

# Thanks Yoram! Now What?

## Introspection on the past, present, and future of aerosol remote sensing

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**Kaufman Symposium**

**NASA Goddard Space Flight Center June 21<sup>st</sup>, 2016**



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Jeffrey



“In a portrait, you have room to have a point of view. The image may not be literally what is going on, but it’s representative.” - Annie Leibovitz



# Life before Terra: Everything was a hard slog



## Measurements of Atmospheric Aerosol Optical Thickness over Water Using ERTS-1 Data

**Michael Griggs**

Science Applications, Inc., La Jolla, California

Journal of the Air Pollution Control Association, 25:6,  
622-626, DOI: 10.1080/00022470.1975.10470118, 1975

*Adv. Space Res.* Vol.2, No.5, pp.95-104, 1983  
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0273-117

INVESTIGATION OF THE  
ATMOSPHERIC AEROSOLS BY THE  
VISIBLE AND IR CHANNELS OF THE  
AVHRR RADIOMETER ON NOAA-6

T. Takashima and Y. Takayama

*Meteorological Research Institute, Tsukuba, Japan 305*

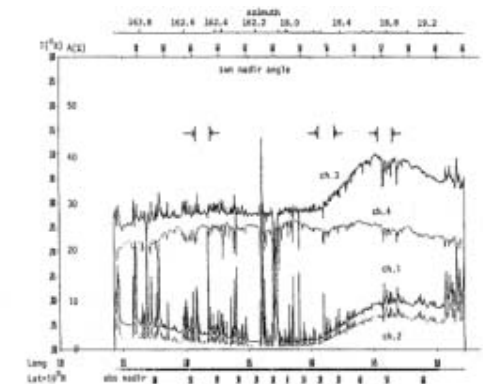


Fig.7 The same as Fig.6, but for the case on May 8, 1981 (local time is 7:27am).

## THE EFFECT OF SUBPIXEL CLOUDS ON REMOTE-SENSING

By: KAUFMAN, YJ

INTERNATIONAL JOURNAL OF REMOTE SENSING Volume: 8 Issue: 6 Pages: 839-857 Published: JUN 1987

Times Cited: 22

(from All Databases)

## REMOTE-SENSING OF AEROSOLS OVER THE OCEANS USING AVHRR DATA THEORY, PRACTICE AND APPLICATIONS

By: RAO, CRN; STOWE, LL; MCCLAIN, EP

INTERNATIONAL JOURNAL OF REMOTE SENSING Volume: 10 Issue: 4-5 Pages: 743-749 Published: APR-MAY 1989

Strategy for direct and indirect methods for correcting the aerosol effect on remote sensing: From AVHRR to EOS-MODIS

By: Kaufman, YJ; Tanre, D

REMOTE SENSING OF ENVIRONMENT Volume: 55 Issue: 1 Pages: 65-79 Published: JAN 1996

It was a long way from there to here. The blues is a mighty long road. Or it could be a river, one that twists and turns and flows into a sea of limitless musical potential.

-Billy Gibbons

# 1995 SCAR-B

## It was a good time to be a grad student



Without the quest, there  
can be no epiphany.  
— Constantine E. Scaros

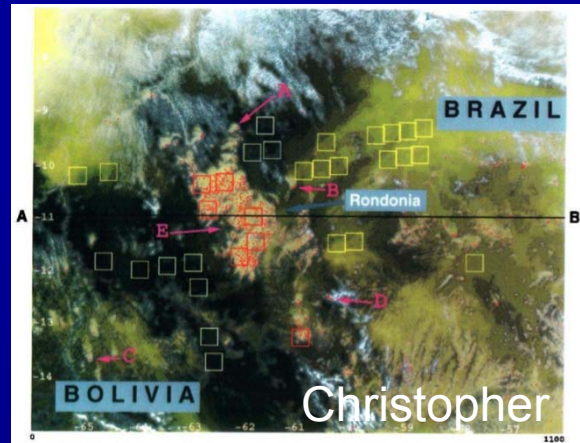


Plate 1. AVHRR three-band overlay of one image over Rondonia province, Brazil from September 3, 1985 (Red, channel 1; Green, Channel [(1-4)(1+4)]; Blue, MEAN [(1-4)(1+4)]). Fires displayed in red and white boxes represent selected collocated ERBE footprints. In this image land appears dark, dense smoke as tan, haze as light yellow, and water clouds as blue.

