2. Derivation of the Dayside F_2-Region Data Products

This section contains the derivations of all SSUSI Dayside F_2-Region data products. The first subsection, “General Algorithm Expectations”, exposes the linkage and preprocessing expectations common to all of the derivations. Implied subtleties are also included there.

Following the “General Algorithm Expectations” subsection are the individual data-product derivations. Each derivation begins with a listing of the input parameters required, the calculated output from the derivation, a formal “Begin” indicator, the steps in the derivation, and a concluding “End” indicator. Within each step, variance calculations are provided where appropriate. Items which represent variances are prefaced with a “V”.

2.1 General Algorithm Expectations

A quick inspection of the “Required Input to the Derivation” sections will reveal that there are several cross links among the derivations. The cross-linked items refer to the intermediate data items calculated in some other step (possibly in another derivation). Whatever the case, the step in which the cross-linked item is calculated can be quickly located by searching the step lists in the Table of Contents.

Note that there is a dependency on the disk derived QEUV value in several of the dayside limb data product derivations. This dependency implies that a value of QEUV must be determined from the dayside disk before any dayside limb data product derivations can occur. The QEUV value used in the dayside limb algorithm is actually an average of the QEUV values derived by the disk algorithm between -30 deg latitude and +30 deg latitude. QEUV is assumed to be constant over the dayside disk region.

All variances are determined by applying the standard error propagation formula to each stated expression. For a derived quantity x = F(u,v), the error propagation formula is given by

$$\sigma_x^2 = \left(\frac{\partial x}{\partial u}\right)^2 * \sigma_u^2 + \left(\frac{\partial x}{\partial v}\right)^2 * \sigma_v^2 + 2*\left(\frac{\partial x}{\partial u}\right)*\left(\frac{\partial x}{\partial v}\right)*\sigma_{uv}^2$$

2.2 Dayside Disk

2.2.1 The Ratio of O and N_2 Vertical Column Densities (ROVCDN2VCD)

2.2.1.1 Required Input to the Derivation

I1356	The measured 1356 intensity (Rayleighs).
VI1356	The variance associated with I1356 $(\text{Rayleighs})^2$.
ILBH2	The measured LBH2 (1650-1800 A) intensity (Rayleighs).
VILBH2	The variance associated with ILBH2 $(\text{Rayleighs})^2$.
CVI1356ILBH2	The covariance associated with I1356 and ILBH2 $(\text{Rayleighs})^2$.

SZA	The Solar Zenith Angle at the current disk pixel (radians).

2.2.1.2 Calculated Output of the Derivation

ROVCDN2VCD	The ratio of O and N_2 vertical column densities (dimensionless)
VROVCDN2VCD	The variance associated with ROVCDN2VCD (dimensionless).

2.2.1.3 The Derivation

2.2.1.3.1 Begin

2.2.1.3.2 Calculate the ratio of O and N_2 vertical column densities (ROVCDN2VCD)

TempA = I1356/ILBH2

Note: The variance of the derived TempA value is obtained by applying the error propagation formula to the expression for TempA above. The sources of uncertainty in TempA are uncertainties in both I1356 and in ILBH2 (including a covariance term).

$$\text{VTempA} = \left(\frac{1}{ILBH2^2}\right) * VI1356 + \left(\frac{I1356}{ILBH2^2}\right)^2 * VILBH2 -$$

$$2 * \left(\frac{1}{ILBH2}\right) * \left(\frac{I1356}{ILBH2^2}\right) * CVI1356ILBH2$$

ROVCDN2VCD = The value calculated by the ROVCDN2VCD Data Table Function (ROVCDN2VCDDTF) (see Appendix). The following values should be used as input into the ROVCDN2VCD Data Table Function:

For ROVCDN2VCDDTF RI1356ILBH2 $\xrightarrow{\text{Use}}$ *TempA*
For ROVCDN2VCDDTF VRI1356ILBH2 $\xrightarrow{\text{Use}}$ *VTempA*
For ROVCDN2VCDDTF SZA $\xrightarrow{\text{Use}}$ *SZA*

Calculate the variance associated with the ratio of the O and N_2 vertical column densities (VROVCDN2VCD).

