CERES Edition 3 beta Calibration Theory and Results

CERES Instrument Working Group
GERB/CERES Science Team Meeting,
UKMO, Exeter UK, 25/10/06

Contributors: Norman Loeb, Costy Loukachine, Bruce Wielicki

- A new climate ERB calibration stability goal and Rev1 Adjustment Results for Terra and Aqua
- Stability metric of DCC albedo to replace MAM data and darkening model required to meet needs of climate community
- Contamination model spectral response and gain estimates for Terra and Aqua generated for Edition 3 beta test run
- Edition 3 Beta SW validation results
- Proposal to balance all channels on same EOS platform
- Application of contamination model to 3 channel/Total SW response calibration
- Suggest significant increase to all CERES daytime LW and comparisons with CRS trends
- Request for commentary

Ohring et al (2005) suggests that ERB measurement stability needs to reach 0.3% per decade

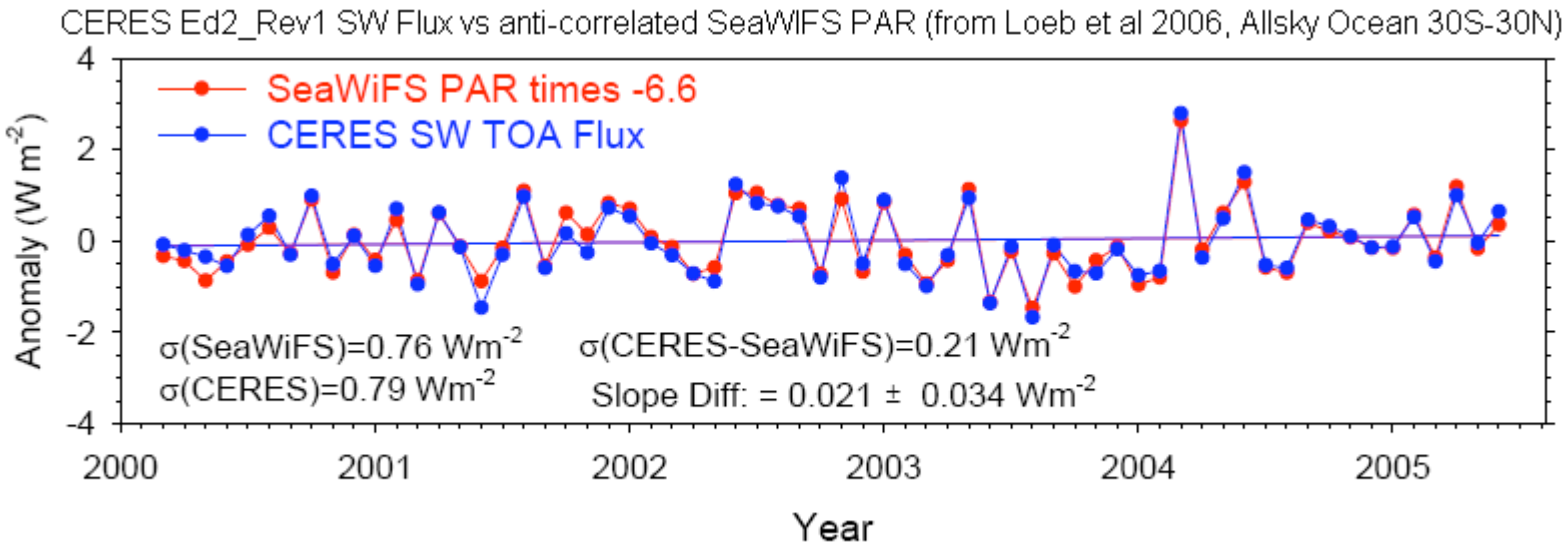
MEETING SUMMARIES

Satellite Instrument Calibration for Measuring Global Climate Change

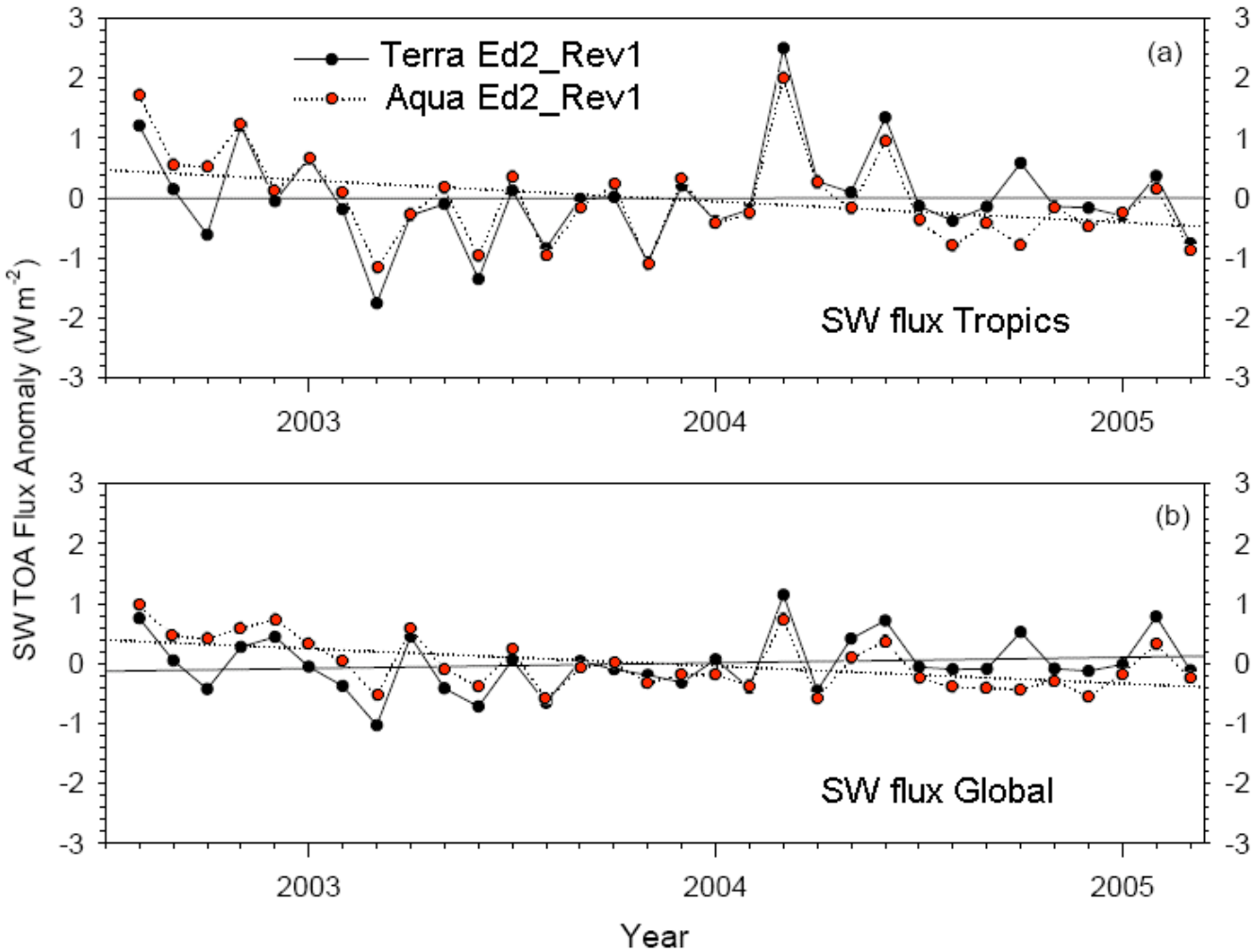
Report of a Workshop

This is near to an order of magnitude greater than CERES instrument design specification stability (note: not data products)

The resulting comparison with anti-correlated SeaWiFS PAR shows that the Rev1 adjustment to CERES Terra SW data yields stability comparable to that of SeaWiFS:



However, even after the Rev1 adjustment the Aqua SW flux anomaly continues to drop relative to Terra:



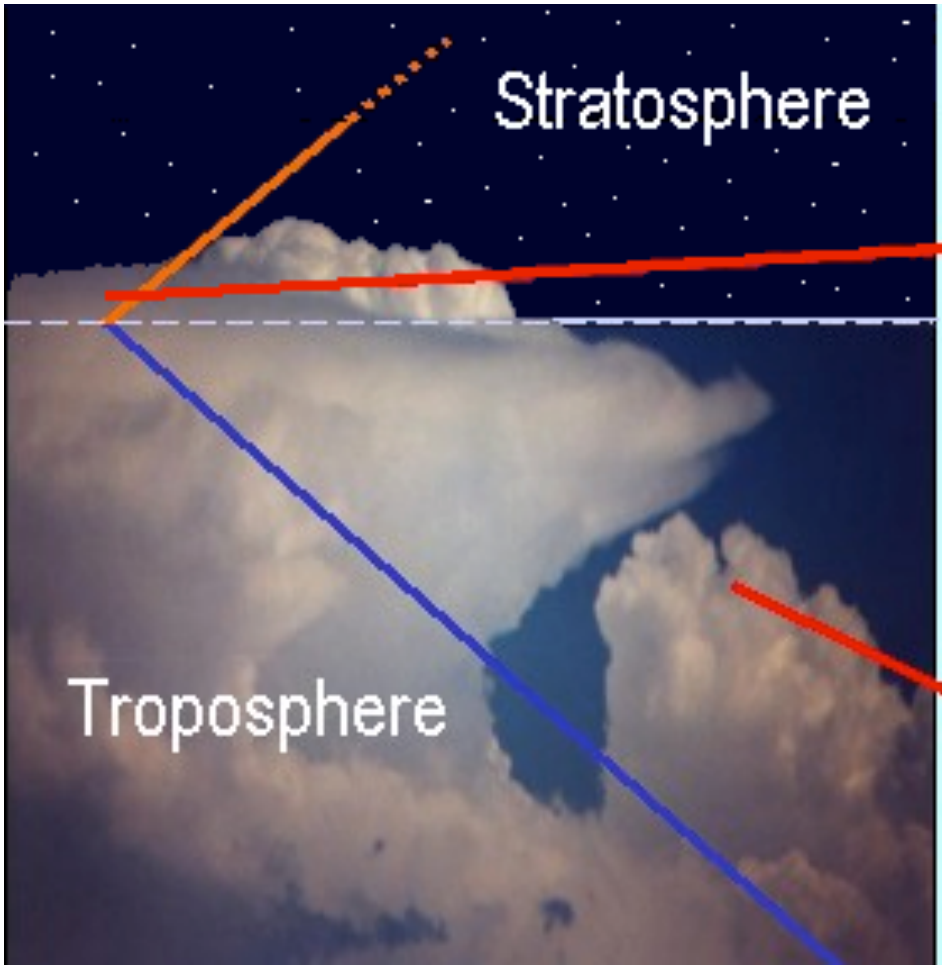
SW Ed3 beta calibration: Model Derived Gains and Spectral reaponse

This shows deficiencies in the Aqua Rev1 adjustment, perhaps due to significant cross-track instrument darkening or on-board lamp drift. Hence for Edition 3, a new calibration methodology is needed:

- **Deep Convective Cloud albedo:** Find the albedo of the coldest, brightest and most uniform clouds in the tropics. These become your 'solar diffuser' stability metric.

- **Constrain contamination model using direct compare:** Contamination/UV exposure model is adjusted to best match the direct compare of nadir footprints between two instruments on the same platform. Use of clear ocean and allsky scenes allows the model to determine coloration of spectral response changes.

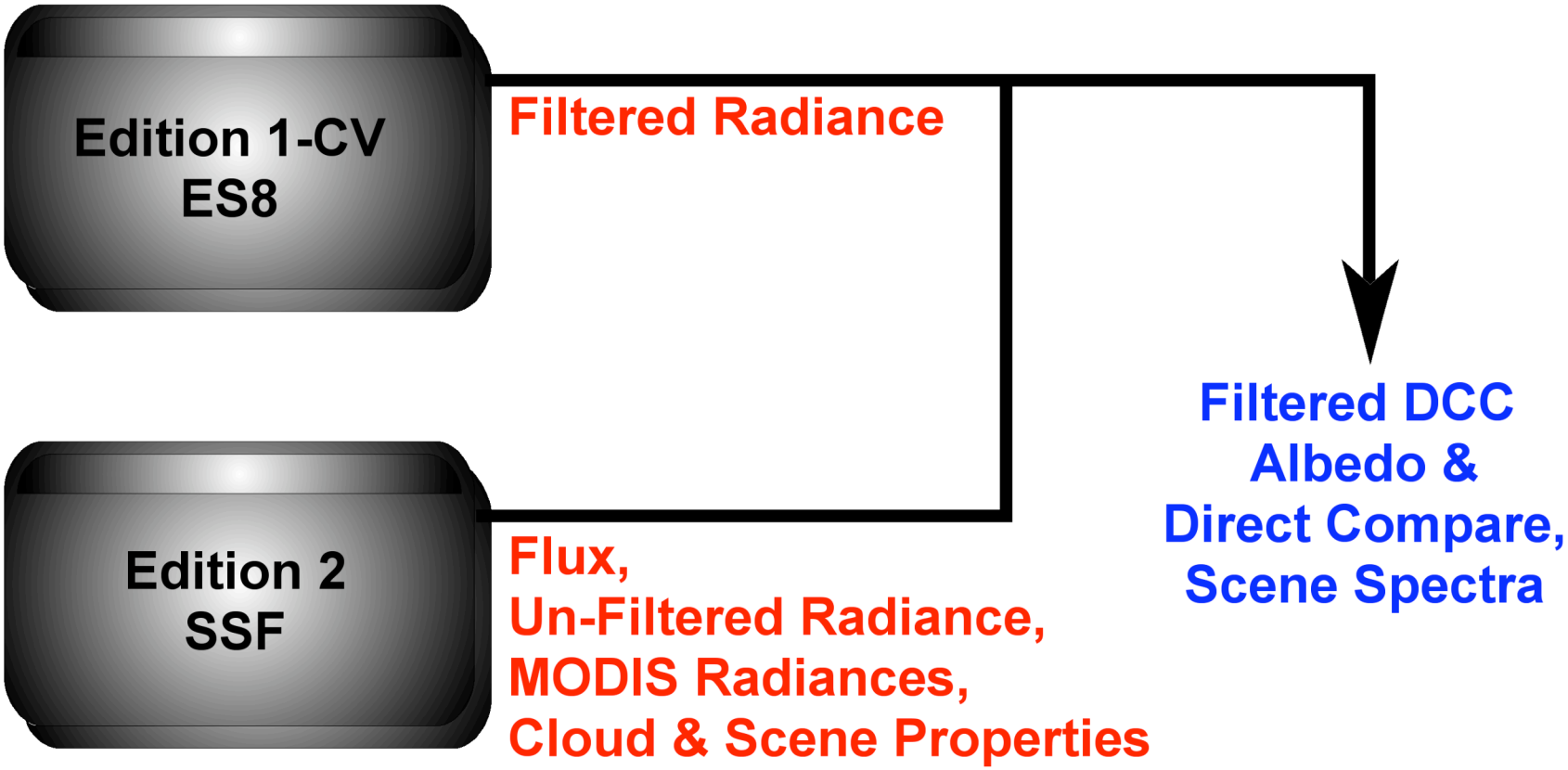
Use MODIS to find Ed1-CV filtered SW footprints of thickest, coldest and most uniform tropical ocean DCC



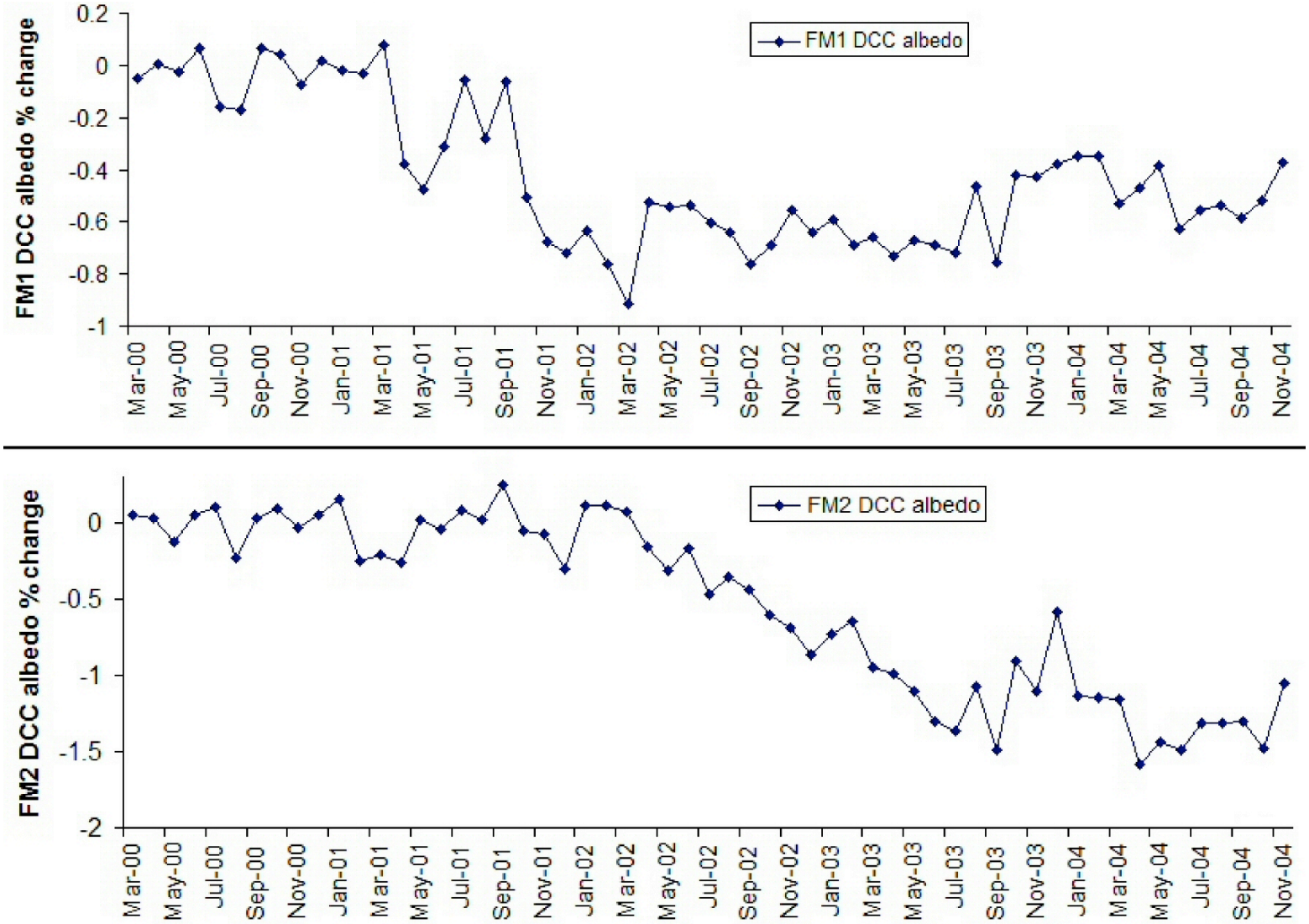
Temp < 205K
Tau > 120
0.6um rad stdev <3%
phase = 2 (ice)
cloud % = 100

latt= +/- 30
IGBP =17 (ocean)

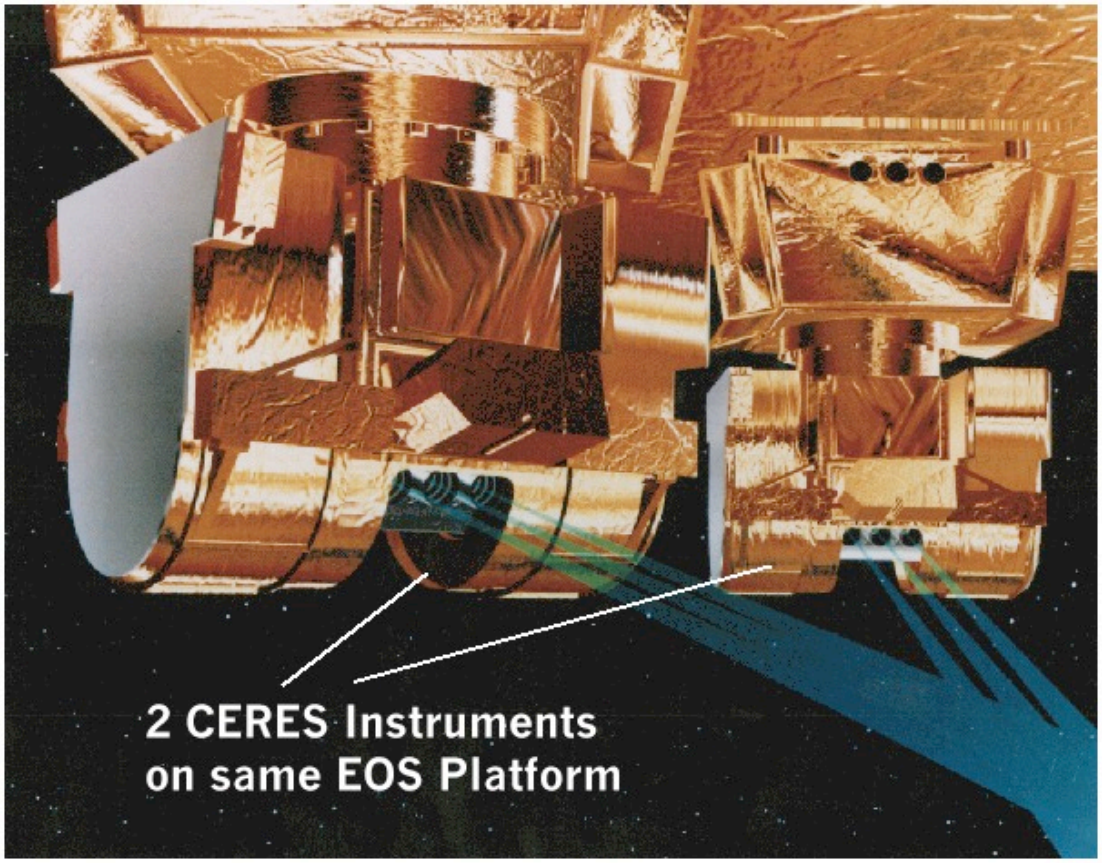
In order to use filtered radiance as a diagnostic, a run of CERES ES8 data was generated with fixed calibration and production code (Edition 1-CV). Filtered radiance footprints are then matched with SSF information on ADMs, scene type & MODIS radiances.



Edition1-CV DCC albedo change (no cal adjustments)

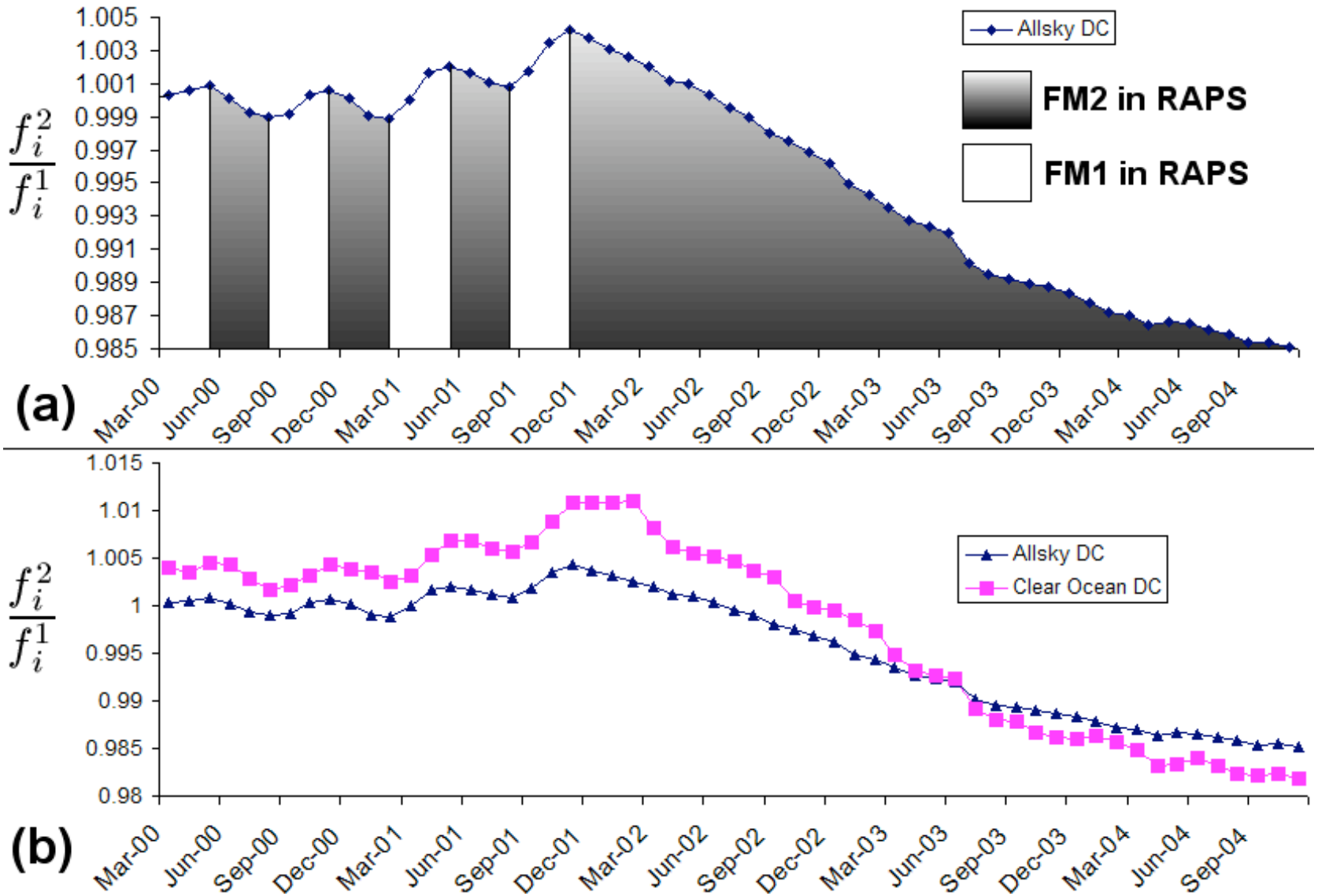


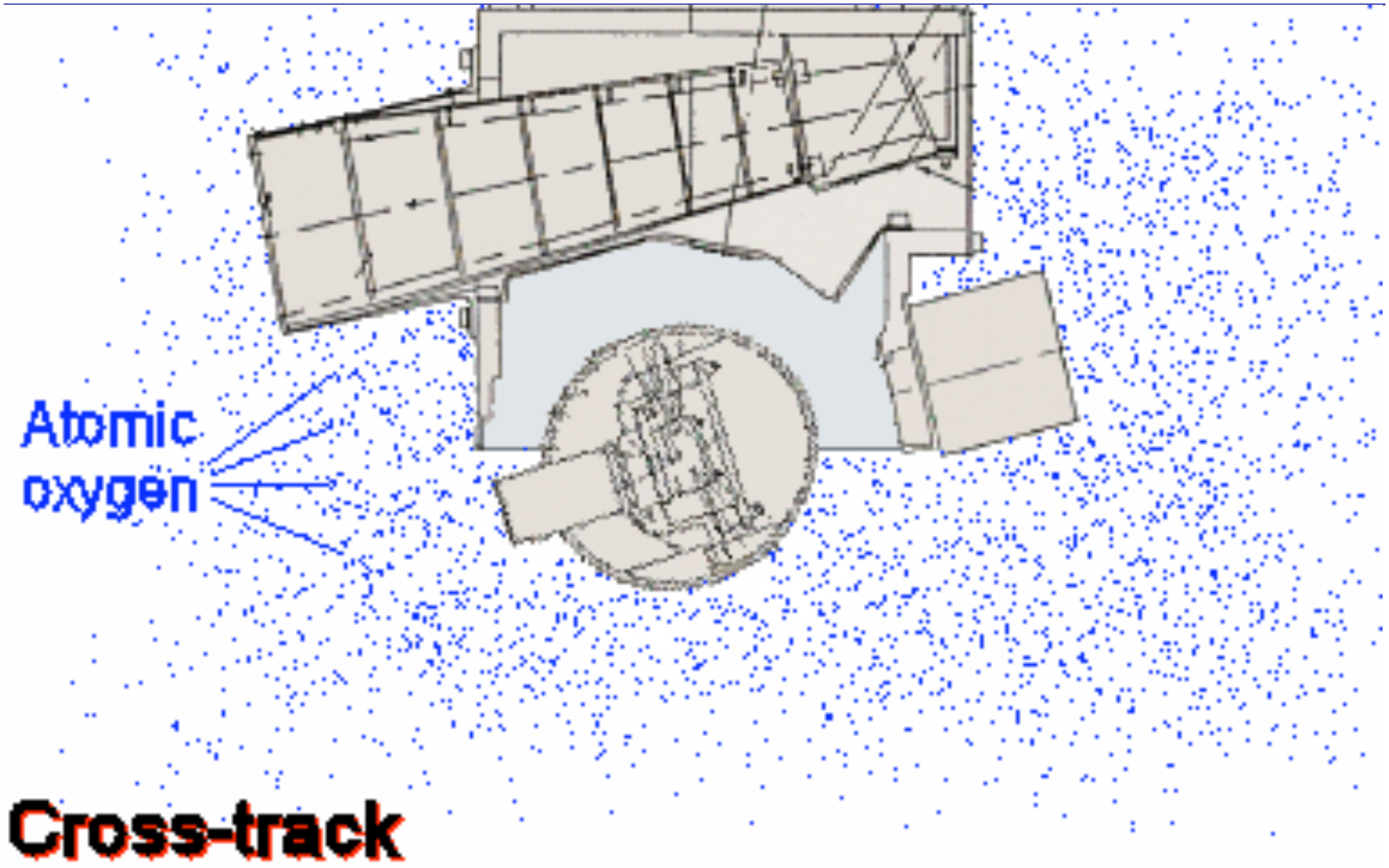
1 RAPS, 1 Xtrack instrument at anytime. Direct Compare (DC) is the ratio of simultaneous nadir filtered radiance

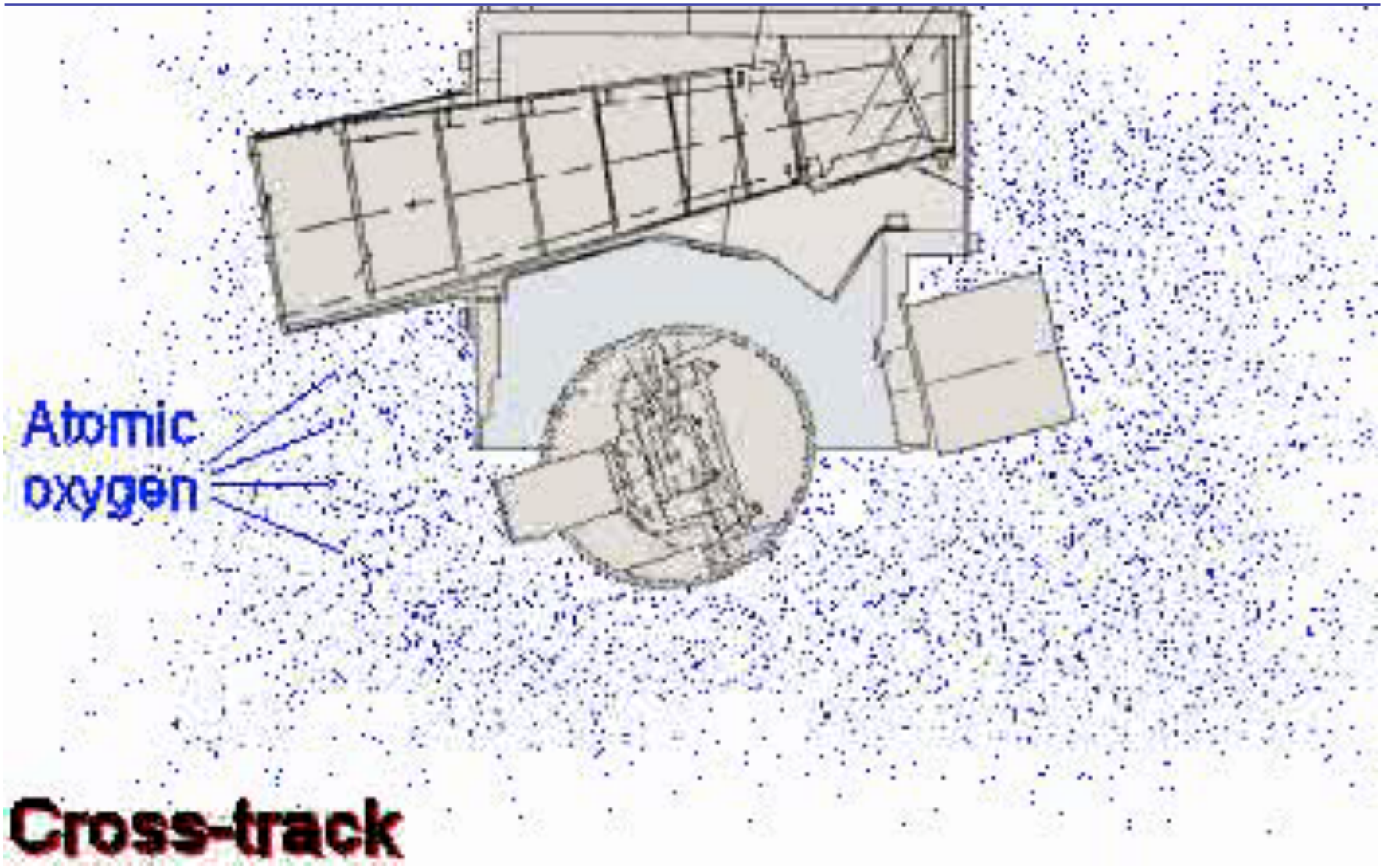


$$
\begin{aligned}
DC_i &= \frac{LF_i^2}{LF_i^1} \\
&= \frac{L_i \times f_i^2}{L_i \times f_i^1} \\
&= \frac{f_i^2}{f_i^1}
\end{aligned}
$$

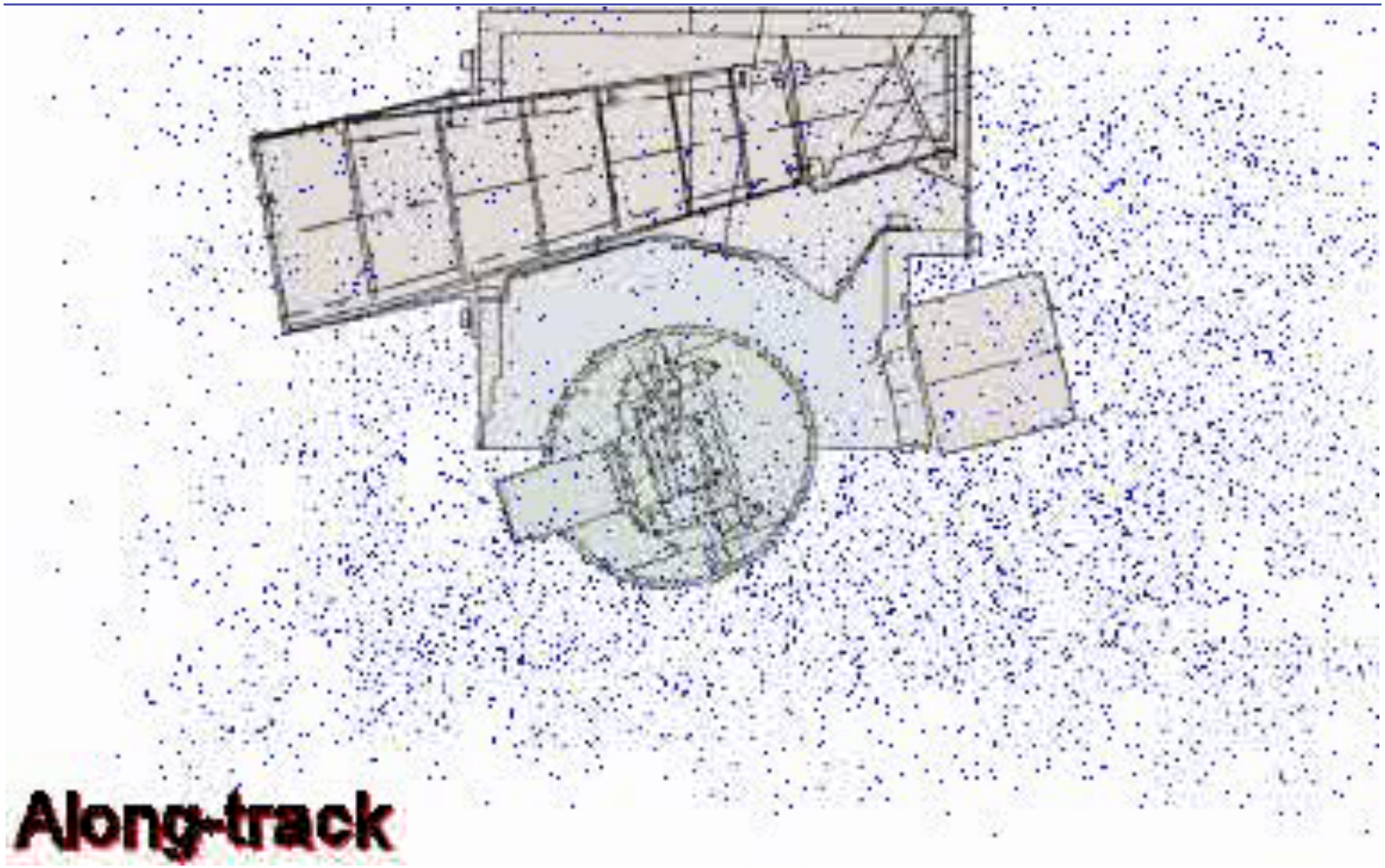
Instrument diagnostic that is <u>INDEPENDENT OF CLIMATE</u>

