SCCER SoE

SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

Integrated simulation of HP system operation

Presented by *Paolo Burlando*

Team: *Daniela Anghileri, Andrea Castelletti, Nadav Peleg, Paolo Burlando*

Chair of Hydrology and Water Resources Management, ETH Zurich

In cooperation with the CTI

Energy funding programme
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI

SCCER-SoE Annual Conference
Birmensdorf, 14-15 September 2017

Task 2.5 Research Objective Phase 1

SCCER SoE

To develop:

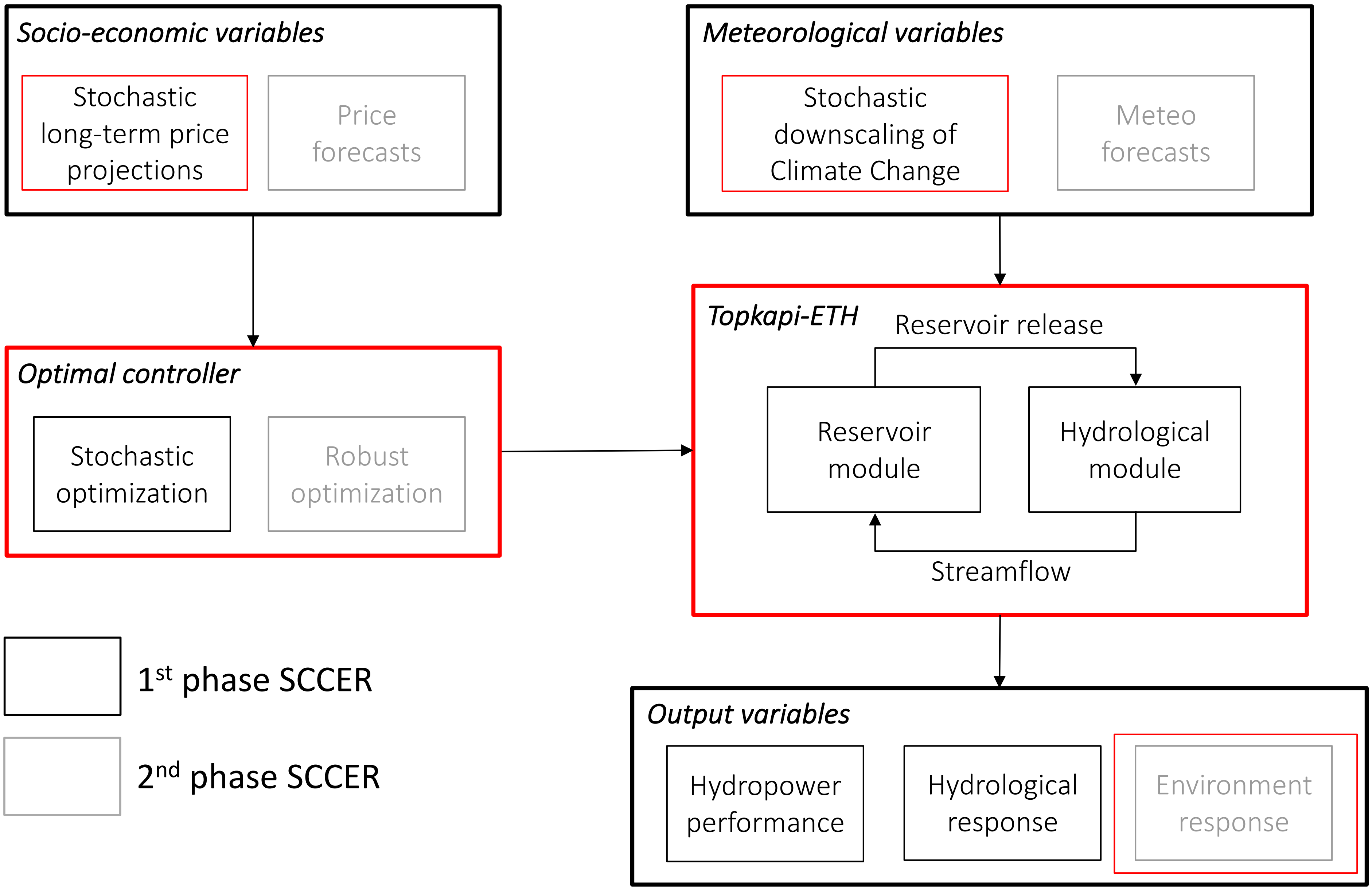
an ***advanced modelling framework*** for the ***integrated continuous simulation*** of streamflow regimes and of *operation of HP systems* under future climate scenarios, operational constraints, and technical solutions.

Tool for exploration of capacity of HP systems

➜ *to achieve desired goals in production, reliability, flexibility of operation, etc. for given forcing and constraints*

➜ *to analyse **trade-offs** among conflicting goals under **uncertainty***

Integrated modeling framework



Performed numerical experiments

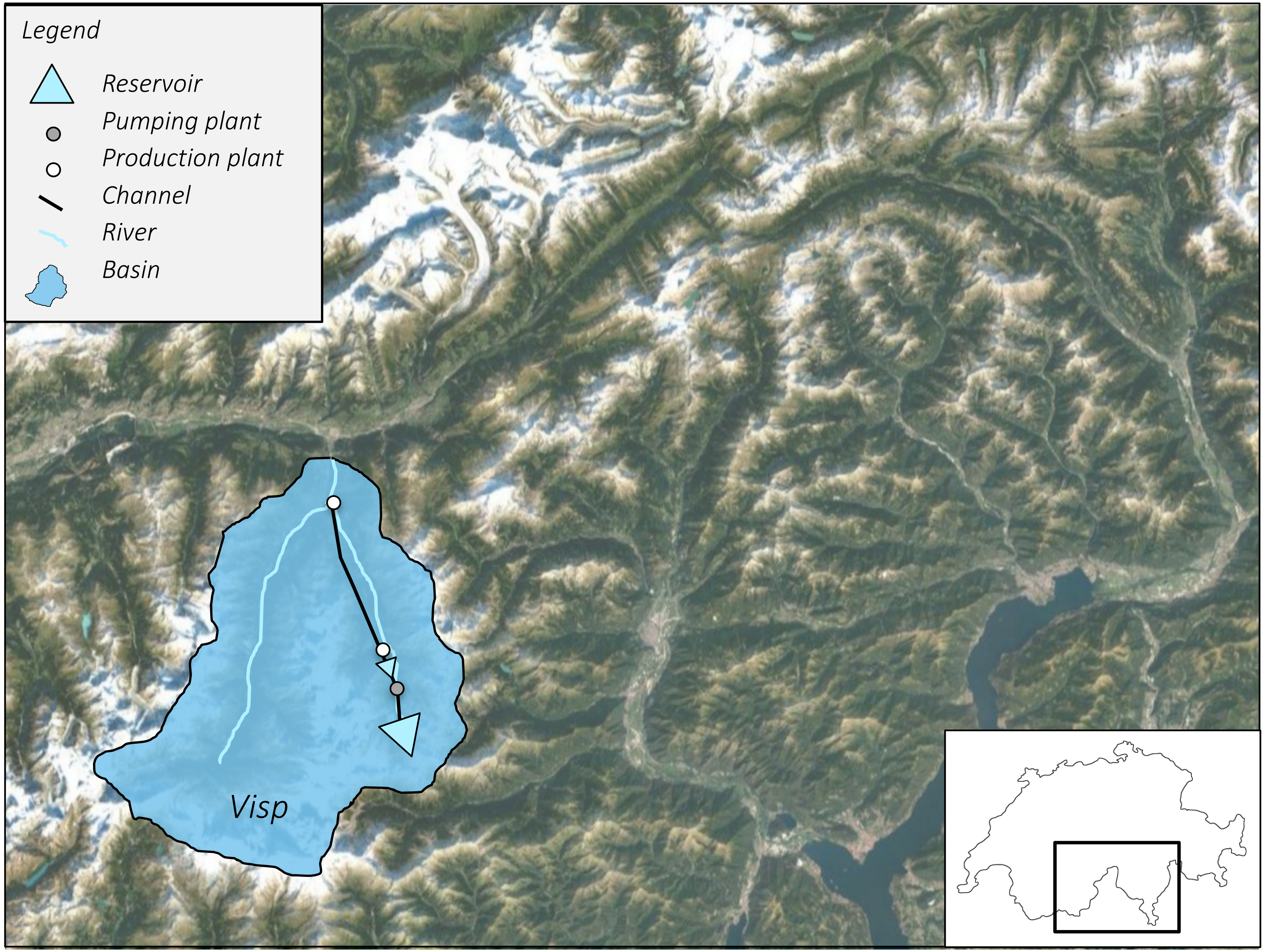
A. Stochastic Multi-Objective optimization of HP system operation.

