ITR and UW

Team:

Tad Anderson
Yi Jiang, graduate student
Yonghua Wu, post doc

Role:

- somewhat external/tangential to ITR (trial users?)
- assimilation
  - provide aerosol data and guidance on its use
  - focus on aerosol optics (in-situ and satellite)
- applications
  - push project toward current scientific questions (direct forcing of climate by aerosols)

Overview

ACE-Asia Harmony (platform comparison, 2 planes, ship, surface):

Side-by-side: in-situ uncertainties

Campaign-wide statistics: good CTM test

ACE-Asia chem/optics correlations

What should the CTM be assimilating?

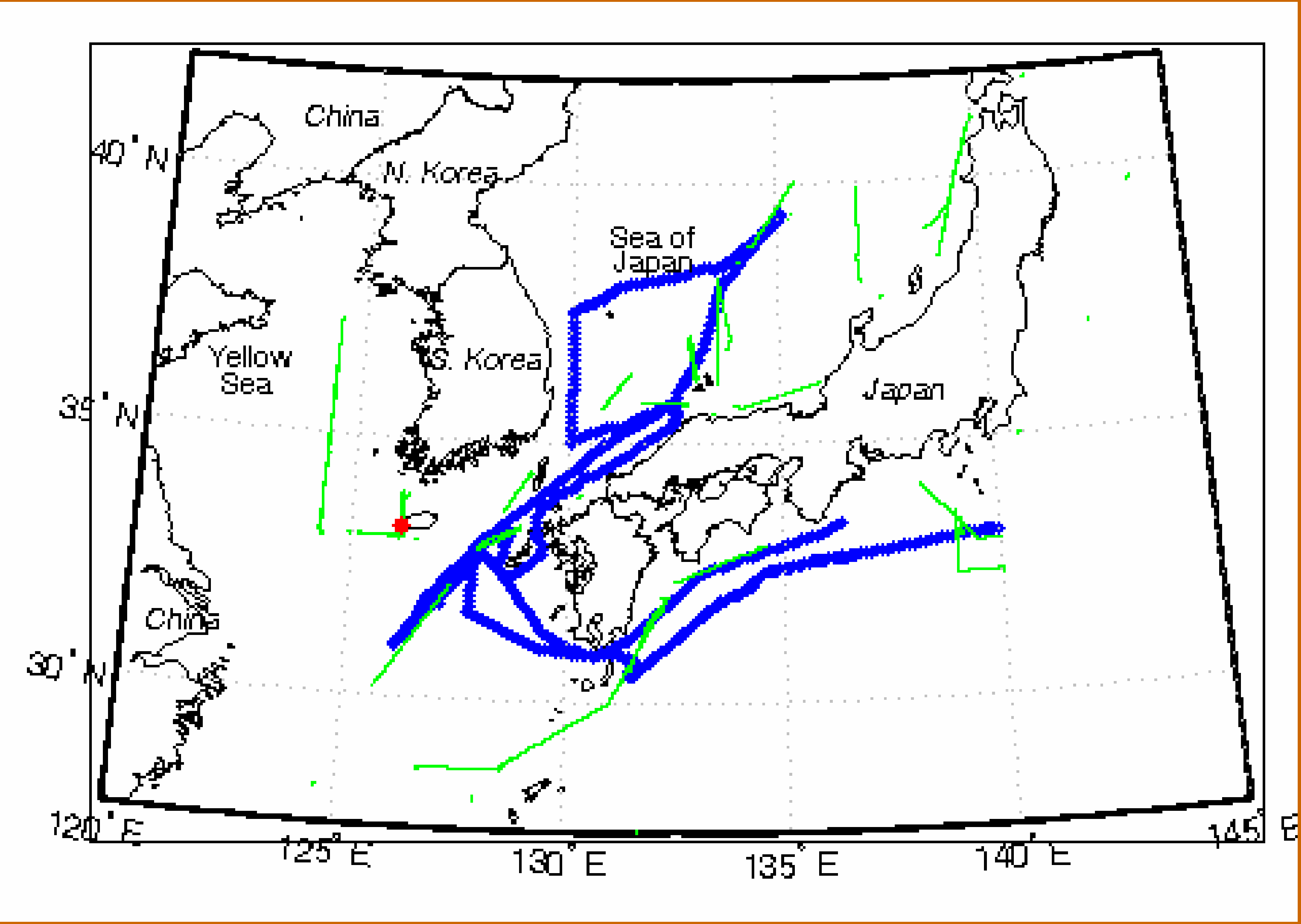
ACE-Asia test satellite retrieval of FMF

MODIS FMF is not ready for assimilation!

A-Train (satellite) strategy for Direct Aerosol Forcing

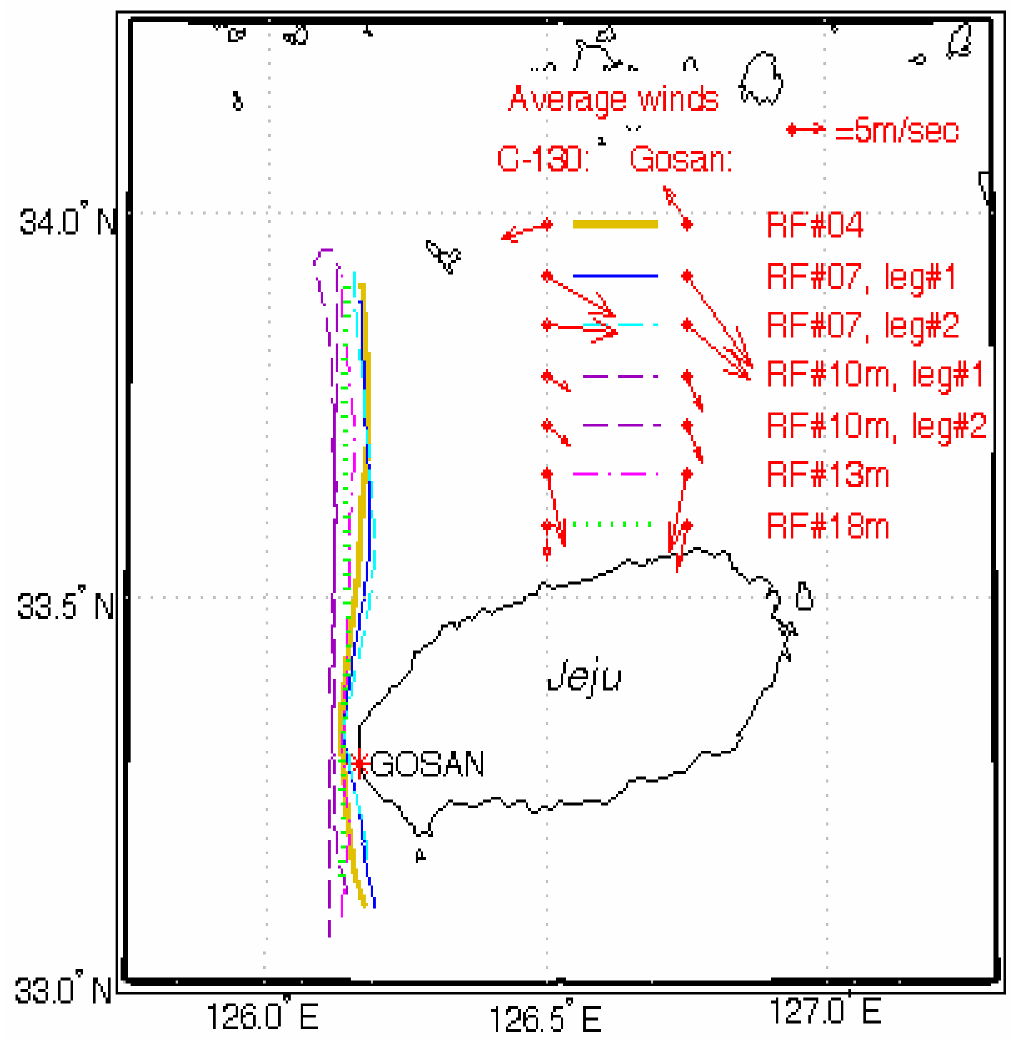
- *CTMs critical to the strategy (role for ITR?)*
- *assess global knowledge of 3 parameters: AOD, FMF, RFE*
  - *AOD and FMF: CTM intercomparison indicates large uncertainty*
  - *RFE: observational intercomparison*

*** ACE-Asia "Harmony" ***



Harmony Side-by-Side: C-130 / Gosan

The C-130 flew seven low-altitude (<100m) legs to the west of the Gosan surface station. The average wind direction and speed as measured from the C-130 and at Gosan during each comparison are indicated by the direction and length, respectively, of the arrows. Also shown is the length of an arrow corresponding to a wind speed of 5m/sec.



