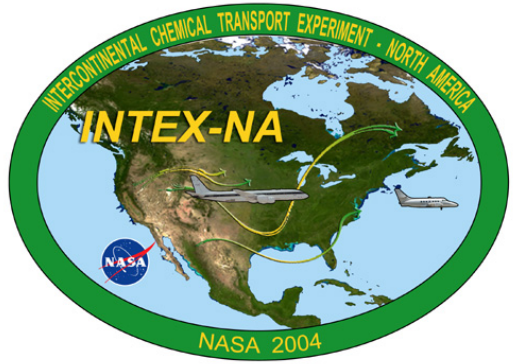
Photolysis frequency measurements on the DC-8 during INTEX-NA

Rick Shetter

Barry Lefer

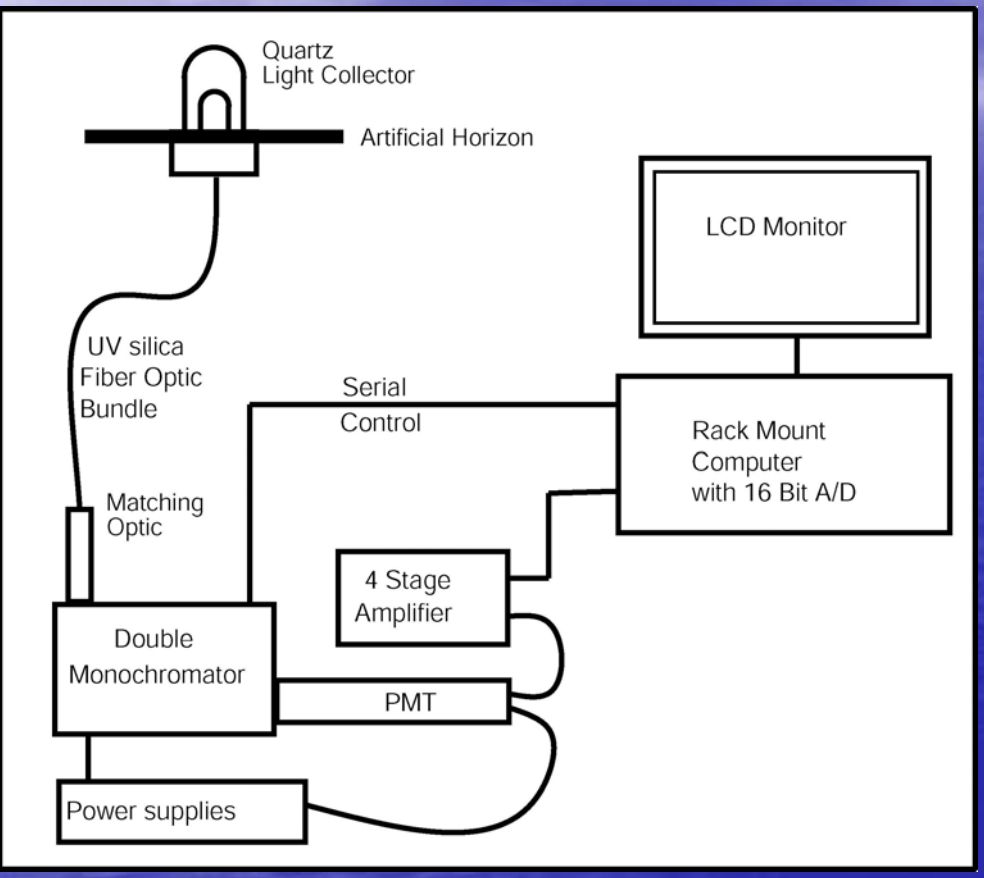
Sam Hall

NCAR



SAFS Instrument

Scanning Actinic Flux Spectroradiometer (SAFS)



Quartz optical collection head
- 2π steradian light collection
- 30 cm Artificial Horizon

Fiber Optic Bundles for light transfer
- High OH fused silica for high UV throughput
- 10 meter length, 37 fibers
- Round to slit configuration for max throughput

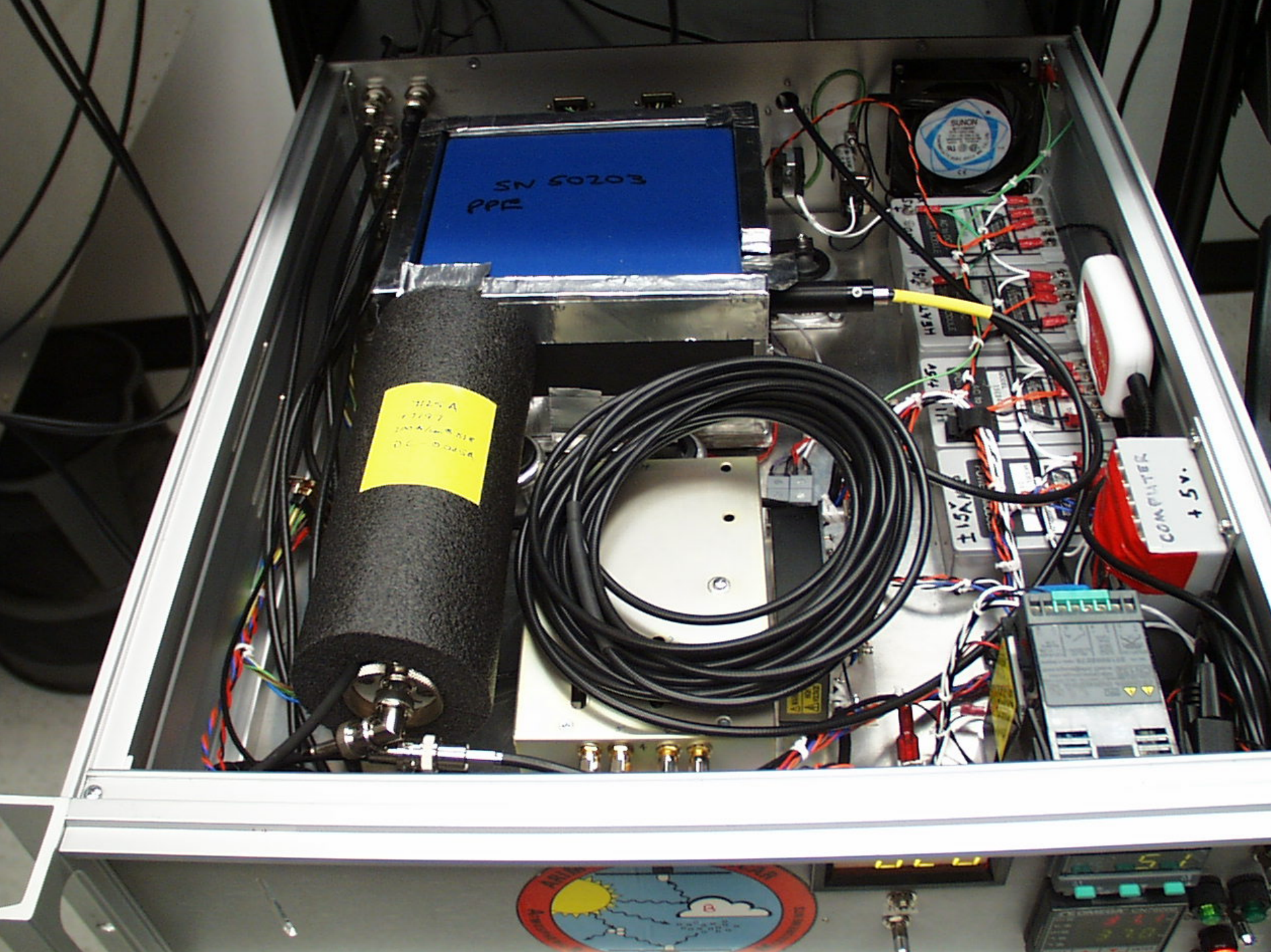
1/8 meter Double Monochromator
- Focal Length 110 mm
- Wavelength accuracy <0.1 nm
- Stray light rejection $<10^{-9}$
- Resolution 1 nm FWHM

