# Greenland Climate Network (GC-NET)
# Data Reference

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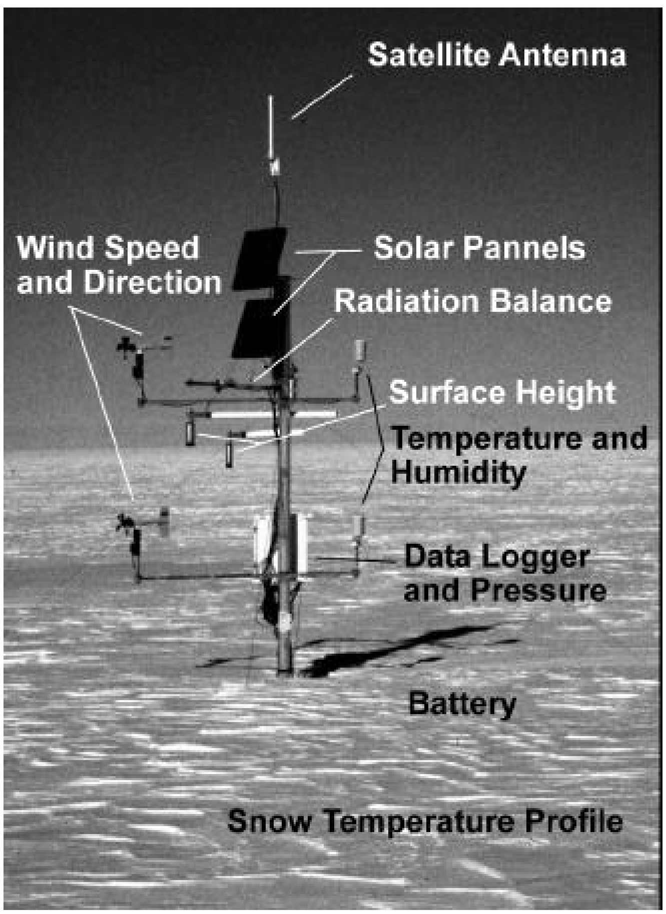


