WSI – Water Scarcity Index

Application to the Piave River Basin (Italy)

Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto

ARPAV – Alp Water Scarce
Project Partner 11
dst@arpa.veneto.it

THIS PROJECT IS CO-FUNDED BY THE EUROPEAN REGIONAL DEVELOPMENT FUND
investing in your future

Index

1) Water Scarcity Index (WSI): application to the Piave River Basin (Italy)

2) WSI real application (2012 drought in Veneto Region)

Piave River basin

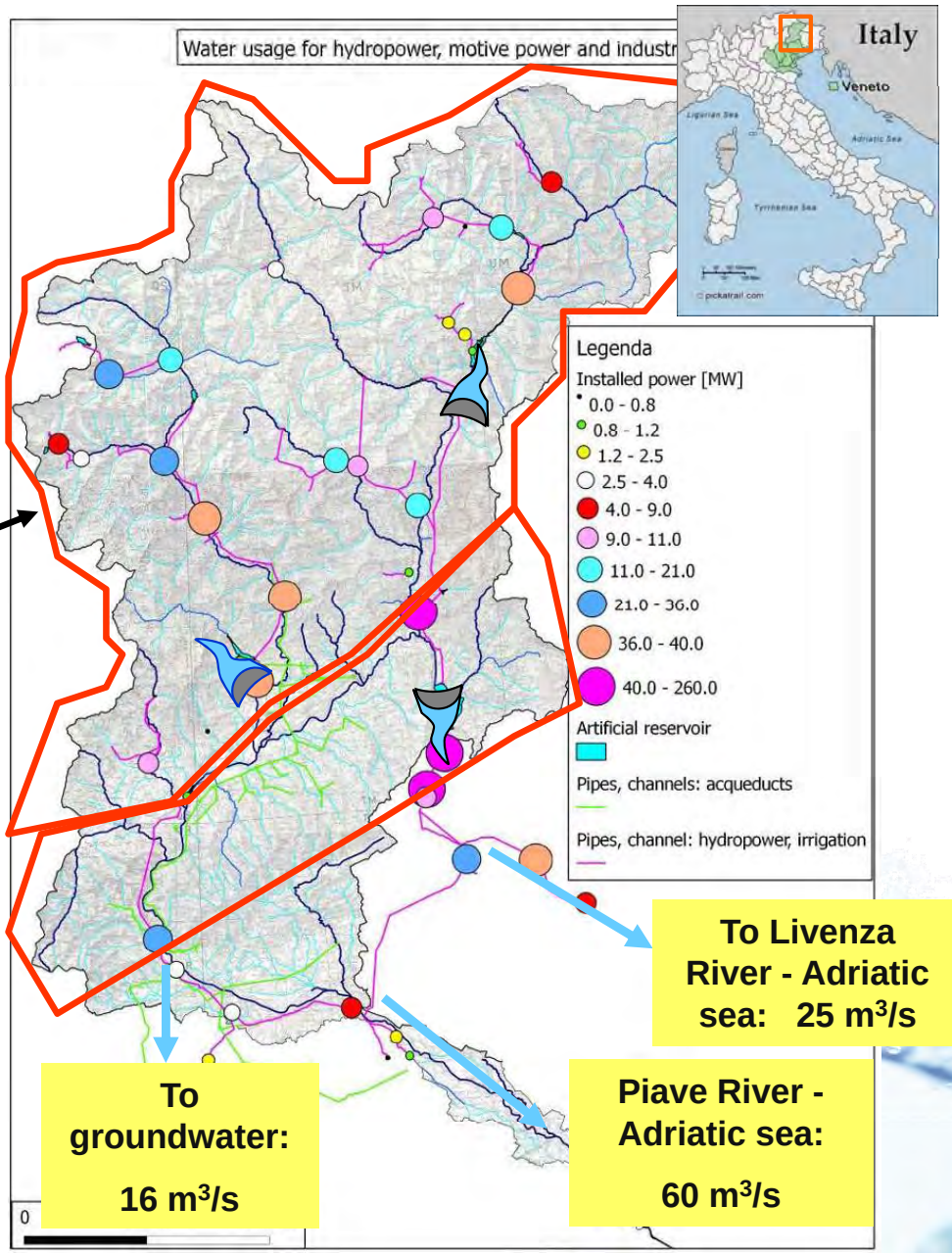
- Natural river network
- Artificial river network
  - hydroelectric
  - aqueducts and irrigation

Alps area

Pre-Alps area

Main HP reservoirs:

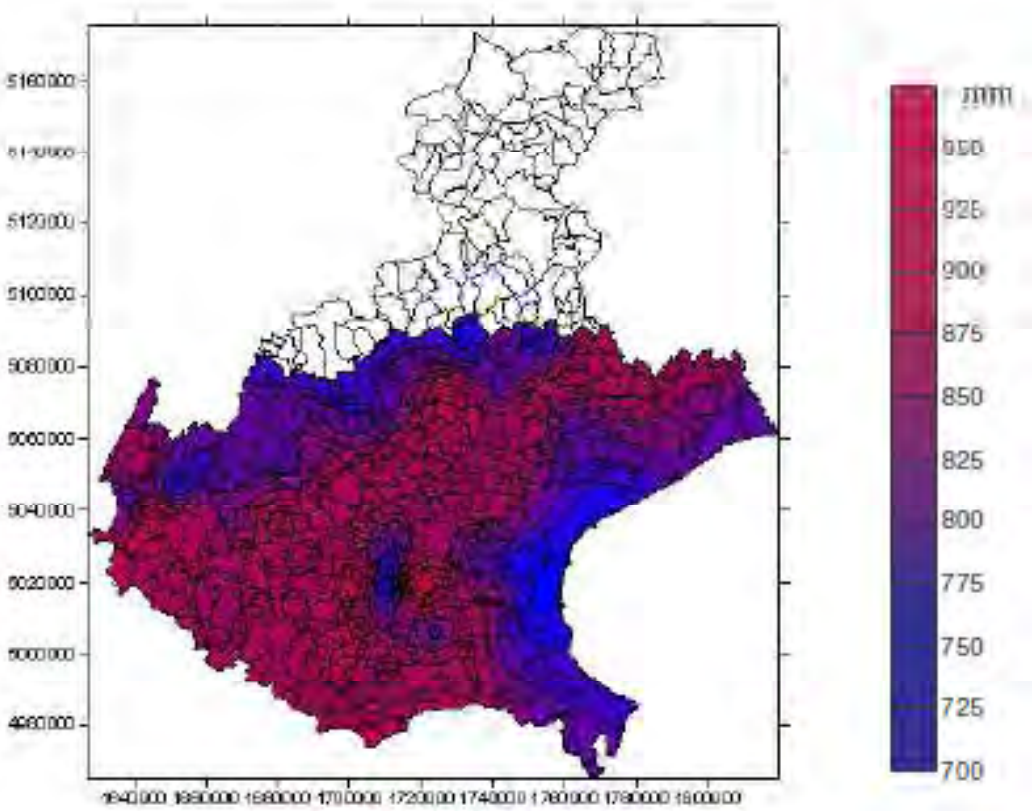
- Mis: 35 Mm^3
- Centro Cadore: 48 Mm^3
- Santa Croce: 86 Mm^3



