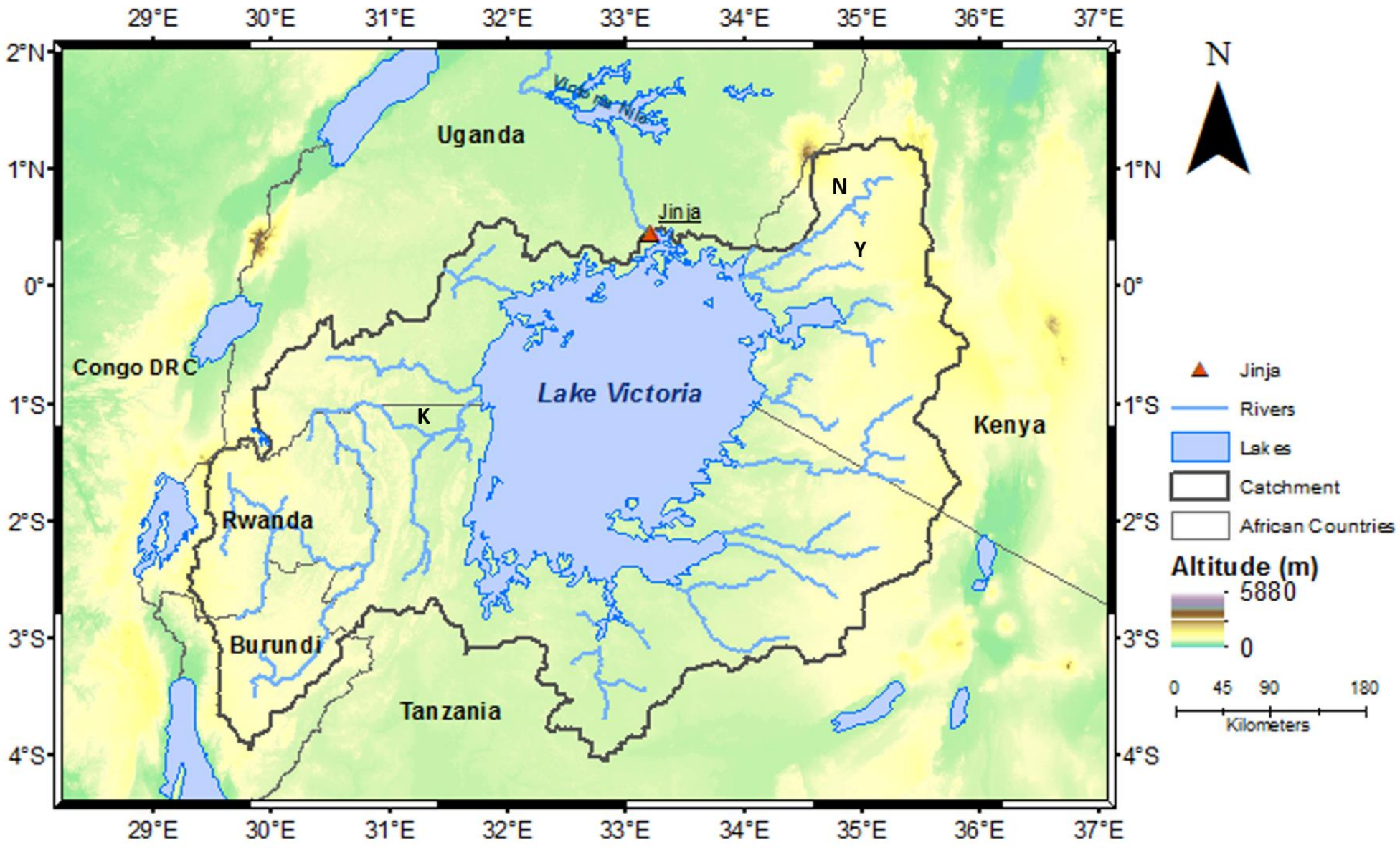
VRIJE UNIVERSITEIT BRUSSEL

KU LEUVEN

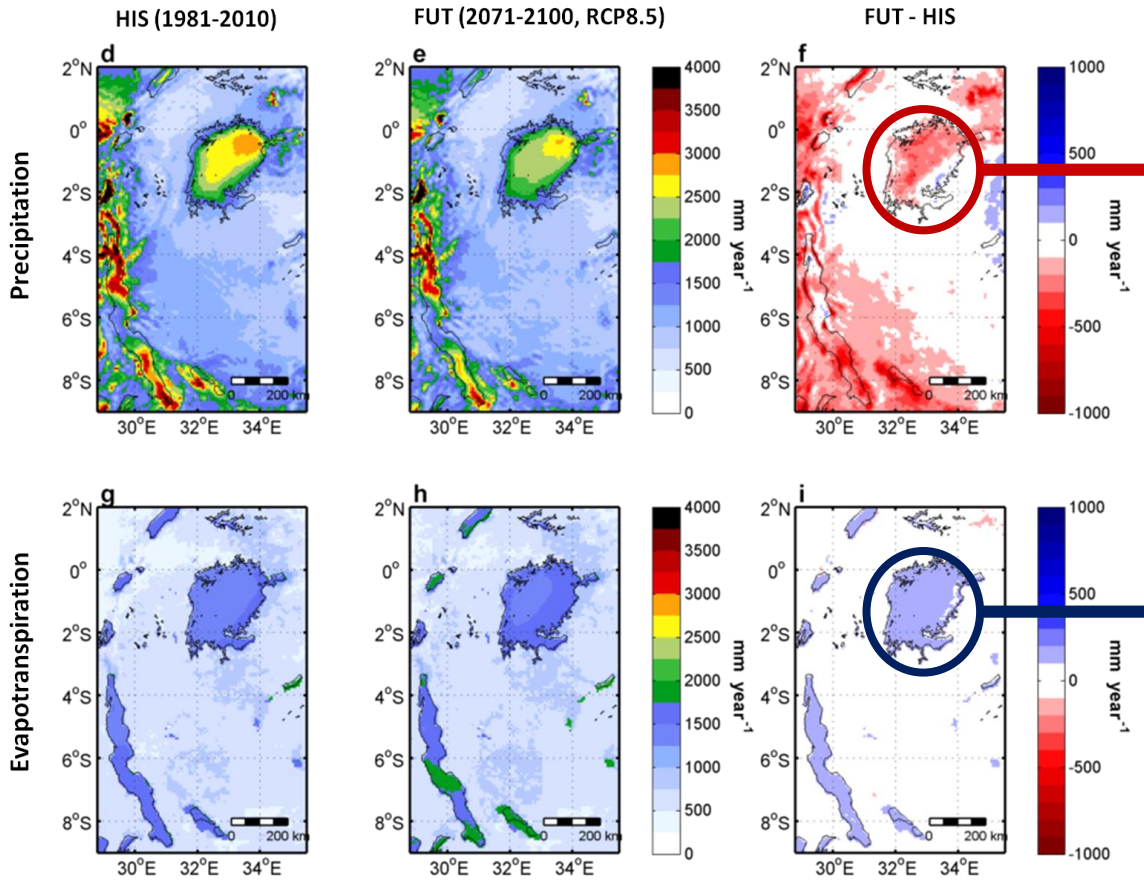
Projecting the future levels of Lake Victoria

Inne Vanderkelen

Promotor: Prof. Dr. Nicole Van Lipzig
Copromotor: Prof. Dr. Wim Thiery


29°E
30°E
31°E
32°E
33°E
34°E
35°E
36°E
37°E
2°N
1°N
0°
1°S
2°S
3°S
4°S
N
Uganda
Jinja
N
Y
Congo DRC
Lake Victoria
K
Kenya
Rwanda
Burundi
Tanzania
Jinja
Rivers
Lakes
Catchment
African Countries
Altitude (m)
5880
0
0
45
90
180
Kilometers

Future climate projections (RCP8.5)



Decreasing lake precipitation

Increasing lake evaporation

Source: Thiery et al (2016)

Previous studies with water balance models

Publication	Precipitation	Evaporation	Inflow	Outflow	Period	Resolution
Kite, 1981	Weighted average from lake shore stations and from island stations when available	Heat budget method for 1970-1974, Afterwards mean value for these years. Evaporation data from Kishanda station for 1977,1978 and 1979	Measured for 16 years, other years estimated by regression on Kagera River annual runoff	Annual discharge data for 1957-1979.	1950-1975	Yearly
Piper, 1986	Equally weighted from of 8 lakeshore stations, rescaled for higher lake precipitation based on solving WB model for precipitation	Penman method for stations around the lake	Measurements of gauged tributaries for 1956-1978. Flow of ungauged perimeter estimated by WMO for 1969 and 1970. Inflow before 1956 estimated by rainfall-runoff model	Agreed curve	1925-1978	Yearly
Sene and Plinston, 1994	Method of Piper, 1986	Constant (1600 mm/yr) (Piper, 1986)	Method of Piper, 1986. Extended and more relying on measurements	Agreed Curve up to 1950, measurements from 1954	1900-1990	Monthly
Yin and Nicholson, 1998	Estimated from average catchment precipitation from 19 catchment stations, using a satellite-data based relationship between lake and catchment precipitation				1956-1978	Monthly
Tate, 2004	Series of Sene and Plinston, 1994		inflow		1925-2000	Monthly
Swenson and Wahr, 2009	Satellite observations (TRMM 3B43) combined with rain gauge data	Bulk formulae with satellite derived wind speeds, sea surface temperatures, near surface atmospheric humidity and temperature. Surface pressure from operational analyses	Decomposing of inflow in overland flow and subsurface flow. Overland flow: modelled proportional to precipitation. Subsurface flow: related to groundwater storage (GRACE satellite data)	Measurements until 2005 Afterwards: (i) residual term in WB. (ii) estimated from downstream satellite observations	1993-2008	Monthly
Smith, 2014	Non-linear function of average rain gauge precipitation at 6 stations. Station precipitation obtained by interpolating satellite derived gridded precipitation (CRU TS 3.2)	Constant (1595 mm/yr)	Solved following parametrization of Tate (2007).	Agreed Curve solved iteratively	1959-2009	Monthly

→ Lack of observations over the lake
→ Large uncertainties
→ No research on future lake levels
→ GCMs have too coarse resolution

