Proposed TEAM Minimum Climate Data Quality Standards

TEAM follows the quality control standards for climate data as described in Estevez et al (2011). These build upon WMO quality standards (Zahumensky 2004b). This document summarizes the quality standards for a number of data properties (range, step, internal consistency and persistence) for each of the climate variables collected (air temperature, relative humidity, solar radiation, precipitation). For a summary of the proposed standards, jump to Table 1 & 2 on page 8 and 9.

Range Test

The purpose of a range test is to ensure that collected meteorological data is within an expected range of values based on the performance specifications for each sensor as well as climatological norms for a particular season and region where the station is located. If a record does not pass the range test, it will be flagged.

Solar Radiation

Three range tests are performed for solar radiation measurements.

Test 1: The first test is adapted from Shafer et al. (2000) and tests for climatological norms in a semi-hourly (30 minute) window. Acceptable values for semi-hourly (30 minute) global radiation (W/m^2) range between 0 and 1,500.

Test 2: As explained in Allen (1996), Geiger et al. (2002), and Moradi (2007), the second test compares collected solar radiation values with expected extraterrestrial solar radiation (R_a). R_a is seasonally dependent and varies by calendar day (and the distance between earth and the sun). Acceptable values for daily global radiation ($MJ/m^2/day$) will be greater than or equal to 0.03 * R_a. Acceptable values for semi-hourly (30 minute) global radiation (W/m^2) will be less than or equal to R_a.

Test 3: The final test for collected solar radiation values, also explained in Allen (1996), Geiger et al. (2002), and Moradi (2007), compares these values with solar radiation expected under clear sky conditions (R_{so}). R_{so} is the product of R_a and a "clearness" index, K_T, which is dependent on station elevation. Acceptable values for daily ($MJ/m^2/day$) or semi-hourly (30 minute) global radiation (W/m^2) should not exceed 1.1 * R_{so}.

Relative Humidity

One range test is performed for relative humidity measurements. Acceptable values for relative humidity, adapted from Shafer et al. (2000), will range between 0 and 100%. These values are based on climatological norms and performance specifications of the sensor.

Temperature

Two range tests are performed for air temperature measurements.

Test 1: The range of acceptable values for collected air temperature values, from Shafer et al. (2000), is -30 and 50°C. These values are primarily based on performance specifications of the sensor and extreme climatological events.

Test 2: The second test involves the use ancillary data from long-term observatories close to each TEAM climate station as proxies for regional climatological norms, and will need to be acquired before this test can be performed. Acceptable values for air temperature will fall between the minimum temperature value and maximum temperature values measured at these long-term observatories, following AEMET (2008).

Precipitation

Three range tests are performed for precipitation measurements.

Test 1: Acceptable values for semi-hourly (30 minute) precipitation, adapted from Zahumensky (2004), will be greater than or equal to 0 mm and less than or equal to 250 mm. These limits are primarily based on the performance specifications of the sensor.

Test 2: Acceptable values for total daily precipitation, adapted from Shafer et al. (2000), will be greater than 0 mm and less than 750 mm. these limits are based on extreme climatological events and performance specifications of the sensor.

Test 3: The final test is two-fold, based on AEMET (2008). First, total daily precipitation must be greater than or equal to 0 mm to be accepted, based on climatological norms. Second, daily or semi-hourly (30 minute) precipitation must be less than or equal to the corresponding maximum value measured by a long-term observatory close to each TEAM station. This ancillary data will need to be collected before the second part of the test can be performed.

Step Test

The purpose of a step test is to ensure that the difference between successive meteorological measurements is within an expected range of values based on climatological norms for each parameter. Both observations are flagged if the difference exceeds an allowed value.

Solar Radiation

One step test is performed for solar radiation measurements. The acceptable difference between one semi-hourly (30 minute) global radiation (W/m^2) measurement and the semi-hourly (30 minute) global radiation (W/m^2) measurement one hour before it will be greater than or equal to 0 and less than or equal to 555, following Meek and Hatfield (1994). These accepted values are based on climatological norms.

Relative Humidty

One step test is performed for solar radiation measurements. The acceptable difference between one semi-hourly (30 minute) relative humidity (%) measurement and the semi-hourly (30 minute) relative humidity (%) immediately preceding it will be less than 45, following Zahumensky (2004). These accepted values are based on climatological norms.

Temperature

Five step tests are performed for air temperature measurements.

Test 1: The acceptable difference between one semi-hourly (30 minute) air temperature measurement and the semi-hourly (30 minute) air temperature measurement one hour before it will be less than 4°C, following WMO (1993). These accepted values are based on climatological norms.

Test 2: The acceptable difference between one semi-hourly (30 minute) air temperature measurement and the semi-hourly (30 minute) air temperature measurement two hours before it will be less than 7°C, following WMO (1993). These accepted values are based on climatological norms.

Test 3: The acceptable difference between one semi-hourly (30 minute) air temperature measurement and the semi-hourly (30 minute) air temperature measurement three hours before it will be less than 9°C, following WMO (1993). These accepted values are based on climatological norms.