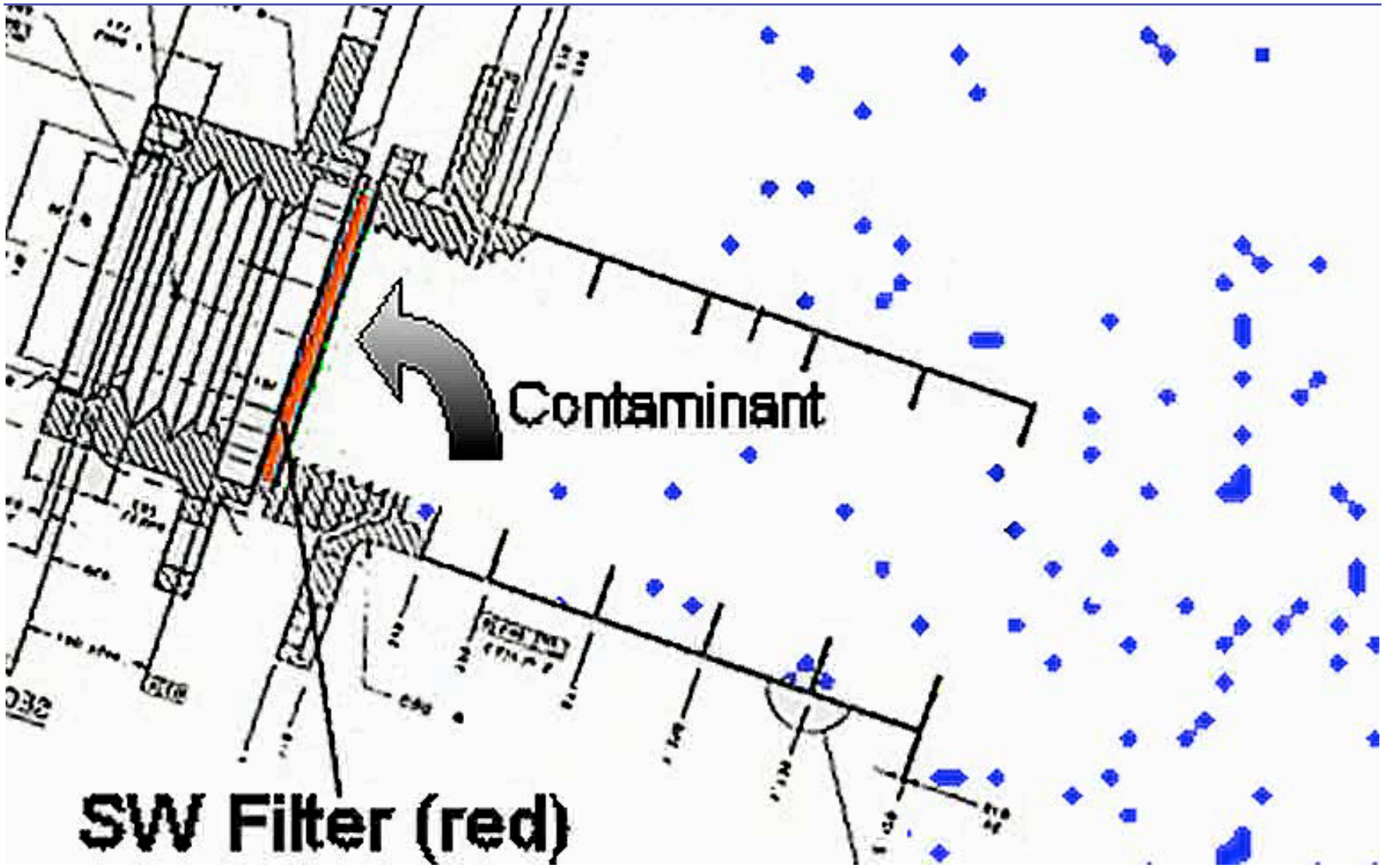

1.005
1.003
1.001
0.999
0.997
0.995
0.993
0.991
0.989
0.987
0.985
$\frac{f_i^2}{f_i^1}$
Allsky DC
FM2 in RAPS
FM1 in RAPS
(a)
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
$\frac{f_i^2}{f_i^1}$
Allsky DC
Clear Ocean DC
(b)
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04


Atomic
oxygen
Cross-track

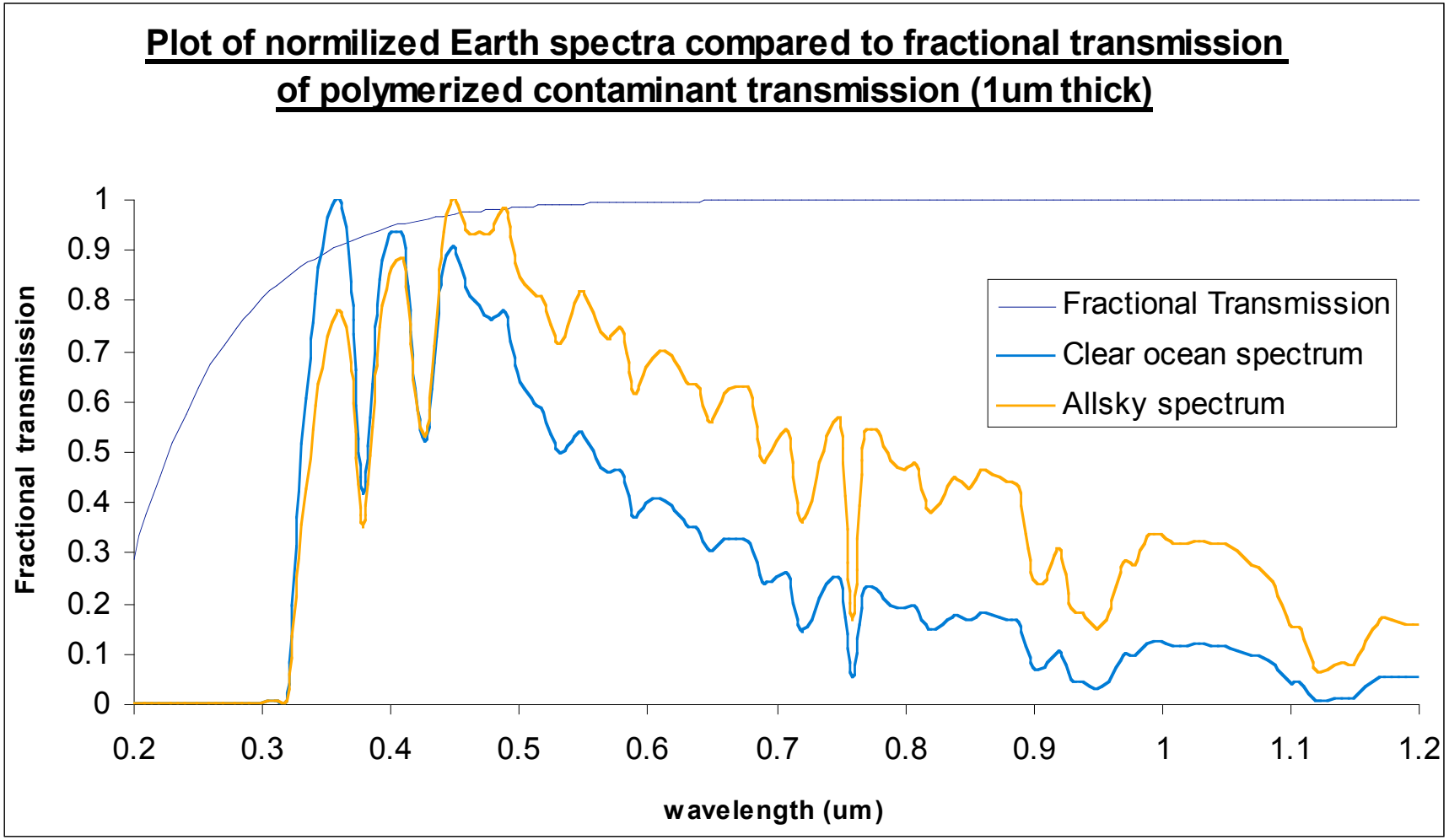

Atomic
oxygen
Cross-track

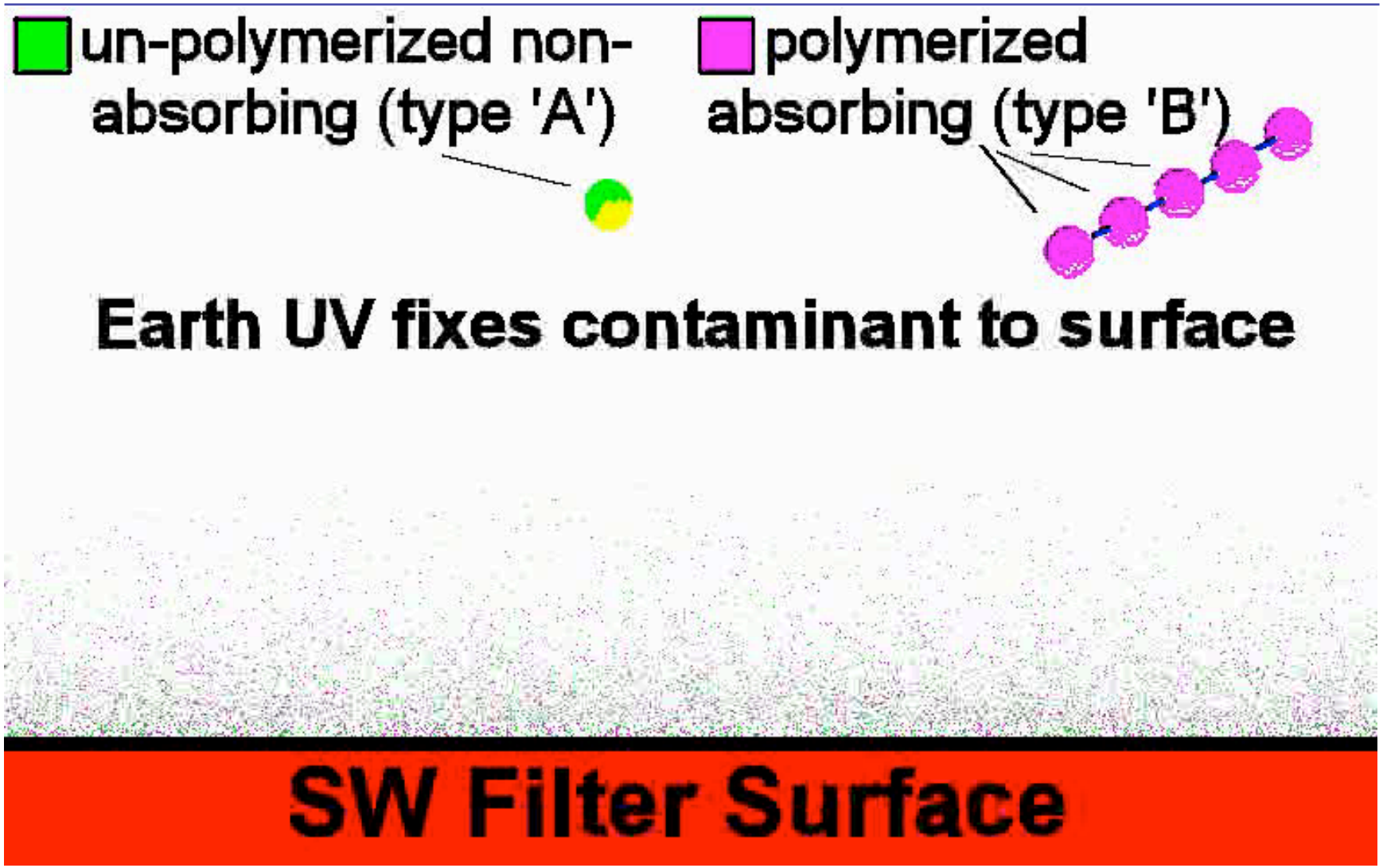
RAPs

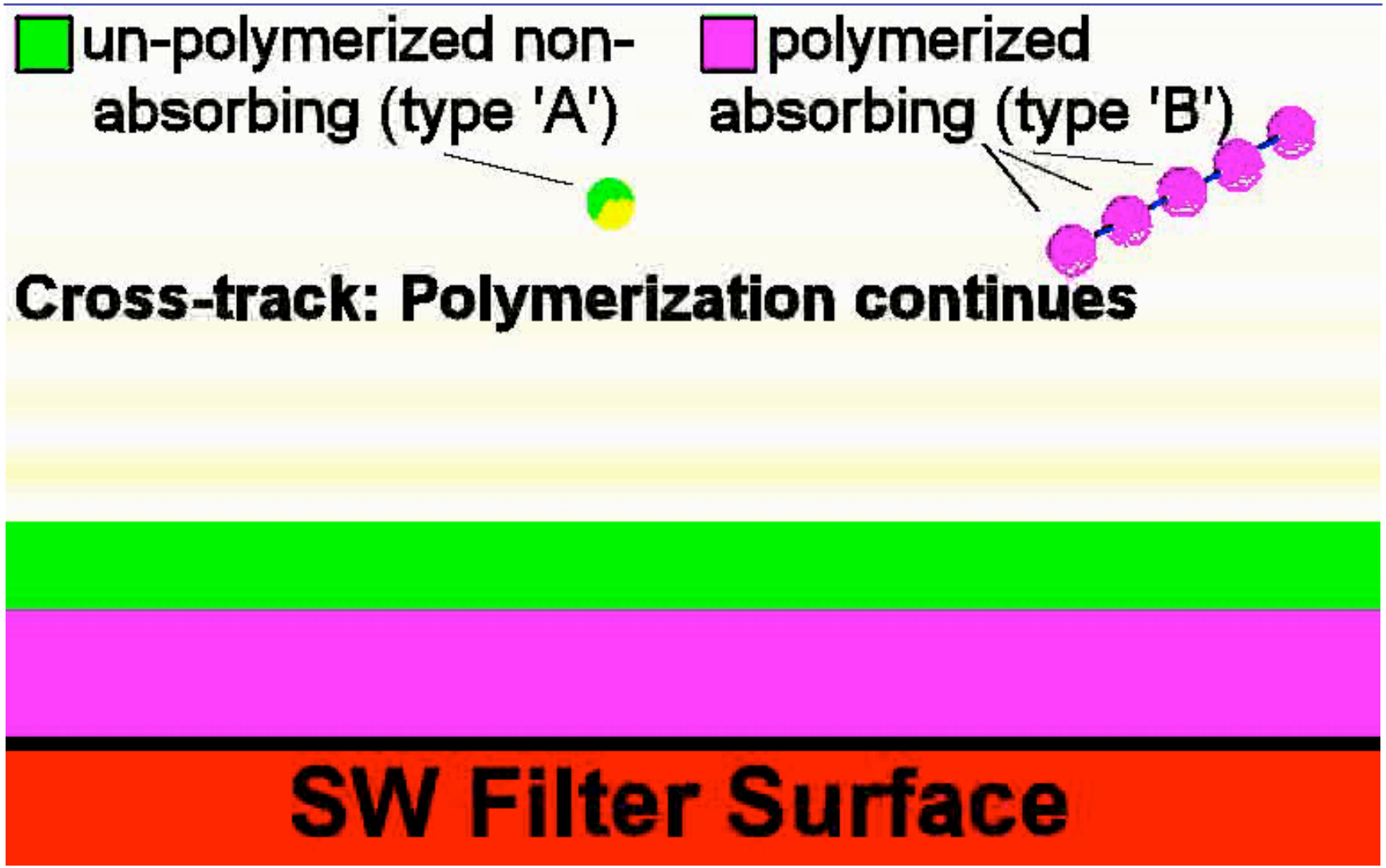

Along-track


Contaminant
SW Filter (red)

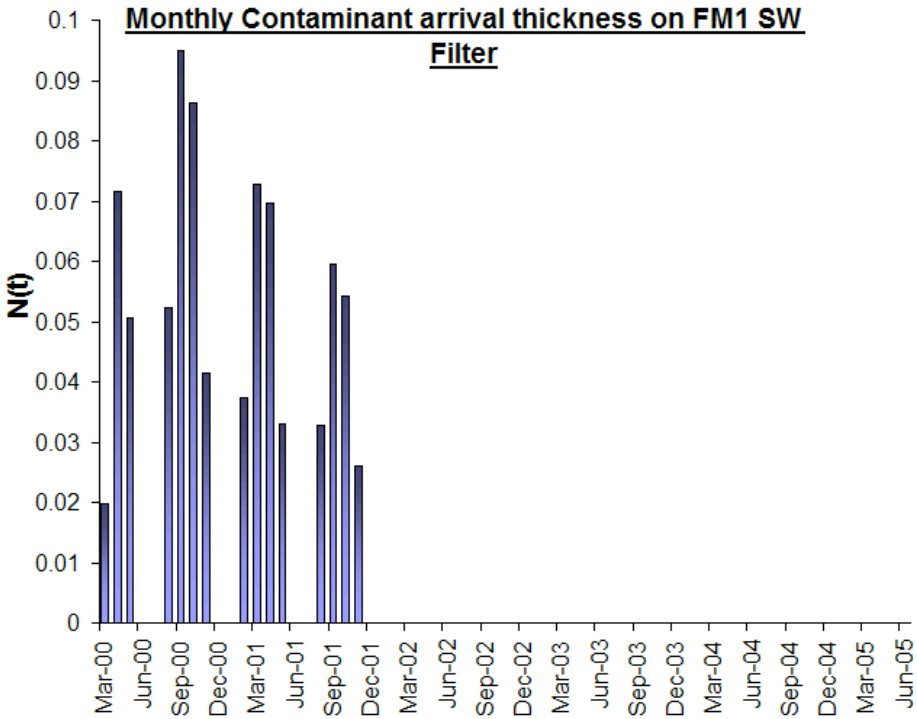
$$D(\lambda) = [1 - M.e^{-\alpha\lambda}]$$

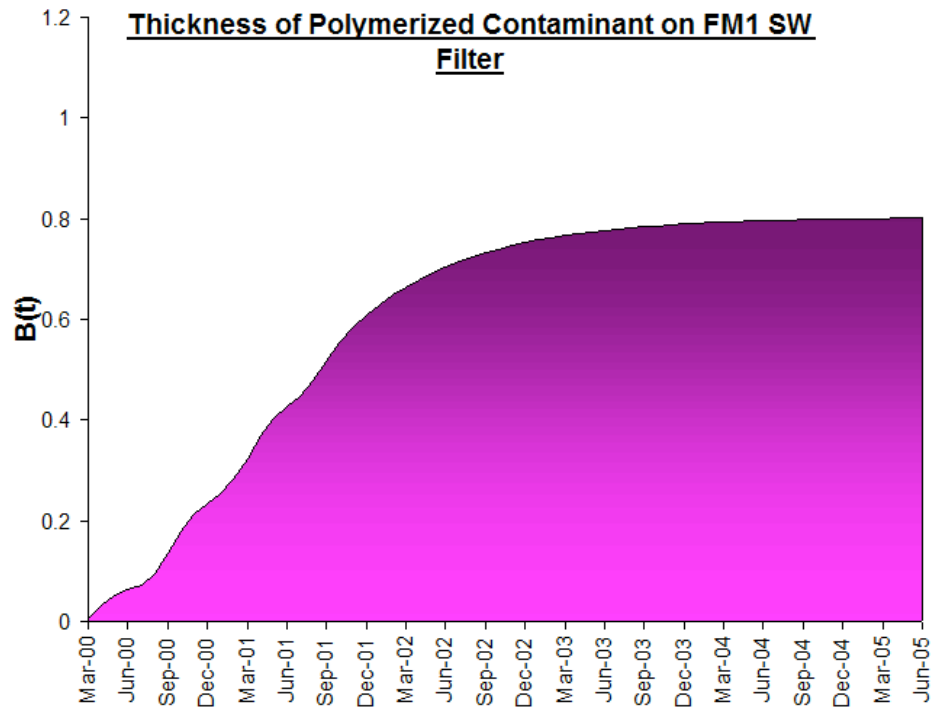



un-polymerized non-absorbing (type 'A')
polymerized absorbing (type 'B')
Earth UV fixes contaminant to surface
SW Filter Surface


un-polymerized non-absorbing (type 'A')
polymerized absorbing (type 'B')
Cross-track: Polymerization continues
SW Filter Surface

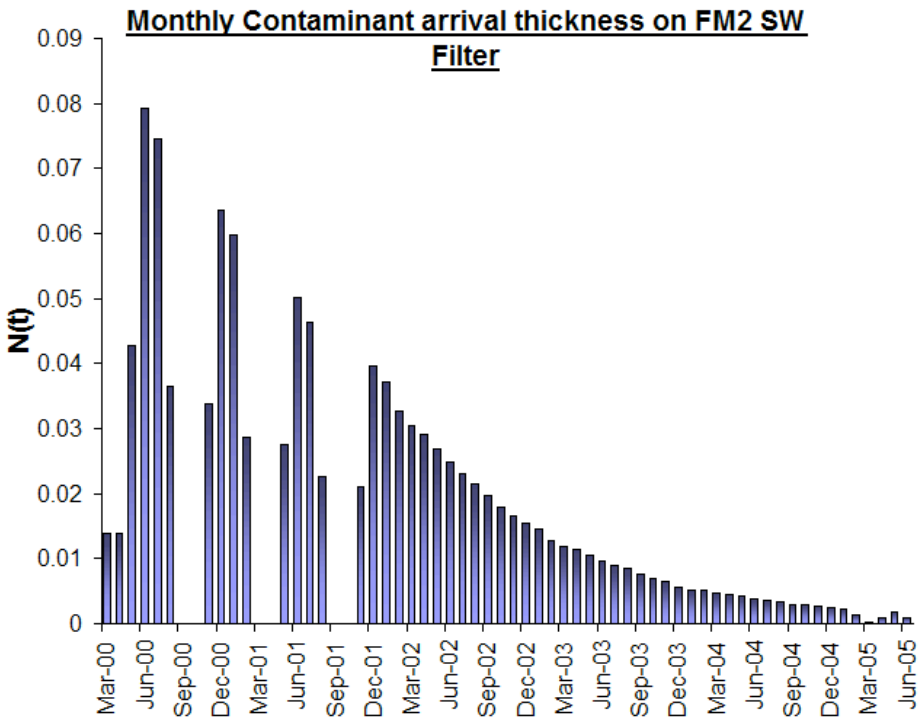
FM1 Contaminant Thickness

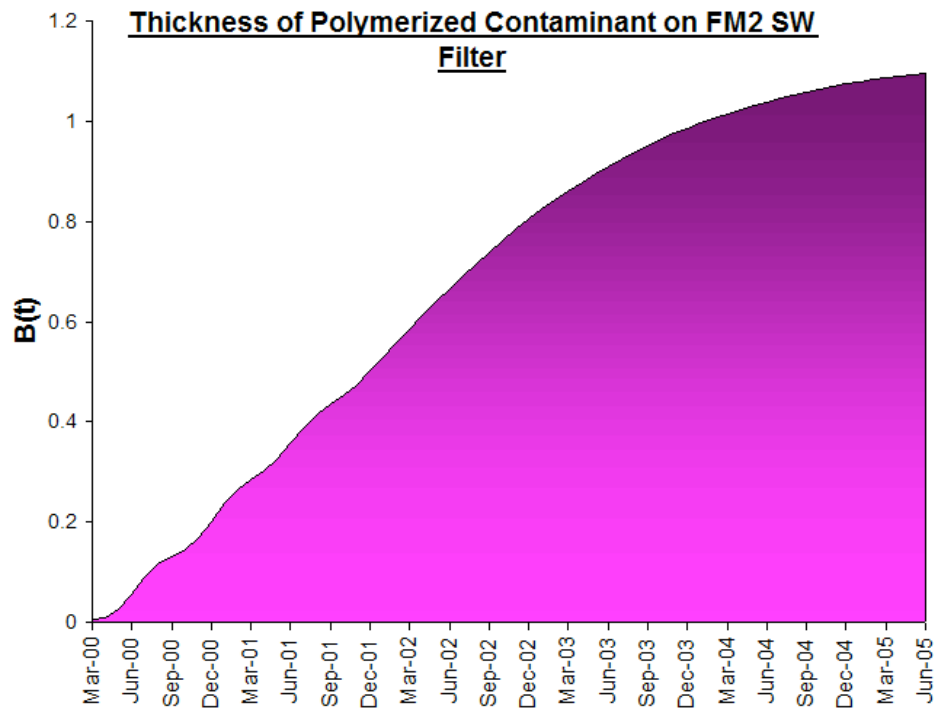




$$\frac{dB(t)}{dt} = \rho \left[\int_0^t N(\xi) d\xi - B(t) \right] + \beta . N(t)$$

FM2 Contaminant Thickness

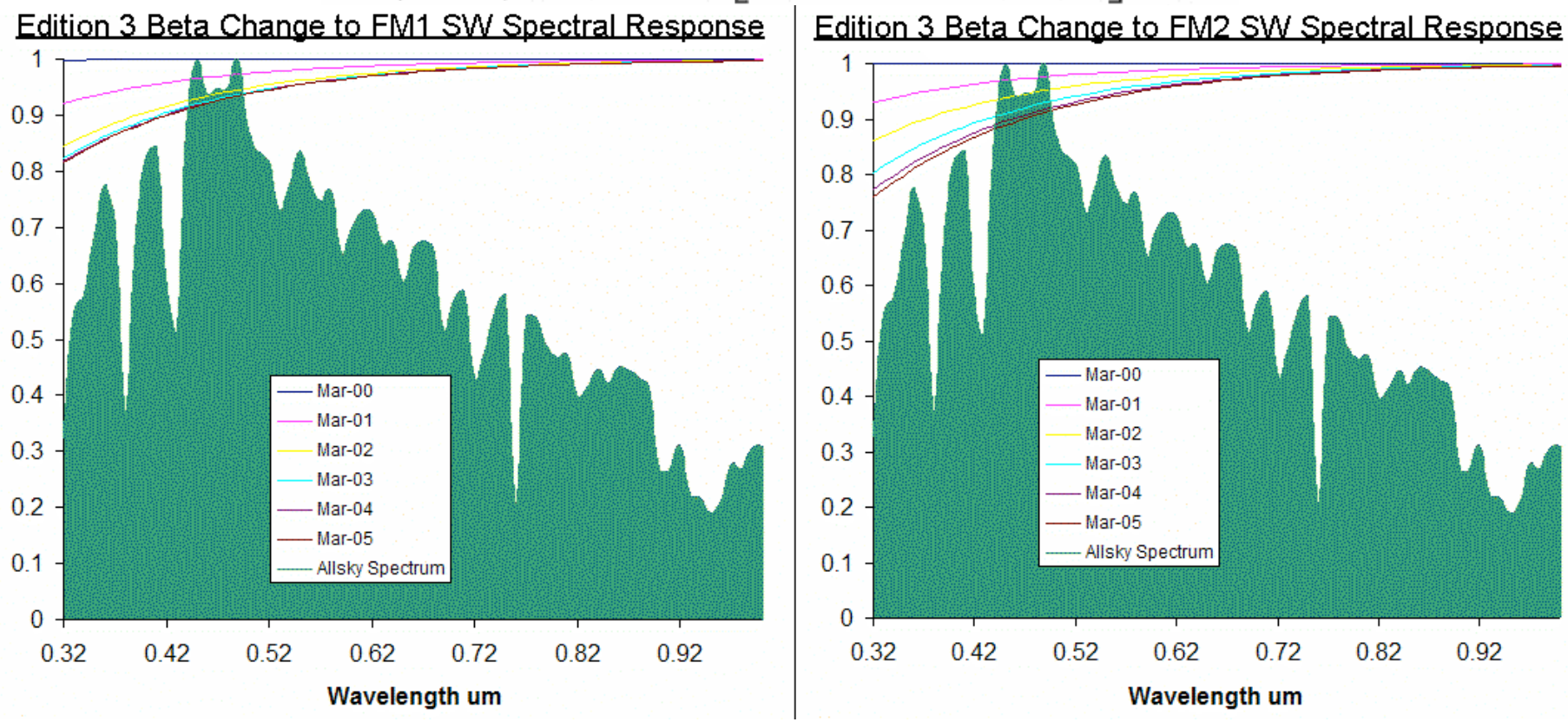




$$\frac{dB(t)}{dt} = \rho \left[\int_0^t N(\xi) d\xi - B(t) \right] + \beta . N(t)$$

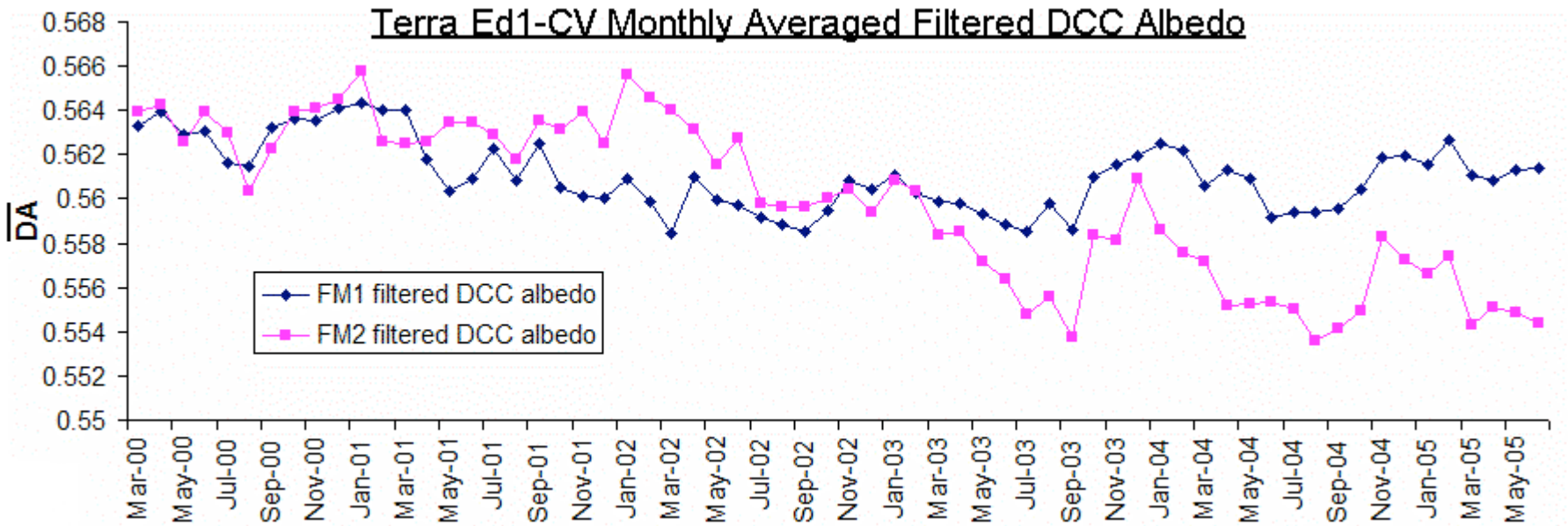
Changes to Terra SW Spectral responses R(λ) for Edition 3 Beta

$$D(\lambda, t) = \left[1 - M.e^{-\alpha\lambda}\right]^{B(t)}$$



$$r_{sw}(\lambda, t) = D(\lambda, t) \times R_{sw}(\lambda)$$

Use of model spectral response and DA to find gain change



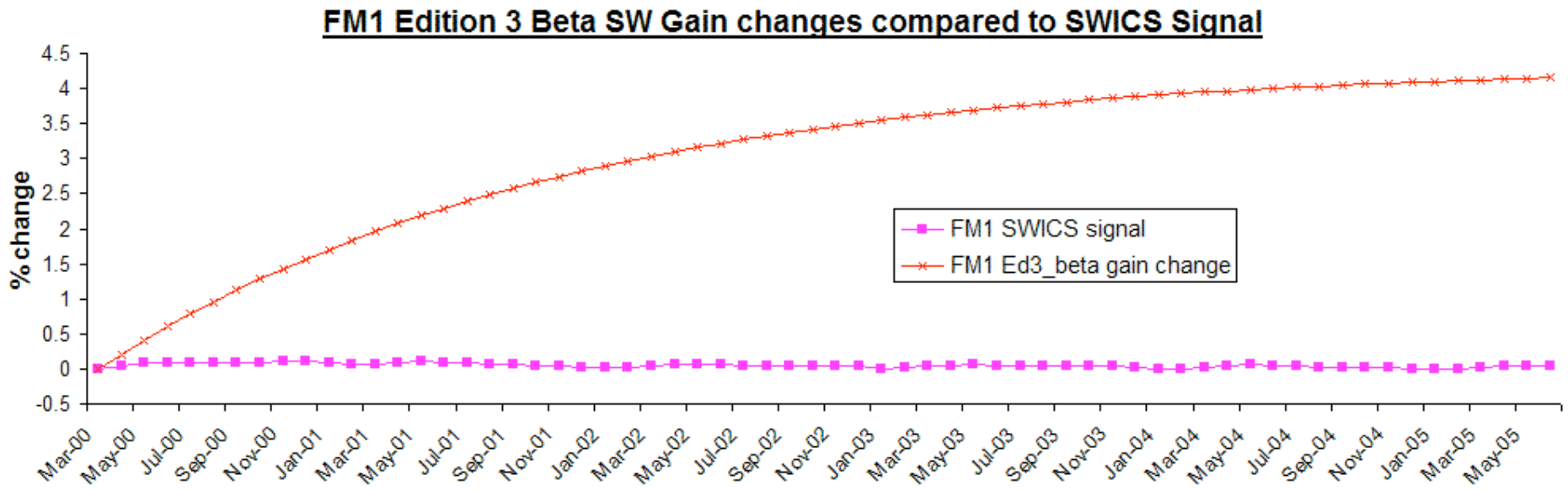
$$DA = \frac{LF_{dcc}^{sw} \times AR(\theta_{vz}, \phi_{raz}, \Phi_{sz}) \times DM(\Phi_{sz})}{F_s} \times \left(\frac{Z}{Z_0}\right)^2 \times \left(\frac{m \times 65\mu m + C)}{m \times \Omega_{icediam} + C)}\right)$$

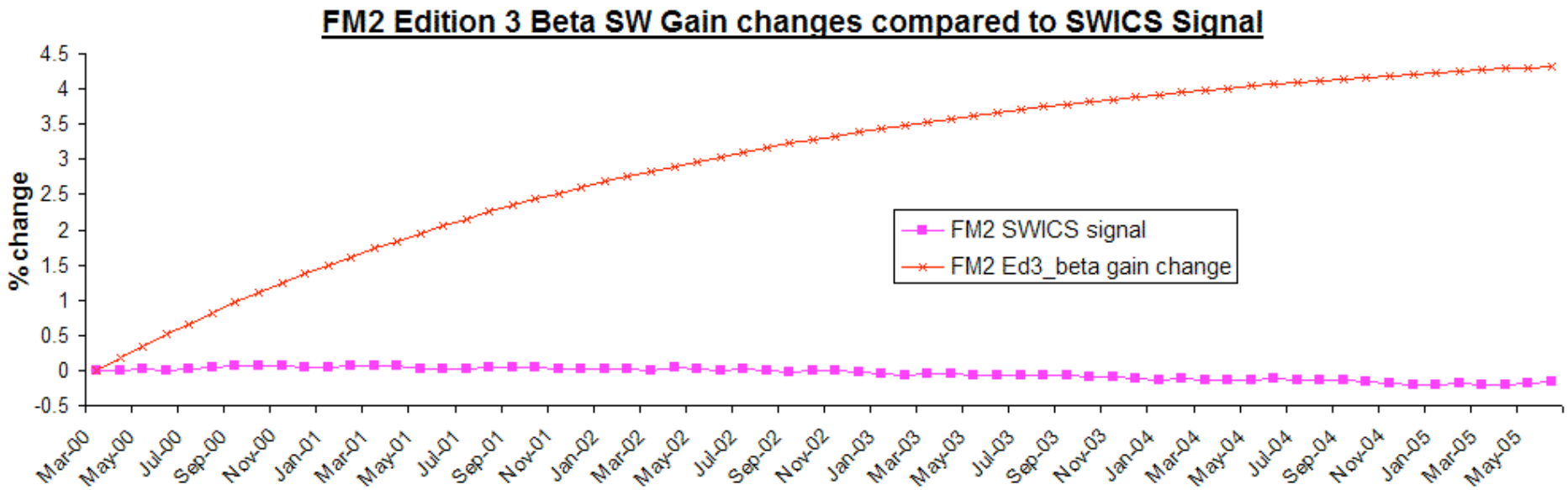
CERES Un-filtering:

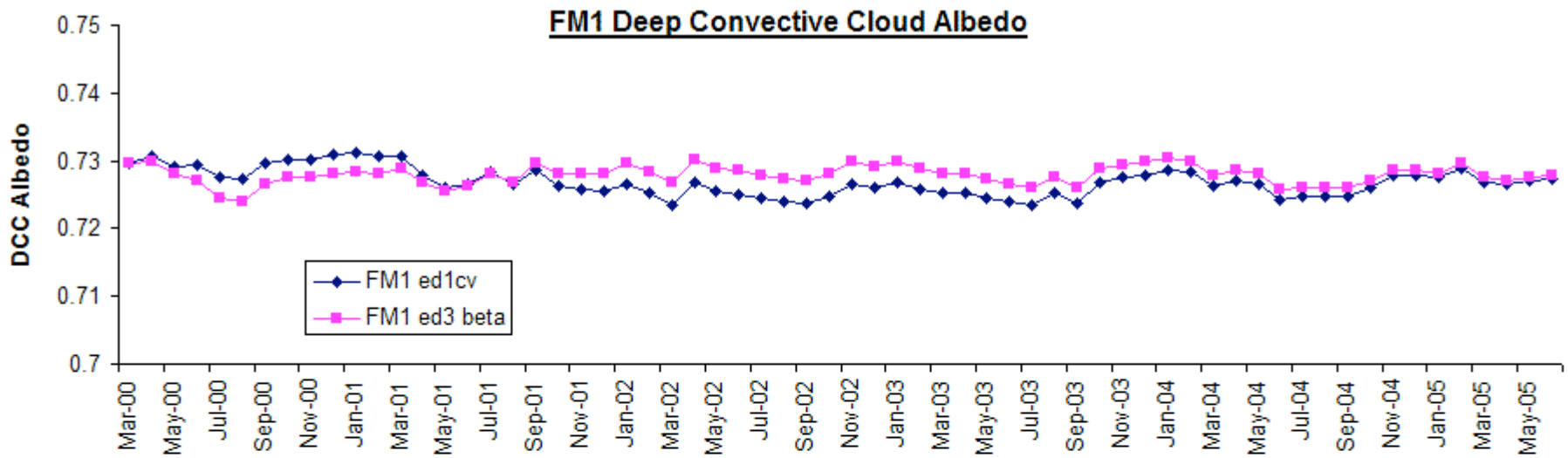
$$
\begin{aligned}
L_i^{sw} &= \int_0^\infty b_i(\lambda) I^s(\lambda) d\lambda \\
LF_i^{sw} &= g_{sw} \int_0^\infty r_{sw}(\lambda) b_i(\lambda) I^s(\lambda) d\lambda \\
f_i &= \frac{\int_0^\infty r_{sw}(\lambda) b_i(\lambda) I^s(\lambda) d\lambda}{\int_0^\infty b_i(\lambda) I^s(\lambda) d\lambda} \\
L_i^{sw} &= \frac{LF_i^{sw}}{g_{sw} \times f_i}
\end{aligned}
$$

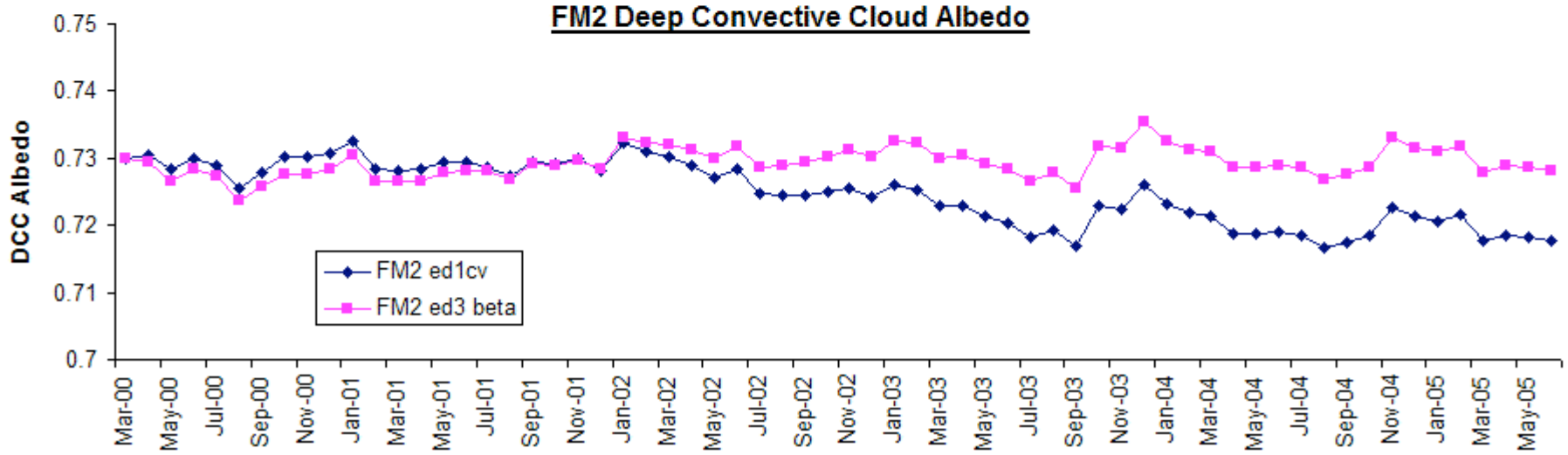
Re-arrange to give gain change g(t) from DCC Filtered albedo:

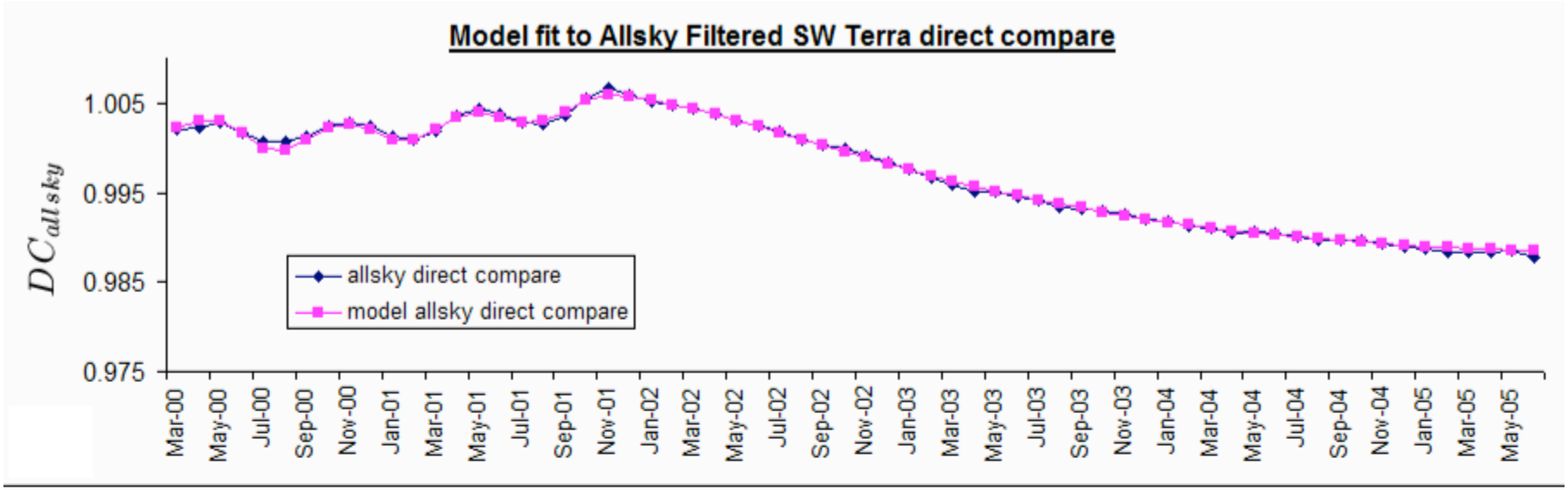
$$
\begin{aligned}
\frac{\overline{DA}(t)}{f_{dcc}(t)} &= UDA \times g_{sw}(t) \\
&= UDA \left[1 + \Delta g (1 - e^{t/\tau_g}) \right]
\end{aligned}
$$

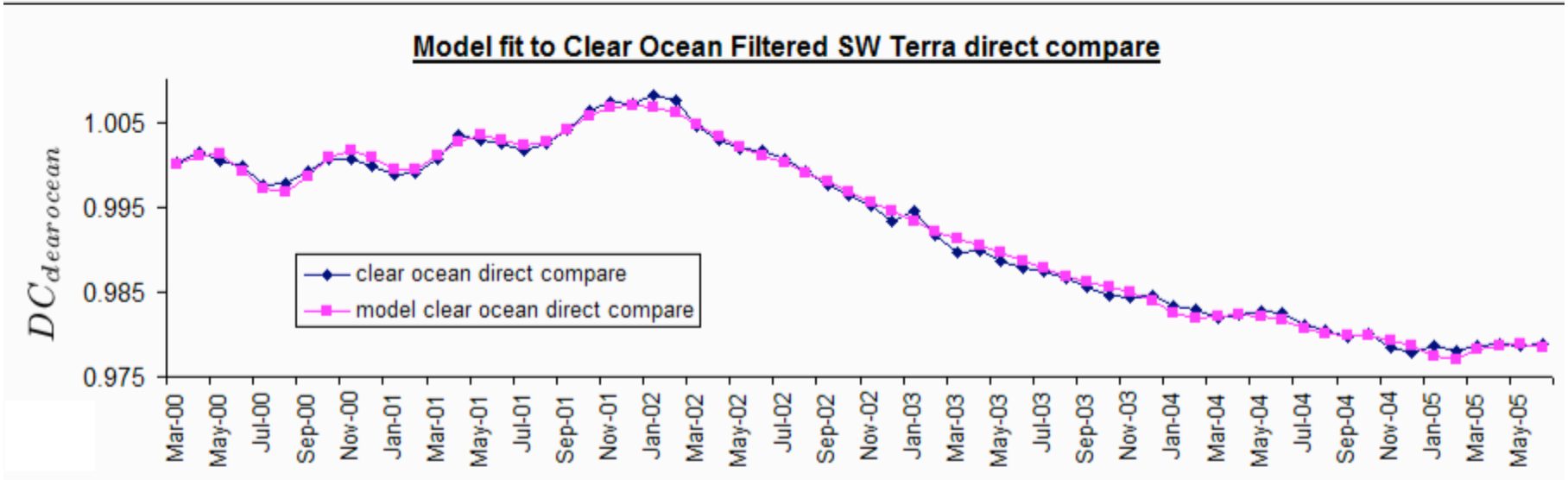

FM1 Edition 3 Beta SW Gain changes compared to SWICS Signal
% change
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
FM1 SWICS signal
FM1 Ed3_beta gain change
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05


FM2 Edition 3 Beta SW Gain changes compared to SWICS Signal
% change
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
FM2 SWICS signal
FM2 Ed3_beta gain change
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05

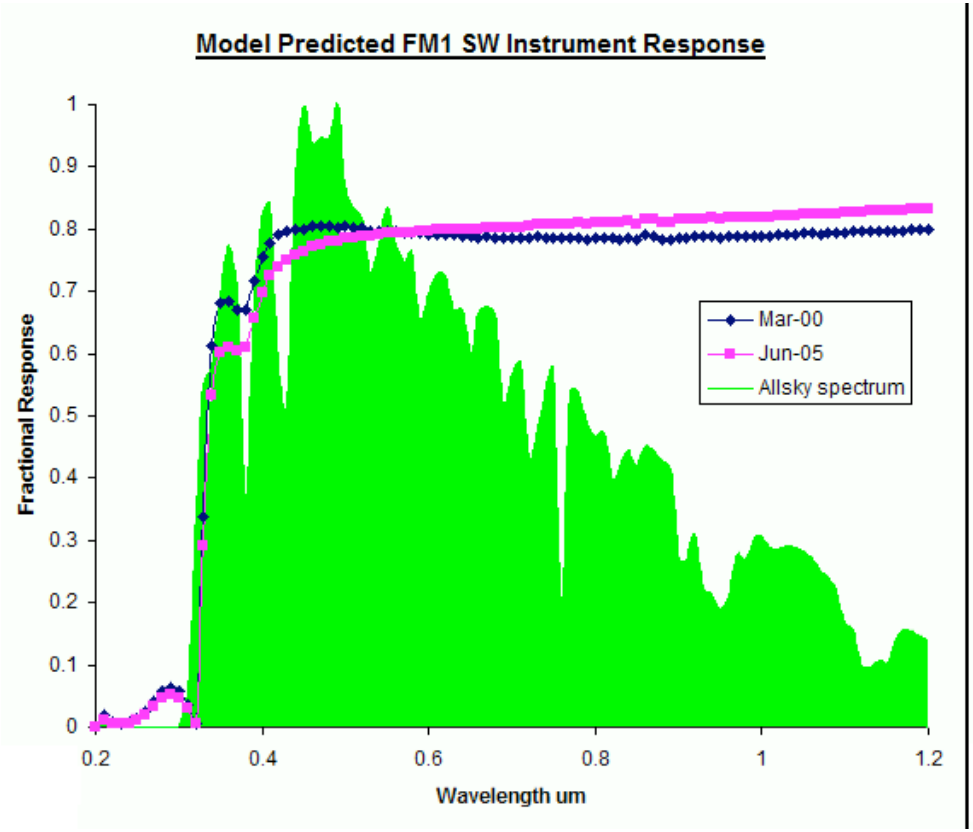

FM1 Deep Convective Cloud Albedo
DCC Albedo
0.75
0.74
0.73
0.72
0.71
0.7
FM1 ed1cv
FM1 ed3 beta
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05

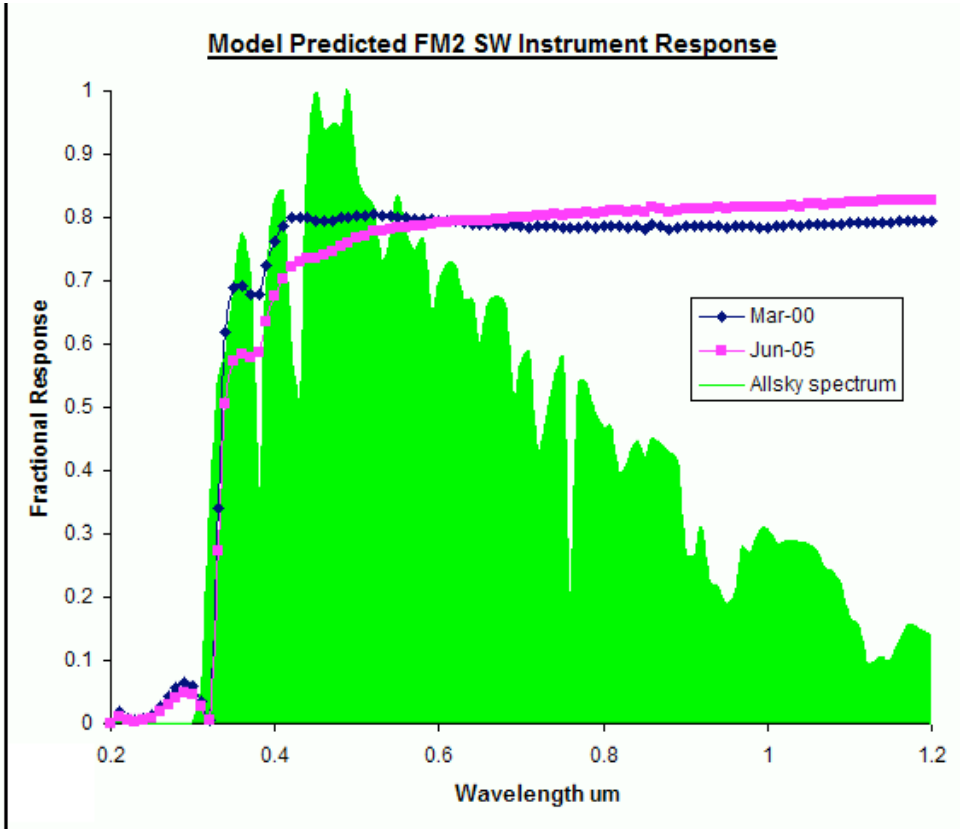

FM2 Deep Convective Cloud Albedo
DCC Albedo
0.75
0.74
0.73
0.72
0.71
0.7
FM2 ed1cv
FM2 ed3 beta
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05

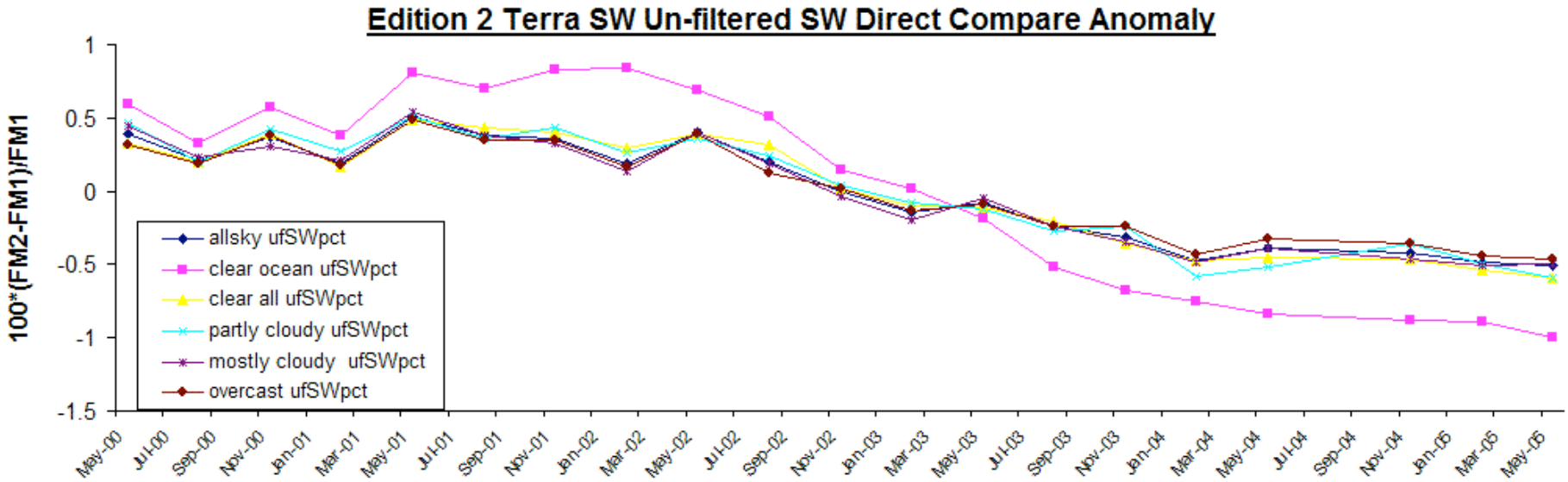

Model fit to Allsky Filtered SW Terra direct compare
DC_{allsky}
1.005
0.995
0.985
0.975
allsky direct compare
model allsky direct compare
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05

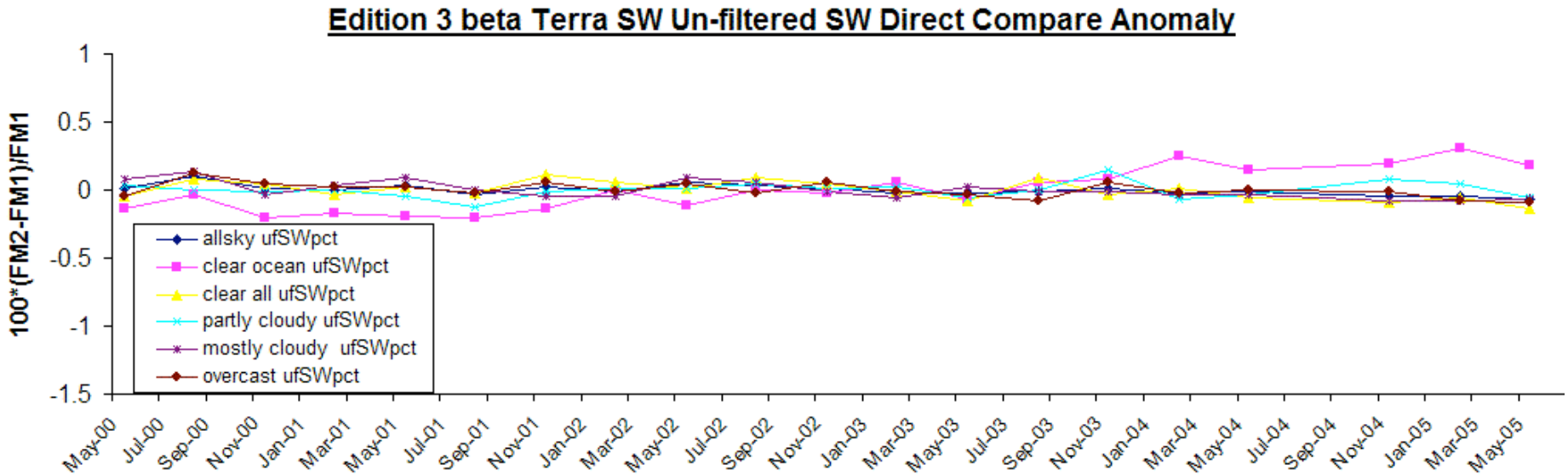

Model fit to Clear Ocean Filtered SW Terra direct compare
$DC_{clear\,ocean}$
1.005
0.995
0.985
0.975
clear ocean direct compare
model clear ocean direct compare
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05

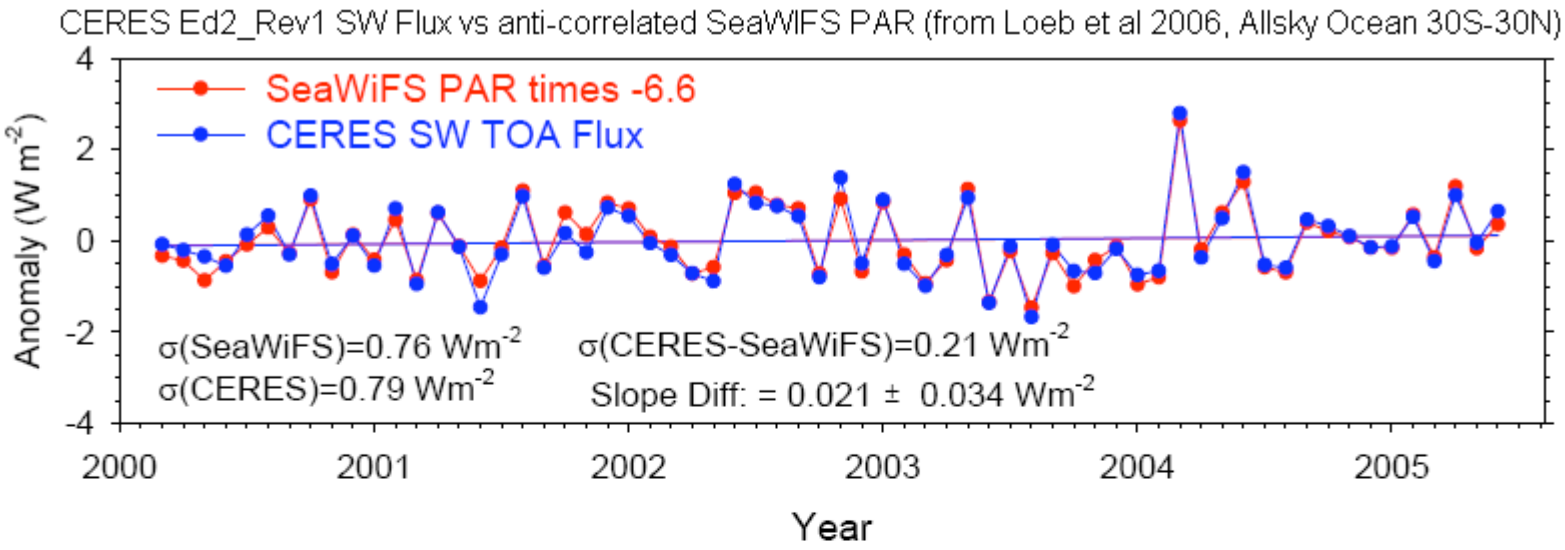
Net Instrument Response = Gain * Spectral Response

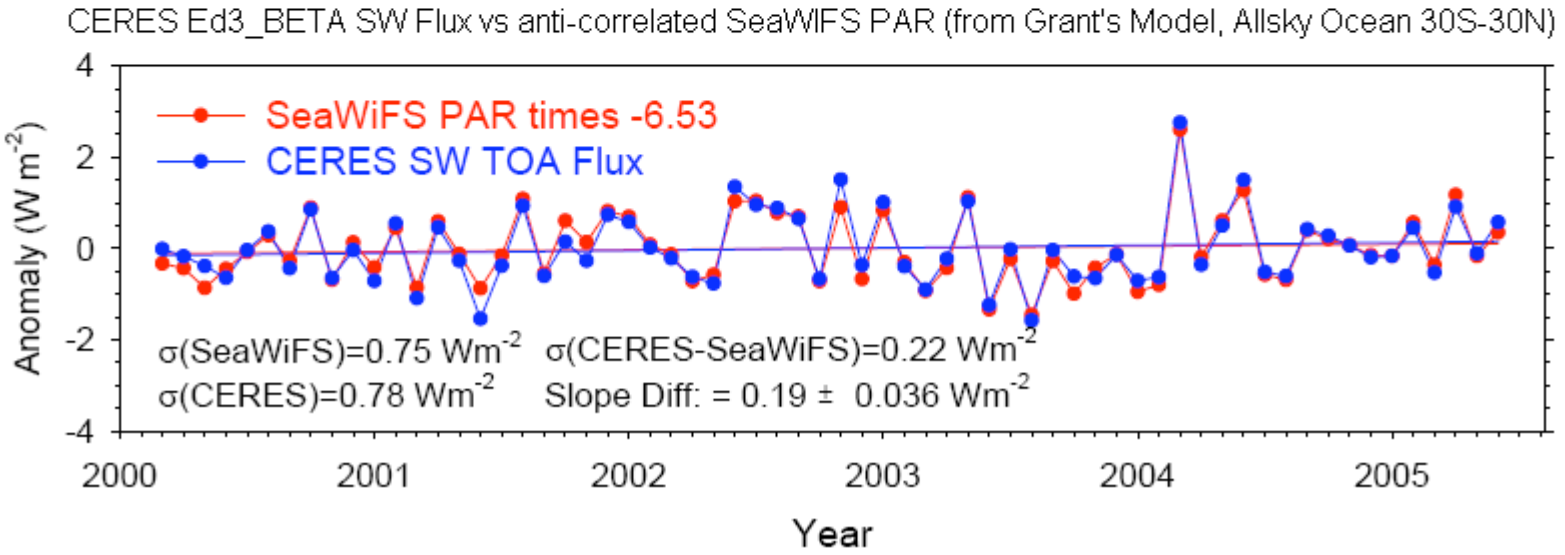




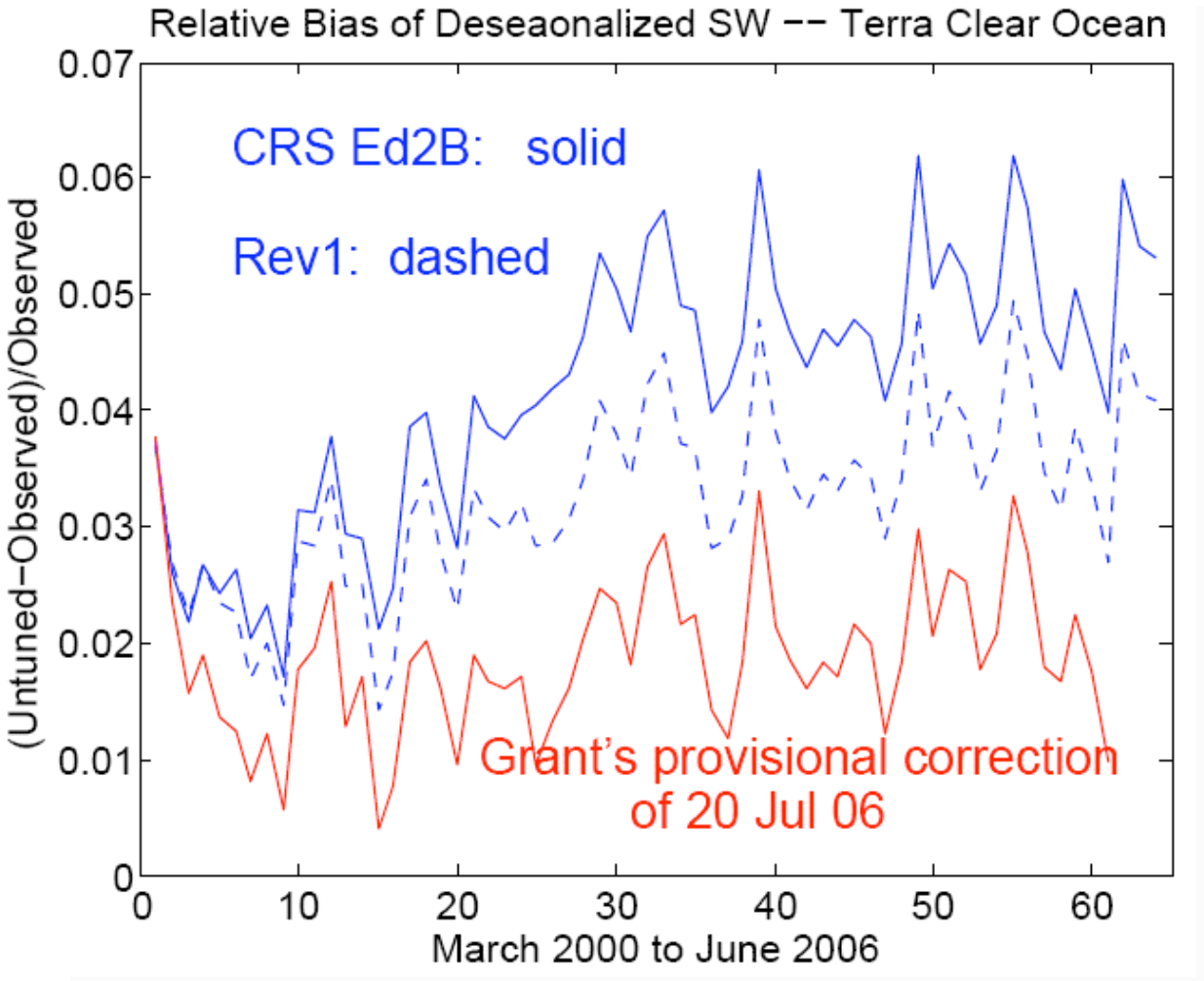

Edition 2 Terra SW Un-filtered SW Direct Compare Anomaly
100*(FM2-FM1)/FM1
1
0.5
0
-0.5
-1
-1.5
allsky ufSWpct
clear ocean ufSWpct
clear all ufSWpct
partly cloudy ufSWpct
mostly cloudy ufSWpct
overcast ufSWpct
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05


Edition 3 beta Terra SW Un-filtered SW Direct Compare Anomaly
100*(FM2-FM1)/FM1
1
0.5
0
-0.5
-1
-1.5
allsky ufSWpct
clear ocean ufSWpct
clear all ufSWpct
partly cloudy ufSWpct
mostly cloudy ufSWpct
overcast ufSWpct
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05


CERES Ed2_Rev1 SW Flux vs anti-correlated SeaWIFS PAR (from Loeb et al 2006, Allsky Ocean 30S-30N)
SeaWiFS PAR times -6.6
CERES SW TOA Flux
σ(SeaWiFS)=0.76 Wm-2
σ(CERES)=0.79 Wm-2
σ(CERES-SeaWiFS)=0.21 Wm-2
Slope Diff: = 0.021 ± 0.034 Wm-2
Anomaly (W m-2)
4
2
0
-2
-4
2000
2001
2002
2003
2004
2005
Year

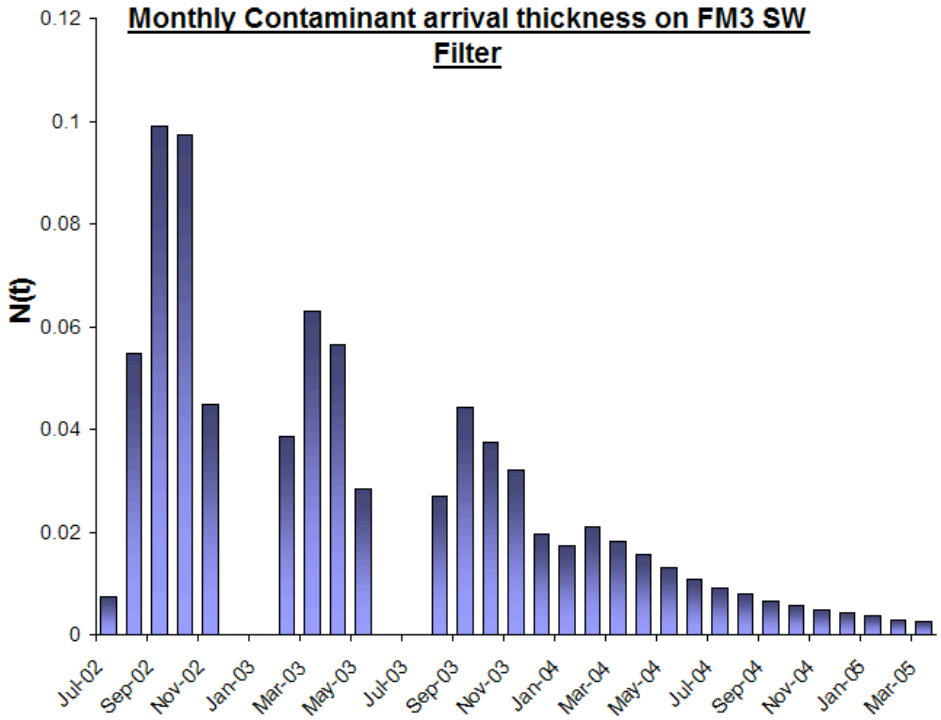

CERES Ed3_BETA SW Flux vs anti-correlated SeaWIFS PAR (from Grant's Model, Allsky Ocean 30S-30N)
SeaWiFS PAR times -6.53
CERES SW TOA Flux
σ(SeaWiFS)=0.75 Wm-2
σ(CERES)=0.78 Wm-2
σ(CERES-SeaWiFS)=0.22 Wm-2
Slope Diff: = 0.19 ± 0.036 Wm-2
Anomaly (W m-2)
4
2
0
-2
-4
2000
2001
2002
2003
2004
2005
Year

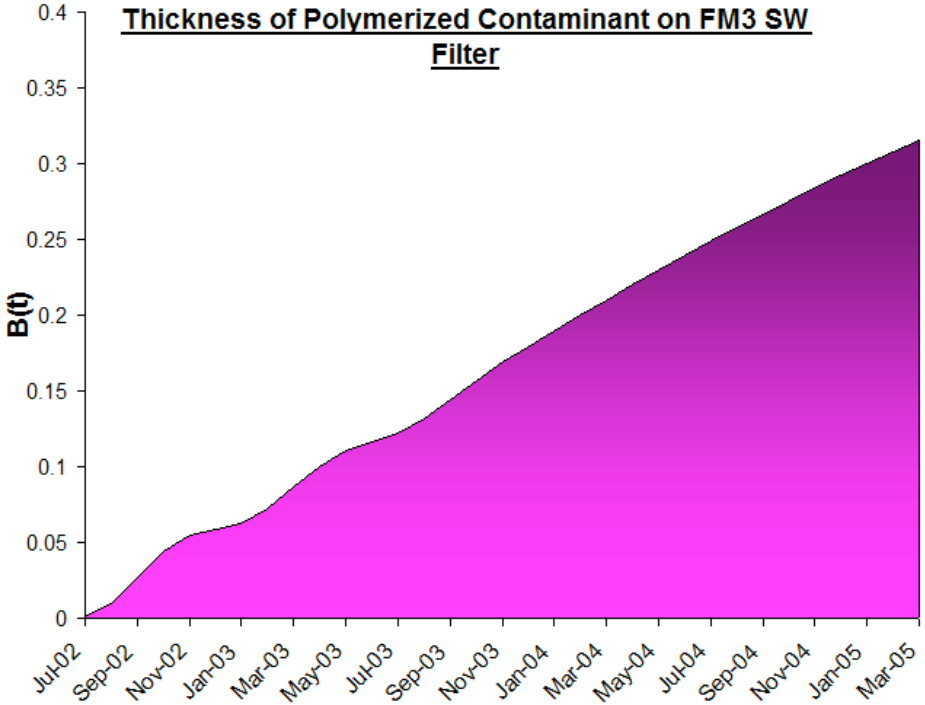
We gave Tom some Clear Ocean Ed3_beta/Ed2 values which he applied to his CRS model comparisons:



SW Ed3 beta calibration: Aqua

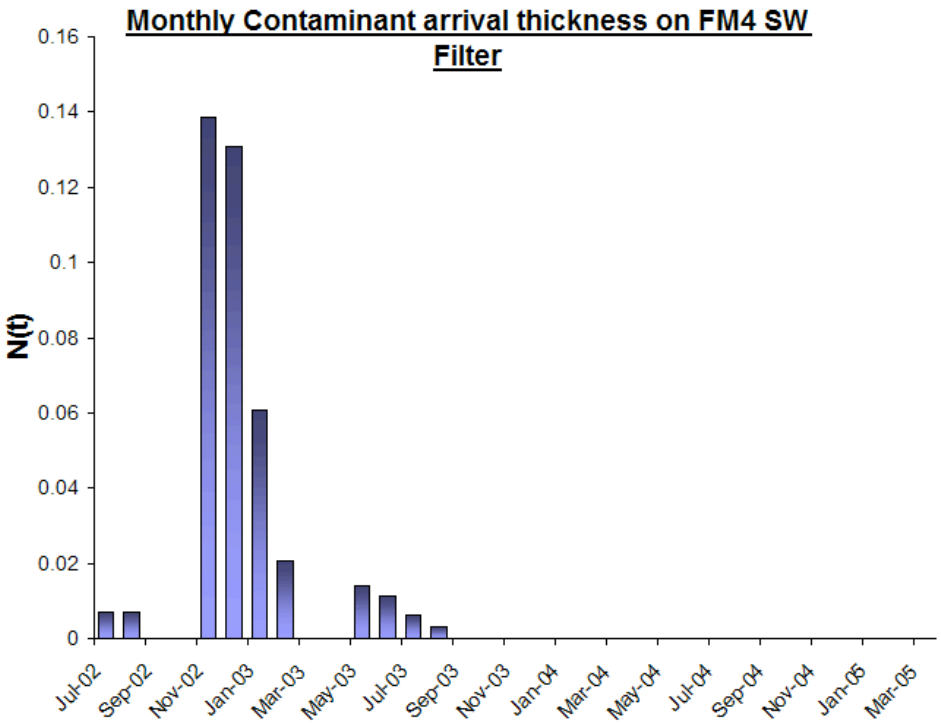
FM3 Contaminant Thickness

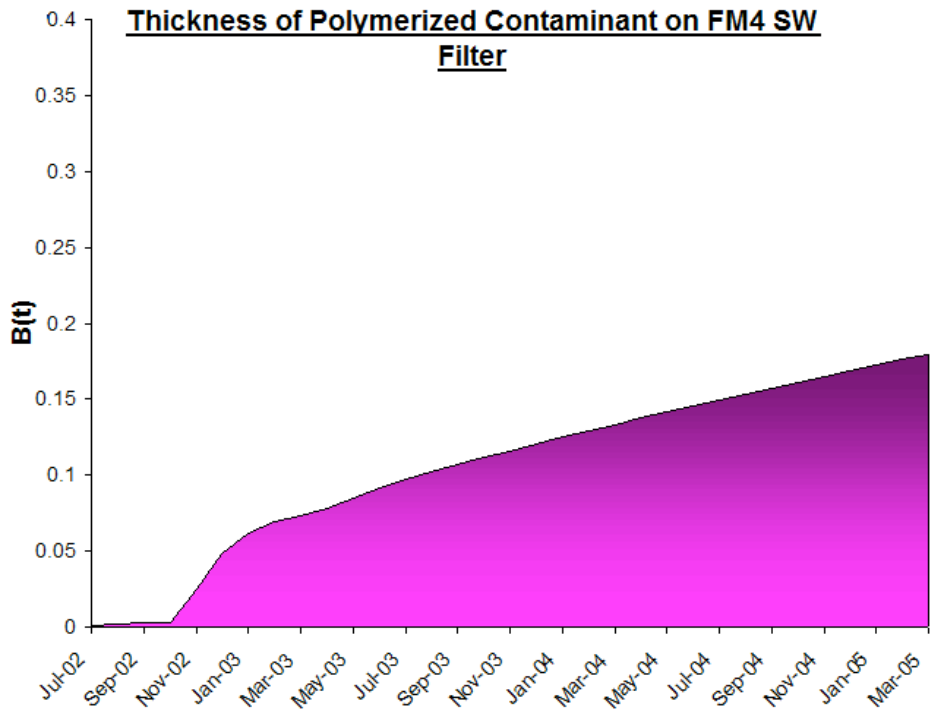




$$\frac{dB(t)}{dt} = \rho \left[\int_0^t N(\xi) d\xi - B(t) \right] + \beta . N(t)$$

FM4 Contaminant Thickness

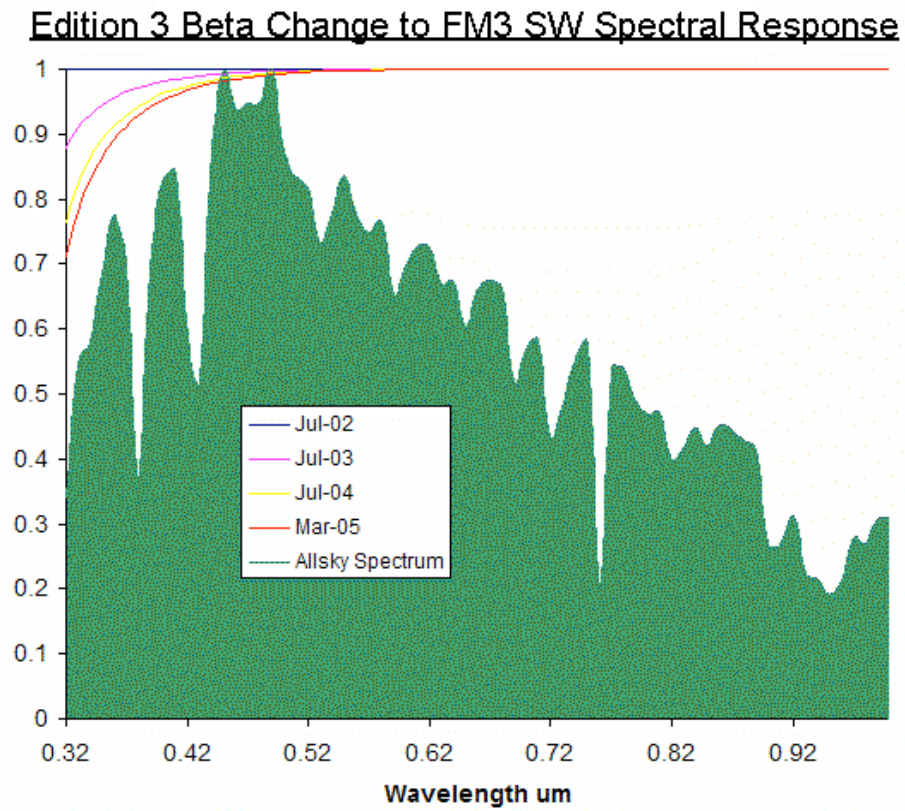


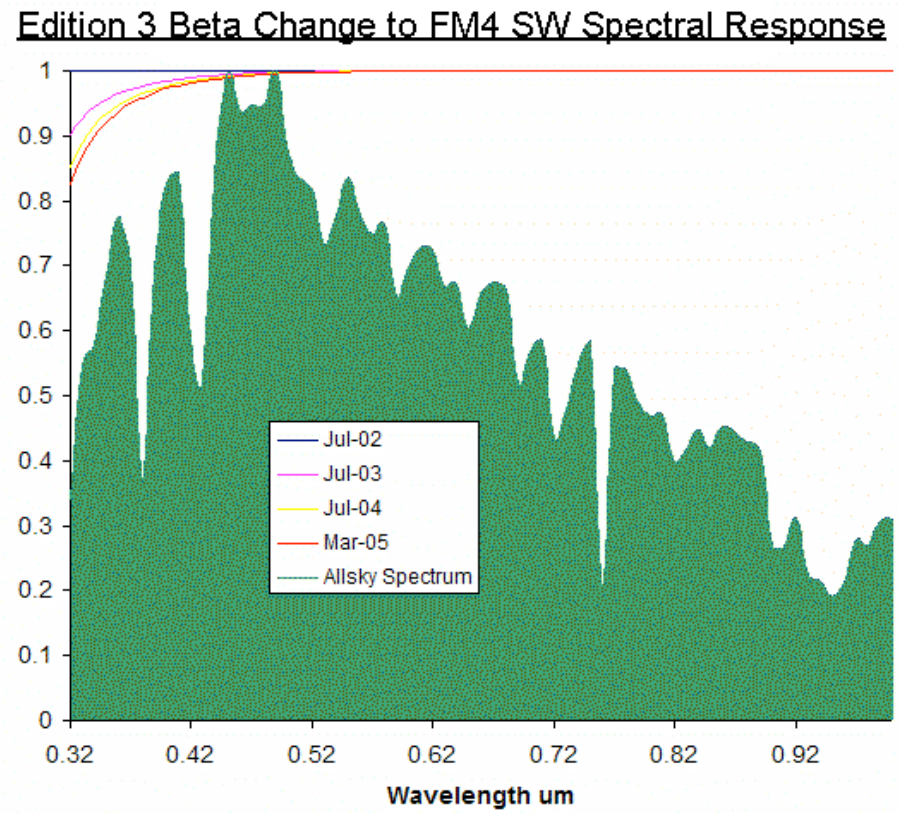


$$\frac{dB(t)}{dt} = \rho \left[\int_0^t N(\xi) d\xi - B(t) \right] + \beta . N(t)$$

