Monitoring the Climate of Glacier Bay

2005 Progress Report

Studies Conducted As Part of Research Project: Long-term tidewater and terrestrial glacier dynamics, glacier hydrology, and Holocene and historic glacier activity and climate change in Glacier Bay National Park and Preserve

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Introduction

For the last 15 years, we have conducted long-term, integrated monitoring and site-specific multidisciplinary studies of glacial, marine and terrestrial physical systems to improve our understanding of physical processes and their interactions within the freshwater, marine and terrestrial ecosystems of the Park. Climate and its variability in time and space is an overarching driver of the Park ecosystems. Global changes in climate will have significant ramifications for environmental and ecosystem responses in the near and long-term, an understanding of which will be useful to management in designing and implementing plans for utilizing and protecting its resources while accommodating visitors to the park in the future.

We continue to monitor contemporary climate throughout the Glacier Bay watershed, building upon the first systematic monitoring of the climate in the park which we initiated in 1999. Climate data are a critical component to most of our research, as well as those of other researchers working within Glacier Bay. In particular, they characterize important daily, seasonal, annual and decadal controls on the marine, freshwater and terrestrial environments, and our data will provide the baseline for future Park applications.

Climate sites are distributed regularly within the interior Glacier Bay watershed so that regional trends can be identified and correlated with temporal variations. These data will allow us to analyze storm patterns in the Park, assess differences in weather between the East and West arms, and evaluate impacts of short-term climatic changes. For our paleoclimate investigations (Lawson *et al* 2004; 2006), we will use these data to calibrate tree-ring records and examine any spatial variability (local climatic effects) that may have affected ancient tree-ring records.

Methods

Currently, 24 sites are active with all but one located along fiord margins at or near sea level (Figure 1). Each site has a minimum of two rain gauges (for redundancy), a temperature gauge, and a bulk precipitation collector for heavy isotope analysis (Lawson *et al* 2004; Finnegan *et al* 2006). The rain gauges (Onset RG-2 Tipping Bucket; Peet Electronic) record rainfall to Hobo event data loggers in 0.01 inch increments (Figure 2). Temperature is measured to 0.1 ° C accuracy at a 20 minute interval using two separate thermistors that are housed within a solar radiation shield (Figure 2). Snow gauges previously used at three sites are being repaired and upgraded and will be returned to active use in September 2007.

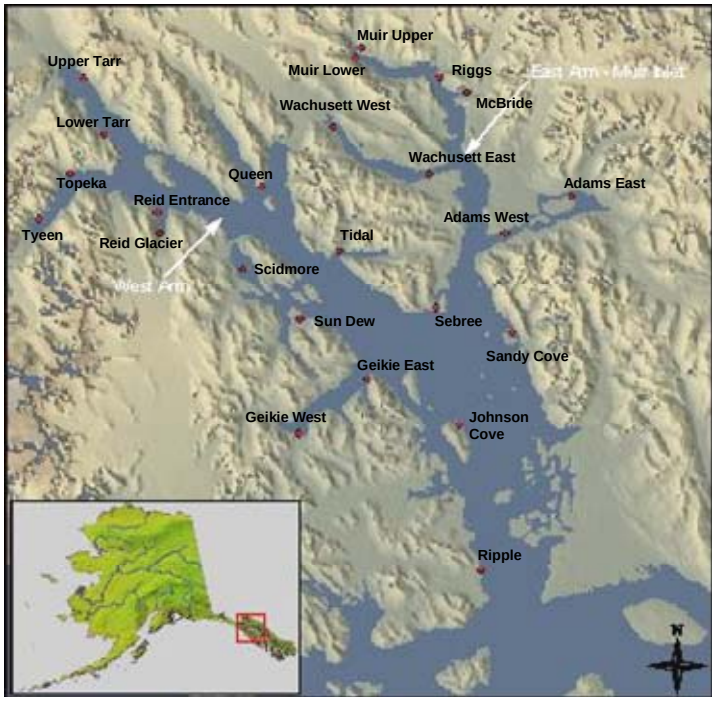

Figure 1. Locations of CRREL climate monitoring locations within the Glacier Bay watershed.

Two sites (Queen Inlet, Tyeen) are utilizing GOES (Geostationary Operational Environmental Satellite) satellite transmitters for year-round, near-real time data transmission to include precipitation, temperature, solar radiation and wind measurements (Figure 3). By using the GOES transmission system, data are collected at regularly timed intervals (15 minutes) and transmitted via the GOES system for processing hourly. Once the data are transmitted, the information is decoded at a central receiving station located at the New England District Corp of Engineers Reservoir Control Center in Concord, MA. These data are quality checked and then pushed to a central database server at CRREL where the information is disseminated via the World Wide Web. The site address is: https://rsgis.crrel.usace.army.mil/ltir/GBweb.GBindex. We plan additional GOES transmitters as funds allow, reducing the need for costly site

visits especially in areas where access may be limited by vessel restrictions and providing data in near real time for park managers, staff and researchers.

Figure 2. Typical monitoring set up at climate sites. Upper left photo shows white solar radiation shield housing temperature sensors and a tipping bucket rain gauge installed on 1-meter tall post at the McBride Glacier site. Photo on lower right shows the tipping bucket and electronic rain gauges in steel housings as mounted on the ground at the Sun Dew site. A post is only used where animals are unlikely to damage rain gauges, but preferred to reduce snow cover effects early in the winter season.

By installing the GOES systems throughout the Park, we will also reduce impact on biologically sensitive areas at critical times of the year. The remote monitoring systems are ultimately expandable to include new instruments as research needs arise, and allows for collaboration with other researchers who likewise may benefit from near real-time data transmission. Furthermore, easy and rapid access to climate data in remote areas of the park through our web-based interface may be especially useful to Park resource

managers for planning, to interpreters and naturalists for daily climate information, and to Park Rangers during emergency situations.

Each climate site is routinely maintained during late spring or early summer and again in late summer or early fall. Typically we require 5 days to complete servicing, download, repair and maintenance of all 24 sites. We record the condition of the site in a field book upon arriving, sometimes photographing more serious problems such as animal or natural destruction of instruments and mounting equipment. The levelness of the rain gauges is measured and any deviation noted as this affects the volume recorded. The data loggers of each instrument are then downloaded to portable recorders and batteries and desiccant are replaced, while clearing the memory of older data and reinitializing loggers to begin a new data collection cycle. Any problems with data loggers or instruments are noted in our field books, and we replace problematic loggers and broken instruments in the field with spares we carry with us to minimize the time required to service each site and insure that we have fully operational equipment for the next period of monitoring. Simple repairs or download issues are addressed on board the vessel used to access the site or back in the office or lodging that night. More serious problems are repaired back at the CRREL Hanover laboratory. Details of each instrument recorded in the field book include condition and operation of the data loggers and any problems noted that may have affected the operation and recording of data (for example leaves or spiders in the rain gauge orifice). If loggers or entire instruments must be replaced, the new serial numbers and time of start up are recorded. Bulk water samples are collected in 60 ml Nalgene bottles and assigned sample numbers recorded in the notes for the particular site. On board the vessel, we download all files on the data recorder to a folder on a laptop

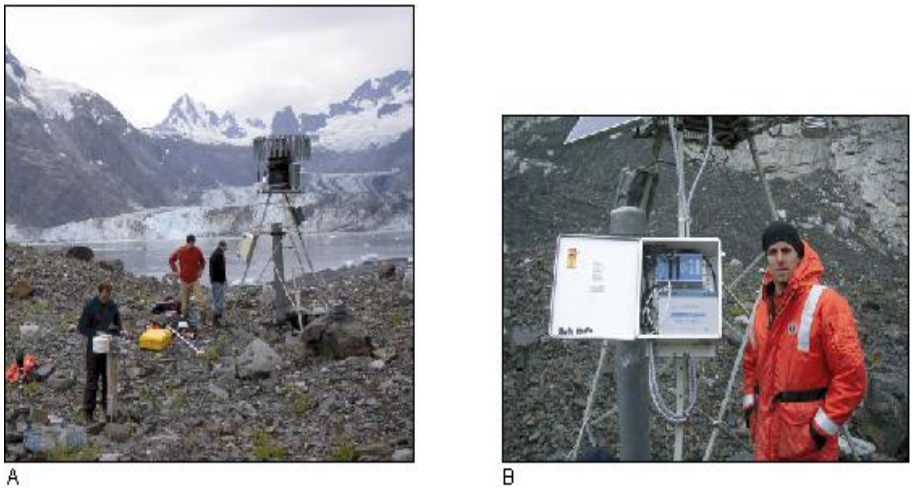

Figure 3. GOES test site at Tyeen in Johns Hopkins inlet (A). A GOES satellite transmission system transmits hourly data on precipitation and temperature, while also storing these data as a backup on Campbell data logger (B).

computer and as a back up onto a data key. During travel between sites, we prepare spare data loggers and instruments in case they are needed at the next climate site.

Once back at the office, all data files are archived on the CRREL server and its back up, as well as on personal computers being used to process and analyze the climate data. Water samples are logged and then stored pending analysis of their oxygen and hydrogen isotopic composition.

2005 Monitoring Activities

The loss of the park boat M/V Nunatak during the winter of 2005 had a significant impact on our monitoring of climate. We were unable to visit any sites until 21 June, resulting in several precipitation and temperature data logger's memory chip being completely full and thus a gap in the data record for a period of time. In addition, not all sites could be accessed twice at the beginning and end of the summer season as required for downloading the temperature and precipitation data loggers, and servicing the instruments for the subsequent data collection period. We were able to visit and service 22 sites at least once during the 2005 season, while two sites (Muir Upper and McBride) could not be accessed. Site visits were accomplished on 21 and 24 June via the Capelin, 22 June by skiff, August 1 and 3 via the Kasteen, and September 19 to 22 via the Capelin.

The raw data as collected from the temperature data loggers are plotted by site name in Appendix A and from the rainfall gauge loggers in Appendix B. These data have not yet been fully processed and corrected for any problems noted in the field or as the result of instrumentation or data logger problems. This processing will be undertaken by a Dartmouth College student as part of her thesis during 2006 – 2007. The data should NOT be interpreted or used without this processing. We ask that all requests to use the climate data be made directly to CRREL; we will be pleased to share the data. Potential users should provide us a description of how it will be used in their investigations to insure there are no conflicts with our research and publication. Once processed and applied to our research, all data will be open to the general public.

Continuing Work

We plan to visit each climate site in the spring and fall of 2006 to insure that a complete record of the temperature and precipitation of each site is acquired (barring problems over which we have no control). Additional processing and analysis of the 2005 and 2006 data will be combined with the existing database as part of a planned thesis at Dartmouth College. We have recently (July 2006) provided a DVD with all raw data that includes the 2005 dataset to Bill Eichenlaub for archiving on the NPS Glacier Bay server. As new data are acquired, these will be sent to Bill for archiving as well.

We will continue our tests of GOES instrumentation to develop a robust system for deployment at the existing climate sites as funds become available for purchase of equipment. Data from the climate monitoring will continue to be acquired annually to develop the long duration record necessary to discern and analyze long-term trends versus short-term variability inherent in natural systems. The five year record we now

have is significant, but not yet sufficiently long to analyze for multi-year (like El Nino) and longer (like Pacific Decadal and Arctic Oscillations) influences on climate, but it is approaching a length sufficient to begin to see overall trends related to global warming within the range of normal variability inherent in natural systems.

We have also begun discussions with Justin Smith (NPS) and Tom Ainsworth (NWS) to collaborate in providing a climate station at Bartlett Cove. The current plan is for CRREL to provide a GOES system, precipitation gauge and solar radiometer, while the Weather Service provides the mounting, temperature gauges, barometric pressure gauge and related equipment for local weather download. This station would provide current weather conditions for the Park staff at the Visitor Center, while the GOES will provide the Weather Service data hourly via the CRREL GOES system. The climate site will provide new coverage for the lower eastern side of the bay, supplementing the 24 existing CRREL sites. Additional sensors may be added, including a tide gauge, if funding can be acquired.

Acknowledgements

This project has been funded in part by the US Army Cold Regions Research and Engineering Lab, National Science Foundation, Rockefeller Center for Public Policy and the Social Sciences and the Institute of Arctic Studies at Dartmouth College, and private donations. We are extremely grateful to the staff and management of Glacier Bay National Park and Preserve for their continuing support, assistance and encouragement, including importantly boat transport (M/V Nunatak, M/V Gyre and M/V Capelin) and their respective crew, without which this research could not have been conducted.

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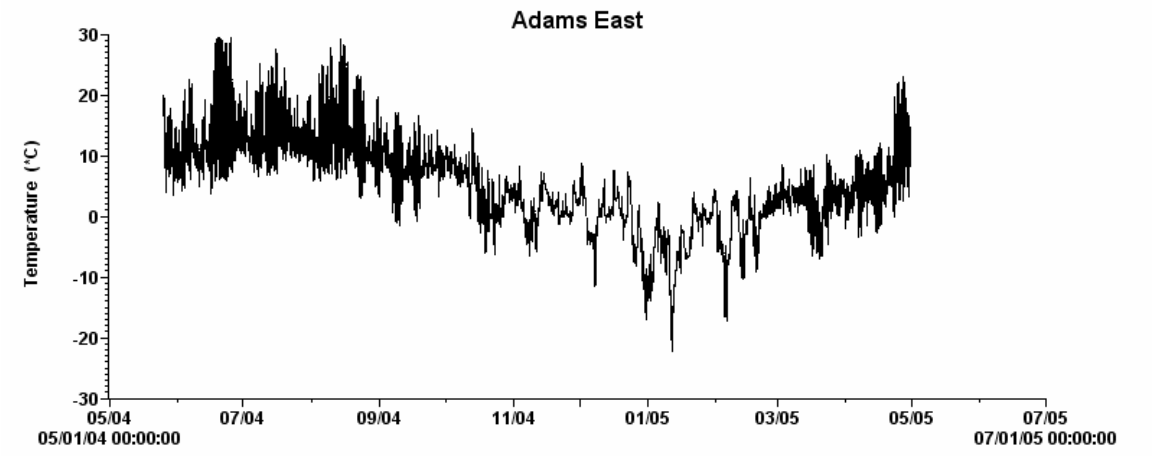
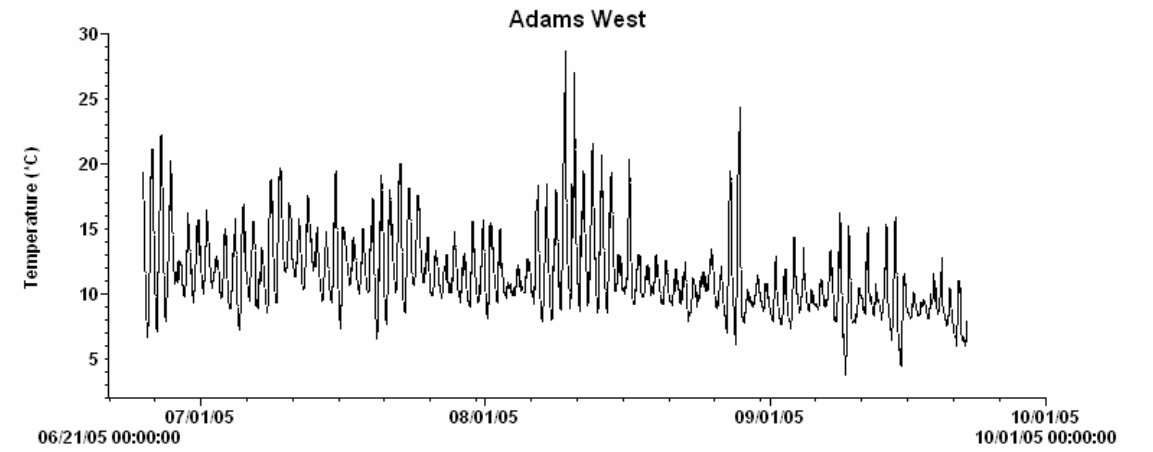
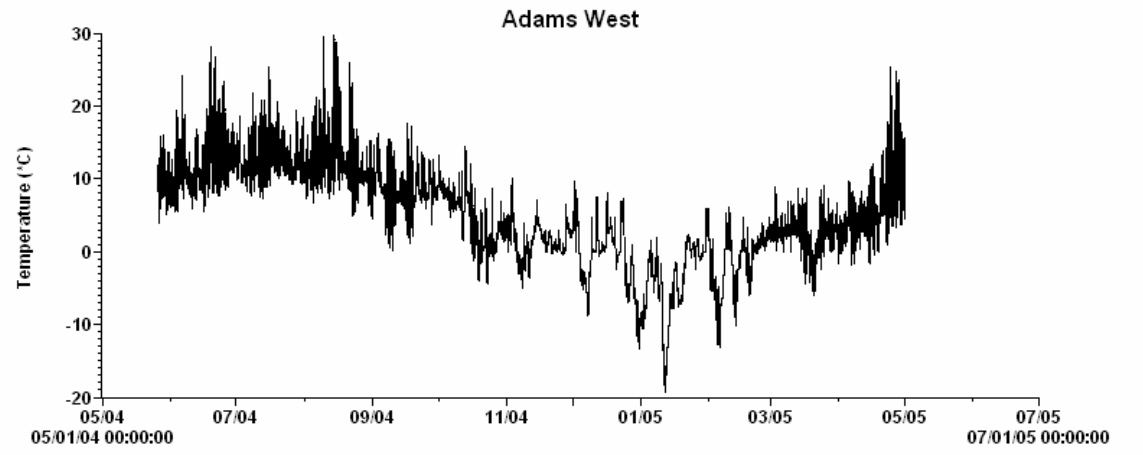
Lawson, D.E., Finnegan, D. C., Kopczynski, S. and Bigl, S., 2004. Long-term studies of tidewater and terrestrial dynamics, glacier hydrology and Holocene and historic climate activity, Glacier Bay National Park and Preserve, Southeast Alaska. Annual Report; Prepared for Glacier Bay National Park and Preserve, Gustavus, AK (March).

