INTRODUCTION

This article attempts to explain several interacting physical climatic and ecological processes that play critical roles in maintaining Earth's ecological support systems, particularly those related to fish and fisheries. Always necessary for studies of complex systems are reasonable monitoring schemes, operated for sufficiently long periods so that they capture the full system dynamics. For example, there are few long-term observations that provide time series that cover more than one or two complete rise and fall cycle for the fisheries involved. Even fewer are accompanied by observations of the forcing system(s) that directly or indirectly affect them. This last problem determines the limits of our capabilities to forecast ecological changes. Rarely is the necessary data available to avoid "surprises", simply because our observation systems are so young, our time series so short, and our measurements so local, despite the recent emergence of observing satellites.

Earth's most widely observed Physical Dynamics start with surface wind measurements. These typically reflect Earth's relative temperature gradients, regional and over-all. Usual regional seasonal patterns are somewhat similar on decadal and longer climatological scales. The shortest term perturbations of expected climate are associated with El Niño Southern Oscillation (ENSO) scale atmospheric dynamics or with volcanic activity. Volcanoes eject gases and particles into the upper atmosphere. These form long-lived, reflective clouds that generally cause cooling under them. Both volcanoes and ENSO Events impose unique signatures on seasonal weather. Both are defined as Climate Change.

All of the processes that are related here started long before humans existed, and will likely persist long after we have gone. Ecosystem processes in part regulate themselves. They are also strongly influenced by physical forcing processes that drive the Earth's atmosphere and oceans, hence most human activities.

Providing adequate protein is a paramount goal if humanity is to be sustained within these constantly changing conditions. The oceans, large lakes, and connecting waterways provide the majority of protein for human consumption. Hence our focus on the ebb and flow of the aquatic ecosystems and fisheries within the larger context of Earth's System Dynamics. The main points will be illustrated using analyses of several regional fisheries activities, recognizing the increasing influences of fishing and non-fishing activities on humanity's major protein food supply as humanity expands, and changes the world's waterways and shorelines. Core concepts about the major natural factors that force aquatic ecosystems are "melded" within a larger whole. Various insights and concepts are generally attributed to their originators, while still maintaining cause-and-effect links necessary to understand the interdependencies.

The following points will be discussed: (1) Earth's recent million years of climate variation, from paleoclimate research; (2) fisheries variability, as understand from a century of in-depth research and analysis of various proxies, in particular, bioindicators; (3) the basics of the solar irradiance information from the satellite generation; followed up with Hoyt and Schatten's estimation of solar variations over the last few centuries; (4) introduce climate forecasts by Doug Hoyt, Werner Mende, and others as brought together by Dr Joseph Fletcher in a recent lecture series on Climate of the twenty-first century. The decadal to centennial future casts are supported by Klyashtorin and Nikolaev's recent look into forecasting fisheries regimes from monitoring Earth's rotation rate (-LOD); and finally, (5) a brief review of regional fisheries responses to likely climate change as inferred from the previously described work. These discussions will be interpreted regionally from a meld of all these studies, employing insights from Marcel Leroux's (1998) climate-system concepts, and the lead author's penchant for integration and describing connections from recent efforts to explain decadal to century-term ecological variations leading to fisheries variations. These descriptions will introduce readers to important results of emergent environmental and geophysical science.

The fundamental message promoted herein is about coping with constant change. The larger picture that results from these collaborations is intended to help laymen and scientists alike to refocus their objectives within our Solar-System and our own Earth's Grand Fugue in which humans hold so many instruments, but… alas, not the Time-Keeper's baton.

1. GLOBAL CHANGE VS GLOBAL WARMING – ISSUES

Climate is the result of the exchange of heat and mass between the land, ocean, atmosphere, polar regions (ice sheets) and space. Barnett, Pierce and Schnur (2001) point out that "A major component of the global climate system is the oceans; covering roughly 72 percent of the planet's surface, they have the thermal inertia and heat capacity to help maintain and ameliorate climate variability. Although the surface temperature of the oceans has been used in detection and attribution studies, apparently no attempt has been made to use changes in temperature at depth. A recent observational study (Levitus *et al.* 2000) has shown that the heat content of the upper ocean has been increasing over the last 45 years in all the world's oceans, although the warming rate varies considerably among different ocean basins." Barnett, Pierce and Schnur (2001) also point out that "... a climate model that reproduces the observed change in global air temperature over the last 50 years, but fails to quantitatively reproduce the observed changed in ocean heat content, cannot be correct", thereby providing fuel for the arguments against the recent and early reports of the Intergovernmental Panel on Climate Change, (IPCC 1990, 1996 and IPCC 2001) and modeling future climate scenarios choosing to emphasize anthropogenic greenhouse gas forcing to explain the recent 150 years of Earth's surface warming.

German researchers Zorita and Gonzalez-Rouco (2000) compared the Arctic Oscillation (AO) in two sophisticated state-of-the-art Global Climate Models (GCM). That particular oscillation is important because it is strongly related to winter climate in the Northern Hemisphere, and some of the world's more productive fisheries. When the AO is strong, for example, Eurasia has milder-than-normal winters, and west African pelagic fisheries thrive. They then compared AO forecasts using two models: the Hadley Center GCM and the Max-Planck Institute of Meteorology model. First, both models agree with each other in reproducing the mean Northern Hemisphere winter circulation patterns, and their variability. But when the models are forced by increasing greenhouse gas levels, these model predict different AO trends that should also impact the simulated regional air-temperature change. A negative AO trend should weaken the [predicted] temperature increases over Eurasia and Southeastern USA and reinforce temperature increases over Greenland and Western Canada; positive trends should show opposite tendencies. They conclude, "the predictions of the intensities of the main patterns of atmospheric circulation, even at planetary scales, are either not yet reliable or they depend strongly on internal model variability."

Similarly, Giorgi and Francisco (2000) assembled the output of five different GCMs for 23 terrestrial regions across the globe and compared model predictions for temperature and precipitation for the years 2070–2099 relative to the 1961–1990 baseline period. First, they determined how good each model was at reproducing the 1961–1990 baseline climate. This latter comparison is very important, for if the models fail to reproduce current climate, then what they say about the future is irrelevant. They found that some models were pretty close to the base observations (no error) in some regions, but data points were quite scattered about the mean. In some cases the temperature errors were more than 5ºC. Some precipitation errors approached 200 percent but most were generally less than 100 percent, at least from June to August. No one model does much better than any other across all regions. Given their inability to map present conditions, it is not worthwhile to consider model projections as valid for the future. At present, GCMs provide little information about either future general circulation, or oceanic responses.

The present document is not intended as one more redundant refutation of the IPCC's Global Warming scenarios, but is intended to help others recognize the larger scale climate forcing that has been recorded in natural systems. Such records have been extracted from laminated sediments, ice cores, and a variety of other sources such as tree rings and corals, located in diverse environments over the globe. For example, in the same volume as the previously referenced Barnett, Pierce and Schnur (2001) article, Zachos *et al*. (2001) showed climate and ocean carbon chemistry variances were concentrated at all Milankovitch frequencies (see Glossary), reflecting various Solar System forces that modify Earth's annual orbits around the sun, as the sun's dominant gravitational forces drag our Solar System along it's path through space.

Zachos *et al*. (2001) performed spectral analyses on an uninterrupted 5.5-million-year chronology of the late Oligocene – early Miocene from two deep-sea cores. These cores were recovered in the western equatorial Atlantic. They revealed climate-related spectral power recorded at the 406 000-year period eccentricity band over a 3.4-million-year period (20 to 23.4 million years ago) as well as in the 125– and 95–1 000 year bands over a 1.3-million-year period (21.7 to 23 million years ago). Moreover, a major transient glaciation at the epoch boundary (~23 million years), Mi-1, corresponds with a rare orbital congruence involving obliquity and eccentricity of Earth's orbit about the sun. The anomaly, which consists of low-amplitude variance in obliquity (a node) and a minimum in eccentricity, results in an extended period (~200 000 years) of low seasonality orbits favourable to ice-sheet expansion on Antarctica.

