Calculation Method for Predicting AM0 Isc from High Altitude Aircraft Flight Data

Matthew G. Myers, David B. Snyder (Ret.)
NASA Glenn Research Center, Cleveland, Ohio 44135

Introduction

High altitude aircraft are used by the space photovoltaic (PV) community to estimate the air mass Zero (AM0) performance of solar cells, however a correction of around 1 to 4 percent is needed due to atmospheric effects. Shown here is the correction method for NASA's ER-2 calibration platform.

Method

The Isc and temperature of a solar cell are measured over a range of high altitudes while monitoring ambient pressure. The ER-2 flights typically range from 70,000ft (AM = 0.04) to 55,000ft (AM = 0.07). The cell Isc data are corrected for the effects of atmospheric ozone and cell temperature followed by a Langley plot extrapolation and earth-sun distance correction to estimate the AM0 performance of the solar cell. This process takes the following inputs:

Data	Units	Source
AM0 Spectral Model	nm, W/m^{2}nm	ASTMG173 [1]
Ozone Absorbance Spectrum	nm, mDU^{-1}	NREL Solar Spectral Model [2]
Cell EQE	nm, decimal	Experimentally determined
Solar Cell Flight Data	Atm., Amps, K	Experimentally determined
Ozone vs. Pressure Profile	atm, DU	TOMS, OMI on Aura satellite [3]
Cell Isc Temp. Coef.	μA/K	Experimentally determined
Solar Elevation	degrees	NOAA website [4]
Earth-Sun Distance	AU	NASA Landsat 7 handbook

Ozone and Temperature Correction:

Each flight Isc value is individually corrected first for ozone with equations (1) and (2), and then for temperature using equation (3) where:

Iozc:	Ozone corrected Isc	Oz:	Est. optical path ozone
Isc:	Measured Isc	Itc:	Temp. corrected Isc
$P_{AM0}(\lambda)$:	Model of AM0 irradiance	Tt:	Target temperature
$P(\lambda)$	Ozone attenuated irradiance	Tc:	Measured cell temperature
$EQE(\lambda)$:	Solar cell EQE	α :	Cell Isc temp. coefficient
$\beta(\lambda)$:	Ozone abs. spectrum		

$$I_{ozc} = I_{sc}\frac{\int P_{AM0}(\lambda)EQE(\lambda)d\lambda}{\int P(\lambda)EQE(\lambda)\,d\lambda} \quad (1)$$

$$P(\lambda) = P_{AM0}(\lambda)e^{-\beta(\lambda)Oz} \quad (2)$$

$$I_{tc} = I_{ozc} + (T_T - T_C)\alpha \quad (3)$$

Langley plot method and Heliocentric Distance Correction:

The log of the corrected Isc is plotted as a function of airmass. A linear fit is used to extrapolate this plot to AM0 and the log is reversed to give an Isc value. This is then corrected for earth-sun distance by multiplying the Langley plot value by the distance in AU squared.

[1] rredc.nrel.gov/solar/spectra/am1.5/astmg173/astmg173html, ASTM G173-03, Extraterrestrial Radiation