GC-NET Automated Weather Station

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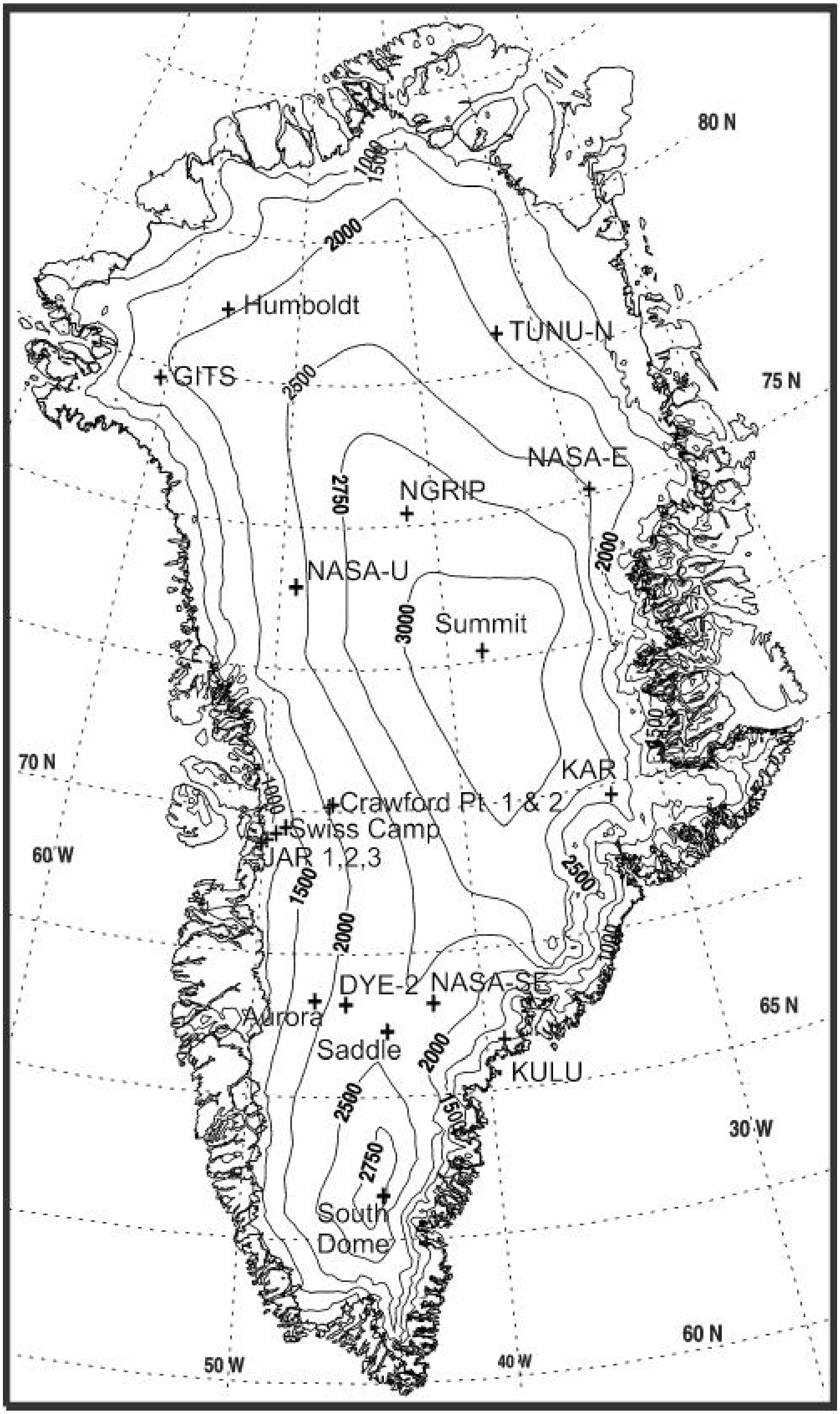
**Overview map of GC Net Stations**



### GC-NET Overview

The Greenland Climate Network (GC-NET) currently consists of 18 stations with a distributed coverage over the Greenland ice sheet. GC-Net AWS are equipped with instruments to measure surface energy and mass balance. So far, the GC-NET archive contains 42+ station years of measurements (Fig.1). These data have been quality controlled and calibrated.

