The efforts to culture fishes, and then enhance natural populations is closely related, perhaps even analogous to the transition from hunting and gathering to early herding and farming activities in the middle east. During the third–fourth millennia BC, when people began to plow, channel waterways and create large-scale irrigation projects (c.f. Fagan 1999). These activities provided support and access to exotic species. Many dilemmas occurred as a result of these introductions, including fish from other geographic locations.

Historically, aquatic and other species have been introduced from various homelands and from many ecosystems into otherwise once-isolated ecosystems, including islands and lakes, to provide food and sport. There were many unintended "exotic species" introductions that have plagued humans since migrations and ocean explorations began. Favoured food and servant species were also shipped as people immigrated and colonized other continents and oceanic islands via the ocean. Today, ballast water, shipping containers, and various other sources dominate these "surprise" deliveries, and created havoc and unplanned species competition wherever waterways are involved. Entire ecosystems have been modified, and in some cases, "natural" fish production substituted with culture or introduction of more valued species such as tropical shrimp, and Nile perch.

3. REGIONAL ECOLOGICAL RESPONSES TO CLIMATE CHANGE

Regional ocean primary productivity is a measure of growth and reproduction of algae and other plants (see reviews: Smith 1978; Ursin 1982; Pauly and Tsukayama 1987, Pauly *et al* 1989; Longhurst 1995; Longhurst *et al*. 1995; Polovina*,* Mitchum and Evans 1995; Ware 1995; Sharp, Klyashtorin and Goodridge 2001a,b; 2002). Like a backyard garden, the resulting growth is a complex consequence of available nutrients, light, and temperatures. The ocean, and therefore oceanic plants respond to local weather such as wind speed, cloud cover, and incident sunlight. Primary production is only the first of several stages in transformation of nutrients and carbon dioxide into living cell building blocks.

To help introduce ecological and regional scale dynamics, focus has been given on the COADS data set, above, with the periods of greatest transition in the available fisheries records outlined, as in the Pacific sardine or northwest Africa's fisheries. Wind speed is directly related to thermal energy (temperature), and resulting global hydrologic cycle dynamics. There are many measured proxies for regional climate states. Analyses of various atmosphere and wind indices are described. One of the results of climate-ocean-atmosphere-biosphere dynamics are measured changes in the Earth's rotation rate, or negative Length of Day (-LOD). The intent of the following discussions is to help promote the general understanding about these nested processes, their proxies, and the several time and space scales that need considered in order to make better decisions.

3.1 Long-term productivity changes

Twentieth Century fisheries scientists have provided abundant examples and documentation to show that fisheries dynamics involves much more than only fish and fishermen. (c.f. reviews by: Hjort (1914, 1926), Revelle (1947 note to John Isaacs, quoted in Scheiber 1990), Bakun *et al*. (1982), Bakun (1996), Sharp and Csirke (1983), Csirke and Sharp (1983), Glantz (1992), Sharp (1997), Boehlert and Schumacher (1997), amongst many others). Their common thesis is that the oceans, hence fisheries are connected to larger scale dynamic processes and remote forces. Together, these forces and processes reach downward to the all-important local scales where the individual critical life-history processes of fishes take place. Fisheries related questions have converged on somewhat direct local and regional measures of an array of factors, from wind speed, upwelling/downwelling rates, primary production, and species interactions. This has evolved slowly, and quite independently from limnological science. The basis derives from laboratory and field studies on early history of ocean fishes (reviewed in Sharp 1981a, 2000). Systems Ecology has finally arrived in the pragmatic world of fisheries management.

Most ocean species thrive near the middle of their temperatures tolerence ranges, see Figure 14 below, in which the commonest ecostrata are represented by the separate colours. For most local species, increased thermal stress occurs at or beyond either warm or cold extremes (Sharp 1998). Primary production is driven by seasonal processes, modulated by wind and light levels and often is most active at the interfaces of these “compartments”. Species with broader tolerances often have unique physiological and anatomical features, and many of this group have evolved large adult sizes, and wide migrations. There are not really many generalities about where in the food web that these species are most likely to be found, as most of the fishes start life as small, lower trophic level feeders, and work their way upwards. Others, like the balleen whales, whale shark and manta rays, never graduate from their need to filter feed on planktonic forms. These species thrive within the edges, while sea turtles consume primarily jelly fish, which comprise 90% water, a seemingly impossible scenario.

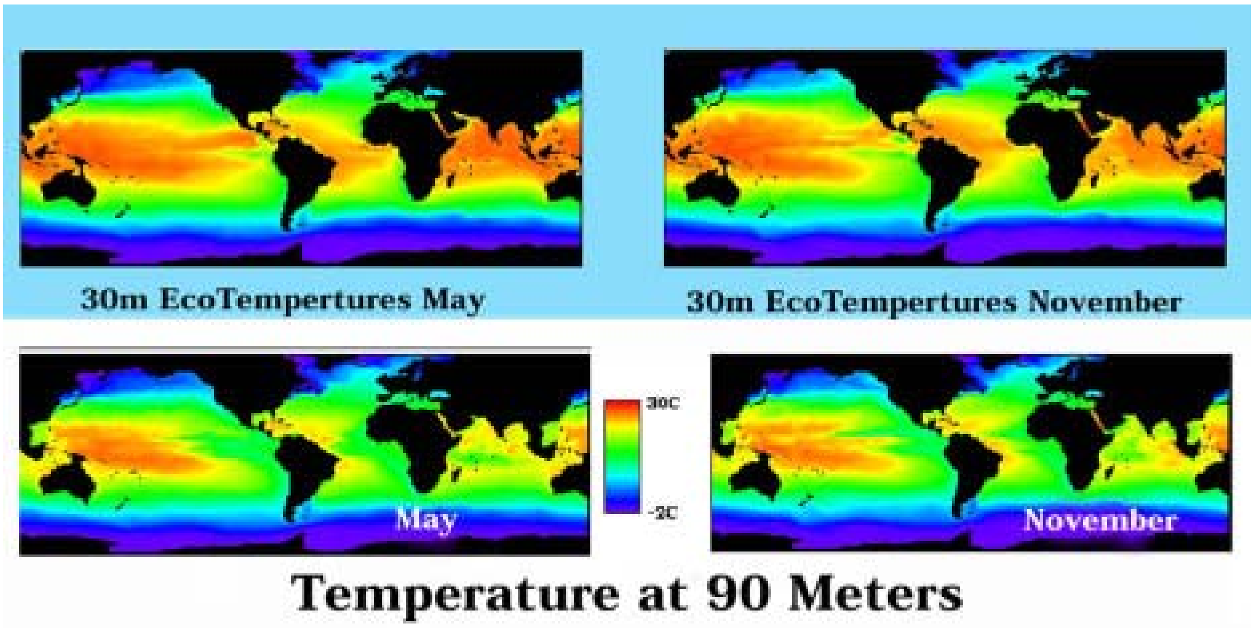


Figure 14 Provides pragmatic perspectives of the seasonal Global Oceans Climate Zones, for May and November, the months with the most extreme seasonal signals. The transition zones in the climatological 30 meter temperatures, i.e. where thermal gradients are strongest, form natural EcoTemperature compartments, or ecotomes. Temperature boundaries are >26ºC; 23ºC; 20ºC; 14ºC; 9ºC; 5ºC; and 2ºC and below – within which the various ocean ecosystems have evolved. The 90 meter patterns imply more about light limitations and temperature related primary production than do SSTs, alone. Each ecotome’s seasonal overall productivity reflects dynamic physical and ecological interactions.

