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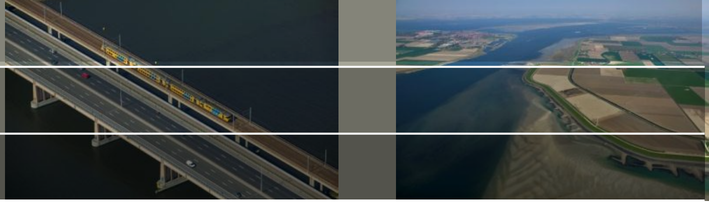
Enabling Delta Life

Conditional weather resampling for ensemble streamflow forecasting

Joost Beckers, Albrecht Weerts (Deltares Delft)
Edwin Welles (Deltares USA)
Ann McManamon (BPA)

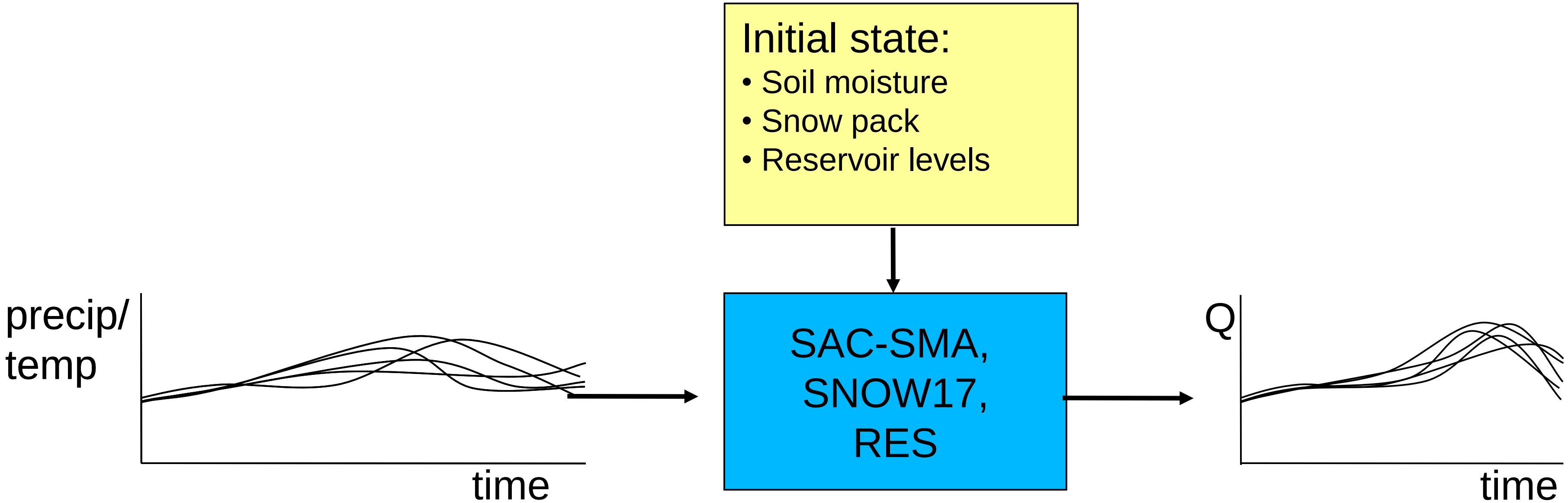
HEPEX 10th anniversary workshop
Washington DC, June 2014



ESP

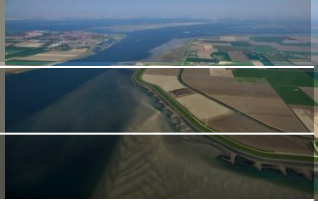
Seasonal streamflow forecasting by Bonneville Power Administration (BPA) :

- Classical ESP
- Meteo from 55 historical years to represent climate
- Run a hydrologic model starting from the current initial state



Day, G.N., 1985. Journal of Water Resources Planning and Management 111, 157–170.

Gerald Day, 1985



Extended Streamflow Forecasting Using NWSRFS[a]

By Gerald N. Day,[1] A. M. ASCE

Abstract: Extended forecasting using the National Weather Service River Forecast System (NWSRFS) is done with the NWS Extended Streamflow Prediction (ESP) program. This paper examines the theory, capabilities, and potential applications of the ESP procedure. ESP uses conceptual hydrologic/hydraulic models to forecast future streamflow using the current snow, soil moisture, river, and reservoir conditions with historical meteorological data. The ESP procedure assumes that meteorological events that occurred in the past are representative of events that may occur in the future. Each year of historical meteorological data is assumed to be a possible representation of the future and is used to simulate a streamflow trace. The simulated streamflow traces can be scanned for maximum flow, minimum flow, volume of flow, reservoir stage, etc., for any period in the future. ESP produces a probabilistic forecast for each streamflow variable and period of interest. The procedure was

One area of future research for ESP is the ability to incorporate knowledge of the current climatology into the procedure. Historical years of precipitation and temperature may or may not be equally representative of the current climatology.

by the National Weather Service (NWS) and the Soil Conservation Service (SCS). Both of these agencies currently rely primarily on regression procedures to forecast seasonal water supply volumes. The regression procedures use a combination of monthly precipitation, first of the month snow water equivalent measurements, and past streamflow to predict streamflow volumes. The 10 and 90% exceedance probability levels are estimated from historical knowledge of how forecast accuracy varies throughout the forecast season. In most years, the regression procedures provide excellent forecasts of seasonal streamflow volumes; however, they sometimes fail to perform well in extreme years.

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El Niño effects on local weather in PNW