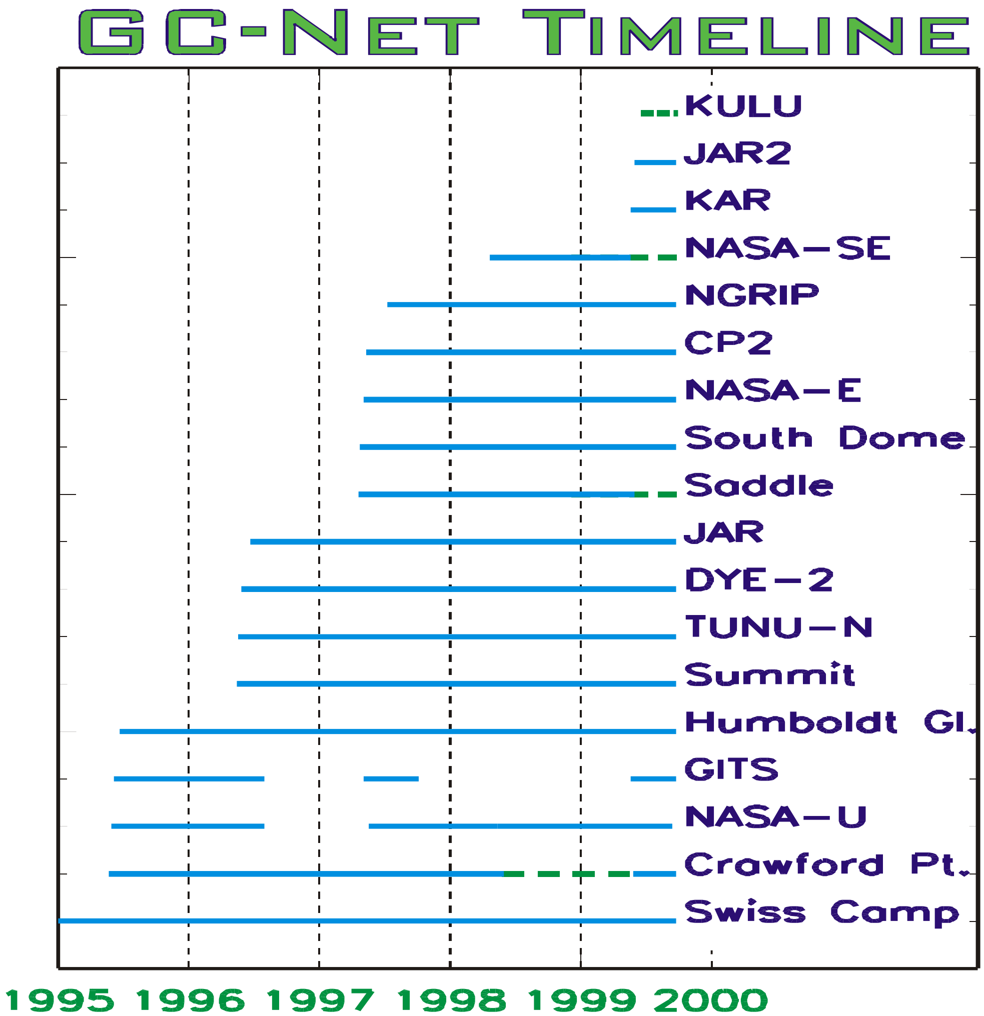



*Figure 1, AWS Timeline*

### Data Status

The task of calibration and quality control has been updated for the majority of GC-Net stations. We use transmitted data to extend the GC-NET record to the present. The quality-controlling task is complicated by the fact that up to 20% of the data are not transmitted. We have developed a set of procedures to optimize our data record using interpolation techniques. Once a station is re-visited, continuous data can be retrieved to replace the transmitted data. Quality control procedures are applied to all AWS data sets.

### Citing the GC-NET

These data represent an immense effort on the part of the authors. Please consult the authors before you publish portions of the raw data. Remember to acknowledge the authors when publishing results from these data. Use the reference below for citing the Greenland Climate Network.

*Steffen, K., J. E. Box, and W. Abdalati, 1996 "Greenland Climate Network: GC-Net", in Colbeck, S. C. Ed. CRREL 96-27 Special Report on Glaciers, Ice Sheets and Volcanoes, trib. to M. Meier, pp. 98-103.*

## Station and Instrument Failures

1997 Two data losses occurred at NASA-U and at GITS, both due to power failures. At NASA-W the power cable got pulled out as a result of snow compression At GITS, the battery voltage dropped below 9 VDC due to a power leak. Both stations were reactivated in April 1997.

1998 At Crawford Pt., the data logger was found with a short circuit.

1999 At Swiss Camp, water infiltrated into the battery box. Fortunately, there are 2 AWS at Swiss Camp, so much of the record was maintained. At Crawford Pt., the battery failed due to a power leak. At GITS, the power cable was pulled out. All of these stations were reactivated and safeguarded from repeat failure.

The Campbell Scientific CS-500 Vaisala humidity instruments have been replaced at several of the colder sites after repeatedly breaking. We are now testing a different humidity instrument to replace these. These instruments have otherwise performed well at the warmer AWS sites at lower elevations.

## Description of Measurement Problems Encountered By the GC-Net

The user of GC-Net data should be aware of all sources of error and be critical of the data to avoid misinterpretation. The following paragraphs describe problems identified in GC-Net measurements. The user is reminded that unattended measurements are subject to many potential problems. Some problems are difficult to detect.

