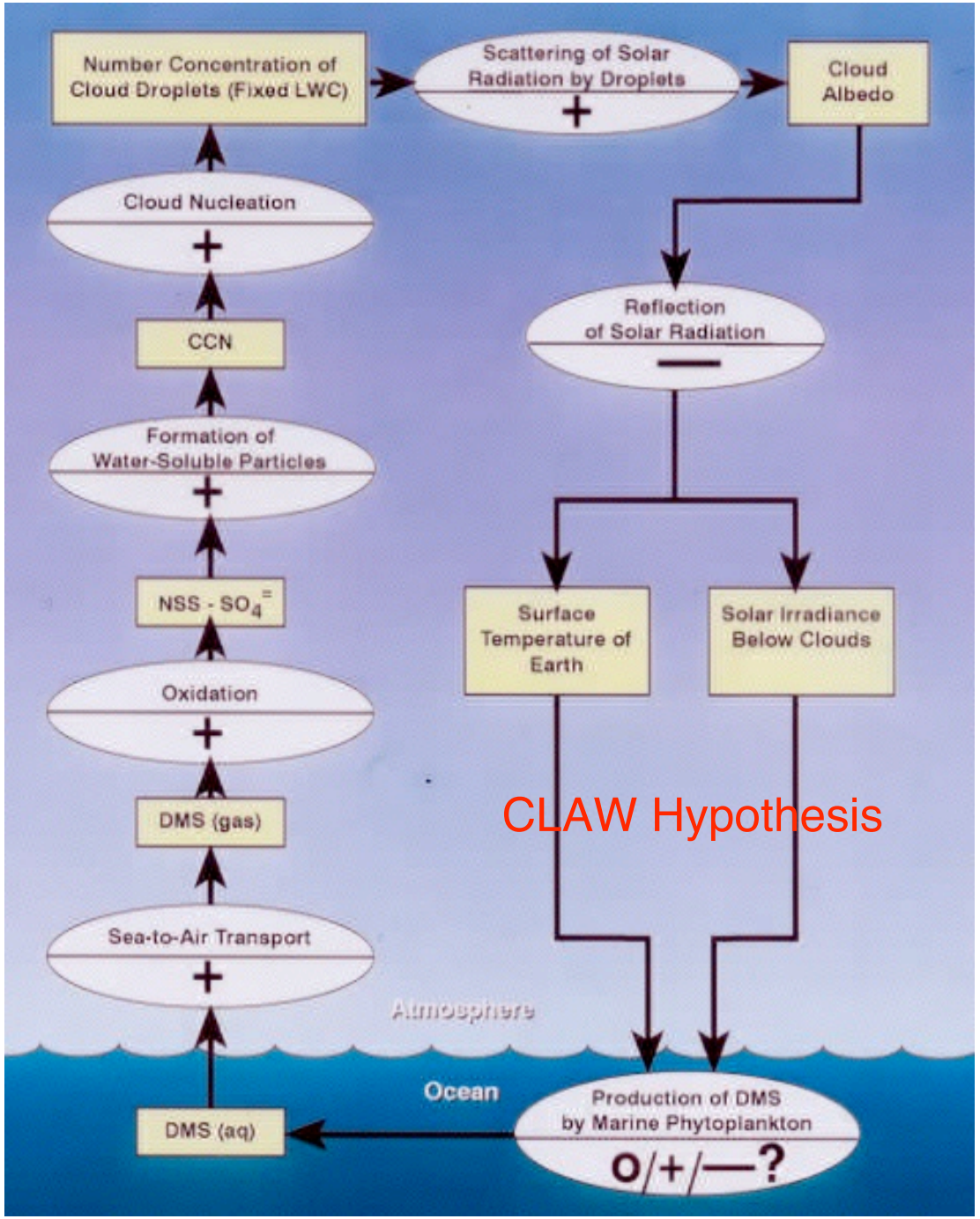
The CLAW Hypothesis

Does anyone believe that this feedback loop works as advertised?

It is *possible* that it does, although most steps are too poorly quantified to be certain.

Charlson, Lovelock, Andreae, and Warren, Oceanic phytoplankton, atmospheric sulfur, cloud albedo and climate, *Nature*, *326*, 655-661, 1987.

