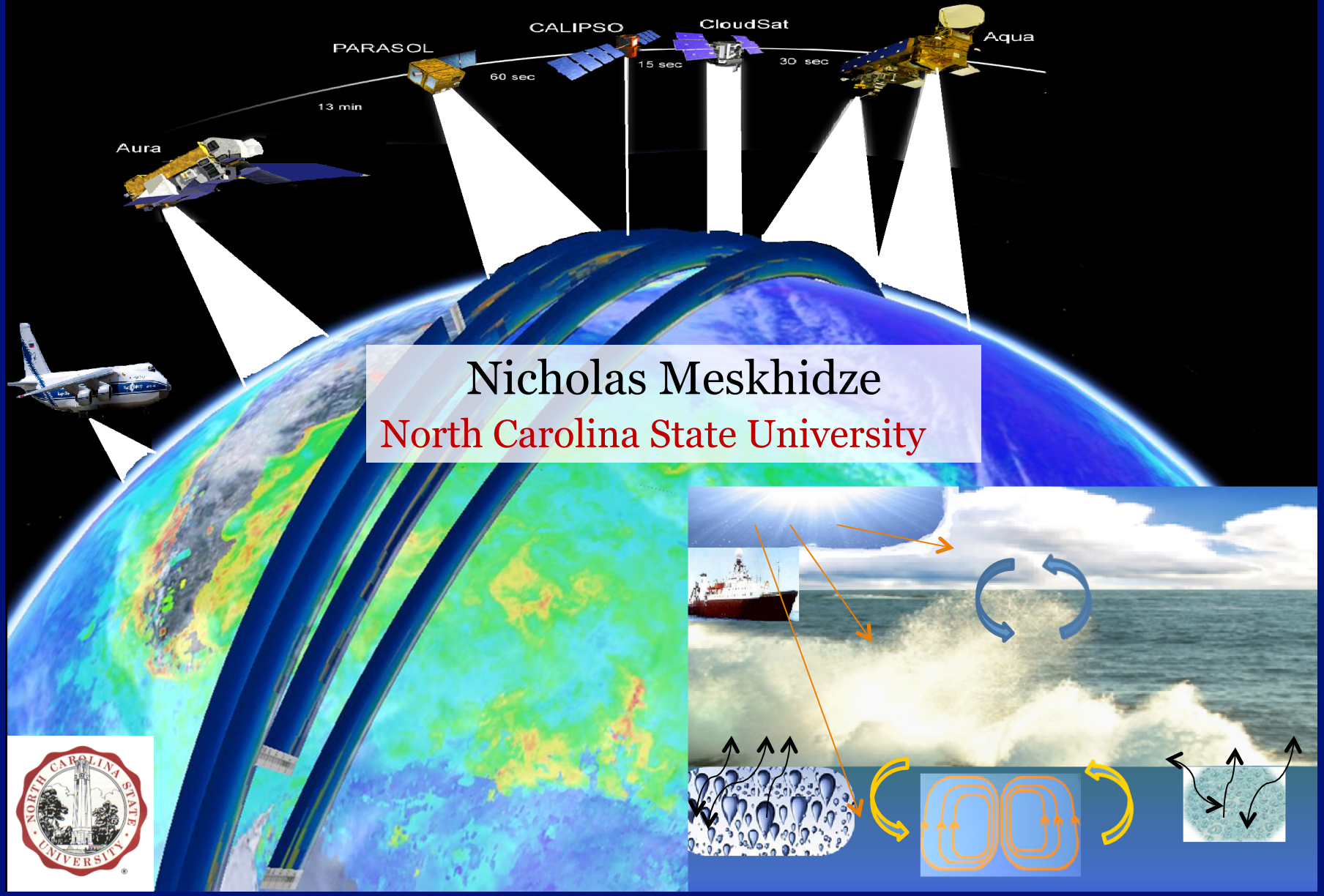
Ocean-Aerosol Science and STM



Nicholas Meskhidze
North Carolina State University

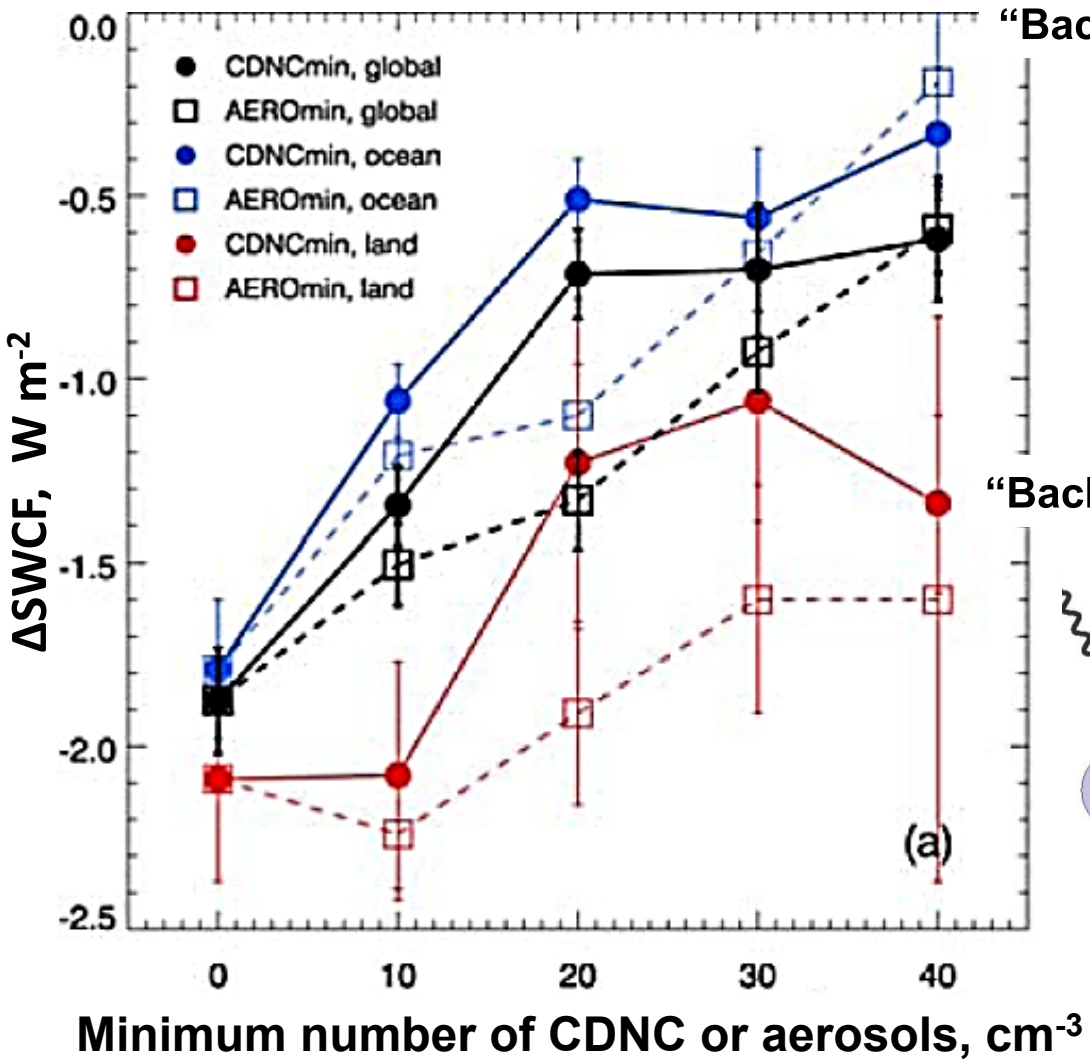
The Ocean-Aerosol Science ACE Objectives

- Combine and cross-benefit observations all "**A**" , "**C**" and "**E**" parts of the mission
- Explore the complex interplay between aerosols, clouds, and the global ocean ecosystems
- *Q1. How do aerosols and clouds influence ocean ecosystems & biogeochemical cycles?*
- *Q2. How do ocean biological & photochemical processes affect the atmosphere and Earth system?*
- Identify and *quantify the potential climate forcings and feedbacks*
- Develop/constrain model parameterizations and improve modeling and data assimilation capabilities

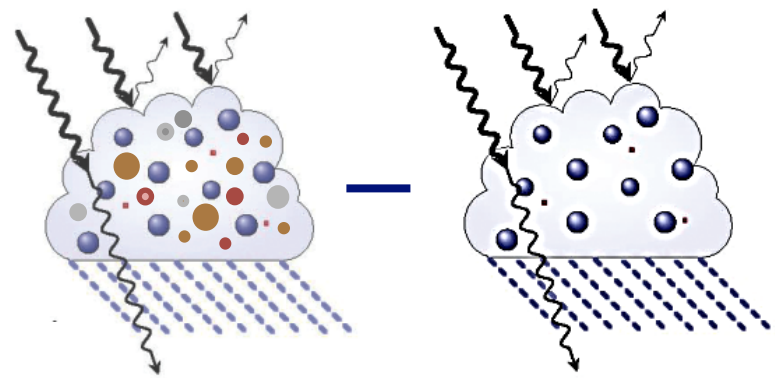
Importance of Marine Ecosystem for Anthropogenic Climate Forcing Assessments

