Airborne measurements of spectral direct aerosol radiative forcing - a new aerosol gradient method applied to data collected in INTEX/ITCT, 2004

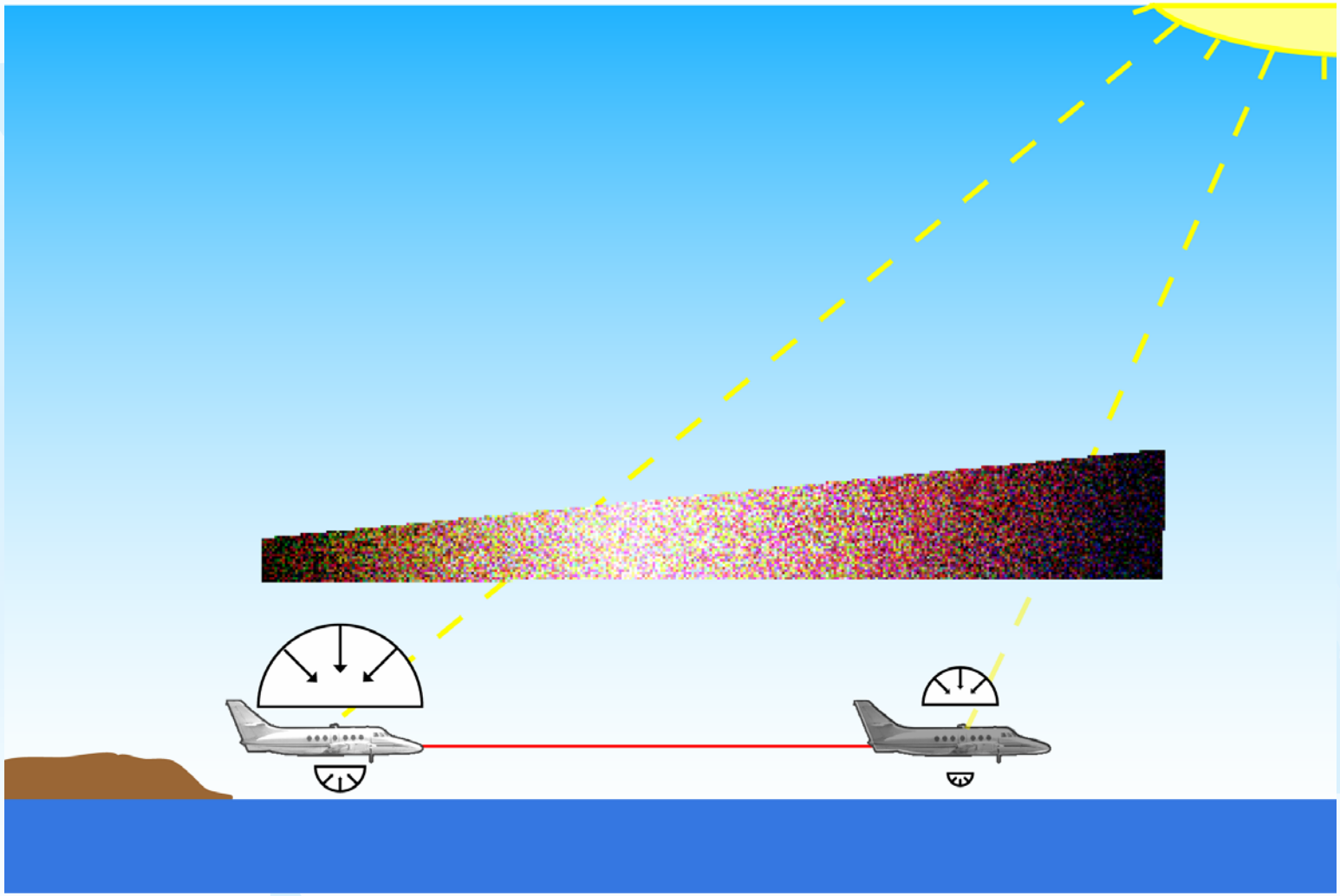
J. Redemann (1), P. Pilewskie (2), J. Livingston (3), S. Howard (1), P. Russell (4), B. Schmid (1), J. Eilers (4), M. Wendisch (5)

(1) Bay Area Environmental Research Institute, Sonoma, USA,
(2) University of Colorado, Boulder, USA,
(3) SRI International, Menlo Park, USA,
(4) NASA Ames Research Center, Moffett Field, USA,
(5) Institute for Tropospheric Research, Leipzig, Germany

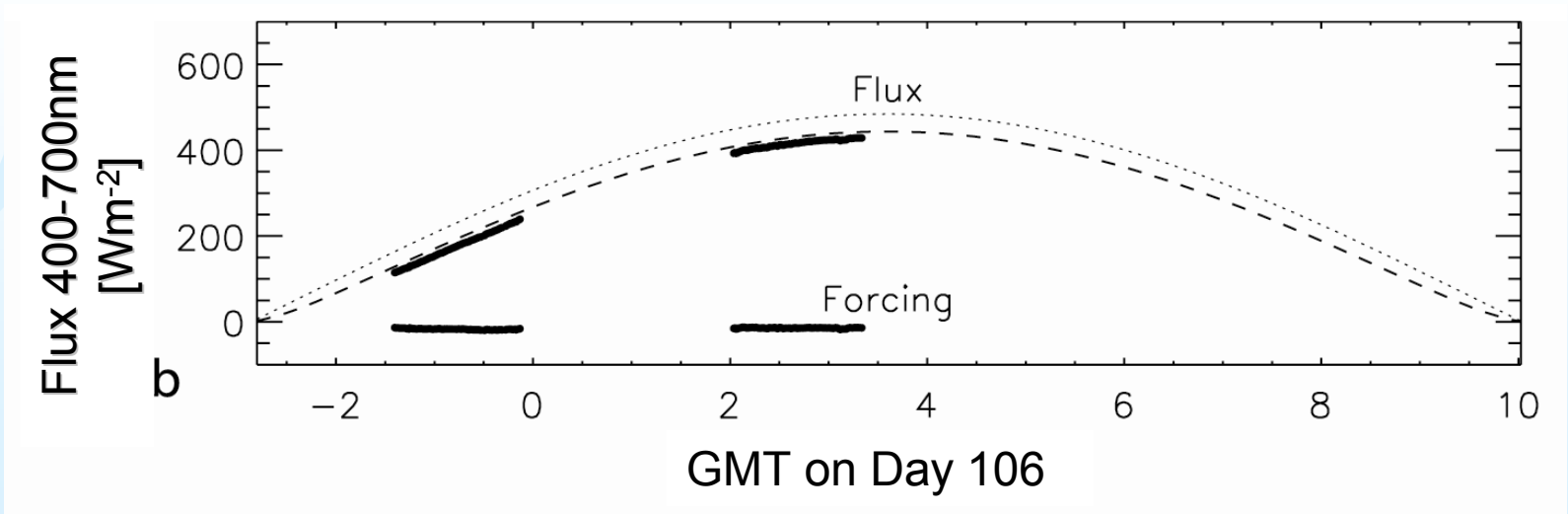
Methodology for studying aerosol radiative forcing from horizontal AOD gradients