B. Effect of different HP system operation strategies on the hydrology and river downstream.

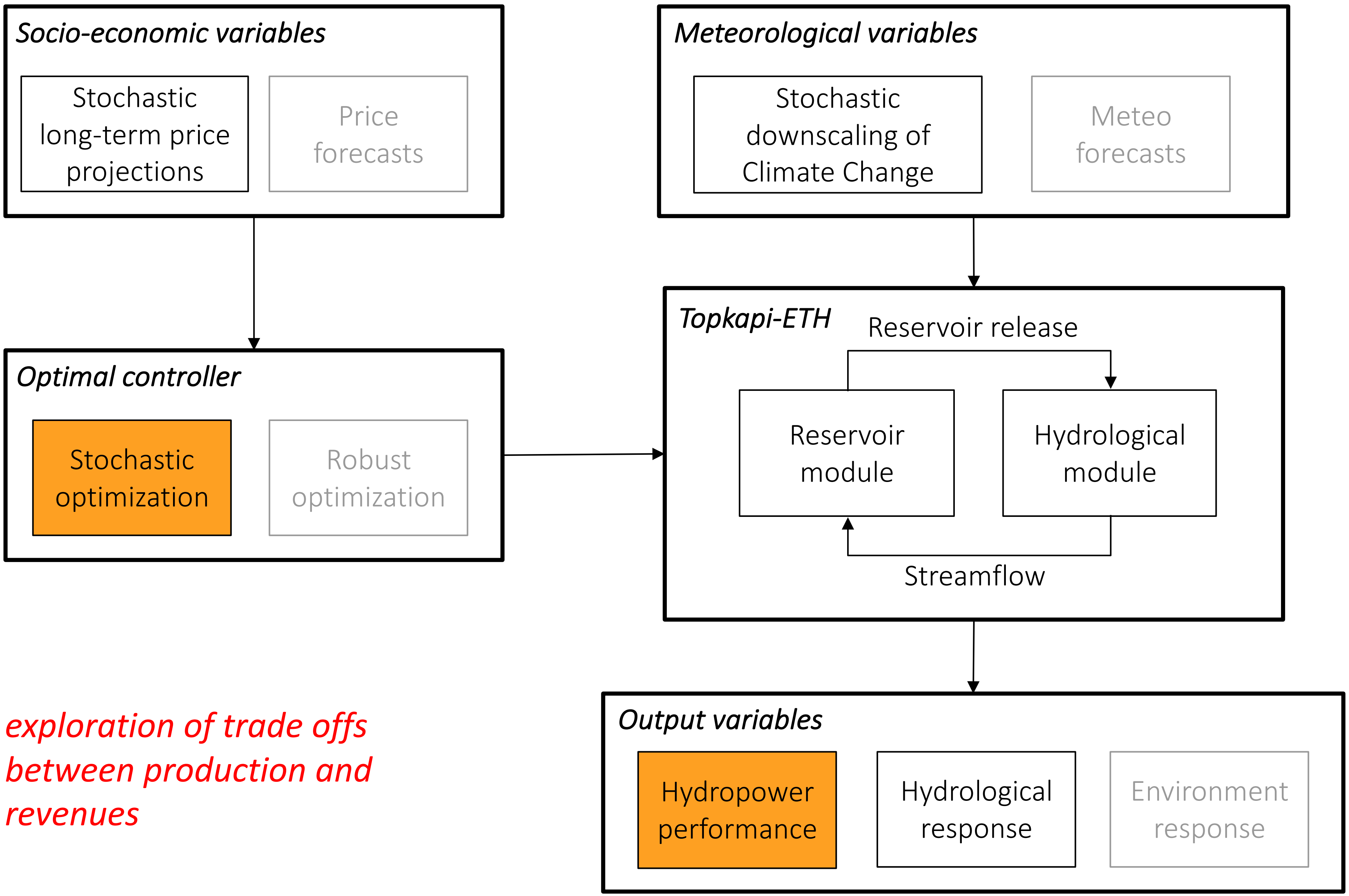
C. Effect of climate change on glacier retreat and water availability.

