EXport Processes in the Ocean from RemoTe Sensing

EXPORTS
An Opportunity to Help Plan a Major Field Campaign for NASA

Dave Siegel (UCSB), Ken Buesseler (WHOI) and the EXPORTS Science & Implementation Plan Writing Team

(EXPORTS was formally known as COOPEX)
What is NASA Field Campaign?

• Supports NASA science objectives
• Multiple PI’s working on identified science issue
• Can be regional or process focused
• Lead to improvement in remote sensing algorithms, reduction in uncertainties, etc.
• Examples include ICESCAPE, SO-GasEx, LBA, BOREAS, ARC-TAS, SEAC4RS etc.
• Competed field campaigns are new for NASA Ocean Biology & Biogeochemistry program
What Is “The Process”?  

- Scoping studies are competed (via ROSES calls)  
  Identify scientific questions and develop initial study design & implementation concepts  
  Bottom up needs community inputs  

- Science & Implementation Plan is submitted  

- NASA HQ selects one plan from its portfolio  
  Competes a Science Definition Team that recommends a field program implementation  

- If selected, the Field Campaign is competed  

- Key: **Competition & Community Input**
What is EXPORTS?

- **EXport Processes in the Ocean from RemoTe Sensing**

- **Focus:** Surface ocean plankton patterns & the functioning of the biological carbon pump

- First competed scoping study for NASA OBB

- Science & Implementation Plan will be delivered to NASA HQ by February 2014

- If selected, SDT call 2015, EXPORTS ROSES call 2016, Fieldwork starts 2017 (a notional timeline….)
EXPORTS Progress

• Writing team formed in the scoping proposal
  Responsible for completion of the plan
  Behrenfeld, Benitez-Nelson, Boss, Brzezinski, Buesseler, Burd, Carlson, D’Asaro, Doney, Perry, Siegel, Stanley, Steinberg

• June meeting at UCSB addressed Goals, Questions & Experimental Plan (23 invitees)

• Remember, this is a work in progress…
  Inputs are VERY welcome and timely!!
  Talk to those of us here, visit the poster, …
Food web processes transfer organic matter to depth

*pathway for rapid C sequestration*

Quickly remove C from surface ocean

*turn off bio pump & 200 ppmv increase atm. CO₂*

Global C Export estimates range from 5 to ≥20 GtC y⁻¹

*we must do better*
High-Level Objectives

• Field campaign will provide critical information for assessing the biological pump from satellite obs

• Science plan will greatly improve understanding of upper ocean carbon cycle & the functioning of the biological pump

• Implementation plan efficiently addresses science questions by integrating field, satellite & modeling

• Provide path for carbon cycle research for NASA’s Pre-Aerosol-Clouds-Ecosystem (PACE) mission
Overall Goal & Rationale

**Predict the consequences of changing plankton patterns on the strength and efficiency of the biological pump.**

- *Plankton patterns* include food web structure & their spatiotemporal variability
- Recent advances in the remote sensing of plankton patterns (PFT, PSD, etc.) & autonomous in situ tools make achieve our goal possible

**Hypothesis**: The biological pump can be quantified by observing surface ocean plankton patterns
Three Science Questions

1. How do plankton community composition & ecological-physical interactions determine the vertical transfer of organic carbon from the well-lit surface ocean?

2. What controls the efficiency of vertical transfer of organic carbon below the well-lit surface ocean?

3. Can this process-level knowledge be used to reduce uncertainties in contemporary & future estimates of the biological pump?

See the poster for the underlying sub-questions!
High-Level Experimental Approach

• Focus on contrasting states of the biological pump
• Resolve range of conditions (multiple observations)
• Balance scientific returns & project efficiency ($’s)
  – Leverage on-going programs & establish new partners
• Multiscale sampling using BGC proxies to resolve submesoscale process (floats, gliders, ship & satellite)
• Measure the “right things” too (process cruises)
• Integrate modeling (eco/bgc, SMS, process, RS algo)
• Document measurement protocols & uncertainties
Required Observables

