**Help on module operational\_sep\_quantities:**

**NAME**

operational\_sep\_quantities

**AUTHOR**

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**FILE**

operational-sep/operational\_sep\_quantities.py

**DATA**

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**VERSION**

V2.0

**FUNCTIONS**

**all\_program\_info()**

: This program will calculate various useful pieces of operational

information about SEP events from GOES-08, -10, -11, -12, -13, -14, -15

data and the SEPEM (RSDv2) dataset.

**SEP event values are always calculated for threshold definitions:**

>10 MeV exceeds 10 pfu

>100 MeV exceed 1 pfu

The user may add multiple additional thresholds through the command line.

This program will check if data is already present in a 'data' directory. If

not, GOES or EPHIN data will be automatically downloaded from the web. SEPEM

(RSDv2) data must be downloaded by the user and unzipped inside the 'data'

directory. Because the SEPEM data set is so large (every 5 minutes from 1974

to 2015), the program will break up the data into yearly files for faster

reading.

The values calculated here are important for space radiation operations:

Onset time, i.e. time to cross thresholds

Onset peak intensity

Onset peak time

Maximum intensity

Time of maximum intensity

Rise time (onset to peak)

End time, i.e. fall below 0.85\*threshold for 3 points (15 mins for GOES)

Duration

Event-integrated fluences

Proton fluxes at various times after threshold crossing (UMASEP option)

User may choose differential proton fluxes (e.g. [MeV s sr cm^2]^-1) or

integral fluxes (e.g. [s sr cm^2]^-1 or pfu). The program has no internal

checks orrequirements on units - EXCEPT FOR THE THRESHOLD DEFINITIONS

OF >10, 10 and >100, 1. If you convert those thresholds in the main program

to your units, you should be able to generate consistent results.

Also, all of the plots and messages refer to MeV, pfu, and cm. Change those

labels everywhere if you choose other units. Currently no features to change

units automatically.

User may specify various options, that currently only apply to GOES data:

Choose corrected or uncorrected GOES fluxes.

Choose to apply Bruno (2017) or Sandberg et al. (2014) effective

energies to GOES uncorrected data.

--options uncorrected

--options uncorrected,S14,Bruno2017 (recommend using background subtraction)

Users may choose to perform a background subtraction by specifying:

--SubtractBG --BGStartDate YYYY-MM-DD --BGEndDate YYYY-MM-DD

The user should look at the data and select an appropriate time frame

prior to the event when the background is calm and well-defined. If

performing background subtraction, the mean background will be subtracted

from the fluxes in the SEP time frame (StartDate to EndDate). Plots

showing the mean background level, the background flux only, and the

background-subtracted SEP fluxes will be created by derive\_background to

verify the quality of the background estimation and subtraction.

If a previous event is ongoing and the specified time period starts with a

threshold already crossed, you may try to set the --DetectPreviousEvent

flag. If the flux drops below threshold before the next event starts, the

program will identify the second event. This will only work if the

threshold is already crossed for the very first time in your specified

time period, and if the flux drops below threshold before the next event

starts.

If the event has an initial increase above threshold for a few points, falls

below threshold, then continues to increase above threshold again, you

may try to use the --TwoPeak feature to capture the full duration of the

event. The initial increase above threshold must be less than a day. An

example of this scenario can be seen in >100 MeV for 2011-08-04.

A flag was added with the "UMASEP" option. When this flag is used

(--UMASEP), the code finds all information for four energy channels and

thresholds used by UMASEP: >10 MeV, 10 pfu; >100 MeV, 1 pfu; >30 MeV, 1 pfu;

>50 MeV, 1 pfu. The proton flux in each of these channels is reported for

multiple times after threshold crossing (Ts). The applied time delays are

as follows:

>10 MeV - Ts + 3, 4, 5, 6, 7 hours

>30 MeV - Ts + 3, 4, 5, 6, 7 hours

>50 MeV - Ts + 3, 4, 5, 6, 7 hours

>100 MeV - Ts + 3, 4, 5, 6, 7 hours

**RUN CODE FROM COMMAND LINE (put on one line), e.g.:**

python3 operational\_sep\_quantities.py --StartDate 2012-05-17

--EndDate '2012-05-19 12:00:00' --Experiment GOES-13

--FluxType integral --showplot --saveplot

**RUN CODE FROM COMMAND FOR USER DATA SET (put on one line), e.g.:**

python3 operational\_sep\_quantities.py --StartDate 2012-05-17

--EndDate '2012-05-19 12:00:00' --Experiment user --ModelName MyModel

--UserFile MyFluxes.txt --FluxType integral –showplot

**RUN CODE FROM COMMAND LINE AND PERFORM BACKGROUND SUBTRACTION AND APPLY**

**Sandberg et al. (2014) and Bruno (2017) effective energies to the GOES bins.**

**(note: cannot bg-subtract GOES integral fluxes), e.g.:**

python3 operational\_sep\_quantities.py --StartDate 2012-05-17

--EndDate '2012-05-19 12:00:00' --Experiment GOES-13

--FluxType differential --showplot --options uncorrected,S14,Bruno2017

--SubtractBG --BGStartDate 2012-05-10 --BGEndDate --2012-05-17

**RUN CODE IMPORTED INTO ANOTHER PYTHON PROGRAM, e.g.:**

import operational\_sep\_quantities as sep

start\_date = '2012-05-17'

end\_date = '2012-05-19 12:00:00'

experiment = 'GOES-13'

flux\_type = 'integral'

model\_name = '' #if experiment is user, set model\_name to describe data set

user\_file = '' #if experiment is user, specify filename containing fluxes

showplot = True #Turn to False if don't want to see plots

saveplot = False #turn to true if you want to save plots to file

doBGSub = False #Set true if want to perform background subtraction

bgstart\_date = "2012-05-10" #Dates used to estimate mean background if

bgend\_date = "2012-05-17" #doBGSub is set to True

detect\_prev\_event = True #Helps if previous event causes high intensities

two\_peaks = False #Helps if two increases above threshold in one event

umasep = False #Set to true if want UMASEP values (see explanation above)

threshold = '100,1' #default; modify to add a threshold to 10,10 and 100,1

FirstStart, LastEnd, ShortEvent, LateHundred, sep\_year, sep\_month, \

sep\_day = sep.run\_all(start\_date, end\_date, experiment, flux\_type, \

model\_name, user\_file, showplot, saveplot, detect\_prev\_event, \

two\_peaks, umasep, threshold, options, doBGSub, bgstart\_date, \

bgend\_date)

Set the desired directory locations for the data and output at the beginning

of the program in datapath and outpath. Defaults are 'data' and 'output'.

In order to calculate the fluence, the program determines time\_resolution

(seconds) from two (fairly random) data points at the start of the SEP

event. GOES and SEPEM data sets have a time resolution of 5 minutes. If the

user wishes to use a data set with measurements at irregular times, then the

subroutine calculate\_fluence should be modified.

**OUTPUT:** This program outputs 3 to 4 files, 1 per defined threshold plus

a summary file containing all of the values calculated for each threshold.

A file named as e.g. fluence\_GOES-13\_differential\_gt10\_2012\_3\_7.csv contains

the event-integrated fluence for each energy channel using the specified

threshold (gt10) to determine start and stop times.

A file named as e.g. sep\_values\_GOES-13\_differential\_2012\_3\_7.csv contains

start time, peak flux, etc, for each of the defined thresholds.

Added functionality to output the >10 MeV and >100 MeV time series for the

date range input by the user. If the original data were integral fluxes,

then the output files simply contain the >10 and >100 MeV time series from

the input files. If the original data were differential fluxes, then the

estimated >10 and >100 MeV fluxes are output as time series.