Why should such ancient records and processes be of relevance to our futurecast? The most important thing to remember as we move through time and space is that *change is the rule*. Stability is unlikely at almost any scale – given the hierarchy of external forcing, the transfer of energy and momentum between these external forces and Earth's atmosphere, oceans, and internal structures. And, more importantly, if a pattern of change related to the behaviour of Earth within the larger solar system has happened before, it its likely to re-occur. The message form these paleo-studies' is that the climate patterns are repetitive, hence they provide regional process and consequence forecasts via historical analogy. That concept is the basis for what follows, and why there are extensive descriptions of relevant studies.

1.1 The big picture

First, it must be accepted that Earth is a warm, wet planet that has undergone a complex series of changes that initiated and evolved life, under a sequence of very different conditions. These, in turn, led to such dramatic changes as to successively destroy many of the resultant species. The first such dramatic environmental crisis occurred millions of years after the initial sulfur-fixing bacteria became dominant life forms. Carbon dioxide-fixing photosynthetic life forms eventually evolved, and began shedding oxygen as a result of their night or dark time metabolism, creating an oxygen rich atmosphere that was not just toxic, but “poisonous” to innumerable susceptible species. Today, there are many oxygen sensitive anaerobes that survive, that still perform important roles in Earth’s ecosystems, included amongst our own and other animal’s intestinal flora, where these symbiont bacteria convert an array of carbohydrate chemical forms such as cellulose and complex sugars into various soluble compounds that sustain us. Methane, CO_2 and water are the result of any metabolic work that gets done by us and our symbionts.

Nitrogen fixation was the next step toward a productive interactive ecology, as the resource that provides the building blocks for proteins. Given the naturally high levels of nitrogen in Earth’s atmosphere, it turns out that carbon dioxide is the limiting factor in ecological production, and as such, any extra CO_2 steps up plant production, and “greens” our world, producing both more carbohydrate food stuff, as well as more oxygen. Extra CO_2 is not a big problem, despite the news media rhetoric (c.f. Idso 1982). Many colonial ocean species, such as Coccolithophores, incorporate CO_2 into their shell structures, and as they sink to the ocean floor, and over time they can build up to form remarkable geomorphological features, e.g. the White Cliffs of Dover. Plant and animal carbon can also be stored as coal beds, or in petroleum fields, given adequate time and climatic conditions. Nor is carbon dioxide the only limiting chemical element in bio-productivity. Martin, Gordon and Fitzwater (1991) pointed out that iron can be limiting to primary and secondary production in the oceans. Iron is made available in the upper ocean via offshore winds, volcanism, or from disturbed sediments and resurfaced via strong turbulence.

Next, it must be understood that the Earth’s heat budget is controlled by two distinct processes. There is a continuous loss of heat at the poles, and similarly, nearly continuous heat absorption into the equatorial regions, particularly the oceans – both modulated by cloud cover dynamics. The resulting energy dynamics across the planet are manifested in the interplay of atmospheric moisture (i.e. clouds and cloud types, and various forms of precipitation), ground-level heating and cooling, and ocean motion. These all interact with different inbound and outbound portions of the electromagnetic energy spectra. It is only from the most recent generations of orbiting satellites that there is now a more complete view of the Earth’s heat dynamics. It must also never be forgotten that the upper few meters of the ocean contains more thermal energy than the entire atmosphere. Also, the majority of atmospheric energy is located within a few thousand meters of the Earth’s surface. In fact, you can think of the Earth as a warm ball, covered by thin fuzzy warm fluid layers, with two cold poles. All the heat/energy flows follow stringent physical Laws of Thermodynamics, which humans cannot perturb.

History provides clear evidence that a warm wet world is optimal for humans. Societies can be distinguished by their abilities to cope, or not, with the Earth System changes of the recent 3–4 million years. Dependencies have shifted continuously, in order to survive. There are no guarantees that we can continue along our present growth pattern, particularly as habitats are altered and other resource bases that have provided options in the past. The obligation to manage our growth and competitive interactions is too often ignored while some place blame for misfortune on wrong causes. Denial is one of humanity’s worst personality traits.

Figures 1a to 1c show that the Earth is more often than not, a warm, wet planet, providing for the array of habitats and species that have been used to support human development. Another important fact is that all extant species evolved and adapted within these same climate dynamics. The more mobile and adaptable species are most likely to survive any future climate dynamics, while locally adapted species with lesser capabilities to move from location to location as their habitats are overlain by new climate conditions are most likely to be lost – to go extinct.

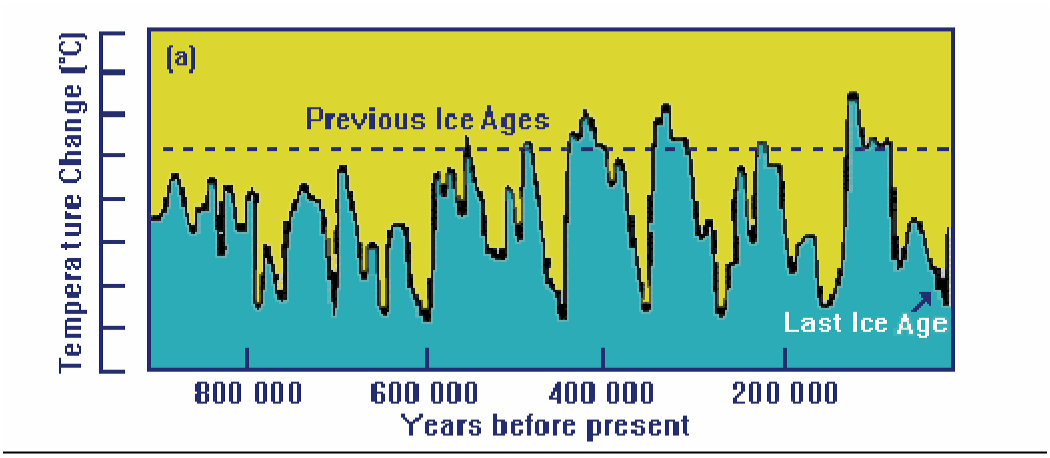

Figure 1a Is a 900 000 year long picture of the changes in the Earth's surface temperatures, as interpreted by many paleo-climate scientists from various proxy records in sedimentary rock strata, laminated ocean bottom sediments, selected high and low latitude ice cores, and, more recently, tree rings, and other time-sequenced laminae. Extensive temperature declines resulting in glacial expansion have occurred more than ten times, with the most recent interglacial warming having occurred only about 18 000 years ago. This suggests that many species have recolonized the higher latitudes (>45 degrees North or South) since the ice cover abated.

