

Examination of Temperature Change Over Time with Latitude

Term Project for: Global Warming: The Science of Climate Change

University of Chicago Coursera Offering

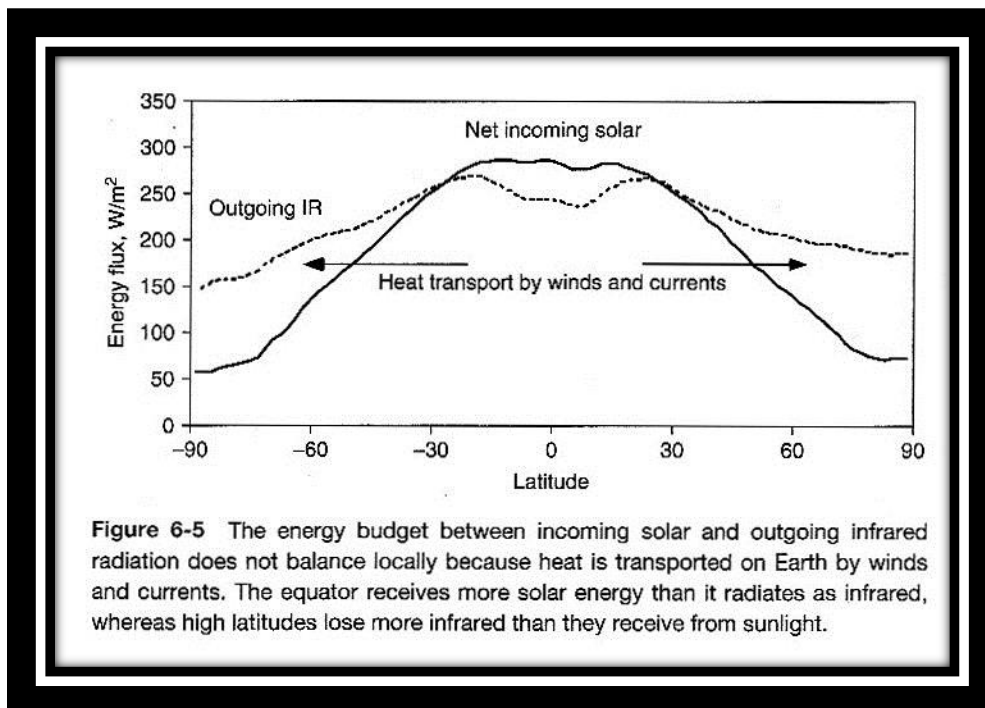
December 12, 2013

Introduction

The question I am investigating is whether the earth is warming at the same rate at all latitudes. I examine temperature data around the world and see if I can find a pattern in warming rates as a function of latitude.

As covered in the course material, the flux of outgoing IR local to the equator is insufficient to balance the incoming solar energy local to the equator. Energy balance at the equator is obtained with the assistance of heat transport by atmosphere and ocean which carry heat away from the equator. As a result, the climate at earth's equator is not as warm as it would be if it was only cooled by outgoing IR.

This graph appears in "Global Warming, Understanding the Forecast, 2nd Edition", by David Archer, John Wiley and Sons, ©2012.



This diagram clearly shows that because of the atmosphere and ocean heat transport mechanisms, the temperature in the polar regions of earth are warmer than can be accounted for by the incoming solar radiation. The graph does not, however, say anything about the change that will result when greenhouse gases are added to the atmosphere. With addition of greenhouse gases, the outgoing IR of the earth will be reduced until a new equilibrium at a higher temperature is achieved. During the time in which this new equilibrium is being achieved, i.e., "now", what will happen to the heat transport? Will it increase thereby adding to the warmth of the polar regions?

There are other effects that may contribute to increased warming at higher latitudes. One notable one is a change in the earth's albedo at the poles, i.e., with less snow and ice cover at the poles, heat retention would be expected to increase greatly. A similar effect would not exist at lower latitudes.

My investigation does not attempt to identify which effect is responsible but only show that there is a pattern that can be seen in historical data. If there is accelerated warming in the polar regions it may well be caused by both the effects of additional heat transport from the equatorial region and of additional polar solar energy retention due to a lower albedo.

I have set out to find evidence for this in the historical temperature data available at the Climate Time Series Browser (<http://climatemodels.uchicago.edu/timeseries/>).

My method was to use the latitude banding feature to select temperature data from a number of stations a latitude band starting with 80-90N, and working my way down to the equator, and finally to 80-90S. However, for the analysis, I need long term data so that I can normalize the data and combine it for several stations so that I can get a single estimate of degrees per decade of temperature change for each band of latitude. As a result, there is only adequate data available from 70-80N down to 60-70S. The result from each of 15 analysis runs is a set of degrees C/ decade temperature change per latitude band. A simplifying assumption was made that the nominal latitude for the band was the midpoint in the band, e.g., the temperature change rate for the latitude band 40-50N was taken to be for the latitude $(40+50)/2 = 45$ degrees. These 15 data points were then scatter plotted showing temperature change rate versus latitude band midpoint and a linear regression was run to determine if there is a trend. Finally, the slope of the trend line was taken to provide an estimate of how temperature change per decade varies with degrees of latitude away from the equator.

Analysis

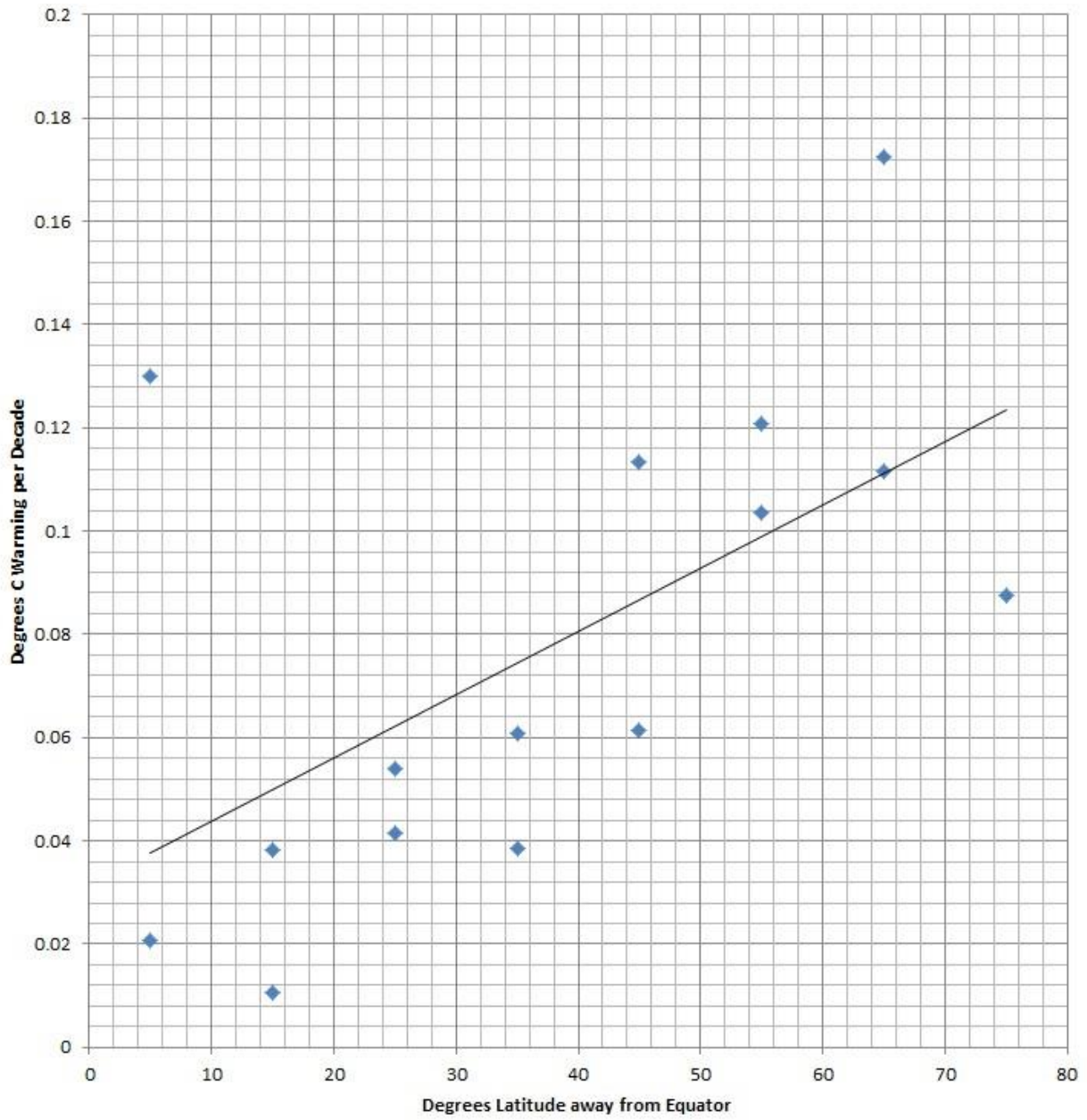
The plot of degrees per decade against latitude was done such that degrees north and degrees south are treated the same. This seems valid since the earth's behaviour with respect to solar energy balance ought to be symmetrical about the equator.