- Current GCMs poorly quantify fluxes of marine primary aerosols and ocean biologically generated reactive gases
- Correct assessments of aerosol number concentration and size distribution over pristine marine regions may have profound effect on **model predicted extent of human-induced climate change**
- One of the *tuning* knobs in the models

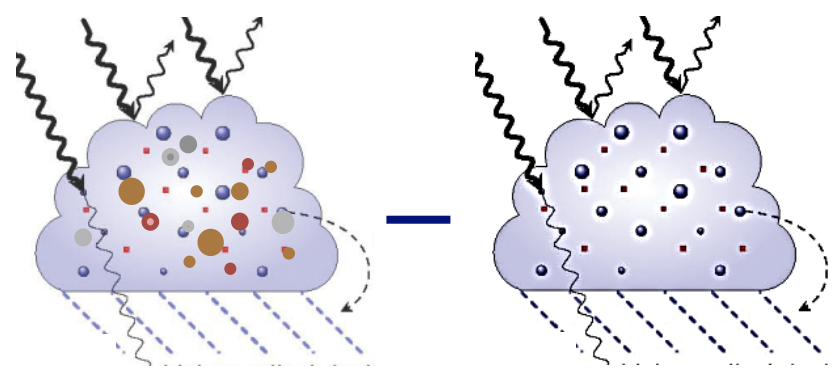
Difference in Short-wave Cloud Forcing (SWCF)



"Background" CCN or CDNC ~10 to 20 cm^{-3}

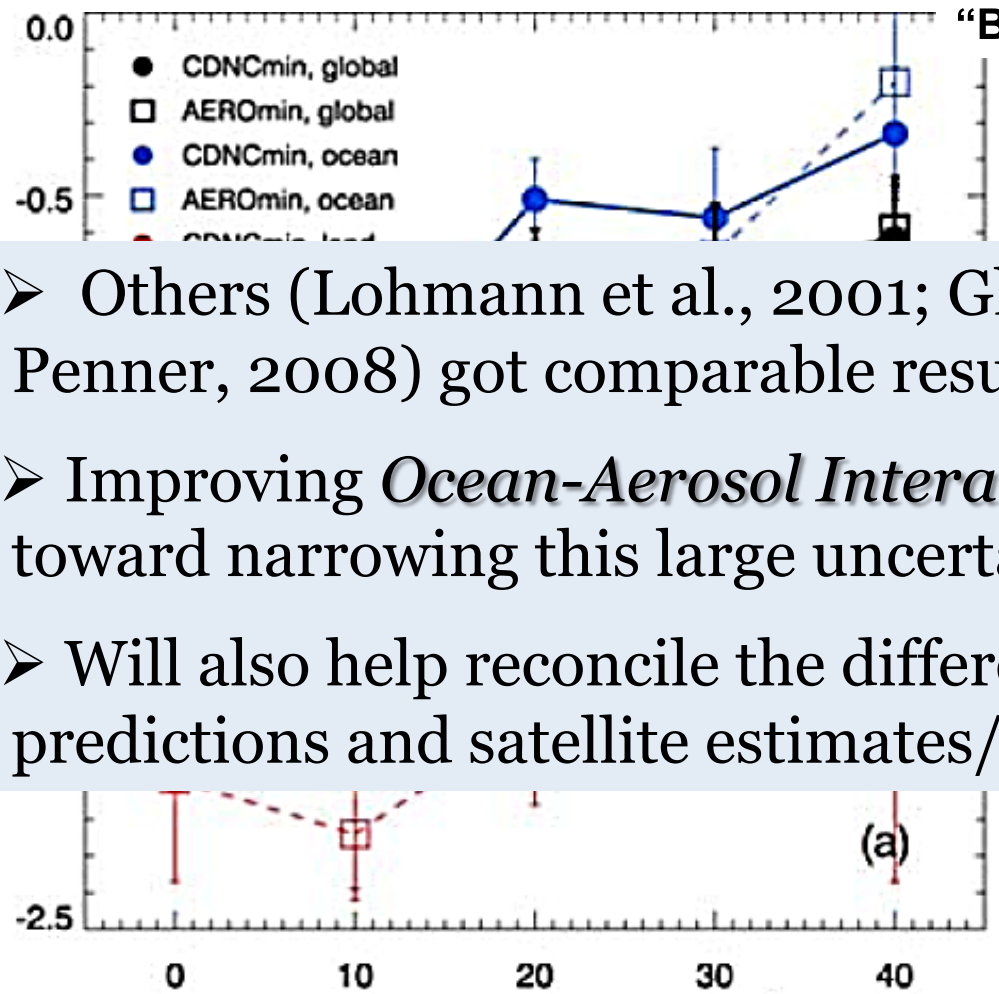


"Background" CCN or CDNC ~30 to 40 cm^{-3}

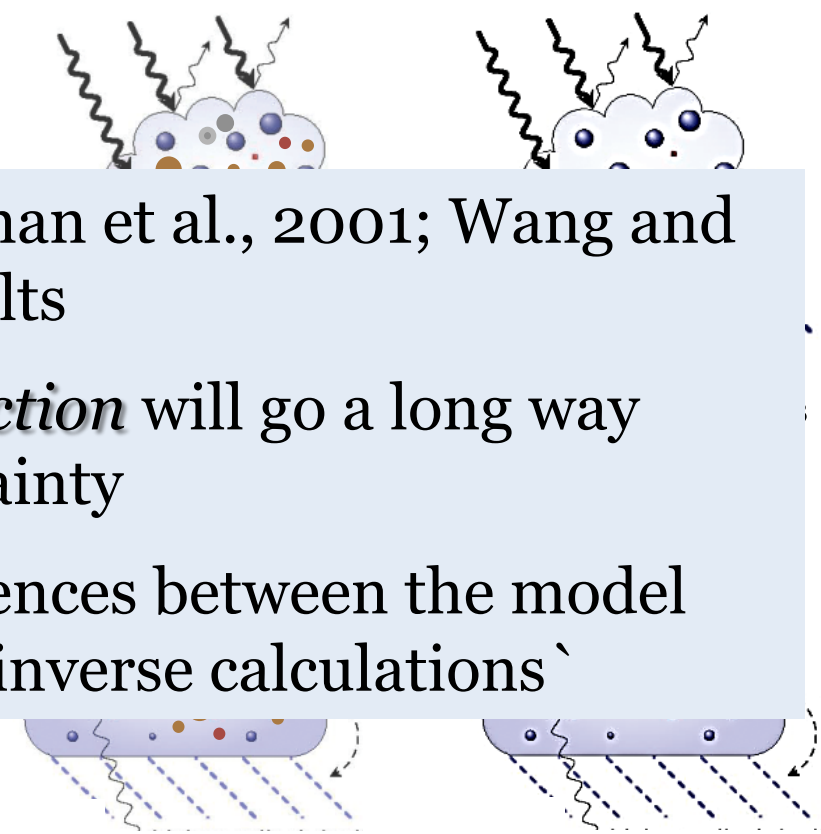


[Source: Hoose et al., 2009]

Difference in Short-wave Cloud Forcing (SWCF)