Appendix A.
Raw Temperature Data 2005

The graphs provided in this appendix illustrate the raw temperature data acquired in 2005 during site visits in June, August and September. Data were downloaded at different times due to restrictions imposed by the loss of the vessel Nunatak and thus site access during our normal download and servicing in late May and late September. These data are for illustration only and need to be quality checked as well as assessed for site-related problems. They generally cover the period of mid-2004 to September 2005. The interval between temperature measurements was changed from 15 minutes to 20 minutes during the first download of the instrument this year to permit longer records to be recorded between servicing of a site; hence, the difference in appearance of the 2004 – 2005 and summer 2005 graphs.



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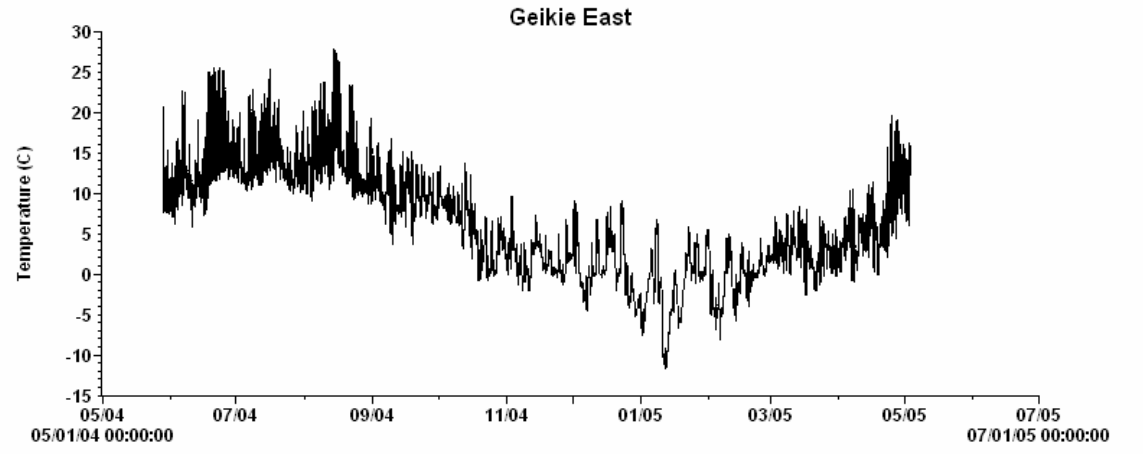
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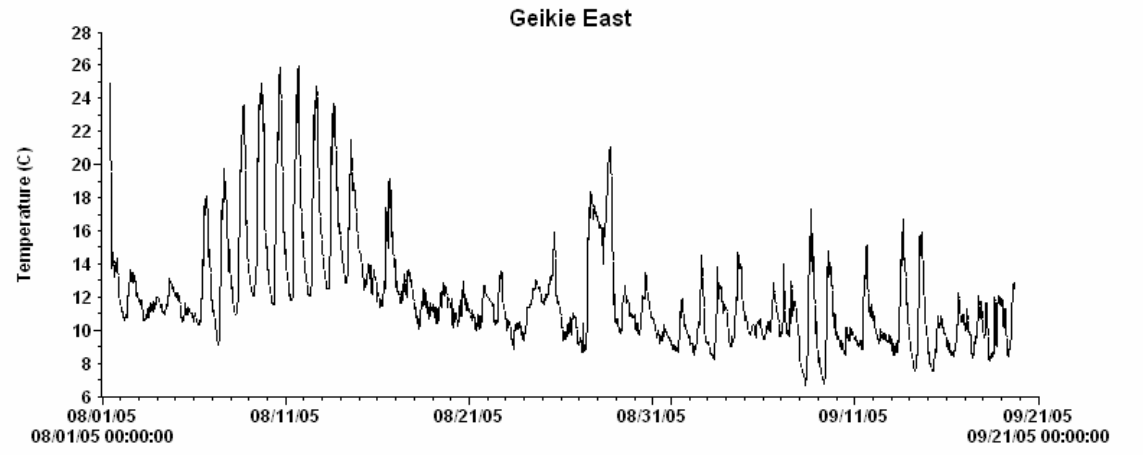
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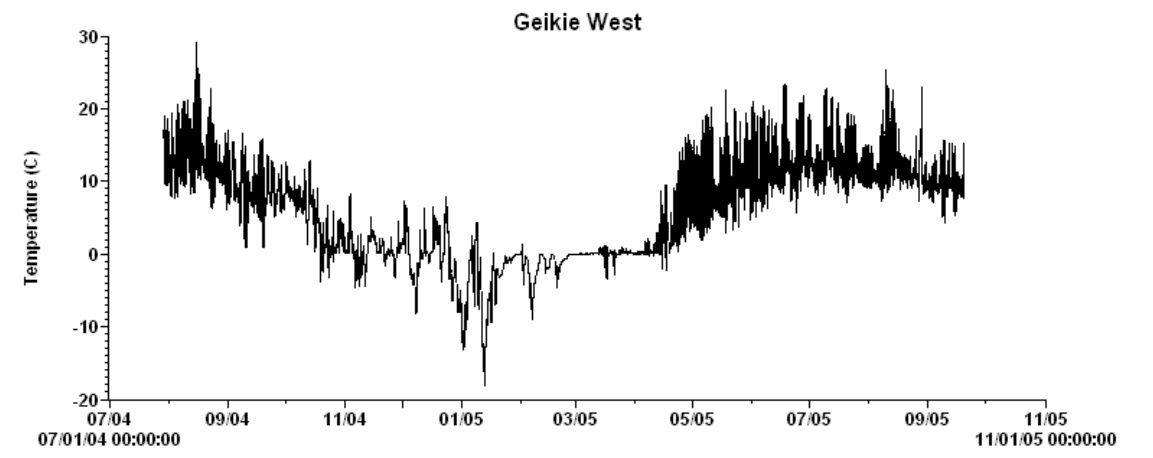
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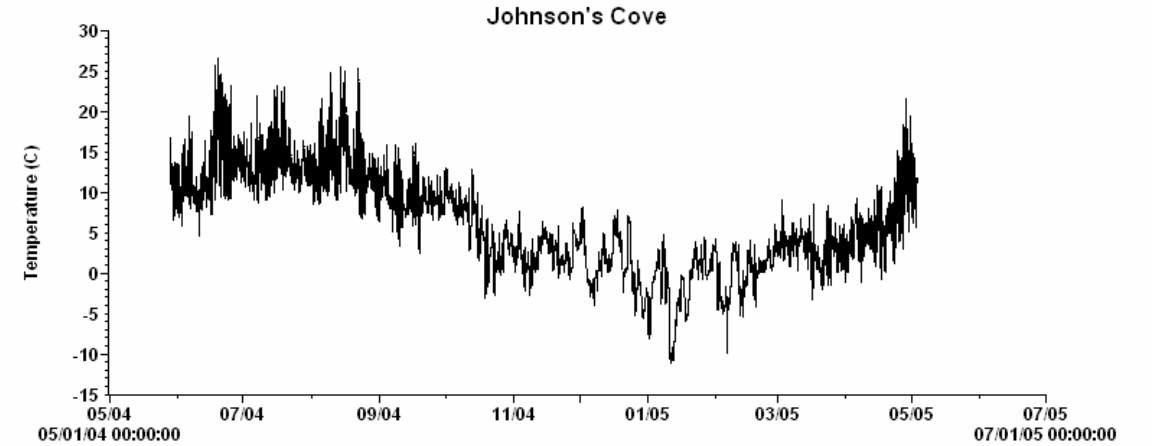
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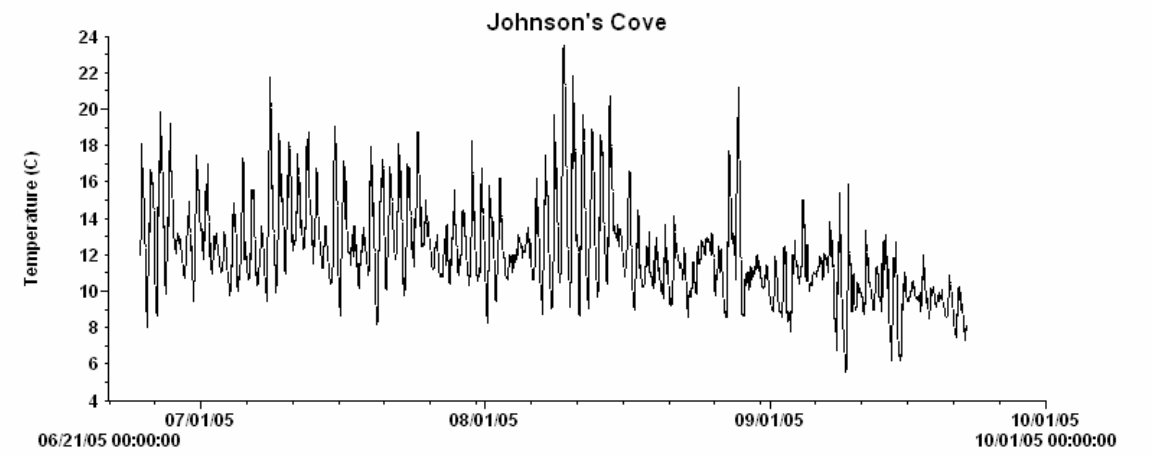
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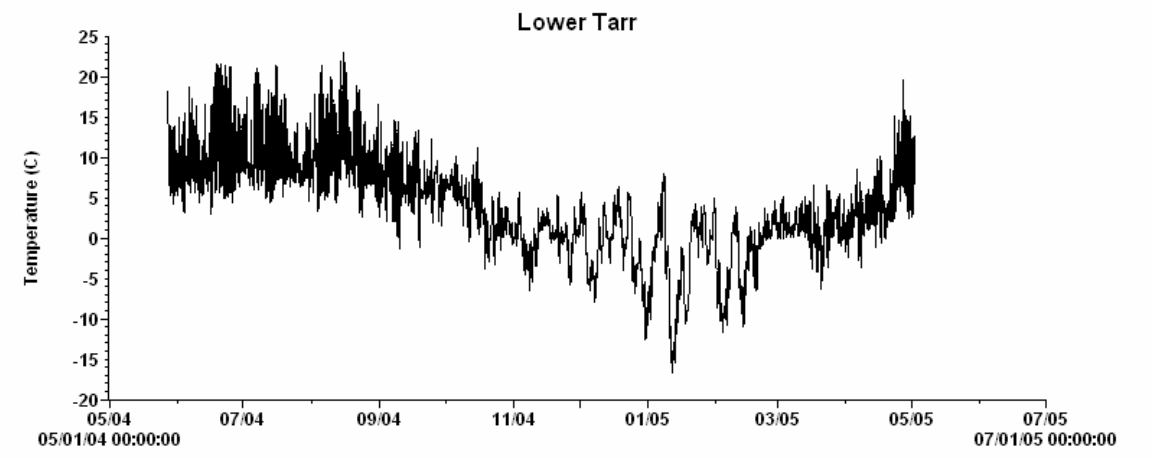
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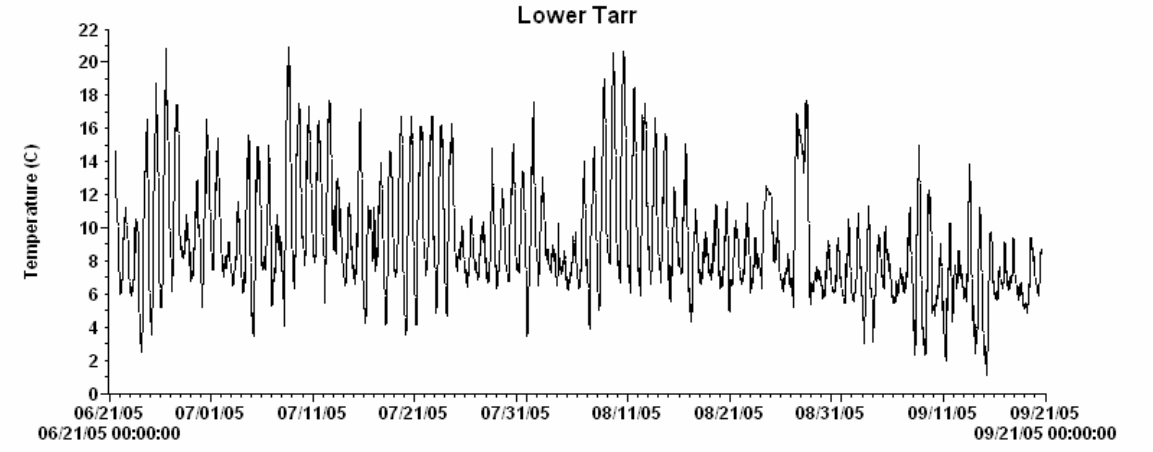