Photomultiplier
- Bialkali photocathode
- Low dark current selected <0.04 nA

Picoammeter/Amplifier
- 4 output stages with 10^8, 10^7, 10^6 and 10^5 gains

Scan Acquisition Time
- 10-30 s

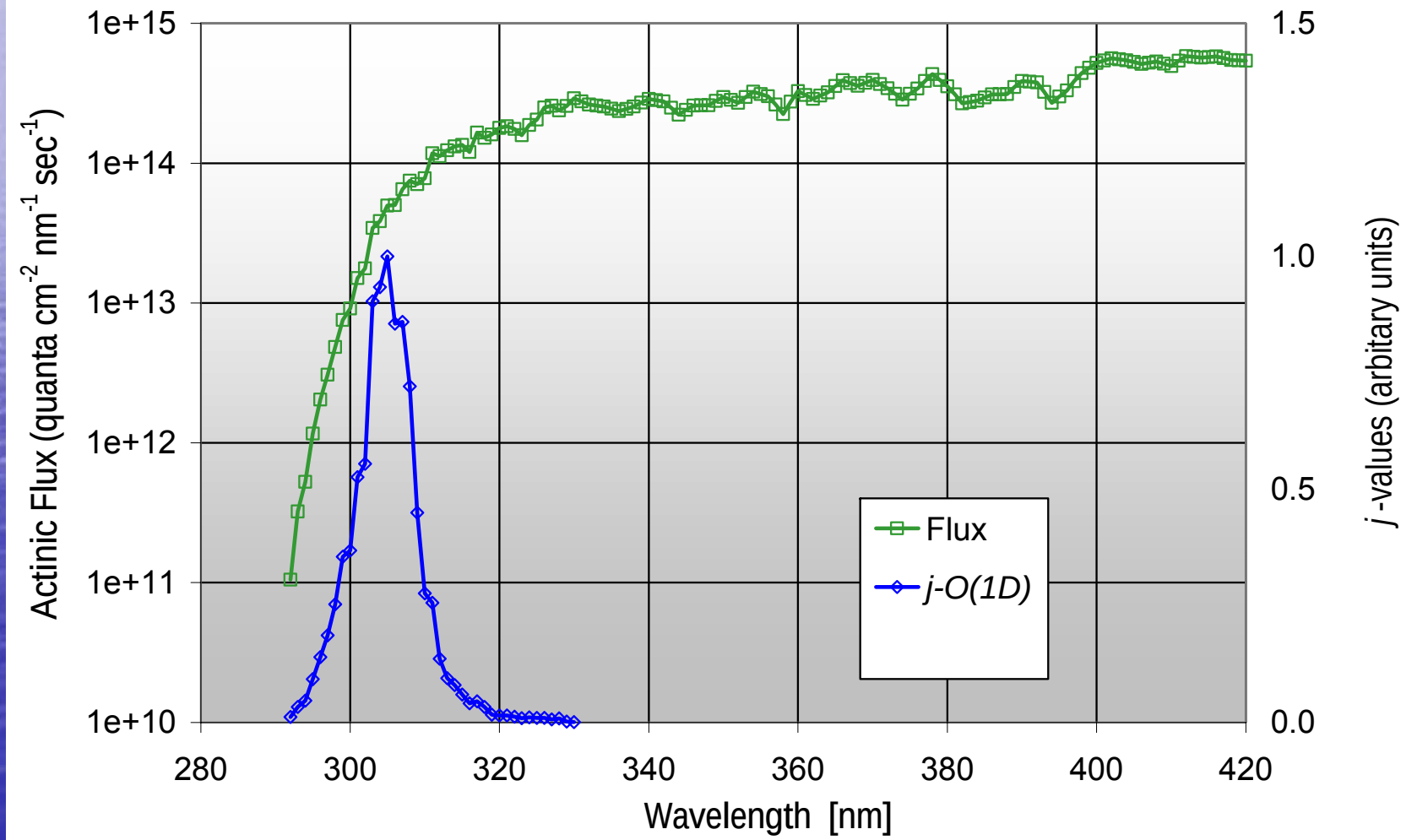

STA 1330


SN 50203
PPE
+5V
COMPUTER

UV-VIS Actinic Flux Spectrum

$O_3 + h\nu \rightarrow O_2 + O(^1D)$ [j-$O(^1D)$]

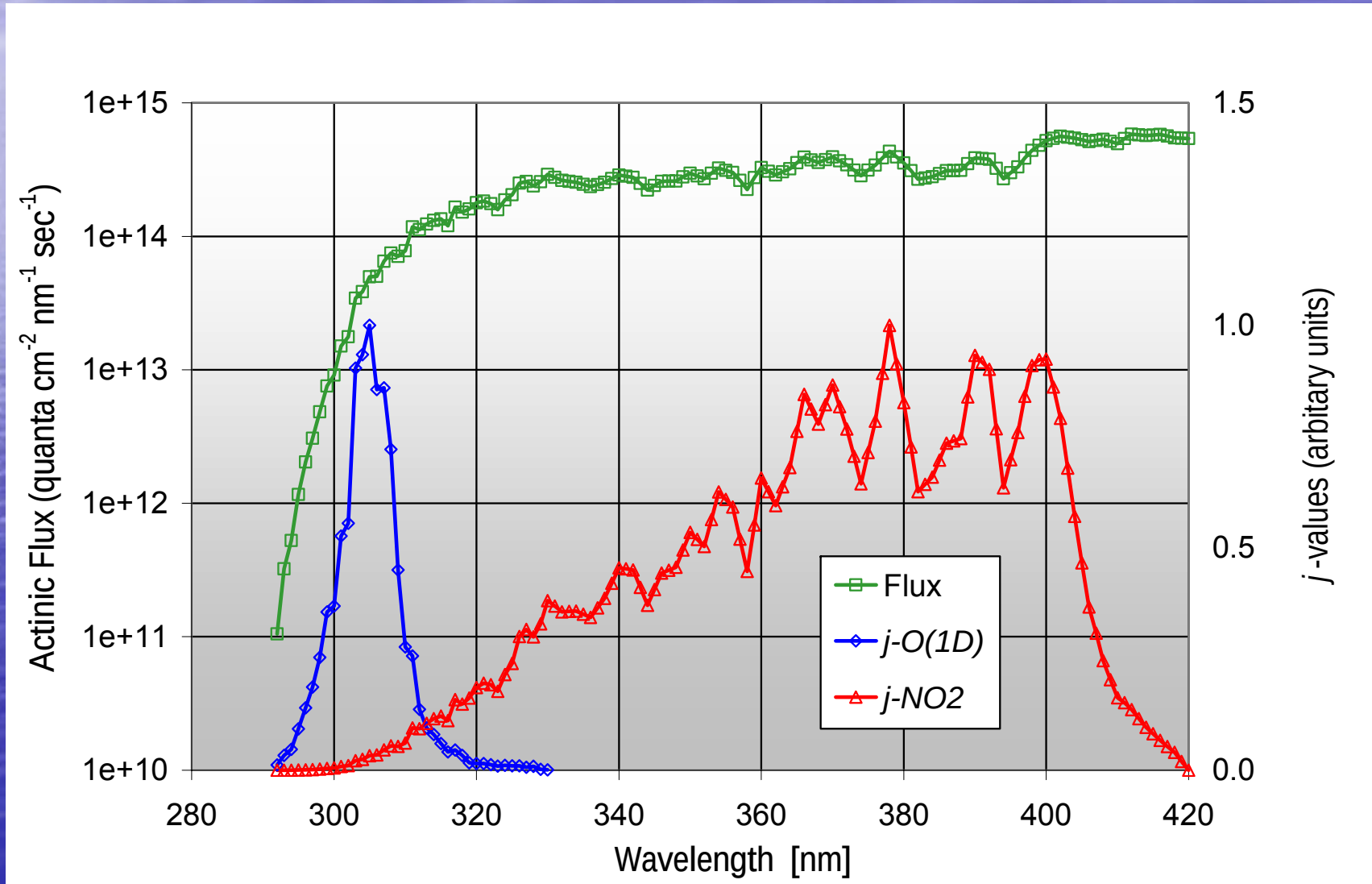
$$J = \int F(\lambda)\sigma(\lambda)\phi(\lambda)d\lambda$$