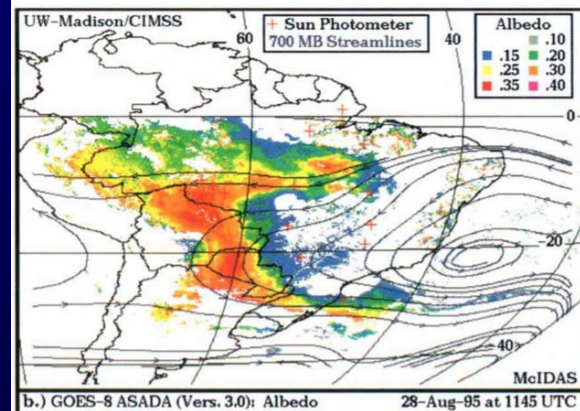
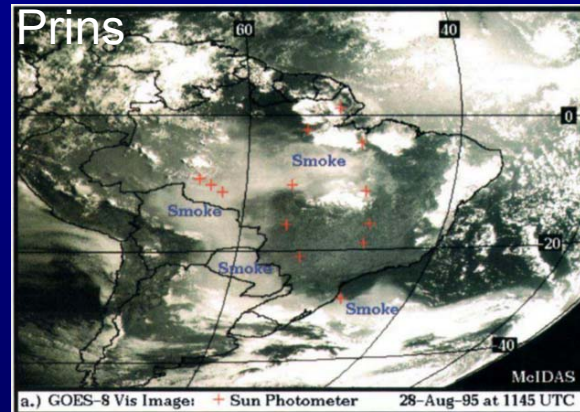
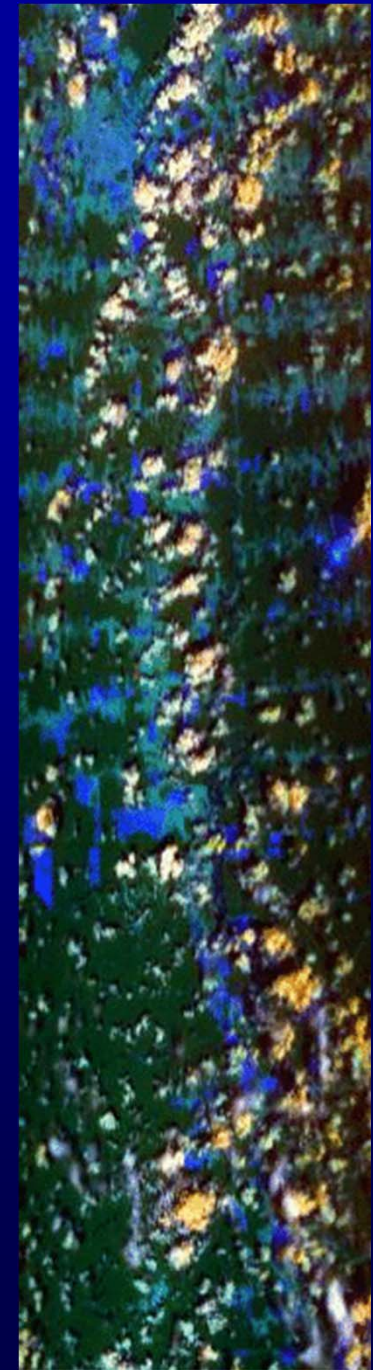