D. Effect of climate change and price projection on HP performances.

Visp catchment, Mattmark reservoir



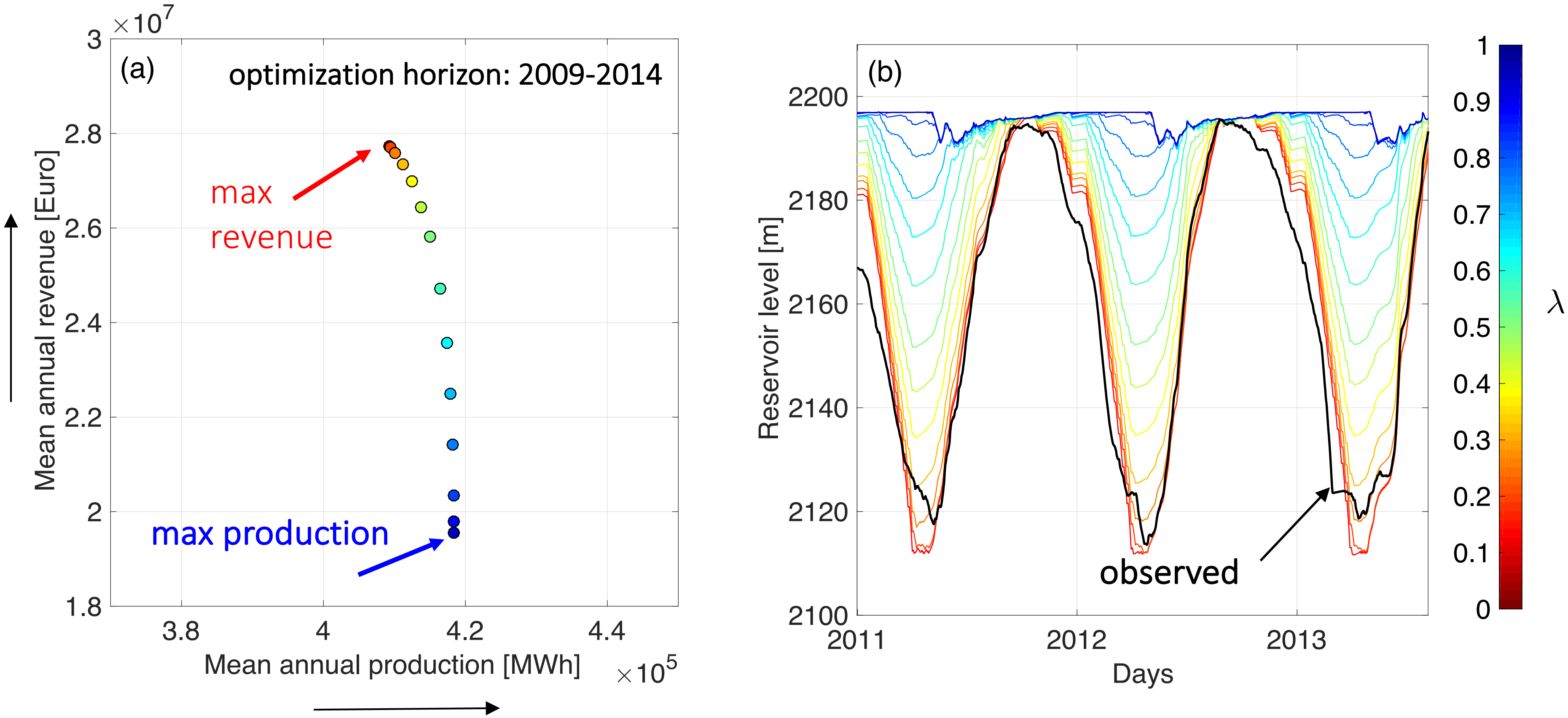
A. Stochastic Multi-Objective optimization of HP system operation (1/2)



exploration of trade offs between production and revenues

A. Stochastic Multi-Objective optimization of HP system operation (2/2)

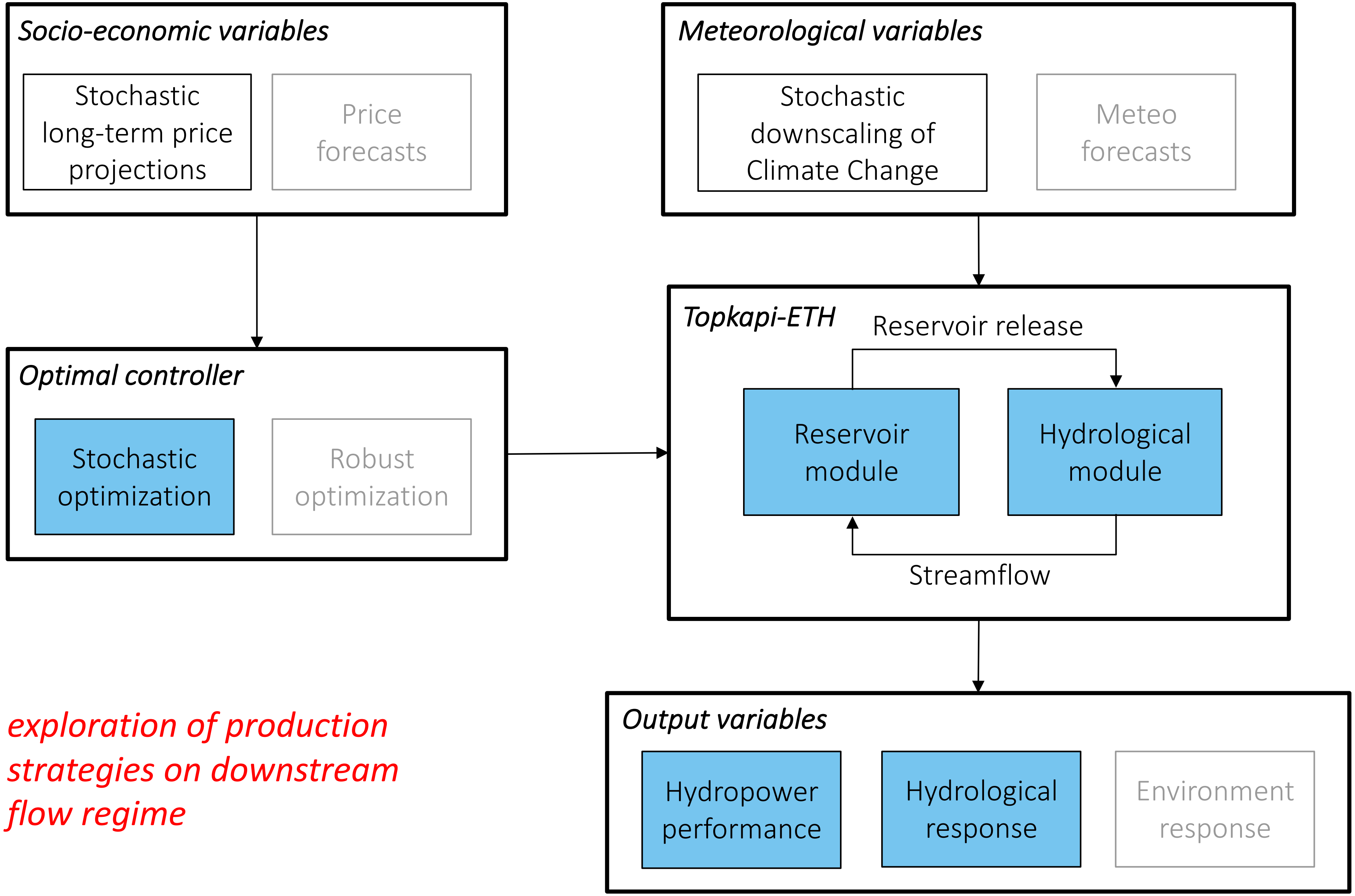
SCCER SoE



➜ *historical trajectories captured even in the absence of full system knowledge (e.g. pumping)*

