CERES Surface and Atmospheric Radiation Budget (SARB)

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CERES Data Products Workshop (Norfolk Airport, 29 January 2003)

”CRS” product has fluxes at surface, 500-200-70 hPa, and TOA,
cloud and aerosol forcing

Inputs: SSF (TOA flux, clouds, aerosols), ECMWF, MATCH (Collins)
aerosol assimilation, NCEP O3 (SBUV & HIRS)

Langley Fu-Liou 2 stream SW (2/4 LW with Kratz-Rose window)

Adjustments (tuning) to PW, Upper Tropospheric H2O, skin T, aerosols
Cloud LWP/IWP, cloud fraction, cloud height

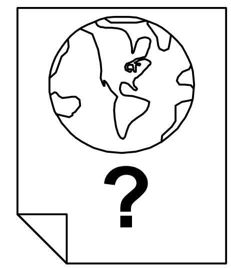
A priori uncertainties assigned to each adjustable parameter

Mininum sum of squares of normalized differences between
(1) computed TOA fluxes and adjusted inputs
and
(2) observed TOA fluxes and initial inputs

Q: Is belief in CERES possible? And this mad SARB “everything” stuff?

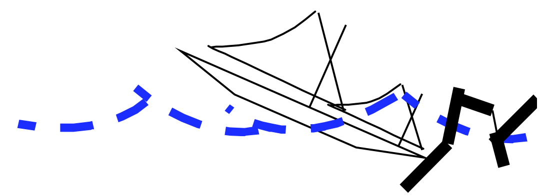
A: Virginia is not Boulder. Belief is allowed here. But history comes first.

1700s:

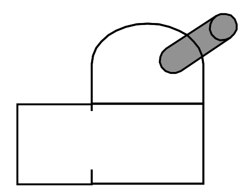


Lacking precise time keeping,
longitude could not be determined accurately.

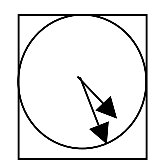
GSFC



Not surprisingly, many ships were lost due
to errors navigation.



Greenwich Royal Observatory (astronomy!) was supported
to solve the problem.



The solution was the invention of a superior
mechanical chronometer, the modern clock.

LaRC

Rough accuracies of some instruments

Common digital wristwatch: 10e-5
Mercury thermometer (undergraduate calibration): 10e-4
Meter stick: 10e-3
Very high quality radiometer (i.e., BSRN, EOS): 10e-2

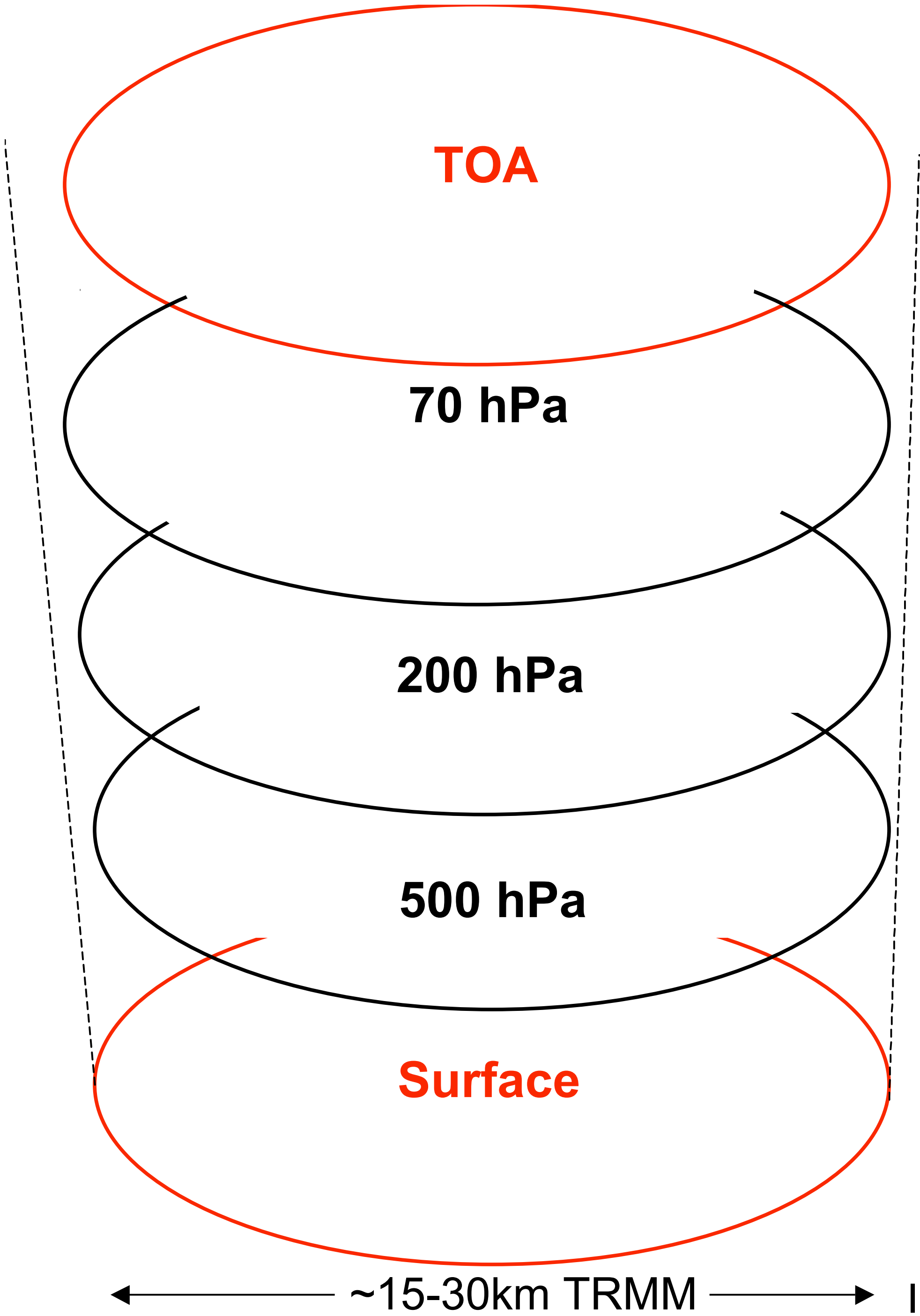
Clocks in 1700s were better than our radiometers are now. And then the king offered a great prize for a better measurement of time…

Believe as you wish. Jefferson's proposal for religious freedom is here law.

You indeed will hear of the"everything" CERES SARB.

But pay closer attention to the ways we test it.

And tell us later what you believe, what you don't believe, how we can make it better, and what science we call all make of it.



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

Tuned fluxes at all 5 levels
All-sky & Clear- sky
SW, LW, 8-12.5um non-CERES Window
Up & Down

Surface & TOA also have Untuned fluxes & Pristine (no aerosol) fluxes

Emulated 8-12um CERES Window at TOA

Photosynthetically Active Radiation (PAR 400-700nm) at surface

Tuning does NOT yield a perfect match to TOA observations.

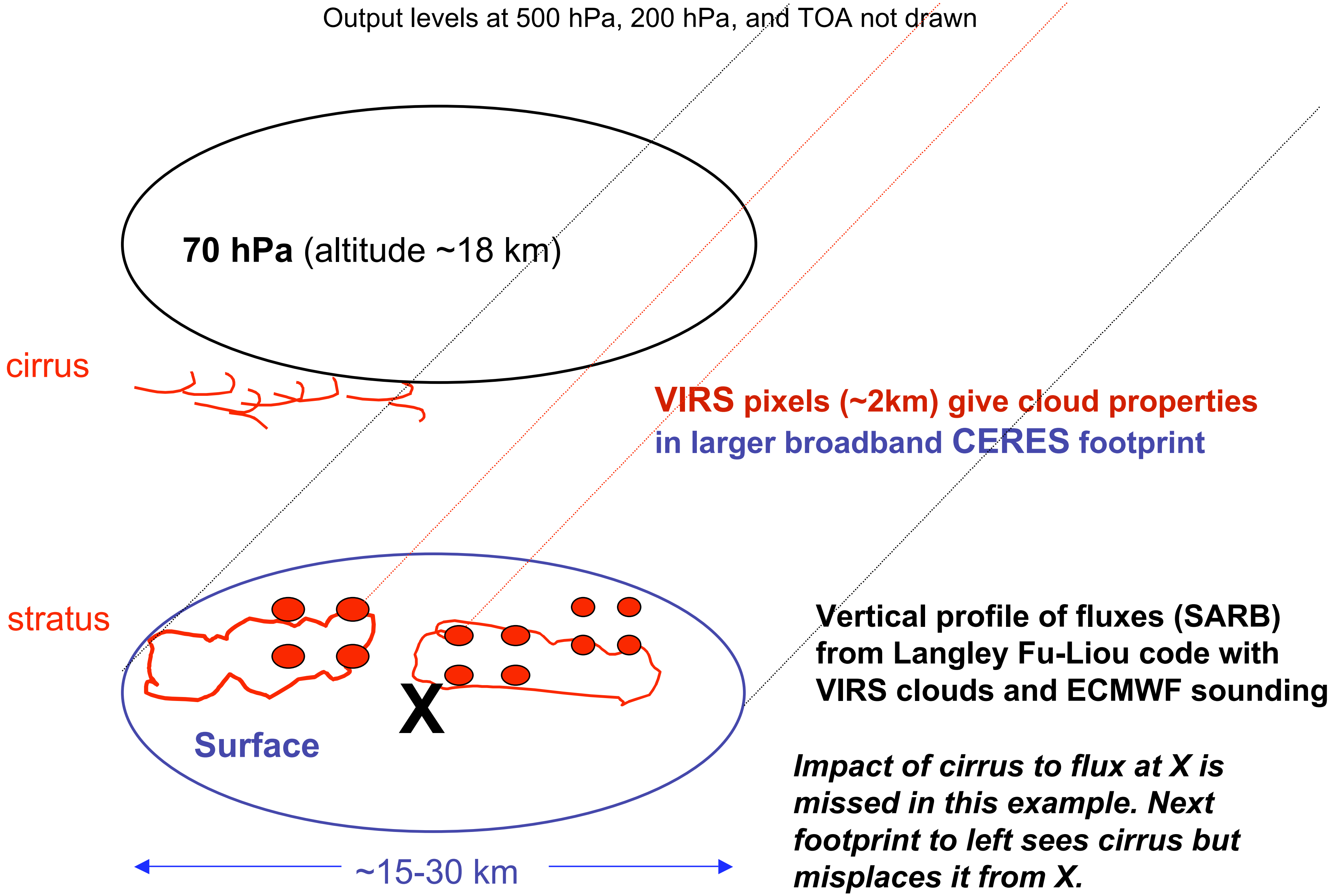
Parameters adjusted when clear:
Skin temperature, aerosols,
lower & upper tropospheric humidity

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

Instantaneous, geolocated at surface, ungridded

Viewing geometry and vertical profile of SARB fluxes

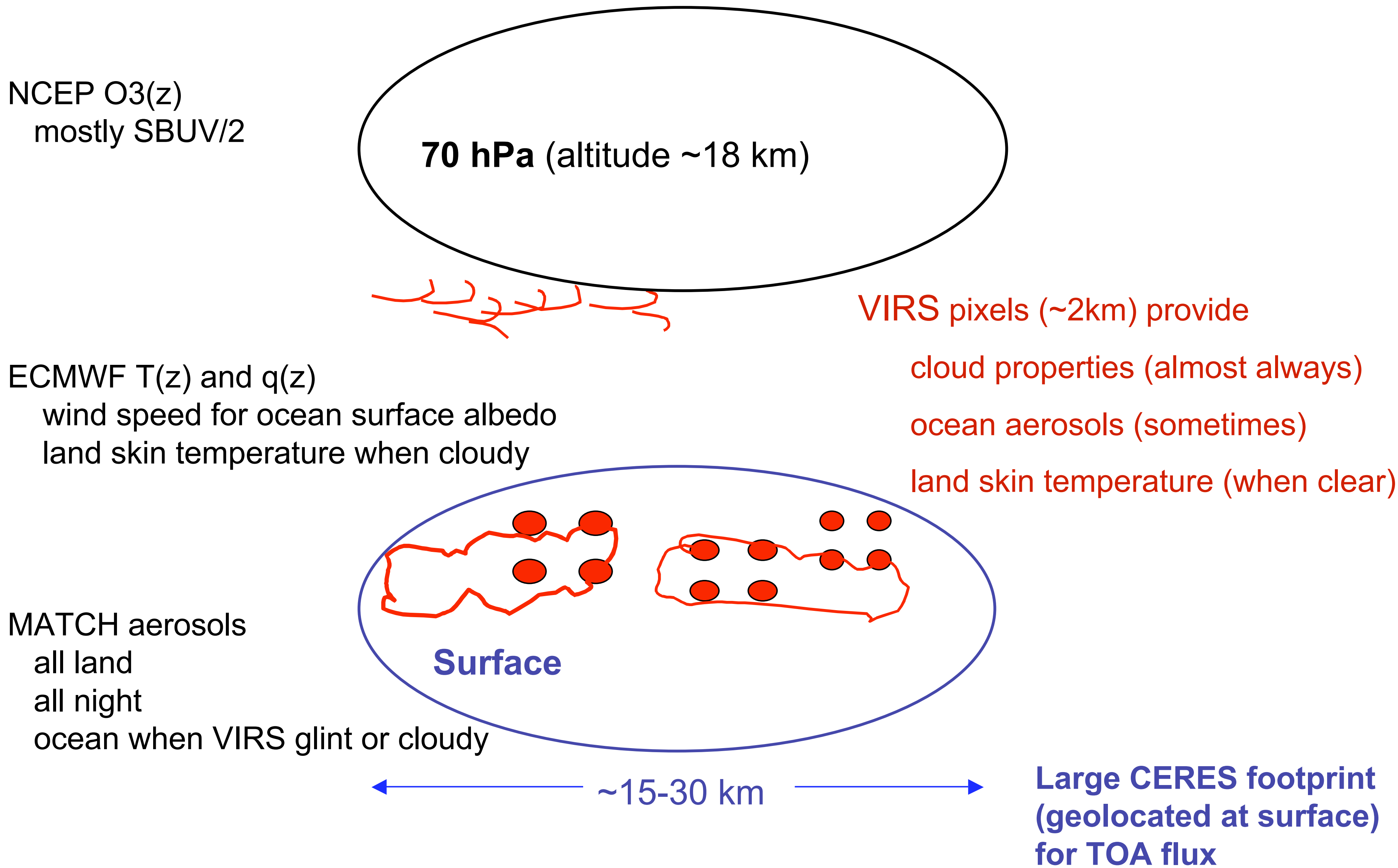
Output levels at 500 hPa, 200 hPa, and TOA not drawn

