ZEMA LUNCH AND LEARN
Geneva, CH. June 26, 2014

Who are Speedwell Weather ?

Phil Hayes
Head of Weather Data and Forecast Products

Speedwell Weather Limited
An Introduction

- Providing weather services since 1999
- Our background is weather risk management and meteorology: emphasis on quality
- Main product range includes:
  - Weather Data
  - Weather Forecasts
  - Weather Derivative Software
  - Weather Station Installation
  - Services / Consultancy
- Dominant provider of OTC settlement data for parametric weather risk contracts worldwide
- Dominant provider of software (SWS) to the weather derivative industry for pricing and portfolio management
  SWS - Speedwell Weather System
- Clients in energy, agriculture, banking, insurance, financial exchanges, renewables and other weather-risk sectors world-wide
- Offices in the United States and the United Kingdom

www.SpeedwellWeather.com

Environmental Finance 2013 Annual Market Rankings Winner

Best Global Weather Risk Management Advisory / Data Service
Winner for 6 years in a row

EnergyRisk Software Rankings 2013
#1 Weather Data Management

Data Services: Quality Data sets

We carry tens of thousands of historical weather data sets from around the world.

We quality-control thousands of data sets every day.

We are the dominant settlement agent for over-the-counter weather risk contracts around the world.

We consider weather data as a form of financial market data

Speedwell SuperPack® makes available an unprecedented range of quality historical weather data and weather data feeds for a single annual fee.

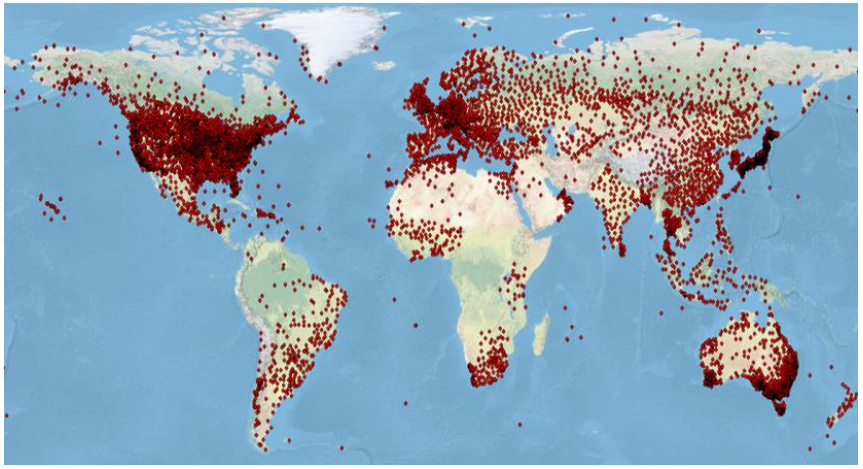
Single Point of contact for Global Weather Data

Albania	Greece	Panama
Algeria	Greenland	Pakistan
Antarctica	Guatemala	Paraguay
Antigua	Honduras	Philippines
Argentina	Hong Kong	Poland
Armenia	Hungary	Portugal
Aruba	India	Puerto Rico
Australia	Indonesia	Romania
Austria	Iran	Russia
Bangladesh	Ireland	Saudi Ar.
Barbados	Israel	Senegal
Belarus	Italy	Serbia
Belgium	Jamaica	Singapore
Belize	Japan	Slovakia
Benin	Kazak.	Slovenia
Bolivia	Kenya	S. Africa
Bosnia	Korea S.	Spain
Botswana	Latvia	Sri Lanka
Brazil	Lebanon	Syria
Bulgaria	Liechtenst'n	Sweden
Burkina Faso	Lithuania	Switz.
Canada	Lux.	Taiwan
Cape Verde	Macedonia	Tajikistan
Chile	Malaysia	Tanzania
China	Maldives	Thailand
Columbia	Mali	Togo
Croatia	Malta	Trinidad
Cyprus	Mauritania	Tunisia
Czech R.	Mauritius	Turkey
Denmark	Mexico	Turkmenist'
Dominican	Moldova	UK
Egypt	Mongolia	Ukraine
Estonia	Montenegro	Uruguay
Ethiopia	Morocco	USA
Faroe Isles	Netherlands	Uzbekistan
Finland	New Zeal.	Vietnam
France	Niger	Zambia
Georgia	Nigeria	Zimbabwe
Germany	Norway	
Gibraltar	Oman	

Speedwell Cleaned Data

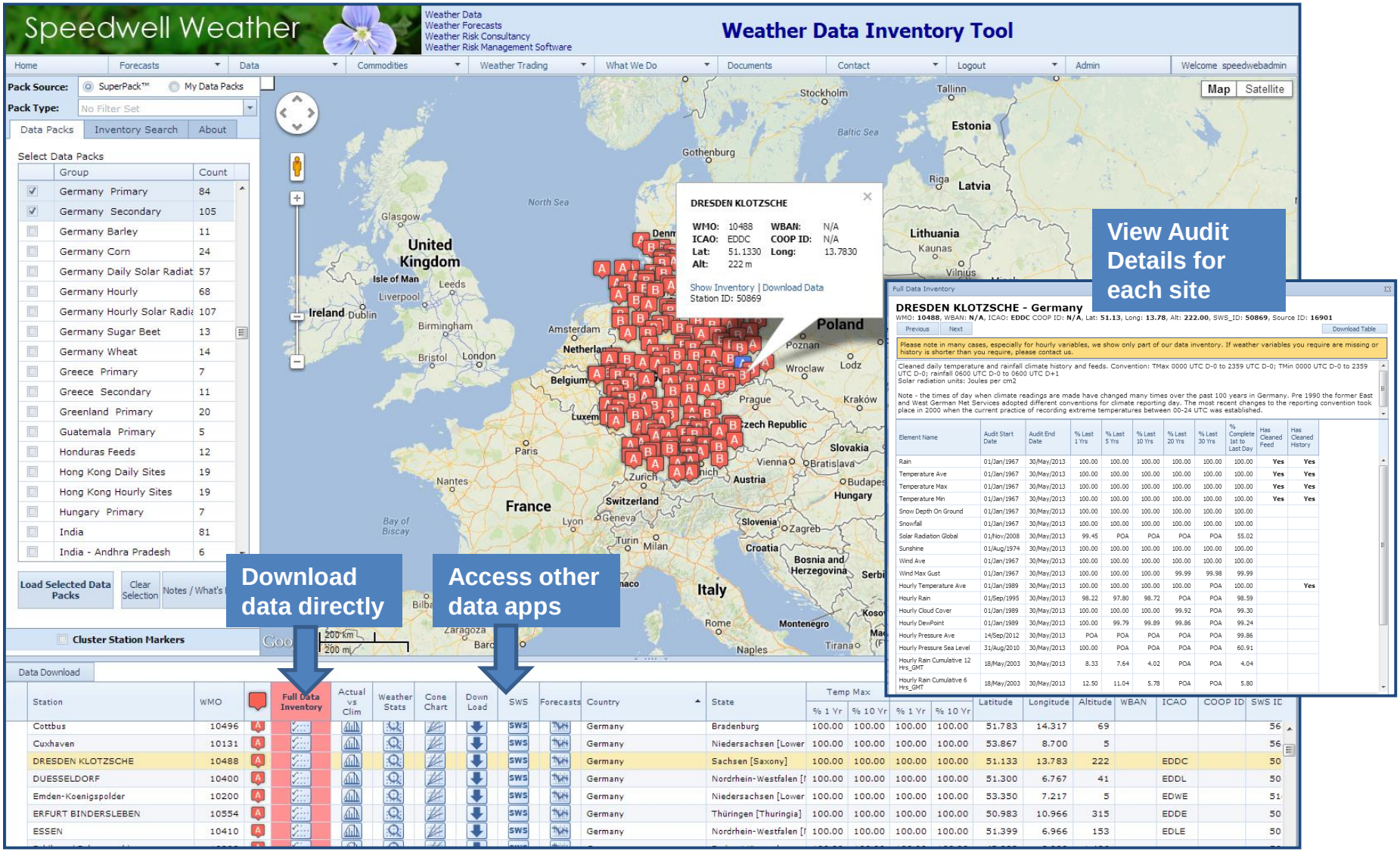
Cleaned data is data that has been processed to fill missing values and correct erroneous observations. The end result is a data set that is ready to be used for analysis. We clean weather data from thousands of weather stations every day.

Speedwell's proprietary cleaning methodologies use a mixture of automated processing but always overseen with meteorological expertise.



Data Services: Data Inventory Tool

The Speedwell Inventory Tool shows what data sets are available and provides direct data download for subscribers.
http://www.speedwellweather.com/Pages/Others/DataInventory.aspx



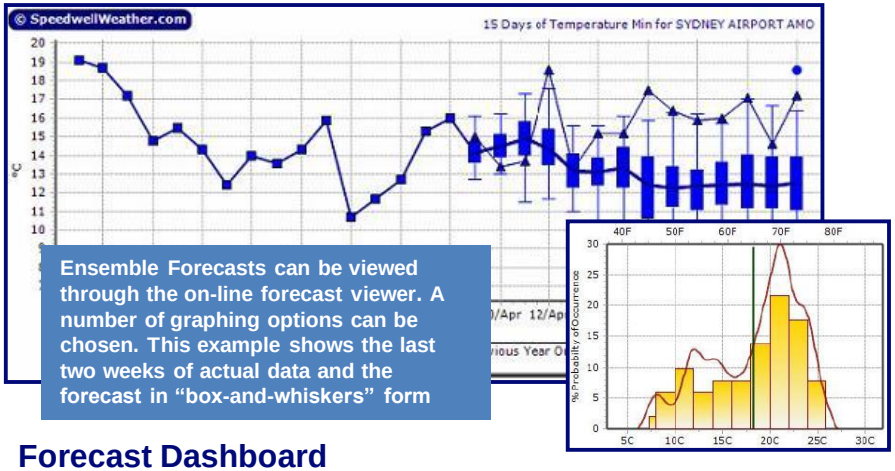
Forecast Products: Ensemble Forecasts

Speedwell Weather

Speedwell Site-Specific Ensemble Forecasts

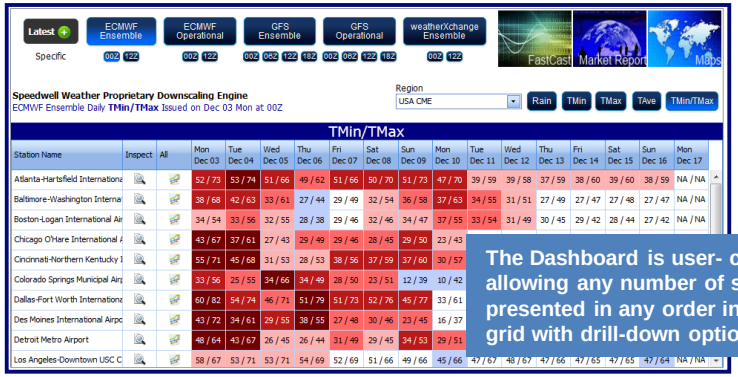
Speedwell site-specific downscaled ensemble forecasts for single sites and weighted baskets are available for over 2,000 sites across the world covering 15-day and monthly periods.