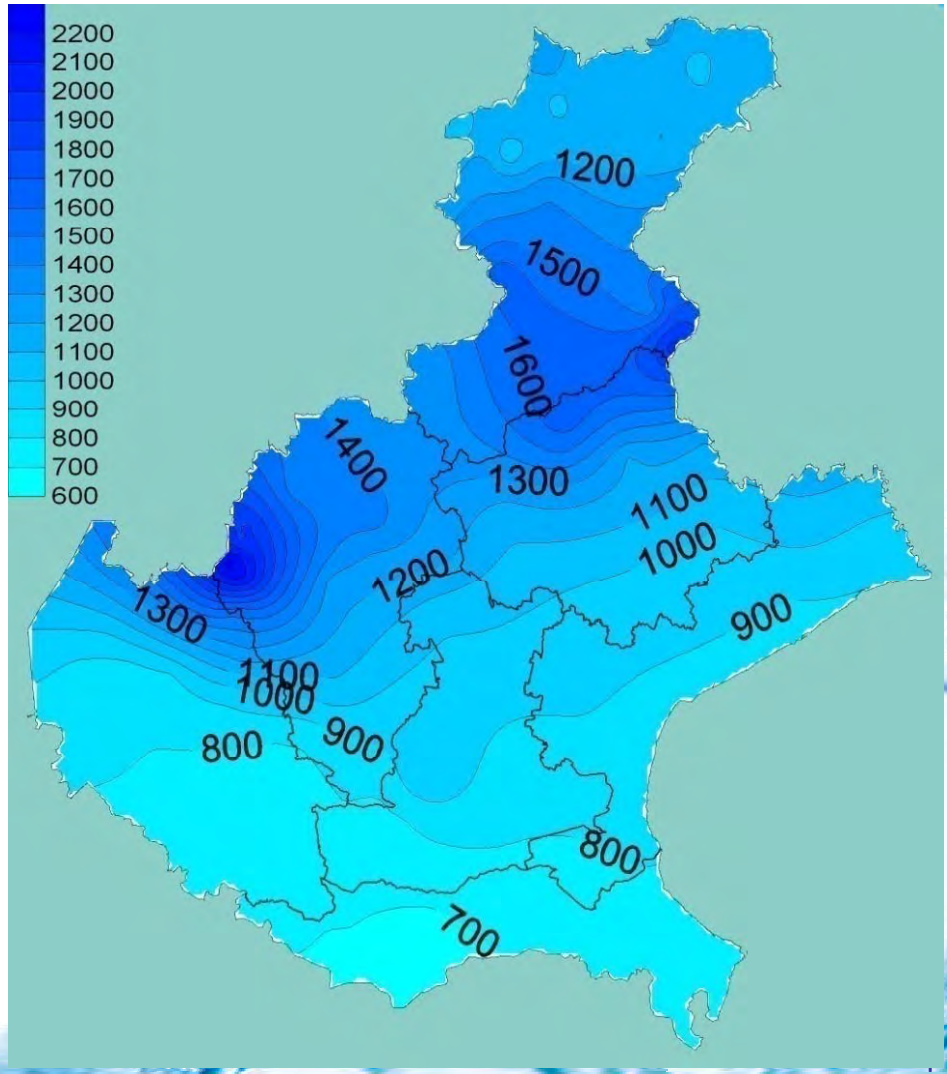
Evapotranspiration vs Precipitation

In many areas potential annual evapotranspiration > annual precipitation
potential summer evapotranspiration can be >> summer precipitation

Annual ET_0 for the plain zones
(Carobin, Berti, Chiaudani, 2008)