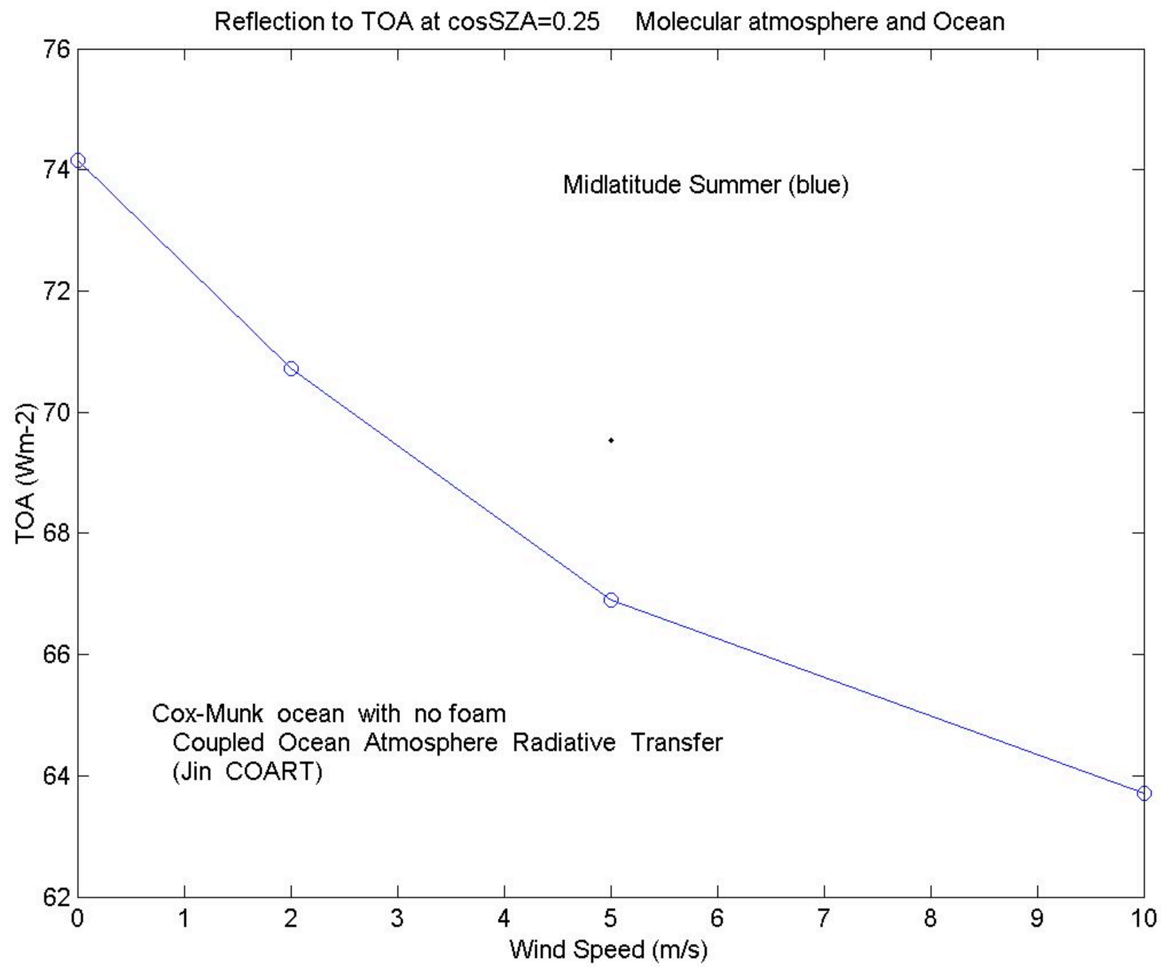


Impact of cirrus to flux at X is missed in this example. Next footprint to left sees cirrus but misplaces it from X.

Input data for computing SARB vertical profile at ~4,000,000 footprints/day

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

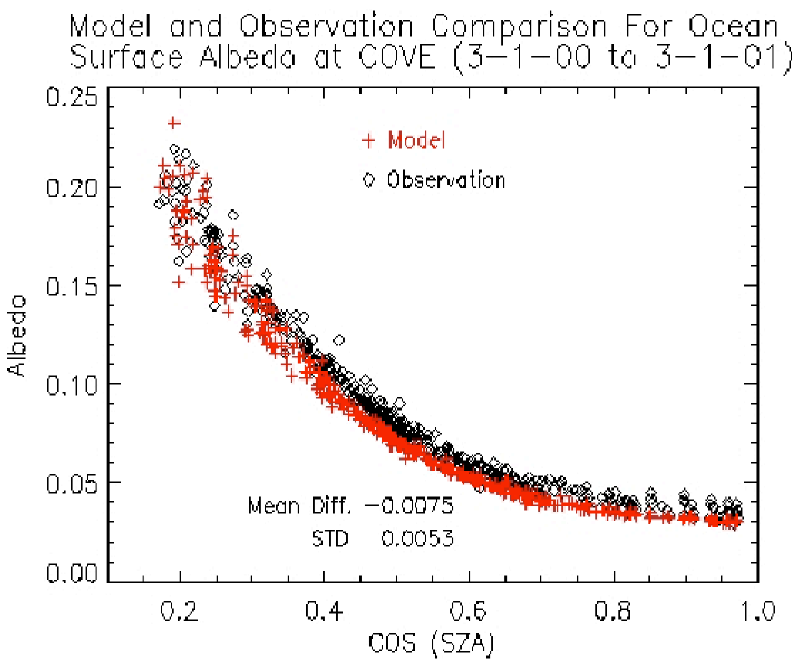




Example of why we need good boundary conditions:
For large SZA, signal of change in ocean albedo at very low wind speeds could be confused with aerosol.

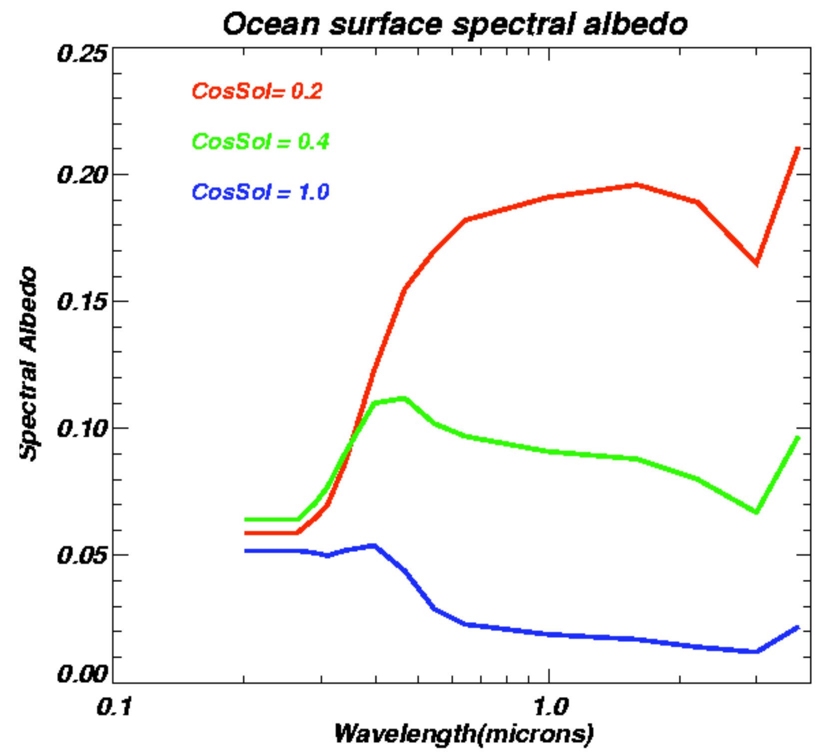
Coupled Ocean Atmosphere
Radiative Transfer (COART)

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 SARB calculation

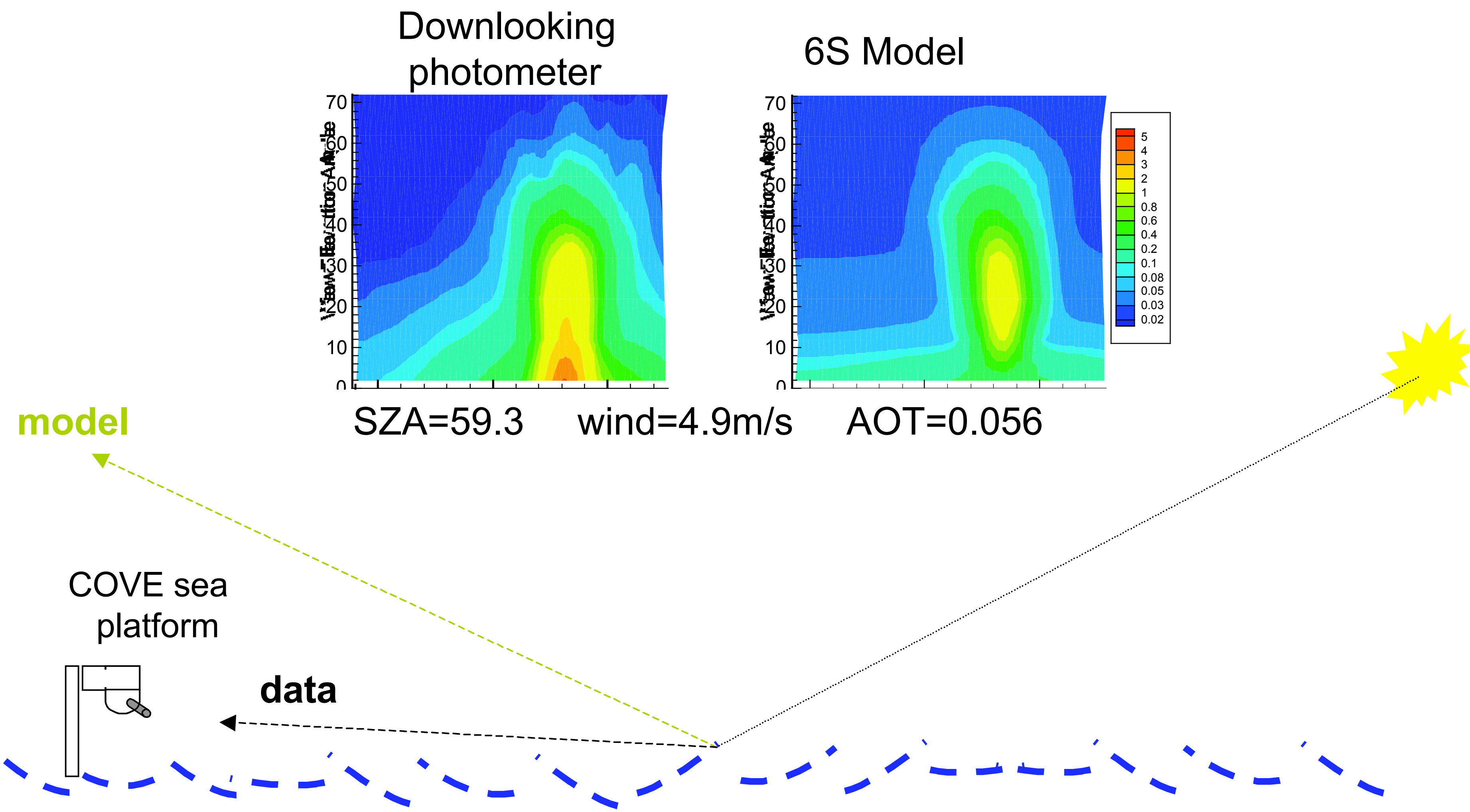


f(wind speed, cosSZA, tau)

wind = 5m/s   aerosol tau = 0.1

Checking basic assumptions for ocean boundary conditions

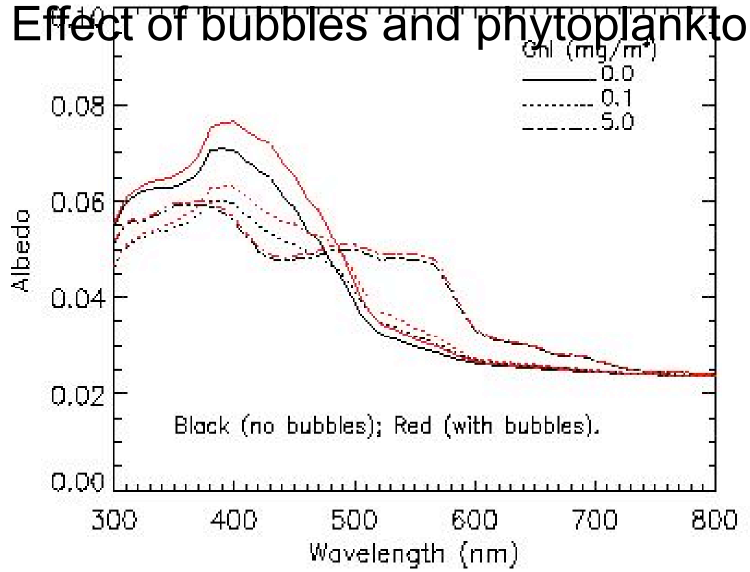
Cox-Munk statisitcs of wind waves → mirror facets



Su, W., T. Charlock, and K. Rutledge, 2002: Observed ocean reflection around sunglint at CERES Ocean Valiation Experiment (COVE) site. Applied Optics, 41, 7369-7383.

Coupled Ocean Atmosphere Radiative Transfer (COART)
Modeled Ocean Spectral Albedo

Effect of bubbles and phytoplankton



Phytoplankton and Dissolved Organic Matter (DOM):
Tested in CLAMS field campaign at low wind speeds, matching observed spectral albedos from MFRSRs on sea platform.

Bubbles: Measurements for foam/bubble effects starting at CERES Ocean Validation Experiment (COVE) sea platform.

