MEGS A & B SURF Calibrations

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MEGS Calibration Algorithms

$$C'(i,j,t)=\left[\frac{C(i,j,t,T_{CCD},tap)}{\Delta t}-D(i,j,T_{CCD},C,tap)\right]\cdot G(i,j,T_{CCD},tap)\cdot Mask(i,j,C,tap)$$

$$R_{SURF}(i,j,E_{beam},filter,\alpha,\beta)=\frac{\frac{1}{n}\sum_{k=1}^{n}\frac{C'_k(i,j,t,E_{beam},filter,\alpha,\beta)}{I_{SURF}(t)}}{F_{SURF}(i,j,E_{beam},\alpha,\beta)\cdot A_{slit}\cdot\Delta\lambda(i,j)}$$

$$R_{flight}(i,j,filter)=\frac{\lambda(i,j)}{h\cdot c}\cdot A_{slit}\cdot\Delta\lambda(i,j)\cdot\left[\sum_{\alpha,\beta}w(\alpha,\beta)\cdot R_{SURF}(i,j,E_{beam},filter,\alpha,\beta)\cdot f_{OS}(i,j,E_{beam},filter,\alpha,\beta)\right]$$

$$I(i,j,t)=\frac{C'(i,j,t,filter)}{R_{flight}(i,j,filter)}\cdot f_{degrad}(i,j,t,filter)\cdot f_{1AU}(t)$$

Calculated from SURF data

Equations used for data processing

Correcting Raw Counts

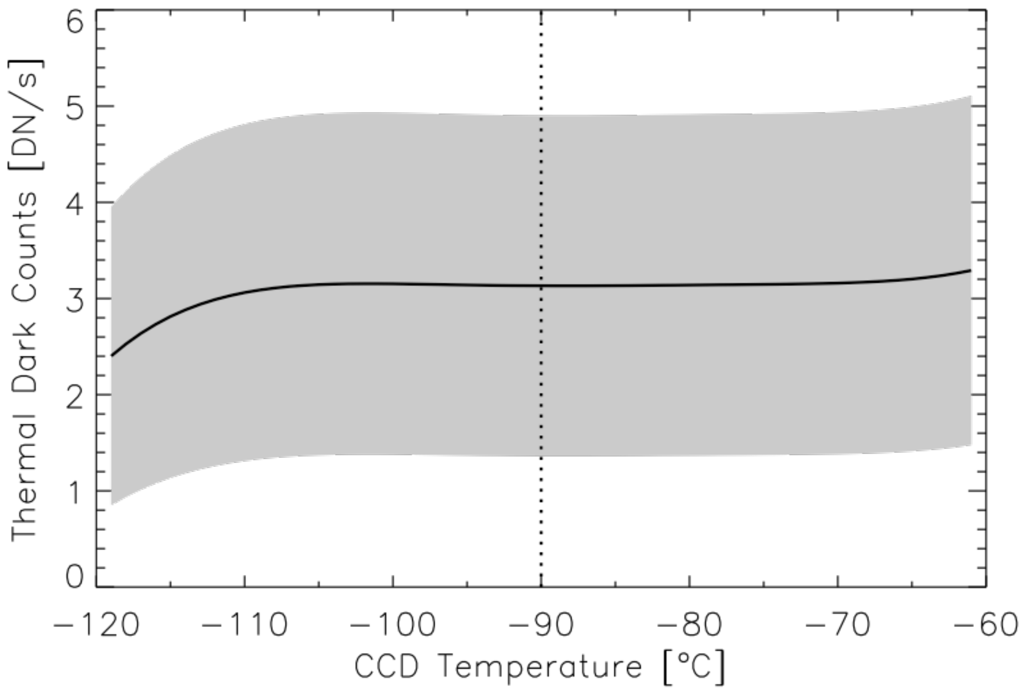
$$C'(i,j,t) = \left\lfloor \frac{C(i,j,t,T_{CCD},tap)}{\Delta t} - D(i,j,T_{CCD},C,tap) \right\rfloor \cdot G(i,j,T_{CCD},tap) \cdot Mask(i,j,C,tap)$$

$$\sigma_{C'}^2 = (C')^2 \cdot \left[\frac{\left(\frac{C}{\Delta t}\right)^2 \cdot \left(\frac{\sigma_C^2}{(C)^2} + \frac{\sigma_{\Delta t}^2}{(\Delta t)^2} \right) + \sigma_D^2}{\left(\frac{C}{\Delta t} - D\right)^2} + \frac{\sigma_G^2}{(G)^2} \right]$$

Dark Correction

- Electronic bias: average of 4 “virtual pixel” columns
- Thermal dark: measured during thermal vacuum testing & will be repeated once on orbit

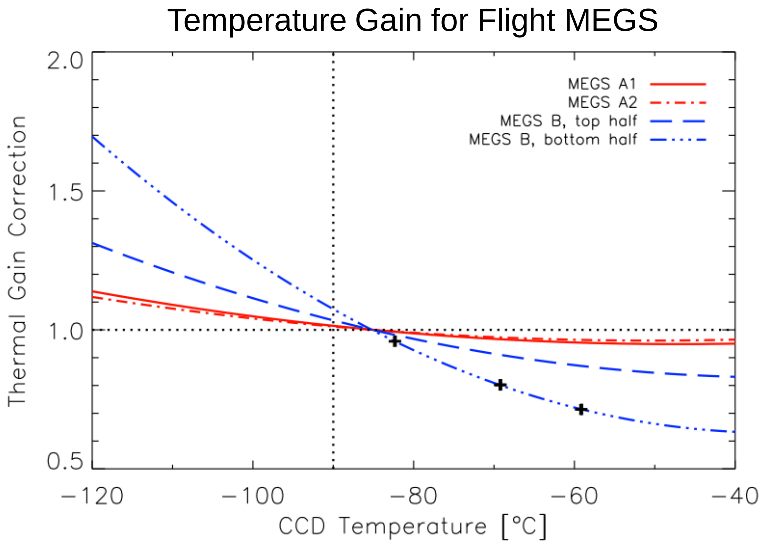
Example of thermal dark for a MEGS A pixel. Dashed line shows the expected operating temperature



Gain Correction

- Readout mode gain: normalize to default readout mode; 1 number for each half of CCD; will be recalculated on-orbit
- Temperature gain: normalize counts to -85ºC

$$G_{thermal}(T_{CCD}) = a + b(T_{CCD} + 85) + c(T_{CCD} + 85)^2$$



Instrument	Readout mode	a	b	c
Flight MEGS A	Left (top half)	1.028	3.363E-03	3.572E-05
	Right (top half)	1.046	3.801E-03	3.832E-05
	Left (bottom half)	1.068	3.869E-03	3.612E-05
	Right (bottom half)	1.044	3.285E-03	3.251E-05
Flight MEGS B	Left (top half)	0.904	4.422E-03	6.526E-05
	Right (top half)	0.842	2.674E-03	5.327E-05
	Left (bottom half)	0.774	9.350E-03	1.409E-04
	Right (bottom half)	0.814	1.046E-02	1.484E-04
Rocket MEGS A	Left (top half)	1.007	8.288E-04	8.826E-06
	Right (top half)*	1.000	0.000E+00	0.000E+00
	Left (bottom half)*	1.000	0.000E+00	0.000E+00
	Right (bottom half)	1.003	6.739E-04	7.550E-06
Rocket MEGS B	Left (top half)	0.977	1.171E-03	1.705E-05
	Right (top half)*	1.000	0.000E+00	0.000E+00
	Left (bottom half)*	1.000	0.000E+00	0.000E+00
	Right (bottom half)	0.940	3.474E-04	1.235E-05