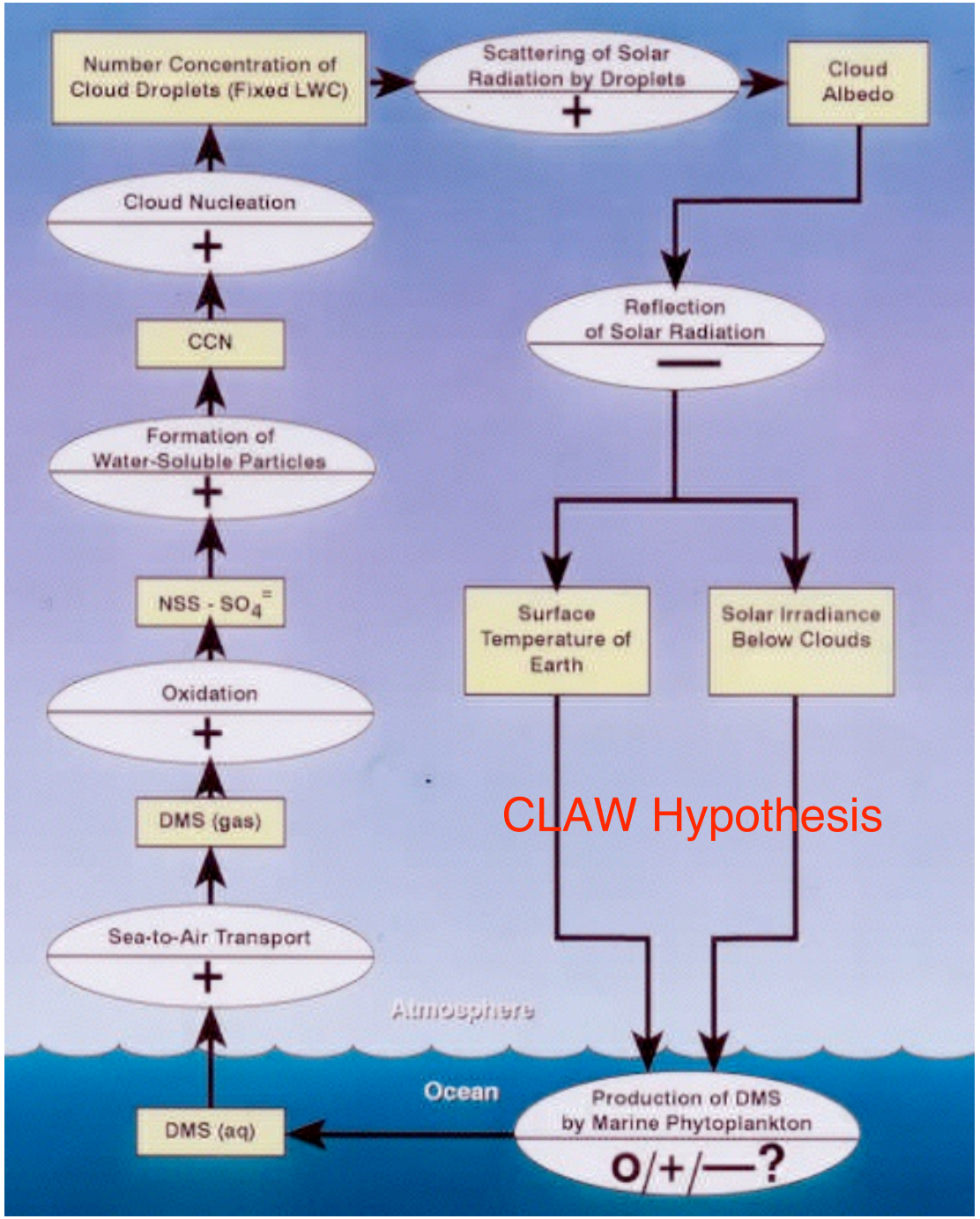


The CLAW Hypothesis

DMS fluxes probably control the growth of aerosols into the CCN size range. These CCN help control the radiative properties of stratocumulus clouds.

