METADATA
Swamp Angel Study Plot

Swamp Angel Study Plot (SASP) data: http://snowstudies.org/data1.html
Senator Beck Basin Study Area (SBBSA), Red Mountain Pass, San Juan Mountains
Center for Snow and Avalanche Studies (CSAS)

I. Swamp Angel Study Plot (SASP)

1) Type of Site
   a) Study Plot: this large generally 'flat' and planar subalpine meadow is very well sheltered from wind by the surrounding terrain and, therefore, provides an excellent site for measuring precipitation and monitoring snowpack properties minimally influenced by wind redistribution of snow. Snow cover is conserved, undisturbed, within a 30m x 30m plot surrounding the instrumentation for a time series of snowpack profiles throughout the snow season and for researchers requiring undisturbed snowcover for their projects. See our archived data for SASP snow profiles, by season.

2) Site Datum
   a) Location: August 2008 GPS Lat 37° 54' 24.89088", Lon -107° 42' 40.75924"
      i) Originally estimated as 37° 54' 25" N, 107° 42' 41" W; per USGS Ironton, Colorado quadrangle 1955, NAD 1927
   b) Elevation: August 2008 GPS 11,059.6 feet (3371 meters)
      i) Originally estimated as 11,050 feet (3368 meters) per USGS Ironton, Colorado quadrangle 1955, NAD 1927
   c) Aspect & Slope: study plot generally slopes 3 degrees NNE
   d) Soils: deep, colluvial gravels; shallow "A" horizon; minimal 'O' horizon
   e) Vegetation: grasses and vascular annual plants; no shrubs, no trees within study plot
   f) Ownership: SASP is located on public lands and authorized by the Uncompahgre National Forest under a Special Use Permit issued to the CSAS
   g) Changes to site: no trees or brush cleared from site; no changes to ground surface
   h) Photographs: see CSAS website at http://snowstudies.org/sasp1.html

3) System Operation
   a) SASP began operating in Winter 2003/2004, on November 8, 2003
   b) SASP performs continuous collection of 'Winter' and 'Summer' datasets spanning the 'Water Year' (October 1 through September 30)
      i) 'Winter' datasets begin October 1 (start of 'Water Year') through midnight of the last day of Spring (through the day before summer solstice)
      ii) 'Summer' datasets extend from Summer Solstice through September 30 (through the day before start of new 'Water Year')
   c) Data Arrays
      i) 1 hour data arrays: *Flag* field = 301
      ii) 3 hour data arrays: *Flag* field = 303
      iii) Solar Noon arrays: *Flag* field = 312 (2 minute arrays through solar noon period)

iv) 24 hour data arrays: *Flag* field = 324

d) All data are collected on Mountain Standard Time, by day-of-year (DOY)
   i) Datalogger clocks are *not* switched from/to Mountain Daylight Time
   ii) 24 hour summary datasets (*Flag* = 324) are calendar day, ending at midnight.

e) Total precipitation (data in Location #38, from Noah II precipitation gauge) is reset to 0 mm H_2O on October 1st each season, the start of the Water Year

4) System Operation Notes (see also Sensor History notes for individual sensors):

a) Notable changes in operations (additions of sensors, recalibrations, etc.), or sensor or system malfunctions with extended periods of missing data, are listed below. Other, brief periods of missing data exist.

Year	Date(s)	Day of Year	Note
2016	July 1 – Sept 7	183-251	All pyranometers and pyrgeometer removed for recalibration; restored to service on Sept 7 2016 (DOY 251). No radiation data during this period.
2016	Aug 23-Sept 10	236-254	DOY 236-254, Lower Temp/RH sensor inoperable. Replaced CS500-U with HMP60 on Sept 10, 2016.
2015	Nov 9, 11, 16, 20, 2015, Jan 4, 2106	313, 315, 320, 324, 004	Logger malfunction was causing NOAH precip gauge to reset the YTD precip values on Nov 9, 11, 16, and 20, 2015, and Jan 4, 2016. Updated programs sent to SASP logger on these dates to correct YTD precip values. Hourly data is fine. 24 hour was recomputed. Also, precip gauge had spruce needle in check valve, precip values (hourly, 3-hr, 24-hr, YTD) for storm #4, Nov 10 –Nov 11 are constructed from SNOTEL data.
2015	Nov 3 – Nov 9	307-313	Power outage in office. Files updated. NOAH II Precipitation gauge values recomputed
2013	June 29, 2013	180	Datalogger partial failure DOY 180 (June 29, 2013), 1400 hrs through the 24hr array.
2013	May 14-18, 2013	134-138	Temporarily used 'Min' height-of-snow instruction for SR50 ultrasonic depth sensor rather than 'Sample' due to high number of erroneous values (defaulting to higher than actual values).
2012	Sep 15-Nov 2	259-307	All pyranometers and pyrgeometer removed for recalibration; restored to service on Nov 3, 2012 (DOY 308). No radiation data during this period.
2012	Feb 17	48	Loggernet 2.1c program measurement execution interval changed from 5 seconds to 6 seconds to address increasing "table overrun" errors on primary datalogger (see discussion at section #13 below)
2012	Feb 17	48	Ground-snow moisture measurement discontinued to address increasing "table overrun" errors on primary datalogger
2011	Nov 24-25	328-329	Malfunction in the precipitation gauge with coincident malfunction in the datalogger, resulted in missing data on those days; 13 mm of precipitation measured on a storm board at SASP on those days (Storm #8) was allocated, by hour, using SASP HS data as an indicator of precipitation rates.

