CERES Surface and Atmospheric Radiation Budget (SARB)

Overview part of CERES/ARM Science Team Meeting Nov. 2004

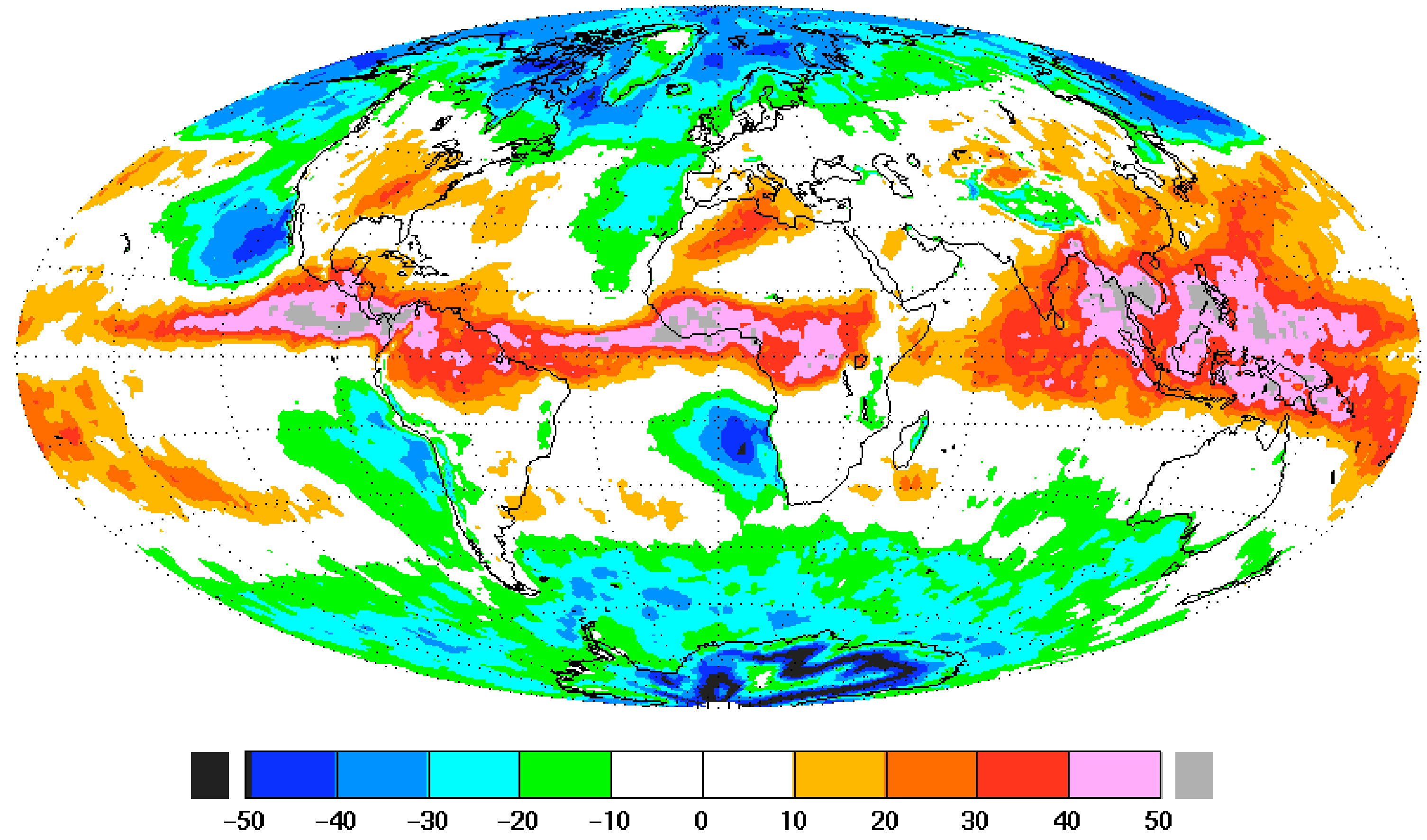
T. P. Charlock (NASA LaRC)
Fred G. Rose (AS&M) - algorithm
David A. Rutan (AS&M) - CAVE validation and calculation facility
Zhonghai Jin (AS&M) - coupled radiative transfer
Lisa H. Coleman, Thomas E. Caldwell, Scott Zentz (SAIC)
- Data Management Team
Seiji Kato (H.U.) - modifications to operational radiative transfer
David Fillmore & Bill Collins (NCAR) - MATCH
Wenying Su (H.U.)- surface UV algorithm & balloon broadband

CRS footprint *[SYN gridded]* product has *[will have]* fluxes

at surface, 500-200-70 hPa, and TOA,cloud & aerosol forcing

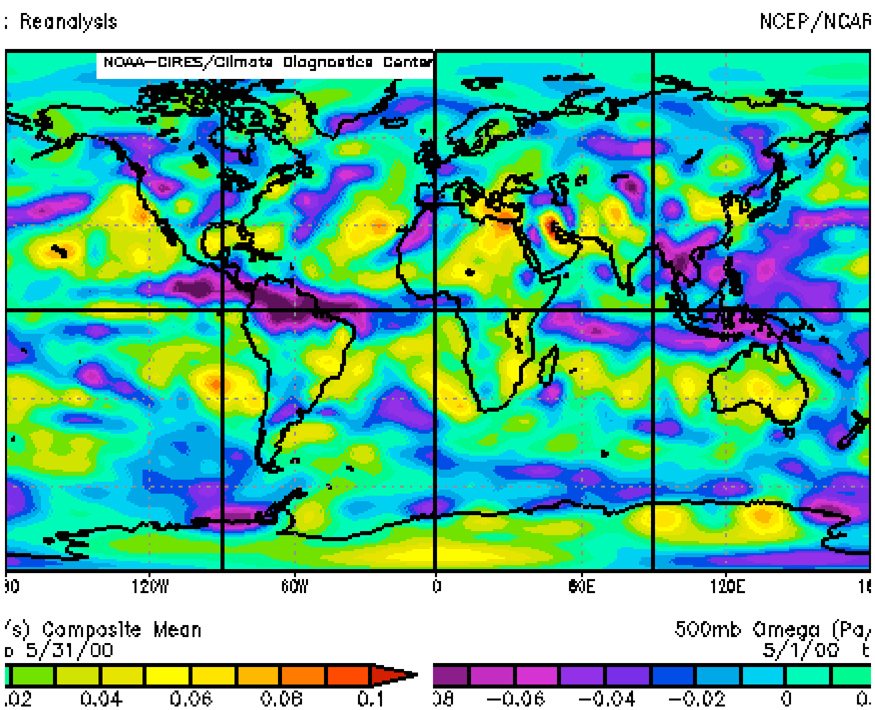
[and surface UVA, UVB]

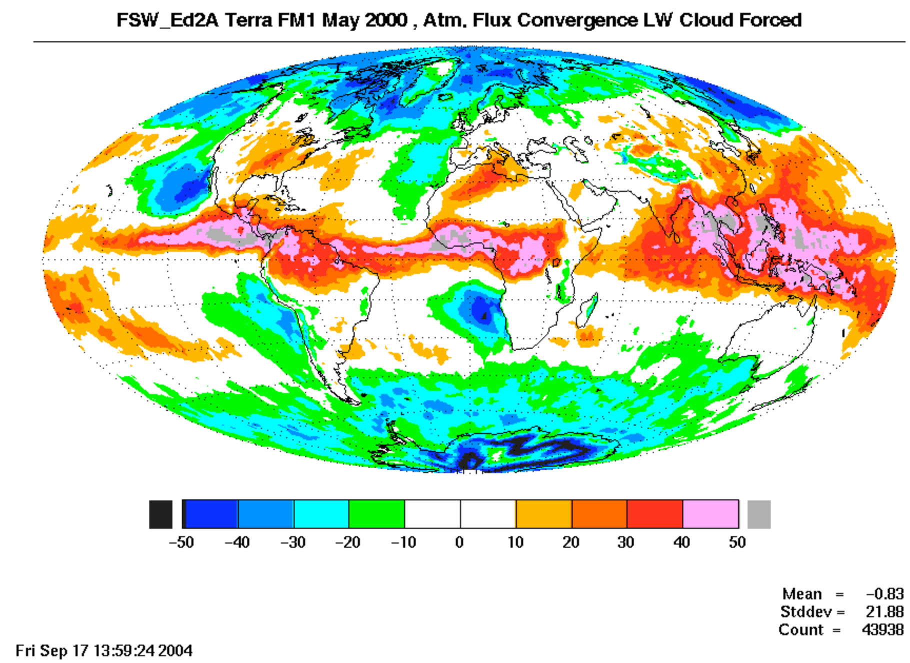
FSW_Ed2A Terra FM1 May 2000 , Atm. Flux Convergence LW Cloud Forced



Mean = -0.83
Stddev = 21.88
Count = 43938

Fri Sep 17 13:59:24 2004





Size 40%
Left crop L 4.20”
Right crop L 1.15” R 3.65”

CERES Surface and Atmospheric Radiation Budget (SARB)

CRS (footprint)/SYN (gridded) product has fluxes
at surface, 500-200-70 hPa, & TOA, cloud & aerosol forcing

Inputs: SSF (TOA flux, clouds, aerosols), NWP meteorology,
MATCH, aerosol assimilation, NCEP O3
Langley Fu-Liou 2 stream SW
2/4 LW with Kratz-Rose window
Kato gamma-weighted τ

Adjustments (tuning) to PW, UTH, skin T, aerosol τ,
cloud LWP/IWP, cloud fraction,& cloud height

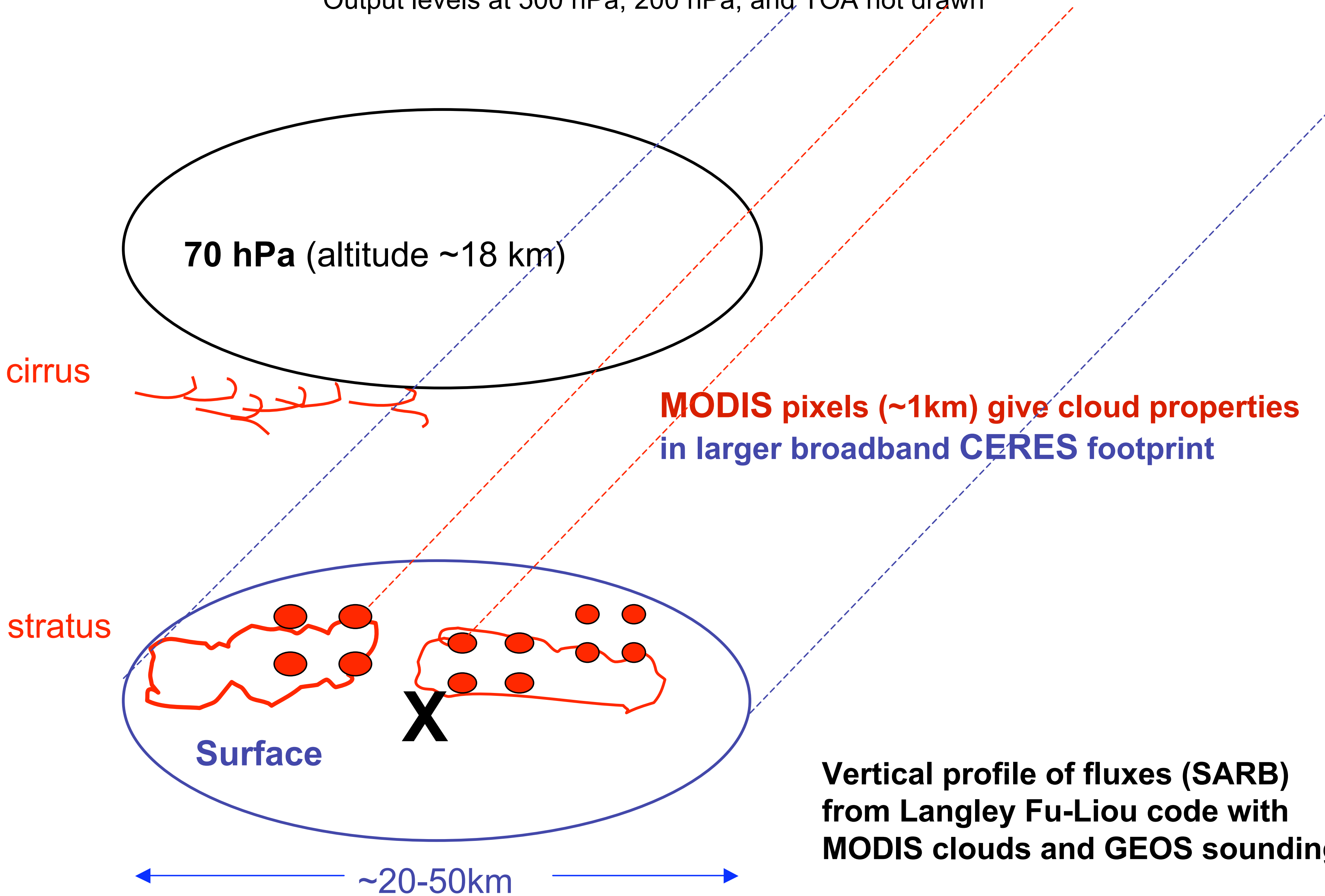
A priori uncertainties assigned to each adjustable parameter