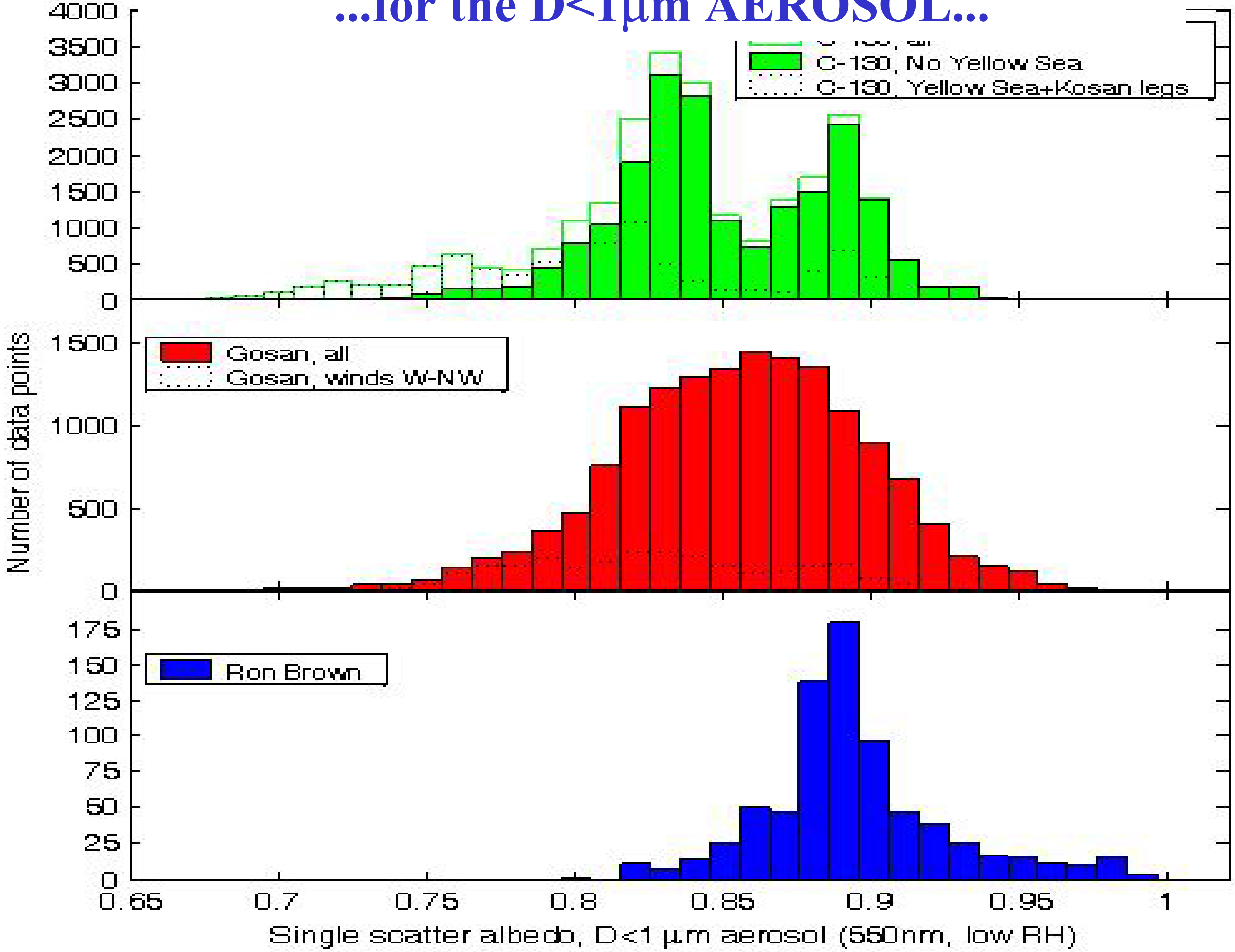
Harmony Side-by-Side: Results

Parameter	Discrepancy Description	Discrepancy Magnitude
Fine-mode fraction	C-130 lower (more coarse)	10-20%
Single scattering albedo	Twin Otter lower	0.03 to 0.09
Hemispheric backscatter fraction	C-130 lower	5-25%
$f(RH)_{40\text{-}85\%}$	Twin Otter and C-130 lower	25-50%

Harmony Statistics: SSA Histograms

SINGLE SCATTER ALBEDO

...for the D<1μm AEROSOL...



*** ACE-Asia Correlations ***

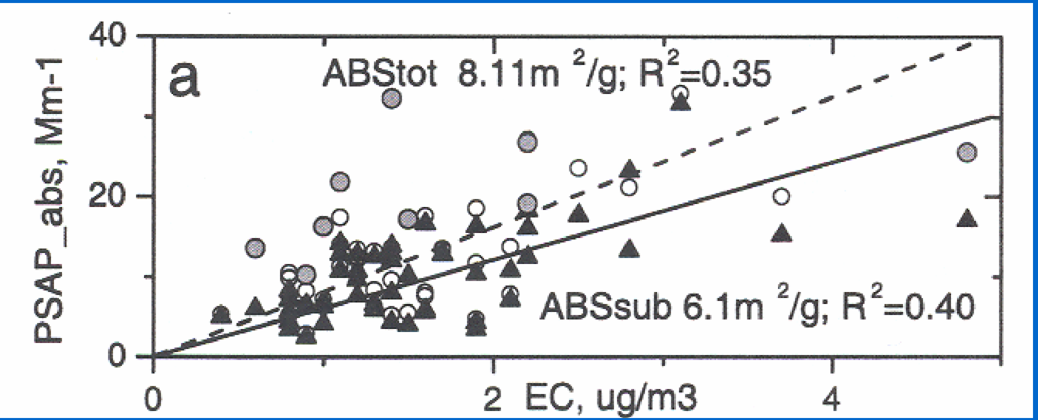
Issue:

Chemical measurements on C-130 have poor correlation with optical measurements.

Assimilation question:

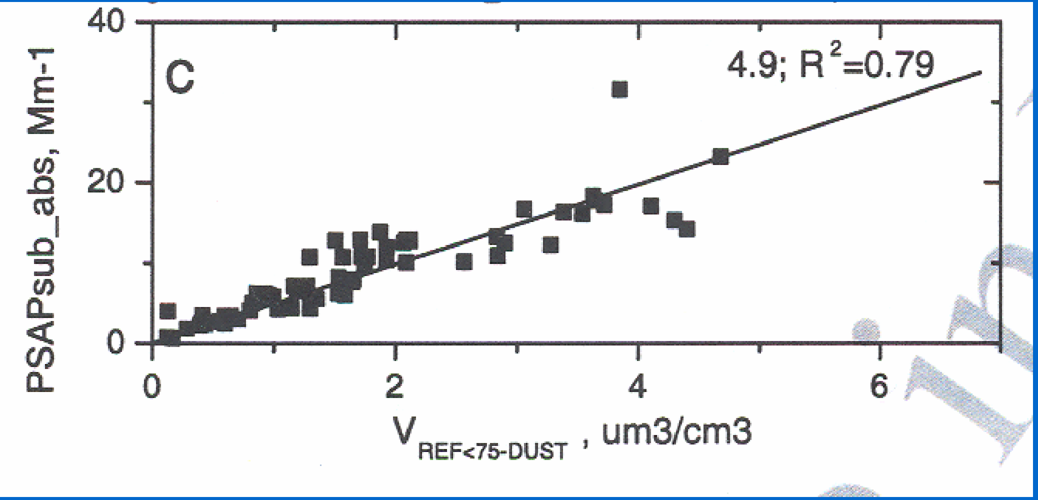
Should we use chemical measurements to constrain CTMs (if our goal is to calculate optical properties)?