The predator-prey network, known as the food web, takes over after the initial light-driven chemical transformations, defining the relays of energy and materials throughout the Trophic Pyramid, and on into the broader Ecosystem. In all aquatic ecosystems, primary production is seasonal, as the winds, light levels, and needed nutrients vary over time, with the weather/climate. So the first connection to biological variability is found. From the results of paleoclimatic, paleosediment and climate studies, global patterns of climate change and marine ecological responses are clearly being dealt with. For example, studies of undisturbed anoxic sediments from the Santa Barbara Basin, off Los Angeles, provided a dynamic changing abundance sequence for sardine, anchovy, and other fishes for nearly two millennia (c.f. Soutar and Isaacs 1974, Baumgartner *et al*. 1989, Sharp 1992b), obviously not driven by fisheries, as none existed prior to the late nineteenth century.

Because the majority of instrumental environmental measurement records extend from about 1950 or more recently to the present, it is too easy to make graphics, do analyses, and present trends from these short series that often turn out to be misleading relative to future climate patterns. The key to understanding and relating the relationships between the available extended time scale observations and the shorter record sets used by Global Warming buffs, is to compare the relative variability of the shorter and longer sequences, on a standard scale. One of the more important points that are made is the fact that the recent 50 year period of extensive climate records is notable for its lack of dynamics, and low variance, in comparison to century or longer time-scale records. Despite the Earth's longer term changes in energy balance these appear to provide for reasonably stable seasonal climatic patterns, although there is clear evidence that these can shift from one extreme state to another in very short term (i.e. a few decades – c.f. Shen *et al*. 1992; Southward, Butler and Pennycuick 1975; Southward, Balch and Mattock 1988; Allen and Anderson 1993). These are referred to as Climate Changes. Climate is the long-term average expected seasonal pattern, while weather is the more variable seasonal phenomena that are observed. ismissal of these dynamics, and their fisheries contexts (i.e. Gulland 1983; Hilborn and Walters 1992 – reviewed in Sharp 2000) has driven the continual resource management model failures.

3.2 Behaviours of particular ocean ecosystems

1. **Tropical Systems,** provide one of the best examples of general beneficiaries of intensification of climatic processes, or climate change, as the boundaries expand and contract, accordingly, but the interior near-equatorial portions undergo little that threatens any particular ecological dynamic. The vast tropical shelves and reef systems are pretty much defined by their abilities to cope with rapid changes. It is worth remembering that even the Great Barrier Reef system is a relative newcomer into the recent warming since the last Ice Age, only 18 000 years ago. The 130 meter or so rise in sea level has not been a hindrance, as much as it has created new substrate, and allowed this great system to advance it's ecological offerings.

(a) Volcanically active islands and seamounts have wakes or Taylor Columns that provide regional oceanic species with upper water column mixing, and nutrients that create, in turn, either steady, or sometimes seasonal production. Within and around these features an amazing amount of species interact, and thrive. Reefs, depending upon their locations and climate zone, provide for incredible numbers of species, some of the larger sessile forms such as Tridacna, the giant clam, attain very large size and old age, while others live briefer, more frantic lives, as they struggle up the size hierarchy, and graduate from one "refuge" or niche to the next size, as these are opened up by Top-Down predation (Polovina 1984a,b).

(b) Oceanic migrators such as the dolphin fishes and scombroids also have amazing growth rates, and huge appetites that keep them on the move from one location to another throughout their lives, looking for ever-larger prey (Abbes and Bard 1999, Bertrand and Josse 1999). Local recruitment of most reef and island fishes is certainly affected more by currents, seasonal winds, and occasional storms, but most of the species tend to stay put as adults. The young are subject to transport to and from their nursery habitats by living at or near the surface, where they "blow with the winds", to either be eaten, or eventually find an open "hole" to fill. Failure rates for each reef species are likely unimaginably large. Or perhaps it is better to state the problem thus: survival rates are erratic, and small, at best.

Figure 15 Tropical waterspouts and stratocumulus clouds mark active deep convection cells from the ocean surface. Ocean energy, in the form of water vapour, is transferred to the atmosphere, for transport downstream, and poleward.

(c) Deep convection (Figure 15, above) in the equatorial warm ocean and along the Intertropical Convergence Zone (ITCZ), differs conceptually from surface wind forcing that drives the predominantly evapourative heat loss at higher latitudes, and the subsequent upper ocean energetic changes. Cloud cover is the primary driving force for heat retention in the higher latitudes, while the marine layer dynamics, higher water-vapour capacity and somewhat rapid nighttime turnover and sequestration of tropical ocean heat loading (particularly at SSTs >27.5C) dominates equatorward. What this implies is that under every nightime cloud, the tropical ocean deepens, and the tropical habitat grows. Several advantages accrue to oceanic tropical predators such as tunas, billfishes and marine mammals at the highly mobile transition interfaces where temperature gradients form ecotome boundaries. These gradients induce, in turn, nutrient concentrations, primary production, plankton species, and aggregations of predators, small and large. The gradients also generate surface pressure differences, hence wind to affect convergence and divergence, both important forces in the ecological interplay, and fisheries production and vulnerabilities.

During periods of ENSO Warm Events, the ITCZ shifts equatorward, e.g. the ITCZ spends more time over south Central America and North Africa, and causes great changes in hydrological and precipitation patterns over the land, as well as changes in seasonal locations of ocean features. These weather dynamics form another set of opportunities. Climate events such as ENSO Warm and Cold events promote different levels of productivity. Warm Events and fresh water run-off often cause dramatic algal blooms that sometimes cause anoxia or toxic effects, and subsequent vast fish die-offs that result in rapid energy dispensation into lower trophic forms, promoting a certain level of directed nutrient recycling that avoids the Top-Down predation pathways. Guano islands are particularly important to local production. Benthic and insular invertebrates can thus obtain irregular “boosts” in food resources that can help them attain high population levels, via enhanced reproduction and unique current-related dispersion. Erratic currents can provide for colonization of sparse or depauperate habitats. These colonies might not attract predators away from more densely populated coastal and island areas, allowing for future repopulation via habitats beyond anoxia, toxins, or predator blooms.

2A. Subtropical Transition Ecoystems – are well documented fisheries systems. After the collapse of the California sardine, in the 1940–50 period, and then the Peruvian anchoveta in the early 1970s, fisheries research was intensified in the eastern boundary currents (c.f. reviews by Schwartzlose *et al.* 1999, Sharp 2000). Throughout this century, lessons from regional fisheries studies were carried around the world, and eventually applied to many coastal and offshore species by analogy. The collapse of the cod and other major fisheries in the northwest Atlantic in the 1980s caused another shift in emphasis, as the public finally understood that it takes more than good science to manage living resources. Policy making is at least as important to consider, as are catch statistics and/or badly conceived fisheries independent survey techniques. Overzealous fleet developments seem to be a common denominator in today’s crises, as national governments and foreign aid programs have pushed to increase catches, despite obvious biological and economic signals that limits have been reached or exceeded.

(a) The California and Humboldt Currents share an amazing array of species, and periodic cycling of their distributions and abundances, but differ dramatically in production potential. The peak sardine catches in the 1930–40 period off California ranged from about 500 000 to 700 000 tonnes per year, while anchovy catches peaked in the early 1980s at about 300 000 tonnes. The California sardine fishery was kept at low levels, while the Gulf of California sardine fishery bloomed starting in about 1980, and peaked at just over 250 000 tonnes in 1988, with another rise in 1996–97 to around 200 000 tonnes. The west coast of Baja California sardine catches delivered by the Cedros Island and Magdalena Bay fleets totaled from 10–35 000 tonnes since 1960. Recent total catches of California sardine that now range from Baja California to British Columbia, are stabilized at around 360 000 tonnes.