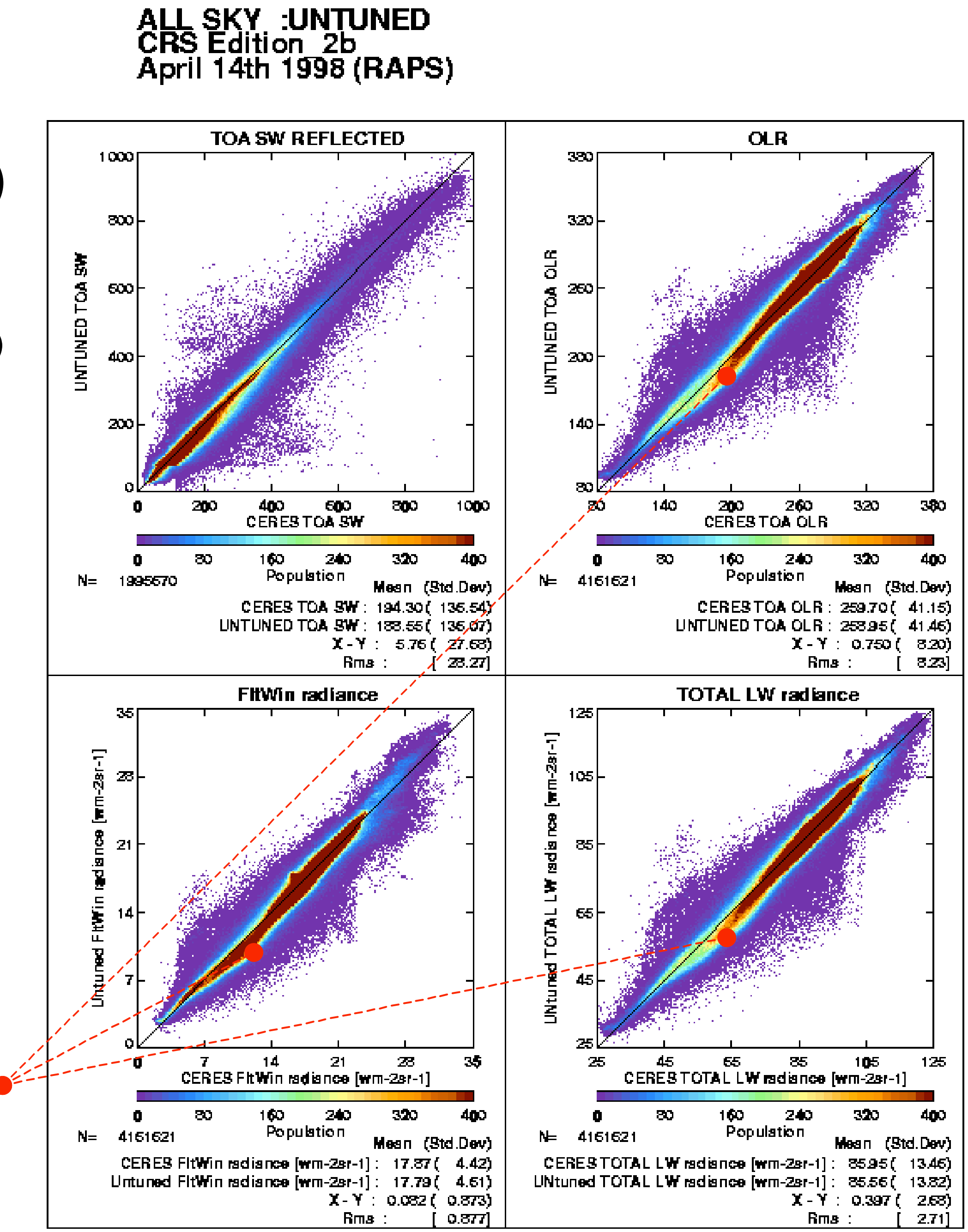
X axes: observations

Y axes: calculations (no tuning)

bias = observations – calculations (Wm -2)

	bias	rms
untuned SW	**5.8**	**28.3**
untuned OLR	**0.8**	**8.2**
tuned SW	-0.3	14.7
tuned OLR	0.4	4.2

Plots of tuned SW, OLR are not shown



Significant IR bias for high clouds

X axes: observations
Y axes: calculations (untuned)

OVERCAST ICE CLOUDS

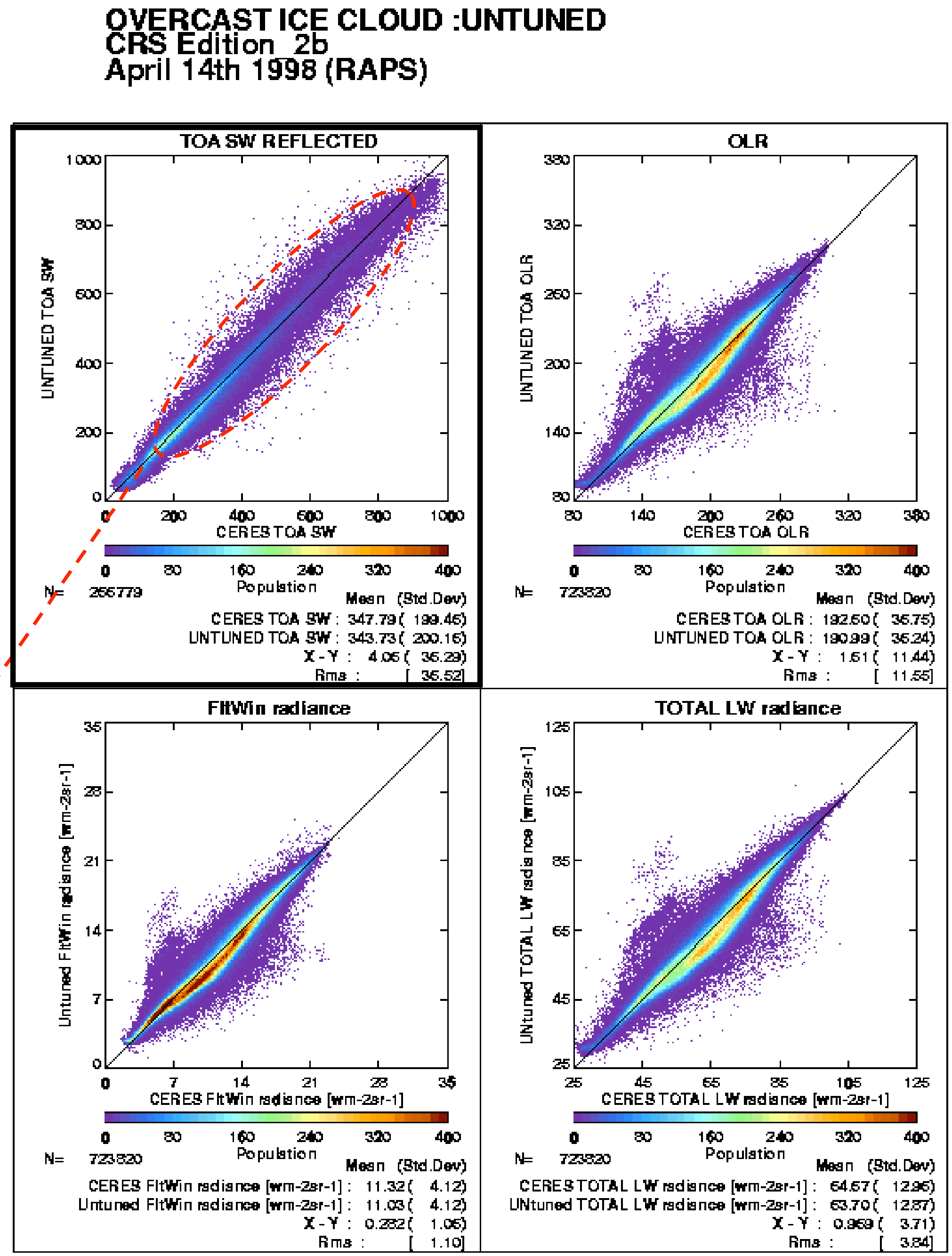
Both cloud retrievals and broadband calculations assume for ice:

Hexagonal crystals
Random orientation
Gamma size distribution

RAPS: cloud retrievals (VIRS) and broadband observations (CERES) have different look angles.

Untuned SW rms = 36.5 Wm-2
for Overcast Ice

Untuned SW rms = 28.3 Wm-2
for All Sky (previous page)



X axis: observations
Y axis: calculations (untuned)

Clear ocean only

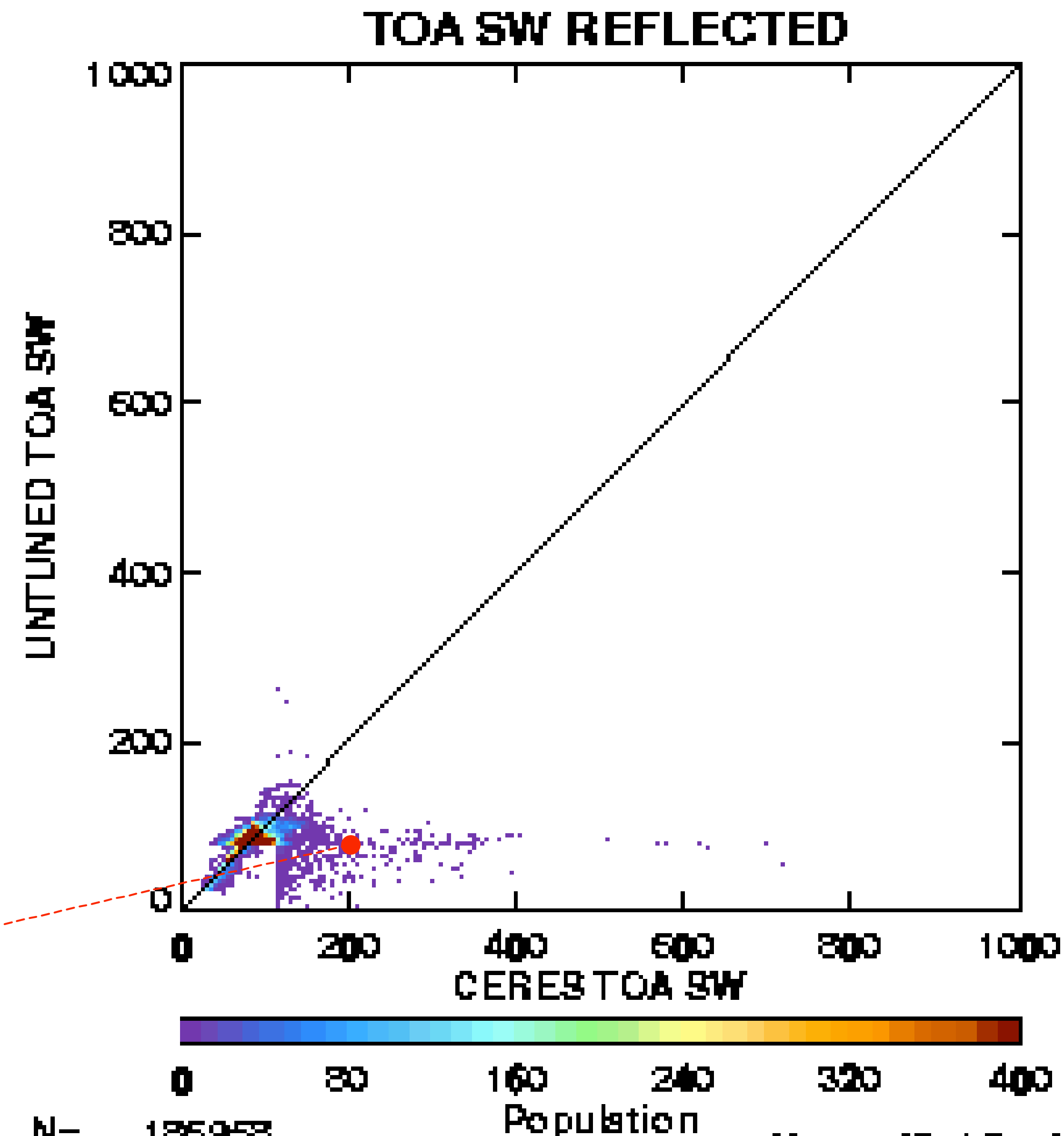
Aerosols from
SSF (VIRS)
or MATCH assimilation

Wind speed from ECMWF

Lookup table for
ocean spectral albedo

Calculated << Observed

Tiny number of footprints where sunglint bugs observed TOA flux.



N= 185958

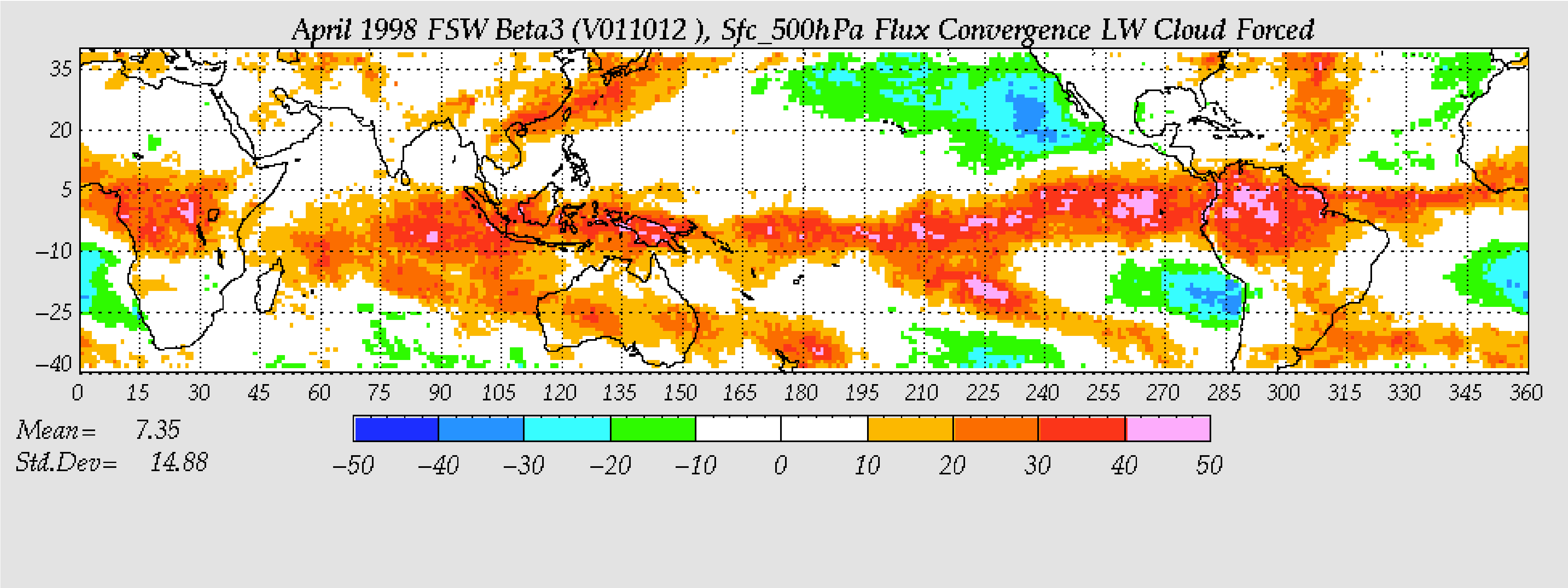
	Mean	(Std.Dev)
CERES TOA SW :	84.73	(16.47)
UNTUNED TOA SW :	83.97	(10.38)
X - Y :	0.763	(14.36)
Rms :		[14.38]

Cloud forcing to LW “convergence” (Surface to 500hPa) April 1998

All sky LW convergence is generally negative.

gridded “FSW Beta3”= hourly mean of ungridded “CRS Ed2B”

Gridding here does not account for diurnal effects, but should give reasonable estimate for LW during this month.