Objectives

1. Develop observation-based **water balance model** for Lake Victoria

2. Assess the skill of **present-day regional climate models** in reproducing historical levels of Lake Victoria

3. Project the **future levels** of Lake Victoria

4. Investigate the **role of the human management scenarios** at the dam for future fluctuations in water level of Lake Victoria

Water Balance Model

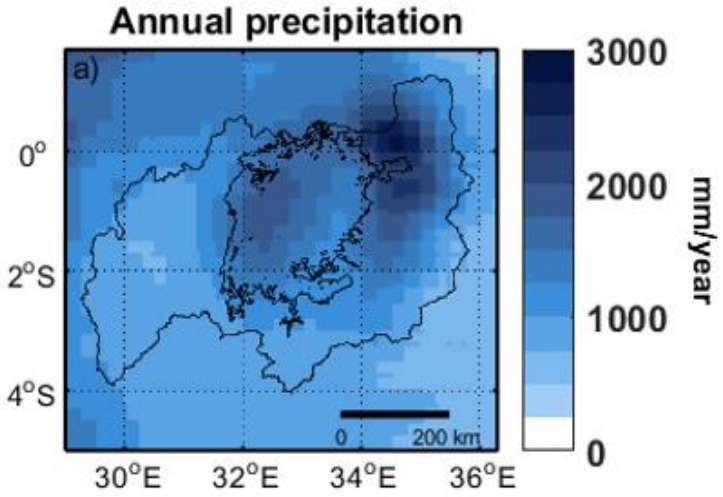
$$\frac{dL}{dt} = P - E + \frac{Q_{in} - Q_{out}}{A_{lake}}$$

L = lake level [m/day]
P = precipitation on the lake [m/day]
E = lake evaporation [m/day]

Q_{in} = inflow (rivers) [m^3/day]
Q_{out} = outflow (dam) [m^3/day]
A_{lake} = lake surface area [m^2]

- Daily basis
- Observational period: 1993-2014 (21 years)

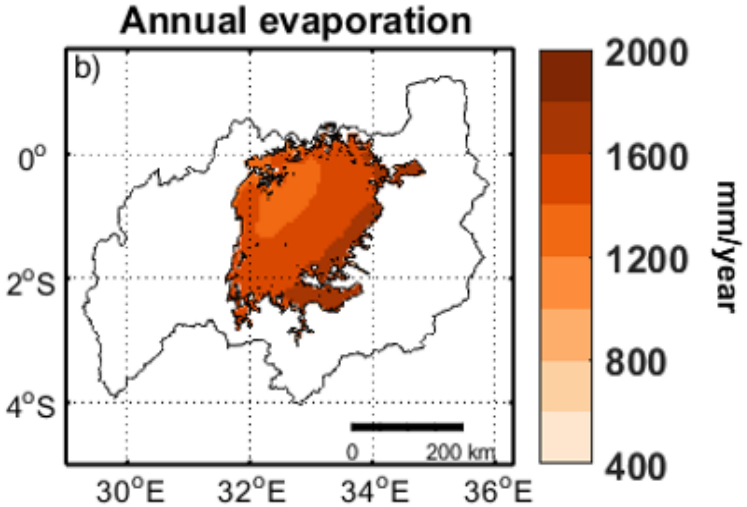
Precipitation



PERSIANN-CDR satellite product
(Ashouri et al., 2015)

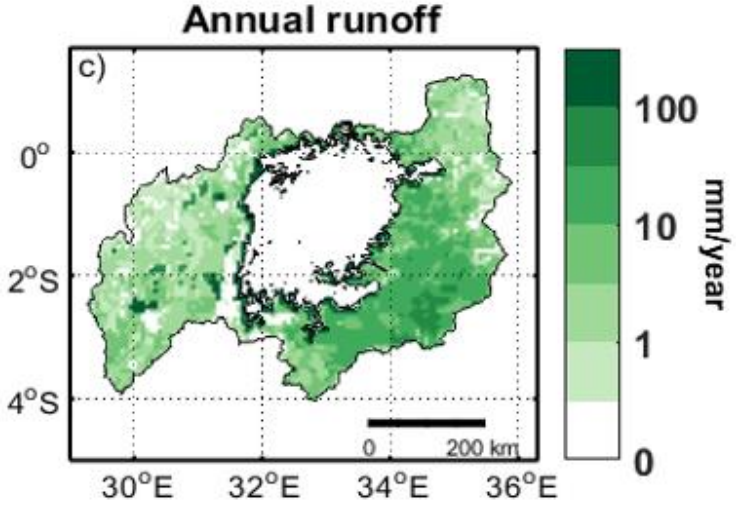
Evaporation

COSMO-CLM² model output
(Thiery et al., 2015)