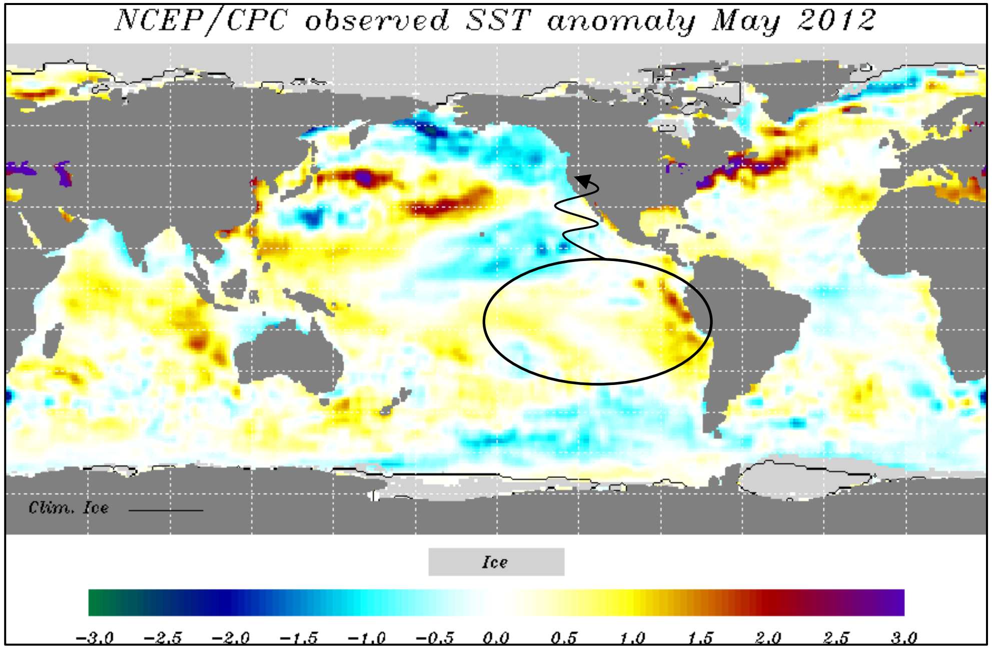
El Niño
Warm and dry

La Niña
Cold and wet

Climate Mode Indices

MEI
QBO.esrl
QBO.org
QBO.anom
QBO.std
SOI.anom
SOI.std
NINO
TNI
NAO
EA
WP

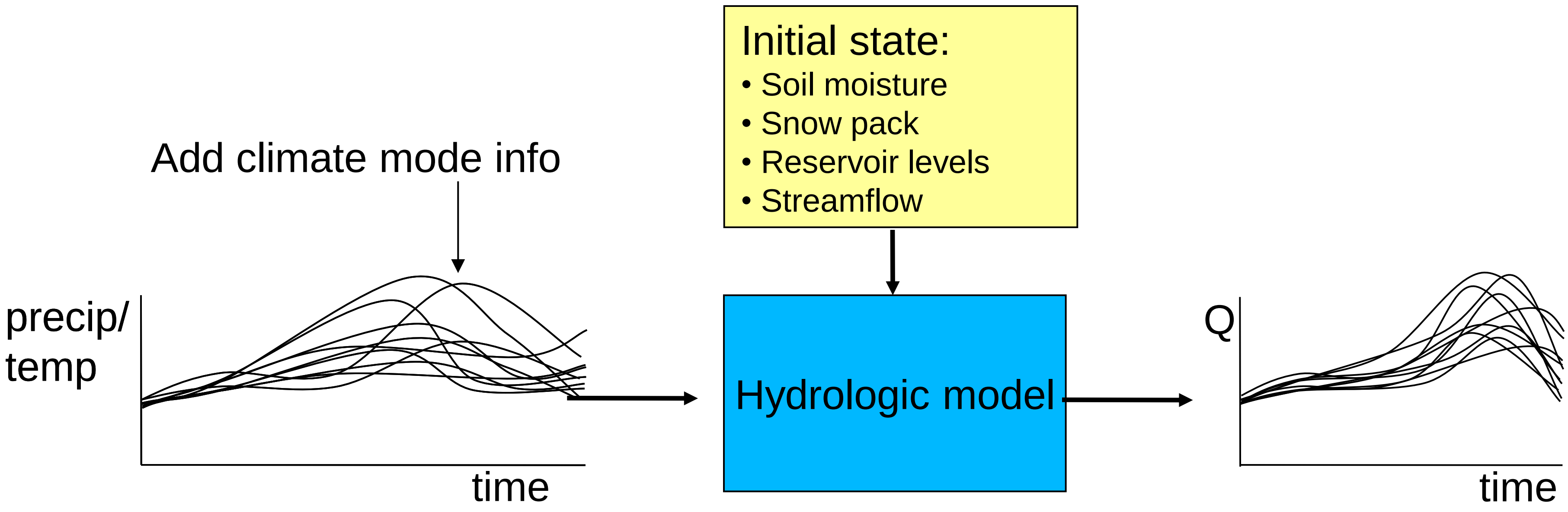
PNA
EA/WR
EP/NP
SCA
TNH
POL
PT
AMO
AO
PDO
MJO.phase
MJO.ampl



Historical and current phases available online:
http://www.cpc.ncep.noaa.gov/
http://www.esrl.noaa.gov/psd/
http://www.cawr.gov.au/ (MJO)
http://jisao.washington.edu/ (PDO)