Annual precipitation in Veneto

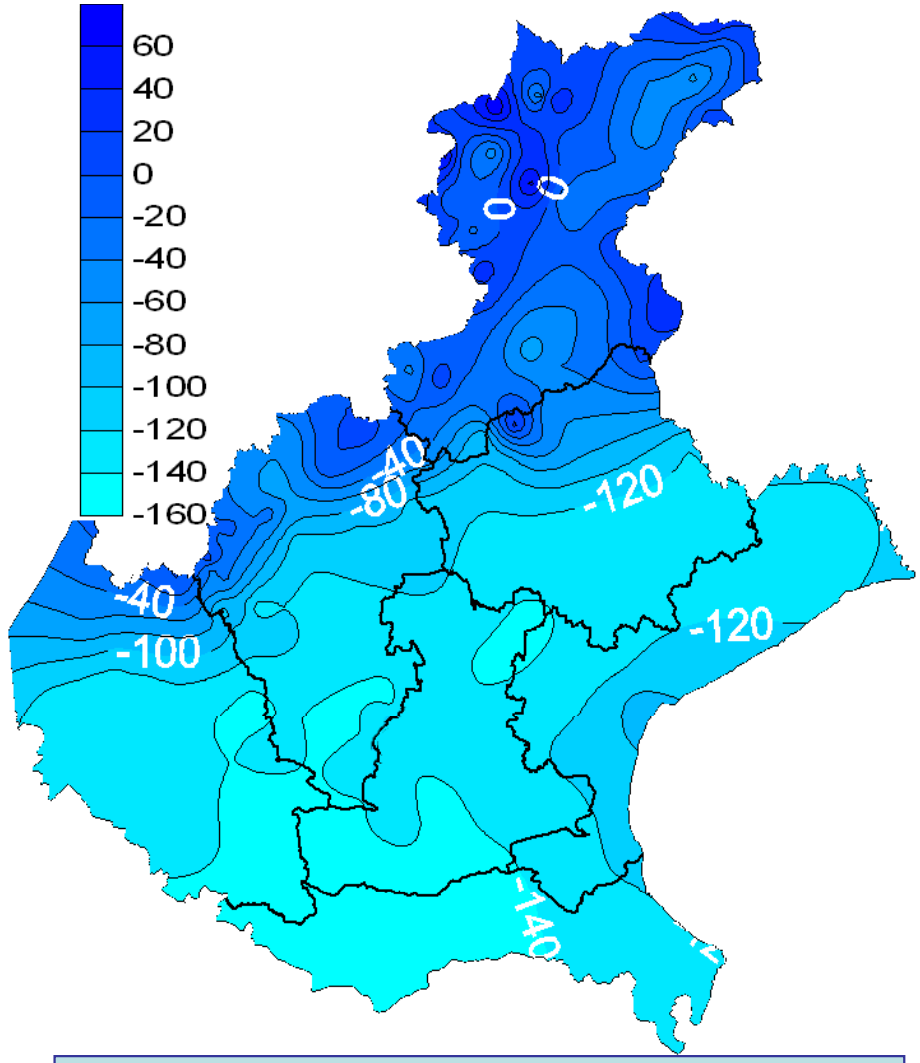


Alp-Water-Scarce

Alpine space In Movement

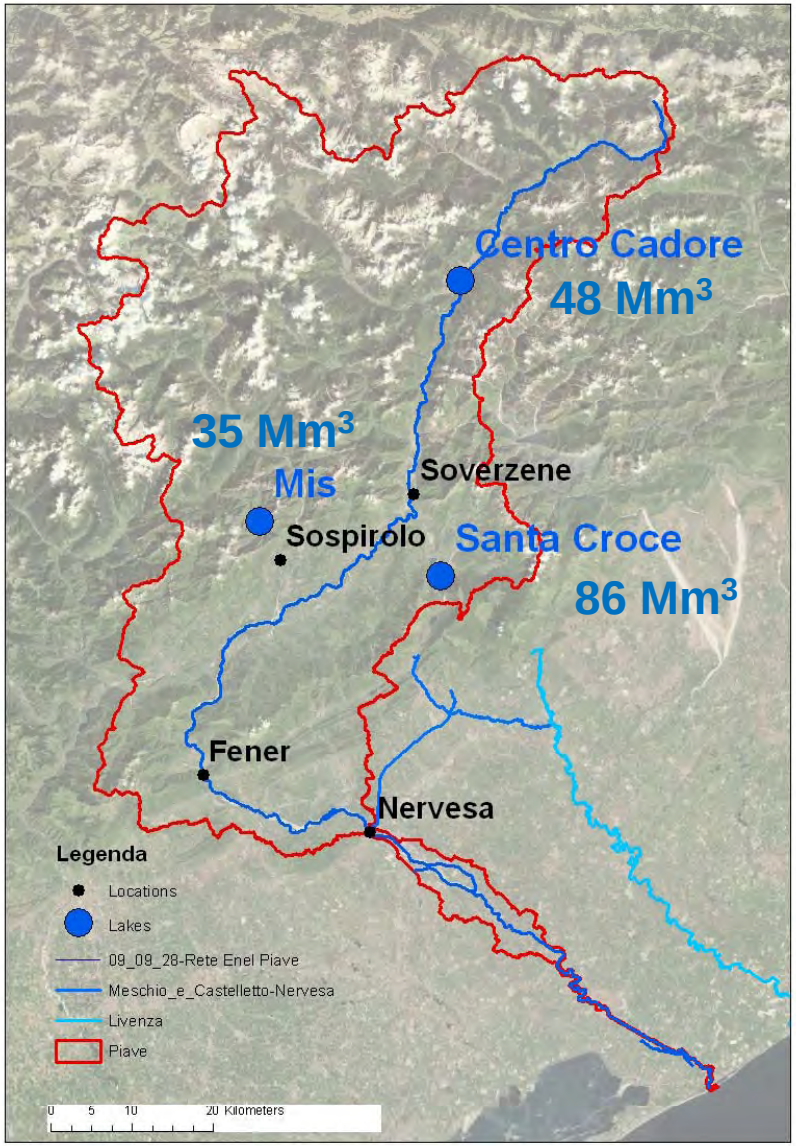
Hydro-climatic balance

- Hydro-climatic balance:
  - P – EPT (Hargreaves)
- in August 2011
  - Mountain: balance null
  - Plain: deficit over 100 mm (equivalent to 940 Mm^3)



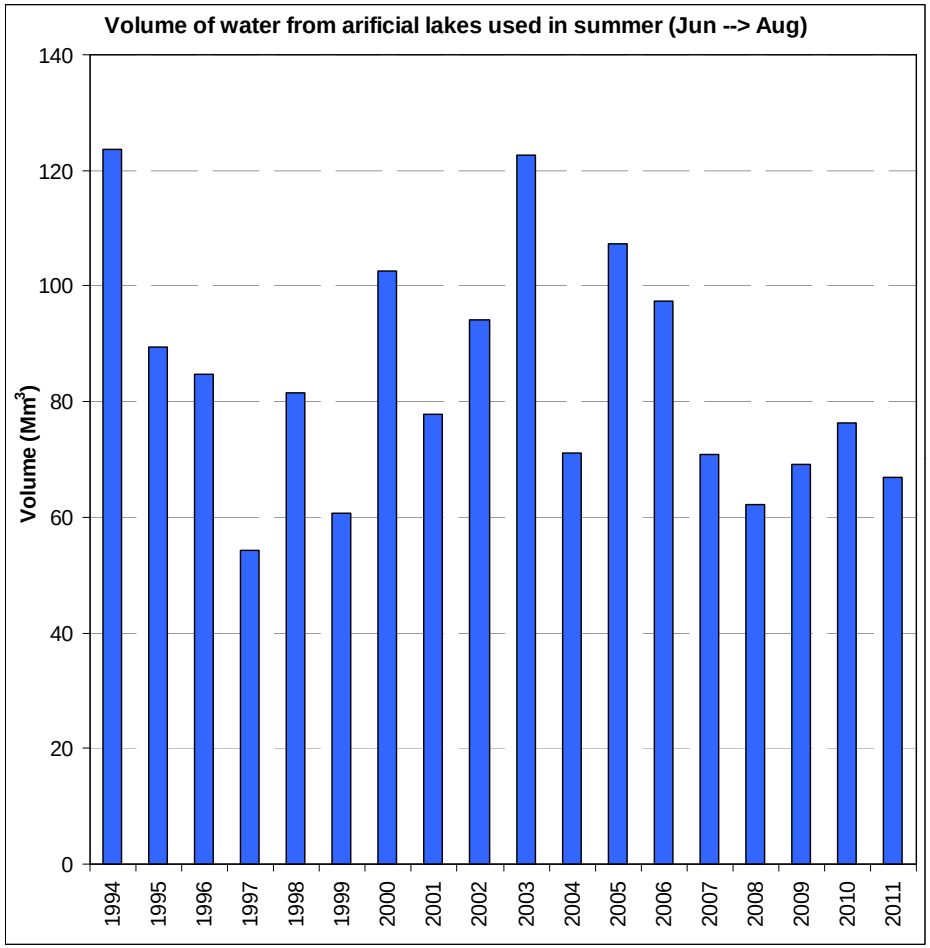
Hydro-climatic balance in August 2011

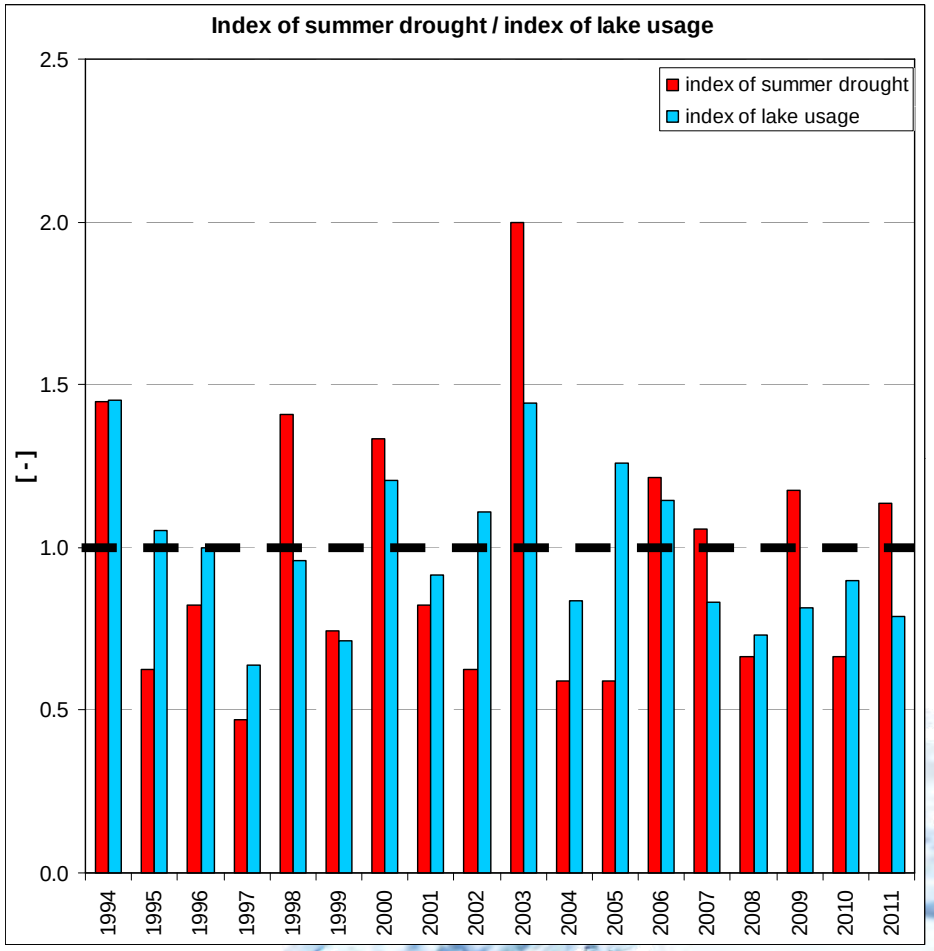
Artificial reservoirs – Upper Piave River