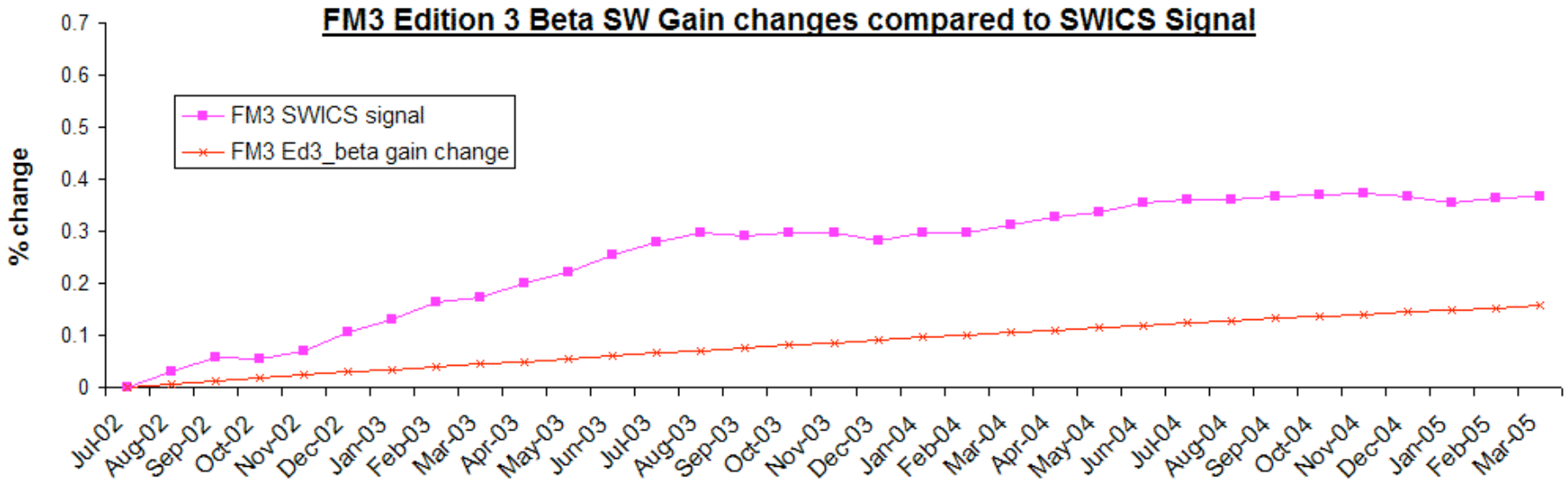
Changes to Aqua SW Spectral responses R(λ) for Edition 3 Beta

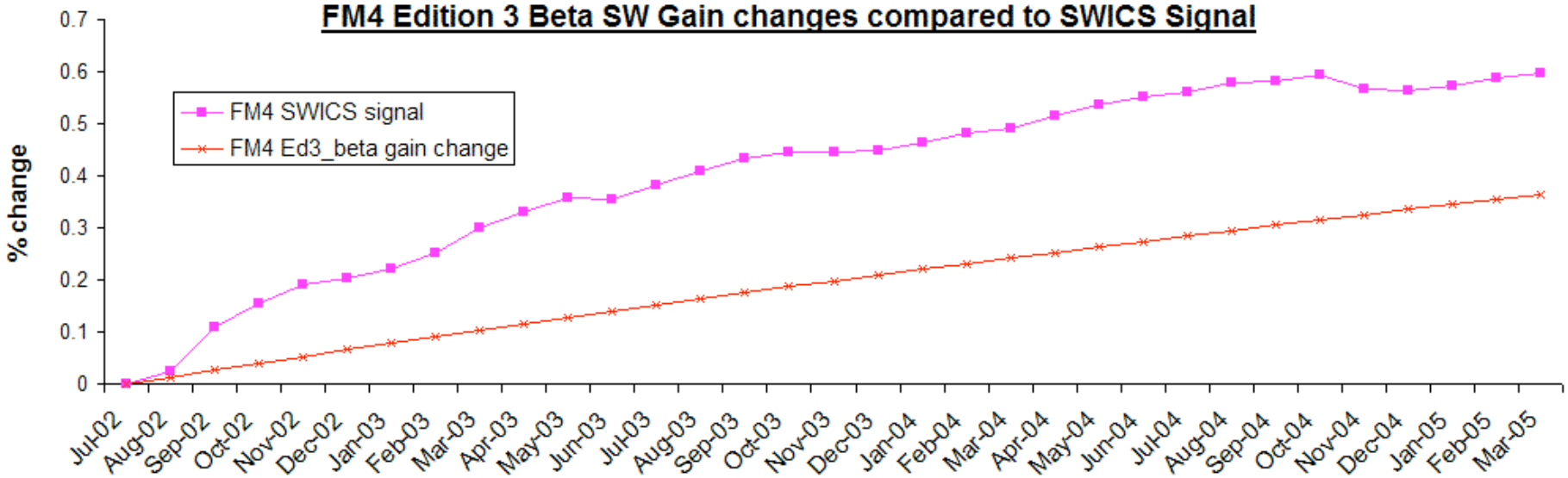
$$D(\lambda, t) = \left[1 - M.e^{-\alpha\lambda}\right]^{B(t)}$$

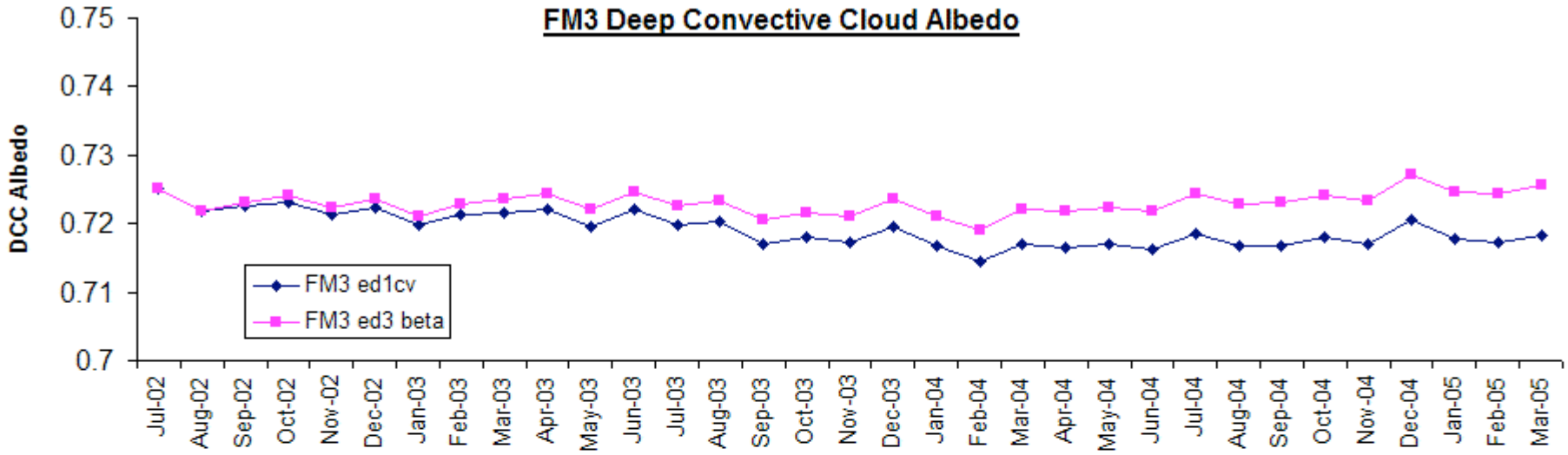


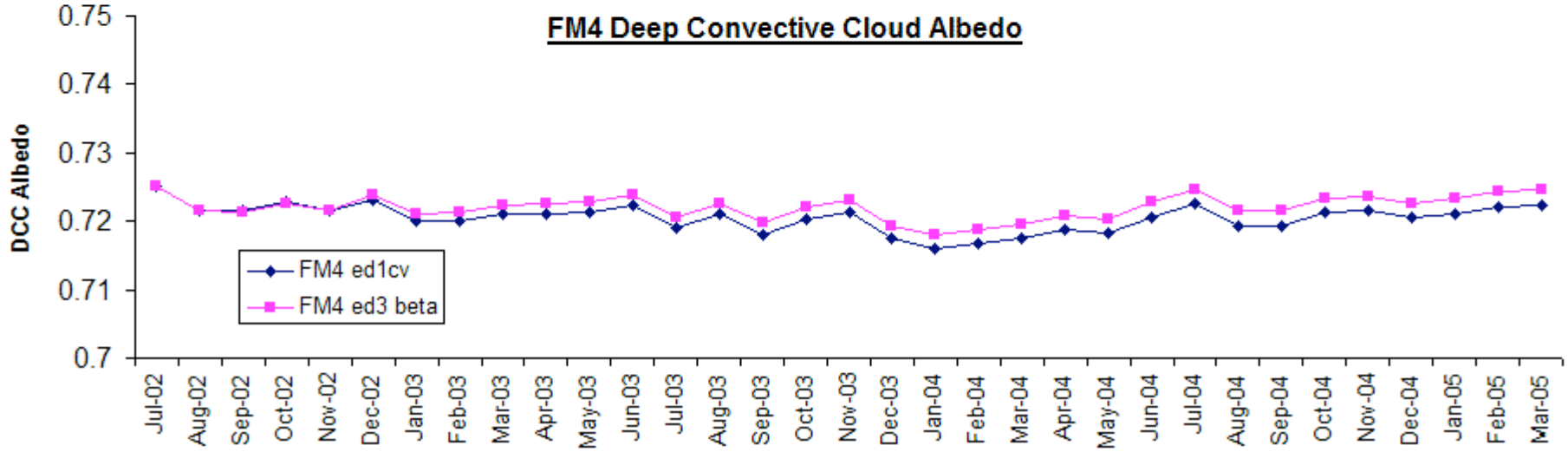


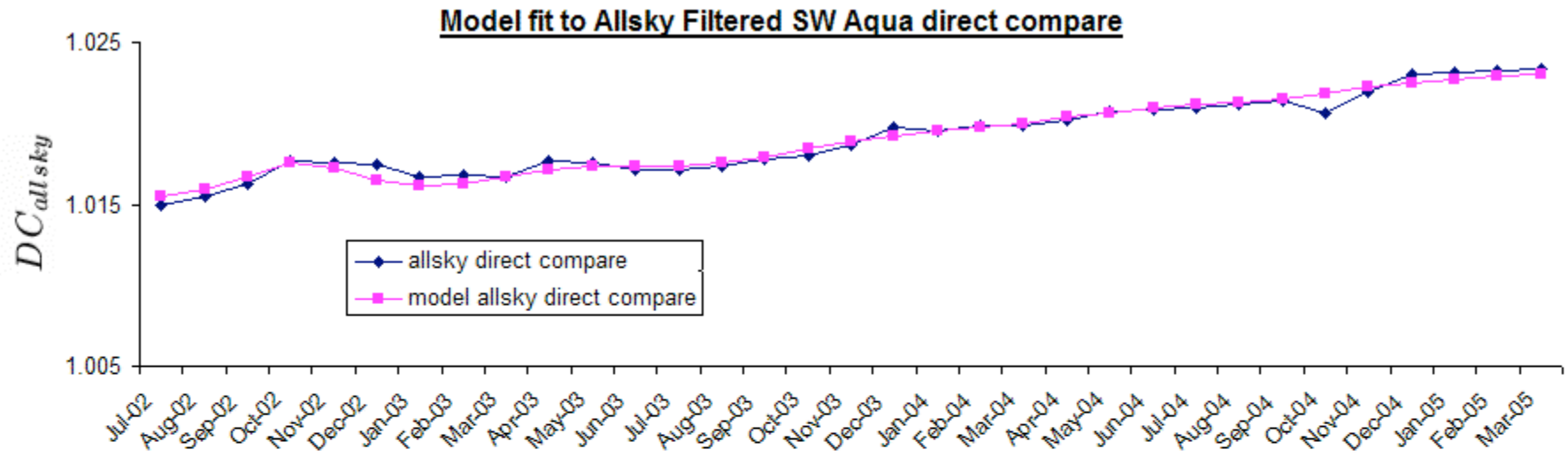
$$r_{sw}(\lambda, t) = D(\lambda, t) \times R_{sw}(\lambda)$$

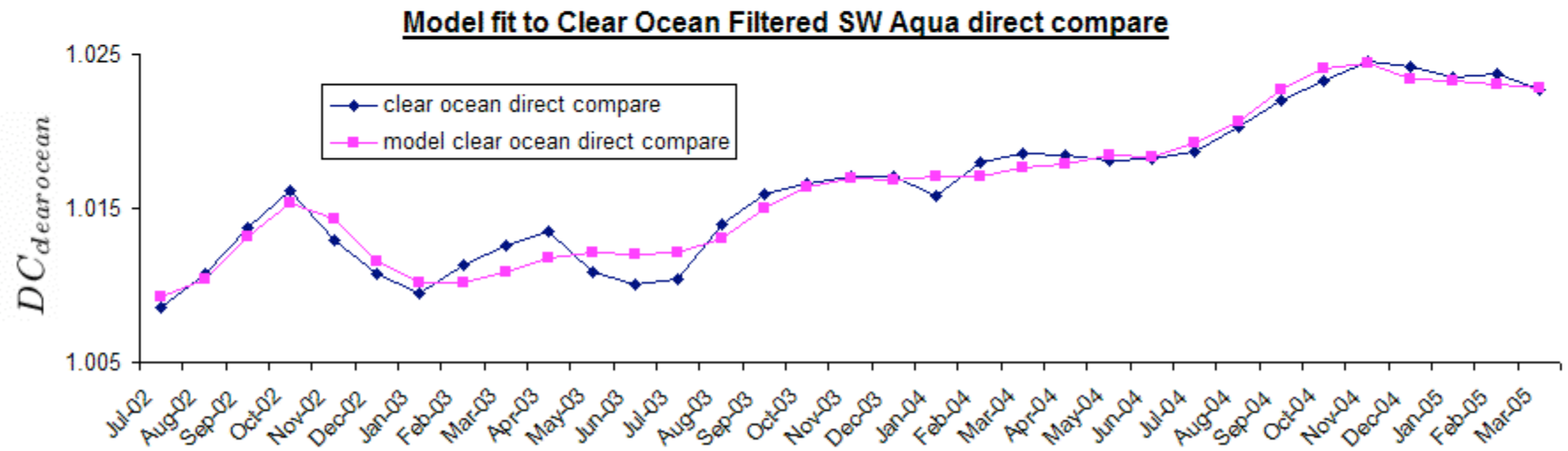

FM3 Edition 3 Beta SW Gain changes compared to SWICS Signal
% change
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
FM3 SWICS signal
FM3 Ed3_beta gain change
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05


FM4 Edition 3 Beta SW Gain changes compared to SWICS Signal
% change
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
FM4 SWICS signal
FM4 Ed3_beta gain change
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05

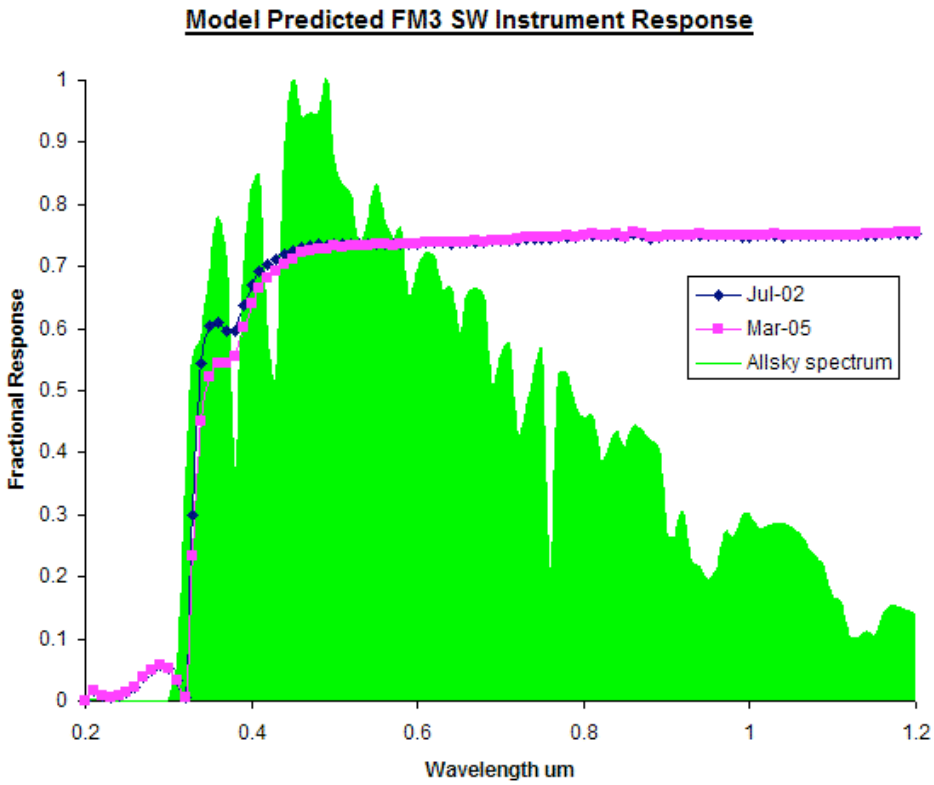

FM3 Deep Convective Cloud Albedo
DCC Albedo
0.75
0.74
0.73
0.72
0.71
0.7
FM3 ed1cv
FM3 ed3 beta
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05

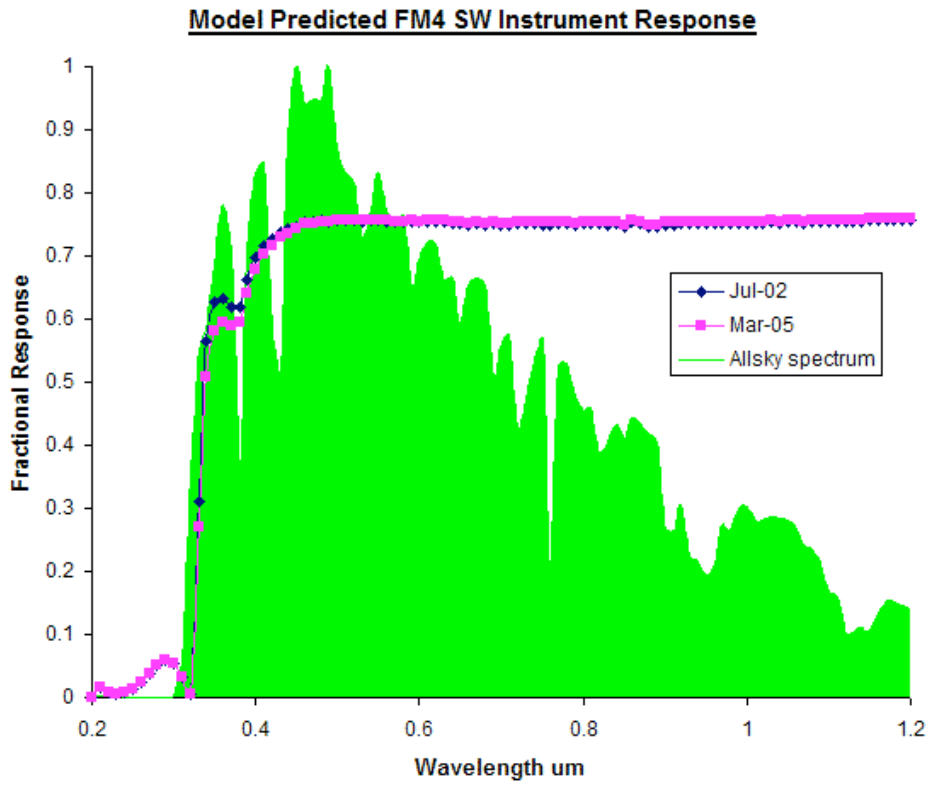

FM4 Deep Convective Cloud Albedo
DCC Albedo
0.75
0.74
0.73
0.72
0.71
0.7
FM4 ed1cv
FM4 ed3 beta
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05

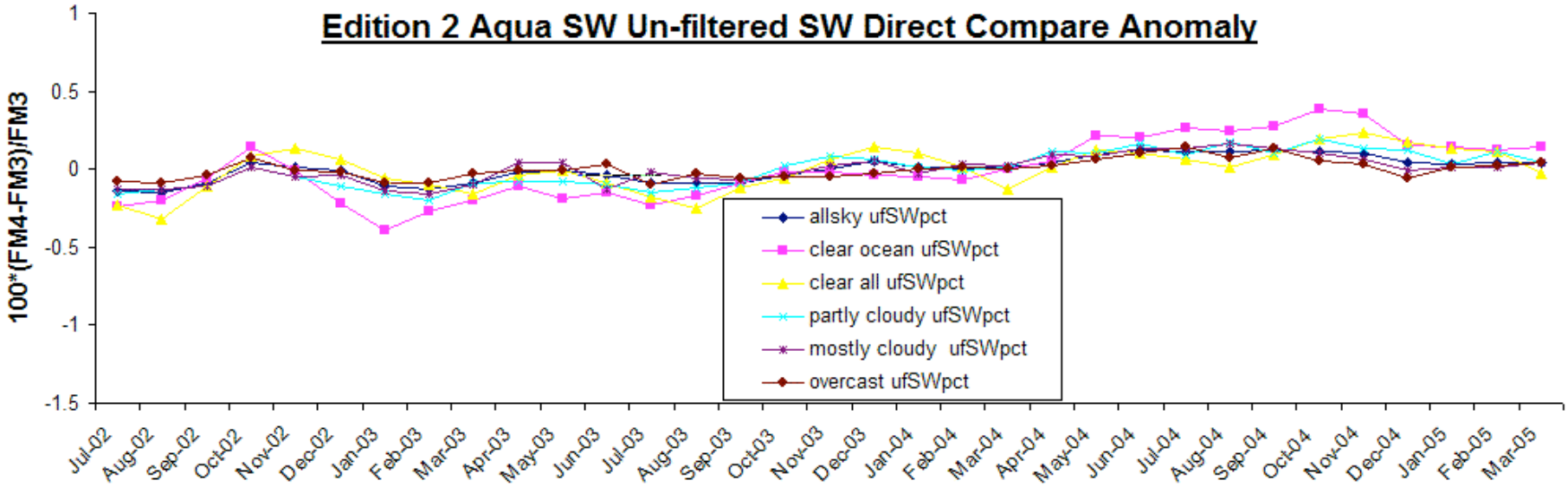

Model fit to Allsky Filtered SW Aqua direct compare
DC_{allsky}
1.025
1.015
1.005
allsky direct compare
model allsky direct compare
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05

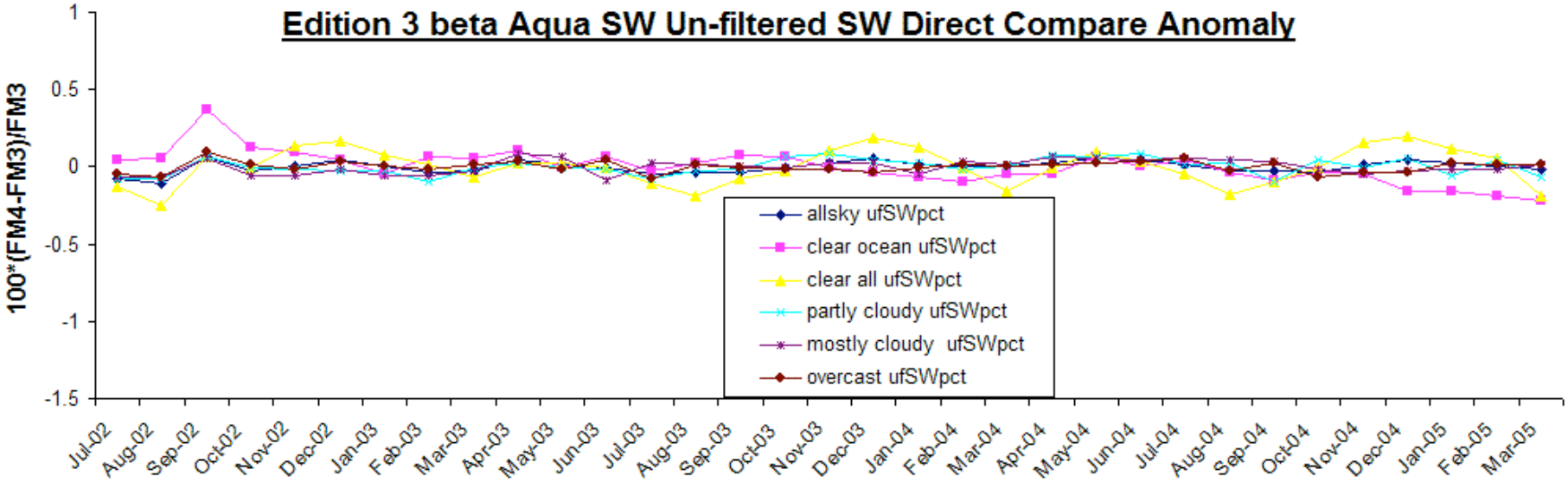

Model fit to Clear Ocean Filtered SW Aqua direct compare
$DC_{dearocean}$
1.025
1.015
1.005
clear ocean direct compare
model clear ocean direct compare
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05

Net Instrument Response = Gain * Spectral Response

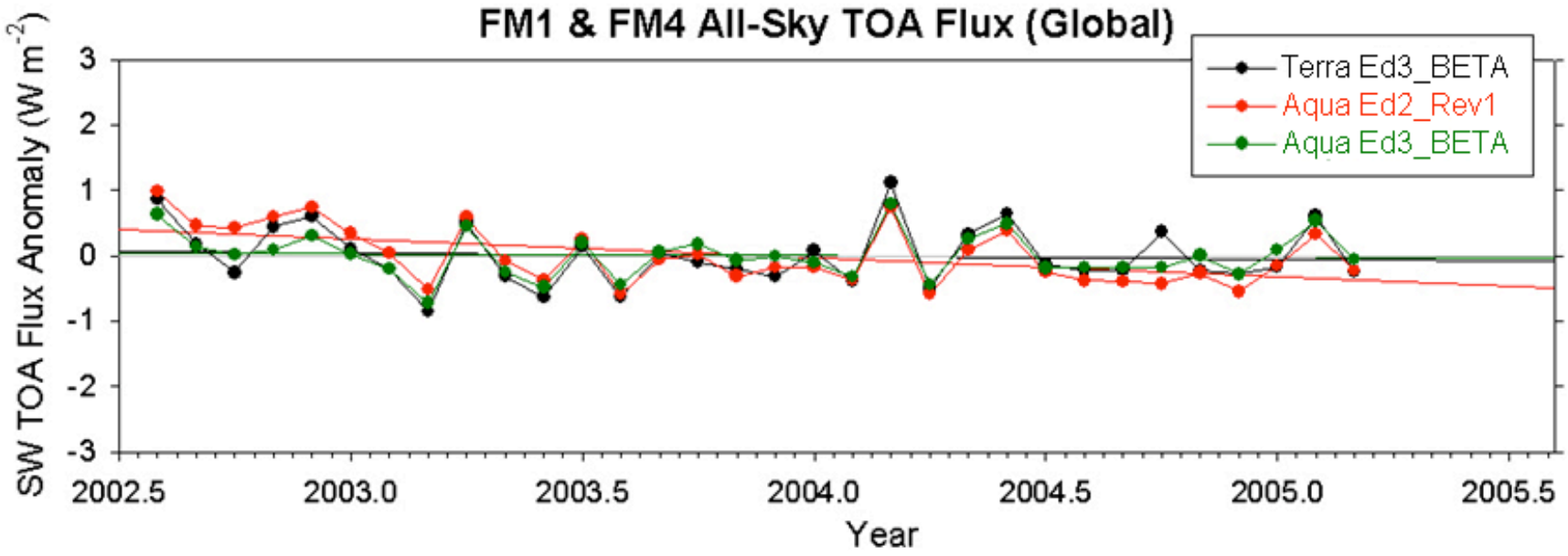




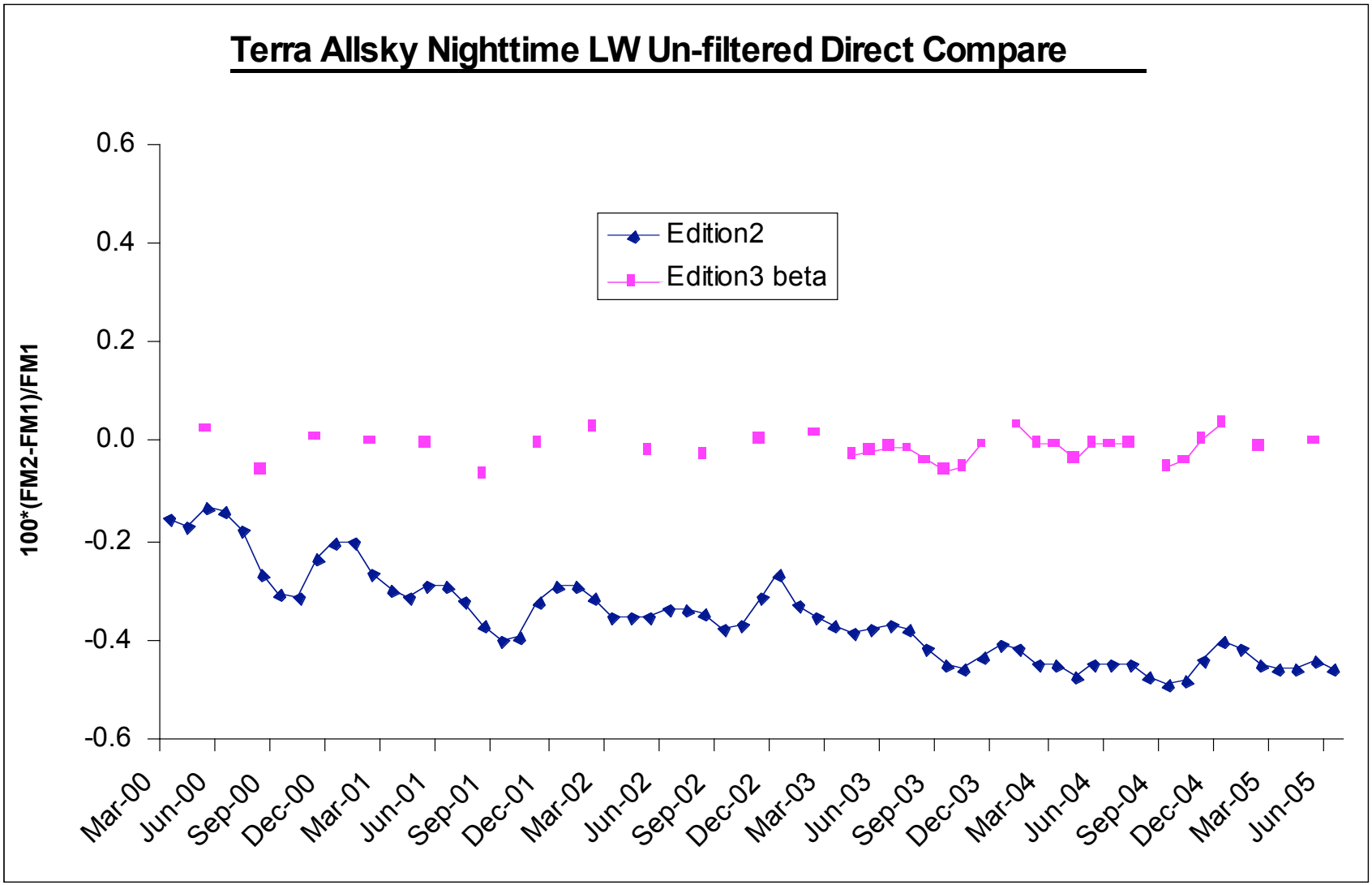

Edition 2 Aqua SW Un-filtered SW Direct Compare Anomaly
100*(FM4-FM3)/FM3
1
0.5
0
-0.5
-1
-1.5
allsky ufSWpct
clear ocean ufSWpct
clear all ufSWpct
partly cloudy ufSWpct
mostly cloudy ufSWpct
overcast ufSWpct
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05

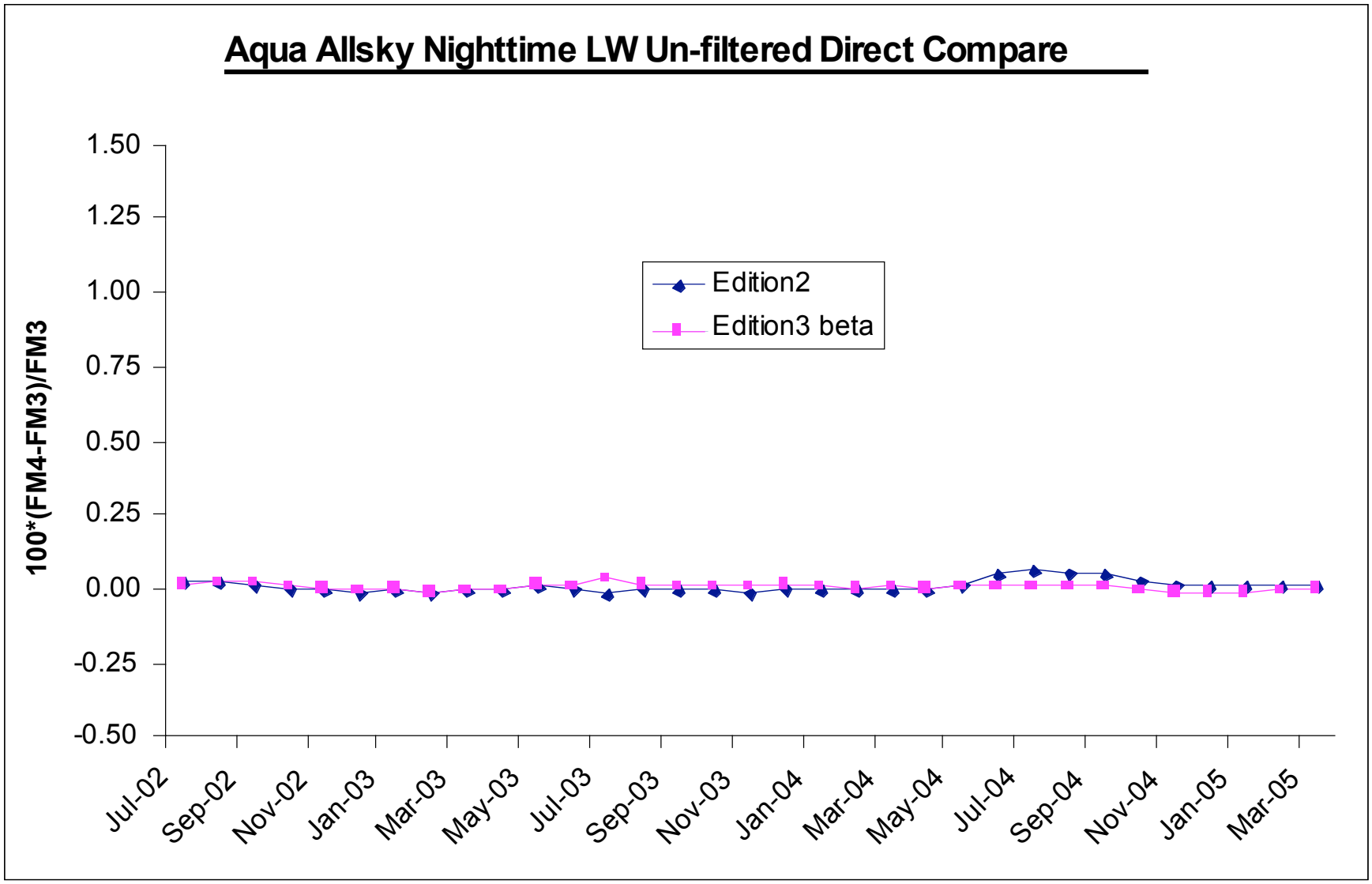

Edition 3 beta Aqua SW Un-filtered SW Direct Compare Anomaly
100*(FM4-FM3)/FM3
1
0.5
0
-0.5
-1
-1.5
allsky ufSWpct
clear ocean ufSWpct
clear all ufSWpct
partly cloudy ufSWpct
mostly cloudy ufSWpct
overcast ufSWpct
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05