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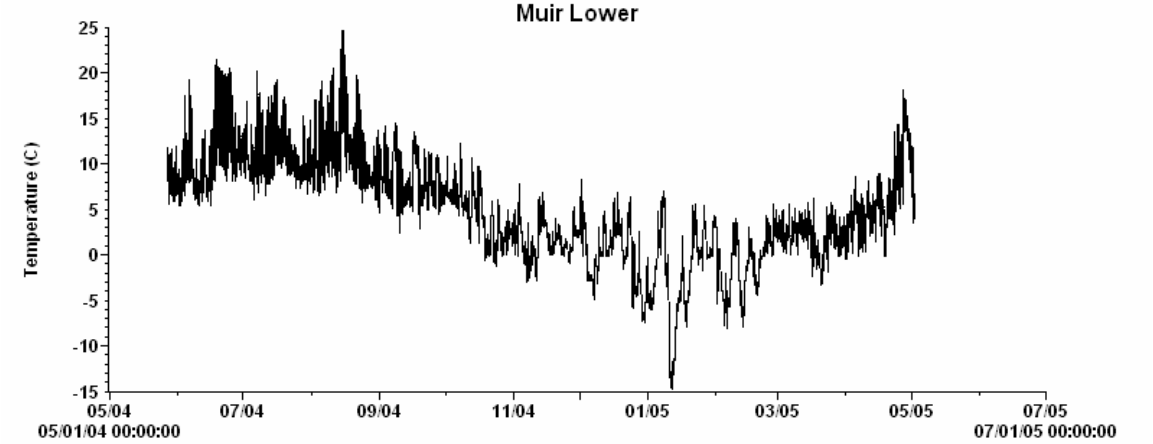
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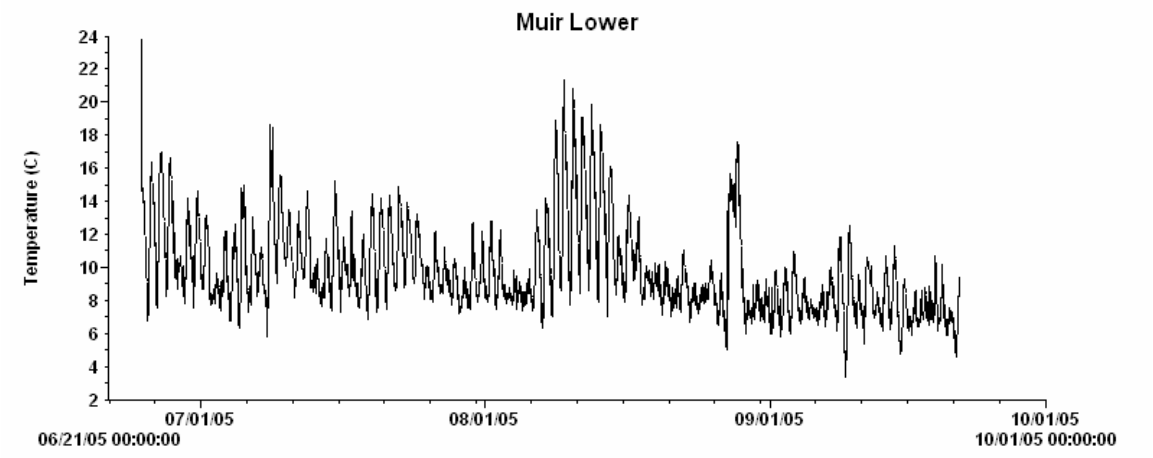
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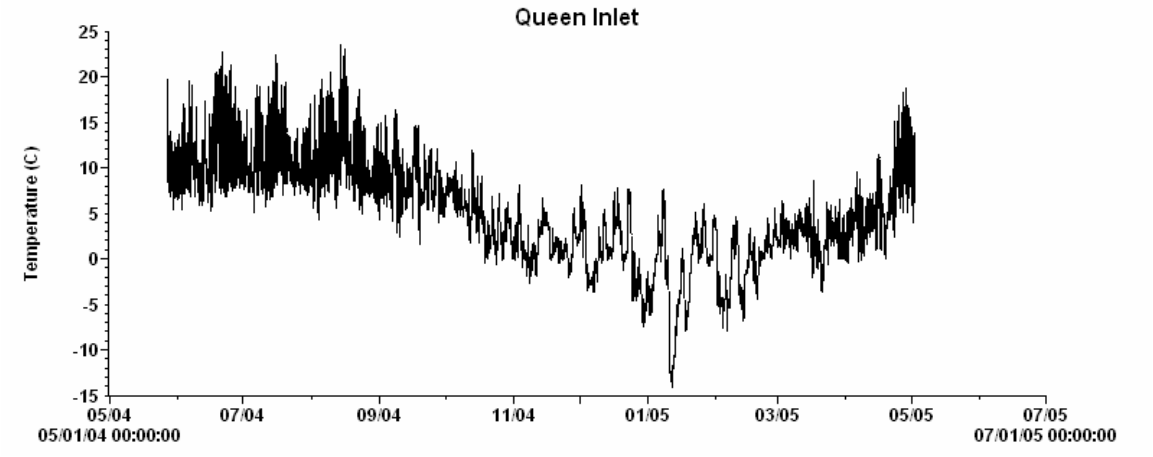
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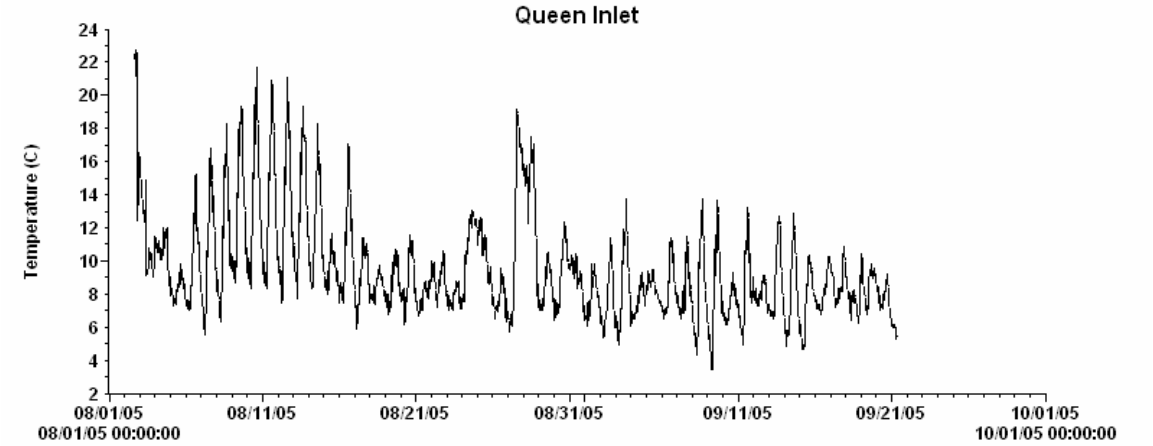
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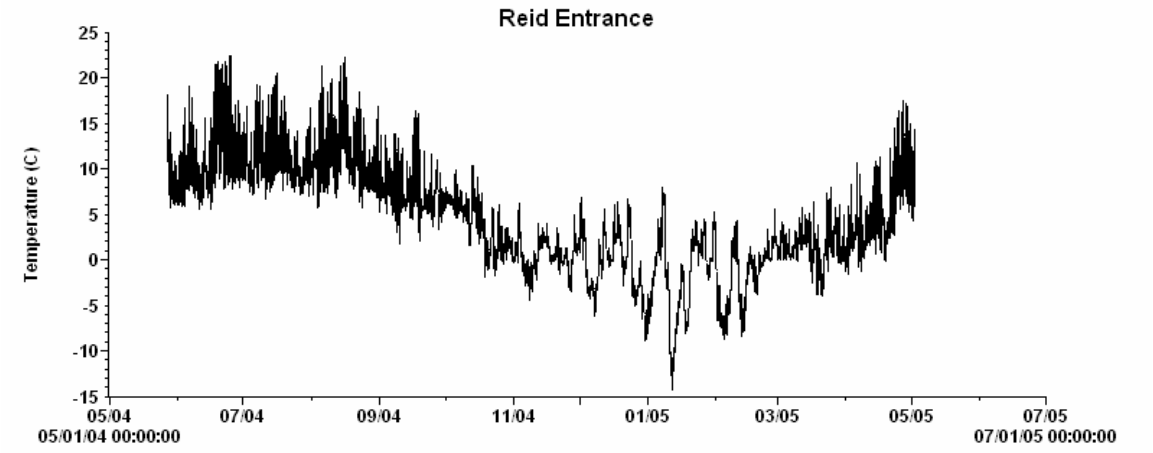
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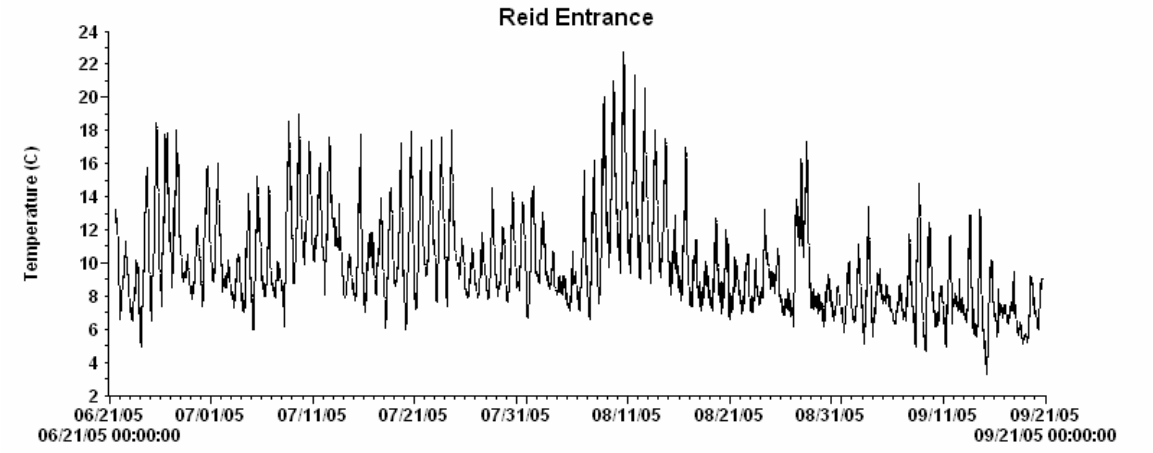
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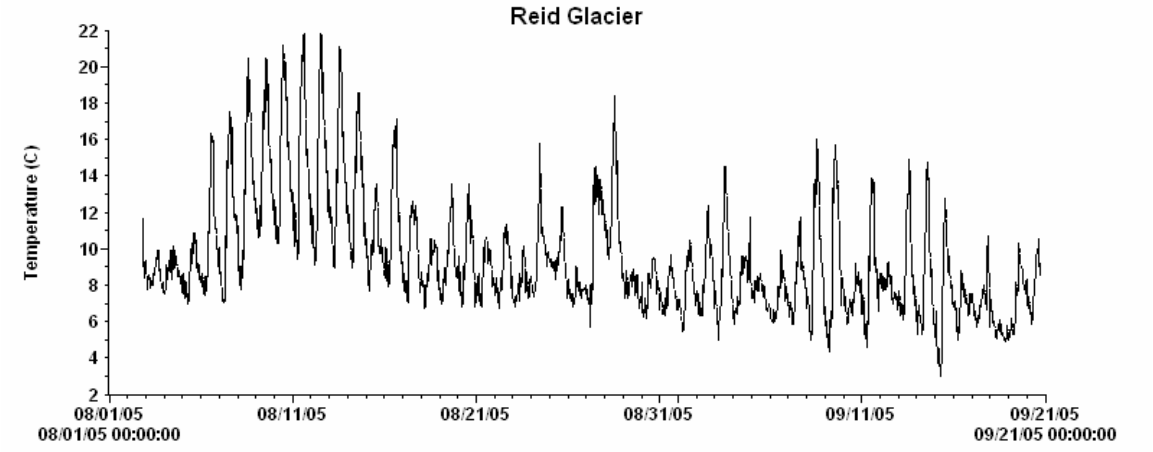
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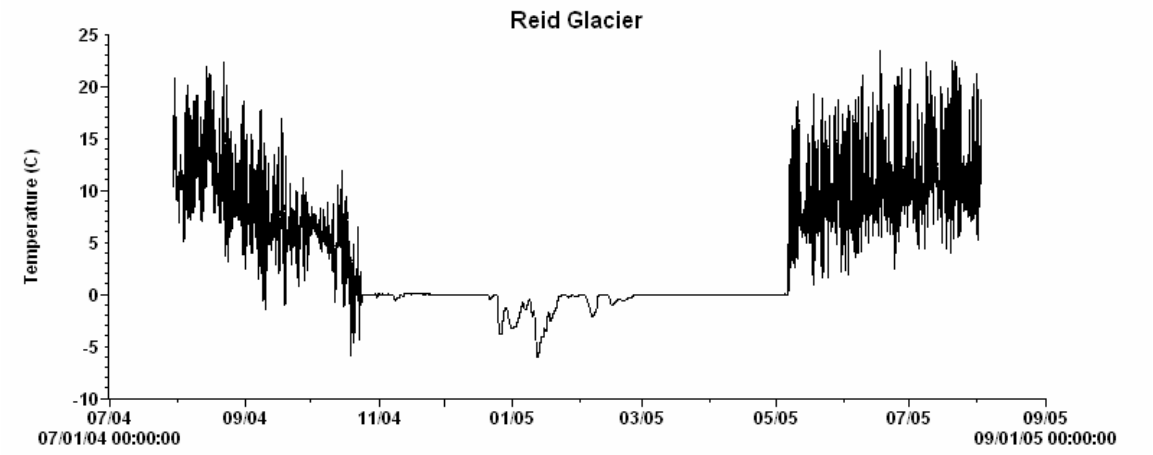
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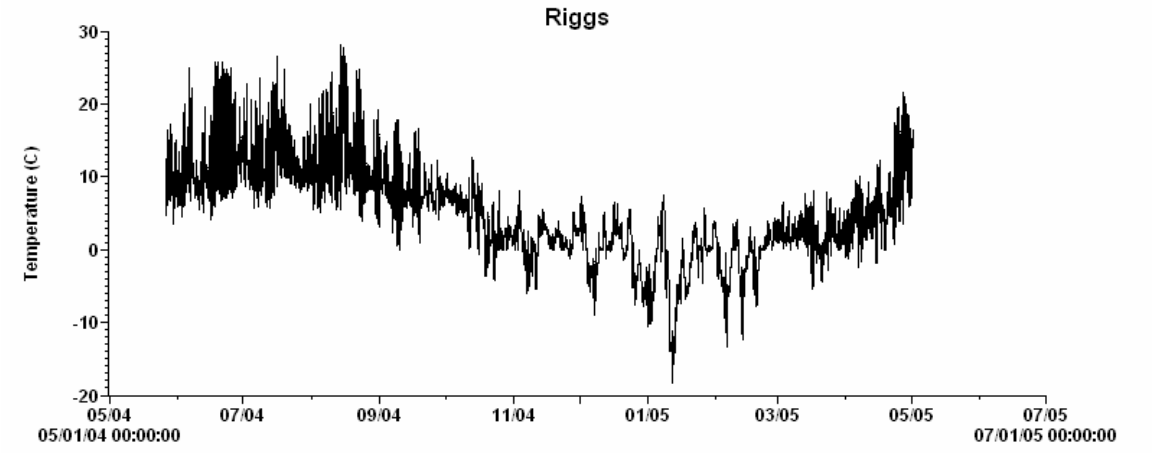
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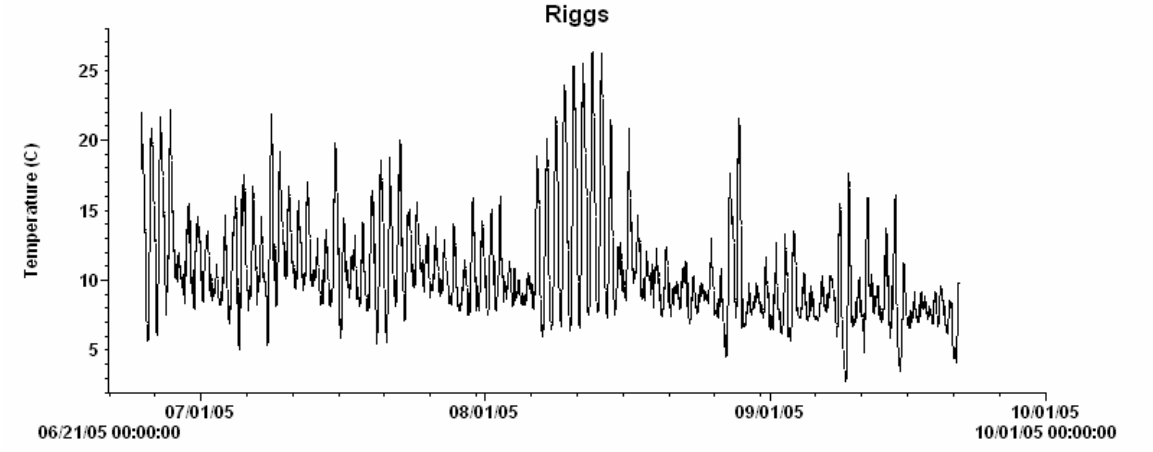
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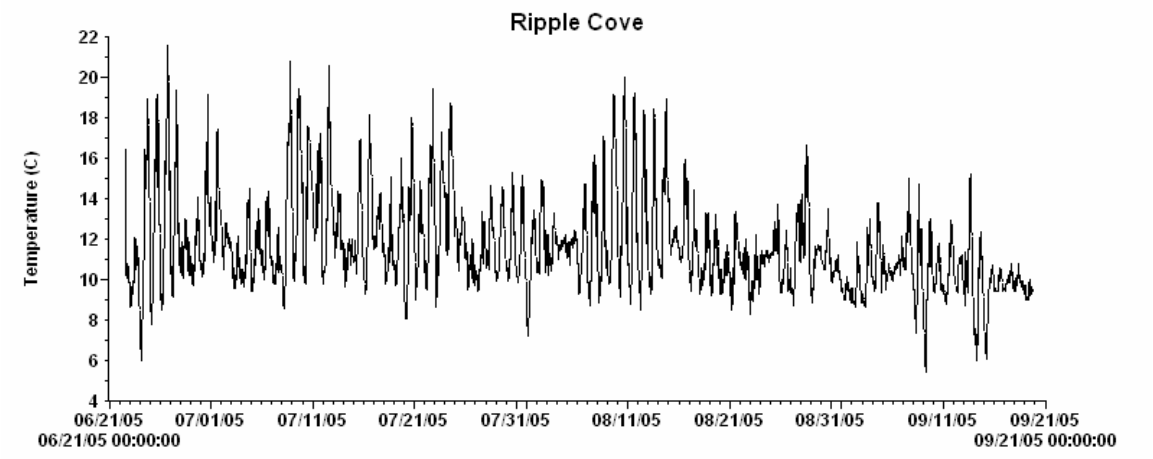
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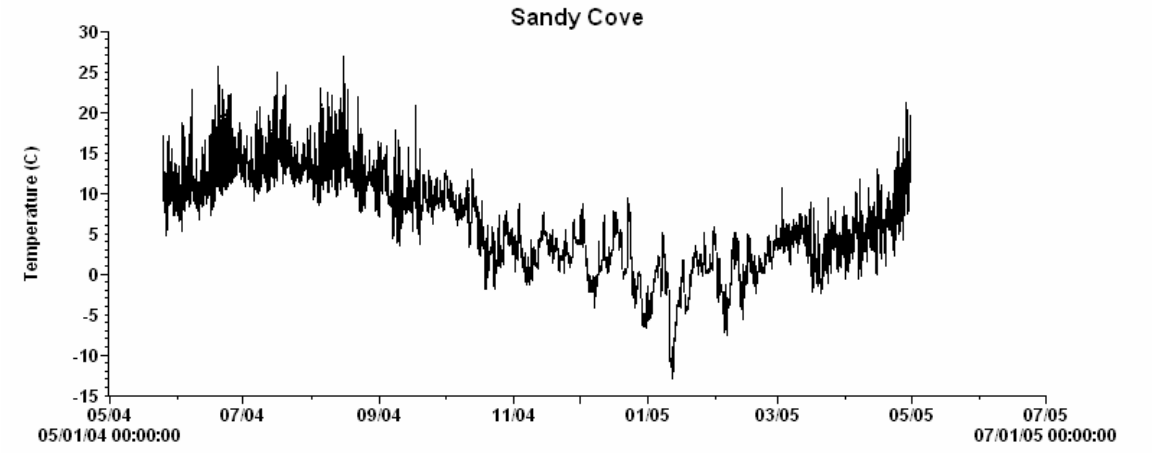
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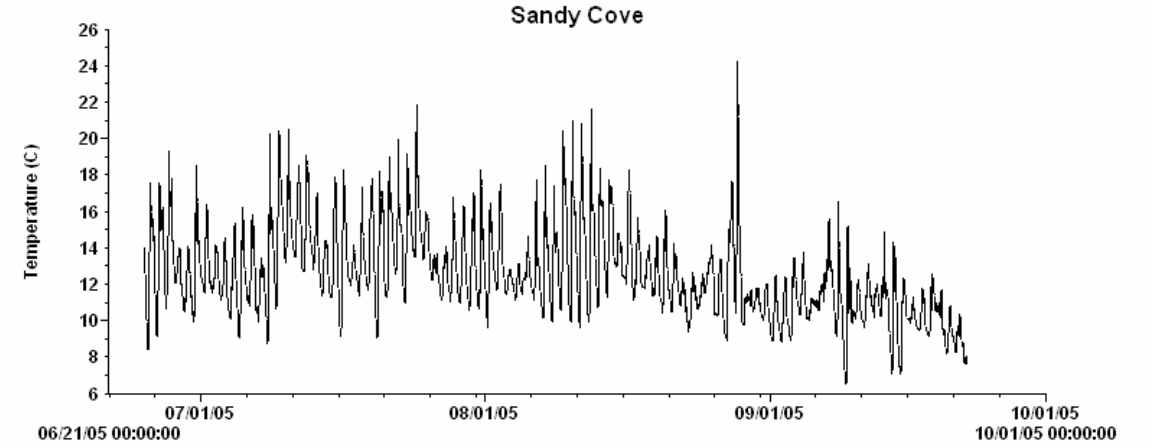
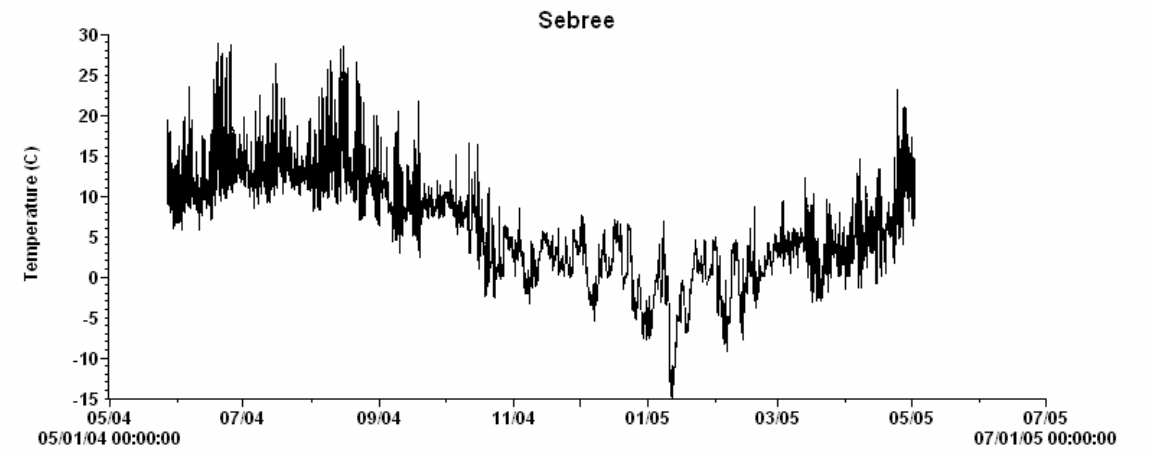
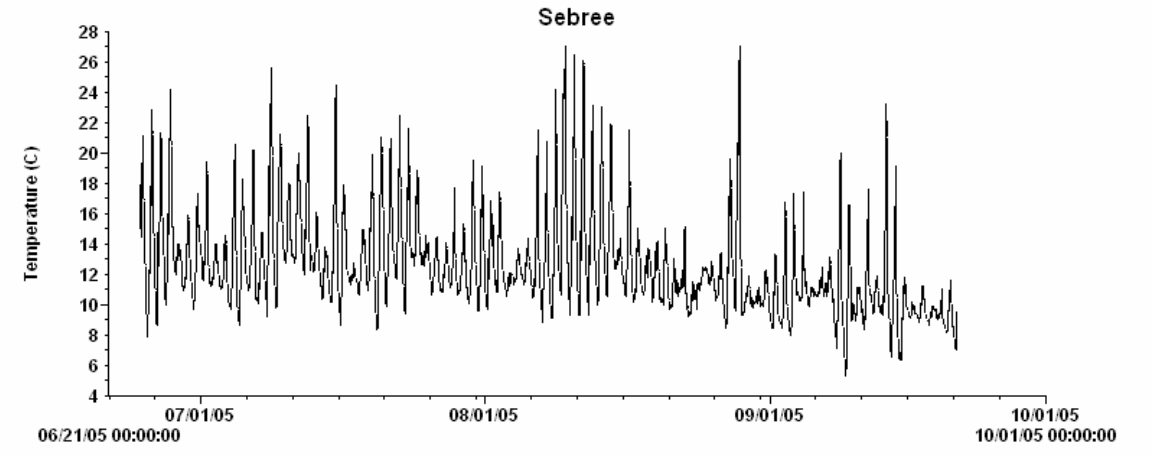
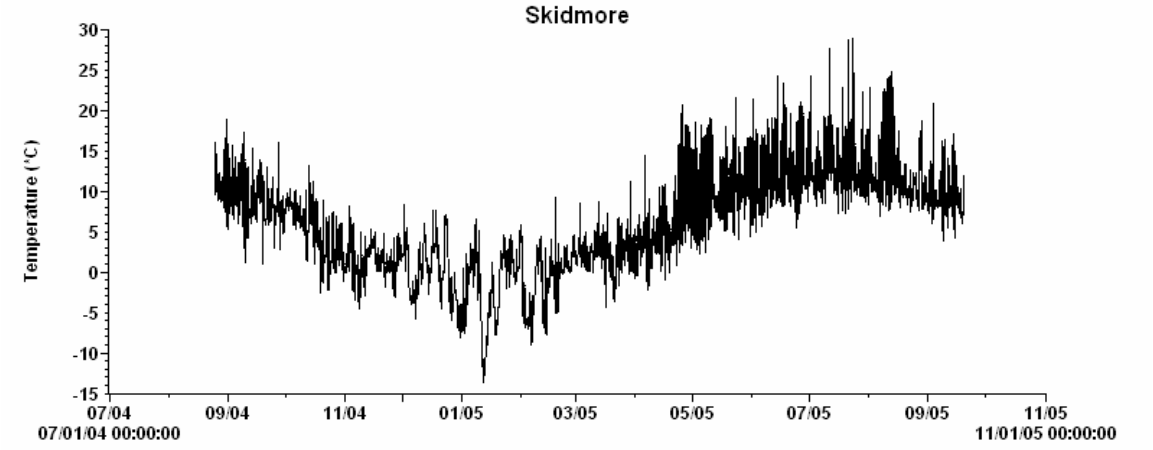
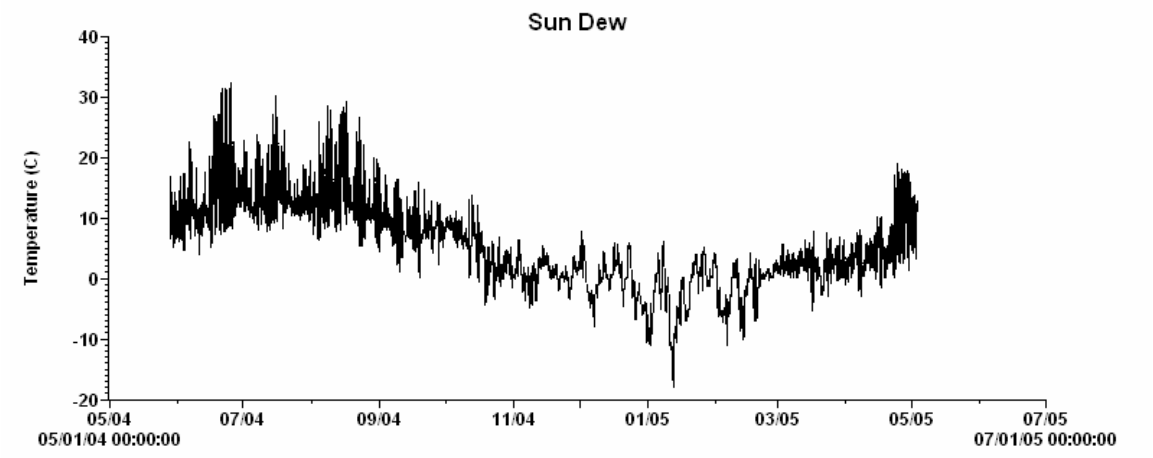
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00