UV-VIS Actinic Flux Spectrum

$NO_2 + h\nu \rightarrow NO + O(^3P)$ [j-NO_2]

$$J = \int F(\lambda)\sigma(\lambda)\phi(\lambda)d\lambda$$



Calculated photolysis frequencies

$O_3 \rightarrow O(1D) + O_2$	$CH_3ONO_2 \rightarrow CH_3O + NO_2$
$NO_2 \rightarrow NO + O(3P)$	$CH_3CH_2ONO_2 \rightarrow CH_3CH_2O + NO_2$
$HONO \rightarrow OH + NO$	$CH_3COCH_3 \rightarrow CH_3CO + CH_3$
$HO_2NO_2 \rightarrow HO_2 + NO_2$	$PAN \rightarrow CH_3COO_2 + NO_2$
$HO_2NO_2 \rightarrow OH + NO_3$	$CH_3CHO \rightarrow CH_3 + HCO$
$HCHO \rightarrow H + HCO$	$CH_3CHO \rightarrow CH_4 + CO$
$HCHO \rightarrow H_2 + CO$	$CHOCHO \rightarrow HCO + HCO$
$HNO_3 \rightarrow OH + NO_2$	$CH_3CH_2CHO \rightarrow CH_3CH_2 + HCO$
$N_2O_5 \rightarrow NO_3 + NO + O(3P)$	$CH_3CH_2CH_2CHO \rightarrow C_3H_7 + HCO$
$N_2O_5 \rightarrow NO_3 + NO_2$	$CH_3CH_2CH_2CHO \rightarrow C_2H_4 + CH_2CHOH$
$HOOH \rightarrow 2\ OH$	$CH_3COCHO \rightarrow CH_3CO + HCO$
$CH_3OOH \rightarrow CH_3O + OH$	$CH_3COCH_2CH_3 \rightarrow C_2H_5 + CH_3CO$

CCD Actinic Flux Spectroradiometer (CAFS) system

Detector Enclosure

Actinic Flux Optical Collector

- Quartz domes and light guide optimized for angular and azimuth independent light collection
- Artificial horizon to limit field of view to 2π steradians

Custom UV fiber optic bundle

- Multi-fiber bundle with homogenizers on both ends

Monolithic monochromator

- Ceramic body with epoxy attached slit, grating, and CCD detector for temperature and vibration stability

Back thinned blue enhanced windowless cooled CCD detector

- Detector maintained at -1.0 °C
- Detector electronics average multiple spectra on electronics to minimize detector read noise

Electronics Enclosure

Power supplies for CCD cooling and logic

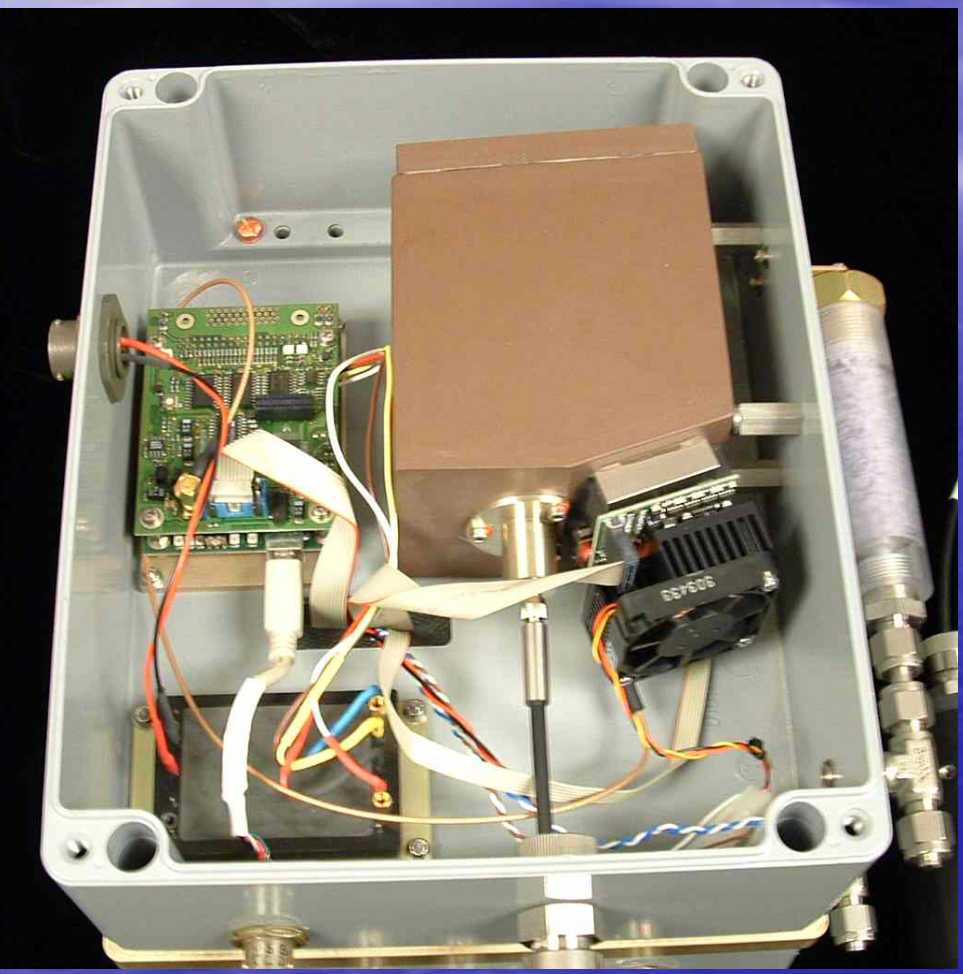
PC-104 data acquisition and control computer