VROVCDN2VCD = The variance associated with the ROVCDN2VCD value calculated by the ROVCDN2VCD Data Table Function (ROVCDN2VCDDTF) (see Appendix).

2.2.1.3.3 End

2.2.2 The Solar EUV Flux Below 450 A (QEUV)

2.2.2.1 Required Input to the Derivation

I1356	The measured 1356 intensity (Rayleighs).
VI1356	The variance associated with I1356 $(\text{Rayleighs})^2$.
ROVCDN2VCD	The ratio of O and N_2 vertical column densities (dimensionless). The ROVCDN2VCD is a product of the Dayside Disk ROVCDN2VCD derivation.
VROVCDN2VCD	The variance associated with ROVCDN2VCD (dimensionless). VROVCDN2VCD is a product of the Dayside Disk ROVCDN2VCD derivation.
SZA	The Solar Zenith Angle at the current disk pixel (radians).

2.2.2.2 Calculated Output of the Derivation

QEUV	The solar EUV flux below 450 A (erg cm^{-2} s^{-1}).
VQEUV	The variance associated with QEUV $(\text{erg cm}^{-2}\ s^{-1})^2$.

2.2.2.3 The Derivation

2.2.2.3.1 Begin

2.2.2.3.2 Calculate the solar EUV flux below 450 A (QEUV)

QEUV = The value calculated by the QEUV Data Table Function (QEUVDTF) (see Appendix). The following values should be used as input into the QEUV Data Table Function:

For QEUVDTF I1356 $\xrightarrow{\text{Use}}$ *I1356*
For QEUVDTF VI1356 $\xrightarrow{\text{Use}}$ *VI1356*
For QEUVDTF ROVCDN2VCD $\xrightarrow{\text{Use}}$ *ROVCDN2VCD*
For QEUVDTF VROVCDN2VCD $\xrightarrow{\text{Use}}$ *VROVCDN2VCD*
For QEUVDTF SZA $\xrightarrow{\text{Use}}$ *SZA*

Calculate the variance associated with the solar EUV flux (VQEUV).

VQEUV = The variance associated with the QEUV value calculated by the QEUV Data Table Function (QEUVDTF) (see Appendix).

2.2.2.3.3 End

2.2.3 The F_2-Region Peak Density (NmF2)

2.2.3.1 Required Input to the Derivation

ROVCDN2VCD	The ratio of O and N_2 vertical column densities (dimensionless). The ROVCDN2VCD is a product of the Dayside Disk ROVCDN2VCD derivation.
VROVCDN2VCD	The variance associated with ROVCDN2VCD (dimensionless). VROVCDN2VCD is a product of the Dayside Disk ROVCDN2VCD derivation.
QEUV	The solar EUV flux below 450 A (erg cm^{-2} s^{-1}). The QEUV is a product of the Dayside Disk QEUV derivation.
VQEUV	The variance associated with QEUV (erg cm^{-2} $s^{-1})^2$. The VQEUV is a product of the Dayside Disk QEUV derivation
MONTH	The month of the year (dimensionless).
GMLT	The geomagnetic local time of the current pixel (hours).
Ap	The magnetic index (dimensionless).
GMLAT	The geomagnetic latitude of the current pixel (radians).
GMLON	The geomagnetic longitude of the current pixel (radians).

2.2.3.2 Calculated Output of the Derivation

NmF2	The F_2-Region peak density (cm^{-3}).
VNmF2	The variance associated with NmF2 $(cm^{-3})^2$.