Mininum sum of squares of normalized differences between

(1) computed TOA fluxes & adjusted inputs
and
(2) observed TOA fluxes & initial inputs

Viewing geometry of Surface and Atmophere Radiation Budget (SARB)

Output levels at 500 hPa, 200 hPa, and TOA not drawn

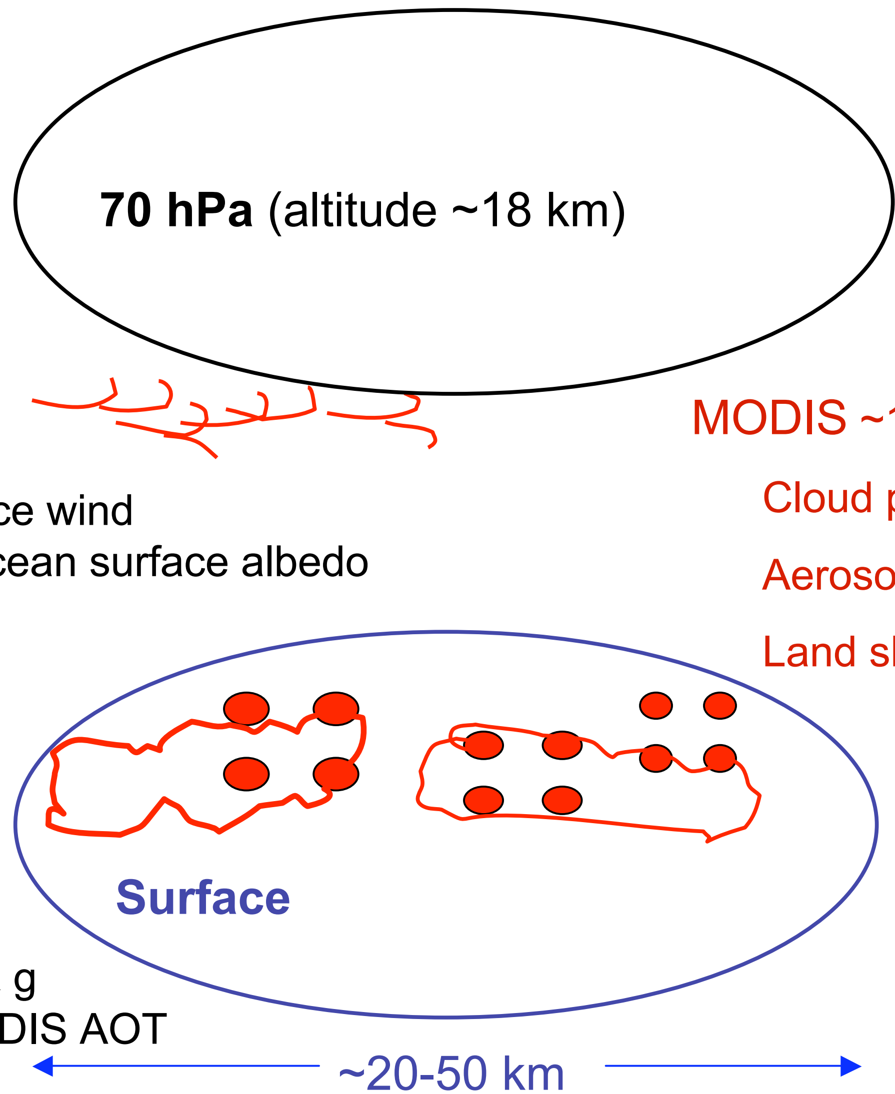


Vertical profile of fluxes (SARB) from Langley Fu-Liou code with MODIS clouds and GEOS sounding

Input data for computing SARB vertical profile at ~2,000,000 footprints/day

Absolutely no ground-based radiometric data are used for input

NCEP O3(z)
Mostly from SBUV/2



MODIS ~1km pixels provide

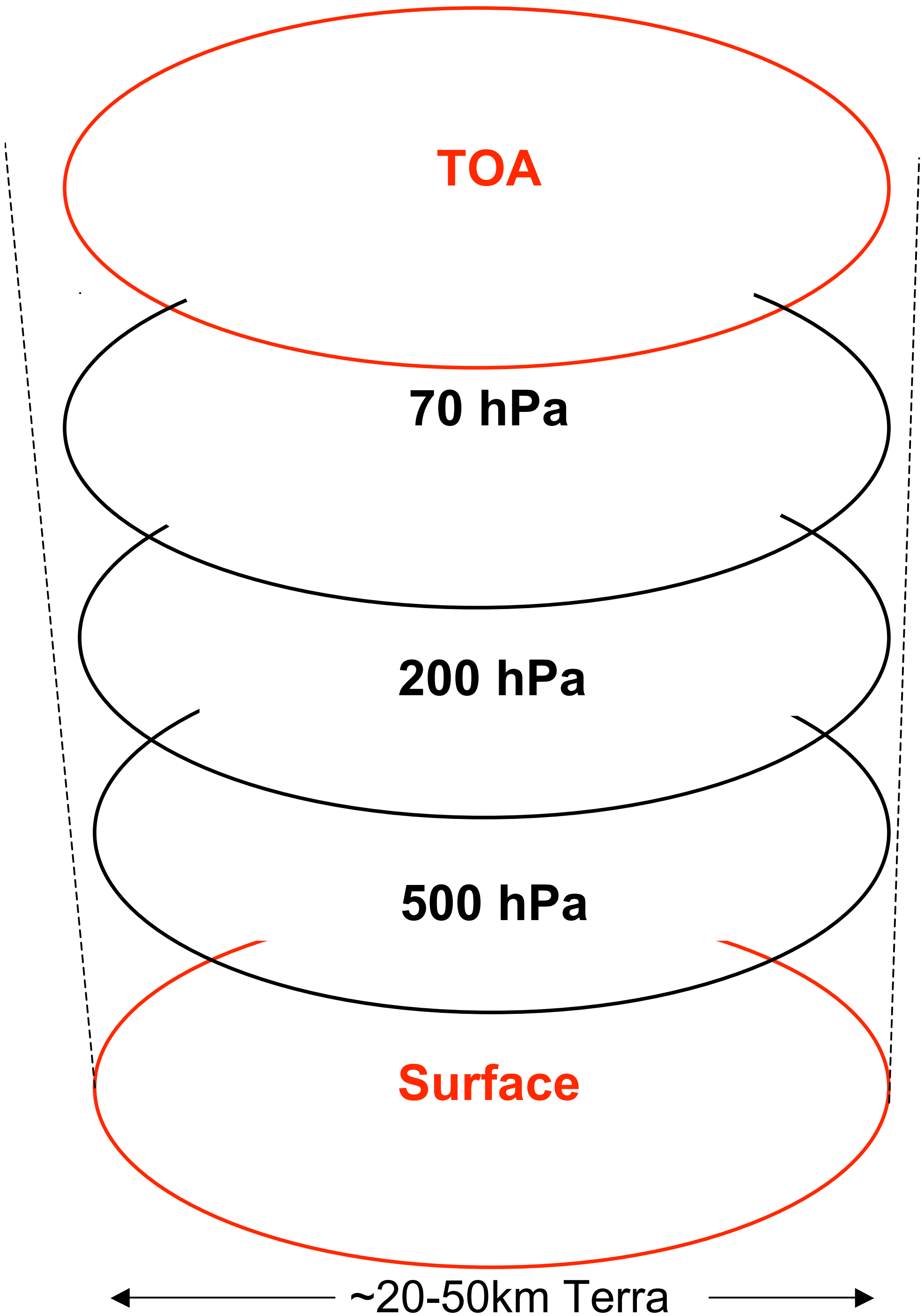
- Cloud properties (almost always)
- Aerosol AOT (sometimes)
- Land skin temperature (if clear)

GEOS4 T(z), q(z), surface wind
Wind speed affects ocean surface albedo

MATCH aerosols
Always used for SSA & g
Used for AOT if no MODIS AOT

Large CERES footprint for TOA flux

CERES CRS: Surface and Atmosphere Radiation Budget (SARB) Product



Tuned fluxes at all 5 levels
All-sky & Clear-sky, Up & Down,
SW and LW

Surface & TOA also have Untuned fluxes
Fluxes with aerosols
Pristine fluxes (no aerosols)

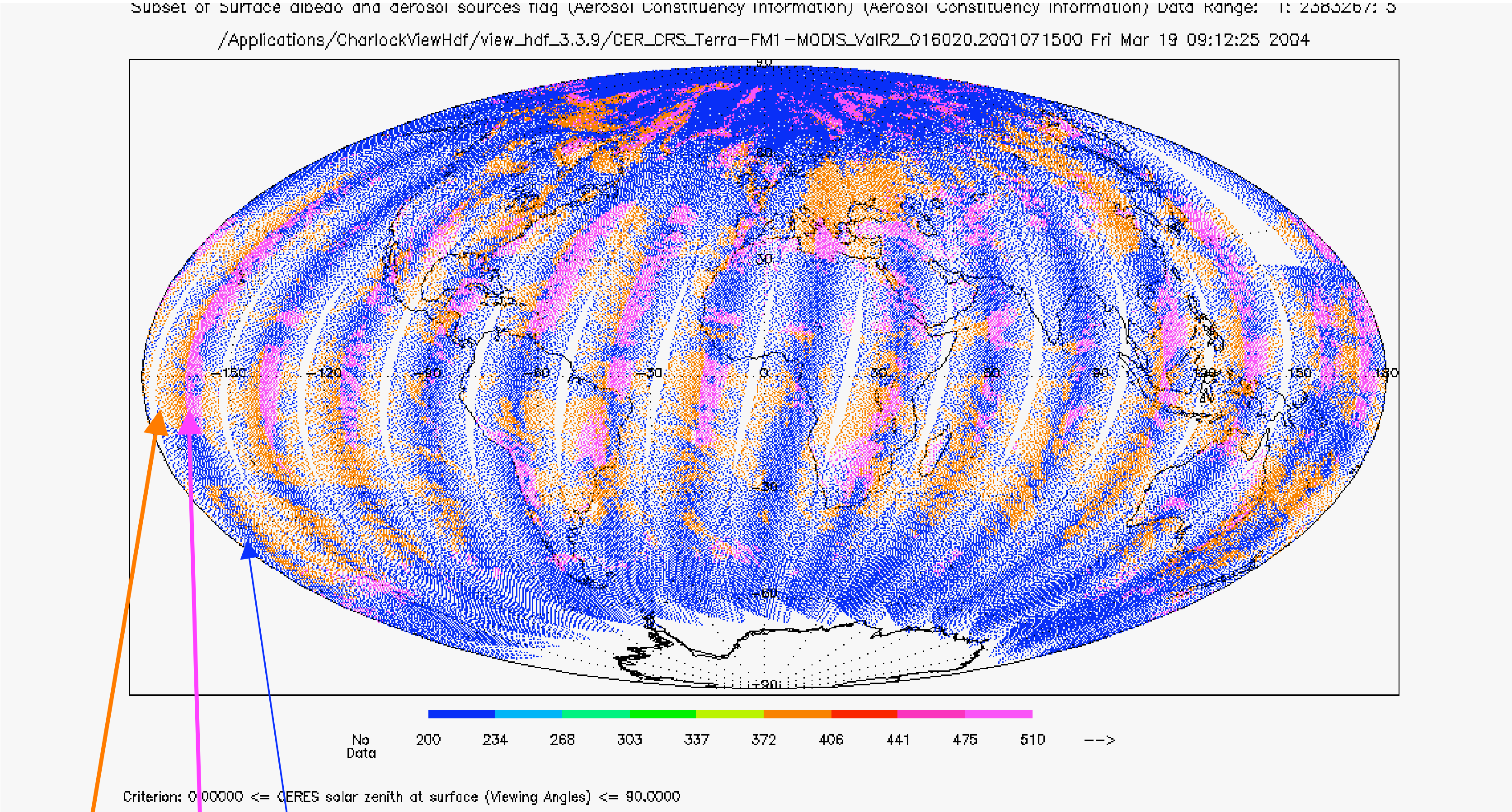
Aerosol forcing for all-sky & clear-sky

Tuning does NOT yield a perfect match to TOA observations.