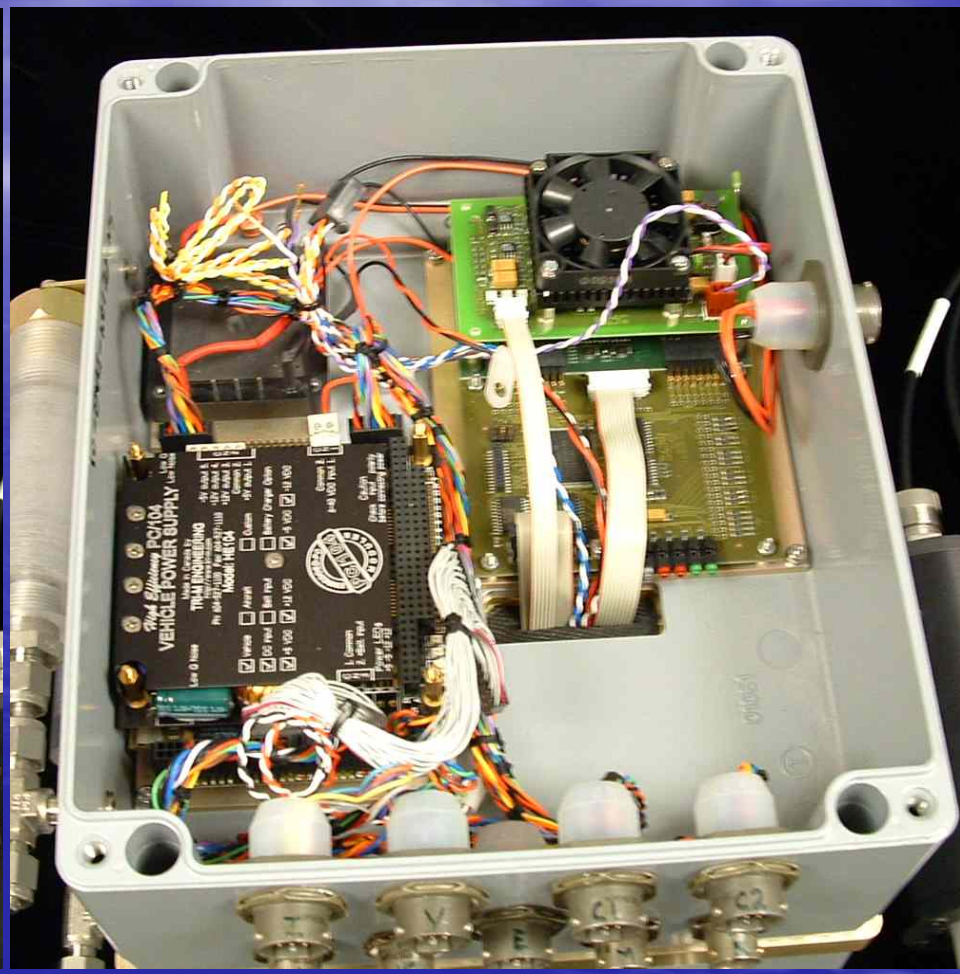
Instrument Specifications

Wavelength Dependent Actinic Flux Measurements

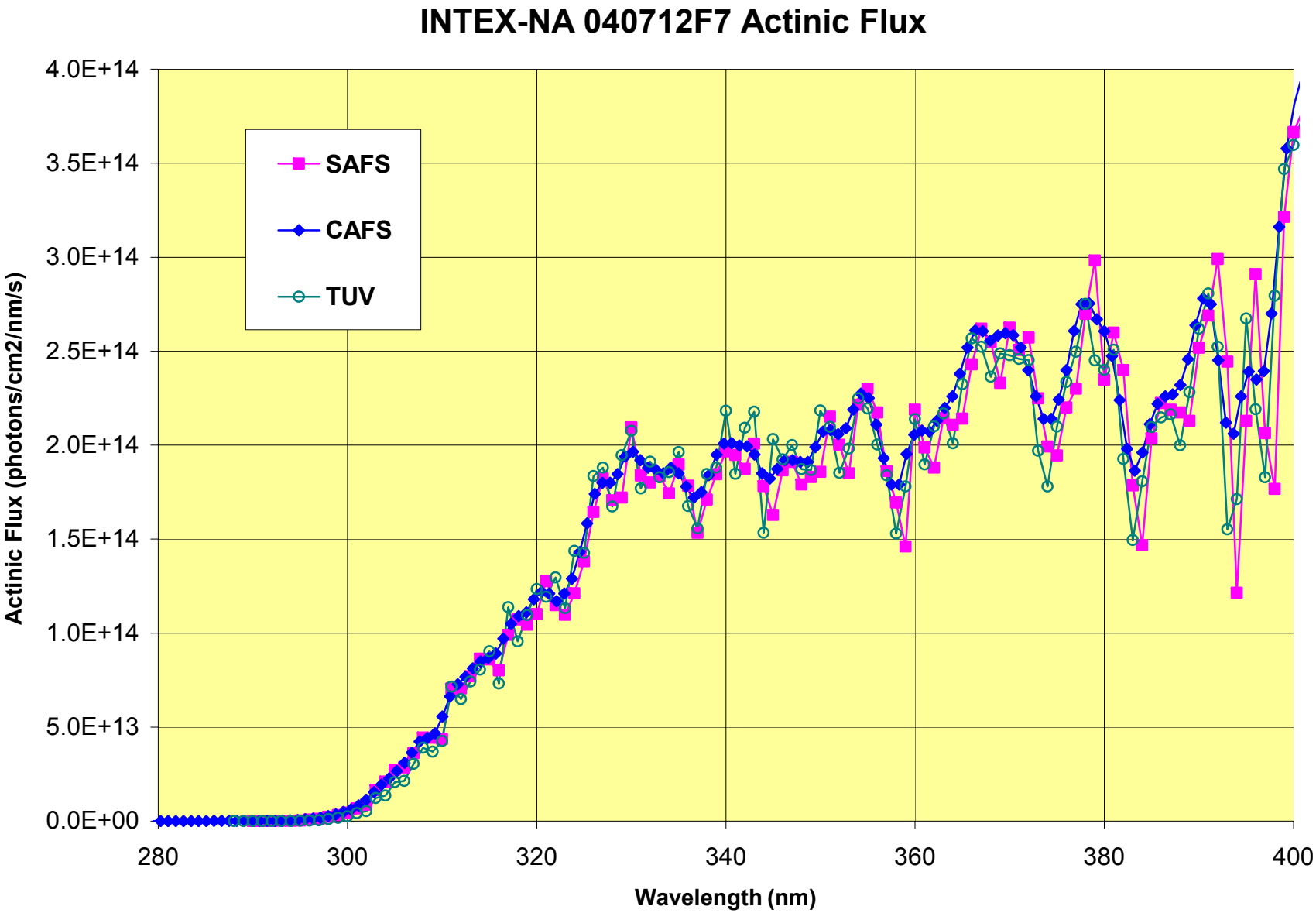
Wavelength range:	280-400 nm (limited by UG-11 filter)
Wavelength resolution:	~2.2 nm FWHM at 297 nm
Accuracy:	5% in UV-B, 3% in UV-A/VIS dependent on NIST standards
Detection limit:	~0.04 mW/m2/nm at 300 nm
Precision:	<1 % depending on wavelength
Spectral acquisition:	70 and 200 ms spectra (2 sec)
Weight:	<23 kg per instrument
Power:	<15 amps of 28 volt DC per inst
Location on DC-8:	Zenith 1