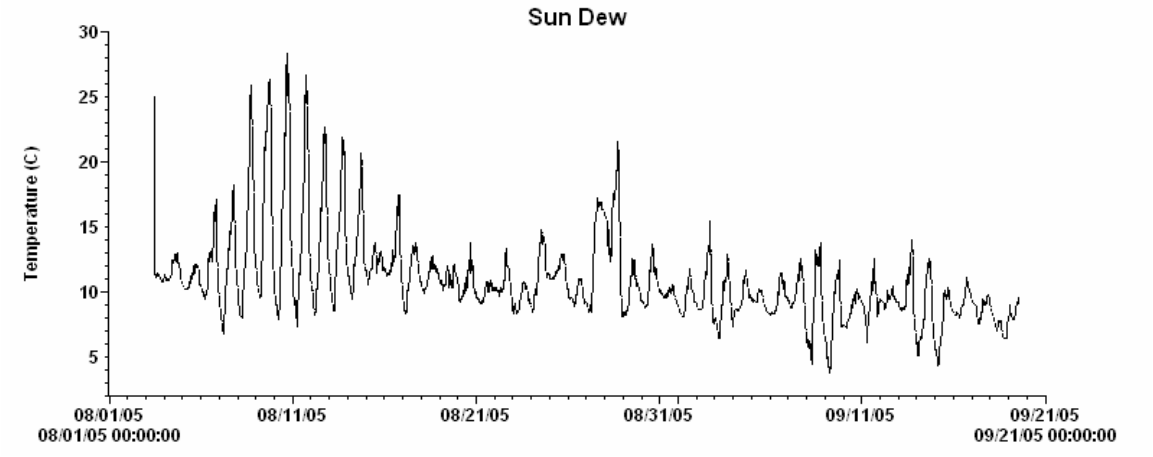

Sandy Cove
Temperature (C)
26
24
22
20
18
16
14
12
10
8
6
07/01/05
08/01/05
09/01/05
10/01/05
06/21/05 00:00:00
10/01/05 00:00:00

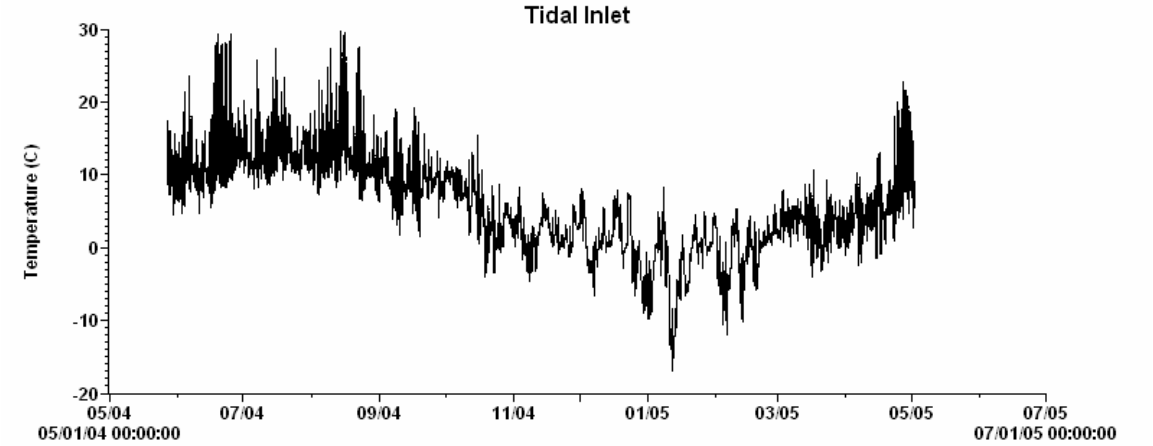

Sebree
Temperature (C)
30
25
20
15
10
5
0
-5
-10
-15
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00

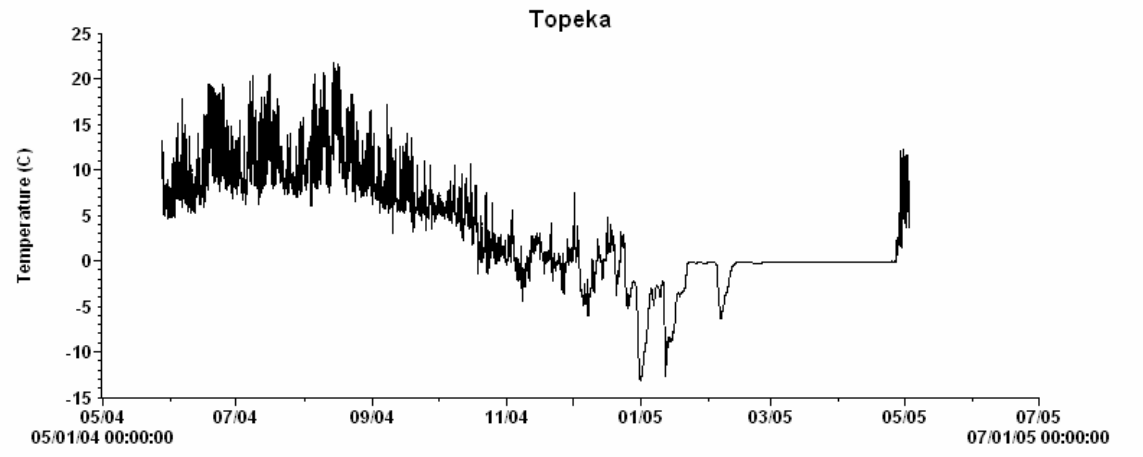

Sebree
Temperature (C)
28
26
24
22
20
18
16
14
12
10
8
6
4
07/01/05
08/01/05
09/01/05
10/01/05
06/21/05 00:00:00
10/01/05 00:00:00

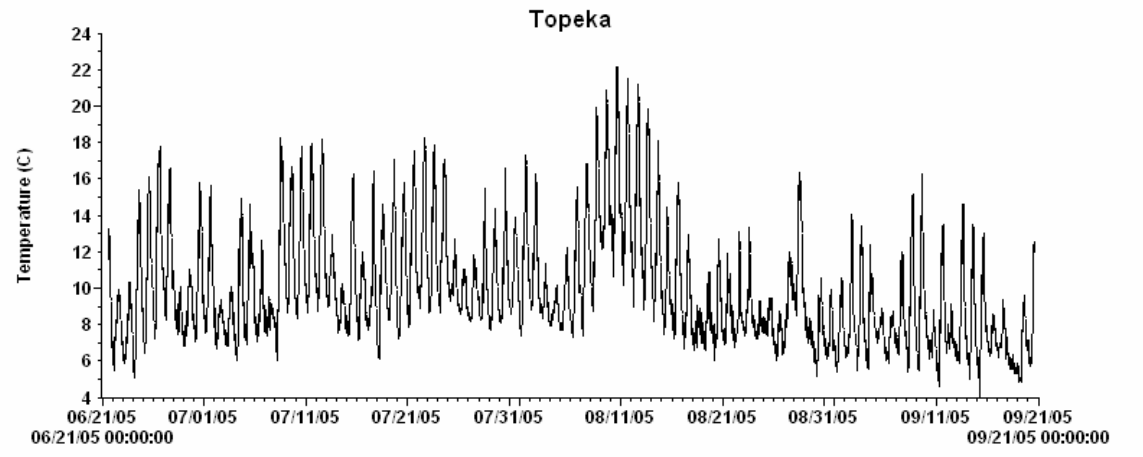

Skidmore
Temperature (°C)
30
25
20
15
10
5
0
-5
-10
-15
07/04
09/04
11/04
01/05
03/05
05/05
07/05
09/05
11/05
07/01/04 00:00:00
11/01/05 00:00:00

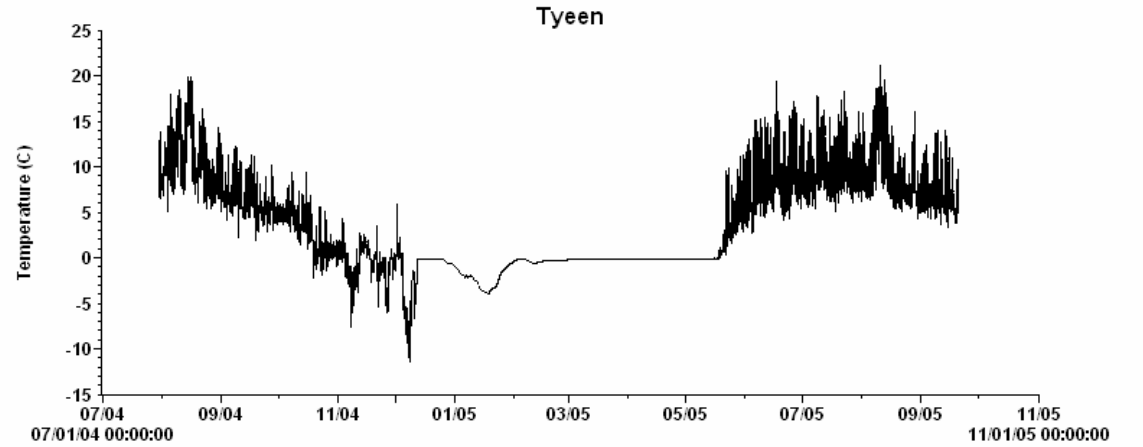

Sun Dew
Temperature (C)
40
30
20
10
0
-10
-20
05/04
05/01/04 00:00:00
07/04
09/04
11/04
01/05
03/05
05/05
07/05
07/01/05 00:00:00

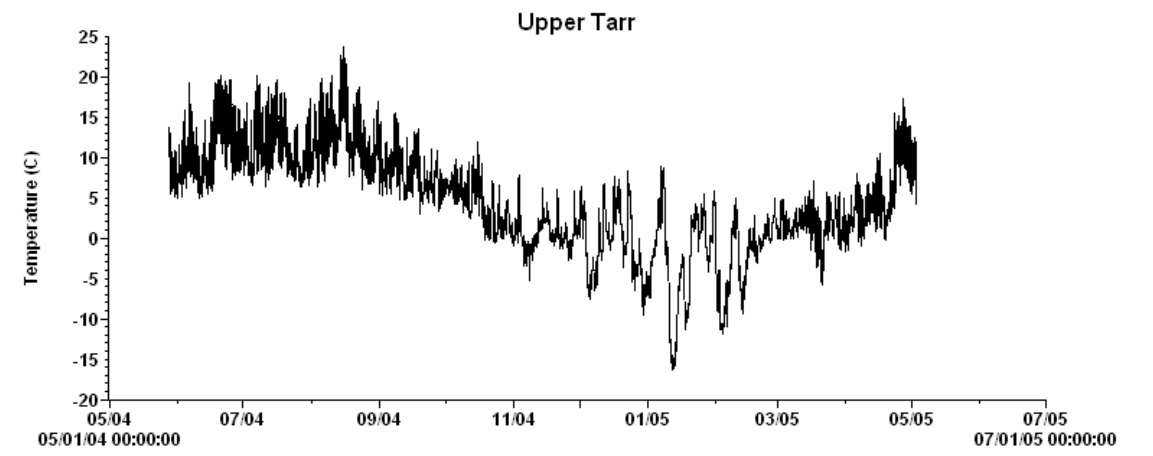

Sun Dew
Temperature (C)
30
25
20
15
10
5
08/01/05
08/01/05 00:00:00
08/11/05
08/21/05
08/31/05
09/11/05
09/21/05
09/21/05 00:00:00