- **Phytoplankton** (C stock, size, PFT, NPP, etc.)
- **Particles** (export w/ vertical profile, PSD, sinking rate, rates of turnover, ballast, etc.)
- **Biogeochemistry** ($O_2$, P/DIC, Nuts, P/DOC, etc.)
- **Food Web Interactions** (grazing, fecal flux, sinking particle degradation, energy flow, etc.)
- **Scales** (patch to experimental, trap funnels, etc.)
- **Context** ($R_{rs}(\lambda)$, IOP’s, physics, etc.)
Experimental Plan (1)

- Sample contrasting “states” of the pump
  Dynamic range of sites
  Measure enough states to test predictions
- Choose three sites with fundamentally different ecological energy flows
  HOT (or BATS?): Oligotrophic ocean
  NAtl: Evolving communities following spring bloom
  Station P: Fe-limited ecosystem
Experimental Plan (2)

• Lagrangian following process stations

• Follow particles from production to trap
  Measure export to ~500 m
  Station duration of about 20 days

• Deploy gliders to sample around the process studies (10 to 300 km scale)

• Maintain long-term presence at the sites with gliders, floats & traps (> year)
Autonomous Sampling

• Many parameters are now accessible
  T, S, O₂, Chl, NO₃, POC, IOPs, PSD, export proxy, ...

  Need a plan for inter-calibration

• Lagrangian stations follow well-instrumented mixed layer float

• Gliders sample spatially

• Floats provide long-term context
  Bio-Argo, flux proxy, PSD, spectral irradiance, etc.

• Time series sediment traps between cruises
Draft Process Cruises

• 2 North Atlantic cruises
  – 1 longer (45 d; April-May Bloom) & 1 shorter (30 d; Aug)
  – Leverage PAP time series & potential Intl. collabs.

• 2 Station P cruises
  – Each 30 days to capture 2 BCP states (April/May, Aug)
  – Leverage Line P, OOI assets & NOAA mooring

• 1 HOT/BATS cruise
  – One cruise for 15 days
  – Could supplement existing programs
  – Shakedown cruise…
HOT NE Atl
4 gliders/2 lines 300km
ML float/TS traps/2 gliders <30 km

Floats- BioARGO; PSD; flux; etc.
= process include- 5 multi depth traps, MOCNESS, CTD/Rosette, optics, etc

= deploy

2017 2018 2019

NE Atl
2020 2021 2022

Synthesis & modeling

data process/model

NE Pac

6F 3F 3F
4 gliders/2 lines 300km
ML float/TS traps/2 gliders <30 km

data process/model
Numerical Modeling

• Part of the field campaign plan from the beginning
• Model food web / biological processes that are not easily observable
• Gyre-scale models of eco/bgc
  – provide experimental / climate context
  – test globally ideas generated from the field program
• Apply models that resolve submesoscale physical processes along with eco/bgc processes
• Observing System Simulation Experiment (OSSE)
Next Steps…

• Continue collecting input from the community
  – Visit the poster…
  – Town Hall at 2014 Ocean Sciences Meeting
  – Remember, EXPORTS will be competed…

• Reconcile breadth of science questions, required measurements, number of berths & costs

• Establish the scientific trades with possible de- & re-scope options

• Address required technology developments

• Write the #$%^& report…
Thank you for your attention!!
Q1: How do community composition & ecological-physical interactions determine the vertical transfer of organic carbon from the surface ocean?

- How does plankton community structure set the magnitude and efficiency of export?
- How do the pathways that drive export vary with community structure? (sinking, DOC advection, zoo migration, etc.)
- What are the controls on particle aggregation / disaggregation and how are they related to export?
- How important are submesoscale physical processes in the vertical transport of organic carbon?
Q2: What controls the efficiency of vertical transfer of organic carbon below the surface ocean?

• How does vertical transfer efficiency with depth vary with the pathway of export?

• What regulates the importance of biological and physical processes in controlling export attenuation?

• Are surface ocean C consumption rates related to those below the surface ocean?

• How do changes in the abundance and composition of carrier materials (Si, dust, CaCO$_3$, etc.) influence the remineralization length scale of organic carbon?
Q3: How can this knowledge be used to reduce uncertainties in contemporary & future estimates of the biological pump?

• What surface ocean ecosystem characteristics are required to accurately model the biological pump?
• Do these characteristics change with shifts in food-web structure and/or physical dynamics?
• Can these be determined using satellite observations alone, or are in situ data required too?
• How can the knowledge gained be used to improve our parameterizations of the biological pump under future climate scenarios?