Parameters adjusted when clear:
Skin temperature, aerosol AOT, precipitable water (PW)

Parameters adjusted when cloudy:
LWP/IWP, cloud top temperature, cloud fractional area within footprint

CERES SARB Aerosol Optical Thickness (τ_λ): Daylight on 15 July 2001

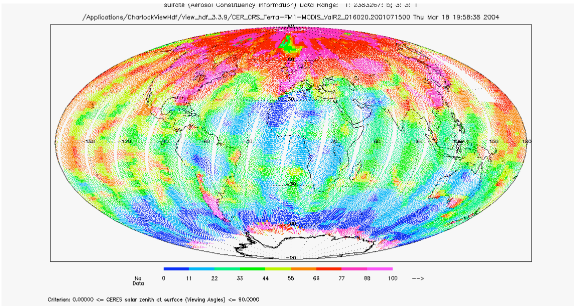


ORANGE: Instantaneous MODIS (MOD04) Kaufman algorithm

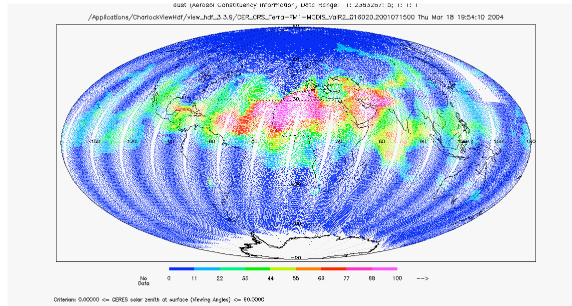
PURPLE: Time interpolation from MODIS Daily Gridded Product

BLUE: MATCH (which uses MODIS as one input)

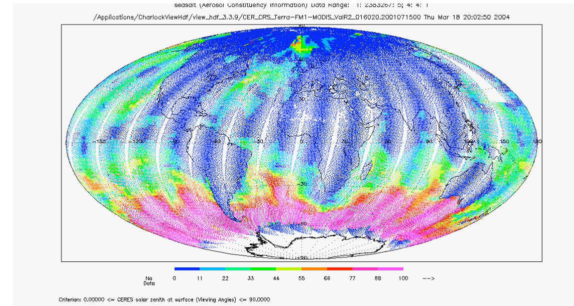
Aerosol types from MATCH on 15 July 2001



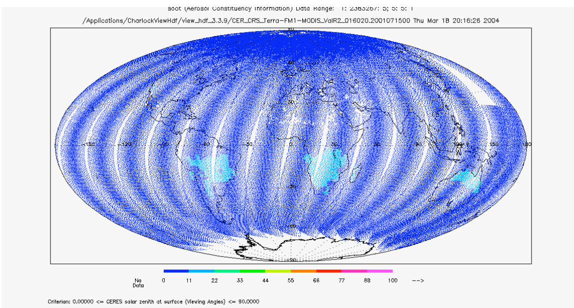
Sulfate (%)



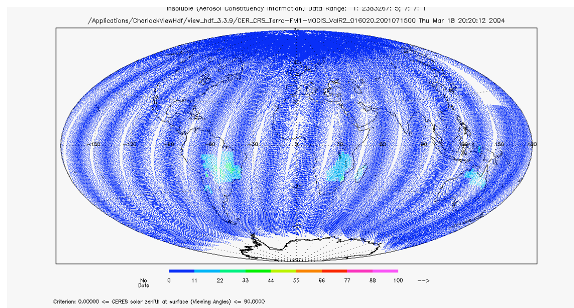
Dust (%)



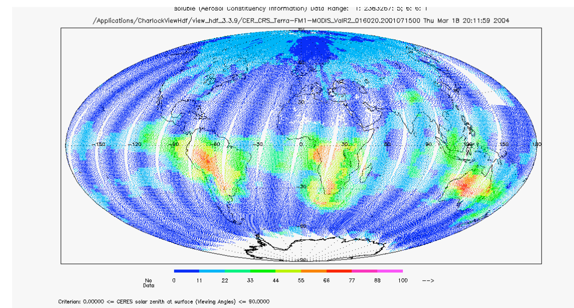
Sea Salt (%)



Soot (%)



Insoluble Organic (%)



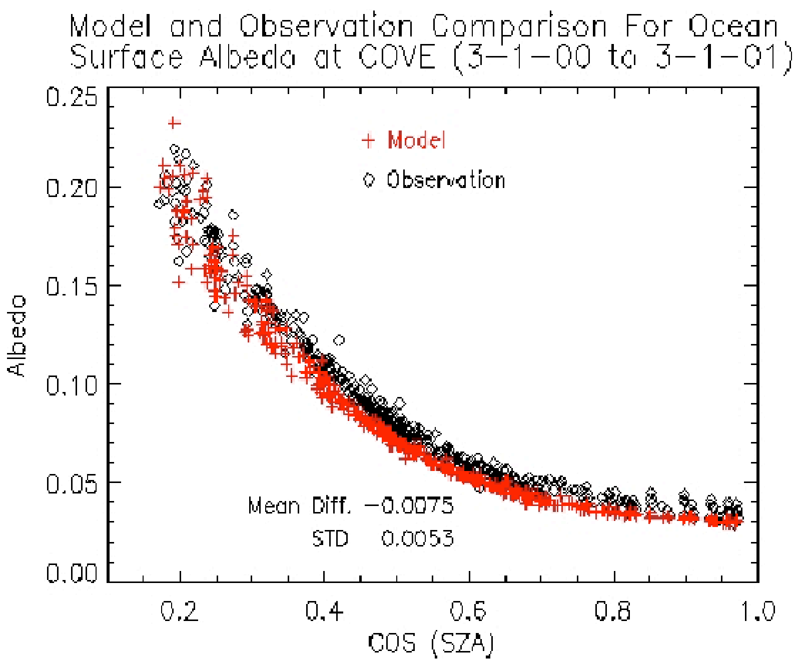
Soluble Organic (%)

Model for Atmospheric Transport and Chemistry (MATCH; Fillmore, Collins, Rasch) generates, transports, assimilates MODIS τ_λ, and removes species with wet &dry processes

As such models advance, application to ocean research may include arerosol deposition to ocean surface and adjustment of atmospheric correction τ_λ to satellite Chl

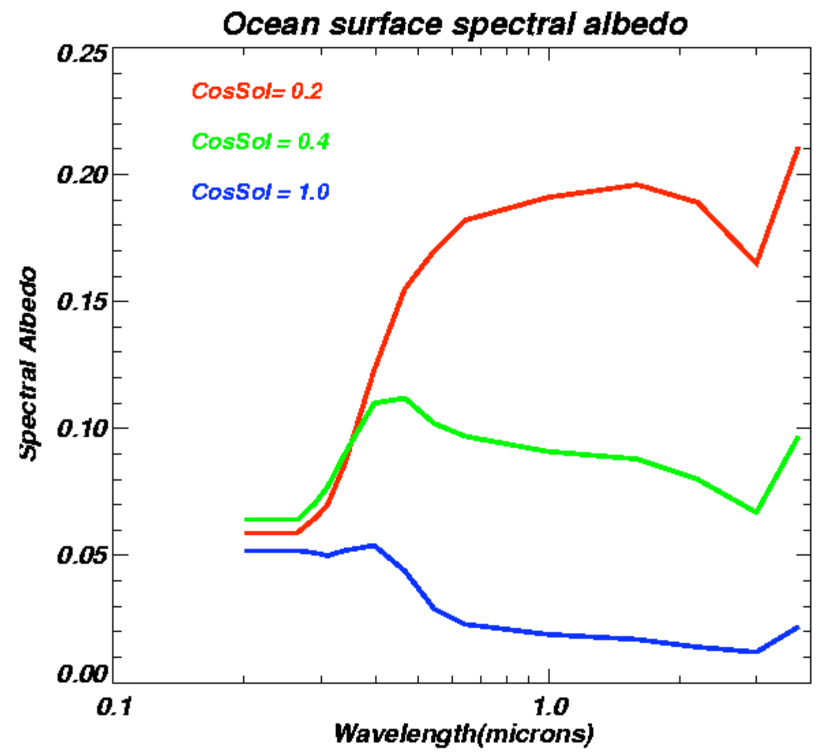
Coupled Ocean Atmosphere Radiative Transfer (COART)

Explicit scattering in both air & sea
(i.e., aerosols and phytoplankon)



Jin, Charlock, and Rutledge, 2002: Analysis of broadband solar radiation and albedo over the ocean surface at COVE. J. Ocean. Atmos. Tech., Vol 19, pp. 1585-1601.

COART look up table (LUT) for flux calculation



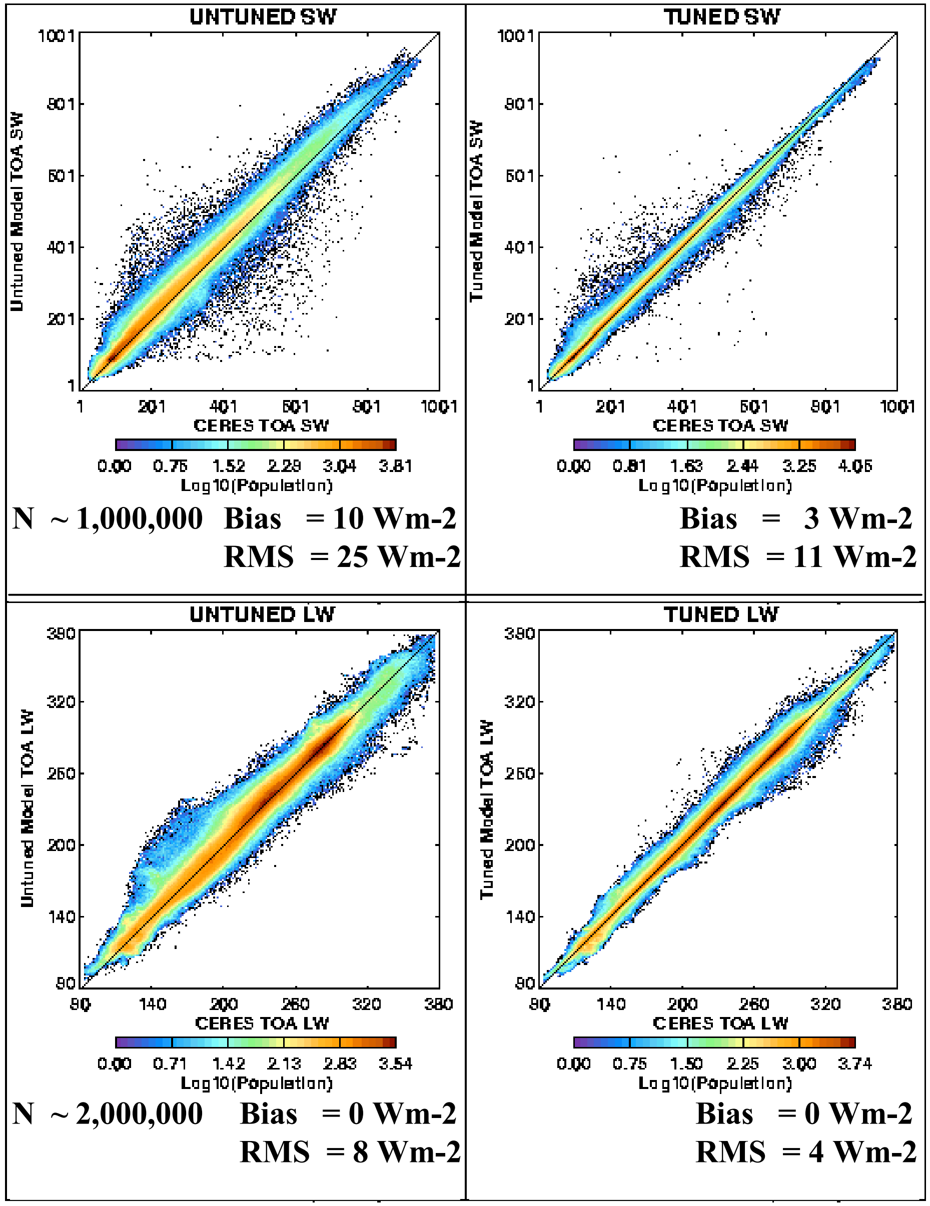
f(wind speed, cosSZA, tau)