Challenge

Use climate mode information to improve the skill of the ESP



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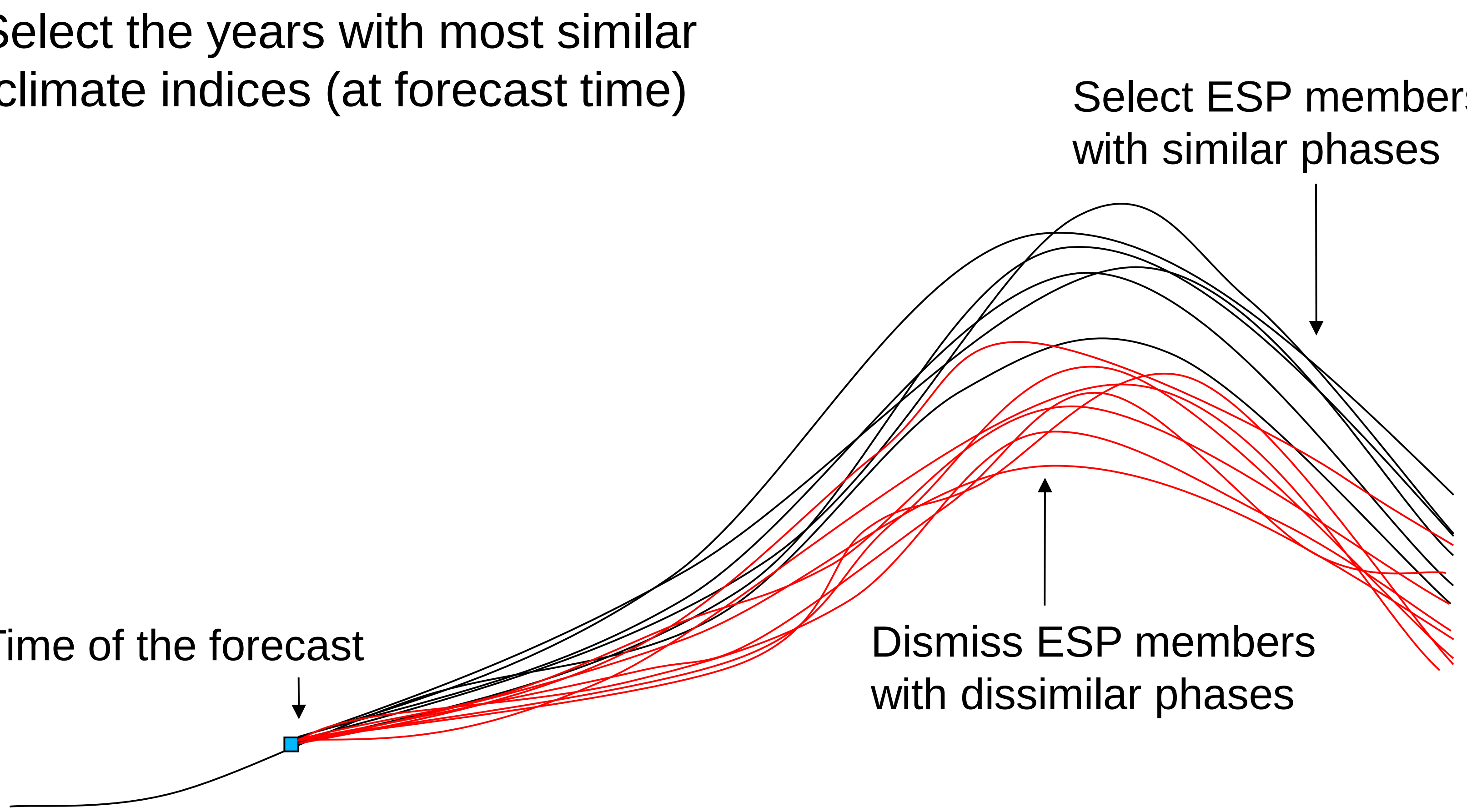
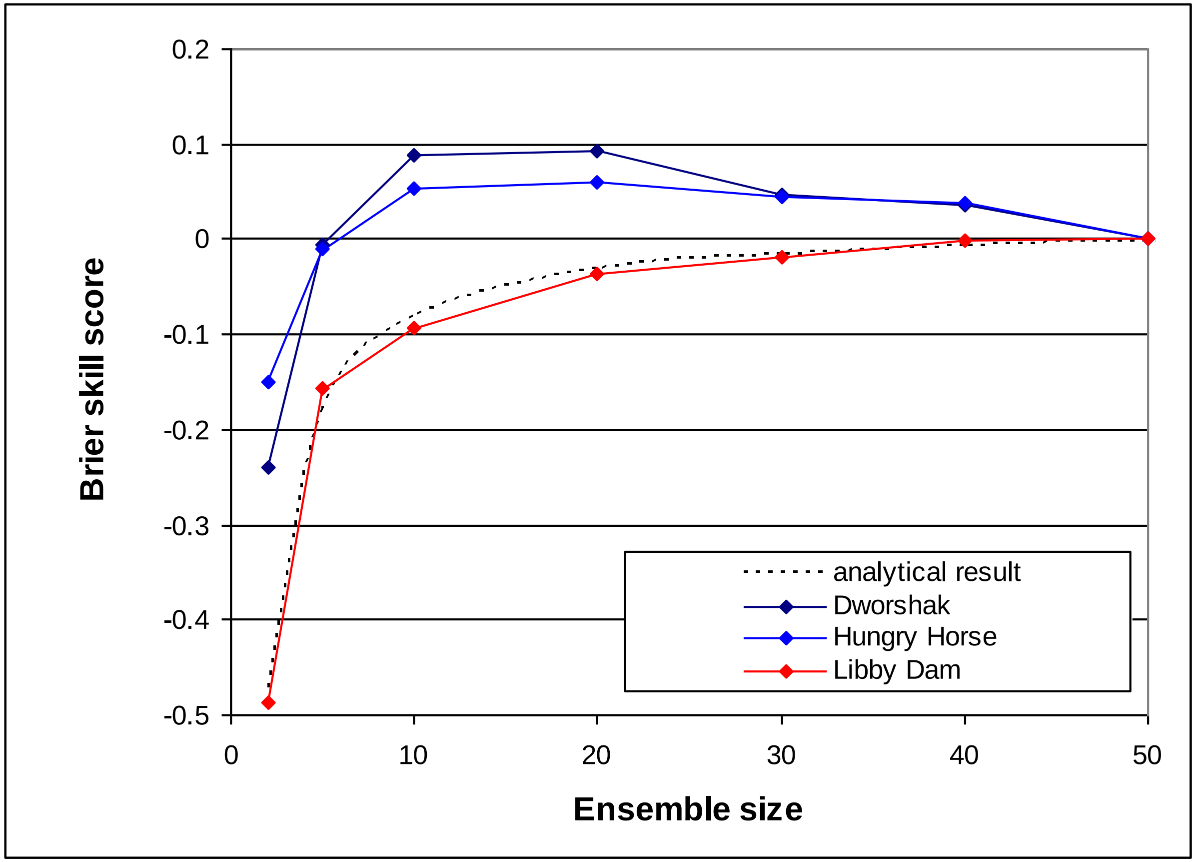
Conditioning of the ESP



Hamlet, A., Lettenmaier, D., (1999) Journal of Water Resources Planning and Management 125, 333–341.

Problem

Smaller ensemble leads to more sampling uncertainty, less accurate quantile estimates and less forecast skill



C.A.T. Ferro: Weather and Forecasting 22, pp 1076-1088 (2007).

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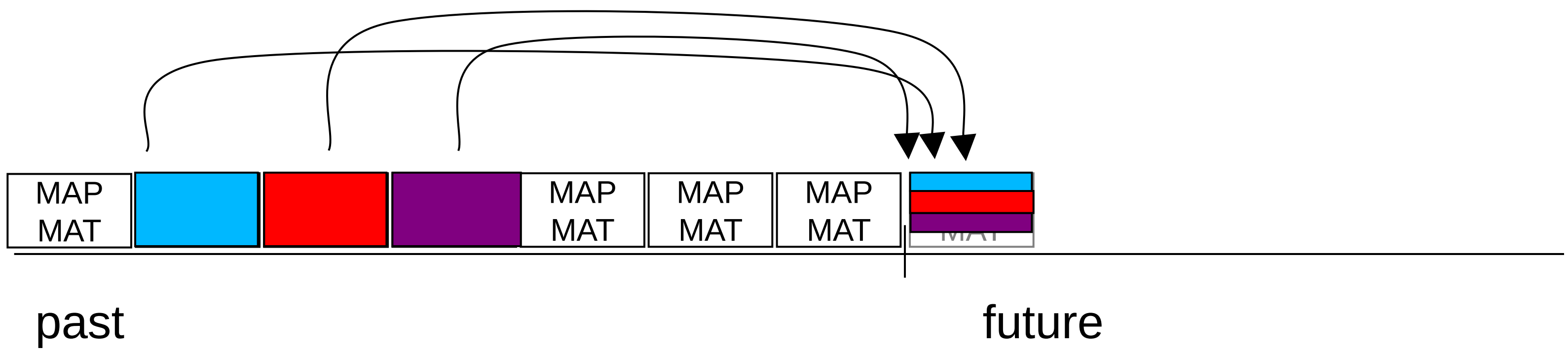
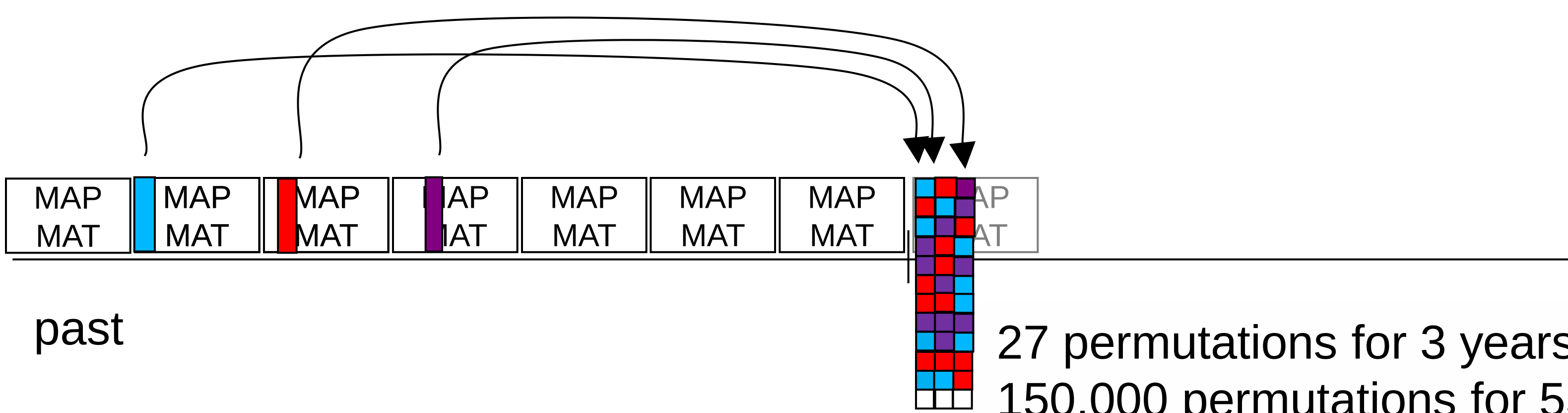
Solution

