Water and Global Change

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CREATION OF THE WATCH 20TH CENTURY ENSEMBLE PRODUCT

Table 2: Daily descriptors in the WATCH 20th Century Ensemble.

Descriptor	Explanation
mean	Average of nmodels variable values
nmodels	Number of models contributing data (excludes outlier)
max	Maximum model value of nmodels
min	Minimum model value of nmodels
maxmodel	Integer code for model providing maximum value (max)
minmodel	Integer code for model providing minimum value (min)
sem	Standard error of the mean
outmodel	Integer code for model value excluded as an outlier (= 0 if no outlier)

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Introduction.

WorkBlock 1 of the WATCH EU Programme is designed to assess the global terrestrial water cycle in the twentieth century. Here the creation of a new data set is described which provides a “best estimate” of four key hydrological variables based on averages of daily output from seven hydrological models.

All models used a common reporting format (including the ALMA convention for variable names and units, full latitude-longitude grid in netCDF files) as established within WATCH for the WaterMIP exercise (Haddeland et al., 2011). All models were run using naturalised conditions for the using the WATCH Forcing Data (WFD) described by Weedon et al. (2010; 2011). The precise model outputs sourced, as obtained from the /watch section of the IIASA ftp site in Vienna, are listed in Table 1. Since the WaterMIP effort preceded the full twentieth century runs, some models provided data for the full twentieth century in the /WorkBlock4/MultiModel_Extremes/1901_1957/ folder (i.e. the 1958-2000 data in the /1901_1957/ folder supercede the data in the /1957_2001/ folder). MPI-HM provided new twentieth century data in the /20th_Century_Ensemble_Data folder of WorkBlock1.

The Ensemble product is stored as daily data in monthly netCDF files in the folder /WorkBlock1/20th_Century_Ensemble_Product/.

Table 1: Source of model outputs used in creation of the WATCH 20th Century Ensemble. Note: LSM = Land surface model, GHM = General hydrological model.

Model name	**LSM or GHM**	**Year range**	**ftp folder data source (naturalised runs)**
GWAVA	GHM	1901-1970	/WorkBlock4/MultiModel_Extremes/1900_1957/GWAVA/
		1971-2000	/WorkBlock4/Multimodel_Extremes/1957_2001/GWAVA/
Htessel	LSM	1905-2000	/WorkBlock4/MultiModel_Extremes/1900_1957/Htessel/
LPJml	GHM	1901-1957	/WorkBlock4/MultiModel_Extremes/1900_1957/LPJ/
		1958-2000	WorkBlock4/MultiModel_Extremes/1958_2001/LPJ/
MPI-HM	GHM	1901-2000	/WorkBlock1/20th_Century_Ensemble_Data/MPI-HM_daily/
Orchidee	LSM	1906-1957	/WorkBlock4/MultiModel_Extremes/1901_1957/Orchidee/
		1958-1962	/WorkBlock4/MultiModel_Extremes/1901_1957/Orchidee /or_1958_1963_cwrr_nat/
		1963-2000	/WorkBlock4/MultiModel_Extremes/1901_1957/Orchidee /or_1963-2001_cwrr_nat/
WaterGAP	GHM	1906-2000	/WorkBlock4/MultiModel_Extremes/1901_1957/WaterGAP/
JULES	LSM	1901-2000	/WorkBlock4/MultiModel_Extremes/1901_1957/Jules/

Creation of the Ensemble Product.

The WATCH 20th Century Ensemble contains daily averages and associated descriptors for every half-degree land grid box in the WFD as stored in monthly full latitude-longitude grid netCDF files. The hydrological variables involved are: snow water equivalent (“swe”), total evaporation (i.e. bare soil evaporation plus canopy evaporation/transpiration, “evap”), total soil moisture (i.e. the sum of all soil layer moisture values, “soilmoist”) and surface runoff plus subsurface runoff (i.e. Qs + Qsb, “qs+qsb”).

Discharge was not averaged as it was not available for two models, but it can be derived from the Ensemble qs+qsb data via a river routing model such as TRIP. There were no daily swe data available from Orchidee. Surface plus subsurface runoff from WaterGAP appears to be highly anomalous (consistently much lower than all other models and with different seasonality patterns). Consequently, like swe the total runoff Ensemble has been based on using only 6 models (rather than seven for total evaporation and soil moisture).

At the start of the twentieth century less than the full numbers of models were available as some models used the initial years for "spin-up" (see Table 1).

The descriptors derived for each hydrological variable in the Ensemble are listed in Table 2.

Table 2: Daily descriptors in the WATCH 20th Century Ensemble.