There is a trend such that the farther a point is away from the equator, the more warming per decade appears to be occurring. **The rate of warming per decade increases by an amount of 1.225×10^{-3} degrees C/decade with every degree of latitude that you move away from the equator.**

This interpretation is not without problems. One point in particular has an issue. The band of latitude between the equator and 10 degrees south deviates strongly from the trend. The data within this latitude band shows a warming rate of 0.12 degrees C/decade. This rate of warming is higher than all latitudes except 60 – 70S. There does not appear to be anything specifically wrong with the source data. It can only be concluded that the geography local to the locations where this data was collected has features that have enhanced the warming.

It should be said that at all latitudes there is a problem of limited data of a sufficiently long span of time to make this analysis feel confident. This is particularly evident in the polar regions to the point where there is no old data in the polar extremes.

Plot of Warming per Decade against Degrees Latitude away from Equator



Analysis Data Derived from Time Series Browser Plots

Latitude Degrees from Equator	Degrees C Warming per Decade
75N	0.087600771
65N	0.111506618
55N	0.120675317
45N	0.113451221
35N	0.060716483
25N	0.041517564
15N	0.010666587
5N	0.020616149
5S	0.13004456
15S	0.038183373
25S	0.054125083
35S	0.038685943
45S	0.061430934
55S	0.103574497
65S	0.172498217

Time Series Browser plots

70 - 80 N

<http://climatemodels.uchicago.edu/timeseries/#CmzGEgxCzo>

C/decade = 0.087601

Met. Station Data | Forcings | Records | AR5 Models

Vegetation ▾

- WARM DECIDUOUS
- HEATHS, MOORS
- WATER
- WARM FOR./FIELD
- MED. GRAZING
- HIGHLAND SHRUB
- WARM GRASS/SHRUB
- HOT DESERT
- SAND DESERT
- COOL FOR./FIELD
- TROP. SAVANNA
- TROP. SEASONAL
- WARM FIELD WOODS
- COASTAL EDGES
- TROPICAL DRY FOR

Station Names

Search...

- (Odry) Riyan/Aden Protec
- 100 Mile House.Bc
- Aachen
- Abadan
- Abag Qi
- Abashiri
- Abbaissia/Cairo Hq
- Abeche
- Abercorn
- Aberdeen
- Aberdeen
- Aberdeen Exp Stn
- Aberdeen Rgnl Ap

Showing 7169 stations

Number of stations selected: 4
 Number of models selected: 0
 Number of scenarios selected: 0
 Number of model/scenario couples: 0
 Number of datasets on the plot: 4