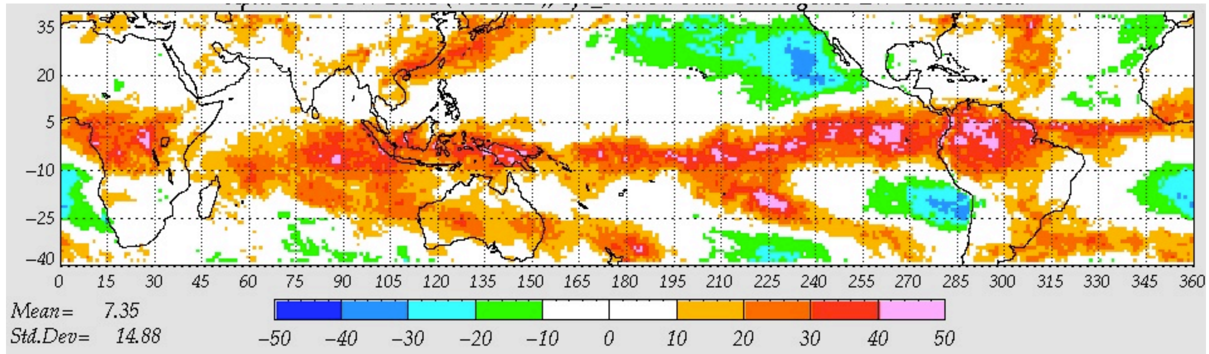


Cloud Forcing

LW Conv   Sfc-500hPa

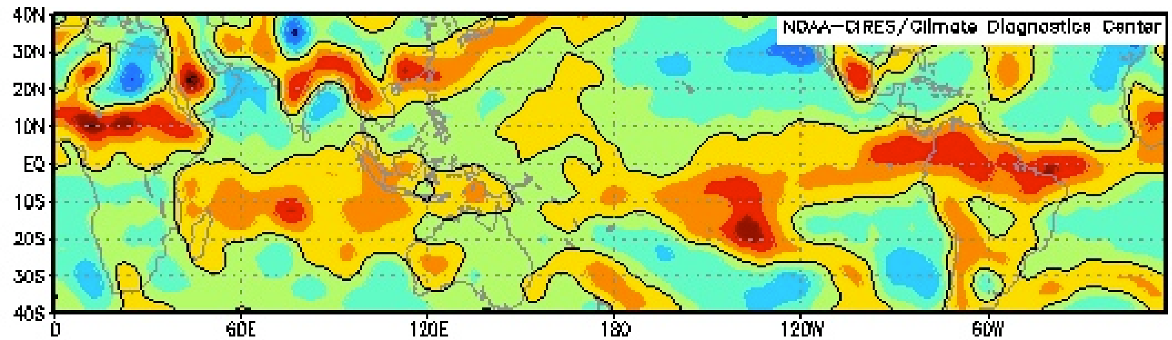
crude mean = 7 Wm-2

range -50 to +50 Wm-2



Omega at 700 hPa
red = ascent

NCEP/NCAR April 98

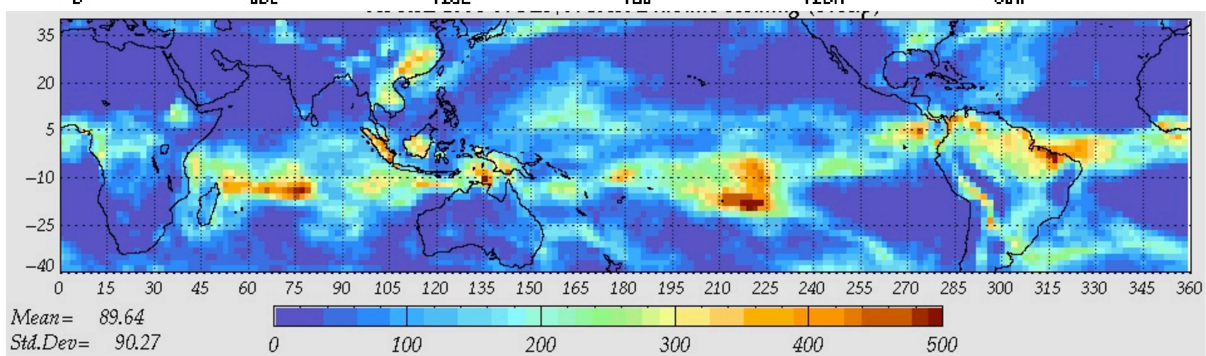


Precipitation expressed

as Diabatic Heating

mean = 89 Wm-2

range   0 to 500 Wm-2

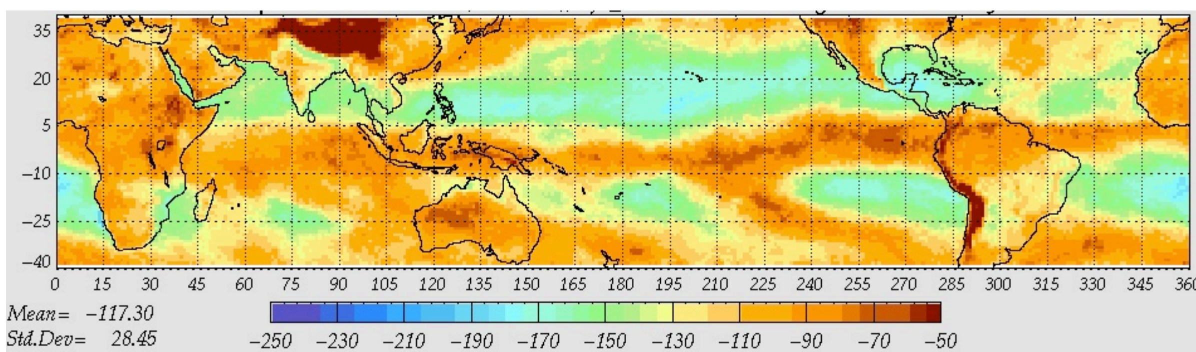


All Sky

LW Conv   Sfc-500hPa

crude mean = -117 Wm-2

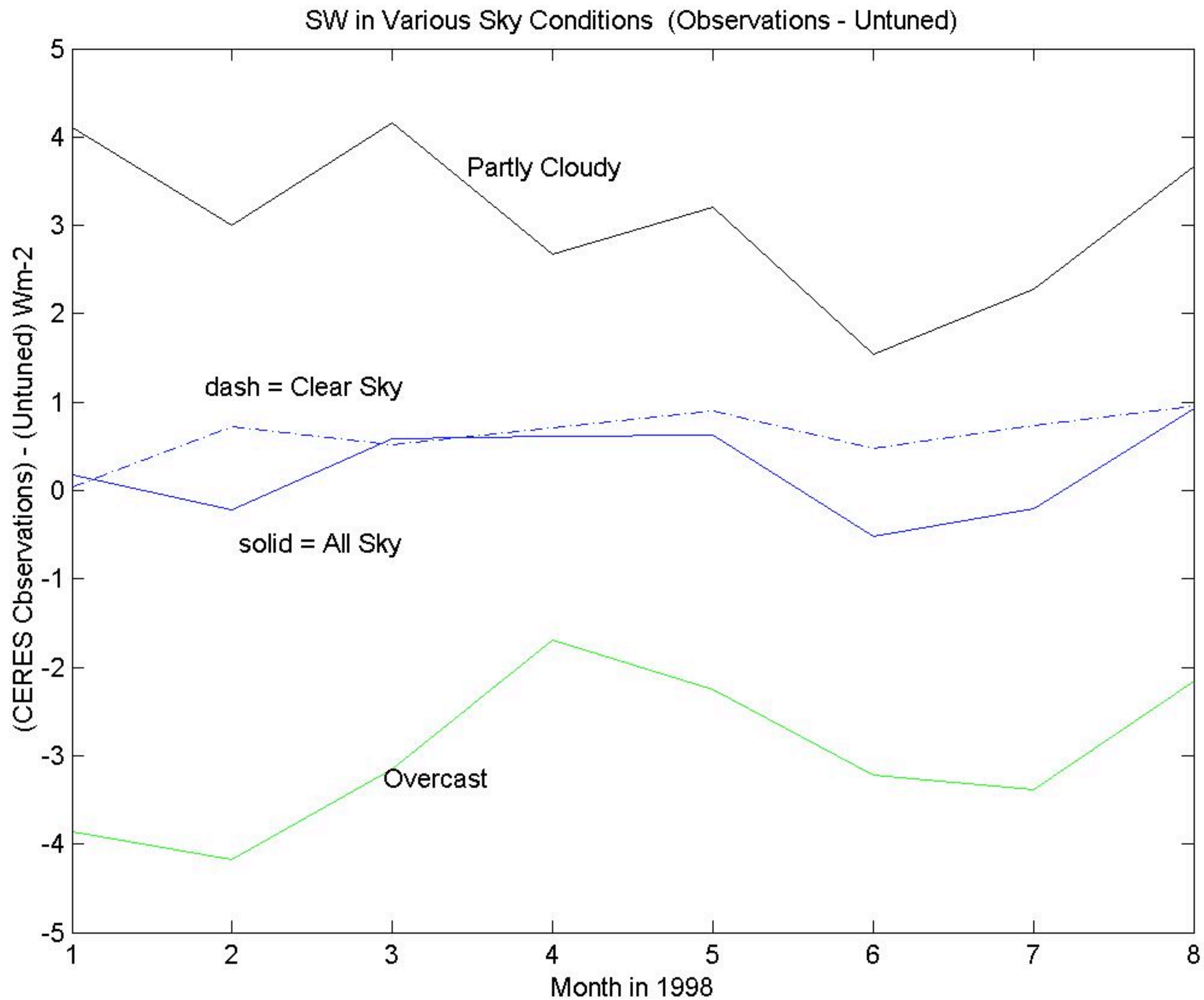
range -170 to -70 m-2



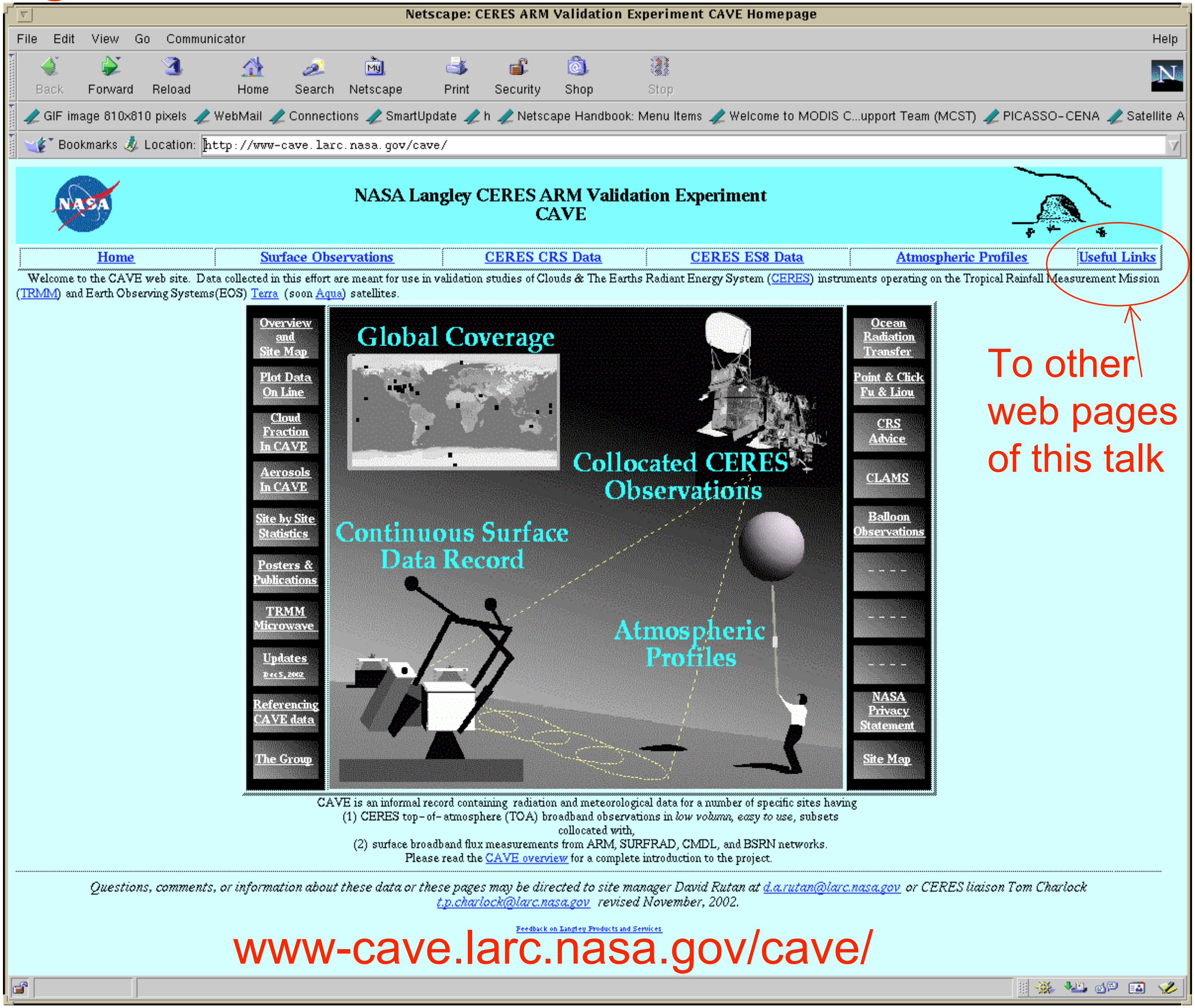
Reflected SW at TOA as coarse means (Jan-Aug 98)

(CERES Observations) minus (untuned Calculations)

For SW, errors in simulating partly cloudy and overcast are significant but compensating.



Google "CERES CAVE": fruitful domain of David Rutan



To other web pages of this talk

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

Netscape: CAVE Projects Page

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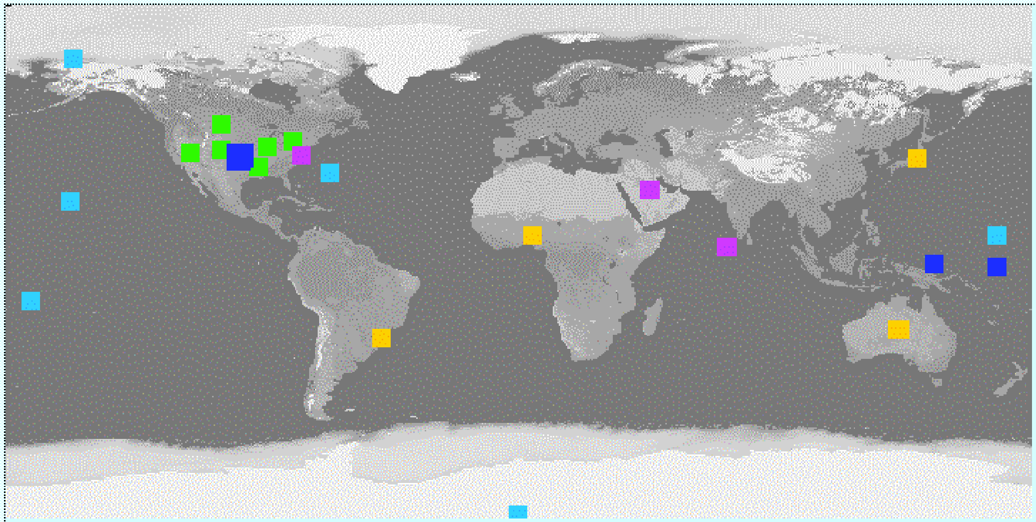
Bookmarks Location: http://www-cave.larc.nasa.gov/cave/cave2.0/Projects.html

Contributing Projects

Home | Surface Observations | CERES CRS Data | CERES ES8 Data | Atmospheric Profiles | Useful Links



ARM – Atmospheric Radiation Measurement

The Department of Energy's Atmospheric Radiation Measurement (ARM) project supplies to CAVE a number of surface observations at 23 different locations. There are 21 sites in and around Kansas and Oklahoma, and two on the islands of Nauru and Manus in the Tropical West Pacific Ocean.

