# EXport Processes in the Ocean from RemoTe Sensing

# EXPORTS

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

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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: <u>Competition</u> & <u>Community Input</u>

# 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

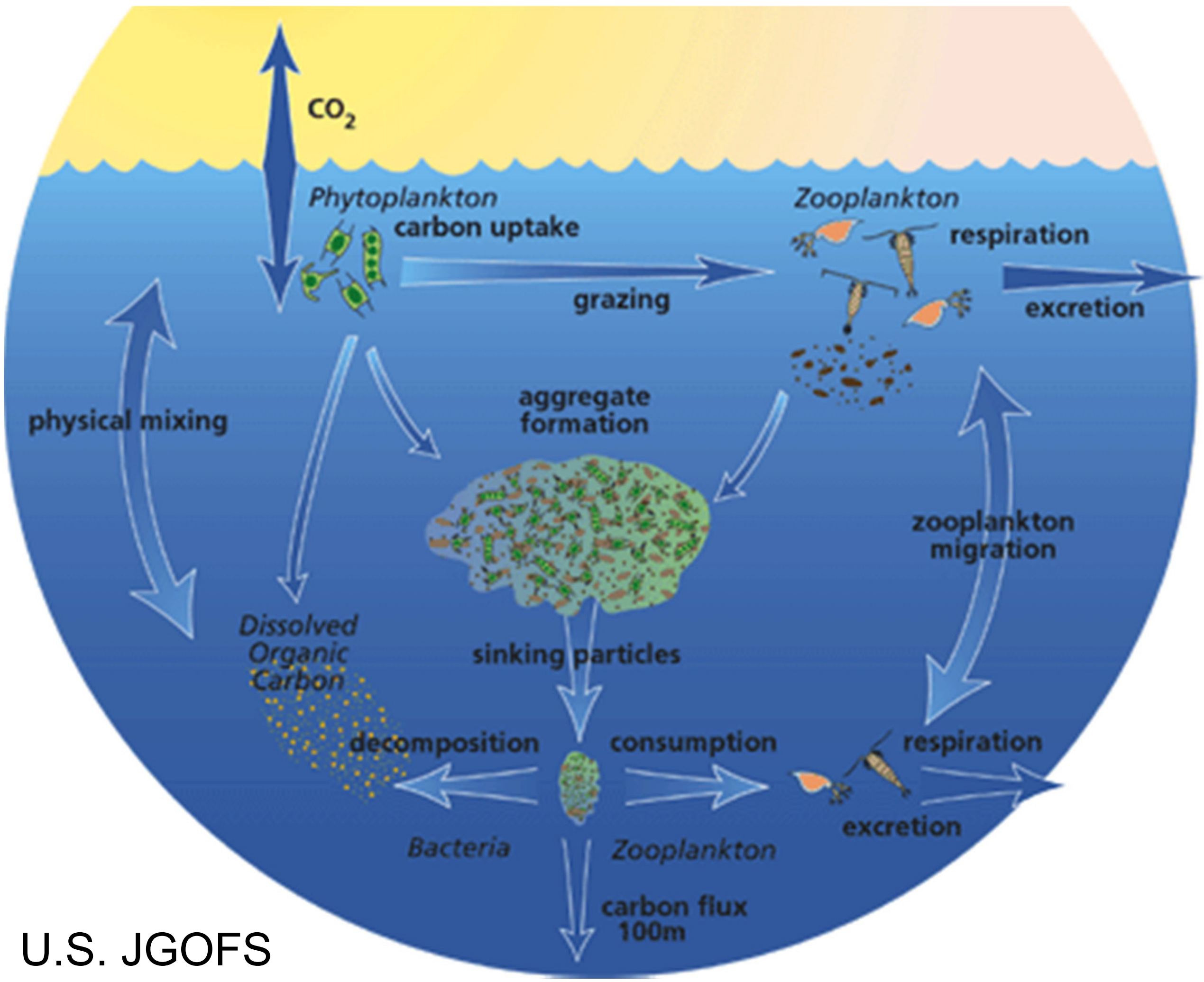
- June meeting at UCSB addressed Goals, Questions & Experimental Plan (23 invitees)

- Remember, this is a work in progress…

  Inputs are VERY welcome and timely!!

  Talk to those of us here, visit the poster, …

# The Biological Pump




U.S. JGOFS

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. $CO_2$*

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

*<u>Predict</u> the consequences of <u>changing plankton patterns</u> on the <u>strength and efficiency</u> 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

<u>Hypothesis</u>: 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

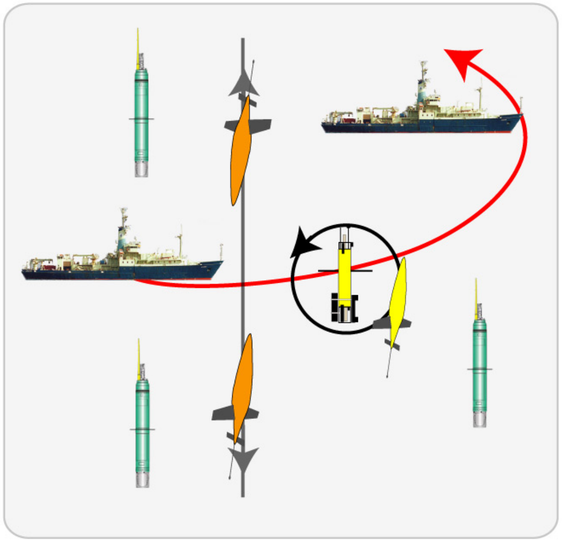
- Deploy gliders to sample around the process studies (10 to 300 km scale)
- Maintain long-term presence at the sites with gliders, floats & traps (> year)