2011	Oct 29	302	SASP battery bank replaced; system lost power between 0800 and 1100 hours; no data for 301 arrays for 0900 and 1000 hours; no data for 312 arrays; 324 array for this day is calculated from 22 hours of data
2011	Aug 10 to Sep 5	222-248	Pyranometer intercalibration from noon August 10 (DOY 222) through noon September 5 (DOY 248); no valid downlooking data during that period; no valid shadow array data during that period. Pyrgeometer data uninterrupted during that period.
2011	Jul 12 to Sep 19	193-262	Lower Wind sensor removed for servicing July 12, 2011 (day-of-year 193); no lower wind speed and direction data from then until 1500 hrs, September 19, 2011 (DOY 262).
2011	May 10-12	130-132	Noah II precip gauge malfunctioned from 2300 hrs DOY 130 (May 10) through 1100 hrs DOY 132 (May 12); pine needle jammed drain valve open; repaired shortly after end of precipitation; Storm #31 storm precipitation data inferred from new snow slab data at SASP and from SASP sonar data.
2011	Feb 10-11	41-42	Primary datalogger malfunction from 0900 DOY 41 (Feb 10, 2011) through DOY 42 (Feb 11, 2011); most data missing during that period; datalogger replaced, tested, recalibrated, reinstalled
2009	Oct 1	274	Data lost during Winter 2009/2010 re-programming for 1300 hour 301 (1-hour) array; 324 (24-hour) array calculated using 23 hours of data.
2009	Aug 10 – Sep 3	222-246	Pyranometer intercalibrations; shadow array arm removed; all pyranometers mounted up-looking at top of mast; no valid shadow array or down-looking pyranometer data for this period; no interruption to pyrgeometer operation
2007-2008	Oct 1 – Jun 20	274-172	Experimental snow moisture sensor trials begun during winter 2007/2008, discontinued winters 10/11 (mid) and 11/12 (lower); experimental lysimeter deployed during winter 2007/2008, discontinued Aug 2009
2007	Jul 20 – Sep 15	201-258	All pyranometers recalibrated by AccuFlux, in multi-step process, with periods of missing data
2007	Jul 18 – Aug 11	199-223	Primary CR10x S#40363 removed for recalibration and temporarily replaced by SASP ‘Slave’ CR10x S#39210; DOY 199 1000 and 1100 hrs 301 (1-hour) arrays lost; no valid 324 (24-hour) array for July 18 (DOY 199)
2007	Jul 18-27	199-208	No ‘Slave’ datalogger; temporary ‘Slave’ datalogger S#37168 installed Jul 27 until original ‘Slave’ S#39210 was recalibrated and then reinstalled Sep 5, 2007 (DOY 208)
2007	Jul 7-17	188-198	Pyrgeometer intercalibrated to new unit; no missing data
2007	Jun 21 – Jul 28	172-208	No valid Upper Wind data; sensor moved from Primary to Slave datalogger and data resume on July 28, 2007 (DOY 208); Lower Wind data interrupted DOY 199-207 during system maintenance
2007	Feb 17 – Jun 20	48-171	Upper Wind “peak gust” and “scalar average” data gaps due to processing failure
2006	Sep 20-25	263-268	Upper and Lower Wind malfunction; no valid data
2006	Aug 2-16	214-228	Barometer removed for recalibration, reinstalled August 16, 2006 (DOY 228)
2006	Sep 2 – 17	245-260	Pyranometer intercalibrations; shadow array arm removed; all pyranometers mounted up-looking at top of mast; no valid

			shadow array or down-looking pyranometer data for this period; no interruption to pyrgeometer operation
2006	Jun 22 – Sep 1	173-244	PyUpFiltered (CM21 RG-695 pyranometer) removed for testing; no valid data for this period
2006	Feb 8	39	Installed Upper Air Temp & RH sensor
2005	Sep 19-30	262-273	Pyranometer intercalibrations; shadow array arm removed; all pyranometers mounted up-looking at top of mast; no valid shadow array or down-looking pyranometer data for this period; no interruption to pyrgeometer operation
2005	Jul 11	192	Installed soil sensor array, began data collection
2005	Mar 9	68	Installed Everest Series 4000.4ZL infrared snow surface temperature sensor; sensor failed in summer 2005 and Winter 2004/2005 data are suspect (see discussion below)

Table continues next page

System Operation Notes continued:

Year	Date(s)	Day of Year	Note
2005	Feb 16	47	Raised arm containing Snow Depth, Low Air, Snow Surface Temp, and Downlooking Pyranometer sensors to 4.5 m above ground due to depth of snowpack
2005	Jan 25-29	25-29	Major instrumentation upgrade requiring occasional system shutdowns resulting in missing data; added lower wind sensor, all pyranometers and pyrgeometer, snow temperature array, multiplexer, slave datalogger.
2003	Nov 8	312	SASP Startup with Snow Depth, Upper Wind, Low Air Temp & RH, Barometer, Snow Temp (3), Solar Flux (single, up-looking pyranometer) sensors (only)

5) Power
   a) Solar powered by 40 watt photovoltaic panel providing regulated charge to four 12V gel DC batteries. Battery bank has total 320 amp hours nominal capacity.
      i) DC supply from datalogger to Noah II regulated at 13.0 volts maximum
      ii) 320 amp hour battery bank installed Fall 2004
         (a) Entire battery bank replaced (four new batteries) October, 2009