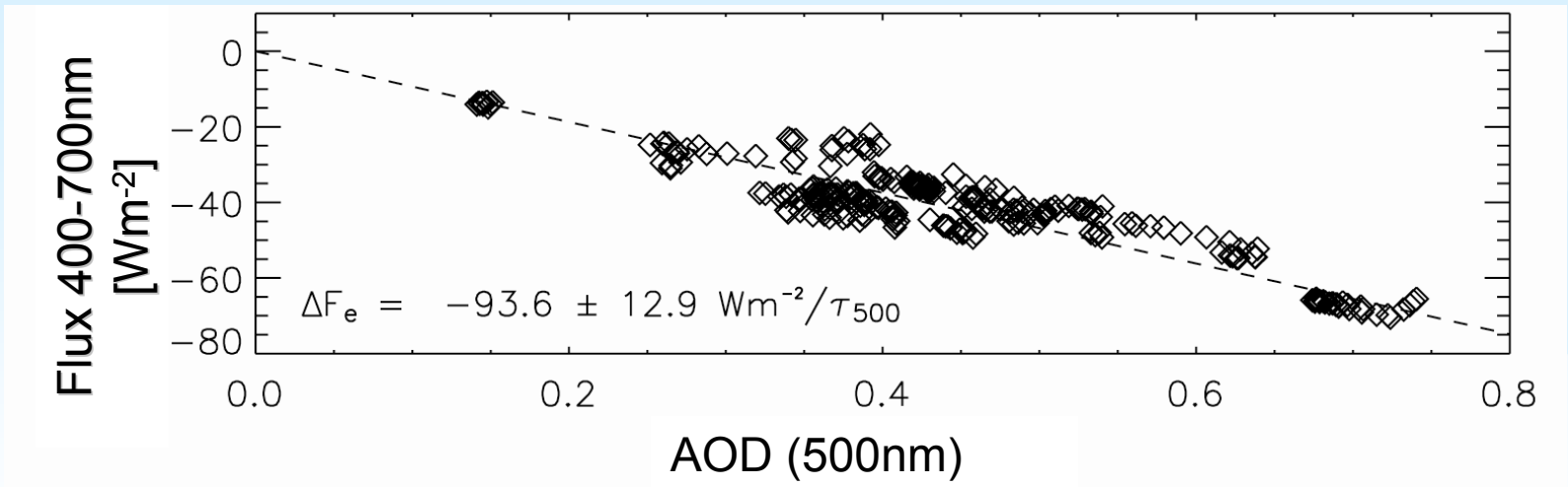
- Measure simultaneous change in spectral aerosol optical depth (AATS-14) and spectral net irradiance (SSFR) → $\Delta F_{net}/\Delta AOD$ = aerosol radiative forcing (efficiency)
- Observationally-based estimate of aerosol radiative effect
- Advantage over ground-based methods – quasi-instantaneous – because of short horizontal distances
- Need to check (and correct for) effects of changing solar zenith angle and changing column water vapor contents