The ensemble forecast is a fully downscaled **probabilistic** forecast which inherently captures information that is normally lost in a traditional deterministic forecast: the uncertainty of the forecast at each time step.



Ensemble Forecasts can be viewed through the on-line forecast viewer. A number of graphing options can be chosen. This example shows the last two weeks of actual data and the forecast in "box-and-whiskers" form

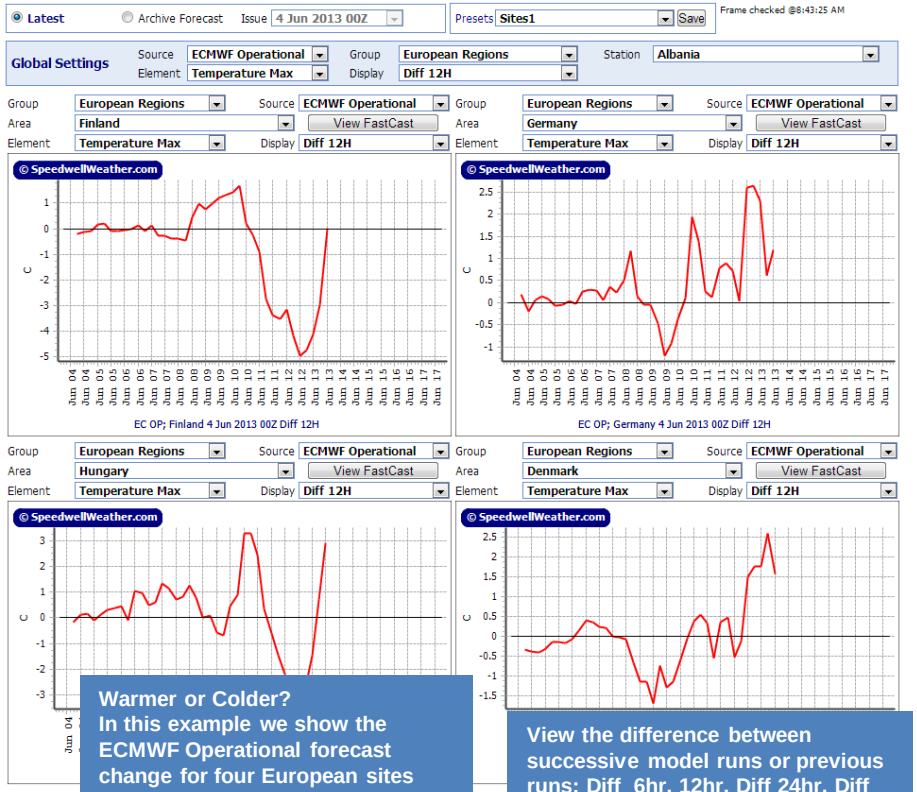
Forecast Dashboard



The Dashboard is user- configurable allowing any number of sites to be presented in any order in a numerical grid with drill-down options

FastCast® Forecasts

Ultra-fast graphical representation of the change in forecast from the previous run. Updated as each time step becomes available.



Warmer or Colder?
In this example we show the ECMWF Operational forecast change for four European sites simultaneously. Also available: US cities and power regions

View the difference between successive model runs or previous runs: Diff 6hr, 12hr, Diff 24hr, Diff 48hr, Diff 72hr

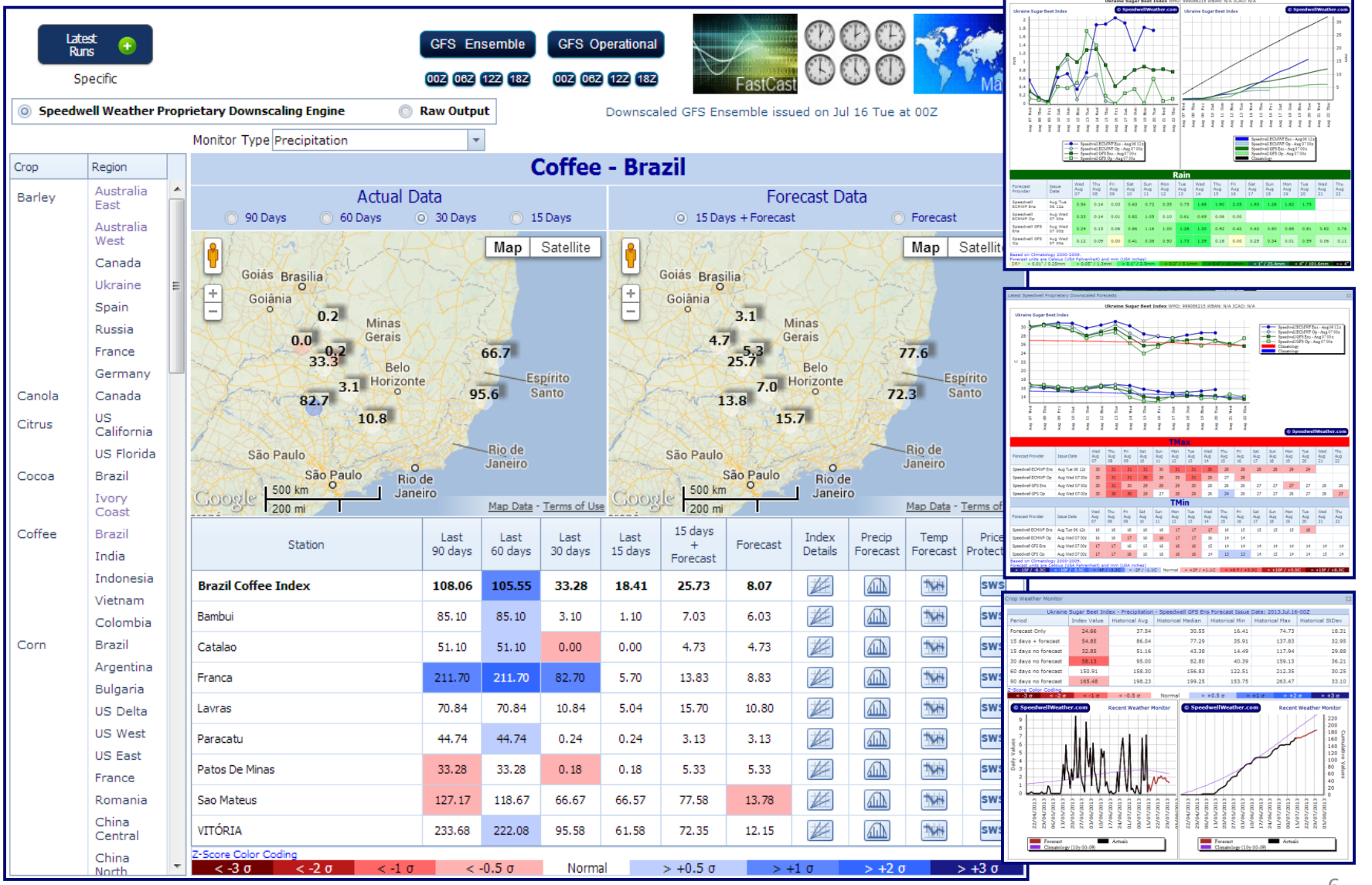
WDD: U.S. Weighted Degree Days

Uses weather data and forecasts combined with regional population data to estimate the EIA natural gas storage and withdrawal statistics.

Commodity Monitor Tool

Speedwell Weather

An interface providing access to regional crop baskets for agri-products and population weighted baskets for understanding energy demand. The tool shows the behaviour of recent weather vs normals and providing ensemble forecasts based on both the ECMWF and GFS models.



Services / Consultancy

Speedwell as Settlement Agent

Speedwell is the dominant provider of settlement data for weather risk contracts world-wide. Our involvement avoids problems that might arise even when using data sourced from national met offices. These include:

- Unexpected closure of weather stations
- Missing data points
- Failure of instruments under extreme conditions
- Problems arising from odd reporting conventions such as multi-day rainfall reports
- Late data provision
- Data reporting errors

Weather Station Installation

We have many years of experience in the data requirements necessary for cost-effective weather risk placement. A parallel weather installation can improve the quality of data used in weather risk transactions and may have a positive impact on risk premia.

Weather Risk Placement/Consultancy:

Speedwell Weather Derivatives (SWD) is the regulated subsidiary of Speedwell Weather Limited.
SWD have many years of experience in structuring and advising on the placement of weather risk. We are also able to provide independent opinions on the valuation of individual weather risk deals and to value portfolios of weather risk contracts to satisfy independent audit requirements.

SWD is authorised and regulated by the Financial Conduct Authority

Speedwell Weather Station: Armerillo, Chile installed to support settlement data for a large rainfall hedge

Speedwell Weather

Weather Data
Weather Forecasts
Weather Risk Consultancy
Weather Risk Management Software

Speedwell Weather Acts as Settlement Agent for World Bank Weather Risk Transaction

January 29th, 2014, CHARLESTON, SC, USA– Speedwell Weather, a leader in the provision of weather data, forecasts and weather risk services are pleased to announce that we have been appointed as the Settlement Agent for what is believed to be the largest public weather risk transfer transaction to date.