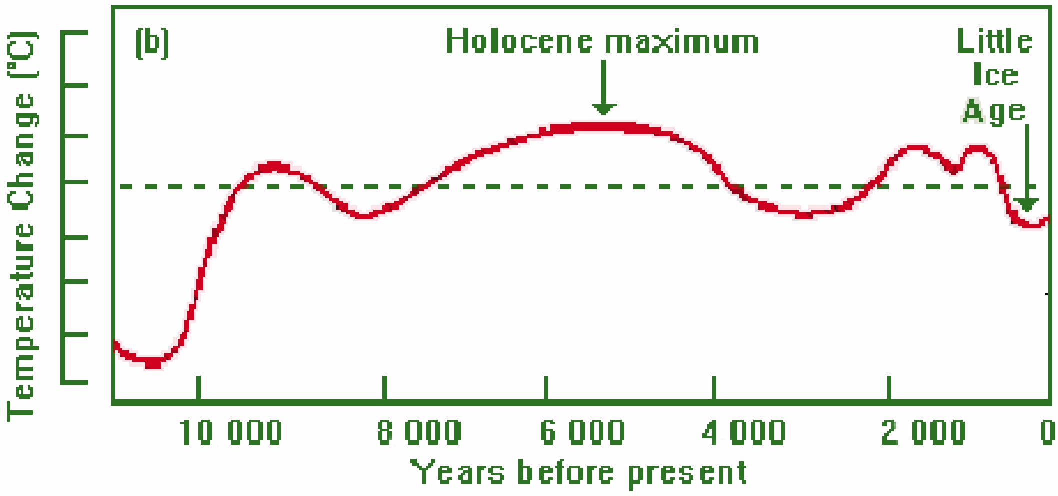

Figure 1b Shows the global temperature pattern since 11 000 years Before Present (BP), with a mean temperature reference line provided to help visualize this period (which would start in the lower right corner of Figure 1a).The extended periods of relative warm climate provided a backdrop for most of humanities civilization, and expansion into the higher latitudes, as well.

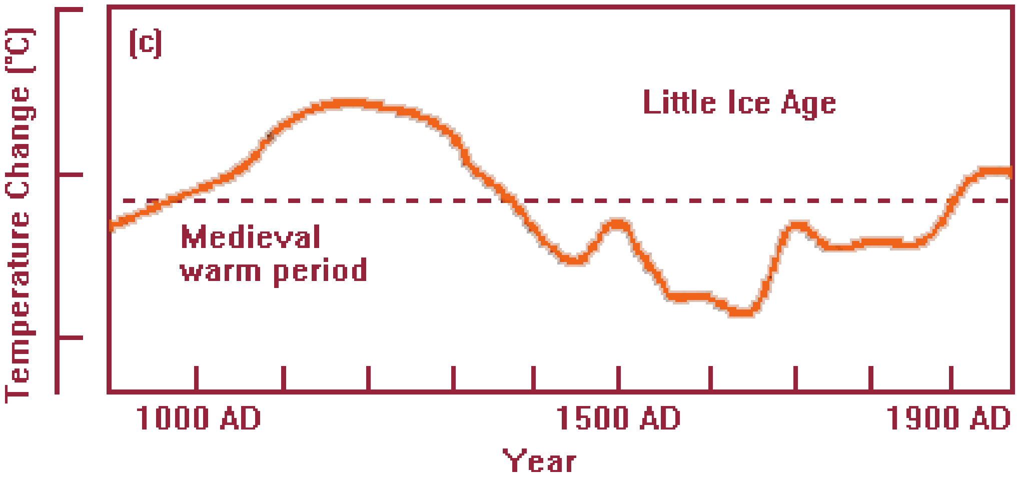

Figure 1c Shows the global temperature record since 900CE, again with a mean temperature reference line provided. This graph starts at about the mid-point of the right hand double hump in Figure 1b. Note the time scale is the modern calender.

1.2 The seasons as a basis for understanding Earth's variability

It is important to accept that the Earth is a warm, wet planet that endures excursions into colder periods, with more ice formation. The seasonal oscillations of Earth's sunlight/energy levels are exaggerated at the poles, while they remain relatively constant about the equator. The lower seasonal variability and the relatively vast amount of light and heat absorbing ocean around the equator leads to the general warming at the equator. Historical paleo-proxy records show that the equatorial ocean does not change temperature dramatically during Ice Ages. However, the polar oceans expand greatly, therefore the North-South thermal gradients also steepen, narrowing the climate zones.

The annual seasonal weather cycle that is experienced is the basis for Earth's major ecological patterns and species diversity, both consequences of continuous changes in Earth's physical contexts. Continuous change is paramount in Earth's contextual framework, within which life as we know it has evolved. Virtually all species are adapted to change, or they do not have any chance of surviving beyond a few generations. The near-spherical nature of the Earth, and the direct relation between incident light/energy and available heat, along with Earth's slowly varying central axis of rotation intensifies regional differences in solar irradiation. The imbalance is a result of the waxing and waning of incident sunlight, as the Earth orbits around the sun, spinning on its somewhat wobbly, 28 degree off-centre axis. Thus seasonality is the result of Earth's off-axis wobble. If there were no wobble, the Earth would have no seasons.

Absorption of the sun's irradiance energy and the re-radiation of infra-red (IR) energy are affected by albedo, or relative reflective-absorptive properties of the Earth's atmosphere, water bodies, and various land-cover surfaces. Albedo is strongly affected by cloud cover and type, ice cover, vegetation types and their developmental phase, as well as both liquid water and water vapour. All of these have dynamic seasonal distributions.

An excellent example of our relatively new insights comes from the solar science community, whose centuries of observations have shown that the sun's surface exhibits a pattern of rise and decline in sunspot numbers that take place with about an 11–13 year period. The occurrence of large numbers of sunspots was "assumed" to mean that the sun was less active. Also, until satellites were finally deployed to measure the sun's output from beyond the earth's atmosphere, scientists readily accepted the concept of a "solar constant". Only recently was it recognized that there were remarkable changes in solar emissions, associated with the sunspot cycle, and that more sunspots meant more solar energy emission – just the opposite case of the "general assumption" made previously. Also, there are actually two cyclical phenomena involved, the added one being the reversal of the sun's magnetic polarity with every solar cycle, leading to a double peaked pattern, with a period of about 22 years.

While it is now quite clear that the sun's irradiance output is not "constant", from satellite measurements made since 1979, the variation is still relatively small (~2 Watts per square meter – Figures 2a and 2b) so far – from the short available time series. Despite this relatively small variation, there are innumerable studies that show climate change patterns that suggest the double (2 x 11–13) ~22 year solar cycles of irradiance and solar magnetic field reversal are involved (Friis-Christensen and Lassen 1991), and are often observed in regional hydrologic patterns (c.f. Perry 1994; 1995; 2000).