BSRN – Baseline Surface Radiation Measurement

The BSRN project is an international effort to obtain long–term high–quality surface observations of downwelling broadband radiation. We are downloading data for 4 sites around the globe.

CMDL – Climate Monitoring & Diagnostics Laboratory

The National Oceanic & Atmospheric Association (NOAA) CMDL supplies a high quality data set of primarily downwelling radiation from a number of remote sites about the globe.

SURFRAD – Surface Radiation Budget

SURFRAD supplies a complete set of radiation and surface meteorology from 6 sites located within the US. These sites provide a reliable data set of both upwelling & downwelling radiation, and located in a diverse set of surface vegetation types.

Indpendent Sites

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

INDOEX – Indian Ocean Experiment

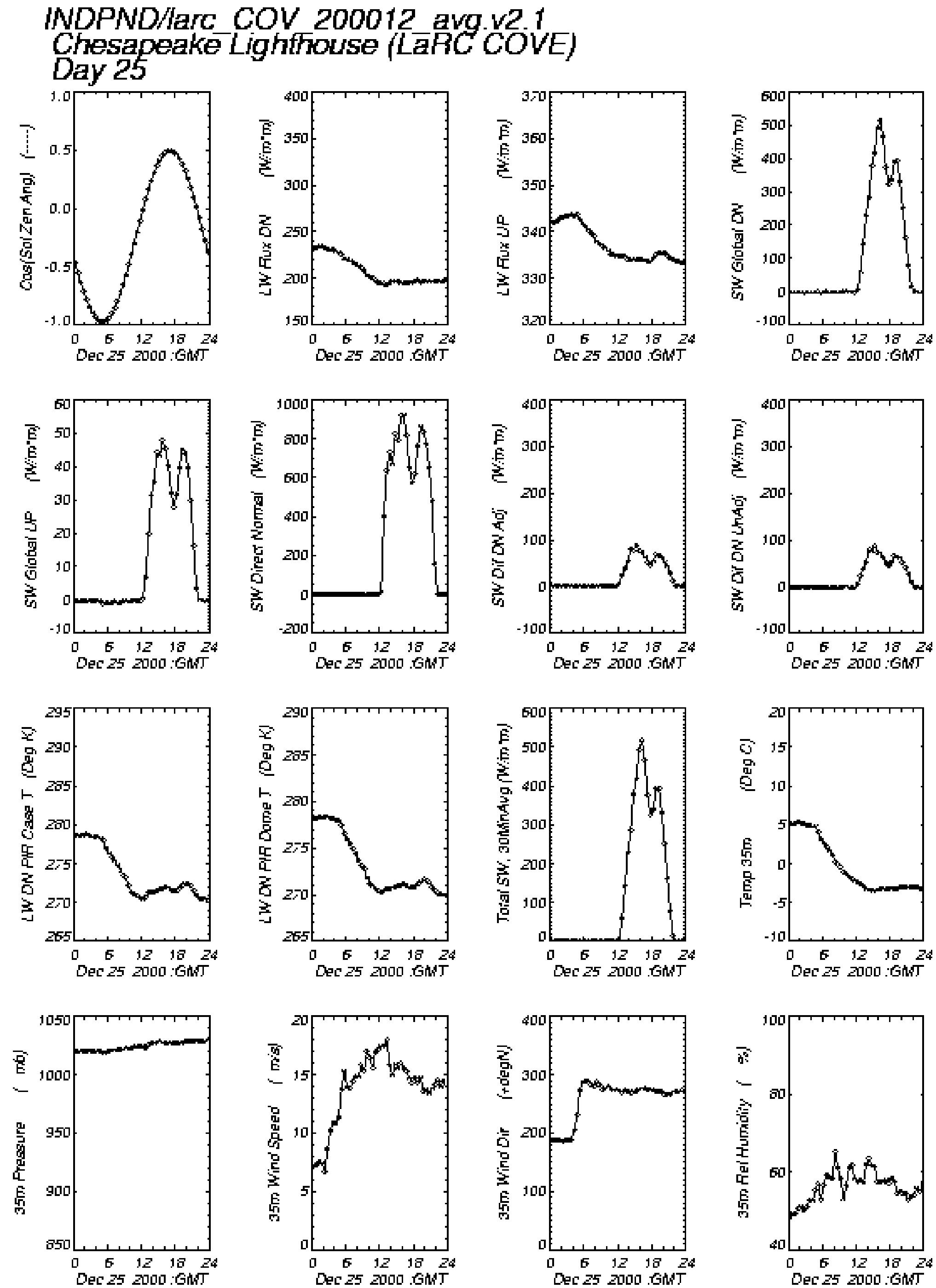
CAVE: On line plots at over 30 surface radiation sites

CERES TOA also plotted

Files by ftp

Half-hourly (30 min.) means

Record starts 1 January 1998



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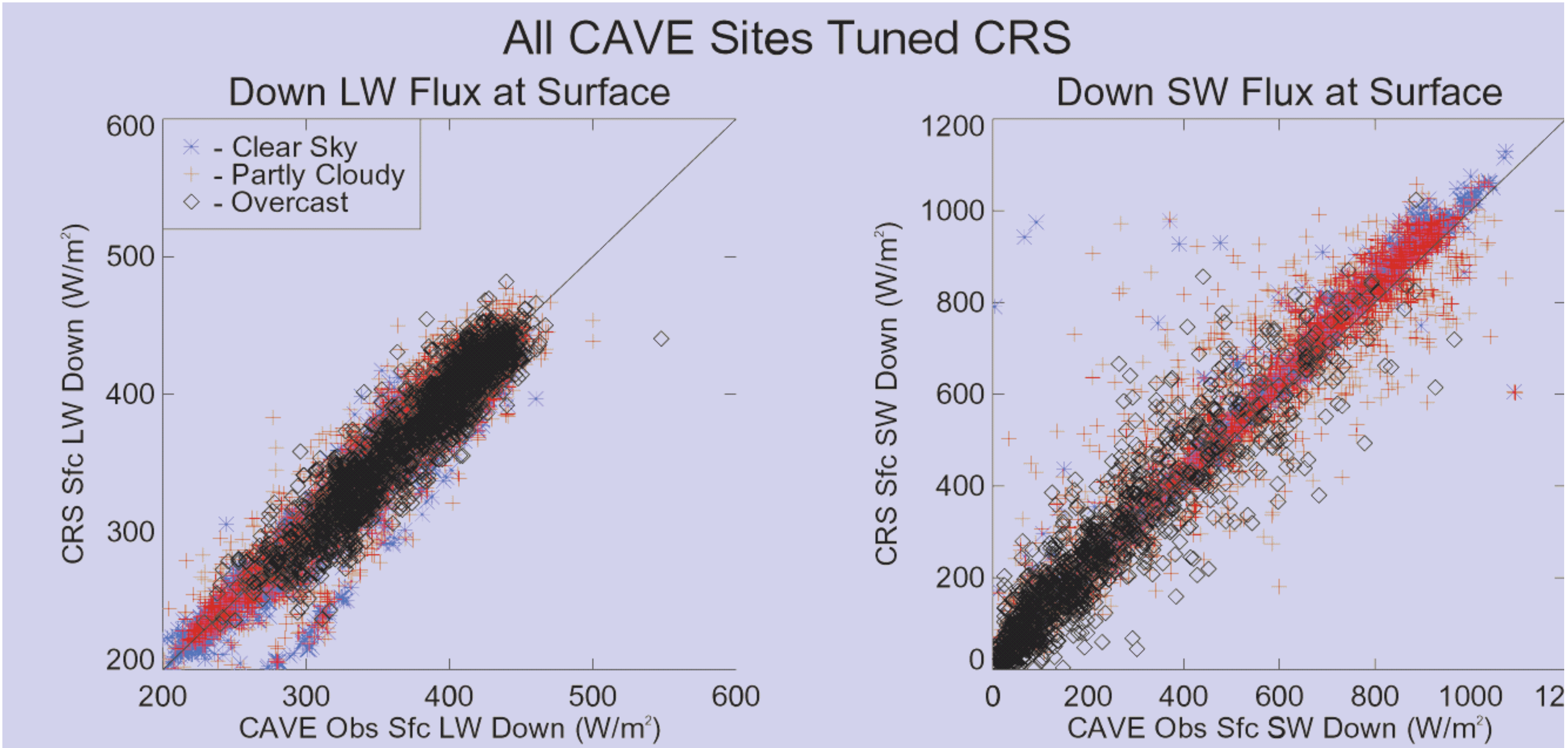


	Obs Mean	N	Bias Obs-CRS	RMS	Cld Forc All-Clr
ALL SKY					
LW Dn Sfc	358	8601	2	19	18
LW Up Sfc	429	6780	2	20	
SW Dn Sfc	443	4990	-34	89	-142
SW Up Sfc	91	4162	12	26	
LW Up TOA	252	9282	0	4	-24
SW Up TOA	219	5158	1	17	89

24 hour SW bias = -34/2 Wm-2

www-cave.larc.nasa.gov/cave/ select “Site Statistics”

Satellite retrieval uses NO ground radiometer data. Pyranometers corrected for IR offset.

ARM SGP E-13 Collocated with Central Facility

	Obs Mean	N	Bias Obs-SARB	RMS	Cloud forcing
ALL SKY					
LW Dn Sfc	349	455	-3	18	17
LW Up Sfc	416	430	-3	16	
SW Dn Sfc	428	260	-21	60	-128
SW Up Sfc	87	260	11	20	
LW Up TOA	247	457	0	4	-27
SW Up TOA	224	258	2	10	87
OVERCAST					
SW Dn Sfc	243	68	-27	87	
CLEAR VIRS					Aer Forc
SW Dn Sfc	512	94	-23	29	-16/0.6 SW/LW
CLEAR VIRS + pyranometer					
SW Dn Sfc	324	17	-14	17	-12/0.5
SW direct			-5		
SW diffuse			-9		

24 hour SW bias = -21/2 Wm-2

We do not see “anomalous cloud absorption” (i.e., 25 Wm-2 of unexplained 24-hour SW cloud forcing).
Insolation biases in clear and cloudy skies are similar.

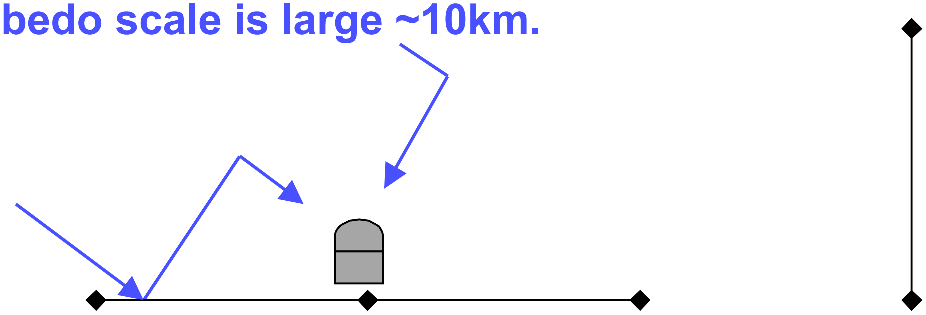
Surface insolation measured at a point is affected by surface albedo

MODIS retrieves surface spectral albedo, but aerosol correction is tenuous.

Aircraft can observe spectral albedo, but aircraft radiometry is tricky.

- **Very low altitude: small area covered**
- **Moderate altitude: larger area covered, but aerosol correction required.**

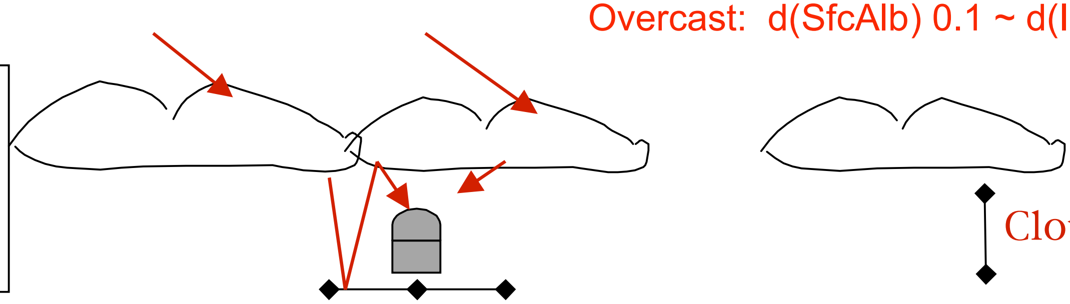
Clear sky: surface albedo impact on insolation is usually small. Relevant albedo scale is large ~10km.



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.