(b) The three production regions for sardine and anchovy off northern Peru, southern Peru-Northern Chile, and Central Chile produced peak catches of anchovies of 12 million tonnes (mostly from northern Peru) in the early 1970s, then collapsed. Nearly nil landings of South American sardines began to rise in about 1976, and peaked after they had recolonized all three regions, to attain 12 million tonnes, in 1984–85. Recent catches total just over 400 000 tonnes. Meanwhile, the South American anchoveta landings have been around 8 million tonnes per year, except for 1998, when the very strong El Niño caused landings to fall below 1.7 million tonnes.

(c) The jack mackerel that coexists within the coastal region feeding on these other two pelagic species apparently undergoes similar blooms, on a slightly extended schedule. They extend their range from the coastal feeding areas, along the west-wind convergence zone from Central Chile to New Zealand, and into the Tasman Sea. Early museum samples in New Zealand were dated 1946. The most recent bloom, range extension, and collapse took place from the mid-1980s until about 1995, when nearly 5 million tonnes were reported.

(d) South Africa-Namibia fisheries enjoy a similar patterned bloom and collapse as do Japan, and South America, with two primary production centres, one off the Cape region, the other north of Walvis Bay. Both are regions of strong coastal upwelling, with the Cape region more directly under the influences of Indian Ocean ENSO dynamics. Direct transport of warm surface water from Indonesia, southwestward to South Africa as a consequence of ENSO Warm Events creates extended periods of coastal warming and cooling that create very different opportunities for the two dominant pelagic species, and their predators.

(e) Fréon (1984) and Belvèze and Erzini (1983) studied relationships between upwelling indices (wind speed and direction), and changes in sardine catches off west Africa, for the same period described by Gray and Scheaffer (1991) in Figure 16, and described the relation between these 1969–1971 transitional processes and the region's fisheries production shifts. Today, these results would not surprise anyone, as other eastern boundary current systems. In fact, most other fisheries exhibit similar epochal regime shifts, which are focused on later.

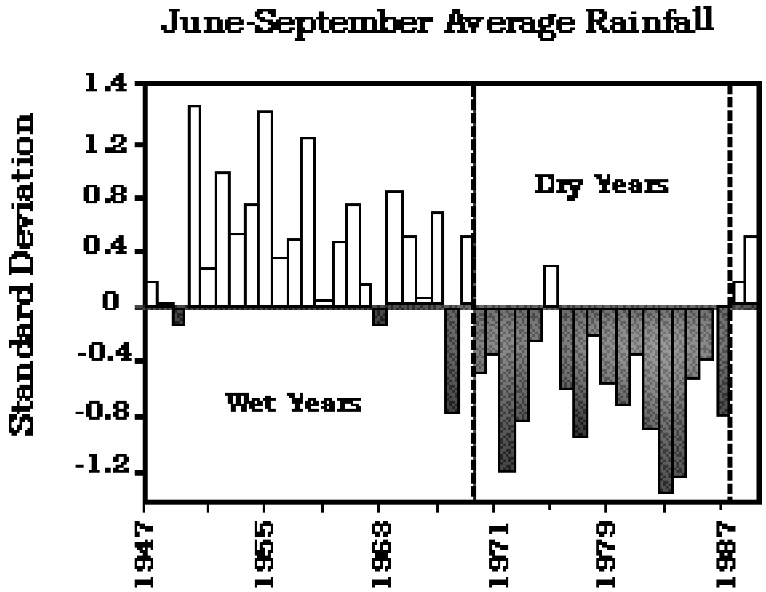


Figure 16 Provides insights into a regional climate shift in the Sahel just east of Morocco's coastal upwelling fisheries system during the late 1960s from studies by Gray and Scheaffer (1991).

2B. Western Boundaries – The South Atlantic Bight – Gulf Stream, the Brazil Current, and Kuroshio Current have very little in common, in either species arrays, or productivity levels. The South Atlantic Bight and Gulf of Mexico coast provide North America with one of its largest fisheries, for menhaden. The array of predator species, tunas, billfishes, striped bass, etc., that form the majority of the region's fisheries are seasonal, in response to annual nearshore upwelling-driven production cycles. The Brazil Current is very coastal, creating a much warmer, more tropical situation with more influence from the fresh water delivered from the Amazon and other rivers than observed in the other two example regions. Brazil's sardinella fishery is the only equivalent species, and catches are much less variable, tending to vary from about 100–200 000 tonnes per year.

(a) The Northwest Pacific Ocean borders the Warm Pool, and responds to those dynamics, and as well, the Sea of Japan is directly influenced by the cold Oyashu Current that derives from the Polar region, and has its own decadal scale pulses. The sardine cycle has been well described, and exhibits the same off-cycle pattern with regional anchovy abundances. Sardine appears to benefit from stronger southerly influences, that enhance the temperatures in the Japan Sea and along the east coasts of Korea and Japan, while anchovies and Hokaido herring seem to thrive on a more northerly influence, when the Oyashu is stronger and Hohaido and the Sea of Japan are subject to more cold inflow from the north. In 1998 landings of Japanese anchovy attained over 2 million tonnes, up from around 1 million tonnes caught by Chinese and Taiwanese fleets, and less than 200 000 tonnes around Japan. Landings of Japanese sardine peaked in the late 1980s at around 5.5 million tonnes, and then declined steadily to around 300–500 000 tonnes in recent years (c.f. Figure 7).

(b) Somalia – Arabian Sea Dynamics, as pointed out, are directly responsive to the monsoon, as are the various fisheries that operate within this highly seasonal, and productive region. There are abundant sardinella within the region, but only minor fisheries, and those that exist are quite seasonal, as affected by nearshore anoxia from hyper-development of algae, under the influence of monsoonal winds. The sardinella are forced into estuaries, or to migrate into more amicable conditions, or they die. Their predators face similar conditions, and are even more sensitive, thus their migrations reflect the region's seasonal dynamics, and exit the stressful coastal regions for more oceanic, conditions, creating abundant resources for the region's many island communities.

3. Temperate Zones and Ocean Gyres – the Sub-Polar ocean ecosystems seem to respond well to all stages and phases of climate forcing. The North Sea is another unique situation, in which the majority of the species that occupy the habitat were excluded for thousands of years, during the recent Ice Age. The recolonization and development over this relatively shallow environment of the many species that have become the basic fish resources of so many diverse cultural groups is interesting on its own. Then again, the species that make up the major fisheries resources seem to be particularly adept at taking advantage of short-term climate changes. There is a strong message in that fact, as well.

(a) The eastern North Atlantic and North Sea fisheries is where fisheries research began its long arduous journey toward understanding of climate and fisheries relations. Southward, Butler and Pennycuick (1975) described changes in the sardine eggs and plankton nearer the base of the food web in the English Channel, that shifts in synchrony with what has been called the "Russell Cycle" (c.f. Russell 1973 – Figure 17 next section). Cushing and Dickson (1976) reviewed the state of knowledge for the North Atlantic fisheries in response to climate forces, and arrived at several limits. Recognizing that the various regions were "connected" by atmospheric processes and that several distinct "states" existed, and varied on different time scales, they posed connections.

(b) Cushing (1982) eventually took advantage of the growing long-term collations that became more available, and made great strides toward integrating the information sets from various locations around the globe. Of particular value were his interpretations of the northward movements of animals during the warm period from the 1920s into the 1940s. He identified various species transport patterns with changes in surface wind direction, and others with intensified currents, while more oceanic species clearly responded to expansion of their warmer habitats into higher latitudes. A review of his Chapter 5, and its tables, offer good preparation for forecasts of fish behaviours in response to warming for specific regions. It is now known that such observations are invaluable.

