta P_v}{\Delta P}\beta = C_\beta[0] + C_\beta$$

Source: CNRM/GMEI/TRAMM

References:

3.5 Potential Temperature

Algorithm name: temp_potential_cnrm

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 [?].

3.6 Equivalent Potential Temperature

Algorithm name: temp_potential_equiv_cnrm

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 $L = 3136.17 - 2.34T_s$ (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.

3.7 Static Temperature

Algorithm name: temp_static_cnrm

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:

3.8 Virtual Temperature

Algorithm name: temp_virtual_cnrm

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.

3.9 True air speed

Algorithm name: velocity_tas_cnrm

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 [?]

3.10 Longitudinal true airspeed

Algorithm name: velocity_tas_longitudinal_cnrm

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 4

Microphysics