➜ *low margin for production increase, higher for revenue*

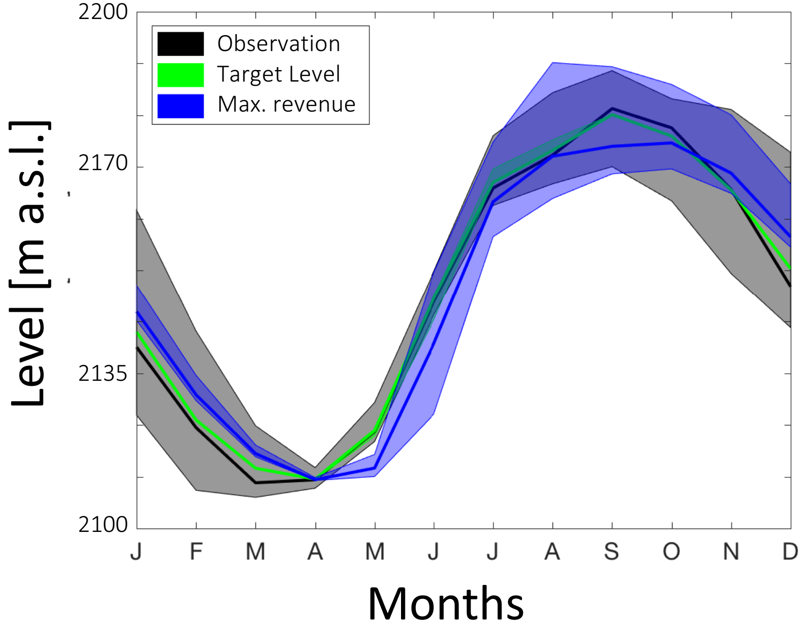
B. Effect of HP system operation strategies on downstream streamflow regime (1/2)

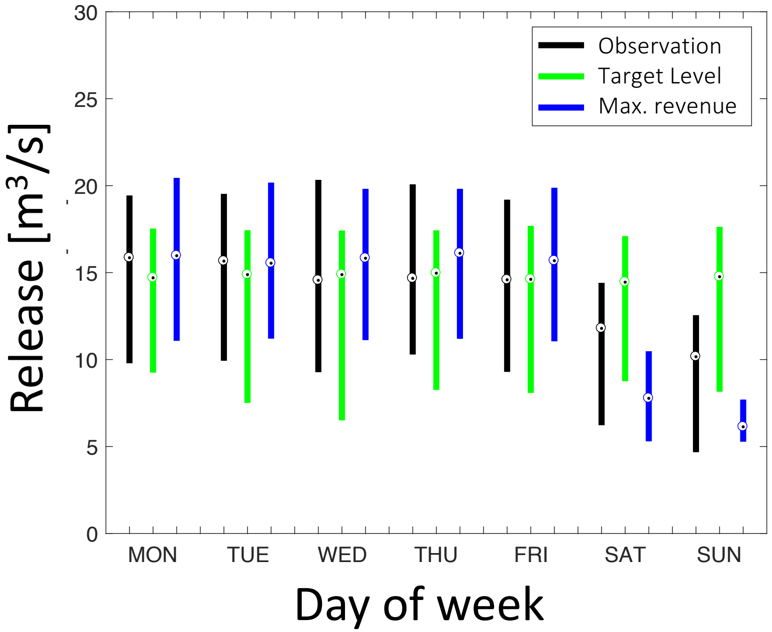


exploration of production strategies on downstream flow regime

B. Effect of HP system operation strategies on downstream streamflow regime (2/2)

SCCER SoE

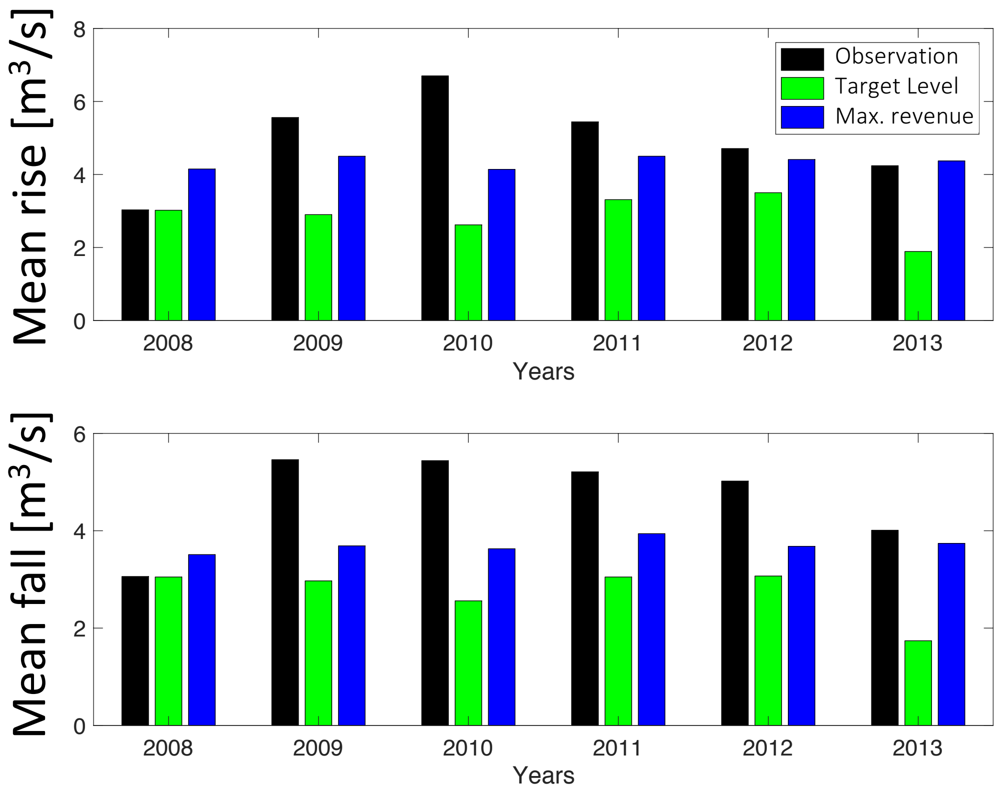




Comparison of different HP operations in terms of:

- HP reservoir dynamics
- Index of Hydrological Alteration (Richter, 1996).