standard "BC"
(evolved gas analysis)
vs
light absorption



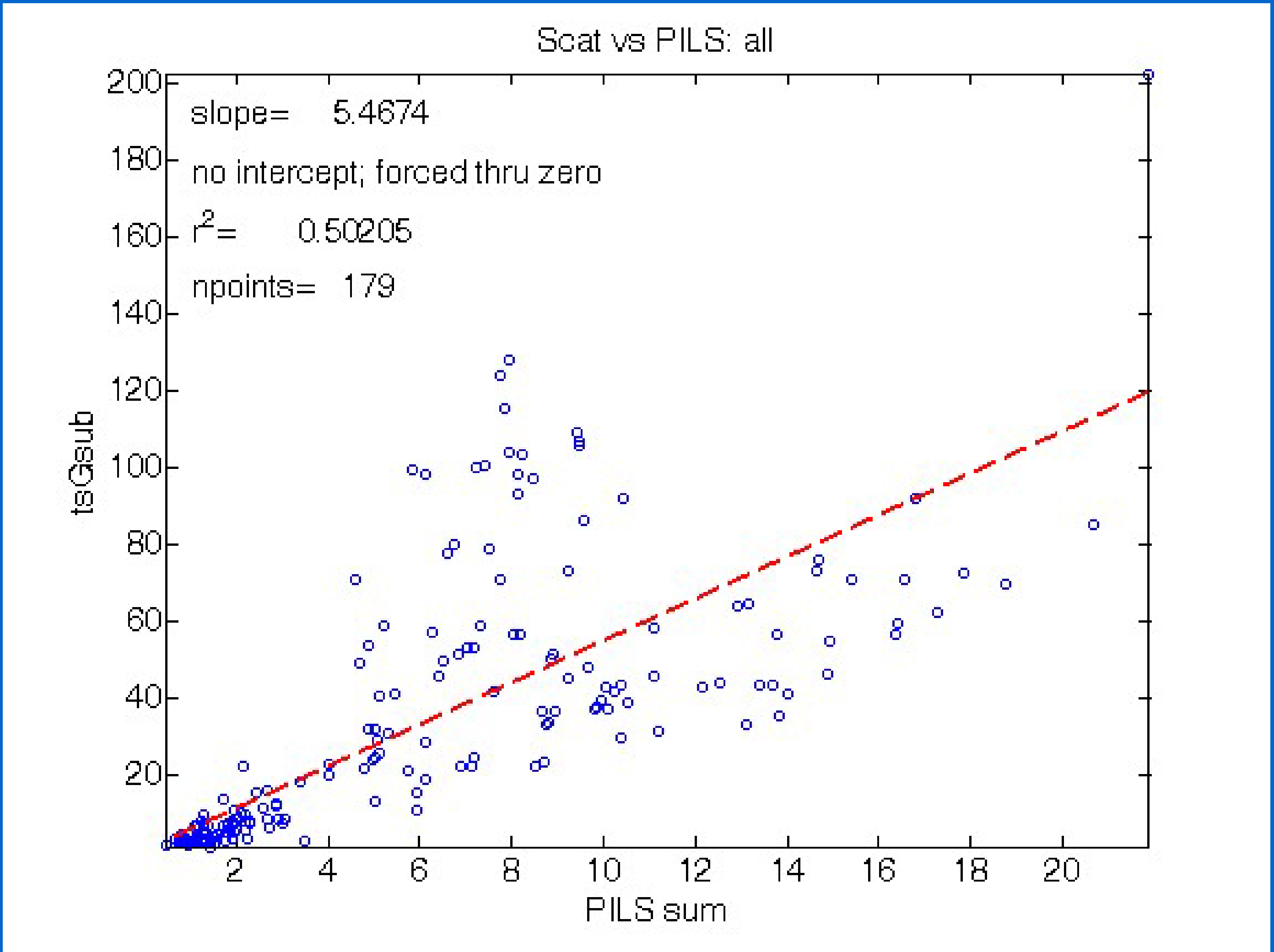
BC Correlations

refractory sub-µm volume
(after dust correction)
vs
light absorption



ref: Clarke et al. (2004) JGR 109 doi:10.1029/2003JD004378

ACE-Asia C-130 correlations: **Fine Scat vs Fine Chem, GT-1**



reasonable slope (5.5 m2/g) but poor correlation, perhaps due to diversity of chemical compositions

*** FMF test ***

MODIS:

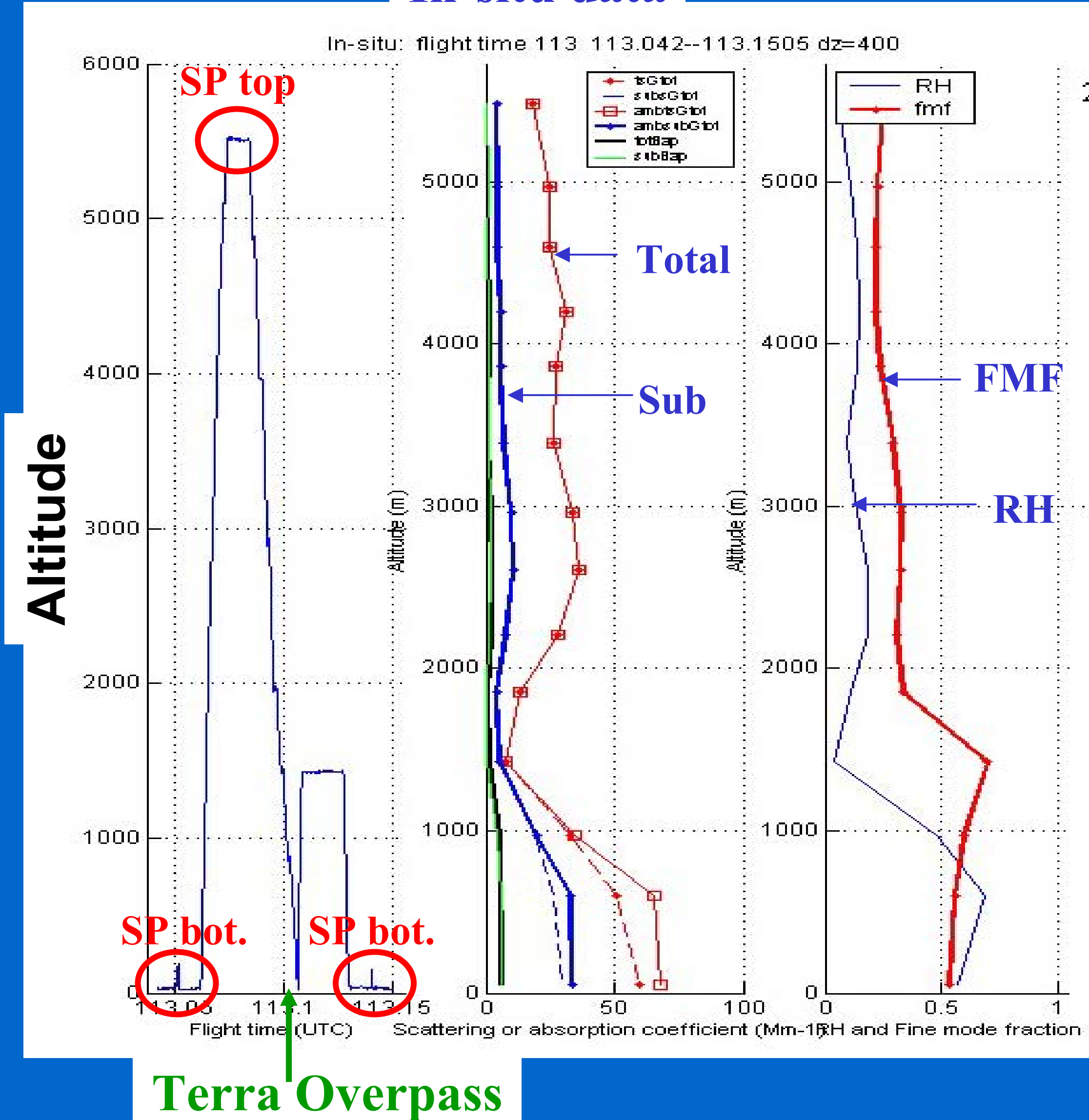
- *fine-mode-fraction of optical depth (FMF) at 550nm is a standard retrieval product over both land and ocean*
- *global data is available from April, 2000 on*
- *accuracy has yet to be examined*
- *AERONET provides only a partial check (one retrieval vs another)*

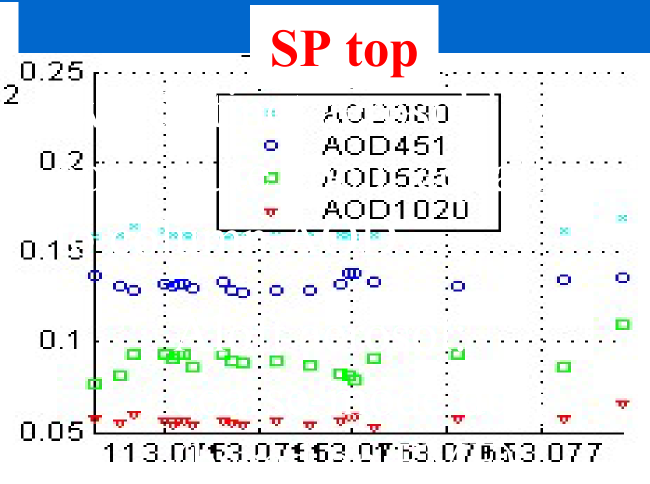
ACE-Asia:

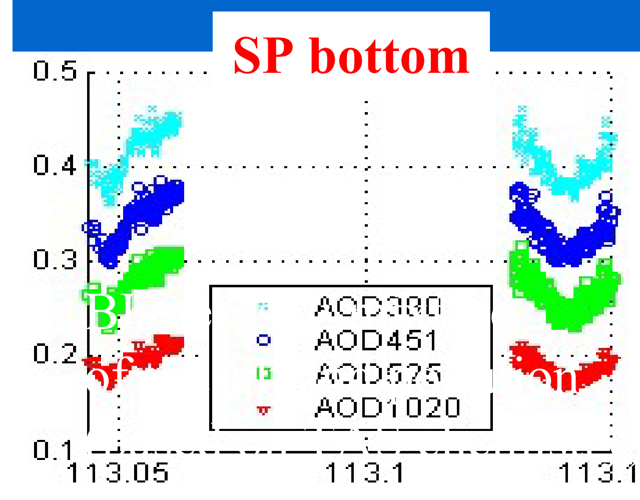
- *in-situ measurements on C-130 aircraft using a novel, low-turbulence inlet provide accurate measurement of extinction even for coarse-mode dominated cases (Redemann et al., 2003)*
- *in-situ provides accurate and independent measure of FMF*
- *combine with airborne sunphotometer for over-the-top aerosol*
- *about 10 cases with coincident column characterization and MODIS retrievals*