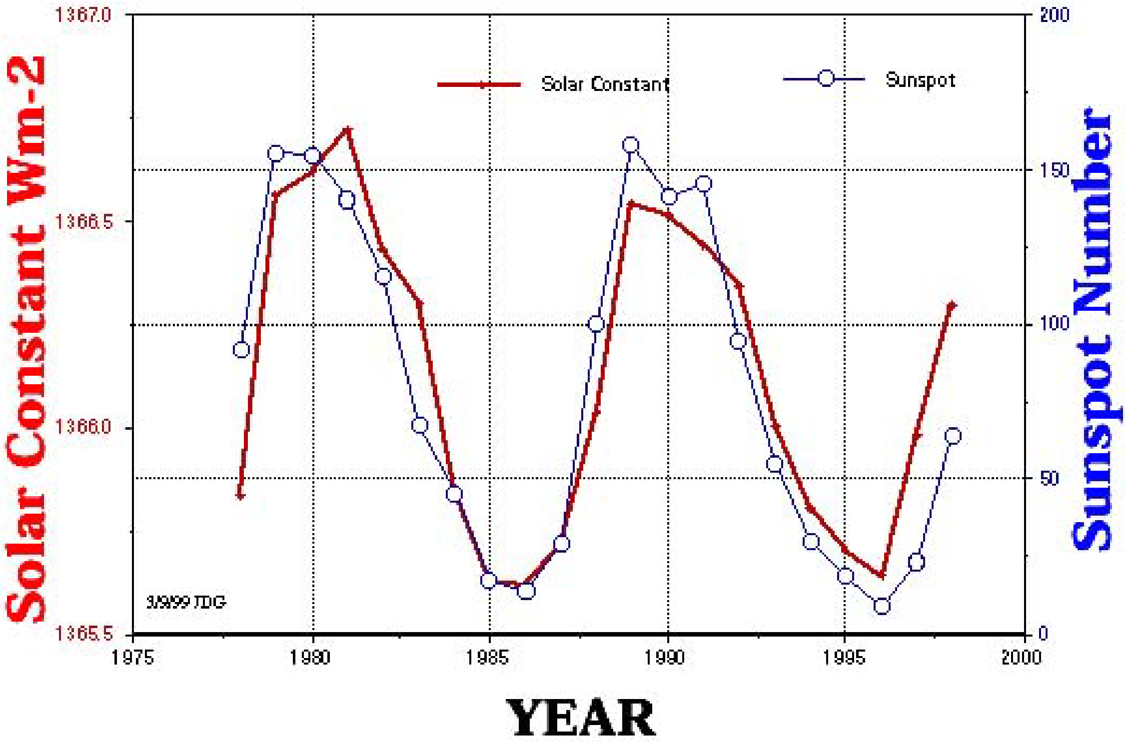

Figure 2a Is a time-plot of satellite measurements of solar irradiance and observed sunspot numbers since satellite measurements began, in 1979 from Hoyt and Schatten (1997). Measured solar irradiance differences are very small, around 0.05 percent between maxima and minima. Therefore the estimated values are quite small, too. But a long-term increase of approximately 0.2 percent in total irradiance seems to have occurred since the Maunder Minimum.

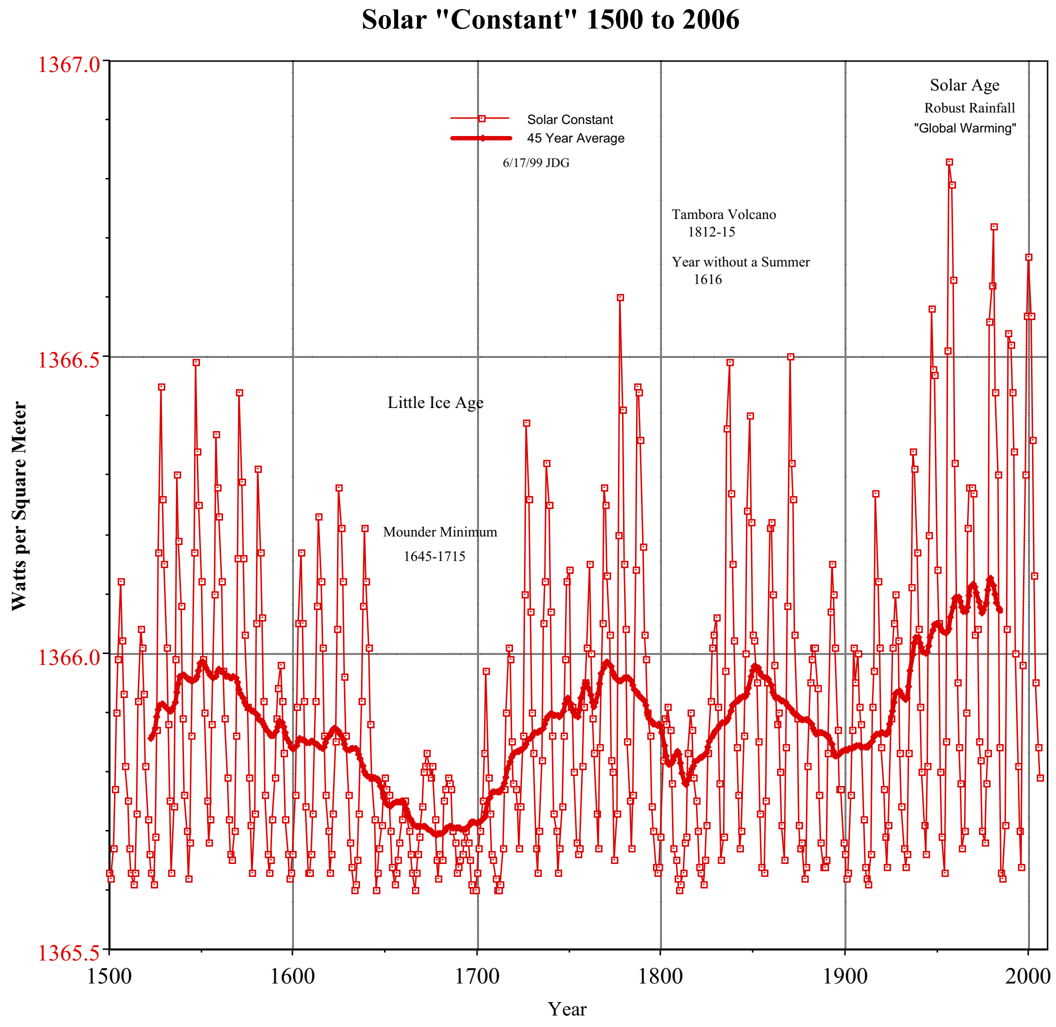

Figure 2b Shows the solar irradiance in this annual translation of the SunSpot observations into solar irradiance, using the Hoyt and Schatten (1997) calibration derived from observations depicted in Figure 2a. The Solid lines shows the application of forty-five year smoothing, to expose the long-term trends in solar activity.

To summarize basic facts: (1) there is continuous heat loss at the poles, and simultaneously, (2) nearly continuous heat absorption into the equatorial oceans. The resulting energy dynamics over the planet are manifested in the interplay of atmospheric moisture (i.e. clouds, cloud types, and various forms of precipitation); ground heating/cooling; and ocean motion. These all interact with inbound and outbound radiant energy spectra. It must also never be forgotten that the upper few meters of the ocean contains more thermal energy than the entire atmosphere. Most atmospheric energy is located within a few thousand meters of the Earth’s surface.

1.3 Hydrological cycle and climate zones

The equatorial regions (the tropical zone) receives relatively more energy input, depending upon the sun’s electromagnetic spectral irradiance patterns. Clouds moderate both the irradiance reaching the surface, and the retention rate of the IR back radiation at all such interfaces. The seasons cycle within earth’s annual orbit, with the atmosphere transferring any energy disparities at the most rapid rate. For example, starting with deep convection – in which the ocean's surface energy is transferred to the atmosphere – the ensuing cloud movements and precipitation deliver warmth (energy) from the tropical zone, poleward into the Temperate Zone. These processes can take days to weeks. While an entire transfer cycle to the polar regions via the atmosphere can take months to years, if the energy is retained in the form of snow, ice, or even dependent on spring river flows. At the Poles heat is lost continuously into the void of space lost in the form of IR.

The cycle of delivery out of tropical zone heat into the higher latitudes via the ocean currents occurs at a much slower rate. Forced by winds and thermo-haline dynamics, currents form and their pathways are subject to Earth's rotational forces – described by Ekman in the last century (c.f. Bakun 1996 for descriptions), and tidal forces. Oceans, lakes, and rivers perform similar energy transfers, subject to local seasonal precipitation patterns, surface wind stress, and gravitational forces as liquid seeks its own equilibrium level within various basins. The Earth's internal ocean-atmosphere dynamics and hydrologic cycles are the all-important result.

All these mass and energy transfers create local dynamics. These dynamics are functions of local heat disparities that also generate subsidence or convection; that in turn cause surface winds; that again interact to either evapourate the water (cooling the local surfaces); or bring in more precipitation. Evaporative surface cooling can cause both condensation, increased salinity and increased density that in turn induces surface water sinking – at various scales of current formations. Whether or not our present situation is unique, or not, is not really the prime question, as some would have you believe.