Masking of Invalid Pixels

- Exclude certain pixels
  - Saturated pixels
  - “Virtual pixel” columns
  - Cosmic rays
  - “Bad” pixels identified from flatfield images
- Solar data: interpolate spatially & temporally to fill the missing data

SURF Responsivity

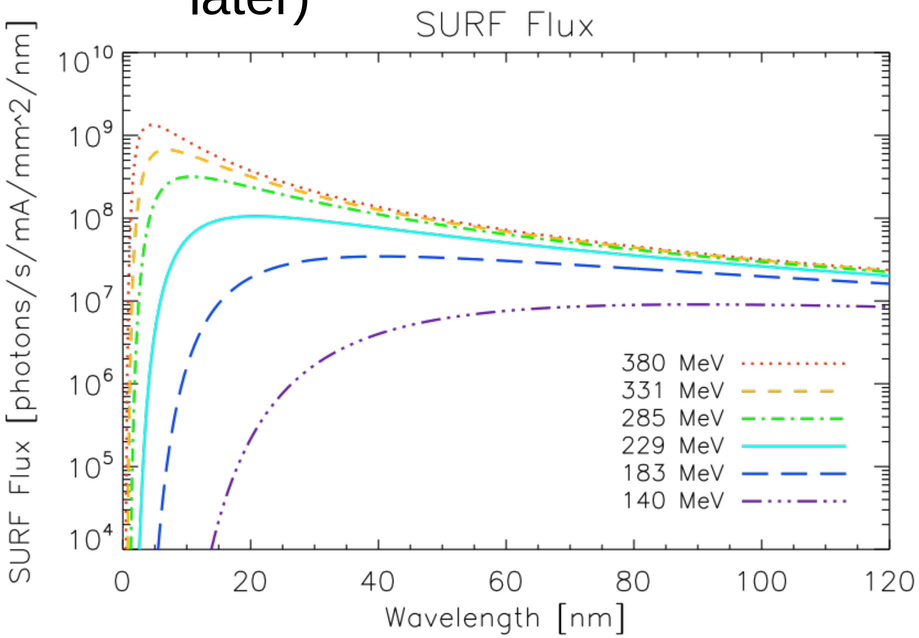
Reduces uncertainties by a factor of 4-5

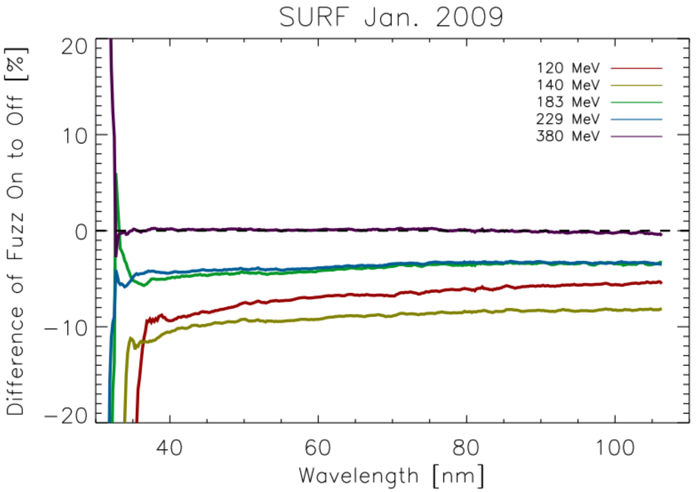
$$R_{SURF}(i,j,E_{beam},filter,\alpha,\beta)=\frac{\frac{1}{n}\sum_{k=1}^{n}\frac{C'_k(i,j,t,E_{beam},filter,\alpha,\beta)}{I_{SURF}(t)}}{F_{SURF}(i,j,E_{beam},\alpha,\beta)\cdot A_{slit}\cdot\Delta\lambda(i,j)}$$

$$\sigma^2_{R_{SURF}}=(R_{SURF})^2\cdot\left[\frac{\frac{1}{n^2}\sum_{k=1}^{n}\left(\frac{C'_k}{I_{SURF}}\right)^2\cdot\left[\frac{\sigma^2_{C'}}{(C'_k)^2}+\frac{\sigma^2_{I_{SURF}}}{(I_{SURF})^2}\right]}{\left(\frac{1}{n}\sum_{k=1}^{n}\frac{C'}{I_{SURF}}\right)^2}+\frac{\sigma^2_{F_{SURF}}}{(F_{SURF})^2}\right]$$

SURF Flux

- Inconsistencies
  - Fuzz on/off
  - Between difference beam energies in the OS data (discussed later)





Order Sorting Correction

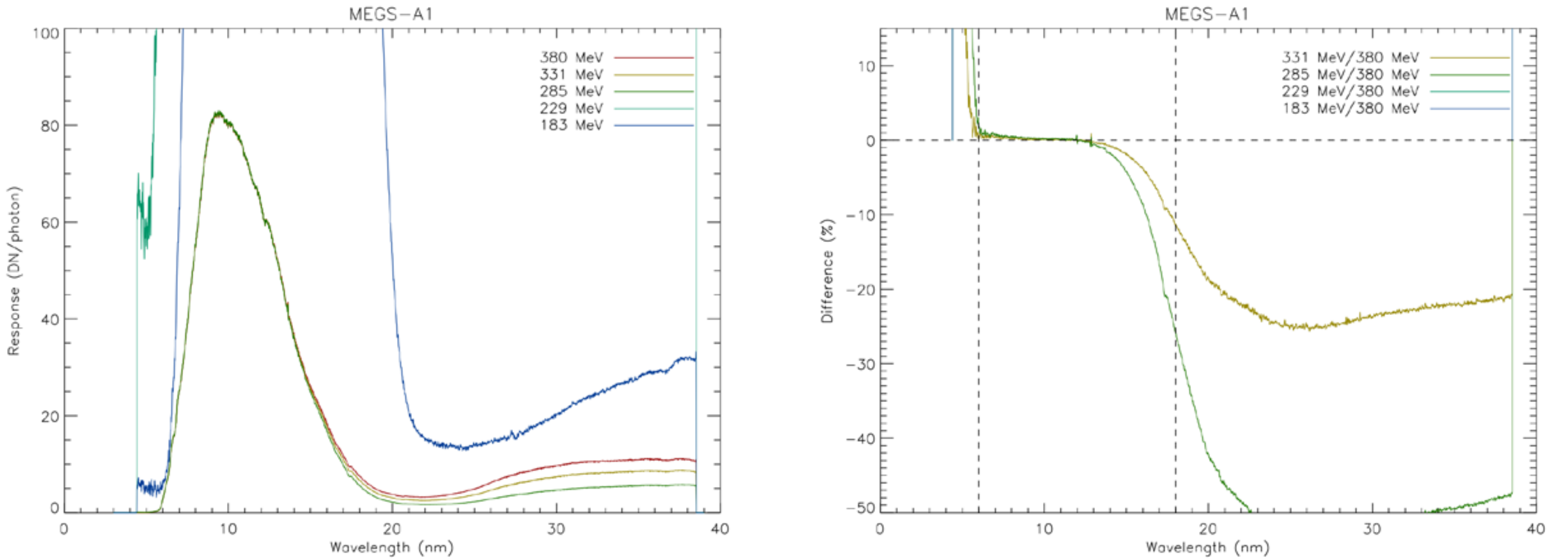
$$R_{SURF}(i,j,E_{beam},filter,\alpha,\beta)=\sum_{k=1}^{m}\frac{1}{k}\cdot\frac{F_{SURF}^{k}(i,j,E_{beam},\alpha,\beta)}{F_{SURF}^{k=1}(i,j,E_{beam},\alpha,\beta)}\cdot R_k(i,j,filter,\alpha,\beta)$$