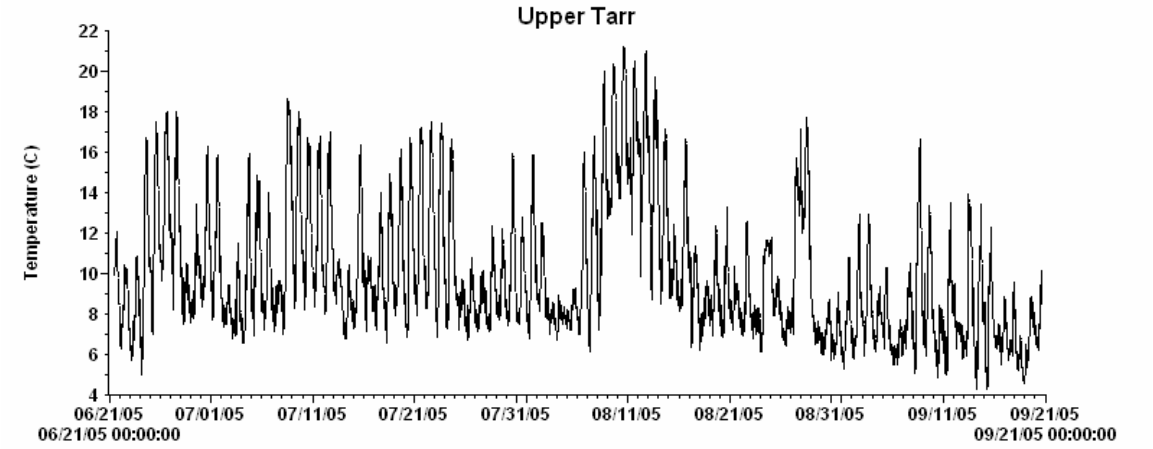

Tidal Inlet
Temperature (C)
30
20
10
0
-10
-20
05/04
05/01/04 00:00:00
07/04
09/04
11/04
01/05
03/05
05/05
07/05
07/01/05 00:00:00


Topeka
Temperature (C)
25
20
15
10
5
0
-5
-10
-15
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00


Topeka
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
06/21/05
07/01/05
07/11/05
07/21/05
07/31/05
08/11/05
08/21/05
08/31/05
09/11/05
09/21/05
06/21/05 00:00:00
09/21/05 00:00:00


Tyeen
Temperature (C)
25
20
15
10
5
0
-5
-10
-15
07/04
09/04
11/04
01/05
03/05
05/05
07/05
09/05
11/05
07/01/04 00:00:00
11/01/05 00:00:00


Upper Tarr
Temperature (C)
25
20
15
10
5
0
-5
-10
-15
-20
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00


Upper Tarr
Temperature (C)
22
20
18
16
14
12
10
8
6
4
06/21/05
07/01/05
07/11/05
07/21/05
07/31/05
08/11/05
08/21/05
08/31/05
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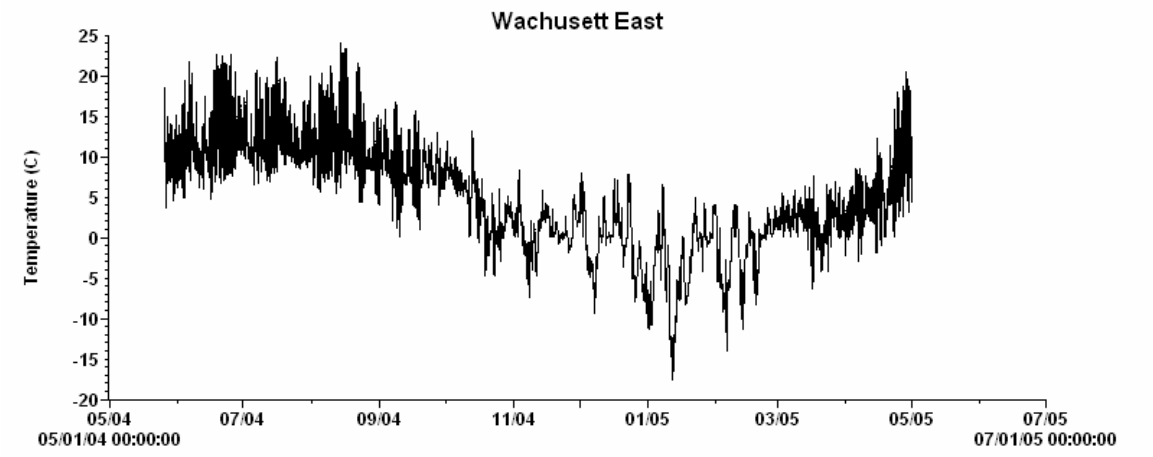
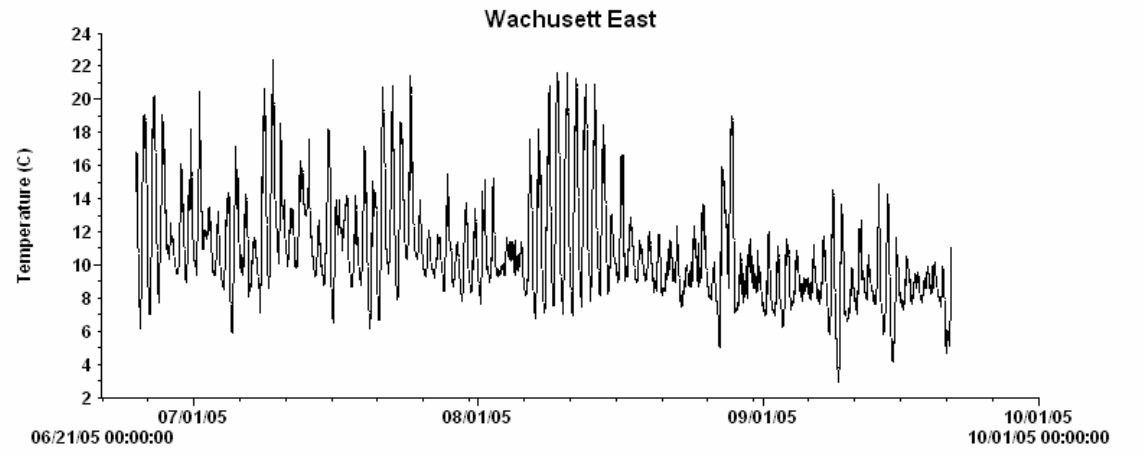
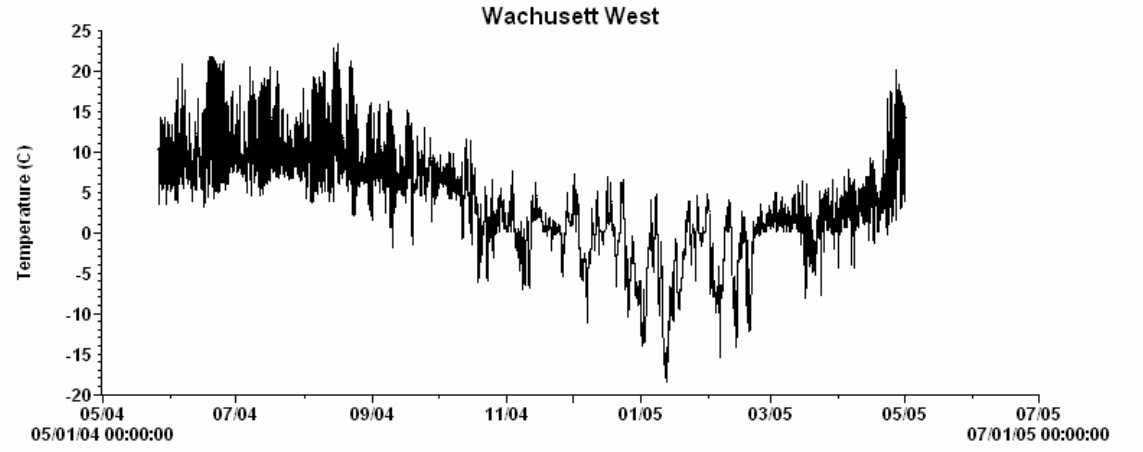
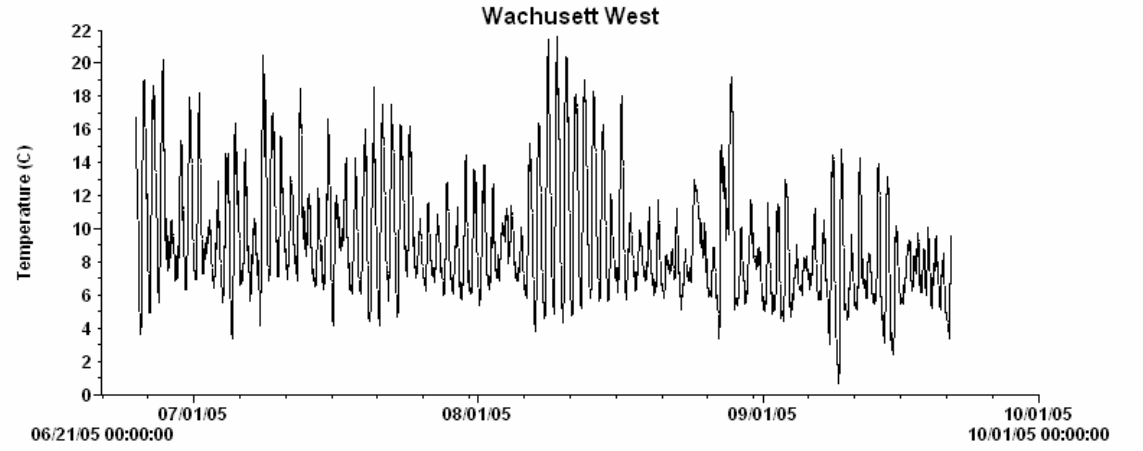
09/21/05
06/21/05 00:00:00
09/21/05 00:00:00


Wachusett East
Temperature (C)
25
20
15
10
5
0
-5
-10
-15
-20
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00

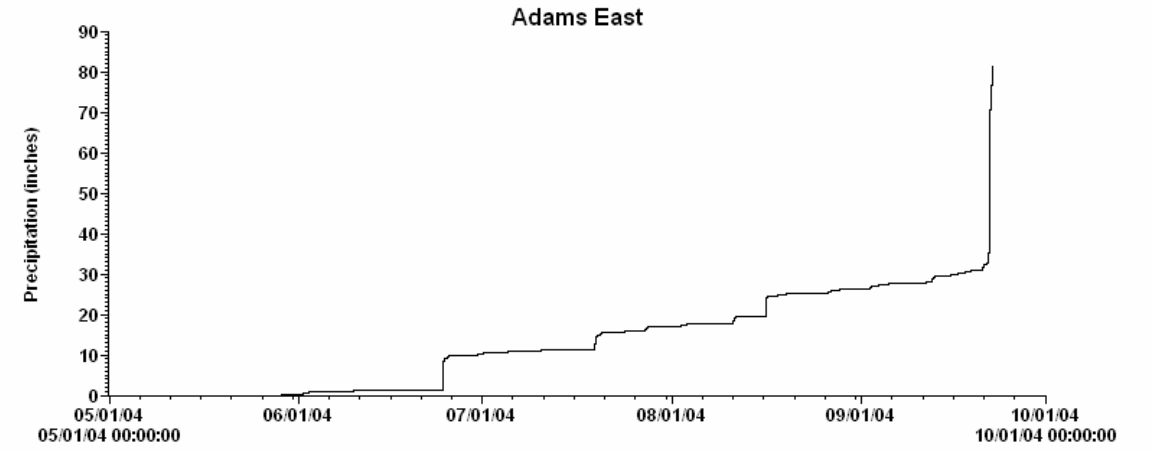

Wachusett East
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
07/01/05
08/01/05
09/01/05
10/01/05
06/21/05 00:00:00
10/01/05 00:00:00

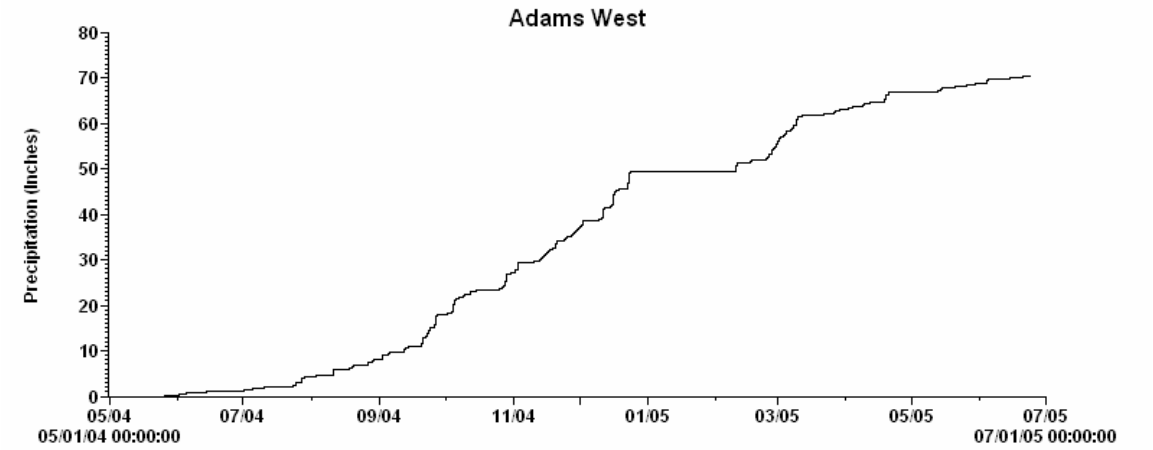

Wachusett West
Temperature (C)
25
20
15
10
5
0
-5
-10
-15
-20
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00

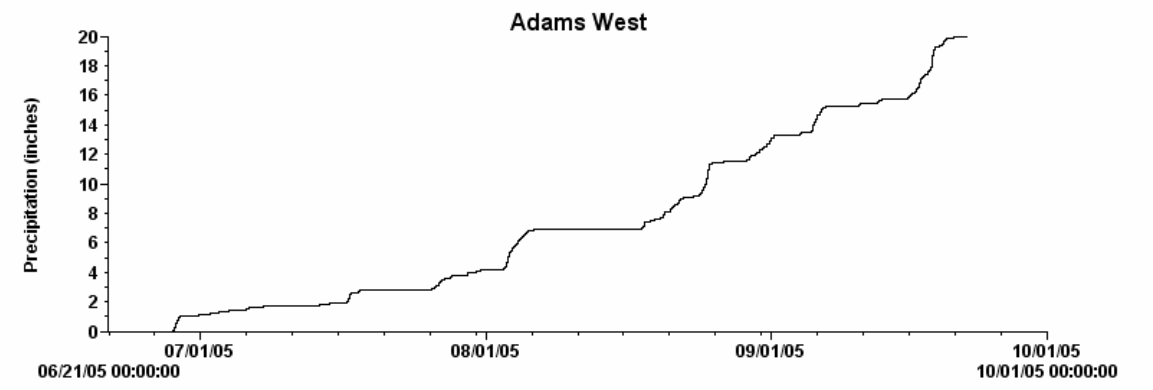

Wachusett West
Temperature (C)
22
20
18
16
14
12
10
8
6
4
2
0
07/01/05
08/01/05
09/01/05
10/01/05
06/21/05 00:00:00
10/01/05 00:00:00

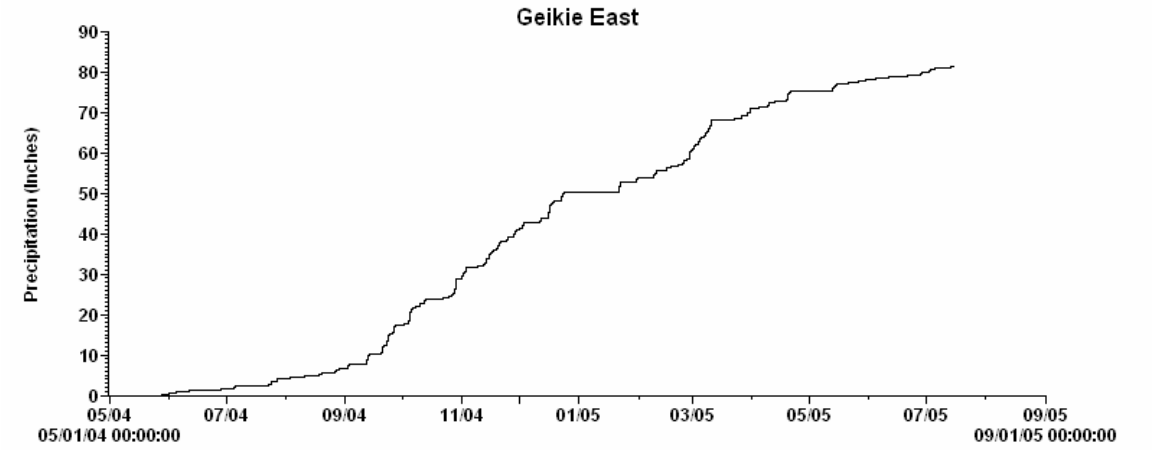
Appendix B.
Raw Precipitation Data 2005

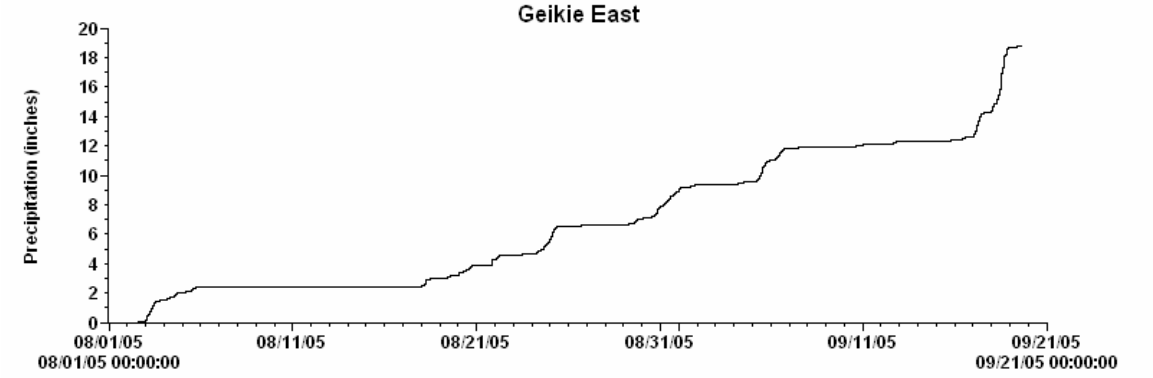
The graphs provided in this appendix illustrate the raw precipitation data acquired in 2005 during site visits in June, August and September. Data were downloaded at different times due to restrictions imposed by the loss of the vessel Nunatak and thus site access during our normal download and servicing in late May and late September was not possible. These data are for illustration only and need to be quality checked as well as assessed for site-related problems. They generally cover the period of mid-2004 to September 2005.