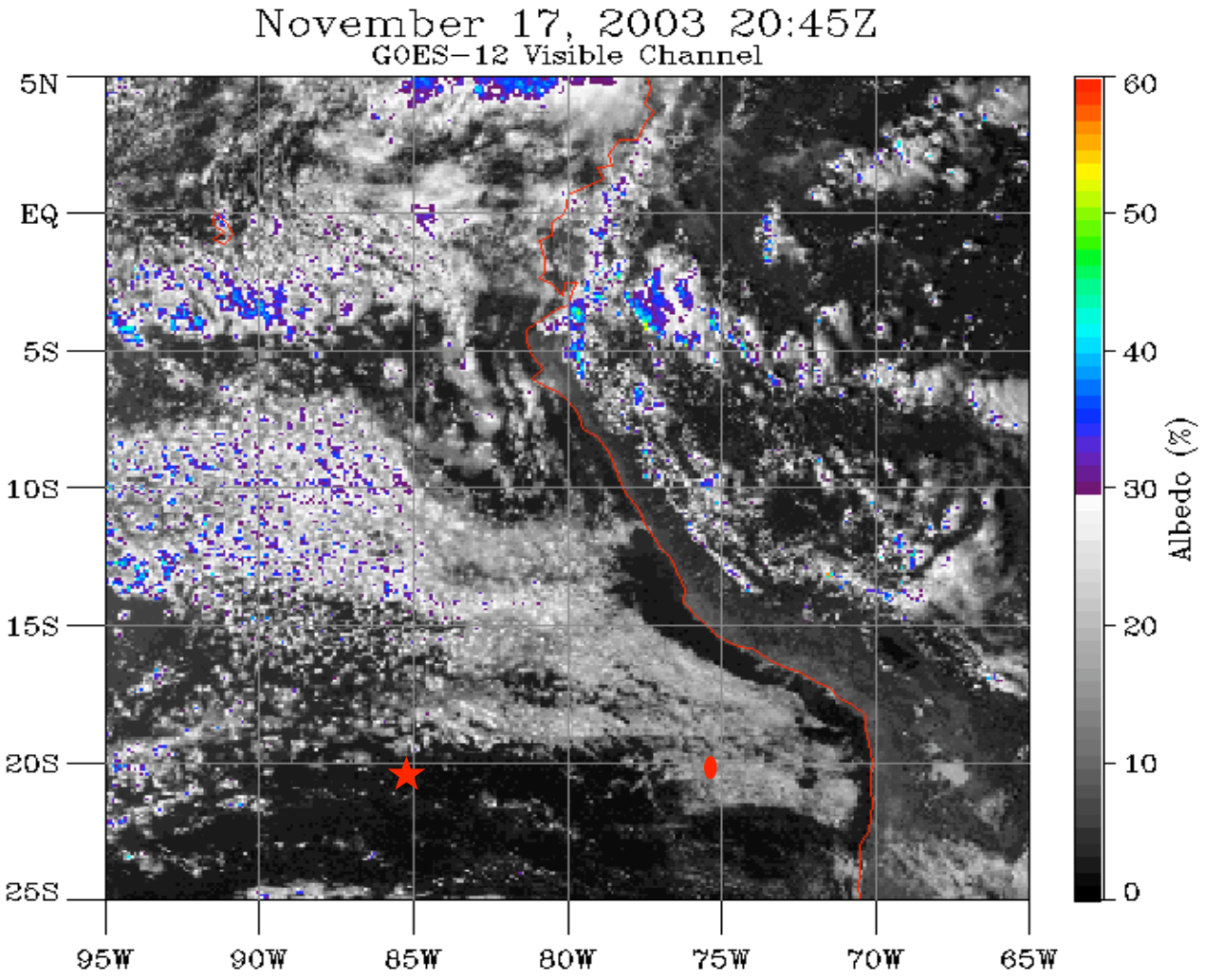
Although CLAW has not been rigorously proven, it is extremely likely that *biological processes are linked to cloud properties via sulfur-containing aerosols*.

Neither can be understood in isolation from the other.



What role do aerosols play in creating these pockets of open cells, POCs?

To improve models of this region, we need to quantify the factors controlling clouds and radiation.



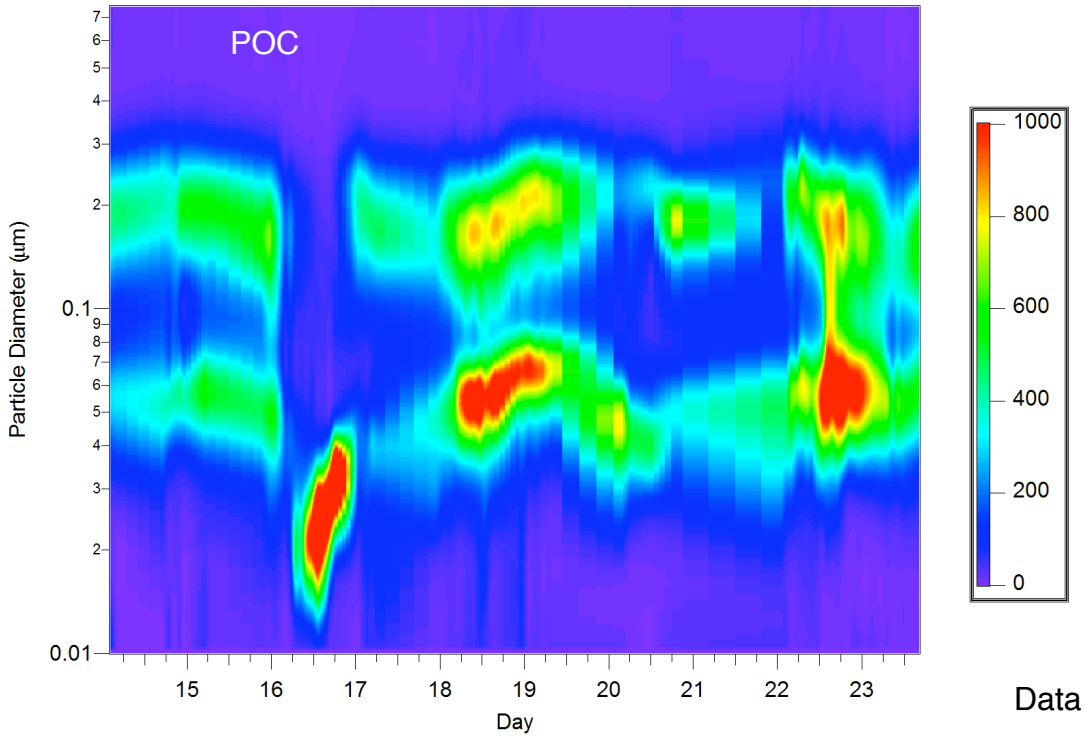
2-300 Wm^{-2} Difference!