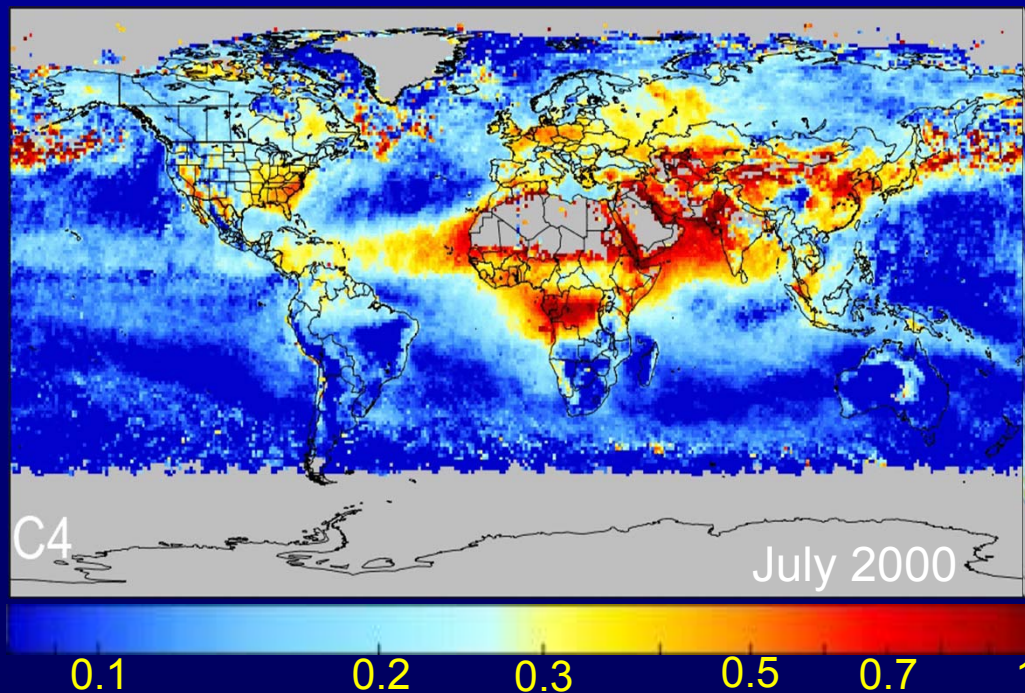
Plate 1. GOES-8 (a) visible and (b) ASADA-derived albedo product for August 28, 1995. Smoke is evident throughout the Amazon Basin, covering over 6 million km<sup>2</sup> and extending out over the Atlantic Ocean at the southern extent. The highest derived smoke albedos are 3 to 4 times greater than clear background values.





# Terra Launched: And then everything changed. And it keeps on changing...

June 2000-PRIDE-the first MODIS Aerosol airborne mission



Terra MODIS L3 DT AOT (550 nm)

“The thing about changing the world... Once you do it, the world's all different.”

-Joss Whedon

The world doesn't change in front of you, it changes behind your back.

-Terry Hayes



# Now everyone does AOT...

## An example of horizontal technology development

### Aerosol product development

The good: We are getting better (I think)

Also good: Each has its niche market.

The bad: We have no other choice than to go down rabbit holes ourselves when it comes to data application. And this takes time=\$\$\$.

The ugly: Everybody does everything a little differently which takes even more time.

Bottom line question: Are these efforts actually getting us a better estimate of AOT?  
How about forcing? Climate change?

“Morality, it could be argued, represents the way that people would like the world to work, whereas economics represents how it actually does work.”

-Steven D. Levit, Freakonomics

AVHRR  
GACP  
PATMOS-X

MODIS  
Dark Target  
Deep Blue  
MAIAC

OMI  
OMAERO  
OMAERUV

PARASOL

SeaWiFS

GEO  
GOES  
Himawari-8  
MSG

MISR  
Operational  
Science

ESA  
CCI  
PMAp



We strive for “vertical” technology development  
but are hung up on horizontal  
(Simplified for production datasets)



Marching on to new measurements!

What's next? EarthCARE? EVs? PACE/ACE??

Temporal: Himawari-8/GOES-R

Active: CALIOP->CATS, EarthCARE?, AEOLUS?