The transaction was arranged by World Bank for UTE, Uruguay's state-run electric utility, and covers an 18-month period paying up to $450 million when low rainfall forces the country to buy oil for power generation.

Speedwell's role in this project includes the installation of back up weather stations across the region and performing in-depth quality control of historical as well as ongoing-rainfall observations supplied by the national meteorological services of Brazil and Uruguay. Speedwell is acting as the settlement agent for the transaction, providing quality controlled weather data for each day of the period as well as supplying in-period valuations for the counterparties.

David Whitehead, Head of US Operations said "We are delighted to have been retained to provide these services for the World Bank. This transaction is one of the most complex that we have seen and is a perfect example of a weather hedge tailored to meet the exact needs of the client."

Stephen Doherty, CEO said "Speedwell has established itself over the last decade as the dominant provider of settlement services to the weather risk industry. With the largest private data base of cleaned world-wide weather data and as the provider of SWS, the pre-eminent weather risk valuation software, we are well placed to act in this role across the world. The World Bank transaction brings together our extensive experience in providing quality weather data, our experience in installing weather stations and our ability to value weather risk transactions"

About Speedwell Weather:
Founded in 1999, Speedwell Weather provides quality weather data, weather forecasts, software, and consultancy. From offices in the UK and the USA we serve clients world-wide in sectors including weather-risk, energy, and agriculture. Our data products include SuperPack® which provides unlimited access to our thousands of high quality world-wide weather data sets. Speedwell Weather is the dominant settlement agent for parametric weather risk contracts.

Environmental Finance 2013 Annual Market Rankings Winner

Best Global Weather Risk Management Advisory / Data Service Winner for the 6th consecutive year

EnergyRisk Software Rankings 2013
#1 Weather Data Management

Further Information

Regarding world-wide weather data and forecast services please see www.SpeedwellWeather.com or contact:
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david.whitehead@SpeedwellWeather.com

Speedwell Weather

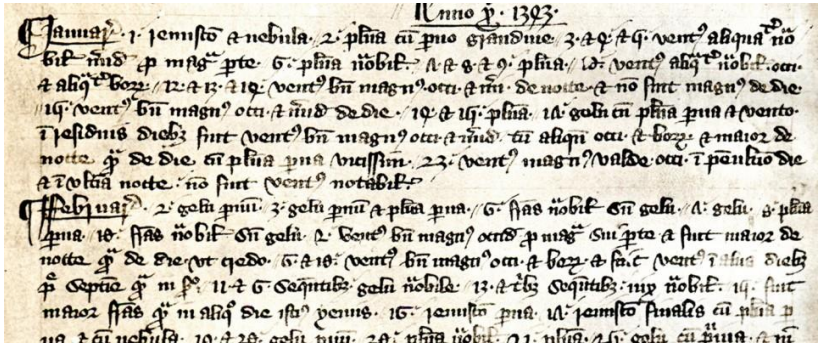
Weather Risk Settlement Services: World Bank Uruguay Transaction

The largest to date

What exactly is weather data and where does it come from ?

Speedwell Weather

Weather observations are not new, they have been around since the middle ages !
William Merle made detailed diary observations in Oxford between 1337 and 1344 during The Little Ice Age



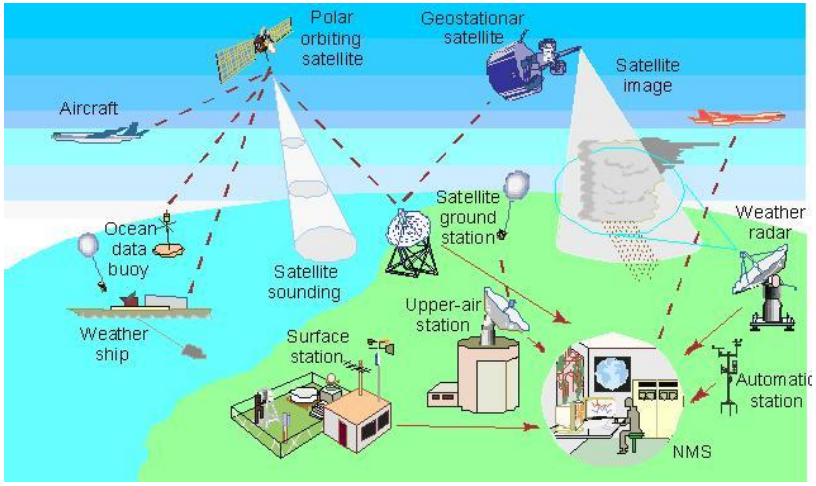
Extract from William Merle's weather diary c1393

Modern day observations come from a variety of sources and record a wide range of meteorological parameters

Who observes the weather ? We all do !

Recorded measurements come from a variety of sources: National Met Services, Hydromet networks, ships, aircraft, satellite, buoys, weather Radar, amateur networks, private institutions and individuals.

Measurements are made at both fixed and mobile locations – coverage is not consistent



Observations are continuously recorded around the globe in order to forecast the weather

Data provenance

- Data sources include – National Met Services, hydro-meteorological services, agri-networks, academic bodies, observatories, airport operators, Coop observing networks, schools, private companies, private individuals, our own instruments.
- It is important to know the origin of the data so that the user can ask questions later.
- It is important to know the origin of the data so that the user can match any important metadata to the series.
- Knowing where the data originates helps us to better understand how it has been recorded, stored, processed and any changes to the method of measurement.
- All of the above sources of data can produce high quality weather data as well as data that is unfit for our purposes.
- Speedwell Weather use data under licence from official and quality sources only.

Data - Metadata

Speedwell Weather

In order to fully appreciate the data series and understand how it has been recorded, the station metadata is an essential additional information series.

- Should describe reporting conventions used (times, period).
- Should describe changes in instruments over time (updated technology, changes from manual readings to fully automated sampling.
- Provide a record of changes in location – site moves.
- Should if possible provide a plan of the site and changes over time.
- Confirm the reporting units for each element/parameter.

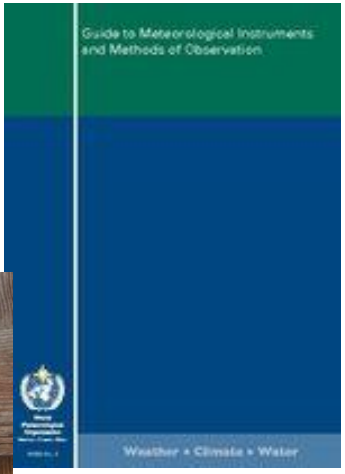
Land	StaTyp	Status	STATION!	Name	Höhe	BG	BM	BS	LG	LM	LS	Geo_von	Geo_bis	Gerät_von	Gerät_bis	Gerät	h-Geber	MESSVERFAHREN_NAME
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		01/08/1997		Barometer Hg, unbekannt		Luftdruckmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		01/08/1997		Großer Barograph		Luftdruckmessung, Aneroiddose
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		01/01/1975		Niederschlagsschreiber (behe	1.2	Niederschlagsmessung, Hellmann
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		01/05/1964		Wolkenhöhenmesser (Tag+Nacht)		Wolkenhöhenbestimmung, optisch
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		01/02/1964		Windmessanlage 90z (unbehe	26	Windregistrierung, elektromechanisch
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		01/11/1955		Mikrobarograph		Luftdruckmessung, Aneroiddose
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		01/08/1953		Thermograph		Temperaturmessung, Bimetall
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		01/08/1953		Hygrograph		Feuchtemessung, Frankenberg, Haar
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Minimumthermometer	2.1	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Maximumthermometer	2.1	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Schneeausstecher		Wasseräquivalentmessung, manuell
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Sonnenscheinautograph (Cam	18	Sonnenscheindauer, Campbell-Stokes
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Erdbodenthermometer	-0.1	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Niederschlagsmesser	1	Niederschlagsmessung, Hellmann
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Erdbodenthermometer	-0.5	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Erdbodenthermometer	-3	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Transmissometer		Sichtmessung, elektrisch
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Erdbodenthermometer	-1	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Alle_Geräte_EDVSTADA		
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Wetterhütte Standard		
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Erdbodenthermometer	-2	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Erdbodenminimumthermomete	0.05	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Stationsthermometer	1.9	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Erdbodenthermometer	-0.05	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	01/08/1997		03/10/1951		Erdbodenthermometer	-0.2	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	03/10/1951	31/07/1997	01/01/1975		Niederschlagsschreiber (behe	1.2	Niederschlagsmessung, Hellmann
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	03/10/1951	31/07/1997	01/05/1964		Wolkenhöhenmesser (Tag+Nacht)		Wolkenhöhenbestimmung, optisch
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	03/10/1951	31/07/1997	01/02/1964		Windmessanlage 90z (unbehe	26	Windregistrierung, elektromechanisch
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	03/10/1951	31/07/1997	01/06/1963	31/12/1974	Niederschlagsschreiber (behe	1.2	Niederschlagsmessung, Hellmann
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	03/10/1951	31/07/1997	01/11/1955		Mikrobarograph		Luftdruckmessung, Aneroiddose
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	03/10/1951	31/07/1997	01/09/1954	31/01/1964	Windmessanlage 90z (unbehe	26	Windregistrierung, elektromechanisch
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	03/10/1951	31/07/1997	01/08/1953		Thermograph		Temperaturmessung, Bimetall
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	03/10/1951	31/07/1997	01/08/1953		Hygrograph		Feuchtemessung, Frankenberg, Haar
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	03/10/1951	31/07/1997	03/10/1951		Erdbodenthermometer	-0.05	Temperaturmessung, Quecksilber
BE	Wst	aktiv	403	Berlin-Dahlem (FU)	58	52	27	50	13	18	6	03/10/1951	31/07/1997	03/10/1951		Stationsthermometer	1.9	Temperaturmessung, Quecksilber

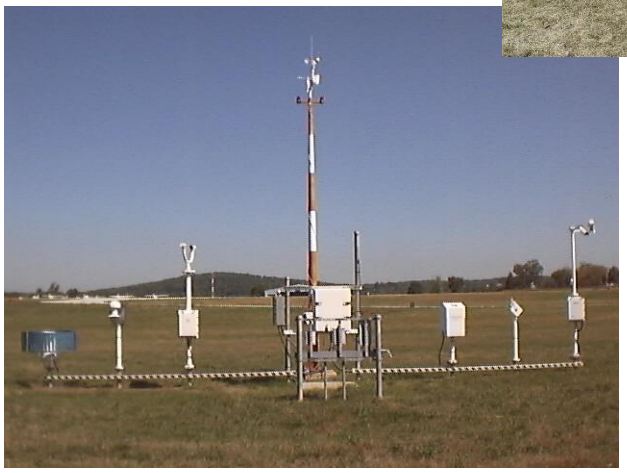
Extract of station metadata for instruments used at Berlin Dahlem – courtesy DWD

Data quality

Speedwell Weather

Weather measurements are made using wide ranging array of instruments, not all record to the exacting standards of the World Meteorological Organisation (WMO).