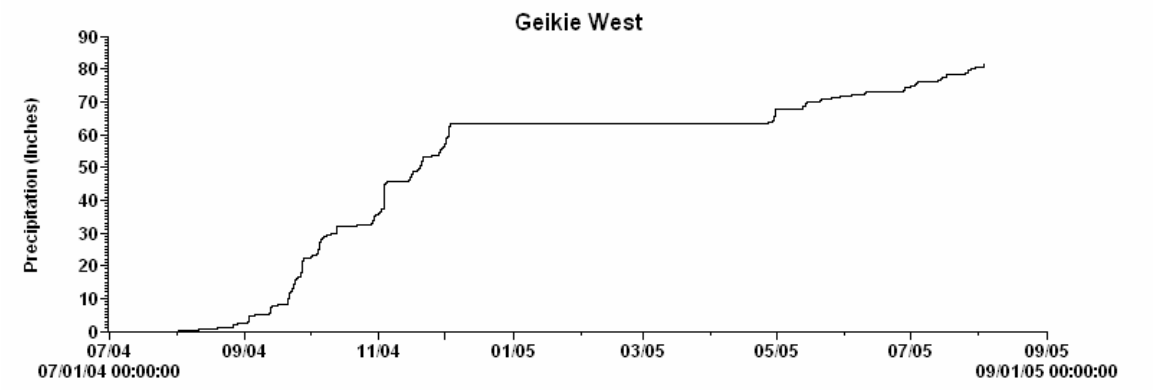


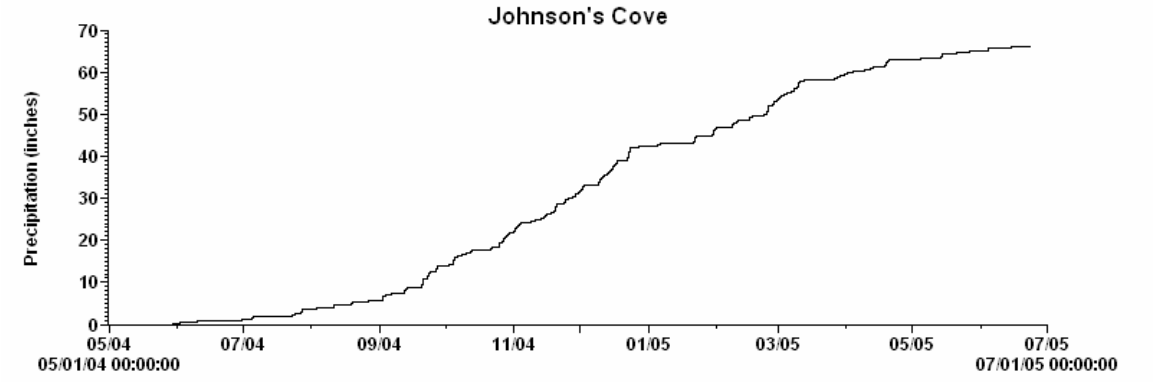


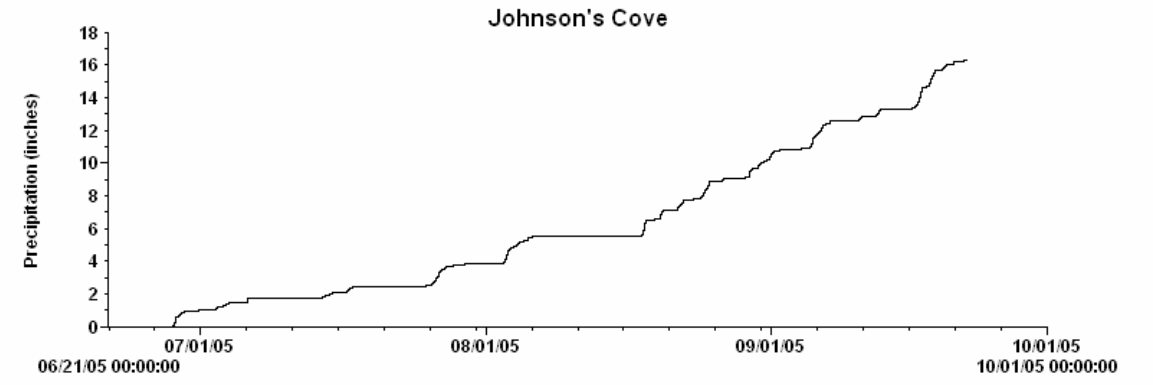

Adams West
Precipitation (inches)
0
2
4
6
8
10
12
14
16
18
20
07/01/05
08/01/05
09/01/05
10/01/05
06/21/05 00:00:00
10/01/05 00:00:00

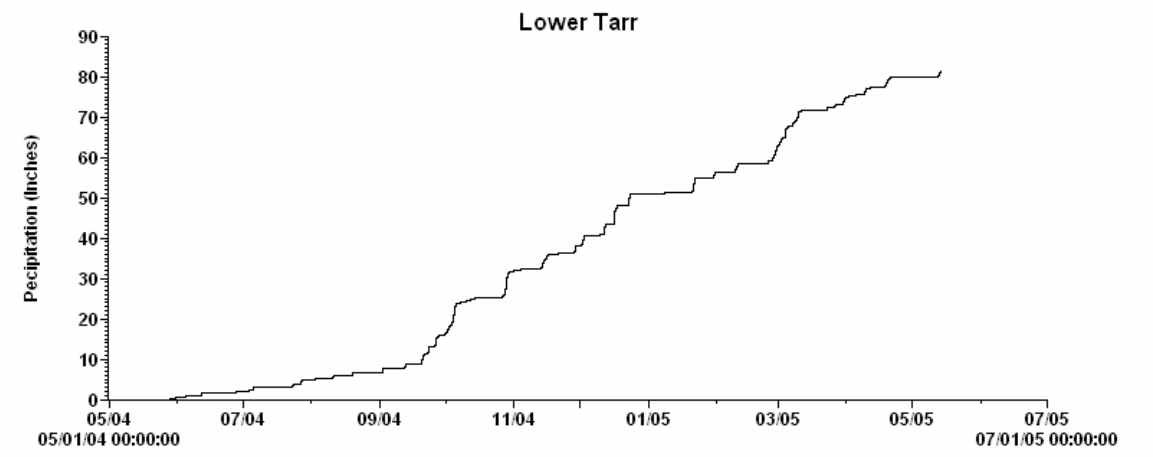

Geikie East
Precipitation (inches)
0
10
20
30
40
50
60
70
80
90
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
09/05
05/01/04 00:00:00
09/01/05 00:00:00

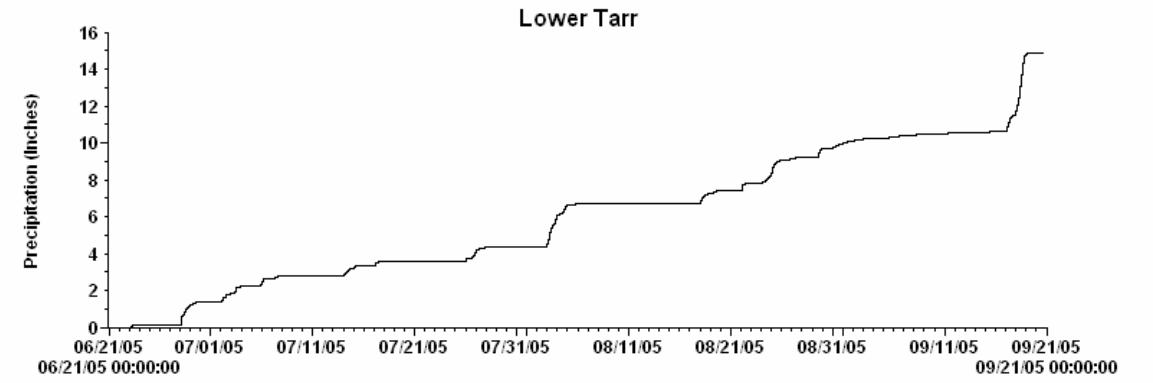

Geikie East
Precipitation (inches)
0
2
4
6
8
10
12
14
16
18
20
08/01/05
08/11/05
08/21/05
08/31/05
09/11/05
09/21/05
08/01/05 00:00:00
09/21/05 00:00:00

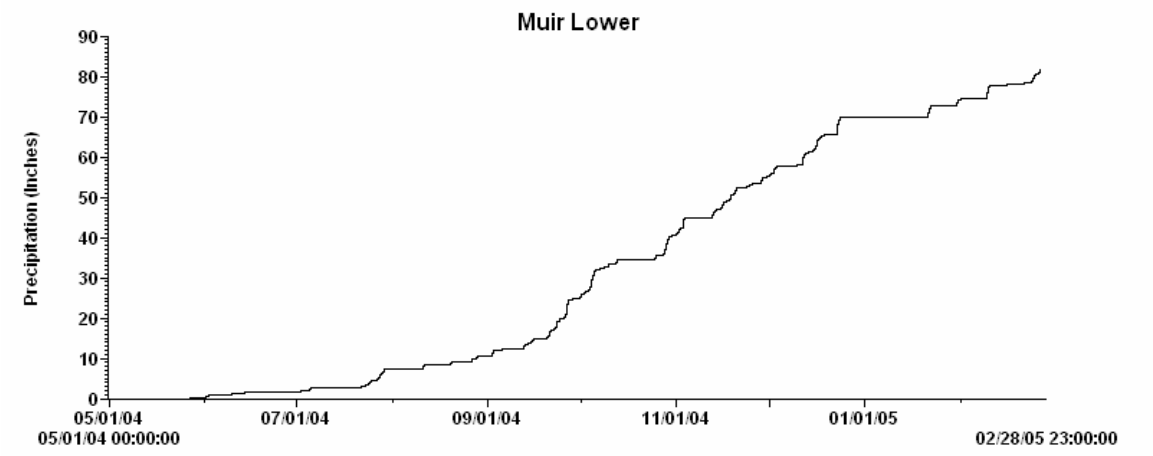

Geikie West
Precipitation (Inches)
90
80
70
60
50
40
30
20
10
0
07/04
09/04
11/04
01/05
03/05
05/05
07/05
09/05
07/01/04 00:00:00
09/01/05 00:00:00

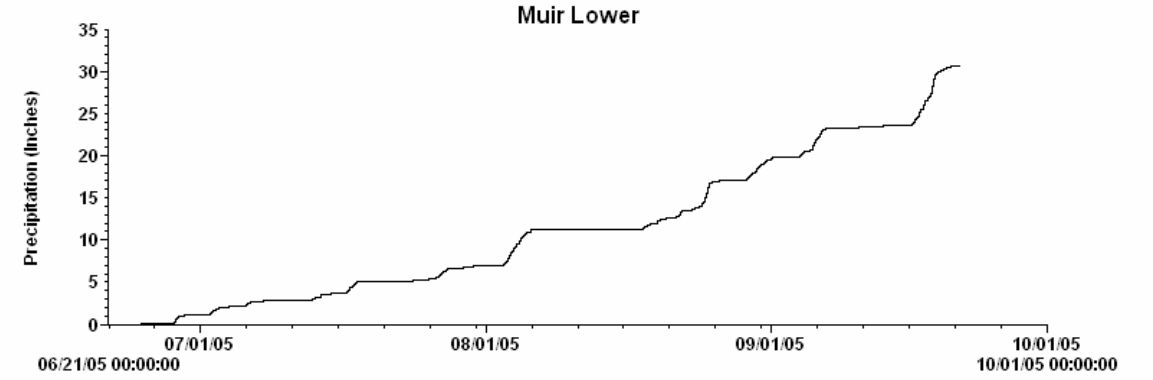

Johnson's Cove
Precipitation (inches)
70
60
50
40
30
20
10
0
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00

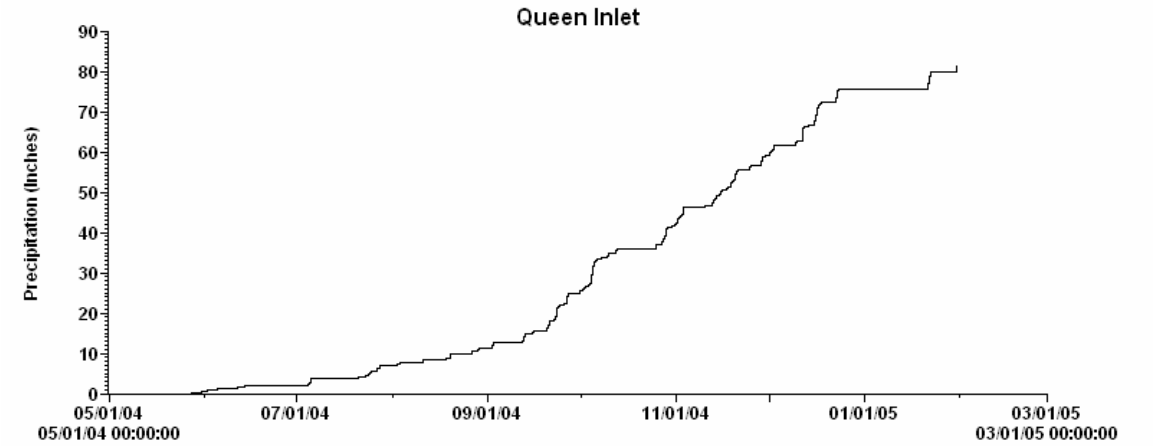

Johnson's Cove
Precipitation (inches)
18
16
14
12
10
8
6
4
2
0
07/01/05
08/01/05
09/01/05
10/01/05
06/21/05 00:00:00
10/01/05 00:00:00

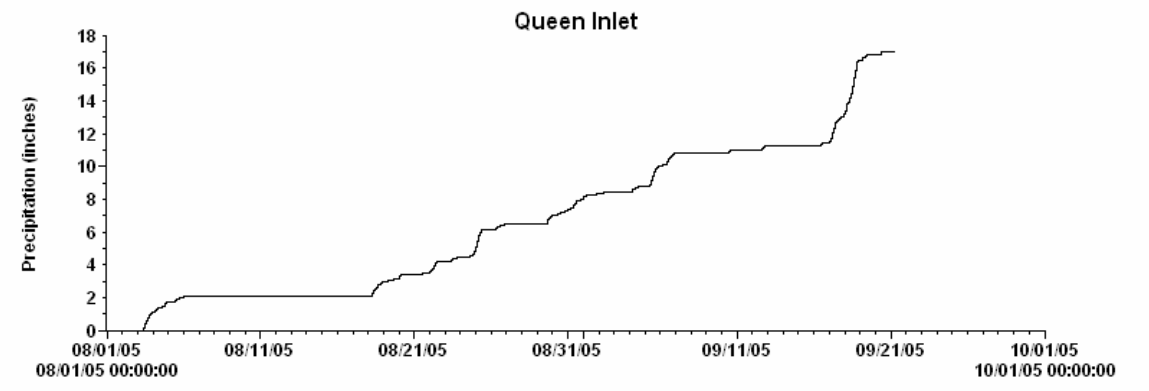

Lower Tarr
Pecipitation (Inches)
90
80
70
60
50
40
30
20
10
0
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00

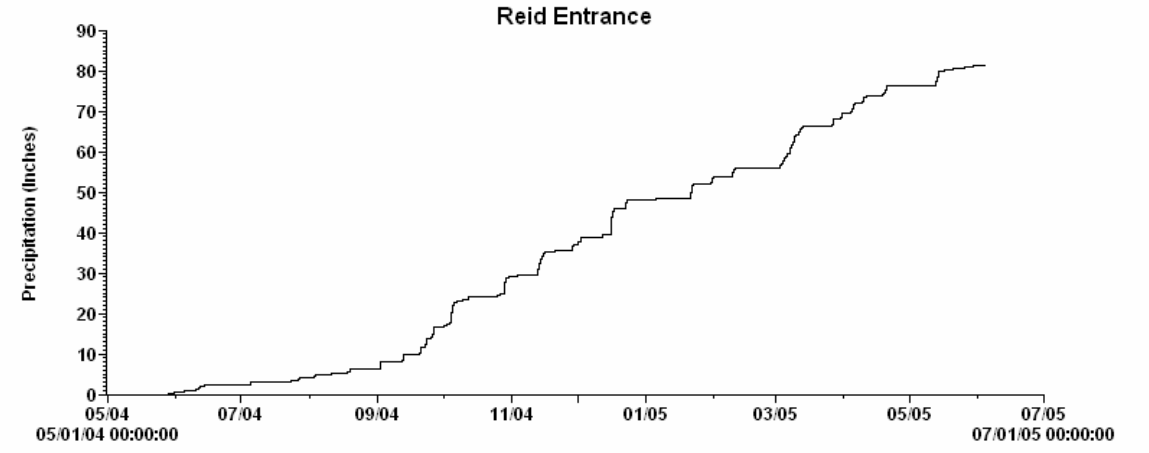

Lower Tarr
Precipitation (Inches)
16
14
12
10
8
6
4
2
0
06/21/05
07/01/05
07/11/05
07/21/05
07/31/05
08/11/05
08/21/05
08/31/05
09/11/05
09/21/05
06/21/05 00:00:00
09/21/05 00:00:00

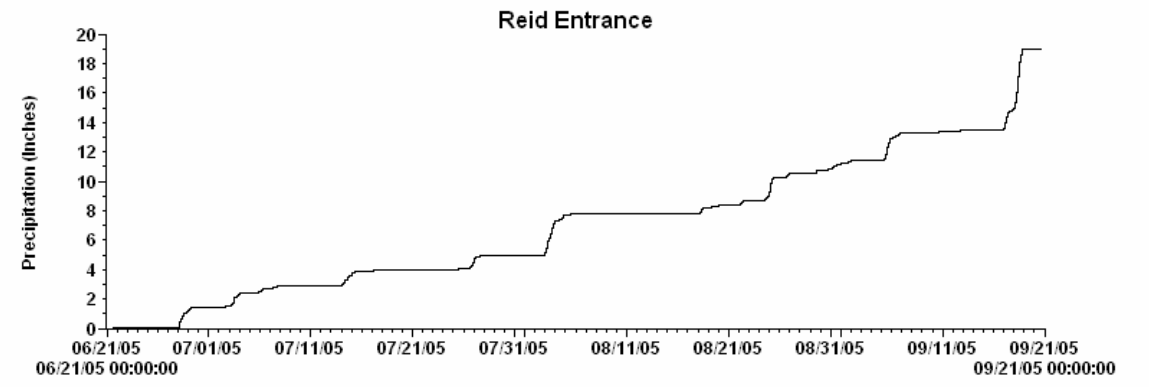

Muir Lower
Precipitation (Inches)
0
10
20
30
40
50
60
70
80
90
05/01/04
07/01/04
09/01/04
11/01/04
01/01/05
05/01/04 00:00:00
02/28/05 23:00:00