$$\frac{dL}{dt} = P - E + \frac{Q_{in} - Q_{out}}{A_{lake}}$$

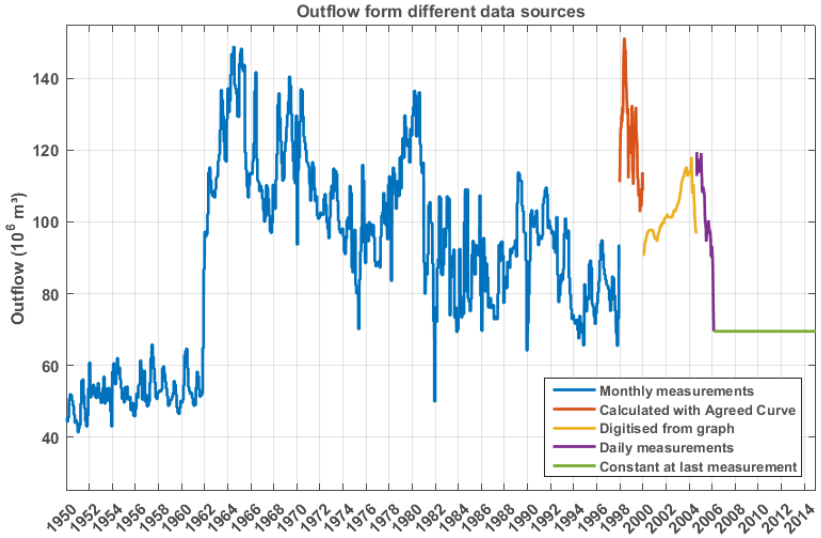
Inflow



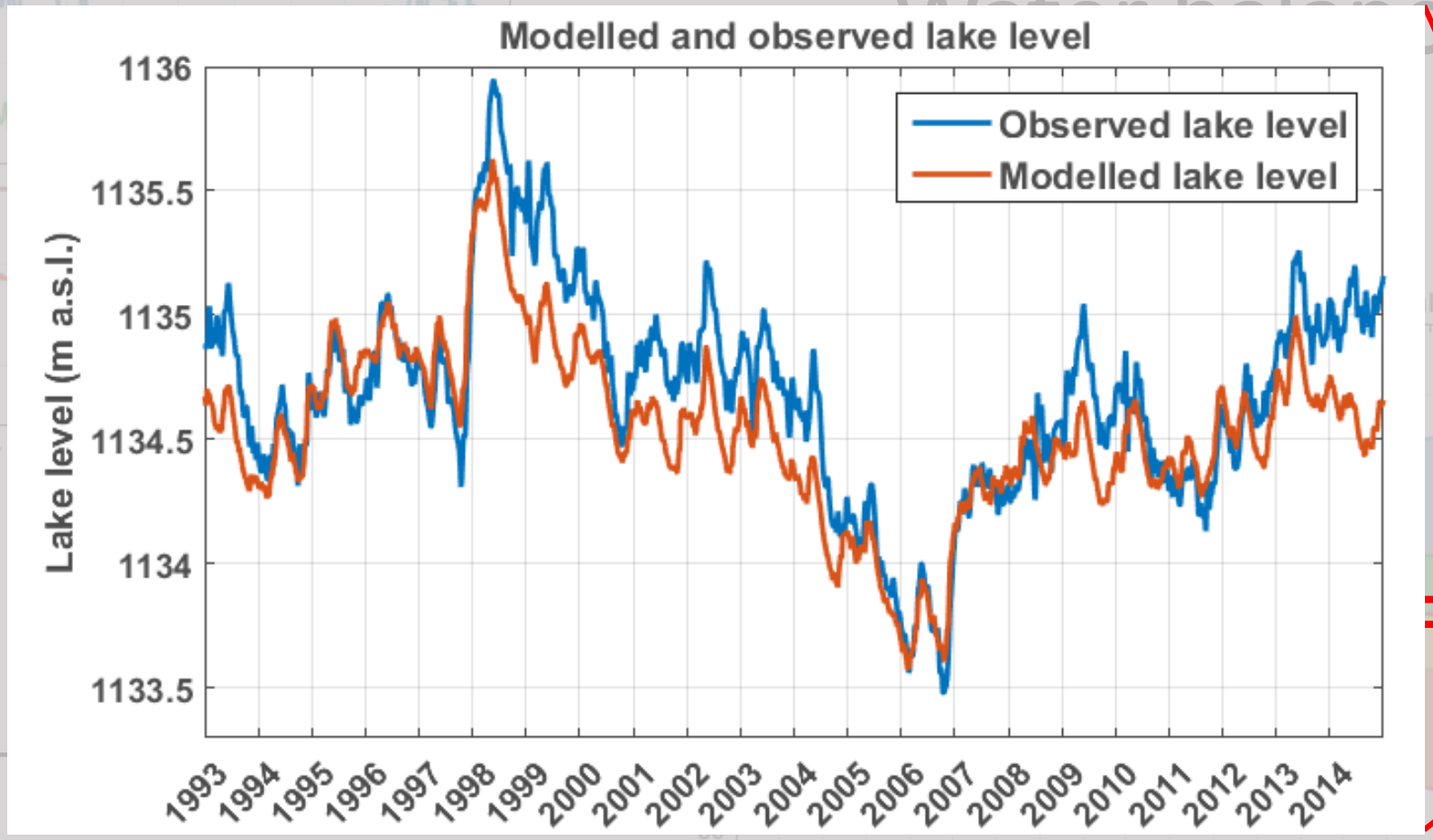
Curve Number method

Outflow

Agreed Curve



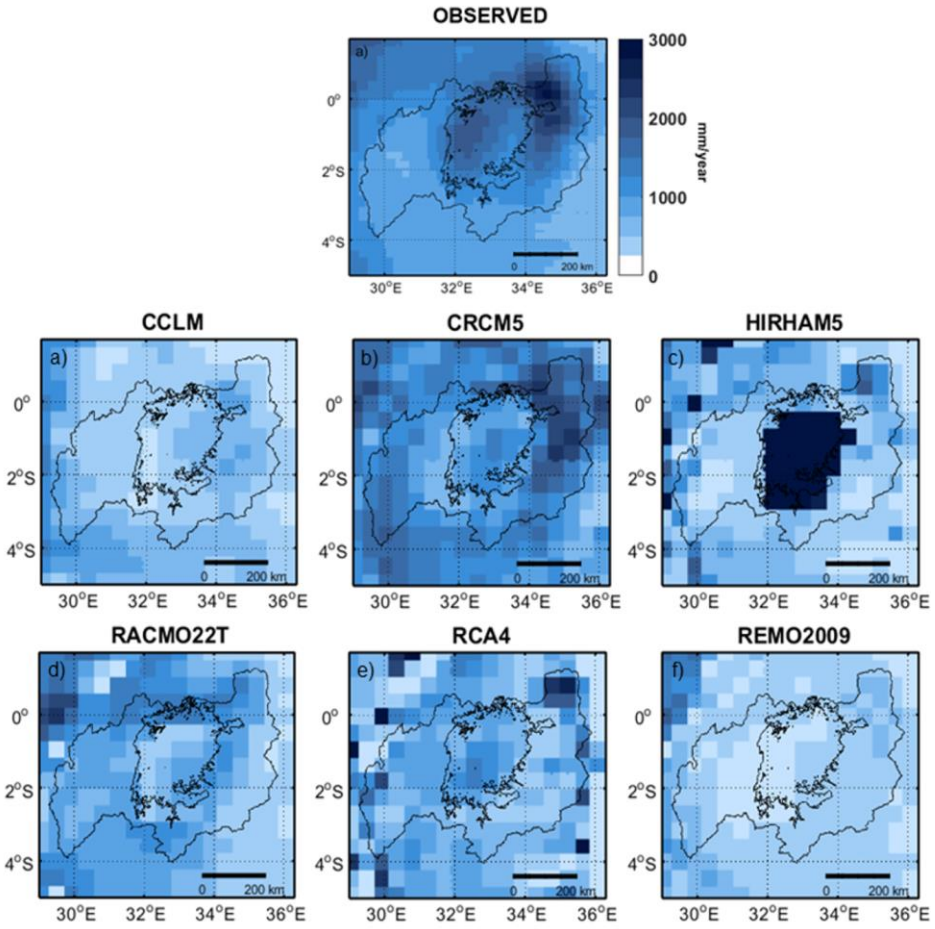
Water balance



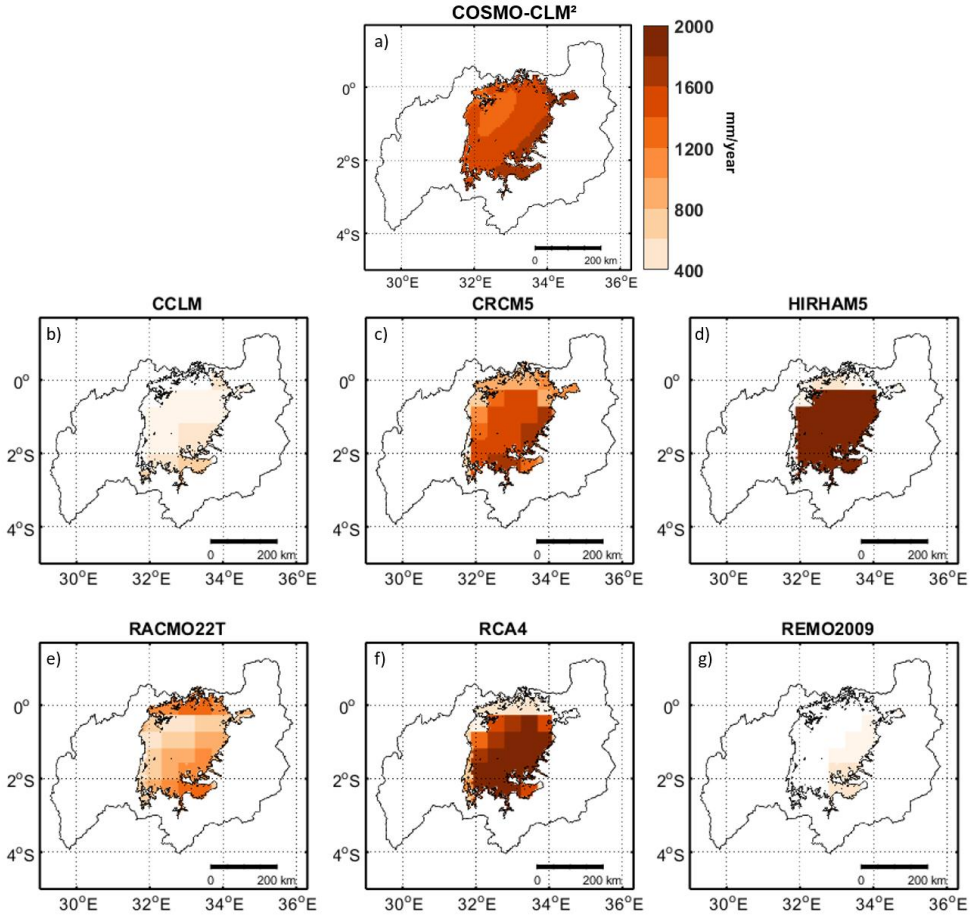