Some can be good, some less so – which is the official site ?

A private network installation (Speedwell, Chile)

Official US COOP site (NCDC)

Weather Data Conventions

- We tend to think of weather data as being unambiguous. This is not the case.
- Care needs to be taken. For example a daily maximum temperature can be 12 hour max/24 hour max and apply to different measurement periods
- We are scrupulous in storing data to respect different reporting conventions. We log those conventions. We can supply a document detailing reporting conventions around the world.
- A deep understanding of data conventions is necessary before data can be quality controlled, otherwise any comparison is flawed.

Reporting Conventions

Country	*File Type*	Data Type	Data Type	Description	TMax	TMin	TAvg24	TAvg	Rainfall
Jamaica									
	Synoptic	*Delivery: 0600 UTC to 0900 UTC (once per 60 minutes)*							
		Synop Cleaned	10						1200 UTC $_{D-1}$ to 1200 UTC $_{D-0}$
		Synop U	2						1200 UTC $_{D-1}$ to 1200 UTC $_{D-0}$
	Climate	*Delivery: 1000 UTC to 1600 UTC (once per 60 minutes)*							
		Climate Cleaned	15						1200 UTC $_{D-1}$ to 1200 UTC $_{D-0}$
		Climate U	1						1200 UTC $_{D-1}$ to 1200 UTC $_{D-0}$
Japan									
	CME HDD/CDD Monthly								
		Exchange	20/25	Speedwell Cleaned	-----	-----	Γ $_{D-0}$ to 240	-----	
	Synoptic	*Delivery: not available*							
		Available for som		Not available as a standard SWD data feed. Please contact us if you require					
			XX	SYNOP data	-----	-----			0000 UTC $_{D-0}$ to 0000 UTC $_{D+1}$
	Climate	*Delivery: 1600 UTC to 2000 UTC (once per 60 minutes)*							
		Synop E	5	Synoptic Edited data (c-24 TAvg)	0000 JST $_{D-0}$ to 2359 JST $_{D-0}$	0000 JST $_{D-0}$ to 2359 JST $_{D-0}$	0100 JST $_{D-0}$ to 2400 JST $_{D-0}$		
		Climate E	6	AMeDAS Edited data (c-24 TAvg)	0000 JST $_{D-0}$ to 2359 JST $_{D-0\ (from\ 2}$	0000 JST $_{D-0}$ to 2359 JST $_{D-0\ (from\ 24\ s}$	0100 JST $_{D-0}$ to 2400 JST $_{D-0}$		
		Synop U	2	Synoptic Preliminary data (c-24 TAvg)	0000 JST $_{D-0}$ to 2359 JST $_{D-0}$	0000 JST $_{D-0}$ to 2359 JST $_{D-0}$	0100 JST $_{D-0}$ to 2400 JST $_{D-0}$		
		Climate U	1	AMeDAS Preliminary data (c-24 TAvg)	0000 JST $_{D-0}$ to 2359 JST $_{D-0\ (from\ 2}$	0000 JST $_{D-0}$ to 2359 JST $_{D-0\ (from\ 24\ s}$	0100 JST $_{D-0}$ to 2400 JST $_{D-0}$		
		LQ	50	Synoptic Raw data (computed TAvg)	0000 JST $_{D-0}$ to 2100 JST $_{D-0}$	2100 JST $_{D-1}$ to 0900 JST $_{D-0}$	N/A		
		LQ2	51	AMeDAS Raw data (computed TAvg)	0000 JST $_{D-0}$ to 2359 JST $_{D-0}$	0000 JST $_{D-0}$ to 2359 JST $_{D-0}$	N/A		
Kazakhstan									
	Synoptic	*Delivery: 0600 UTC to 0900 UTC (once per 60 minutes)*							
		Synop Cleaned	10		0300 UTC $_{D0}$ to 1500 UTC $_{D0}$	1500 UTC $_{D-1}$ to 0300 UTC $_{D0}$			0300 UTC $_{D-0}$ to 0300 UTC $_{D+1}$
		Synop U	2		0300 UTC $_{D0}$ to 1500 UTC $_{D0}$	1500 UTC $_{D-1}$ to 0300 UTC $_{D0}$			0300 UTC $_{D-0}$ to 0300 UTC $_{D+1}$
Korea, South									

Common Misconceptions About Weather Observations

Observation Convention

All data is observed from midnight to midnight (the calendar day)

[FALSE]

1

In reality, observation convention varies from country to country and network to network. In general it can be assumed that the observation of a given variable (such as daily maximum temperature) will be consistent across an entire network. The convention is set by the network owner. When asked, data vendors should be able to describe the observation convention for all datasets.

Why is this important?

- When comparing / merging datasets, it is important to compare like with like.
- When verifying forecasts, make sure the observation convention matches the forecast day convention.
- For weather risk contracts, reporting conventions can have a material impact on settlement values.

Did You Know?

In the UK and France Climate TMax & TMin are observed over different 24hr periods!

Many US COOP obs are taken at 7am because that is when observers wake!

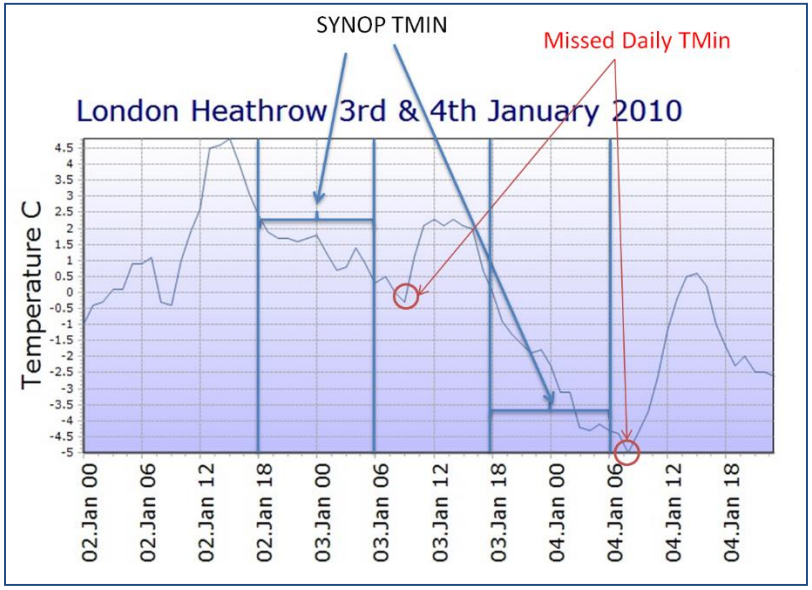
Common Misconceptions About Weather Observations

2 Daily Observations

All "daily" observations represent a full day (24 hour period)

[FALSE]

The truth is that "Daily" data, especially those derived from the SYNOP network sometimes only represents a partial day. A nighttime TMin or daytime TMax is common practice. When asked, a data vendor should be able to explain the convention used.



Why is this important?

- Some examples
  - people consume electricity 24 hours a day
  - frost events damage plants at all hours
  - crops don't care when it rains as long as it rains

Common Misconceptions About Weather Observations

3 Data Quality

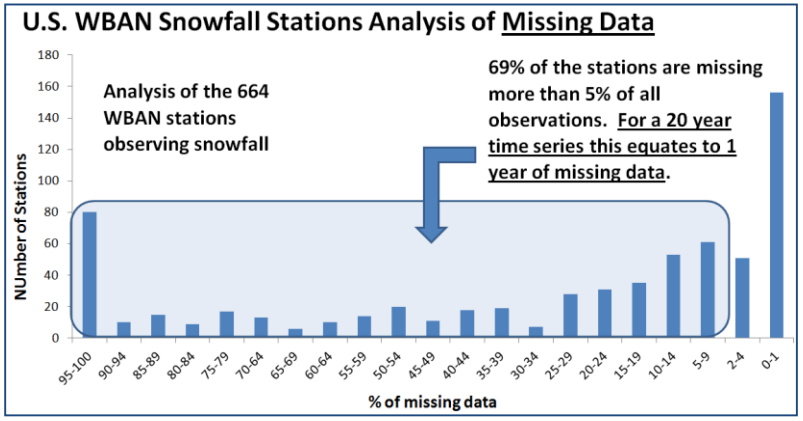
Missing and erroneous observations are uncommon

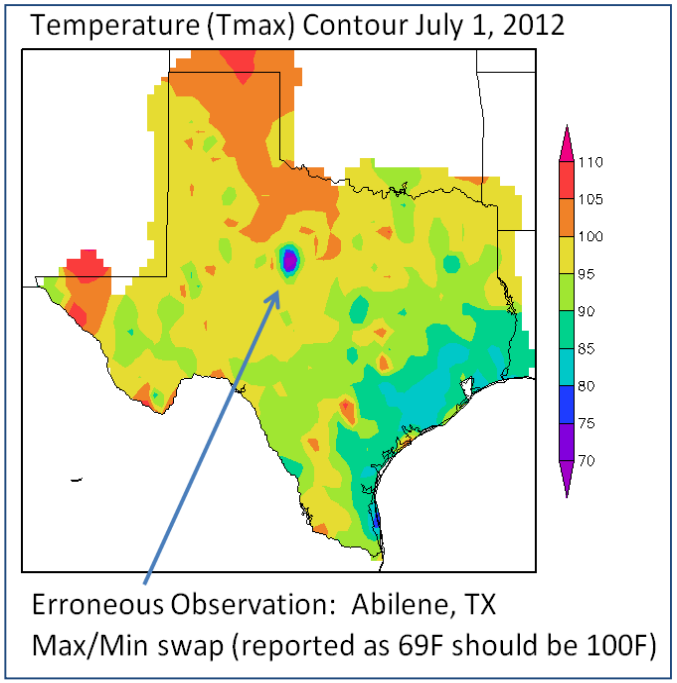
[FALSE]

The truth is that missing values and erroneous values are common. The best solution is to only use CLEANED data. This is data where missing and erroneous values are filled and replaced.