$$F_{SURF}^{k}(\lambda)=F_{SURF}\left(\frac{\lambda}{k}\right)$$

$$f_{OS}(i,j,E_{beam},filter,\alpha,\beta)=\frac{R_1(i,j,filter,\alpha,\beta)}{R_{SURF}(i,j,E_{beam},filter,\alpha,\beta)}$$

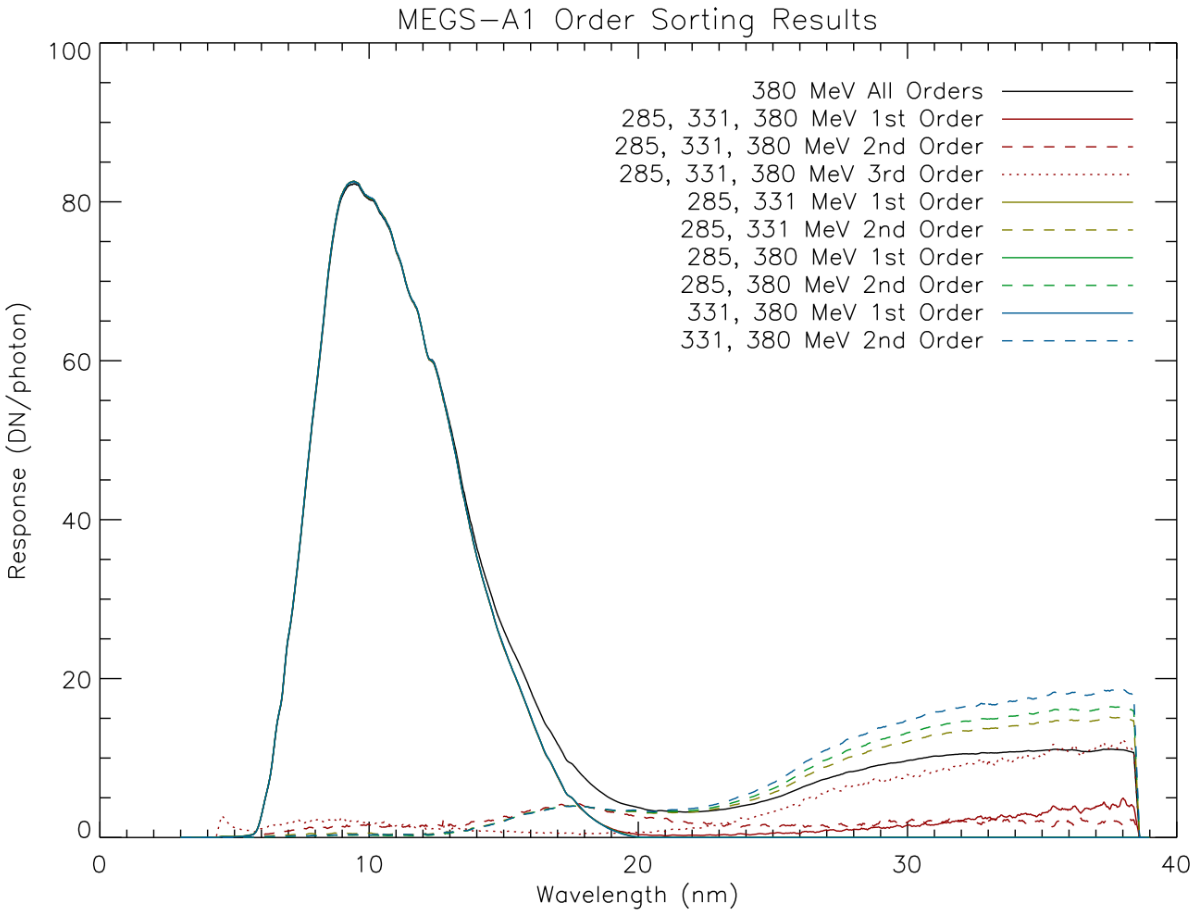
Inconsistencies in SURF Fluxes (1)