6) Measurements and Sensors
   a) Upper Wind Speed and Direction
      i) Properties
         (a) Make: RM Young
         (b) Model: #05103-5
         (c) Serial Number: 61999
         (d) Type: Wind Monitor
         (e) Specifications: CSI_RMYoung_WindMonitor_05103_manual.pdf
      ii) Installation
         (a) Height above ground: 6.0 m
            (i) Refer to Sensor Status Workbooks, by winter season, for sensor height above snowpack surface
         (b) Distance from tower or obstacle: 1.0 m
         (c) Data begin: October 22, 2004
         (d) Comments: Data recorded on 'Slave' Campbell Scientific CR-10 datalogger, SDI-12 linked to the SASP Primary datalogger.
         (e) Comments: Sensor initially programmed to collect only scalar average wind speed; programming was changed on Jan 25, 2005 to calculate both scalar and resultant average speed (and resultant direction) data; see table of programming instructions at end of metadata.

iii) Sensor History:

Serial #	Date	Action	Condition
61999	Aug 25, 2011	Installed as SASP Upper	Refurbished Aug 2011, CSI
61653	Aug 25, 2011	Removed for refurbishing	Good, on CSI inspect
61653	Oct 22, 2004	Replaced #12387	New, calibrated Jun 2004
12387	Nov 8, 2003	Installed as SASP Upper	Used, operating normally

b) Lower Wind Speed and Direction
   i) Properties
      (a) Make: RM Young
      (b) Model: #05103-5
      (c) Serial Number: 22659
      (d) Type: Wind Monitor
      (e) Specifications: CSI_RMYoung_WindMonitor_05103_manual.pdf
   ii) Installation
      (a) Height above ground: 3.8 m
         (i) Refer to Sensor Status Workbooks, by winter season, for sensor height above snowpack surface
      (b) Distance from tower or obstacle: 1 m
      (c) Data begin: January 29, 2005
      (d) Comments: Data recorded on secondary Campbell Scientific CR-10 datalogger (Ser. #14652, recalibrated December 2004), SDI-12 linked to the SASP primary datalogger.
      (e) Comments: programed on Jan 29, 2005 to calculate both scalar and resultant average speed (and resultant direction) data; see table of programming instructions at end of metadata.
   iii) Sensor History:

Serial #	Date	Action	Condition
22659	Sep 19, 2011	Installed as SASP Lower	Refurbished Aug 2011,CSI
no sensor installed 7/12/2011 to 9/19/2011 – data gap			
12387	July 12, 2011	Removed for refurbishing	Good, on CSI inspect
12387	Jan 29, 2005	Installed as SASP Lower	Refurbished Nov 2004

c) Lower Air Temperature and Humidity
   i) Properties
      (a) Make: Campbell/Vaisala
      (b) Model: HMP60 (replaced CS500-U Ser #P4810054))
      (c) Serial Number: HMP60
      (d) Type: thermistor
      (e) Specifications: CSI_HMP60_manual.pdf
   ii) Installation
      (a) Height above ground: 3.4 m above ground (see Feb 2005 Note in Operations Notes above)
         (i) Refer to Sensor Status Workbooks, by winter season, for sensor height above snowpack surface
      (b) Distance from tower or obstacle: 1.2 m

(c) Data begin: November 8, 2003
(d) Comments: none

iii) Sensor History:

Serial #	Date	Action	Condition
HMP60	Sept 10, 2016	HMP60 replaced CS500	New sensor
P4810054	Oct 22, 2004	Replaced HMP35-C	Refurbished Jul 2004, CSI
7063	Nov 8, 2003	SASP startup	Used, calibrated Aug 1996

d) Upper Air Temperature and Humidity
i) Properties
(a) Make: Campbell Scientific
(b) Model: HMP-50YA
(c) Serial Number: A4210022
(d) Type: platinum resistance temp detector (PRT) and capacitive RH sensor
(e) Specifications: CSI_hmp50_manual.pdf
ii) Installation
(a) Height above ground: 5.95 m above ground
(i) Refer to Sensor Status Workbooks, by winter season, for sensor height above snowpack surface
(b) Distance from tower or obstacle: 0.15 m
(c) Data begin: February 8, 2006 (DOY 39)
(d) Comments: property of NSIDC
iii) Sensor History:

Serial #	Date	Action	Condition
A4210022	Feb 8, 2006	Installed	New

e) Snowpack Depth
i) Properties
(a) Make: Campbell Scientific
(b) Model: SR50 (replaced UDG01 in Oct 2005)
(c) Serial Number: C3852
(d) Type: ultrasonic depth sensor
(e) Specifications: CSI_sr50_manual.pdf
ii) Installation
(a) Height above ground: 3.2 m above ground
(i) February 16, 2005 (DOY 47): raised to 4.3 m above ground for remainder of season due to depth of snowpack
(b) Distance from tower or obstacle: 2.0 m; sensor mounted at end of arm extending south from mast
(c) Data begin: November 8, 2003
(d) Comments: wherever possible, bad data for short intervals (1-3 hours) are corrected by interpolation (for all interpolated data since fall 2011 see our Data Notes). When bad data occur over longer time periods no interpolation is performed and bad data are removed resulting in missing data.

iii) Sensor History:

Serial #	Date	Action	Condition
C3852	Sep 2015	Maintenance	New transducer by CSI
C3852	Sep 2014	Maintenance	New transducer by CSI
C3852	Jul 2013	Maintenance	New transducer by CSI
C3852	Jul 2011	Maintenance	New transducer by CSI
C3852	Aug 2008	Maintenance	New transducer by CSI
C3852	Oct 2007	Maintenance	New transducer by CSAS
C3852	Mar 23, 2005	Re-installed	Repaired by CSI
C3852	Feb 26, 2005	Unit failed, removed	Replaced by loaner SR50
C3852	Oct 22, 2005	SR50 Installed (replaced UDG01)	New unit
C1374	Nov 8, 2003	SASP Startup w/UDG01	Used, operating normally

iv) Spring date of "snow all gone" (SAG), by winter season

(a) Data begin ~October 1 each season, regardless of presence of snow on the ground, and may reflect plant heights until snow cover begins to accumulate. Early season snowfalls may melt and reveal bare ground or plants until persistent snow cover develops.