Why is this important?

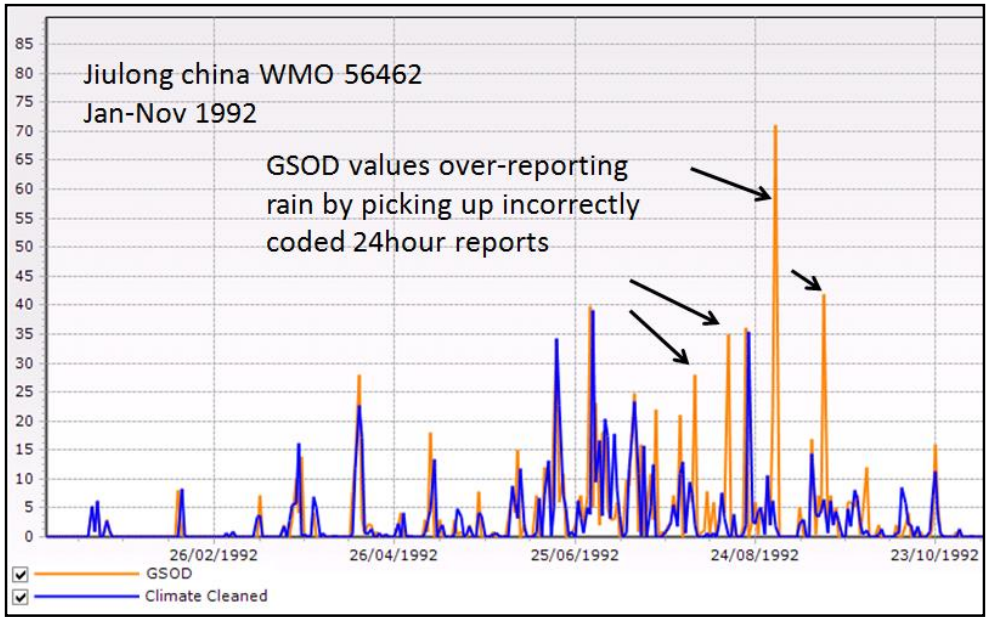
- Missing values make an analysis difficult if not impossible. You cannot ignore missing values.
- An erroneous 100mm of rain can make the difference between drought and flood.
- **Often erroneous or missing values are the most important values: observations that arise in weather extremes are more likely to fail**





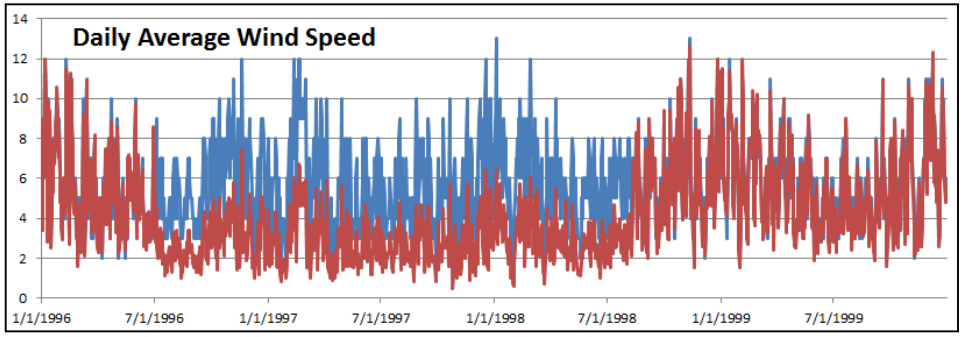
Understanding the limitations of the GSOD data set

The GSOD or “Global Summary of Day” data set is an important data resource and is freely available from NWS/NCDC. However, the usability of this data varies depending upon the intended analysis to be performed. In certain circumstances the data can be very useful while in others it needs to be used with caution. The difficulty is not knowing when the data *can* be trusted. We caution that this data **should *never* be relied upon** to price weather risk contracts and should be avoided where possible when analyzing weather risk for commodity transactions, crop yield models, as well as other sensitive analyses.



Shown above is daily precipitation for Jiulong, China for 1992. The blue line is Speedwell Cleaned Climate data which is overlaid on top of GSOD data in orange. **In this period GSOD over estimates rainfall by 24%.**

Shown below is the daily wind for Dublin Airport, Ireland. The blue line is official quality controlled data from the Irish Met Office. The red is GSOD. We can see that there is a two-year period where the GSOD data is incorrect. Minor differences are found in other years.



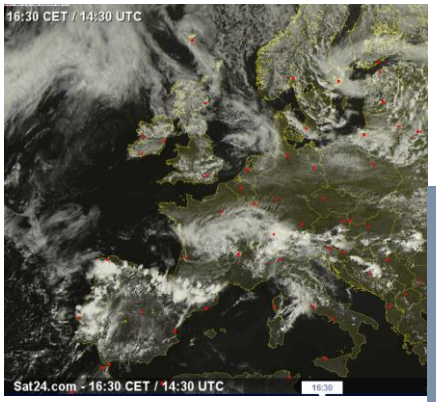
So far we have been considering data for a single location

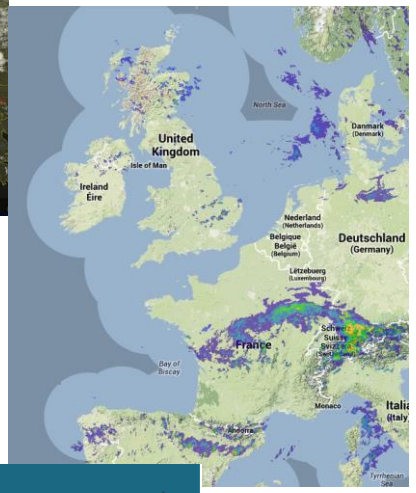
Speedwell Weather

In terms of data, there is much more than a single series of data for a given location.

Examples include:

- **Satellite imagery** providing large area data for such variables as temperature, cloud cover, solar radiation, potential precipitation, fog…
- **Rainfall Radar** which can provide information at high resolutions, both temporal and distance
- **Model re-analysis** which is a uniform gridded snap-shot taken from the global and regional forecast model output (in essence a T+0 forecast field)





Summary of Atmospheric Reanalysis products

Name	Source	Domain	Period of Record	available timestep(s)	available resolution	available format(s)	Model Resolution	scheme & model vintage
Arctic System Reanalysis (ASR)	Byrd Polar Research Center/ David Bromwich, Sheng-Hung Wang,NCAR,CIRES,U Illinois	Arctic	2000/01 to 2012/12	Sub-daily, Monthly	30 km; 71 levels; 10hPA top, 10 km	netCDF	30 km and 10 km	WRF-VAR
Climate Forecast System Reanalysis (CFSR)	NCEP	Global	1979/01 to 2010/12	Sub-daily, Monthly	.5°x.5° & 2.5°x2.5°, 0.266 hPA top	GRIB	T382 x 64 levels	3DVAR | 2009
ERA-15	ECMWF	Global	1979/01 to 1993/12	Sub-daily, Monthly	T106, 2.5 x 2.5	GRIB	T106 (1.125)	
ERA-Interim	ECMWF	Global	1979/01 to 2013/08	Sub-daily, Daily, Monthly	0.75°x0.75°x60 lev 0.1 hPA top	netCDF, GRIB	T255, 60 levels	4DVAR | 2006
ERA40	ECMWF	Global	1957/01 to 2002/12	Sub-daily, Monthly	2.5°x2.5° / 1.125°x1.125°; 60 levels 0.1 hPA top	netCDF, GRIB	T159, 60 levels	3DVAR | 2004
JRA-25	Japanese Meteorological Agency	Global	1979/01 to 2004/12	Sub-daily, Monthly	1.125x1.125/2.5x2.5; 0.4 hPA top	GRIB	T106, 40 levels	3DVAR | 2004
JRA-55	Japanese Meteorological Agency	Global	1958/01 to 2012/12	Sub-daily, Monthly	T319 x 60 levels, 0.1 hPA top	GRIB	T319 x 60 levels	4DVAR | 2009
NASA MERRA	NASA	Global	1979/01 to 2013/01	Sub-daily, Monthly	0.5° x 0.667° x 72 , 0.01 hPA top	netCDF, HDF	0.5° x 0.667° x 72	GEOS IAU | 2009
NCEP NARR	NCEP	North America	1979/01 to 2012/09	Climatology, Sub-daily, Monthly	32km	GRIB	32km x 45 eta	3DVAR | 2003
NCEP Reanalysis (R2)	NCEP,DOE	Global	1979/01 to 2012/12	Sub-daily, Daily, Monthly	2.5°x2.5° 28 levels 3 hPA top	netCDF, GRIB	T62 28 levels	3DVAR | 2001
NCEP-NCAR (R1): An Overview	NCEP,NCAR	Global	1948/01 to 2013/01	Sub-daily, Daily, Monthly	2.5°x2.5°; 3 hPA top	netCDF, GRIB	T62 - 28 levels	3DVAR | 1995
NOAA 20th-Century Reanalysis, Version 2	NOAA ESRL,CIRES CDC / Gil Compo	Global	1871/01 to 2011/12	Sub-daily, Daily, Monthly	2°x2°, 28 levels 10 hPA top	netCDF, GRIB	T62 28 levels	Ensemble Kalman Filter | 2009

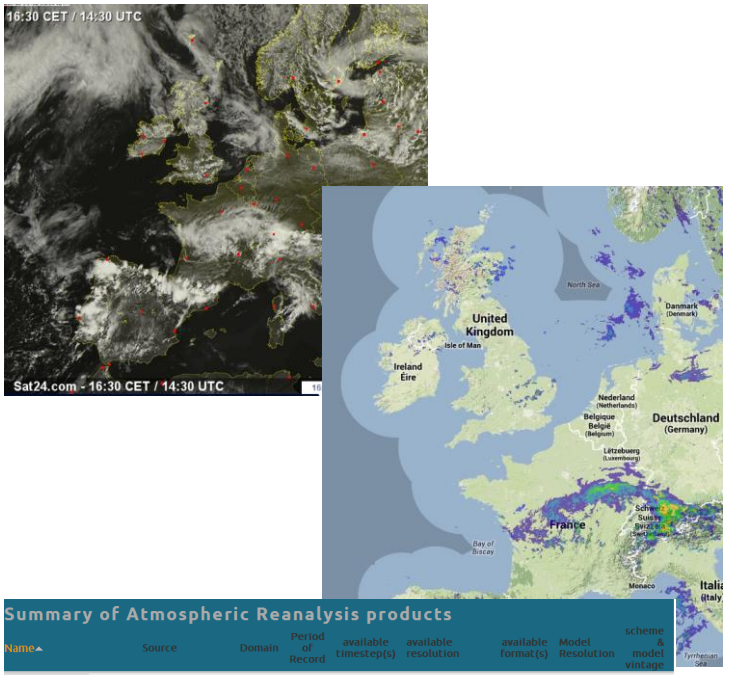
Regional weather data products

Speedwell Weather

Large scale weather data products can be very helpful to infill data sparse regions and to assist in the quality control of ground truth measurements.