MEGS A1 from Jan. 2009

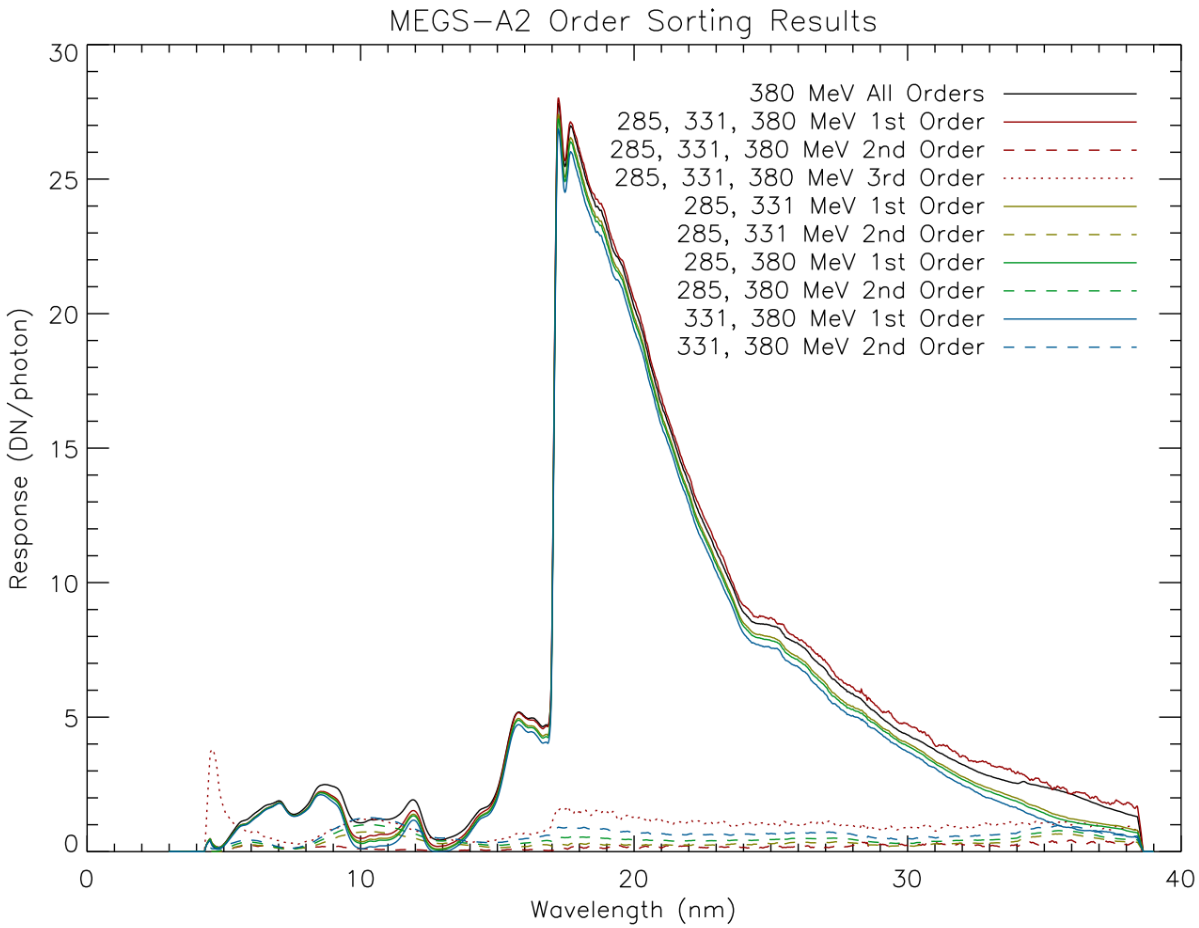


- For valid OS data, we expect no difference in R_{SURF} at short wavelengths.
- Here, compared to 380 MeV, 331 & 285 MeV are "good" energies.

OS Results: MEGS A1 (rocket)

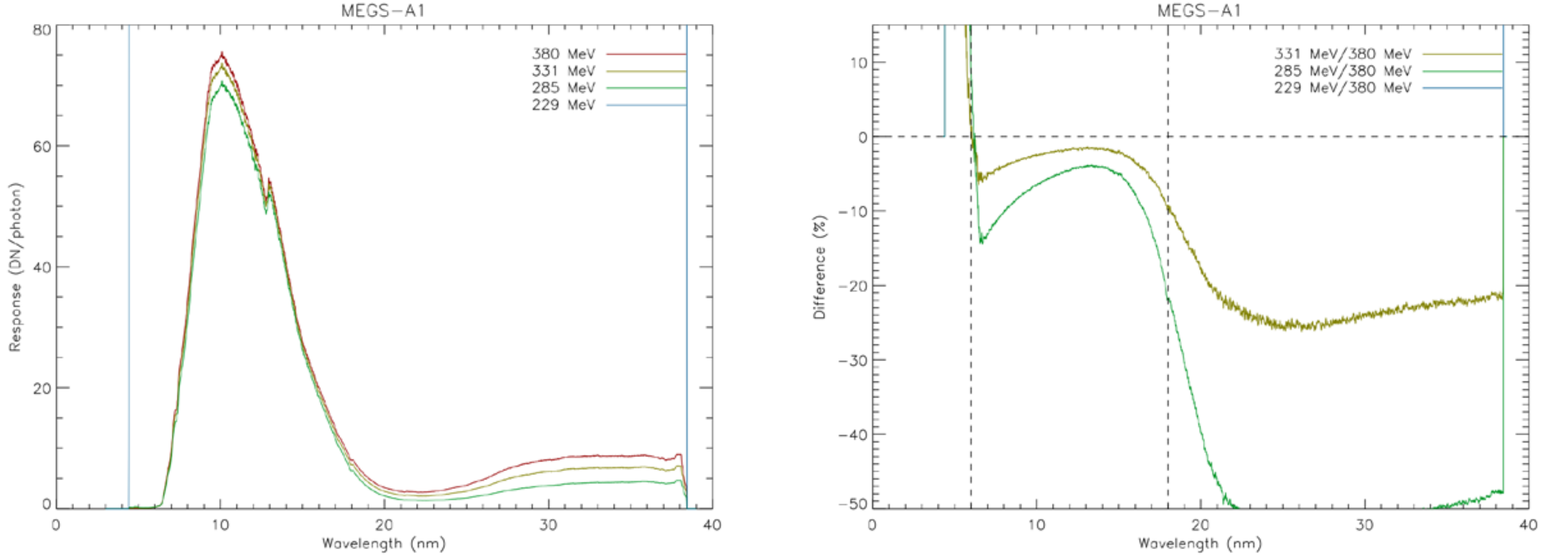


OS Results: MEGS A2 (rocket)



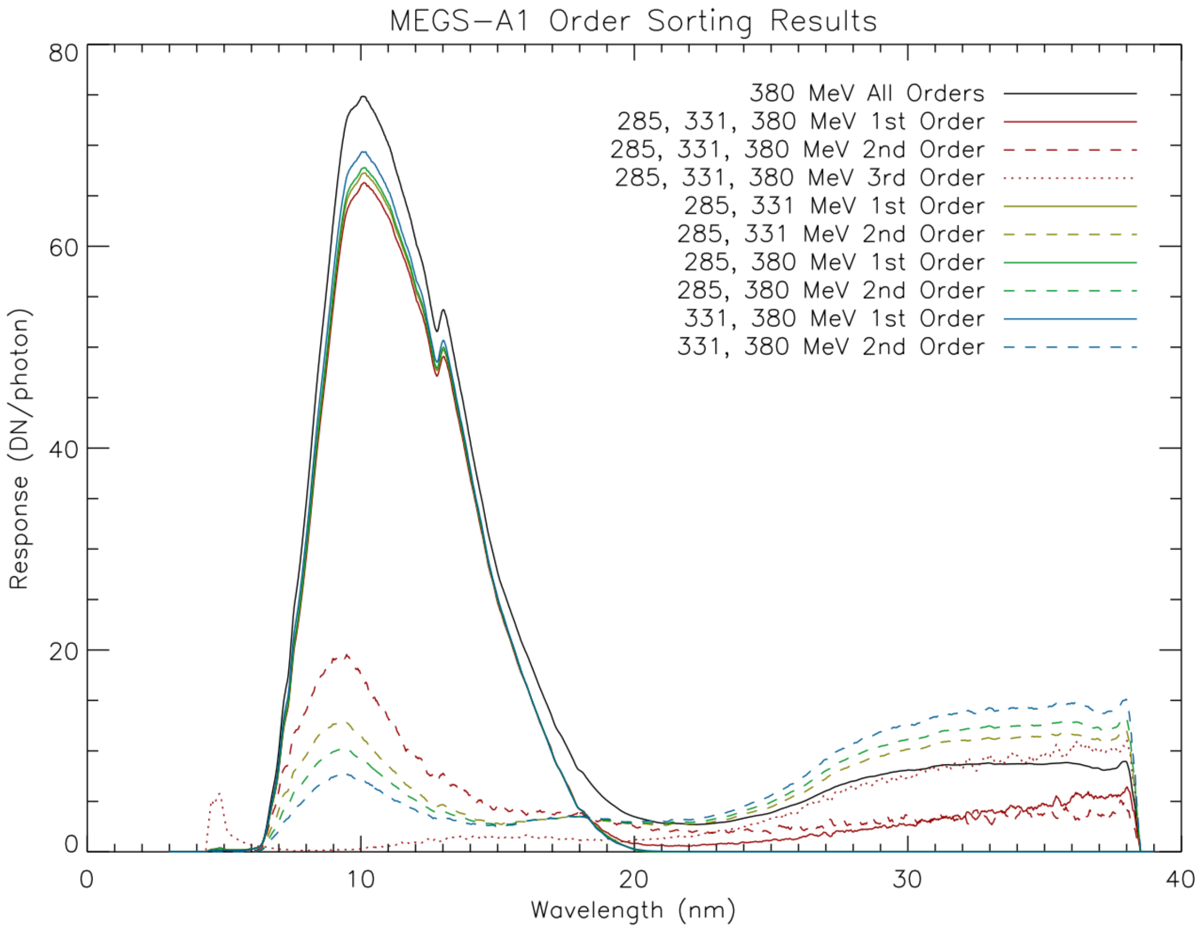
Inconsistencies in SURF Fluxes (2)