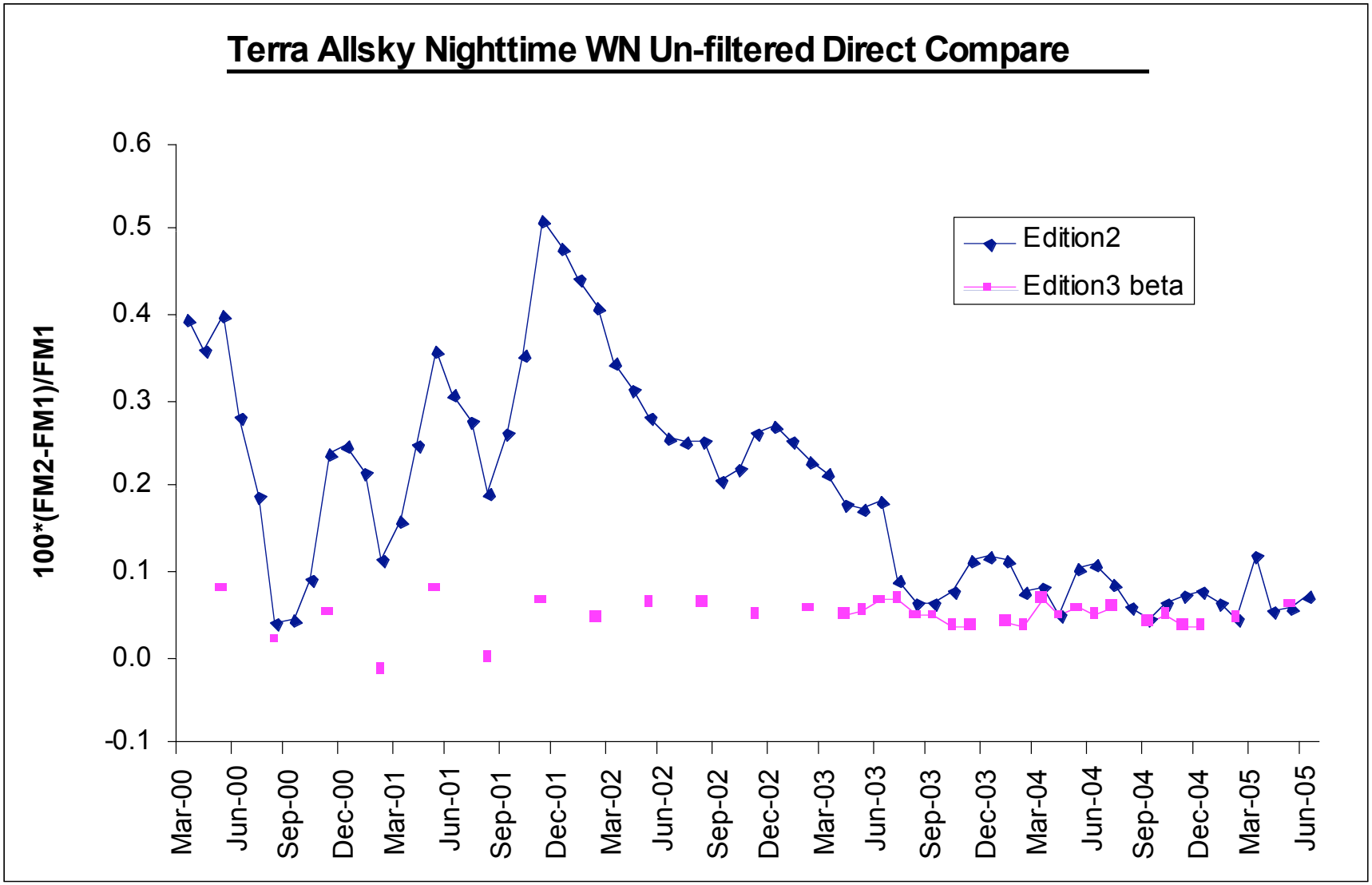
Edition 3 `BETA' that is inverted using the contamination model derived gains and spectral responses also now gives excellent agreement between Terra and Aqua SW flux:

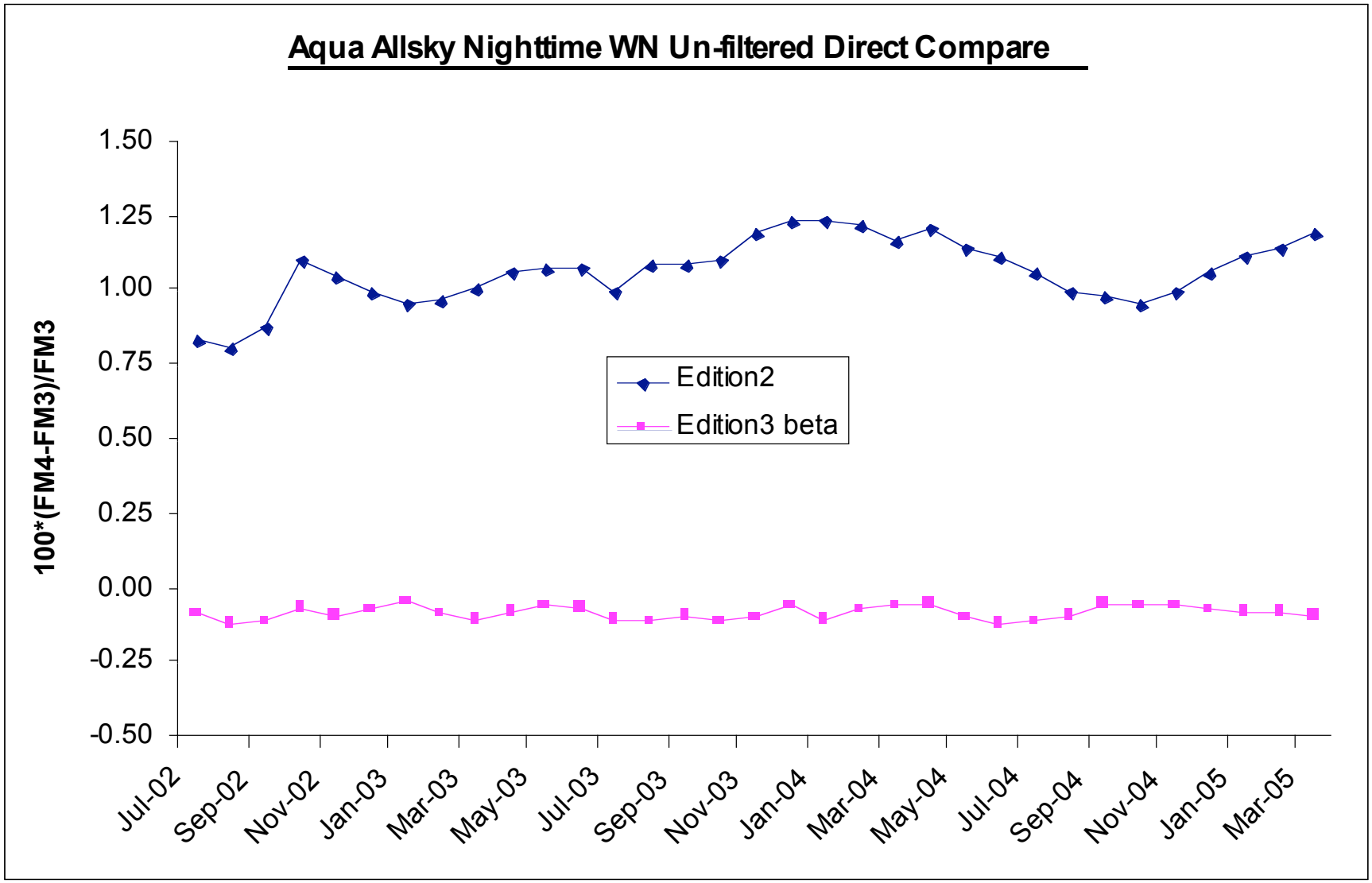


LW Ed3 beta calibration: Nighttime Balancing between instruments


Terra Allsky Nighttime LW Un-filtered Direct Compare
100*(FM2-FM1)/FM1
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Edition2
Edition3 beta
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05

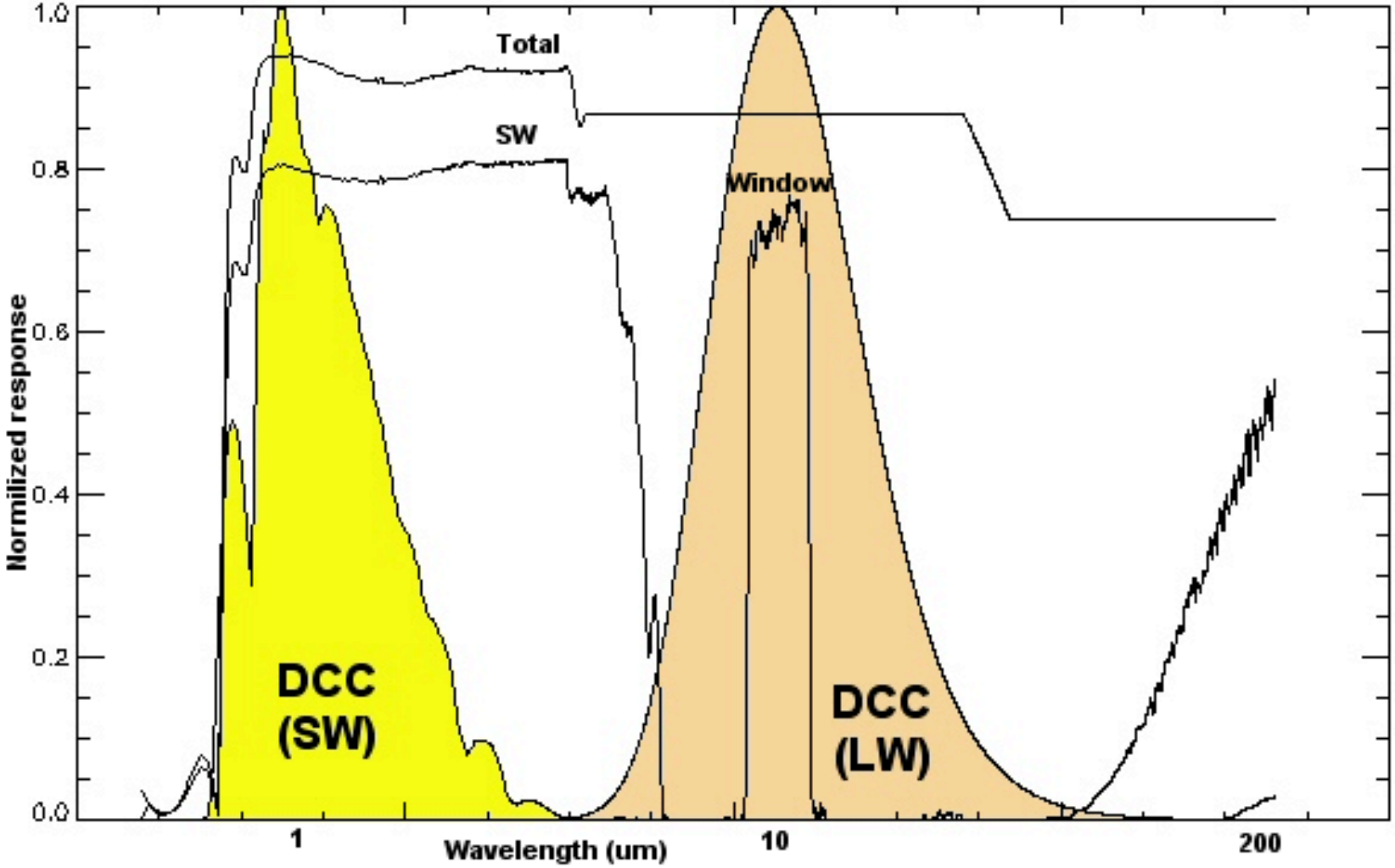

Aqua Allsky Nighttime LW Un-filtered Direct Compare
100*(FM4-FM3)/FM3
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
Edition2
Edition3 beta
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05

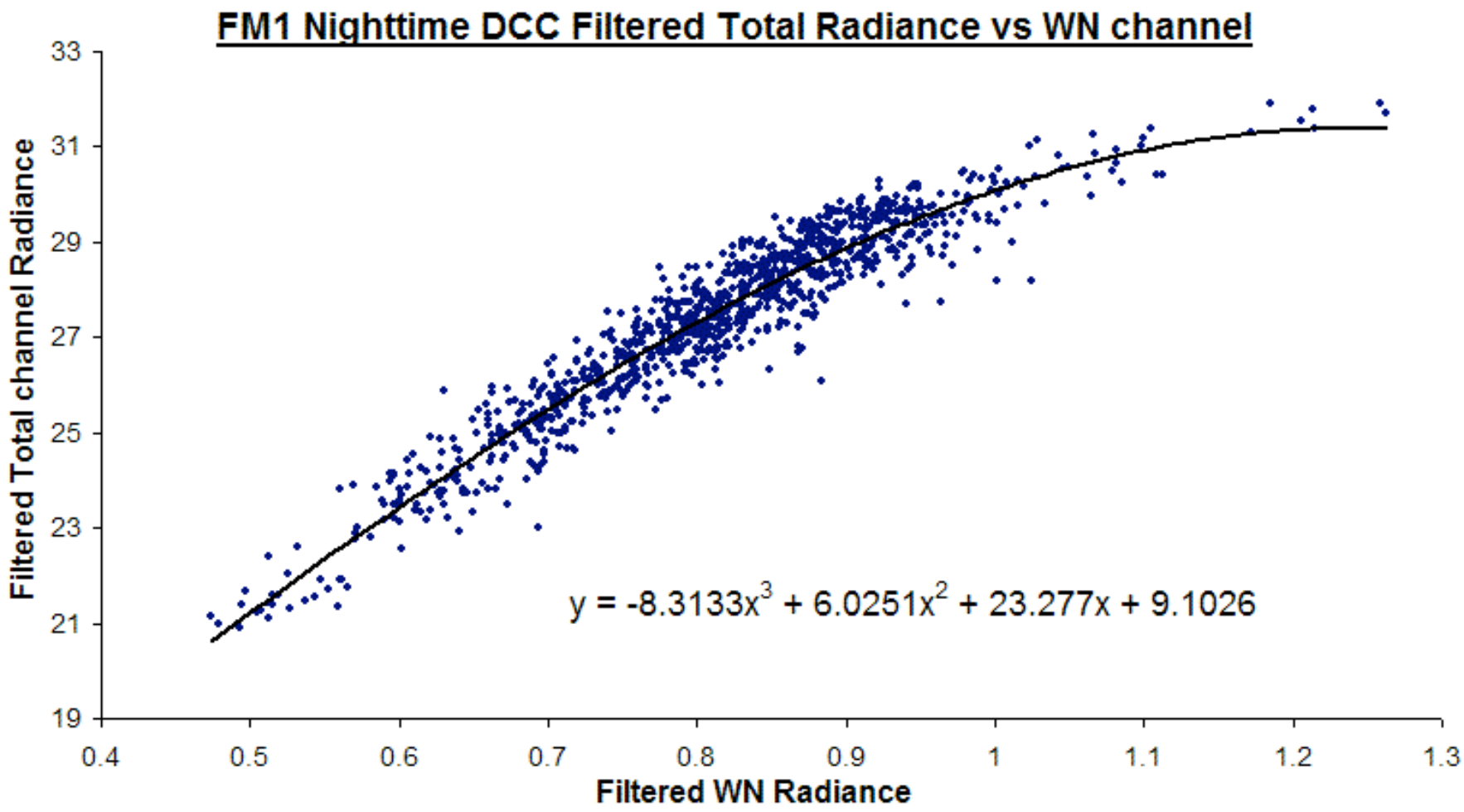

Terra Allsky Nighttime WN Un-filtered Direct Compare
100*(FM2-FM1)/FM1
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
Edition2
Edition3 beta
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05

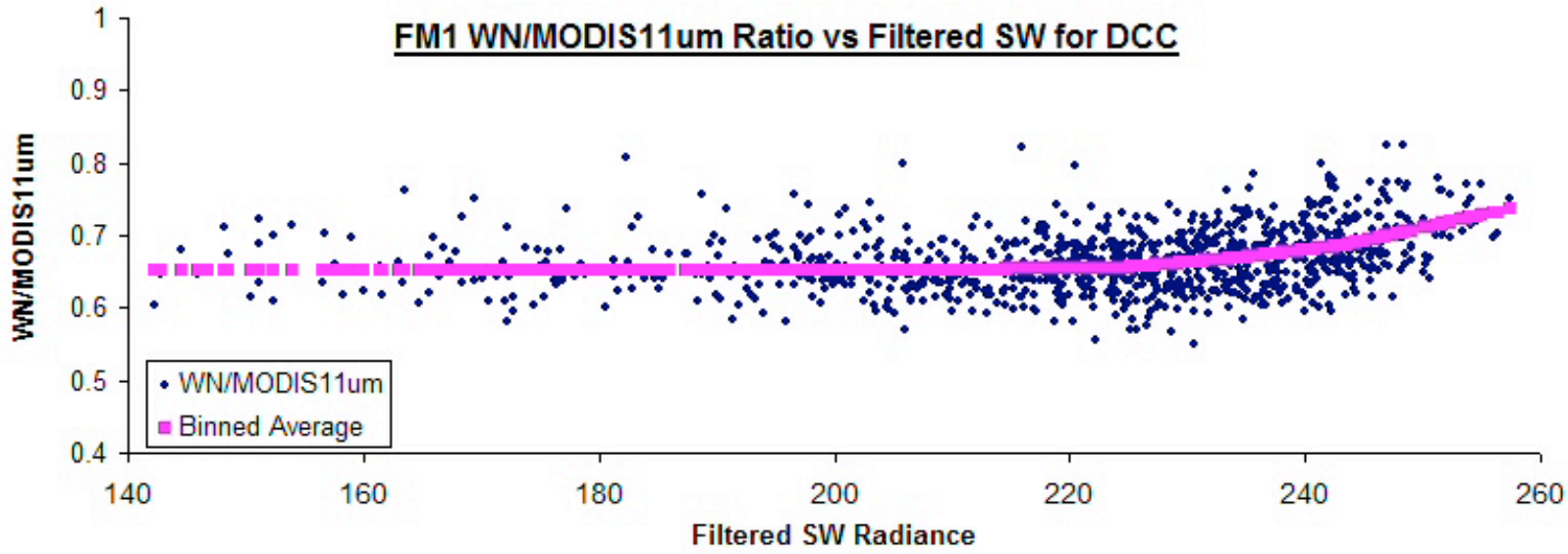

Aqua Allsky Nighttime WN Un-filtered Direct Compare
100*(FM4-FM3)/FM3
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
Edition2
Edition3 beta
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05

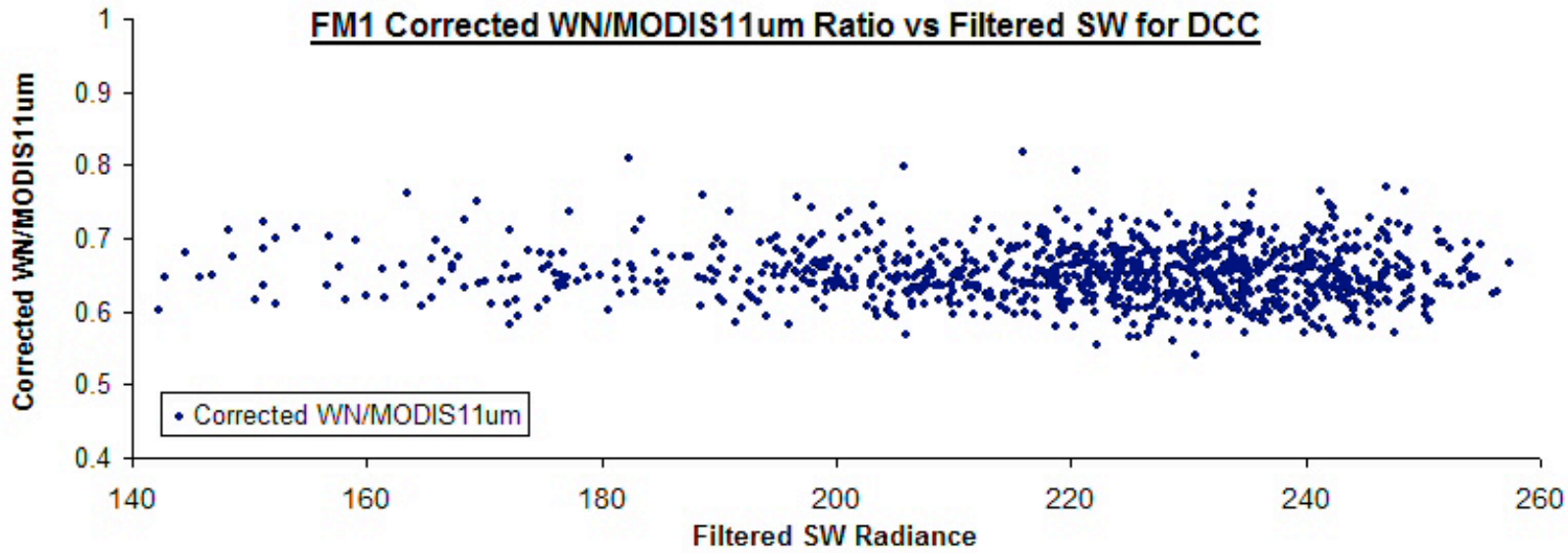
LW Ed3 beta calibration: Daytime Balancing between SW and Total Channels

Re-analysis of 3 channel Deep Convective Cloud balancing to determine SW potion of Total channel response

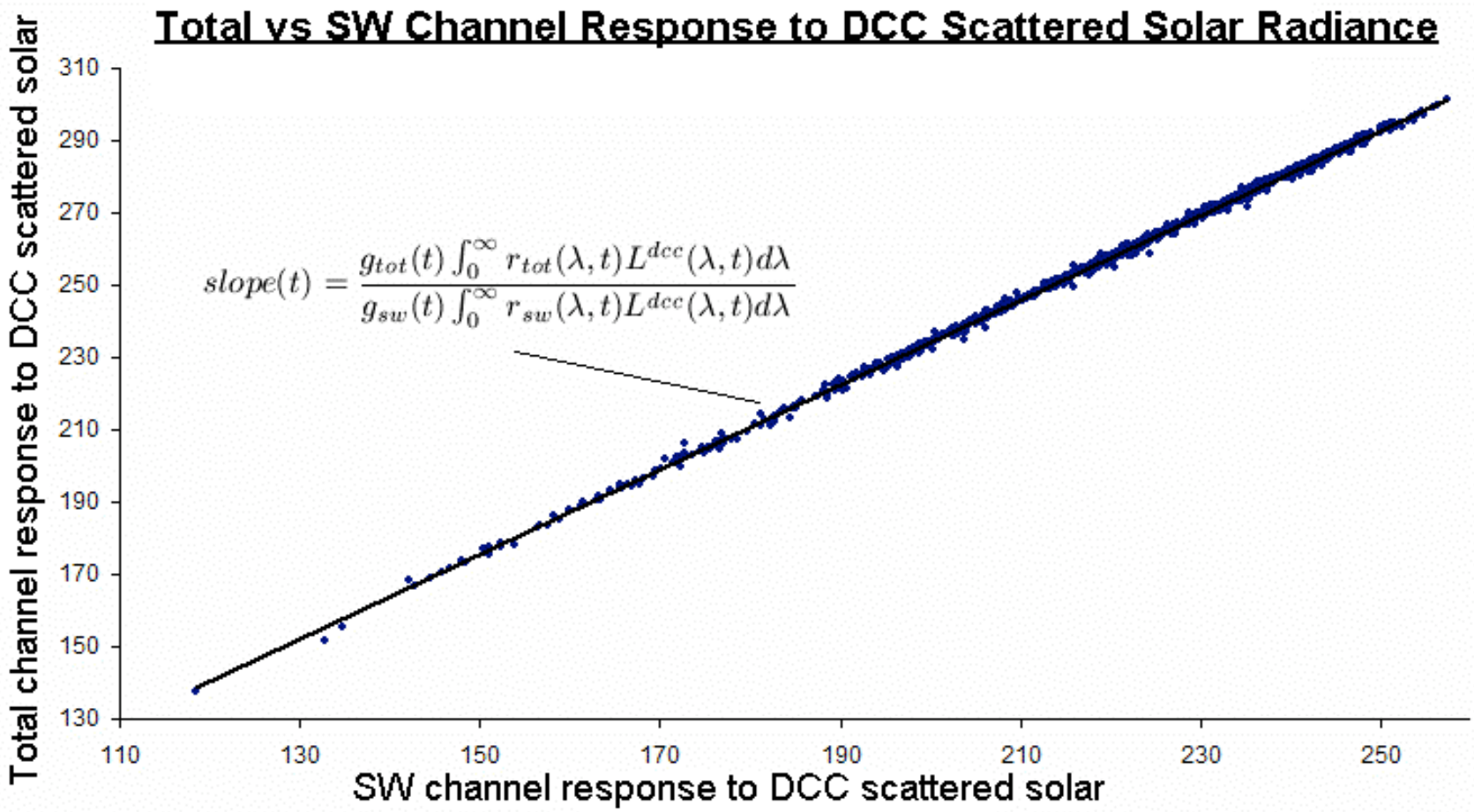


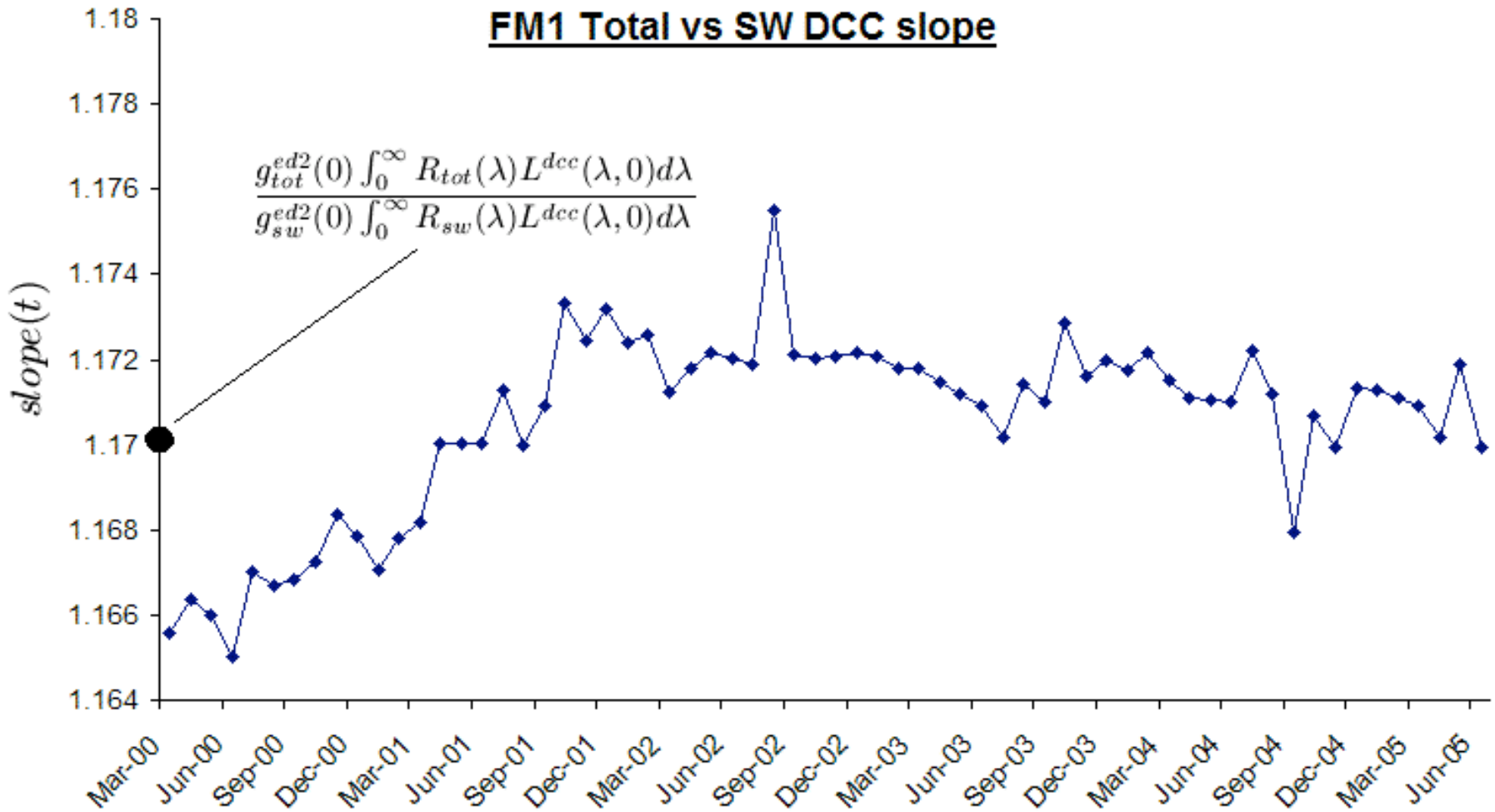

FM1 Nighttime DCC Filtered Total Radiance vs WN channel
Filtered Total channel Radiance
33
31
29
27
25
23
21
19
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
Filtered WN Radiance
y = -8.3133x3 + 6.0251x2 + 23.277x + 9.1026

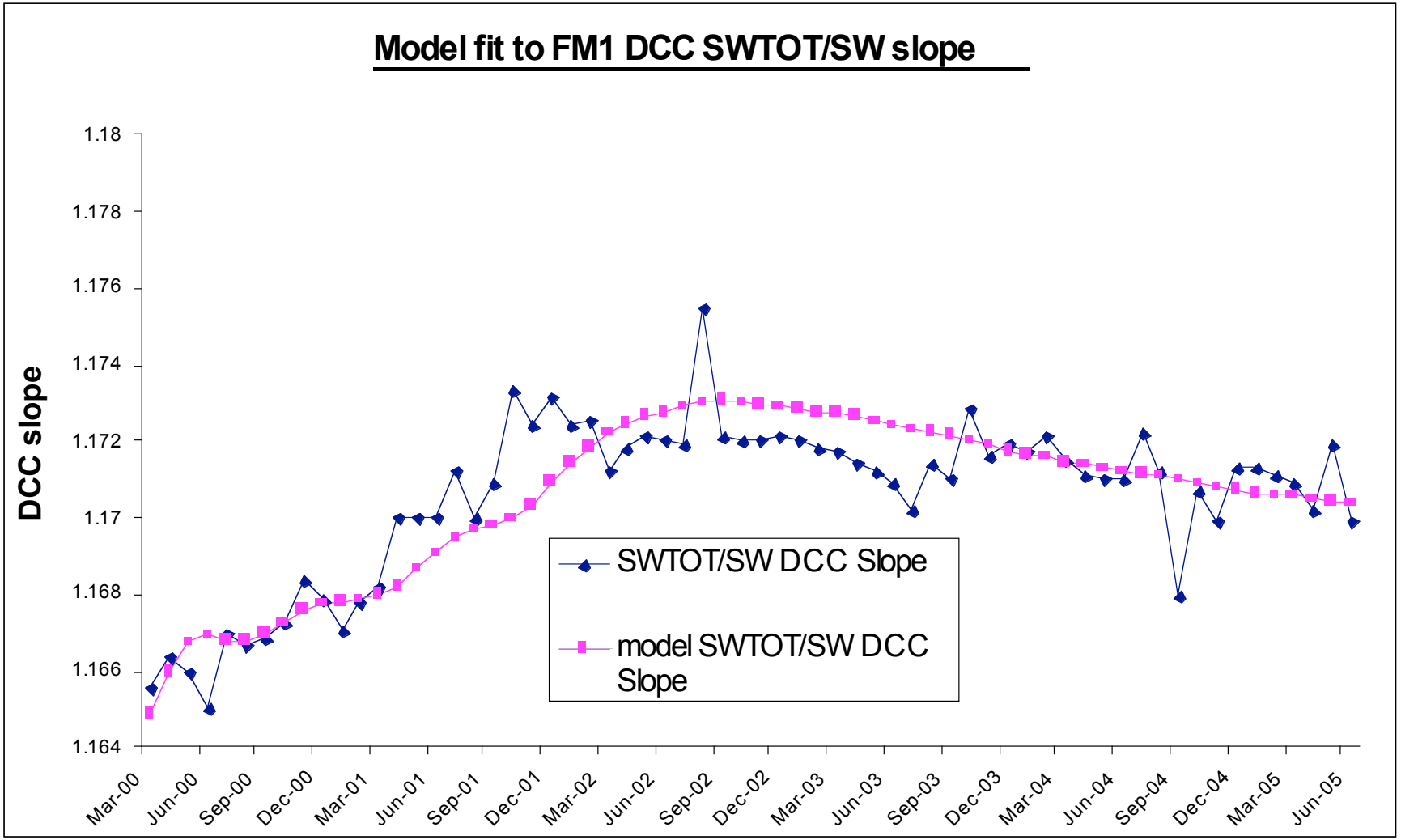

FM1 WN/MODIS11um Ratio vs Filtered SW for DCC
WN/MODIS11um
1
0.9
0.8
0.7
0.6
0.5
0.4
140
160
180
200
220
240
260
Filtered SW Radiance
WN/MODIS11um
Binned Average

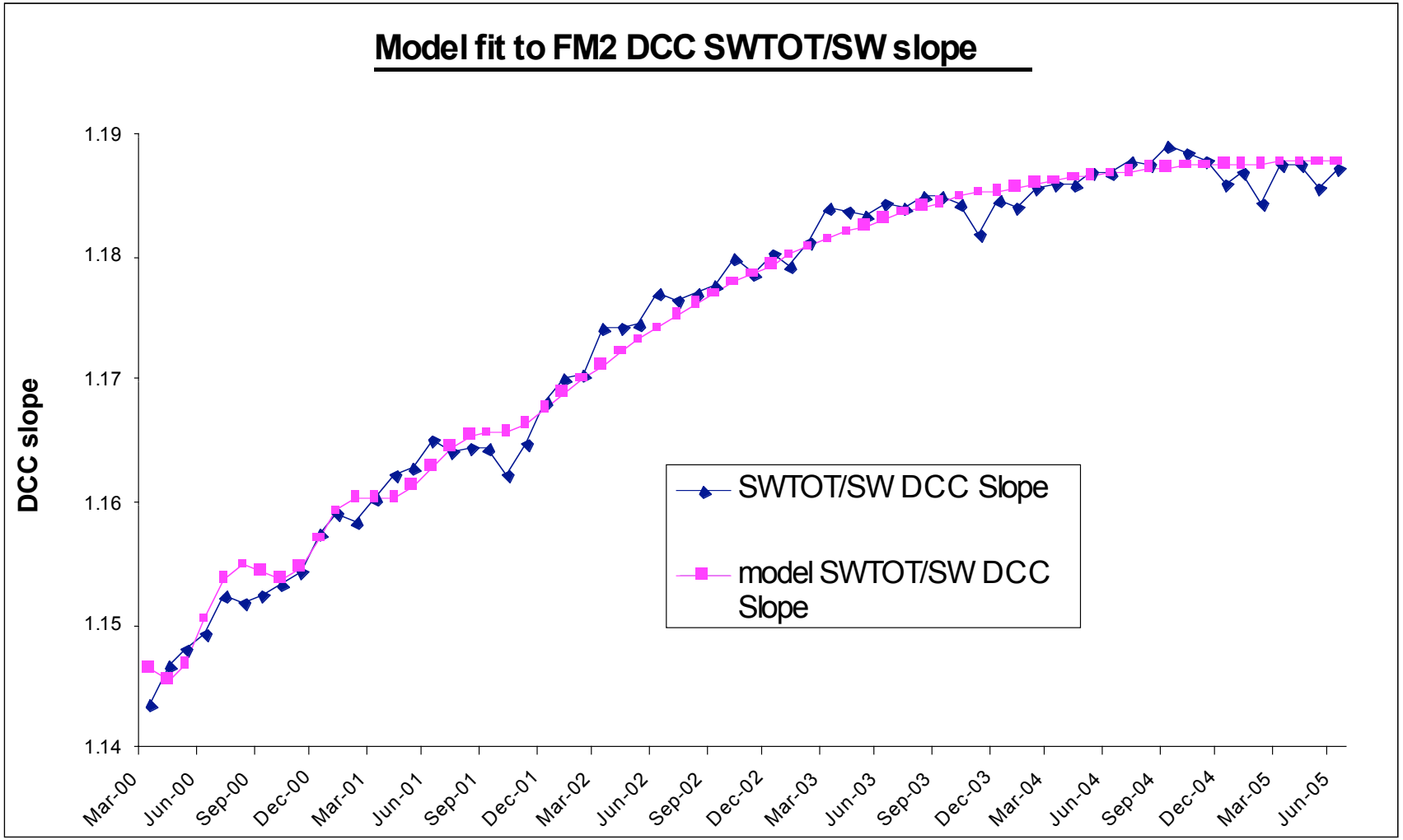

FM1 Corrected WN/MODIS11um Ratio vs Filtered SW for DCC
Corrected WN/MODIS11um
1
0.9
0.8
0.7
0.6
0.5
0.4
140
160
180
200
220
240
260
Filtered SW Radiance
Corrected WN/MODIS11um

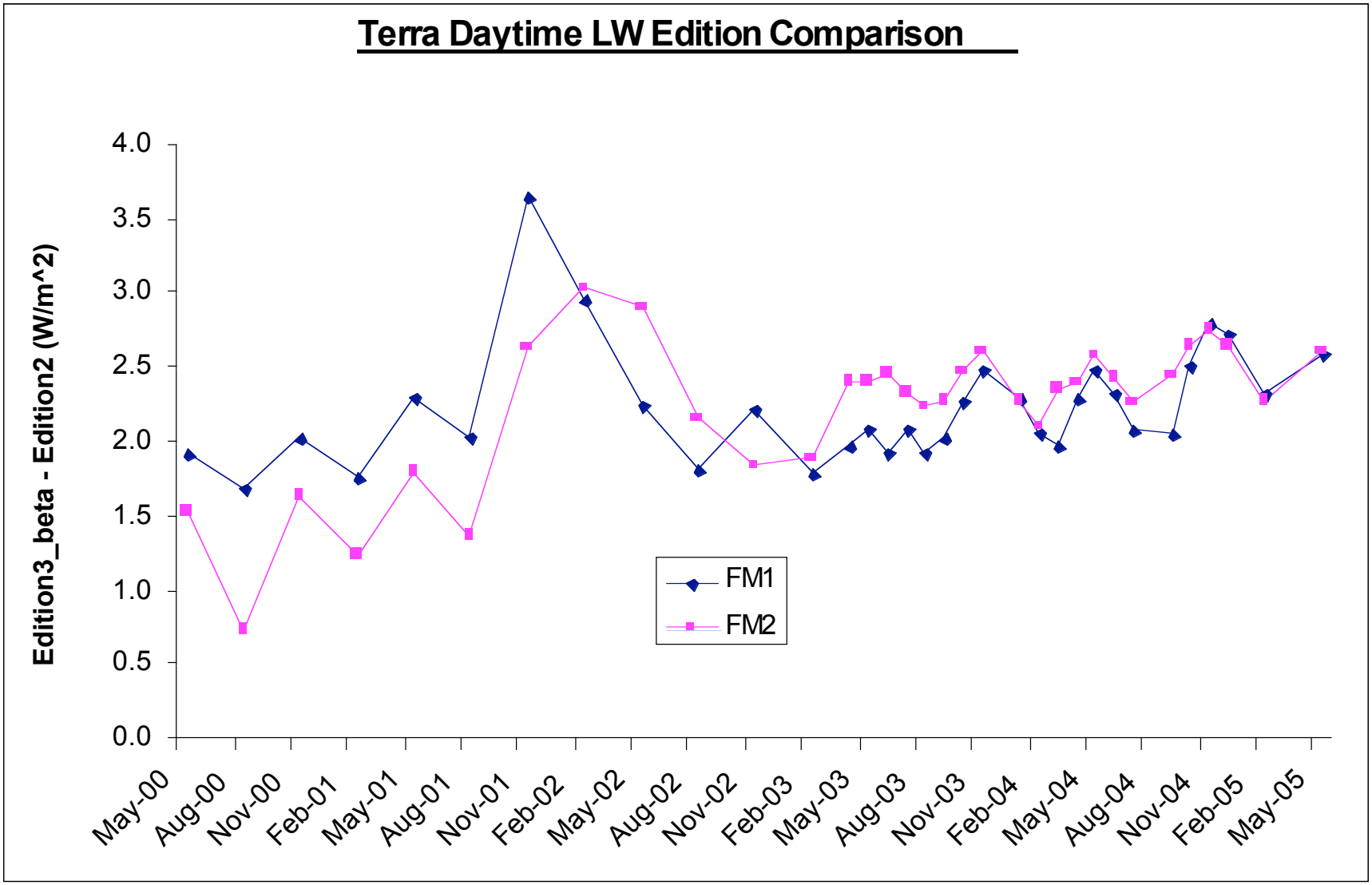
During day use window channel to remove the filtered LW DCC signal from filtered radiances. Compare Total and SW response to DCC SW radiance:

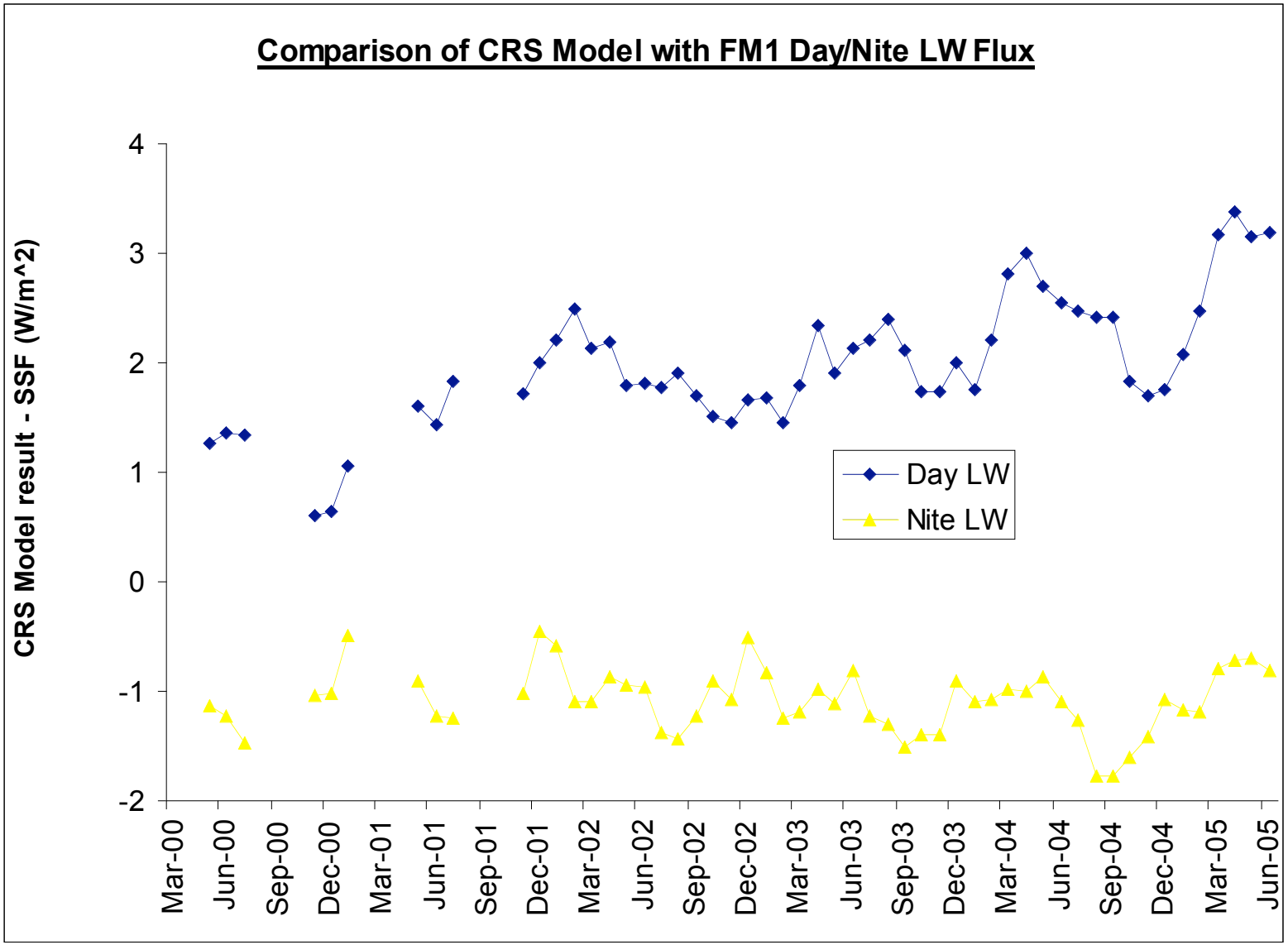


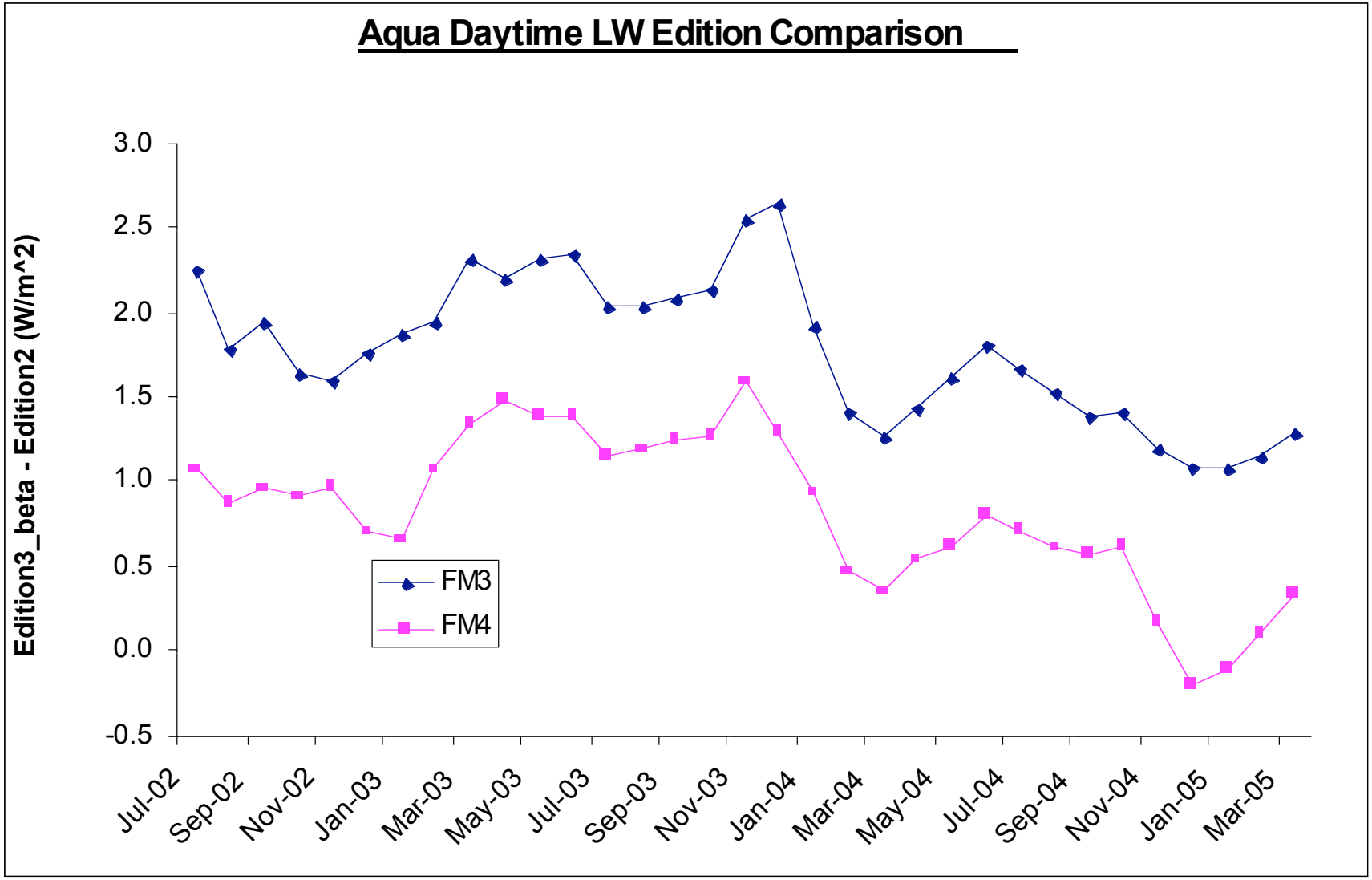

FM1 Total vs SW DCC slope
$\frac{g_{tot}^{ed2}(0)\int_0^\infty R_{tot}(\lambda)L^{dcc}(\lambda,0)d\lambda}{g_{sw}^{ed2}(0)\int_0^\infty R_{sw}(\lambda)L^{dcc}(\lambda,0)d\lambda}$
slope(t)
1.18
1.178
1.176
1.174
1.172
1.17
1.168
1.166
1.164
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05

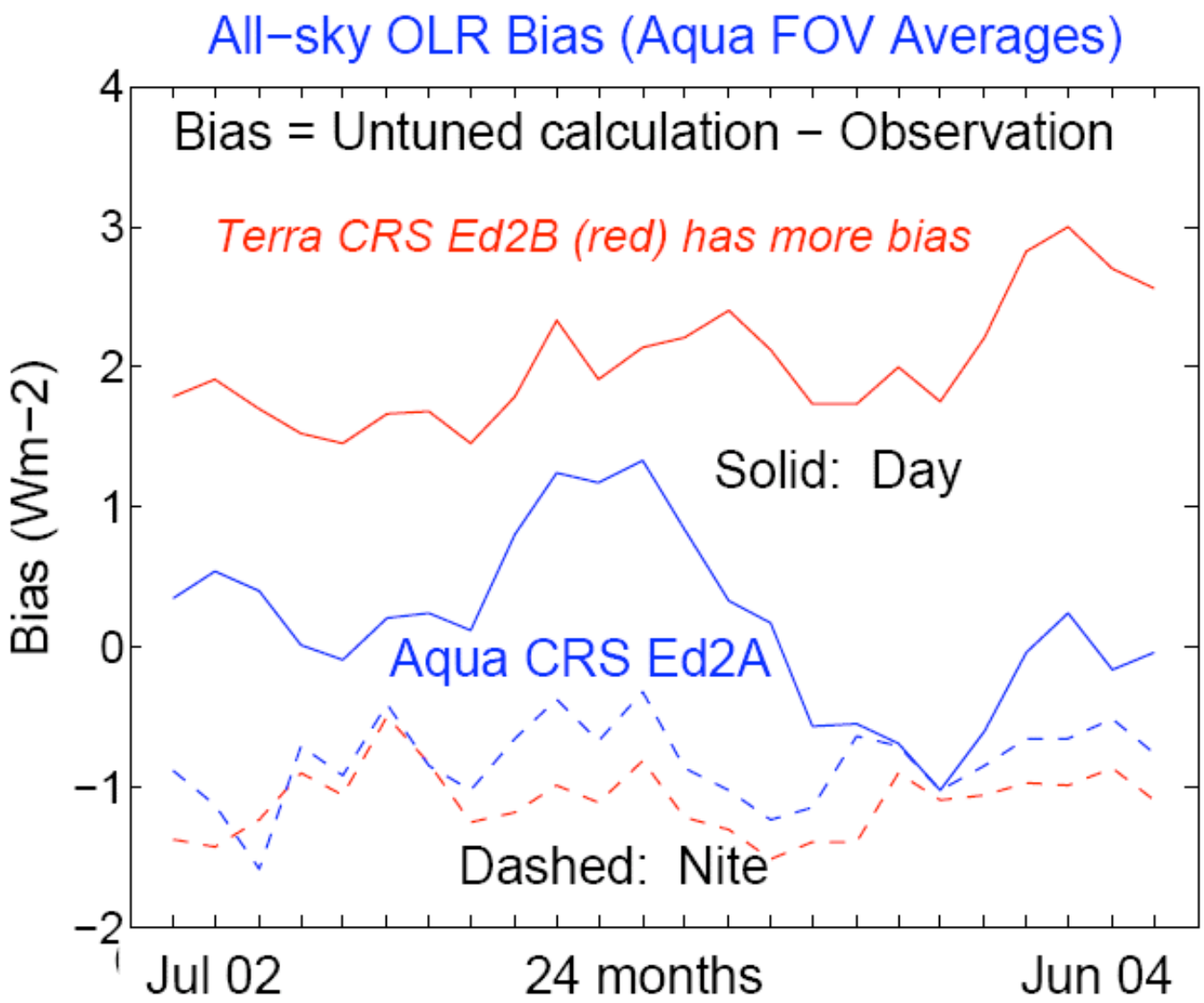

Model fit to FM1 DCC SWTOT/SW slope
DCC slope
1.18
1.178
1.176
1.174
1.172
1.17
1.168
1.166
1.164
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05
SWTOT/SW DCC Slope
model SWTOT/SW DCC Slope


Model fit to FM2 DCC SWTOT/SW slope
DCC slope
1.19
1.18
1.17
1.16
1.15
1.14
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05
SWTOT/SW DCC Slope
model SWTOT/SW DCC Slope

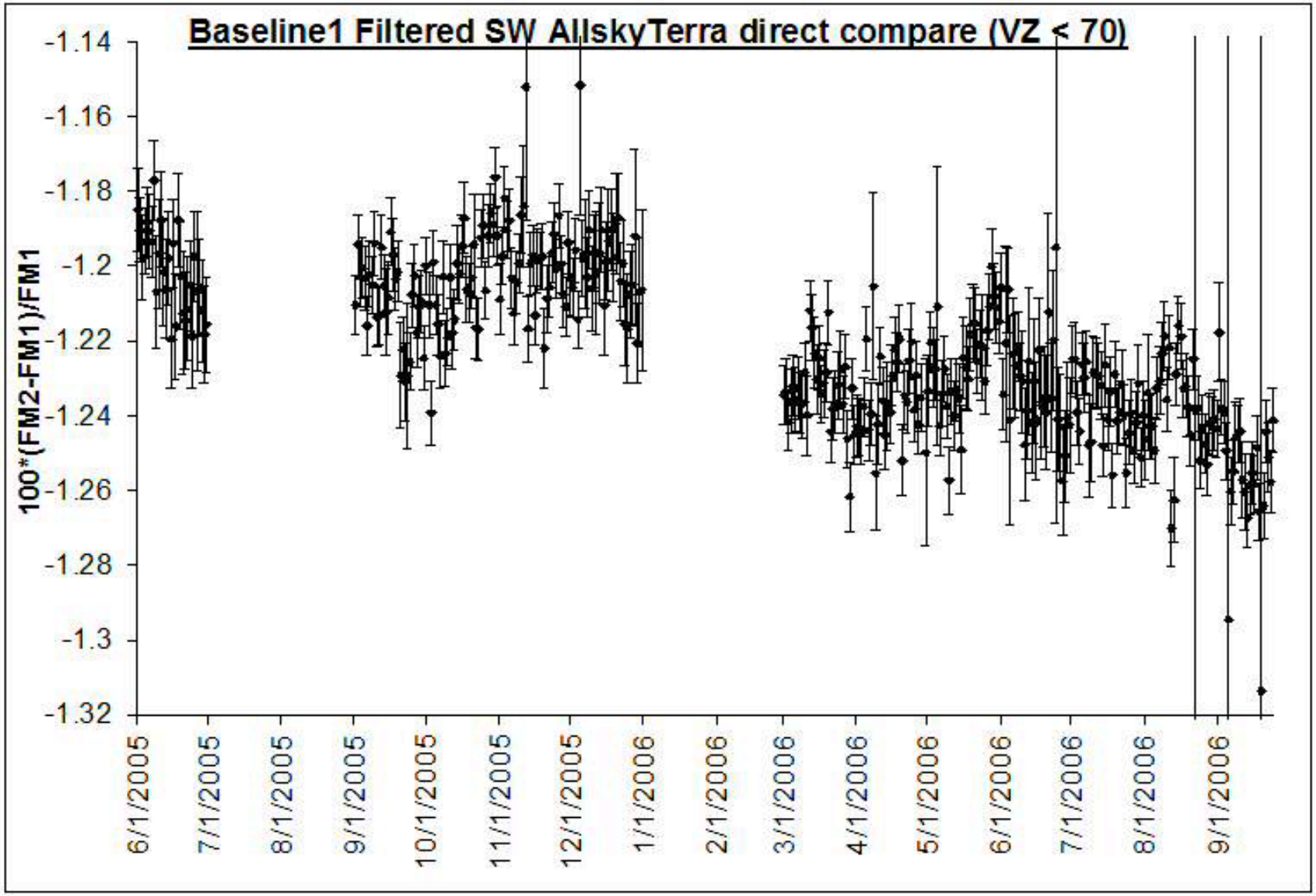

Terra Daytime LW Edition Comparison
Edition3_beta - Edition2 (W/m^2)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
May-00
Aug-00
Nov-00
Feb-01
May-01
Aug-01
Nov-01
Feb-02
May-02
Aug-02
Nov-02
Feb-03
May-03
Aug-03
Nov-03
Feb-04
May-04
Aug-04
Nov-04
Feb-05
May-05
FM1
FM2

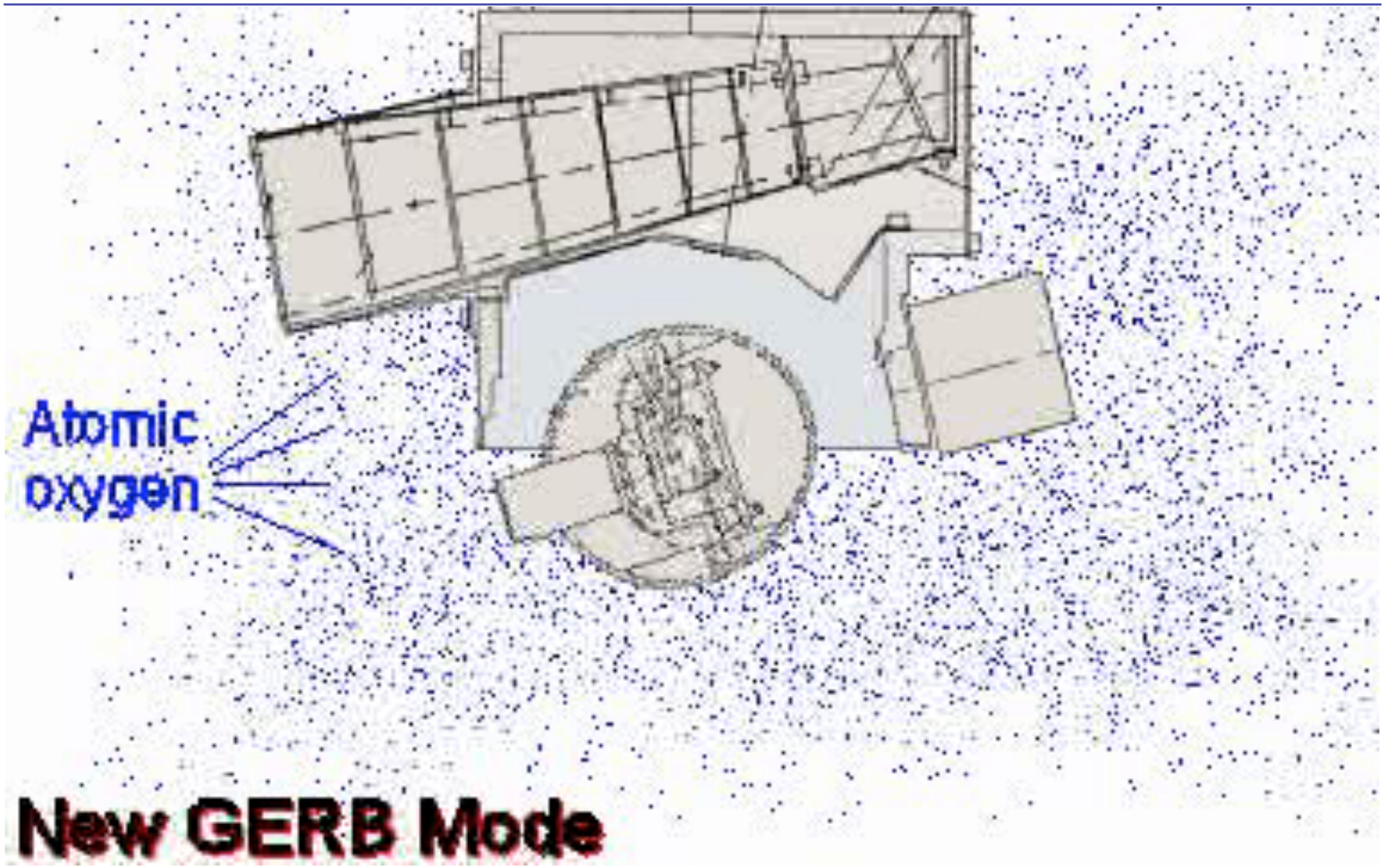

Comparison of CRS Model with FM1 Day/Nite LW Flux
CRS Model result - SSF (W/m^2)
4
3
2
1
0
-1
-2
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05
Day LW
Nite LW

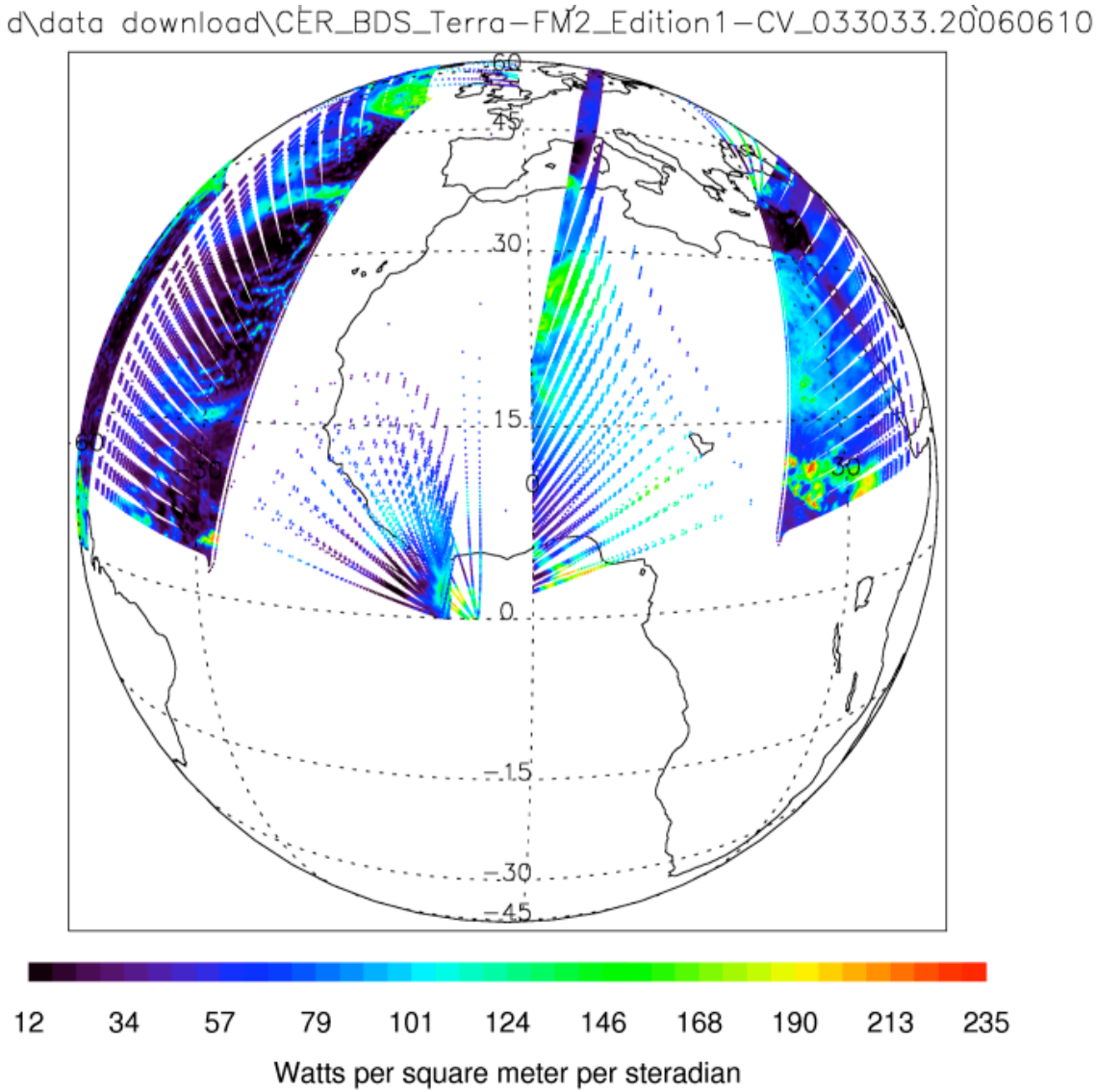

Aqua Daytime LW Edition Comparison
Edition3_beta - Edition2 (W/m^2)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
FM3
FM4
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05


All−sky OLR Bias (Aqua FOV Averages)
Bias = Untuned calculation − Observation
Terra CRS Ed2B (red) has more bias
Solid: Day
Aqua CRS Ed2A
Dashed: Nite
Bias (Wm−2)
4
3
2
1
0
−1
−2
Jul 02
24 months
Jun 04

Edition 3 Calibration Beyond 2006

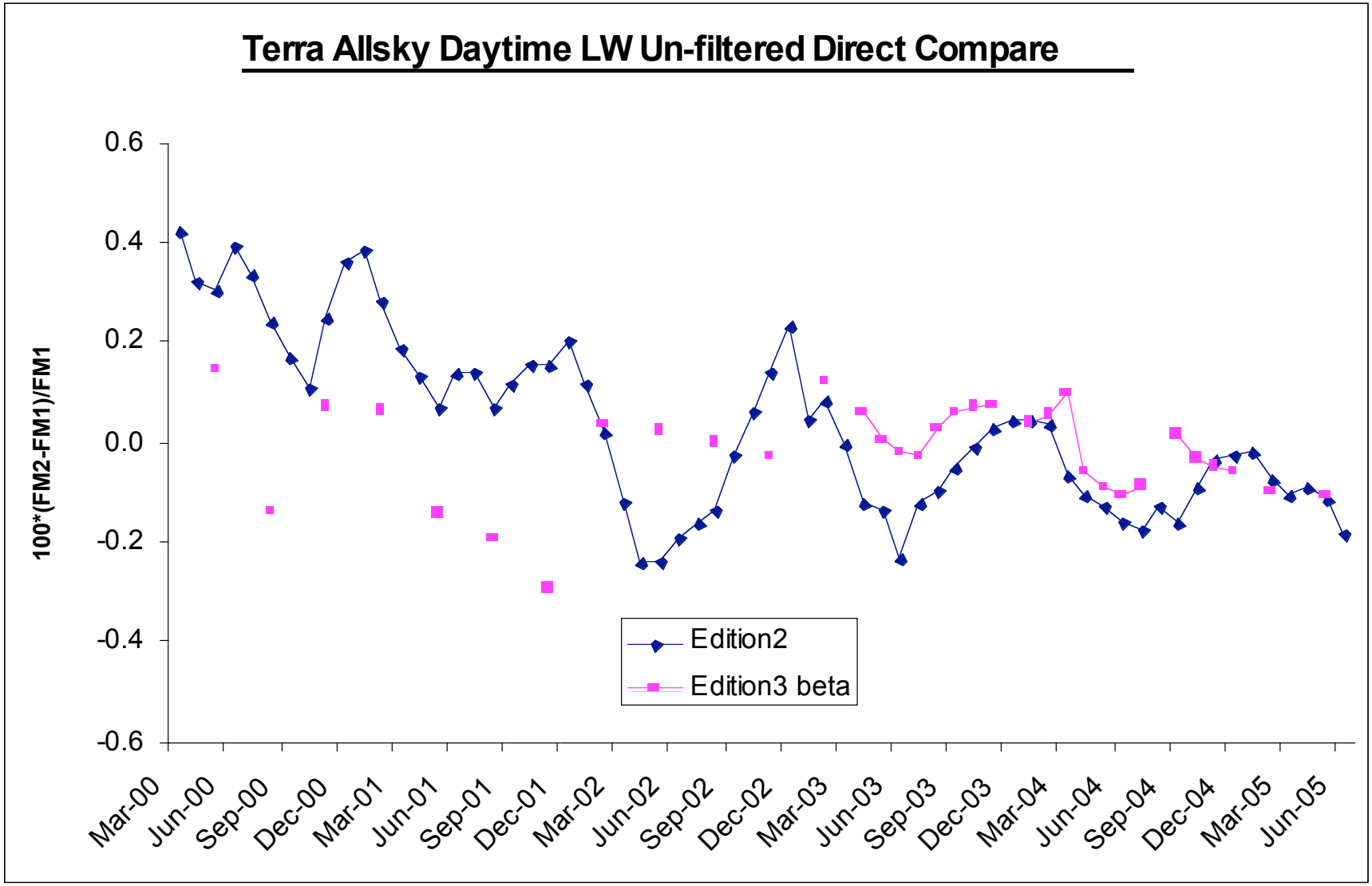

Baseline1 Filtered SW AllskyTerra direct compare (VZ < 70)
100*(FM2-FM1)/FM1
-1.14
-1.16
-1.18
-1.2
-1.22
-1.24
-1.26
-1.28
-1.3
-1.32
6/1/2005
7/1/2005
8/1/2005
9/1/2005
10/1/2005
11/1/2005
12/1/2005
1/1/2006
2/1/2006
3/1/2006
4/1/2006
5/1/2006
6/1/2006
7/1/2006
8/1/2006
9/1/2006

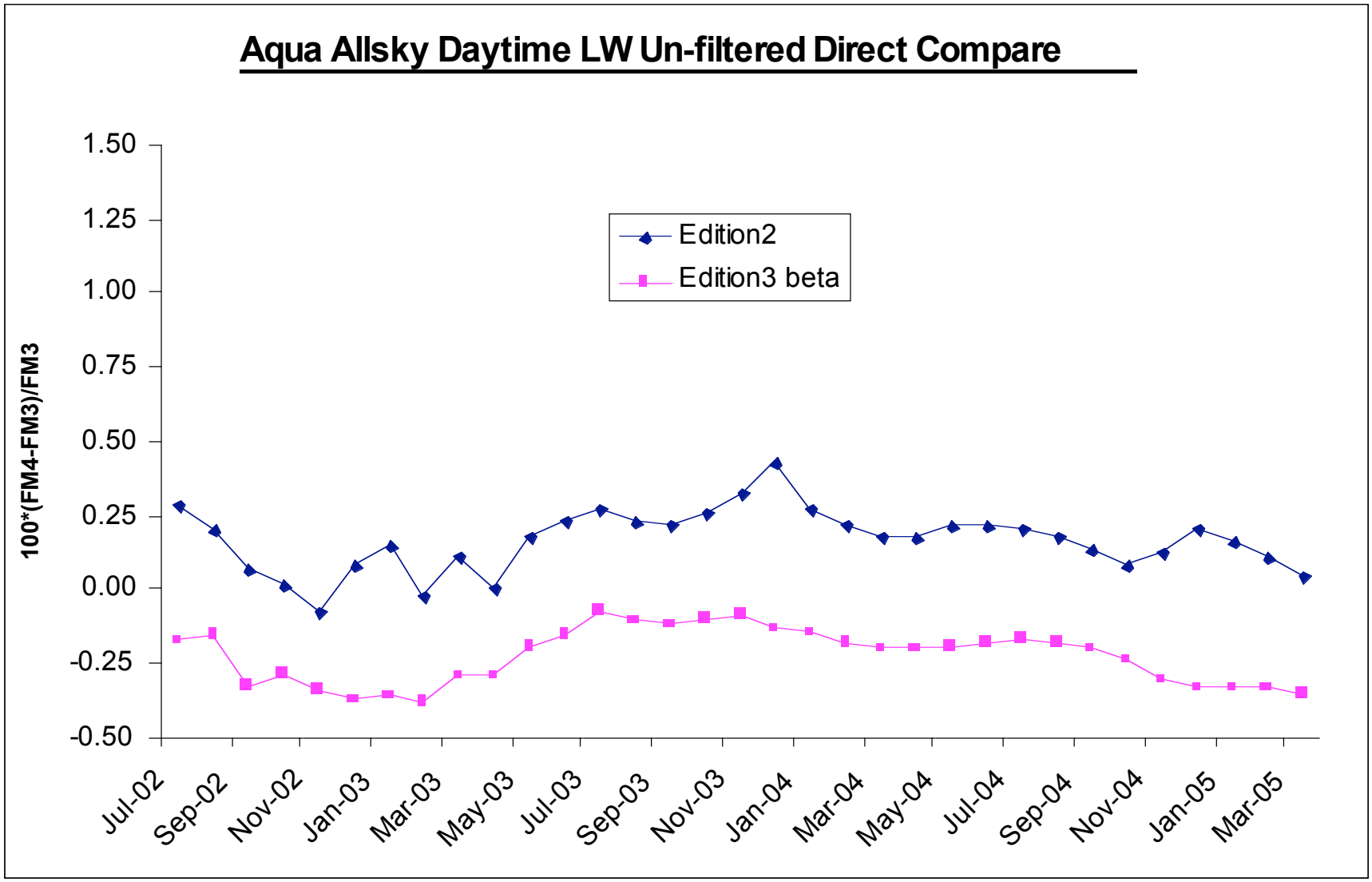

Atomic
oxygen
New GERB Mode


d\data download\CER_BDS_Terra-FM2_Edition1-CV_033033.20060610
60
45
30
15
0
-15
-30
-45
12
34
57
79
101
124
146
168
190
213
235
Watts per square meter per steradian

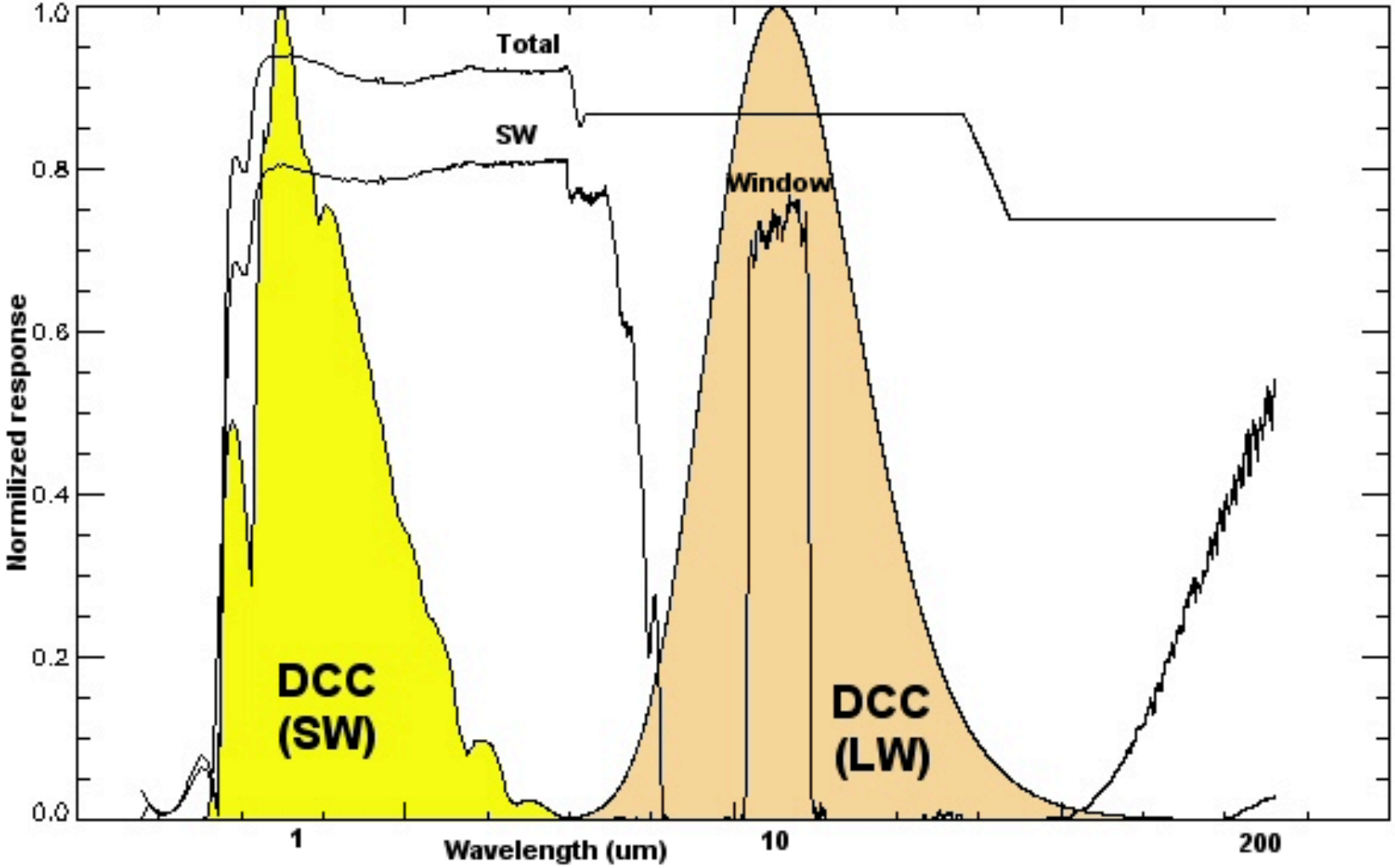
Thoughts for Comment

- How stable is DCC albedo?
- The darkening model appears to be successful at providing good stability to CERES inversion but does not have fully solid physical basis (e.g. Terra SW 4% gain change). Development continues.
- Do we want all CERES instruments on same radiometric scale (Terra/Aqua using DCC), how do we do it?
- Is the significant absolute changes to daytime LW for all CERES data realistic?