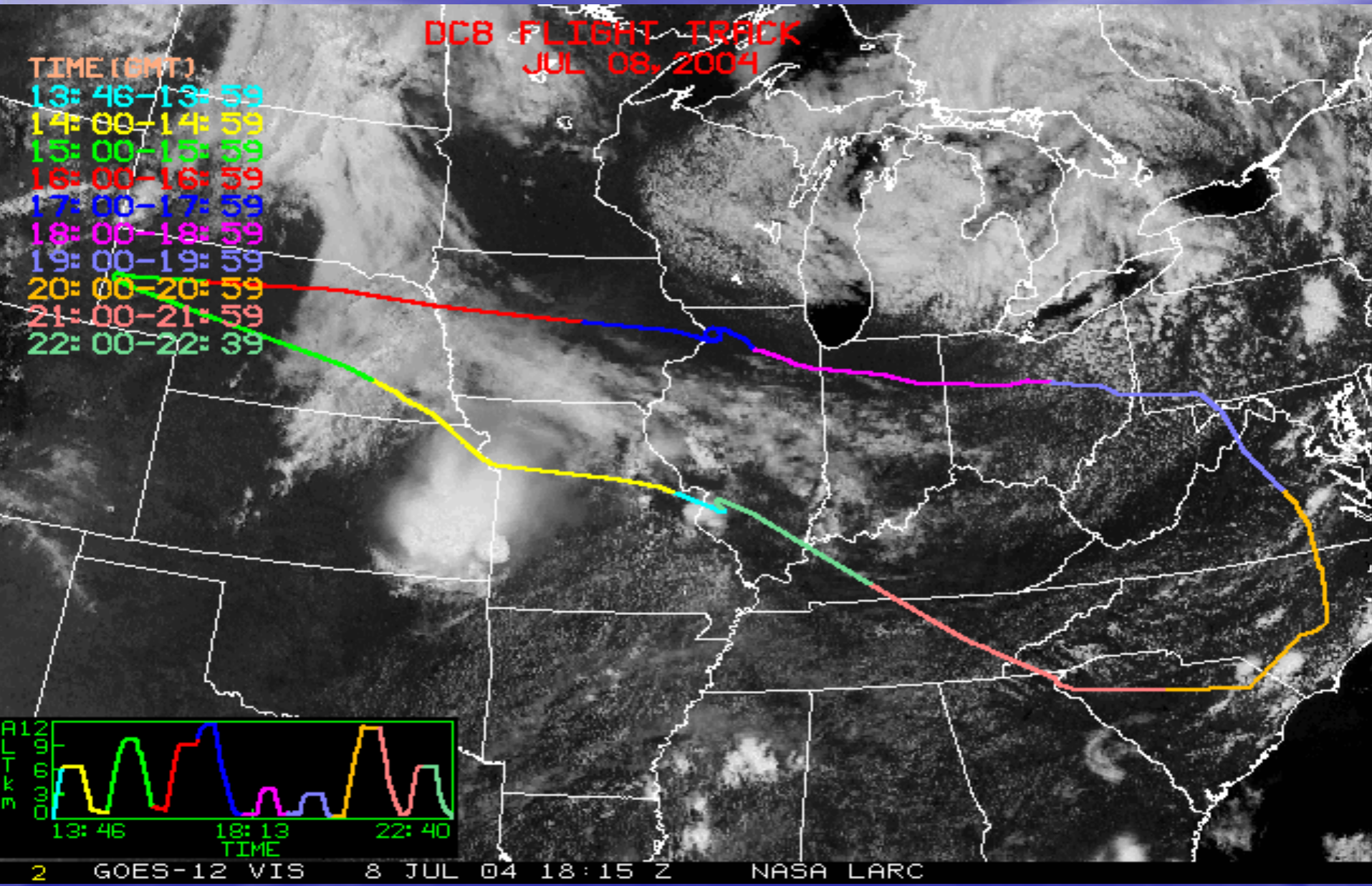
CAFS system components

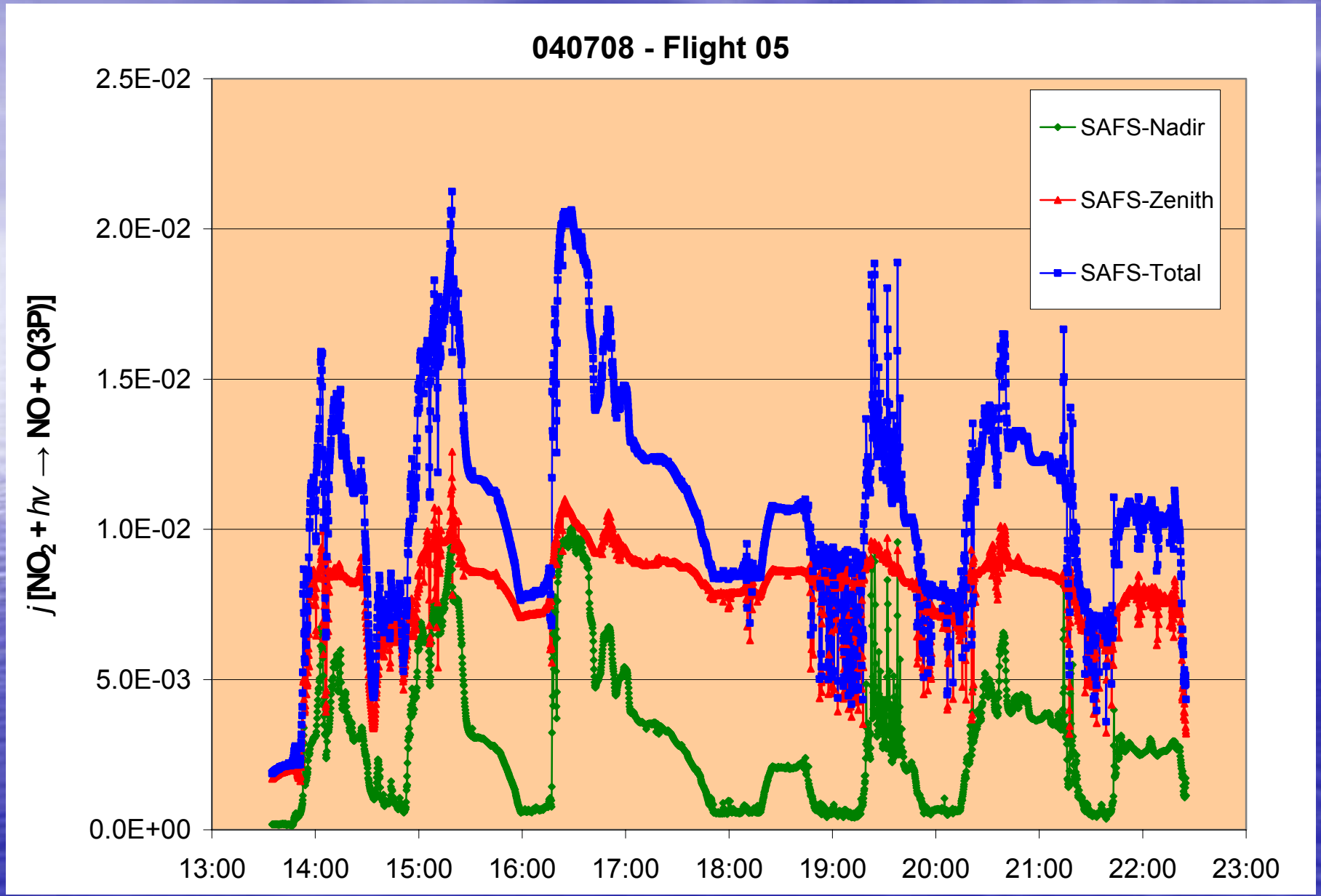


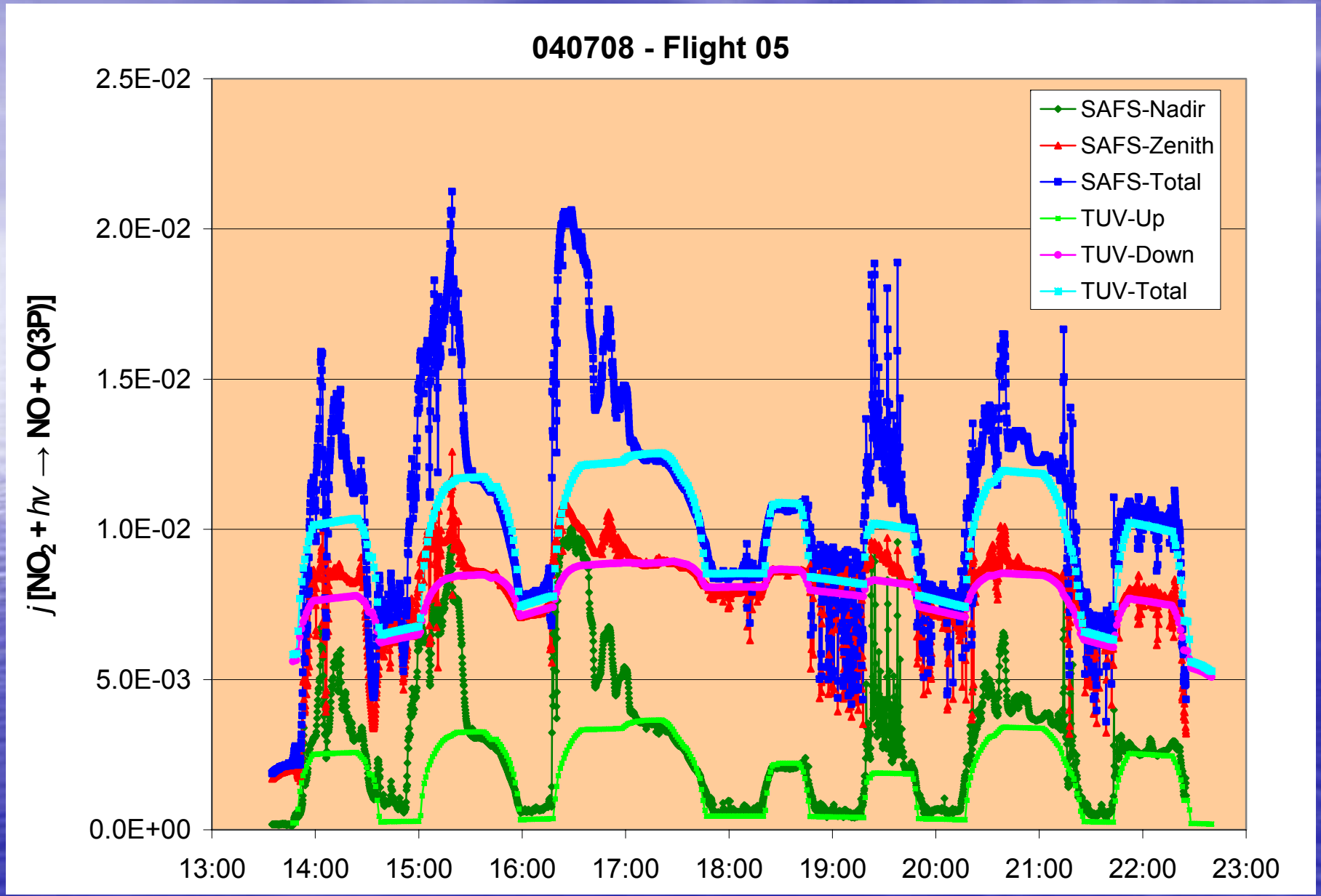


SAFS and CAFS Actinic Flux




DC8 FLIGHT TRACK
JUL 08, 2004
TIME (GMT)
13: 46-13: 59
14: 00-14: 59
15: 00-15: 59
16: 00-16: 59
17: 00-17: 59
18: 00-18: 59
19: 00-19: 59
20: 00-20: 59
21: 00-21: 59
22: 00-22: 39
ALT km
12
9
6
3
0
13: 46
18: 13
22: 40
TIME
2 GOES-12 VIS 8 JUL 04 18:15 Z NASA LARC


040708 - Flight 05
2.5E-02
2.0E-02
1.5E-02
1.0E-02
5.0E-03
0.0E+00
j [NO2 + hν → NO + O(3P)]
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
SAFS-Nadir
SAFS-Zenith
SAFS-Total


040708 - Flight 05
2.5E-02
2.0E-02
1.5E-02
1.0E-02
5.0E-03
0.0E+00
j [NO2 + hν → NO + O(3P)]
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
SAFS-Nadir
SAFS-Zenith
SAFS-Total
TUV-Up
TUV-Down
TUV-Total

Tropospheric Ultraviolet and Visible (TUV) Radiation Model

TUV version 4.1

8-stream discrete ordinate radiative transfer method with a pseudo-spherical modification

- Model Inputs:

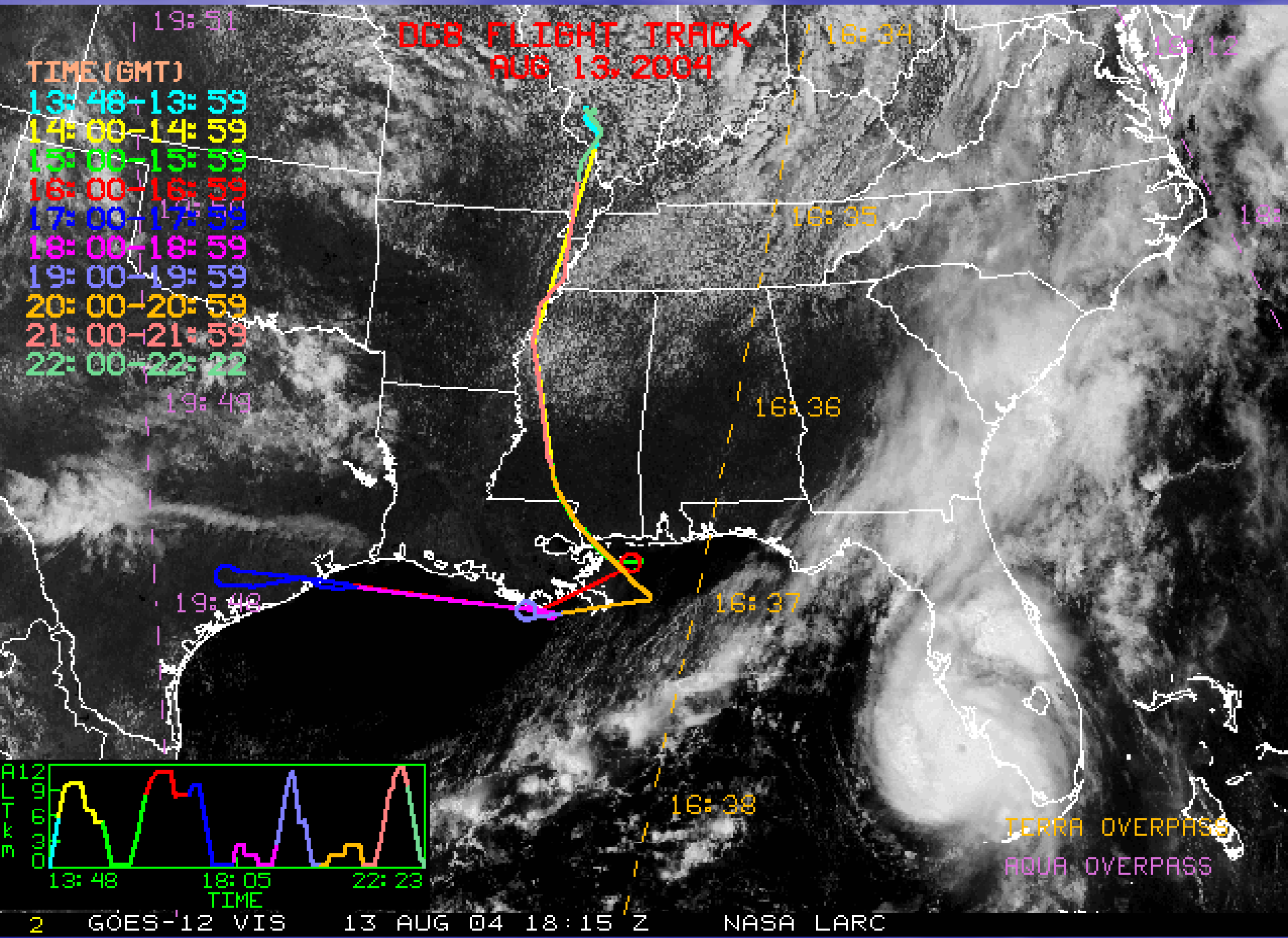
  Latitude
  Longitude
  Altitude
  Surface albedo
  Vertical profiles of SO_2, NO_2, O_3
  Aerosol / cloud properties

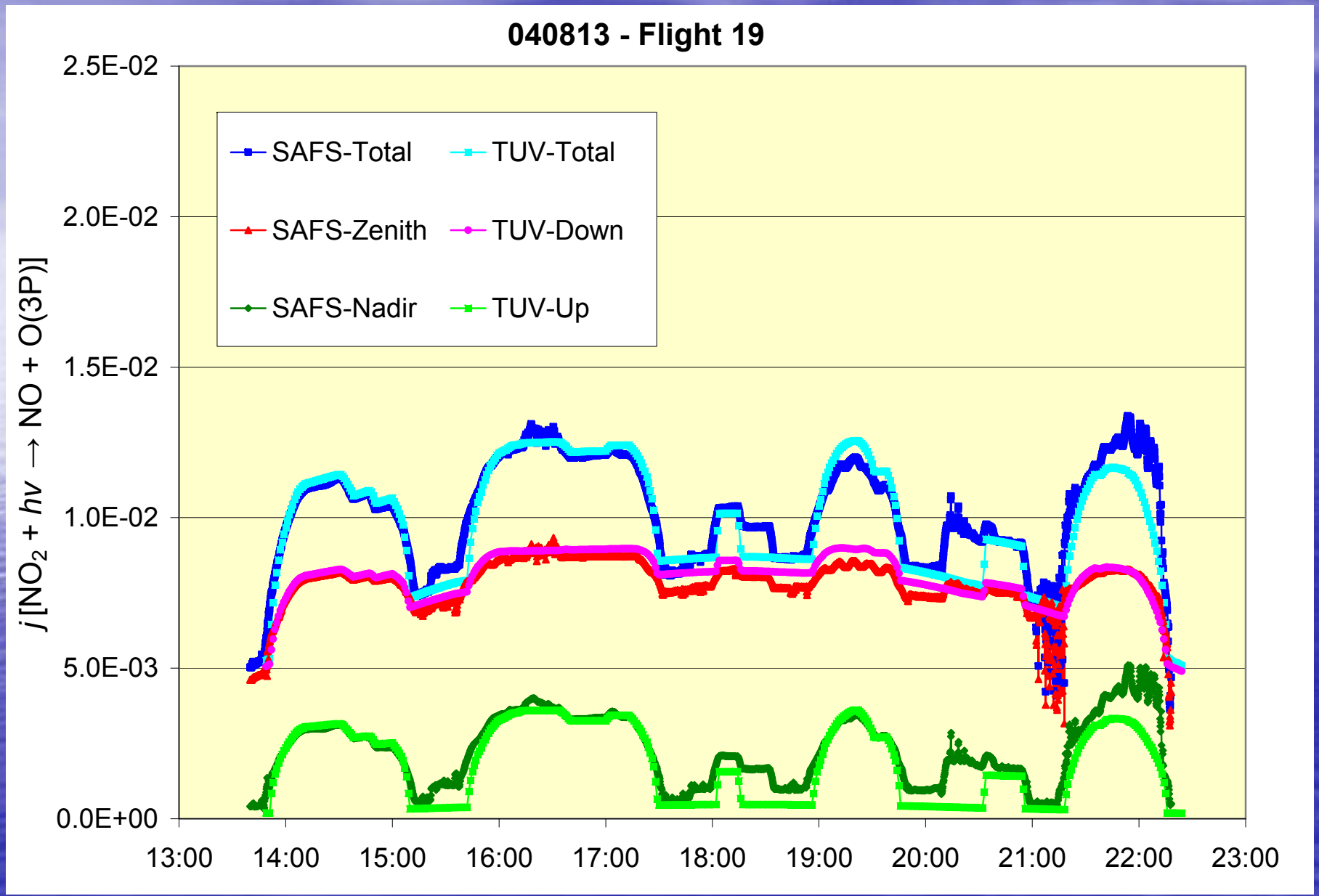
[http://www.acd.ucar.edu/TUV/]

Tropospheric Ultraviolet and Visible (TUV) Radiation Model

Aerosol Properties in TUV

- Aerosol optical depth (τ)
- Angstrom Coefficient (α)
- Aerosol single scattering albedo (ω)
- Aerosol asymmetry factor (g)


DC8 FLIGHT TRACK
AUG 13, 2004
TIME(GMT)
13:48-13:59
14:00-14:59
15:00-15:59
16:00-16:59
17:00-17:59
18:00-18:59
19:00-19:59
20:00-20:59
21:00-21:59
22:00-22:22
19:51
16:34
19:12
16:35
19:49
16:36
19:48
16:37
16:38
ALT km
12
9
6
3
0
13:48
18:05
22:23
TIME
TERRA OVERPASS
AQUA OVERPASS
2 GOES-12 VIS 13 AUG 04 18:15 Z NASA LARC