(b) Date of SAG refers to total loss of snowcover directly under sensor in spring; snowpack depth data are discontinued thereafter and sensor is removed for summer, then reinstalled in early fall.

Winter	Date of Spring SAG	DOY
2015/2016	June 9, 2016	161
2014/2015	June 15, 2015	166
2013/2014	June 6, 2014	157
2012/2013	May 18, 2013	138
2011/2012	May 11, 2012	132
2010/2011	June 23, 2011	174
2009/2010	May 29, 2010	149
2008/2009	May 21, 2009	141
2007/2008	June 16, 2008	168
2006/2007	June 5, 2007	156
2005/2006	May 26, 2006	146
2004/2005	June 18, 2005	169
2003/2004	June 5, 2004	157

f) Precipitation

i) Properties

(a) Make: ETI Instrument Systems

(b) Model: Noah II

(c) Serial Number: #144

(d) Type: 'TBO' simulating gauge

(e) Specifications: ETI_NoahII_precip_gauge_manual.pdf

ii) Installation

(a) Height above ground: 4.5 m
(b) Distance from tower or obstacle: free standing 0.30 m diameter standpipe located aprox. 8 m from primary instrument mast, 15 m from nearest (lone) tree
(c) Data begin: November 8, 2003
(d) Comments: gauge utilizes alcohol antifreeze covered with oil skim and transducer to collect and weigh precipitation in 12" orifice collection chamber; ETI-style vinyl windscreen; gauge automatically cycles (dumps fluid into storage standpipe) and self-charges with fresh antifreeze
(e) Sensor History:

Serial #	Date	Action	Condition
144	Jan 13, 2004	Reinstalled	Operating normally
144	Dec xx, 2003	Malfunction, removed	Sent to ETI for test, repair
144	Nov 8, 2003	SASP Startup	Used, operating normally

g) Solar Flux & Albedo Sensors (six total)
i) Properties
(a) Make: all units Kipp & Zonen
(b) Model: CM21 (all five pyranometers) and CG4 (pyrgeometer)
(c) Serial Numbers, by unit/location:
(i) Up-looking broad band CM21 pyranometer: Ser. #041359
(ii) Up-looking NIR to SWIR CM21-RG695 filtered pyranometer: Ser. #041354
(iii) Up-looking shadowed broad band CM21 pyranometer: Ser. #041360
(iv) Up-looking CG4 pyrgeometer: Ser. #040743
(v) Down-looking broad band CM21 pyranometer: Ser. #041358
(vi) Down-looking NIR to SWIR CM21-RG695 filtered pyranometer: Ser. #041353
(d) Type: spectral response, by types:
(i) Broad band CM21 pyranometer: 305-2800 nm (50% points)
(ii) NIR to SWIR CM21-RG695 pyranometer: 780-2800 nm (50% points)
(iii) CG4 pyrgeometer: 4.5-42 µm (50% points)
(e) Specifications
(i) CM21 (including RG695): Kipp_Zonen_cm21_pyranometer.pdf
(ii) CG4: Kipp_Zonen_cg4_pyrgeometer_manual.pdf
ii) Installation
(a) Height above ground:
(i) Up-looking array: 5.7 m
(ii) Down-looking array: 3.1m above ground
(b) Distance from tower or obstacle:
(i) Up-looking array: 0.8 - 1.0 m
(ii) Down-looking array: 1.5 - 1.6 m
(c) Data begin: January 25, 2005 (DOY 25)
(i) Single up-looking LiCor LI200S (S# PY16599) utilized for Winter 2003/2004 only; contact CSAS for data

(d) Comments: snow surface albedo calculations are influenced by the slope and aspect of the reflective (snow) surface. In order to monitor the slope and aspect of the snowpack surface within the domain of the SASP downlooking pyranometers, arrays of manually observed, 3m "height of snow" (HS) stakes are installed around the SASP tower, as described in a separate HS Stake Array Metadata document. SASP HS Stake Array data are contained in Sensor Status Workbooks, by winter season.

(e) Comments: no ventilation units are installed; up-looking radiometers at SASP are routinely buried by new snow and subsequently swept clean; CSAS suggests referencing SBSP up-looking radiometer data during and immediately after periods of precipitation, since wind consistently prevents SBSP up-looking radiometers from being buried, and riming is extremely rare in our continental snow climate; Sensor Status Workbooks for each winter season detail the state (buried, swept, AOK(clear)) of up-looking radiometers at both SASP and SBSP sites.

(f) Comments: up-looking shadowed CM21 pyranometer is deployed in Swiss ASRB-style array for aprox. 5 minutes of shadowing at/about solar noon each day. See "312" Solar Noon arrays.