wind = 5m/s   aerosol tau = 0.1

TOA CRS vs. SARB (All Sky) 21-06-04

Shortwave

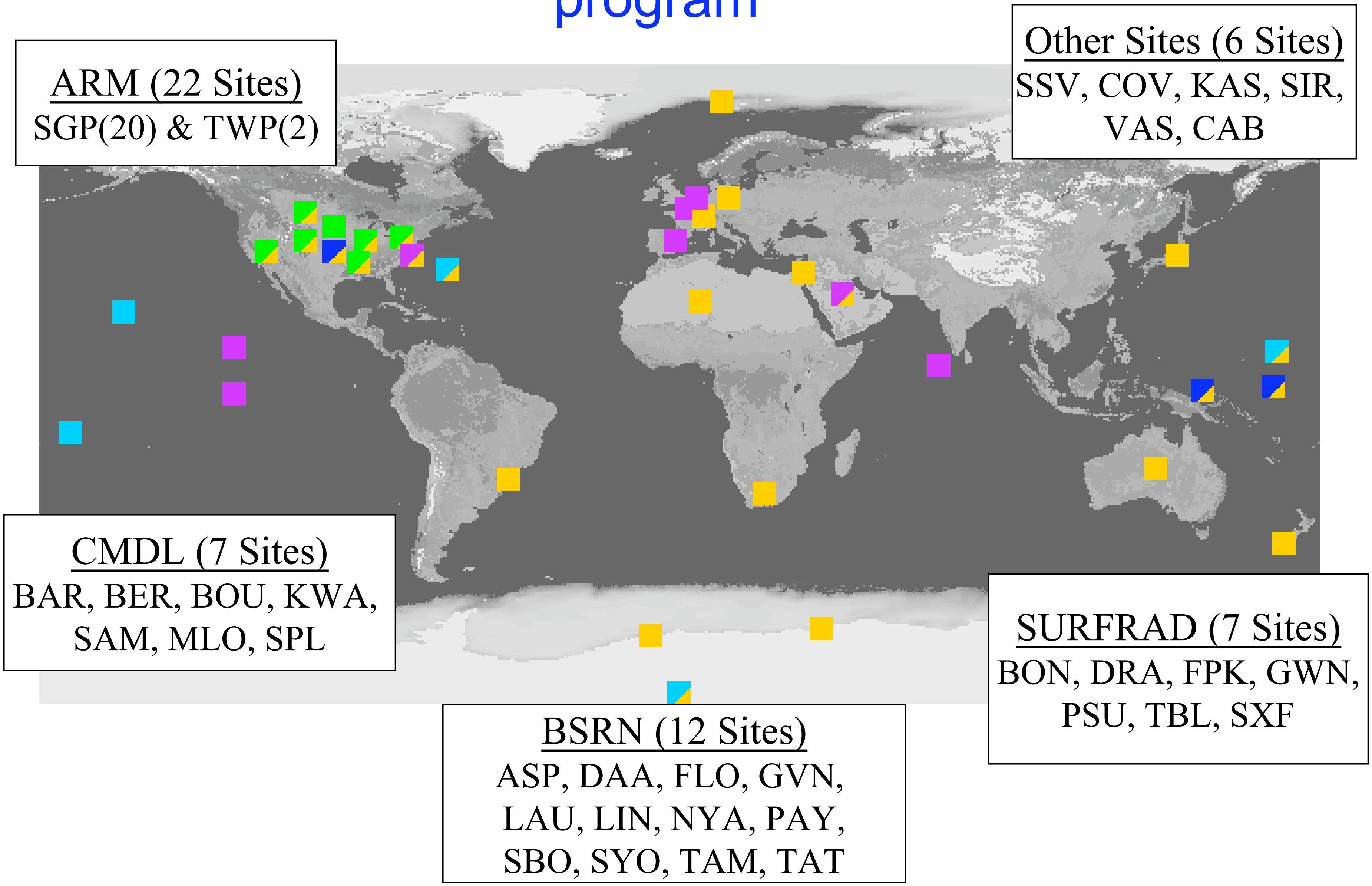
Longwave



Similar plots are made for a number of cloud and surface conditions.

y axes: model
x axes: observations
color: population

Surface sites in CAVE surface validation program



SARB Surface Flux Validation

(Terra, 20 Months of CRS Ed2A)

Downward Tuned Surface Flux Biases (Model-Obs)(W/m2)					SFC Aerosol Forcing		
	All Sky		Clear Sky		Clear-Pristine		SW
	LW	SW	LW	SW	LW	SW	CNA*
ARM/SGP	-9	+8	-10	+4	+1	-19	-19
Island Sites	-4	+33	-4	+20	+1	-14	-7
Polar Sites	-2	+10	-7	-4	+1	-6	-4
SURFRAD	-6	+13	-8	+5	+1	-17	-17
Coastal	+1	+15	+2	-3	+2	-23	-16
Validation Sites	-5 (24)	+13 (93)	-9 (18)	-3 (34)	+3	-16	-10

Upward Tuned TOA Flux Biases (Model-Obs)(W/m2)					TOA Aerosol Forcing		
	All Sky		Clear Sky		Clear-Pristine		SW
	LW	SW	LW	SW	LW	SW	CNA*
ARM/SGP	+1	-0	-0	-0	-1	+5	+4
Island Sites	-0	+4	-3	+3	-1	+6	+4
Polar Sites	+2	+2	-1	+1	-0	-0	+1
SURFRAD	+1	-0	-1	+0	-1	+6	+5
Coastal	+1	+9	-0	+1	-1	+20	+9
Validation Sites	+1(5)	+2 (12)	-1(3)	+1(3)	-1	+1	+2

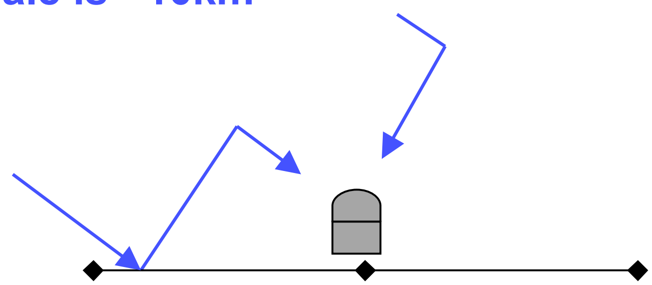
* Difference model run with clouds and aerosols and model run with clouds, no aerosols.

Mismatch of surface albedo and surface insolation in SARB.

We retrieve surface albedo for clear CERES footprints ~10-100km

Surface insolation measured at a point is affected by surface albedo.

Clear sky: surface albedo impact on insolation is small. Relevant albedo scale is ~10km



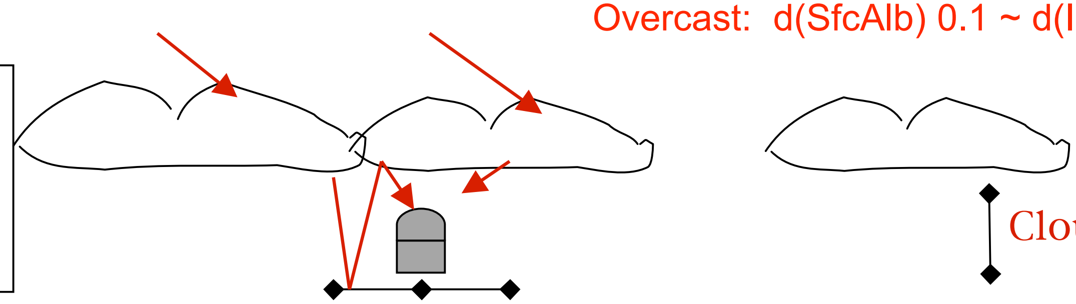
500 hPa at ~6km

50% of Rayleigh scattering to surface comes from above 5 km

Cloudy sky: surface albedo impact on insolation can be large. Relevant albedo scale is ~2 X cloud base height.

Overcast: d(SfcAlb) 0.1 ~ d(Ins) 30 Wm-2

Not a problem at COVE sea platform, where we know the surface albedo.