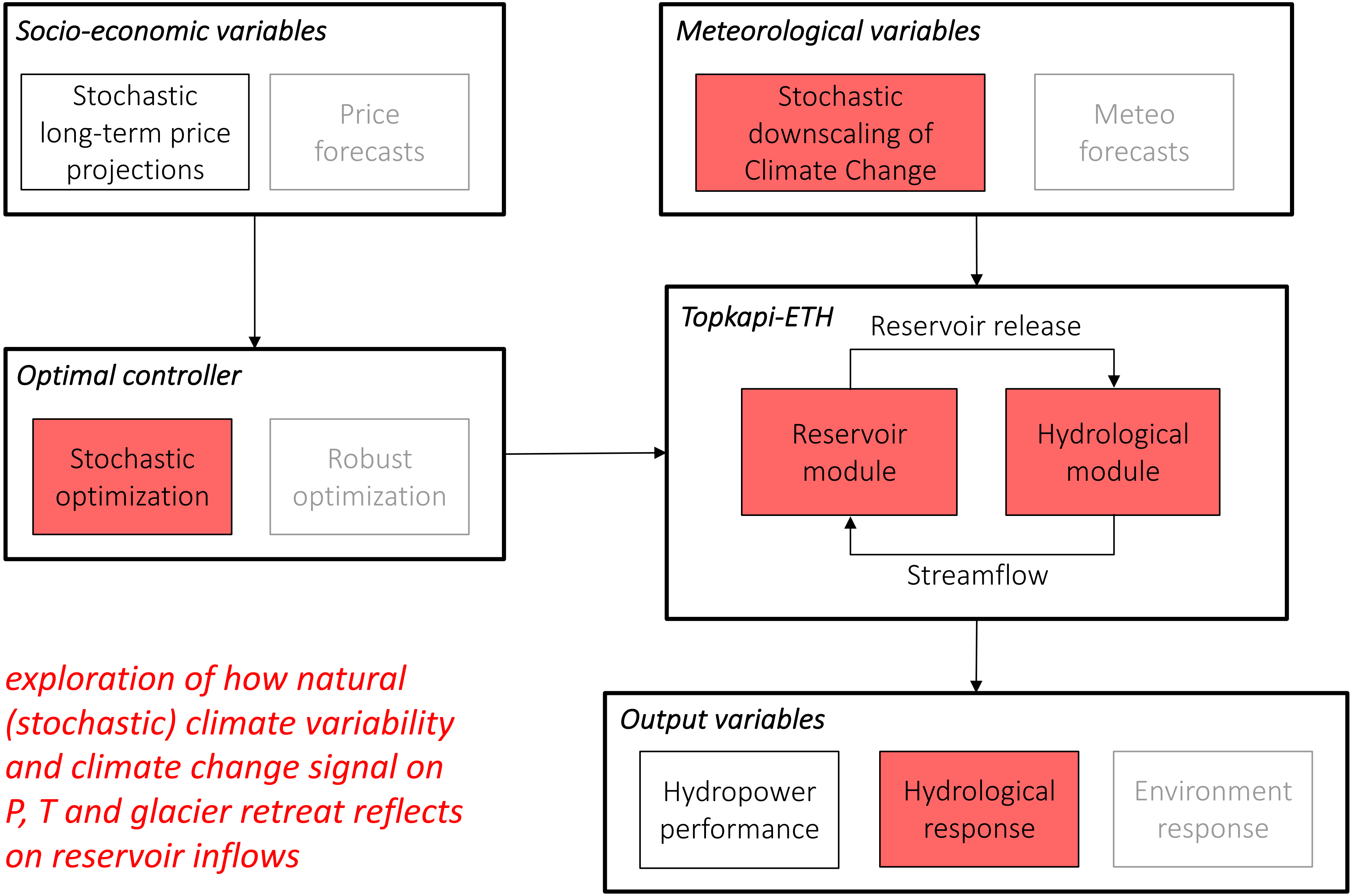
➜ *optimised operation captures the variability*



rate and frequency of water condition changes

C. Effect of climate change on water availability (1/3)

SCCER SoE

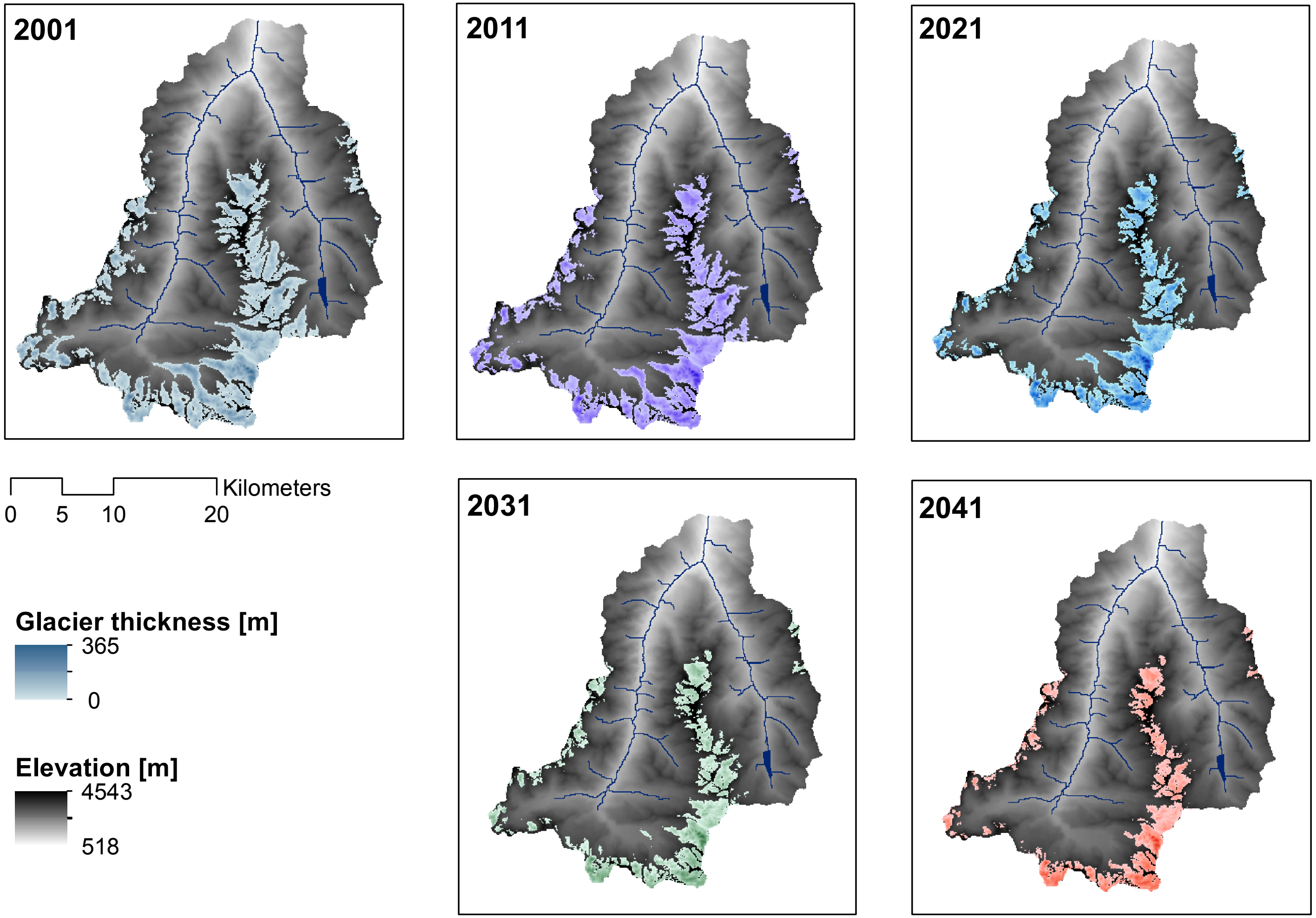


exploration of how natural (stochastic) climate variability and climate change signal on P, T and glacier retreat reflects on reservoir inflows

C. Effect of climate change on water availability (2/3)

- Initial glacier thickness map as in Huss and Farinotti (2012);
- Explicitly modelled glacier retreat (downwasting parameterisation by Huss et al. 2010)
- Stochastic downscaling of climate scenarios