Methodology for radiative effect studies from AOD gradients

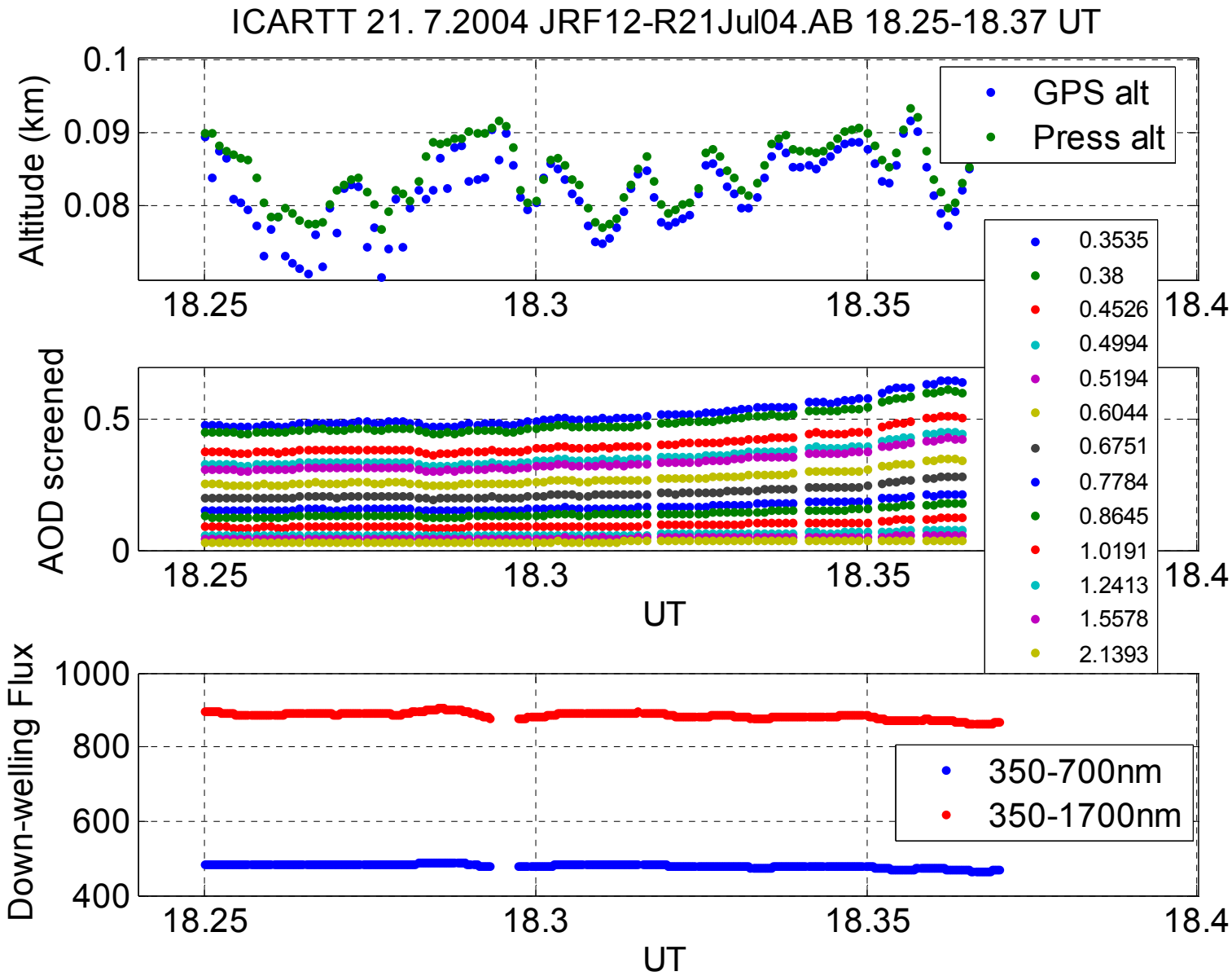


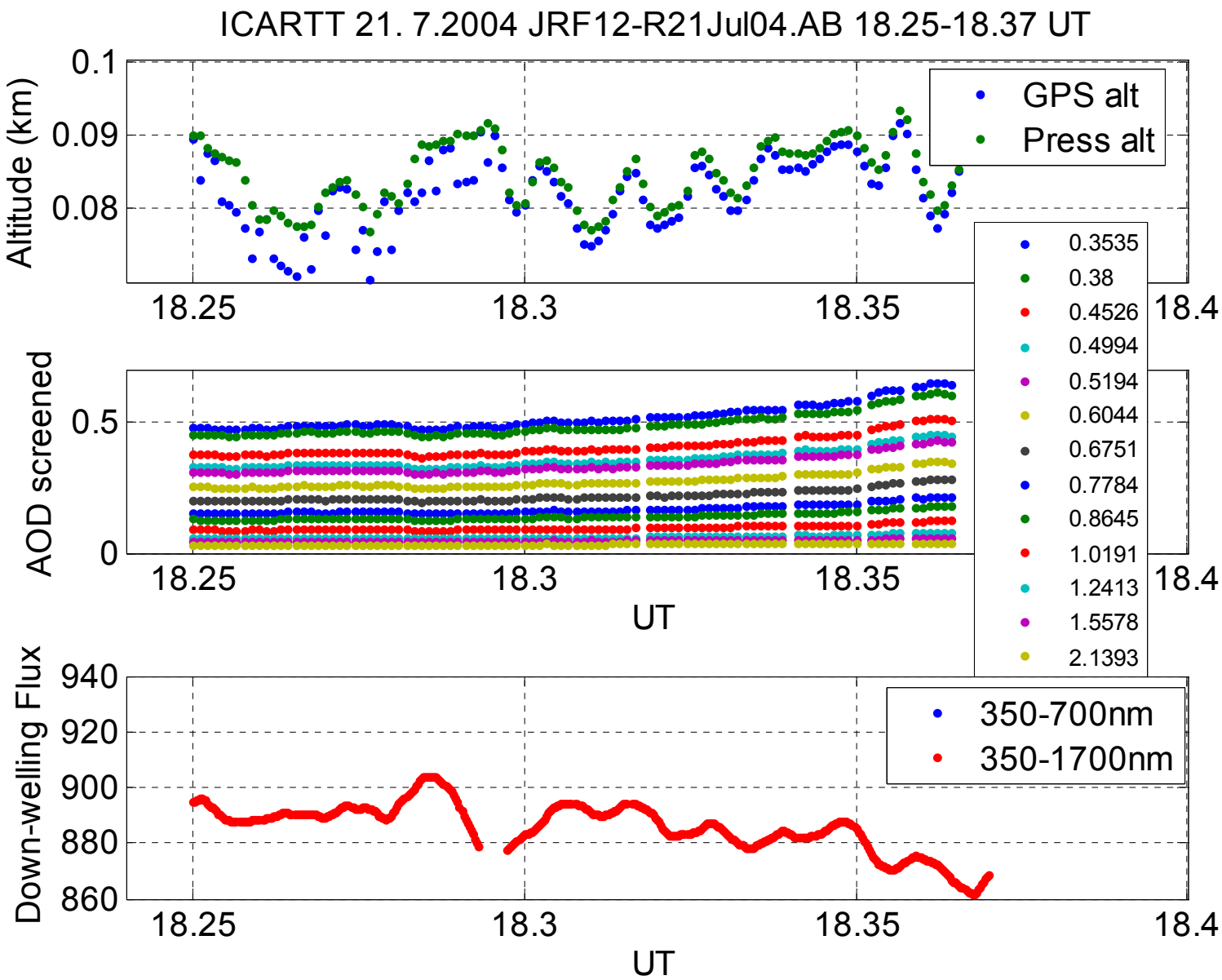
Previous methodologies for aerosol radiative forcing studies