2.2.3.3 The Derivation

2.2.3.3.1 Begin

2.2.3.3.2 Calculate the F_2-region peak density (NmF2)

NmF2 = The value calculated by the EDPP Data Table Function (EDPPDTF) (see Appendix). The following values should be used as input into the EDPP Data Table Function:

$$\textit{For EDPPDTF ROVCDN2VCD} \xrightarrow{\text{Use}} \textit{ROVCDN2VCD}$$
$$\textit{For EDPPDTF VROVCDN2VCD} \xrightarrow{\text{Use}} \textit{VROVCDN2VCD}$$
$$\textit{For EDPPDTF QEUV} \xrightarrow{\text{Use}} \textit{QEUV}$$

For EDPPDTF VQEUV $\xrightarrow{\text{Use}}$ *VQEUV*
For EDPPDTF Ap $\xrightarrow{\text{Use}}$ *Ap*
For EDPPDTF MONTH $\xrightarrow{\text{Use}}$ *MONTH*
For EDPPDTF GMLT $\xrightarrow{\text{Use}}$ *GMLT*
For EDPPDTF GMLAT $\xrightarrow{\text{Use}}$ *GMLAT*
For EDPPDTF GMLON $\xrightarrow{\text{Use}}$ *GMLON*

Calculate the variance associated with the F_2-Region Peak Density (VNmF2).

VNmF2 = The variance associated with the NmF2 value calculated by the EDPP Data Table Function (EDPPDTF) (see Appendix).

2.2.3.3.3 End

2.2.4 The Height of the F_2-Region Peak Density (hmF2)

2.2.4.1 Required Input to the Derivation

ROVCDN2VCD	The ratio of O and N_2 vertical column densities (dimensionless). The ROVCDN2VCD is a product of the Dayside Disk ROVCDN2VCD derivation.
VROVCDN2VCD	The variance associated with ROVCDN2VCD (dimensionless). VROVCDN2VCD is a product of the Dayside Disk ROVCDN2VCD derivation.
QEUV	The solar EUV flux below 450 A (erg cm^{-2} s^{-1}). The QEUV is a product of the Dayside Disk QEUV derivation.
VQEUV	The variance associated with QEUV (erg cm^{-2} $s^{-1})^2$. The VQEUV is a product of the Dayside Disk QEUV derivation
MONTH	The month of the year (dimensionless).
GMLT	The geomagnetic local time of the current pixel (hours).
Ap	The magnetic index (dimensionless).
GMLAT	The geomagnetic latitude of the current pixel (radians).
GMLON	The geomagnetic longitude of the current pixel (radians).

2.2.4.2 Calculated Output of the Derivation

hmF2	The height of the F_2-Region peak density (km).
VhmF2	The variance associated with hmF2 $(km)^2$.

2.2.4.3 The Derivation

2.2.4.3.1 Begin

2.2.4.3.2 Calculate the height of the F_2-region peak density (hmF2)

hmF2 = The value calculated by the EDPP Data Table Function (EDPPDTF) (see Appendix). The following values should be used as input into the EDPP Data Table Function:

$$\begin{array}{lll}
\text{For EDPPDTF ROVCDN2VCD} & \xrightarrow{Use} & \text{ROVCDN2VCD} \\
\text{For EDPPDTF VROVCDN2VCD} & \xrightarrow{Use} & \text{VROVCDN2VCD} \\
\text{For EDPPDTF QEUV} & \xrightarrow{Use} & \text{QEUV} \\
\text{For EDPPDTF VQEUV} & \xrightarrow{Use} & \text{VQEUV} \\
\text{For EDPPDTF Ap} & \xrightarrow{Use} & \text{Ap} \\
\text{For EDPPDTF MONTH} & \xrightarrow{Use} & \text{MONTH} \\
\text{For EDPPDTF GMLT} & \xrightarrow{Use} & \text{GMLT} \\
\text{For EDPPDTF GMLAT} & \xrightarrow{Use} & \text{GMLAT} \\
\text{For EDPPDTF GMLON} & \xrightarrow{Use} & \text{GMLON}
\end{array}$$

Calculate the variance associated with the height of the F_2-Region Peak Density (VhmF2).

VhmF2 = The variance associated with the hmF2 value calculated by the EDPP Data Table Function (EDPPDTF) (see Appendix).