Terra Allsky Daytime LW Un-filtered Direct Compare
100*(FM2-FM1)/FM1
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05
Edition2
Edition3 beta


Aqua Allsky Daytime LW Un-filtered Direct Compare
100*(FM4-FM3)/FM3
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
Edition2
Edition3 beta
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05

Re-analysis of 3 channel Deep Convective Cloud balancing to determine SW potion of Total channel response



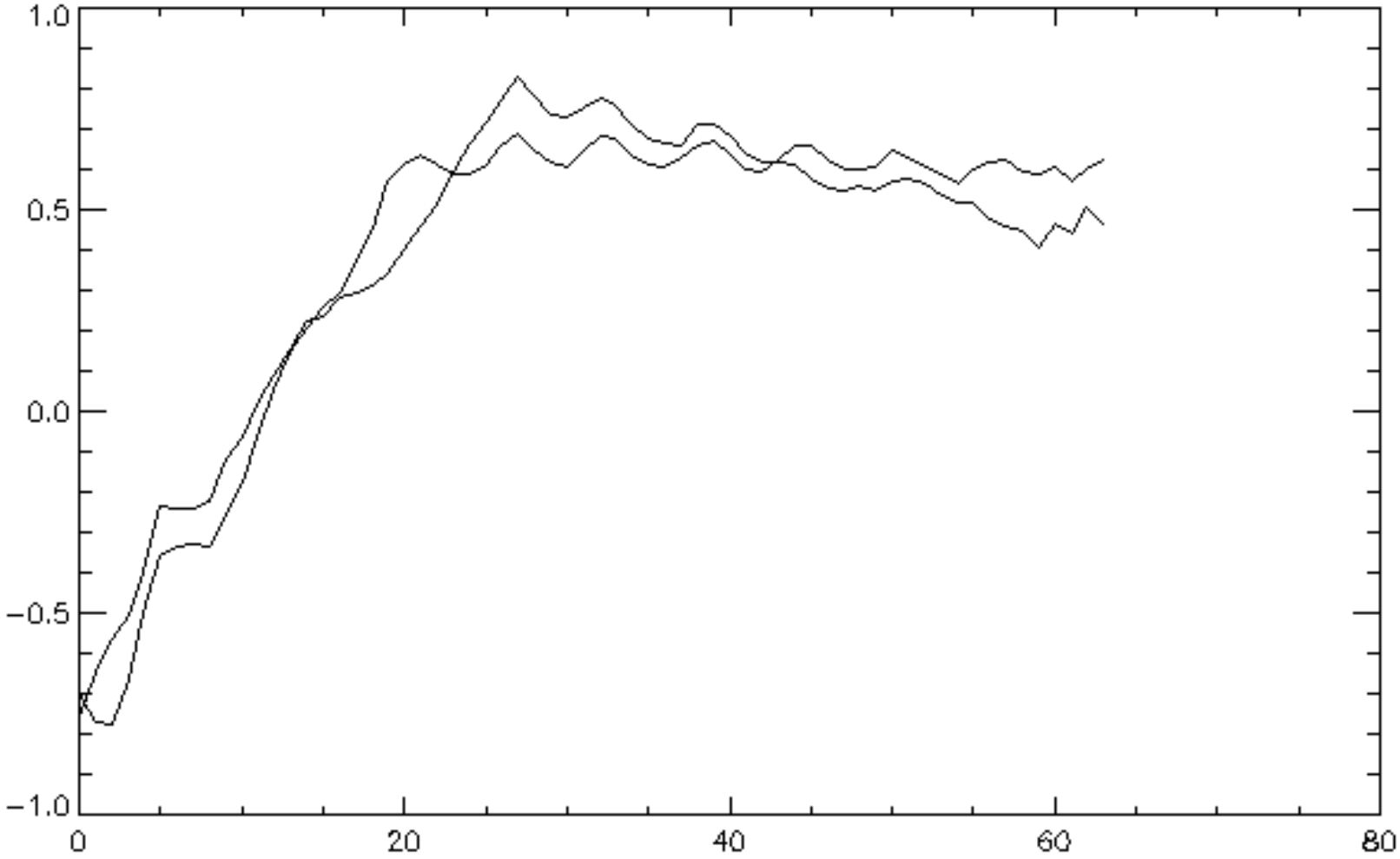
$$LF^i_{tot}(NIGHT) = LF^i_{lw}$$

$$\begin{aligned} LWR &= \frac{LF^2_{tot}(NIGHT)}{LF^1_{tot}(NIGHT)} \\ &= \frac{LF^2_{lw}}{LF^1_{lw}} \end{aligned}$$

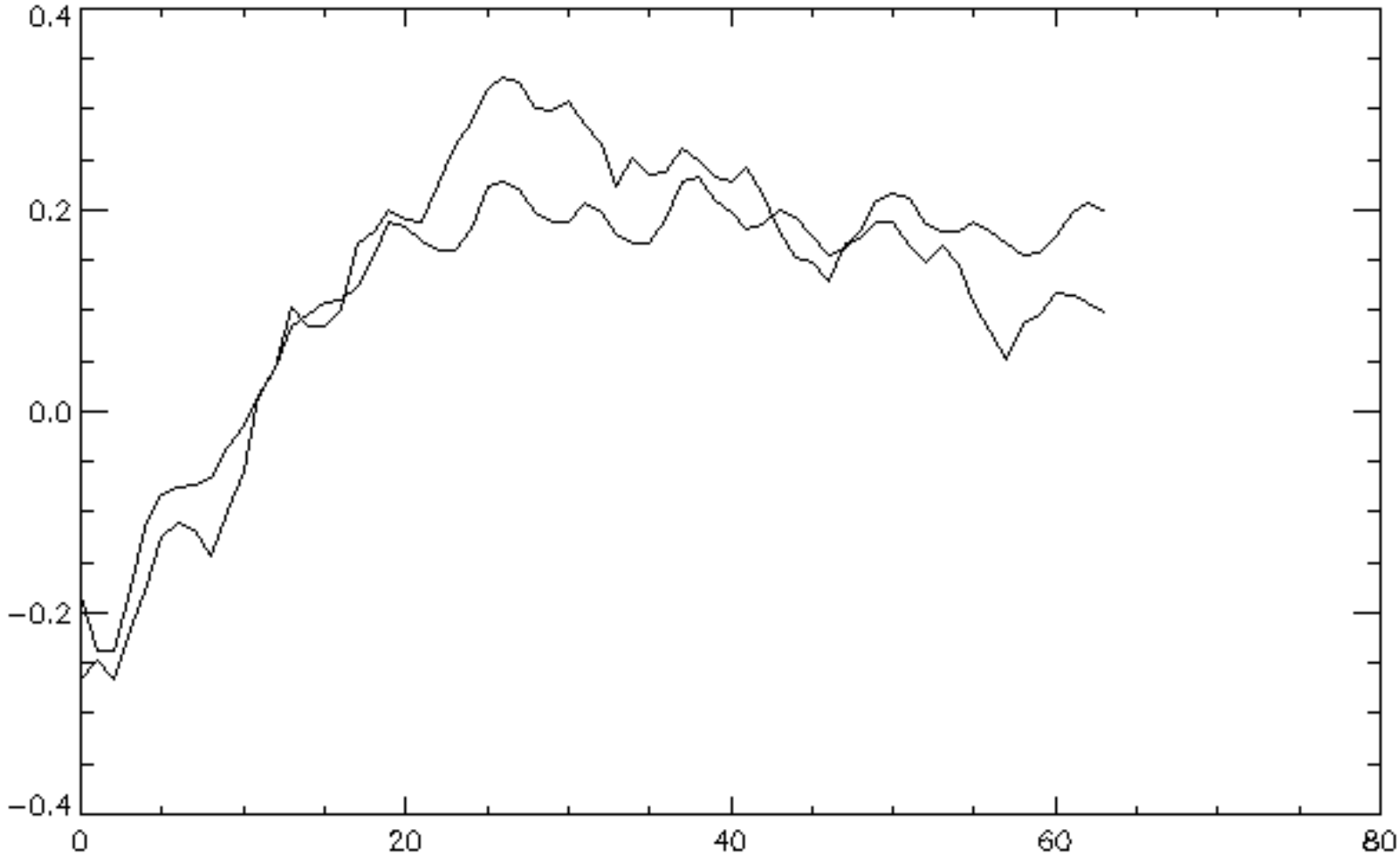
$$LF^i_{tot}(DAY) = LF^i_{sw} + LF^i_{lw}$$

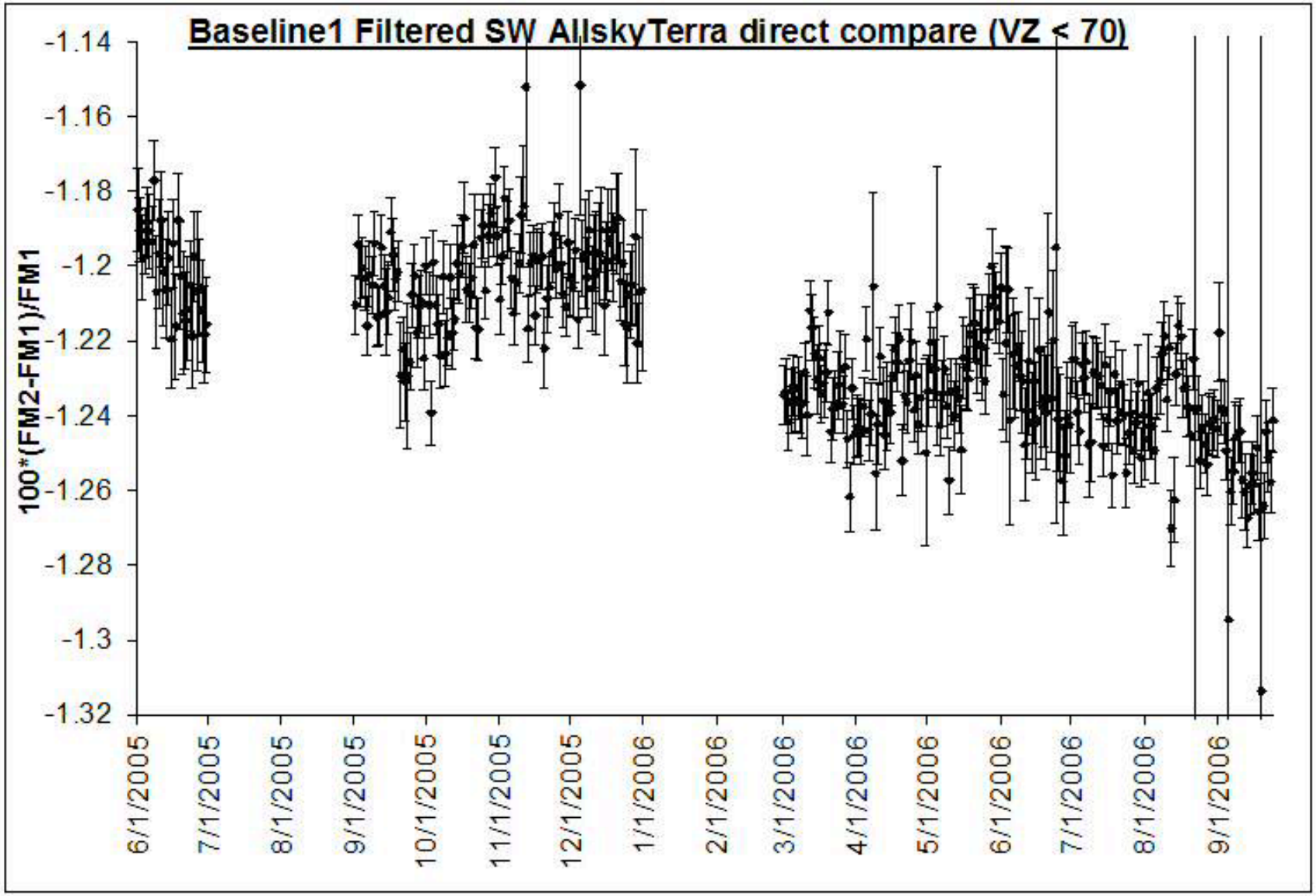
$$\begin{aligned} TOTSWDC &= LF^2_{tot}(DAY) - LWR \times LF^1_{tot}(DAY) \\ &= LF^2_{sw} - LWR \times LF^1_{sw} \end{aligned}$$

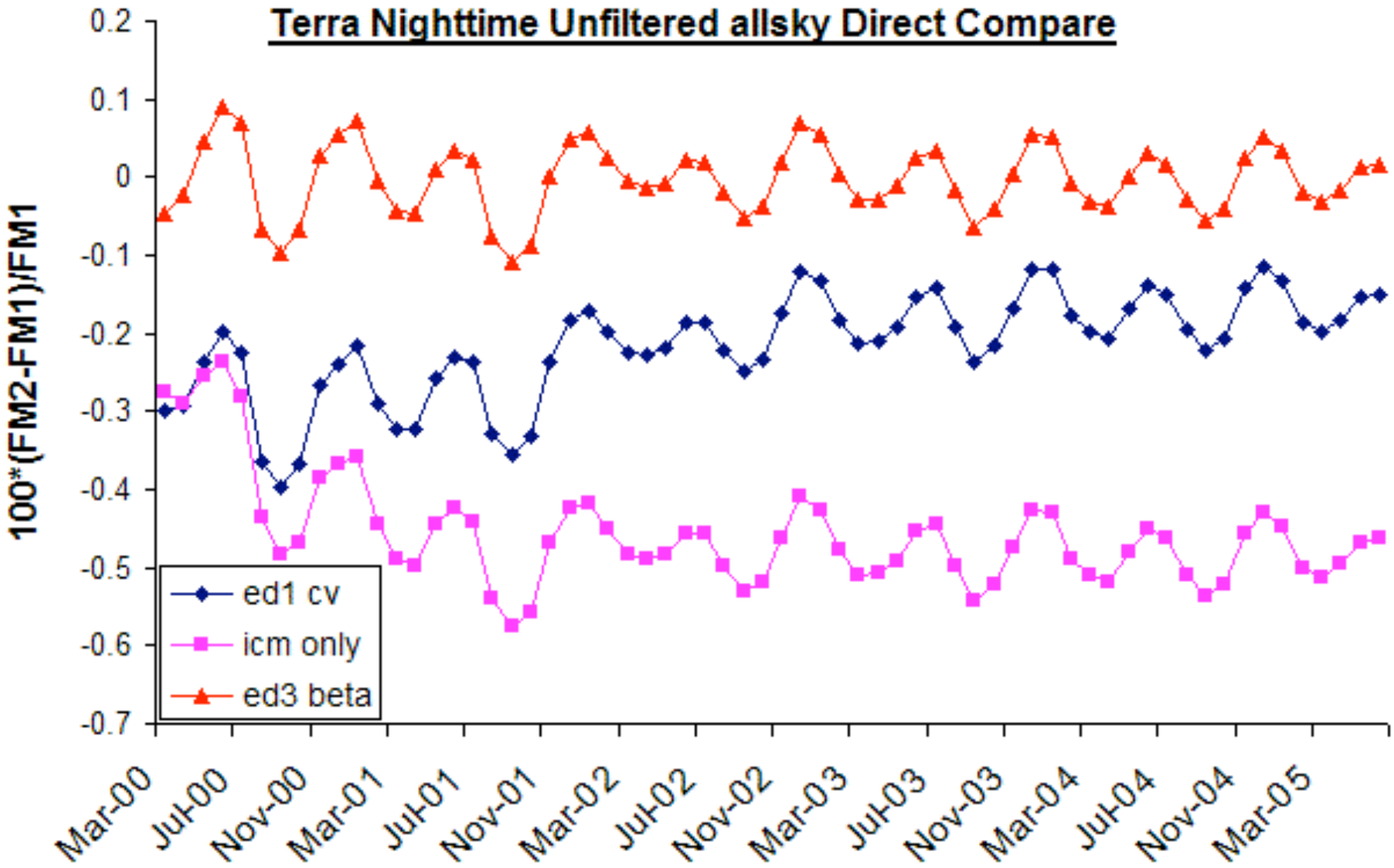
allsky

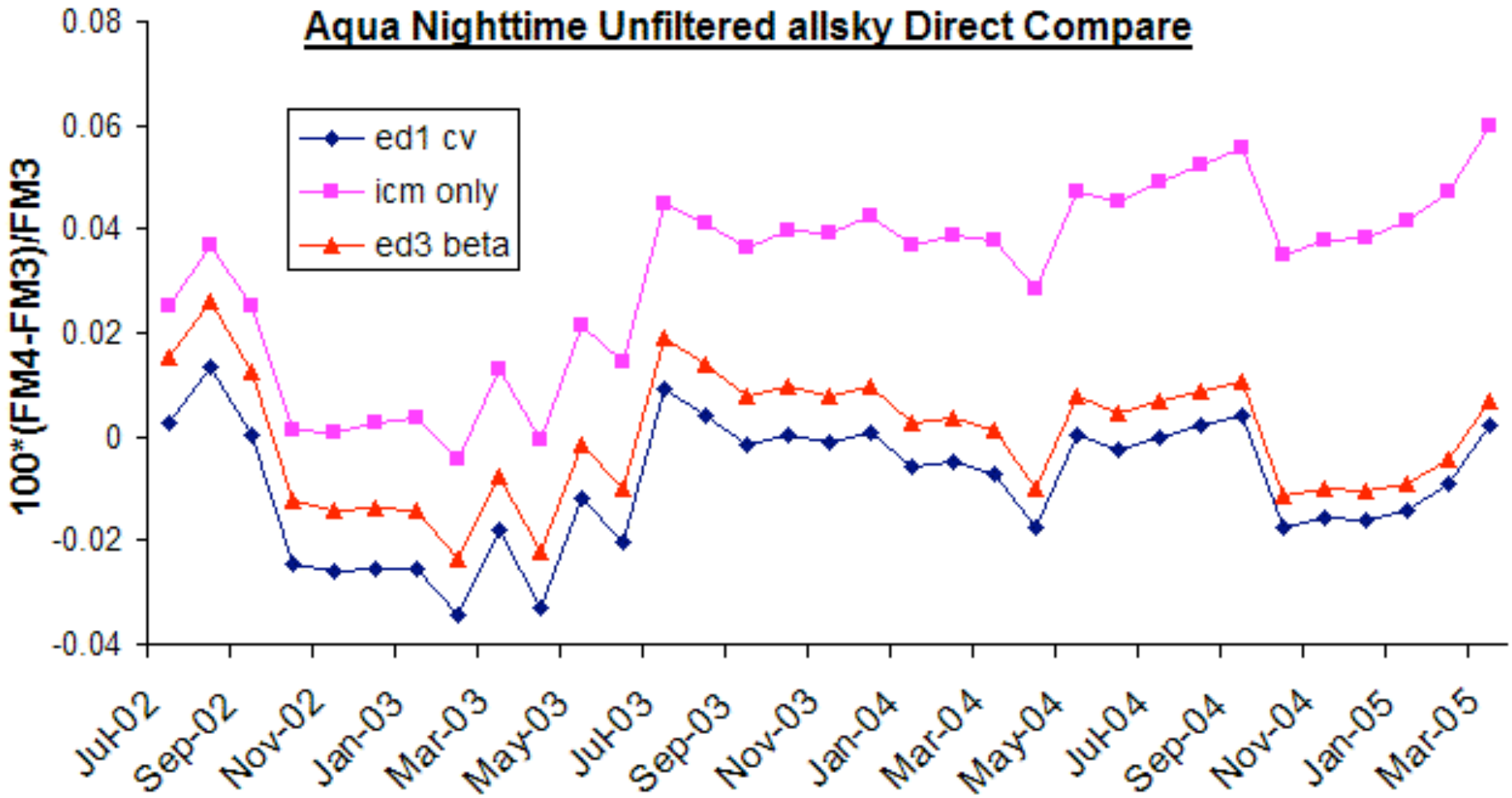


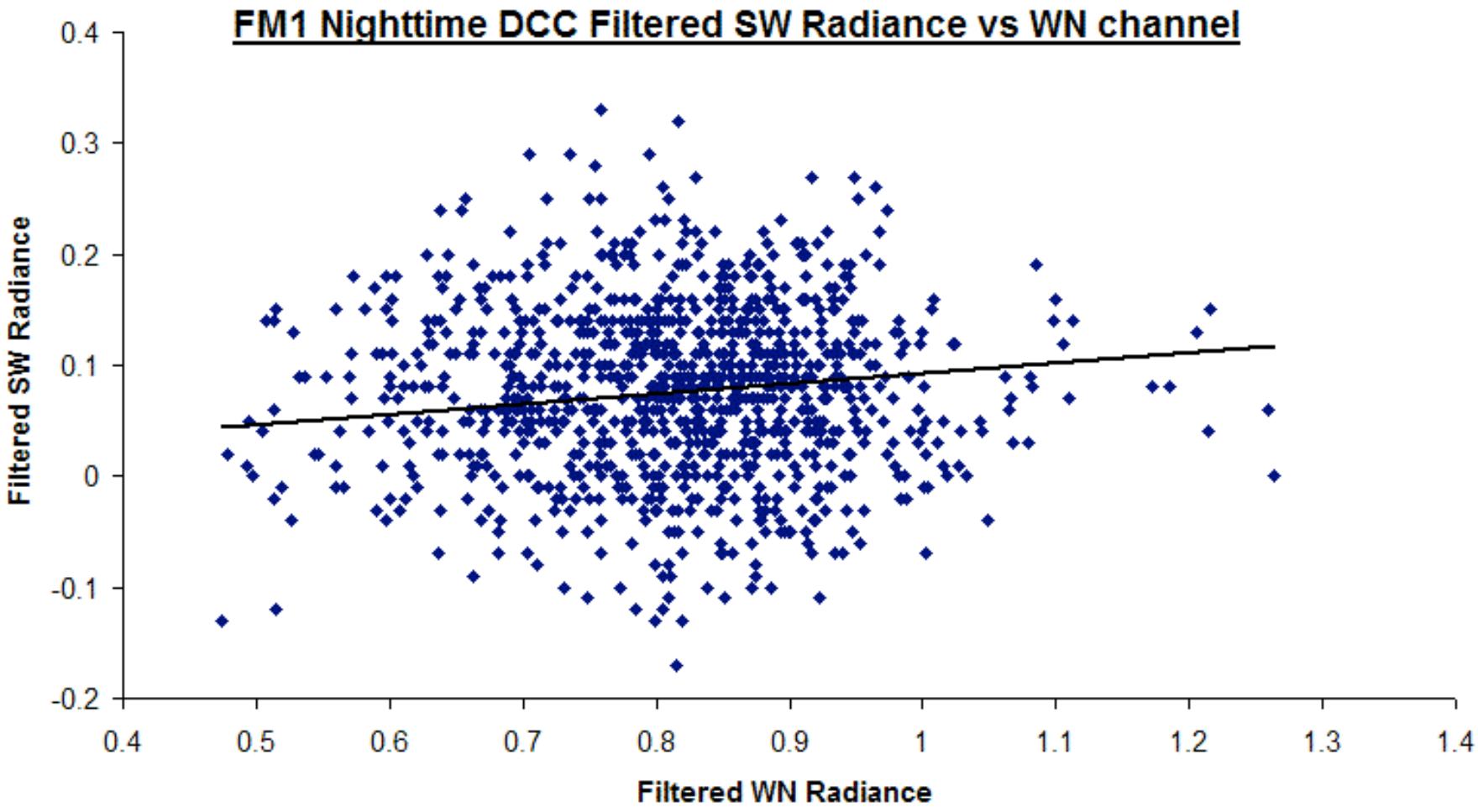
Clear ocean




Baseline1 Filtered SW AllskyTerra direct compare (VZ < 70)
100*(FM2-FM1)/FM1
-1.14
-1.16
-1.18
-1.2
-1.22
-1.24
-1.26
-1.28
-1.3
-1.32
6/1/2005
7/1/2005
8/1/2005
9/1/2005
10/1/2005
11/1/2005
12/1/2005
1/1/2006
2/1/2006
3/1/2006
4/1/2006
5/1/2006
6/1/2006
7/1/2006
8/1/2006
9/1/2006


Terra Nighttime Unfiltered allsky Direct Compare
100*(FM2-FM1)/FM1
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
ed1 cv
icm only
ed3 beta
Mar-00
Jul-00
Nov-00
Mar-01
Jul-01
Nov-01
Mar-02
Jul-02
Nov-02
Mar-03
Jul-03
Nov-03
Mar-04
Jul-04
Nov-04
Mar-05


Aqua Nighttime Unfiltered allsky Direct Compare
100*(FM4-FM3)/FM3
0.08
0.06
0.04
0.02
0
-0.02
-0.04
ed1 cv
icm only
ed3 beta
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05


FM1 Nighttime DCC Filtered SW Radiance vs WN channel
Filtered SW Radiance
0.4
0.3
0.2
0.1
0
-0.1
-0.2
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Filtered WN Radiance

Polymerized absorbing contaminant molecule (category B)

Un-polymerized contaminant molecule (non-absorbing category A)

RAPS

Contaminant Thickness

CERES Edition 3 beta Calibration Theory and Results

CERES Instrument Working Group
CERES Science Team Meeting, UKMO,
Exeter UK, 25/10/06

Contributors: Norman Loeb, Costy Loukachine, Bruce Wielicki

- Introduction: Desired ERB data product measurement stability stretches CERES design specification
- Improved model uses Ed1-CV matched to SSF-MODIS information used to identify scenes and estimate spectra
- Deep convective cloud albedo used to derive SW gain changes rather than SWICS in order to increase stability
- Iterative SW darkening model is tuned using allsky and clear ocean direct compare
- Initial results very promising for Aqua (Terra Model still being tuned)
- Re-analysis of 3 channel: suggests adjustments SW total channel response that result in an increase in CERES daytime LW
- Future considerations and topics for discussion

Ohring et al (2005) suggests that ERB measurement stability needs to reach 0.3% per decade

MEETING SUMMARIES

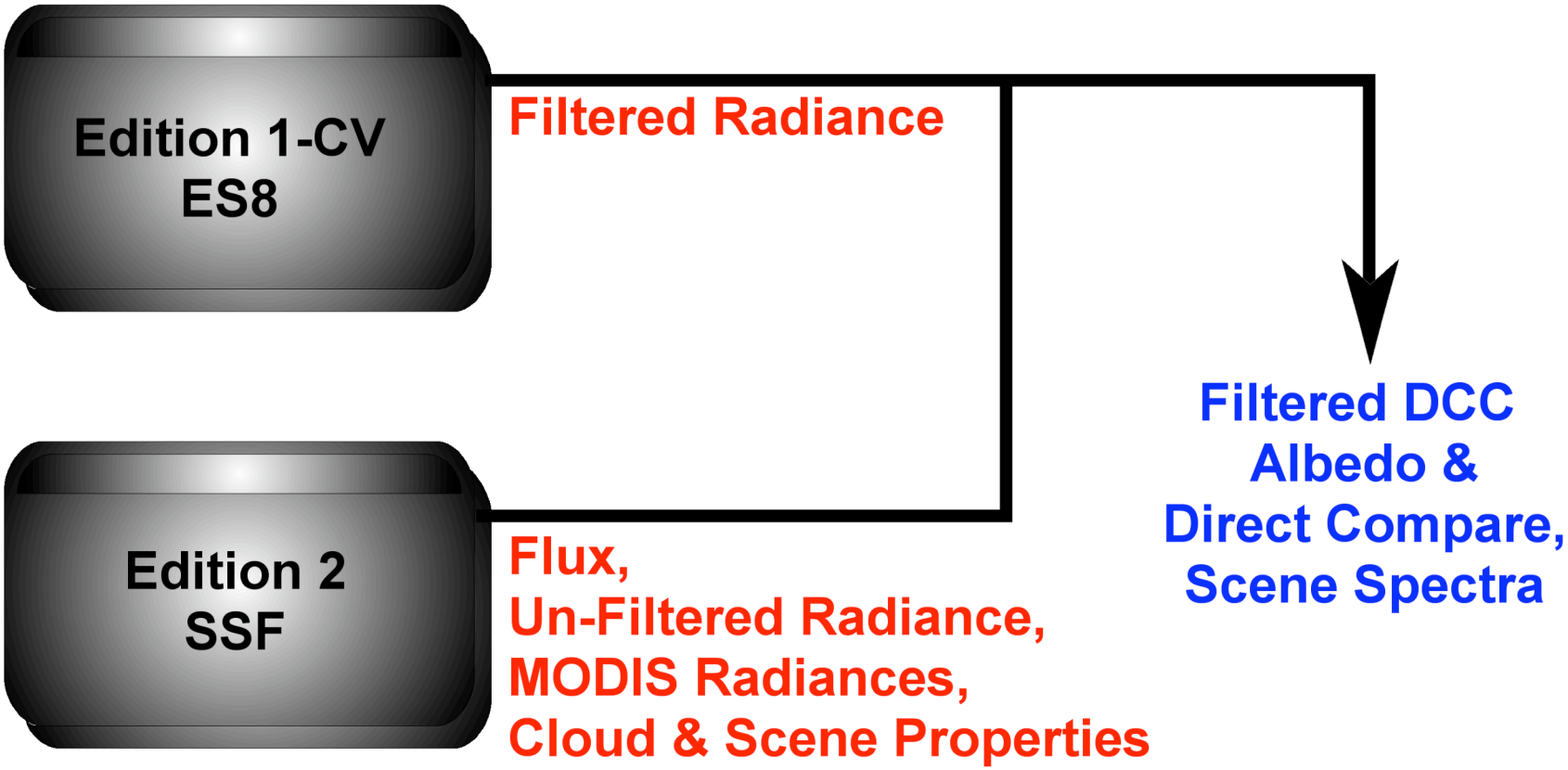
Satellite Instrument Calibration for Measuring Global Climate Change

Report of a Workshop

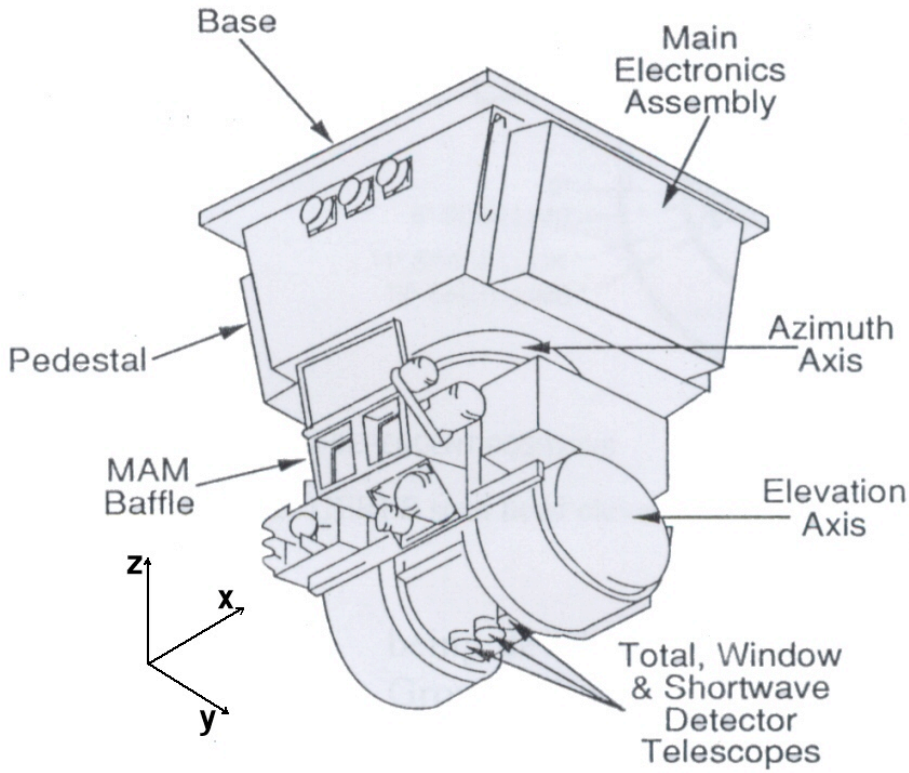
This is near to an order of magnitude greater than CERES instrument design specification stability (note: not data products)

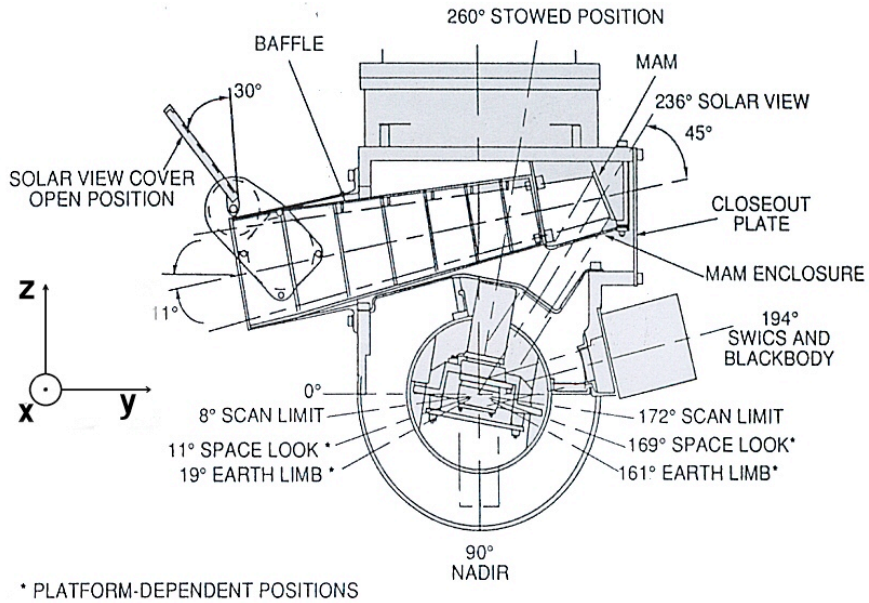
- Introduction: CERES Instrument and spectral darkening
- CERES Edition 2 Revisions, Terra & Aqua results
- Deep convective cloud albedo, proposed stability metric for CERES Edition 3
- Contaminant fixing and polymerizing model to derive Edition 3 spectral response and gains.
- Preliminary results from test run with model derived calibration parameters
- Summary

In order to use filtered radiance as a diagnostic, a run of CERES ES8 data was generated with fixed calibration and production code (Edition 1-CV). Filtered radiance footprints are then matched with SSF information on ADMs, scene type & MODIS radiances.

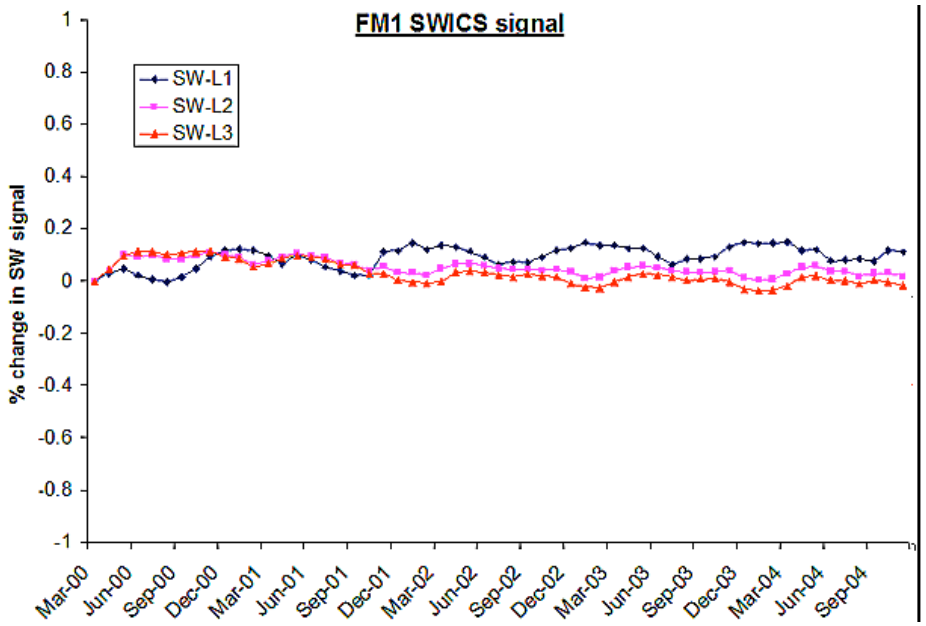


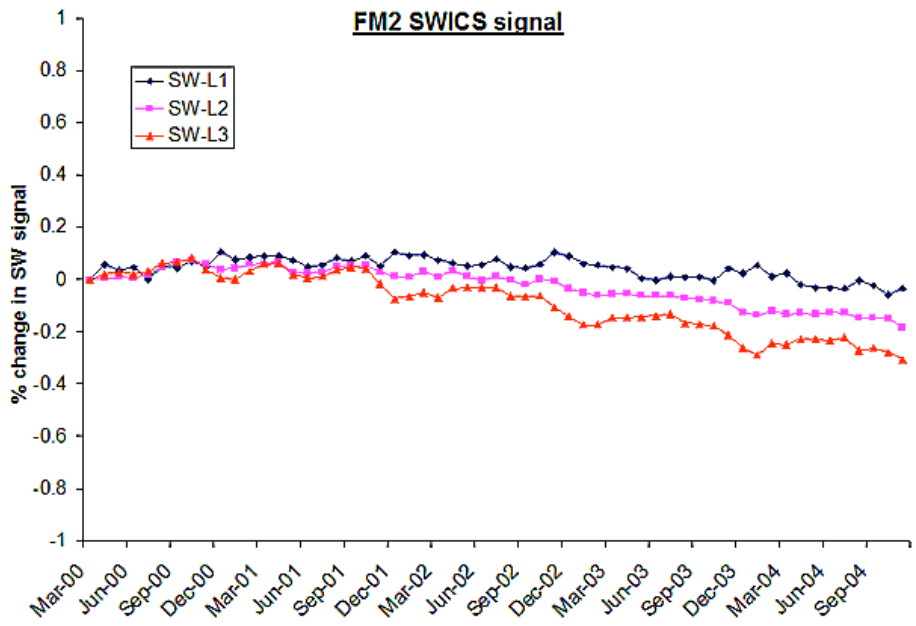
CERES Scanning Radiometer Instrument





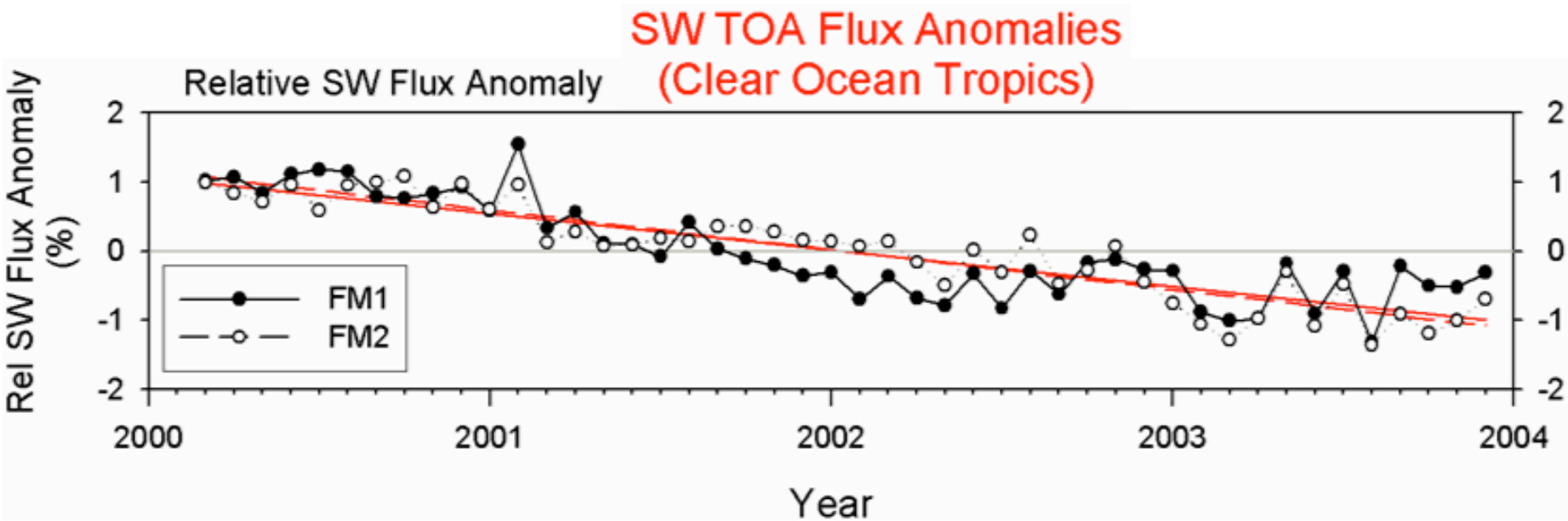
What does SWICS data imply about change SW gains gains on the Terra instruments?



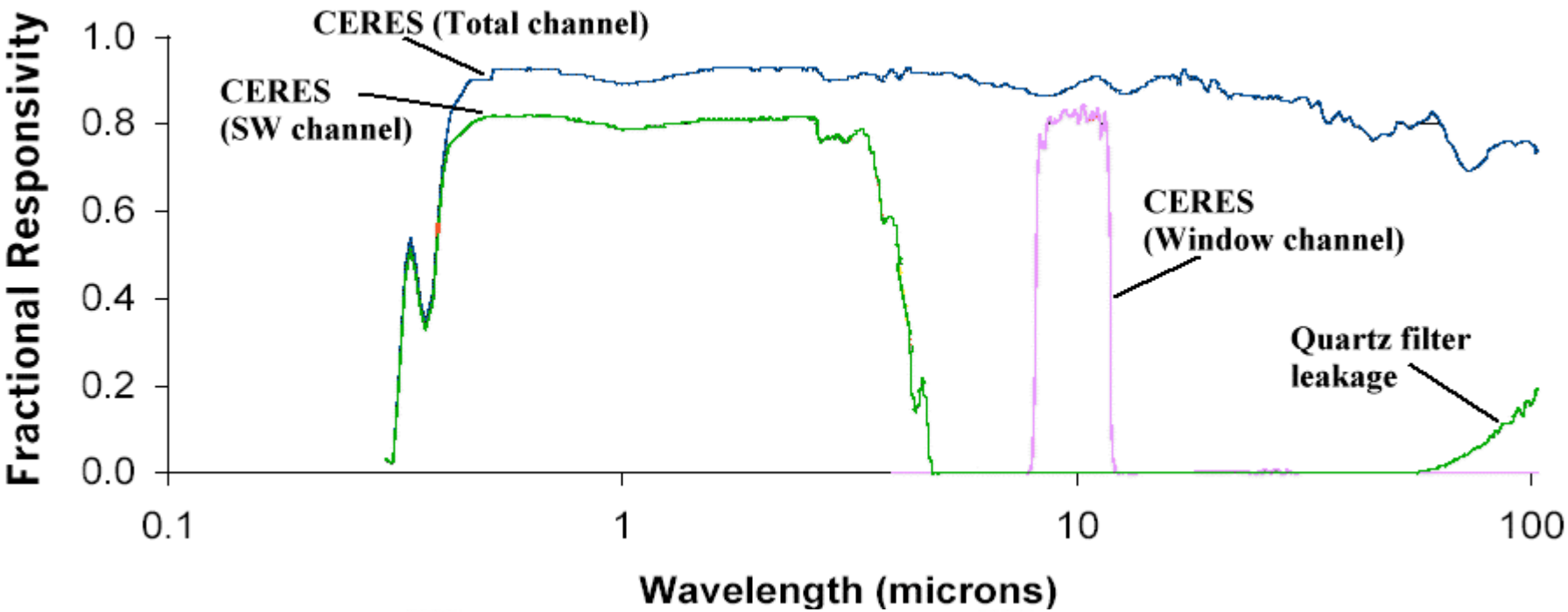


Answer: The lamps suggest SW channel gains are stable to 0.1% on both Terra instruments FM1 and FM2

Anomalous -2% drift in Edition 2 Terra measured global SW Flux from the Earth?