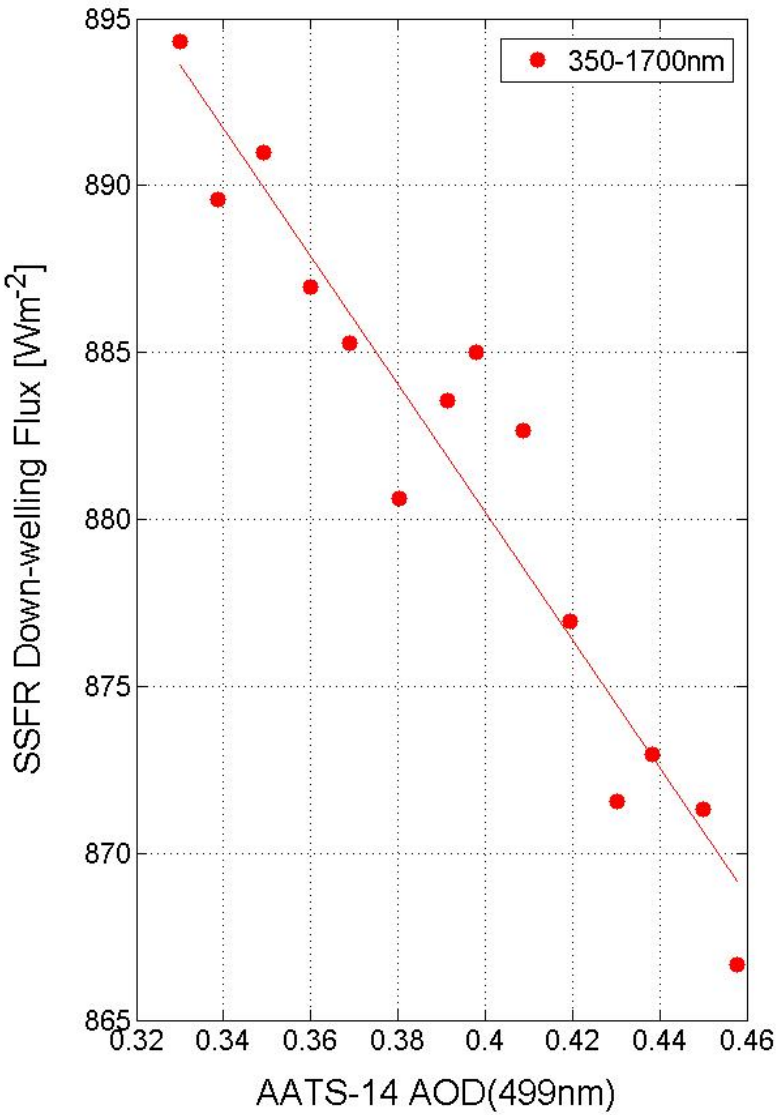


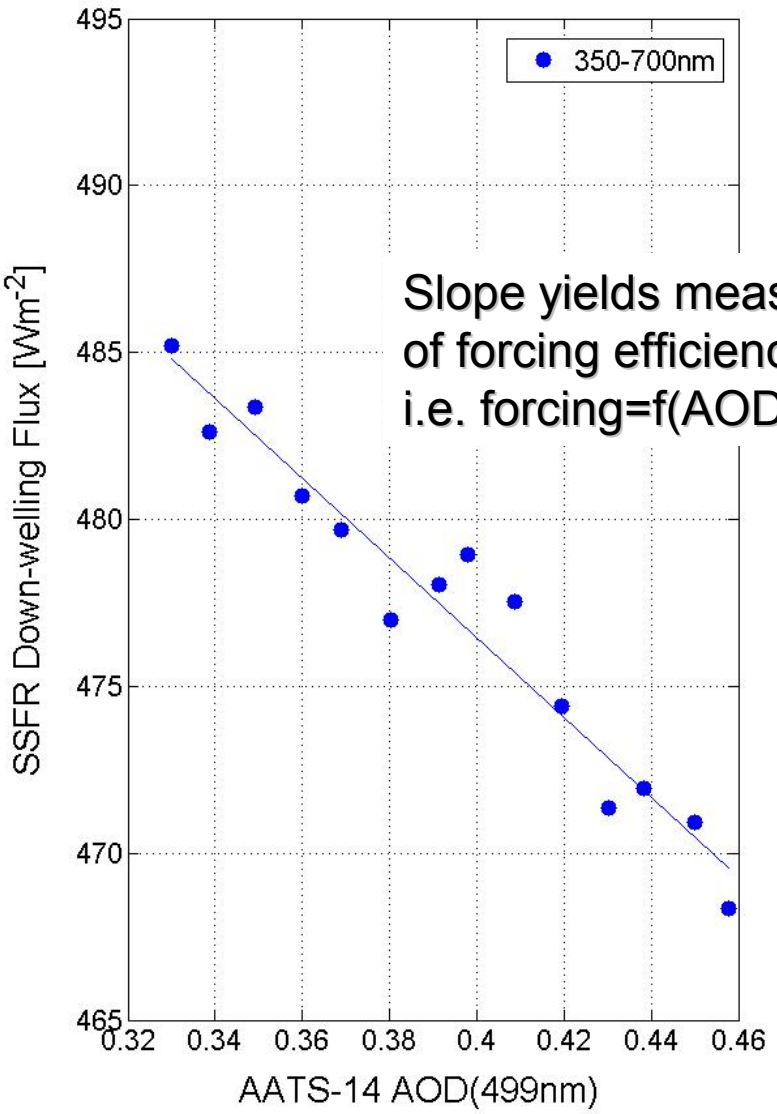
Bush and Valero, 2002 ACE-Asia


ICARTT 21. 7.2004 JRF12-R21Jul04.AB 18.25-18.37 UT
Altitude (km)
0.1
0.09
0.08
GPS alt
Press alt
18.25
18.3
18.35
18.4
AOD screened
0.5
0
0.3535
0.38
0.4526
0.4994
0.5194
0.6044
0.6751
0.7784
0.8645
1.0191
1.2413
1.5578
2.1393
UT
Down-welling Flux
1000
800
600
400
350-700nm
350-1700nm
UT


ICARTT 21. 7.2004 JRF12-R21Jul04.AB 18.25-18.37 UT