# Autonomous Sampling

- Many parameters are now accessible

  T, S, $O_2$, Chl, $NO_3$, POC, IOPs, PSD, export proxy, …

  Need a plan for inter-calibration



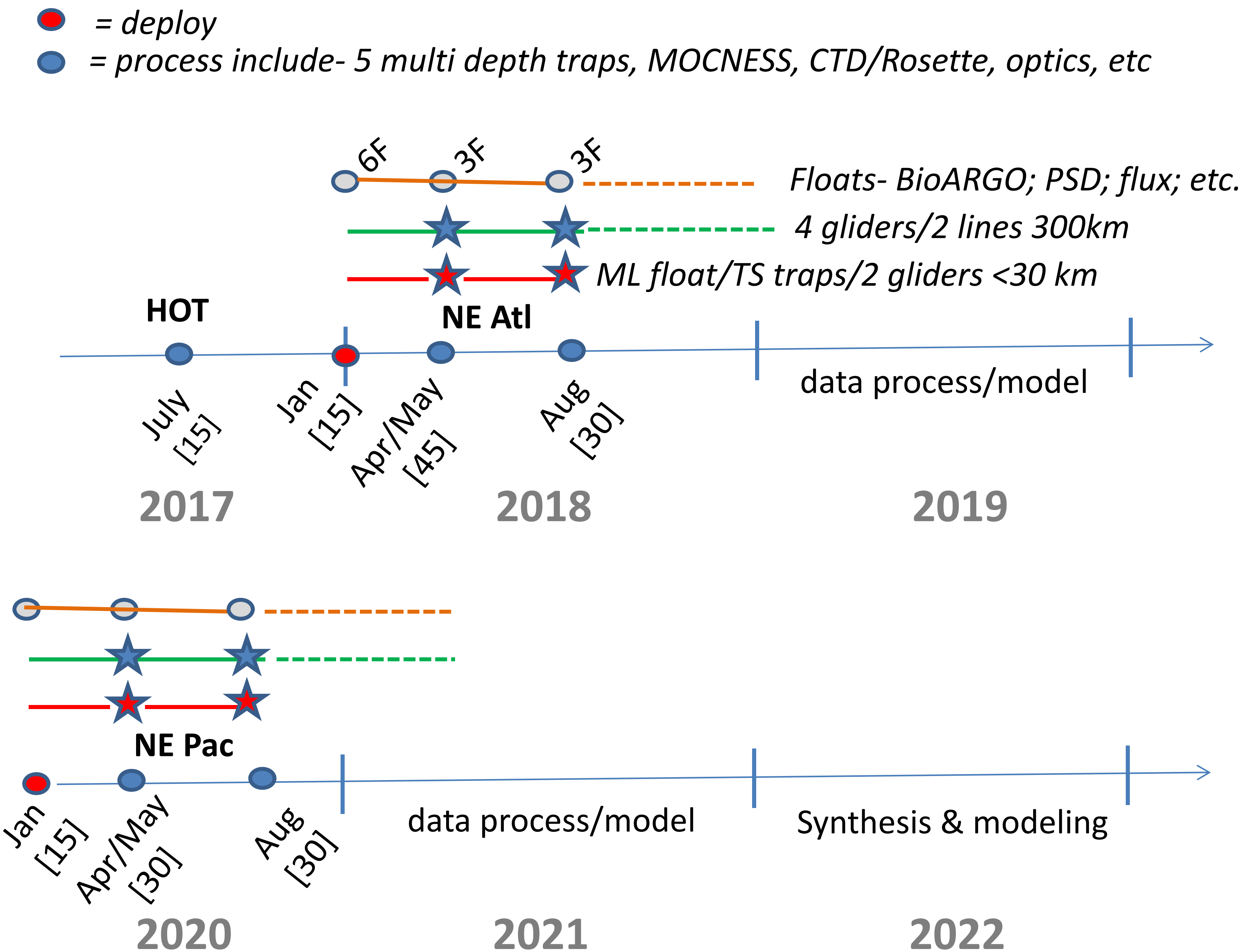
- Lagrangian stations follow well-instrumented mixed layer float
- Gliders sample spatially
- Floats provide long-term context

  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…



= deploy
= process include- 5 multi depth traps, MOCNESS, CTD/Rosette, optics, etc
6F
3F
3F
Floats- BioARGO; PSD; flux; etc.
4 gliders/2 lines 300km
ML float/TS traps/2 gliders <30 km
HOT
NE Atl
data process/model
July [15]
Jan [15]
Apr/May [45]
Aug [30]
2017
2018
2019
NE Pac
data process/model
Synthesis & modeling
Jan [15]
Apr/May [30]
Aug [30]
2020
2021
2022

# 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?