$$\frac{dL}{dt} = \boxed{P} -$$

CORDEX ensemble members

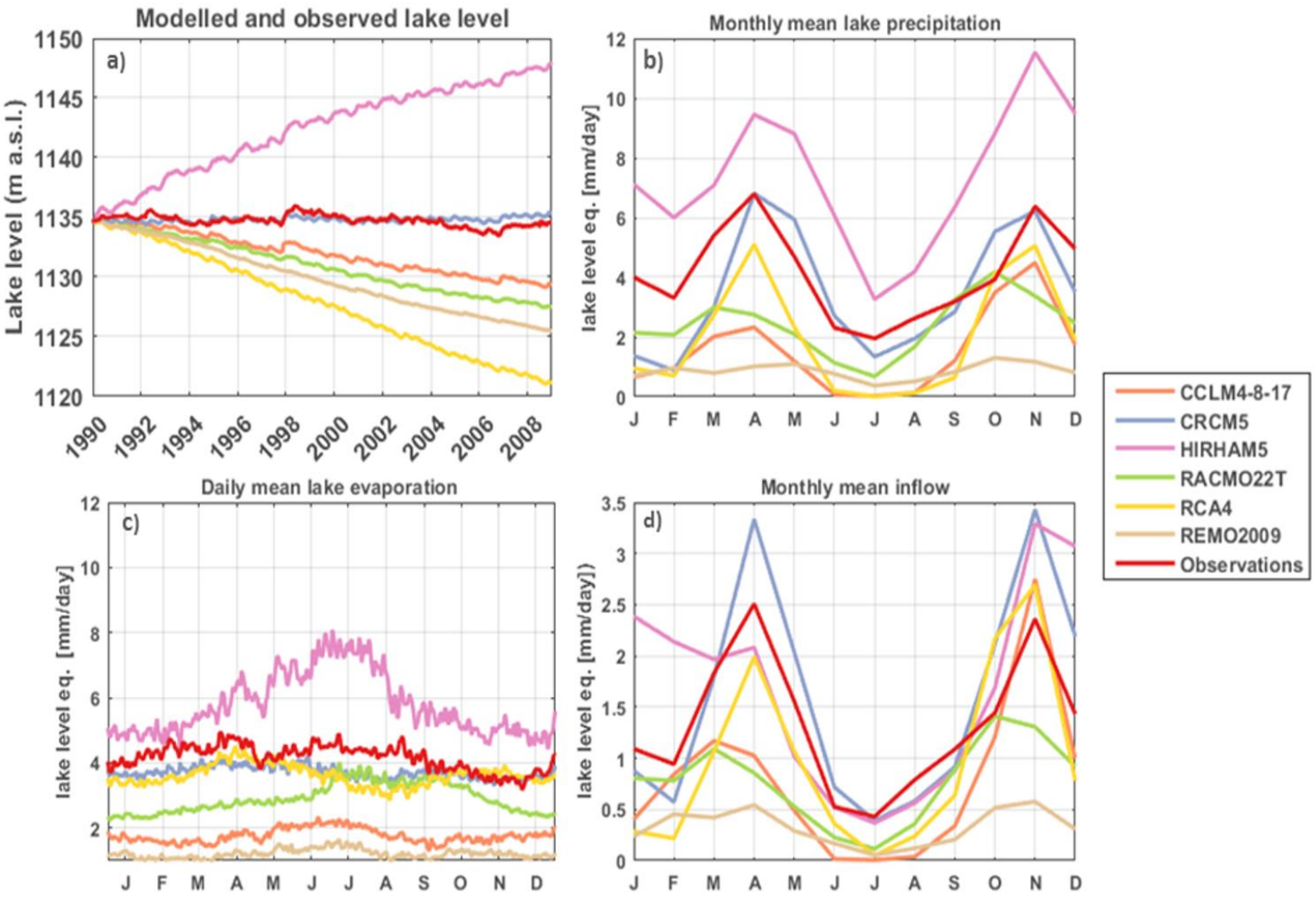
Precipitation



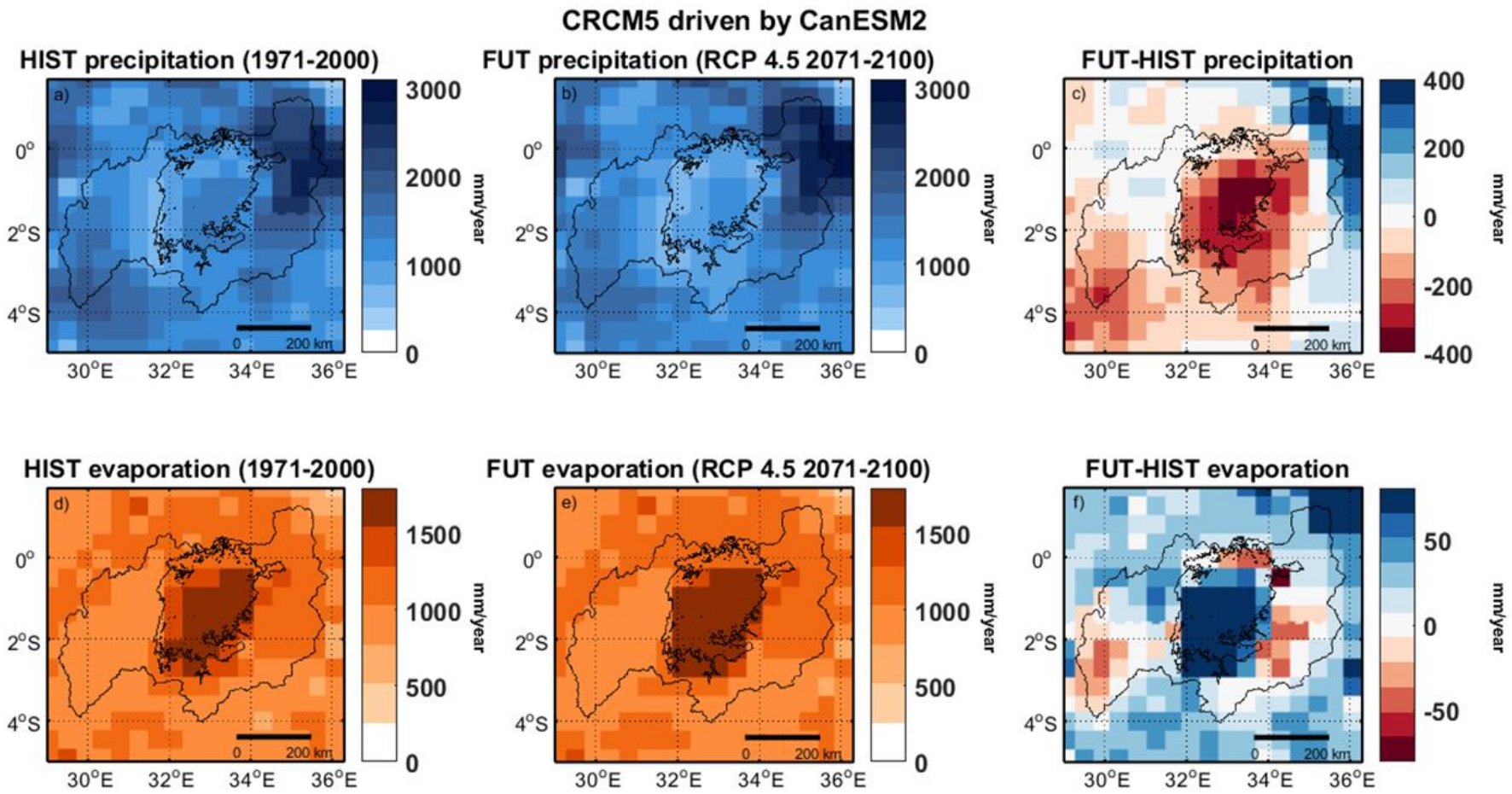
Evaporation



CORDEX ensemble members



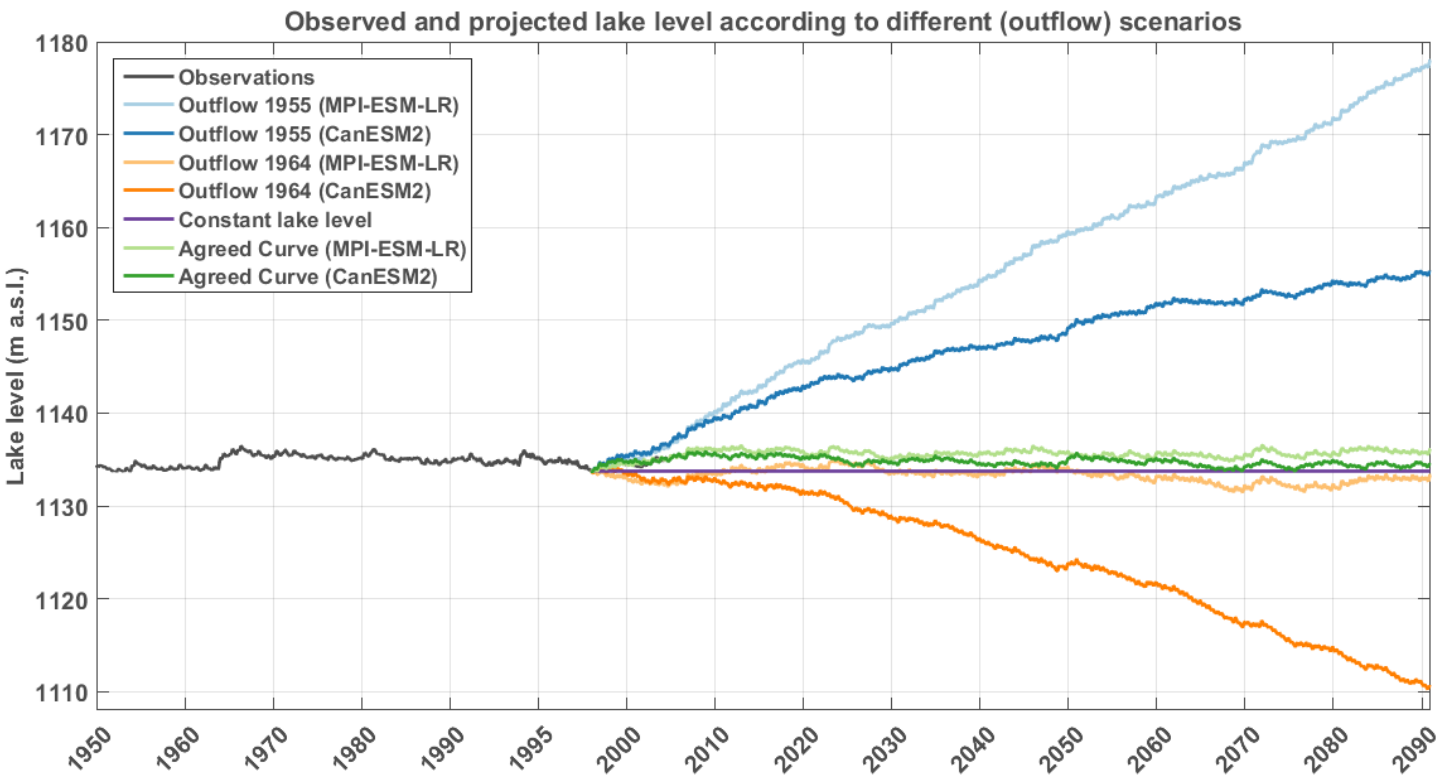
CRCM5 – two model simulations (RCP4.5)