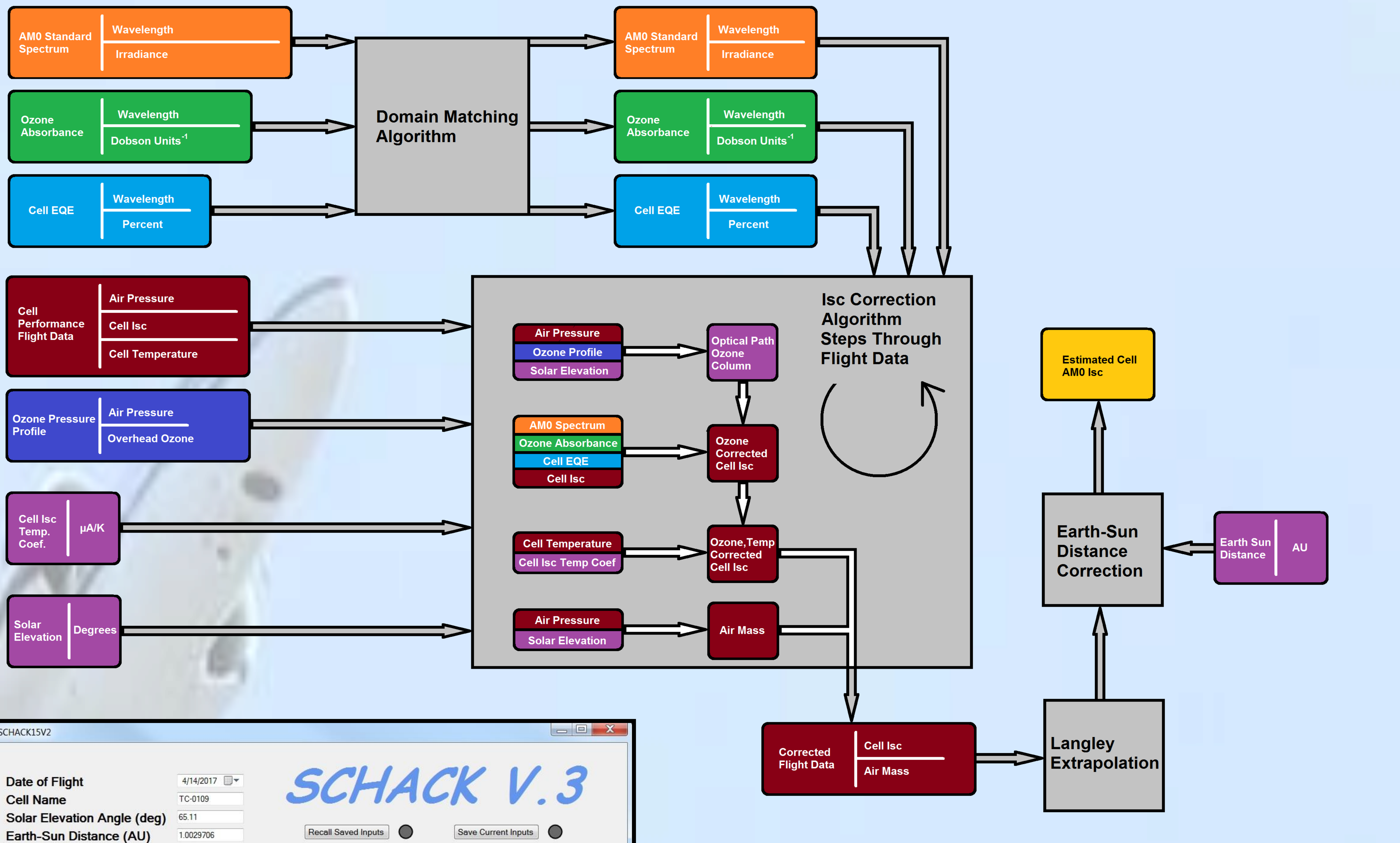
[2] Bird, R., and Riirdan, C.. "Simple Solar Spectral Model for Direct and Diffuse Irradiance on Horizontal and Tilted Planes at the Earth3 Surface for Cloudless Atmospheres", SERI/TR-215-2436, December 1984.

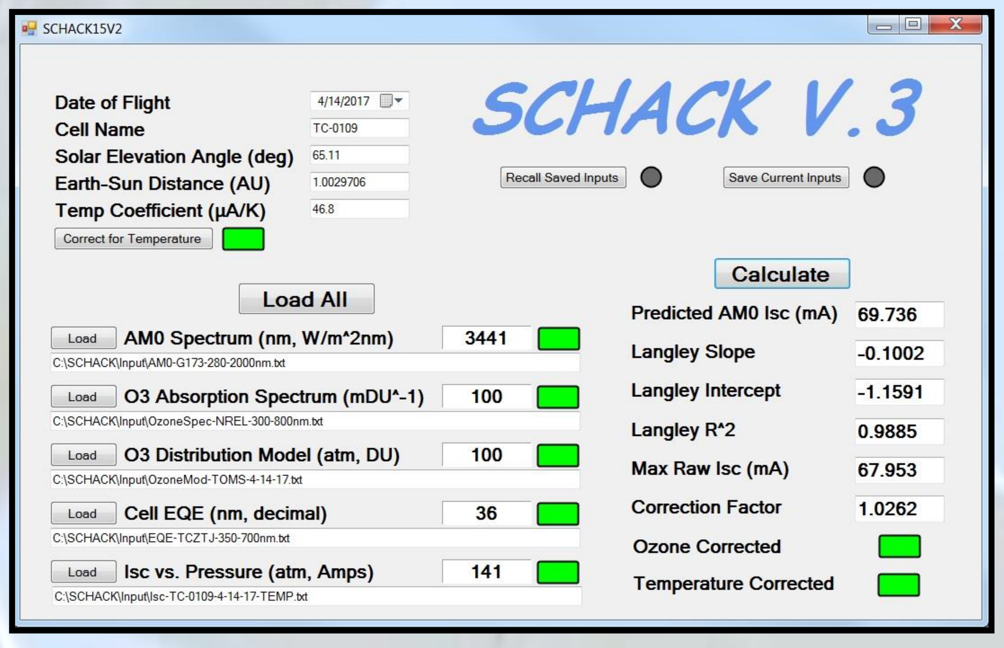
[3] ftp//toms.gsfc.nasa.gov/pub/omi/data/ozone, NASA Total Ozone Mapping Spectrometer satellite