MEGS A1 from Aug. 2007



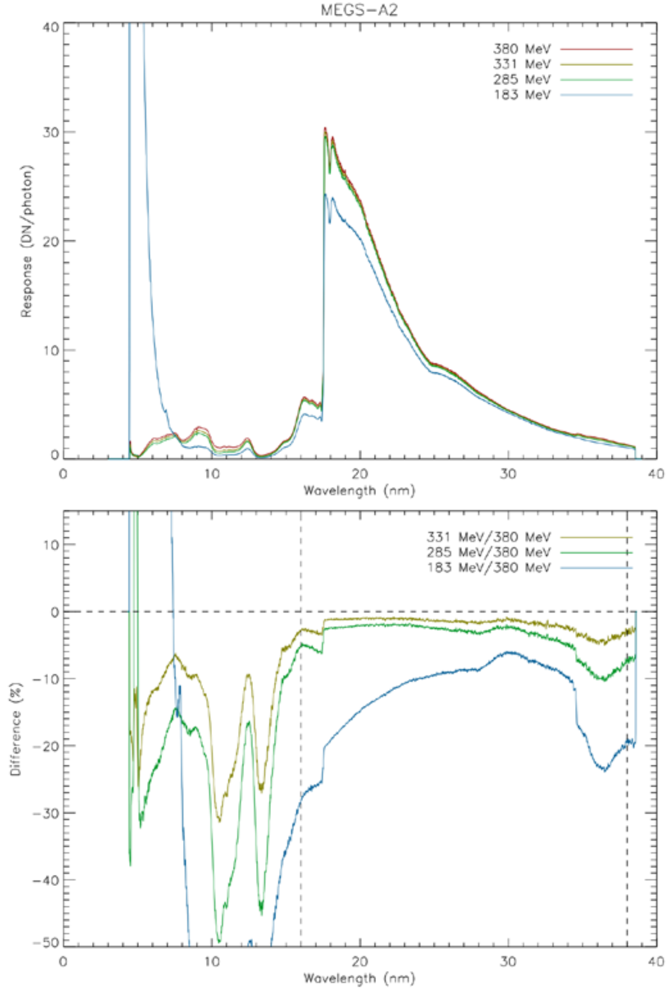
- For invalid OS data, there are significant differences in R_{SURF} at short wavelengths.
- Here, compared to 380 MeV, both 331 & 229 MeV are off by up to 15%

OS: MEGS A1 (flight)

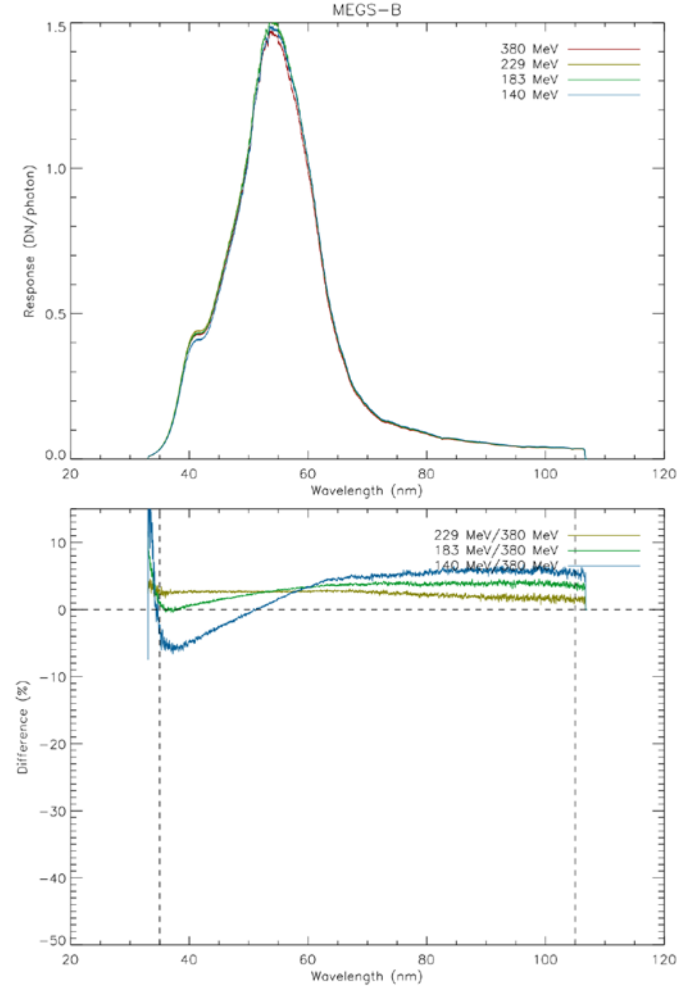


Inconsistencies in SURF Fluxes (3)