➜ *ready for link to T2.1 (advanced glacier mapping)*

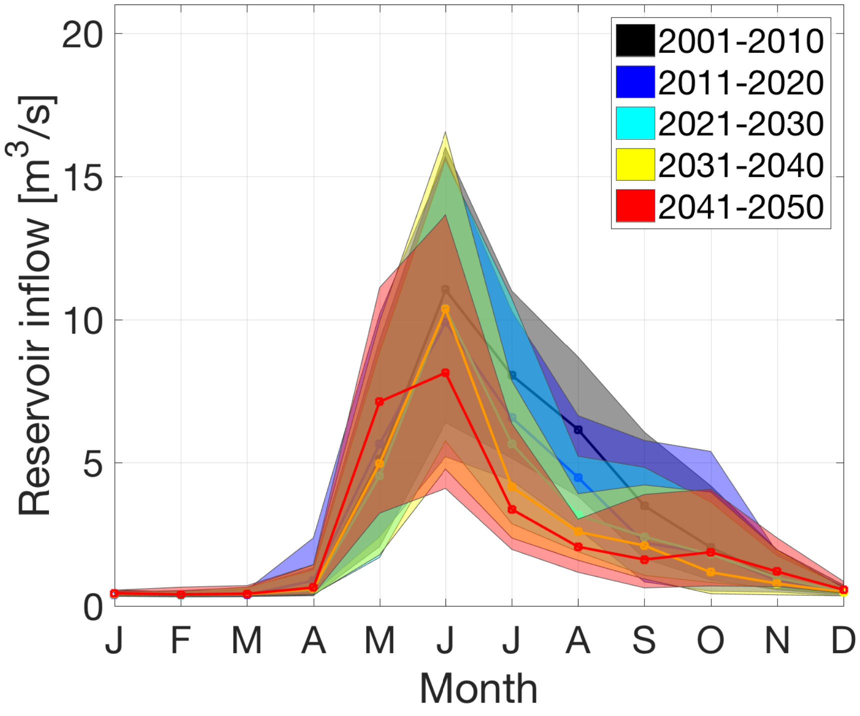


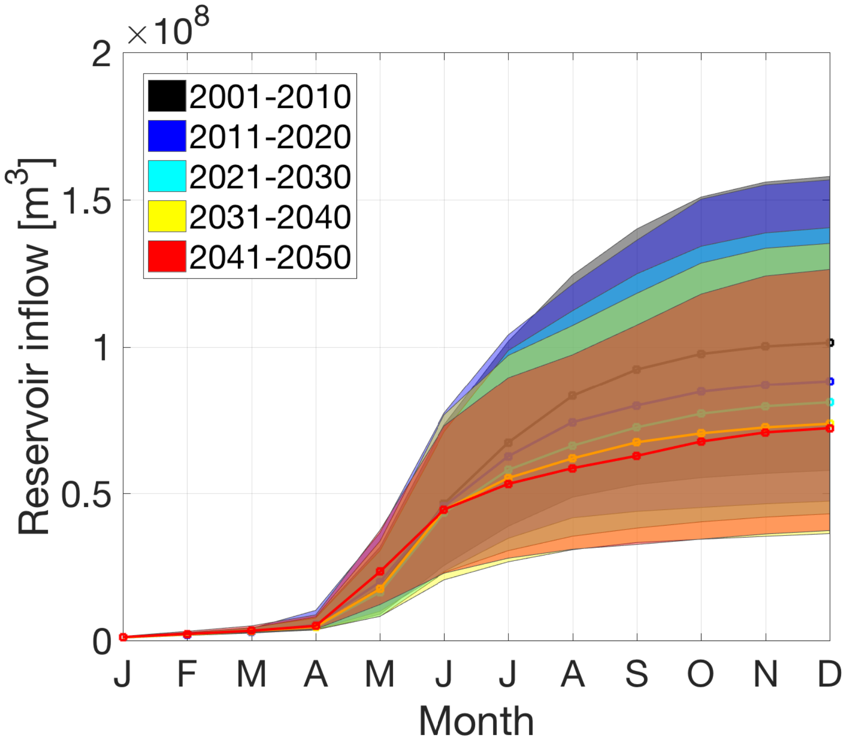
C. Effect of climate change on water availability (3/3)

SCCER SoE

Stochastic projections of reservoir inflows (10th-90th percentiles) according to:
- middle emission scenario A1B (SRES, 2000),
- downscaled GCM ECHAM5 (Roeckner et al., 2003), and RCM REMO (Jacob et al., 2001) scenarios.