"Background" CCN or CDNC ~10 to 20 cm^{-3}



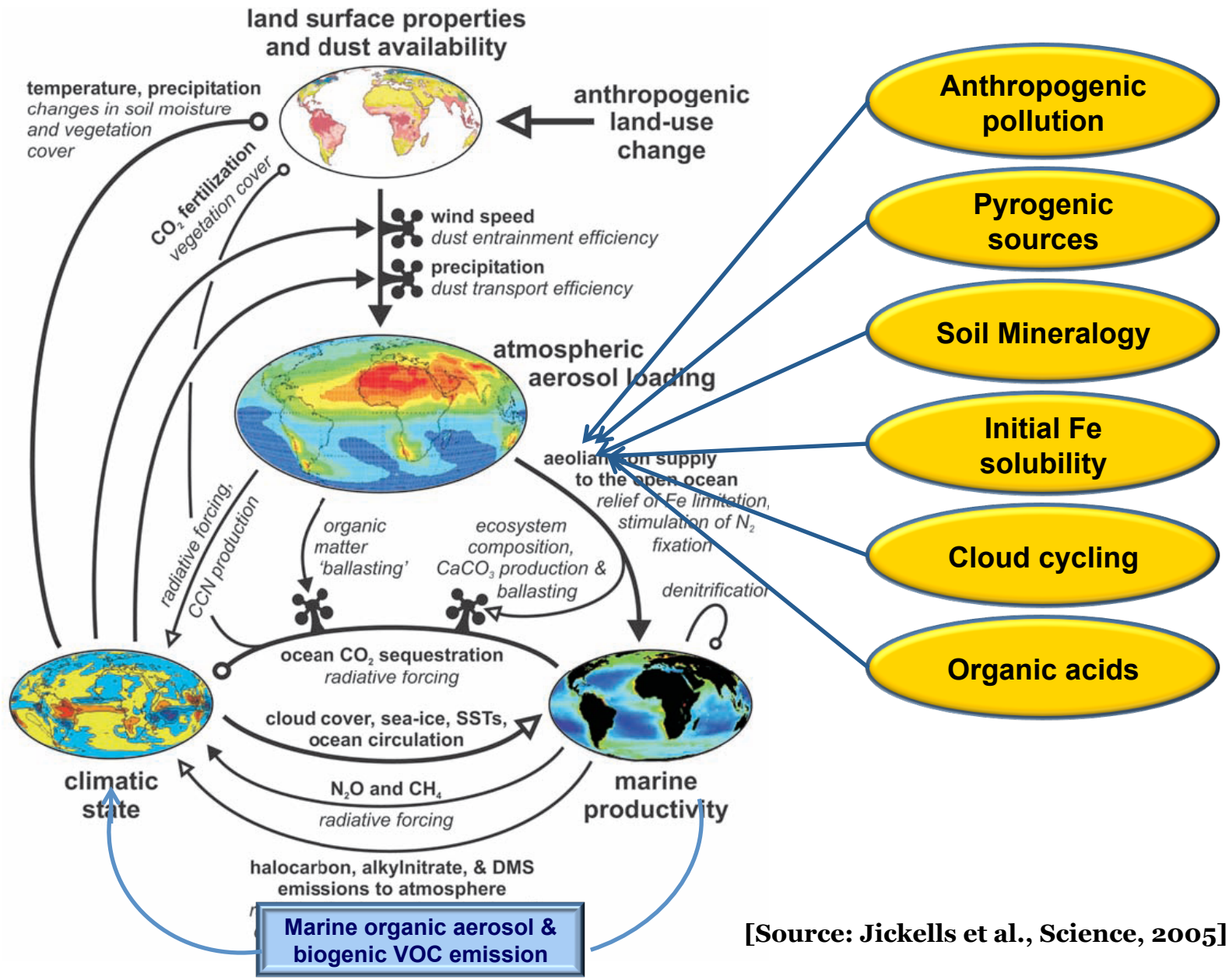
- Others (Lohmann et al., 2001; Ghan et al., 2001; Wang and Penner, 2008) got comparable results
- Improving *Ocean-Aerosol Interaction* will go a long way toward narrowing this large uncertainty
- Will also help reconcile the differences between the model predictions and satellite estimates/inverse calculations`

[Source: Hoose et al., 2009]

Q1. How do Aerosols and Clouds Influence Ocean Ecosystems & Biogeochemical Cycles?

- *The extent of anthropogenic activities on CO_2 exchange with the ocean and global C-cycle*
- *Effect anthropogenic deposition of nutrient/toxic aerosols into the oceans*
- *Contribution to applications and policy making*

Schematic View of Global Iron & Dust Connections

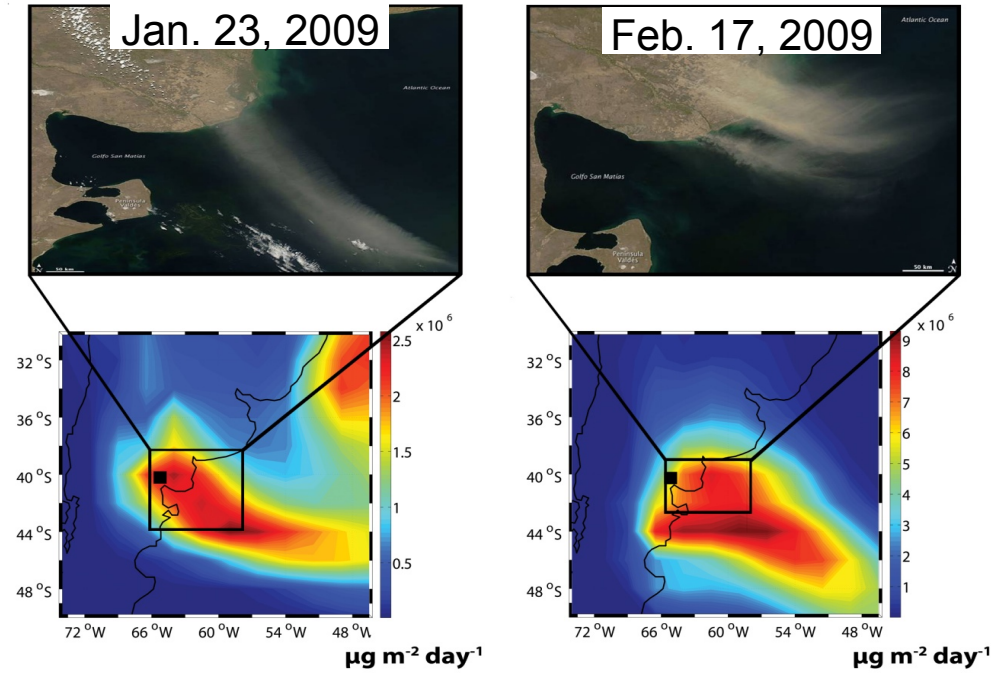


[Source: Jickells et al., Science, 2005]

Horizontal Transport Pathways of Dust

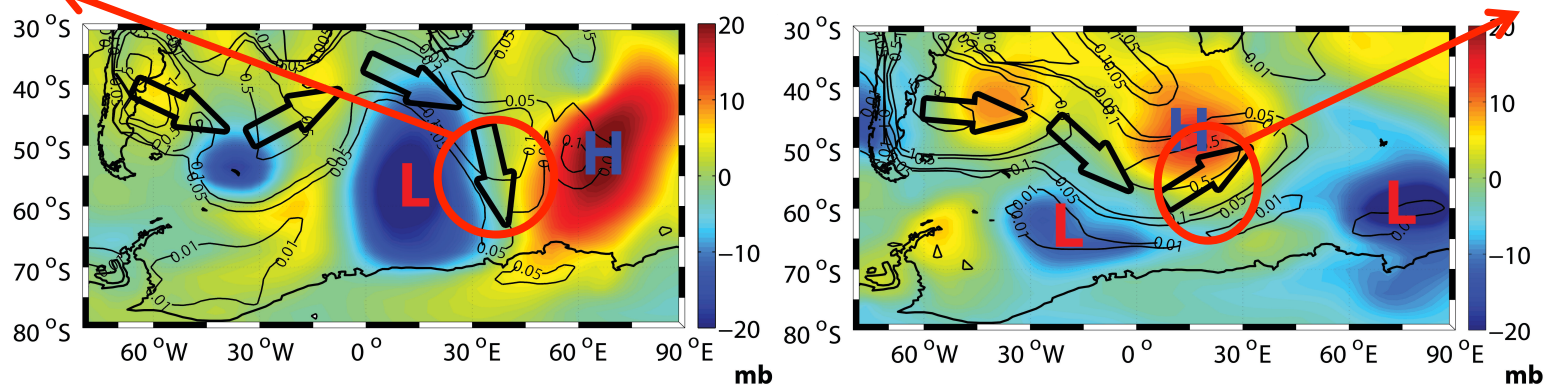
***Aqua* MODIS real-time imagery**

GEOS-Chem-predicted dust concentration



Pathway #1

Pathway #2

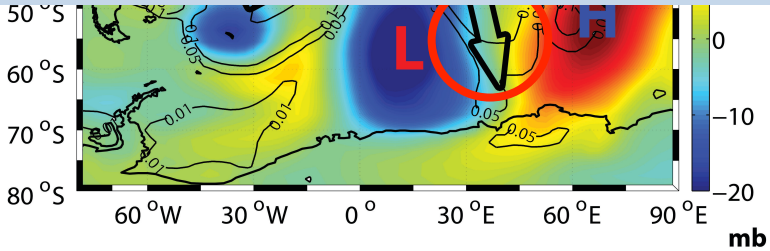


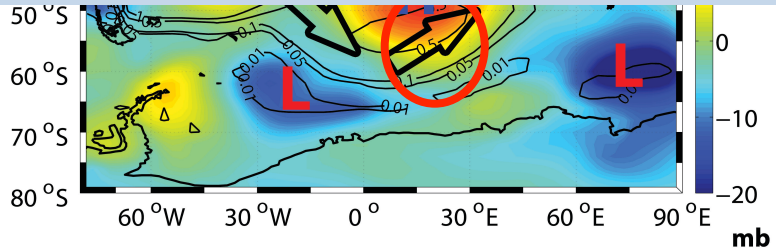
[Source: Johnson, Meskhidze et al., ACPD, 2010]