3 main reservoirs		
Potential volume	**169**	**Mm³**
In summer (Jun, Jul, Aug) 1993 - 2011		
Mean used V	84	Mm³
min used V	54	Mm³
MAX used V	124	Mm³
Mean Q	10.6	m³/s
MAX Q	15.6	m³/s

Reservoirs volume & summer droughts



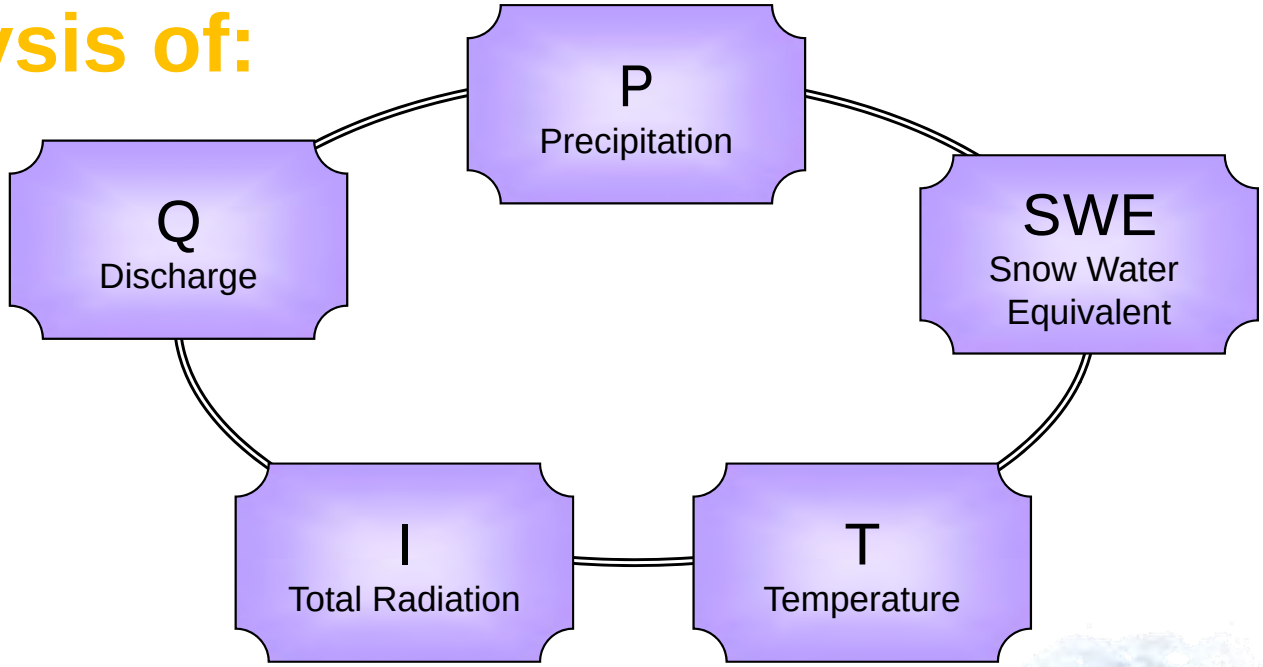


Index of summer droughts takes into account:

- number of days with temperature > 30°C;
- number of days with temperature > 35°C;
- number of days with no precipitation during summer;
- max number of consecutive days without precipitation

EWS – Early Warning System

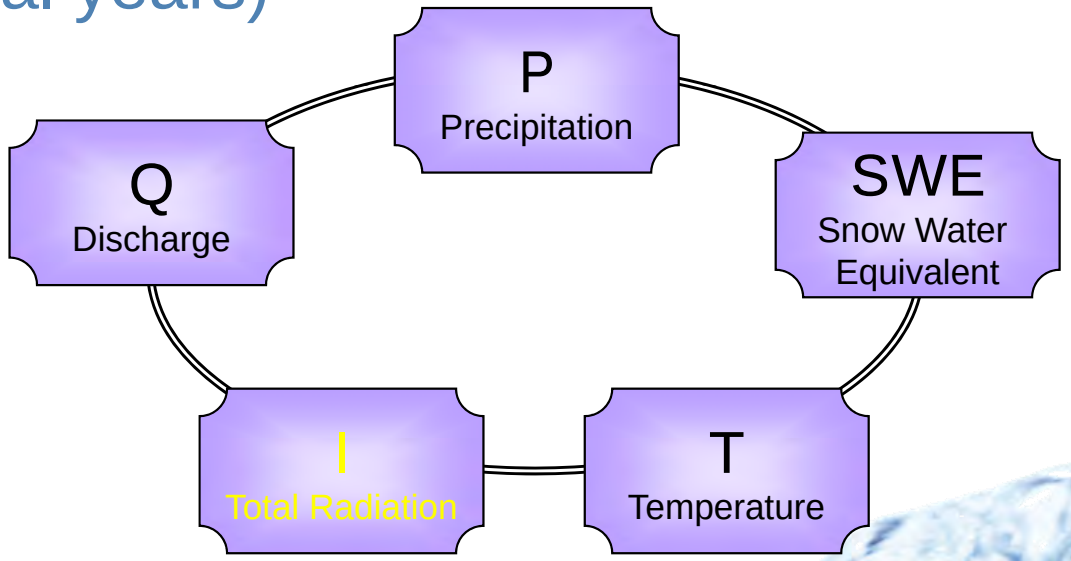
- **Statistical analysis of:**
  1. precipitation
  2. discharge
  3. temperature
  4. snow
  5. total radiation



- **Method:**
  - ➢ combined analysis of the main hydrological variables during the most important period for reservoirs refilling
- **Purpose:** ALERT in spring against Water Scarcity

EWS – Water Scarcity Index (WSI)