From the perspective of an observer or laboratory scientist, the individual transfers can appear reasonably simple, and readily modeled. That is until one begins to follow each and every process from its source(s), through the myriad interaction points, each a site of transition or transformation. For example, physical oceanographers treat fresh or open-ocean water as simple systems of wind-driven densities, and gravitational forces. However, as each water type encounters a more or less saline environment, these interfaces are immediately modified, as interactions ensue. The usual patterned subtle density changes of either the fresh water – or the more complex interactions of temperature and salinity of saline water – are recognizable by their physically measurable interfaces, each of which can lead into another time-scale, and a usually slower resolution of any disparate energy contents. The end result is Earth's quite complex hydrological System (c.f. Enzel *et al.* 1989; Gray 1990; Gray and Scheaffer 1991; Gross *et al.* 1996; Perry 1994, 1995, 2000; Perry and Hsu 2000; White *et al.* 1997; White, Chen and Peterson 1998; Lean and Rind 1998).

There are myriad discontinuities and phase changes, each interacting at another spatio-temporal scale of resolution of energy disparities. Changes in state or chemical composition of water are the principle contributors to the many important physical climate patterns in which time scales vary. These interfaces can also form somewhat identifiable ecological boundary conditions. These too shift, depending upon their general position: (1) within Earth's slowly changing geomorphology, and, (2) with the relatively mobile seasonal boundaries – as Earth makes its annual foray around the sun, and onward through time and space. These dynamic patterns are referred to as climate zones, or at the local scale – so-called micro-climates.

At sea level, near the coast, the climate reflects the average seasonal thermal dynamics of the ocean's surface and surface winds that push-and-pull their energy loads toward a more stable state. Each medium works to reach some more uniform energy state. As we climb the beach onto the terrain relief, we often encounter various scales of hilly coastal area, or even a mountain. These orographic features rapidly lift the often near saturated water-vapour laden surface air into a generally cooler atmosphere, forming clouds, or even ice crystals, depending upon the latitude and season. As this air mass continues upward, to follows a path of energy/density resolution, precipitation may form and fall. Depending upon what conditions are encountered below, the moisture can again evapourate, or fall as rain, or aggregate to be blown upward in updrafts, sometimes to form and fall as hail stones, that melt as they gain heat energy from the surface air and terrain.

Similar events over the ocean are often more quickly resolved, by dilution. However, ocean surface water can quickly be sealed over with lenses of fresh, warmer, low salinity water. This phenomenon is often reinforced by river run-off, resulting in another layer of complexity, as these fresh water lenses can suppress normal wind mixing, until the salinity profile eventually becomes more amenable to mixing, functions of both salinity differences and external forcing. For example, if there is strong atmospheric subsidence, lets say from a polar region, the fresh surface water can freeze, sealing even more firmly the underlying ocean against surface wind mixing. On the other hand, when little precipitation has occurred, the same polar subsidence can evapourate the saline ocean water, creating super-cooled, high density currents which can sink well into the ocean's interior, along density interfaces that are specific to temperature and salinity conditions. The warmer, moist air produced is transferred often very long distances before it is cooled, condenses, and eventually precipitates.

Snow often results when dense dry cold air masses meet moister, warmer air masses – from another climate zone – creating rapidly cooled strata in which the water vapour freezes into crystalline forms. These crystals, or flakes, settle relatively slowly to the ground, again forming an insulating cover; or drifts in the wind, to be transported to eventually coalesce into banks – even glaciers under specific conditions – or merely melt to join local water resources. Which process occurs where, depends as much on altitude as latitude, providing for glaciers on the equator at 5 000 meters, or seasonal rainfall from 60°N or 60°S at lower altitudes. Seasonal snowmelt generates freshwater flows, often entering the oceans hundreds to thousands of miles downstream from the initial precipitation events.

Freshwater flow is critical to many fisheries, such as shrimp, crabs, and anadromous species such as salmon and eels. Even seasonal ice formation has its ecological consequences (Loeb *et al.* 1997). Any climate processes that shift climate zone boundaries will affect precipitation patterns and will therefore affect these species' fisheries. Regional and Global Climate can and does change rapidly if certain thresholds are crossed. Certain fisheries systems reflect these changes quite dramatically, as noted by Hjorth (1914, 1926) and Russell (1931, 1973) in their seminal works. Today it is well recognized, although poorly accounted for in regional fish stock assessments, that fisheries catches provide unique ecological climate indicators, as described in recent literature (Southward 1974a,b; Southward, Butler and Pennycuick 1975; Southward, Boalch and Mattock 1988; Sharp and Csirke 1983; Loeb, Smith and Moser 1983a,b; Garcia 1988; Ware and McFarlane 1989; Glantz and Feingold 1990; Kawasaki *et al.* 1991; Ware and Thompson 1991; Glantz 1992, Gomes, Haedrich and Villagarcia 1995; Mantua *et al.* 1997; Taylor 1999; Klyashtorin 1998, 2001). We have come a long way since Baranov's (1918, 1926) insights.

1.4 Paleo-observations and climate shifts

In the recent few decades, high resolution paleoclimate researchers – using long-term records such as ice cores, coastal ocean and lake sediments, corals, and other living systems – have reached the remarkable conclusion that dramatic climate patterns changes have occurred frequently, on time scales of a few years to decades. For example, a consortium of paleoscientists studied long sediment cores from Elk Lake, Wisconsin (Anderson 1992; Dean *et al.* 1984). Using an array of modern techniques, on materials teased from annual sediment cores containing up to 11 000 years in sequence, they learned that climate-driven ecological switches from prairie, to northern forest, to eastern forest ecotomes took place in only a few years to a decade.

The first – the prairie ecotome – represents the dominance of our now-normal North Pacific High weather systems. The latter – the eastern forest ecotome – represents the dominance and onshore movement of the atmospheric feature labelled the Bermuda High, that pumps warm, moist air into the heartlands of North America to support pine forests. The Mid-type, or northern forest ecotome periods, occur during periods when both the North Pacific and Bermuda Highs are weaker, farther offshore, and seasonal patterns are dominated by Arctic subsidence, i.e. Mobile Polar Highs (c.f. Leroux 1998) dominate the terrain, bringing harsh dry winters that support northern forest species, and push the two other ecotomes equatorward and oceanward.

These sorts of pattern changes are “written” in sediments, ice cores, and plant distribution patterns around the world (c.f. Markgraf 2001). How do we learn about the oceans, given their dynamics? The problems are not trivial, as oceans are indeed more difficult to sample, and processes unravelled and described in terms that can be translated into “climate analogies”. Yet, there are growing numbers of studies, particularly since the hallmark work of Soutar and Isaacs (1974) and the follow-up by Baumgartner *et al.* (1989) that show that ocean realms undergo parallel patterned shifts, with dramatic results in species abundance, composition, and distribution changes.

These climate related changes have had notable consequences on local to regional societies, from the Arctic to Tierra del Fuego, Australia, South Africa, and into the world’s oceans. There are compelling reasons to address any and all options to forecast, or identify symptoms of pending Climate Transitions, or Regime Shifts. There have been several recent advances in the geosciences that might lead toward this objective. For example, the Earth’s rotation rate or negative day length (-LOD) varies, apparently also reflecting the sum of all the Earth System’s “internal” dynamics. Russian fisheries and geophysical scientists (Klyashtorin, Nikolaev and Klige, (1998) and Klyashtorin, Nikolaev and Lubushin, in review) find that changes in –LOD as well as patterned Atmospheric Circulation Indices (ACI) lead the manifestation of some important processes related to fisheries. These concepts are critical to changing the manner in which fisheries are managed, from hindcast methods to true proactive forecast approaches. Our working hypothesis is that changes in Earth’s surface air temperature (dT) and regional atmospheric circulation dynamics (ACI) can provide insights into ocean and environmental variations, hence fisheries production patterns (Klyashtorin 1998; Sharp 2000; Sharp, Klyashtorin and Goodridge 2001).