Passive vertical: MISR, OMI, AIRS, SCIAMACHI

IR Properties: AIRS, CrIS etc...

Fire: AVHRR, DMSP, ATSR, Geo->MODIS, AATSR, VIIRS

Absorption AOT: TOMS/OMI, POLDER, SCIAMACHI, PMAp

“Speciated” AOT & Typing: MISR, POLDER

Fine & Coarse AOT: MISR, POLDER, ~MODIS/VIIRS...

AOT-land & ocean: MODIS/MISR-> SeaWiFS, POLDER, VIIRS...

AOT-ocean: AVHRR -> SeaWiFS, MODIS/MISR, VIIRS...

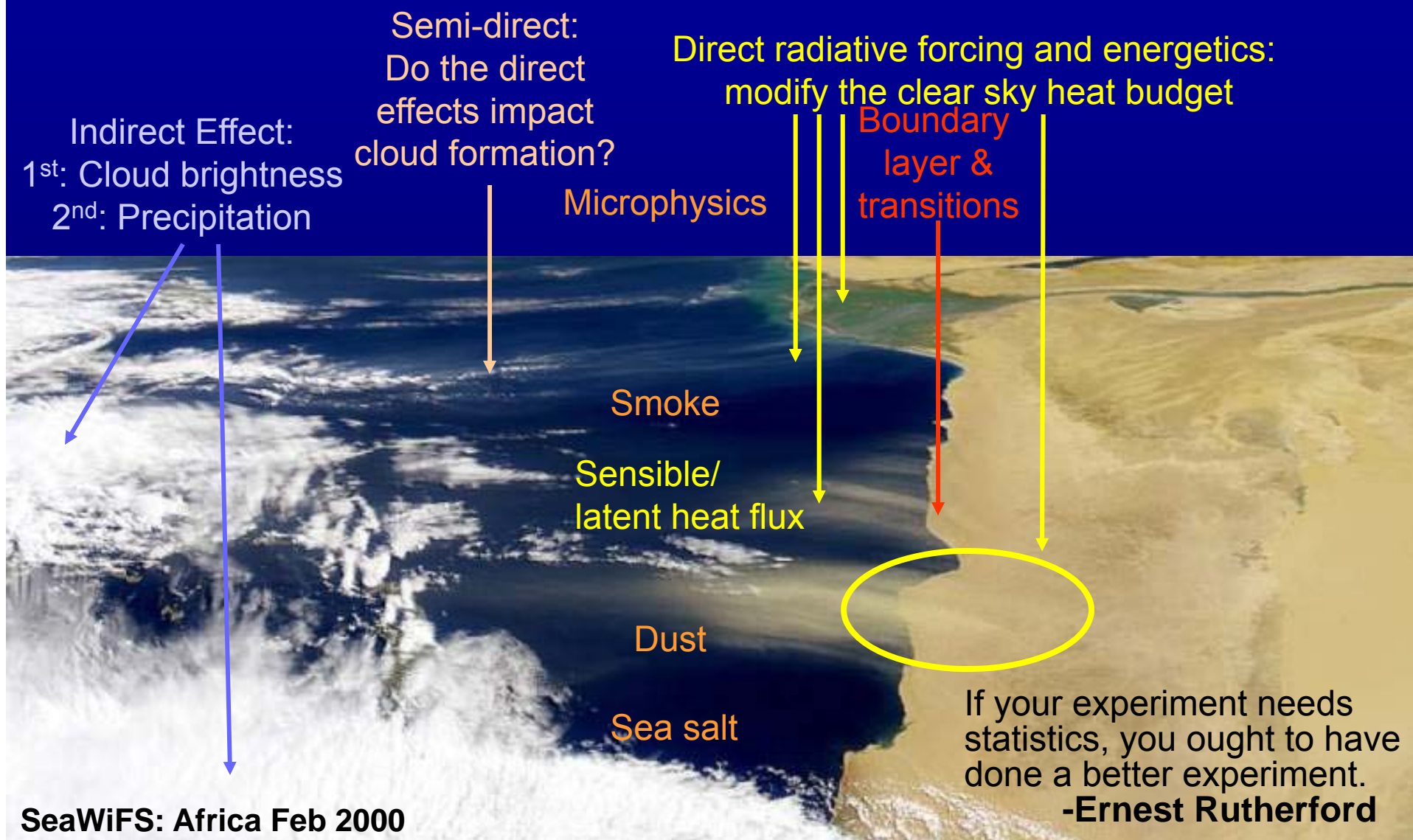
Yet, we are always projecting back  
to the most fundamental property