(c) More recently Alheit and Hagen (1997) described the European herring and sardine fisheries' relation to winter weather and the influence of the North Atlantic Oscillation (NAO). The history of the herring fisheries of the Bohuslan region that connects the Baltic Sea with the North Sea is a series of lessons needing learned. Figure 6 provides the approximate periods of the coming and going of the Baltic herring. Alheit and Hagen show various periods of strong winters – periods of fresh water flows, subsequent overturn and anoxia in the Baltic Sea region – that force these fishes out into the more amicable offshore environments, via the Bohuslan region, where there are deep fjords. There are decade-long periods when the herring are found onshore, where they were caught with beach seines and set nets, and others when they were simply unavailable nearshore. This situation was changed once the purse seine was adopted, and fishermen became more mobile.

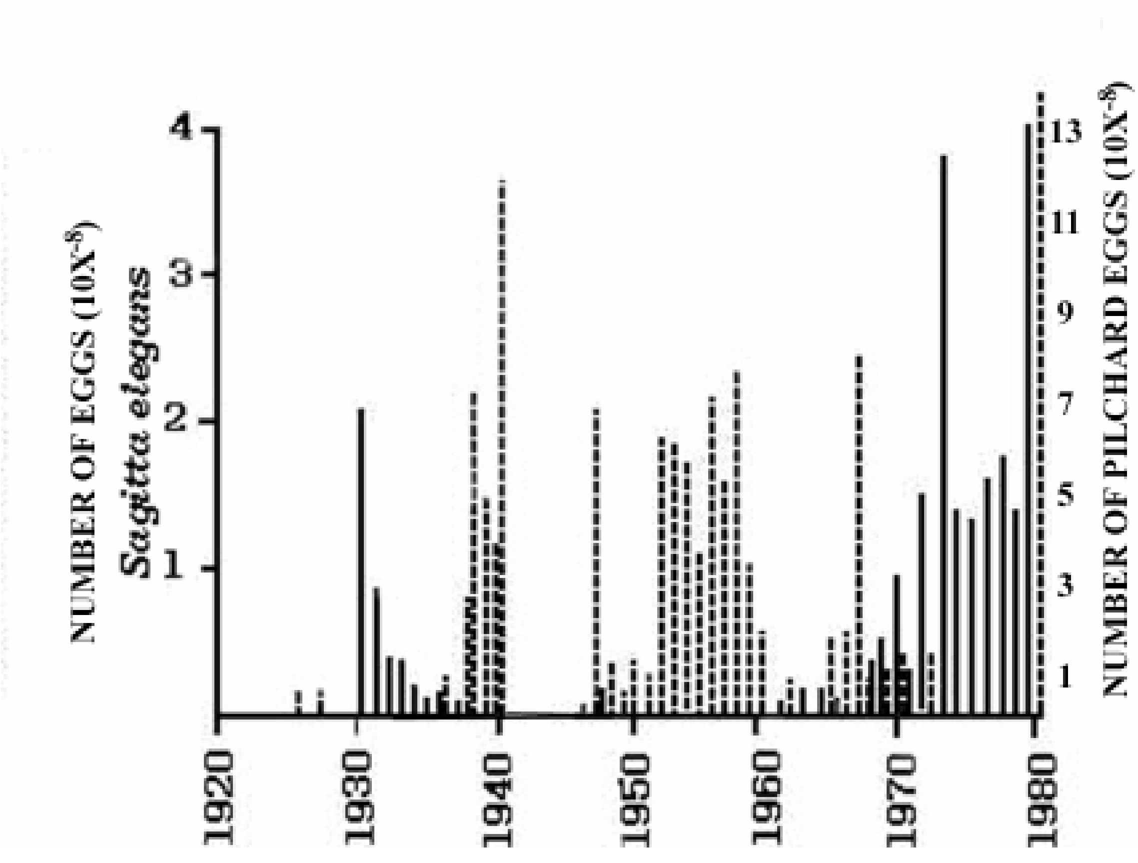


Figure 17 Provides data from Southward (1974a,b), and Southward, Butler and Pennycuick (1975) that show a bipolar (Russell Cycle) shift in English Channel fauna starting about 1938, that reversed in the late 1960s.

The European sardine prefers a warmer habitat than do the herrings, and has been observed to have abundance periods that alternate with the Bohuslan herring fisheries. The Norwegian spring-spawning herring fisheries follow the similar pattern to the sardine. The oscillations are apparently tied to the severity of the winters, that is forced by the low NAO in response to low sea level pressures off Iceland, that allow cold air masses from Siberia. The high NAO alternate state enhances the westerlies that preclude the Siberian air masses, and bring in warmer air from over the North Atlantic.

These two states of the NAO have somewhat opposite consequences on the western North Atlantic, in that the high NAO state draws cold air masses from the Alaska-Greenland region, that force the Labrador Current, and enhance its cooling effects and subsidence, likely leading to the Canadian/US region's cod and herring cycles. Similar forces are at work in the Sea of Japan where the herring come and go from the North Korean coastline, in alternation with the previously described sardine periods. The dynamics are more thoroughly described in Kawasaki *et al*. (1991).

(d) The Ocean Gyres have been given short shrift by many fisheries researchers, due to the biological oceanographer's definition of these being oceanic deserts, due to the low levels of primary production that they have measured within these regions. However, the perusal of time series of oceanic longline fisheries (Fonteneau 1997, reviewed in Sharp 2001) tells another story. The obvious question becomes: "if these gyres are so unproductive, why are so many hundreds of thousands of tonnes of predator fishes and marine mammals found in them, spawning, feeding, and otherwise thriving?" Of course, much of fishing success depends upon seasonal forcing, and the attendant availability of the various species to the fishing gear (c.f. Hela and Laevastu 1971; Sharp1976, 1978; Marsac and Hallier 1991; Abbes and Bard 1999). Mostly, these fishes and their prey live deep.

4. Polar – or Deep-Ocean Species are the least well understood group of fish species. Fish from very high latitudes are difficult to access on a year-round basis, and most fisheries for these were essentially subsistence level, until relatively recent developments in the Antarctic domain. Deep-Ocean fishes are also poorly understood. Longevity of some these species has attained a near-mythological situation, where some species have been guesstimated to live well over 200 years. Yet, many other deep-water species, notably the decapod molluscs, are known to have annual or comparatively limited life cycles. The group of arctic and deep water species' annual recruitment successes are quite difficult to assess as year classes tend to move about, and then the complex issues of aging individuals (Gauldie *et al.*1991; Gauldie and Sharp 2001).

Clearly, the denizens of the very high latitudes and very deep oceans have the least to be concerned about under potential climate cooling epochs. They might, however, be affected by great warming epochs, for no other reason than their shrinking habitat will also be encroached upon by many more predators, as they too respond to concentration effects due to expansion of the warmer climate zones. The result will be shortening of distances, hence steepened gradients between the various ocean eco-compartments – defined by the temperature ranges within the gradients. The majority of deep-sea fishes are simply unavailable to commercial scale fisheries, due to their relative diffuse nature. One of the more productive single species fisheries in the world is that for Alaska pollock, that produces about 4 million tonnes per year. Given the species' omnivory, and fundamental cannibalism, it seems unlikely that much will change its relative abundance, other than too much focus onto breeding groups, should these be concentrated by the same set of ecological and physiological pressures described above.

Now, there are some questions needing answers, particularly about the apparent synchrony of many of the observed, hemispheric and ocean basin–wide regime shifts. It seems that what is needed is an organized look into Polar Forcing.