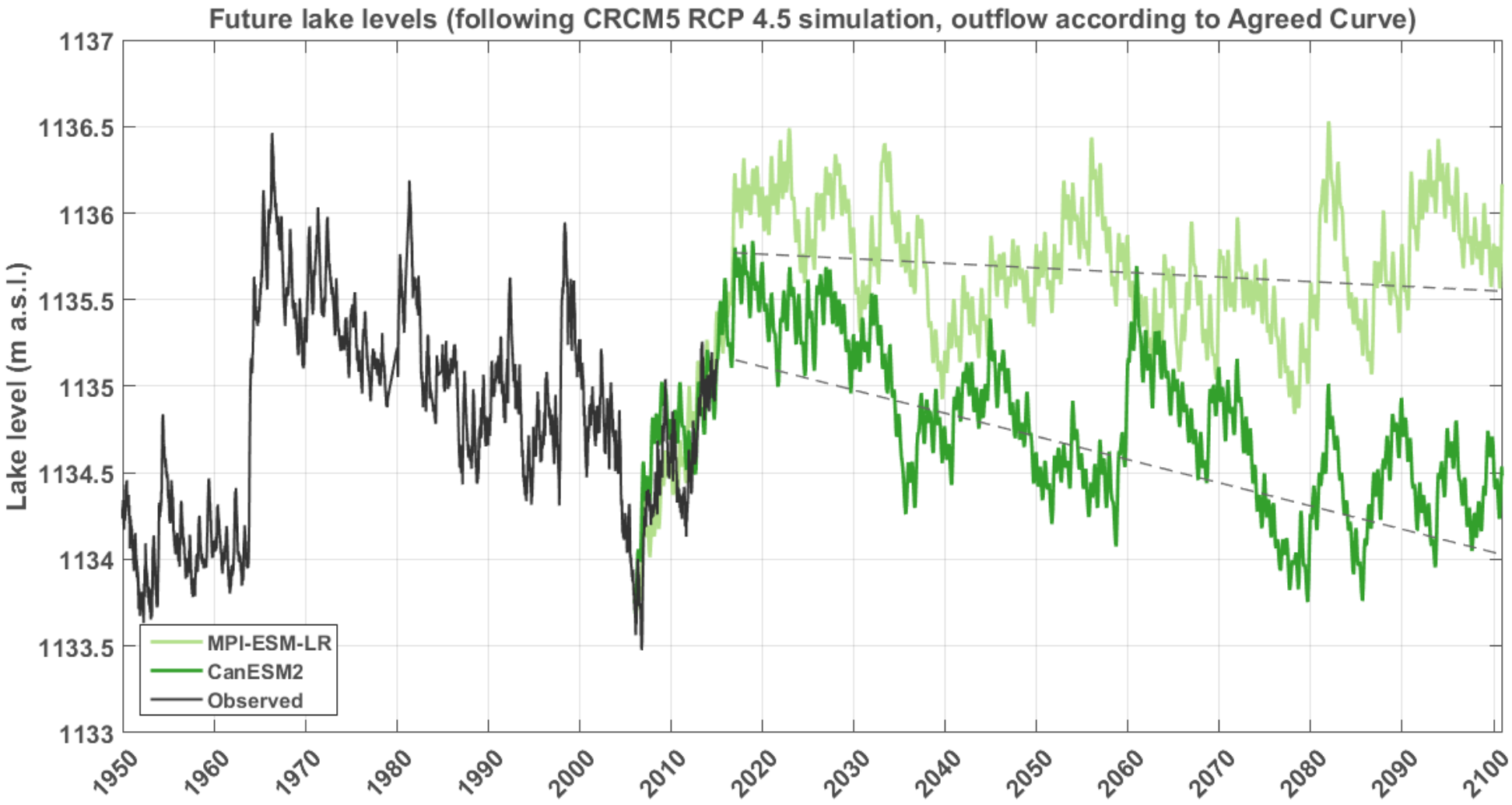
Future dam management scenarios

1. Constant outflow
   - low (outlfow 1955)
   - high (outflow 1964)

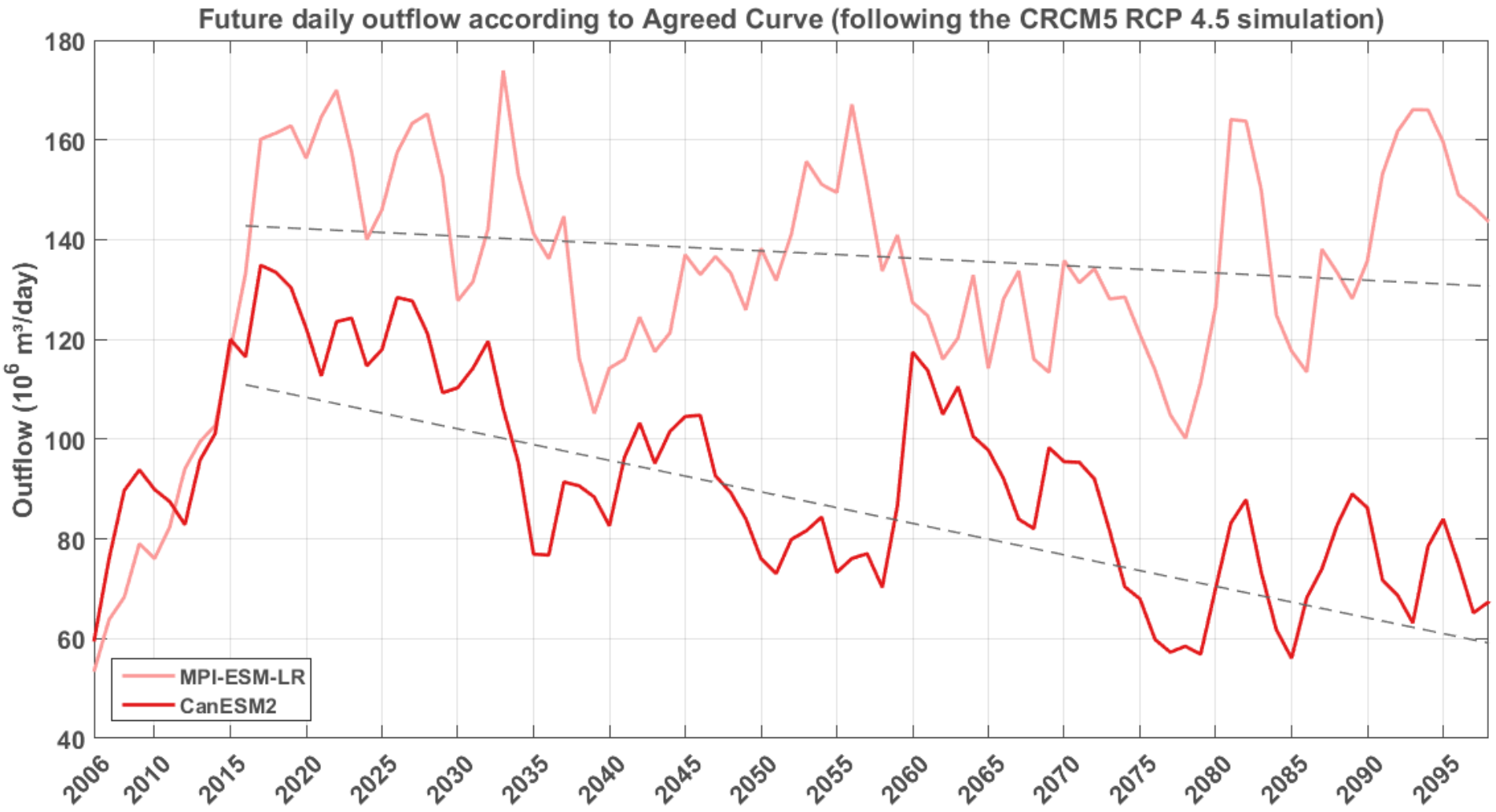
2. Following Agreed Curve



Future lake levels following the Agreed Curve



Future outflow following the Agreed Curve



Main conclusions and outlook

1. Water balance model based on observations works

2. Current generation models are typically not able to reproduce the observed lakel levels

3. Future lake levels according to one RCM and RCP4.5: decreasing trend following Agreed Curve outflow scenario

More climate simulations are needed!

- Bias correction on CORDEX simulations

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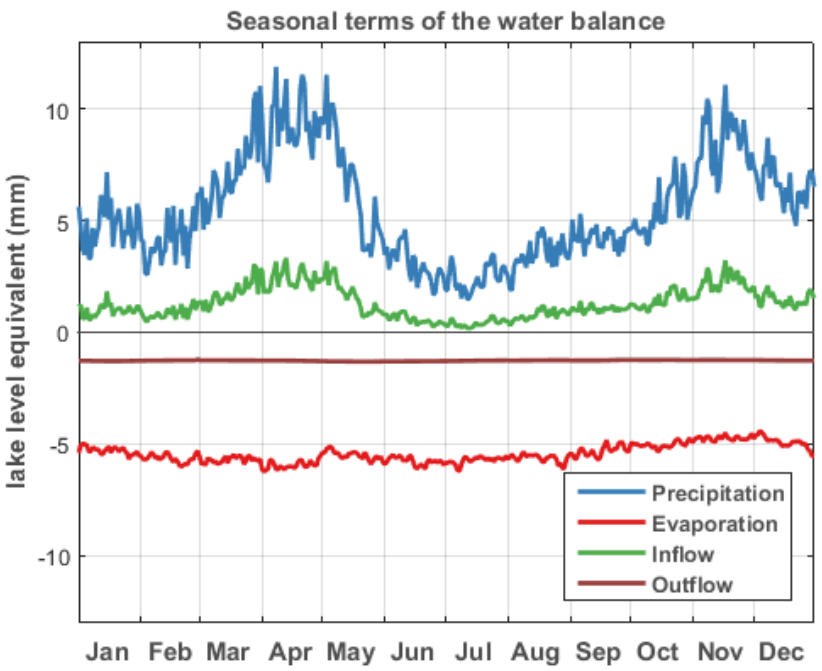
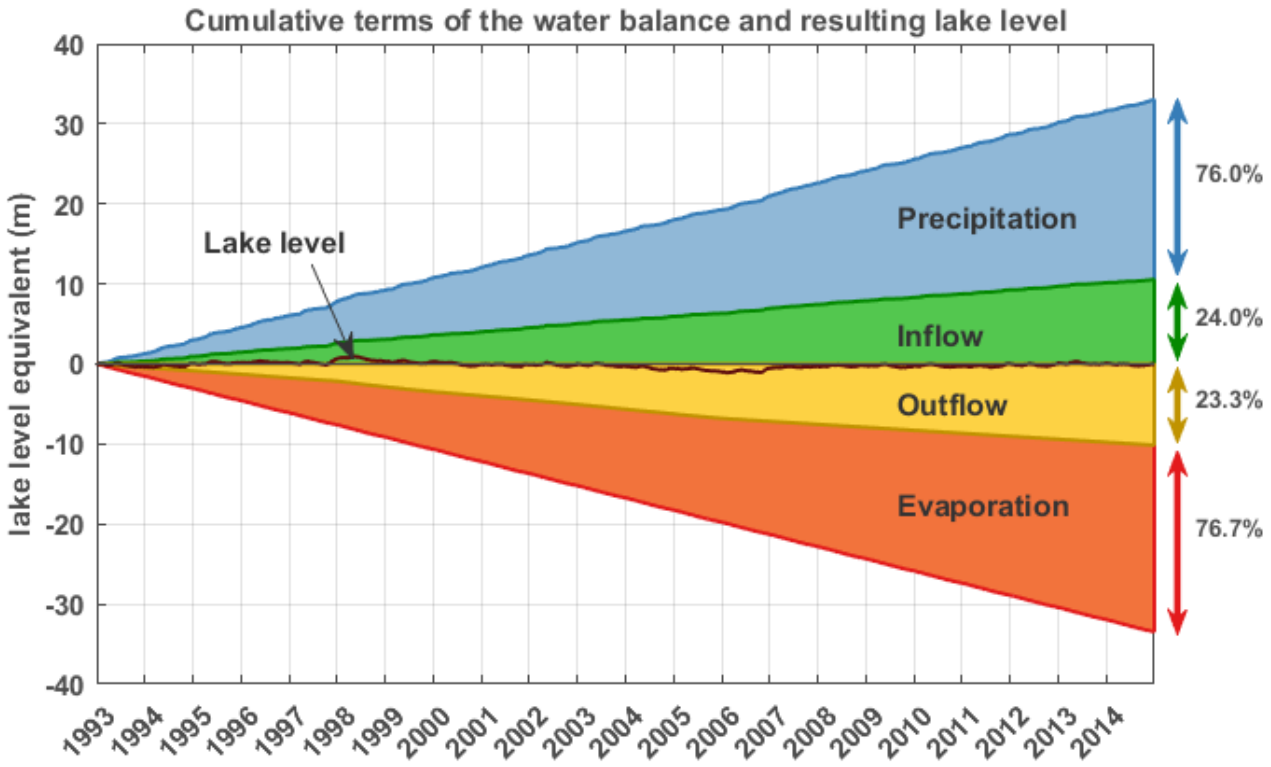
Thank you for your attention