An index of global climate changes is the surface air temperature anomaly (dT) that has been measured continuously over 140 years. Annual variability of dT is known to be very high, and a considerable (13 years) smoothing of the corresponding time series is necessary to reveal long-term temperature trends (Figure 3a). Smoothed time series of the average annual dT (Figure 3b) exhibit several multidecadal fluctuations with maximums at the 1880s, 1930s, and 1990s (Halpert and Bell 1997; Bell *et al*. 2000), and ACI (Figure 3c) also responds. These fluctuations take place on the background of the age-long ascending trend of 0.06°C/10 years (Sonechkin, Datsenko and Ivaschenko 1997, Sonechkin 1998).

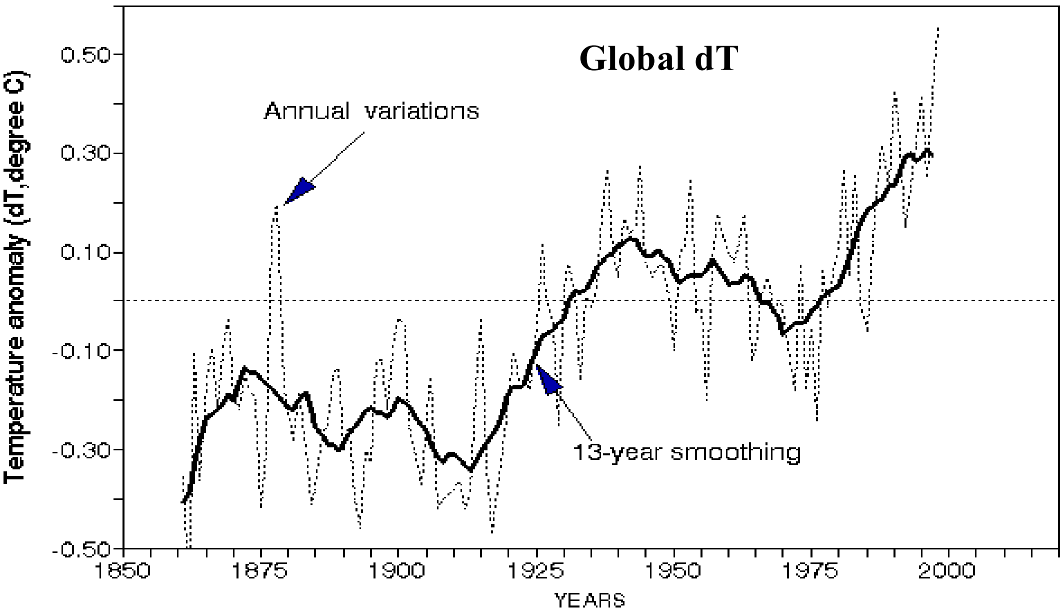

Figure 3a

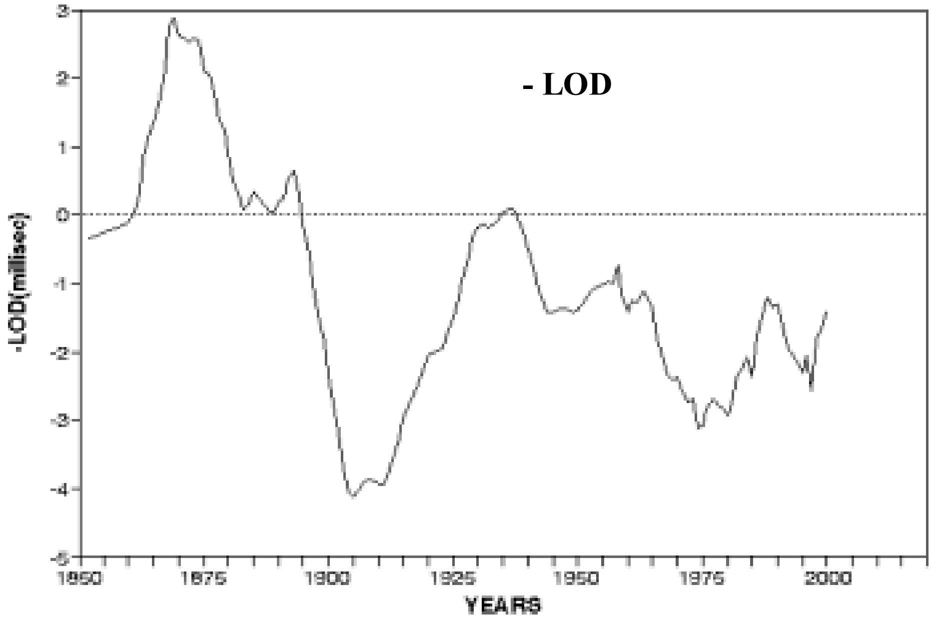

Figure 3b

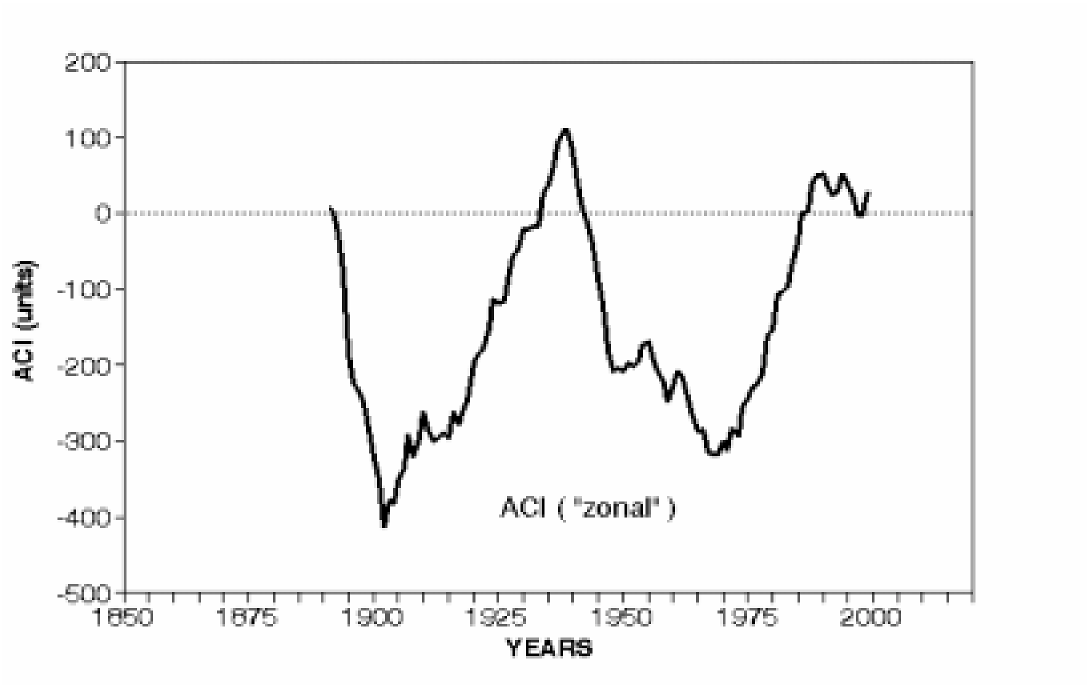

Figure 3c

Figure 3 Long-term dynamics of the investigated climatic and geophysical indices: **3a** The global temperature anomaly (dT): 1- average annual, 2 - average annual, smoothed by 13-years running average; **3b** The earth rotation velocity index (-LOD); **3c** The latitudinal atmospheric circulation Index (zonal ACI) Figures provided by Leonid Klyashtorin, personal communication.