### Solar Radiation

When the sun is near the horizon, the values of upwelling solar radiation flux are occasionally larger the downwelling flux. This will not effect energy balance calculations much. During the polar day at midnight, the AWS platform causes a shadow on the up-looking pyranometer and on the surface beneath the downward looking pyranometer. Radiometers are on an aluminum arm, which is directed due south. By having the measurement arm pointing south, direct solar beam shading is minimized, occurring at midnight when the sun is either below the horizon or when solar fluxes are the smallest for each day. Shading pollutes one or two hourly means near midnight. Reflections from the tower and solar panels can also lead to spurious measurements. Instrument level can drift through time, leading to errors. Frost can obscure the detectors, although due to the small size and thermal mass of our pyranometers, there are few cases where frost poses a problem.

### Net Radiation

Frost has been found inside the polyethelene domes almost without exception at the high elevation sites. Alternatively, at the lower elevation sites, < 1100 m, net radiometer performance is thought to be quite good. The silica gel desiccant is not very effective owing to the very small partial pressure of water vapor at cold temperatures. We are considering calcium hydride, another desiccant though to be more effective than silica gel.

### Temperature

The largest potential errors are in absolute temperature caused by overheating when wind speeds are small and solar radiation is great. We have made an experiment to compare ventilated and non-ventilated temperature sensor shields. We plan to use a correction algorithm based on wind speed and solar radiation.

### Wind Speed

When the AWS is upwind of the anemometer, wind speeds are in general reduced, leading to spurious wind speed magnitudes and momentum gradients. Other problems: frost, leveling, and bent anemometer axle.

### Wind Direction

Some spurious wind directions have occurred when the anemometer is frozen by frost. These are removed from the final data product.

### Humidity

Low signal to noise occurs because at cold temperatures, the partial pressure of water vapor is near zero. The humidity data have also been corrected to reflect RH with respect to ice instead of liquid. This correction is dependant on temperature and the saturation vapor pressure curves for a plane surface of pure water and ice.

### Surface Height

Accumulation rates based on surface height change only will be underestimates due to compaction. The AWS causes a depression in the lee of the mast at most sites. The mote has been measured to be as deep as 50 cm, although the footprint of the sonic ranging device is less affected since it is on a boom arm about 1.5 m from the mast. The mote decreases in depth with distance from the AWS mast to zero at about 1 to 1.5 m. Frost, instrument leveling, air temperature and blowing snow are smaller sources of error for sonic ranging measurements of surface height change.

### Pressure

Vaisala, the instrument manufacturer cautions against use of the barometer below -40° C, saying that it would damage the instrument permanently. Our measurements however agree very well with other observations even after winters at high elevation and cold sites.

*Table 1, GC-NET AWS Positions*

| Station ID # | Station Name | Latitude and Longitude | Latitude and Longitude | Elevation m] | Magnetic Decl. |
|---|---|---|---|---|---|
| **01** | Swiss Camp | 69° 34' 06" N, 49° 18' 57" W | 69.56833, 49.31582 | 1149 | 45° W |
| **02** | Crawford Pt. | 69° 52' 47" N, 46° 59' 12" W | $69.87975, 46.98667 | 2022 | 44° W |
| **03** | NASA-U | 73° 50' 31" N, 49°, 29' 54" W | $73.84189, 49.49831 | 2369 | 49° W |
| **04** | GITS | 77° 08' 16" N, 61° 02' 28" W | $77.13781, 61.04113 | 1887 | 65° W |
| **05** | Humboldt | 78° 31' 36" N, 56° 49' 50" W | +78.5266, 56.8305 | 1995 | 63° W |
| **06** | Summit | 72° 34' 47" N, 38° 30' 16" W | $72.57972, 38.50454 | 3254 | 41° W |
| **07** | TUNU-N | 78° 01' 0" N, 33° 59' 38" W | 78.01677, 33.99387 | 2113 | 42° W |
| **08** | DYE-2 | 66° 28' 48" N, 46° 16' 44" W | $66.48001, 46.27889 | 2165 | 39° W |
| **09** | JAR | 69° 29' 54" N, 49° 40' 54" W | +69.498358, 49.68156 | 962 | 45° W |
| **10** | Saddle | 66° 00' 02" N, 44° 30' 05" W | $65.99947, 44.50016 | 2559 | 40° W |
| **11** | South Dome | 63° 08' 56" N, 44° 49' 00" W | $63.14889, 44.81717 | 2922 | 35° W |
| **12** | NASA-E | 75° 00' 00" N, 29° 59' 59" W | 75.00000, 29.99972 | 2631 | 36° W |
| **13** | CP2 | 69° 54' 48" N, 46° 51' 17" W | $69.87968, 46.98692 | 1990 | 42° W |
| **14** | NGRIP | 75° 05' 59"N, 42° 19' 57" W | +75.09975, 42.33256 | 2950 | 46° W |
| **15** | NASA-SE | 66° 28' 47" N, 42° 30' 00" W | $66.4797, 42.5002 | 2425 | 36° W |
| **16** | KAR | 69° 41' 58" N, 33° 00' 21" W | $69.69942, 33.00058 | 2579 | 33° W |
| **17** | JAR 2 | 69º 25" 12" N, 50º 03' 27" W | 69.42000, 50.05750 | 568 | 45° W |
| **18** | KULU | 65° 45' 30" N 39° 36' 06" W | 65.75845 $, 39.60177 | 878 | 34° W |