A man with a watch knows what time it is. A man with two  
watches is never sure. -Segals Law



# The aerosol-climate system in one “easy” picture

Now, how do we generalize? Statistics!





# OK, Back to Basics: Information Content & Observability



## Possible measurement contributions:

Spatial resolution  
Temporal resolution  
Angular information  
Number/ spectral range of bands  
Spectral resolution  
Polarization  
Backscatter  
Radiometric precision/accuracy  
Spatial precision/accuracy

## The real world:

Physical meteorology  
Land /oceanography  
Economics  
Composition/microphysics  
Radiation/Heat physics

Optical projections to  
Spectral variability  
Spatial variability  
Temporal variability  
Scene polarization

*You can't squeeze blood  
out of a turnip.*

King James Bible -> Cheryl Strayed?

Adpt. from P. Pilewskie, CU



# Umm, how do we pull it all together? Models! More statistics!

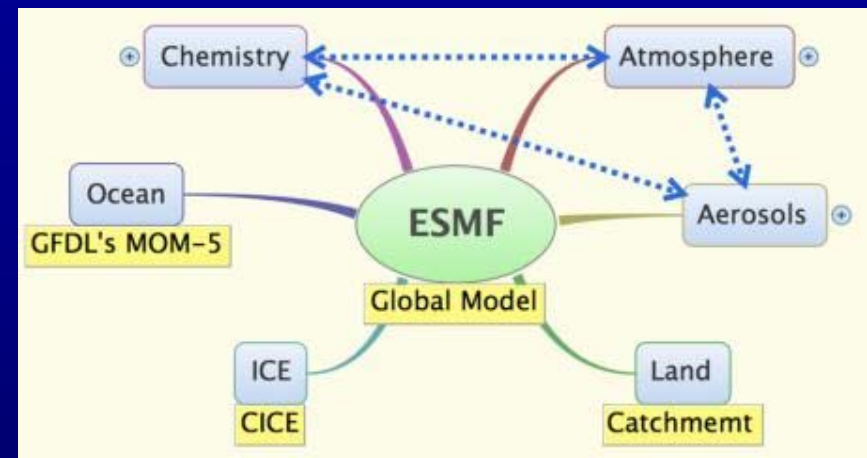


- Model initialization/assimilation by satellite observation is *the* growth industry and provides a framework for interdisciplinary earth science.
- How about adding large domain 3D – radiative transfer? Warm up your super computer...
- Add ensembles? X 100.
- Radiance assimilation has been repeatedly demonstrated.

Models as a great integrator? What if the data is contradictory? What if the modeler assumes the wrong fundamental physics?