The Atmospheric Transfer (AT anomaly and Atmospheric Circulation Index), global temperature anomaly (dT), and Length of Day Index (-LOD) have been well measured for the last 100–150 years. The long-term regular fluctuations of these indices are well correlated, although shifted in time. The multidecadal oscillations of the AT anomaly are ahead of periodical fluctuations of LOD (for 14–16 years) and dT (for 16–20 years) making it possible to predict probable dynamics of the latter well in advance. For practical reasons, meteorologists do not work with the AT anomaly itself, but they use the product of its accumulation (i.e. sequential summation of the AT anomalies).

The Atmospheric Circulation Index (ACI) was suggested by Vangeneim (1940) and Girs (1971) to characterize atmospheric processes on a hemispheric (global) scale. Reliable time series for these indices exist for only the recent 110+ years. The predominant direction of the air mass transport for each component depends on the atmospheric pressure pattern over a huge territory, e.g. from the Atlantic to West Siberia. This information is first analyzed and then presented as daily maps of the atmospheric pressure fields over the region limited by 45°W, 75°E and 20°N to the North Pole. Similar patterns likely exist for the southern hemisphere, for similar data.

The occurrence of each component (C, W or E) is defined as the number of days with corresponding predominant direction of air mass transfer. Total occurrence of all three components in a year is equal to 365. For each range of years, the occurrence of predominant atmospheric transfer is expressed as the Atmospheric Transfer anomaly (AT anomaly) which as have shown, is the result of subtraction of the corresponding average for some defined time period. Therefore, the sum of the AT anomalies of three basic components (C, W and E) for the same period is always equal to zero. The resulting time series (accumulated AT anomaly) is called the Atmospheric Circulation Index (ACI), where ACI is the AT anomaly time series integrated for any period of measurements. Klyashtorin (1998) pointed out the strong relation between commercial fish catches from the world's major fisheries and the Russian Arctic Institute's ACI indices (Figure 4).

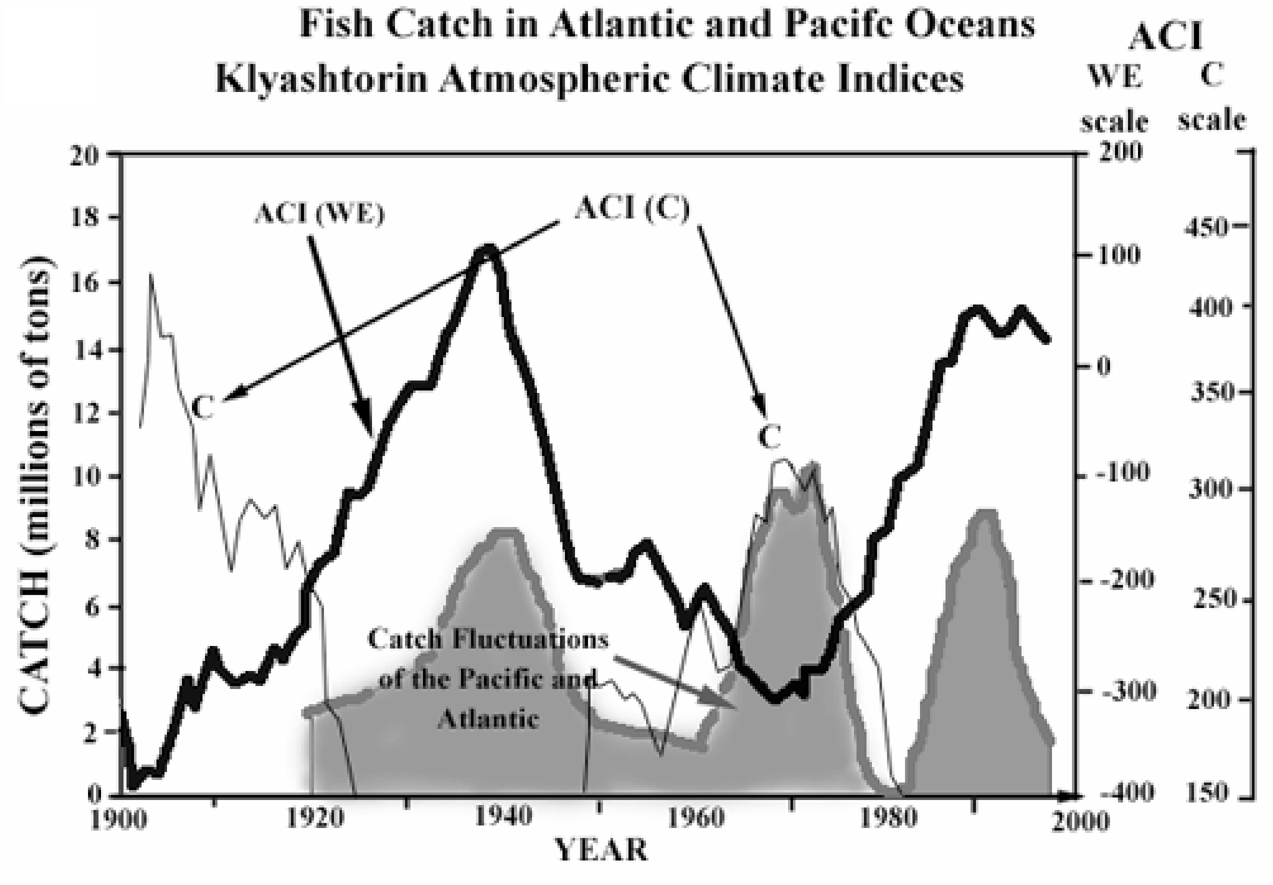

Figure 4 Shows the Atmospheric Climate Indices for the same period plotted with regional "warm regime" Commercial Landings Data for the twelve major fisheries described in Klyashtorin (2001 c.f. Figure 14). ACI (W-E) designates periods when the dominant surface wind fields are zonal, and ACI (C) indicates the periods when the wind fields are predominantly meridional. Note the relative coherence of the fisheries production peaks within the two ACI (WE & C) patterns.

The concept that hemispheric weather patterns are cyclical, and related to atmospheric forces is neither new, nor particularly controversial. The typical relations between Climate Regimes Shifts and large system hydrological records can be quickly accepted, given the data sets are coherent, long term and correct. The rise and fall of continental lake systems have been recorded for many decades, and in some cases, such as the Nile River Flows, for nearly 2 000 years. For example, it is well known to Russian water resources specialists that the dominant ACI-C atmospheric pressure-form means an increase of north to south transfer of precipitation. Alternatively, regional climate as a whole become more continental during "meridional epochs", i.e. difference between summer and winter temperatures are greater.

Over the recent few decades there has been considerable debate over the cause of the lowering of the Aral Sea and other Russian waterways, as agriculture has expanded, and more waterways have been tapped for irrigation. Figure 5 helps explain the previously disturbing long-term decreases in the level of the Aral Sea, just to the west of lake Balkhash.