Generate more ensemble members

Have a closer look at the ESP:





27 permutations for 3 years

150,000 permutations for 55 years

Solution

Instead of full historical years (ESP), use parts of historical years:

- Monthly resampling period (1 seam per 30 days)
- Assemble historical MAP and MAT into forecast time series
- Condition on climate mode indices

Conditional sampling

Historical time series of monthly climate index

	JUN	JUL	AUG	SEP
1995	0.5	0.2	-.2	-.5
1996	0.0	-.2	-.4	-.5
1997	2.3	2.7	3.0	3.0
1998	1.1	0.2	-.4	-.7
1999	-.4	-.5	-.8	-1
2000	-.2	-.2	-.1	-.2
2001	-.1	0.2	0.4	-.1
2002	0.9	0.6	0.9	0.8
2003	0.0	0.1	0.2	0.4
2004	0.2	0.4	0.7	0.5
2005	0.5	0.5	0.3	0.3
2006	0.5	0.6	0.7	0.8
2007	-.4	0.3	-.5	-1.2
2008	0.1	0.0	-.3	-0.7
2009	0.9	0.9	0.9	0.8
2010	-.5	-1.2	-1.8	-2.0
2011	-.2	-.1	-.5	-0.8

Simulated time series

	ENSO	MAP/MAT
2014-JUN	0.9	
2014-JUL	0.2	1998-JUL
2014-AUG	0.4	2001-AUG
2014-SEP	0.3	2005-SEP
…		

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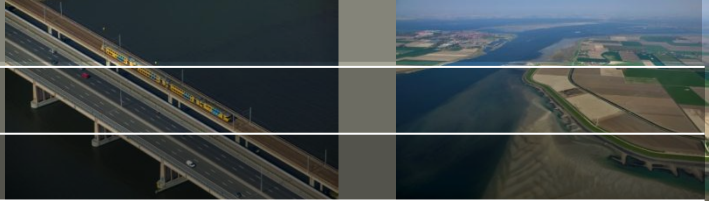
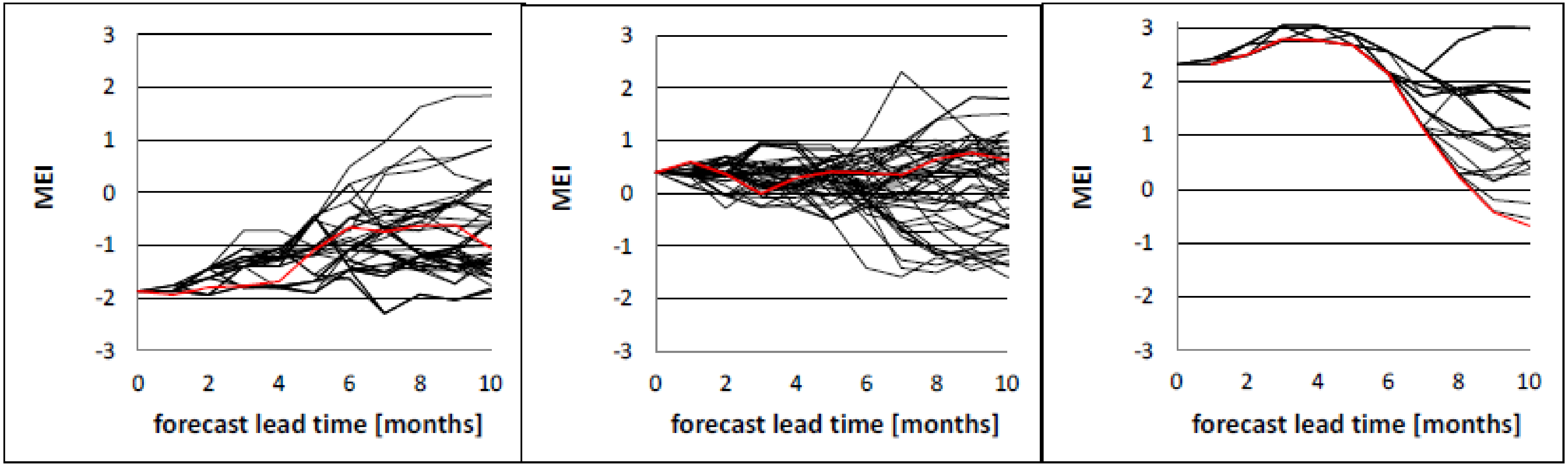
Results