Each of these products, whilst being extremely useful and in general consistent over time do have limitations:

- All of these products require fine calibration, so are susceptible to bias
- Satellite imagery often cannot penetrate to the surface due to cloud cover/obscuration
- Rainfall radar contains ‘blind spots’ – especially in hilly terrain or very close to the earth’s surface
- Reanalysis products are constantly evolving in line with forecast model improvements – these are also highly sensitive to calibration and require very high quality data input
- Each time a reanalysis data set is created you need to re-process the entire history, or risk finding step changes in any series produced



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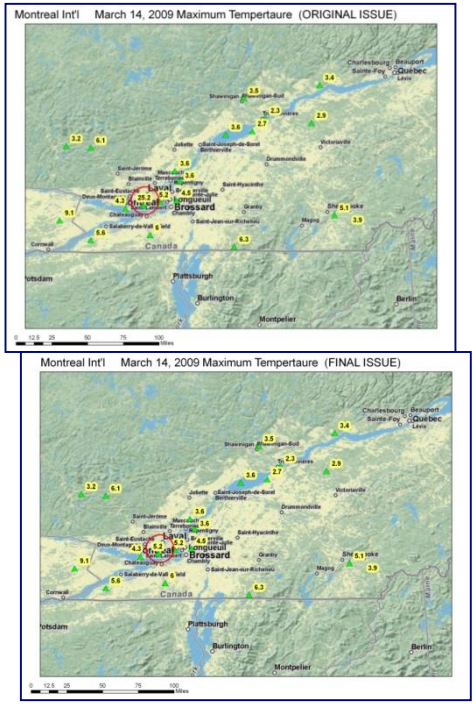
Data Cleaning

- The quality of meteorological observations varies significantly
- Missing / erroneous observation are common place
- A lot of weather data available in public archives is stored in an inconsistent manner and is of low quality
- Speedwell has invested heavily in software, data and human resources to quality control weather data



Fundamentals of a proper data cleaning

(1) Organization

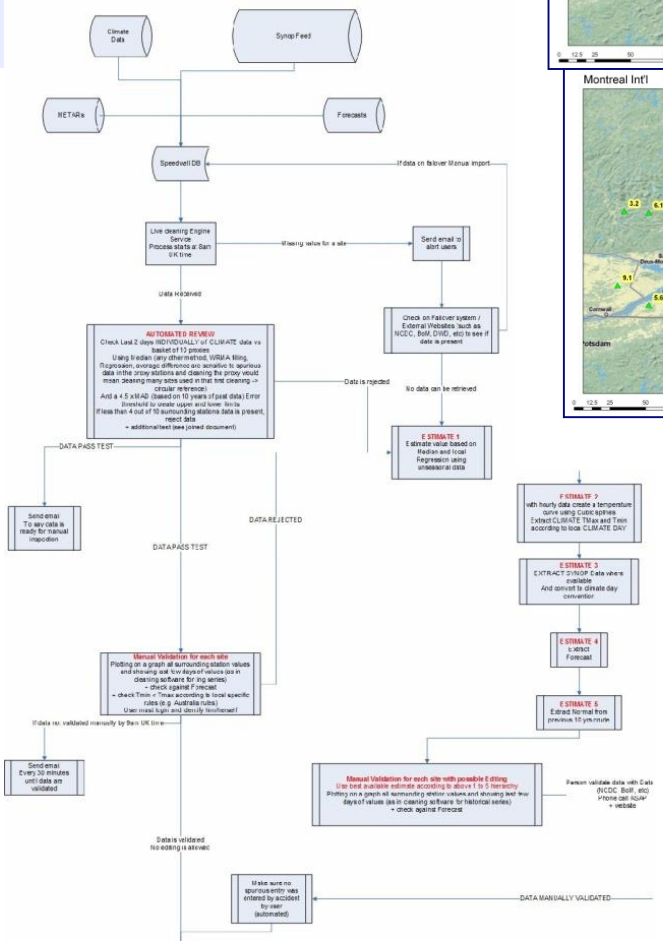
(2) Redundancy

(3) Flexibility

(4) Human interaction

(5) Transparency

<u>Fundamental to satisfying the above is the implementation of software systems infrastructure...but data cleaning cannot and should NOT be FULLY automated</u>



Part of the Speedwell Data cleaning process diagram

Data Cleaning..Organization

Fundamentals of a proper data cleaning

(1) Organization

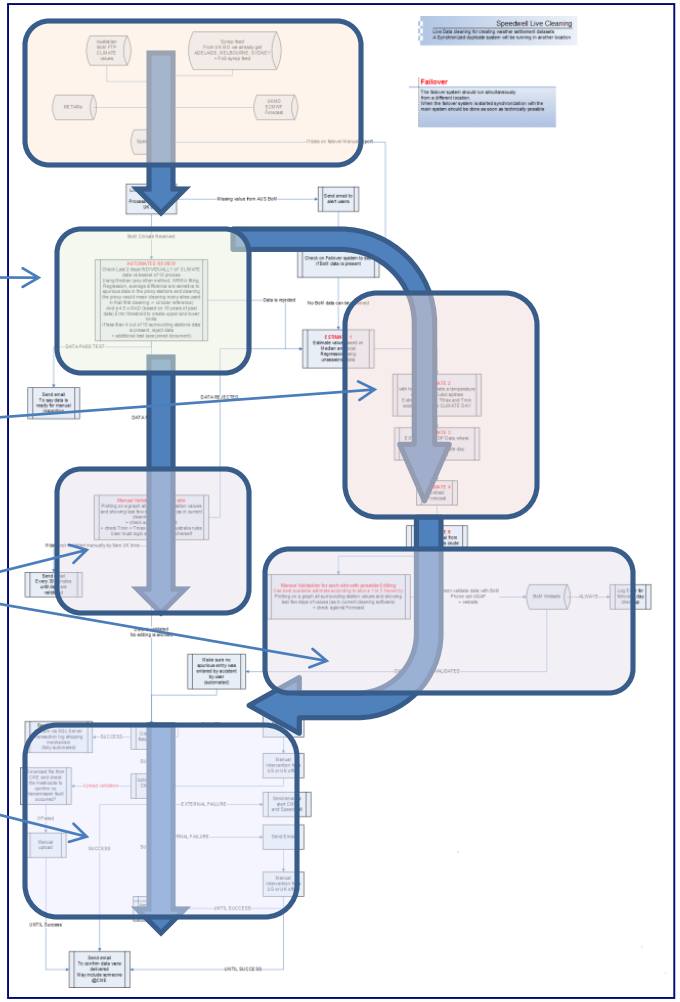
- ***logical flow***
- ***data management***
- ***handling large amounts of data***

(2) Redundancy

(3) Flexibility

(4) Human interaction

(5) Auditability



- **SYNOP U - NOAA U:** Unedited synop/NOAA data
- **SYNOP E - NOAA E:** Edited synop/NOAA data
- **SYNOP Cleaned:** Cleaned Synop data (a Speedwell Product only)
- **Climate U - NCDC U:** Unedited climate/NCDC data
- **CLIMATE E - NCDC E:** Edited climate/NCDC data
- **CLIMATE Cleaned:** Cleaned Climate data (a Speedwell Product only)
- **Exchange Initial:** Exchange Initial / Preliminary Settlement data (a Speedwell Product only)
- **Exchange Final:** Exchange Final Settlement data (a Speedwell Product only)
- **RECONS U -:** Unedited reconstructed data
- **RECONS E:** Edited reconstructed data
- **RECONS E2:** Edited reconstructed data series

