1.1.1.1 Tree rings

A cross section of a temperate forest tree shows variation of lighter and darker bands that are usually continuous around the circumference of the tree. These bands are the so-called tree rings and are due to seasonal effects. Each tree ring is composed of large thin-walled cells called early wood and smaller more densely packed thick walled cells called late wood. The average width of a tree ring is a function of many variables including the tree species, tree age, stored carbohydrates in the tree, nutrients in the soil, and climatic factors including sunlight, precipitation, temperature, wind speed, humidity, and ~~even~~ carbon dioxide availability in the atmosphere. Obviously there are many confounding factors so the ~~problem~~ **challenge** is to extract the temperature signal and ~~to~~ **thus** distinguish the temperature signal from the noise caused by the many confounding factors. Temperature information is usually derived from inter-annual variations in the ring width as well as inter-annual and intra-annual density variations. Density variations are valuable in paleo-climatic temperature reconstructions because they have a relatively simple growth function that, in mature trees, is approximately linear with age. The density variations have been shown empirically to contain a strong climatic temperature signal. Two values of density are measured within each growth ring: minimum density representing early wood and maximum density representing late wood. Maximum density values are strongly correlated with April to August mean temperatures in trees across the boreal forest from Alaska to Labrador~~, Schweingruber et al., (1993~~). Both tree ring width and density data are used in combination to extract the maximal climatic temperature signal.

Climate signal is strongest in trees that are under stress. Trees growing in sites where climate does not limit growth tend to produce rings that are uniform. Trees that are growing close to their extreme ecological range are greatly influenced by climate ~~.Climate~~ variations **that** strongly influence annual growth increments. Two types of stress are commonly recognized, moisture stress and temperature stress. Trees growing in semi-arid regions are limited by water availability**,** and thus variations in ring width reflect this climatic moisture signal. Trees growing near ~~to~~ their ecological limits either in terms of latitude or altitude show growth limitations imposed by temperature and thus ring width variations in such trees contain a relatively strong temperature signal. However, the biological processes are extremely complex**,** so ~~that~~ very different combinations of climatic conditions may cause similar ring width increments. Tree growth and carbohydrate production by a tree in one year will precondition the tree for strong growth in the subsequent year so that there is a strong autocorrelation in the ring width time series. Photosynthetic processes are accelerated with the increased availability of carbon dioxide in the atmosphere and, hence, it is conjectured that ring growth would also be correlated with atmospheric carbon dioxide~~; see Graybill and Idso (1993~~). **Robinson, Robinson and Soon (2007) and … [3 inserted sentences omuitted].** In addition, oxides of nitrogen are formed in internal combustion engines that can be deposited as nitrates also contributing to fertilization of plant materials. It is clear that while there are temperature signals in the tree rings, the temperature signals are confounded with many other factors including fertilization effects due to use of fossil fuels. **[New paragraph omitted in Rapp].** Wider rings are frequently produced during the early life of a tree. Thus**,** the tree rings frequently contain a low frequency signal that is unrelated to climate or, at least, **is** confounded with climatic effects such as temperature. In order to use tree rings as a temperature signal successfully, this low frequency component must be removed. This is typically done by a nonlinear parametric trend fit using a polynomial or modified exponential curve. Because the early history of tree rings confounds climatic signal with low-frequency specimen**-**specific signal, tree rings are not usually effective for accurately determining low frequency, longer-term effects. Once there is reasonable confidence that the tree ring signal reflects a temperature signal, ~~and then~~ a calibration is performed using the derived tree ring data and **the** instrumented temperature data **over the (comparatively recent) period during which actual climatic temperature measurements were made**. The assumption in this inference is that when **the** tree ring structure observed during the instrumented period that is similar to **the** tree ring structure observed in the past, both will have correspondingly similar temperature profiles **(Beckman and Mahoney, 1998).** [**New paragraph in Rapp only]**

However, as ~~As~~ pointed out earlier, many different sets of climatic conditions can **(**and do**)** yield similar tree ring profiles. Thus**,** tree ring proxy data alone is not sufficient to determine past climate variables **(Mann, Bradley, and Hughes, 1998)**.

As Soon and Baliunas (2003a, b) pointed out:
"[Long block quote omitted.]"

Despite these repeated warnings and cautions by a number of scientists, paleo-climatologists have used tree rings widely and repeatedly to infer past temperature variations, although the variations from investigator to investigator are large (Esper et al., 2005a).