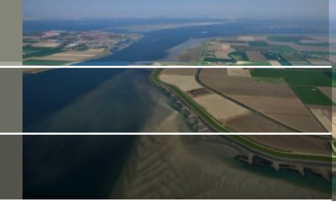


Ensembles of synthetic ENSO index time series

1973	1978	1997
La Niña year	Average year	El Niño year
Negative MEI		Positive MEI

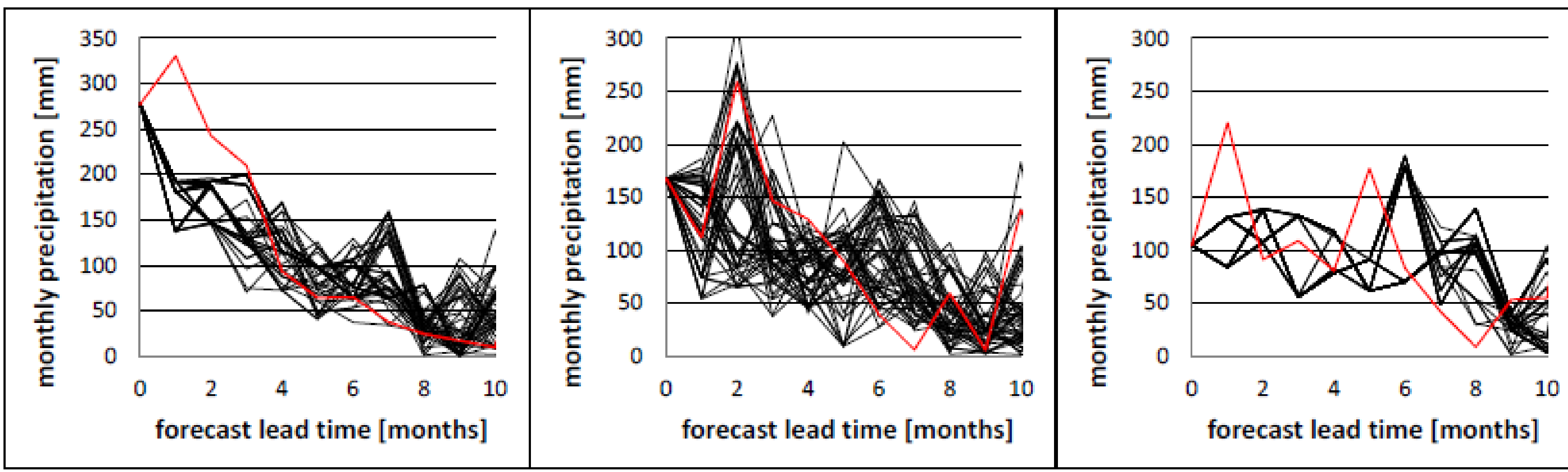


Results



Ensembles of monthly precipitation

1973	1978	1997
La Niña year	Average year	El Niño year
Wet winter		Dry winter



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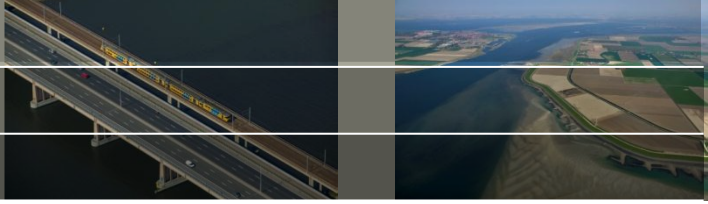
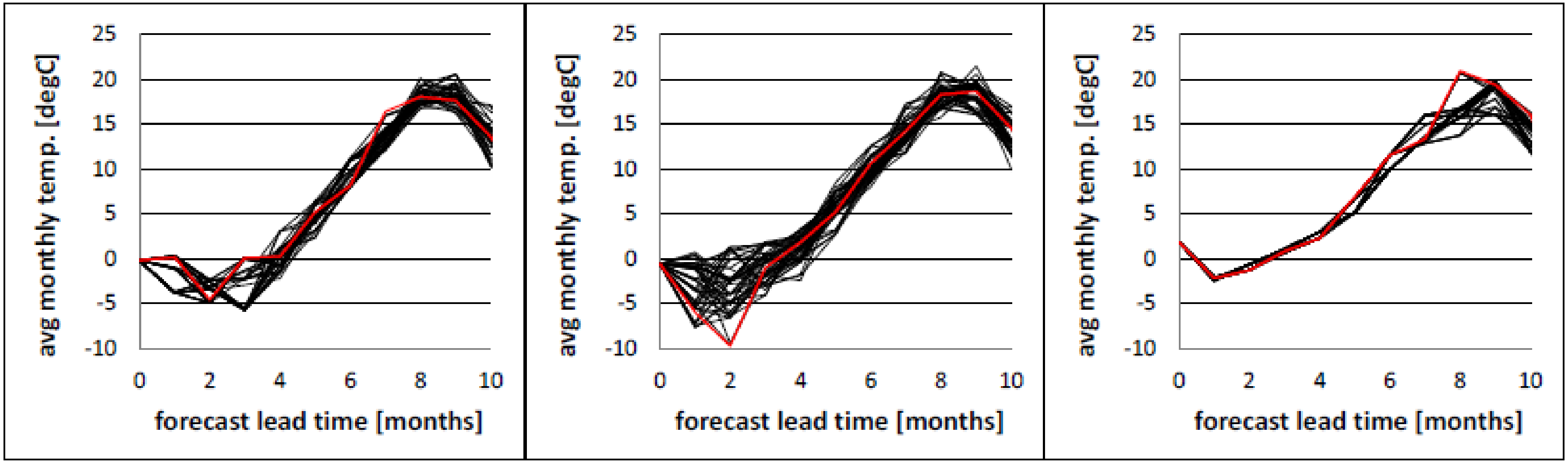
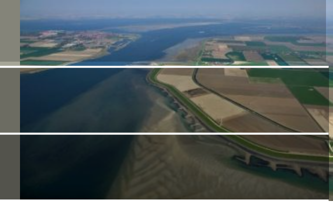