This aerosol data from an EPIC cruise shows the loss of aerosols when a POC passes overhead.

Tony Clarke observed this re-growth from freshly-nucleated particles in the Eastern Pacific MBL during PEM-Tropics.

Drizzle Removal > Nucleation > DMS-Controlled Growth is one plausible explanation for several-day POC lifetimes.

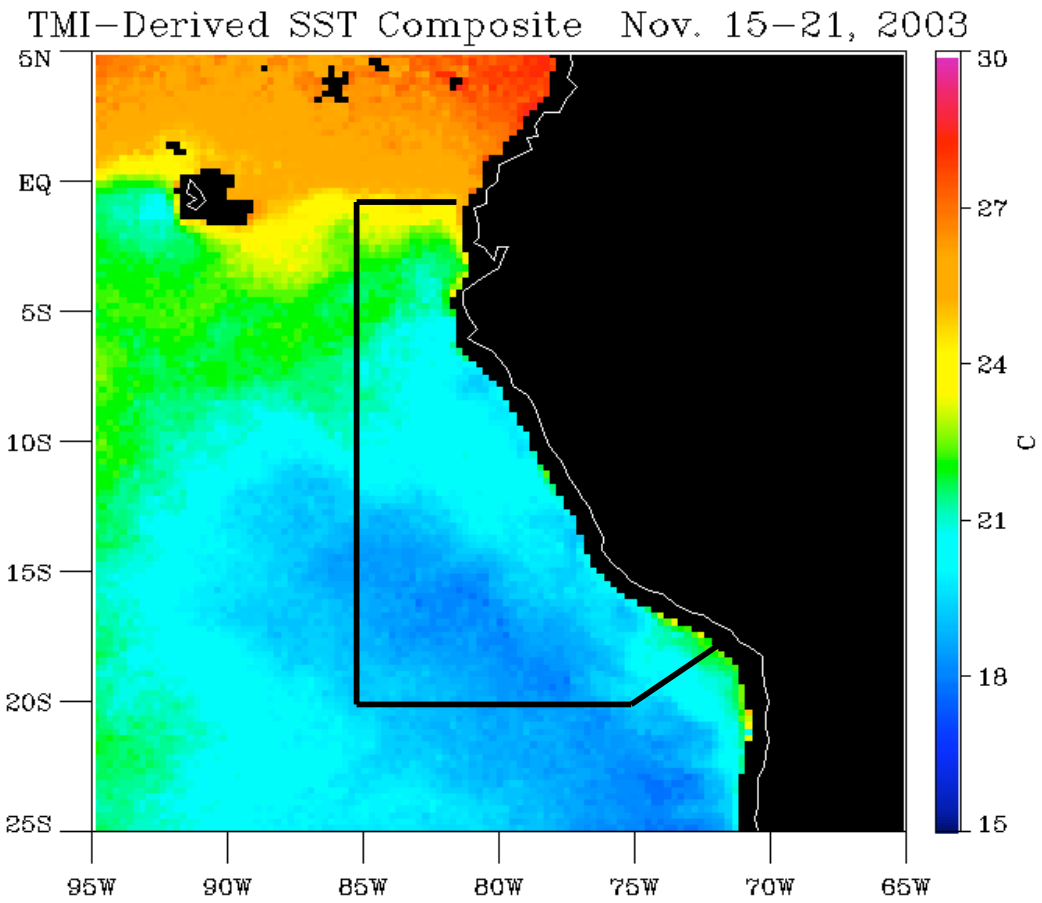
How much of the recovery is from entrainment vs growth?



Data courtesy Fairall & Collins

The upwelling of cold, nutrient rich deep water creates gradients in biological productivity that should translate into gradients of DMS emissions and other .

We can exploit these gradients to study the factors controlling fluxes, aerosol chemistry, and cloud properties.