Case Study, April 23, 2001, open ocean SE of Tokyo

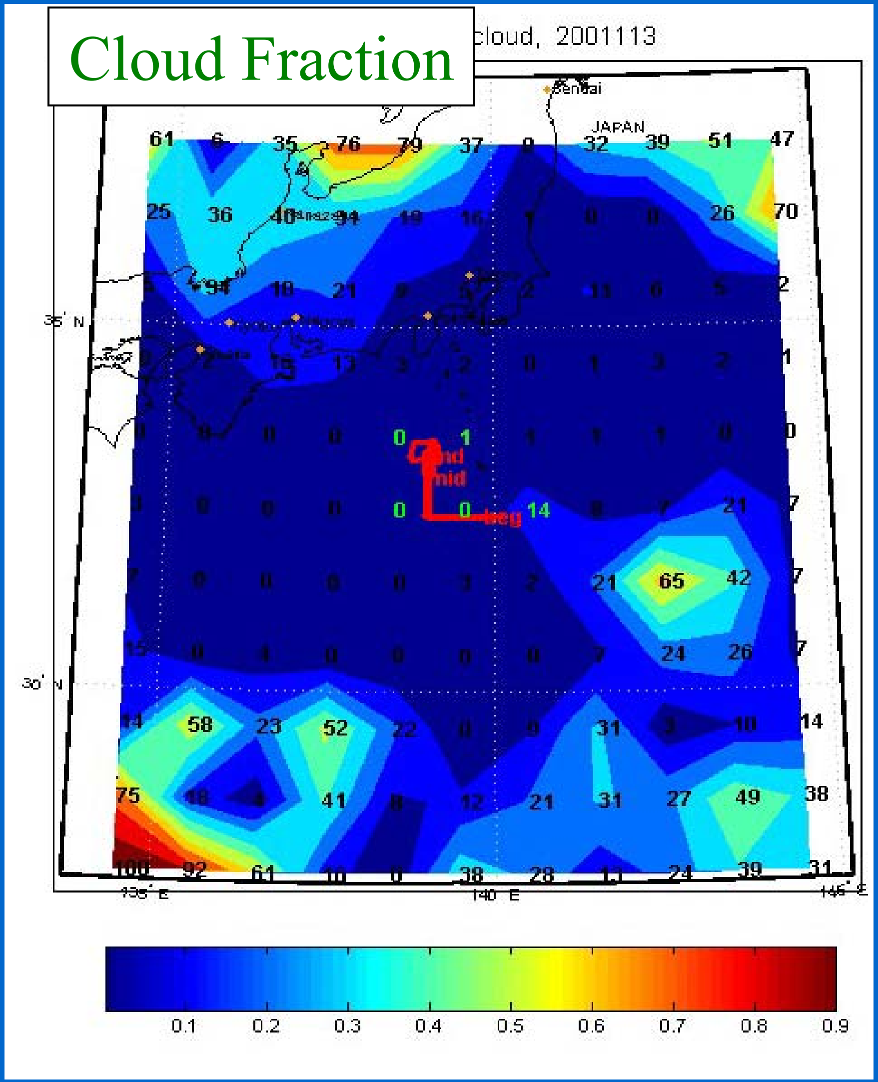
In-situ data

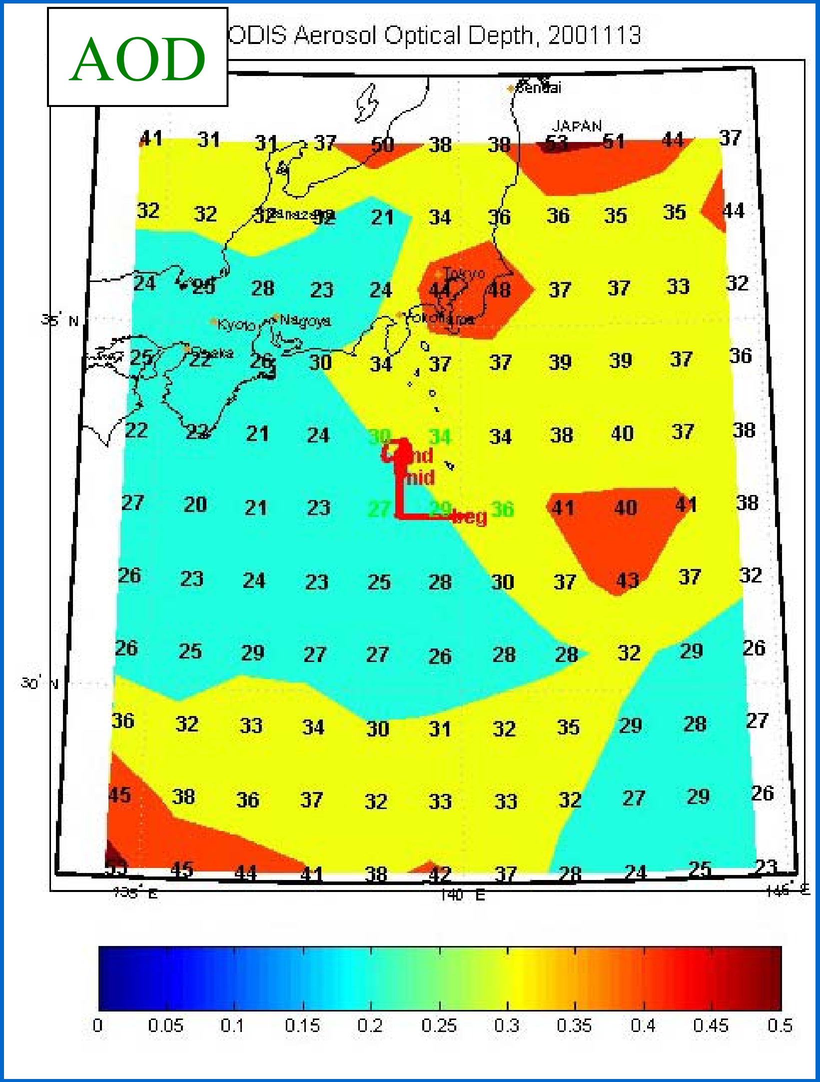






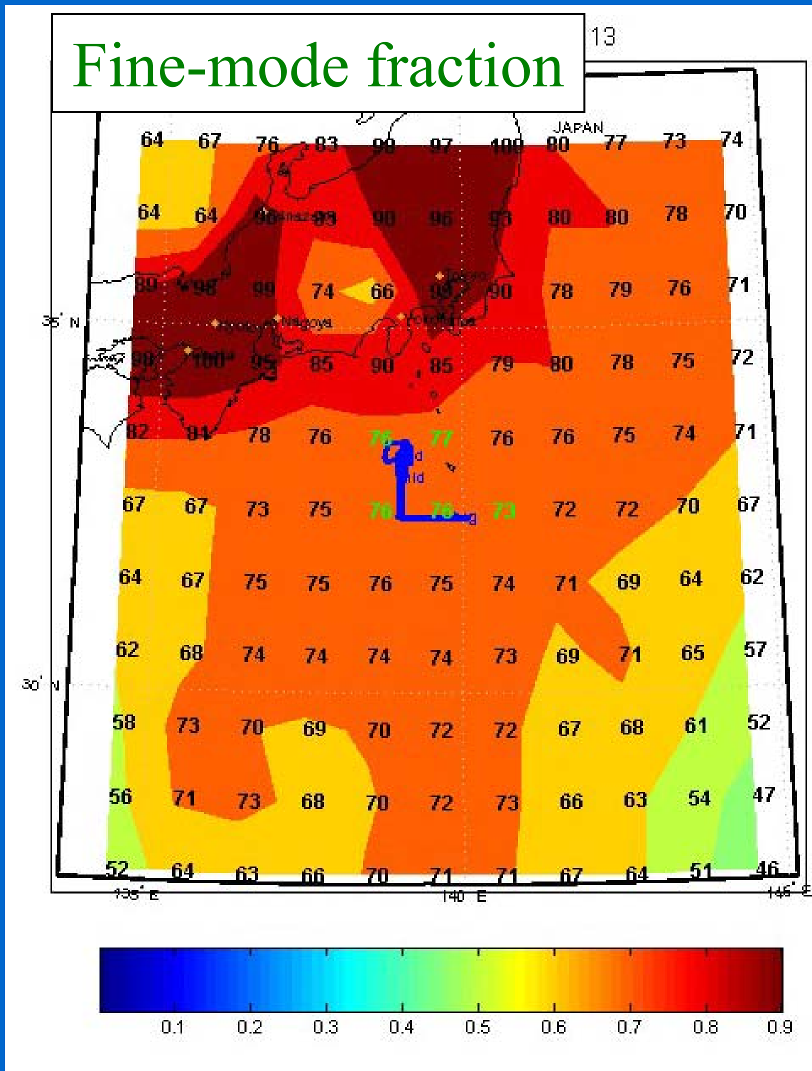
MODIS retrievals for April 23, 2001

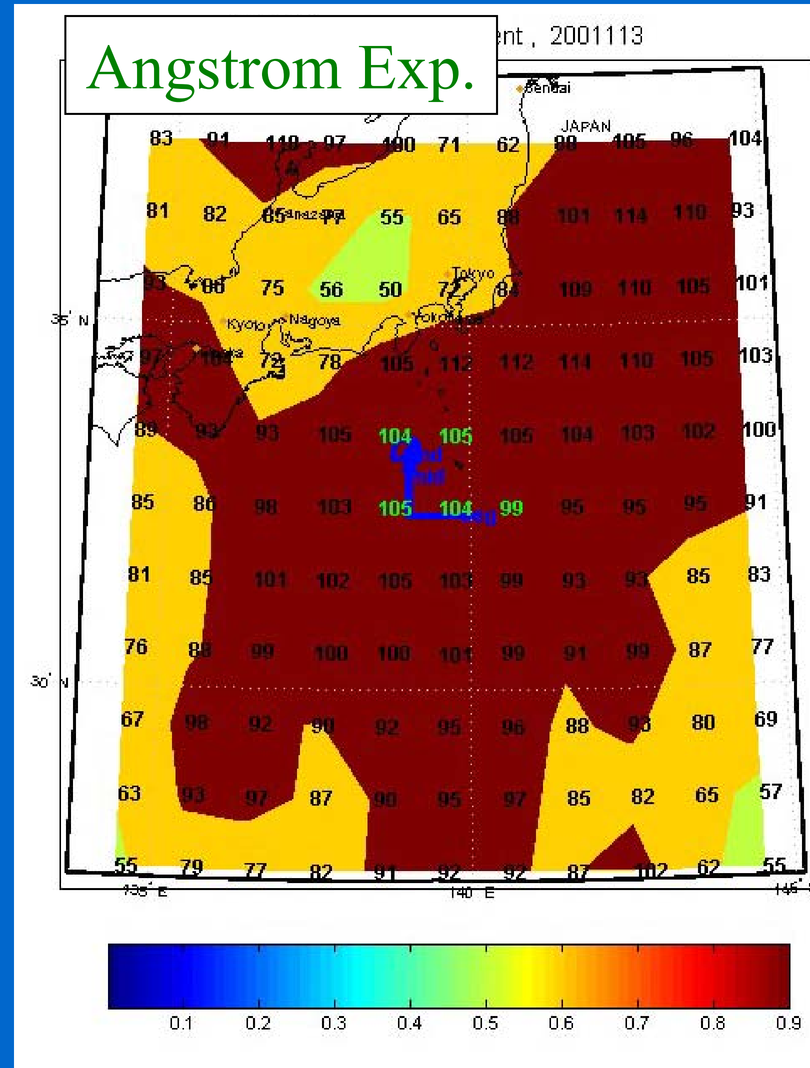




MODIS data from EOS Data Gateway: MOD08-D3, ver 4, 1x1deg global

MODIS retrievals for April 23, 2001