2.2.4.3.3 End

2.2.5 The F_2-Region Total Electron Content (TEC)

2.2.5.1 Required Input to the Derivation

ROVCDN2VCD	The ratio of O and N_2 vertical column densities (dimensionless). The ROVCDN2VCD is a product of the Dayside Disk ROVCDN2VCD derivation.
VROVCDN2VCD	The variance associated with ROVCDN2VCD (dimensionless). VROVCDN2VCD is a product of the Dayside Disk ROVCDN2VCD derivation.
QEUV	The solar EUV flux below 450 A (erg cm^{-2} s^{-1}). The QEUV is a product of the Dayside Disk QEUV derivation.
VQEUV	The variance associated with QEUV (erg cm^{-2} $s^{-1})^2$. The VQEUV is a product of the Dayside Disk QEUV derivation
MONTH	The month of the year (dimensionless).

GMLT	The geomagnetic local time of the current pixel (hours).
Ap	The magnetic index (dimensionless).
GMLAT	The geomagnetic latitude of the current pixel (radians).
GMLON	The geomagnetic longitude of the current pixel (radians).

2.2.5.2 Calculated Output of the Derivation

TEC	The F_2-Region Total Electron Content (10^{16} e^- m^{-2}).
VTEC	The variance associated with NmF2 (10^{16} e^- $m^{-2})^2$.

2.2.5.3 The Derivation

2.2.5.3.1 Begin

2.2.5.3.2 Calculate the F_2-region total electron content (TEC)

TEC = The value calculated by the EDPP Data Table Function (EDPPDTF) (see Appendix). The following values should be used as input into the EDPP Data Table Function:

For EDPPDTF ROVCDN2VCD $\xrightarrow{\text{Use}}$ *ROVCDN2VCD*
For EDPPDTF VROVCDN2VCD $\xrightarrow{\text{Use}}$ *VROVCDN2VCD*
For EDPPDTF QEUV $\xrightarrow{\text{Use}}$ *QEUV*
For EDPPDTF VQEUV $\xrightarrow{\text{Use}}$ *VQEUV*
For EDPPDTF Ap $\xrightarrow{\text{Use}}$ *Ap*
For EDPPDTF MONTH $\xrightarrow{\text{Use}}$ *MONTH*
For EDPPDTF GMLT $\xrightarrow{\text{Use}}$ *GMLT*
For EDPPDTF GMLAT $\xrightarrow{\text{Use}}$ *GMLAT*
For EDPPDTF GMLON $\xrightarrow{\text{Use}}$ *GMLON*

Calculate the variance associated with the F_2-Region Total Electron Content (VTEC).

VTEC = The variance associated with the TEC value calculated by the EDPP Data Table Function (EDPPDTF) (see Appendix).

2.2.5.3.3 End

2.2.6 The F_2-Region Plasma Frequency (foF2)

2.2.6.1 Required Input to the Derivation

NmF2	The F_2-Region Peak Density (cm^{-3}). The NmF2 is a product of the Dayside Disk NmF2 derivation.
VNmF2	The variance associated with NmF2 $(cm^{-3})^2$. The VNmF2 is a product of the Dayside Disk NmF2 derivation.

2.2.6.2 Calculated Output of the Derivation

foF2	The F_2-Region plasma frequency (s^{-1}).
VfoF2	The variance associated with foF2 $(s^{-1})^2$.

2.2.6.3 The Derivation

2.2.6.3.1 Begin

2.2.6.3.2 Calculate the F_2-region plasma frequency (foF2)

$$\text{foF2} = 8.98 \times 10^3 \sqrt{\text{NmF2}}$$

Calculate the variance associated with the Plasma Frequency (VfoF2).

Note: The variance of the derived foF2 value is obtained by applying the error propagation formula to the expression for foF2 above. The only source of uncertainty in foF2 is the uncertainty in NmF2.

$$\text{VfoF2} = 2.02 \times 10^7 (\text{NmF2})^{-1} \text{VNmF2}$$

2.2.6.3.3 End

2.3 Dayside Limb

2.3.1 The Exospheric Temperature (Texo)

2.3.1.1 Required Input to the Derivation

I1356P	The measured 1356 A intensity profile (Rayleighs).
VI1356P	The variance associated with I1356P $(\text{Rayleighs})^2$.
ALTGRID	The altitude grid corresponding to the measured 1356 A intensity profile (km). The vector ALTGRID is assumed to be monotonically decreasing.