➜ *ready for link to T2.1 (new and refined downscaling)*

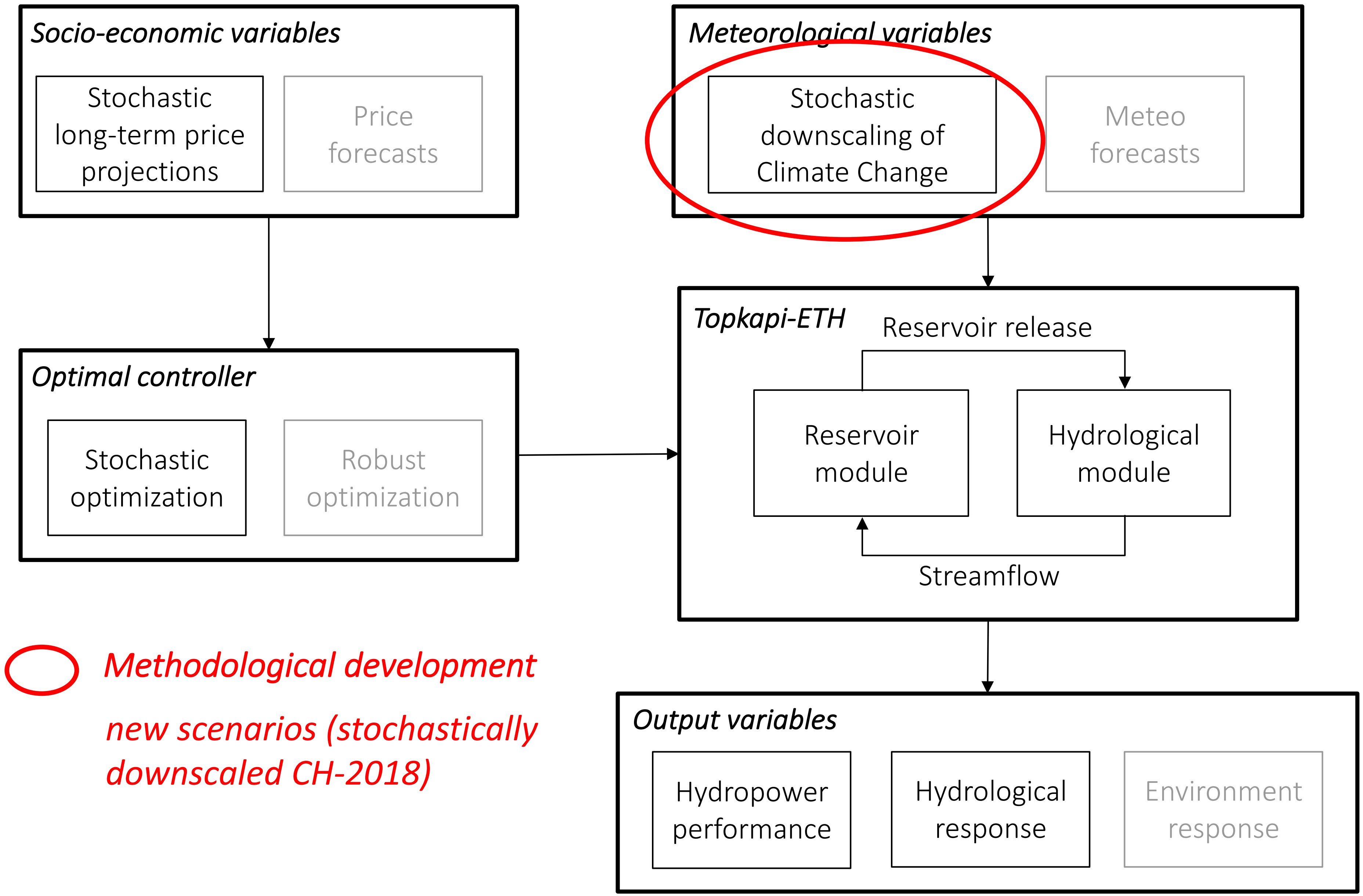




➜ *shift in seasonality and annual volume of inflow*

➜ *large uncertainties due to natural (stochastic) climate variability*

Advanced stochastic weather generator

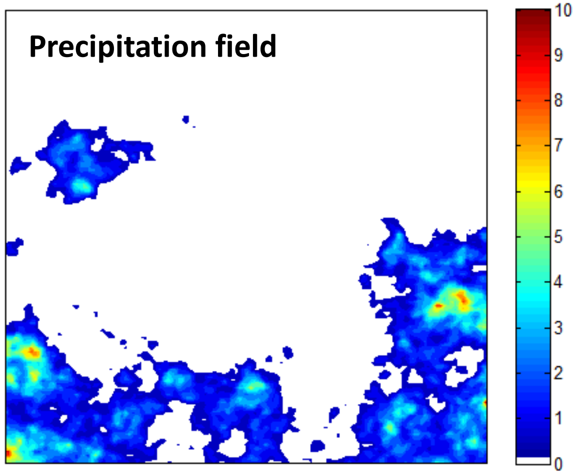


Advanced stochastic weather generator

T2.1 → AWE-GEN-2d (**A**dvanced **WE**ather **GEN**erator for **2-D** grid):

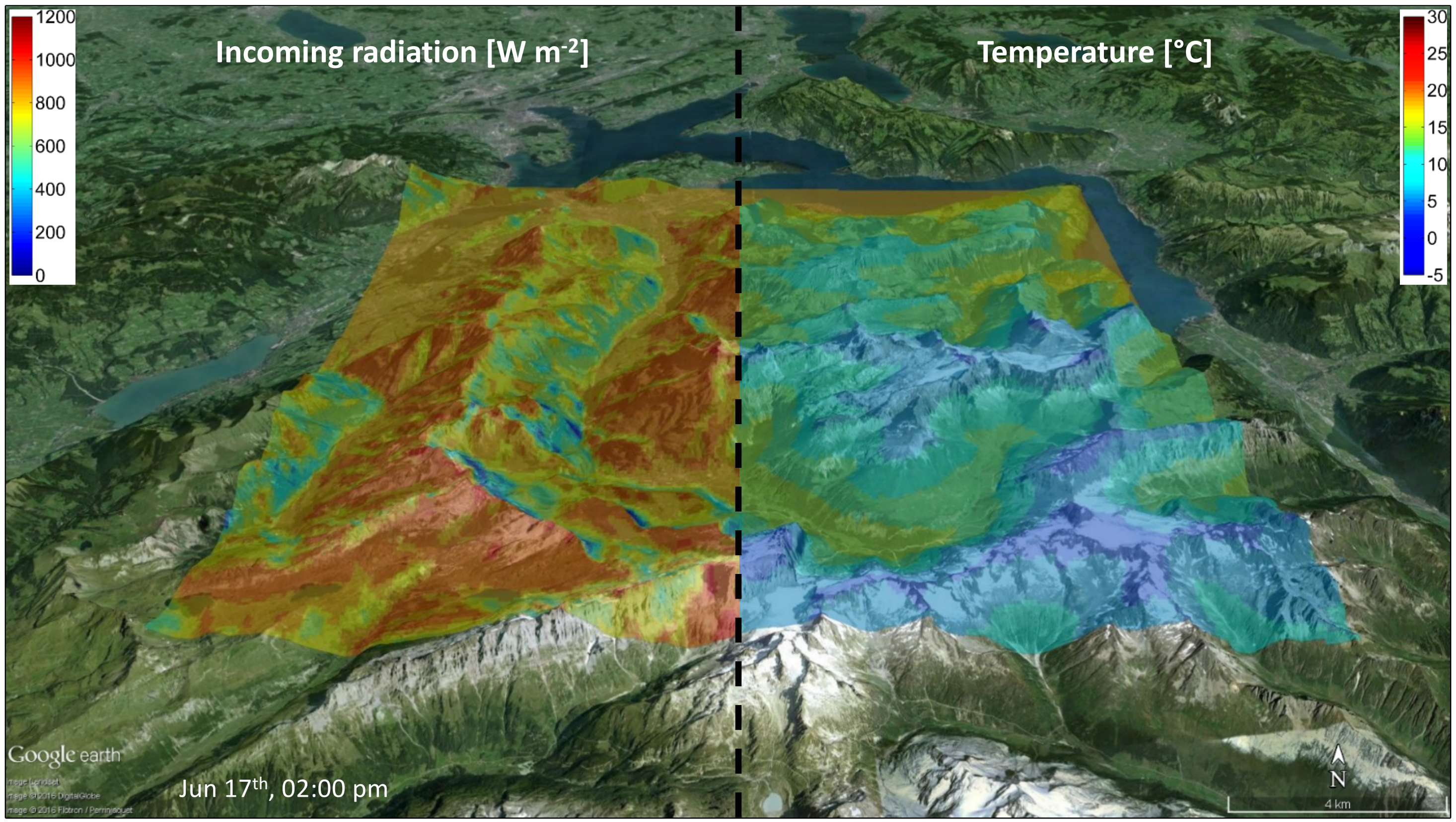
- combine *physical and stochastic* approaches to generate gridded climate variables
- high spatial and temporal resolutions (100s of m to km, min to hour)
- multivariable: P, T, SR, VP, RH, near surface wind fields)
- model re-parameterisation for CC impact studies in Phase II