*+ = initial hand held GPS measurement made when station was installed*
*$ = spatial average of Trimble Geo Explorer II hand held GPS measurements in 1999.*

*** - corrected**

*Table 2, GC-NET Data Format*

| Index | Parameter | Index | Notes/[Units] |
|---|---|---|---|
| 1 | Station Number | A | 01 .. 18 |
| 2 | Year | B | 1995 – 1999 |
| 3 | Julian Decimal Time | C | 0.0000 – 365.9583 |
| 4 | SW↓ | D | [W $m^{-2}$] |
| 5 | SW↑ | E | [W $m^{-2}$] |
| 6 | Net Radiation | F | [W $m^{-2}$] |
| 7 | TC Air 1 | G | Air Temperature [°C] |
| 8 | TC Air 2 | H | Air Temperature [°C] |
| 9 | CS500 T Air 1 | I | Air Temperature [°C] |
| 10 | CS500 T Air 2 | J | Air Temperature [°C] |
| 11 | RH 1 | K | Relative Humidity [%] ** |
| 12 | RH 2 | L | Relative Humidity [%] ** |
| 13 | U1 | M | Wind Speed [m/s] |
| 14 | U2 | N | Wind Speed [m/s] |
| 15 | U Dir 1 | O | degrees [0-360] |
| 16 | U Dir 2 | P | degrees [0-360] |
| 17 | Local Pressure | Q | [mb] |
| 18 | Snow Height 1 | R | [m] |
| 19 | Snow Height 2 | S | [m] |
| 20 | T Snow 1 | T | [°C] |
| 21 | T Snow 2 | U | [°C] |
| 22 | T Snow 3 | V | [°C] |
| 23 | T Snow 4 | W | [°C] |
| 24 | T Snow 5 | X | [°C] |
| 25 | T Snow 6 | Y | [°C] |
| 26 | T Snow 7 | Z | [°C] |
| 27 | T Snow 8 | AA | [°C] |
| 28 | T Snow 9 | AB | [°C] |
| 29 | T Snow 10 | AC | [°C] |
| 30 | Battery Voltage | AD | VDC |
| 31 | U 2m from theory | AE | Wind Speed [m/s] |
| 32 | U 10m from theory | AF | Wind Speed [m/s] |
| 33 | Height of profile 1 | AG | m |
| 34 | Height of profile 2 | AH | m |
| 35 | Albedo | AI | See description |
| 36 | Peak wind speed | AJ | See description |
| 37 | QC identifier col. 1 | AK | See description |
| 38 | QC identifier col. 2 | AL | See description |
| 39 | QC identifier col. 3 | AM | See description |
| 40 | QC identifier col. 4 | AN | See description |

** - RH data are scaled with respect to ice as of Sept 1999.

fixed format…
i2,1x,i4,1x,f8.4,1x,2(f7.2,1x),1x,9f7.2,3f6.1,2f8.3,10f7.2,f6.1,8f7.2,2f8.3