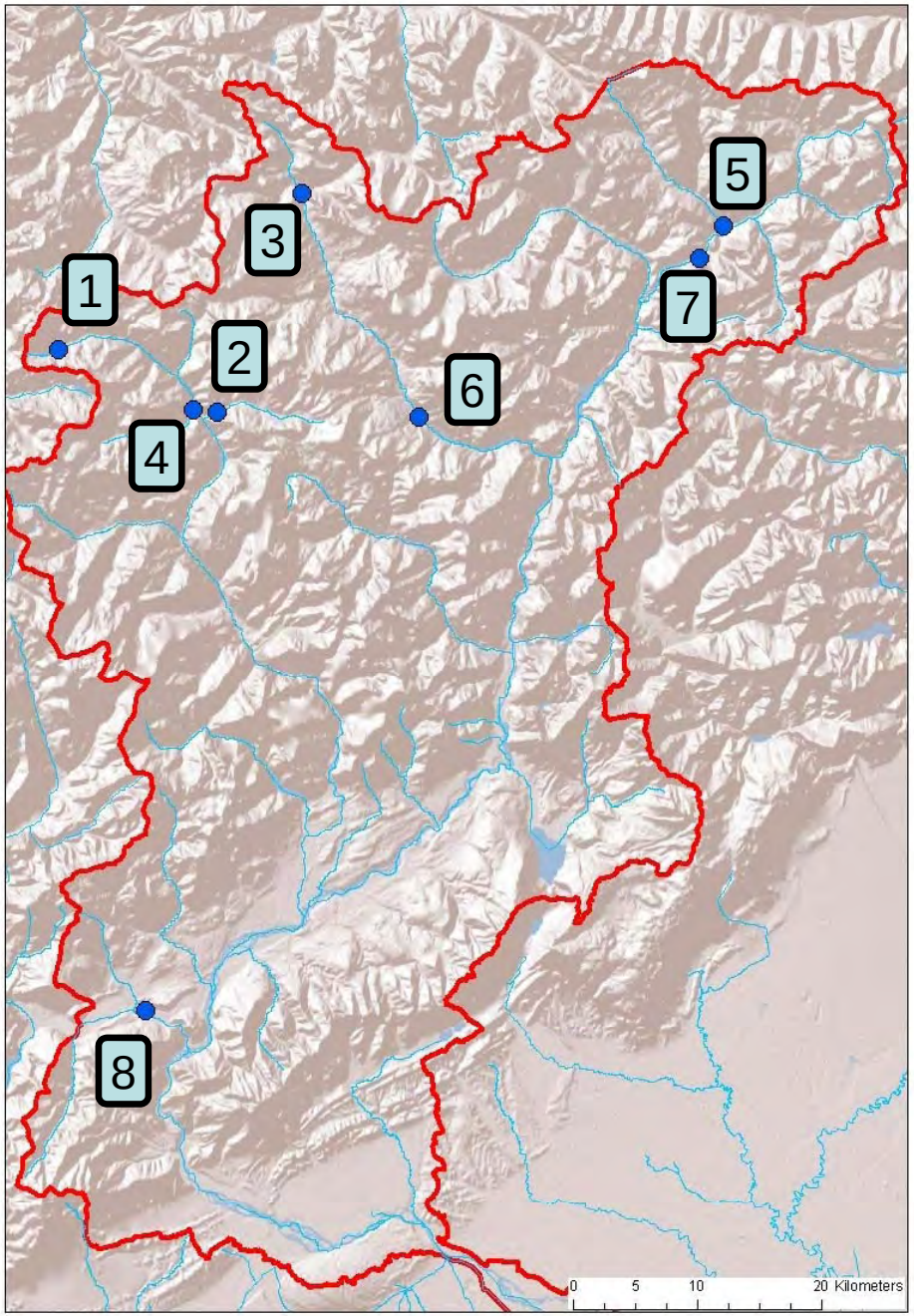
- Evaluation of the percentiles of P, SWE, T, I, Q
- implementation of weights and WSI calculation
- weights and threshold value are calibrated using past data (critical years)



Water scarcity index

$$WSI = \Sigma P_{year}\, w_1 + \Sigma P_{DEC}\, w_2 + SWE\, w_3 + \Sigma h_{snow}\, w_4 + T_{year}\, w_5 + + T_{mar}\, w_6 + (I\, w_7) + q_{year}\, w_8 + q\, w_9 + \Sigma q_{Jan}\, w_{10}$$

EWS approach



Analysis of the natural discharges in 8 mountainous catchments

Alpine rivers:

1. Cordevole at La Vizza - 7.15 km^2
2. Fiorentina at Sottorovei - 56 km^2
3. Boite at Podestagno - 82 km^2
4. Cordevole at Saviner - 109 km^2
5. Padola at Santo Stefano - 134 km^2
6. Boite at Cancia - 310 km^2
7. Piave at Ponte della Lasta - 357 km^2

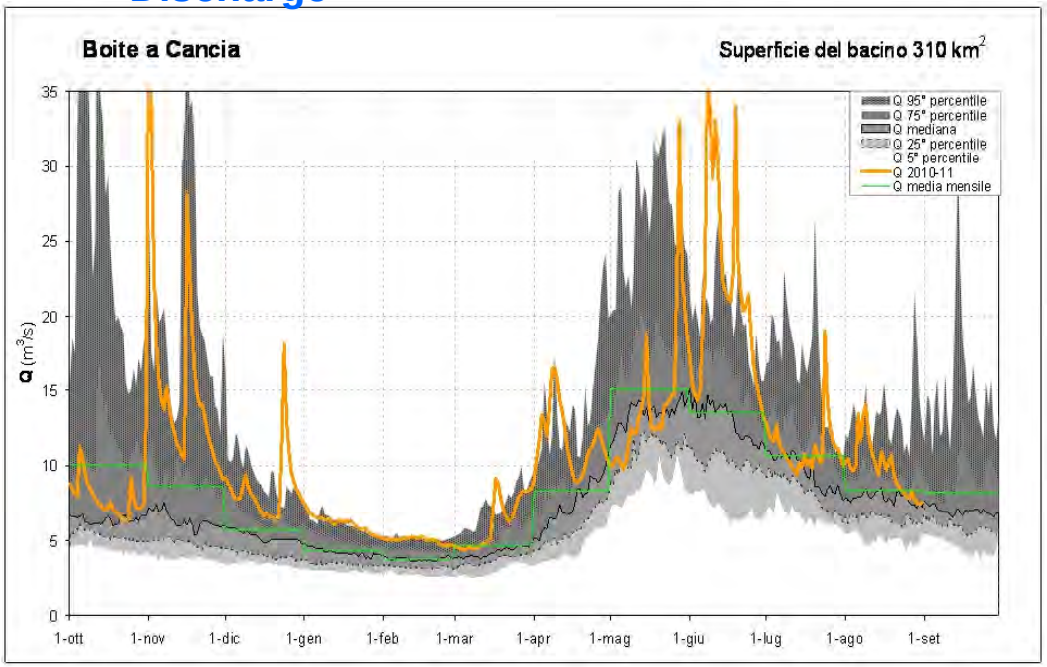
Pre-alpine rivers:

8. Sonna at Feltre 120 km^2

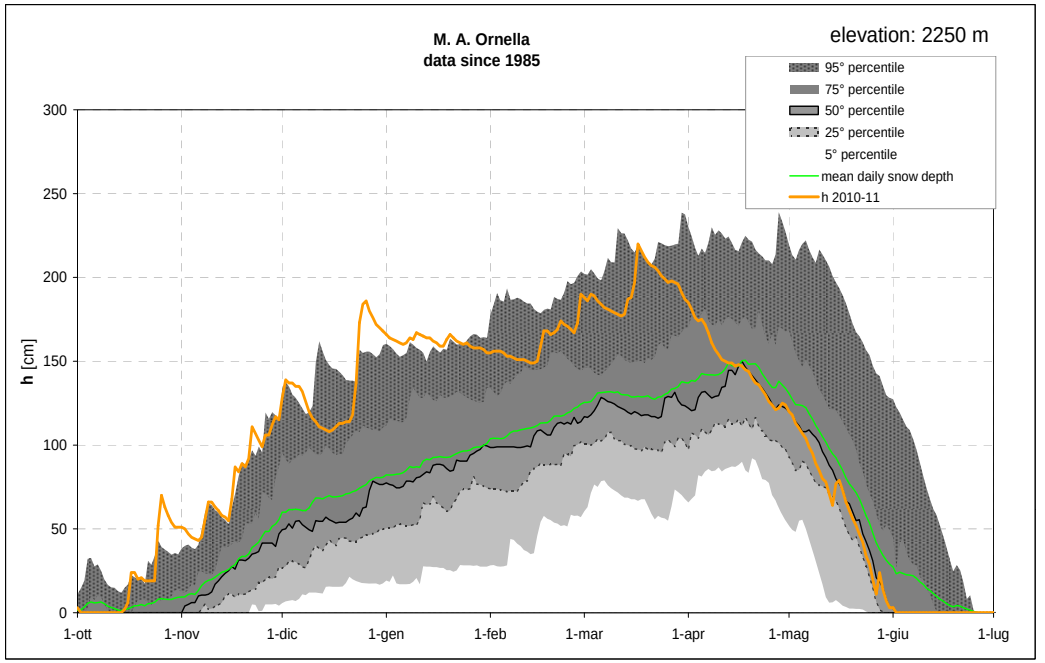
A_{tot} = 1175 km^2 ; 30% of A_{Piave}

Application of the WSI for the hydrological year 2010-2011

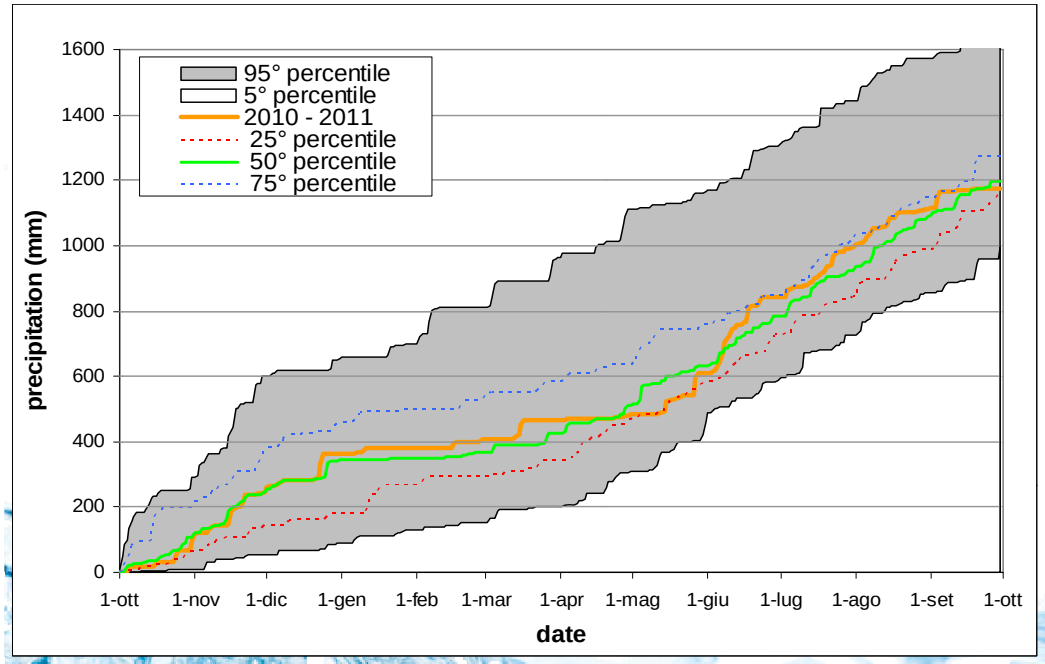
Discharge



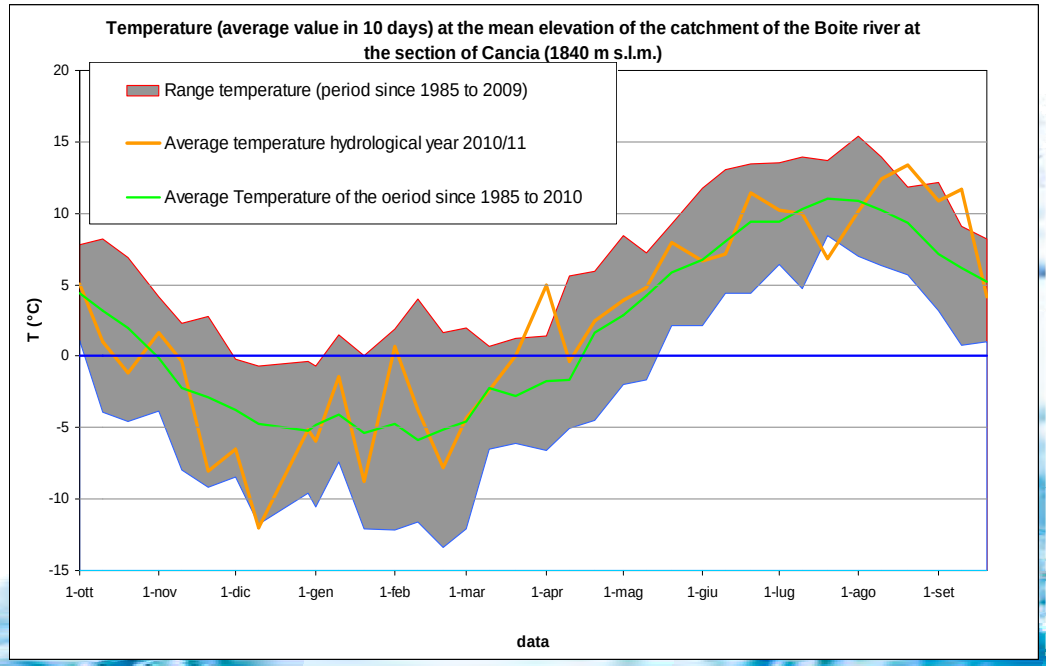
Snow



Precipitation



Temperature



WSI values – from 1990-1991

situation at: 31 January 2013													
Hydrological year (1 Oct - 30 Sep)	percentiles									WSI	Predicted water scarcity (Yes / No)	*Real situation of water scarcity (Yes / No)*	Indicator reliability
	rainfall		discharge			temperature		snow					
	cumulated rainfall from 1 Oct	cumulated rainfall from 1 Dec	mean discharge from 1 Oct	mean discharge till now	cumulated water volume drained from 1 Jan	mean temperature from 1 Oct	mean temperature from 1 Mar	snow pack - mean value of 10 days before now	cumulated snowfall till now				
weight:	***0.05***	***0.15***	***0.20***	***0.10***	***0.10***	***0.05***	***0.10***	***0.15***	***0.10***	***0.50***	***WSI threshold***		
1990 - 1991	0.82	0.67	0.41	0.69	0.59	**0.00**		1.00	0.87	0.74	N	*?*	-
1991 - 1992	0.52	0.52	0.61	**0.39**	0.49	**0.35**		0.69	0.54	0.60	N	*?*	-
1992 - 1993	0.50	**0.12**	0.56	0.43	0.51	0.58		**0.30**	0.74	**0.49**	**Y**	*?*	-
1993 - 1994	0.75	0.50	0.94	0.69	0.71	**0.37**		**0.19**	**0.37**	0.64	N	***Y***	failed alarm
1994 - 1995	**0.05**	**0.33**	0.59	0.61	0.58	0.55		0.61	**0.41**	0.54	N	***Y***	failed alarm
1995 - 1996	**0.00**	**0.20**	**0.38**	**0.15**	**0.18**	**0.23**		**0.11**	**0.00**	**0.29**	**Y**	*N*	false alarm
1996 - 1997	0.72	**0.03**	0.78	0.75	0.74	0.83		0.57	**0.20**	0.56	N	*N*	**OK**
1997 - 1998	**0.25**	0.57	**0.28**	0.65	0.57	0.80		0.65	0.49	0.53	N	***Y***	failed alarm
1998 - 1999	0.62	0.75	0.54	0.48	**0.38**	**0.17**		**0.34**	0.66	0.60	N	*N*	**OK**
1999 - 2000	**0.10**	**0.30**	0.64	0.66	0.63	0.52		**0.00**	**0.04**	**0.44**	**Y**	*N*	false alarm
2000 - 2001	1.00	0.87	0.93	0.93	0.97	0.85		0.92	0.91	0.89	N	*N*	**OK**
2001 - 2002	**0.38**	0.93	**0.16**	**0.18**	**0.13**	0.92		**0.15**	**0.08**	**0.36**	**Y**	*N*	false alarm
2002 - 2003	0.88	**0.02**	0.81	0.90	0.87	0.67		**0.07**	**0.29**	0.54	N	***Y***	failed alarm
2003 - 2004	0.80	0.52	**0.33**	**0.39**	0.41	**0.13**		0.96	0.95	0.65	N	*N*	**OK**
2004 - 2005	**0.22**	**0.15**	**0.36**	**0.38**	**0.35**	**0.38**		0.53	**0.25**	**0.41**	**Y**	***Y***	**OK**
2005 - 2006	**0.37**	**0.28**	0.47	**0.16**	**0.14**	**0.07**		0.42	0.62	**0.46**	**Y**	***Y***	**OK**
2006 - 2007	**0.15**	0.83	**0.05**	**0.12**	**0.09**	1.00		**0.03**	**0.16**	**0.28**	**Y**	*N*	false alarm
2007 - 2008	**0.35**	0.75	**0.15**	**0.29**	**0.22**	0.67		0.73	0.70	0.51	N	*N*	**OK**
2008 - 2009	0.95	1.00	0.65	0.76	0.72	0.60		0.88	1.00	0.83	N	*N*	**OK**
2009 - 2010	0.53	0.72	**0.32**	0.46	0.66	**0.15**		0.84	0.83	0.66	N	*N*	**OK**
2010 - 2011	0.55	0.45	0.72	0.82	0.88	0.67		0.50	0.79	0.68	N	*N*	**OK**
2011 - 2012	**0.08**	**0.15**	**0.38**	**0.21**	**0.25**	0.93		**0.23**	0.45	**0.33**	**Y**	***Y***	**OK**
2012 - 2013	0.77	0.39	0.96	0.89	0.86	0.72		0.92	0.95	0.81	N	*N*	**OK**