*"All models are wrong, but some are useful"* --George E. P. Box

## GEOS-5 Architecture

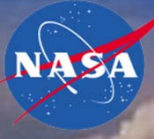


## GEOS-5 Data Assimilation



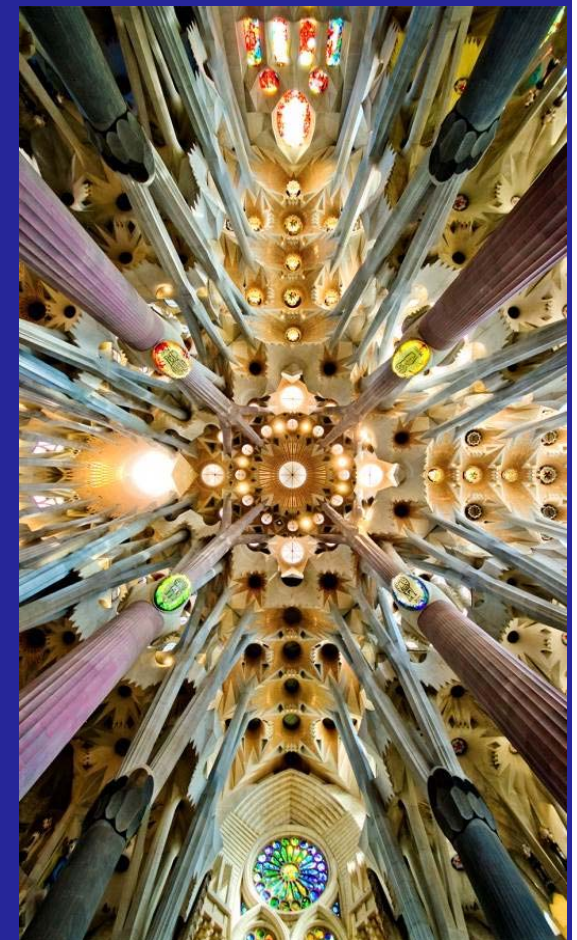


Lets take this to the extreme: The reality of going from plane parallel to three dimensions.



Sep 14, 2009 MISR

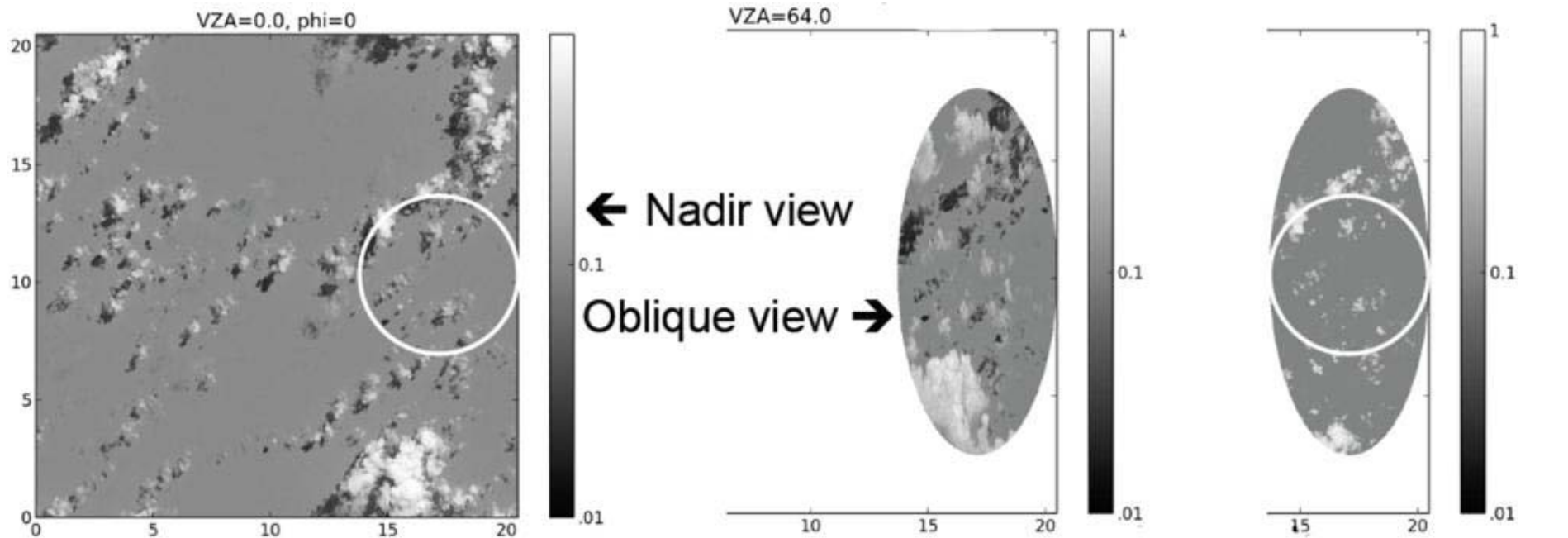
Process this!