Temperature Trend, °C / Decade

Time Range: 1850 - 2013

List Composite

Ostrov Dikson	0.15
Ostrov Chetyr	-0.17
Barrow/W. Pos	0.13
Vardo	0.10

Total Historical Radiative Forcing

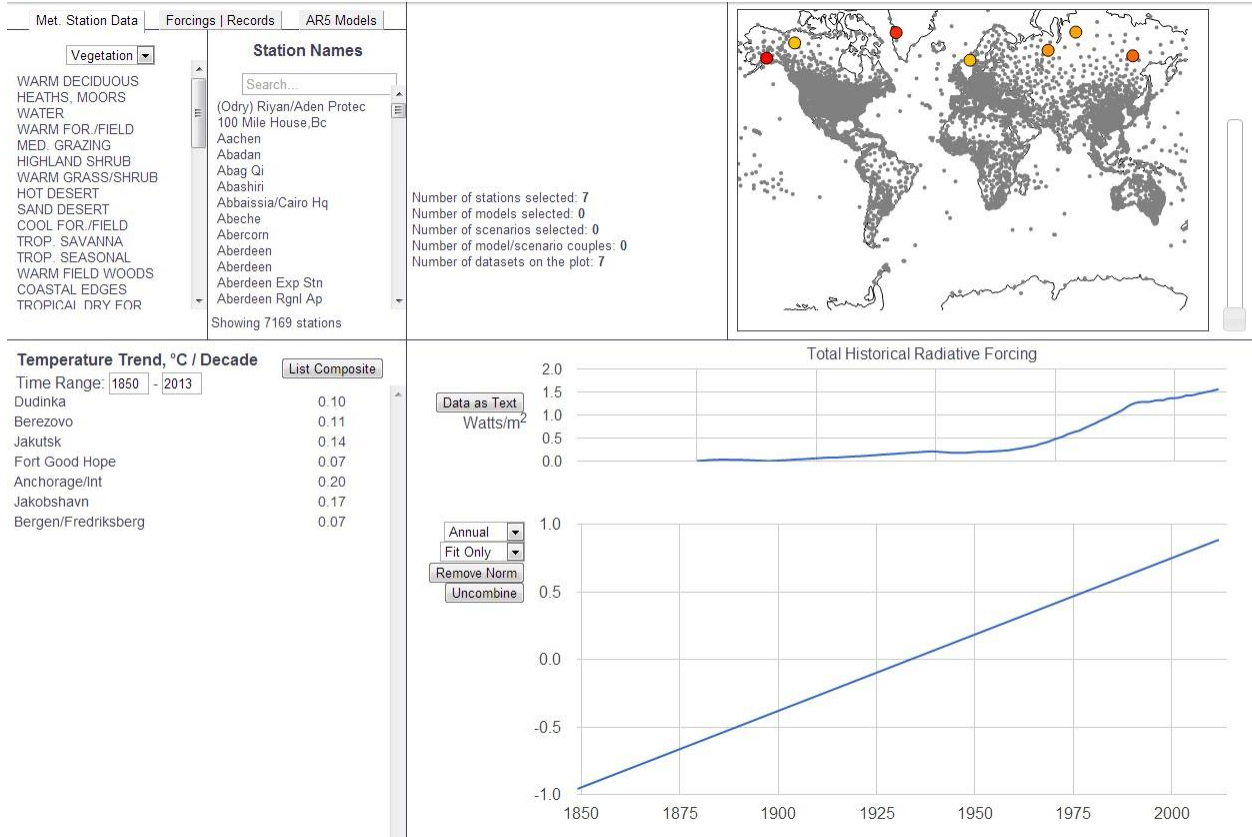
Watts/m²

Annual ▾
 Fit Only ▾
 Remove Norm
 Uncombine

60 - 70 N

<http://climatemodels.uchicago.edu/timeseries/#CniJZVqDldBabByq>

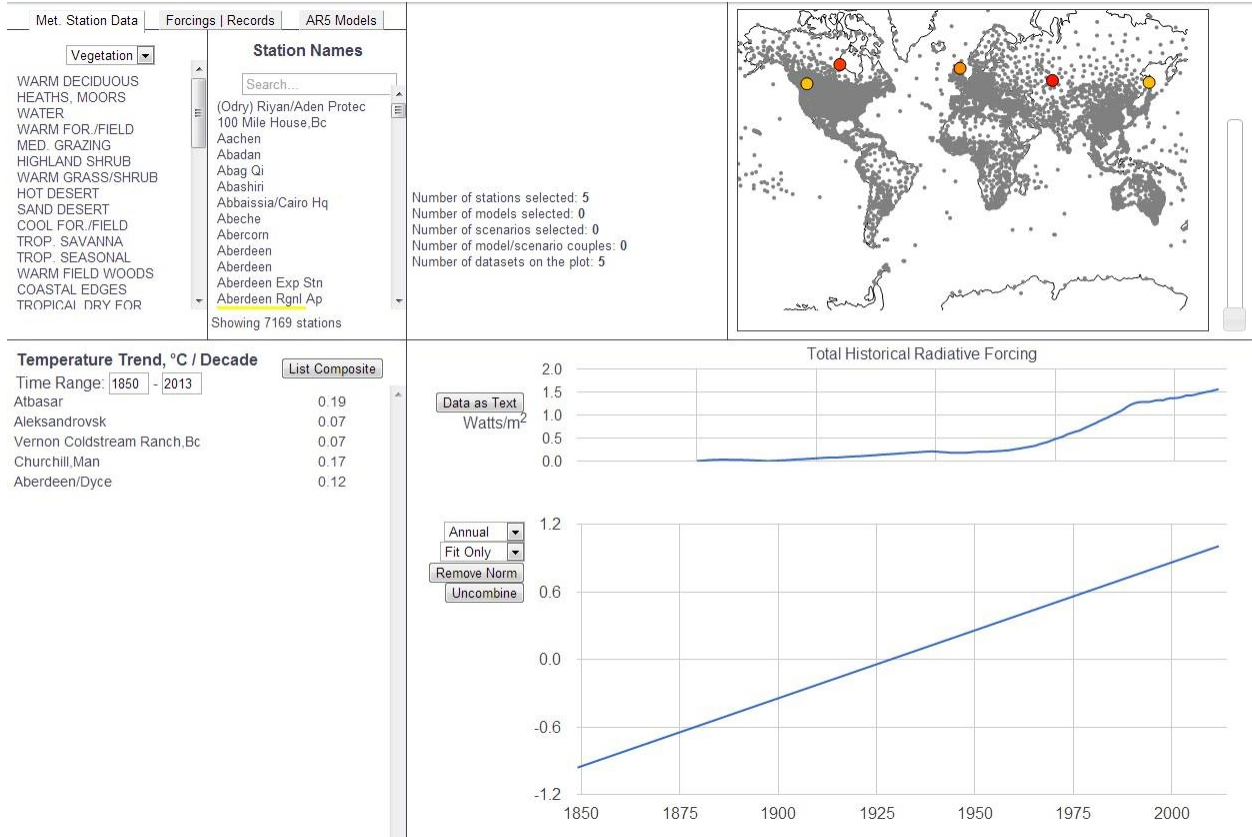
C/decade = 0.111507



50 - 60 N

<http://climatemodels.uchicago.edu/timeseries/#CdbOyVxXvGei>