Results

Ensembles of monthly averaged temperature

1973	1978	1997
La Niña year	Average year	El Niño year
Cold winter		Warm winter

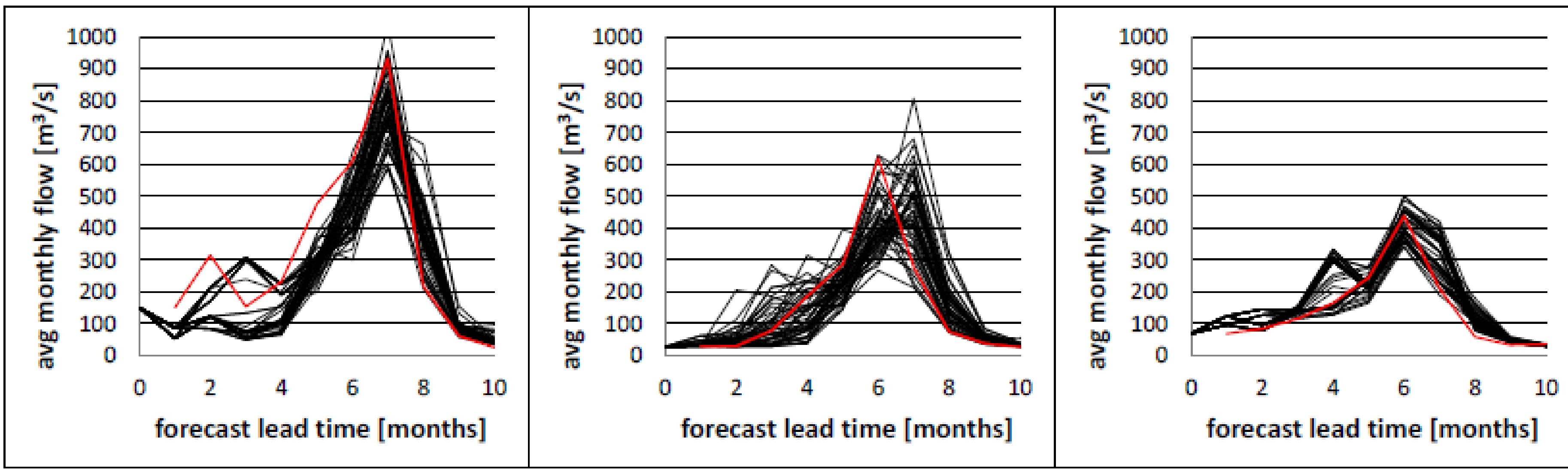


Results

Ensembles of monthly averaged streamflow

1973	1978	1997
La Niña year	Average year	El Niño year
High volume		Low volume



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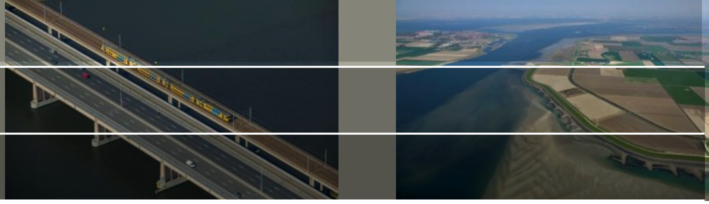
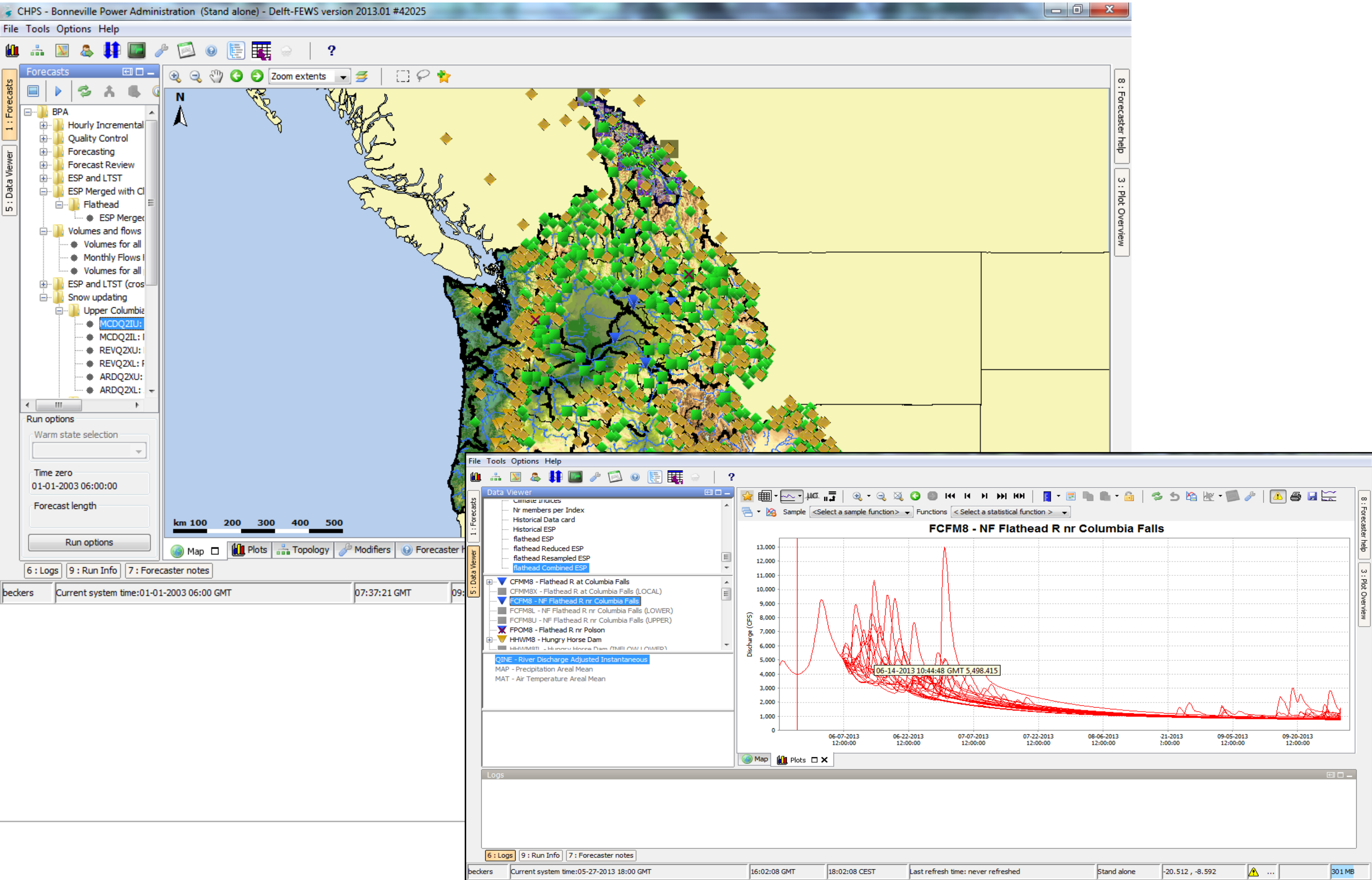
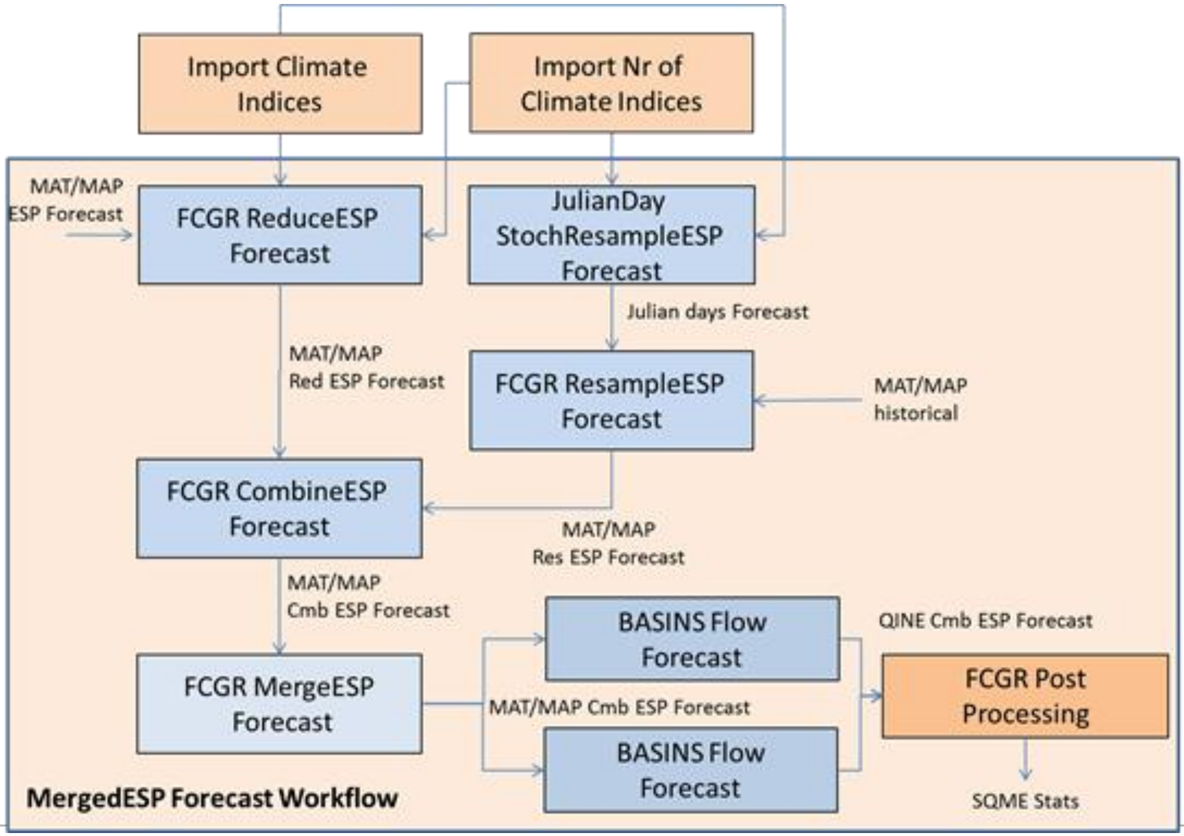
Implemented in CHPS





Hybrid method

- ‘ReduceESP’ selects historical traces from ESP
- ‘StochResampler’ generates additional traces