3.3 Simultaneity vs systematic transitions

Leroux's (1998) book entitled *Dynamic Analysis of Weather and Climate* provides the most probable connections with Polar Cooling Events, as manifest by what Leroux labels Mobile Polar Highs (MPHs). He defines as "huge discs of dense air which are in the main responsible for variations in pressure, the speed and direction of winds, temperature, humidity, cloudiness and rainfall." These are the results of patterned Polar heat loss, chilling the air, causing subsidence and creating cold dense air, that travels eastward, and equatorward, to interact with the terrain and oceans, (as described in the European sardine and herring cases, above). These cold dense air masses pick up surface heat, moisture, and continue on into the warmer latitudes. As they gather sufficient energy, they can eventually interact with highly energized, moist tropical atmosphere that, in turn is a result of the deep convection along the Inter-Tropical Convergence, and the ocean's Warm Pool in the western Pacific and eastern Indian Ocean. The end-result of these local deep convection-generated processes is the poleward transfer of Equatorial Heat. Leroux (1998) lists the reasons why the lower layers of the troposphere, particularly the planetary boundary layer deserves the most attention in explaining local dynamics of weather and ocean forcing:

- "they are the densest, with half the atmosphere contained in the first 5 500 metres…;
- they contain nearly all the water vapour, which is involved in rainfall and supplies energy, and the greenhouse gases which include water vapour), the greenhouse effect being imperceptible above 5 000 metres;
- paradoxically, the principle source of heat is not from the Sun, but the Earth's surface, which warms the atmosphere... interactions… arising from differences in … substratum, thermal gradients, … deep thermal lows … and vast horizontal circulation;
- among geographical factors, and in conjunction with the distribution of oceans and continents, [orographic] relief acts upon surface temperature, and…is a powerful aerological factor, … determining the paths of a great number of meridional exchanges."

Leroux goes on to argue for the importance of Mobile Polar Highs. He further offers the hypothesis that the Mobile Polar Highs " control the perpetual variations of the weather, and climatic variability, on all time scales. This all ends up being related to Earth's long-term Rotation Rate, or negative Length of Day variations, also, as the interactions are all about water vapour moving from the Earth surface, into the atmosphere, and various energy swaps that the contrary motions of the lower atmosphere and terrain/ocean systems. This will get fuller discussion later.

The ecological consequences are manifold, including everything from seasonal flooding, drought, and cloud cover that modifies terrestrial productivity, to the wind speed/direction induced ocean upwellings, cloud modified light levels, and their ecological cascades through aquatic ecosystems. At the end of all this there stands Everyman, with his growing array of technologies, and ever more hungry masses, trying to cope with all the variations. This dilemma is the underlying basis for most of humanity's ecological interactions, and fears about those many Earth System processes that cannot be controlled, compared to those which have already been clearly modified.

On reflection, from our convergent interpretations, it is found that Leroux's arguments comply with much of our own experience, and interpretations of the origins of forcing, particularly manifest in ocean dynamics, and resulting ecosystem responses, on all time scales.

The core of the convergence lies with several "facts":

1. The Polar Regions are always in a state of negative radiation budget, hence generate subsidence via basal cooling that produce these Mobile Polar Highs, that subsequently drift equatorward, and eastward, impelled by the energy of the Earth's rotation, onward through the paths of least resistance, i.e. across the ice and polar ocean, or through the plains, onto continents. In the Antarctic, the MPHs circulate northeastward in the Southern Ocean until they encounter a continental boundary, where they follow that boundary more northward, and then westward, forming the southern Tradewinds, and, as well contributing to seasonal monsoons across the equator in the Indian Ocean.

2. Because there are more and extensive land masses in the northern hemisphere, the MPH circulations are more diverse, and dramatically affected by the seasonal weather along their terrestrial pathways. They create not only the Tradewinds, but also the storm frequency patterns associated with differing modal MPH pathways. Each region in the northern hemisphere has assigned names to seasonally strong MPH interactions with terrain relief, i.e. venturi effect, the Balkan restriction creating etesian (subregionally, also called also meltemi, vardar, struma, or buria) winds (Leroux 1998), and in western North America there are southern California’s Santana winds, or so-called Chinook winds on the eastern side of the Rockies.

3. Where MPHs from the Siberian and Gobi desert, converge with those from the Bering Sea, they are reinforced, and sweep across the southeastward North Pacific until they are deflected southwards by the Rockies. Others forming north and east of the Rockies, pass southeastward down the plains of North America, to bring about such extreme events as the three "freezes" during the winters between 1983 and 1988 that decimated the Florida citrus industry. It had been over 40 years since such an Event had occurred in the region.

4. The strength and frequencies of the MPHs vary, such that their convergences create a broad array of patterns, and consequences, and as well, either reinforce – or not – the "expected" regional Tradewinds. The Equatorial Trades are dominated by eastward surface flows, leading to the erosion of surface ocean temperatures in the eastern portions of the equatorial Atlantic and Pacific Oceans, and a pressure driven accretion of warm, low-salinity surface waters in the western Pacific as evapourated moisture is transported east to west and precipitation occurs. Sea levels are enhanced by these effects combined with those of the Earth's eastward rotation, the Asian-Australian land boundaries, and the shallow sill effects of the Indonesian Archipelago.

Upon relaxation of the Equatorial Pacific Trades, the gravity (or Kelvin) wave that characterizes ENSO Warm Events for many is released. This phenomenon is accompanied by an eastward movement of SSTs, a complex result of the gravity waves’ displacement of Warm Pool surface waters (although the eastward transport is primarily warm subsurface water). Interactive enhancement of deep convection from the expanding eastern edge of the Warm Pool occurs as the processes entrain both equatorial heat and moisture. As the resulting clouds and moisture are transported eastward and poleward, they trap more heat in the upper ocean under the advancing clouds, recreating their origins in a sequential fashion.

The ENSO-related phenomena have attracted immense research effort over the recent decade or so since the 1982–83 El Niño. Despite the intense observing programs, from satellites or in situ, there remain a series of questions regarding the "trigger" mechanism(s) for the relaxation of the equatorial Trades that lead to the release of the stored surface energy in the western Pacific (White *et al*. 1997; White, Chen and Peterson 1998). Analogously, but in reverse, the Indian Ocean stores heat in its Warm Pool-adjacent eastern extremes, the Indonesian Archipelago, where only a few significant gaps permit throughflow of the high temperature, enhanced sea level surface waters from the Pacific Warm Pool. LeBlanc and Marsac (1999) provide a useful description the related western and eastern Indian Ocean behaviour, as well as the relationship to the Pacific Warm Pool dynamics.

Leroux's thesis leads one to examine the true nature of the sources of variation, on all time scales, of the equatorial Tradewinds. Remarkably, a satisfying answer to the ENSO Warm Event "trigger" emerges. A relatively small change in strength and frequency of MPHs would tend to increase or decrease the equatorial Tradewinds. Obviously, their cessation – or great diminishment of the strength, hence reach of the MPHs – perhaps due to lesser heat loss at the poles – could or would decrease the Equatorial Trades, while potentially increasing the higher latitude Trades. These phenomena suggest direct mechanisms that could explain the somewhat seasonal triggering of ENSO Warm Events. Given the previous insights into northern hemisphere Temperate Zone fisheries, and their forcing, the dynamics of MPHs also suggest reasons why there might be epochal changes in frequencies and intensities of ENSO processes.

Winter cooling in the southern hemisphere is very vigorous, and frequent intense MPHs flow freely around the southern ocean – and equatorward. Their frequency and intensities diminish only slightly during the summer season, reflecting both the region's seasonal insolation patterns, and cloud cover dynamics. The northern hemisphere's trans-Asia, trans-north Atlantic, and trans-North America and trans-oceanic MPHs change in frequency and intensity dynamically, as functions of cloud cover over the polar regions, as well as the short-term pre-history climates of the large continental land masses over which they must travel. In order to affect lower latitude processes they must be further enhanced by either the terrain or ocean surface energy – or both. Hot, dry summer months would tend to reinforce the southward transfers of MPH energy across the vast expanses of Asia and North America. Once an energetic MPH encounters the moist equatorial air masses moving eastward and poleward, they reinforce these, to further enhance their poleward motion, moving the latent heat they contain, poleward. Thus, the two phenomena interact to facilitate the energy transfers that are needed to balance the Earth's surface heat gradients. All of these processes, of course, are embedded within the respectively longer ocean surface and subsurface physical dynamics (Broecker 1991, 1997), and longer term climate-driven processes.