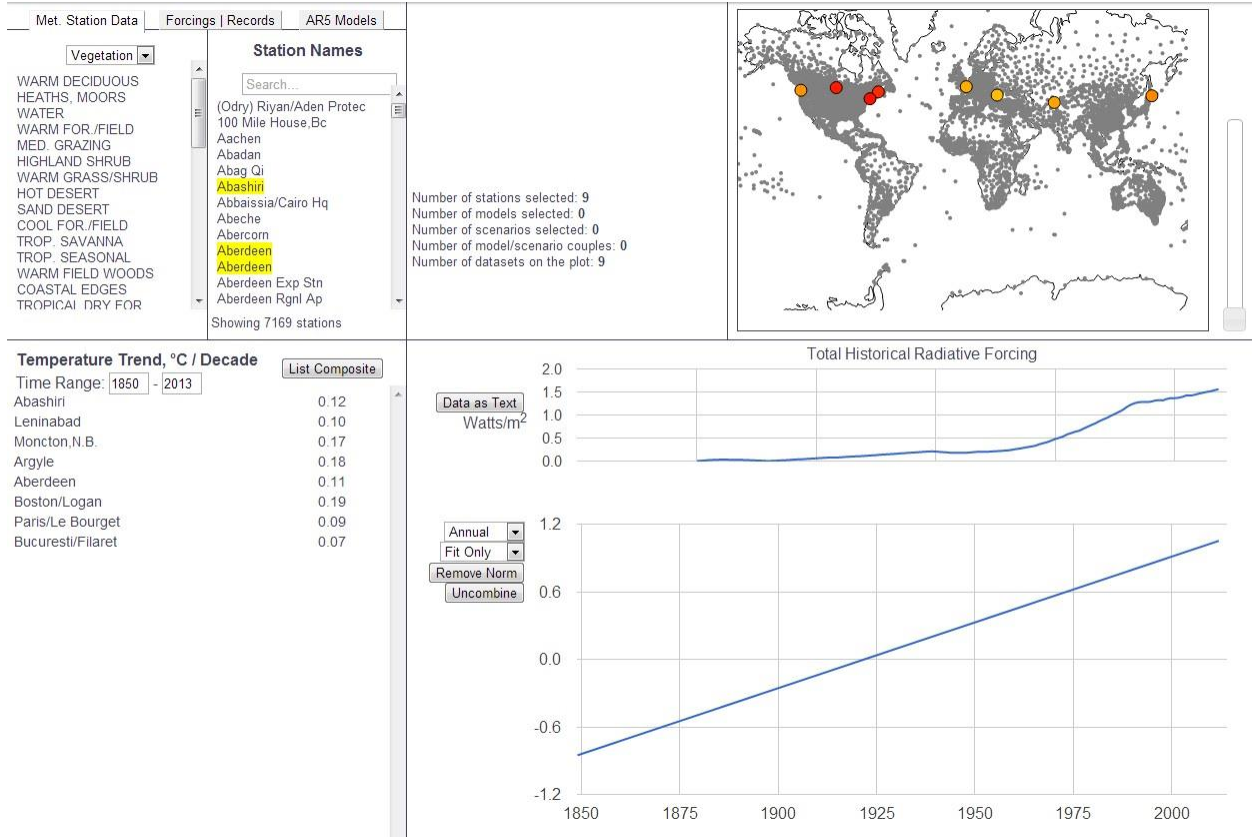
C/decade = 0.120675



40 - 50 N

<http://climatemodels.uchicago.edu/timeseries/#BwtJyMyBcvBttZuTgByoQm>

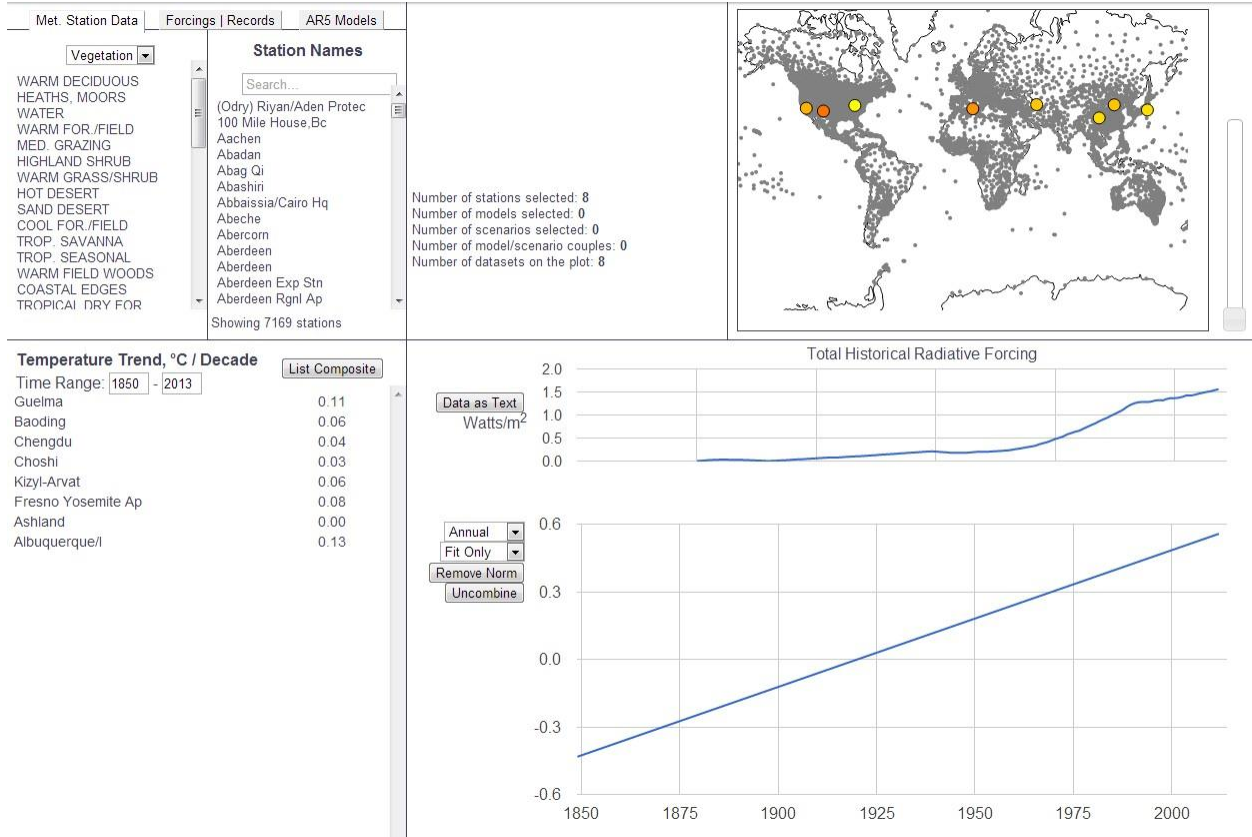
C/decade = 0.113451



30 - 40 N

<http://climatemodels.uchicago.edu/timeseries/#GBhacPrWcCguKnBrd>

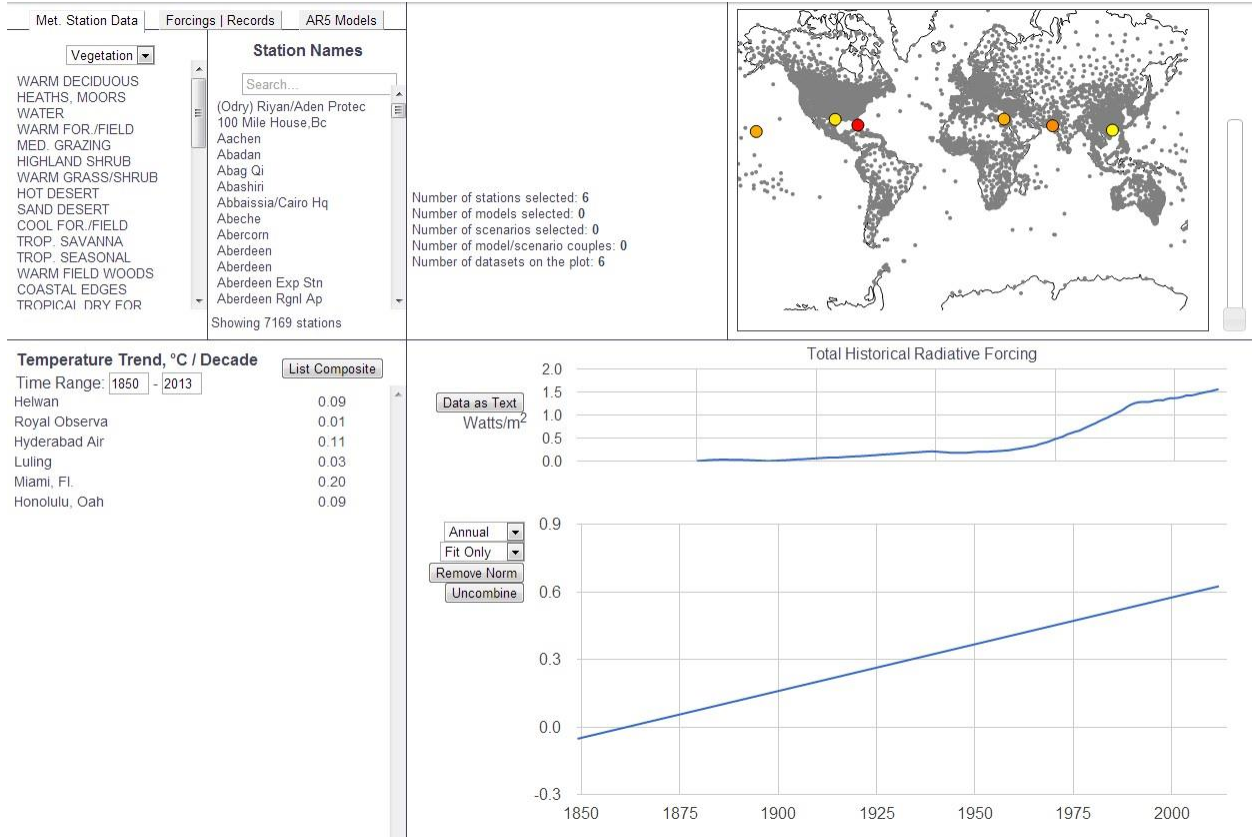
C/decade = 0.060716



20 - 30 N

<http://climatemodels.uchicago.edu/timeseries/#HhToBjdEcsJyYg>

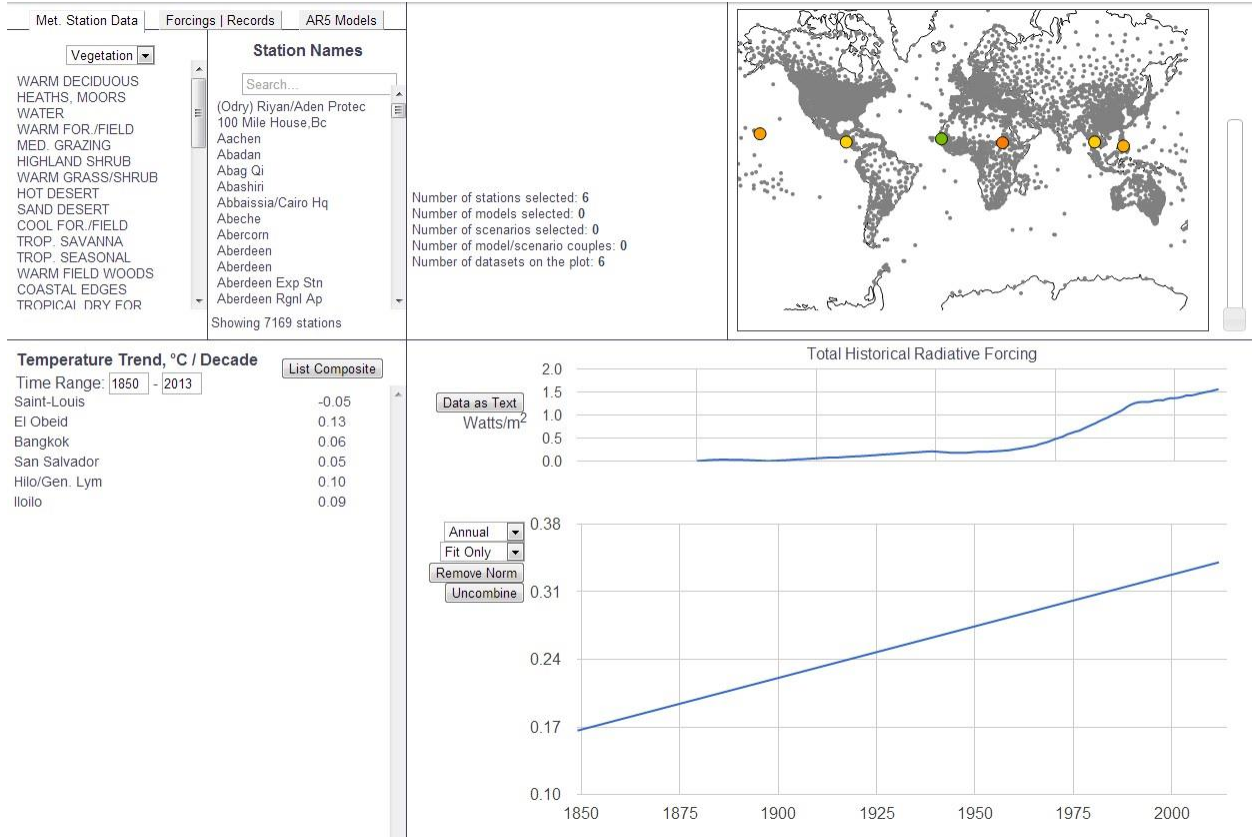
C/decade = 0.041518