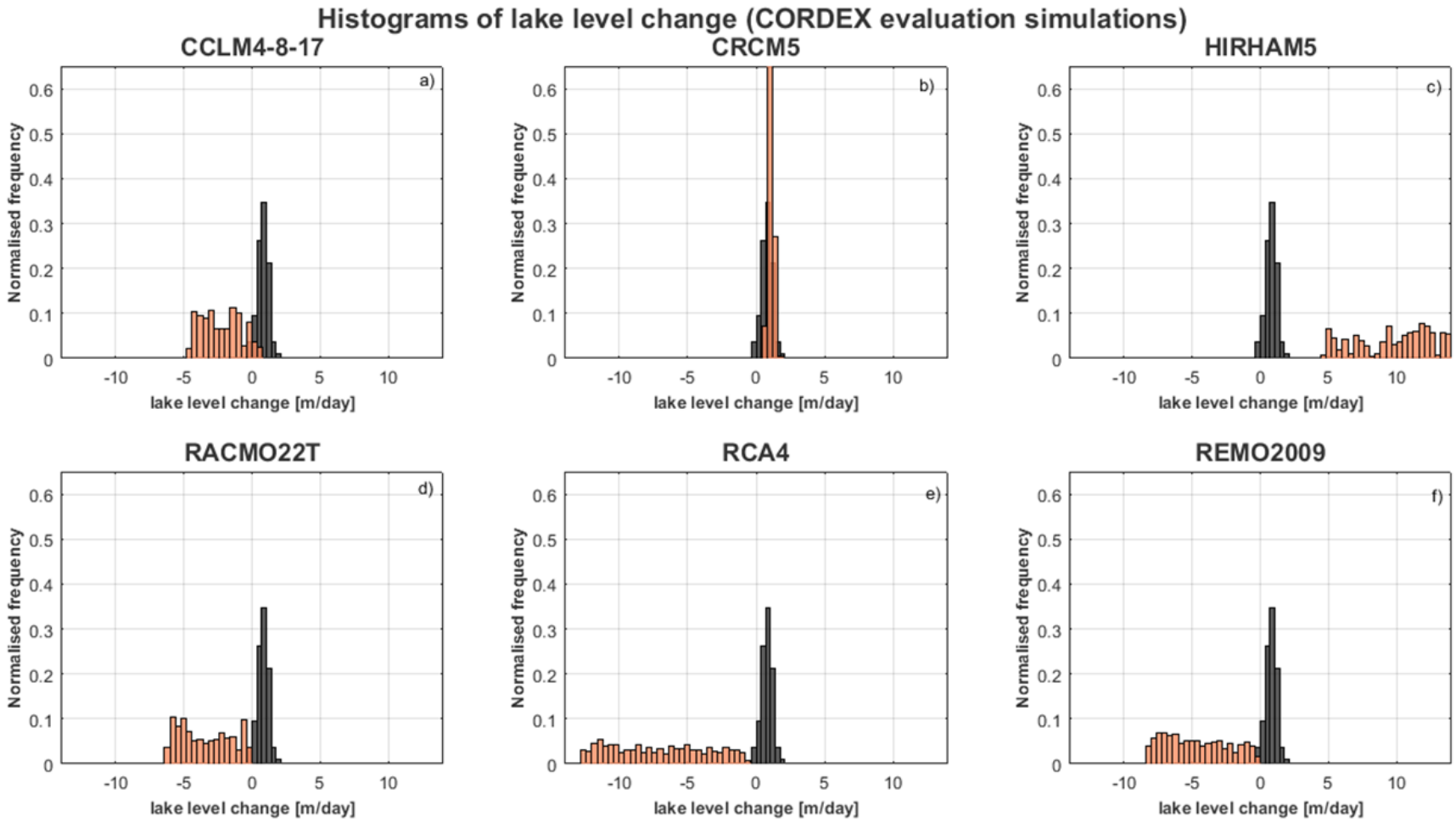
Water balance



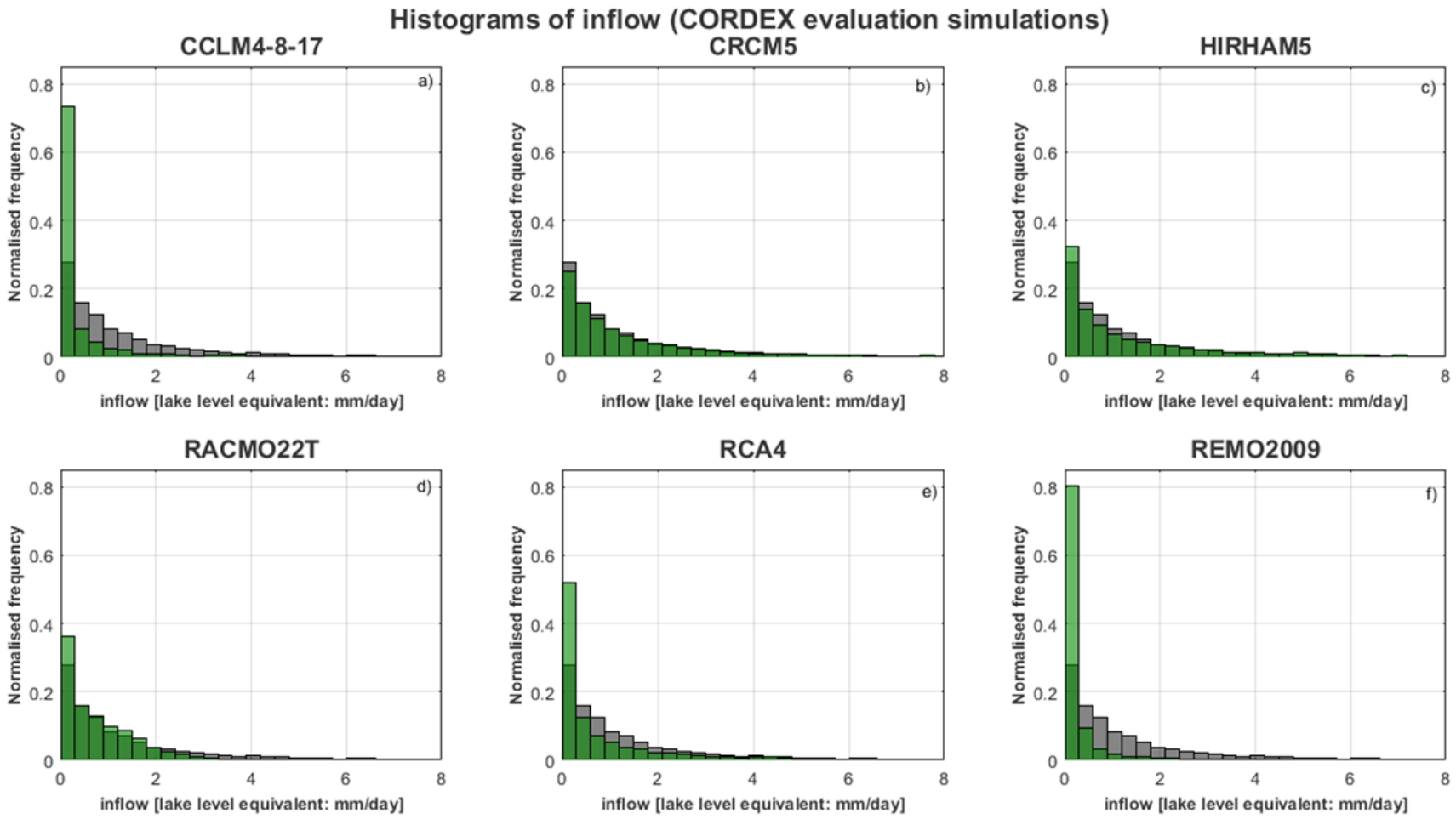
$$\frac{dL}{dt} = \boxed{P} - \boxed{E} + \frac{\boxed{Q_{in}} - \boxed{Q_{out}}}{A_{lake}}$$



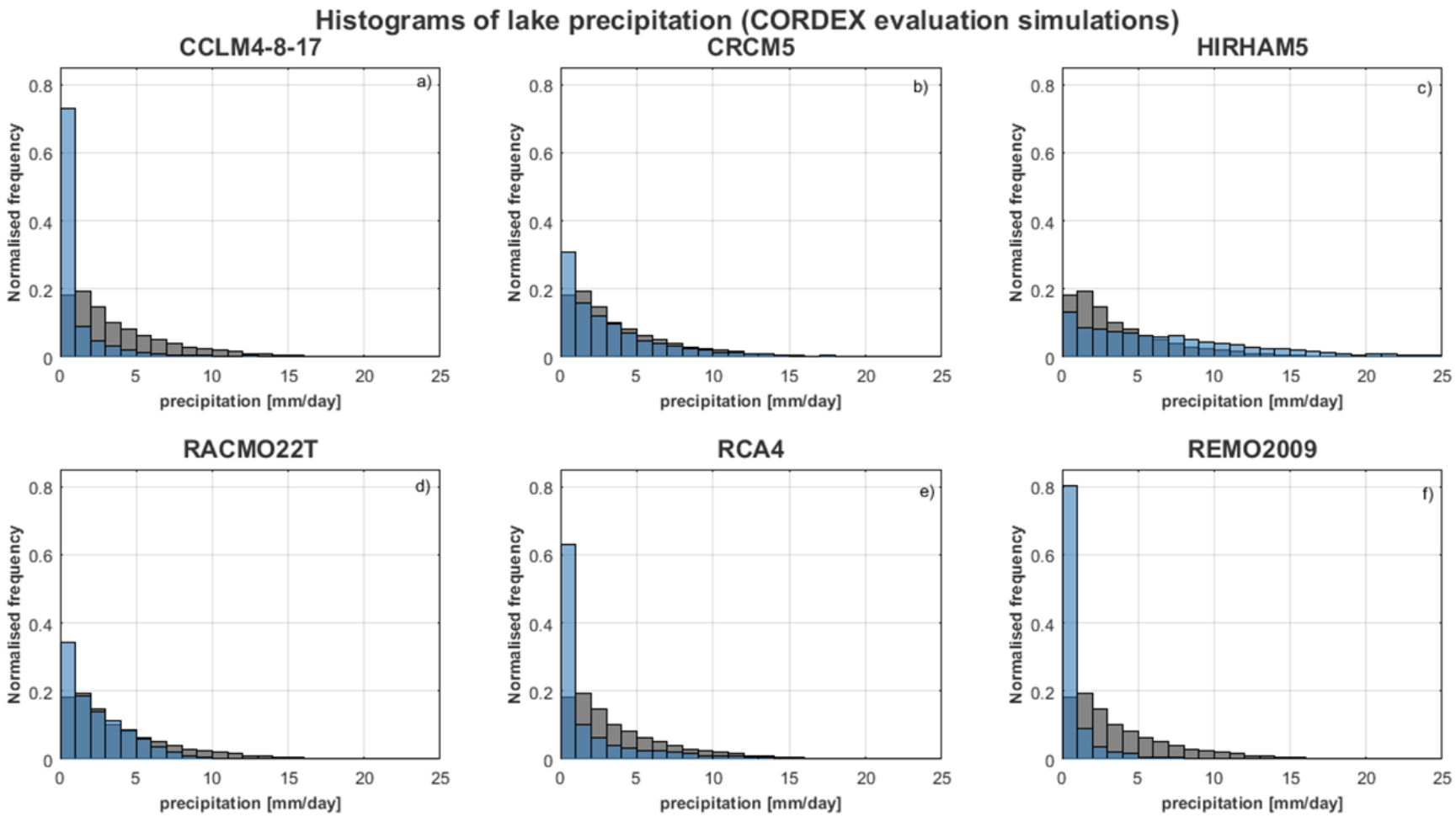
Lake levels


Histograms of lake level change (CORDEX evaluation simulations)
CCLM4-8-17
CRCM5
HIRHAM5
RACMO22T
RCA4
REMO2009
a)
b)
c)
d)
e)
f)
Normalised frequency
lake level change [m/day]
0
0.1
0.2
0.3
0.4
0.5
0.6
-10
-5
0
5
10