In summary, what seems to be a likely dominant scenario is that the intensity of subsidence at both or either of the Poles facilitates thermodynamic balance of the Equator to Pole(s) thermal gradients. As well, the trajectories of strong MPHs contribute to the atmospheric transport of Equatorial heat, both sensible and latent, transported poleward (eastward in the Pacific and Atlantic, westward in the Indian Ocean, c.f. website from the Warm Pool, or other equatorial sources). The available Equatorial Energy is a function of Deep Convection over Tropical SSTs (or rain forests) that exceed the threshold temperatures of 27º–28ºC, and upper tropospheric winds. The common denominator is the loss of heat, and subsidence at the Poles. What regulates these processes? Whatever source, it is has a quasi-periodic 50–70 year pulse that can be read from both physical records, and from patterns of ecosystem changes.

3.4 Forecasts – from the past into the future

The ultimate lessons about climate change are that close attention must be paid to the past, and then learn to deal with the patterns that have occurred before. There are three sets of global climate projections that involve past history, two with more than a thousand years of proxy data by Dr Doug Hoyt (Figure 18) and Dr Joseph Fletcher, both internationally acknowledged climatology experts. The third is a description of the recent century's patterns that have been related the earth's Rotation Rate (-LOD), to ACI and AT, as described in the earlier section. This is from a study that has been submitted, peer reviewed, and finalized for immediate publication in a respected Russian geophysics journal.

If Hoyt's perspective is accepted as realistic expectation, in about 8 000 years the world will be about 3ºC or 5ºF cooler. In the next 2 000 years, the Earth will cool about 0.4ºC. Also note that 70 percent of the last 10 000 years were warmer than the present. A visit to Hoyt's website provides the necessary background information that explains the cause and effect reasoning that he (and others) have used to forecast a relatively near-term cooling trends will begin in around 2016–2020.

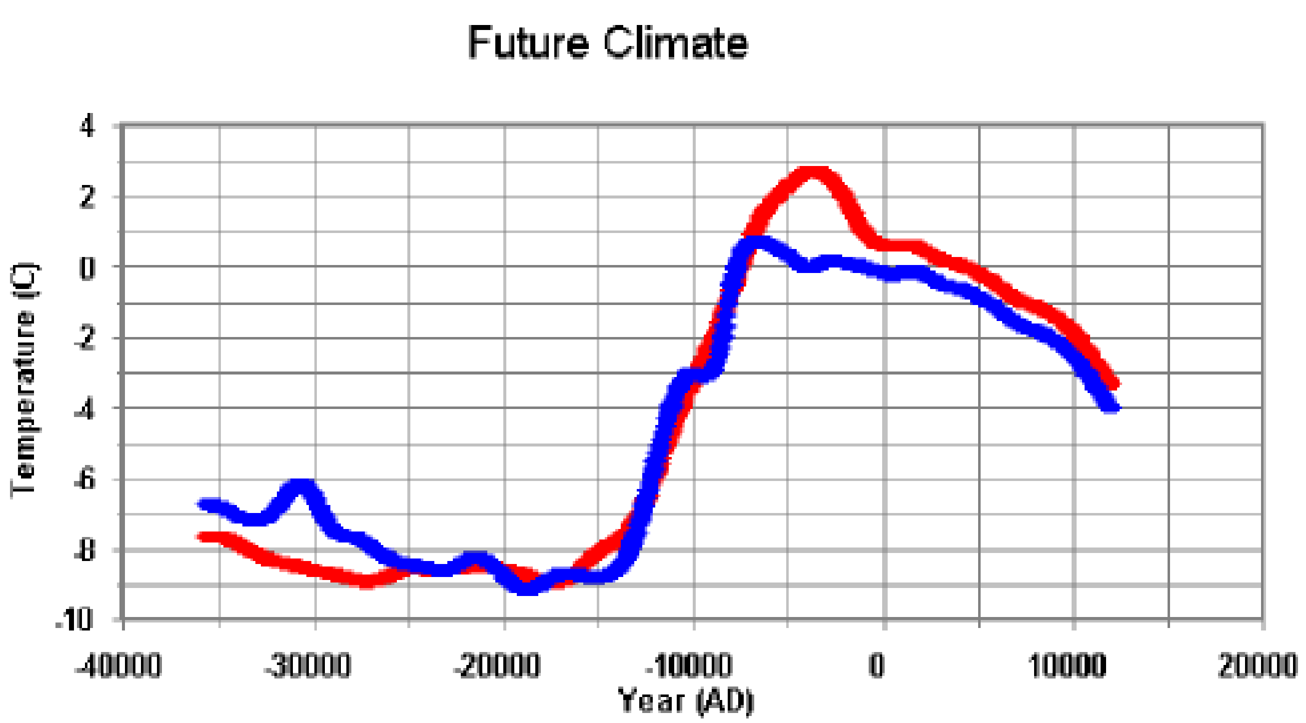


Figure 18 Shows Doug Hoyt's contribution to our Climate Future Cast, in terms of solar influences on Earth's average temperature. The blue line is the present interglacial and the red line is the last interglacial. These curves were lined up so that they matched what occurred when the Earth came out of the previous ice age, following the same time line. (From D. Hoyt's website, URL link in appendix).

Dr Joseph Fletcher, provides a uniquely cogent review of present climate insights, and has made a projection into the next 100 years of Global Climate (Figure 19). Dr Fletcher was the major force behind the initial collation and continuation of the Comprehensive (Consolidated) Ocean and Atmosphere Data Sets (COADS) that provides most of the recent climate research community with their basis in historical observations. He keeps these records up to date as a basis for much of his synthesis. His hypothesis about twenty-first century Climate is based on the likelihood that past processes are cyclic, and will repeat themselves with a period of 170–180 years.

His primary projection is based on the longest available records of solar activity; those from glacial Ice Cores. Beryllium 10 concentrations are used as a proxy of the solar wind driven by the sun's activity. The next step in Dr Fletcher's projection exercise was to find the parts of the historical Be10 data set that matched up with the recent data trends, on a period of about 170 years. The present surface solar emission trend is about 1.3 or so watts per meter warmer than 170 years ago, when the Little Ice Age was left behind and the solar irradiance trended upward toward previous Warm period levels. The projection period was offset by 1.5 Watts per meter beginning about 1970, and extended by using the "clipped" 170 years of records after 1810 or so, overlain on the recent record, and extended.