10 - 20 N

<http://climatemodels.uchicago.edu/timeseries/#PuFhBznBybDcnBer>

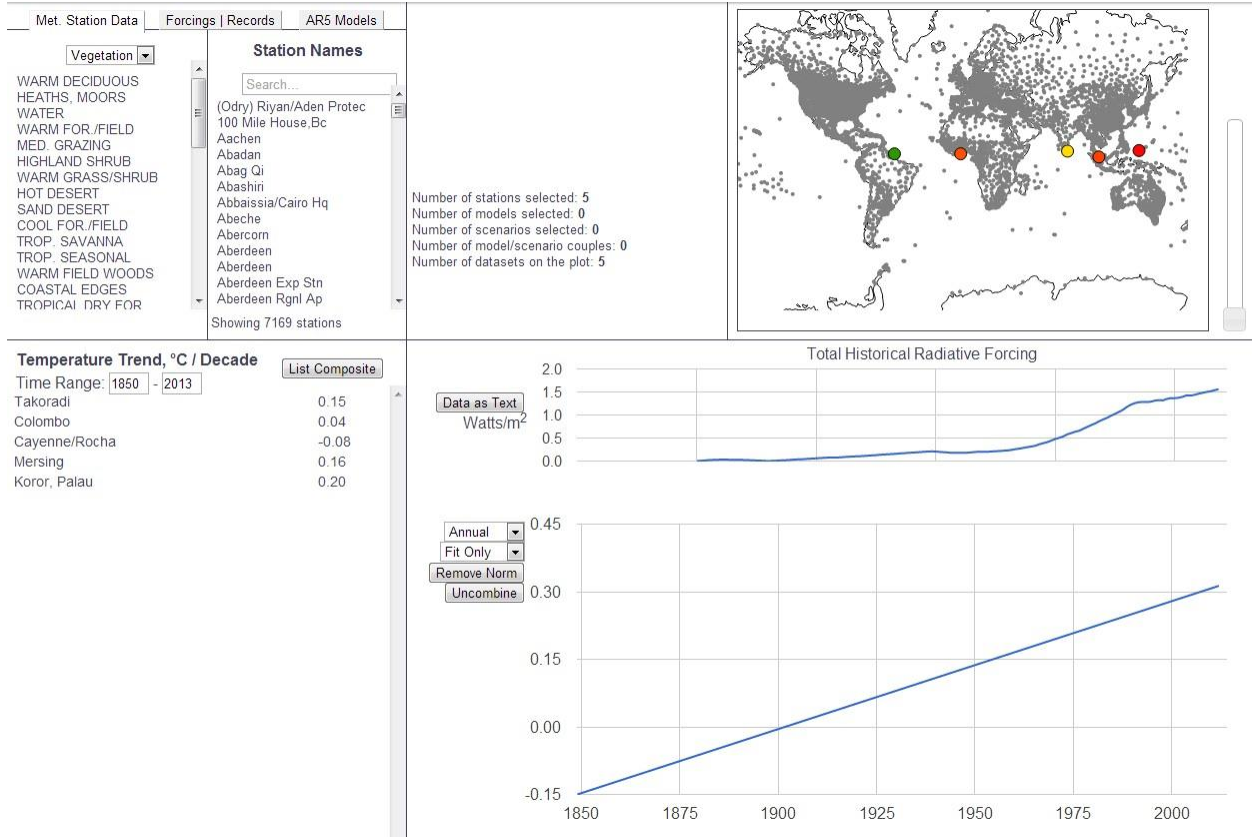
C/decade = 0.010667



0 - 10 N

<http://climatemodels.uchicago.edu/timeseries/#JeCkgQfFncGb>

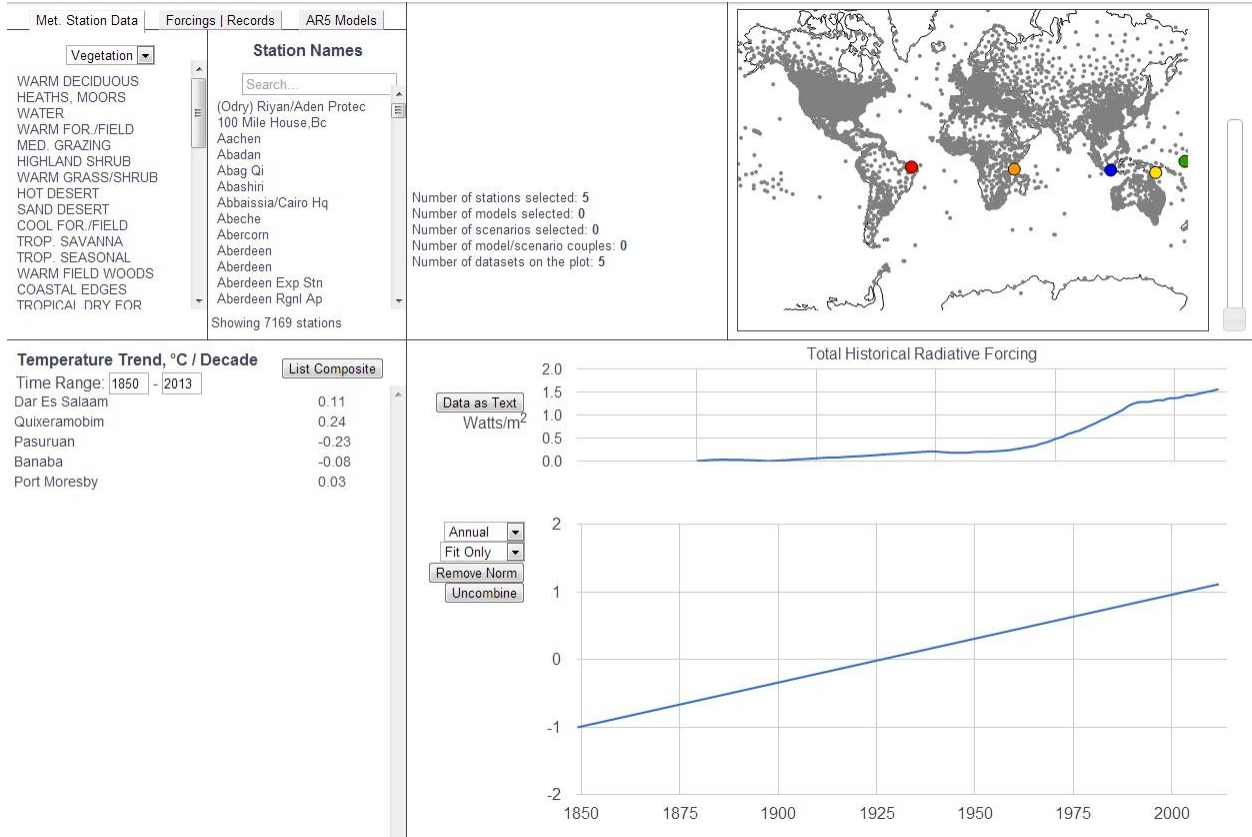
C/decade = 0.020616



0 - 10 S

<http://climatemodels.uchicago.edu/timeseries/#VxCfbFufByBc>

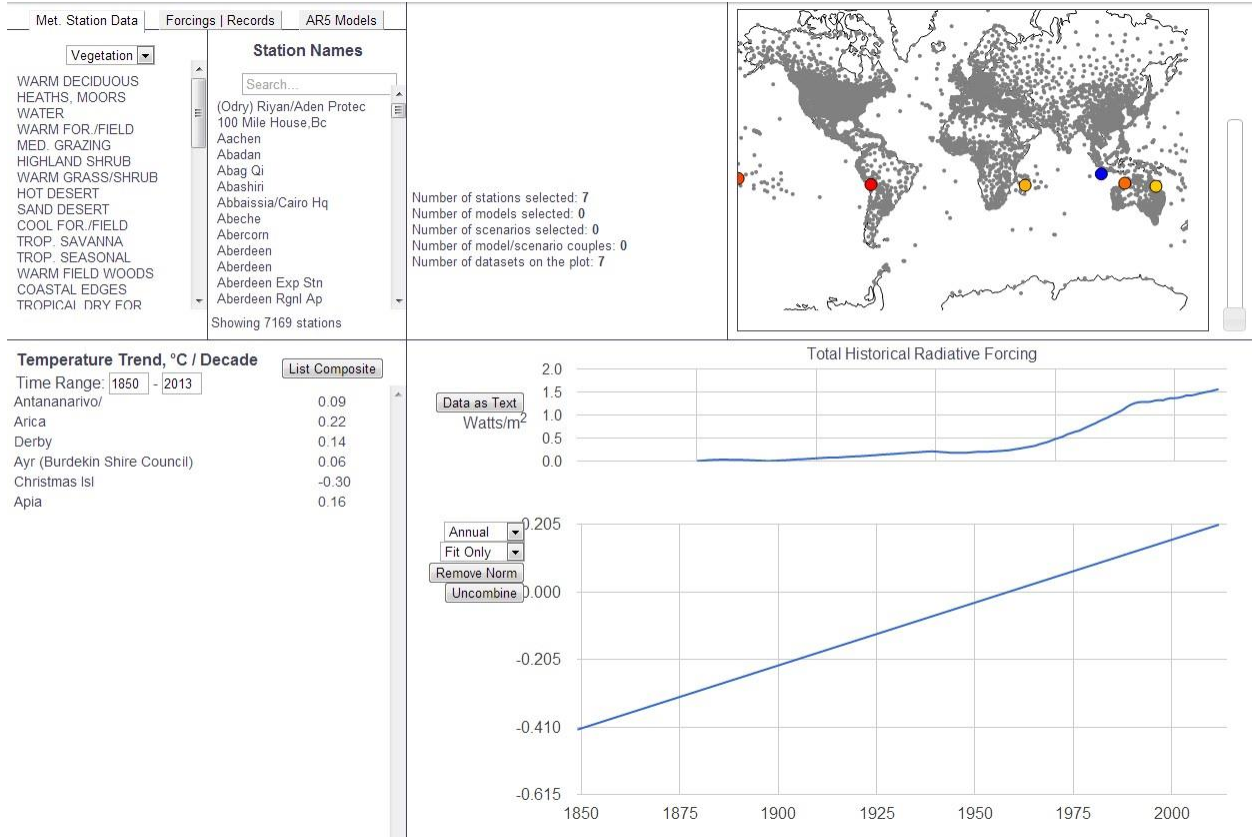
C/decade = 0.130045



10 - 20 S

<http://climatemodels.uchicago.edu/timeseries/#LvHCqoEvgBmBbxBt>

C/decade = 0.038183



20 - 30 S

<http://climatemodels.uchicago.edu/timeseries/#YvChnEvgPaKxBi>

C/decade = 0.054125

Met. Station Data | Forcings | Records | AR5 Models

Vegetation

- WARM DECIDUOUS
- HEATHS, MOORS
- WATER
- WARM FOR./FIELD
- MED. GRAZING
- HIGHLAND SHRUB
- WARM GRASS/SHRUB
- HOT DESERT
- SAND DESERT
- COOL FOR./FIELD
- TROP. SAVANNA
- TROP. SEASONAL
- WARM FIELD WOODS
- COASTAL EDGES
- TROPICAL DRY FOR

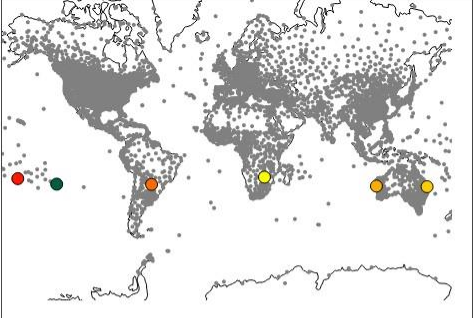
Station Names

Search...