(g) Comments: spring snow albedo data are valid up to the date of "snow all gone" (SAG) underneath the downlooking pyranometers, after which those sensors are viewing bare soil and/or vegetation until snowcover redevelops in the fall (see SAG dates table under *e) Snowpack Depth* section above)

(h) Sensor History:
(i) Contact CSAS for intercalibration and recalibration results
(ii) Recalibrations by AccuFlux per Annex A.3.1 of the ISO-9847 Standard
(iii)Recalibrations on all sensors by Iso-Cal were performed summer 2016.

Sensors	Date	DOY	Action
All	July 1, 2016 – Sept 7, 2016	183-251	All pyranometers and pyrgeometer removed for recalibration; restored to service on Sept 7 2016 (DOY 251). No radiation data during this period.
All	Nov 3, 2012	308	All sensors reinstalled; data resume
All	Sep 15 – Nov 2, 2012	259 - 307	Sensors removed for recalibration by Accuflux; no radiation data during this period
Pyranometers	Aug 10-Sep 5, 2011	222-248	Intercalibrated in-situ, on mast; no down-looking data available for this period
Pyranometers	Aug 10-Sep 3, 2009	222-246	Intercalibrated in-situ, on mast; no down-looking data available for this period
Pyranometers	Jul-Sep 2007	201-258	All units recalibrated by Accuflux; periods of missing data, by sensor

Pyrgeometer	Jul 2007	188-198	Intercal'd, in-situ, to new CG4
Pyranometers	Sep 2006	245-260	Intercalibrated in-situ, on mast; no down-looking data available for this period
Up #041354	Jun 22 – Sep 1, 2006	173-244	Removed for testing
Pyranometers	Sep 2005	262-273	Intercalibrated in-situ, on mast; no down-looking data available for this period
All	Jan 25, 2005	25	All units installed, new
All	Nov 2004		Original calibration by K&Z

h) Infrared Snow Surface Temperature
   i) Properties
      (a) Make: AlpuG GmbH
      (b) Model: AlpuG SnowSurf
      (c) Serial Number: #6004
      (d) Type: millivolt output type
      (e) Specifications: AlpuG_SnowSurf_manual.pdf
   ii) Installation
      (a) Height above ground: 3.2m
         (i) Refer to Sensor Status Workbooks, by winter season, for sensor height above snowpack surface
      (b) Distance from tower or obstacle: 1.3m
      (c) Comments: AlpuG sensors emissivity fixed at 0.98 for snow surfaces, and cannot be reset for soil or plant ground cover (i.e., prior to and after snowcover).
      (d) Comments: sensor is removed for summer and reinstalled in early fall. Periods of measurements above 0.0 C occur during episodic exposure of bare ground during early winter until persistent snow cover develops. Spring snow surface temperature data are valid until bare ground begins emerging in field of view of sensor; data discontinued thereafter.

Winter	End of Valid Spring Data	DOY
2015/2016	June 30, 2016	182
2014/2015	June 11, 2015	162
2013/2014	June 4, 2014	155
2012/2013	May 16, 2013	136
2011/2012	May 9, 2012	130
2010/2011	June 21, 2011	172
2009/2010	May 28, 2010	149
2008/2009	May 18, 2009	138
2007/2008	June 13, 2008	165
2006/2007	June 5, 2007	156
2005/2006	May 23, 2006	143
2004/2005	June 10, 2005	161

      (e) Sensor History:

Serial #	Date	Action	Condition
6004	May 12, 2006	Installed	New, AlpuG cal Mar 2006

i) Snow Temperature (five sensors)
  i) Properties
    (a) Make: Campbell Scientific
    (b) Model: #107 (five sensor array)
    (c) Serial Number: na
    (d) Type: thermistor
    (e) Specifications: CSI_107_temp_probe_manual.pdf
  ii) Installation
    (a) Height above ground, not including any downward displacement caused by settlement of the overlying snowcover (unknown).
      (i) SnoT Lo sensor at the ground surface
      (ii) SnoT 2Lo sensor 10 cm above the ground
      (iii) SnoT Ctr sensor 20 cm above the ground
      (iv) SnoT 2Hi sensor 30 cm above the ground
      (v) SnoT Hi sensor 40 cm above the ground
    (b) During the first four winters (2004/2005 – 2007/2008), sensor deployed relative to snowpack surface was observed during field sessions. Contact CSAS for array's "floating" position within the snowpack for those seasons.
    (c) Distance from tower or obstacle: aprox 3m.
    (d) Date originally installed at SASP: January 25, 2005 (DOY 25)
      (i) Replaced three-sensor array used for Winter 2003/2004
    (e) Comments: all measurements corrected with small offsets derived from calibrating the sensors to isothermal, wet snow at 0.0 C. Comments: values above 0.0 C occurred during exposure of sensors to air during early winter, prior to full burial of the array, and during spring snowmelt as array became exposed to air; data discontinued after SnoT Lo sensor at the ground surface is exposed to air.
    (f) Comments: Sensor array stored on mast for summer.
    (g) Sensor History:

Serial #	Date	Action	Condition
na	January 2005	Installed	New Sensors

j) Barometric Pressure
  i) Properties
    (a) Make: Vaisala (Campbell Scientific supplier)
    (b) Model: PTB101B (CS105)
    (c) Serial Number: B2730009
    (d) Type: silicon capacitive pressure sensor
    (e) Specifications: CSI_CS105_barometer_manual.pdf
  ii) Installation
    (a) Instrument elevation used in measurement instruction (see below)
      (i) From Fall 2003 – Spring 2012
        1. Est., from USGS Ironton Park Quadrangle, at 11,050' (3368m)