Horizontal Transport Pathways of Dust

***Aqua* MODIS real-time imagery**

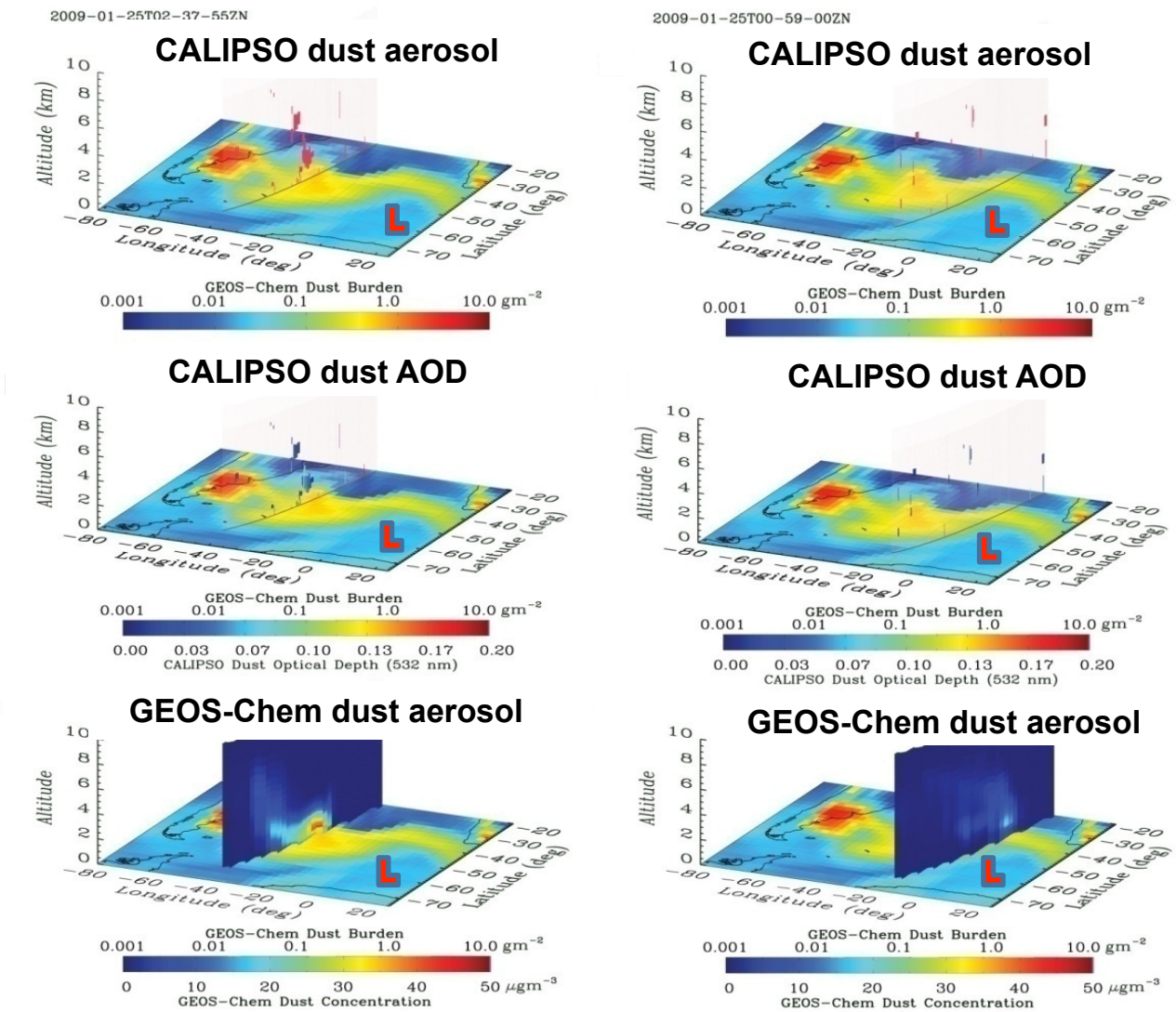
- Important for climate sensitivity estimates
- Hard to track dust over the Southern Ocean
- Need to obtain reliable aerosol size and index of refraction retrievals at low concentrations (AODs from 0.03 to 0.15)





[Source: Johnson, Meskhidze et al., ACPD, 2010]

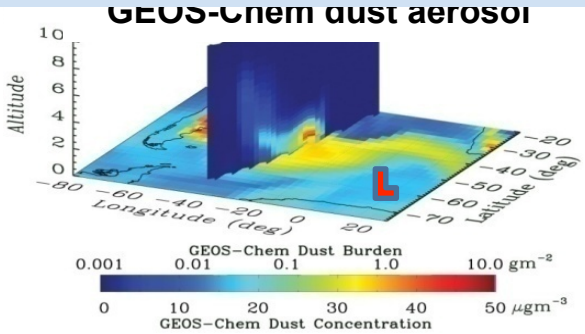
Vertical Transport Pathways of Dust

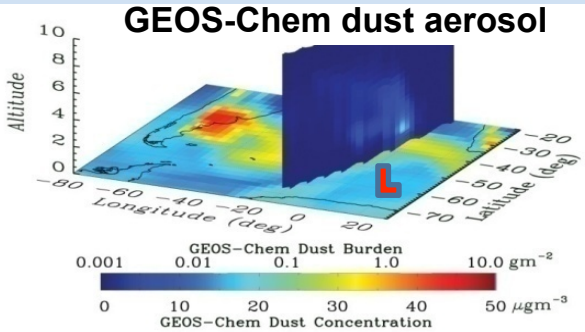


[Source: Johnson, Meskhidze et al., ACPD, 2010]

Vertical Transport Pathways of Dust

- HSRLidar + imaging polarimeter = high quality 3-D data of aerosol optical and microphysical parameters across a wide range of space & time
- Cross-benefiting and interdisciplinary observations with the ocean color multi-channel spectroradiometer
- Improved modeling and data assimilation capabilities





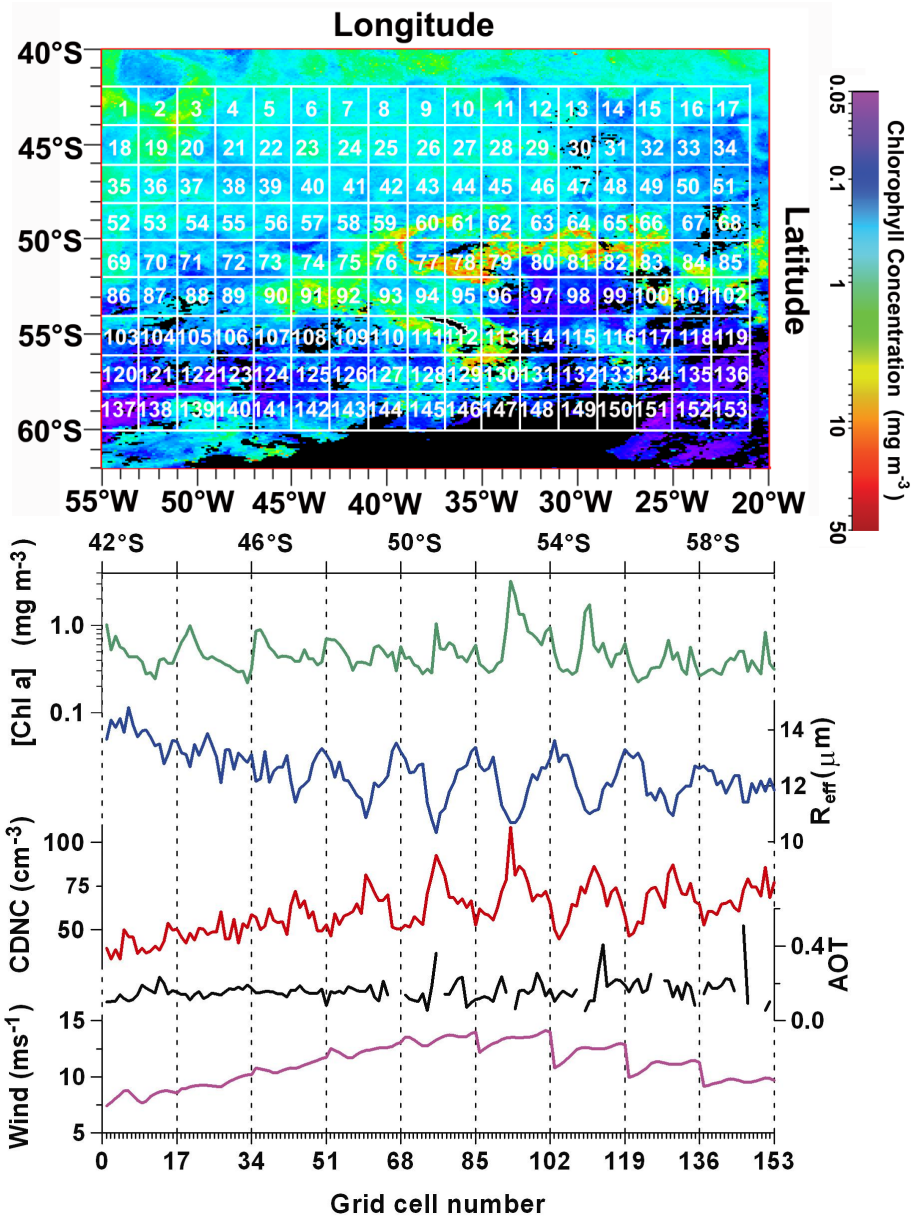
[Source: Johnson, Meskhidze et al., ACPD, 2010]