- (Odry) Riyan/Aden Protec
- 100 Mile House,Bc
- Aachen
- Abadan
- Abag Qi
- Abashiri
- Abbaissia/Cairo Hq
- Abeche
- Abercorn
- Aberdeen
- Aberdeen
- Aberdeen
- Aberdeen Exp Stn
- Aberdeen Rgnl Ap

Showing 7169 stations

Number of stations selected: 6
Number of models selected: 0
Number of scenarios selected: 0
Number of model/scenario couples: 0
Number of datasets on the plot: 6



Temperature Trend, °C / Decade

Time Range: 1850 - 2013

List Composite

Bulawayo	0.00
Asuncion/Aero	0.14
Hamelin Pool (Hamelin Pool)	0.09
Beenwah (Crohamburst)	0.05
Rarotonga	0.19
Pitcairn	-0.13

Total Historical Radiative Forcing

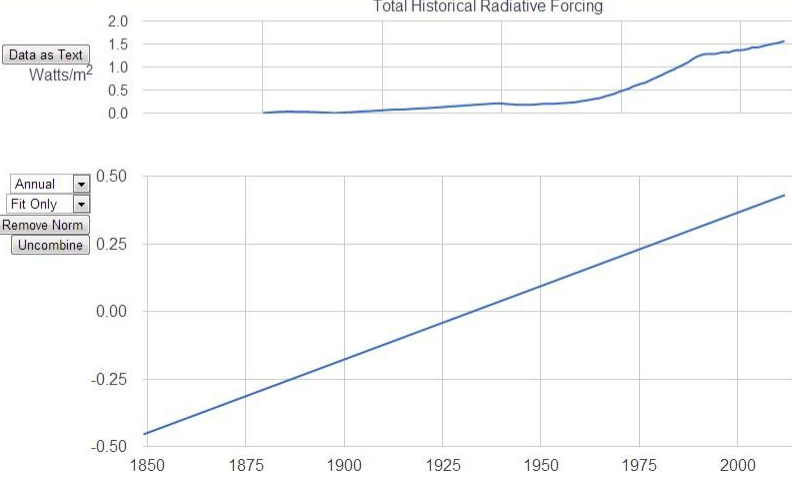
Watts/m²

Annual

Fit Only

Remove Norm

Uncombine

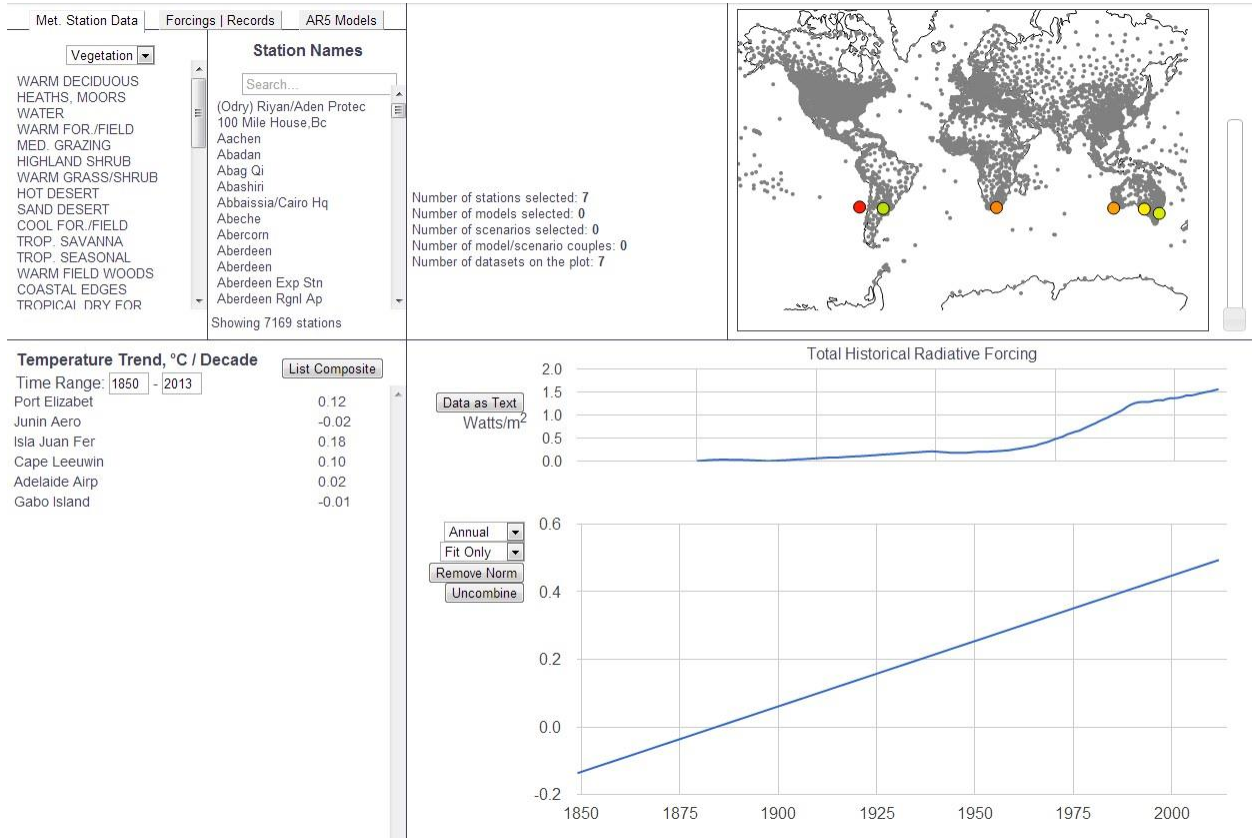


The figure displays two line graphs. The top graph, titled 'Total Historical Radiative Forcing', shows a blue line representing radiative forcing in Watts/m² from 1850 to 2013. The y-axis ranges from 0.0 to 2.0. The line remains near 0.0 until approximately 1950, then rises steadily to about 1.5 by 2013. The bottom graph shows the temperature trend in °C/decade for six stations from 1850 to 2013. The y-axis ranges from -0.50 to 0.50. A blue line shows a consistent upward trend, starting at approximately -0.45 in 1850 and reaching about 0.40 by 2013. The graph includes interactive controls for 'Annual', 'Fit Only', 'Remove Norm', and 'Uncombine'.