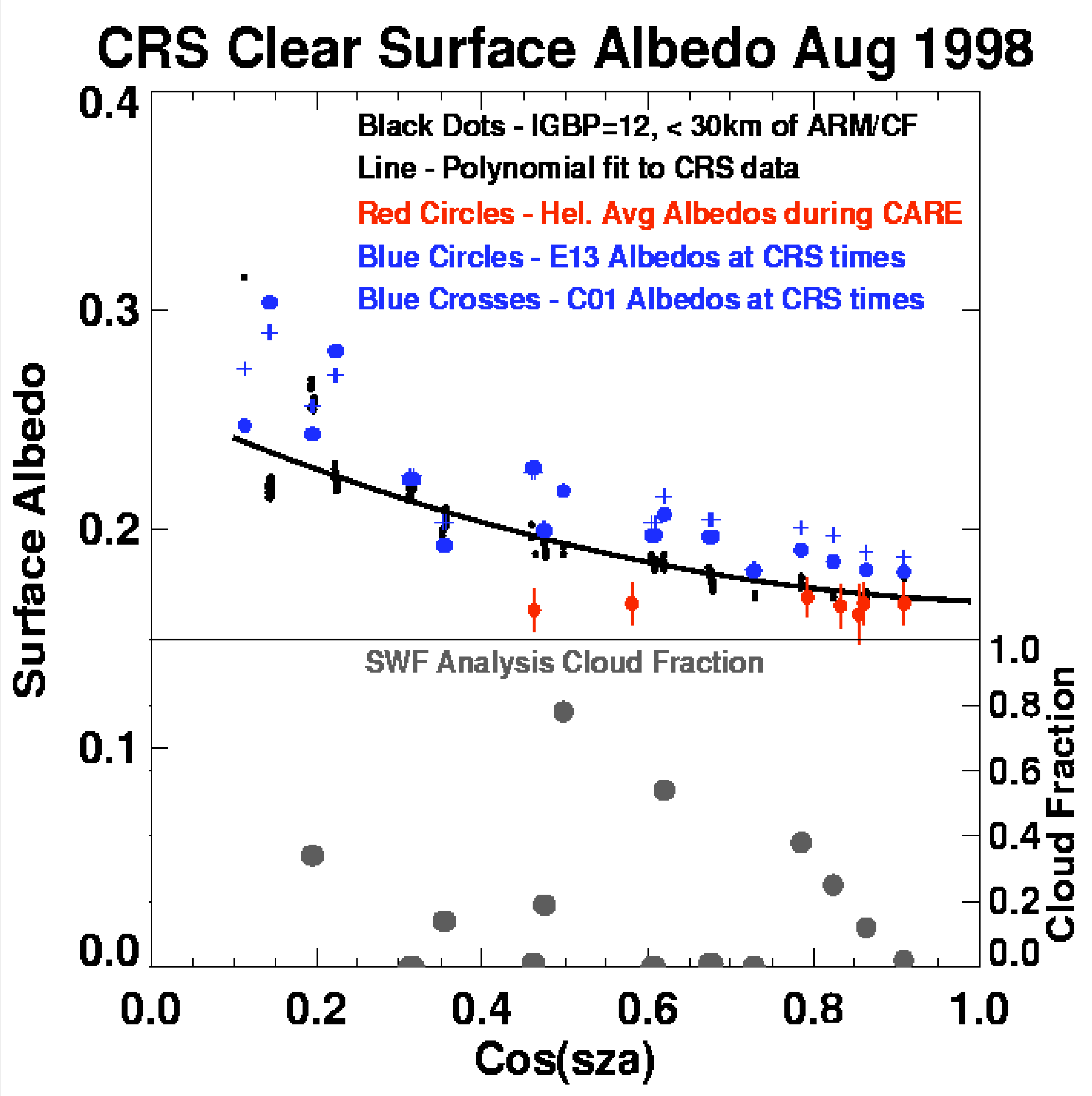
Field Campaign Test of CERES at ARM SGP during August 1998

Black dots: CRS

Red dots: helicopter

Blue: 10m towers

Grey circles: clouds from time series of surface radiometers at TRMM overpass

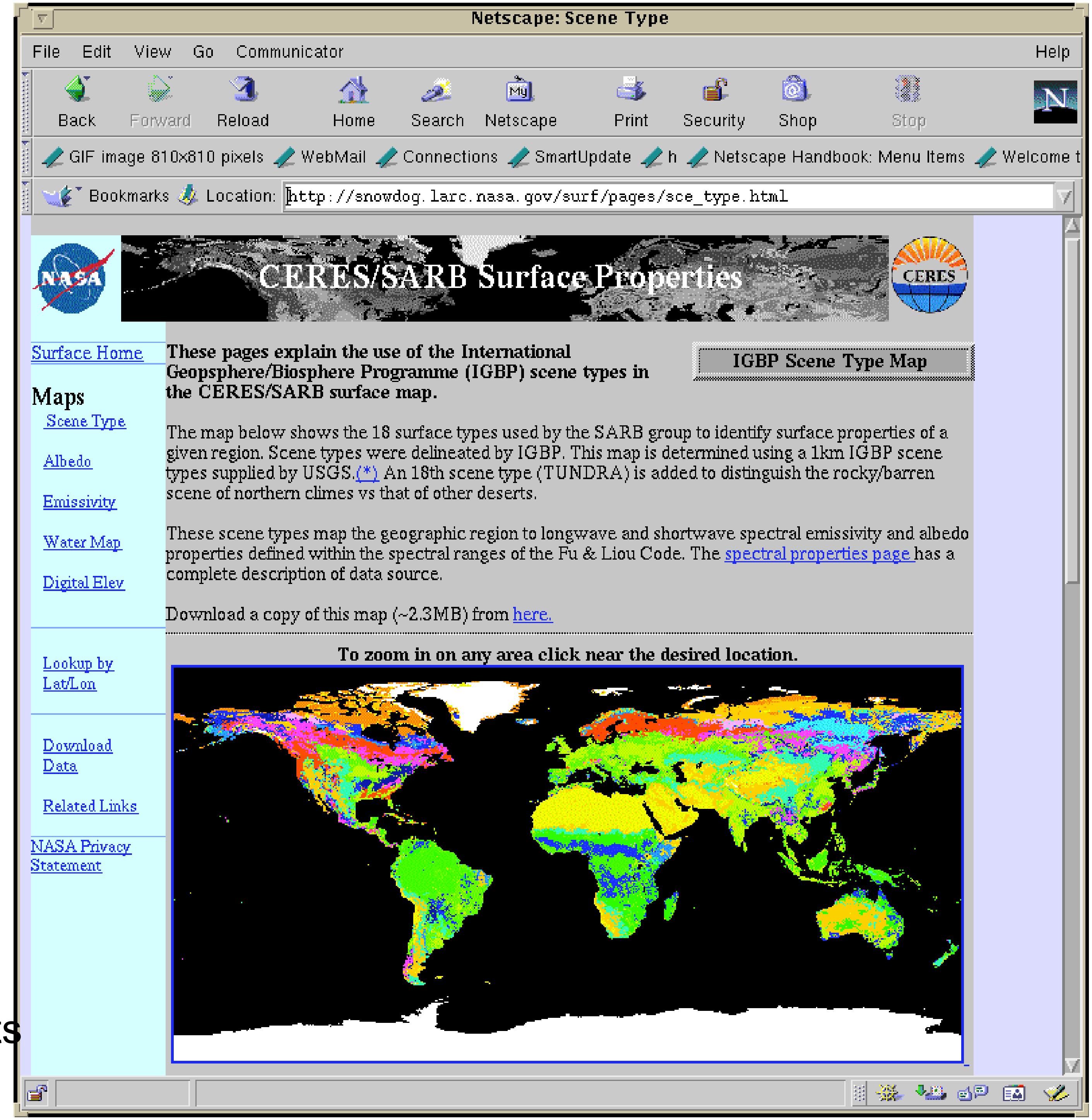


On line surface spectral optical properties

Maps with point and click to reference optics assumed by CERES SARB

SW and LW keyed to IGBP

CAVE “Useful Links”: to CERES ARM Rad. Exp. (CARE) aircraft spectral BRDF measurements

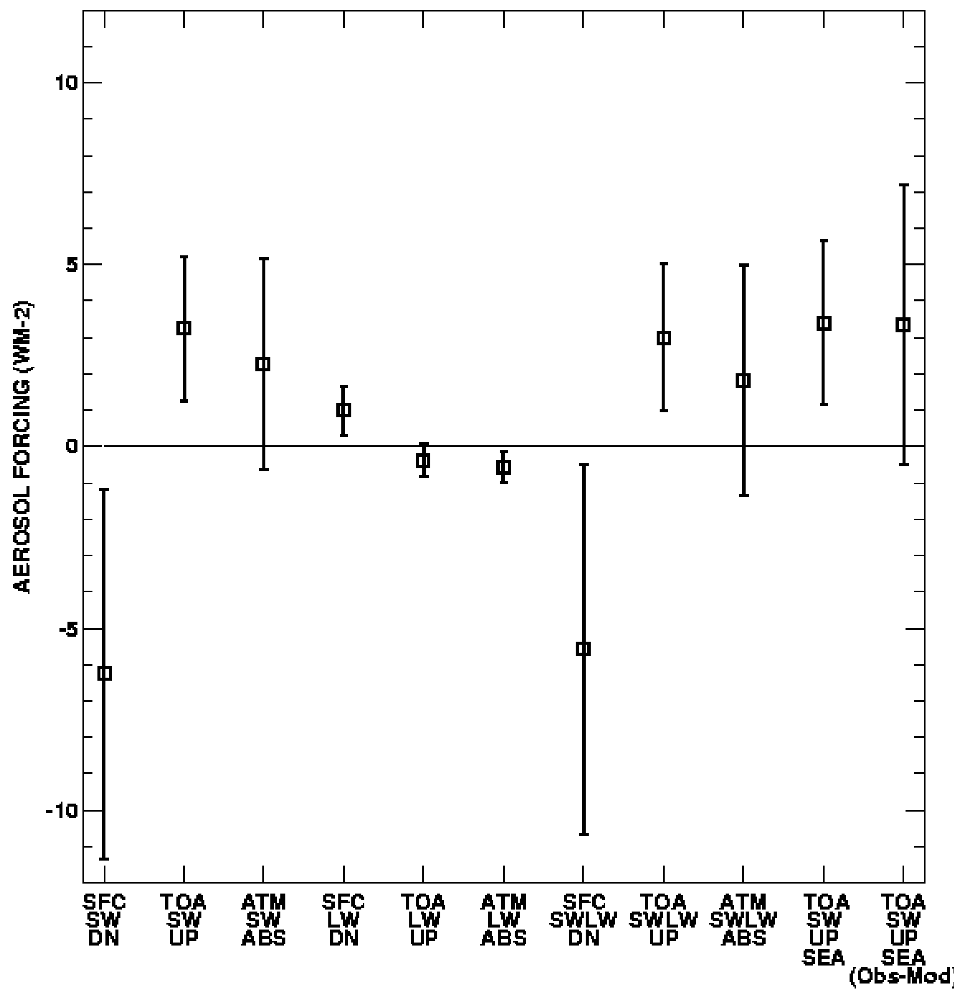


Esimate of clear sky aerosol forcing for April 1998

SARB calculations

Not diurnally smoothed

Raw mean of proto-FSW



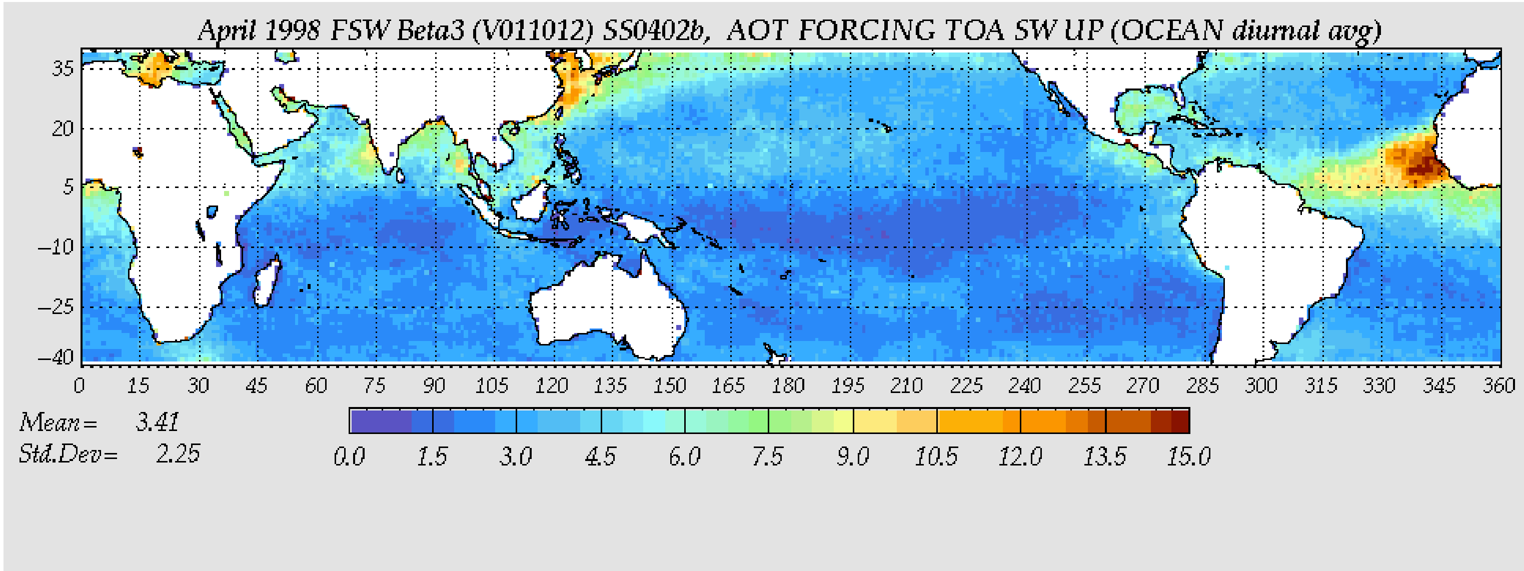
Has more absorption than found by Kaufmann and Dubovik

Assignment of aerosol characteristics: Based on MATCH

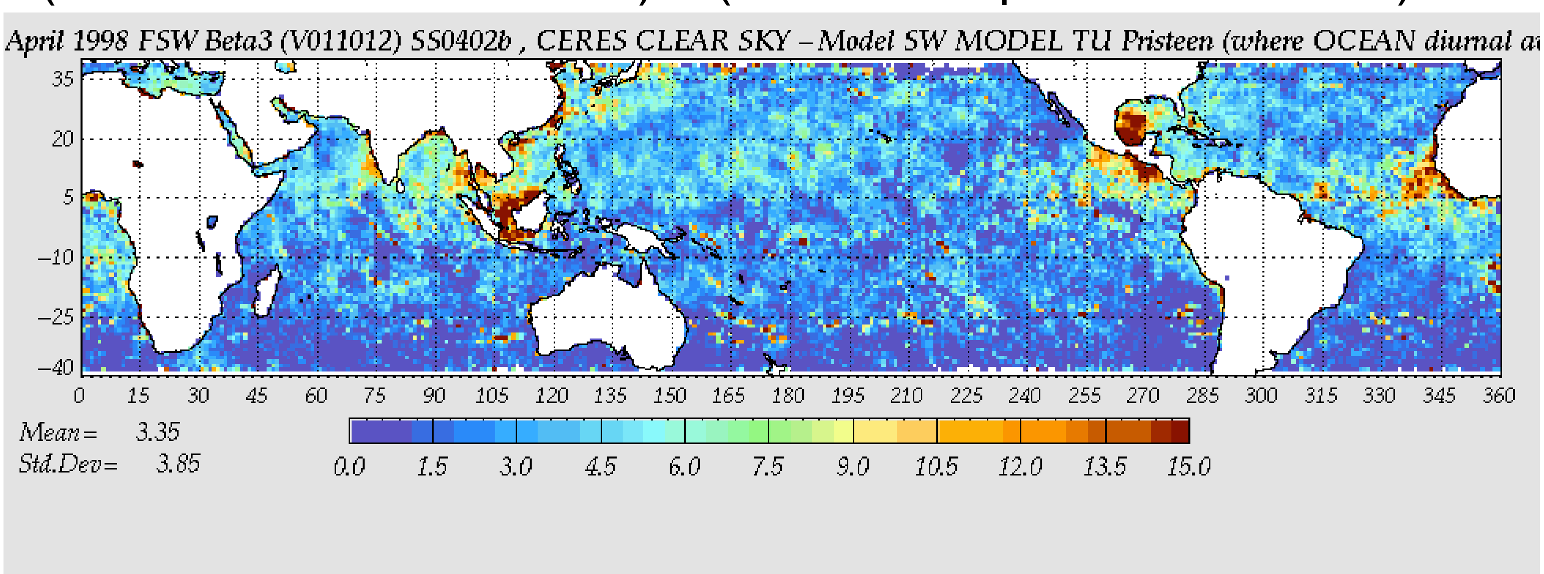
MATCH aerosol type	CRS aerosol optics	scale height
dust (0.01-1.0 um)	dust (0.5 um) Tegen-Lacis	3 km
dust (1-10 um)	dust (2.0 um) Tegen-Lacis	1 km
dust (10-20 um)	dust (2.0 um) Tegen-Lacis	1 km
dust (20-50 um)	dust (2.0 um) Tegen-Lacis	1 km
hydrophilic black carbon	soot (OPAC)	1 km
hydrophobic black carbon	soot (OPAC)	1 km
hydrophilic organic carbon	soluble organic (OPAC)	1 km
hydrophobic organic carbon	insoluble organic (OPAC)	1 km
sulfate	sulfate (OPAC)	1 km
sea salt	sea salt (OPAC)	0.5 km