Light is architectural. It is sculptural.  
-Robert Wilson



Adding information implicitly drives to higher resolution. The most extreme example I can think of 3D -RT. Do we need more of this, or this in more detail? Isn't this why we did SEAC<sup>4</sup>RS?



The devil is in the details.

Ludwig Miles van der Rohe (?)



JPL's LES (Matheou and Chung, 2013) at 10 m<sup>3</sup> degraded to 20x20x40 m<sup>3</sup> to accommodate vMYSTIC 3D RT. Mid-lat summer, solar zenith angle, 33.45°. Adap. A. Davis, JPL



# How will we sort through all of this? Like models, we are naturally moving towards open source retrievals?

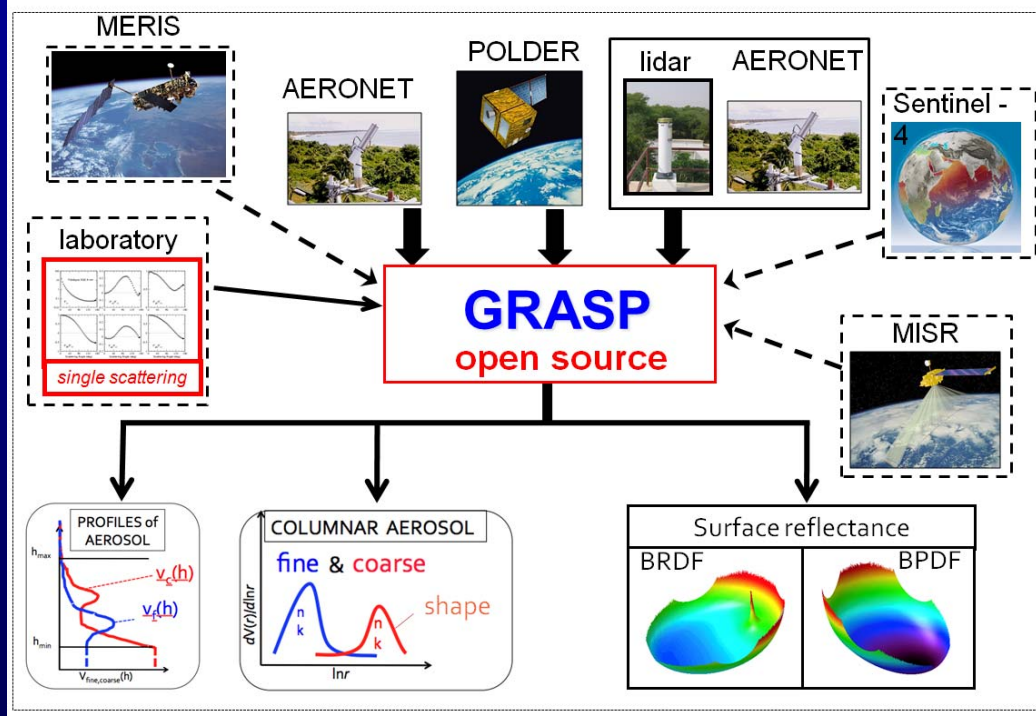


Historically, aerosol retrievals have been stove-piped in sensor teams and developed by individuals or small groups.

But, models are made up of parametrizations. Can a parallel be made for remote sensing?

Non-core science team algorithms are starting to appear. This should be encouraged provided it leads to transparent vertical development.