## AWS DATA Processing

### Calibration

GC-Net instruments come factory calibrated. Nonetheless, on-site relative temperature, humidity and wind speed calibrations are performed to ensure relative accuracy of gradient measurements. The deviation from one sensor to the other is adjusted to zero using a multiplier representing the inverse of the percent mean deviation during a calibrations of at least 7 hours. Some of AWS do not have relative calibration coefficients due to inclement weather and time constraints. Field calibrations are set for at least one half or an entire diurnal cycle in attempt to represent the relative bias between the profile instruments over range of local measurements. The resultant corrections are typically less than 3% (Table 3).

*Table 3, Calibration Coefficients used by GC-Net Profile Instruments*

| **Station** | **TC 1 Coef** | **T 1 Coef** | **RH 1 Coef** | **Wind 1 Coef** |
|---|---|---|---|---|
| Swiss Camp | 0.99981 | 1.00035 | 1.02413 | 1.00046 |
| Crawford Pt. | 1 | 1 | 1 | 1 |
| NASA-U | 1.00017 | 0.99954 | 0.97903 | 1.00761 |
| GITS / | 1.00007 | 0.99941 | 1.02351 | 1.03020 |
| Humboldt Gl. | 1.0003, 1 | 0.9999, 1 | 0.9949, 1 | 1.0038, 1 |
| Summit | 1 | 1 | 1 | 1 |
| TUNU-N | 0.99900, 1.00012 | 1.00000, 0.998909 | 1.01993, 1.02595 | 1.0490, 0.978299 |
| DYE-2 | 0.999803, 1.00069 | 0.999466, 1.00034 | 1.02861, 1.02260 | 1.182118, 1.04372 |
| JAR | 1 | 1 | 1 | 1 |
| Saddle | 1 | 1 | 1 | 1 |
| South Dome | 1 | 1 | 1 | 1 |
| NASA-E | 0.99993 | 0.99802 | 0.99985 | 1.09206 |
| CP2 | 1.0000 | 1.00004 | 0.988039 | 1.00557 |
| NGRIP | 0.999625 | 0.998076 | 1.00412 | 1.00827 |

### Instruments/Measurements

*Table 4, Parameters measured by the GC-Net*

| **Parameter** | **Instrument** | **Instrument Accuracy** | **Sample Interval** | **# per station** |
|---|---|---|---|---|
| Air Temperature | Campbell Sci. CS-500 | 0.1 °C. | 60 sec | 2 |
| Air Temperature | Type-E Thermocouple | 0.1 °C. | 60 sec | 2 |
| Relative humidity | Campbell Sci. CS-500 | 5% < 90% RH<br>10% > 90% RH | 60 sec | 2 |
| Wind Speed* | RM Young propeller-type vane | 0.1 m $s^{-1}$ | 60 sec*, 15 sec | 2 |
| Wind Direction | RM Young propeller-type vane | 5 ° | 60 sec | 2 |
| Station Pressure | Vaisala PTB101B | 0.1 mb | 60 min | 1 |
| Surface Height Change | Campbell SR-50 | 1 mm | 10 min | 2 |
| Shortwave adiation flux [W $m^{-2}$] | Li Cor Photodiode | 5-15% | 15 sec | 1 |
| Net Radiation | REBS Q* 7 | 5-50% | 15 sec | 1 |
| Snow Temperature | Type-T Special Limits of Error Thermocouple | 0.1 ° | 15 sec | 10 |

* wind speed sampled each 15 sec after 1999 visits except NGRIP AWS

**Quality Control**

Statistical procedures are applied to the GC-Net data in effort to check data quality. These include, firstly the rejection of impossible values. Secondly, a gradient threshold compares a measurement with the next sequential hourly. If the change is greater than a threshold (Table X), the later point is rejected. Thirdly, a moving statistics window scans the time series to identify and reject data beyond a variance threshold for a given window size. In some cases, a spectrum of window sizes is employed to reject outliers due to occasional transmission errors. In general, the data that are identified as bad by these filters represent less than a few percent of the total data volume. Missing data are interpolated linearly if there are data available within an autocorrelation threshold of the flagged value (Table 5). If there is a gap of greater than the autocorrelation threshold, then no interpolation is performed.