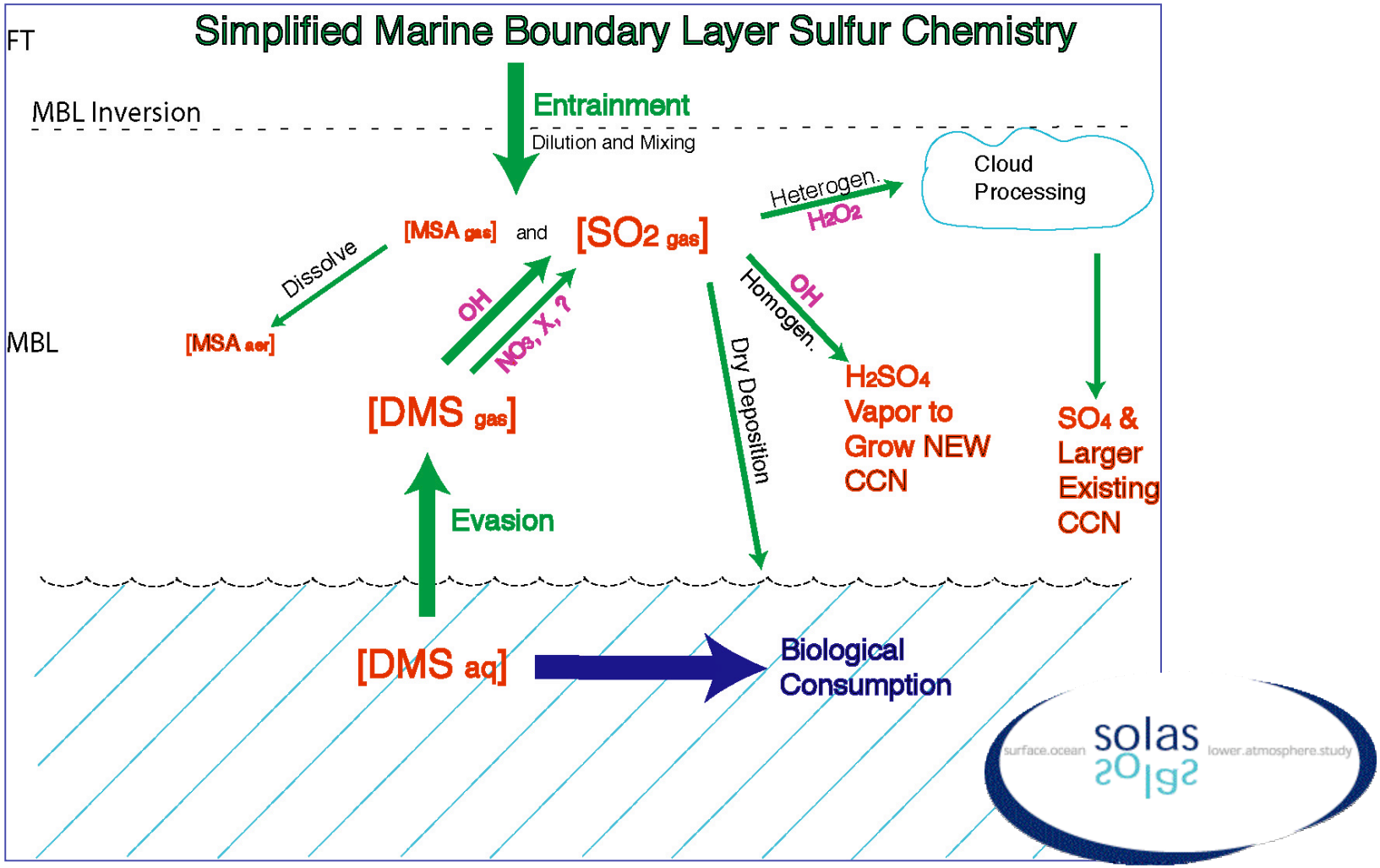


In the remote marine atmosphere the supply of DMS and its oxidation mechanisms limit the rates of new particle nucleation and growth.

These processes probably control the re-filling of POCs with clouds.

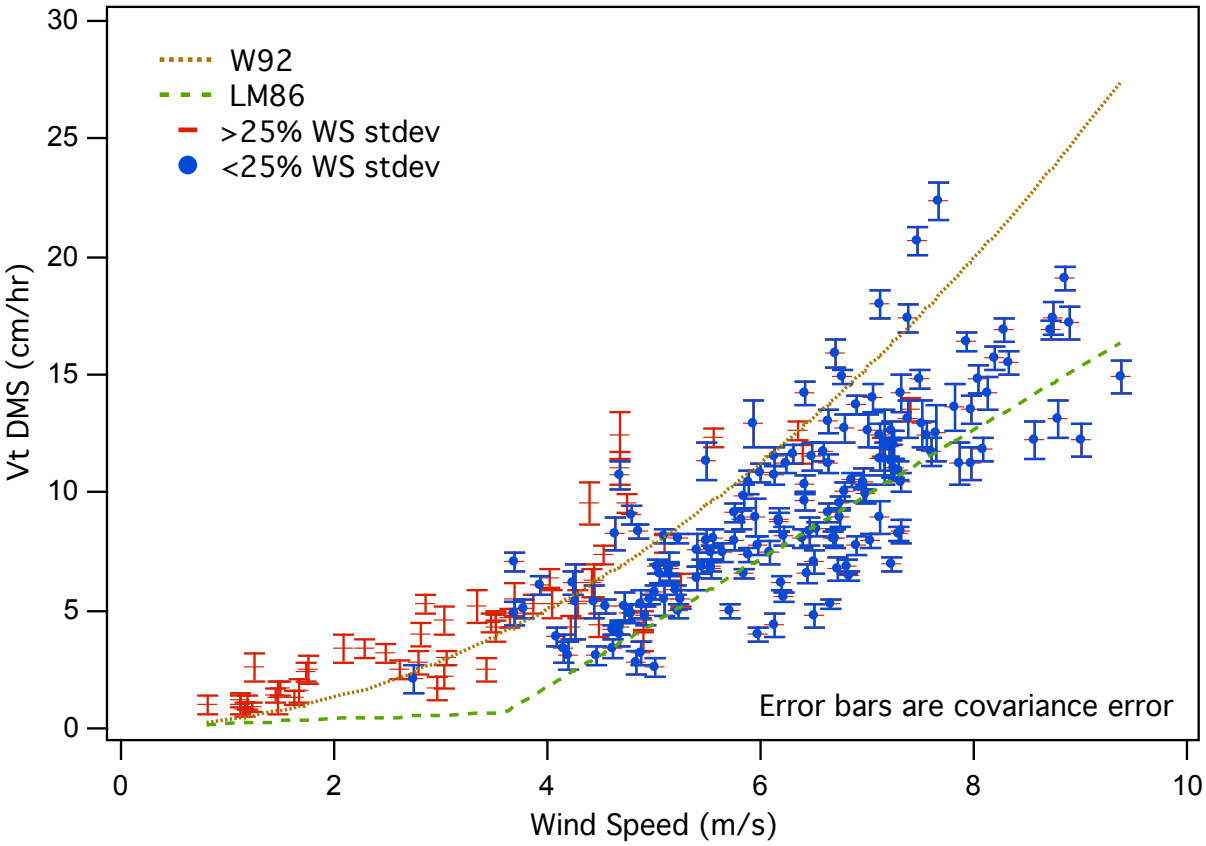
Iodine, ammonia, and organics may also play a role.