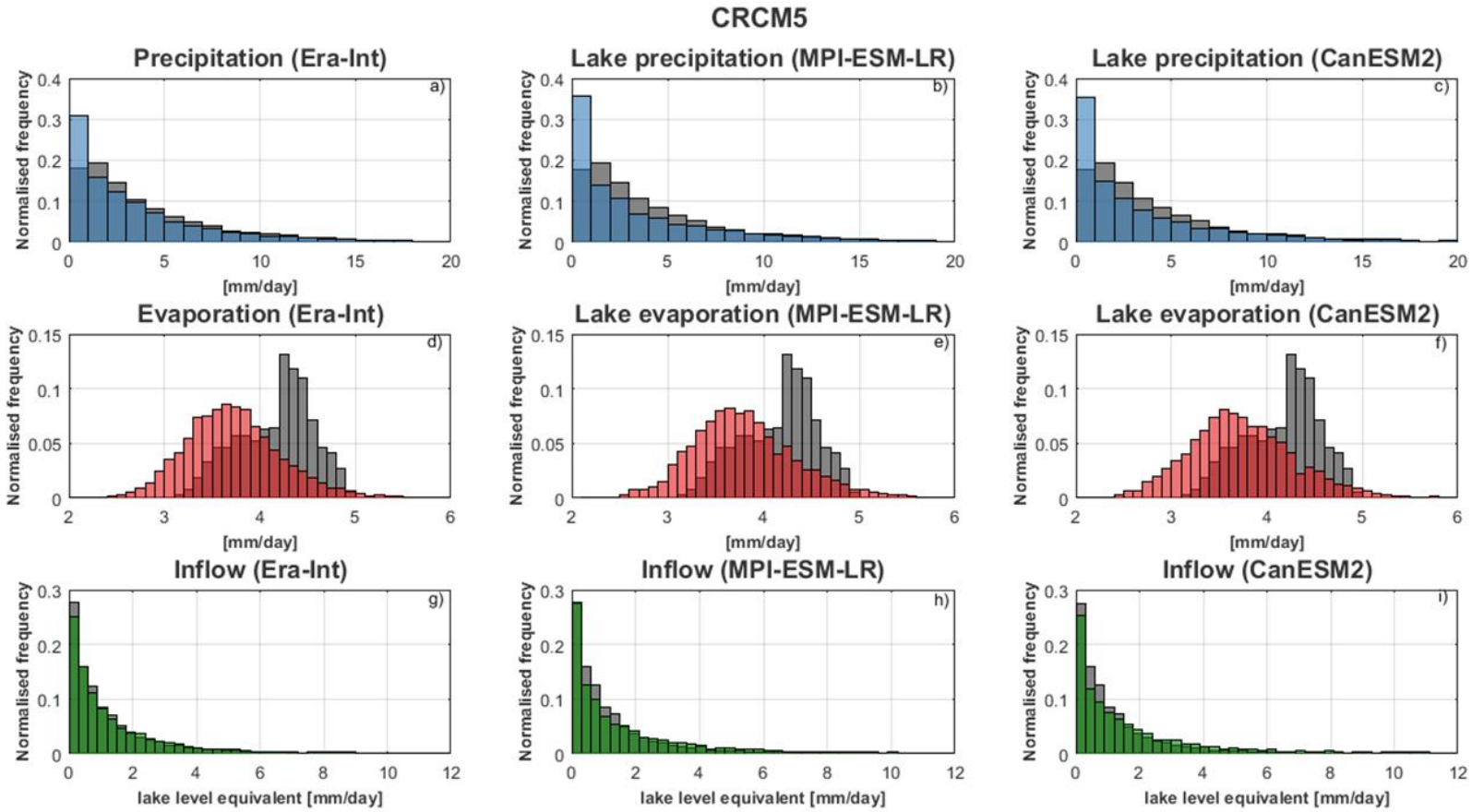
Inflow


Histograms of inflow (CORDEX evaluation simulations)
CCLM4-8-17
CRCM5
HIRHAM5
RACMO22T
RCA4
REMO2009
a)
b)
c)
d)
e)
f)
Normalised frequency
inflow [lake level equivalent: mm/day]
0
0.2
0.4
0.6
0.8
2
4
6
8