**USER INPUT DATA SETS:** Users may input their own data set. For example, if an

SEP modeler would like to feed their own intensity time series into this

code and calculate all values in exactly the same way they were calculated

for data, it is possible to do that. Fluxes should be in units of

1/[MeV cm^2 s sr] or 1/[cm^2 s sr] and energy channels in MeV for the plot

labels to be correct. You can use any units, as long as you are consistent

with energy units in energy channel/bin definition and in fluxes and you

**MODIFY THE THRESHOLD VALUES TO REFLECT YOUR UNITS.** You may then want to

modify plot labels accordingly if not using MeV and cm.

**NOTE:** The first column in your flux file is assumed to be time in format

YYYY-MM-DD HH:MM:SS. IMPORTANT FORMATTING!!

**NOTE:** The flux file may contain header lines that start with a hash #,

including blank lines.

**NOTE:** Any bad or missing fluxes must be indicated by a negative value.

**NOTE:** Put your flux file into the "datapath" directory. Filenames will be relative to this path.

**NOTE:** Please use only differential or integral channels. Please do not mix

them. You may have one integral channel in the last bin, as this is the way

HEPAD works and the code has been written to include that HEPAD >700 MeV

bin along with lower differential channels.

**USER VARIABLES:** The user must modify the following variables in

library/global\_vars.py:

**user\_col** - identify columns in your file containing fluxes to analyze;

even if your delimeter is white space, consider the date-time

column as one single column. SET AT TOP OF CODE.

**user\_delim** - delimeter between columns, e.g. " " or "," Use " " for

any amount of whitespace. SET AT TOP OF CODE.

**user\_energy\_bins** - define your energy bins at the top of the code in the

variable user\_energy\_bins. Follow the format in the subroutine

define\_energy\_bins. SET AT TOP OF CODE.

**user\_fname** - specify the name of the file containing the fluxes

through an argument in the command line. --UserFile The

user\_fname variable will be updated with that filename. ARGUMENT

**time\_resolution** - will be calculated using two time points in your file;

if you have irregular time measurements, calculate\_fluence()

must be modified/rewritten. **AUTOMATICALLY DETERMINED.**

**calculate\_event\_info(energy\_thresholds, flux\_thresholds, dates, integral\_fluxes, detect\_prev\_event, two\_peaks, is\_diff\_thresh)**

: Uses the integral fluxes (either input or estimated from differential

channels) and all the energy and flux thresholds set in the main program

to calculate SEP event quantities.

Threshold crossing time (onset)

Peak Flux in date range specified by user

Time of Peak Flux

Rise Time (onset to peak flux)

Event End Time (below 0.85\*threshold for 3 data points, e.g 15 min)

Duration (onset to end)

If the detect\_prev\_event flag is set to true and the threshold is crossed

on the first time in the specified date range, this indicates that fluxes

were already high due to a previous event. The code will look for the

flux to drop below threshold and then increase above threshold again

during the specified time period. If this flag is not set, then the code

simply take the first threshold crossing as the start of the SEP event.

If the two\_peaks flag is set to true, the code will use the first

identified threshold crossing as the start time. A second threshold

crossing will be allowed. The event end will be determined as the drop

below threshold after the second threshold crossing. The duration will

be the end time - first threshold crossing time. The peak will be

determined as the largest flux value found in both threshold crossings.

The peak and rise times will be calculated from the first threshold

crossing time.

**calculate\_fluence(dates, flux)**

: This subroutine sums up all of the flux in the 1D array "flux". The

"dates" and "flux" arrays input here should reflect only the intensities

between the SEP start and stop times, determined by the subroutine

integral\_threshold\_crossing. "flux" should contain the intensity

time series for a single energy bin or single integral channel (1D

array). The subroutine does not differentiate between differential or

integral flux. dates contains the 1D array of datetimes that

correspond to the flux measurements.

The extract\_date\_range subroutine is used prior to calling this one to

make the dates and fluxes arrays covering only the SEP time period.