We propose to study this chemistry from both ships and aircraft.



Our new ability to directly measure both DMS and SO_2 fluxes (and entrainment rates!) by eddy covariance‡ enables us to constrain the sulfur budget as never before.

By quantifying the fluxes and oxidation rates, we can put reasonable bounds on aerosol growth rates.



Huebert et al., *GRL*, doi: 10.1029/2004GL021567, 2004

‡We are proposing to measure fluxes both from the Ron Brown (time series) and from the C-130 (vertical profiles, across the inversion, and in and out of POCs).

For the CLIVAR/VOCALS Aerosol/Cloud Objectives, what measurements are needed?

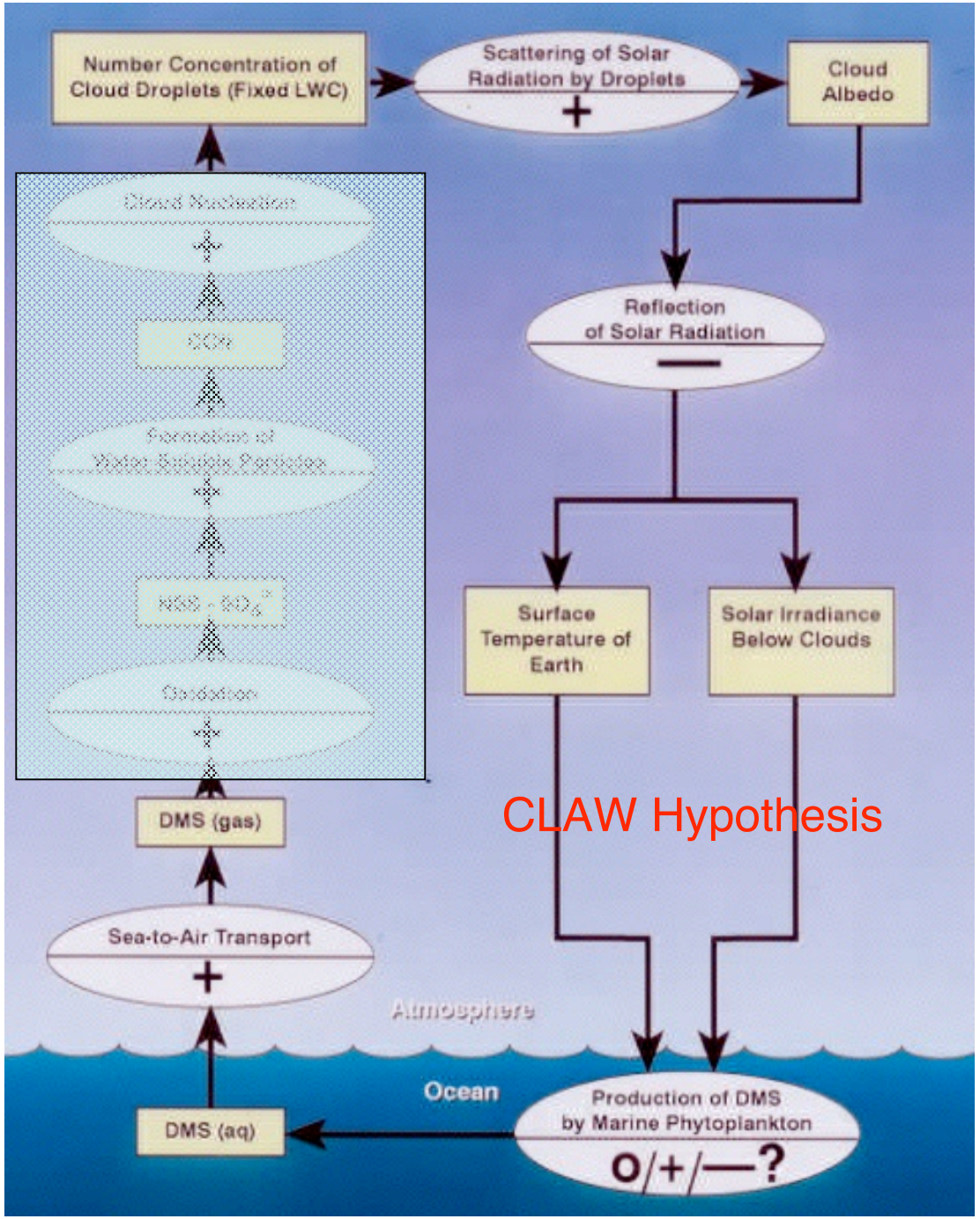
Aerosol temporal and spatial variation scales	Fast measurements to very small sizes, with composition, Lidar
Aerosol Nucleation	Ultrafine CN, SMPS, precursor gases (DMS, SO_2, I?)
Indirect effect sensitivity	Mass and composition vs size (incl. sulfate and organic carbon), CCN
Aerosol vs cloud fraction	Fast number vs size, composition, CVI, CCN
Particle sources and sinks	Precursor gases, sulfate, OC, EC, CW composition