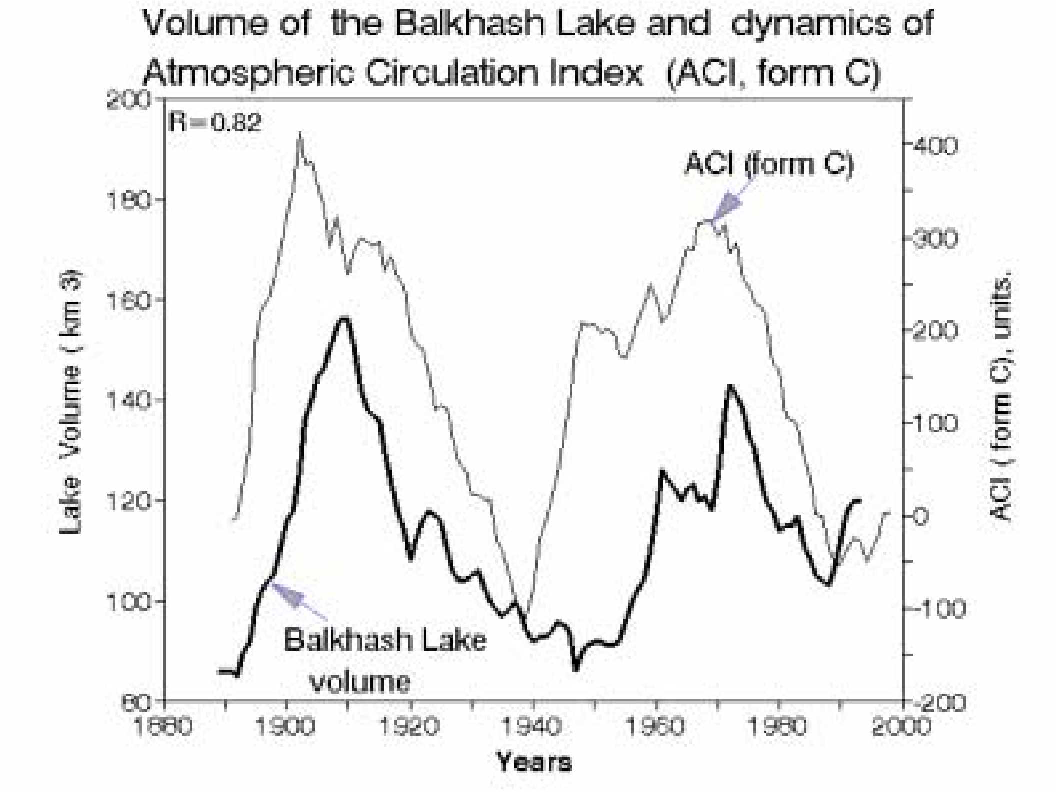

Figure 5 Shows good agreement between Balkhash-lake volume and the ACI-C-form (meridional) of Klyashtorin's (above) atmospheric climate index. The Aral Sea and other regional hydrologic basins have also recently begun to slowly increase. These data also support reasonably positive forecasts for ecological changes.

1.5 Local challenges

The basic need to find food, and in particular, provide adequate protein for an ever-increasing population, is an epic dilemma. The now obvious fact is that with the present leveling off and declines of some ocean fisheries production options have begun to run out as habitats are shifted from agricultural emphasis and as more food fish is used to support fish and shrimp culture. Under the pressures of today's human population growth, perhaps better use could be made of fish protein if a larger portion of the fish catch were sold for direct human consumption rather than used to support culture of higher value products via the added inefficient conversion step of feeding it to another species.

Figure 6 places in temporal and climatic context examples of known social and fisheries pattern changes that appear to be in response to similarly well-described, if somewhat longer term gross climate changes (see Figure 1c). The examples of climate-related responses by the North Atlantic, the Bohuslan herring, and Andean cultures related to changes in to Solar influences do not connect well the local causalities for each phenomenon. The coming and going of glacial ice, general ocean habitat cooling and warming, and sequences of wet and drought periods can be documented across the globe, as is the mission of the PAGES Pole-Equator-Pole Program (C.f. PEP-PAGES website) Regional and Global climate patterns are studied and archived by national institutions (c.f. NOAA Climate Prediction Center website, CSIRO website), the oldest being the Nile River gauge near Cairo. The recent few decade's focus in the applied climate sciences has been on El Niño, now broadened to include alternative La Niña or neutral patterns.

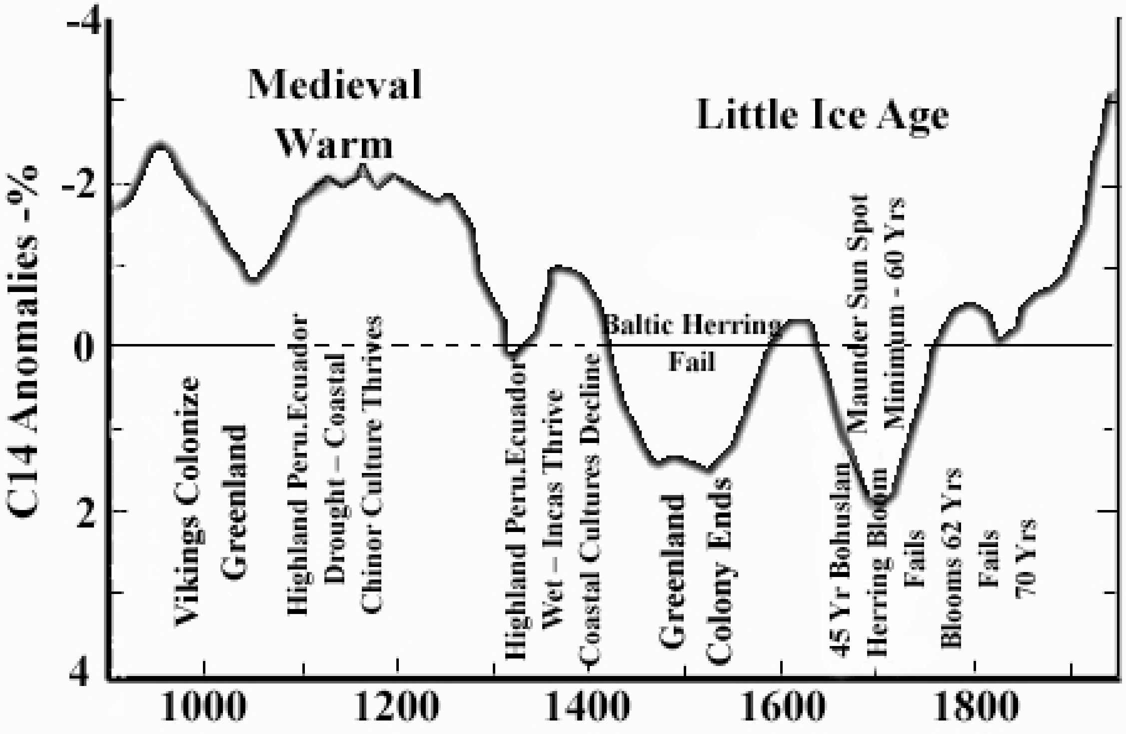

Figure 6 Is a time series of C14 anomalies, resulting from solar emissions, annotated with recognized societal responses, and comparable information about the rise and fall of Baltic herring, and the subsequent formation of the Hanseatic League in response to the region's dramatic cooling/warming patterns during the Little Ice Age. Meanwhile the earlier Norse colonies in Iceland, and Peruvian lowland-highland cultures underwent dramatic changes. Many other social consequences have been identified with both continuous and abrupt changes, supporting the concept that human cultures, too, have responded to such climate changes, as have all species over the course of history.

From the onset of the ~1285AD–1400AD post Medieval Warm period, chronic cool dry weather, local drought and extreme weather, along with regional low food security, started various competitive societal forces into motion (c.f. Thompson *et al.* 1995, Braudel 1985). This epoch of climate-related social stress was further exacerbated by the cooler era now called the Little Ice Age, and was the general motivating social force that began the Age of Exploration.