The flux will be multiplied by time\_resolution and summed for all of the

data between the start and end times. Data gaps are taken into account.

Fluence units will be 1/[MeV cm^2 sr] for GOES or SEPEM differential

fluxes or 1/[cm^2 sr] for integral fluxes.

For SRAG operational purposes, the event start and end is determined by

the >100 MeV fluxes, as they are most pertinent to astronaut health

inside of the space station.

**calculate\_onset\_peak(experiment, energy\_thresholds, dates, integral\_fluxes, crossing\_time, event\_end\_time, showplot)**

: Calculate the peak associated with the initial SEP onset. This subroutine

searches for the rollover that typically occurs after the SEP onset.

The peak value will be specified as the flux value at the rollover

location.

The onset peak may provide a more physically appropriate comparison

with models.

If code cannot identify onset peak, it will return a value of -1 on

the date 1970-01-01.

**calculate\_umasep\_info(energy\_thresholds, flux\_thresholds, dates, integral\_fluxes, crossing\_time)**

: Uses the integral fluxes (either input or estimated from differential

channels) and all the energy and flux thresholds set in the main program

to calculate SEP event quantities specific to the UMASEP model.

Flux at threshold crossing time + 3, 4, 5, 6, 7 hours

**check\_bin\_exists(threshold, energy\_bins)**

: If a user specifies a threshold for a differential energy bin, check

to see that the energy bin is in the requested data set.

threshold is a list of strings.

Expect threshold[0] = lowedge-highedge, threshold[1] = flux value

**extract\_integral\_fluxes(fluxes, experiment, flux\_type, flux\_thresholds, energy\_thresholds, energy\_bins)**

: Select or create the integral fluxes that correspond to the desired

energy thresholds.

If the user selected differential fluxes, then the

differential fluxes will be converted to integral fluxes with the

minimum energy defined by the set energy thresholds.

If the user selected integral fluxes, then the channels corresponding to

the desired energy thresholds will be identified.

If an energy channel with a specified is not present, will return a

None value for the integral fluxes, and remove that threshold in

run\_all. (e.g. if >100 MeV fluxes were not in the data or model

fluxes, return a None value for integral fluxes and remove the

>100 MeV, 1 pfu threshold.)

**from\_differential\_to\_integral\_flux(experiment, min\_energy, energy\_bins, fluxes)**

: If user selected differential fluxes, convert to integral fluxes to

caluculate operational threshold crossings (>10 MeV protons exceed 10

pfu, >100 MeV protons exceed 1 pfu).

Assume that the measured fluxes correspond to the center of the energy

bin and use power law interpolation to extrapolate integral fluxes

above user input min\_energy.

The intent is to calculate >10 MeV and >100 MeV fluxes, but leaving

flexibility for user to define the minimum energy for the integral flux.

An integral flux will be provided for each timestamp (e.g. every 5 mins).

**get\_fluence\_spectrum(experiment, flux\_type, model\_name, energy\_threshold, flux\_threshold, sep\_dates, sep\_fluxes, energy\_bins, is\_diff\_thresh, save\_file)**

: Calculate the fluence spectrum for each of the energy channels in the

user selected data set. If the user selected differential fluxes, then

the fluence values correspond to each energy bin. If the user selected

integral fluxes, then the fluence values correspond to each integral bin.

Writes fluence values to file according to boolean save\_file.

If the user input a threshold for a differential energy bin,

is\_diff\_thresh will be true and the filename will not contain "gt".

**integral\_threshold\_crossing(energy\_threshold, flux\_threshold, dates, fluxes)**

: Calculate the time that a threshold is crossed.

Operational thresholds used by the NASA JSC Space Radiation Analysis

Group to determine actions that should be taken during an SEP event are:

>10 MeV proton flux exceeds 10 pfu (1/[cm^2 s sr])

>100 MeV proton flux exceeds 1 pfu (1/[cm^2 s sr])

An SEP event is considered to start if 3 consecutive points are

above threshold. The start time is set to the first point that crossed

threshold.