SOLAS: This is an excellent natural laboratory to test the CLAW Hypothesis

Possible SOLAS experiments include examining the impact of POC-driven irradiance changes on SST, productivity, and DMS fluxes, all the unshaded parts of this diagram.

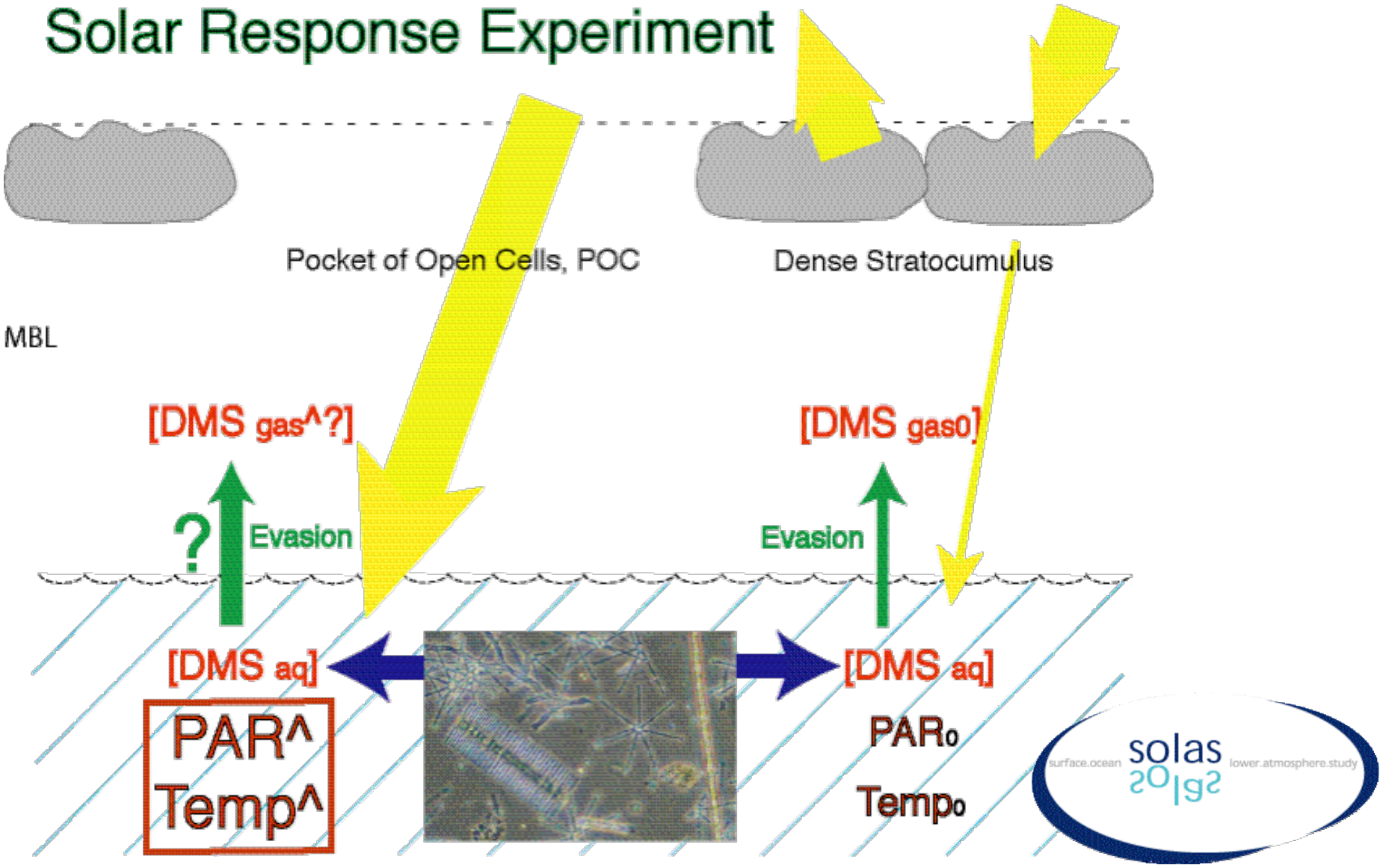
Testing the DMS_{gas} to CCN parts would require Lagrangian observations.