~~See Bradley (1999) for a discussion of the fitting and calibration process for dendritic-based temperature reconstruction.~~ **Anon. (N) provides further details on the use of tree ring proxies.**

1.1.1.2 Ice cores

The accumulated past snowfall in the polar caps and ice sheets provide a ~~very useful record~~ **basis** for paleo**-**climate reconstruction. We shall refer to ice cores in this section even though strictly speaking there is **typically** a combination of snow and ice. Somewhat compressed old snow is called ~~a~~ firn. The transition from snow to firn to ice occurs as the weight of overlying material causes the snow crystals to compress, deform and recrystalize in more compact form. ~~As~~ **When** firn is buried beneath subsequent snowfalls, density is increased as air spaces are compressed due to mechanical packing as well as plastic deformation. Interconnected air passages may then be sealed and appear as individual air bubbles. At this point the firn becomes ice. Paleo**-**climatic information derived from ice cores is obtained from four principal mechanisms: **(**1) analysis of stable isotopes of water and atmospheric oxygen; **(**2) analysis of other gases in the air bubbles in the ice; **(**3) analysis of dissolved and particulate matter in the firn and ice; and **(**4) analysis of other physical properties such as thickness of the firn and ice.

The mechanism by which stable isotopes of oxygen and hydrogen carry a temperature signal is as follows. ~~An oxygen atom can exist in three stable forms with atomic weights of 16, 17 or 18.~~

~~Oxygen with an atomic weight of 16 makes up 99.76% of all oxygen atoms. Similarly, hydrogen can exist in two stable forms with atomic weights of one or two, the latter being called deuterium. Hydrogen with atomic weight of one comprises 99.984% of all hydrogen. Thus water molecules can exist in several heavy forms when compared with normal water, which is made up of two atomic-weight-1 hydrogen atoms and one atomic-weight-16 oxygen atom~~. The vapor pressure of normal water is higher than the heavier forms of water **(containing either ^{18}O or D or both) because the lighter molecules have higher average velocities at the same temperature.** ~~with evaporation resulting in a~~ **When liquid water evaporates, the** vapor ~~that~~ is relatively ~~speaking~~ poor**er** in the heavier forms of water. Conversely, the remaining **liquid** water will be enriched in water containing the heavier isotopes. **In the inverse process,** when condensation occurs, the lower vapor pressure of water containing the heavier isotopes will cause that water to condense more rapidly than ~~normal~~ **lighter isotopes of** water. ~~The greater the fall in temperature, the more condensation will occur; hence, the water vapor will exhibit less heavy isotope concentration when compared to the original (sea) water.~~ **The magnitude of this enrichment is temperature-dependent.** Thus**,** the relative isotope concentrations in the condensate will be a direct indicator of the temperature at which condensation occurred. **The ice presently … [2 sentences omitted]. [New para omitted in Rapp]** In addition to the relative heavy/light isotope ratios, the trapped bubbles in ice cores provide a record of atmospheric concentrations of trace gases including greenhouse gases such as carbon dioxide, methane and nitrous oxide. ~~In addition~~ **Furthermore,** the ice cores contain **a** record of aerosols and dust content resulting from volcanic eruptions and other changes in particulate content in the atmosphere. The relative atmospheric concentrations of greenhouse gases as well as aerosol and particulate content coupled with other climate information gives insight into both the importance of these as drivers of temperature as well as how these drivers might couple in either a positive or negative feedback sense **(Beckman and Mahoney, 1998)**.

According to Soon and Baliunas (2003a,b):
"[Long block quote omitted.]"

However, the process by which precipitated snow is gradually compressed into firn, and then ice, entrapping gas bubbles and preserving isotope concentrations, may take hundreds of years or longer. As a result, ice core data typically represent averages smeared over several hundred (or more) years.

……………..

1.1.1.6 Coral

~~The term "coral" refers to the biological order *Scleractinia*, which~~ **Corals** have hard calcium-based skeletons supporting softer tissues. An important subgroup for paleo**-**climate studies is the reef-building corals in which the coral polyp lives symbiotically with single-celled algae. These algae produce carbohydrates by means of photosynthesis and are affected by water depth, water turbidity, and cloudiness. Much of the carbohydrates diffuse away from the algae providing food to the coral polyp, which in turn ~~provide~~ **provides** a protective environment for the algae. Reef-building corals are strongly affected by temperature and, as temperature drops, the rate of calcification drops with lower temperature potentially presaging the death of the colony. Coral growth rates vary over a year and can be sectioned and x-rayed to reveal high- and low-density bands. High-density layers are produced during times of higher sea surface temperatures. Thus**,** not unlike tree rings, data on corals also can be calibrated to estimate (sea) surface temperatures **(Beckman and Mahoney, 1998)**.

"[Long block quote omitted.] (Soon and Baliunas, 2003a, b).