WSI real application – 2012 drought

situtation at:	15-jan	31-jan	15-feb	28-feb	15-mar	31-mar	15-apr	30-apr	15-may	31-may	15-jun	WSI mean
hydrological year	WSI	WSI	WSI	WSI	WSI	WSI	WSI	WSI	WSI	WSI	WSI	
1990 - **1991**	0.73	0.72	0.75	0.73	0.69	0.75	0.73	0.74	0.77	0.80	0.80	0.75
1991 - **1992**	0.52	**0.49**	**0.45**	**0.41**	**0.31**	**0.36**	0.63	0.68	0.68	0.62	0.56	0.52
1992 - **1993**	0.65	0.63	0.59	0.58	0.55	0.55	0.51	**0.47**	**0.43**	**0.35**	**0.38**	0.52
1993 - **1994**	0.78	0.76	0.80	0.78	0.61	0.57	0.55	0.58	**0.49**	0.55	0.59	0.64
1994 - **1995**	**0.40**	**0.43**	**0.45**	0.50	0.51	**0.47**	**0.35**	**0.38**	**0.35**	**0.45**	0.62	**0.45**
1995 - **1996**	**0.44**	**0.43**	**0.42**	**0.38**	**0.32**	**0.30**	**0.26**	**0.23**	**0.24**	**0.25**	**0.24**	**0.32**
1996 - **1997**	0.76	0.74	0.70	0.67	0.56	**0.49**	**0.35**	**0.33**	**0.37**	**0.34**	**0.34**	0.51
1997 - **1998**	0.57	0.58	0.53	0.53	**0.43**	**0.36**	**0.43**	0.50	0.51	**0.50**	0.52	**0.50**
1998 - **1999**	**0.47**	**0.46**	**0.48**	**0.45**	0.52	0.53	0.52	0.55	0.57	0.58	0.59	0.52
1999 - **2000**	**0.49**	**0.49**	**0.45**	**0.43**	**0.35**	**0.43**	**0.42**	**0.41**	**0.35**	**0.26**	**0.29**	**0.40**
2000 - **2001**	0.89	0.92	0.90	0.87	0.85	0.83	0.83	0.80	0.83	0.82	0.77	0.85
2001 - **2002**	**0.19**	**0.19**	**0.19**	**0.21**	**0.18**	**0.12**	**0.12**	**0.17**	**0.37**	**0.36**	**0.42**	**0.23**
2002 - **2003**	0.73	0.74	0.71	0.67	0.53	**0.46**	**0.47**	**0.39**	**0.35**	**0.30**	**0.36**	0.52
2003 - **2004**	0.61	0.61	0.59	0.64	0.60	0.64	0.63	0.62	0.67	0.70	0.70	0.64
2004 - **2005**	**0.43**	**0.44**	**0.44**	**0.42**	**0.37**	**0.33**	**0.28**	**0.29**	**0.24**	**0.30**	**0.27**	**0.35**
2005 - **2006**	**0.45**	**0.45**	**0.41**	0.51	**0.48**	**0.45**	**0.47**	**0.50**	0.51	**0.47**	**0.40**	**0.46**
2006 - **2007**	**0.22**	**0.30**	**0.33**	**0.33**	**0.29**	**0.41**	**0.37**	**0.31**	**0.21**	**0.20**	**0.30**	**0.30**
2007 - **2008**	**0.42**	**0.44**	**0.49**	**0.46**	**0.48**	**0.46**	**0.43**	**0.50**	**0.44**	0.57	0.56	**0.48**
2008 - **2009**	0.83	0.85	0.87	0.87	0.84	0.85	0.85	0.88	0.87	0.85	0.83	0.85
2009 - **2010**	0.67	0.67	0.66	0.69	0.64	0.67	0.68	0.61	0.76	0.73	0.66	0.68
2010 - **2011**	0.87	0.85	0.80	0.82	0.74	0.75	0.68	0.59	0.52	0.57	0.66	0.71
2011 - **2012**	**0.31**	**0.30**	**0.33**	**0.31**	**0.25**	**0.22**	**0.24**	**0.28**	**0.20**	**0.20**	**0.28**	**0.26**

WSI mean	hydrological year
0.23	2001 - 2002
0.26	**2011 - 2012**
0.30	2006 - 2007
0.32	1995 - 1996
0.35	2004 - 2005
0.40	1999 - 2000
0.45	1994 - 1995
0.46	2005 - 2006
0.48	2007 - 2008
0.50	1997 - 1998
0.51	1996 - 1997
0.52	1992 - 1993
0.52	1991 - 1992
0.52	2002 - 2003
0.52	1998 - 1999
0.64	2003 - 2004
0.64	1993 - 1994
0.68	2009 - 2010
0.71	2010 - 2011
0.75	1990 - 1991
0.85	2000 - 2001
0.85	2008 - 2009

WSI threshold = 0.50

WSI real application – 2012 drought

Year	15/01	31/01	15/02	28/02	15/03	31/03	15/04	30/04	15/05	31/05	15/06	WSI mean
2012	0.31	0.30	0.33	0.31	0.25	0.22	0.24	0.28	0.20	0.20	0.28	**0.26**

WARNING to the River Basin Authority Level of "medium" drought

4 Ordinances of the Veneto Region President: n. 67 (3 April) – 84 (2 May) – 113 (31 May) – 130 (5 July)

Provisions against water scarcity:

- MIF reduction (up to 50%)
- reduction of water withdrawal for agriculture (up to 40%)
- retain additional water in the reservoirs
- maintain high water level in the reservoirs
- avoid water waste (responsible behaviours)

WSI real application - 2012 drought

Enforced monitoring and forecasting of water resources:

- additional discharge measurements about MIF
- additional discharge measurements about water withdrawal for agriculture
- technical boards involving main stakeholders
- website with detailed informations about water availability in Veneto
- hydro-meteorological bulletin (every 7 days) about:
  - previous 7 days water resources (rainfall, discharge, groundwater)
  - weather forecast for the next 7 days