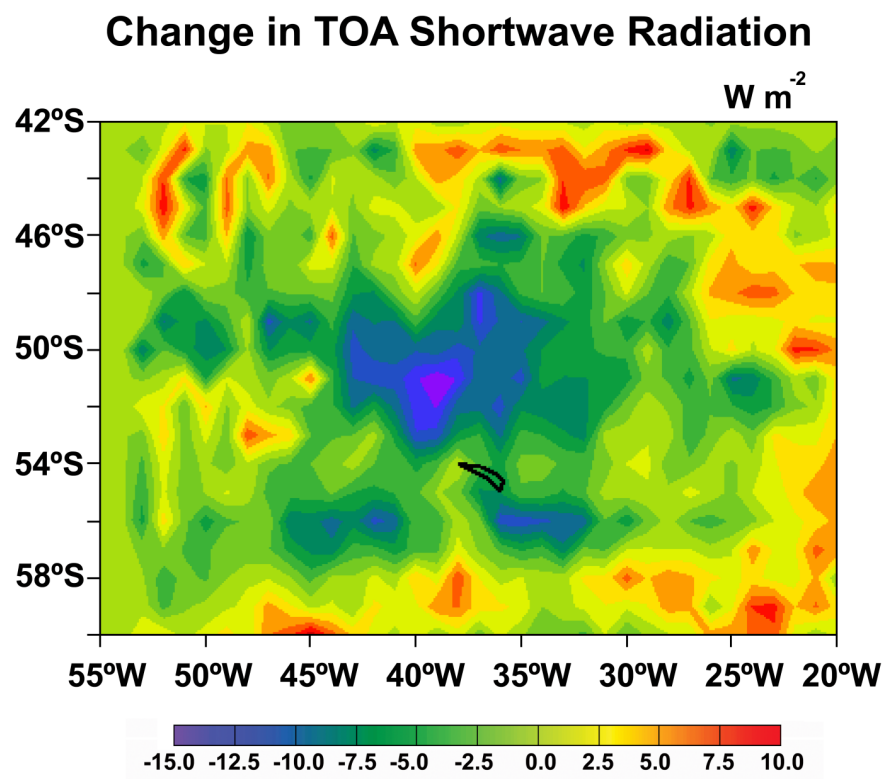
Q2. How do Ocean Biological & Photochemical Processes Affect the Atmosphere and Earth System?

- *Detect and quantify the imprint of oceanic biological processes on the optical and radiative properties of the overlying aerosols and clouds*

- *Integrated approach of satellite, modeling and field campaigns will provide distinctive and unique pieces of information*

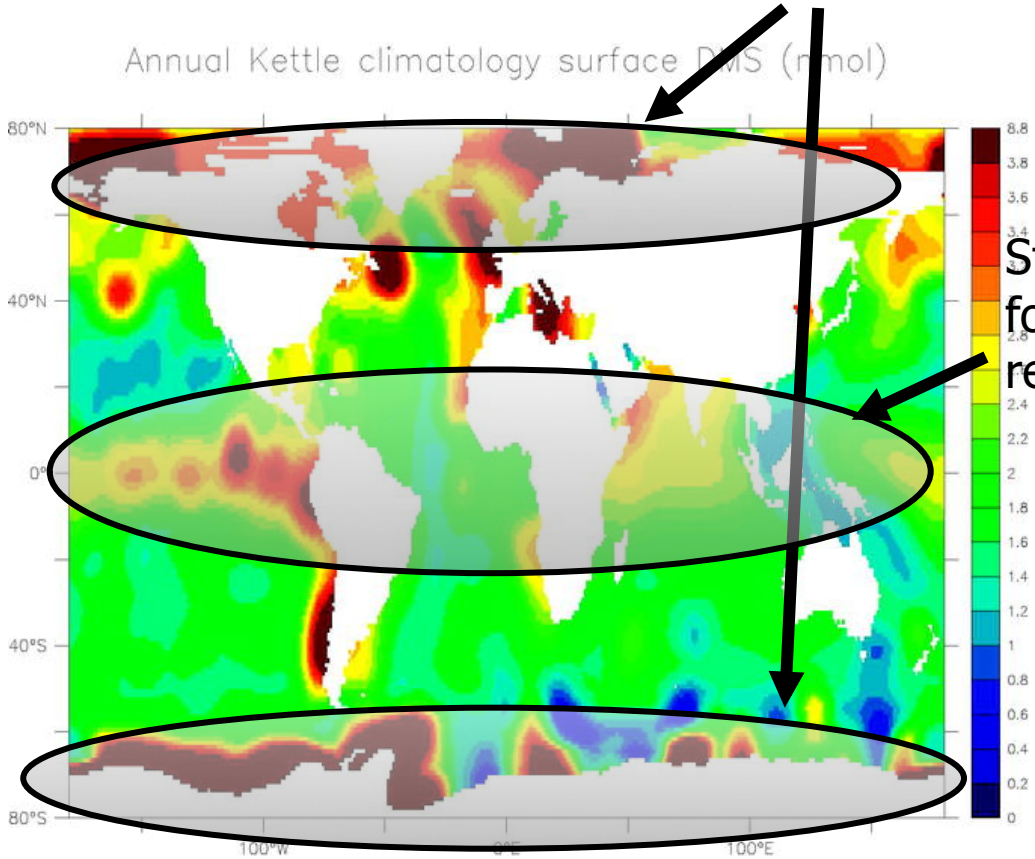
Marine Ecosystems Can Potentially Influence Cloud Radiative Properties



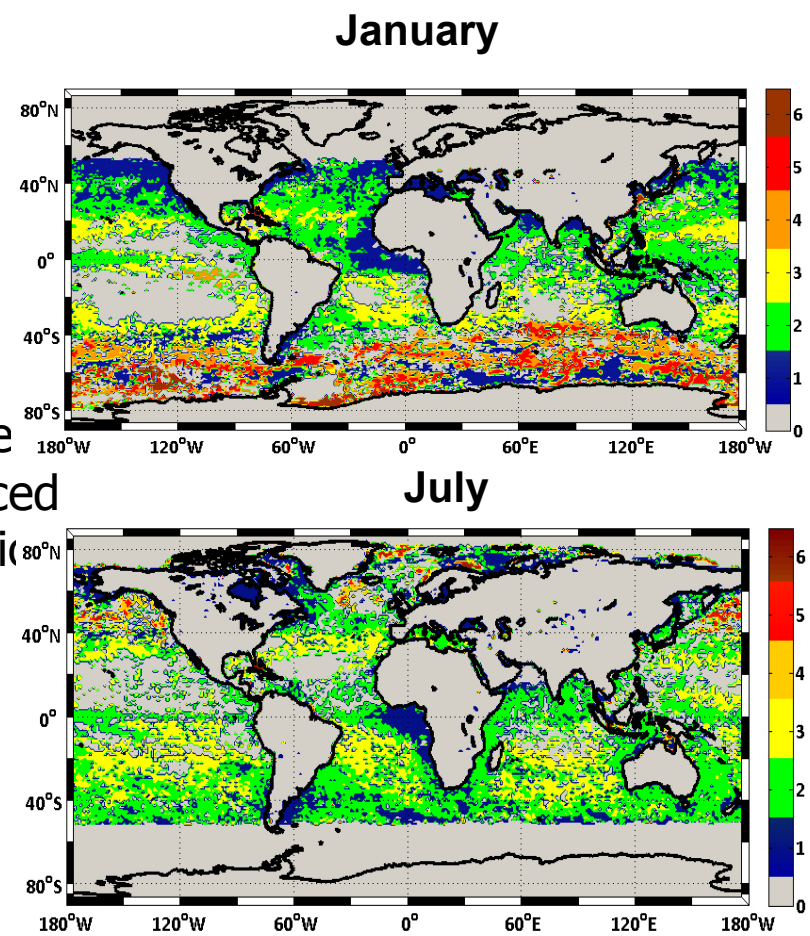


[Source: Meskhidze & Nenes, Science, 2006]

Emissions of Biogenic Trace Gases (DMS, isoprene, monoterpenes, iodine…)



[Source: Toole and Siegel, GRL, 2004]