## GRASP: Generalized Retrieval of Aerosol and Surface Properties



The strategic marketing paradigm of Open Source is a massively-parallel drunkard's walk filtered by a Darwinistic process. —Bruce Perens





# Coming full circle with data, data volume and mining.....



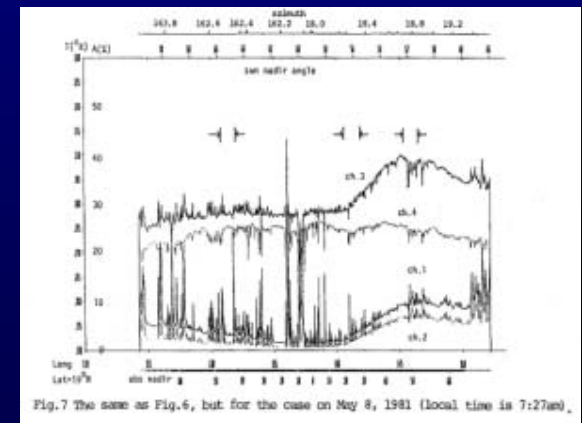
**A lot of data is flying:** In 2014, MODAPS served nearly 60 million files, totaling 130 Tb yr<sup>-1</sup>. MISR data downloads for the last several years average 26 Tb yr<sup>-1</sup>. 301 billion NOAA forecasts per year.

**All of this data has value:** IBM did not buy the weather channel to get into broadcasting. Direct payout for weather information is ~7:1. For climate, in the 100s:1.



**If what we do is so valuable, why are we not all rich?:**  
The economists say, in short our data system  
“Nonexcludable, nonrival”

**Hmmm- need to consider where this train of thought is headed:** Is there now a tension between open source and opaque proprietary products? Where do you draw the line? Will we lose track of what is going on?



Data is not information, information is not knowledge, knowledge is not understanding, understanding is not wisdom. -Clifford Stoll



# Decadal Survey Round 2

## Lets try and prevent the lemming run...



In writing the short novel *Fahrenheit 451*, I thought I was describing a world that might evolve in four or five decades. But only a few weeks ago, in Beverly Hills one night, a husband and wife passed me, walking their dog. I stood staring after them, absolutely stunned. The woman held in one hand a small cigarette-package-sized radio, its antenna quivering. From this sprang tiny copper wires which ended in a dainty cone plugged into her right ear. *There she was, oblivious to man and dog, listening to far winds and whispers and soap-opera cries, sleep-walking, helped up and down curbs by a husband who might just as well not have been there. This was not fiction.*

-Ray Bradbury, 1956, discussing Fahrenheit 451.

We need to recognize the economics of science, and that a rising tide does float all boats. "Open source" philosophy should be embraced in a way that allows transparency and realistic parsing of problems.

There are some things we cannot know (like the true state vector), so consider what systems can realistically deliver, and develop hypotheses that can make progress.

The challenge is integration. This should be tackled by small interdisciplinary teams and respect for system integrators and data centers. At the same time, integrators need to embrace their role. To the work you are entitled, but not the fruits thereof.

-Bhagavad-Gita



Yoram was far more successful than he could  
have possibly imagined



And saving the best quote for the penultimate slide

Everyone must leave something behind  
when he dies . . . Something your hand  
touched some way so your soul has  
somewhere to go when you die . . . It  
doesn't matter what you do, so long as  
you change something from the way it  
was before you touched it into something  
that's like you after you take your hands  
away.



-Ray Bradbury, Fahrenheit 451

So, Thanks Yoram!



# Ultimate Slide...

## But now what????



In an age of data mining of vast holdings, it is easy to loose track of the basics. And the basics are not so basic. There is a lot to know, not the least of which is the basic scientific method. It is time for a resurgence in theory. But this theory has to be grounded in observation.

Have we answered our fundamental questions laid in EOS? Is it we have reached "good enough" or is it that we simply hit the steep part of the power curve? How do we effectively utilize vertical development while maintaining our infrastructure?

The scientific market is shifting. For science we must insist on open source, accessibility, and transparency.

How to shift gears? Interdisciplinary teaming at both the science, engineering, and programmatic levels so we can develop true integrated and open systems.

*70% of "science" is just adult education, as perhaps it should be.*  
*-Jeffrey Reid*