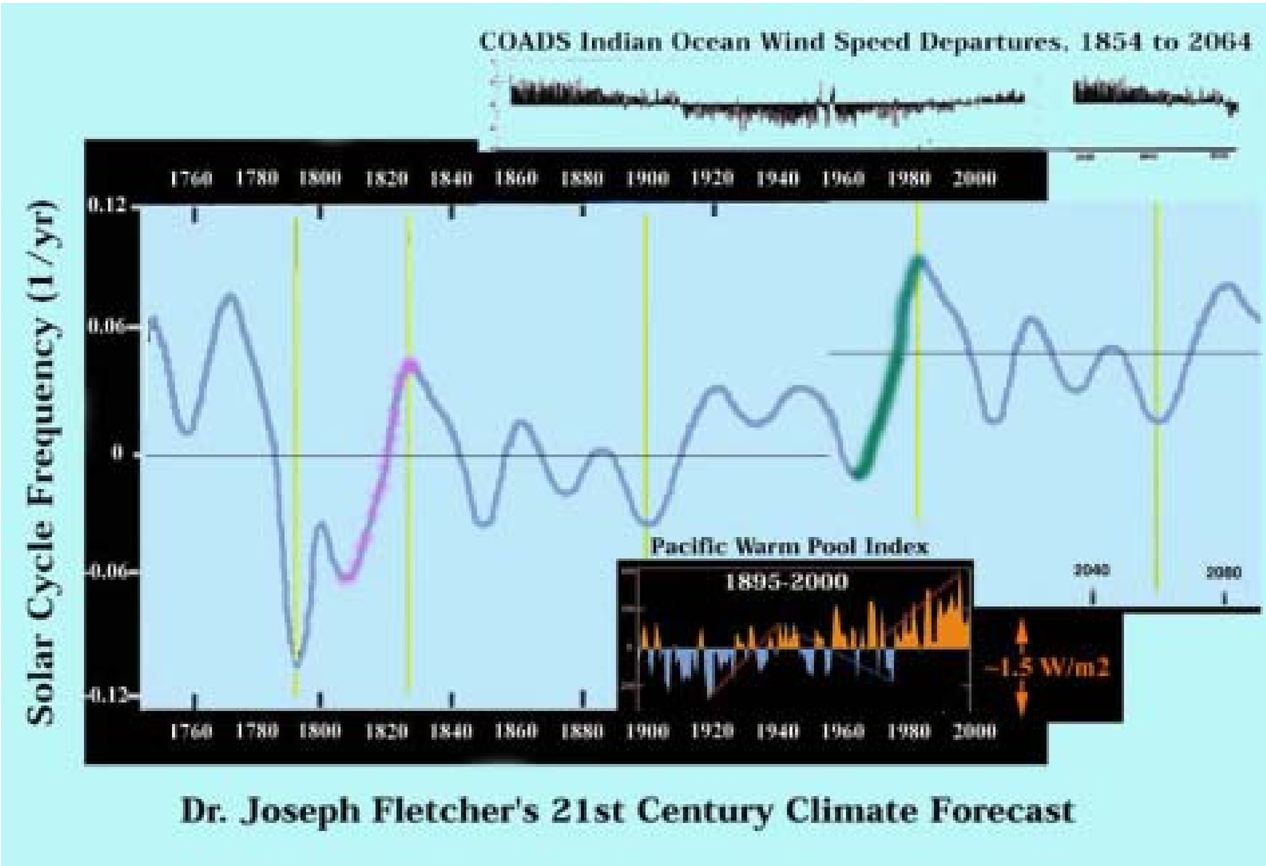


Figure 19 Provides Joseph Fletcher's Global Climate projection, under the basic hypothesis that patterns will repeat on an approximately 170 year cycle. By adding the COADS wind speed departures, along with the Index of the size or coverage of the Indo-Pacific Warm Pool (bottom graph inset), the general agreement of the trends in the various independently collected data sets provide reason to accept Dr Fletcher's projection of climate to be "expected over the next century".

These are marked in purple (historical) and green (matched points beginning the projection) on the trend line in Figure 19. Also included in this figure are two other reliable measures, the one (at the top) is from Figure 12c, in which the southernmost (and most energetic global region) record of the Indian Ocean COADS surface wind speed departures were extended using the 170 year similarity concept. The bottom graphic insert is a simple Index of the number of 4x4 latitude-longitude squares that have SSTs >=29^{o}C in the Indo-Pacific Warm Pool region. The two records accord with the long-term solar record's trends.

Meanwhile, let us not forget what is already known, from other available records, and previous discussion. Recently, Klyashtorin *et al*. (1998, in review) found that the curve of AT anomaly is similar in shape to that of the –LOD. However, the latter trails the first by 14–16 years. Shifting the AT anomaly forward (to the right) by 15 years results in a good coincidence of the AT and -LOD curves (Figure 20). The right part of the AT anomaly curve may therefore serve as an approximation of the -LOD trend into the first decade or so of the twenty-first century. Unlike the AT anomaly, the -LOD dynamics are characterized by doubled peaks (**a** and **b**) – as seen earlier in Figure 4. Primary peaks (a) coincide with the maximums of shifted AT anomalies and secondary peaks (b) are out of phase with these maximums. The reasons of this phenomenon are not clear yet, but the current increase in -LOD is likely to change with a decline by 2004–2007, as occurred within the 1890s and 1950s.

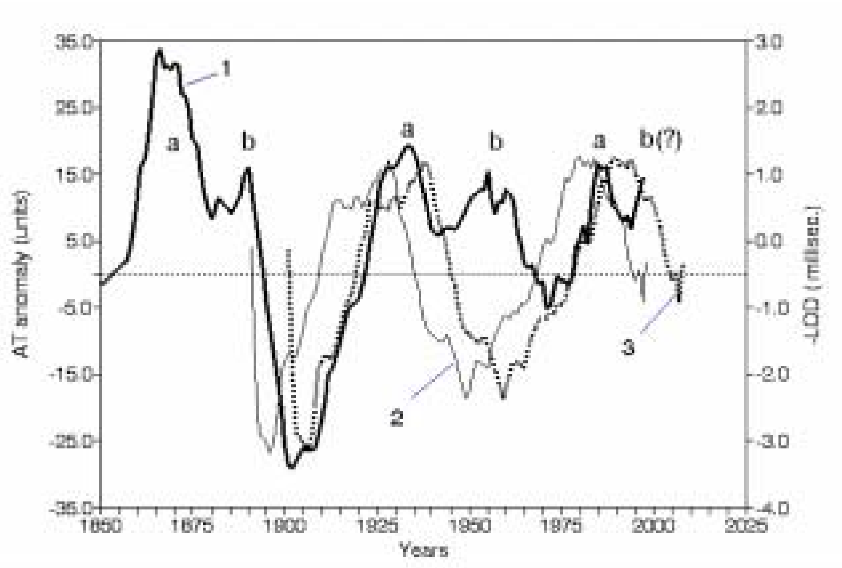


Figure 20 Provides the time series dynamics of -LOD and AT anomaly from 1850 until 2010 or so: (1) -LOD (average annual, detrended); (2) AT anomalies smoothed by 21 year averaging; (3) the latter record shifted to the right 12 years; Peaks denoted with **a** and **b** – are the primary and secondary peaks of -LOD. See the text for fuller explanation.

Figure 21 presents the original detrended Earth surface air temperature (dT) and AT time series and their dominant cyclic trends. The delay in phase of the cyclic trend of dT in relation to that of AT is about 19 years. This accords with preliminary conclusions made on the basis of qualitative analysis (visual comparison) of the time series.

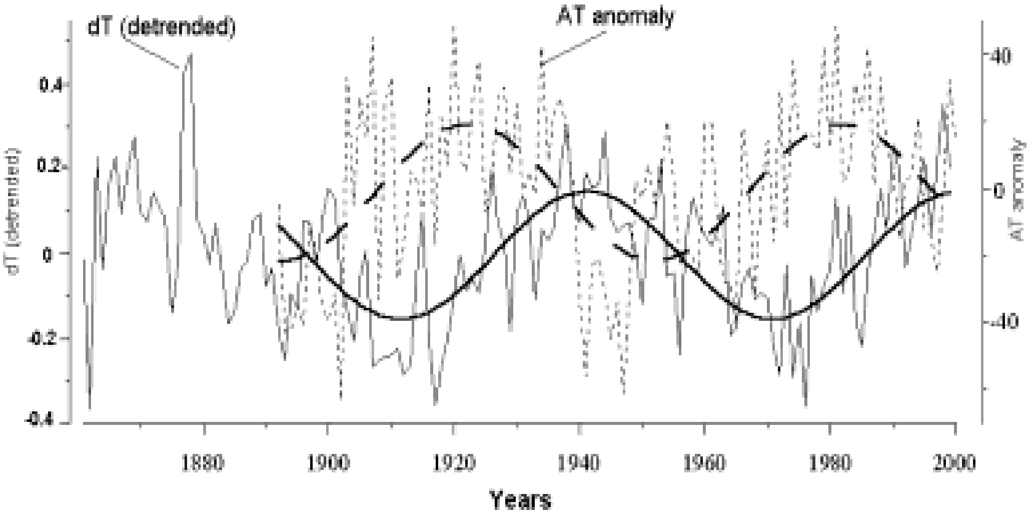


Figure 21 Shows the comparison of AT anomaly and detrended dT dynamics. (1) Thick dashed line – dominating cyclic trend of AT anomaly with a period of 59.35 years; (2) Thick solid line—dominating cyclic trend of detrended dT with a period of 59.42 years). The dT cyclic trend lags the AT anomaly cyclic trend by 19 years.