Muir Lower
Precipitation (Inches)
0
5
10
15
20
25
30
35
07/01/05
08/01/05
09/01/05
10/01/05
06/21/05 00:00:00
10/01/05 00:00:00


Queen Inlet
Precipitation (Inches)
0
10
20
30
40
50
60
70
80
90
05/01/04
07/01/04
09/01/04
11/01/04
01/01/05
03/01/05
05/01/04 00:00:00
03/01/05 00:00:00


Queen Inlet
Precipitation (inches)
0
2
4
6
8
10
12
14
16
18
08/01/05
08/11/05
08/21/05
08/31/05
09/11/05
09/21/05
10/01/05
08/01/05 00:00:00
10/01/05 00:00:00


Reid Entrance
Precipitation (Inches)
0
10
20
30
40
50
60
70
80
90
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00


Reid Entrance
Precipitation (Inches)
0
2
4
6
8
10
12
14
16
18
20
06/21/05
07/01/05
07/11/05
07/21/05
07/31/05
08/11/05
08/21/05
08/31/05
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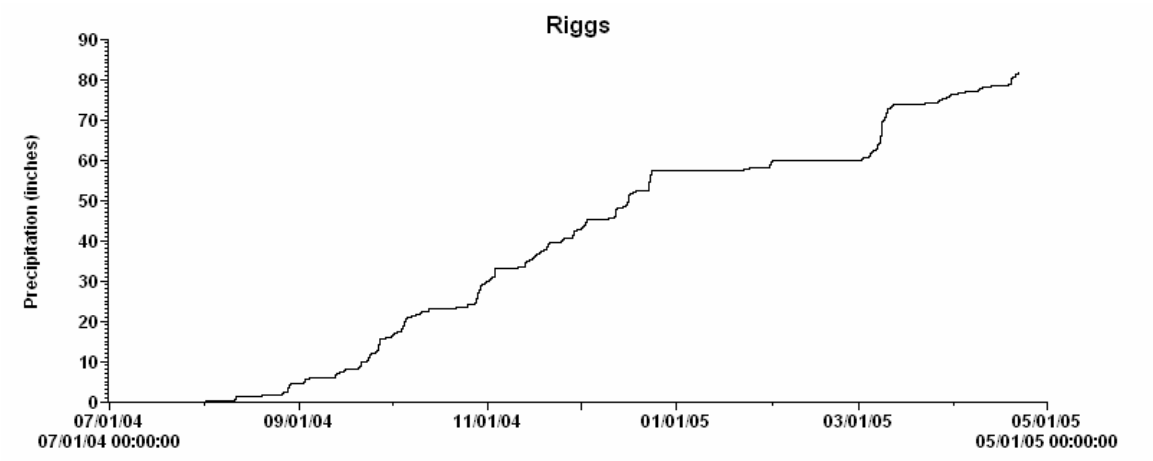
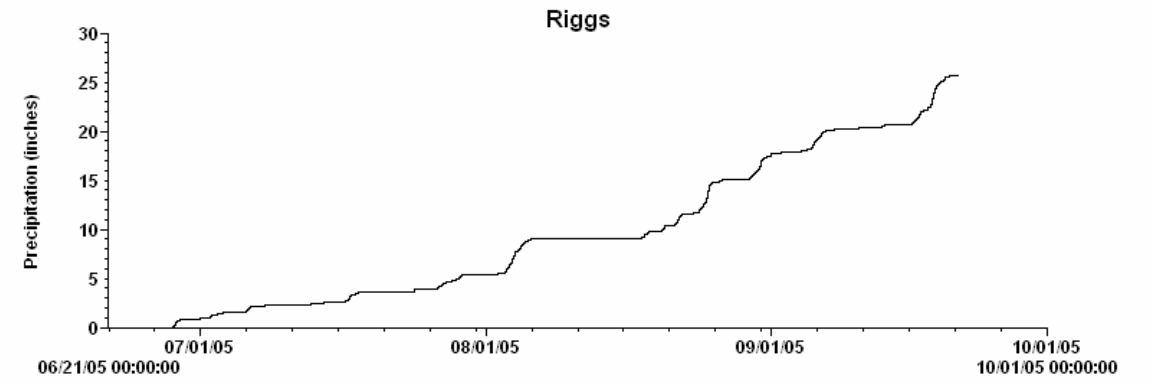
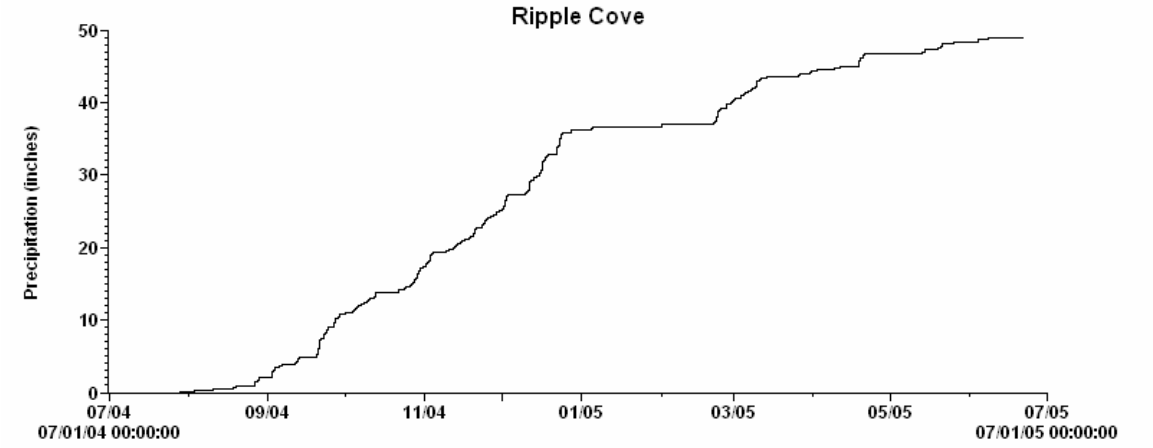
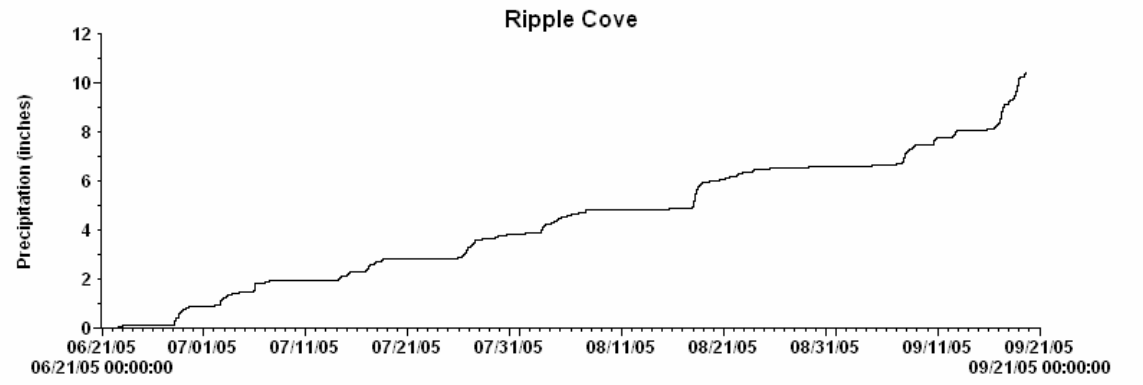
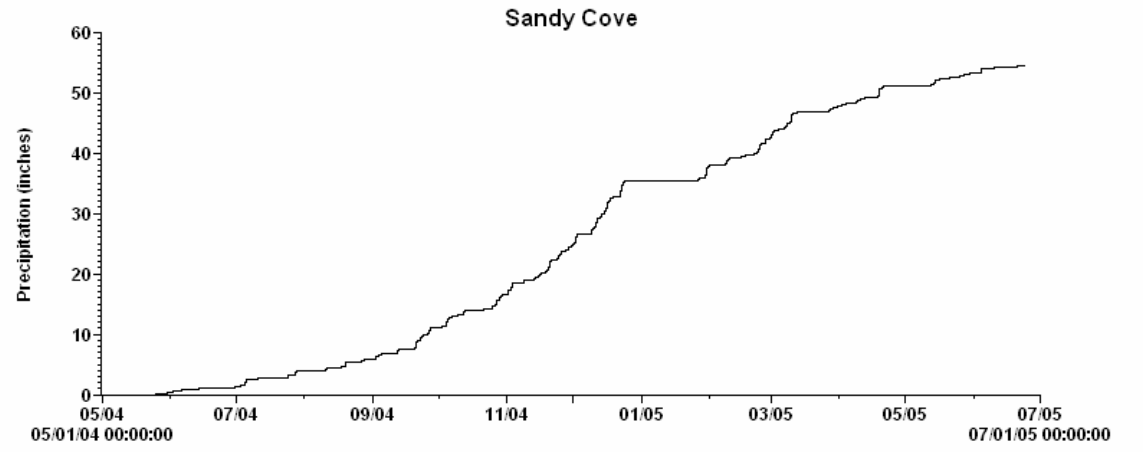
09/21/05
06/21/05 00:00:00
09/21/05 00:00:00

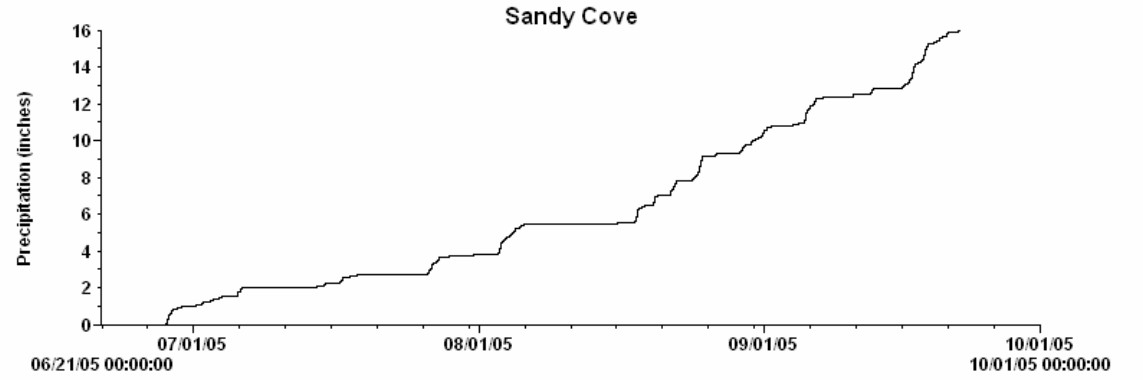

Riggs
Precipitation (inches)
0
10
20
30
40
50
60
70
80
90
07/01/04
07/01/04 00:00:00
09/01/04
11/01/04
01/01/05
03/01/05
05/01/05
05/01/05 00:00:00

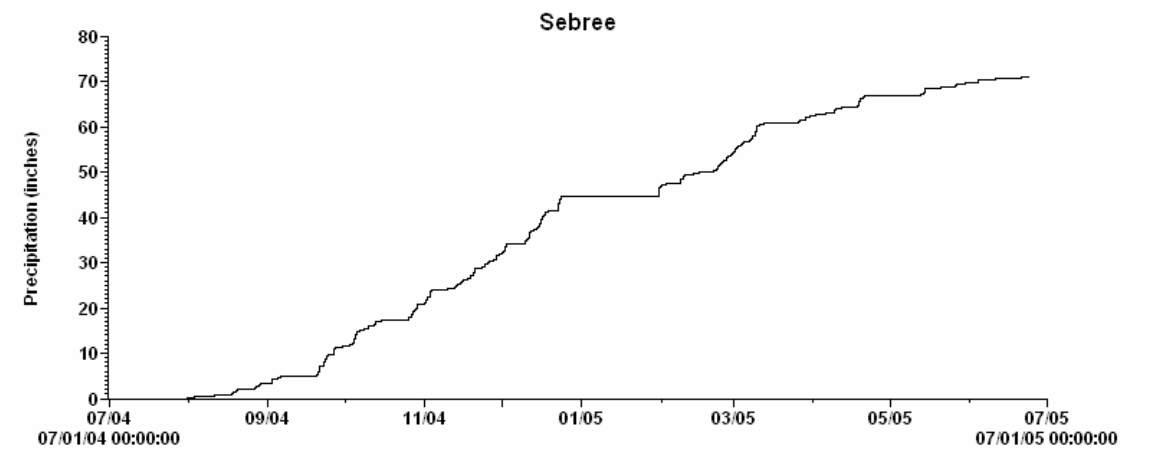

Riggs
Precipitation (inches)
0
5
10
15
20
25
30
07/01/05
06/21/05 00:00:00
08/01/05
09/01/05
10/01/05
10/01/05 00:00:00

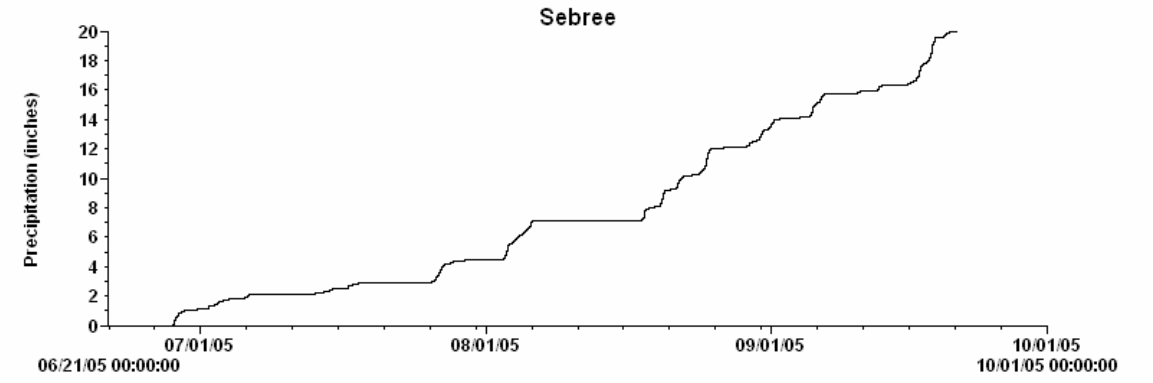

Ripple Cove
Precipitation (inches)
0
10
20
30
40
50
07/04
07/01/04 00:00:00
09/04
11/04
01/05
03/05
05/05
07/05
07/01/05 00:00:00

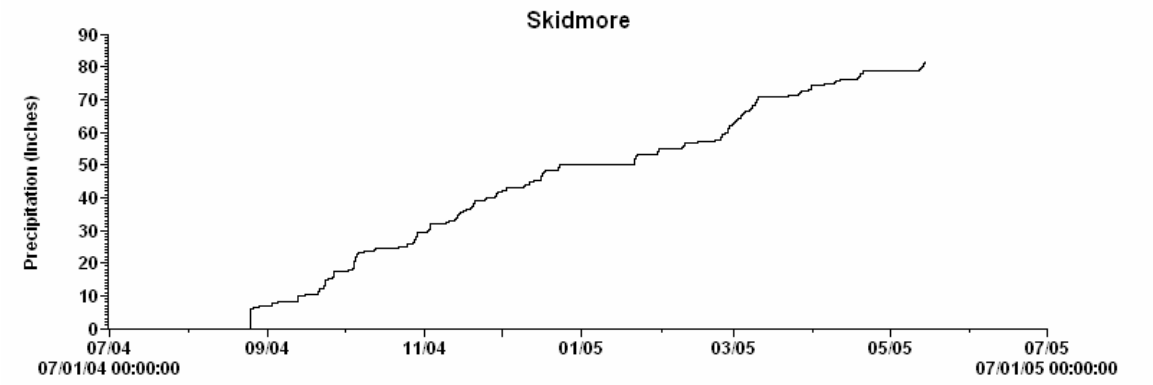

Ripple Cove
Precipitation (inches)
0
2
4
6
8
10
12
06/21/05
07/01/05
07/11/05
07/21/05
07/31/05
08/11/05
08/21/05
08/31/05
09/11/05
09/21/05
06/21/05 00:00:00
09/21/05 00:00:00

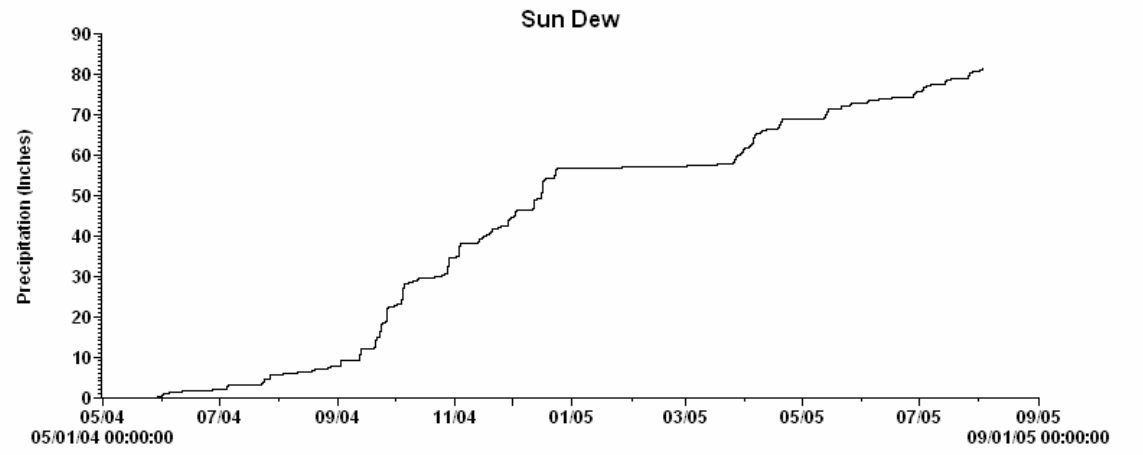

Sandy Cove
Precipitation (inches)
0
10
20
30
40
50
60
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00