(ii) Summer 2012 – present
1. Measured, with Survey Grade GPS, at 11,070' (3374m)

(b) Height above ground surface, on tower: 3 m
(c) Distance from tower or obstacle: located in datalogger enclosure
(d) Date originally installed at SASP: November 8, 2003
(e) Comments: recalibrated August 8, 2006 by Vaisala
(f) Sensor History:

Serial #	Date	Action	Condition
B2730009	Aug 16, 2006	Reinstalled	Operating normally
B2730009	Aug 8, 2006	Recalibrated by Vaisala	Error was -0.03 in Hg
B2730009	Aug 2, 2006	Removed for recalibration	Operating normally
B2730009	Nov 8, 2003	Installed	Used, operating normally

iii) Data Units
(a) Data are reported as inches of mercury (in Hg), using a multiplier of 0.02953 to convert mb to inches of mercury within the measurement instruction
(b) Data are corrected to sea level pressure using the following offset values (see method in box below, from Campbell Scientific manual):
(i) Winter 2003/2004 – Winter 2011/2012: offset = 344.36 mb
(ii) Summer 2012 – present: offset = 344.88 mb
(c) To calculate actual pressure at the Swamp Angel Study Plot, in mb
(i) Multiply reported value by 33.86 to convert inches of mercury to mb, then
(ii) Subtract offset (344.36 mb through Winter 2011/2012, or 344.88 mb thereafter) from that result to obtain actual pressure, in mb

From Campbell Scientific manual

The weather service, most airports, radio stations, and television stations adjust the atmospheric pressure to a common reference (sea level). Equation 1 can be used to find the difference in pressure between the sea level and the site. That value (*dP*) is then added to the offset (500 mb in our example programs) in the measurement instruction. U. S. Standard Atmosphere and dry air were assumed when Equation 1 was derived (Wallace, J. M. and P. V. Hobbes, 1977: *Atmospheric Science: An Introductory Survey*, Academic Press, pp. 59-61).

$$dP = 1013.25\left\{1-\left(1-\frac{E}{44307.69231}\right)^{5.25328}\right\} \quad (1)$$

The value *dP* is in millibars and the site elevation, *E*, is in meters. Add *dP* value to the offset in the measurement instruction.

k) Soil Heat Flux
i) Properties
(a) Make: REBS (Campbell Scientific)

(b) Model: HFT-3.1
(c) Serial Number: H043140
(d) Type: thermopile
(e) Specifications: CSI_REBS_hft-3.1_manual.pdf

ii) Installation
(a) Height below ground surface ("A" horizon; no "O" horizon present): 3 cm
(b) Distance from tower or obstacle: aprox. 10 feet
(c) Date originally installed at SASP: July 11, 2005
(d) Comments: sensor located at shallow depth to facilitate measurement of snowpack/ground heat flux; sensor collocated with soil temperature array (underneath), volumetric water content sensor, and nearby snow temperature array
(e) Sensor History:

Serial #	Date	Action	Condition
H043140	Jul 11, 2005	Installed	Operating normally
H043140	Oct 7, 2004	Calibrated by REBS	New

l) Soil Temperature (four sensors)
i) Properties
(a) Make: Campbell Scientific
(b) Model: #107
(c) Serial Number: na (none)
(d) Type: thermistor
(e) Specifications: CSI_107_temp_probe_manual.pdf

ii) Installation
(a) Height below ground surface ("A" horizon; no "O" horizon present): at surface, -10 cm, -20 cm, -40 cm
(b) Distance from tower or obstacle: aprox. 10 feet
(c) Date originally installed at SASP: July 11, 2005
(d) Service/calibration dates: new units upon installation; sensors not serviceable;
(e) Comments: sensor array collocated with soil heat flux sensor (above), volumetric water content sensor, and nearby snow temperature array

m) Soil Volumetric Water Content
i) Properties
(a) Make: Campbell Scientific
(b) Model: CS616
(c) Serial Number: na (none)
(d) Type: water content reflectometer
(e) Specifications: CSI_cs616_manual.pdf

ii) Installation
(a) Height *below* ground surface ("A" horizon; no "O" horizon present): -10 cm
(b) Distance from tower or obstacle: aprox. 10 feet
(c) Date originally installed at SASP: July 11, 2005
(d) Service/calibration dates: new units upon installation; sensors not serviceable;

(e) Comments: the sensor is horizontally deployed, with both tines at the same level below, and parallel with, the ground surface. Rocky soils required excavating a trench in which to place the sensor in order to assure a constant distance between the sensor's tines. A soil block was kept intact, the sensor was placed in the trench and covered with loose soil, then the soil block was replaced over the sensor.

n) Ground/Snowpack Interface Moisture Content
   i) Properties
      (a) Make: Campbell Scientific
      (b) Model: CS616
      (c) Serial Number: na (none)
      (d) Type: water content reflectometer
   ii) Experimental data begun in Winter 2007/2008 and discontinued Winter 2011/2012; contact CSAS

o) Mid-Snowpack Moisture Content
   i) Properties
      (a) Make: Campbell Scientific
      (b) Model: CS616
      (c) Serial Number: na (none)
      (d) Type: water content reflectometer
   ii) Experimental data begun in Winter 2007/2008 and discontinued Winter 2010/2011; contact CSAS