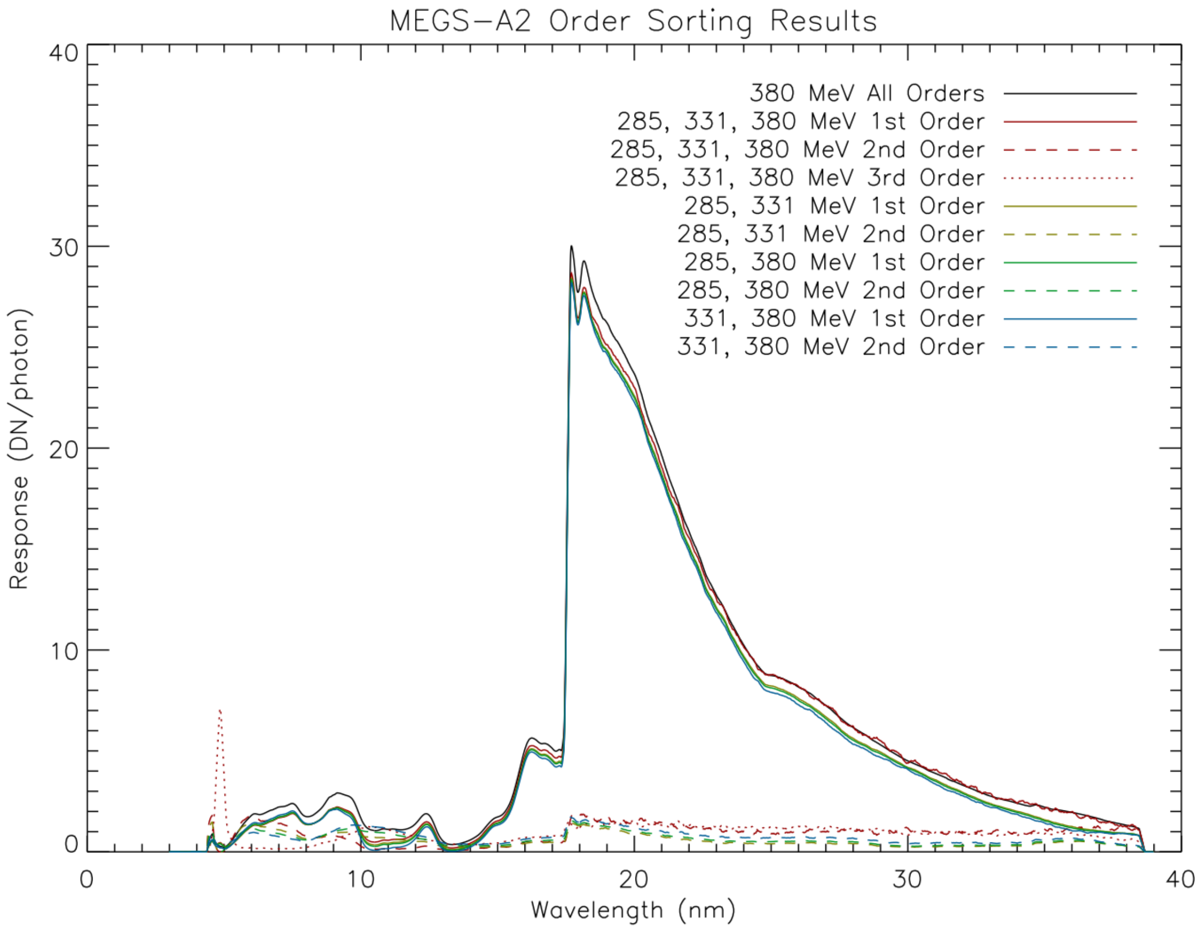
MEGS A2 from Aug. 2007



MEGS B from Aug. 2007

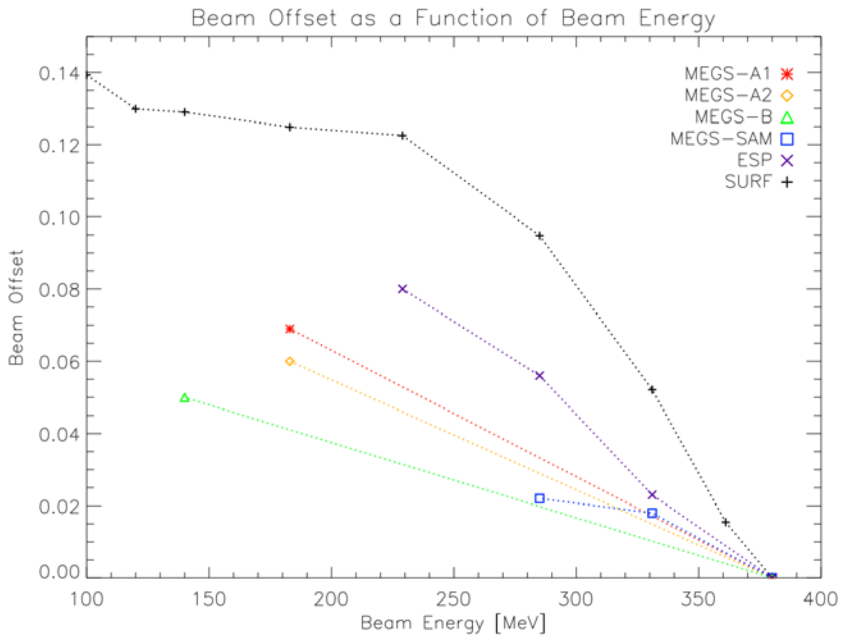


OS: MEGS A2 (flight)



Inconsistencies in SURF Fluxes (4)

- For the Jan. 2009 SURF trip, we performed y-scans to determine the beam center relative to 380 MeV.
- These new values change the SURF flux enough to affect the order sorting results.



Flight Responsivity

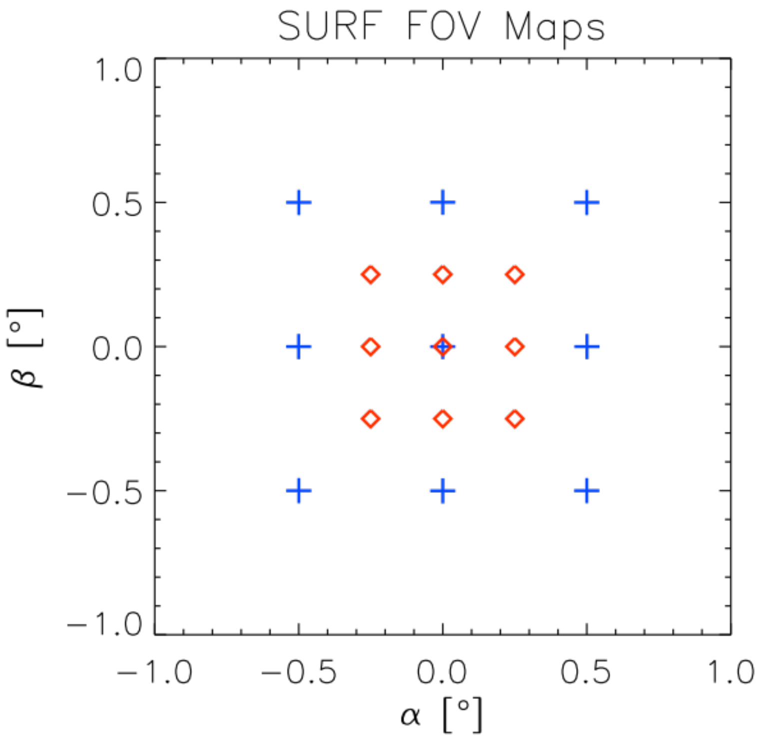
$$R_{flight}(i,j,filter) = \frac{\lambda(i,j)}{h \cdot c} \cdot A_{slit} \cdot \Delta\lambda(i,j) \cdot \left[\sum_{\alpha,\beta} w(\alpha,\beta) \cdot R_{SURF}(i,j,E_{beam},filter,\alpha,\beta) \cdot f_{OS}(i,j,E_{beam},filter,\alpha,\beta) \right]$$

Accounts for differences in size of SURF beam & Sun

Conversion to irradiance from photons

$$\sigma^2_{R_{flight}} = \left(R_{flight}\right)^2 \cdot \left[\frac{\sigma^2_\lambda}{(\lambda)^2} + \frac{\sum_{\alpha,\beta} \left(w \cdot R_{SURF} \cdot f_{OS}\right)^2 \cdot \left[\frac{\sigma^2_w}{(w)^2} + \frac{\sigma^2_{R_{SURF}}}{(R_{SURF})^2} + \frac{\sigma^2_{f_{OS}}}{(f_{OS})^2} \right]}{\left(\sum_{\alpha,\beta} w \cdot R_{all} \cdot f_{OS} \right)^2} \right]$$