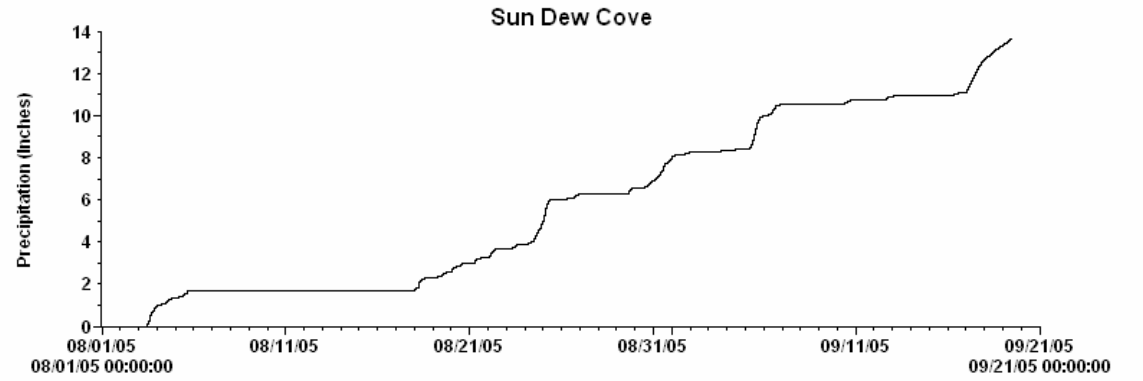

Sandy Cove
Precipitation (inches)
0
2
4
6
8
10
12
14
16
07/01/05
08/01/05
09/01/05
10/01/05
06/21/05 00:00:00
10/01/05 00:00:00

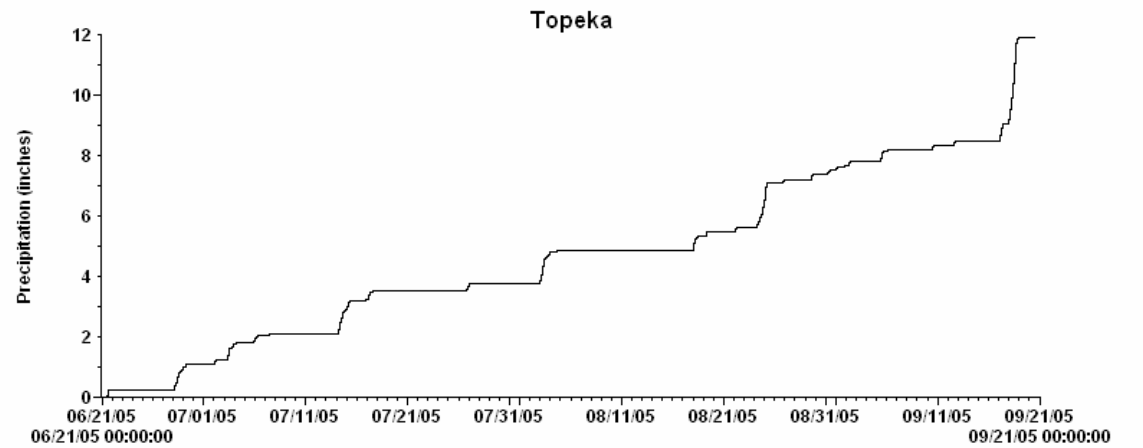

Sebree
Precipitation (inches)
0
10
20
30
40
50
60
70
80
07/04
09/04
11/04
01/05
03/05
05/05
07/05
07/01/04 00:00:00
07/01/05 00:00:00


Sebree
Precipitation (inches)
0
2
4
6
8
10
12
14
16
18
20
07/01/05
08/01/05
09/01/05
10/01/05
06/21/05 00:00:00
10/01/05 00:00:00


Skidmore
Precipitation (Inches)
0
10
20
30
40
50
60
70
80
90
07/04
09/04
11/04
01/05
03/05
05/05
07/05
07/01/04 00:00:00
07/01/05 00:00:00


Sun Dew
Precipitation (Inches)
90
80
70
60
50
40
30
20
10
0
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
09/05
05/01/04 00:00:00
09/01/05 00:00:00


Sun Dew Cove
Precipitation (Inches)
14
12
10
8
6
4
2
0
08/01/05
08/11/05
08/21/05
08/31/05
09/11/05
09/21/05
08/01/05 00:00:00
09/21/05 00:00:00


Topeka
Precipitation (inches)
12
10
8
6
4
2
0
06/21/05
07/01/05
07/11/05
07/21/05
07/31/05
08/11/05
08/21/05
08/31/05
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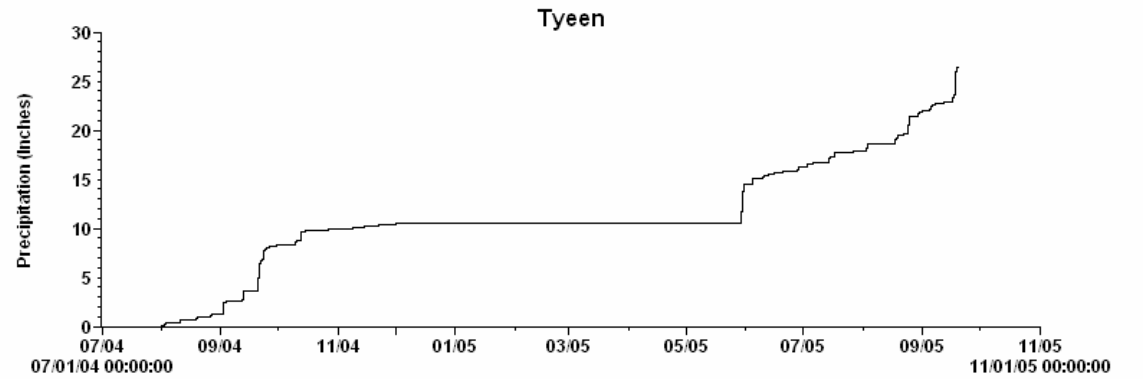
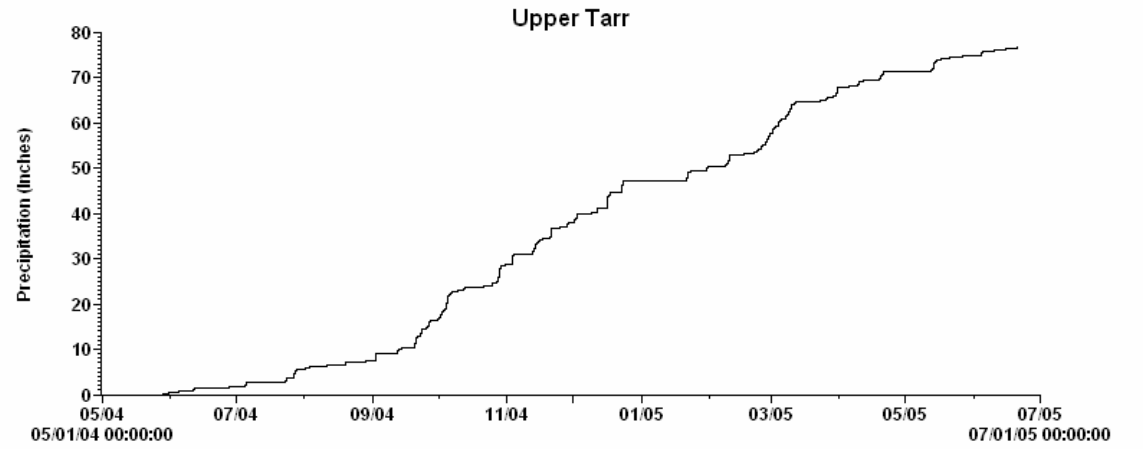
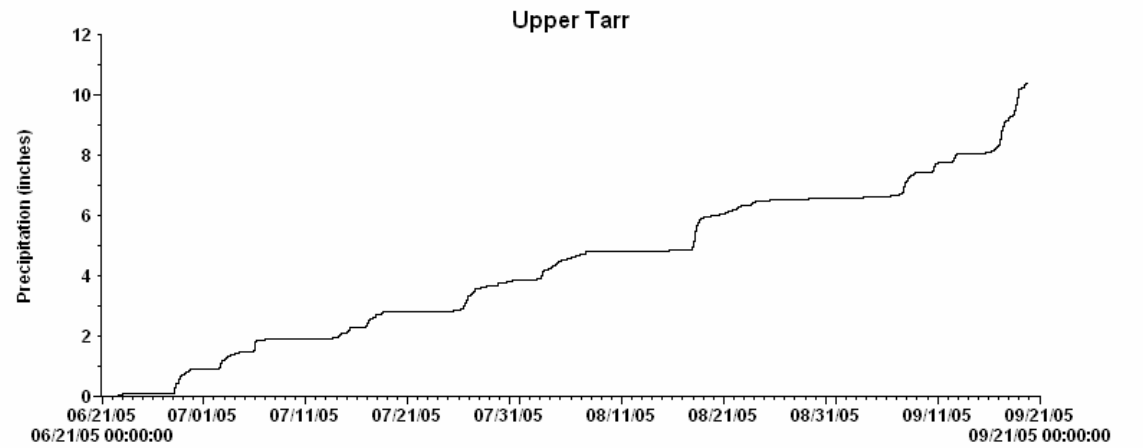
09/21/05
06/21/05 00:00:00
09/21/05 00:00:00


Tyeen
Precipitation (Inches)
30
25
20
15
10
5
0
07/04
09/04
11/04
01/05
03/05
05/05
07/05
09/05
11/05
07/01/04 00:00:00
11/01/05 00:00:00


Upper Tarr
Precipitation (Inches)
80
70
60
50
40
30
20
10
0
05/04
07/04
09/04
11/04
01/05
03/05
05/05
07/05
05/01/04 00:00:00
07/01/05 00:00:00


Upper Tarr
Precipitation (inches)
12
10
8
6
4
2
0
06/21/05
07/01/05
07/11/05
07/21/05
07/31/05
08/11/05
08/21/05
08/31/05
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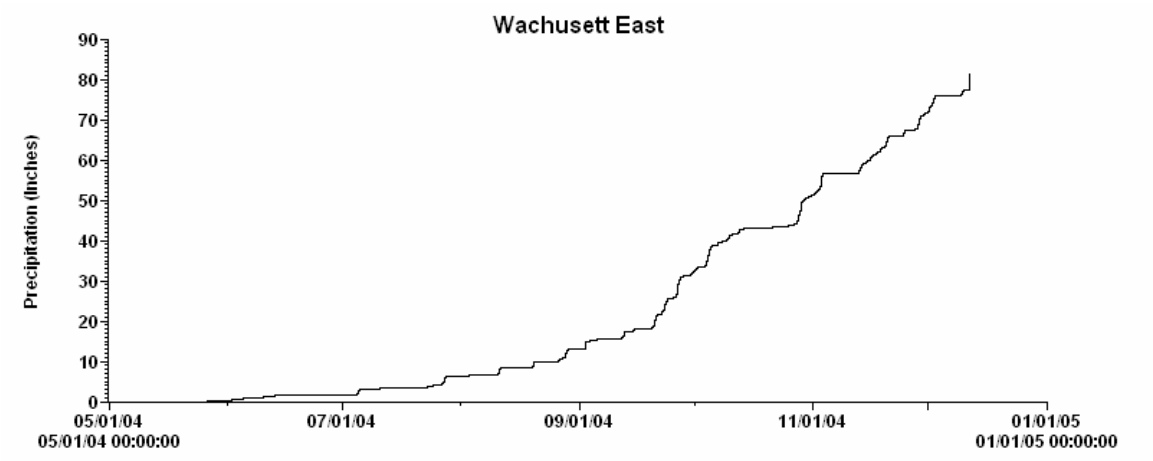
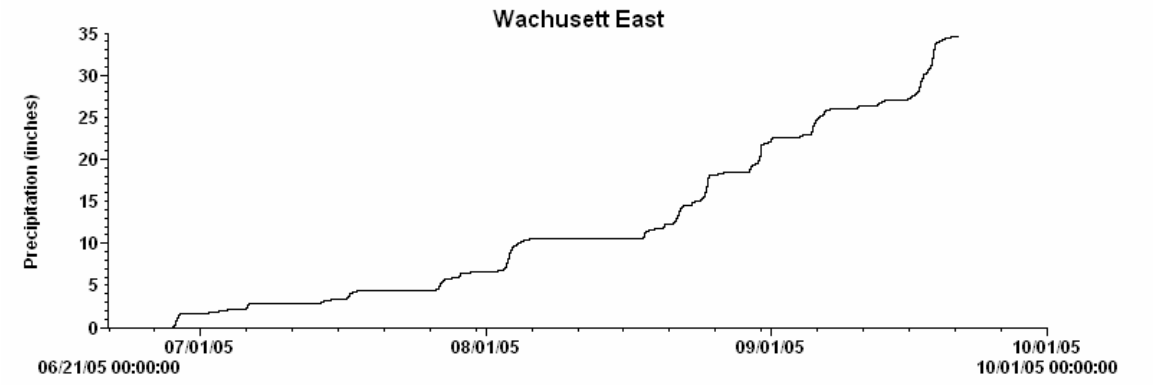
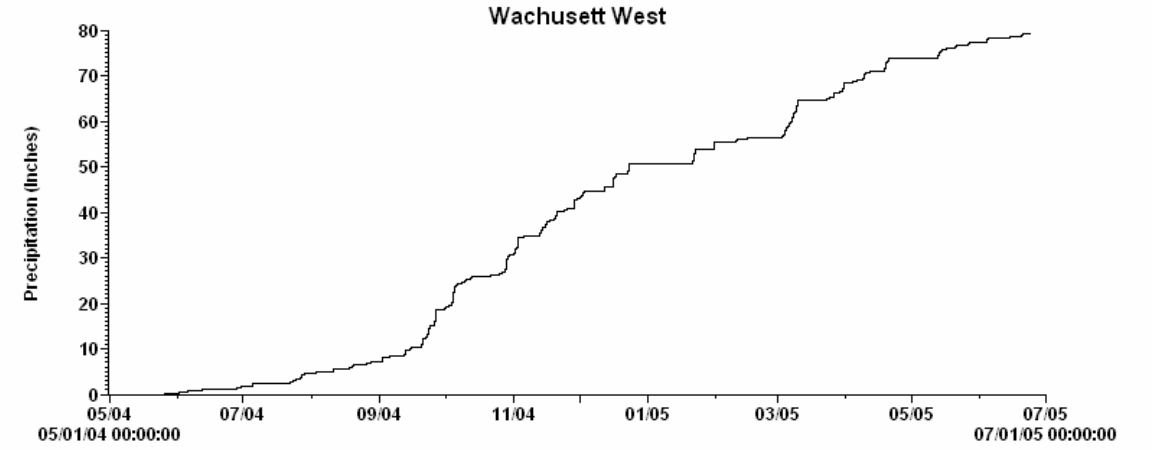
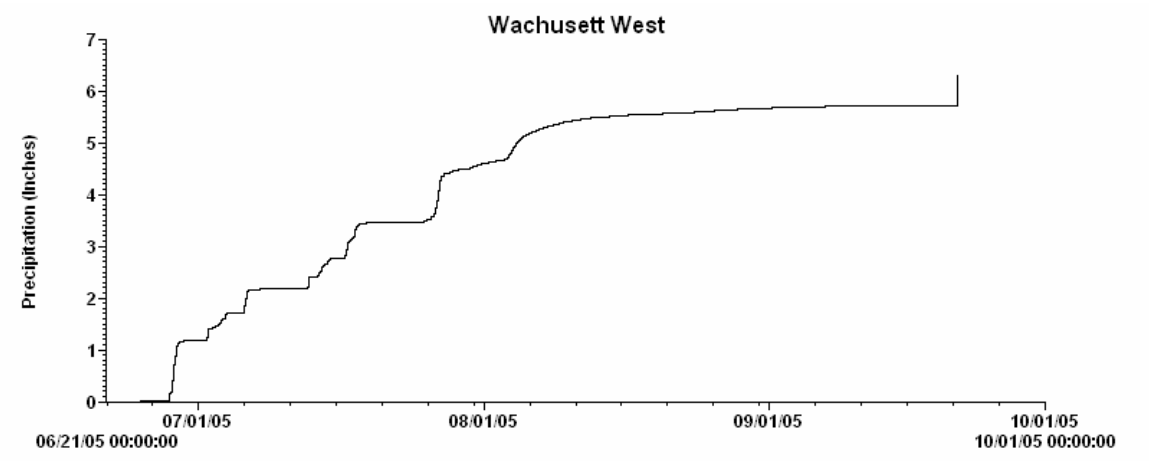
09/21/05
06/21/05 00:00:00
09/21/05 00:00:00


Wachusett East
Precipitation (Inches)
90
80
70
60
50
40
30
20
10
0
05/01/04
05/01/04 00:00:00
07/01/04
09/01/04
11/01/04
01/01/05
01/01/05 00:00:00


Wachusett East
Precipitation (inches)
35
30
25
20
15
10
5
0
07/01/05
06/21/05 00:00:00
08/01/05
09/01/05
10/01/05
10/01/05 00:00:00


Wachusett West
Precipitation (Inches)
80
70
60
50
40
30
20
10
0
05/04
05/01/04 00:00:00
07/04
09/04
11/04
01/05
03/05
05/05
07/05
07/01/05 00:00:00


Wachusett West
Precipitation (Inches)
0
1
2
3
4
5
6
7
07/01/05
08/01/05
09/01/05
10/01/05
06/21/05 00:00:00
10/01/05 00:00:00