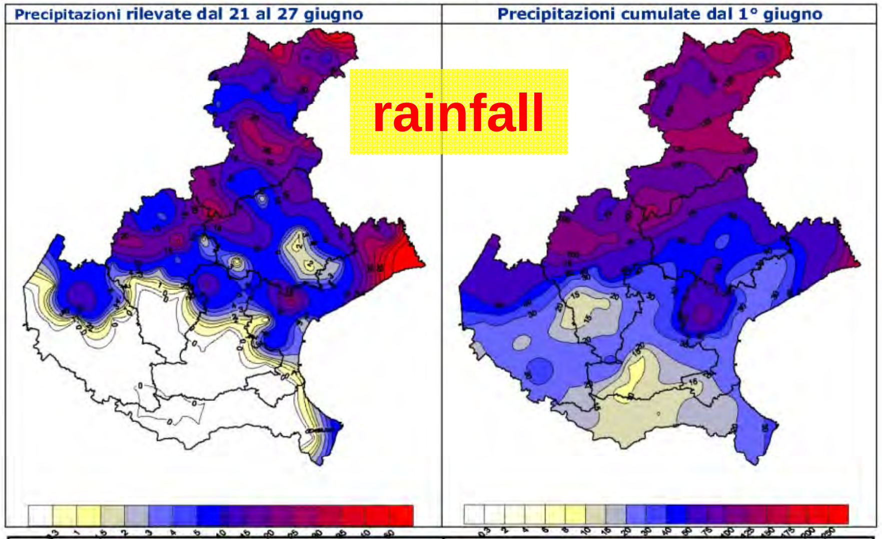
WSI real application - 2012 drought

hydro-meteorological bulletin (every 7 days)

arpav
Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto

Situazione idrometeorologica
Bollettino di aggiornamento del 28 giugno 2012

Distribuzione delle precipitazioni in Veneto (mm)



Portata corsi d'acqua (m^3/s)				
Stazione	Bacino	storica media giugno	2012 media maggio	2012 media 1-27 giugno
Piave a Ponte della Lasta	Piave	12.77	9.52	10.77
Boite a Cancia	Piave	13.80	11.5	11.4
Cordevole a Saviner	Piave	4.70	4.22	3.55
Brenta a Barziza	Brenta	89,7	71,7	52,0
Astico a Pedescala	Bacchiglione	3.75	5.65	4.07
Posina a Stancari	Bacchiglione	2.64	3.88	2.28
Bacchiglione a Montegalda	Bacchiglione	28.2	18.9	10.2
Adige a Boara Pisani	[illegible]	[illegible]	[illegible]	244
Po a Pontelagoscuro	Po	1787	1938	1153

discharge

Freatimetria (m s.l.m.)					
Stazione	Acquifero	storica media giugno	2012 21 giugno	2012 28 giugno	Trend
San Massimo	Alta Pianura VR	49.21	48.30	48.52	+0.22
Dueville	Alta Pianura VI	54.39	54.10*	54.05+	-0.05
Schiavon	Alta Pianura VI	65.18	64.51*	64.61+	+0.10
Cittadella	Alta Pianura PD	40.28	39.67	39.60	-0.07
Castelfranco Veneto	Alta Pianura TV	33.00	31.93	31.92	-0.01
Varago	Alta Pianura TV	24.79	24.78	24.83	+0.05
Mareno di Piave	Alta Pianura TV	30.94	30.83	30.92	+0.09
Castagnole	Alta [illegible]	[illegible]	[illegible]	[illegible]	+0.04
Villafranca Veronese	Alta Pianura VR	48.39	47.33	47.48	+0.15

* dato riferito al 20 giugno; + dato riferito al 26 giugno

groundwater

Dipartimento Regionale per la Sicurezza del Territorio
Via F. Tomea 5, 32100 Belluno Italy Tel. 0437-935600 Fax 0437-935601 e-mail: dst@arpa.veneto.it

arpav
Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto

Situazione idrometeorologica
Bollettino di aggiornamento del 28 giugno 2012

Precipitazioni previste per i prossimi 7 giorni

(previsioni emesse dal Centro Meteorologico di Teolo giovedì 28 giugno e basate principalmente su modello del Centro Europeo ECMWF)

Previsioni per i prossimi 4 giorni (attendibilità alta >70%)

Venerdì 29 e Sabato 30	Condizioni di alta pressione per la rimonta dell'anticiclone Nord-africano porteranno prevalente stabilità atmosferica slavo una moderata variabilità pomeridiana specie venerdì e sulle zone montane orientali. Le precipitazioni saranno generalmente assenti salvo qualche fenomeno probabile sulle zone montane, a prevalente carattere di rovescio o temporale, più probabile venerdì pomeriggio sul Bellunese con quantitativi mediamente scarsi.
Domenica 1 e Lunedì 2	Tra domenica e lunedì l'azione del promontorio di alta pressione sarà ancora prevalente. Le precipitazioni saranno quindi ancora in prevalenza assenti. Solo nel pomeriggio di lunedì il parziale cedimento dell'anticiclone potrà favorire una certa variabilità, specie sui settori montani, con qualche rovescio/temporale.

Tabella probabilistica delle precipitazioni totali (medie areali) previste per i prossimi 4 giorni

Area	assenti	scarse (1-20mm)	contenute (20-60mm)	abbondanti (60-100mm)	molto abbondanti (>100 mm)
A- Alto Piave	■	■■■	0	0	0
B- Brenta	■	■■■	0	0	0
C- Lessini	■■■	■	0	0	0
D- Po di Venezia Tartaro	■■■	■■■	0	0	0
E- Pianura PD e VI	■■■	■■■	0	0	0
F- Sile	■■■	■■■	0	0	0
G- Livenza	■■	■■	0	0	0

Legenda
la probabilità è espressa attraverso le seguenti classi:
0 improbabili o probabilità molto bassa (<10%),
■ possibili o probabilità bassa (10-30%),
■■ probabili o probabilità media (30-70%),
■■■ molto probabili o probabilità alta (>70%)

weather forecast

Nota metodologica: l'attendibilità è basata sul grado di predicibilità del quadro previsionale esposto e sul confronto tra diverse corse dello stesso modello (e di altri modelli). In generale, il livello di attendibilità decade con il passare dei giorni, in particolare per la previsione quantitativa delle precipitazioni.

Tendenza per i successivi 3 giorni (attendibilità media 30-70%)

Tra **martedì 3 luglio e giovedì 5** lo scenario più probabile vede il progressivo cedimento dell'alta pressione con ingresso di correnti in quota occidentali che favoriranno condizioni di maggior variabilità e probabilità in moderato aumento di qualche precipitazione sparsa.

Dipartimento Regionale per la Sicurezza del Territorio
Via F. Tomea 5, 32100 Belluno Italy Tel. 0437-935600 Fax 0437-935601 e-mail: dst@arpa.veneto.it

ARPAV – Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto

Dipartimento Regionale per la Sicurezza del Territorio

Servizio Idrologico

via F. Tomea, 5 - 32100 Belluno (Italy)

tel. +39 0437 935 600

fax +39 0437 935 601

e-mail: dst@arpa.veneto.it

Santa Croce lake (Belluno, Italy) – 4 August 2011

ARPAV – Regional Agency for Environmental Prevention and Protection of Veneto

Regional Department for Land Safety

Hydrological Service

via F. Tomea, 5 - 32100 Belluno (Italy)

tel. +39 0437 935 600

fax +39 0437 935 601

e-mail: dst@arpa.veneto.it

Santa Croce lake (Belluno, Italy) – 12 September 2011