Cloud base 2km

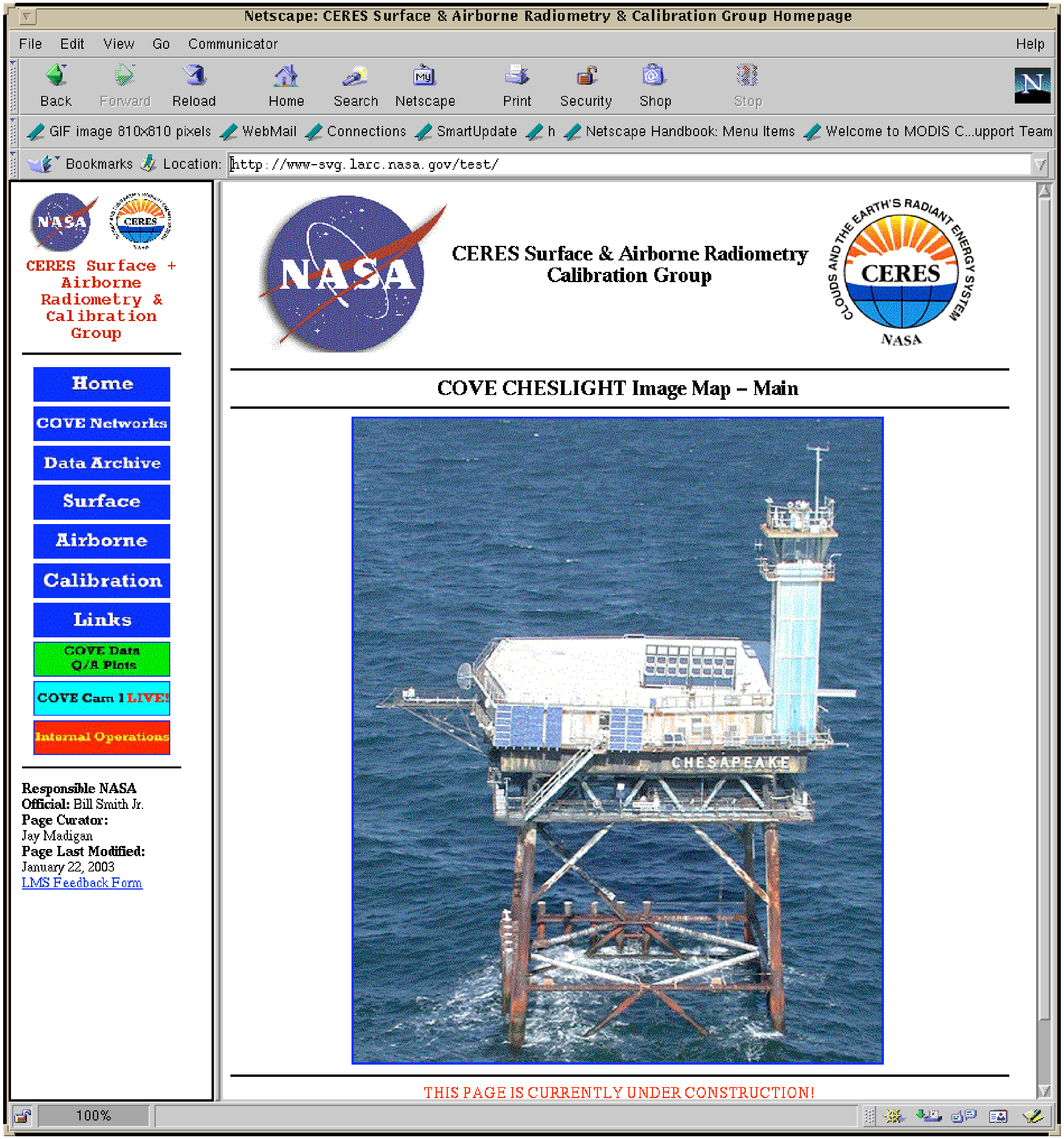
COVE

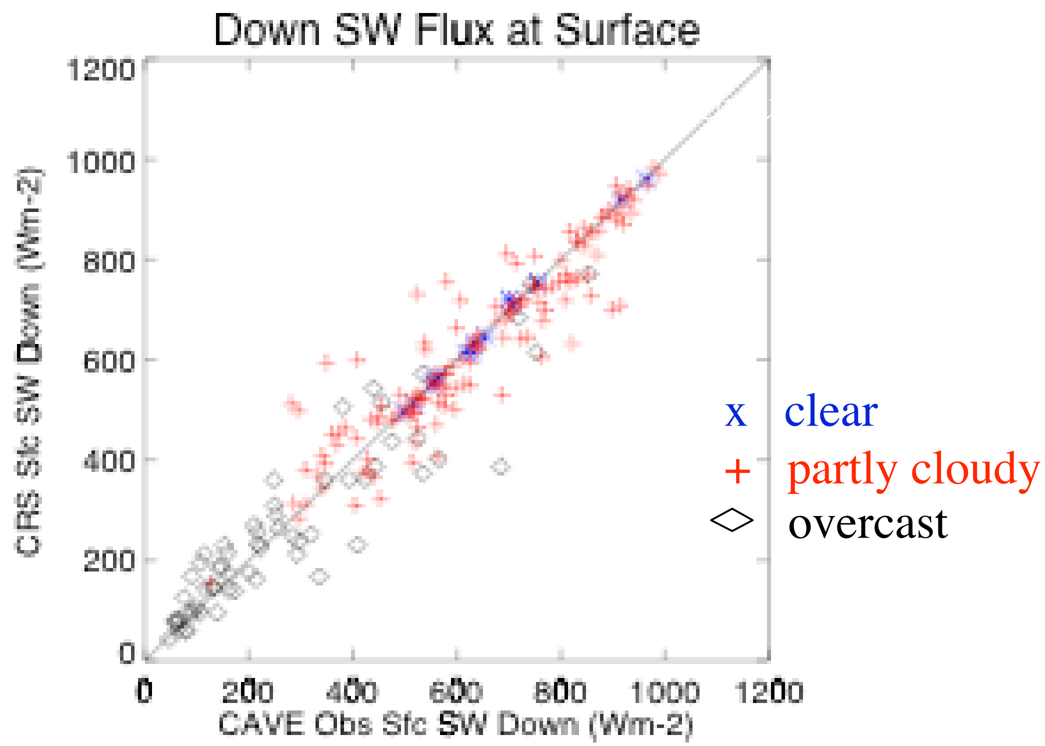
CERES Ocean
Validation Experiment

Rigid sea platform
Continuous
Long-term
Well calibrated
AERONET aerosol
NOAA wind and waves
BSRN surface
radiation
looks DOWN at sea

At COVE:
SW up (time mean)
approximately equals
SW up (space mean)

Various short/medium
term measurements:
SP1A for upwelling
SW spectral radiance
Ocean optics (ODU)



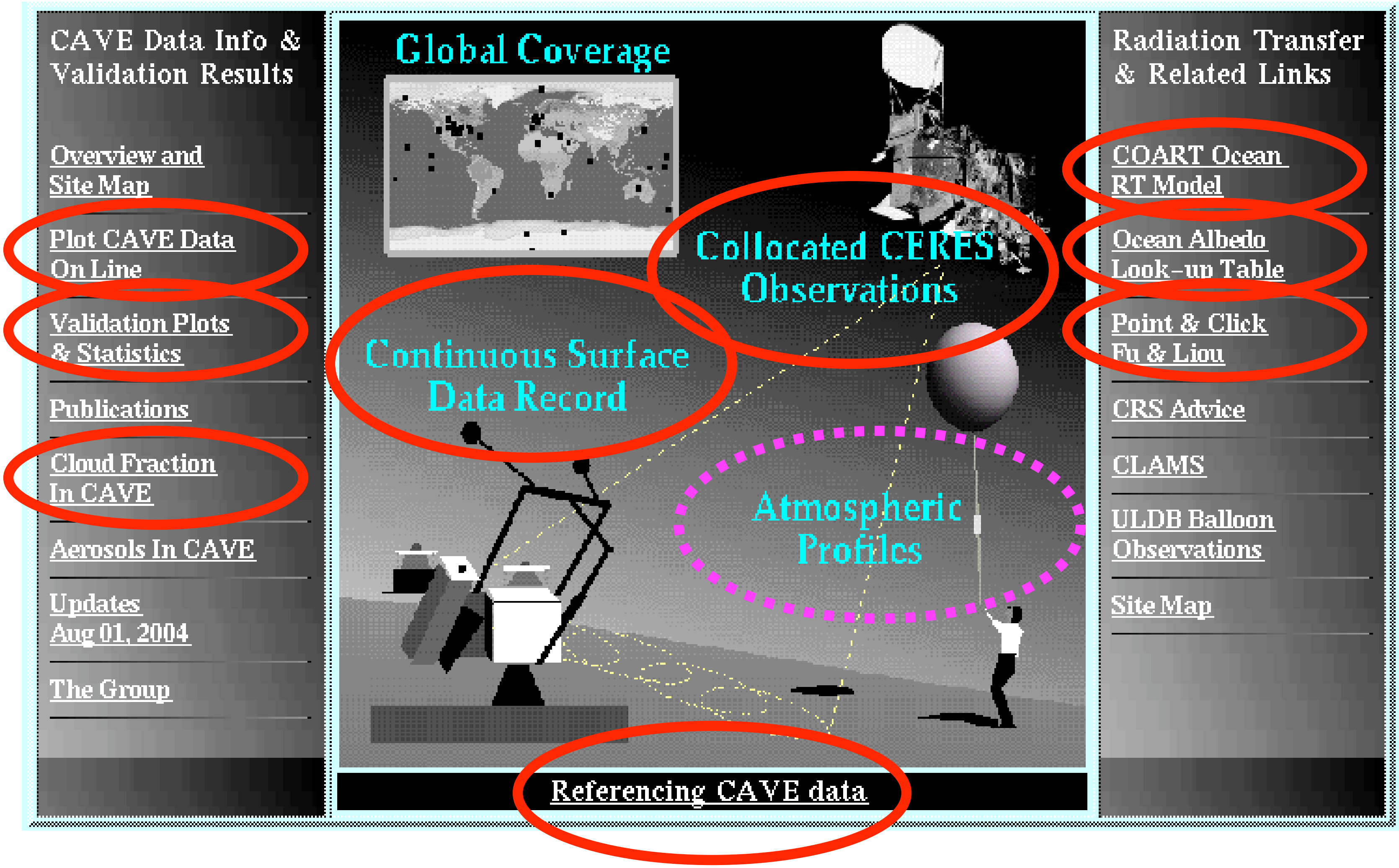


Surface Insolation at COVE
Year 2001 (Terra CRS Edition 2A)

	Observed Wm-2	Bias Wm-2	Samples
All-sky	536	-8	214
Clear-sky	662	-2	14

Bias = (Retrieved - Observed)

CAVE Homepage



http://www-cave.larc.nasa.gov/cave

Google "CERES CAVE" www-cave.larc.nasa.gov/cave/

Netscape: Fu-Liou 0602

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Bookmarks Location: http://www-cave.larc.nasa.gov/rose/flp0602/

On line Fu-Liou radiative transfer

FU-LIOU(0602) Forcing

- Only Aerosol Forcing
- Only Cloud Forcing
- Cloud + Aerosol Forcing

PRESS ME: Compute

Cloud Vis Optical Depth	10.
Cloud Level (Km)	5
Cloud Phase	ICEged_f98
Cloud Particle Size (microns) Water(Re) Ice(De)	60.
Aerosol Constituent 1	
AOT(1)	0.01
Aerosol Type(1)	SOOT
Scale Hgt(1) Km	4.0
Aerosol Constituent 2	
AOT(2)	0.10
Aerosol Type(2)	8.0_dust
Scale Hgt(2) Km	0.4
Atmosphere	jmls.lay
Cos Sol Zen	1.0

Hitran 2000 SW Absorption CONTINUUM CKDv2.4

Control		
Perturbed		
AEROSOL TAU(s)	9.999999776E-3	0.100000001
AEROSOL TYPE(s)	SOOT	8.0_dust
Input Cloud Vis Optical Depth	10.	
ICE Water Content	0.187169656	
ICE Particle Size(microns)	46.315197	
Cloud Level (km)	5	

	Shortwave					
	TOA			SURFACE		
	Control	Perturbed	Forced	Control	Perturbed	Forced
Up	146.5	667.4	521.0	106.8	36.8	-70.0
Down	1368.3	1368.3	0.0	1067.8	368.3	-699.5
NET	1221.8	700.9	-521.0	961.0	331.5	-629.6
ALBEDO	0.107	0.488	0.381	0.100	0.100	0.000
Direct				1011.6	5.5	-1006.1
Diffuse				56.2	362.7	306.6
	Longwave					
Up	280.1	232.6	-47.5	423.3	423.4	0.0
Down	0.0	0.0	0.0	349.8	397.1	47.3
NET	-280.1	-232.6	47.5	-73.5	-26.3	47.2

Window Flux:	105.02	69.57	35.45
LW radiance:	93.65	76.51	17.14
Flt Window radiance:	20.63	13.26	7.37
Nadir anisotropy:	1.05	1.03	

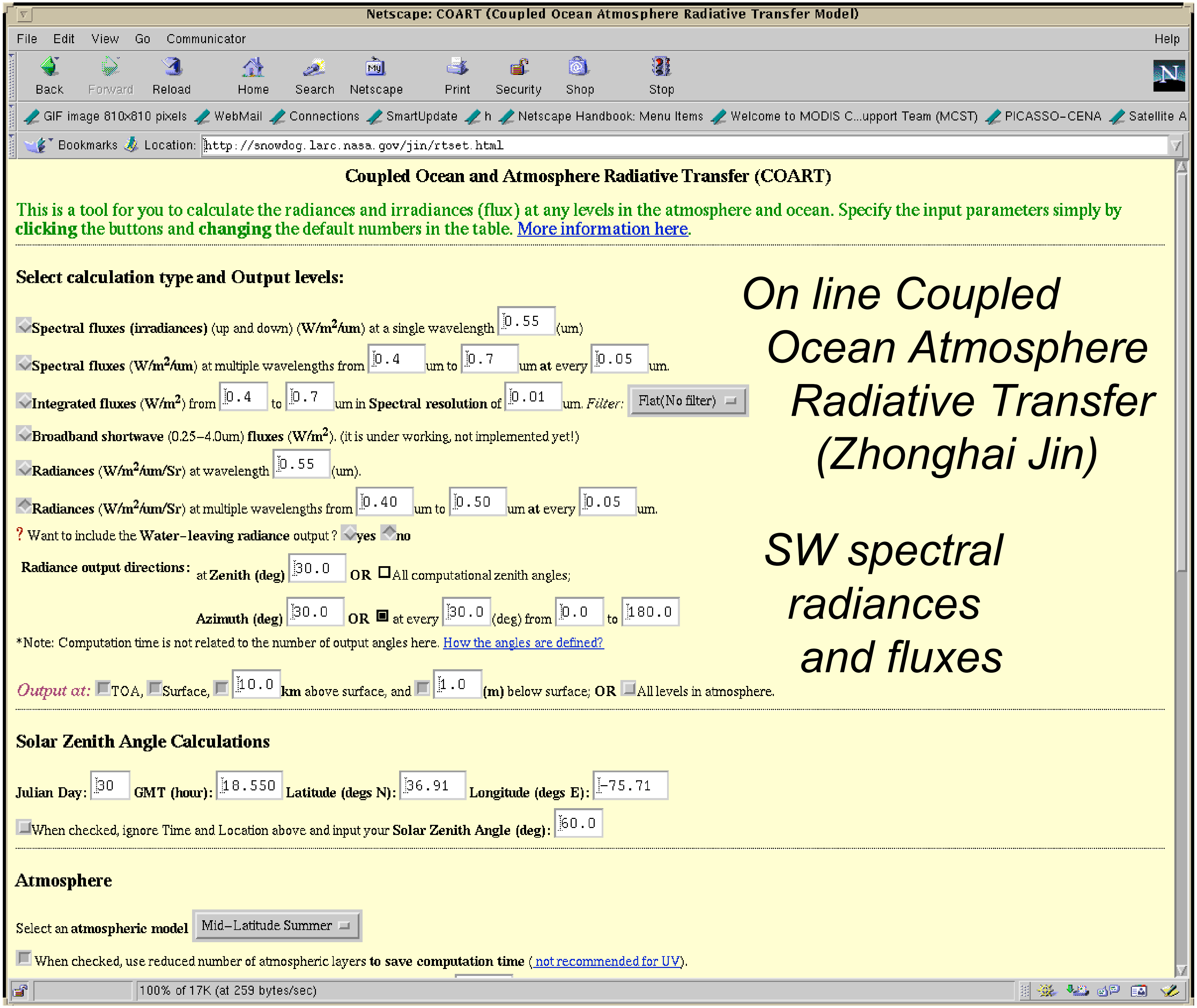
Top of Atmosphere Fractional SW in 15 bands														
0.001	0.001	0.005	0.005	0.011	0.025	0.080	0.088	0.133	0.112	0.356	0.112	0.037	0.029	0.004
Surface Fractional SW in 15 bands														
0.000	0.000	0.000	0.000	0.005	0.029	0.101	0.115	0.174	0.151	0.393	0.025	0.007	0.000	0.000
Top of Atmosphere Spectral Albedo in 15 bands														
0.011	0.003	0.002	0.003	0.114	0.618	0.644	0.627	0.582	0.582	0.552	0.180	0.128	0.006	0.032
Surface Spectral Albedo in 15 bands														
-9.999	-9.999	-9.999	-9.999	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	-9.999	-9.999