2.3.1.2 Calculated Output of the Derivation

Texo	The exospheric temperature (K).

VTexo	The variance associated with Texo $(K)^2$.

2.3.1.3 Internal data-items used by the Derivation.

Texo_Grid	The one-dimensional vector of Texo values corresponding to the one-dimensional vector Slope (K). (Texo_Grid = [800.0, 1000.0, 1200.0, 1400.0, 1600.0]).
Slope	The one-dimensional vector of model-determined values equal to the slope of the natural logarithm of model-determined 1356 A intensity profiles (which are a function of Texo). (Slope = [-0.0231967, -0.0190635, -0.0157256, -0.0133726, -0.0115364]).

2.3.1.4 The Derivation

2.3.1.4.1 Begin

2.3.1.4.2 Calculate the index corresponding to the element of ALTGRID which is closest to 500 km (INDEX_500KM).

INDEX_500KM = The index corresponding to the element of the vector ALTGRID which is closest to the value 500.0. The value INDEX_500KM is calculated by the Search Function (SEARCH). The following values should be used as inputs to the Search Function:

For SEARCH X $\xrightarrow{Use}$ *ALTGRID*
For SEARCH U $\xrightarrow{Use}$ *500.0*

2.3.1.4.3 Calculate the index corresponding to the element of ALTGRID which is closest to 400 km (INDEX_400KM).

INDEX_400KM = The index corresponding to the element of the vector ALTGRID which is closest to the value 400.0. The value INDEX_400KM is calculated by the Search Function (SEARCH). The following values should be used as inputs to the Search Function:

For SEARCH X $\xrightarrow{Use}$ *ALTGRID*
For SEARCH U $\xrightarrow{Use}$ *400.0*

2.3.1.4.4 Calculate the coefficients from a linear least squares fit to the natural logarithm of the values of the measured 1356 A intensity profile between 500 km and 400 km.(COEFF)

Note: Each element of the vectors TempA, TempB and VTempB (the variance associated with TempB) are calculated in the same manner. For the ith element (i = INDEX_500KM to INDEX_400KM), the values of TempA, TempB, and VTempB are calculated as:

TempA[i] = ALTGRID[i]

TempB[i] = ln (I1356P[i])

Note: Each element VTempB[i] (the variance associated with TempB) is obtained by taking the derivative of the natural logarithm of TempB[i] with respect to I1356P[i].

$$\text{VTempB[i]} = \left(\frac{VI1356P[i]}{I1356P[i]^2} \right)$$

where

ln = The natural logarithm function.

COEFF = The coefficients calculated by the Linear Least Squares Fitting Function (LLSFIT) (see Appendix). The following values should be used as input into the Linear Least Squares Fitting Function:

$$\textit{For LLSFIT Y} \xrightarrow{\text{Use}} \textit{TempB}$$
$$\textit{For LLSFIT VY} \xrightarrow{\text{Use}} \textit{VTempB}$$
$$\textit{For LLSFIT X} \xrightarrow{\text{Use}} \textit{TempA}$$

2.3.1.4.5 Calculate the exospheric temperature (Texo)

Note: A linear least squares fit to the natural logarithm of the measured 1356 A intensity profile between 500 km and 400 km returns two coefficients, the first being the offset, and the second being the slope of the line fit to the natrual logarithm of the measured 1356 A intensity profile between 500 km and 400 km.

Texo = The value calculated by the Interpolation Function INTERPOLATE (see Appendix). The following values should be used as input to the Interpolation Function:

$$\textit{For INTERPOLATE Y} \xrightarrow{\textit{Use}} \textit{Texo\_Grid}$$
$$\textit{For INTERPOLATE X} \xrightarrow{\textit{Use}} \textit{Slope}$$
$$\textit{For INTERPOLATE U} \xrightarrow{\textit{Use}} \textit{COEFF[2]}$$

Calculate the variance of the exospheric temperature (VTexo).

Note: The variance of the derived Texo value is obtained from the derivative of the vector Slope with respect to the vector Texo_Grid and the variance of the slope of the line fit to the natural logarithm of the measured 1356 A profile. The only significant source of uncertainty in Texo is due to uncertainty in COEFF[2].

