Key Unknown questions (big missing pieces):

- Nitrification (f-ratio 58%, compared to global average at 23%) – huge amount of nitrification within the euphotic zone. Is this right? How nitrification impacts the f-ratio
- What are the real interactions between sources and sinks (N fixation vs. denitrification)
- Archaebacteria – are they responsible for nitrification in the ocean?
- Denitrification rates of DOM (especially in sediments in continental shelves) – shifts in the C:N due to preferential uptake (N depleted DOM) At what critical concentration would this shift occur?
- Uncertainty of transport of material to depth (particle fluxes – how much C gets below the euphotic zone?)
- Close the new and export production cycle
- Mesopelagic remineralization scales? (Fe, N, nuts, etc)
- Anamox
- We have not really focused on the rates (perhaps not an issue of interaction, but a control on N fixation rate, denitrification, etc). We need to identify rates and making the right measurements (need better controls). Before measuring rates, we need to understand controls. Implications of N fixation? Implications of rates of Denitrification? What the effect is on the system? (controls and so what?)
- Long term change of global warming in different parts of the world?
- Extent of anoxia in the ocean – following the pattern of hypoxia & models, there should be a lot more anoxia in the oceans. But because there are not, there has to be something controlling the extent of the anoxia in the ocean. What is this? Biogeochemical mechanism? Biogeochemical processes that are slowed down because of the hypoxia (slow-down the transition to total anoxia) the Hypoxia Barrier Hypothesis. Why is there a suboxic layer that does not go all the way anoxic?
- There should be a link between particle transport, remineralization and anoxia – need to look at the big picture
- Metal – role of atmospheric deposition on the ocean and submarine (ground water) discharge – vertical sources (terrestrial transport of particulate matter from rivers is important, e.g. Fe)
- Sources of key trace metals, solubility and bioavailability of trace metals
- Connect chemical species in waters relative to biological acquisition strategies
- Nitrogen fixation by single cells (we don't know what happens to N fixation once it happens). *Trichodesmium* is not found in sediment traps, what are the pathways the n fixation is following?
- Atmospheric N deposition to open ocean is comparable to N fixation in the ocean. How does the increase in atmospheric N deposition affect the oceans? Different or similar to biological N?
- Global budgets – the perturbation coming off the continents is enormous and we don't have a good constrain on what is coming into the ocean. We don't even know what's coming in the ocean (we don't see the terrestrial matter on the continental shelf). Perhaps it's an issue of sampling – we don't have a good

constrain on the burial rate for example – we know where a lot of it goes. However, is the bulk really different?

- Phosphorous. Why don't we see so much P limitation when we measure it? Is the way we measure and define limitation is perhaps not what is limiting the biology. Perhaps we need to look at the organism and not what's in the water. Not all is Redfield.
- What about silica? Load ratios (N, P, Si) are changing in coastal areas. Pushing coastal systems into P or Si limitation (e.g. Mississippi plume). Need to constrain these changes.
- What determines the efficiency? Is it just Fe? How is the recycling coupled? What determined stoichiometric ratios?
- What's zero in trace metals? Is pico, nano, etc. effective zero?
- Ultimately, it depends on the kinetics. Turnover time is important, when we think about nutrient limitation, we need to think about turnover times and how they change
- Function of microbial communities – how these processes are coupled and oscillate (connection between processes depending on where and who is in the community)
- Processes like hydrothermal vents, volcanic input of metal
- Community needs to rethink the f-ratio; it is a historical concept that perhaps needs to be revised in light of the new findings. However, it still is a useful concept that will be even more useful as we better define concepts.
- Measurement issues? We need to understand the relationship between what we measure and the interpretations we give to them, e.g. f-ratio
- What is new vs. export production? Is DOM new production? When do you draw the line on what is open and what is coastal? Some of these things need to go together. Active transport by zooplankton (vertical migration of DOM/POM through the water column)
- Need a better understanding of DON linked to processes (chemical characterization, reactivity, etc). DON/DOP slow-released fertilizers? What chunk? As you transition from the coast to open ocean, what is the release rate change? DOM composition?
- What does the rest of the pool of DOM look like? (the one that does not cycle rapidly). Not all DOM is the same, it is environment-specific
- Measurement recommendation – technology issue. The more precise you can make it the better. If we had trustworthy global scale measurements of metals and DOM, we would be able to make connections and inferences, especially in the upper 300m of the water column
- Transient phenomena vs. global phenomena? What dominates? We have a hard time measuring ephemeral responses that may be important
- Role of near-bottom permanent particle resuspension layers? Do they act as significant DOM transformation and remineralization zones? How do these rates important C burial and sequestration?
- Photochemistry between Fe, P and particles. Desorption, absorption and their reaction to light. Transport of material from land to open ocean

- CDOM. CDOM composition in different areas of the ocean, relationships between DOC and CDOM, global scale distribution, platforms to measure CDOM and its relationship between other DOM
- Mapping the space and time scales of two theme questions of the meeting on to the questions being asked, help prioritize the list of current questions.
- Scale of remineralization, supply of nutrients to the euphotic zone. short-time scale ecosystem processes related to nutrient limitation and exchange

WHAT OBSERVATIONS/MODELS NEEDED TO IMPROVE UNDERSTANDING?

- Lack of strategy of linked biogeochemical measuring. We don't have a good schedule to put things into the needed schedule. We need to make global measurements as a community on a timely basis. Lack of continuous remote sensing measurements, like ocean color.
- Regeneration length scales. JGOFS, OCCC, all have recommended this, but has not been addressed. This needs to be looked at ASAP. What does the community need to do to constrain this? The models have already been done. How is the ecosystem going to respond (sinking, regeneration)? Ballast, Temperature, life in the mesopelagic zone, etc. have been looked at somewhat, but just as a start. Need a unified community effort to get more data into the models to produce real predictions. Intensive studies for a short period of time, broad scale studies for a long time (key parameters measured routinely to improve understanding). We need to define what observations we want to do for an extensive time frame (few things done well for a long time). Biogeochemical suite of measurements? The Global ocean observing system should be addressing this. Unfortunately, biogeochemical measurements can't define as specifically as physical measurements the desired scale or necessary improvements. Can we really state what we need to do to address the biogeochemical unknowns?
-