368.288 211.545 156.744 0.944

Flux Profiles

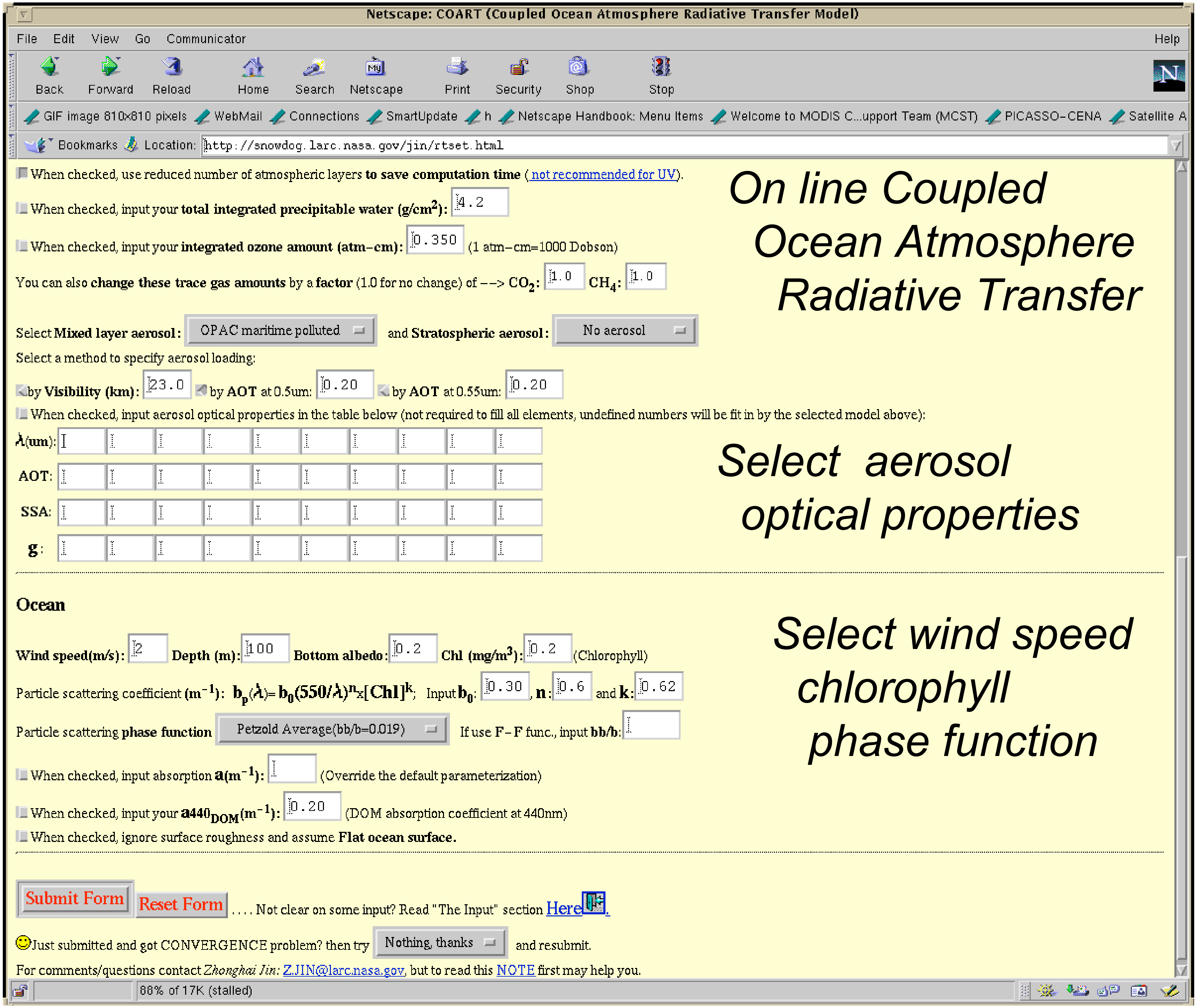
Pressure (hPa)	swdn(c)	swdn(p)	swup(c)	swup(p)	lwdn(c)	lwdn(p)	lwup(c)	lwup(p)
0.0	1368.3	1368.3	146.5	667.4	0.0	0.0	280.1	232.6
0.1	1368.1	1368.1	146.4	667.4	0.0	0.0	280.1	232.6

SW uses HITRAN 2000 (Rose-Kato)



On line Coupled
Ocean Atmosphere
Radiative Transfer
(Zhonghai Jin)

SW spectral
radiances
and fluxes



Netscape: COART (Coupled Ocean Atmosphere Radiative Transfer Model)

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Bookmarks Location: http://snowdog.larc.nasa.gov/jin/rtset.html

When checked, use reduced number of atmospheric layers **to save computation time** (not recommended for UV).

When checked, input your **total integrated precipitable water (g/cm^2):** 4.2

When checked, input your **integrated ozone amount (atm-cm):** 0.350 (1 atm-cm=1000 Dobson)

You can also **change these trace gas amounts** by a **factor** (1.0 for no change) of --> **CO_2:** 1.0 **CH_4:** 1.0

Select **Mixed layer aerosol:** OPAC maritime polluted and **Stratospheric aerosol:** No aerosol

Select a method to specify aerosol loading:

by **Visibility (km):** 23.0 by **AOT** at 0.5um: 0.20 by **AOT** at 0.55um: 0.20

When checked, input aerosol optical properties in the table below (not required to fill all elements, undefined numbers will be fit in by the selected model above):

λ(um):										
AOT:										
SSA:										
g:										

Ocean

Wind speed(m/s): 2 **Depth (m):** 100 **Bottom albedo:** 0.2 **Chl (mg/m^3):** 0.2 (Chlorophyll)

Particle scattering coefficient **(m^{-1}):** $b_p(\lambda)=b_0(550/\lambda)^n x[Chl]^k$; Input b_0: 0.30, **n**: 0.6 and **k**: 0.62

Particle scattering **phase function** Petzold Average(bb/b=0.019) If use F-F func., input **bb/b**:

When checked, input absorption **$a(m^{-1})$:** (Override the default parameterization)

When checked, input your **$a440_{DOM}(m^{-1})$:** 0.20 (DOM absorption coefficient at 440nm)

When checked, ignore surface roughness and assume **Flat ocean surface.**

Submit Form | Reset Form .... Not clear on some input? Read "The Input" section Here

Just submitted and got CONVERGENCE problem? then try Nothing, thanks and resubmit.

For comments/questions contact *Zhonghai Jin*: Z.JIN@larc.nasa.gov, but to read this NOTE first may help you.

88% of 17K (stalled)

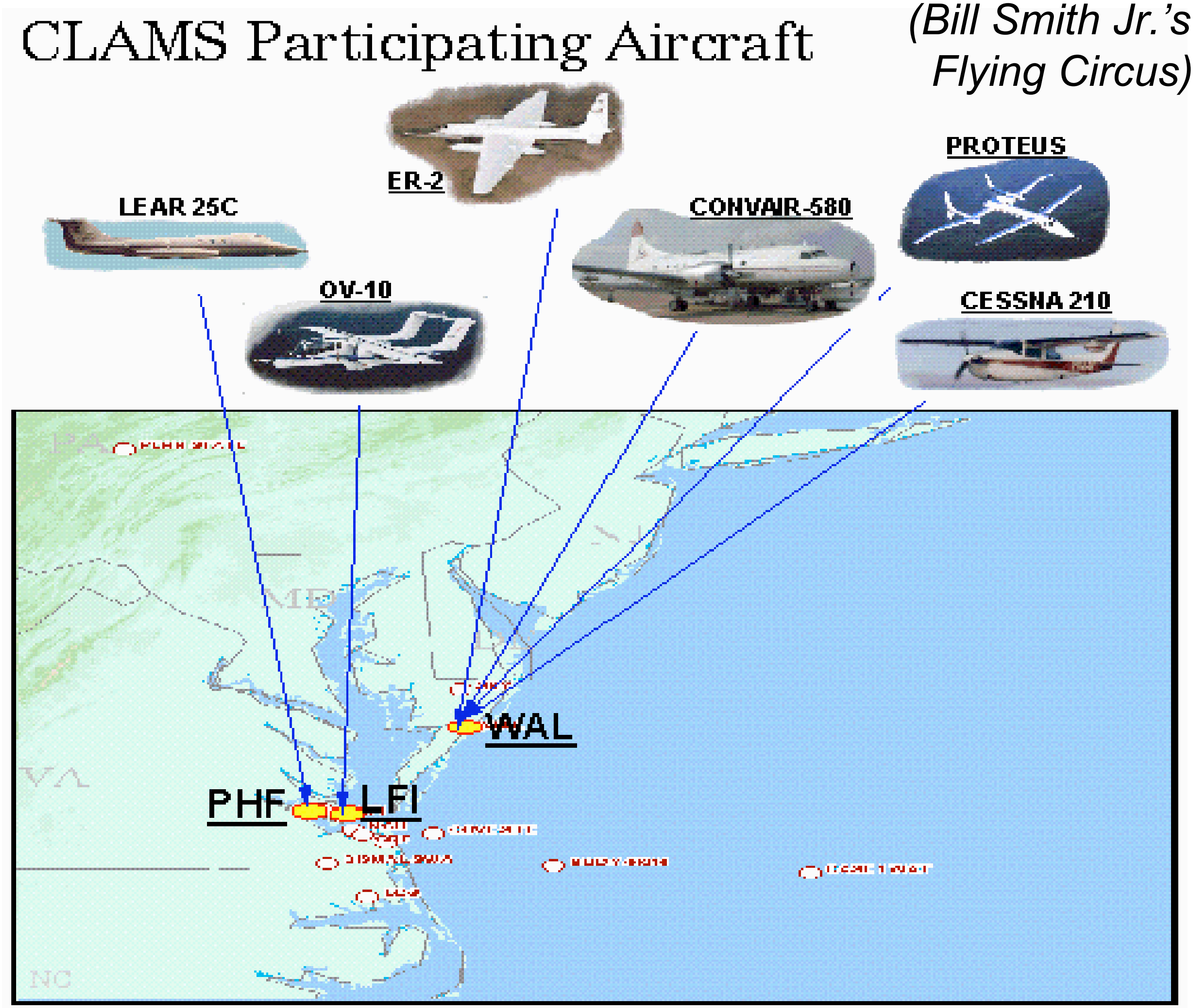
On line Coupled Ocean Atmosphere Radiative Transfer