Mistake: organic carbon was zeroed out (~10% of aerosol)

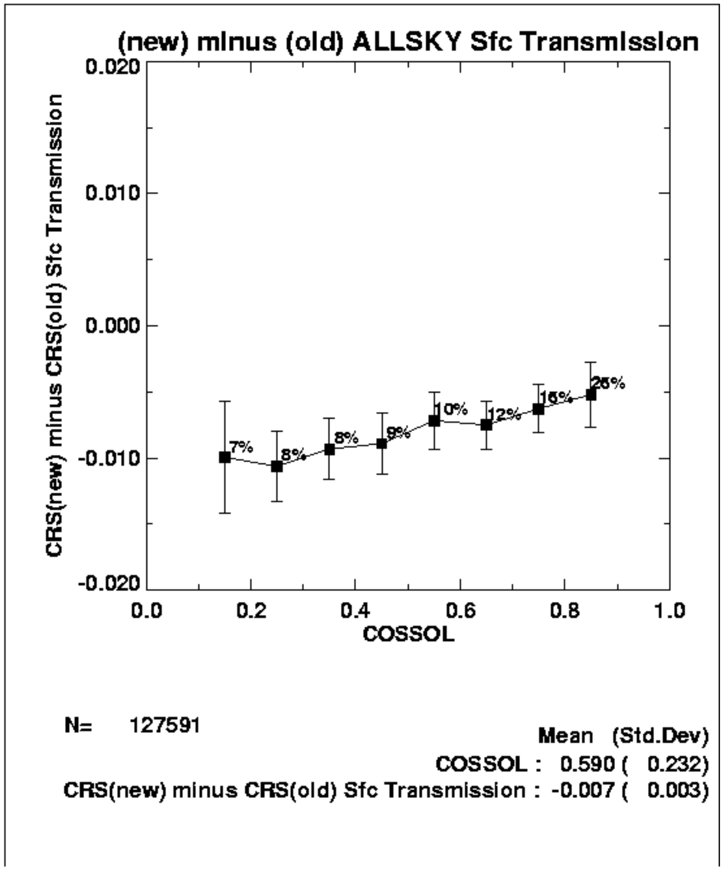
Tuned calculations: (Clear TOA SW) – (Pristine TOA SW)

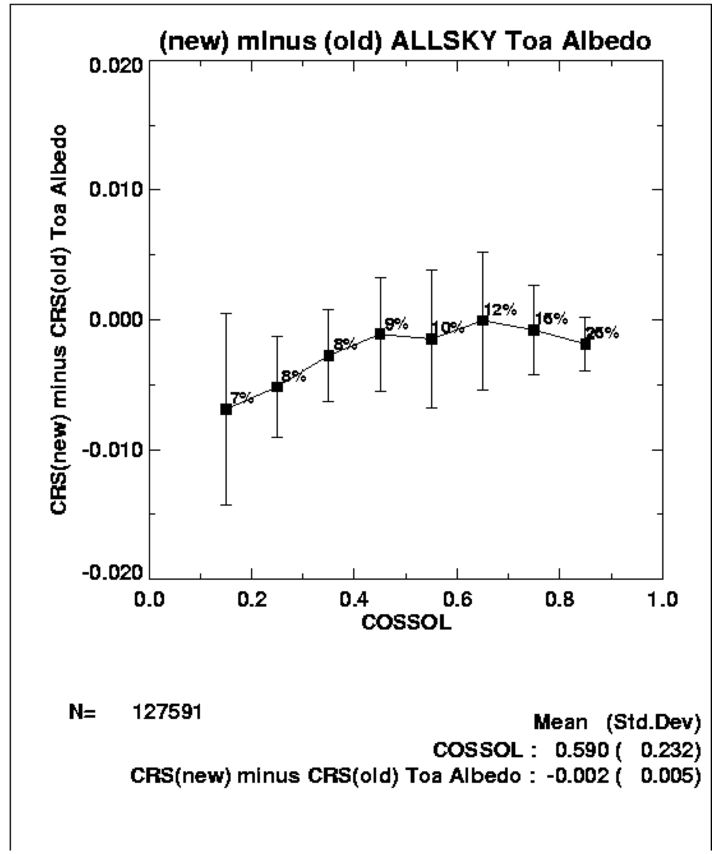


(Observed SSF clear SW) – (Calculated pristine TOA SW)



NEW Langley Fu-Liou SW (H_2O, O_3, CO_2, O_2, CH_4, Kato-Clothaux k's, Rose)
OLD " " " (H_2O, O_3, gerry rigged insert of Chou O_2, CO_2)
All CERES SARB (CRS) shown earlier used OLD code

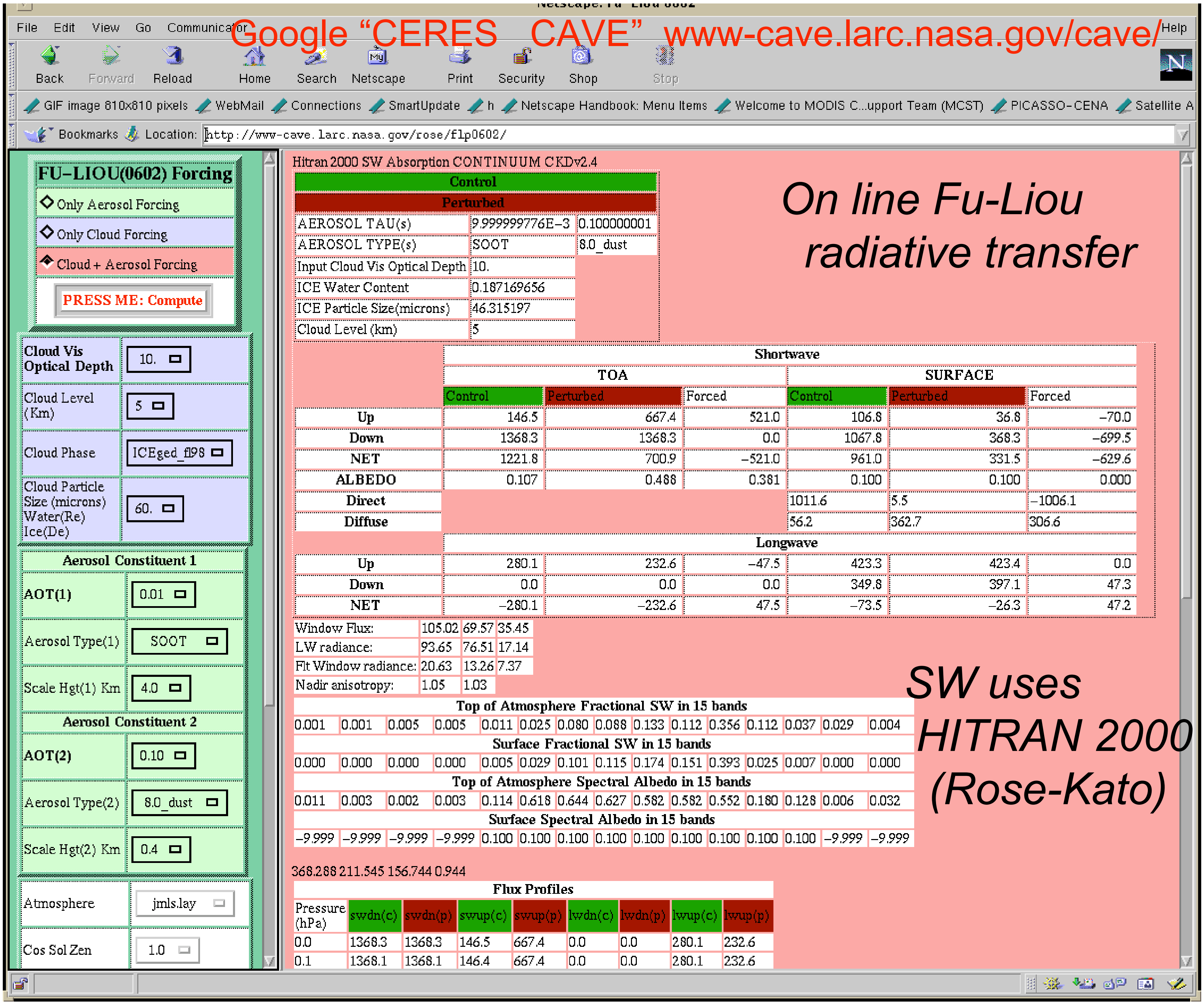




Excuses for error in surface insolation: Old code, aerosol forcing, surface albedo, questionable measurement of diffuse insolation.

Chesapeake Lighthouse and Aircraft Measurements for Satellites (CLAMS):
New code here, aerosols measured to death, & we know surface albedo.

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



File Edit View Go Communicator Help

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

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

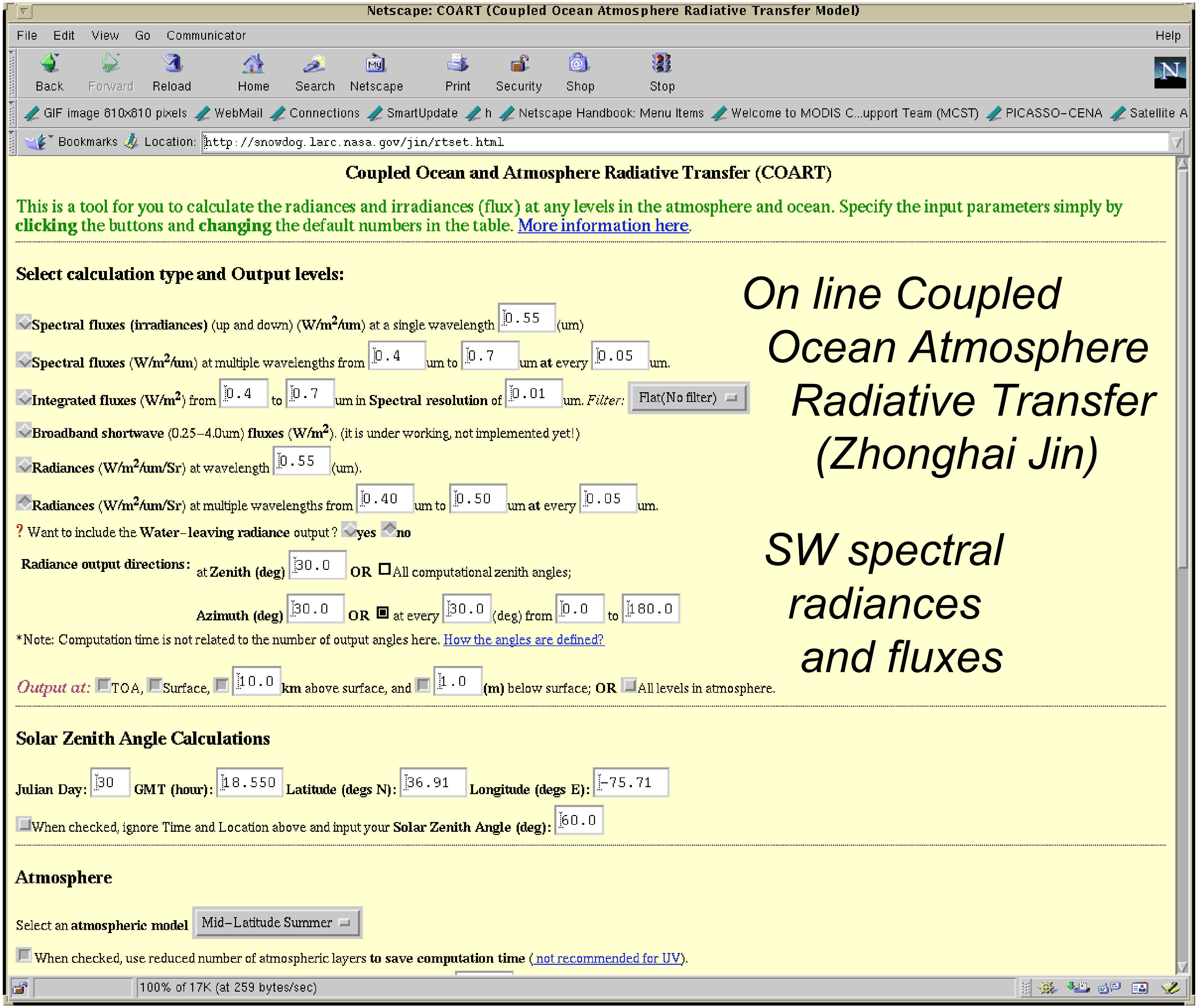
Pressure (hPa)	swdn(c)	swdn(p)	swup(c)	swup(p)	lwdn(c)	lwdn(p)	lwup(c)	lwup(p)
0.0	1368.3	1368.3	146.5	667.4	0.0	0.0	280.1	232.6
0.1	1368.1	1368.1	146.4	667.4	0.0	0.0	280.1	232.6

On line Fu-Liou radiative transfer

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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GIF image 810x810 pixels | WebMail | Connections | SmartUpdate | h | Netscape Handbook: Menu Items | Welcome to MODIS C...upport Team (MCST) | PICASSO-CENA | Satellite A

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

On line Coupled Ocean Atmosphere Radiative Transfer

☐ 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):

Select aerosol optical properties

λ(um):										
AOT:										
SSA:										
g:										

Ocean

Select wind speed chlorophyll phase function

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)