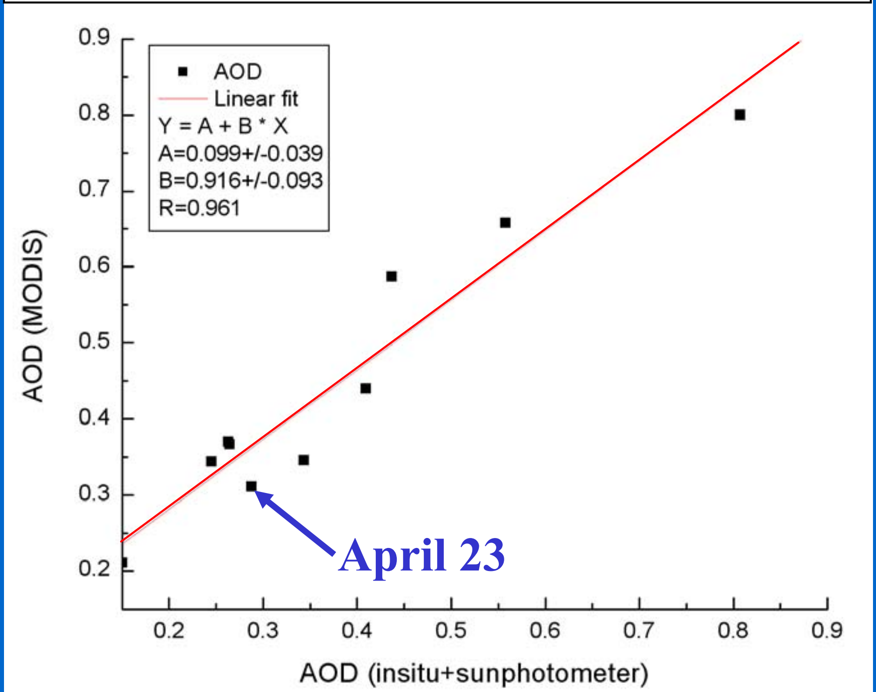




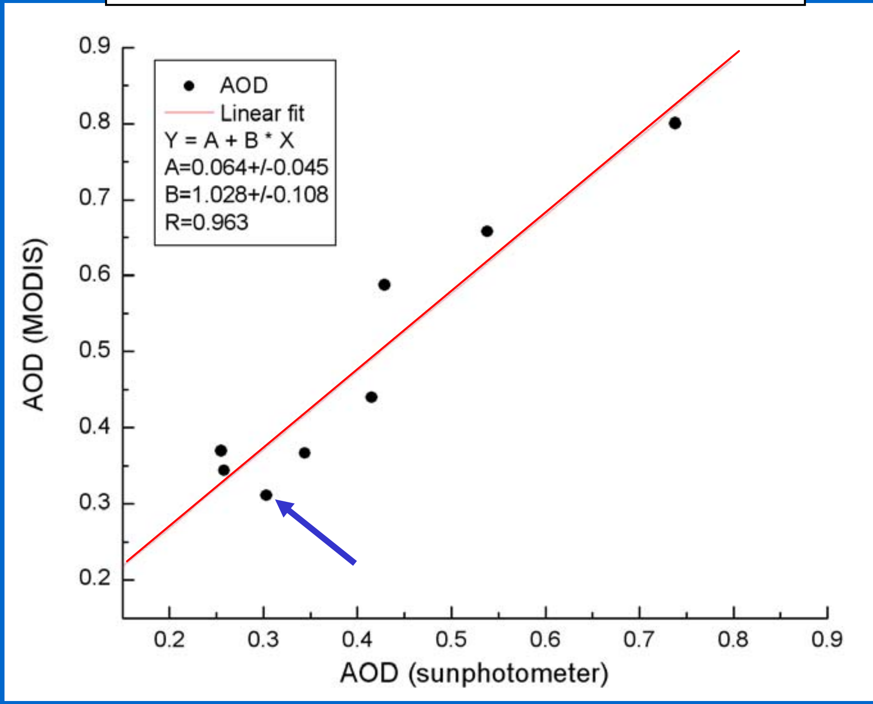
MODIS data from EOS Data Gateway: MOD08-D3, ver 4, 1x1deg global

AOD Test

MODIS vs In-situ + SP(aloft)

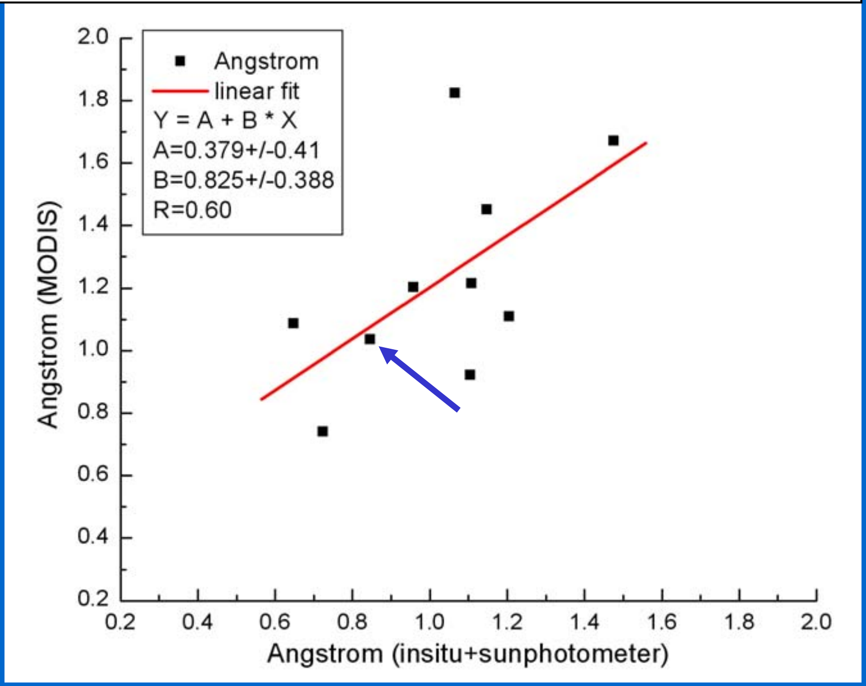


MODIS vs SP(surface)

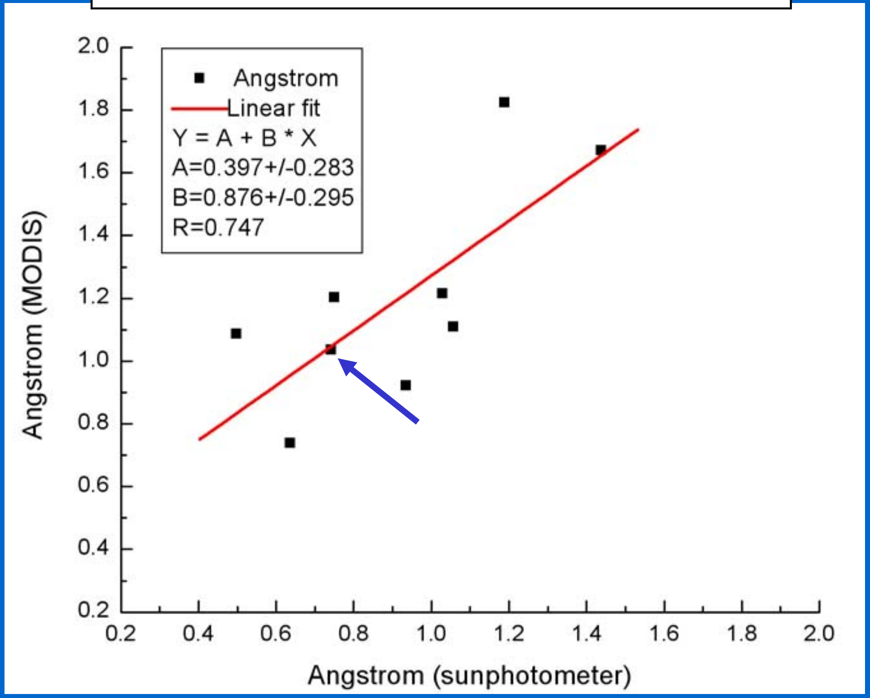


Angstrom Exponent Test

MODIS vs In-situ + SP(aloft)