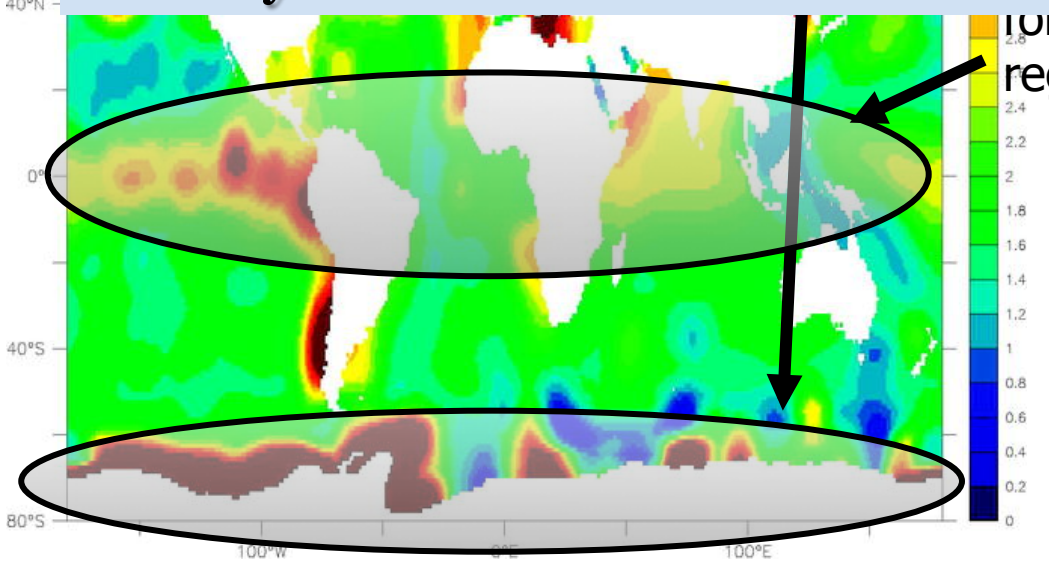
[Source: Gantt, et al., 2009]

6. Coccolithophores
5. Phaeocystis
4. Diatoms
3. *Synechococcus*
2. *Prochlorococcus*
1. Nanoeukaryotes
0. Unclassified

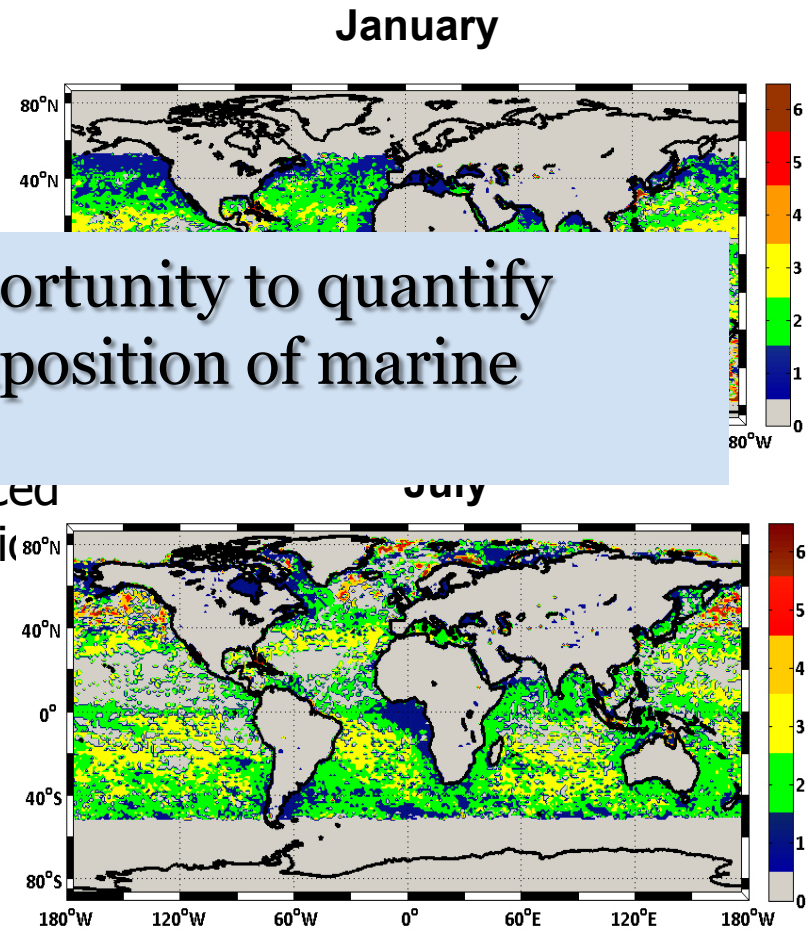
Emissions of Biogenic Trace Gases (DMS, isoprene, monoterpenes, iodine…)

Bloom-forced regions

- ACE will offer extraordinary opportunity to quantify taxonomic/functional group composition of marine ecosystems



[Source: Toole and Siegel, GRL, 2004]



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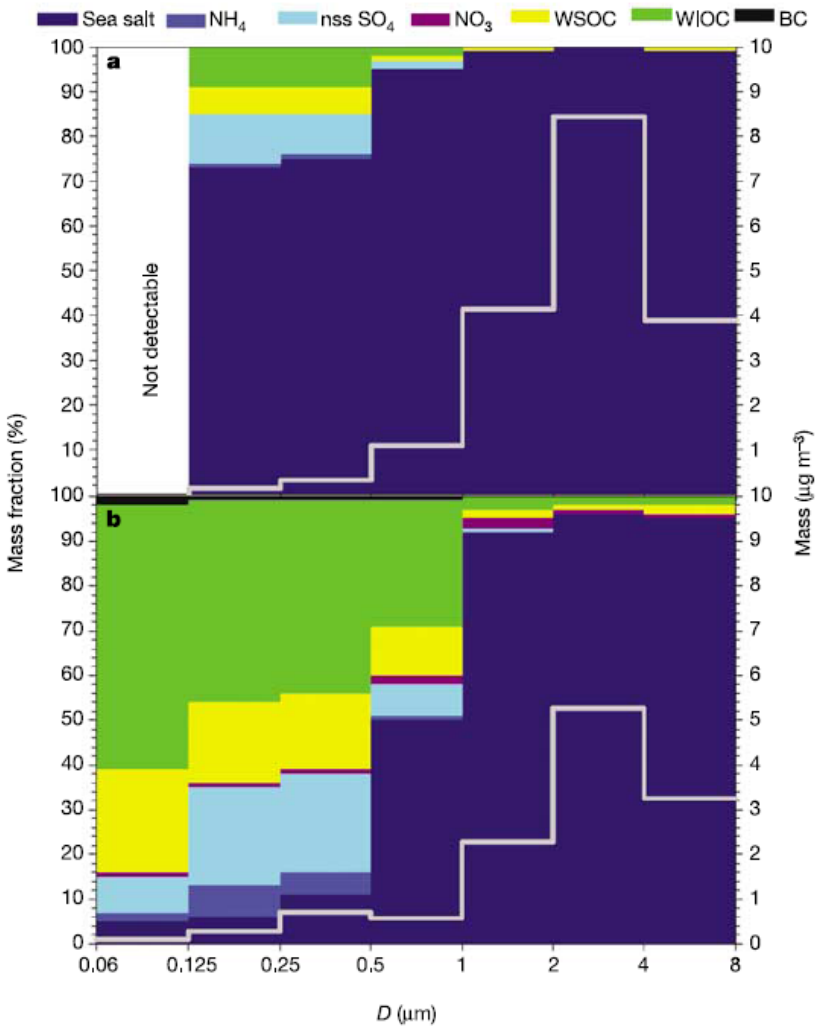
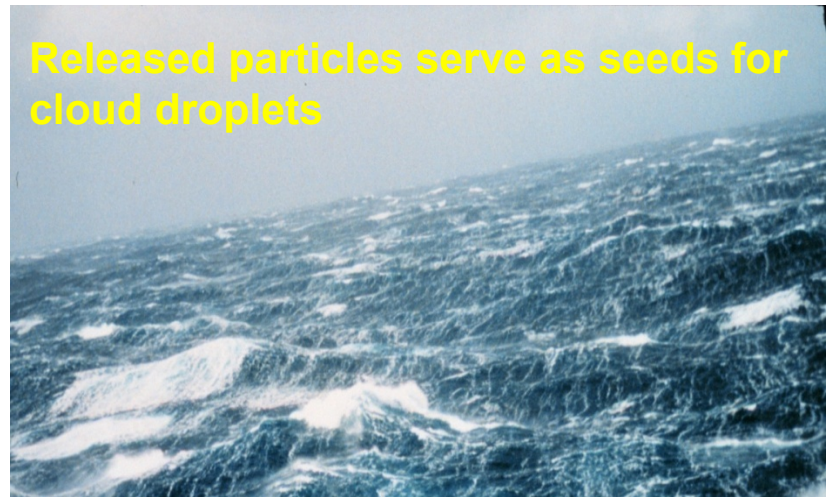
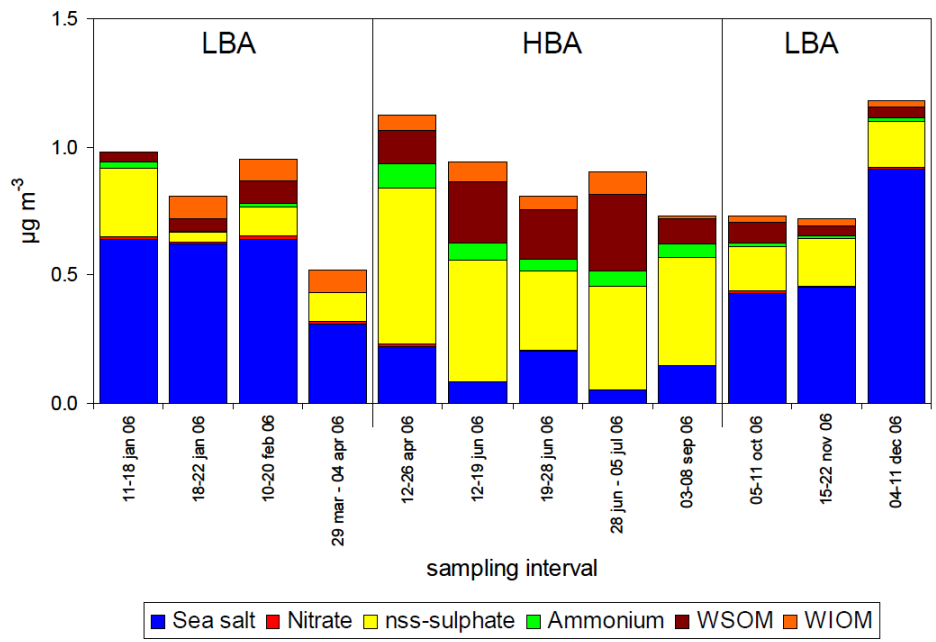
Aerosol Emissions From Oceans: Organic Enrichment of Sea Spray