Weighting of FOV Maps

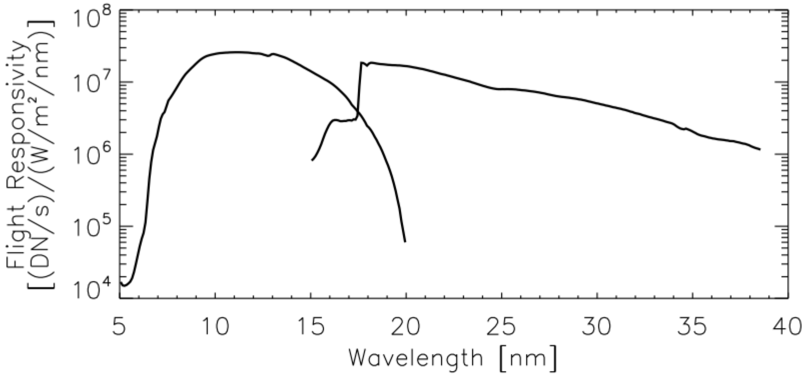


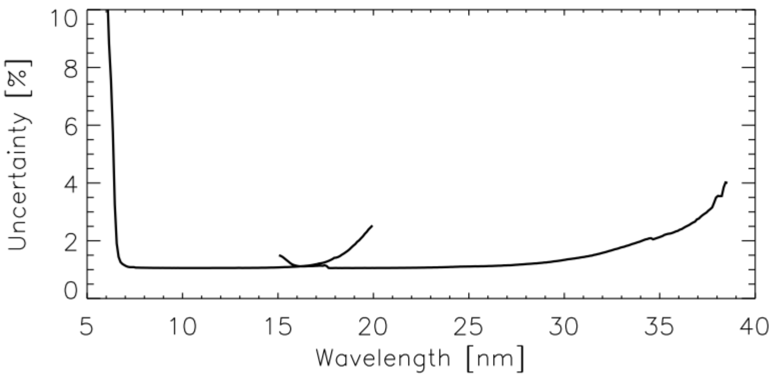
Weights for expected on-orbit pointing
(α_{MEGS}=0°,β_{MEGS}=0°)

		α [°]				
		-1.0	-0.5	0.0	+0.5	+1.0
β[°]	+1.0	0.0000		0.0000		0.0000
	+0.5		0.0249	0.1455	0.0249	
	0.0	0.0000	0.1455	0.3180	0.1455	0.0000
	-0.5		0.0249	0.1455	0.0249	
	-1.0	0.0000		0.0000		0.0000

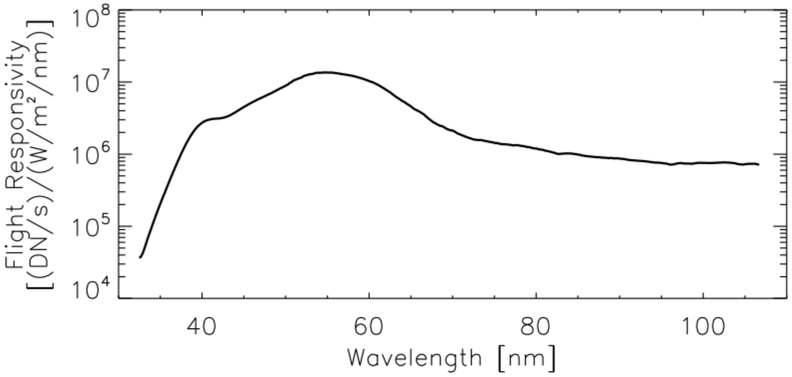
R_{flight} for Expected On-orbit Pointing