Test 4: The acceptable difference between one semi-hourly (30 minute) air temperature measurement and the semi-hourly (30 minute) air temperature measurement six hours before it will be less than 15°C, following WMO (1993). These accepted values are based on climatological norms.

Test 5: The acceptable difference between one semi-hourly (30 minute) air temperature measurement and the semi-hourly (30 minute) air temperature measurement twelve hours before it will be less than 25°C, following WMO (1993). These accepted values are based on climatological norms.

Precipitation

No step tests are performed for precipitation measurements due to the unpredictability of rainfall events.

Internal Consistency Test

The purpose of an internal consistency test is to ensure that observed parameters adhere to physical and climatological principles (e.g., the average of a parameter should not exceed the maximum value for that parameter).

Solar Radiation

No internal consistency tests are performed for solar radiation measurements.

Relative Humidity

Three internal consistency tests are performed for relative humidity measurements.

Test 1: On each day, maximum relative humidity must be greater than mean relative humidity, which must be greater than minimum relative humidity for that day, following Reek et al. (1992) and Feng et al. (2004). All values for the day will be flagged if this test is failed.

Test 2: On each day, maximum relative humidity for that day must be greater than or equal to each semi-hourly (30 minute) maximum, following Vejen et al. (2002). Both values will be flagged if this test is failed.

Test 3: On each day, minimum relative humidity for that day must be less than or equal to each semi-hourly (30 minute) minimum, following Vejen et al. (2002). Both values will be flagged if this test is failed.

Temperature

Five internal consistency checks are performed for air temperature measurements.

Test 1: On each day, maximum air temperature must be greater than mean air temperature, which must be greater than minimum air temperature for that day, following Reek et al. (1992) and Feng et al. (2004). All values for the day will be flagged if this test is failed.

Test 2: Maximum air temperature on a particular day must be larger than the minimum air temperature of the previous day, following Reek et al. (1992) and Feng et al. (2004). Both values will be flagged if this test is failed.

Test 3: Minimum air temperature on a particular day must be less than or equal to the maximum air temperature of the previous day, following Reek et al. (1992) and Feng et al. (2004). Both values will be flagged if this test is failed.

Test 4: On each day, maximum air temperature for that day must be greater than or equal to each semi-hourly (30 minute) maximum, following Vejen et al. (2002). Both values will be flagged if this test is failed.

Test 5: On each day, minimum air temperature for that day must be less than or equal to each semi-hourly (30 minute) minimum, following Vejen et al. (2002). Both values will be flagged if this test is failed.

Precipitation

Three internal consistency tests are performed for precipitation measurements.

Test 1: On each day, semi-hourly (30 minute) precipitation for the first three hours of the day must be less than or equal to semi-hourly (30 minute) precipitation for the first six hours of the day, following Vejen et al. (2002). All values involved will be flagged if this test is failed.

Test 2: On each day, semi-hourly (30 minute) precipitation for the first twelve hours of the day must be less than or equal to semi-hourly (30 minute) precipitation for the entire (24 hour) day. All values involved will be flagged if this test is failed.

Test 3: This final test uses a combination of measures to determine if a recorded measurement is an actual precipitation event or caused by incidental exposure to a different water source, as can happen in agricultural landscapes. On each day with precipitation, the precipitation event is accepted if the "clearness" index, K_T, is less than 0.5 and mean relative humidity during the diurnal precipitation event is greater than 80%, following Estévez (2008). All records in the precipitation event will be flagged if the test is failed.

Persistence Test

The purpose of a persistence test is to ensure that sensors are functioning correctly. When a sensor fails it will often report a constant value and the standard deviation will be very low. If values do not change over several days or the standard deviation reaches a threshold limit, the data will be flagged.

Solar Radiation

Two persistence tests are performed for solar radiation measurements.

Test 1: On a given day, daily global radiation (MJ/m^2/day) must not equal the daily global radiation (MJ/m^2/day) of the day before, which must not equal the daily global radiation (MJ/m^2/day) of the day before that, following Meek and Hatfield (1994). All values will be flagged if this test is failed.

Test 2: For a given semi-hourly (30 minute) window, global radiation (W/m^2) must not equal semi-hourly (30 minute) global radiation (W/m^2) one, two, and three hours before the original semi-hourly (30 minute) global radiation (W/m^2) value, following Meek and Hatfield (1994). All values will be flagged if this test is failed.

Relative Humidity

Two persistence tests are performed for relative humidity measurements.

Test 1: On a given day, daily maximum/minimum/mean relative humidity must not equal daily maximum/minimum/mean relative humidity of the day before or the day before that, following Meek and Hatfield (1994). All values will be flagged if this test is failed.

Test 2: For a given semi-hourly (30 minute) window, the standard deviation must be greater than 1 to be accepted, following Zahumensky (2004); otherwise all of the data in the 30 minute window will be flagged.

Temperature

Two persistence tests are performed for air temperature measurements.

Test 1: On a given day, daily or semi-hourly (30 minute) air temperature must not equal the air-temperature for that period on the previous day or the day before that, following Meek and Hatfield (1994). All values will be flagged if this test is failed.

