Notes from Breakout 4, Group 1

*(Draft – a new version with more informationon observational will be coming from Uwe soon)*

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We started the breakout with a presentation by Uwe guiding us to discuss geographic framework, overall approach, and some existing observational strategies. In particular, we discussed the geographical framework – whether program should just be about Arctic/subpolar Atlantic or whether it should address issues relevant to all of Atlantic – and we decided on being inclusive to all of Atlantic and the Arctic. We then discussed some approaches for conducting studies, focusing on need to build on existing infrastructure and to combine a range of techniques including observatories, process studies, and modeling.

We next tried to distill the reports we heard earlier this morning from Breakout 3 (key questions/research foci breakout, organized by discipline) and to **look for commonalities between the disciplines**. What are the key concepts that were deemed especially important in multiple different groups of physics, biogeochemistry, foodwebs, and ecosystem health? To that end, we extracted a few keywords from each of the morning’s reports, and then highlighted (in red below) the key concepts that seemed to bridge disciplines and/or were mentioned many times.

* Physics: lateral **exchanges**, vertical processes, deep circulation, shelf-basis interactions, FW processes, **sea ice**, sea level, models.
* Biogeochemistry: **connectivity between basins**, controls, timing, elemental ratios, and human pressures
* Foodweb/Community Structure: **timing**, trophic linkages, **shifting biogeography**
* Ecosystem Health: changing biogeography, resource use and extraction, extreme events, **carbon budgets**, assessment, **human pressures**

We then set out to developing a research trajectory relevant to the changing environment and its consequences. We discussed two potential approaches. One is a “top-down” approach in which we choose a driver, say melting sea ice, freshening of the Arctic or warming of the North Atlantic, and then determine how that driver effects the key concepts noted above, most notably those in red but also all the issues discussed at the meeting. The second approach is a “bottom-up” approach in which we choose some key systems undergoing intriguing change, especially those that are societally relevant, and think about what we need to understand in order to be able to explain the observable changes and predict future changes. We chose this bottom-up approach, and came up with three potential topics but by no means feel our list was exhaustive. The three topics were (1) anthropogenic CO­2 uptake, (2) shifting distribution of fish (i.e. changing biogeography), and (3) expanding oxygen minimum zones.

We decided to first tackle the shifting distribution of fish. What is causing the shift in biogeography of fish? How can we predict it? A lot is known about fish assessment at the moment but it is still not possible to predict what will happen to a given fish population in 20 years. To understand fish biogeography and its changes, we need to understand what causes patterns in primary productivity, how timing affects these patterns, what the biogeochemical environment is, what the physical environment is, etc. So **what would the research trajectory be?** We will need observations, models, and synthesis of the factors that scientists think determine fish population’s spatial extent and magnitude.

**What fish to choose?** Depending on which species we focus on, we could tie into both sides of the Atlantic, i.e. study the impact of different source waters – for example, tuna spend some time on both sides of the Atlantic so they may be affected by what is being transported from the Arctic into the Atlantic and perhaps (we weren’t sure at all about this point), affect what is being transported from Atlantic into the Arctic. Do we want Eulerian fish or Lagrangian fish? Namely, should we choose to study fish that stay put in a given region and therefore might be sentinels of change in that region or fish that migrate and could be signs of what is happening in a larger domain? Should we choose fish from two different regions, perhaps contrasting a fish species who spent most of its time on West coast of Atlantic, say in the Norwegian Sea, vs. one that is more East coast based, such as a species from the Labrador or Irminger sea.

**What kind of sustained observations do we need?** We would need ship surveys and process studies, autonomous systems (moorings with backscatter), and an ocean tracking network. We were told that much data exists already on fish stocks, making this an excellent opportunity for leveraging existing resourcing. **What kind of modeling?** We would need to incorporate in the model physics, biogeochemistry, fish behavior, prey resources such as zooplankton and phytoplankton and the relationships between all those variables. In particular, it was noted that a significant research gap is that very high resolution models are required in order to capture patchiness that is relevant to fish. We need to know how to model (and thus conceptually understand) how changes in one of these variables affects another. **What kind of process studies?** We would need process studies to understand the tiebacks between fish and zooplankton, phytoplankton, primary production, stratification, temperature changes, etc. These interactions in turn are affected by the coupling of the North Atlantic/Arctic system, e.g., to melting of sea ice, Arctic freshening, coupled ocean-atmosphere-ice feedbacks affecting the circulation, North Atlantic warming, and so on. Thus the key concepts, marked in red above, all emerged from our discussion of how we would tackle this societally relevant problem.

 We finished up with a brief discussion of a second topic – anthropogenic CO­2 storage. Within the 7 minutes left, we only highlighted the main issues. Namely, in order to understand and predict anthropogenic CO2 storage, we need to be able to observe and understand phytoplankton dynamics, rates of productivity, higher trophic levels, stratification and circulation. These in turn come back to issues of connectivity between basins, freshwater input, etc. Thus though the system undergoing change is very different in this case than in the biogeography of fish case, the ultimate factors underpinning the ability to predict effects of climate change and human pressures end up being similar.

In summary, instead of providing an exhaustive (shopping) list of the possible topics for a research plan, we are offering as a template “bottom-up” approaches that can be used to unify the key concepts listed in breakout 3 as well as to motivate the work by clearly showing its links to human pressures and societally relevant problems.