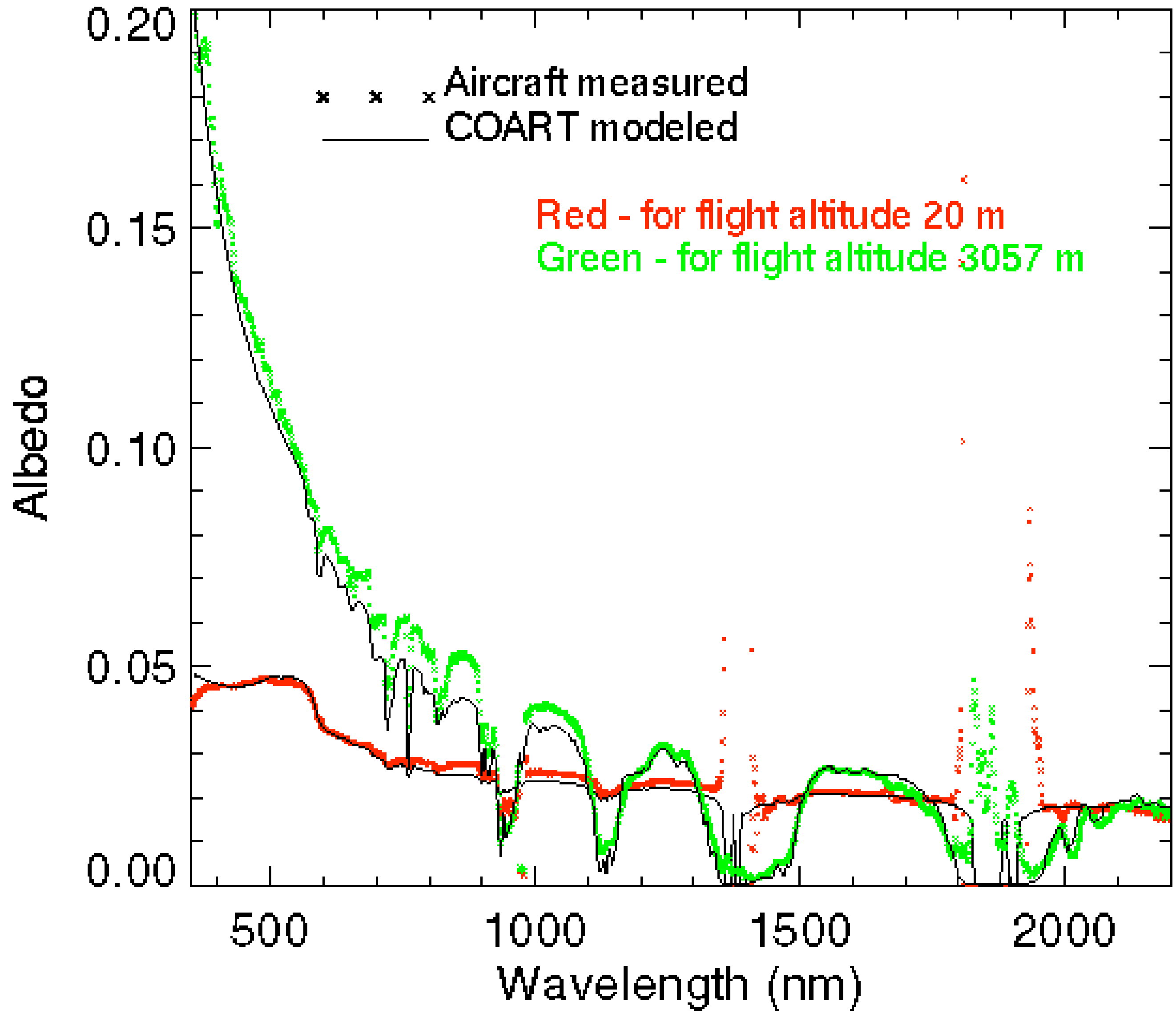
Select aerosol optical properties

Select wind speed chlorophyll phase function

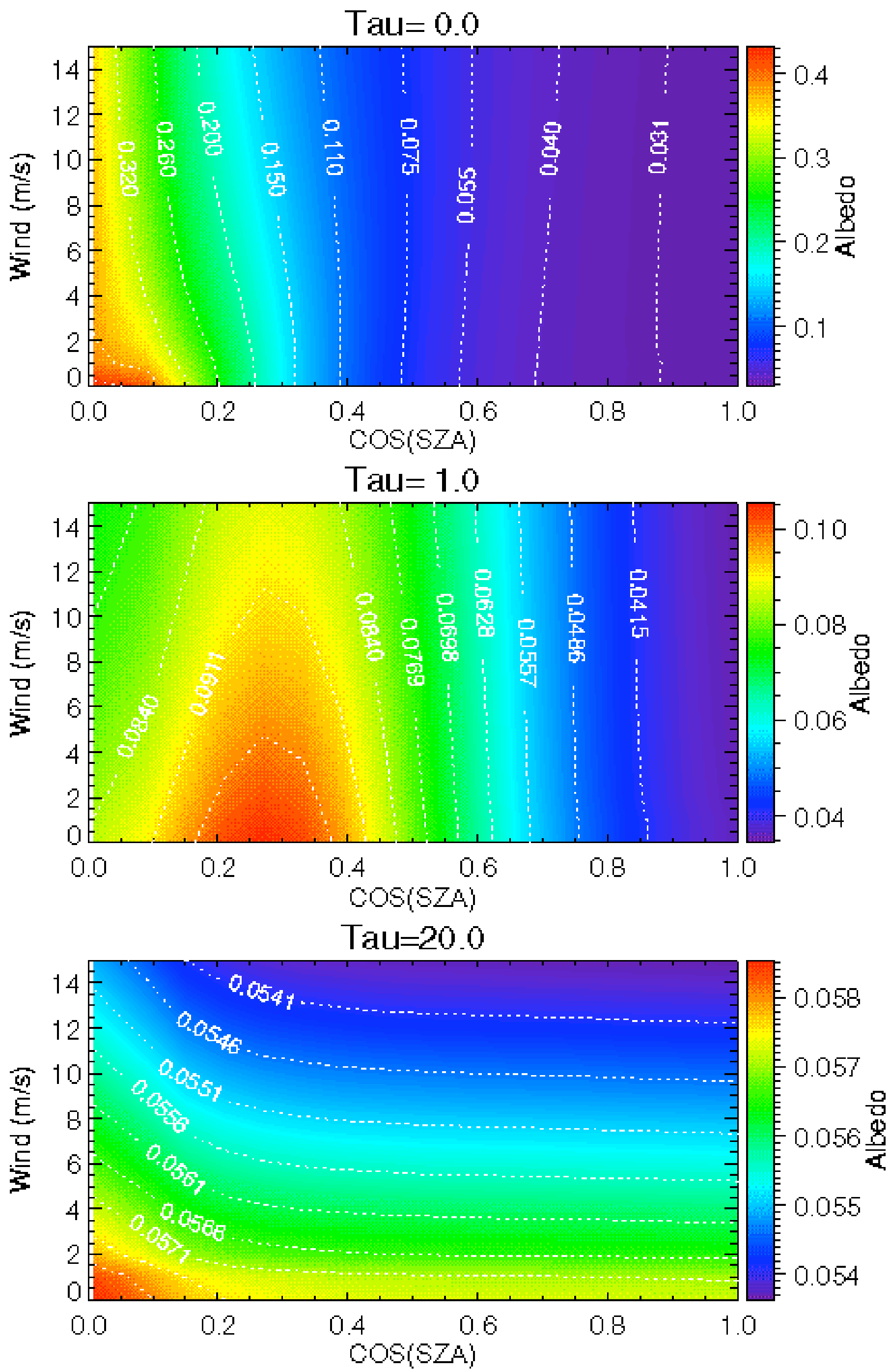
CLAMS: Chesapeake Lighthouse and Aircraft Measurements for Satellites July 2001 CERES-MODIS-MISR-GACP

(Bill Smith Jr.'s Flying Circus)





Comparison of modeled and aircraft measured spectral albedo over COVE.

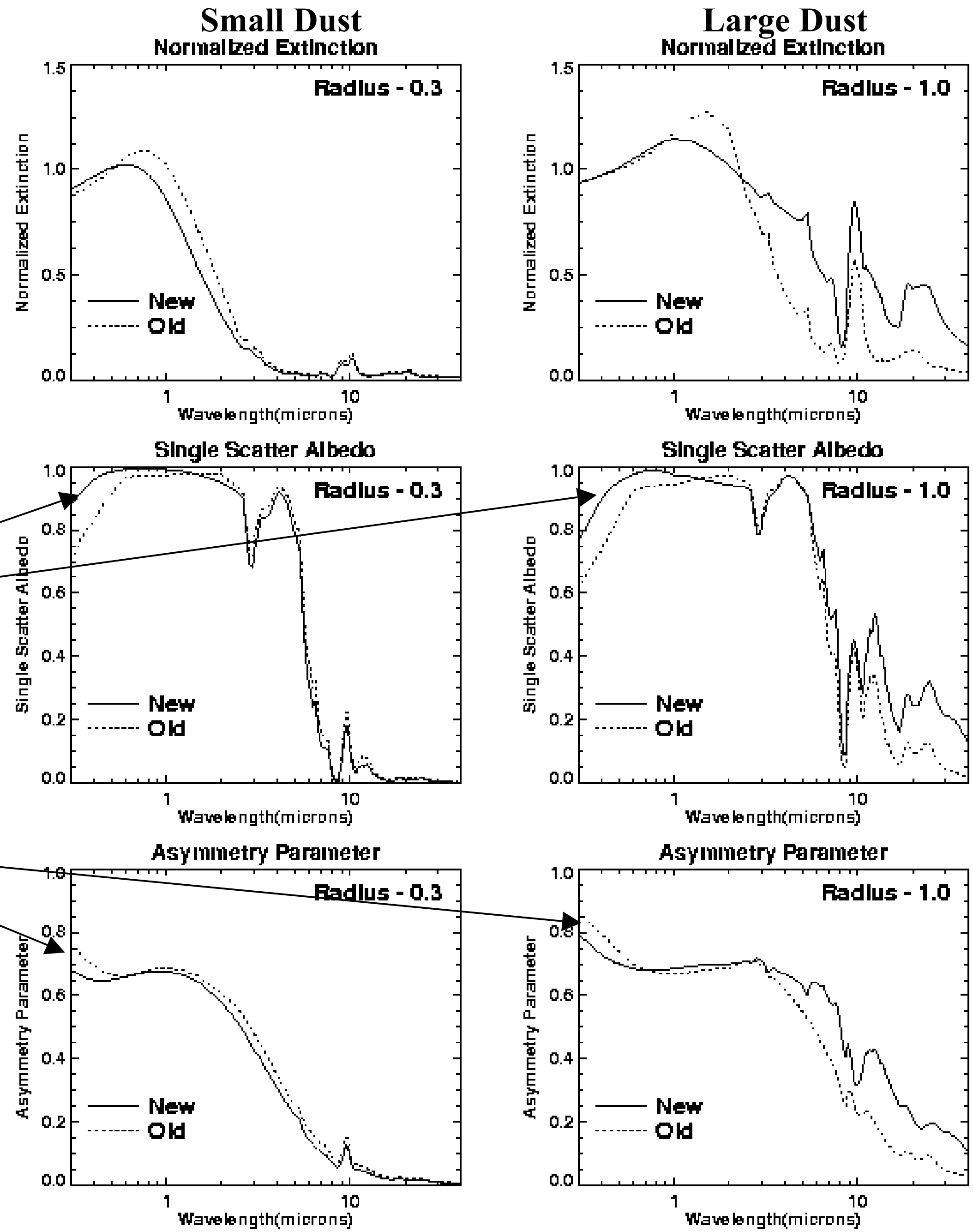


Broadband ocean albedo (color contours) versus wind speed (vertical axes) and cosSZA (horizontal axes) using the LUT.

Change in Tegen and Lacis dust properties

- Significantly less absorption

- More backward scatter in visible.