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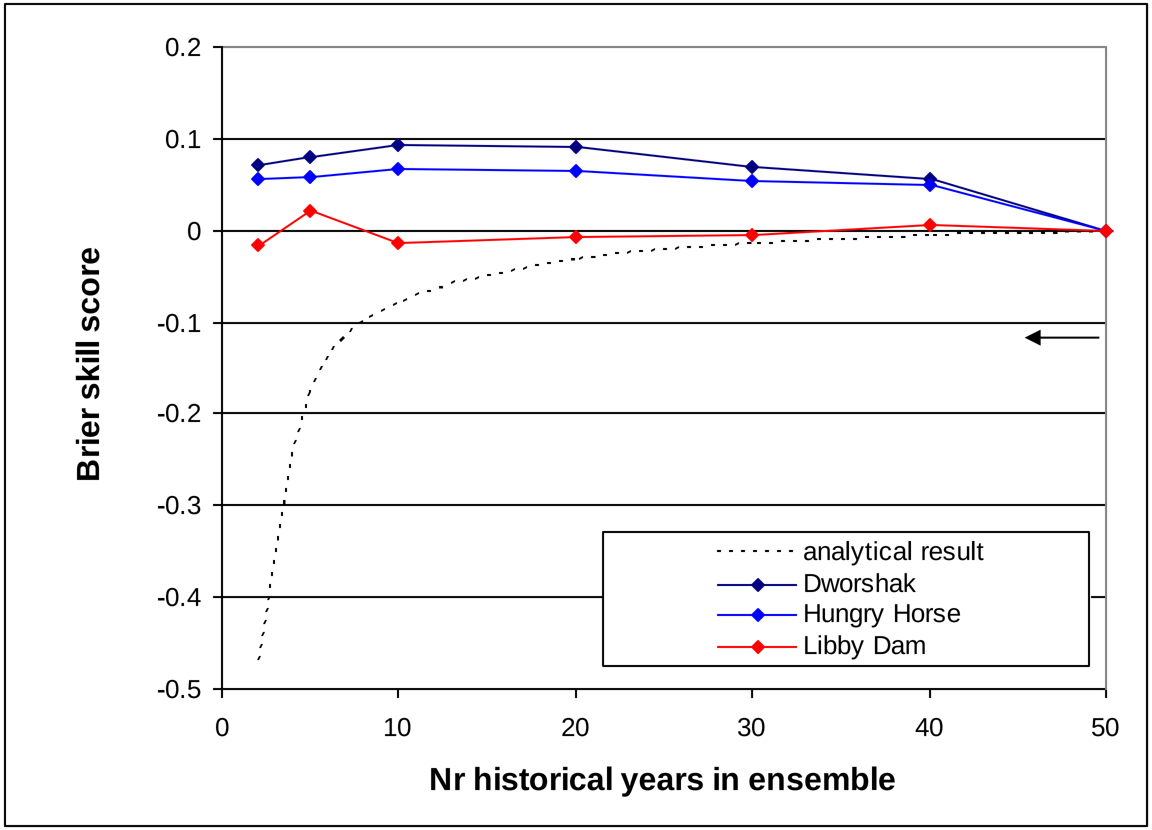
Brier skill score relative to ESP

Ensemble size effect is canceled out

Improvement of skill is found for two out of three test catchments



Improved skill

More ESP traces replaced by resampled traces

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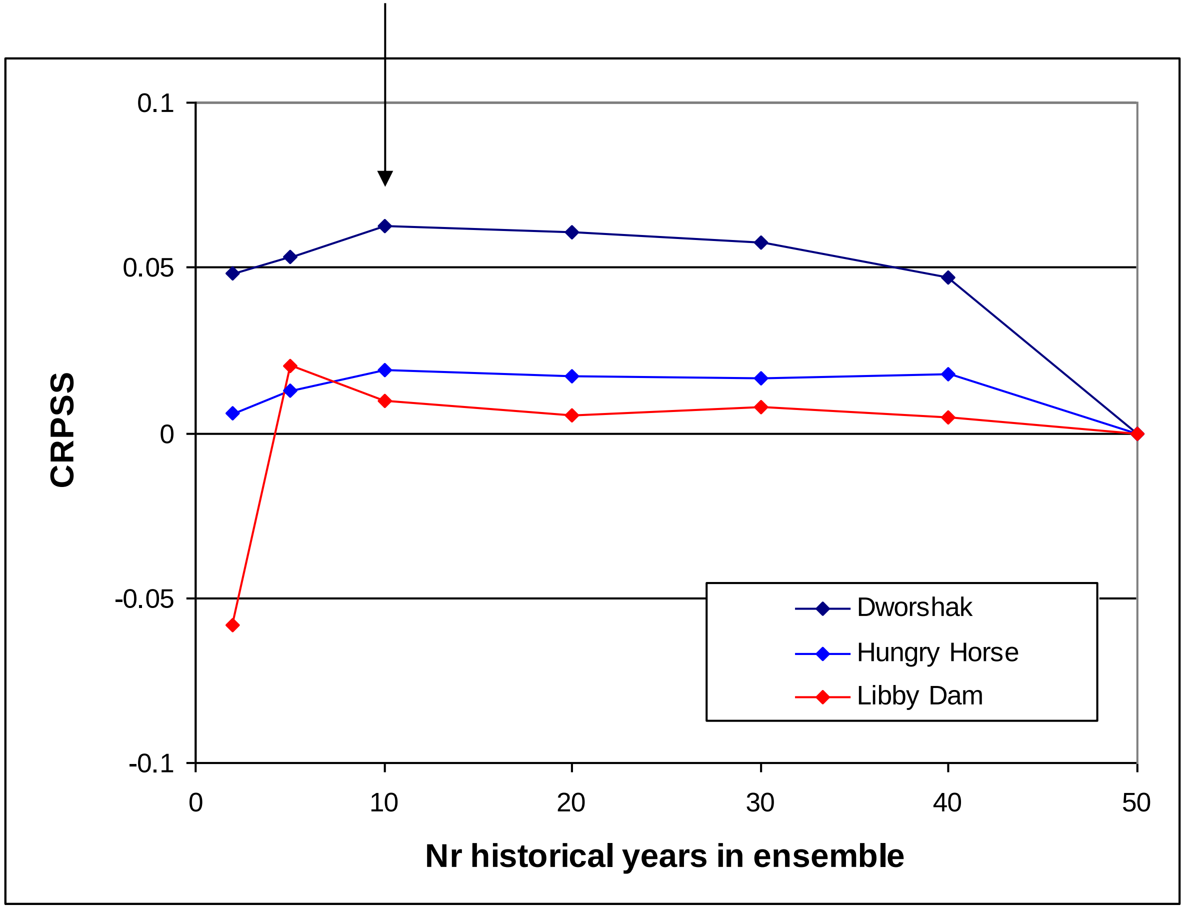
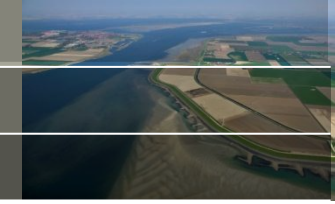
CRPS skill relative to ESP

Mix of 10 full historical years and 40 resampled traces seems optimal



Conclusions

- Improved skill (~5%) found for 2 out of 3 test basins
- No improvement found for one basin, but also no reduction of skill
- Apparently this basin is less affected by ENSO

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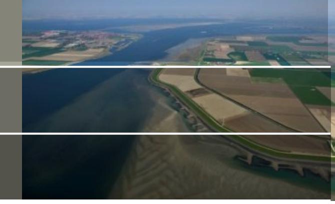