Altitude (km)
0.1
0.09
0.08
GPS alt
Press alt
18.25
18.3
18.35
18.4
AOD screened
0.5
0
0.3535
0.38
0.4526
0.4994
0.5194
0.6044
0.6751
0.7784
0.8645
1.0191
1.2413
1.5578
2.1393
UT
Down-welling Flux
940
920
900
880
860
350-700nm
350-1700nm
UT

J31 Flight 12, 21 July 2004



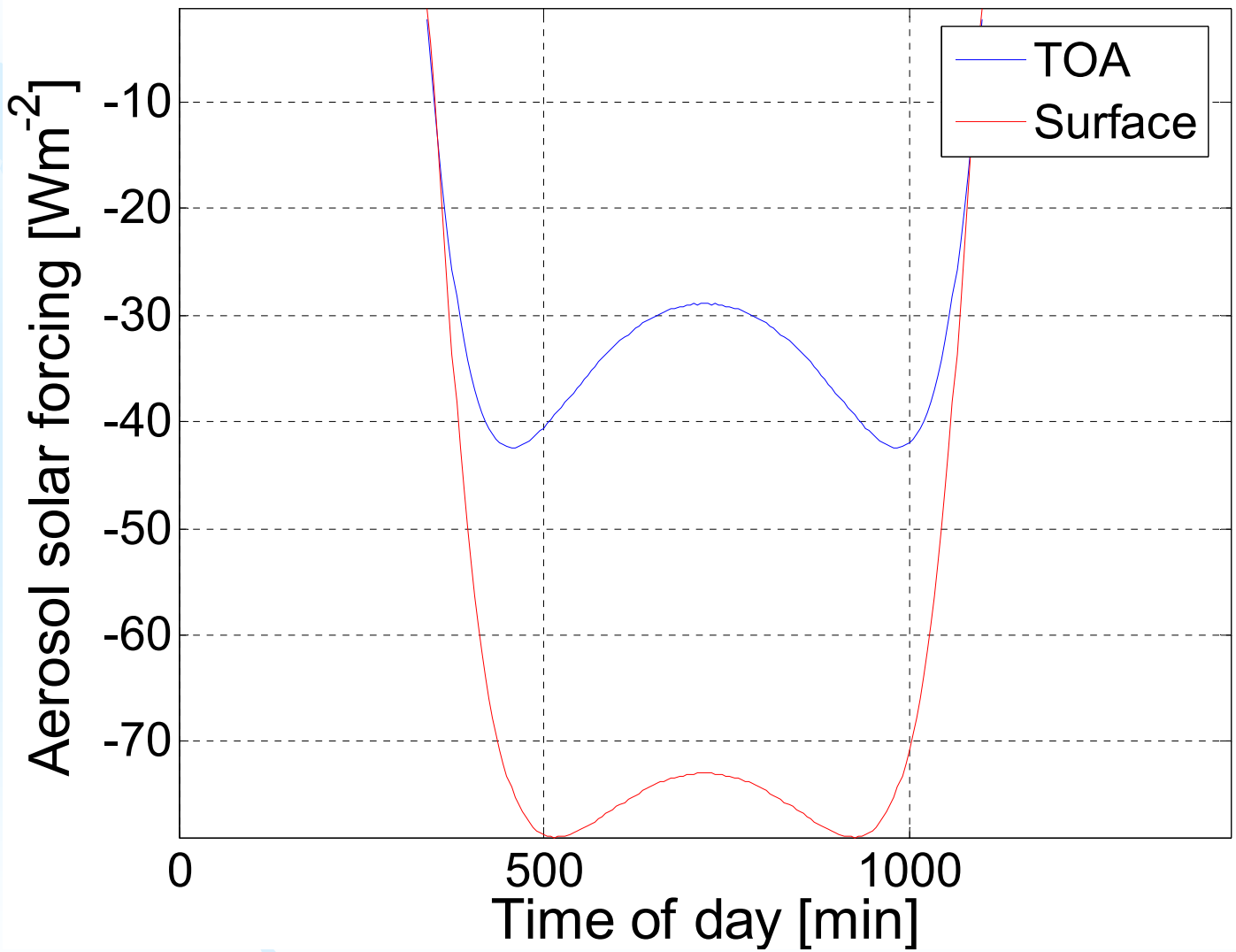


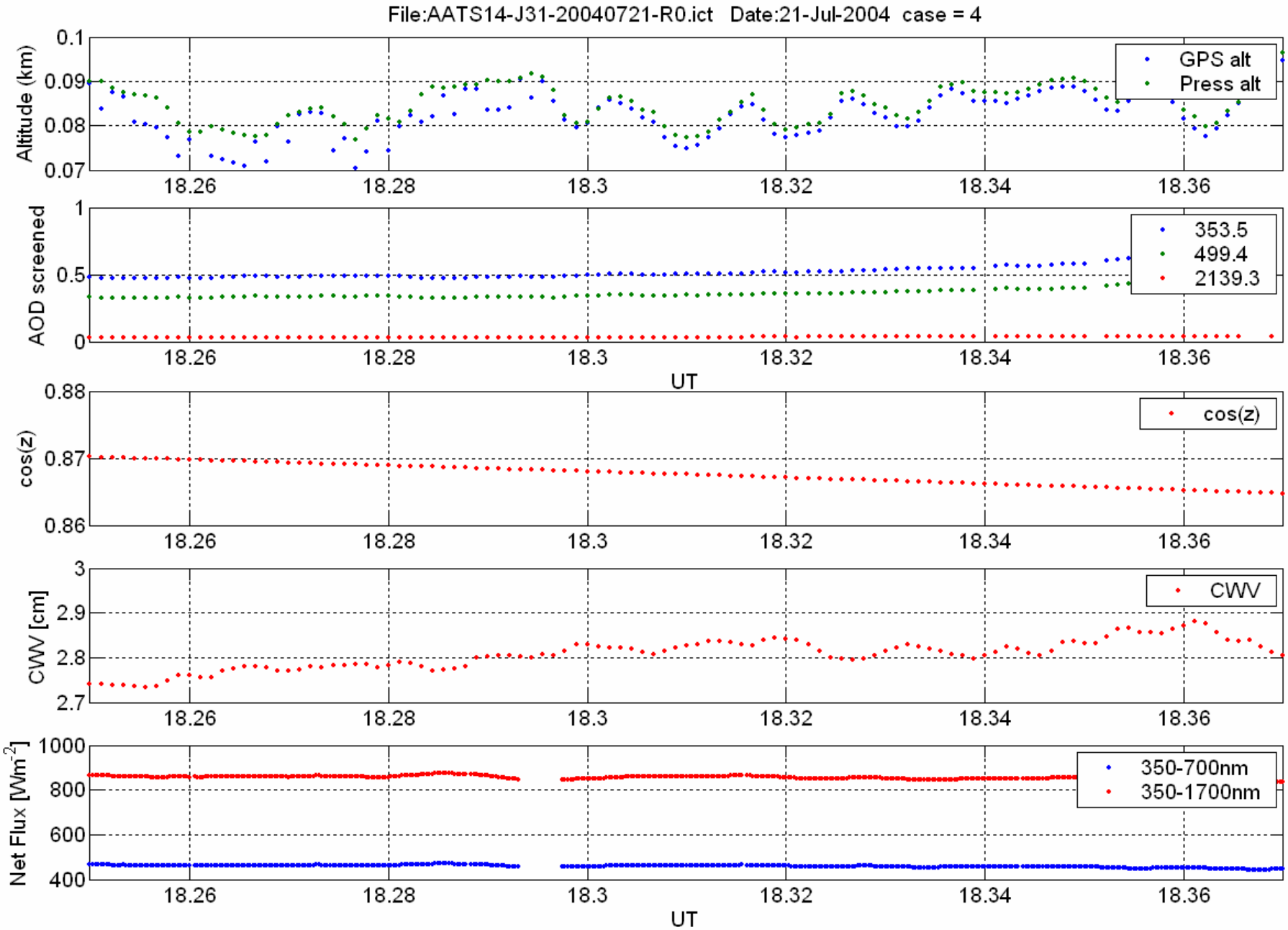
Slope yields measure of forcing efficiency, i.e. forcing=f(AOD)