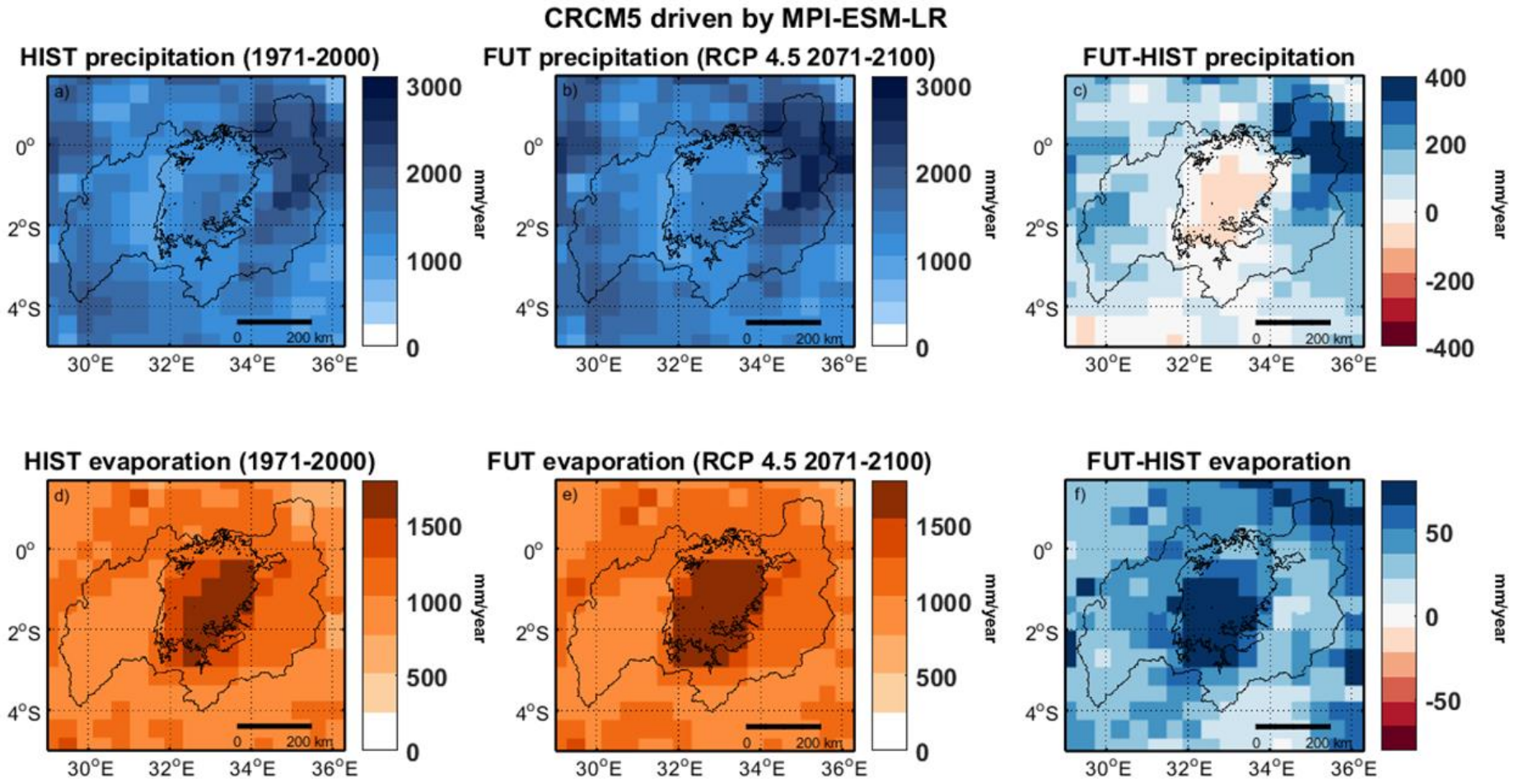
Precipitation



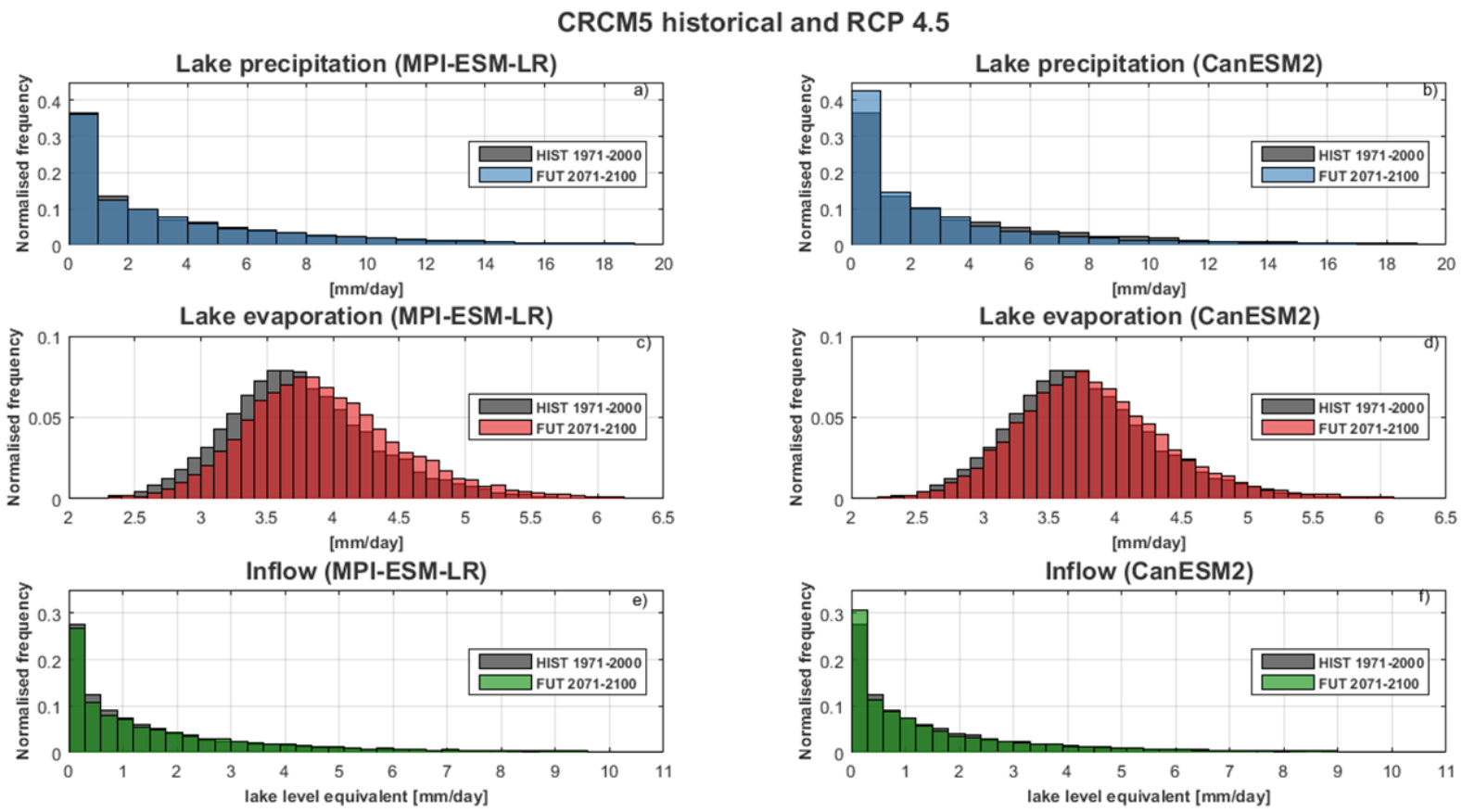
CRCM5 – 2 model simulations



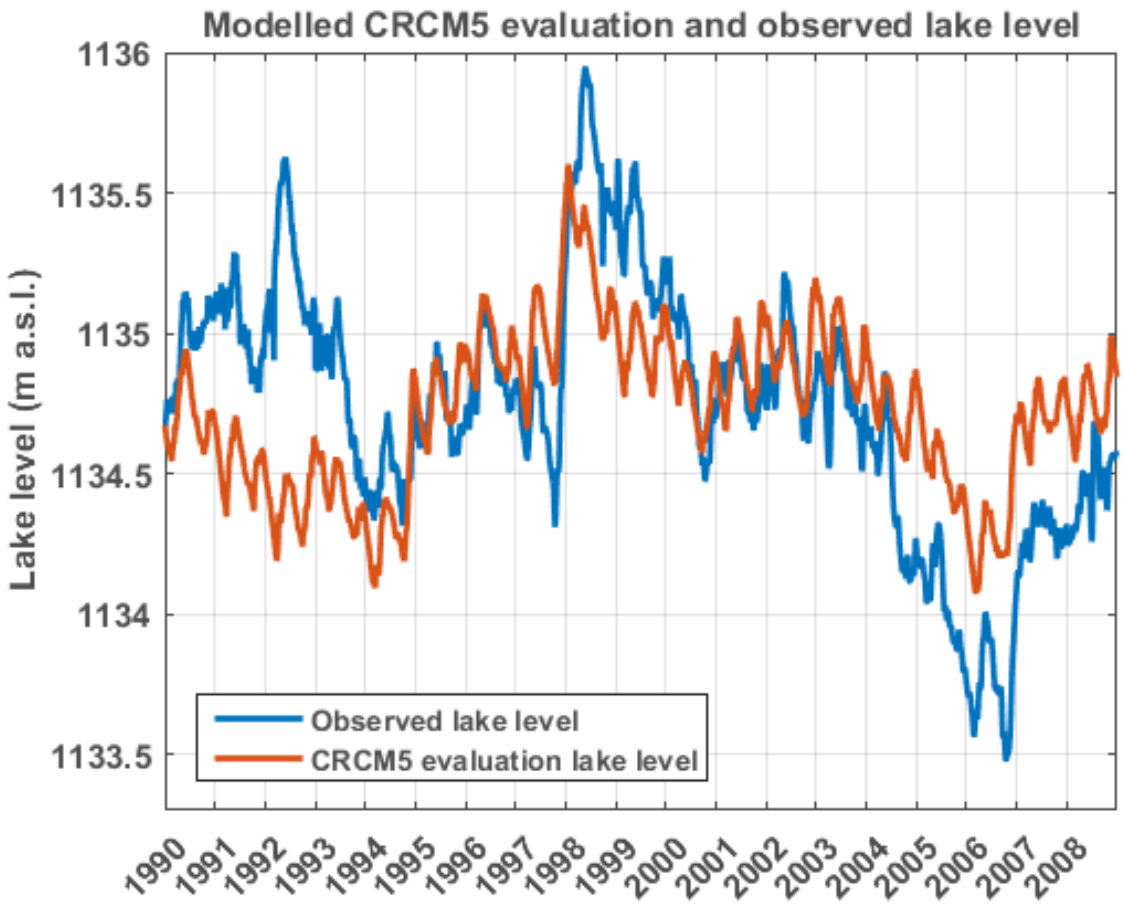
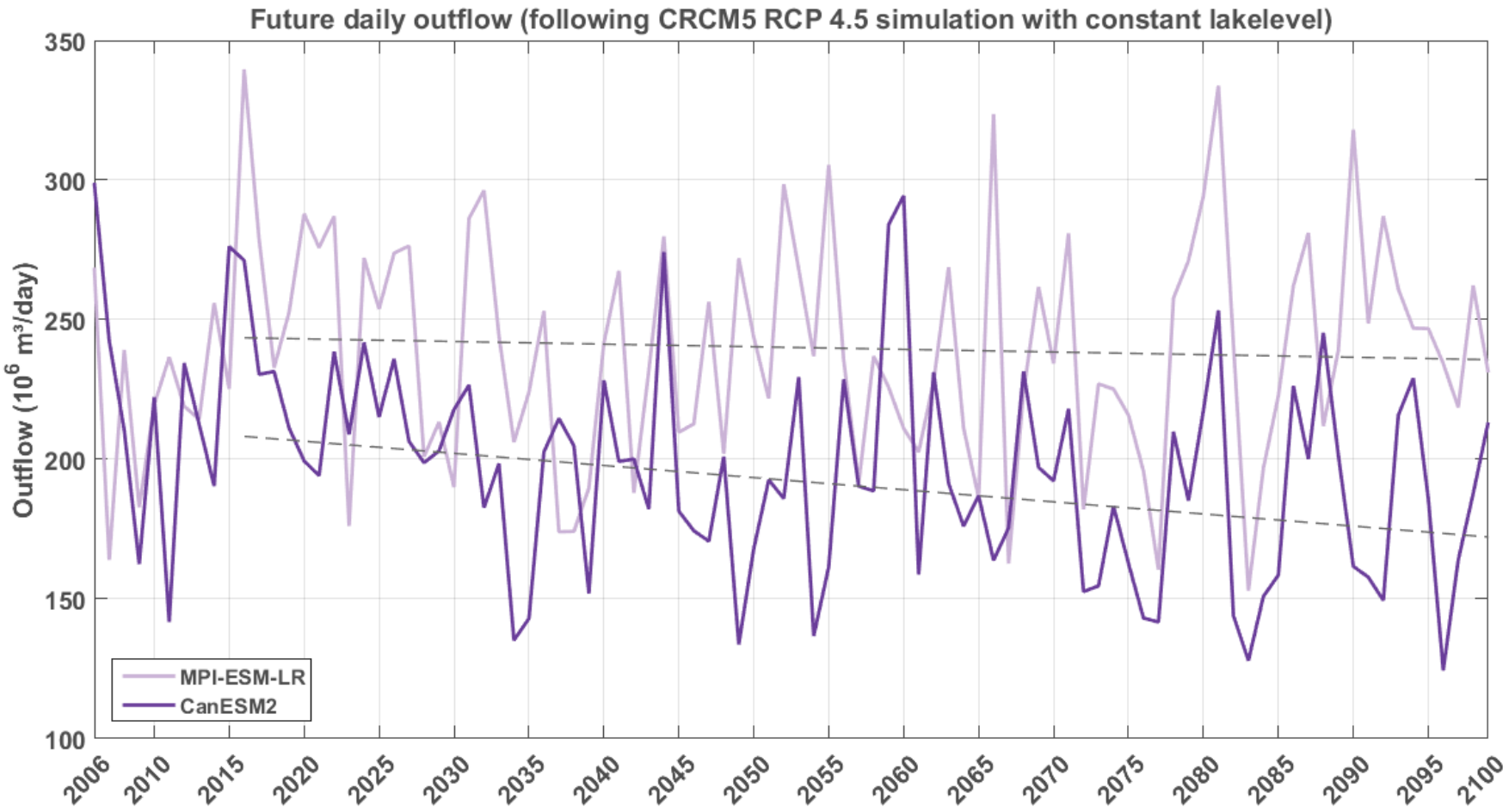
Simulations of CRCM5 with MPI-ESM-LR



CRCM5 – Climate change



CRCM5 – Lake levels



Outflow in constant lake level scenario