040813 - Flight 19
SAFS-Total
TUV-Total
SAFS-Zenith
TUV-Down
SAFS-Nadir
TUV-Up
2.5E-02
2.0E-02
1.5E-02
1.0E-02
5.0E-03
0.0E+00
j[NO2 + hv → NO + O(3P)]
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00

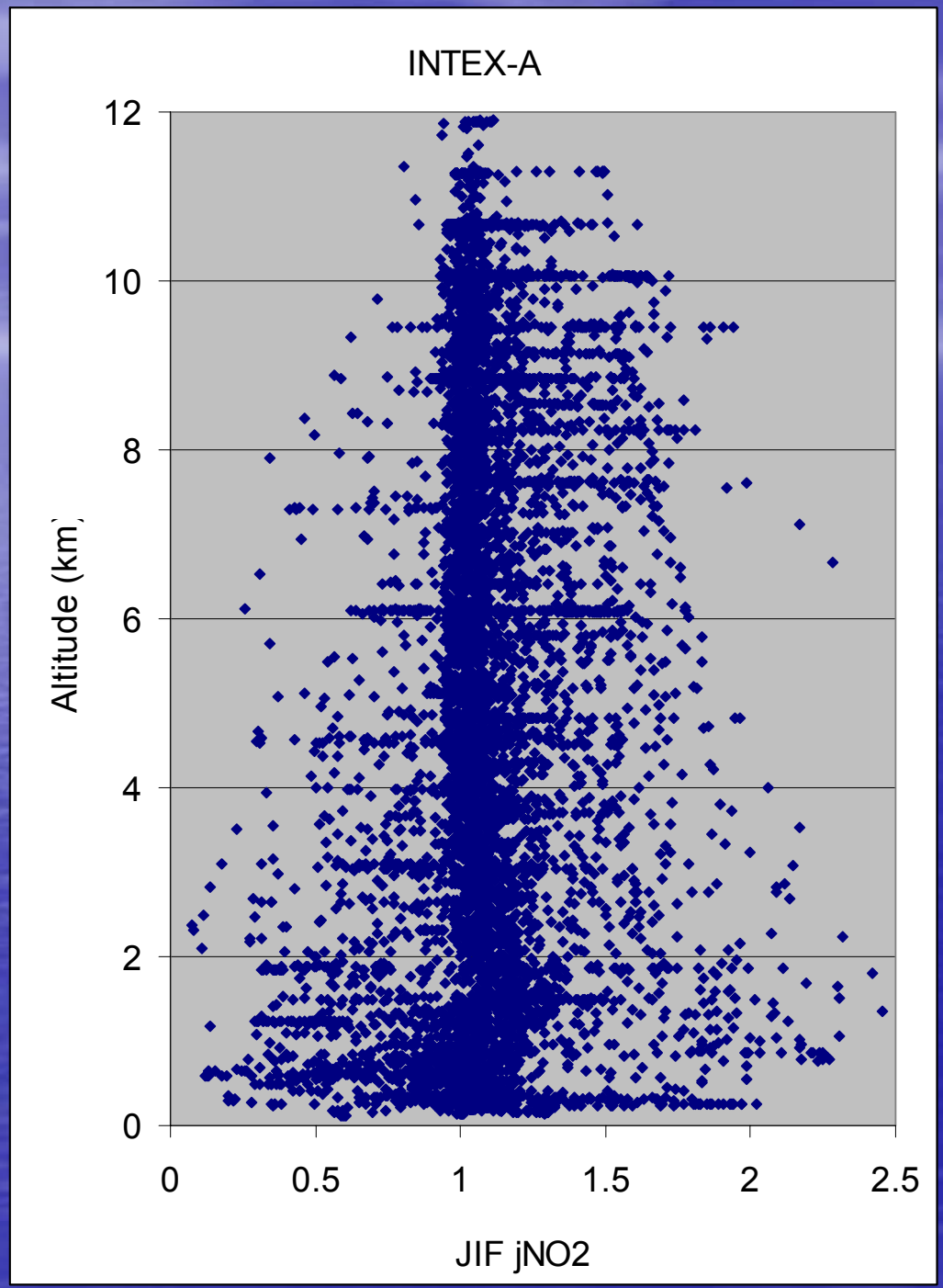
j-value Impact Factor

$$\mathrm{JIF} = \frac{j\,\mathrm{NO_2}\ \text{Measured}}{j\,\mathrm{NO_2}\ \text{Cloud Free Model}}$$

Value close to 1 = Measurements and RT Model Agree

Less than 1 = Cloud/aerosol reduction of *j* -values

Greater than 1 = Cloud/aerosol enhancement of *j* -values


INTEX-A
12
10
8
6
4
2
0
Altitude (km)
0
0.5
1
1.5
2
2.5
JIF jNO2

Satellite Underpass Locations and Flights

Flight	Location	Time	Satellite
Flt 3	Spiral Far West Of Trinidad Head	21:30-22:00	Terra
Flt 4	(In Progress Double Back Pelston,MI)	21:15-21:45	
Flt 5	Spiral N Il Near Rockport	17:15-17:45	Aqua
Flt 6	Spiral West PA	15:45-16:15	(?Aqua)
	Spiral Ga/NC/SC/TN Intersection	18:30-19:00	Aqua
Flt 7	Spiral Northern WI, Rhinelander,	16:00-16:30	
	Spiral North Central OK –ARM Site	19:30-20:00	
Flt 8	Spiral Rhinelander WI	14:15-14:45	
	Rhinelander WI	17:15-17:45	Terra
	In Progress Upmi-North Bay, Ont	18:00-19:00	Aqua
Flt 9	PEI Gulf Of St Lawrence	15:30-16:00	
	South New Foundland	16:30-17:00	Aqua
Flt 10	Northcentral,IL	18:45-19:15	Aqua
Flt 11	Gulf Of Maine	16:00-16:30	Terra
Flt 12	East Of FL	16:30 17:00	Terra
Flt 14	Very Far East Of Cape Cod;	15:00-15:30	Terra
	In Progress, Vf East Hatteras	16:30-17:30	Aqua
Flt 15	North Gulf Of St Lawrence	16:15-16:45	Terra & Aqua
Flt 16	Eastern TN	16:30-17:00	Terra
Flt 17	East Of Cape Cod,	15:15-15:45	Terra
Flt 18	Very Far East Of Cape Hatteras	15:00-15:30	Terra
	Ky/WV	18:40-19:10	Aqua
Flt 19	Gulf Of Mexico/MS	15:40-16:10	Terra
	Gulf Of Mexico/La	18:50-19:20	Aqua
Flt 20	Trinidad Head	22:40-23:10	

INTEX-A
Actinic Flux/Photolysis Frequency Research Questions

- **Impact of clouds and aerosols on photochemistry during INTEX-A (0-D and 3-D models).**

- **Comparison of RT model and measurements using aerosol properties (AOD, ssa, angstrom, etc) from:**

  satellite retrievals
  ***in situ* measurements**
  model calculations

- **SAFS v CAFS: performance, calculated photolysis frequencies.**