Progress on gradient forcing work

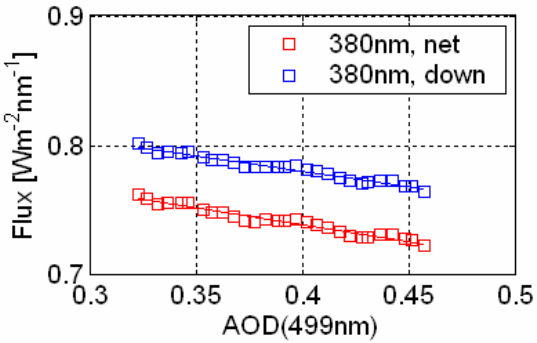
- Identified 16 cases of observed AOD gradients during low-level J-31 legs
- QA for AATS and SSFR data
- Checked for surface effects by looking at down-welling and net irradiance separately
- Extended analysis to forcing efficiencies in 7 SSFR channels (380, 506, 762, 940, 1052, 1201, 1604nm)
- Computed “relative forcing efficiencies”, i.e., forcing efficiency divided by down-welling irradiance in each SSFR channel
- Looked at forcing efficiencies as f(CWV) and f(particle size)

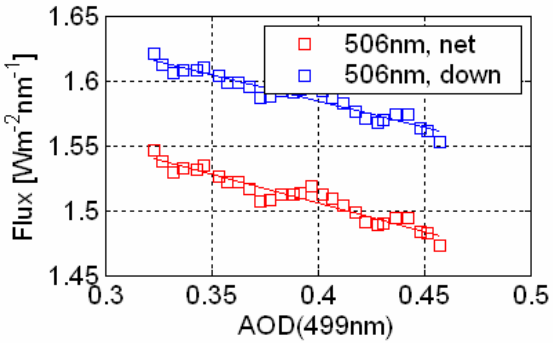
Date	Flight Index	Case Index	UT beg	UT end	AATS hours	AOD Gradient incr./decr. Distance(km)	Solar zenith angle change
07/12/04	JRF07	1	18.360	18.500	0.14	↓ 0.17 (41.7%) / 38.4km	7/12a 1.53%
07/12/04	JRF07	2	19.870	19.940	0.07	↓ 0.09 (19.1%) / 17.5km	7/12b 0.96%
07/17/04	JRF10	3	14.919	14.981	0.06	↓ 0.04 (37.9%) / 20.0km small AOD difficult clouds	7/17 0.65%
07/21/04	JRF12	4	18.250	18.370	0.12	↑ 0.14 (43.2%) / 24.7km	7/21 0.62%
07/22/04	JRF13	5	15.500	15.630	0.13	↓ 0.10 (17.6%) / 22.4km scattered clouds?	7/22 0.96%
07/23/04	JRF14	6	17.793	17.861	0.07	↑ 0.21 (41.1%) / 22.5km	7/23a 0.50%
07/23/04	JRF14	7	17.861	17.892	0.03	↓ 0.07 (10.3%) / 8.1km	7/23b 0.23%
07/23/04	JRF14	8	18.105	18.160	0.05	↑ 0.05 (5.8%) / 5.2km	7/23c 0.26%
07/29/04	JRF16	9	15.600	15.770	0.17	↓ 0.46 (55.1%) / 39.9km very good day	7/29a 0.63%
07/29/04	JRF16	10	15.807	15.900	0.09	↑ 0.38 (93.2%) / 27.7km	7/29b 0.69%
07/29/04	JRF16	11	16.308	16.347	0.04	↓ 0.18 (26.3%) / 6.1km	7/29c 0.01%
08/02/04	JRF19	12	15.210	15.400	0.19	↓ 0.25 (56.2%) / 40.6km great day	8/2a 0.94%
08/02/04	JRF19	13	15.690	15.880	0.19	↑ 0.23 (119.9%) / 59.5km	8/2b 1.51%
08/03/04	JRF21	14	20.450	20.580	0.13	↑ 0.10 (26.4%) / 31.9km	8/3 2.71%
08/07/04	JRF22	15	14.960	15.275	0.32	↓ 0.03 (28.0%) / 71.5km small AOD	8/7 3.46%
08/08/04	JRF24	16	17.550	17.980	0.43	↑ 0.04 (76.5%) / 108.9km small AOD	8/8 3.23%

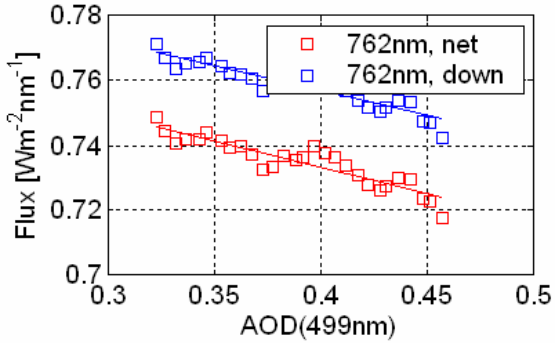

TOA
Surface
Aerosol solar forcing [Wm-2]
-10
-20
-30
-40
-50
-60
-70
0
500
1000
Time of day [min]

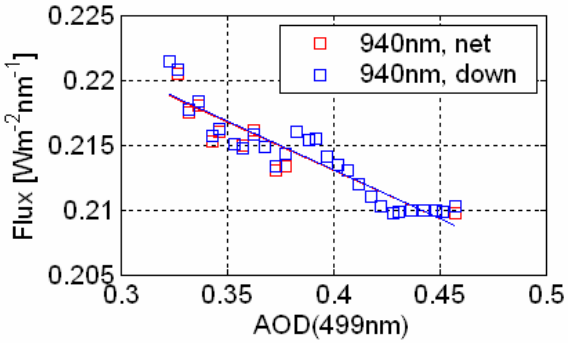

File:AATS14-J31-20040721-R0.ict Date:21-Jul-2004 case = 4
Altitude (km)
0.1
0.09
0.08
0.07
GPS alt
Press alt
18.26
18.28
18.3
18.32
18.34
18.36
AOD screened
1
0.5
0
353.5
499.4
2139.3
UT
cos(z)
0.88
0.87
0.86
CWV [cm]
3
2.9
2.8
2.7
CWV
Net Flux [Wm-2]
1000
800
600
400
350-700nm
350-1700nm