The curves of AT anomaly and dT (Figure 22 below) are also similar in shape, but the AT anomaly leads dT by 16–18 years. Shifting the AT anomaly right by 18 years results in almost complete coincidence of the curves, but in this case the rest of the AT anomaly continues into the future making it possible to predict dT dynamics for at least 15 years ahead.

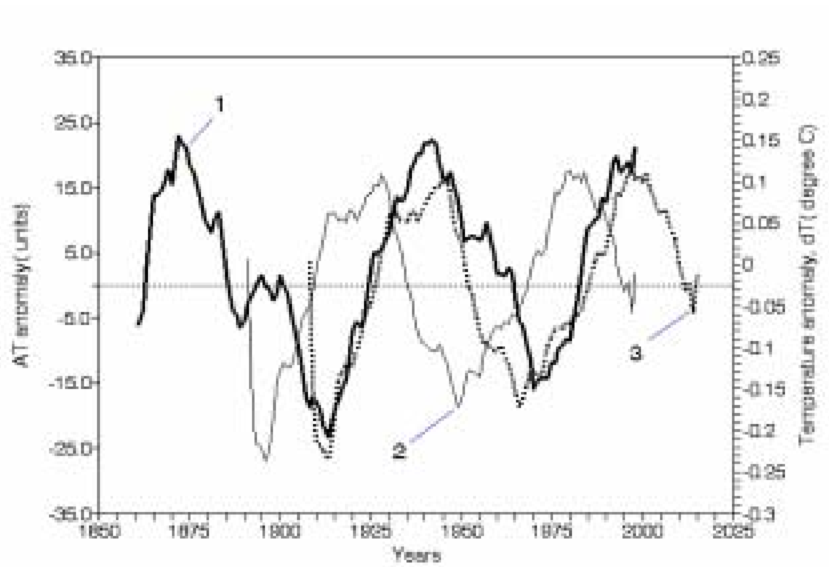
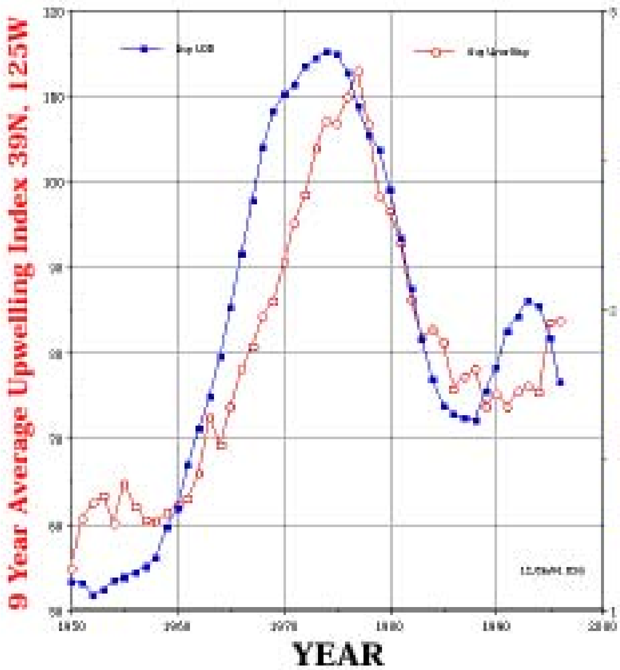


Figure 22 Shows the time series of dynamics of the global temperature anomaly (dT) and AT anomaly: (1) dT (detrended and smoothed by 13-years averaging), (2) AT anomalies smoothed by 21 years averaging; and (3) the latter shifted by 17 years.

The shifted AT anomaly (line 3) in Figure 22 gives grounds to expect that the current increase in global dT will slow down or stop in the next 2–3 years, followed by somewhat steady decrease (by about 0.18°C compared to its present value) by 2015. It should also be taken into account that Figure 21 presents a detrended dT curve. If the current age-long temperature trend (described by Sonechkin 1998; Sonechkin, Datsenko and Ivaschenko 1997) continues into the future, the expected decrease in global temperature anomaly (dT) by 2015 will be about 0.12°C. It is possible, however, that the age-long trend will slow down by the early 2000s. In that case, the expected decrease in dT will be about 0.15°C by 2015. At this point it is emphasized that this forecast refers only to the dT trend, and cannot predict accurately the average global temperature in 2015.

James Goodridge, retired California State Climatologist, maintains constant updates for the State of the newly arrived climate records. He also has a strong interest in the large framework of climate forcing, and prediction, as offered by Klyashtorin and colleagues. Among the first analyses that Goodridge did on learning of the –LOD relations was to some of the local processes, and differences across the Pacific basin. Figure 23 and Figure 24 provide more insights into the linkages between local upwelling and basin-wide sea level pressure with the –LOD signal.

Figure 23 Is a plot of Length of Day and the Upwelling Index off San Francisco California. Both were created using nine year running averages, and scaled to match ranges. This and the graphic in Figure 24 tell us is that there is direct wind-driven forcing that occurs in synchrony with LOD, in accord with Klyashtorins ACI/E-W atmospheric indices.



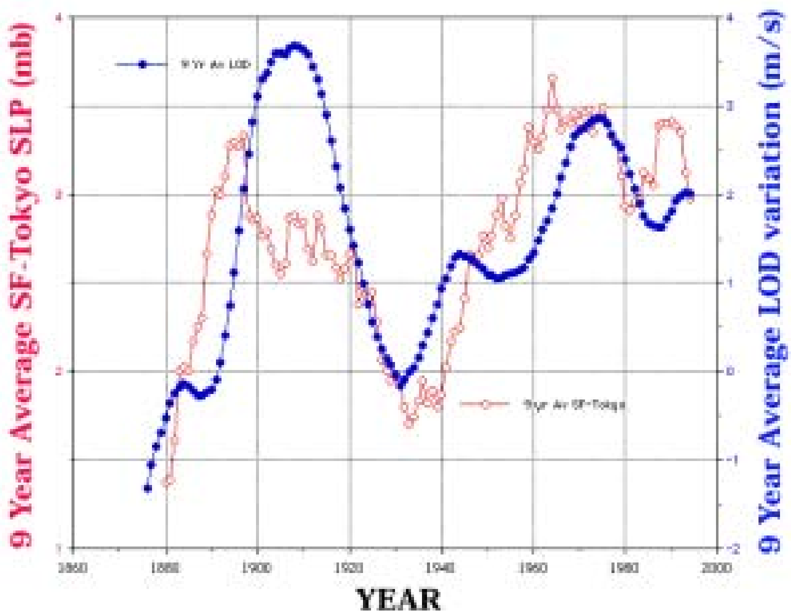


Figure 24 Shows the interesting relationships with Length of Day and the sea level pressure of Tokyo, over the recent 125 years. Note that this is also in synchrony with a Warm/Cold see-saw of ocean surface temperatures that affects the marine faunas of the North Pacific Ocean.