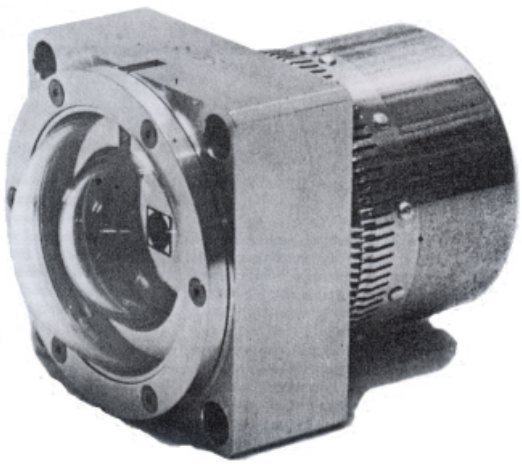
CERES Spectral Response of 3 Channels

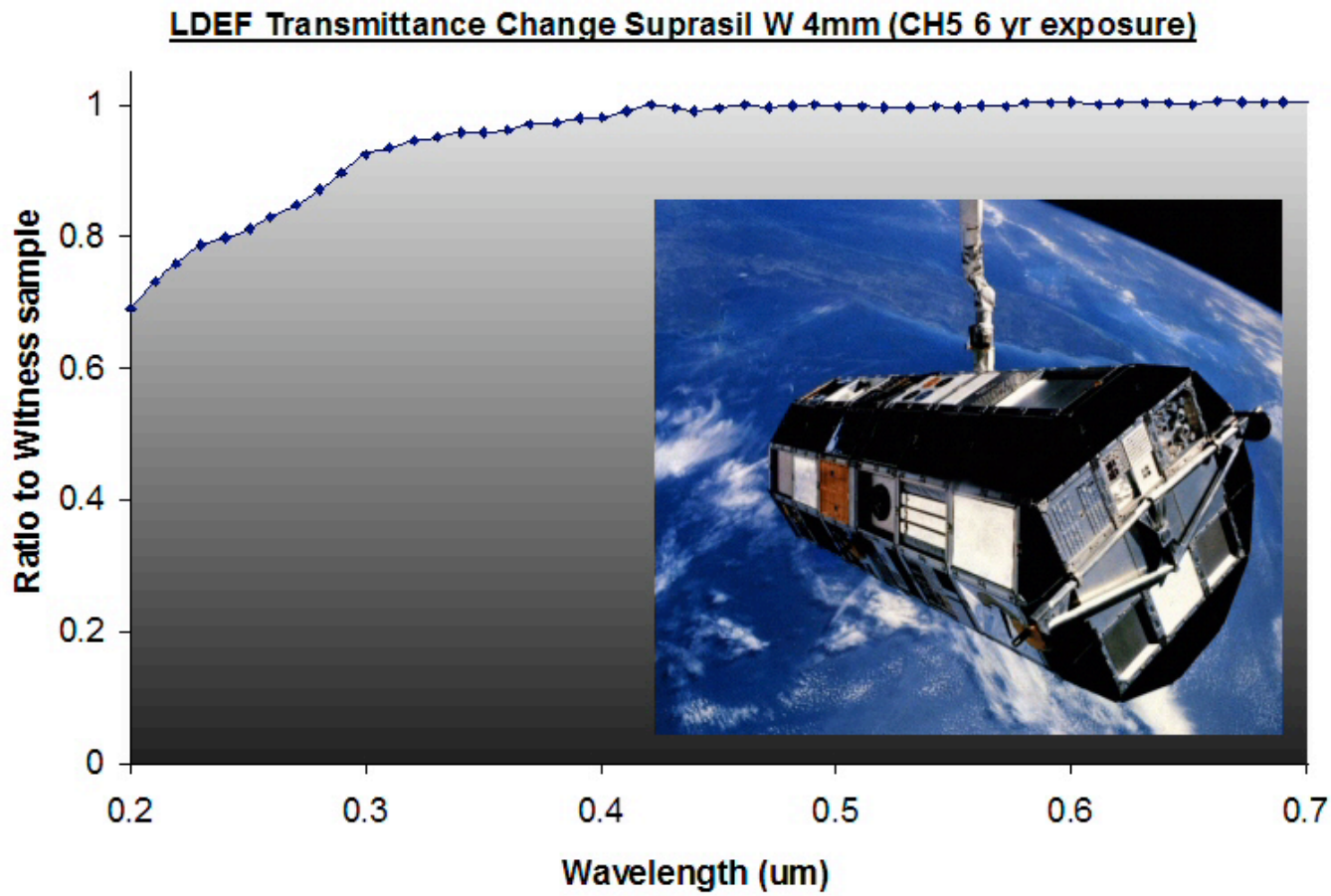


$$L_i^{sw} = \int_0^{\infty} R_i^{sw}(\lambda)d\lambda \qquad LF_i^{sw} = \int_0^{\infty} S^{sw}(\lambda) \times R_i^{sw}(\lambda)d\lambda$$

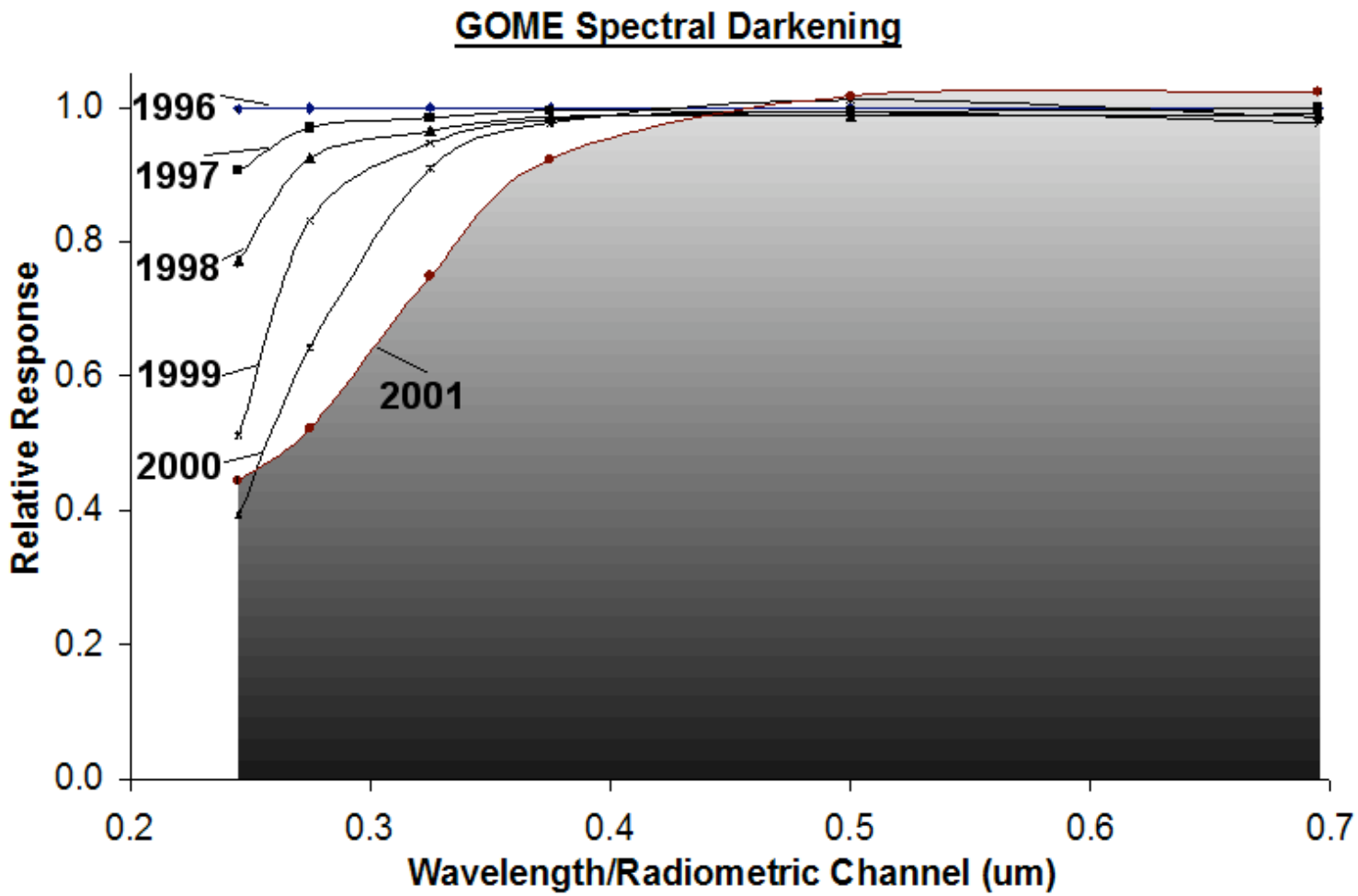
$$LF_i^{sw} = L_i^{sw} \times f_i^{sw} \qquad f_i^{sw} = \frac{\int_0^{\infty} S^{sw}(\lambda) \times R_i^{sw}(\lambda)d\lambda}{\int_0^{\infty} R_i^{sw}(\lambda)d\lambda}$$

Could this be caused by a non-spectrally uniform darkening of the CERES SW optics as occurred on LDEF?

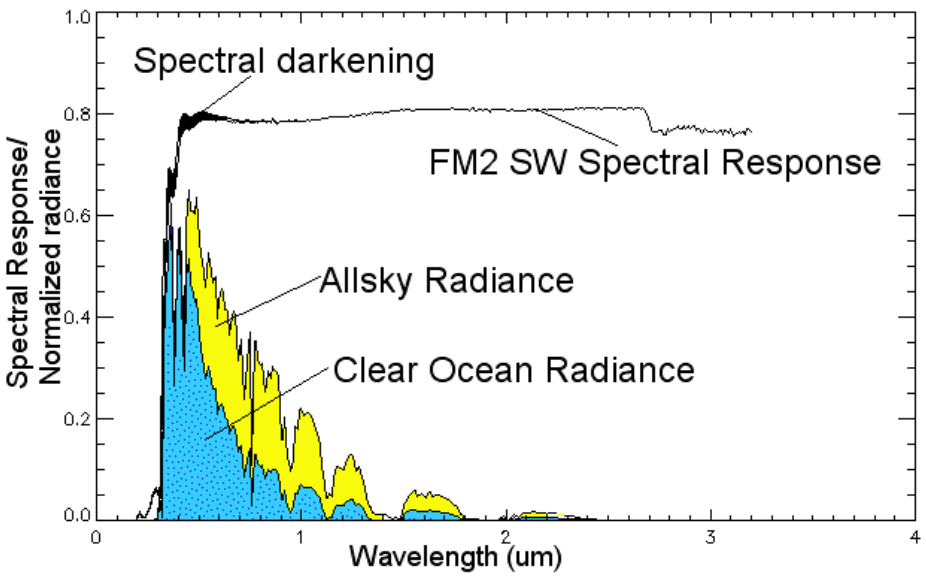


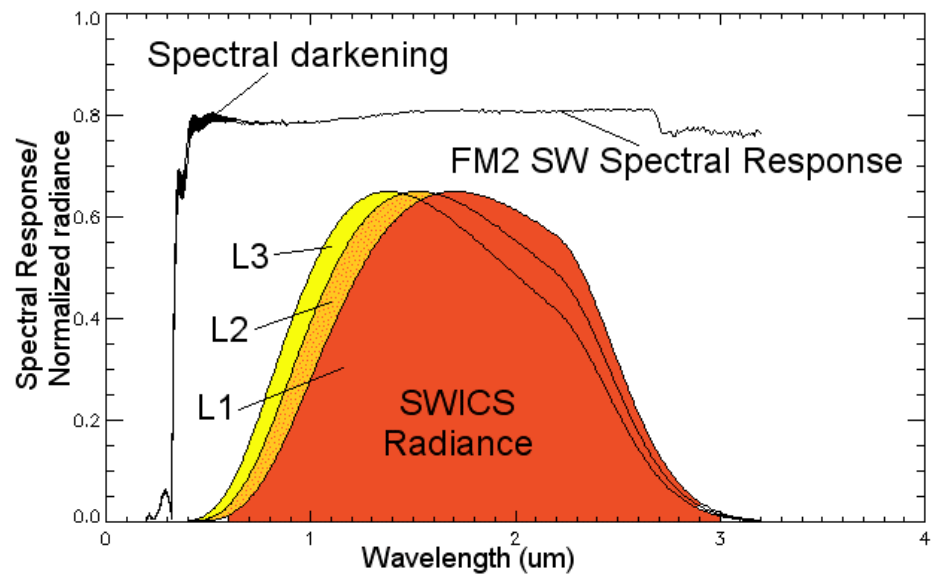


The GOME instrument narrowband channels show a similar spectral shape of darkening:



Could this be caused by a non-spectrally uniform darkening of the CERES SW optics as occurred on LDEF (undetectable by viewing onboard lamps)?

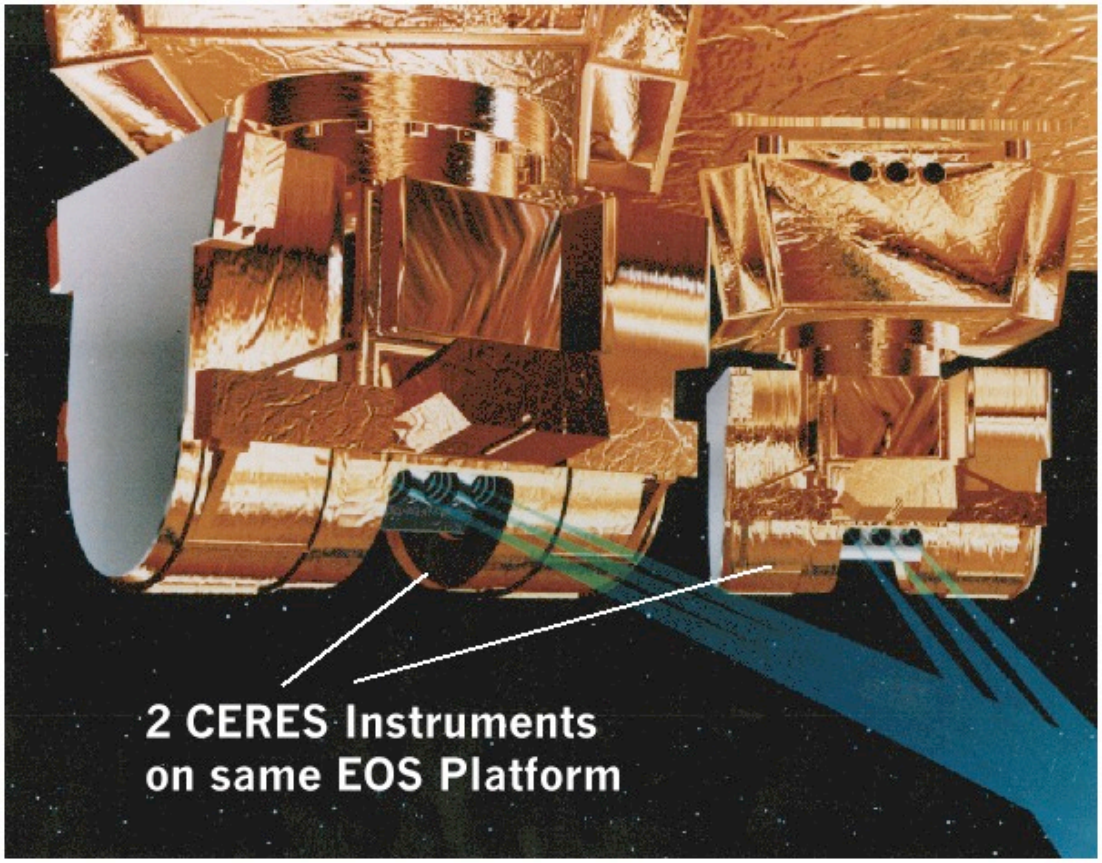




$$f^{sw}_{allsky} \text{ change} \approx -2\%$$

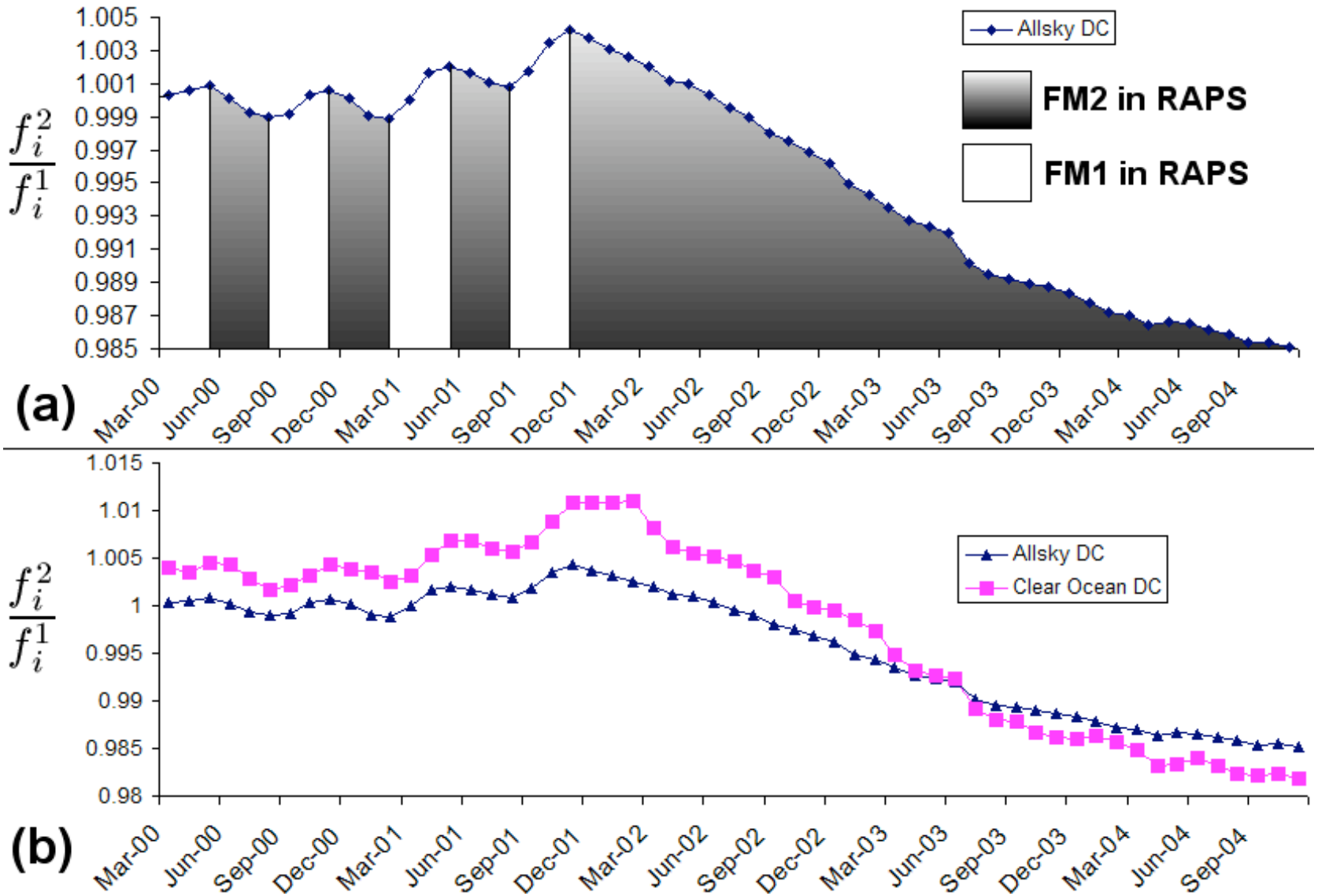
$$f^{sw}_{swics} \text{ change} \approx -0.1\%$$

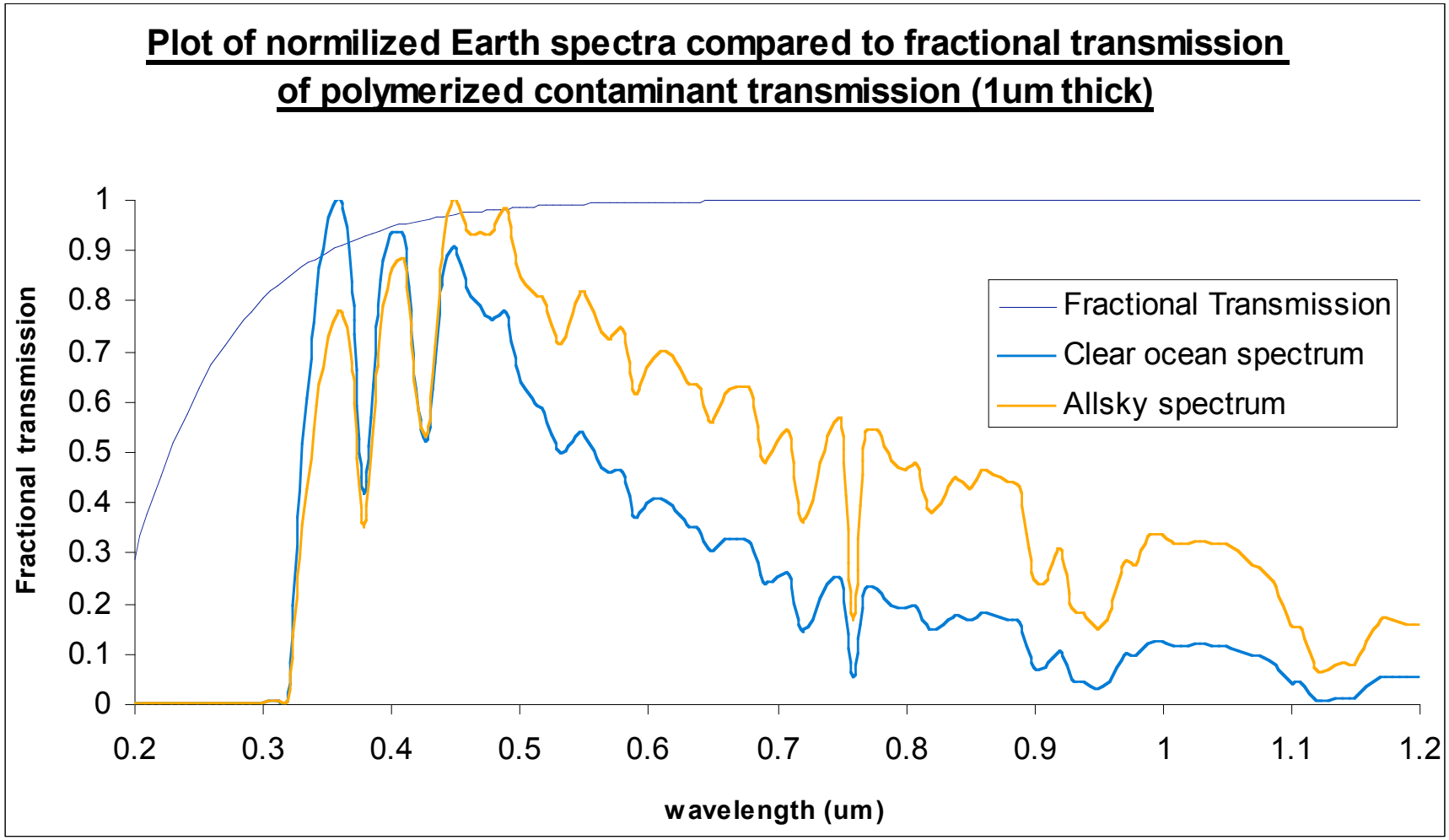
1 RAPS, 1 Xtrack instrument at anytime. Direct Compare (DC) is the ratio of simultaneous nadir filtered radiance



$$
\begin{aligned}
DC_i &= \frac{LF_i^2}{LF_i^1} \\
&= \frac{L_i \times f_i^2}{L_i \times f_i^1} \\
&= \frac{f_i^2}{f_i^1}
\end{aligned}
$$

Instrument diagnostic that is <u>INDEPENDENT OF CLIMATE</u>


1.005
1.003
1.001
0.999
0.997
0.995
0.993
0.991
0.989
0.987
0.985
$\frac{f_i^2}{f_i^1}$
Allsky DC
FM2 in RAPS
FM1 in RAPS
(a)
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
$\frac{f_i^2}{f_i^1}$
Allsky DC
Clear Ocean DC
(b)
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04


Plot of normilized Earth spectra compared to fractional transmission of polymerized contaminant transmission (1um thick)
Fractional transmission
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
wavelength (um)
Fractional Transmission
Clear ocean spectrum
Allsky spectrum

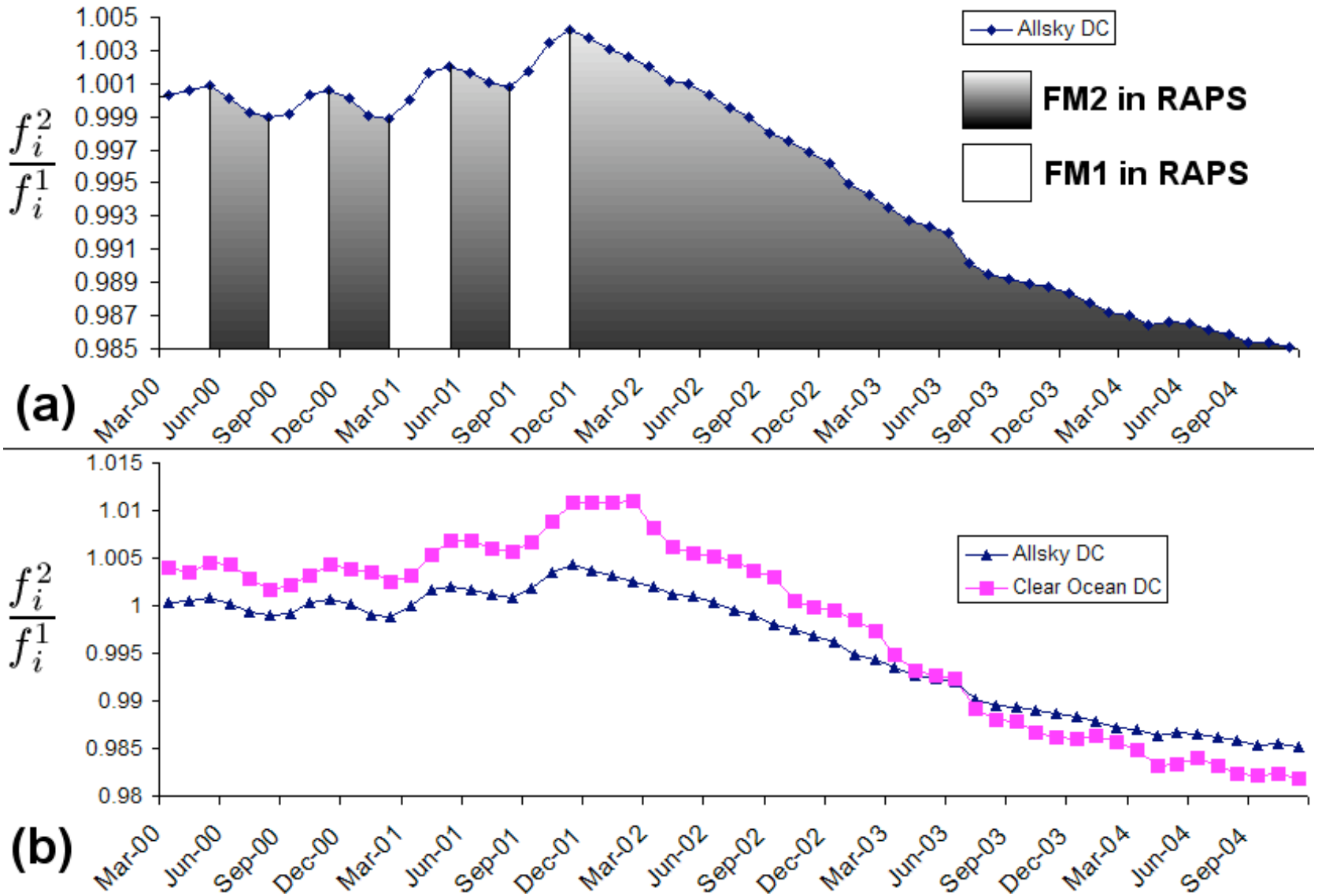
- The LDEF experiment suggests that atomic oxygen in LEO has the effect of removing and mobilizing optical coatings where they are then fixed to optical surfaces by UV photons.

- If this is the cause of CERES spectral darkening, what is it about the RAPs operational mode that allows this to happen?

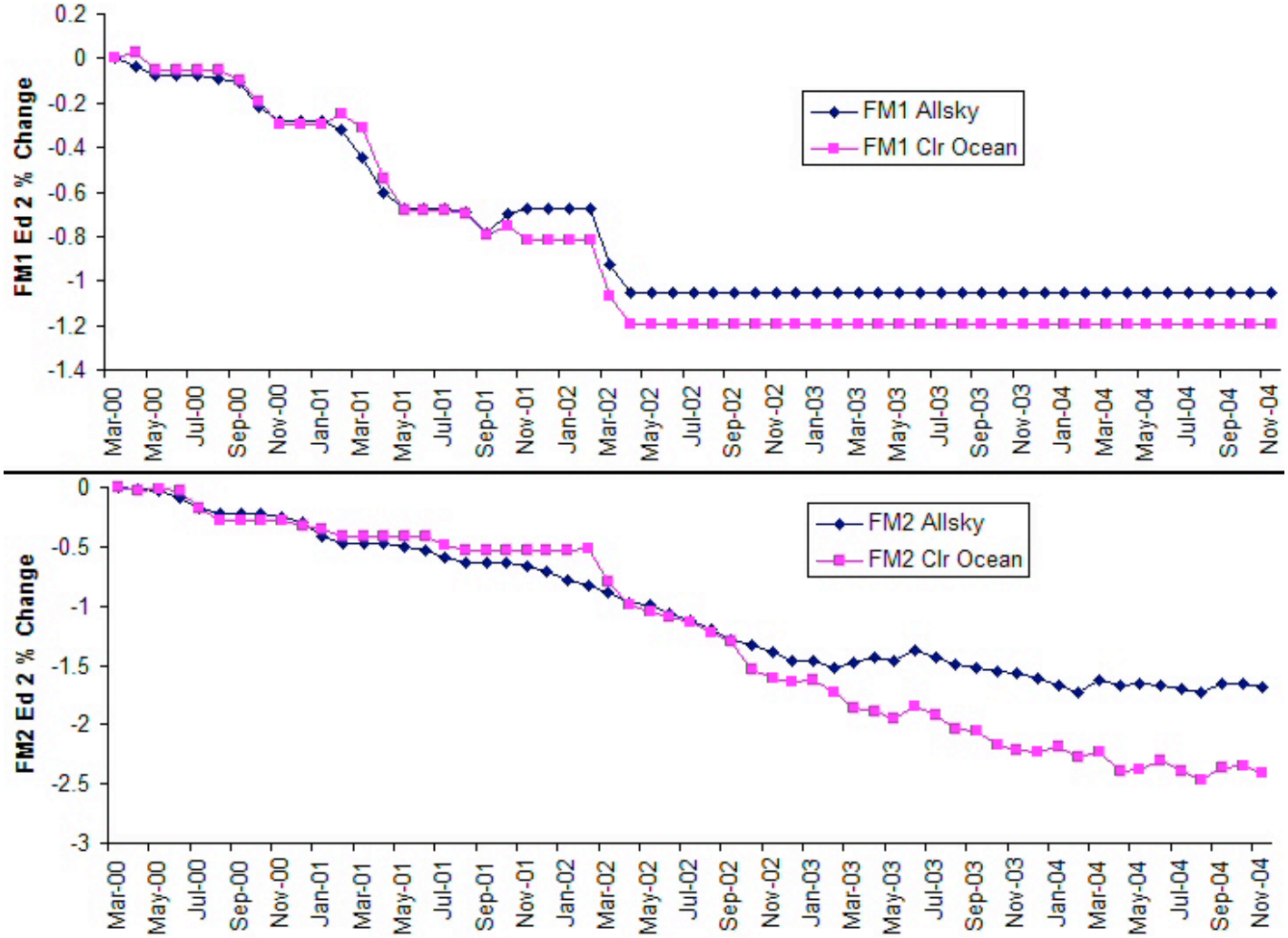
How can we quantify and remove this change in response for each instrument **without removing real climate trends?**

- **Short term (Ed2_Rev1):** Experience from LDEF suggests that the SW response of the instrument in Xtrack mode should remain relatively stable. Hence use Xtrack instrument as calibration standard in **percent** direct compare to derive change in RAPS instrument response to All sky and Clear Ocean.

- **Long term (Ed3):** Develop comprehensive Contamination/UV exposure model and use **percent** direct compare in conjunction with Deep Convective Cloud albedo metric to derive change to instrument spectral response.


1.005
1.003
1.001
0.999
0.997
0.995
0.993
0.991
0.989
0.987
0.985
$\frac{f_i^2}{f_i^1}$
Allsky DC
FM2 in RAPS
FM1 in RAPS
(a)
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
$\frac{f_i^2}{f_i^1}$
Allsky DC
Clear Ocean DC
(b)
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04

Use Xtrack instrument as calibration standard and hence you can derive the separate instrument drift to be taken out in Rev1 adjustment



A table of Rev1 adjustment factors is issued via the quality summary, authors then use the description “Edition2_Rev1”

ATMOSPHERIC SCIENCES DATA CENTER

CERES Terra Revision Table

2000 | 2001 | 2002 | 2003 | 2004 | Tab-delimited file

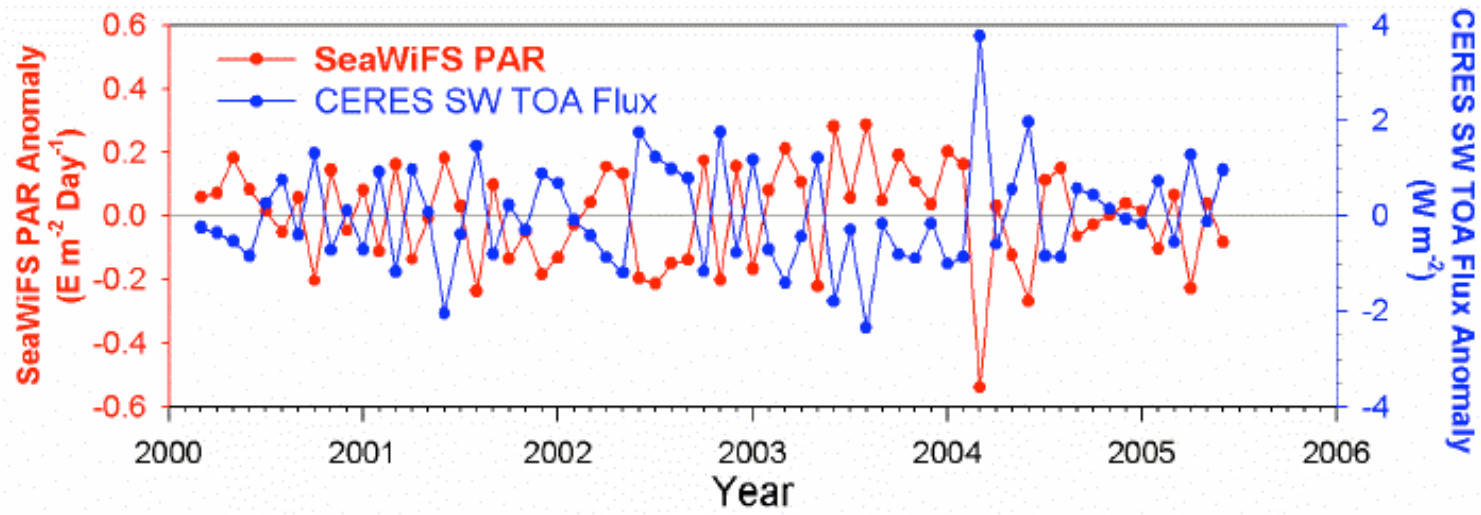
		All Sky		Clear Ocean	
Year	Month	FM1	FM2	FM1	FM2
2003	Jan	1.011	1.015	1.012	1.017
	Feb	1.011	1.015	1.012	1.018
	Mar	1.011	1.015	1.012	1.019
	Apr	1.011	1.014	1.012	1.019
	May	1.011	1.015	1.012	1.020

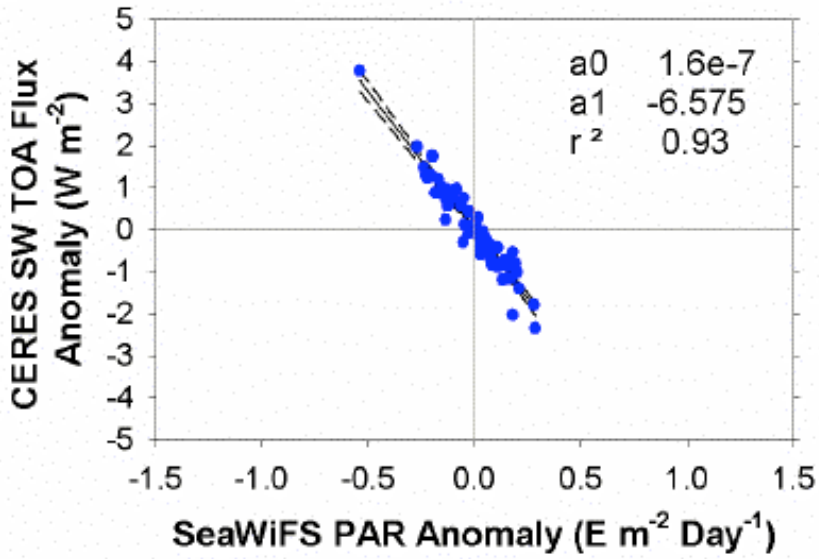
Multiply your May 03 Terra allsky SW fluxes by these values

Multiply your May 03 Terra clear ocean SW fluxes by these values

http://eosweb.larc.nasa.gov/PRODOCS/ceres/ES8/Quality_Summaries/CER_ES8_Terra_Edition2.html

http://eosweb.larc.nasa.gov/PRODOCS/ceres/ES8/Quality_Summaries/CER_ES8_Aqua_Edition2.html


SeaWiFS PAR
CERES SW TOA Flux
SeaWiFS PAR Anomaly (E m-2 Day-1)
CERES SW TOA Flux Anomaly (W m-2)
Year
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
4
2
0
-2
-4
2000
2001
2002
2003
2004
2005
2006


a0 1.6e-7
a1 -6.575
r ² 0.93
CERES SW TOA Flux Anomaly (W m-2)
SeaWiFS PAR Anomaly (E m-2 Day-1)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5