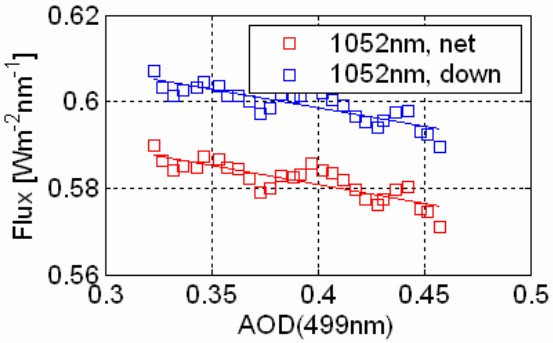
File:AATS14-J31-20040721-R0.ict Date:21-Jul-2004 case = 4

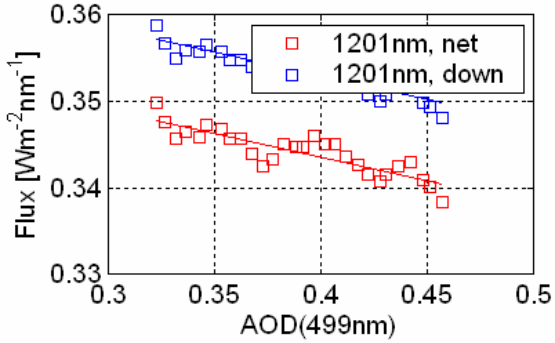


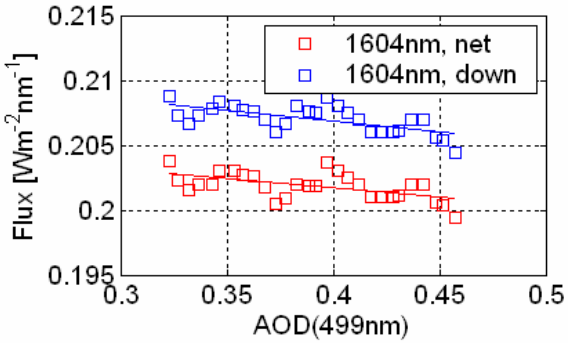


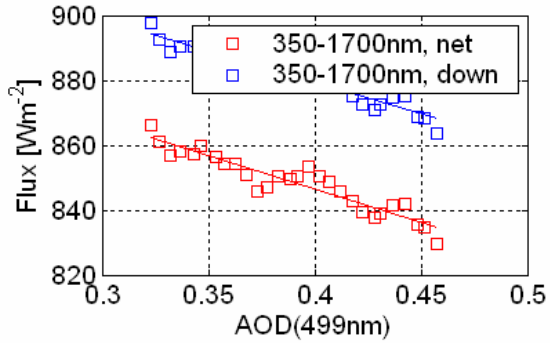


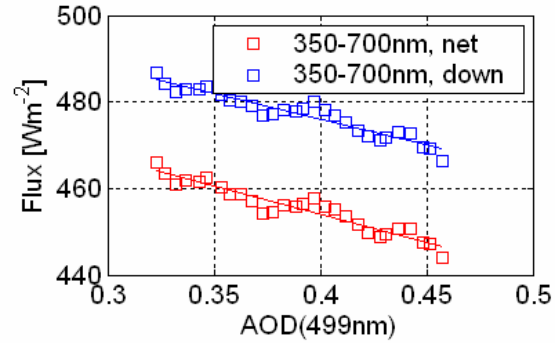




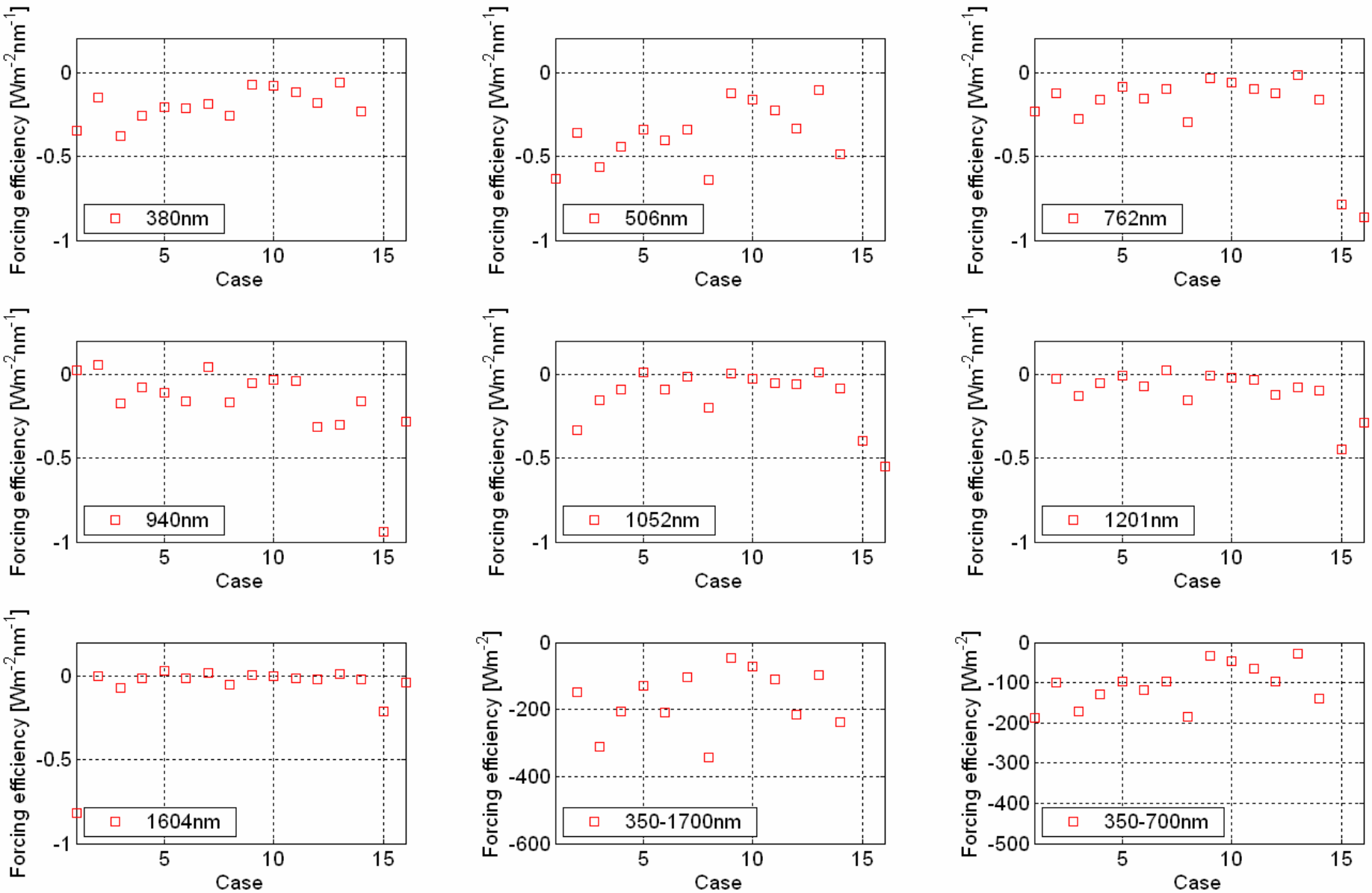




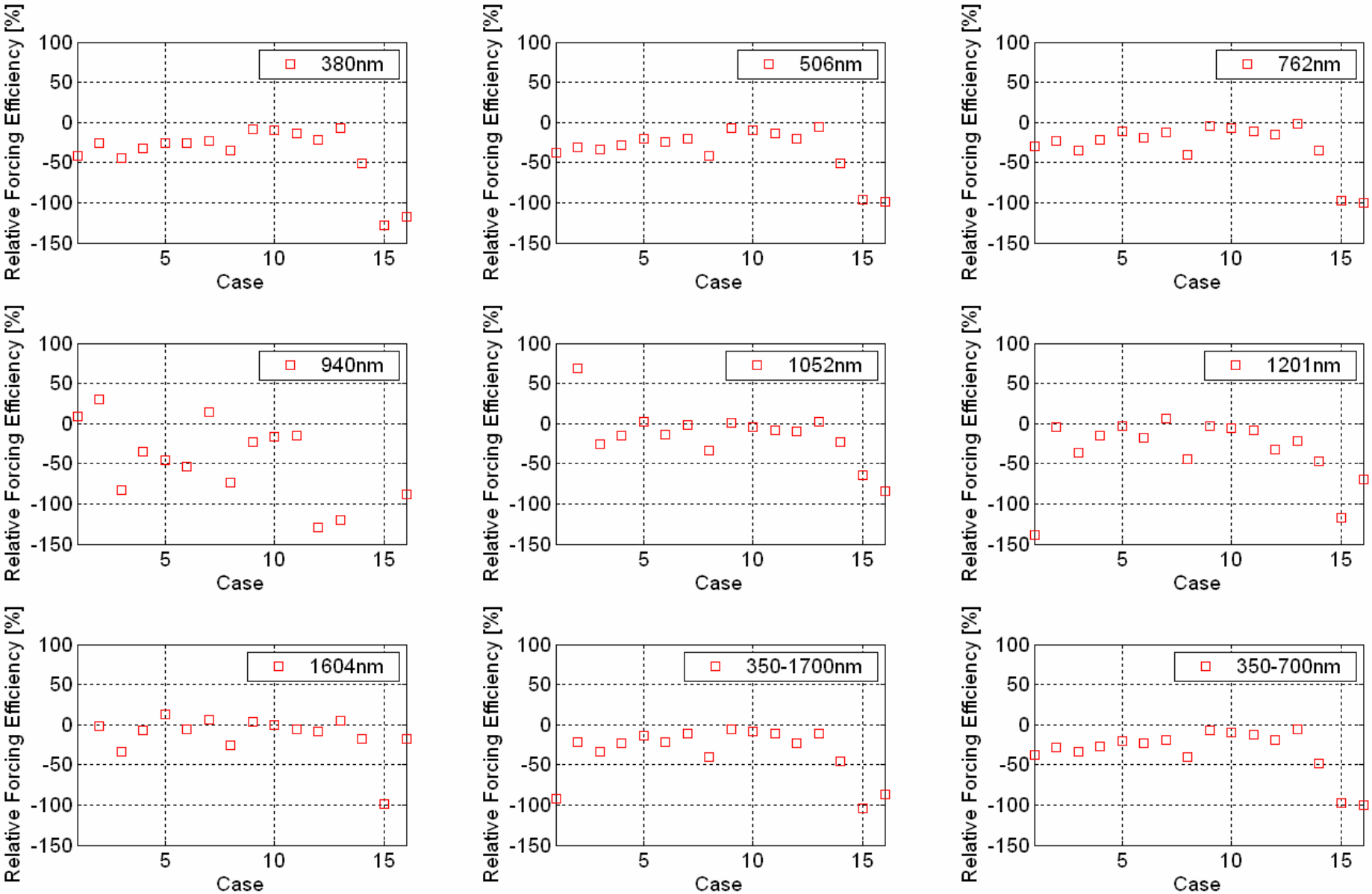




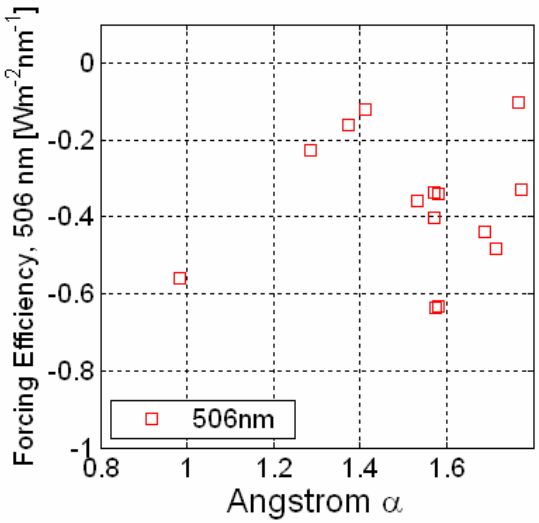
ICARTT Forcing Efficiencies per unit 499nm AOD, all 16 cases

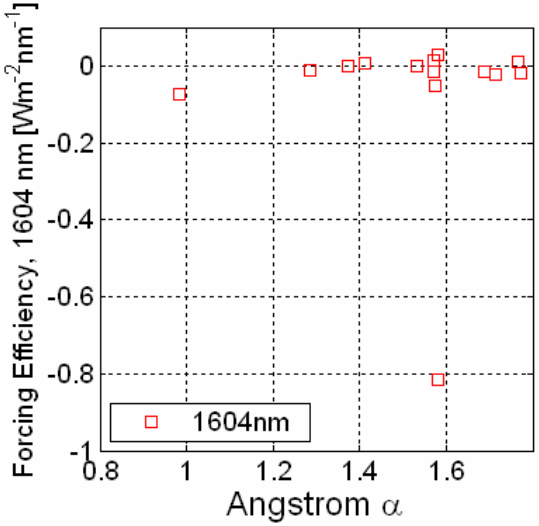


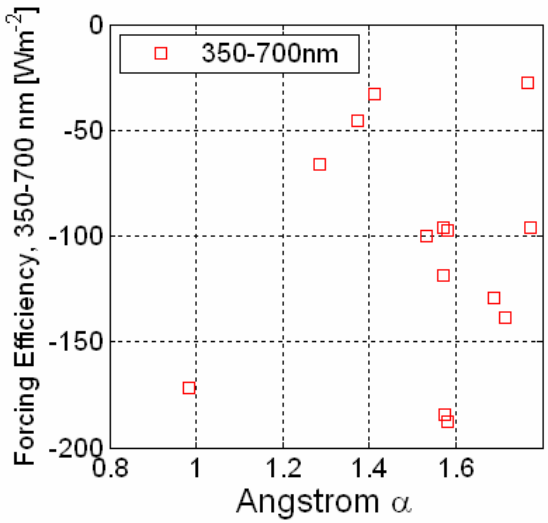
ICARTT Relative Forcing Efficiencies per unit 499nm AOD, all 16 cases