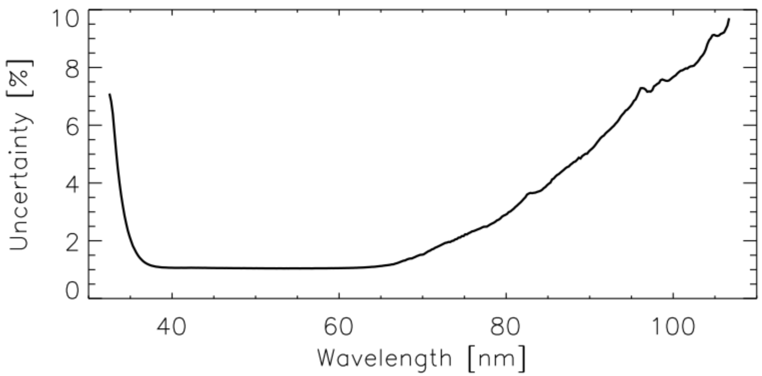
Flight MEGS A





Flight MEGS B

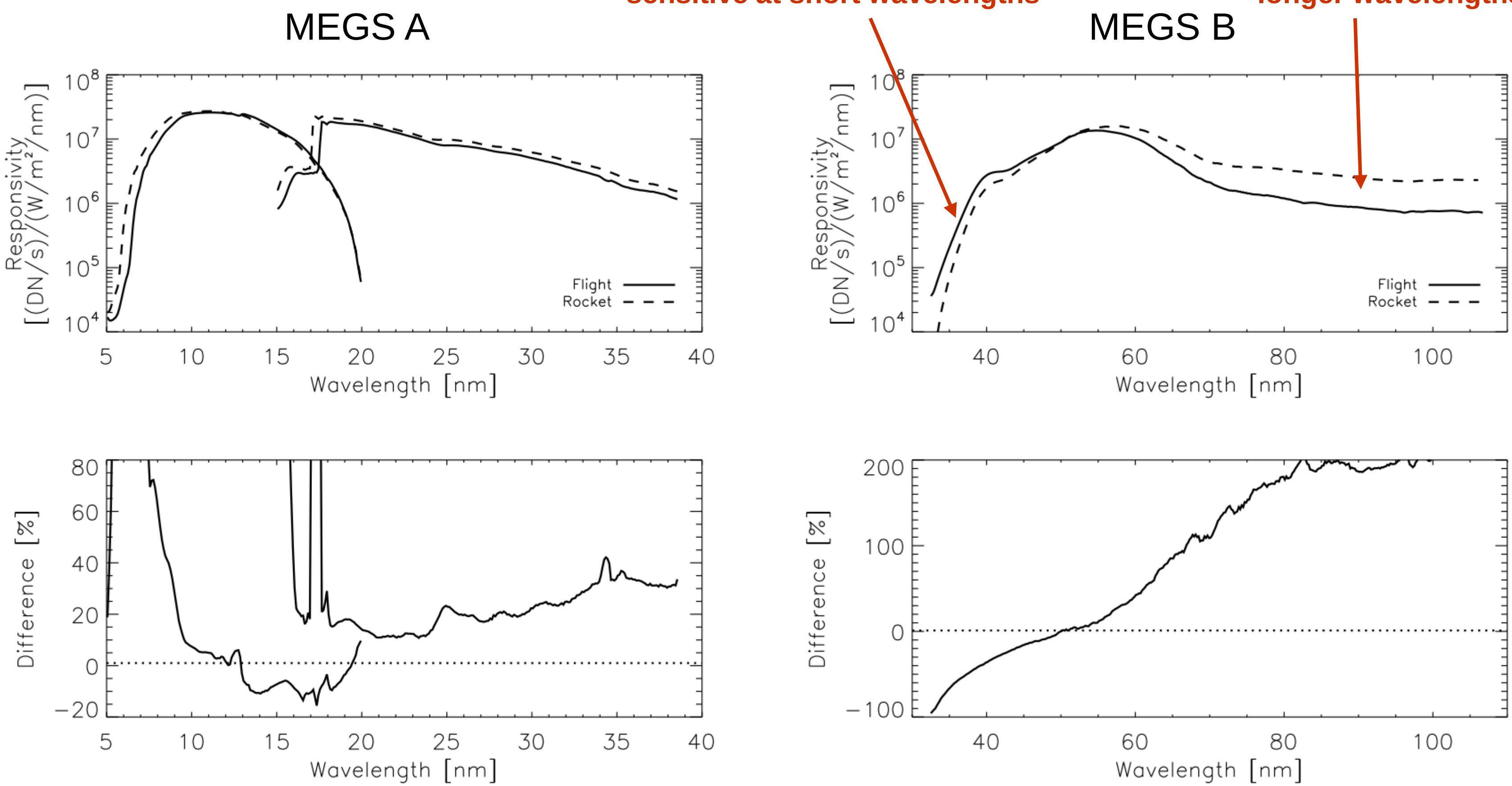




Comparison to Rocket

Expect flight MEGS B to be more sensitive at short wavelengths

… but less sensitive at longer wavelengths



Wavelength shift

Difference in CCDs

Solar Irradiance

$$I(i,j,t) = \frac{C'(i,j,t,filter)}{R_{flight}(i,j,filter)} \cdot f_{degrad}(i,j,t,filter) \cdot f_{1AU}(t)$$

Now calculated using solar data

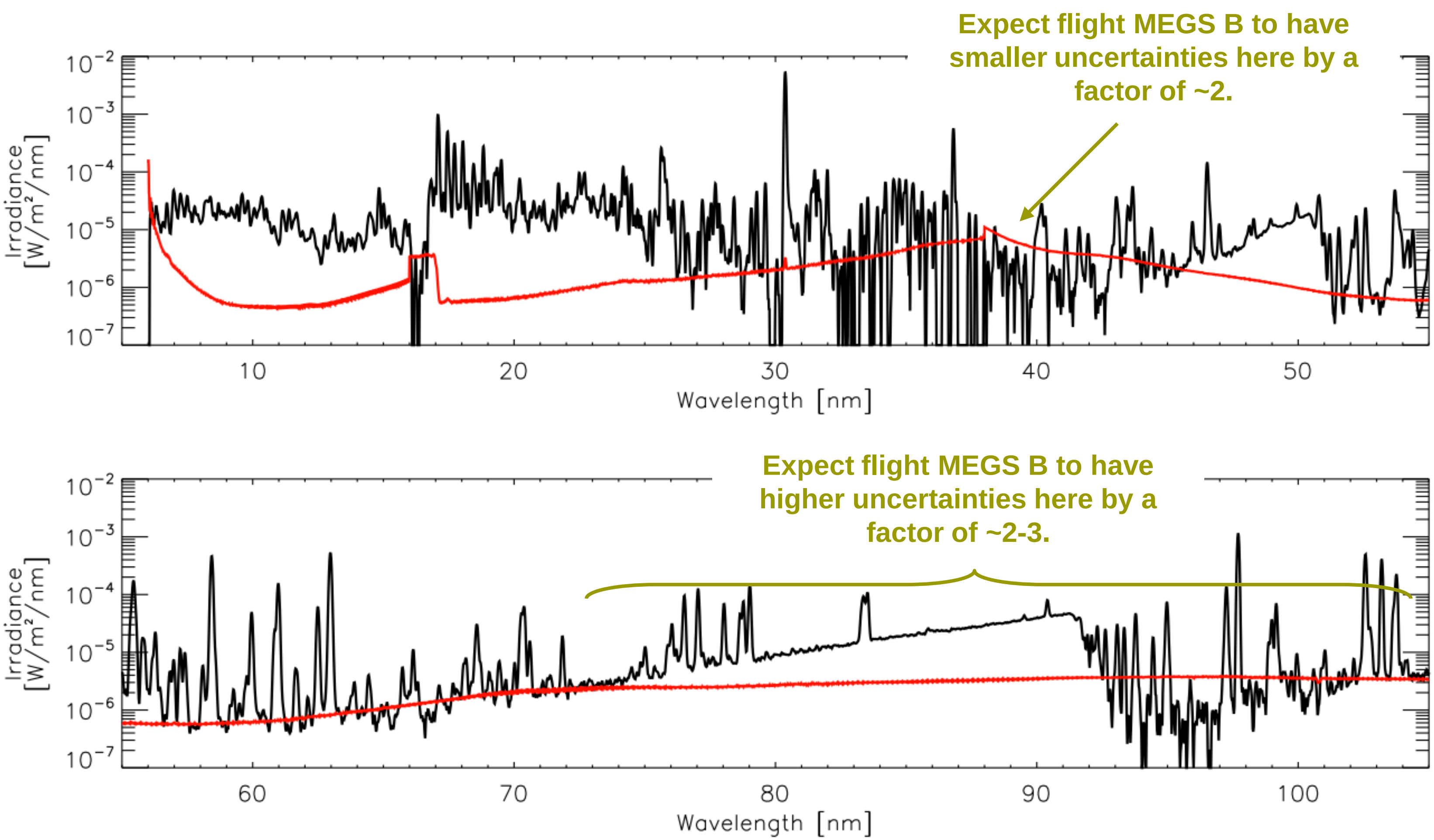
What is in data processing

$$S(i,j,filter) = \frac{1}{R_{flight}(i,j,filter)}$$

$$I(i,j,t) = C'(i,j,t,filter) \cdot S(i,j,filter) \cdot f_{degrad}(i,j,t,filter) \cdot f_{1AU}(t)$$

$$\sigma_I^2 = (I)^2 \cdot \left[\frac{\sigma_{C'}^2}{(C')^2} + \frac{\sigma_{R_{flight}}^2}{(R_{flight})^2} + \frac{\sigma_{f_{degrad}}^2}{(f_{degrad})^2} + \frac{\sigma_{f_{1AU}}^2}{(f_{1AU})^2} \right]$$

April 2008 Solar Spectrum



Future SURF Calibrations

- Continue taking at least 4 minutes of data per FOV point to reduce uncertainties.
- Continue taking temperature gain measurements.
- Need to be careful of what SURF fluxes we use:
  - Avoid fuzz. We are able to make good MEGS B measurements at 183 MeV, which does not need 1 mm fuzz.
  - MEGS A OS: need only 380, 331, & 285 MeV. These have been shown to be more reliable than lower energies and are sufficient to calculate f_{OS}.
  - MEGS B: using a higher beam energy (183 MeV or even 380 MeV). It improves counts at the short wavelengths where we currently have trouble. Plus, we can avoid using fuzz.
  - Performing y-scans at multiple energies may improve OS results for MEGS A and explain the discrepancies for MEGS B.