CAVE Validation, Edition 2a, 2b Summary

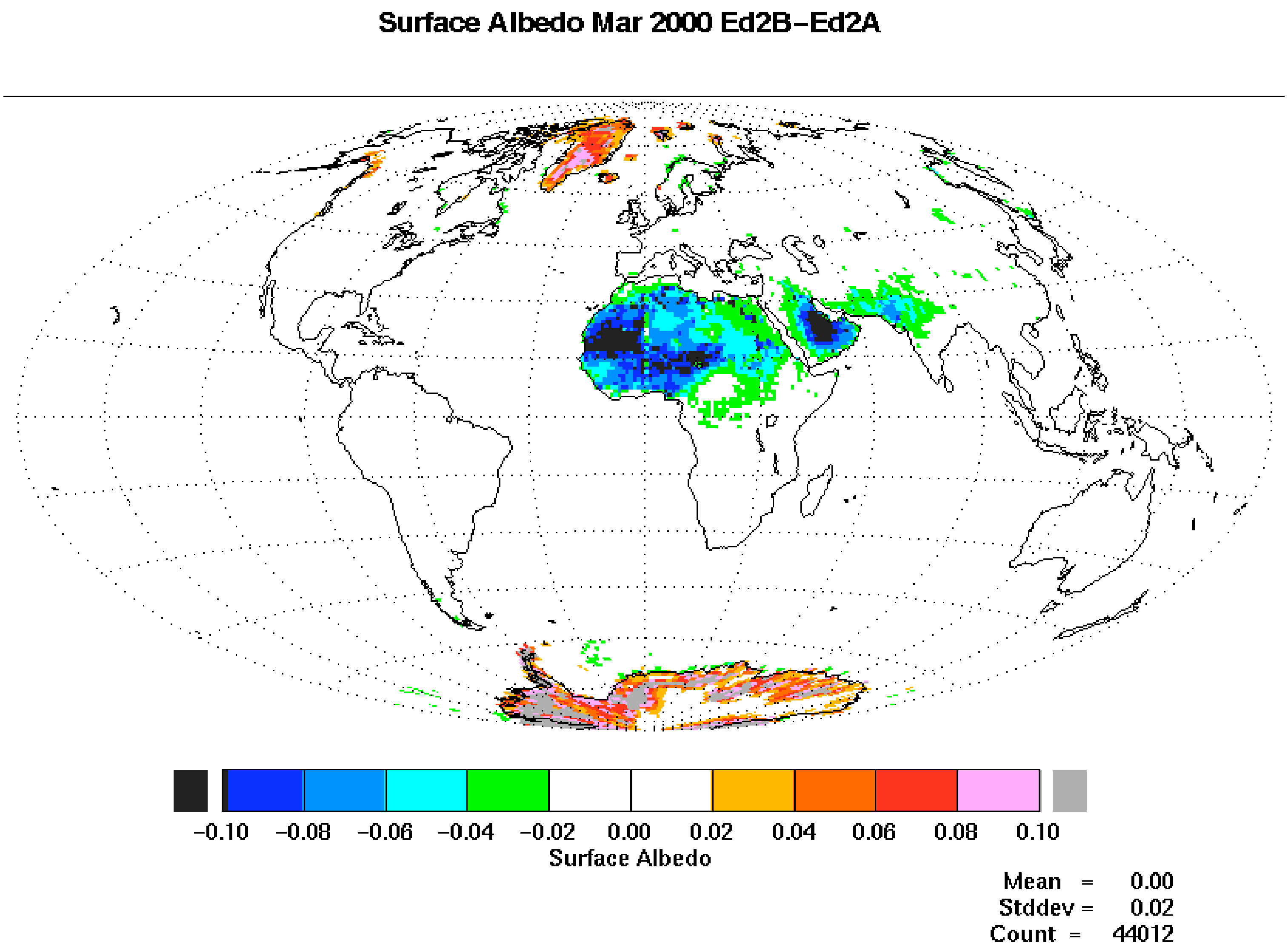
Instantaneous All Sky Mean(RMS) All Wm^{-2}												
	LW Up TOA		SW Up TOA		LW Down Sfc		SW Down Sfc		LW Up Sfc		SW Up Sfc	
	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned
Edition 2A	+1(8)	+1(5)	+4(22)	+2(9)	-4(25)	-4(25)	+12(85)	+13(87)	-0(26)	-0(25)	-12(45)	-12(45)
Edition 2B	+1(8)	+1(5)	+6(22)	+2(8)	-4(25)	-5(25)	+13(85)	+17(87)	-4(34)	-4(33)	-13(45)	-13(45)

Instantaneous Clear Sky Mean(RMS) All Wm^{-2} [clear - imager CF = 0.0]												
	LW Up TOA		SW Up TOA		LW Down Sfc		SW Down Sfc		LW Up Sfc		SW Up Sfc	
	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned
Edition 2A	-1(6)	-1(3)	+3(8)	+1(3)	-9(19)	-9(19)	+1(32)	+1(31)	+0(22)	+1(24)	-11(24)	-10(24)
Edition 2B	-1(5)	-1(3)	-1(6)	-0(2)	-10(19)	-10(19)	+7(27)	+8(27)	+0(23)	+1(24)	-13(25)	-13(24)

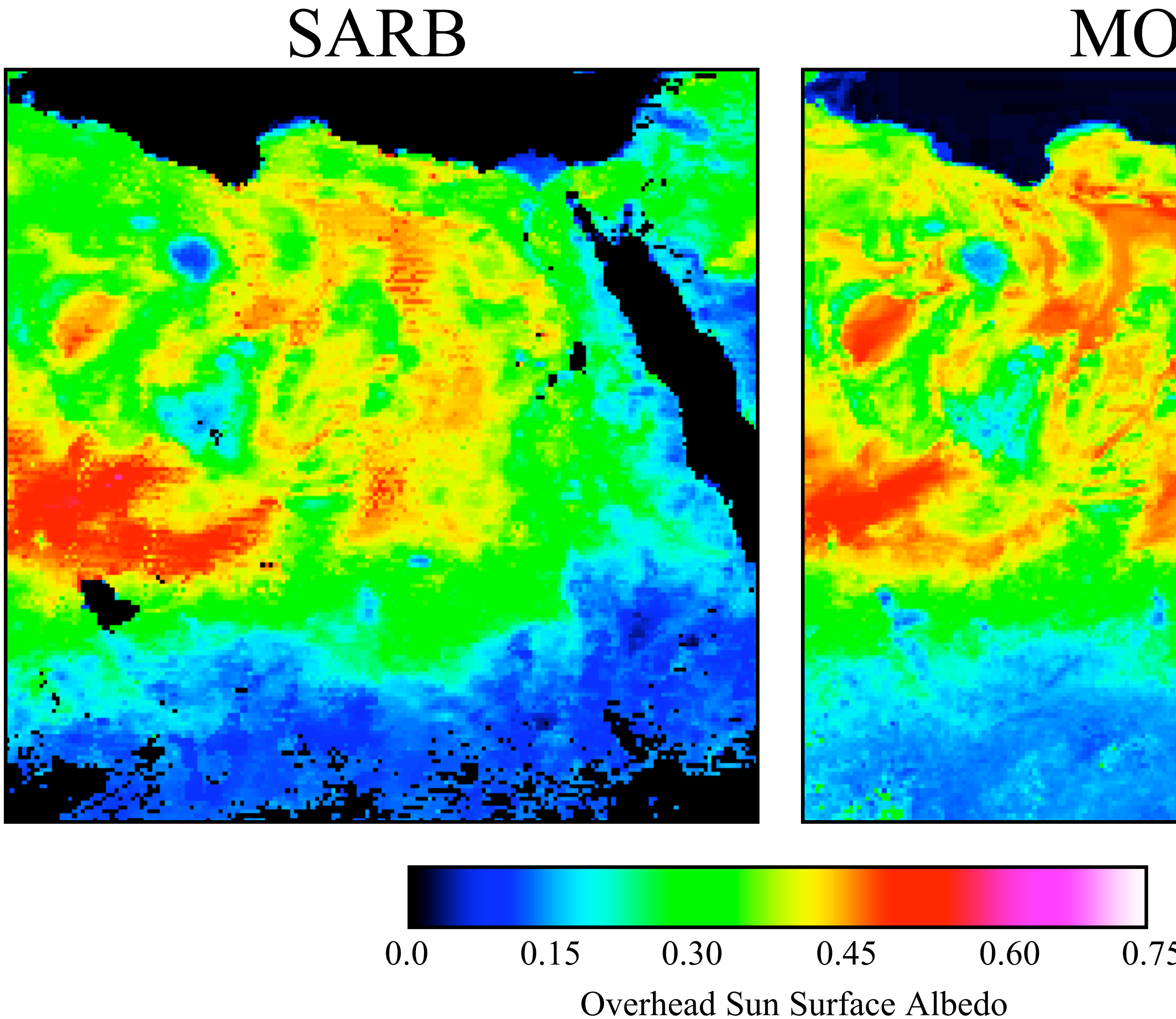
Instantaneous Overcast Sky Mean(RMS) All Wm^{-2} [overcast - imager CF = 1.0]												
	LW Up TOA		SW Up TOA		LW Down Sfc		SW Down Sfc		LW Up Sfc		SW Up Sfc	
	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned	Untuned	Tuned
Edition 2A	+0(9)	+1(4)	+10(31)	+1(12)	-5(24)	-6(25)	+15(90)	+25(97)	+6(24)	+6(24)	-11(40)	-9(40)
Edition 2B	+1(9)	+1(4)	+12(29)	+2(9)	-5(24)	-6(25)	+17(90)	+30(96)	+1(39)	+1(39)	-10(41)	-8(41)

LW – Day and night footprints.
SW – Day time only (not a 24 hour average).

Change in Surface Albedo

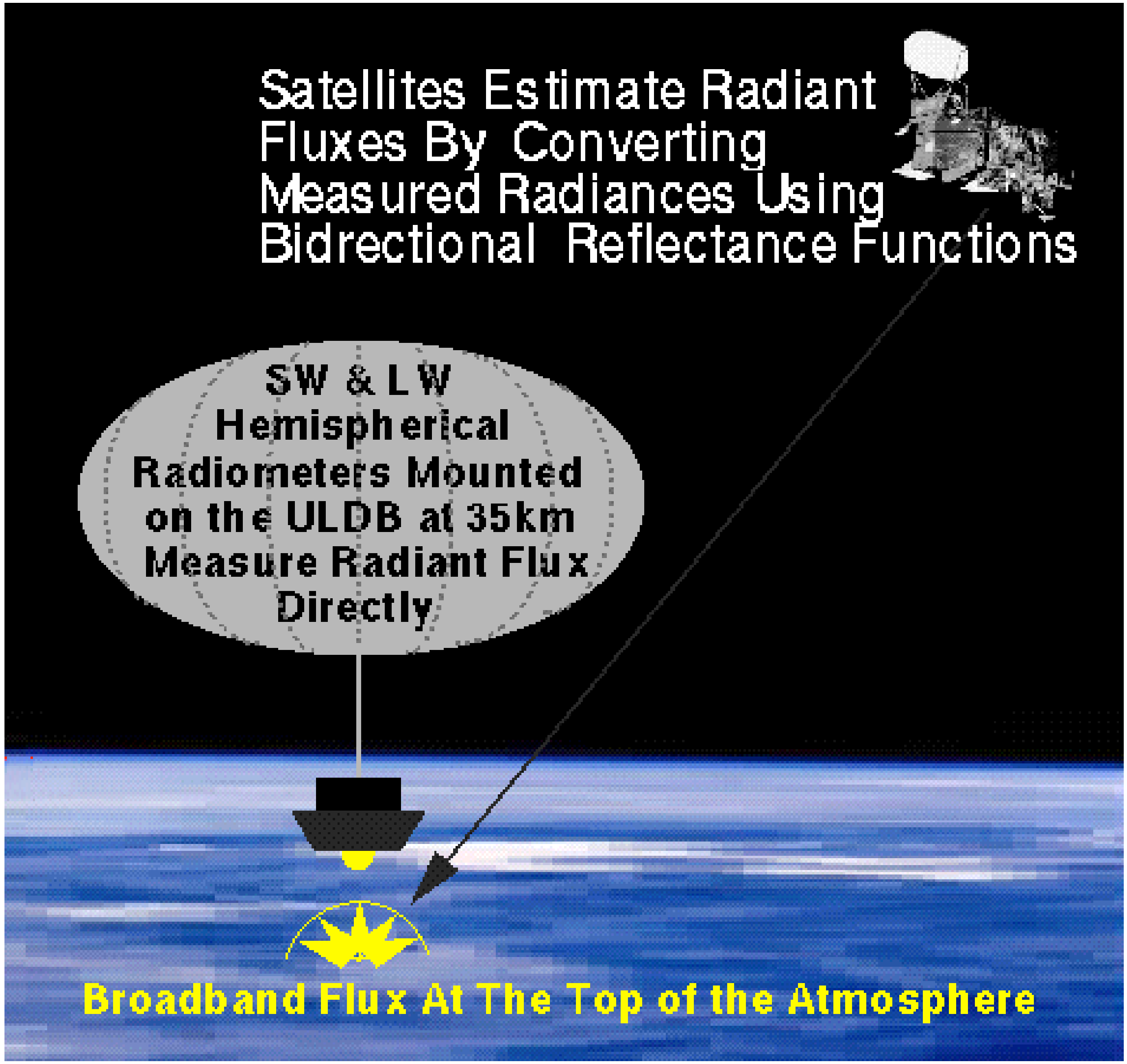


SARB vs. MODIS Albedo Jul 2001



Click “Balloon” from CAVE URL

Wenying Su’s deployement of Haeffelin modified radiometers



Failed launch from Alice Springs, Australia