30 - 40 S

<http://climatemodels.uchicago.edu/timeseries/#TqCegFhFbwCgHrIh>

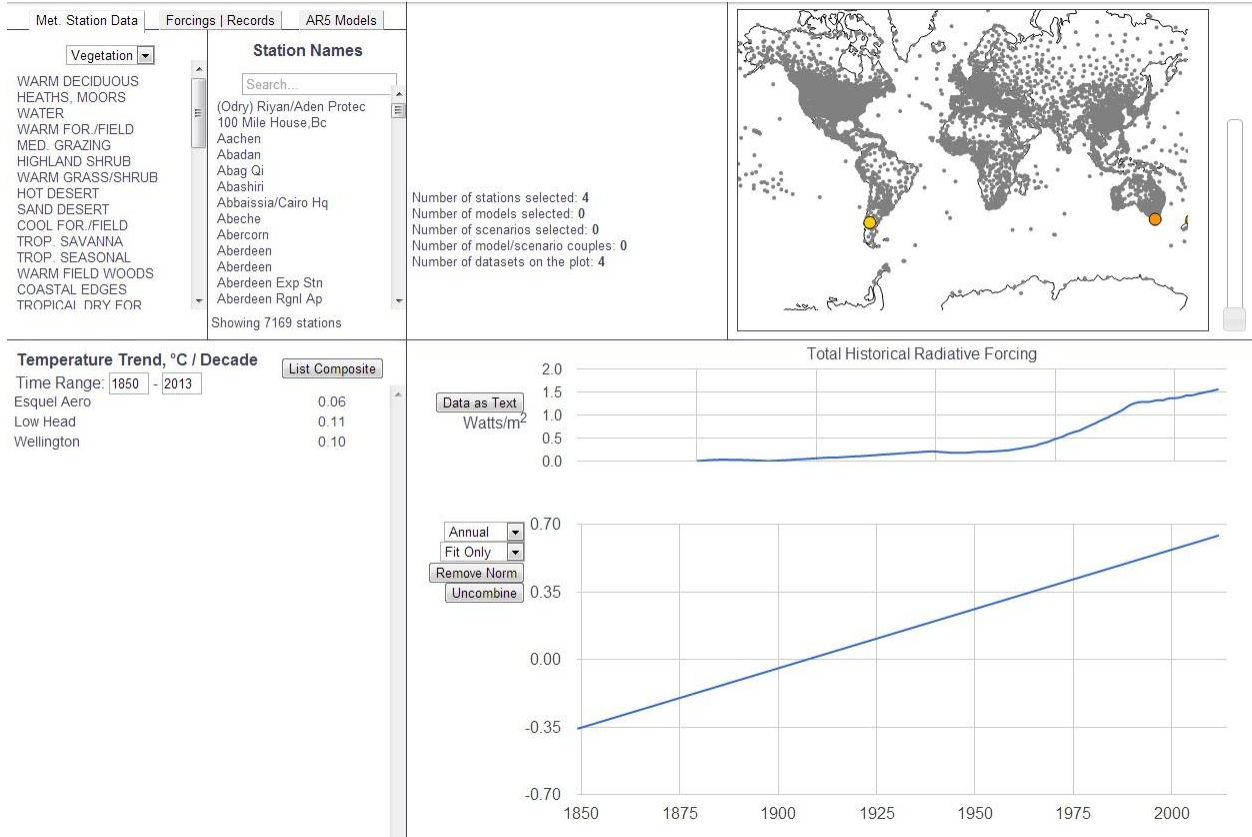
C/decade = 0.038686



40 - 50 S

<http://climatemodels.uchicago.edu/timeseries/#UcCevFqnIb>

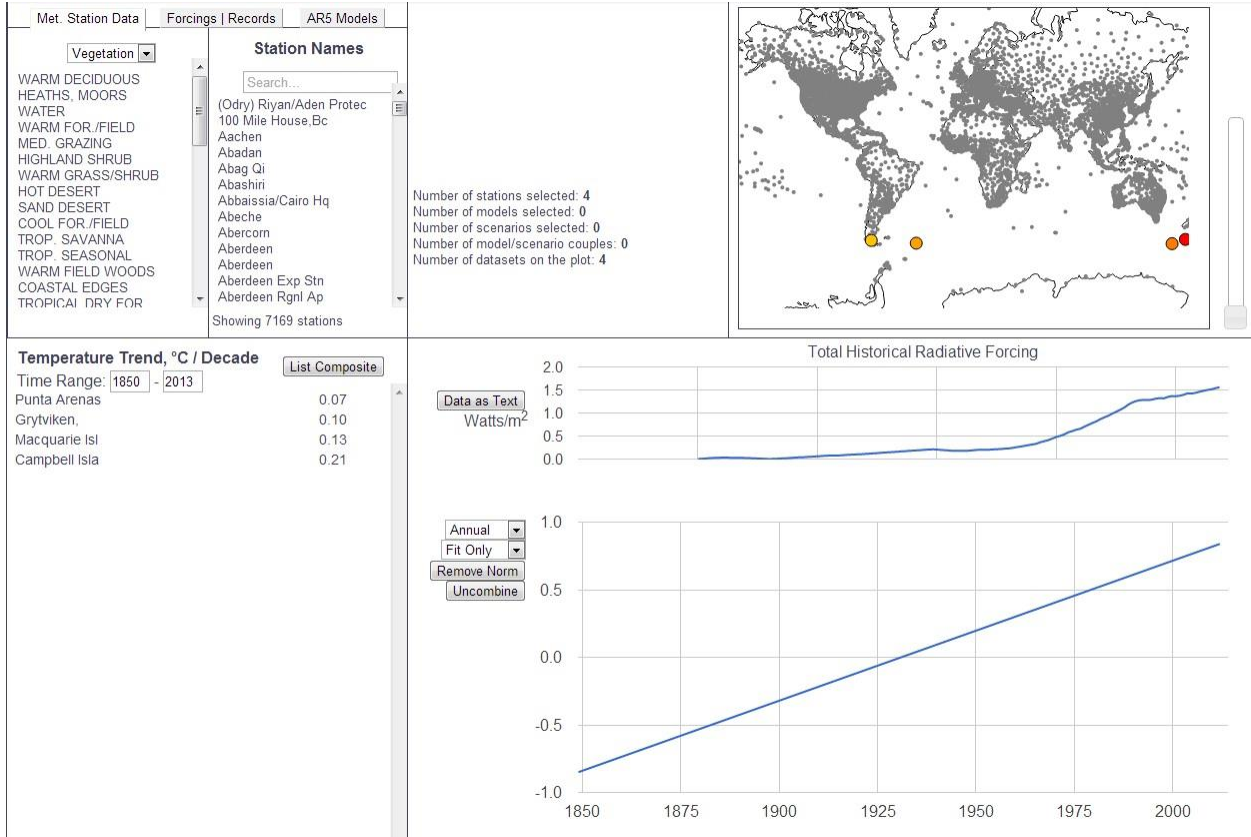
C/decade = 0.061431



50 - 60 S

<http://climatemodels.uchicago.edu/timeseries/#DdsGcFggHt>

C/decade = 0.103574



60 - 70 S

<http://climatemodels.uchicago.edu/timeseries/#KsulFE>

C/decade = 0.172498