[O'Dowd et al., Nature, 2004]

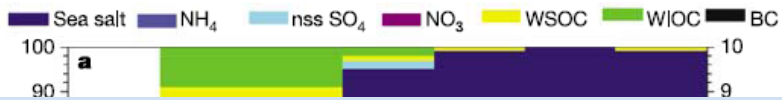


[Source: wikipedia]

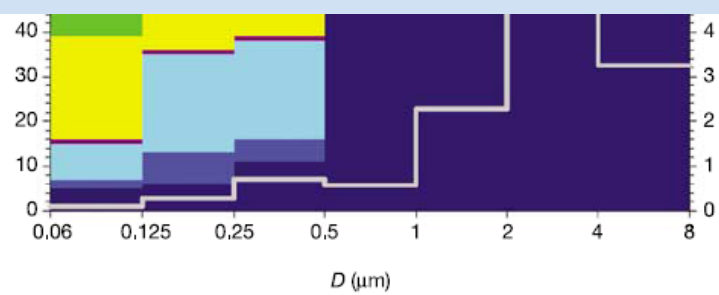


[Rinaldi et al., AMET, 2010]

Aerosol Emissions From Oceans: Organic Enrichment of Sea Spray



- There appears to be a large biogenically driven source of organics over the oceans
- Highly synergistic aerosol and ocean-color measurements can reduce forcing and feedback uncertainties of ocean ecosystems
- Optical and CCN properties of submicron marine aerosols ≠ sea-salt



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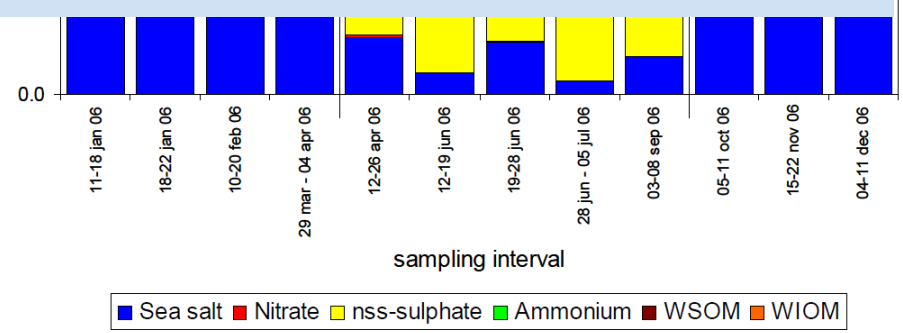
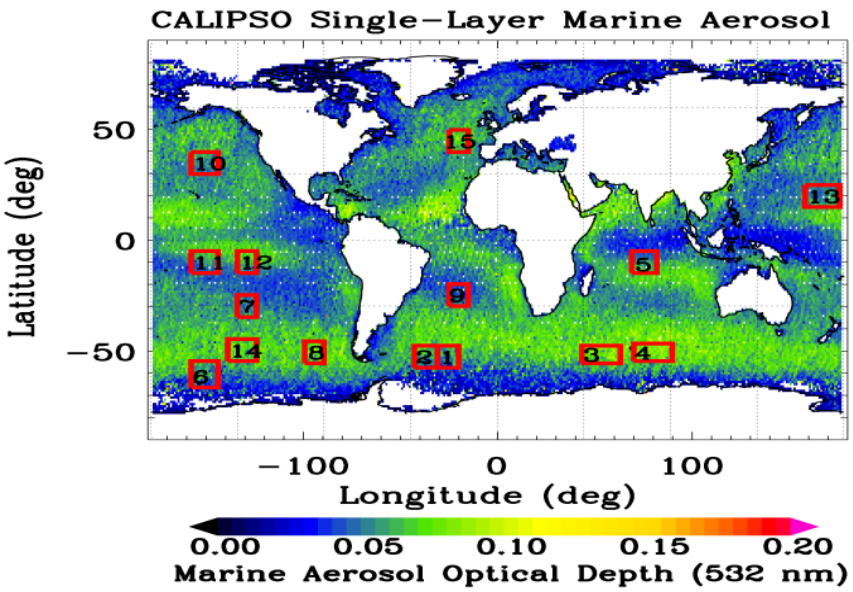
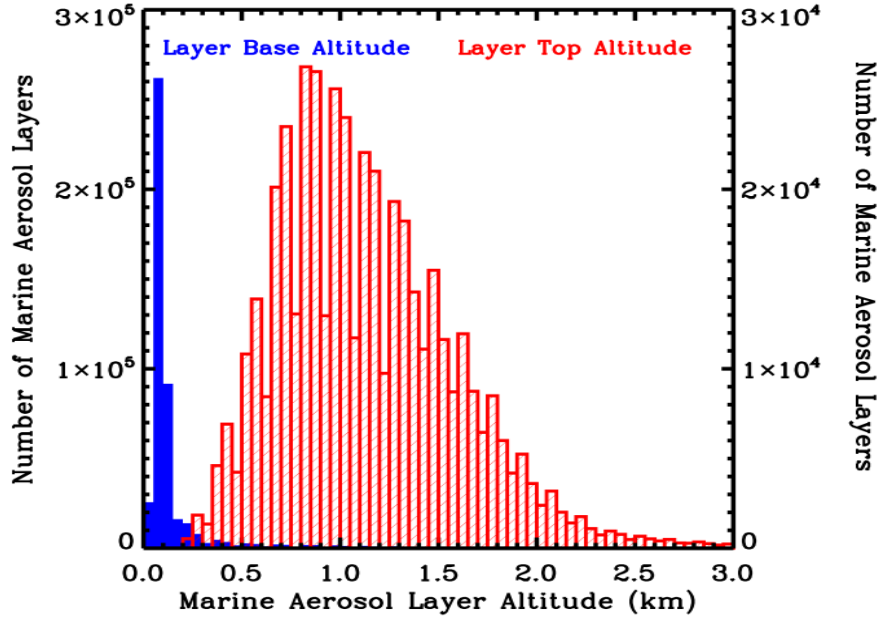
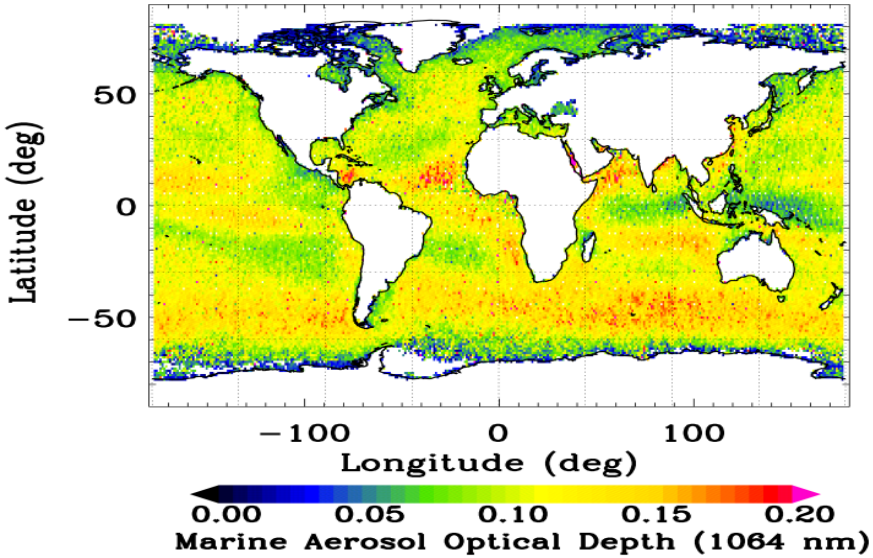