INDEX_TEXO = The index corresponding to the element of the vector Texo_Grid which is closest to the value Texo. The value INDEX_TEXO is calculated by the Search Function (SEARCH). The following values should be used as inputs to the Search Function:

For SEARCH X $\xrightarrow{Use}$ *Texo_Grid*
For SEARCH U $\xrightarrow{Use}$ *Texo*

TempA = The partial derivative of Slope with respect to Texo_Grid at the point Texo_Grid[INDEX_TEXO]. The value TempA is calculated by the Derivative Function (DERIVATIVE). The following values should be used as input to the Derivative Function:

For DERIVATIVE Y $\xrightarrow{\text{Use}}$ *Texo_Grid*
For DERIVATIVE X $\xrightarrow{\text{Use}}$ *Slope*
For DERIVATIVE INDEX $\xrightarrow{\text{Use}}$ *INDEX_TEXO*

VTexo = $VCOEFF[2] \; / \; TempA^2$

where

VCOEFF[2] = The variance of COEFF[2] calculated by the Linear Least Squares Fitting Function.

2.3.1.4.6 End

2.3.2 The Neutral Density Profiles (N2DP, O2DP, ODP)

2.3.2.1 Required Input to the Derivation

Texo	The exospheric temperature (K). The Texo is a product of the Dayside Limb Texo Derivation.
VTexo	The variance associated with Texo $(K)^2$. The VTexo is a product of the Dayside Limb Texo Derivation.
QEUV	The solar EUV flux below 450 A (erg cm^{-2} s^{-1}). The QEUV is a product of the Dayside Disk QEUV derivation.
VQEUV	The variance associated with QEUV (erg cm^{-2} $s^{-1})^2$. The VQEUV is a product of the Dayside Disk QEUV derivation.

SZA	The Solar Zenith Angle at the current limb pixel (radians).
I1356P	The measured 1356 intensity profile (Rayleighs).
VI1356P	The variance associated with I1356P $(Rayleighs)^2$.
ILBH1P	The measured LBH1 (1400 - 1500 A) intensity profile (Rayleighs).
VILBH1P	The variance associated with ILBH1 $(Rayleighs)^2$.
ILBH2P	The measured LBH2 (1650 - 1800 A) intensity profile (Rayleighs).
VILBH2P	The variance associated with ILBH2 $(Rayleighs)^2$.
ALTGRID	The altitude grid corresponding to the measured 1356 A intensity profile, the measured LBH1 (1400-1500 A) intensity profile, and the measured LBH2 (1650-1800 A) intensity profile (km). The vector ALTGRID is assumed to be monotonically decreasing.
VALTGRID	The variance associated with ALTGRID $(km)^2$.

2.3.2.2 Calculated Output of the Derivation

N2DP	The N_2 density profile (cm^{-3}).
VN2DP	The variance associated with N2DP $(cm^{-3})^2$.
O2DP	The O_2 density profile (cm^{-3}).
VO2DP	The variance associated with O2DP $(cm^{-3})^2$.
ODP	The O density profile (cm^{-3}).
VODP	The variance associated with ODP $(cm^{-3})^2$.

2.3.2.3 The Derivation

2.3.2.3.1 Begin

2.3.2.3.2 Calculate the Neutral Density Profiles (NDP)

Note: The N_2, O_2, and O neutral density profiles are simultaneously calculated by the Discrete Inverse Theory Function. The data product NDP is intended to represent an object that includes the N_2, O_2, and O neutral density profiles.

NDP = The values calculated by the Discrete Inverse Theory Function (DITF) (see Appendix). The following values should be used as input into the Discrete Inverse Theory Function:

For DITF Texo $\xrightarrow{\text{Use}}$ *Texo*

For DITF VTexo $\xrightarrow{\text{Use}}$ *VTexo*

For DITF QEUV $\xrightarrow{\text{Use}}$ *QEUV*

For DITF VQEUV $\xrightarrow{\text{Use}}$ *VQEUV*