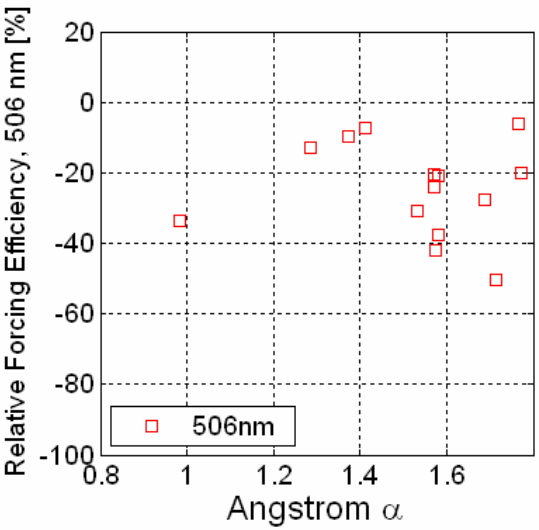


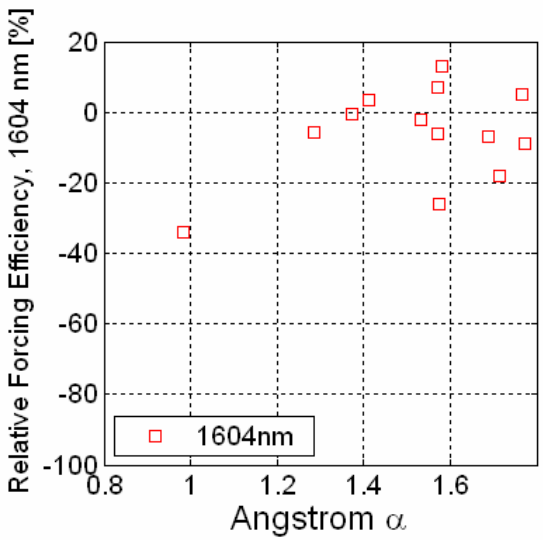
ICARTT Forcing Efficiencies per unit 499nm AOD as f(α)

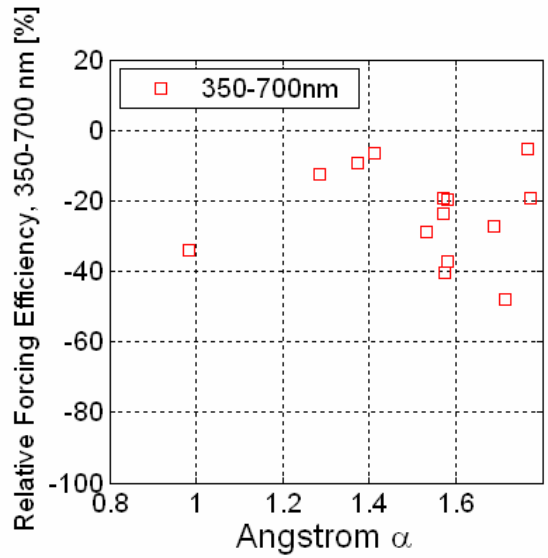




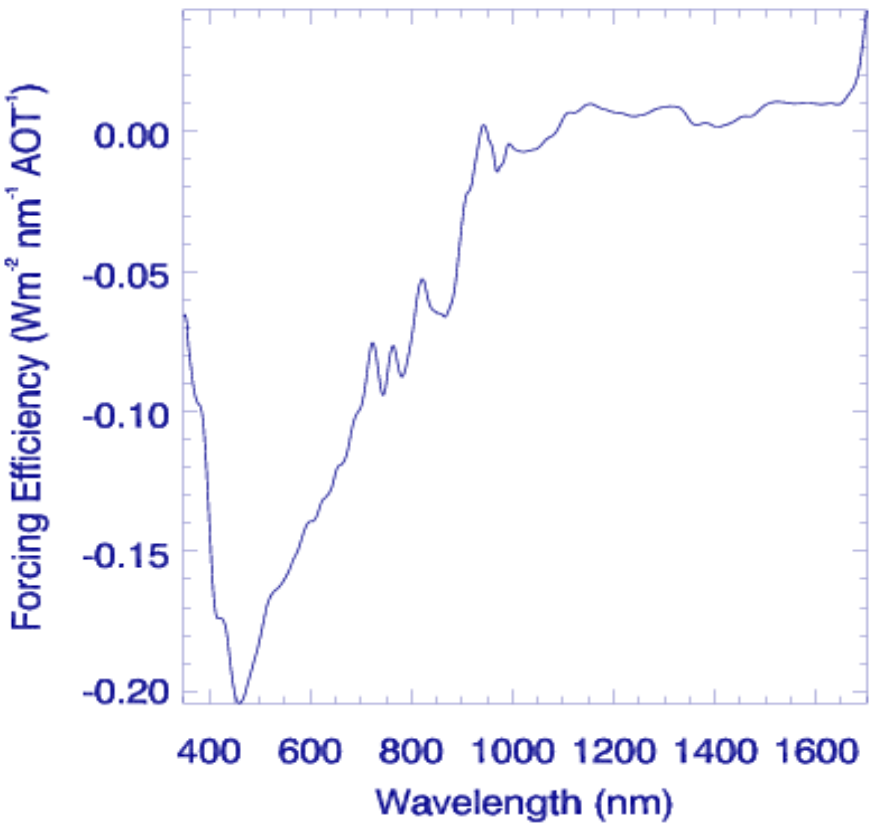


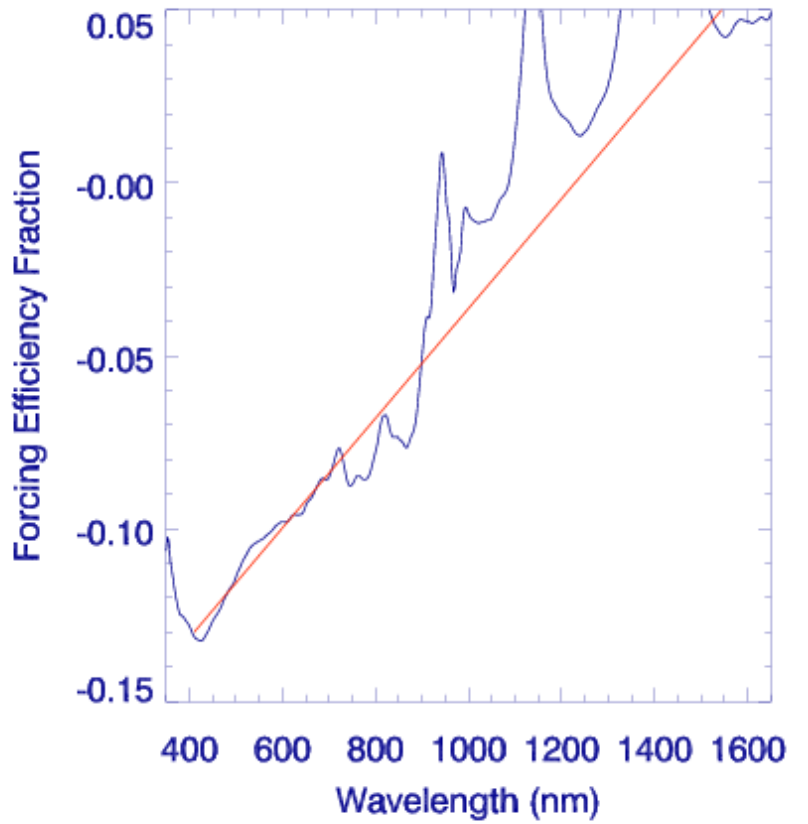






Full spectrum of absolute and relative forcing efficiency





21 July 2004

Next… on gradient forcing work

- Quantify and correct for solar zenith angle effects
- Normalize to common solar zenith angle or compute diurnal average forcing efficiencies
- Compare derived forcing efficiencies to values derived from ground-based methods in previous field campaigns (INDOEX, ACE-Asia)
- Prepare paper by May 30, 2005 – request exception to general INTEX protocol