Descriptor	**Explanation**
mean	Average of nmodels variable values
nmodels	Number of models contributing data (excludes outlier if identified)
max	Maximum model value of nmodels
min	Minimum model value of nmodels
maxmodel	Integer code for model providing maximum value (max)
minmodel	Integer code for model providing minimum value (min)
sem	Standard error of the mean
outmodel	Integer code for model excluded as value identified as an outlier (= 0 if no outlier)

The standard error of the mean (s.e.m.) was selected as the most appropriate indication of uncertainty in the mean value. It is defined here as follows:

s.e.m. = Standard deviation/SQRT(nmodels)

It has several beneficial features (Williams, 1984):

- The standard error of the mean is not biased by the distribution (e.g. sknewness) of the data .
- The size of the s.e.m. decreases as the amount of data increases (unlike standard deviation).
- Multiplied by an appropriate value from a Student's t Table, the s.e.m. allows calculation of, for example, the 95% confidence interval of the mean.
- It is readily converted to standard deviation knowing the value of nmodels.

The range of descriptors in Table 1, will allow detailed investigation of comparative model performances and the s.e.m. compared to the mean will allow study of spatial and temporal variations in uncertainty in the averages of the hydrological model variables.

Identification of outliers.

It became clear during creation of the Ensemble that sometimes one model provided a value that was very significantly different from the other model values. As a result it was decided that it would be desirable to exclude outliers so that the Ensemble provided a less biased estimate of the hydrological cycle. The first approach used was to calculate the initial mean value from all models supplying data (7 for total evaporation and soil moisture, 6 for swe and total runoff). Next outlier values were identified, for each day and each grid box, if a value lay more than three times the standard deviation above or below the initial mean. This method assumed the data would be approximately normally distributed with the outliers not "too far" from the initial mean.

However, in practice it was often found that an extreme value was so far from the other values that the initial mean lay between the extreme value and all the other values – rather than the mean lying somewhere in the middle of the other values. Hence in the final product an outlier was identified when the mean had one value on one side and all other values on the other. After re-calculation of the mean, based on the remaining model values, a second check for outliers was based the original check using three standard-deviation limits.

Although this method for identifying outlier values is believed to have substantially reduced the bias in the Ensemble mean in many cases, the method is rooted in the belief that single models occasionally generate spurious extreme values (for unspecified reasons beyond the scope of this work). However, it appears that occasionally pairs of models produce extreme values simultaneously. This could reflect genuine modelled physics or chance and thus requires further investigation.

The area-weighted daily averages for four of the WATCH target river basins, plus and minus the s.e.m., is illustrated in Fig. 1 for the daily Ensemble mean of total evaporation.

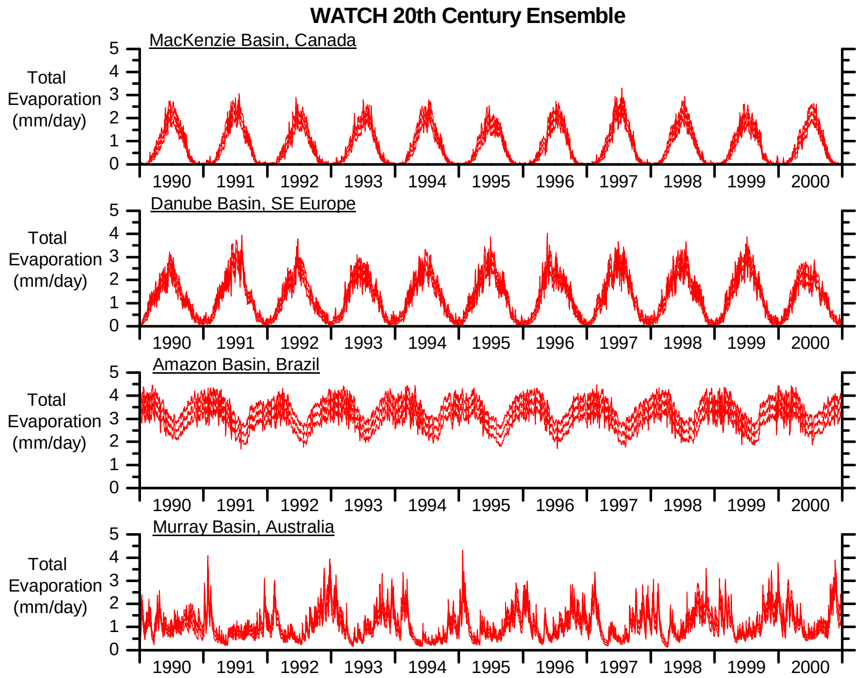

Figure 1: Area weighted basin averages of the daily mean plus and minus standard error of the mean for total evaporation.

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