[4] http://www.esrl.noaa.gov/gmd/grad/solcalc/, NOAA Solar Calc.

SCHACK Software

The SCHACK (Solar Cell High Altitude Correction Calculator) software uses this method as depicted in the flowchart below. For each data point, the program estimates the ozone column and corrects for ozone attenuation. The Isc is then temperature corrected and ambient pressures converted to airmass. The AM0 Isc is then estimated with a Langley plot and corrected for earth-sun distance.

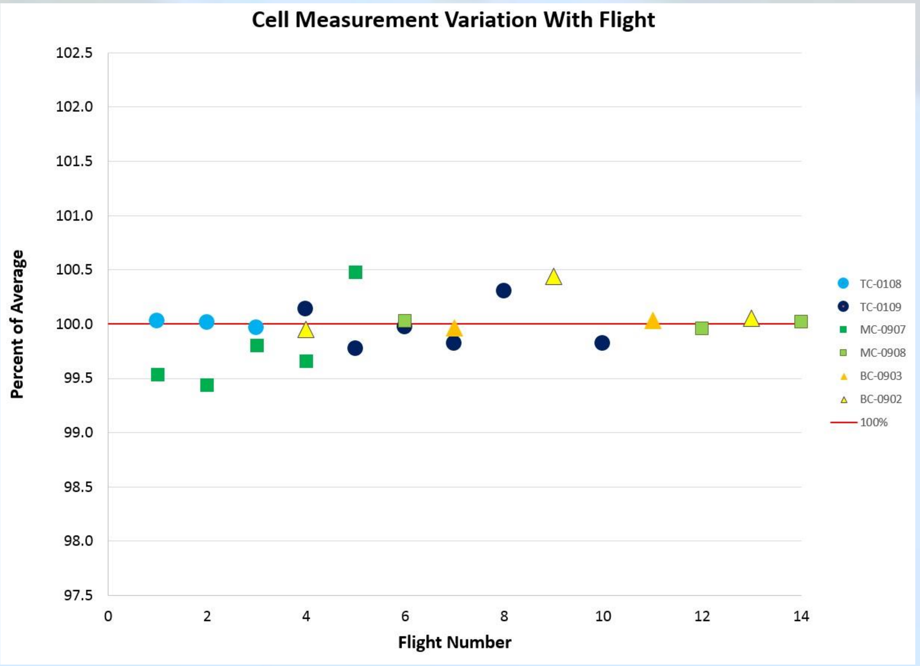




Above: Flowchart for SCHACK Software

Left: SCHACK User Interface

Results



Flight	Date	TC0-108	TC-0109	MC-0907	MC-0908	BC-0902	BC-0903
1	10/8/2014	69.87		65.97			
2	10/10/2014	69.86		65.90			
3	10/14/2014	69.83		66.14			
4	3/26/2015		69.96	66.05			105.73
5	7/16/15		69.71	66.59			
6	7/21/15		69.84		66.25		
7	7/22/15		69.74			105.10	
8	5/18/16		70.08				
9	4/12/17						106.25
10	4/14/17	69.81					
11	5/9/17					105.18	
12	5/11/17				66.20		
13	5/12/17						105.84
14	5/15/17				66.24		
Average		69.84	69.87	66.13	66.23	105.14	105.94
Std Dev.		0.028	0.155	0.273	0.025	0.055	0.274

ER-2 Data:

Four years of AM0 Isc estimates from two sets of 3J isotypes are depicted in the chart and table above and show generally good repeatability despite varying flight conditions.

High Altitude Balloon Comparison:

A CNES PV measurement experiment onboard the CASOLBA balloon flown in April of 2017 measured an IMM four-junction cell previously flown on the ER-2. The AM0 Isc estimate from the CASOLBA balloon differed from the ER-2 estimate by less than 0.2%