7) Primary Datalogger
   a) Make: Campbell Scientific
   b) Model: CR10X
   c) Serial Number: 40363 (replaced #14652 in Oct, 2005)
   d) Type: fully programmable measurement and control system with ring memory
   e) Specifications: CSI_cr10x_specs.pdf
   f) Comments: none
   g) Sensor History:

Serial #	Date	Action	Condition
CR10X 40363	Feb 17, 2011	Recal by CSI, w/out certify	Operating normally
CR10X 40363	Feb 11, 2011	Removed for testing by CSI	Malfunction Feb 10-11
CR10X 40363	Jul 30, 2007	Recal by CSI, with certif	Operating normally
CR10X 40363	Oct 22, 2004	Installed, replaced #14652	New, orig calib Sep 2004
CR10 14652	Nov 8, 2003	SASP startup	Operating normally

8) 'Slave' Datalogger
   a) Make: Campbell Scientific
   b) Model: CR10X
   c) Serial Number: 39210 (replaced CR10 14652 in Aug 2007)
   d) Type: fully programmable measurement and control system with ring memory
   e) Specifications: CSI_cr10x_specs.pdf

f) Comments: 'slave' datalogger required for input channels for wind monitors; connected to primary datalogger using SDI-12 link. Used during CG4 pyrgeometer intercalibrations.
g) Sensor History:

Serial #	Date	Action	Condition
CR10X 39210	Aug 2007	Installed, replaced 14652	Recal by CSI Aug 2007
CR10 14652	Jan 2005	Installed	Recal by CSI Dec 2004

9) Multiplexer
a) Make: Campbell Scientific
b) Model: AM16/32
c) Serial Number: 6695
d) Type: relay
e) Specifications: CSI_am16-32a_manual.pdf
f) Comments: housed in own enclosure
g) Sensor History:

Serial #	Date	Action	Condition
6695	Oct 2004	Installed	New

10) Data Retrieval
a) RF Station ID = 3
b) Radio telemetry using phone-to-RF; direct link to base station; no repeater utilized
i) Campbell Scientific model RF 310M modem; serial #1973
ii) Model RF310 Maxon SD-125 V2 VHF radio: serial #030604719
iii) Omni type antenna

11) Software
a) Campbell Scientific LoggerNet 2.1c
b) Contact CSAS for specific Winter or Summer season Loggernet programming

12) Observer Contact Information
a) Name: Chris Landry - Executive Director
b) Organization: Center for Snow and Avalanche Studies
c) Address: PO Box 190, Silverton, CO, USA 81433
d) Telephone: (970) 387-5080
e) Email: clandry@snowstudies.org
f) Website: http://www.snowstudies.org

13) Data processing and output methods:
a) Loggernet program execution interval: initially set at 5 seconds from original 2003 startup until February 17, 2012, when interval was increased to 6 seconds. This change was required to reduce increasing volume of "table overrun" errors triggered by the recent addition of experimental snow moisture sensors. Data processing for those sensors often exceeded the 5 second allowance, effectively resulting in a doubling of the 5 second execution interval to 10 seconds. Discontinuing those

measurements and increasing the execution interval for the remaining sensors to 6 seconds in February 2012 effectively eliminated table overrun errors.

b) Revised measurements of snow depth: instruction P73 (Maximize) used during early Winters 2003/2004 and 2004/2005 changed to P70 (Sample) beginning Winter 2005/2006, sampling once at the end of all arrays to minimize bad data during storms causedby blowing snow

c) Measurements and Loggernet instructions: see table on following page
   (1) Location # in the table below refers to position in data file string (within a given array) as well as column number in relevant Excel spreadsheet header

Data processing and output methods (data points as labeled in Excel workbooks):

Spreadsheet Labels (some abbreviations expanded)	*Loc'n #*	*LoggerNet 2.1c Instruction*	*Type of Measurement*	*Notes*
ArrayID	1	P80	na	301 = 1 hour array 303 = 3 hour array 312 = solar noon array 324 = 24 hour array
Year	2	P77	Na	Calendar year
DOY	3	P77	na	Sequential day of calendar year
Hour	4	P77	na	Mountain Standard Time at end of array period, in military time; previous day at midnight, 2400 at midnight
LoAir_Min_C LoAir_Min_Time	5 6	P74	Minimize	Array lower air temperature (C) sensor minimum, time of minimum
LoAir_Max_C LoAir_Max_Time	7 8	P73	Maximize	Array lower air temperature (C) sensor maximum, time of maximum
Lo_RH	9	P70	Sample	Lower RH sensor; samples relative humidity (%) once at end of array
Upper Wind Monitor UpWind_PGust_MS UpWind_PGust_Time UpWind_SAvg_MS UpWind_Uavg_MS UpWind_Dir_Uavg UpWind_Dir_StDev	 10 11 12 13 14 15	 P73 P69	 Maximize Wind vector	P69 output option '2': scalar mean horizontal wind speed S; resultant mean wind speed U; resultant mean wind direction; standard deviation wind direction using Campbell Scientific algorithm.
Lower Wind Monitor LoWind_PGust_MS LoWind_PGust_Time LoWind_SAvg_MS LoWind_Uavg_MS LoWind_Dir_Uavg LoWind_Dir_StDev	 16 17 18 19 20 21	 P73 P69	 Maximize Wind vector	P69 output option '2': scalar mean horizontal wind speed S (ms); resultant mean wind speed U (ms); resultant mean wind direction; standard deviation wind direction using Campbell Scientific algorithm.
PyDwn_Unfilt_W	22	P71	Average	Down-looking broadband pyranometer, in average watts/m^2
PyDwn_Filt_W	23	P71	Average	Down-looking NIR & SWIR filtered pyranometer, in average watts/m^2
PyUp_Unfilt_W	24	P71	Average	Up-looking broadband pyranometer, in average watts/m^2
PyUp_Filt_W	25	P71	Average	Up-looking NIR & SWIR filtered pyranometer, in average watts/m^2
PyUp_Shad_W	26	P71	Average	Up-looking shadowed broadband pyranometer, in average watts/m^2
Pyrgeom_W	27	P71	Average	Up-looking pyrgeometer, in average watts/m^2
Sno_IR_C	28	P71	Average	Average infra-red snow surface temp (C)
Sno_Gd_C	29	P71	Average	Mean temperature (C) of lowest snow temperature sensor in five-sensor array
Sno_10cm_C	30	P71	Average	Mean temperature (C) of 2nd lowest snow temperature sensor in five-sensor array
Sno_20cm_C	31	P71	Average	Mean temperature (C) of center snow temperature sensor in five-sensor array
Sno_30cm_C	32	P71	Average	Mean temperature (C) of 2nd highest snow temperature sensor in five-sensor array
Sno_40cm_C	33	P71	Average	Mean temperature (C) of highest snow temperature sensor in five-sensor array