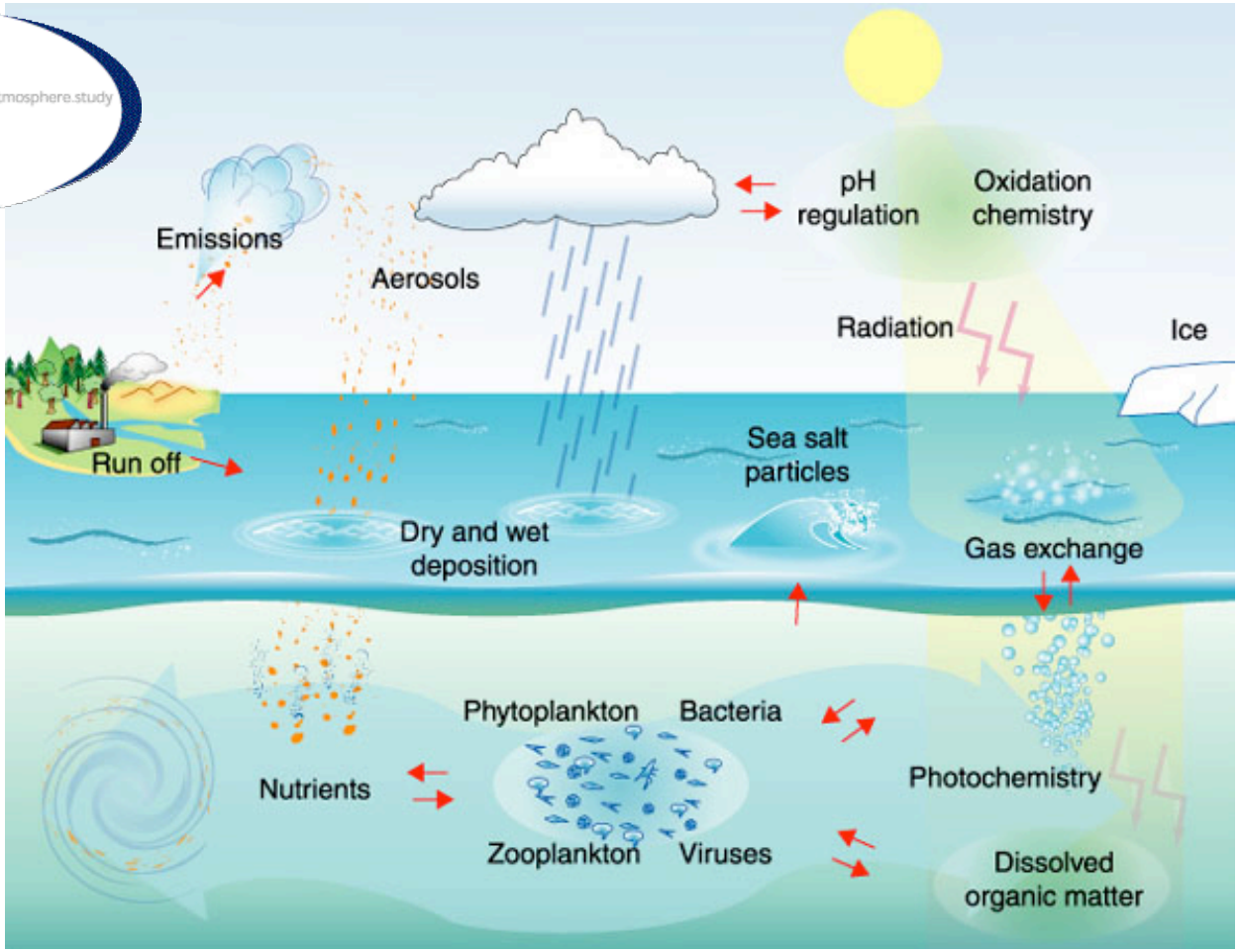
Nature, *326*, 655-661, 1987.



POCs should **change irradiance** (and thus SST) enough to allow a test of the light/temp>biology>DMS emissions parts of the CLAW Hypothesis.

(A SOLAS experiment along these lines might be proposed for 2008 or 2009.)





IGBP's Surface Ocean Lower Atmosphere Study (SOLAS) has formally agreed to collaborate with CLIVAR on VOCALS. http://www.uea.ac.uk/env/solas/

The SEP cloud/radiation system is clearly coupled to the marine biological system via sulfur emissions and aerosol microphysics. We have an opportunity to study them in concert, leveraging the contributions of other programs to make this affordable to the sponsoring agencies.