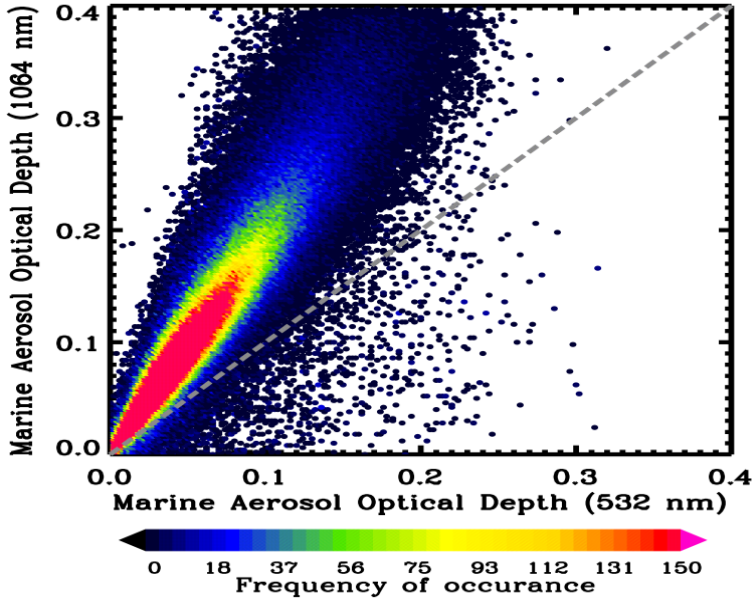
[Rinaldi et al., AMET, 2010]

CALIPSO – Valuable Information to Quantify Marine Aerosols Optical Properties



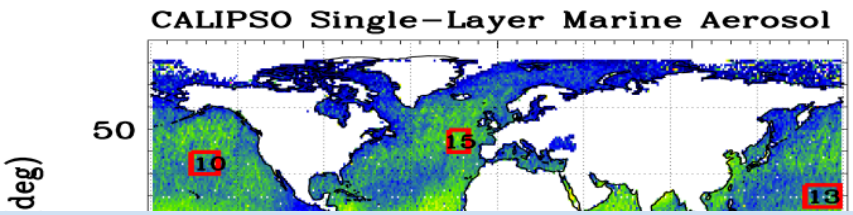


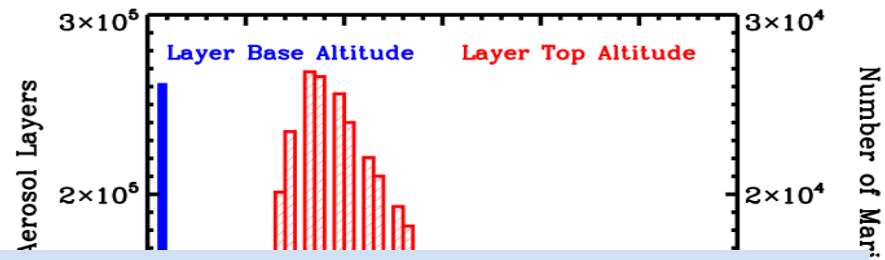




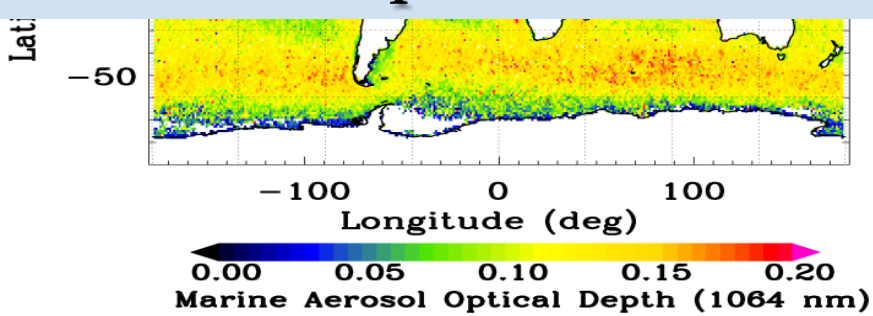
[Source: Meskhidze et al., in prep]

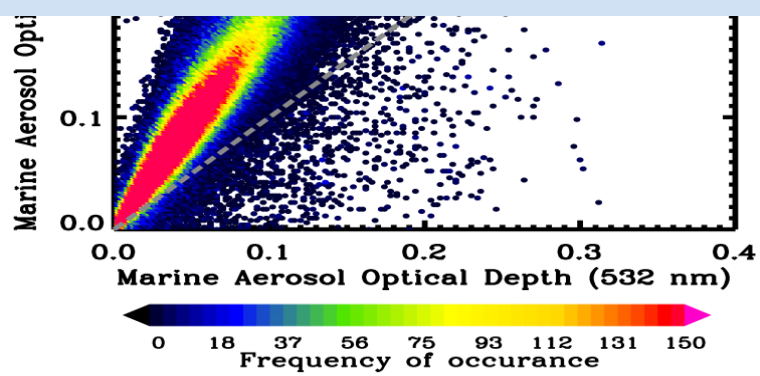
CALIPSO – Valuable Information to Quantify Marine Aerosols Optical Properties





- Estimates that were made using NASA A-Train and inquisitive minds can be tested with CALIPSO
- CALIPSO has limitations – prescribed lidar ratio
- $3\beta + 2\alpha + 2\delta$ HSRLidar can give quantitative information for true "clean marine" aerosol
- Suborbital measurements and the models with the process-level based parameterizations





[Source: Meskhidze et al., in prep]

SUMMARY: ACE Will Advance Fundamental Science and Provide New Capabilities for the Model Improvements

- Simultaneous characterization of ocean surface biology, and the overlying aerosol/cloud fields - timely contribution to the science
- Reduce uncertainty about climate forcing by identifying key processes and feedbacks
- Provide unique space-based observations to detect atmosphere/ ocean coupling and develop *event-based* and *climatological* data sets
- Provide the valuable information to test assumptions and hypothesis
- Evaluate the model biases and errors, identify model weaknesses and figure out methods to correct them

Back up Slides

Aerosol-Ocean Working Group

Chuck McClain: Chair

Paula Bontempi: Co-chair

- Zia Ahmad (GSFC)
- Mike Behrenfeld (Oregon SU.)
- Jacek Chowdhary (GISS)
- Yong Hu (NASA LaRC))
- Norm Nelson (UC/Santa Barbara)
- Dave Siegel (UC/Santa Barbara)

- Natalie Mahowald (Cornell U)
- Nicholas Meskhidze (North Carolina SU)

- Joanna Joiner (GSFC)
- Santiago Gassó (UMBC)
- Stanley Sander (JPL)

- Eric Salztman (UC Irvine)
- Joe Prospero (Miami)
- Yuan Gao (Rutgers)
- Paty Matrai (Bigelow)
- Lorraine Remer (GSFC)

Green= Also in Aerosol group

Red = Also in OB group

Yellow = Aerosol + OB

ACE Science Traceability Matrix (STM)

- STM provides a roadmap from science questions to sensor and mission requirements (i.e., from wishful thinking to concrete measurements)

- STM elements: Category (e.g., Ocean-Aerosol Interaction), Focused Questions, Approach, Measurement Requirements, Instrument Requirements, Platform Requirements, & Other Needs

Aerosol-Ocean STM

Category	Focused Questions	Approach	Maps to Science Question	Measurement Requirements	Instrument Requirements	Platform Requir'ts	Other Needs
Ocean-Aerosol Inter-action	1 What is the flux of aerosols to their temporal and spatial distribution	1) Id prop spect particle size distribution					pporting bal data
	2 What are the physical and chemical characteristics, sources, and depths of aerosols deposited into the oceans?	2) Cl mass flux				radiometer &	nidity es cipitation maldehyde oxal
	3 How are the physical and chemical characteristics of deposited aerosols transformed in the atmosphere?	3) Co valid ocean			in ocean STM	orbit with	er Data
	4 What is the spatial and temporal distribution of aerosols and gases emitted from the ocean and how are these fluxes regulated by ecosystems? (Links to Ocean Ecology Question 4)	4) Us const chem trans exchange and (5) impacts on ocean biology			requirements as		Ground-based ol vational ork
		5) Cl and t form gas-c contr		ratory Measurements		full spectral and	
	5 What are the feedbacks between ocean emissions and the microphysical and radiative properties of the overlying aerosols and clouds? How are these feedbacks changing?	6) M pigm Chl:C dissc relev photo		ing mine sources, composition, and		lidar and radar as detailed in Ocean Aerosol	
		7) Re to aerosol deposition patterns and e	4	• Use satellite data to constrain model aerosol source strengths			
		8) Demonstrate influences of ocean taxonomy, physiological stress, and photochemistry on cloud/aerosol properties, including organic aerosol transfer	1 2 3				

Aerosol flux to

Sources, microphysical & optical properties

Deposited aero & chemical pro

Dust, column mass and elemental composition

Aerosol transfo the atmosphere

Satellite validations

Constrain models

Ocean aerosol e links to ecosyst

Aerosol chemical composition: primary and secondary

Feedbacks betw emissions & atmospheric radiative propert

Global phytoplankton biomass, taxonomic groups, CDOM & POC

Ocean biology-aerosol interaction

Ocean ecosystem-cloud interaction