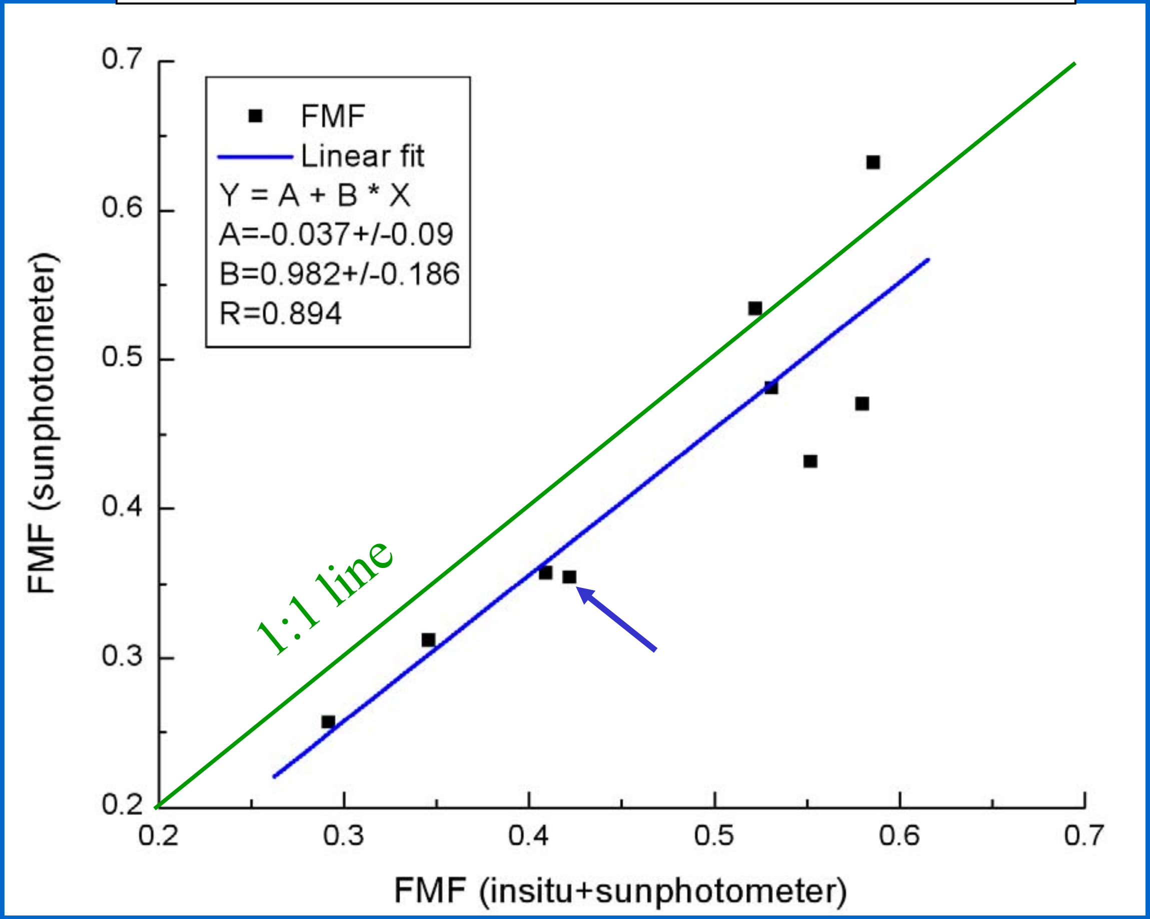


MODIS vs SP(surface)



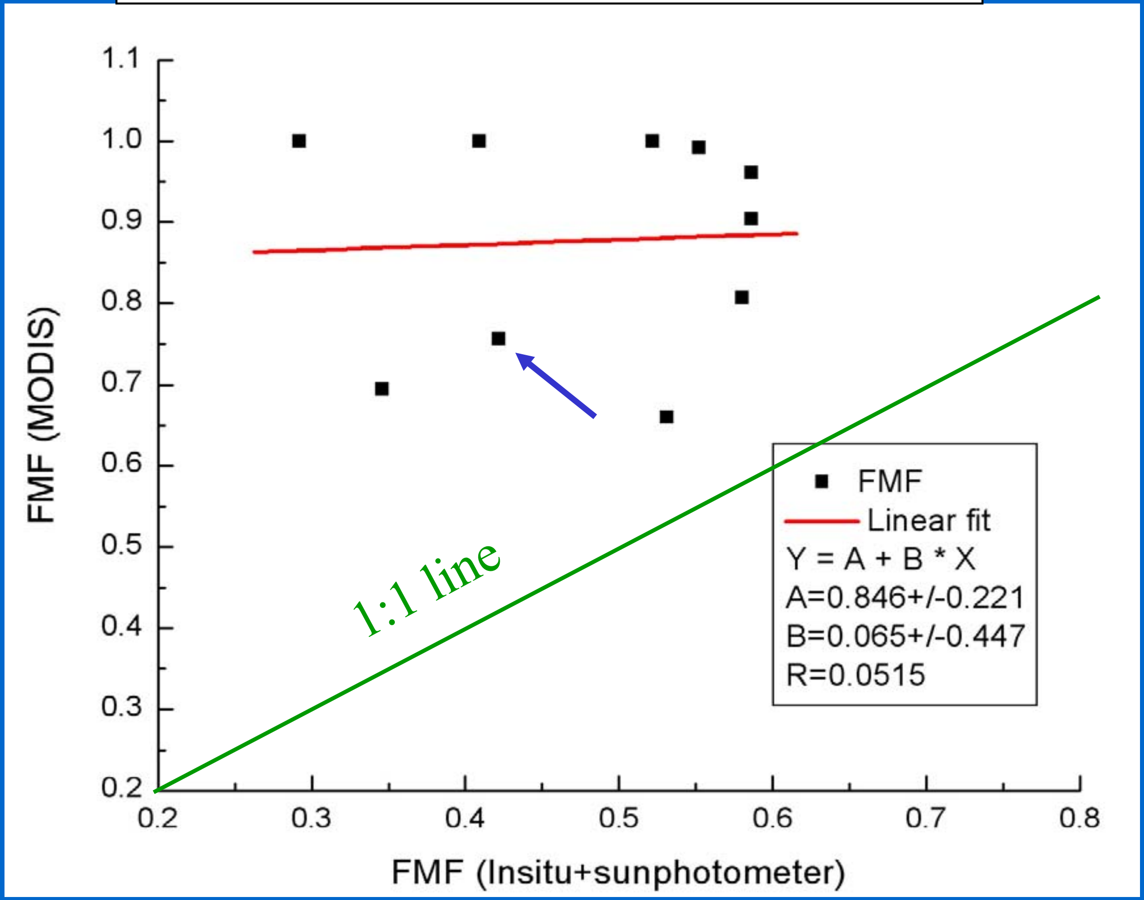
Compare Sub-Orbital Methods for Fine-Mode Fraction

SP(surface) vs In-situ + SP(aloft)



Fine-Mode Fraction Test

MODIS vs In-situ + SP(aloft)



*** DAFC Strategy ***

Steps Toward an Observational Basis for Direct Aerosol Forcing of Climate

** UPDATE **

Tad Anderson
CALIPSO Science Team Meeting
Nice, France, May 5, 2004

Collaborators:
Bob Charlson (U. Washington, Seattle)
Chip Trepte, Dave Winker, Bruce Wielicki (NASA Langley)
Mian Chin, Yoram Kaufman, Lorraine Remer (NASA/GSFC)
Olivier Boucher, Didier Tanré (U. Lille)
Jim Haywood, Nicolas Bellouin (UK Met Office)
Sundar Christopher (U Alabama)
Toshihiko Takemura (Kyushu U., Tokyo)
Stefan Kinne (Max Planck, Hamburg)
Hongbin Yu (Georgia Tech)

Empirical Approach

- Essence of problem is global mapping of three parameters
- All three can be estimated from satellites

$DARF = < \delta(x,y,t)\, E(x,y,t) >$ radiative forcing

$DARF_f = < \delta(x,y,t)\, f_f(x,y,t)\, E_f(x,y,t) >$ fine-mode forcing

$DAFC = < \delta(x,y,t)\, f_a(x,y,t)\, E_a(x,y,t) >$ climate forcing

$< >$ global, annual average

δ aerosol optical depth

f_f, f_a fraction of δ (fine or anthro)

E_f, E_a forcing efficiency (fine or anthro)

Stepwise philosophy

Estimates of DAFC are already possible, based mostly on chemical transport models (CTMs)

Goal is for these estimates, over time, to become increasingly grounded in observations

Integration is needed at each stage along the way, in order to:

- assess uncertainties
- assess knowledge with respect to key scientific questions
- assess information needs for further progress