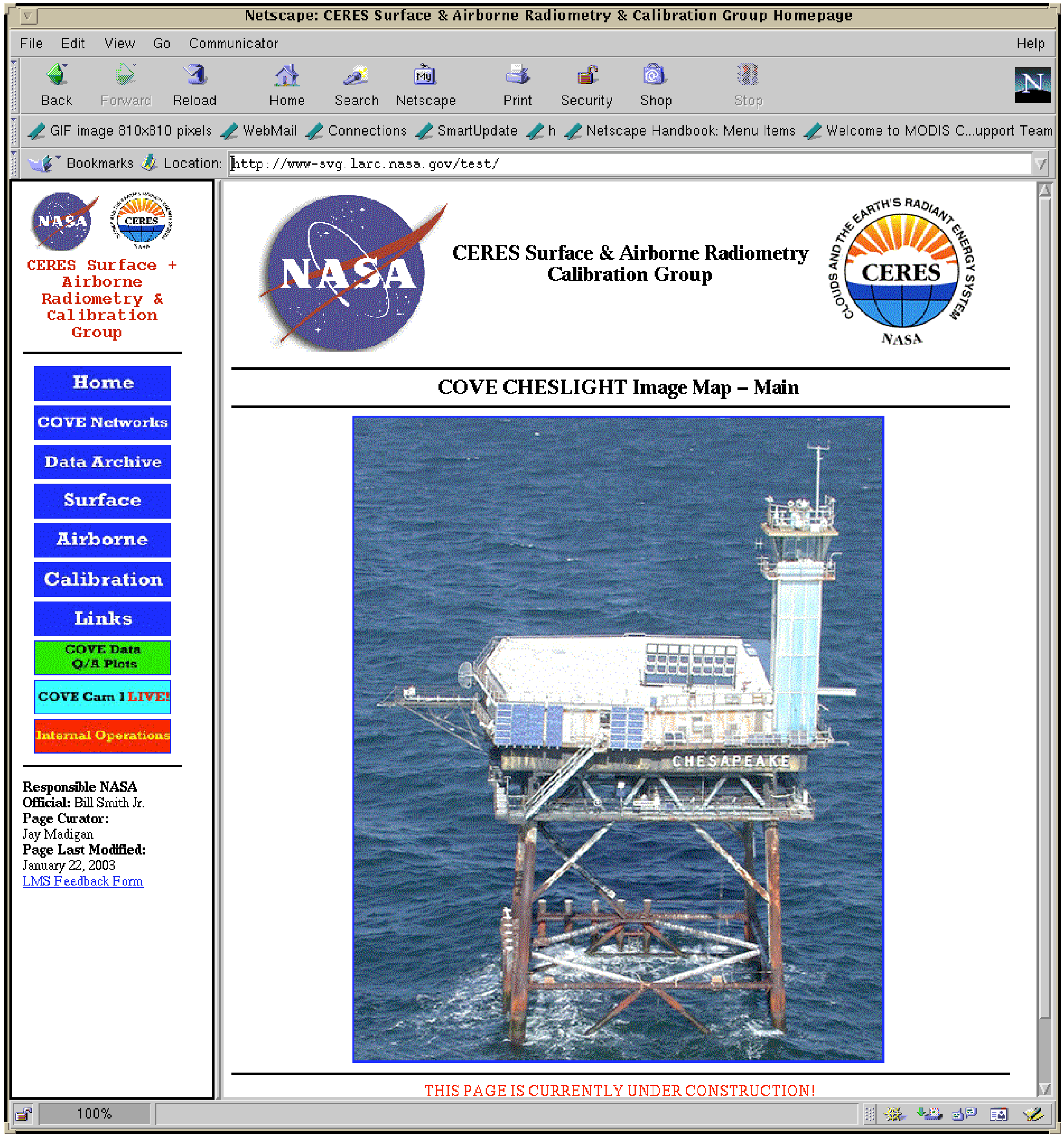
COVE

CERES Ocean
 Validation Experiment

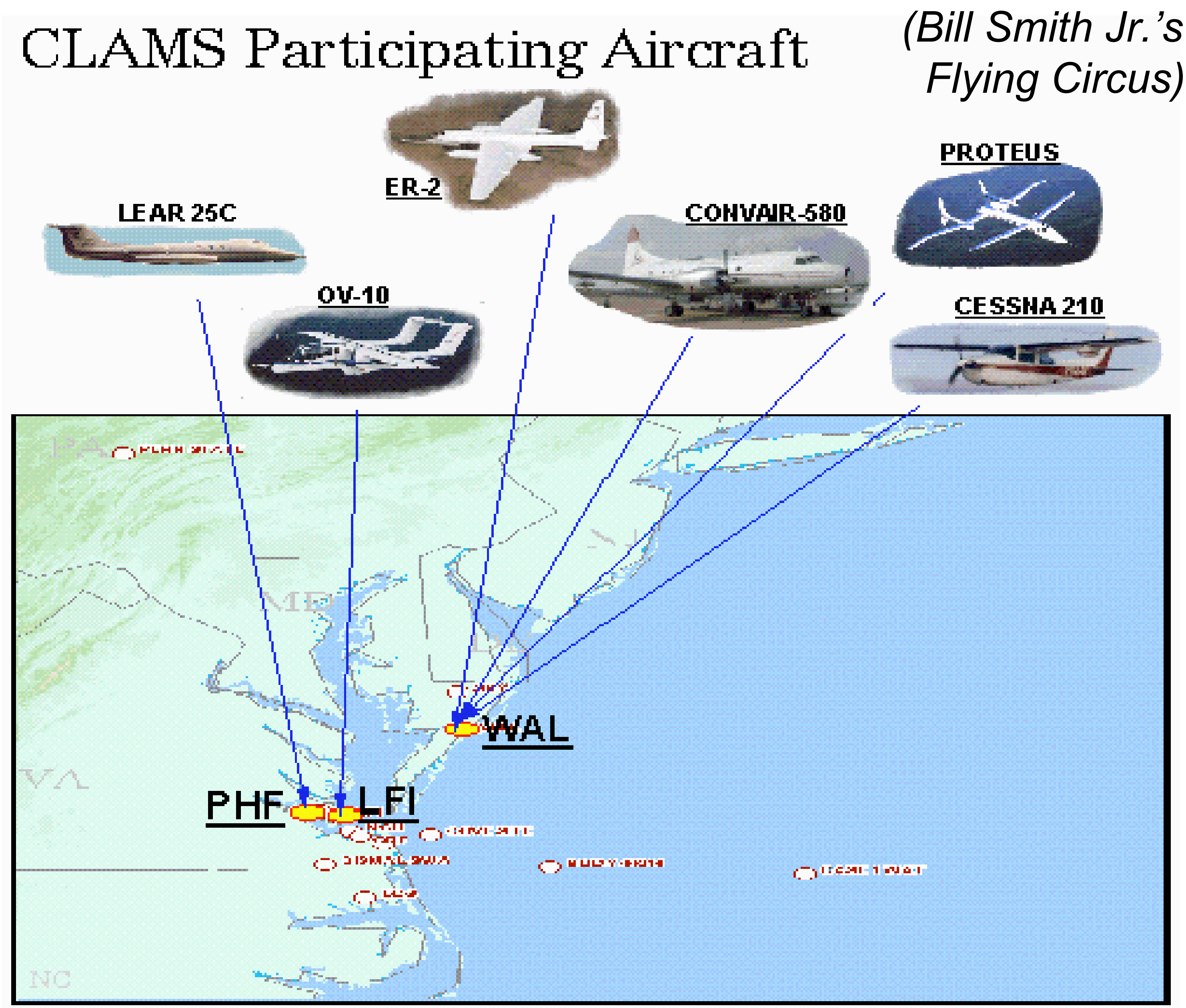
Rigid sea platform
Continuous
Long-term
Well calibrated
AERONET aerosol
NOAA wind and waves
BSRN surface radiation
 looks DOWN at sea

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)



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



CLAMS: The acid test bed for aerosol remote sensing over ocean

ER-2: MODIS Airborne Simulator and AirMISR for near TOA BRDF

CV-580: AATS-14 AOT in situ aerosol CAR BRDF

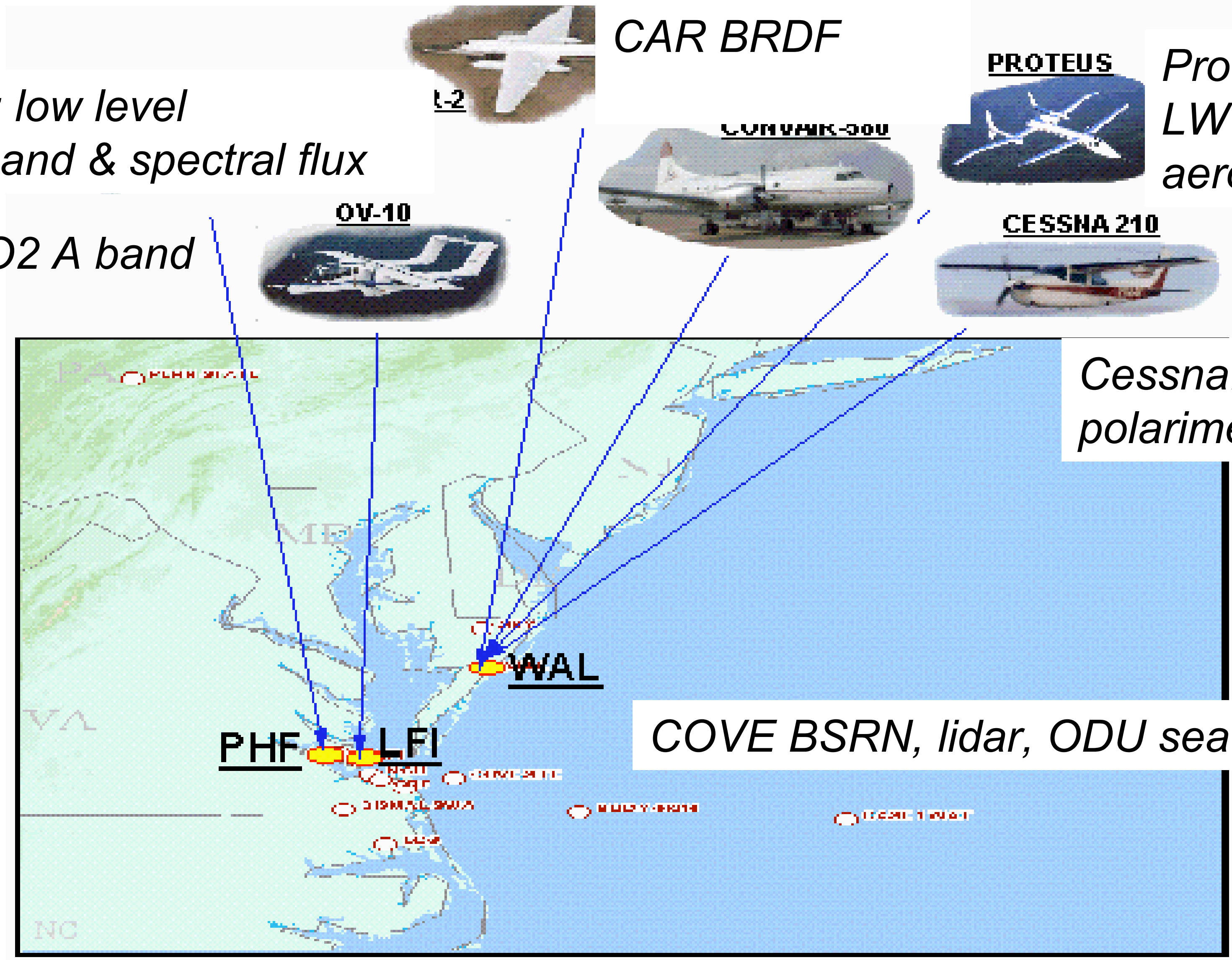
Proteus: LW FTS for aerosol IR

OV-10: low level broadband & spectral flux

Learjet O2 A band

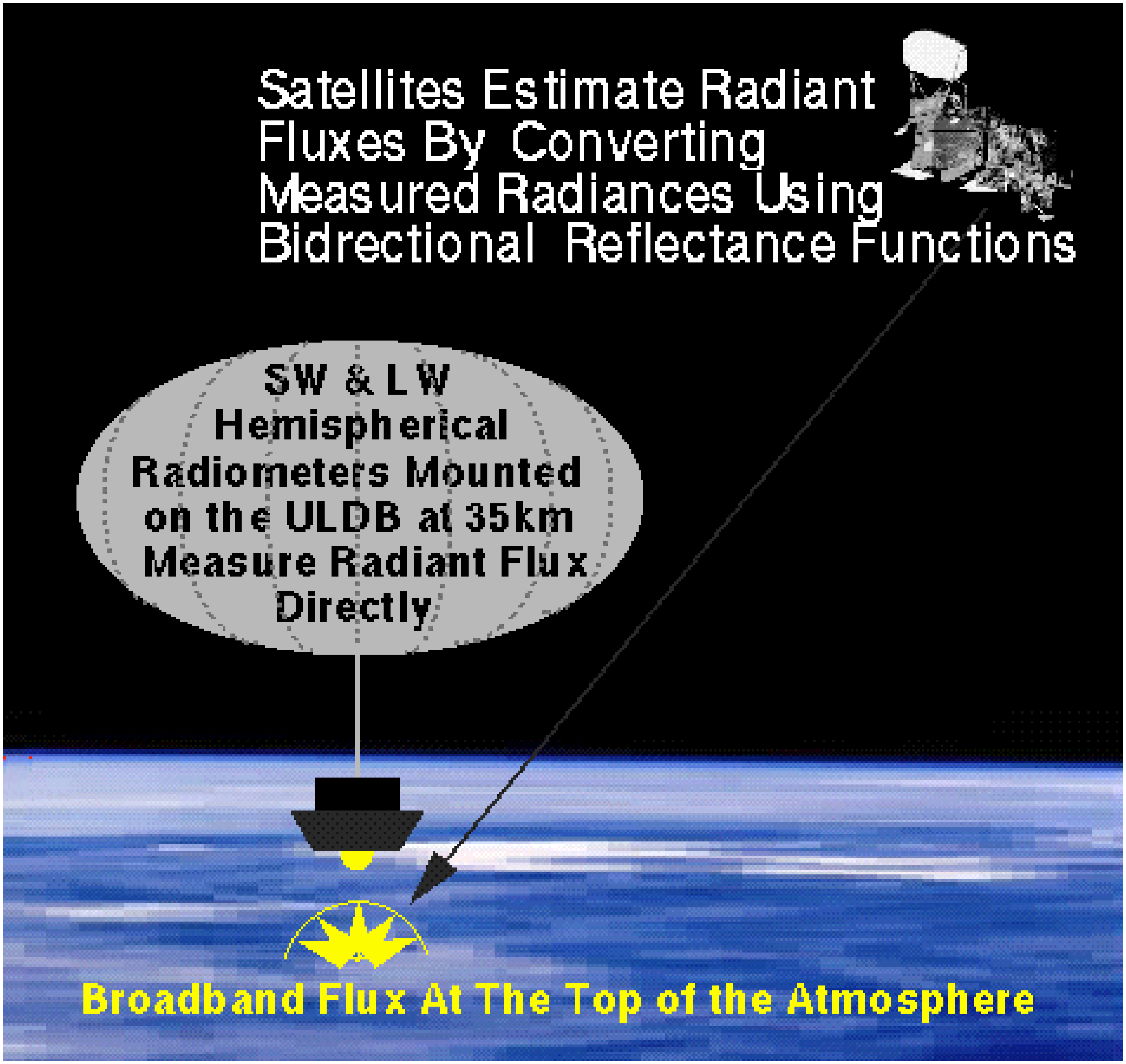
Cessna: polarimeter

COVE BSRN, lidar, ODU sea optics



Click “Balloon” from CAVE URL

Wenying Su’s deployement of Haeffelin modified radiometers



Launch scheduled this week from Alice Springs, Australia