Some of the Speedwell data quality types

Data Cleaning ..Redundancy

Fundamentals of a proper data cleaning

(1) Organization

(2) Redundancy

- *data sources*
- *testing*
- *estimates*
- *delivery*

(3) Flexibility

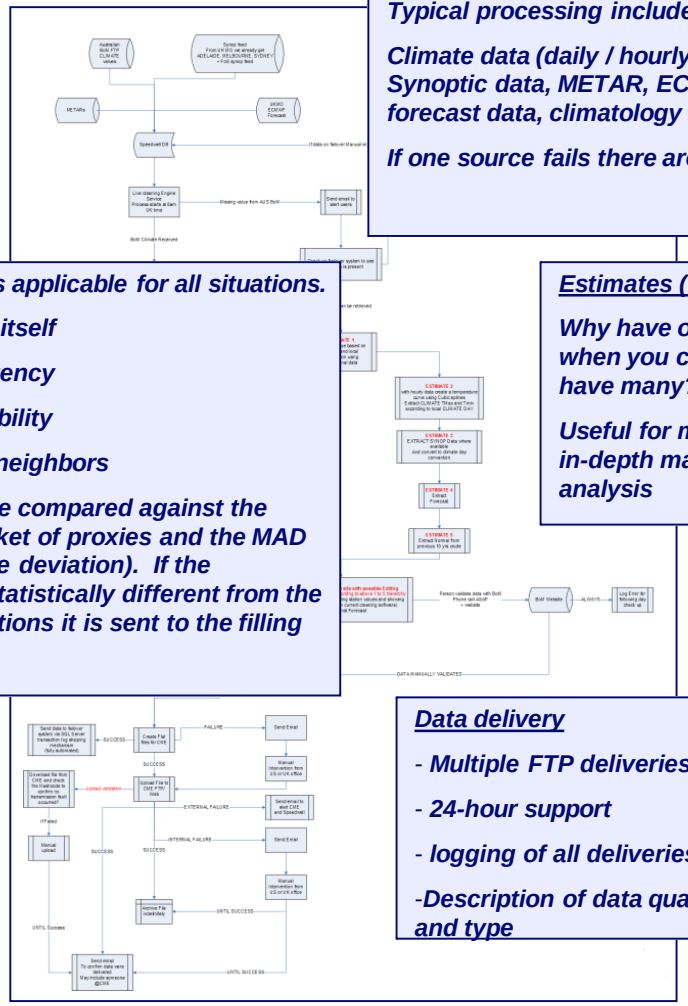
(4) Human interaction

(5) Transparency

Data sources *bring in as much as possible and keep what is useful. Typical processing includes:*

Climate data (daily / hourly), Synoptic data, METAR, ECMWF forecast data, climatology

If one source fails there are others



Testing *no one test is applicable for all situations.*

- comparison against itself

- *physical consistency*
- *statistical probability*

-comparison against neighbors

- *Observations are compared against the median of a basket of proxies and the MAD (median absolute deviation). If the observation is statistically different from the surrounding stations it is sent to the filling process*

Estimates (filling)

Why have one when you can have many?

Useful for more in-depth manual analysis

Data delivery

- Multiple FTP deliveries

- 24-hour support

- logging of all deliveries

-Description of data quality and type

A fundamental pre-requisite for effective data cleaning is access to a library of weather data providing access to near by sites allowing plausibility testing for the site being cleaned.

Speedwell Weather maintains a very large inventory of weather data for over 50 different weather elements. This is all warehoused by us in a manner that fully respects differing data types (Synoptic/Climate, Cleaned/Raw etc) with a full audit trail. This allows us to document data point changes which may occur when national met offices change data records to reflect their internal QC procedures.

We also use satellite and radar data

Data Cleaning..Flexibility

Fundamentals of a proper data cleaning

(1) Organization

(2) Redundancy

(3) Flexibility

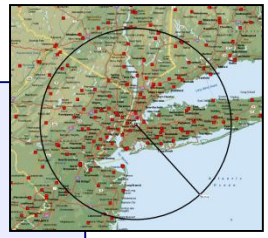
- *consider the situation*
- *appropriateness of tests*

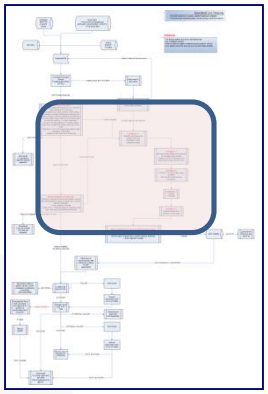
(4) Human interaction

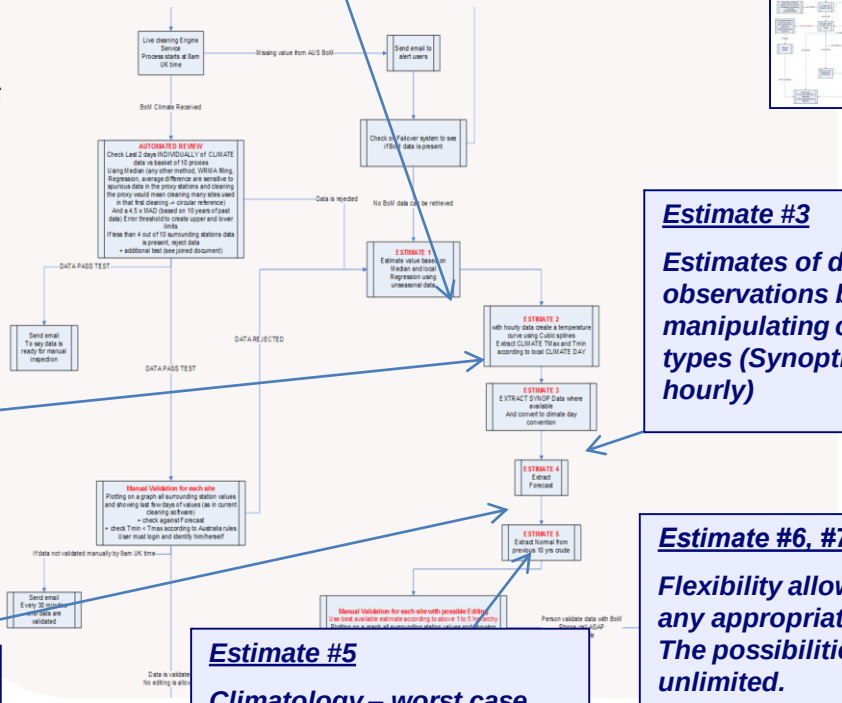
(5) Transparency

Estimate #1

surrounding station regression using deseasonalized data

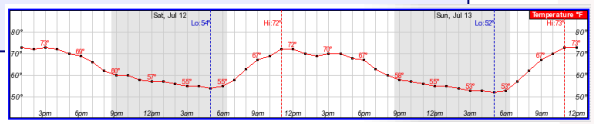






Estimate #2

Estimates of daily observations from hourly observations (curve fitting)

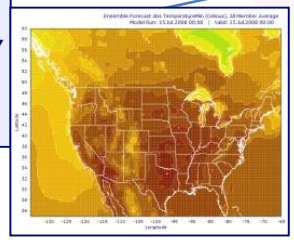


Estimate #3

Estimates of daily observations by manipulating other data types (Synoptic, METAR, ½ hourly)

Estimate #4

Day +1 forecasts can actually be very good…



Estimate #5

Climatology – worst case scenario

Estimate #6, #7, #8,…

Flexibility allows you to add any appropriate estimates. The possibilities are unlimited.
- satellite derived values
- installed stations
- reanalysis