Test 2: For a given semi-hourly (30 minute) window, air temperature must not equal semi-hourly (30 minute) air temperature one, two, and three hours before the original semi-hourly (30 minute) air temperature values, following Meek and Hatfield (1994). All values will be flagged if this test is failed.

Precipitation

No persistence test are performed for precipitation measurements since it is normal to receive many days of zero precipitation.

Additional Quality Control Measures:

E-mail notifications for calibrating/replacing sensors. To ensure that all sensors are functioning properly and recording accurate measurements, automatic e-mail notifications will be sent to site managers when it is time for sensors to be re-calibrated based on the information provided in the climate metadata section of the data management tool on the TEAM website. After the first notification is delivered, weekly e-mails will be sent until the status of the sensor is updated in the data management tool. Additionally, if 10% or more of the monthly measurements from a sensor are flagged through the quality control measures listed above, an e-mail notification will be sent to the site manager indicating that they should replace the sensor.

Possible additional steps:

Include degree of certainty regarding flagged data. For example, if climatological extreme for a station is 500 mm of rain in one day, but a TEAM station records 506 mm of rain, it would be more difficult to confirm the data is erroneous than if the station recorded 1000 mm of rain in a day.

Contact meteorological agencies in TEAM countries and request data. Using data from other climate stations located near TEAM sites, additional quality control measures, including spatial consistency tests, can be performed, further improving data quality.

Cited Sources

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Table 1. Overview of quality control measures from Estevez et al., 2011 (see Table 2 below for key).

Validation Procedure	Solar Radiation Daily (MJ/m2/day) and Semihourly (W/m2)	Relative Humidity (%)	Air Temperature (deg C)	Precipitation (mm)	Type of Flag
Range Test	0 < RSsh < 1500 (0.03 * Ra) <= RS, RSsh <= Ra RS, RSsh < (1.1 * Rso)	0 < RH < 100	-30 < T < 50 Tlow < T < Thigh	0 <= Psh <= 250 0 <= P < 750 0 <= P, Psh <= Pmax	R1 R2 R3
Step Test	0 <= abs(RSsh - RSsh2) <= 555	abs(RHsh - RHsh1) < 45	abs(Tsh - Tsh2) < 4 abs(Tsh - Tsh4) < 7 abs(Tsh - Tsh6) < 9 abs(Tsh - Tsh12) < 15 abs(Tsh - Tsh24) < 25		S1 S2 S3 S4 S5
Internal Consistency Test	None	RHx > RHm > RHn RHx >= max(RHsh) RHn <= min(RHsh)	Tx > Tm > Tn Tx(d) > Tn(d-1) Tn(d) <= Tx(d-1) Tx >= max(Tsh) Tn <= min(Tsh)	Psh(0-3h) <= Psh(0-6h) Psh(0-12h) <= Psh(0-24h) Kt < 0.5 AND RH* > 80%	C1 C2 C3 C4 C5
Persistence Test	RS(d) != RS(d-1) != RS(d-2) RSsh != RSsh2 != RSsh4 != RSsh6	RH(d) != RH(d-1) != RH(d-2) sd(RHsh > 1)	T(d) != T(d-1) != T(d-2) Tsh != Tsh2 != Tsh4 != Tsh6	None	P1 P2

Table 2. A key for explaining the variables in Table 1.

Key		
Radiation	**RSsh**	Semi-hourly (30 min) global radiation (W/m2)
	RSshX	Solar radiation (X * 30-min) before RSsh
	Ra	Daily or semi-hourly extraterrestrial radiation (see Allen et al., 1994, 1996)
	RS	Daily global radiation (MJ/m2/day)
	Rso	Daily or semi-hourly global radiation under clear conditions (MJ/m2/day or W/m2)
RH	**RH**	Daily max, min, or mean relative humidity (%)
	RHsh	Semi-hourly (30 min) relative humidity (%)
	RHshX	Relative humidity X * 30-min before RHsh
	RHx	Daily maximum relative humidity
	RHm	Daily mean relative humidity
	RHn	Daily minimum relative humidity
	RH*	Mean relative humidity during diurnal precipitation event (%)
Temp	**T**	Daily or semi-hourly temperature (deg C)
	Tlow	Minimum temperature measured by observatory close to station
	Thigh	Maximum temperature measured by observatory close to station
	Tsh	Semi-hourly (30 min) temperature (deg C)
	TshX	Temperature (X * 30-min) before Tsh (deg C)
	Tx	Daily maximum temperature
	Tm	Daily mean temperature
	Tn	Daily minimum temperature
Precip	**Psh**	Semi-hourly (30 min) precipitation (mm)
	P	Daily precipitation (mm)
	Pmax	Daily or semi-hourly extreme value measured by observatory close to station
	Psh(0-Xh)	Sum of semi-hourly (30 min) precipitation over the period 0-X hours of the day
Other	**Kt**	Clearness index calculated according to Allen et al. (1994, 1996)
	d-X	Variable value X days before current measurement
	max()	Maximum value in a semi-hourly (30 min) window
	min()	Minimum value in a semi-hourly (30 min) window