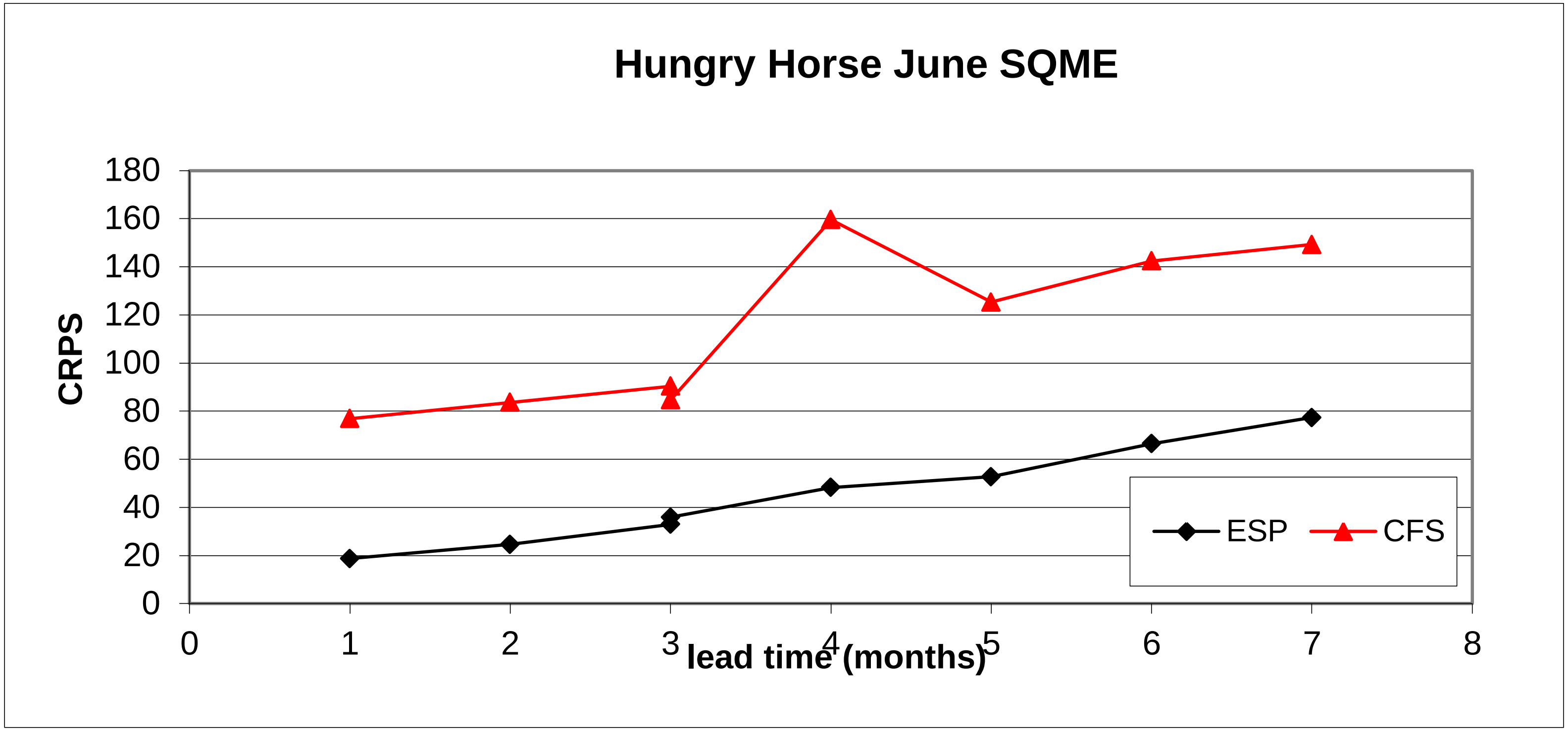
Thanks for your attention

Approach 1: Use NCEP CFS

Mapping the CFS2 100km grid from to Columbia River subbasins

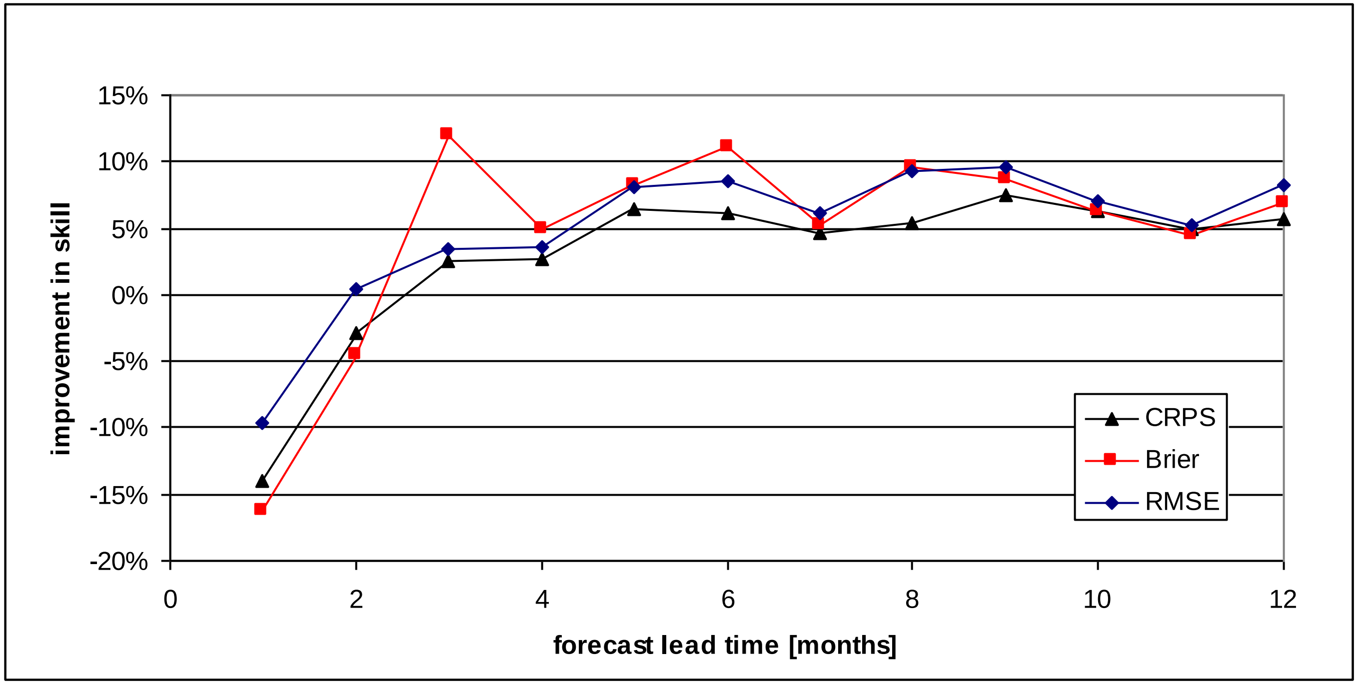
Considerable local bias corrections needed (factor 2 in precip!)

Forecast skill worse than ESP



Forecast lead time

Skill as a function of lead time (10 historical years and 40 resampled):



Improvement of forecast skill for lead times of 3 months and more
Improvement in the order of 5%, depending on the subbasin