Data Cleaning..the Human element and Transparency

Fundamentals of a proper data cleaning

(1) Organization

(2) Redundancy

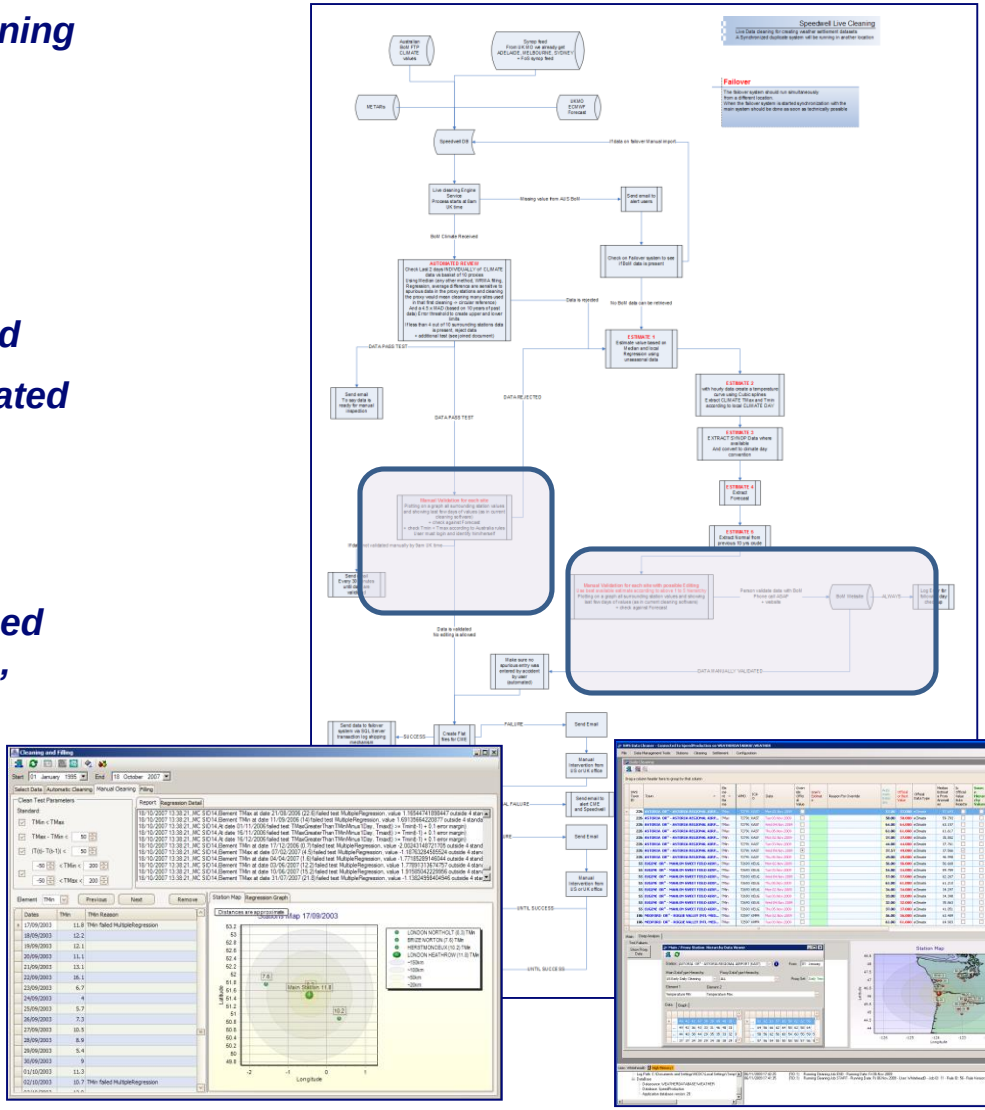
(3) Flexibility

(4) Human interaction

- *meteorology is complicated*
- *introduction of non-automated information*

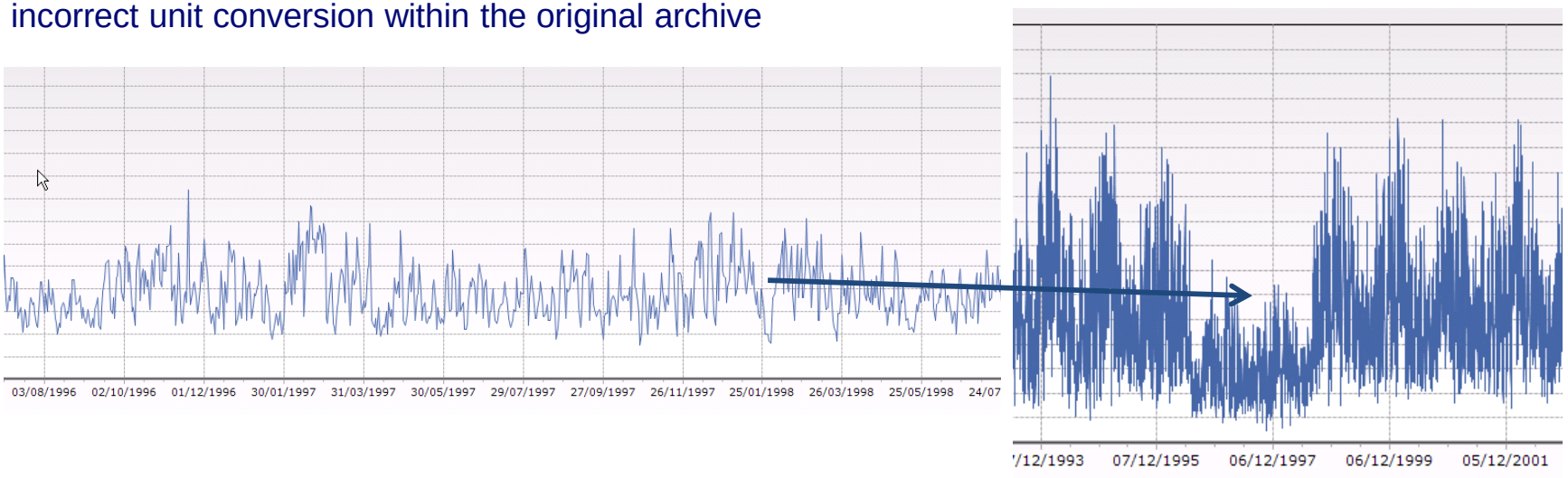
(5) Transparency

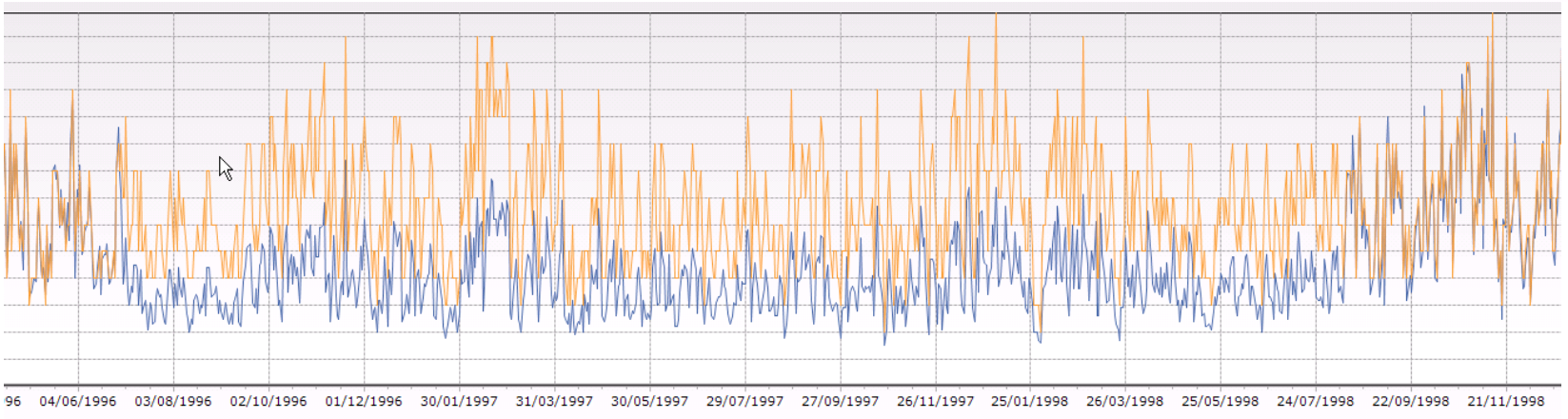
- *explanation of the process*
- *share what has been cleaned*
- *no-one likes “black boxes”*



Data Cleaning the human eye test

The series below is a daily average wind speed series, which on first inspection passes basic quality checks, However when the human eye puts this under scrutiny, a serious error is detected – this proved to be an incorrect unit conversion within the original archive



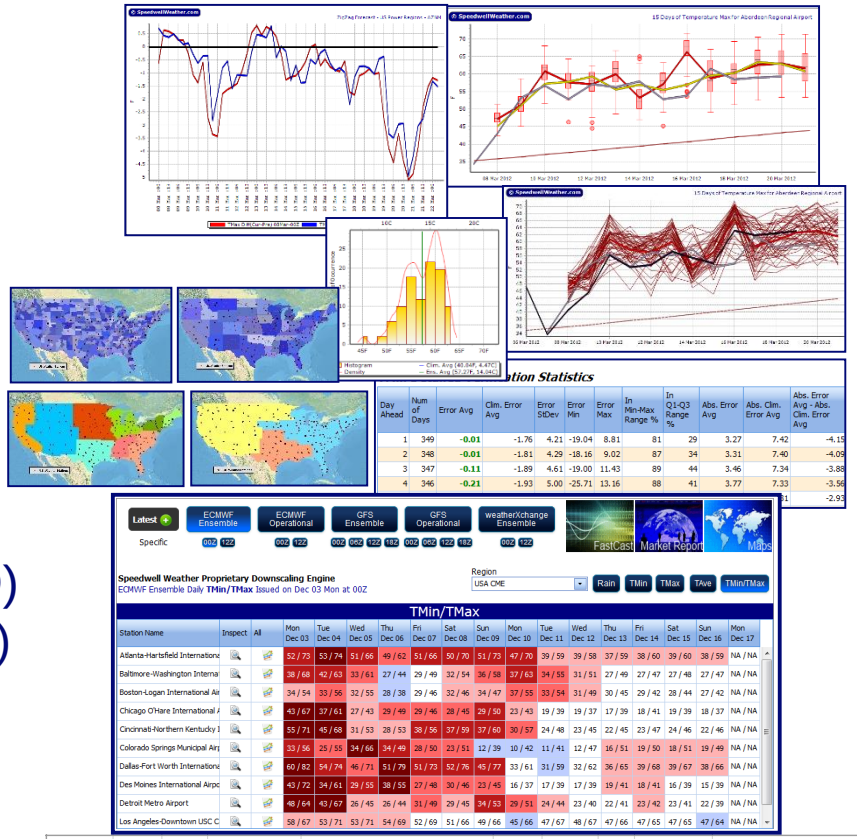


By locating the original coded observations and re-processing, Speedwell is able to produce an improved series, with any missing or incorrect values addressed The incorrect series (blue) with the correct data (yellow)

Forecast Data

Weather forecasts are also types of data, these can take many formats; graphical, time-series, arrays, GRIB, gridded, site/region etc. Forecasts can be delivered in many formats to meet user requirements, however they must include similar information to observed data to be useful:

- Date time of issue
- Model source (ECMWF, GFS, SWD)
- Model run time (00, 06, 12, 18 UTC)
- Type of model (RAW, Site specific)
- Deterministic or ensemble
- Unique site ID (WMO, WBAN, SRCID)
- Element description
- Time periods (daily, hourly)
- Units used
- Location



WMO	WBAN	ICAO	SRC_ID	CITY	LAT	LONG	ALT	DATE	TMAX_ENSEMBLE_AVG	TMIN_ENSEMBLE_AVG
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	25/06/2014	21.44	9.27
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	26/06/2014	22.22	7.49
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	27/06/2014	22.69	7.15
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	28/06/2014	22.62	11.74
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	29/06/2014	20.9	9.11
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	30/06/2014	20.07	6.11
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	01/07/2014	20.14	4.88
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	02/07/2014	20.78	6.13
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	03/07/2014	21.32	15.42
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	04/07/2014	21.85	17.08
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	05/07/2014	22.04	17.88
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	06/07/2014	22.07	17.96
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	07/07/2014	22.05	17.53
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	08/07/2014	22.09	17.59
94578		YBBN	AUS_040842	BRISBANE AERO	-27.39	153.13	9.5	09/07/2014	22.24	17.63
94765		YSBK	AUS_066137	BANKSTOWN AIRPORT AWS	-33.92	150.99	7.5	25/06/2014	17.61	7.47
94765		YSBK	AUS_066137	BANKSTOWN AIRPORT AWS	-33.92	150.99	7.5	26/06/2014	19.26	5.93
94765		YSBK	AUS_066137	BANKSTOWN AIRPORT AWS	-33.92	150.99	7.5	27/06/2014	19.82	6.06
94765		YSBK	AUS_066137	BANKSTOWN AIRPORT AWS	-33.92	150.99	7.5	28/06/2014	19.65	5.7
94765		YSBK	AUS_066137	BANKSTOWN AIRPORT AWS	-33.92	150.99	7.5	29/06/2014	16.74	5.14

Summary

- Data can be complex (multiple sources, formats, units, conventions)
- Understand the origin of the data before using – contact the data vendor or supplier
- Importance of metadata (units, environmental and instrument changes / moves)
- Is the data raw or processed, how can I tell ?
- Is the data fit for purpose ?
- Does this location continue to record and report (important if you want to trade)
- Will the data be homogenous with surrounding or over time ?
- Does the data format work with my system ?

Speedwell Weather in partnership with ZE and the ZEMA application suite address all of the above issues to enable easy integration of quality weather data in to the user's everyday business

Questions ?

Contacts

Regarding world-wide weather data and forecast matters please see www.SpeedwellWeather.com or contact:

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