*Table 5 Autocorrelation thresholds for interpolation*

| Parameter | Gradient Threshold | Autocorrelation Threshold [hours] |
|---|---|---|
| Air Temperature | 8° C, 12° C | 10 |
| Wind Speed | 10 m $s^{-1}$ | 10 |
| Relative humidity | 15% | 10 |
| Pressure | 3 mb | 48 |
| Wind Direction | None | 4 |
| Solar Radiation | 200 W $m^{-2}$ | 5 |
| Net Radiation | 120 W $m^{-2}$ | 5 |
| Snow Temperature | 2° C | 160 |
| Surface Height | 25, 30 cm | Linear interpolation not used |

These autocorrelation threshold values may be too liberal since the significance threshold sometimes falls off very rapidly. In the competing interest of data continuity, liberal thresholds have been selected to eliminate all but extended gaps.

**Output Cleaning Statistics**

Statistics of the amount of missing data in the 'c' dataset are output to a file for each station, i.e. 01stat2.dat is the statistics file for the Swiss camp 'c' dataset. The **stat2.dat files also include the count of synthetic values (those values which are either modified or generated by interpolation).

## GC-Net Data Quality Identification Scheme

The QC procedure tracks the modification history of each AWS data point. There are 4 columns of 8 identification codes per hour in the final data. The codes enable the data user to identify modified and unmodified AWS readings. Column 1 represents the first 8 data channels, i.e. Incoming shortwave radiation through RH 1. The first digit corresponds to the first AWS measurement channel (incoming shortwave radiation).

The last digit of the first identifier column corresponds to the modification history of RH 1. Identifier column 2 has the next 8 AWS measurement channels, RH 2 through sonic height 2. The third identifier column represents snow temperature measurements 1 through 8. The final identifier column represents snow temperature 9 and 10 (those nearest the surface) and the battery voltage indicator.

**Assignment of Codes**

- code = 0 is not used because it causes gaps in the identifier code strip
- code = 1 unmodified data
- code = 2 An linearly interpolated value has an identifier of 2. A snow height value that has been filled with the 'last_fill' sub-routine is given a modification identifier of 2. Linear interpolation is not employed with snow height data. The last_fill routine replaces missing snow height data with the last available data point. This simulates reality better than a linear interpolation, since snow height tends to increase abruptly.
- code = 3 when a value is 'frozen' e.g. with wind direction when the anemometer is frosted over with the exact same value for more than 4 hours.
- code = 5 corresponds to cases when incoming shortwave radiation was less than reflected solar radiation. At this time, the cleaning code, sets incoming to reflected and reflected to the new incoming * the last good albedo value.
- code = 6 corresponds to synthetic wind values. To simulate 2 wind speeds when only one is out, the logarithmic slope-intercept formula is used assuming a roughness length of 5cm (average condition). For some annual data sets, this approach fills in up to 15% of wind data where one wind sensor is out (frozen or low wind speeds?). Some of the cases are obviously frozen wind sensors (when sensor 2 reads zero and sensor 1 is moving). Other such cases occurwhen wind speeds are very low (< 1 m/s), and hence will not strongly affect wind speed averages, counts, or fluxes derived from wind speed.
- code = 7 corresponds to those cases where aerodynamic theory agreed with the measured logarithmic profile above r^2 = 0.97 . In these cases, the theory is selected to predict the 2 and 10 m wind speeds.
- code = 8 represents cases when RH data are used to estimate temperatures below -50 C. Note that RH is saturated at temperatures less than -45 C and hence the RH values are a direct function of temperature. This method has r squared values between 0.8 and 0.98.
- code = 9 when temperature values have been corrected for overheating when wind is small and solar radiation is great.
- code = 9 for some of the 1997 and 1998 Crawford Point snow height data that were synthesized from the regression based on the overlap with CP 2 data.