If the user input differential flux, then the program has converted it

to integral fluxes to calculate the integral threshold crossings.

If the user selected fluxes that were already integral fluxes, then

the correct channel was identified to determine these crossings.

GOES and SEPEM data have a 5 minute time resolution, so initial

crossings are accurate to 5 minutes.

This program also calculates peak flux and time of peak flux for time

period specified by user. It then calculates rise time by comparing:

rise time = time of peak flux - threshold crossing time

If no thresholds are crossed during specified time period, peak time

and rise time will be 0.

The event end time is much more subjective. For this program, I follow

the code that officially calls the end of an event when SRAG supports

ISS operations. When the flux has three consecutive points (15 minutes

of GOES data) below 0.85\*threshold, then the event is ended. The end time

is corrected back to the first of the three data points. This end

criteria has no physics basis. It simply ensures that a new event will

not erroneously begin within the SRAG SEP alarm code due to flux

fluctuations around threshold as the SEP flux decays away slowly.

If the time period specified by the user ends before the event falls

below 0.85\*threshold, then the event\_end\_time is set to the last time

in the specified time range. The program will give a message indicating

that the user may want to extend the requested time frame in order to

better-capture the end of the event.

**print\_values\_to\_file(experiment, flux\_type, model\_name, energy\_thresholds, flux\_thresholds, crossing\_time, onset\_peak, onset\_date, peak\_flux, peak\_time, rise\_time, event\_end\_time, duration, integral\_fluences, is\_diff\_thresh, umasep, umasep\_times, umasep\_fluxes)**

: Write all calculated values to file for all thresholds. Event-integrated

fluences for >10, >100 MeV (and user-defined threshold) will also be

included. Writes out file with name e.g.

output/sep\_values\_experiment\_fluxtype\_YYYY\_M\_D.csv

If the UMASEP option was selected, add on the proton values calculated

at the UMASEP Ts + Xhr time points.

is\_diff\_thresh indicates whether the user input a differential

threshold. If so, the user threshold bin(s) will refer to differential

fluxes.

**report\_threshold\_fluences(experiment, flux\_type, model\_name, energy\_thresholds, energy\_bins, sep\_dates, sep\_fluxes)**

: Report fluences for specified thresholds, typically >10, >100 MeV.

These values are interesting to use for comparison with literature and

for quantifying event severity.

If the user has input integral channels, then this information has also

been saved in the output fluence file. If the user selected differential

channels, then these values come from the estimated integral fluxes.

**run\_all(str\_startdate, str\_enddate, experiment, flux\_type, model\_name, user\_file, showplot, saveplot, detect\_prev\_event, two\_peaks, umasep, str\_thresh)**

: Runs all subroutines and gets all needed values. Takes the command line

areguments as input. Written here to allow code to be imported into

other python scripts.

str\_startdate, str\_enddate, experiment, flux\_type are strings.

model\_name is a string. If model is "user", set model\_name to describe

your model (e.g. MyModel), otherwise set to ''.

user\_file is a string. Defaul is ''. If user is selected for experiment,

then name of flux file is specified in user\_file.

showplot, detect\_prev\_event, two\_peaks, and umasep are booleans.

Set str\_thresh to be '100,1' for default value or modify to add your own

threshold.

This routine will generate boolean flags that indicate if the event

starts at the very first time point, ends on the very last time point,

has a duration less than 12 hours, or has a >100 MeV onset more than

24 hours after the >10 MeV onset. These flags intend to help the user

running the program in batch mode if a certain event might have

incorrect timing.

**save\_integral\_fluxes\_to\_file(experiment, flux\_type, model\_name, energy\_thresholds, crossing\_time, dates, integral\_fluxes)**

: Output the time series of integral fluxes to a file. If the input

data set was in integral channels, then this file will contain exactly

the same values in the time series.

If the input data set was in differential energy bins, then this file

contains the estimated integralfluxes calculated in this program.