This integration can only take place via CTM's

Transport Model Intercomparison: 2004

	LO	LS	SP	CT	MI	EH	NF	NM	OT	OG	IM	GO	GI
MASS (mg/m2)													
SU	4.2	5.4	**2.2**	3.3	3.9	**7.2**	3.3	4.3	3.7	2.8	4.8	3.9	3.1
BC	0.35	0.43	0.73	0.48	0.37	**0.30**	0.37	0.45	0.38	0.37	0.37	0.58	**0.80**
OC	3.5	3.2	3.2	3.6	2.9	2.7	3.2	2.0	**5.3**	**1.5**	3.0	4.0	3.4
DU	26.9	40.0	34.0	**8.8**	43.4	12.1	34.2	30.4	43.0	38.5	67.0	52.4	**84.5**
SS	8.9	24.7	14.4	18.5	10.8	25.5	11.1	25.9	18.0	12.6	**7.1**	**42.5**	10.5
Total	43.9	73.7	54.5	**34.7**	61.4	47.8	52.2	63.1	70.4	55.8	82.3	**103.4**	102.3
fmass	0.18	0.12	0.11	**0.21**	0.12	**0.21**	0.13	0.11	0.13	0.08	0.10	0.08	**0.07**
AOD at 550 nm													
SU	0.042	0.030	0.028	**0.015**	0.027	**0.057**	0.051	0.041	0.042	0.019	0.040	0.032	0.020
BC	0.0033	0.0031	0.0058	0.0030	0.0050	**0.0009**	0.0034	**0.0100**	0.0022	0.0023	0.0035	0.0059	0.0071
OC	0.021	0.016	0.026	0.018	0.021	0.015	0.019	**0.036**	0.031	**0.009**	0.024	0.019	0.017
DU	0.034	0.031	0.024	0.013	0.053	**0.008**	0.033	0.027	0.026	0.038	**0.070**	0.033	0.025
SS	0.027	**0.012**	0.019	0.048	0.030	0.069	0.029	0.028	0.055	**0.089**	0.035	0.036	0.045
Total	0.127	**0.092**	0.103	0.097	0.136	0.150	0.135	0.142	0.156	0.157	**0.173**	0.126	0.114
ff	0.52	0.53	0.58	0.37	0.39	0.49	0.54	**0.61**	0.48	**0.19**	0.39	0.45	0.39

LO=LOA(Lille), LS=LSCE(Paris), SP=SPRINTARS(Kyushu), CT=CANADA(Toronto), MI=MIRAGE(PNNL), EH=ECHAM5(MPI-Hamburg), NF=CCM-Match(NCAR), NM=CCM-M0zart(NCAR), OT=Oslo-CTM(Oslo), OG=OSLO-GCM(Oslo), IM=IMPACT(Michigan), GO=GOCART(NASA-GSFC), GI=GISS(NASA-GISS)

CTM comparison data courtesy of Stefan Kinne, MPI Hamburg

Transport Model Evolution: 2003 - 2004

	UL	SP	MI	EH	NF	GO	GI
AOD at 550 nm							
SU	0%	21%	**-159%**	**53%**	37%	-16%	**-30%**
BC	**66%**	-3%	-12%	**-311%**	59%	-15%	**61%**
OC	-69%	4%	10%	13%	0%	11%	-12%
DU	-70%	-38%	**89%**	**-375%**	15%	-55%	**-4%**
SS	-4%	26%	-10%	**77%**	41%	25%	**78%**
Total	-19%	3%	**2%**	**35%**	28%	-10%	**27%**
f_{AOD}	0.06	0.05	-0.32	0.04	0.00	0.01	-0.18
UL=ULAQ(L'Aquila), SP=SPRINTARS(Kyushu), MI=MIRAGE(PNNL),							
EH=ECHAM5(MPI-Hamburg), NF=CCM-Match(NCAR),							
GO=GOCART(NASA-GSFC), GI=GISS(NASA-GISS)							

CTM comparison data courtesy of Stefan Kinne, MPI Hamburg

Transport Model Uncertainty: Mass

		median		range 1	range 2		mean	RMS
		value		max/min	max/min		change	change
Number of models								
		13		13	13		7	7
MASS (mg/m2)								
SU		3.9		3.3	1.9		-19%	60%
BC		0.4		2.7	2.1		9%	42%
OC		3.2		3.5	2.0		8%	20%
DU		38.5		9.6	5.5		-29%	106%
SS		14.4		6.0	2.9		-2%	64%
Total		61.4		3.0	2.3		-7%	62%
FMF		0.12		3.0	2.6		-0.04	0.14

CTM comparison data courtesy of Stefan Kinne, MPI Hamburg

Transport Model Uncertainty: AOD

		median value		range 1 max/min	range 2 max/min		mean change	RMS change
*AOD at 550 nm * 1000*								
SU		32		3.8	2.7		-13%	67%
BC		3.4		11.1	3.2		-22%	125%
OC		19		4.0	2.1		-6%	27%
DU		31		8.8	4.1		-62%	150%
SS		35		7.4	3.6		33%	46%
Total		135		1.9	1.6		9%	21%
FMF		0.48		3.2	1.6		-0.05	0.14

CTM comparison data courtesy of Stefan Kinne, MPI Hamburg

Transport Model Uncertainty: Ext. Effic.

		median		range 1	range 2		mean	RMS
		value		max/min	max/min		change	change
Extinction Efficiency (m2/g)								
SU		8.2		3.4	2.3		0.9	2.7
BC		8.9		7.4	2.3		-0.3	3.0
OC		5.9		3.8	1.6		-0.8	1.6
DU		0.89		5.0	2.1		-0.12	0.44
SS		2.71		14.5	5.8		0.61	1.37
Total		2.2		2.8	2.4		-0.1	1.4
Fine		7.4		2.6	2.0		0.1	1.5
Coarse		1.37		3.7	3.1		0.04	0.70

CTM comparison data courtesy of Stefan Kinne, MPI Hamburg

Forcing Efficiency Comparison

$$\Delta F = E\,\delta$$

ΔF: forcing (TOA, SW, 24-hr)
δ: aerosol optical depth (550 nm)
E: forcing efficiency per unit optical depth

Table 1 of DAFC strategy paper

- concept is used very widely in literature
- reported values cannot immediately be compared due to differences in definition
- comparison of values over the ocean reveals both large variation and large discrepancies

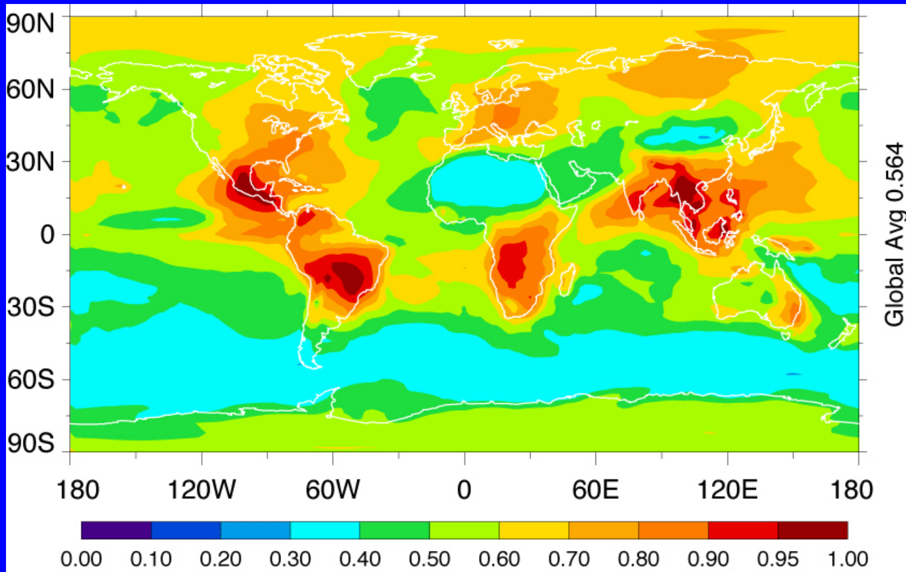
Radiative Forcing Efficiency over the Ocean

Method	Domain	Number of studies	Number of regions		δ (550nm)	DARF W/m2	E W/m2/δ
modeling	global oceans	2	---		0.098 (12%)	-2.4 (28%)	-25 (16%)
satellite	global oceans	5	---	mean → std/mean →	0.125 (13%)	-5 (8%)	-40 (17%)
satellite	regional, annual	1	6		0.112 (45%)	-5.1 (45%)	-44 (30%)
satellite & sunphot.	regional intensives	3	3		0.94 (82%)	-23 (76%)	-27 (11%)
				σ_{sp} m-1	b	ω	
in-situ	regional, annual	1	4	39 (52%)	0.121 (8%)	0.938 (3%)	-81 (2%)
in-situ	regional, intensives	4	6	77 (93%)	0.111 (9%)	0.877 (8%)	-68 (14%)

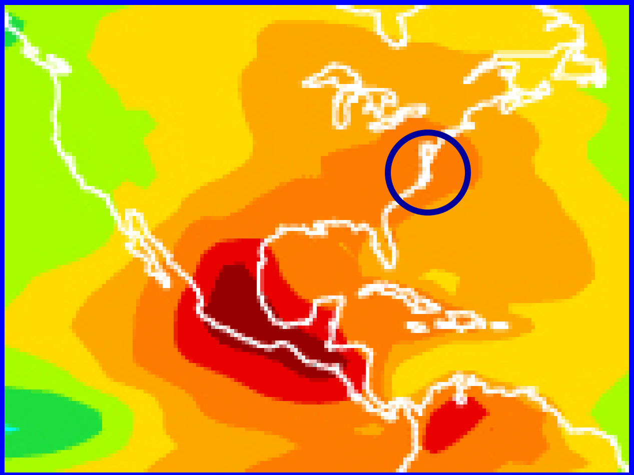
RED: extensive parameters BLUE: intensive parameters

