Full Breakout Report
"Shift in Biome Seasonality"
Breakout Session IV - Impacts and Consequences of Global Change
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Key items discussed:

In general, the role of climate change and human impacts on seasonal biome shifts (length of growing seasons; disrupted seasonal cycles; inter-annual trends) were the focus of this breakout. An understanding of seasonal patterns in terrestrial vegetation activity is useful for land surface monitoring, change analysis, impacts assessment, modeling (carbon, water, nutrients, weather, climate, land use, habitat), and ecological forecasting. An Introduction of the breakout was given by **Alfredo Huete**, followed by 2 ocean talks and 2 land talks. Huete presented examples by Kevin Arrigo on arctic sea ice and longer growing seasons; Jorge Sarmiento's work on light and nutrient limitations on seasonality; Ranga Myneni's work on northern latitude longer growing seasons; and Alfredo Huete's work on greening in the Amazon with increased availability of light and the positive response of the Amazon forests during the 2005 drought (light limiting).

Ocean presentations:

Andrew Irwin and Matt Oliver presented "*Seasonal and Inter-annual changes in Marine Biogeographic Provinces",* that emphasized ocean biologic dynamics, a departure from the pre-existing concept of static biogeographic provinces. Current efforts are aimed at understanding the significance of seasonal and inter-annual trends that have been observed over the different province areas, e.g., strong seasonality has been observed in Gyres, while interannual trends in total carbon fixation is increasing within the Gyres, but decreasing in the tropical seas.

Mike Hiscock et al., presented on "*Biomes in satellite ocean color data",* in which the question of why there is interest to divide the ocean into biomes. It was noted that setting spatial bounds to ecosystems is an essential step towards their quantitative study and that the area within which each characteristic ecosystem may be expected to occur is important to assess.

Findings: "The distribution of characteristic marine ecosystems is predictable from a few ecological principles, a simple understanding of regional oceanography and an elementary knowledge of the ocean's geographical features".

Recent biome maps are based on clustering of SeaWiFS chlorophyll and carbon measurements. The K-means clustering on standard deviation of carbon and mean chlorophyll works effectively in generating biome maps.

-Biomes separate ocean into dynamic and stable regimes

-Dynamic regimes (high latitudes) are light limited and require stratification for increased chlorophyll
-Stable regions (gyres) are nutrient limited and require mixing for increased chlorophyll
-In low latitudes, distance from source of nutrients (either equatorial upwelling or gyre edge) determines chlorophyll
-In variable (high lat) regions, high productivity a result of shut-down of system in winter, due to light limitation
-In stable (low lat) regions, no "reset" of the system (because no light lim), results in nutrient limitation

Land presentations

Geoff Henebry gave a talk entitled, "*Some Thoughts on Shifts in Biome Seasonality*". This discussion covered several issues of terminology, definitions, and approaches that continue to cause confusion among the use and study of seasonality and phenology. The term "phenology" is often used interchangeably with seasonality, however, phenology is generally defined as the study of the timing of recurring biological events, the causes of their timing, their relationship to biotic and abiotic forces, and the inter-relations among phases of the same or different species. Whereas phenology has traditional been linked to species, Land Surface Phenologies (LSPs) are the seasonal spatio-temporal patterns of the vegetated land surface.

Additional comments and discussion were made:

- There are strong latitudinal & altitudinal controls on LSPs, including climate/ atmospheric modulation (ENSO, NAM, PDO, etc.)
- Human modulation of biome seasonality (land use change, agriculture management, pollution, invasive & introduced species, etc.) is important. As an example, changes in LSP following the collapse of the Soviet Union were not uniform across Kazakhstan.
- The aquatic aspects of phenology/seasonality are important over land, and there are commonalities of aquatic with terrestrial phenologies and/or seasonalities.
- There is a NASA Community White Paper on "Phenology" (Friedl et al. 2006) that describes the concept of LSPs and stresses that LSPs are intrinsically mixtures of biotic & abiotic signals,
- There is a land surface phenology variable intercomparison activity on-going, initiated by Michael White (Utah State University) and Kirsten de Beurs (Virginia Tech University)

Xiaoyang Zhang presented a talk entitled, "*Satellite-Based Shift in Vegetation Seasonality*"**.** He discussed various aspects and controls on forest tree canopy seasonality, including temperature and soil moisture controls. He presented results demonstrating the temperature effect on the shift of biome seasonality; the rainfall effect on shifts of biome seasonality; and the effect of human activity (e.g., agriculture, urban heat islands) on biome seasonality. Also discussed were issues of mixed biome seasonality, selection of appropriate temporal composite data, and use of fine with moderate resolution imagery for improving phenology detection, such as spring phenology assessments in northern Wisconsin.

Overall Needs and Recommendations

1. Need for in-situ observations, particularly those providing frequent time series seasonal information (towers, web cams, 'citizen science', moving platforms, fisheries data, new cost-effective sensors & technologies)
2. Satellite vs. surface intercomparisons with respect to seasonality
3. Need for long-term inter-comparability of multiple sensor time series datasets.
4. Integration of fine and moderate resolution sensors (scaling)
5. Integration of passive, active, geostationary satellite data
6. More attention needs to be place upon human modulations of seasonality/ phenology.
7. Need coordinate long-term) measurements on the ground (or water) to link to satellites.
8. Need for standardization of methods for detecting biome seasonality and detection methods (e.g., vegetation index).
9. There is a need to blend data streams from multiple sensors/platforms (active and passive microwave, thermal and mid-IR (3-5 μm), geostationary optical, polar orbiting optical), in order to develop a comprehensive suite for characterizing surface phenologies & seasonalities in different biomes.

List of Challenging Questions:

1. What are the nominal (baseline) variations in biome seasonality
2. What are the controls in biome seasonality? (climate, human activities, nutrients)
3. Can we identify land - ocean seasonal interactions (lags)?
4. What are the mechanisms and drivers of change/ shifts in seasonality observed from satellites? (stress agents, multiple stressors). We see correlations in satellite signals to "seasonality", but there is a lack of understand of the mechanisms involved?
5. What are the *resiliences* of biomes to change?
6. What are thresholds to abrupt changes in seasonality? (extreme events, fire, plants damaged by spring freeze, insects, and hurricanes)
7. What are the potential impacts of biome seasonal shifts on biodiversity, carbon/water cycling, climate, etc..
8. How do we interpret satellite signals? Are finding trends enough?
9. What are the downstream inter-annual temporal effects of in-season changes? And are there non-linear issues?
10. How to Monitor Biome Seasonality in Real Time with, e.g., geostationary satellites.
11. What are appropriate methods to characterize "shifts" and assess their significance?
12. What are appropriate spatial and temporal units for characterizing seasonality? (calendar time, compositing period, thermal time).