Table continued next page

Spreadsheet Labels (some abbreviations expanded)	*Loc'n #*	*LoggerNet 2.1c Instruction*	*Type of Measurement*	*Notes*
Sno_Height_M	34	P70	Sample	Height-of-snow sampled once at end of array
Sys_Volts	35	P70	Sample	Voltage at datalogger (prior to regulation) sampled once at end of array
Array Tot H2O	36	P72	Totalize	Total mm precipitation during array
Day Tot H2O	37	P70	Sample	Running daily total mm of precipitation, 0000 hrs through 2400 hrs
Season Tot H2O	38	P70	Sample	Running water year total mm of precipitation, beginning October 1
Baro In HG	39	P71	Average	Average barometric pressure, in inches of mercury, sampling the last five minutes of 301 (1 hour) arrays only
LoAir_Avg_C	40	P71	Average	Averages all measurements of air temperature collected during a day, from 0000 hrs through 2400 hrs
Soil_Flux_W	41	P71	Average	Average heat flux (watts) entering or exiting soil
Soil_Surf_C	42	P71	Average	Average temperature (C) at soil/air interface (sensor exposed to direct light)
Soil_10cm_C	43	P71	Average	Average temperature (C) at 10 cm below ground surface
Soil_20cm_C	44	P71	Average	Average temperature (C) at 20 cm below ground surface
Soil_40cm_C	45	P71	Average	Average temperature (C) at 40 cm below ground surface
Soil_VWC	46	P71	Average	Volumetric water content (scale 0.0 to 1.0) of soil at 10 cm below ground surface
UpAir_Min_C UpAir_Min_Time	47 48	P74	Minimize	Upper air temperature (C) sensor array minimum, time of minimum
UpAir_Max_C UpAir_Max_Time	49 50	P73	Maximize	Upper air temperature (C) sensor array maximum, time of maximum
Up_RH	51	P70	Sample	Upper RH sensor; samples relative humidity (%) once at end of array
UpAir_Avg_C	52	P71	Average	Averages all measurements of air temperature collected during a day, from 0000 hrs through 2400 hrs
Ground-Snow Moisture	53	P71	Average	'Period' measurement of moisture at ground/snowpack interface – **DISCONTINUED 2/17/2012** Experimental data collected *Winter 2007/2008 to Feb 17, 2012 only; contact CSAS*
Mid-Pack Snow Moisture	54	P71	Average	'Period' measurement of moisture at mid-snowpack **DISCONTINUED** – *experimental data collected Winters 2007/2008 to 2010/2011 only; contact CSAS*
See also: **Table of variables, CF standard names and attributes:** snowstudies.org/data/metadata/SASP_Variable_Table.xlsx				

Web Links for CSAS Metadata and Supplemental Documents:

- CF Standard Name Table for each variable measured:
  http://snowstudies.org/data/metadata/SASP_Variable_Table.xlsx

- Archived Datasets by Season, Snow Profiles, and Storm Reports:
  http://snowstudies.org/data1.html

- Metadata for all CSAS Study Plots:
  Swamp Angel Study Plot: http://snowstudies.org/data/metadata/SASP.pdf
  Senator Beck Study Plot: http://snowstudies.org/data/metadata/SBSP.pdf
  Putney Study Plot: http://snowstudies.org/data/metadata/PTSP.pdf
  Senator Beck Stream Gauge: http://snowstudies.org/data/metadata/SBSG.pdf

- Photographs of all Study Plots:
  Swamp Angel Study Plot: http://snowstudies.org/sasp1.html
  Senator Beck Study Plot: pthttp://snowstudies.org/sbsp1.html
  Putney Study Plot: http://snowstudies.org/sasp1.html
  Senator Beck Stream Gauge: http://snowstudies.org/sbsg1.html

- Height of Snow (HS) Stake Array Metadata:
  http://snowstudies.org/data/metadata/HS_Stake_Array_Metadata.pdf

- Sensor Status Workbooks:
  http://snowstudies.org/data/metadata/SensorStatusWorkbooks/

- Instrument Manuals: http://snowstudies.org/data/metadata/InstrumentManuals/

- Interpolated Data Notes (Winter 2011/2012 and onward) for all CSAS Study Plots:
  http://snowstudies.org/data/metadata/DataNotes.xls