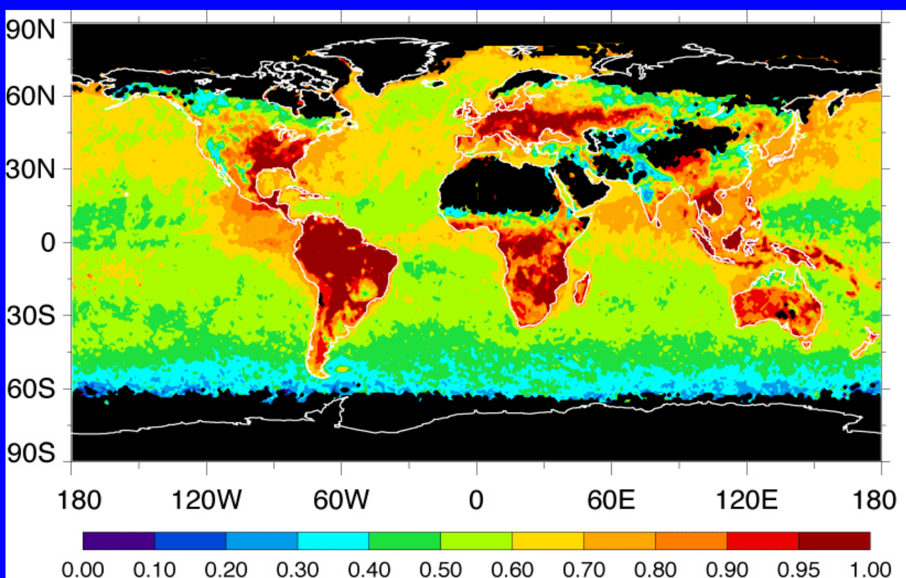
from Table 1 of Anderson et al. (2004), manuscript in preparation

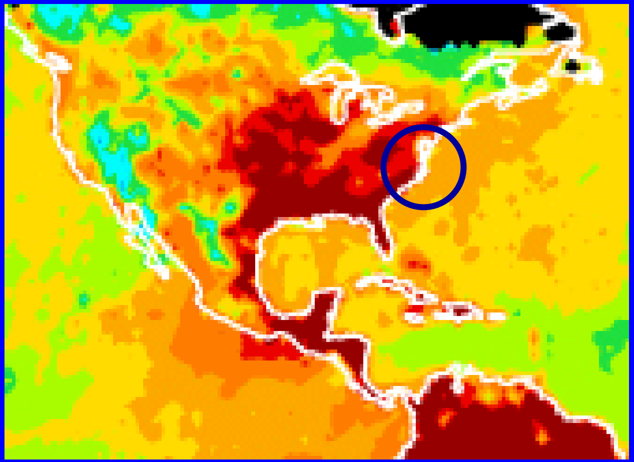
Fine-mode-fraction, April, 2001



MODEL



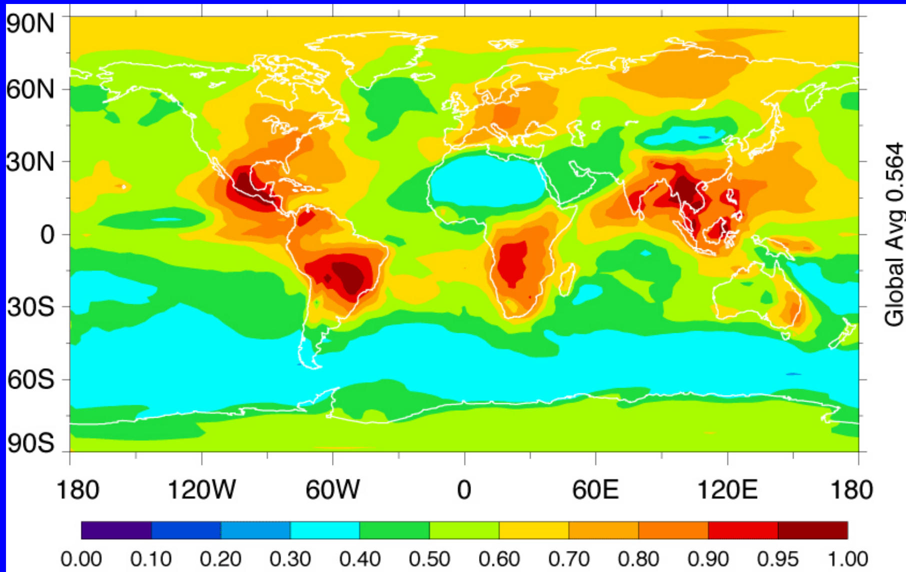




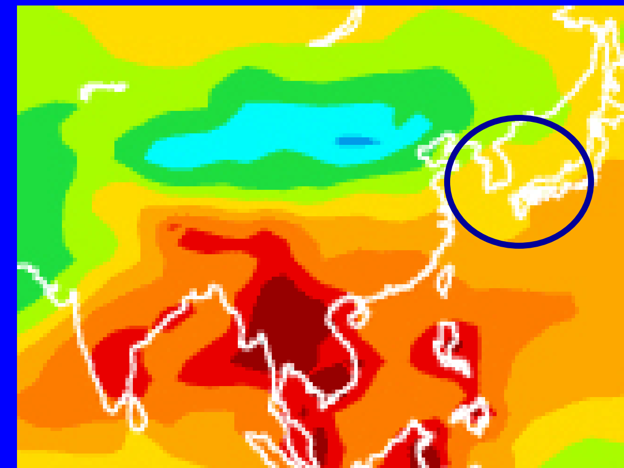
SATELLITE

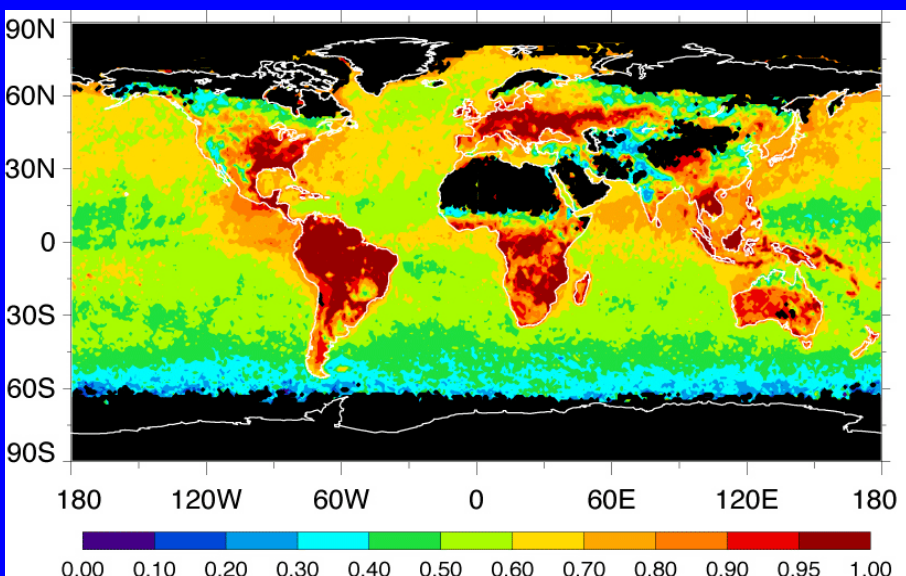
Data and plots courtesy of Mian Chin, NASA/GSFC

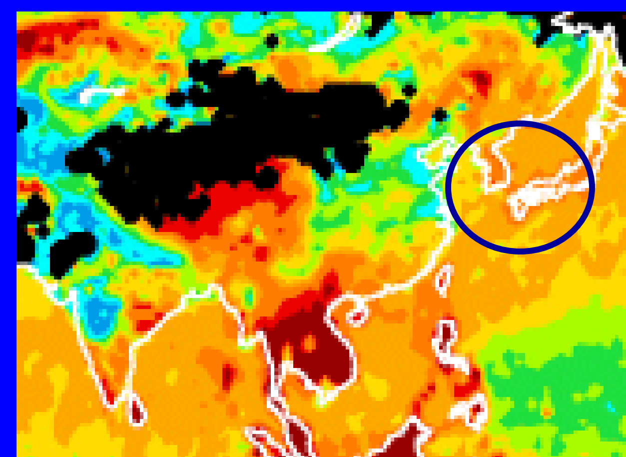
Fine-mode-fraction, April, 2001



MODEL







SATELLITE

Data and plots courtesy of Mian Chin, NASA/GSFC

DAFC Strategy: Questions

$DARF = < \delta(x,y,t)\ E(x,y,t) >$	radiative forcing
$DARF_f = < \delta(x,y,t)\ f_f(x,y,t)\ E_f(x,y,t) >$	fine-mode forcing
$DAFC = < \delta(x,y,t)\ f_a(x,y,t)\ E_a(x,y,t) >$	climate forcing

1. Are we in a position to solve these equations with A-Train?
   - globally representative measurements
   - well-known uncertainties

2. Can A-Train measurements prove which CTMs are wrong?

3. Can A-Train measurements determine the sign and magnitude of correlation terms, such as...

$<\delta_f'\ R_s'> \quad <\delta_f'\ A_c'>$?

Summary ?

ITR approach to aerosols

- *what data to use: validation, uncertainty*
- *guided by science questions (e.g. direct forcing)*
- *mass or optics?*
- *satellites?*

Relationship to A-Train and DAFC strategy?

- *satellite data assessment*
- *sub-orbital measurement design*
- *integration of disparate data sources*

Role in diagnosing CTM differences?