➜ *see poster by Peleg et al. (area T2.1)*

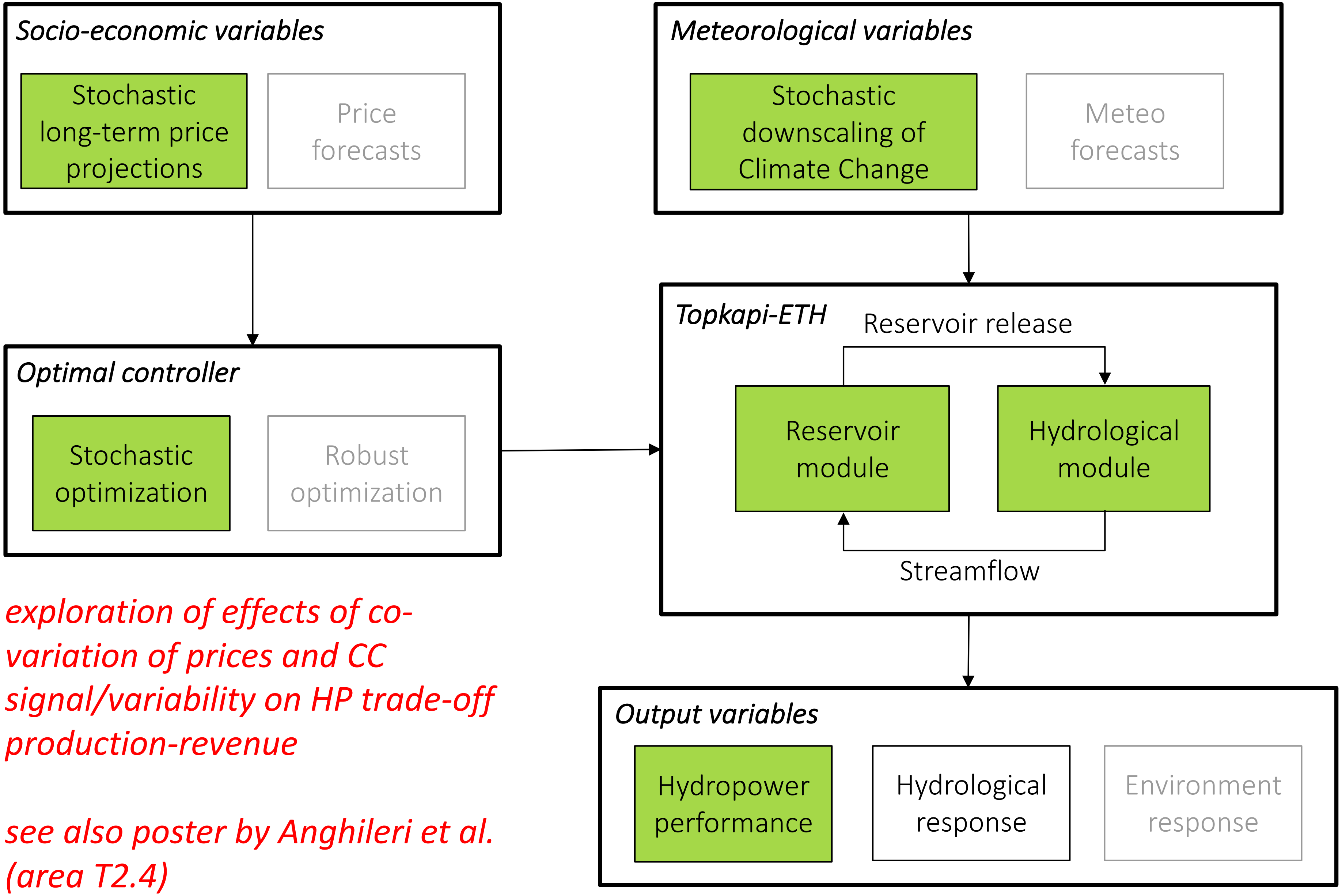


➜ *conceptualisation of reparameterisation completed*

➜ *scenario generation on case studies on going*



D. Effect of climate change and price projection on HP performances (1/2)



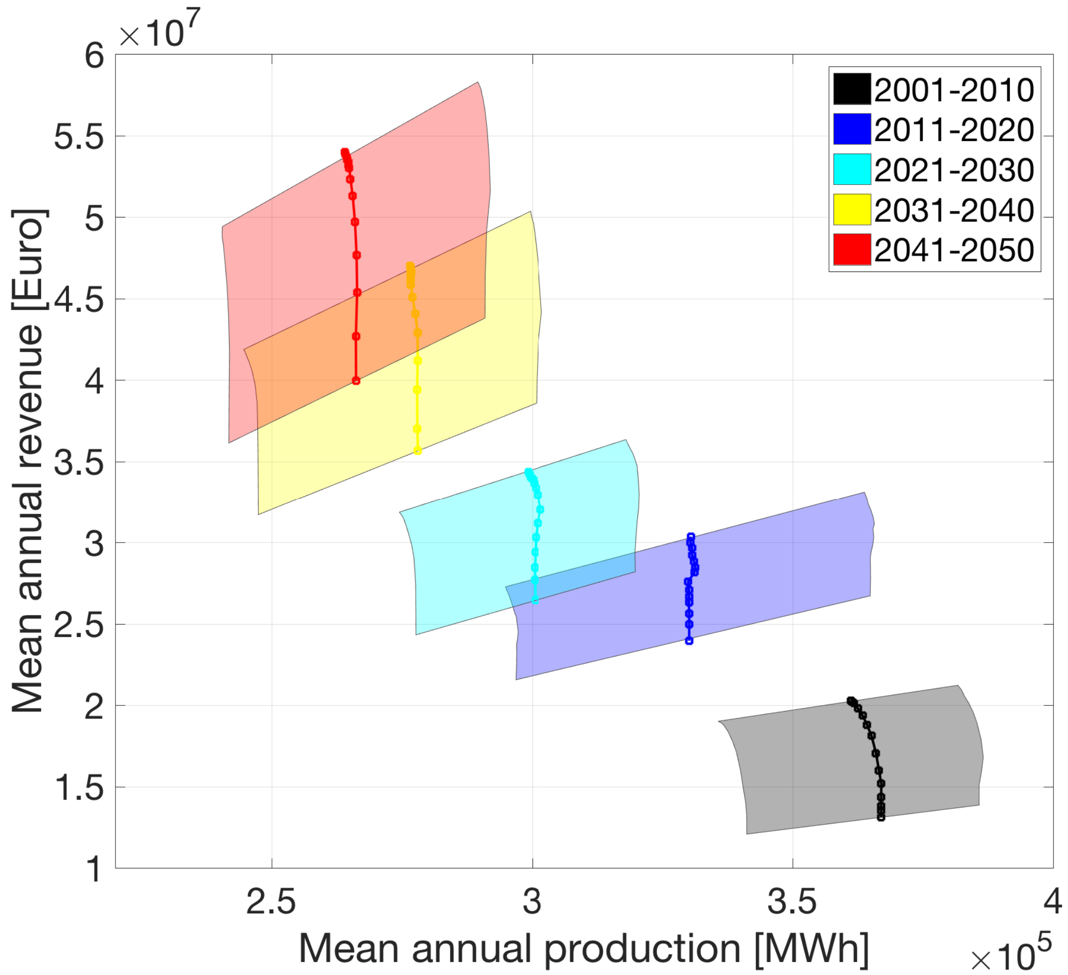
exploration of effects of co-variation of prices and CC signal/variability on HP trade-off production-revenue

see also poster by Anghileri et al. (area T2.4)

D. Effect of climate change and price projection on HP performances (2/2)

SCCER SoE

- Price projections according to SwissMod (University of Basel). ➜ *link to SCCER CREST*
- Data driven stochastic variability of prices
- CC as in C.



➜ *revenue increase because of underlying increase of price projections (≈effect of CO_2 permit price)*

➜ *decrease in production because of lower water availability*

➜ *overlap at mid century due to stabilisation of glacier retreat*

Summary of numerical experiments

SCCER SoE

Integrated HP system model

- capturing historical variability even without perfect knowledge of historical management
- conceptually ready for further applications (multiobjective, more complex systems)
- able to show the margin of trade-off operation of HP, jointly with effects of risks associated with changes of drivers and their co-variation
- ready for new climate scenarios

Current limitations

- incomplete information for calibration on current operation strategies
- speculative exercise vs sensitivity of HP systems in the absence of more information on HP companies objectives

Dissemination

- paper in review + paper ready for submission
- one more application on-going on complex pump-storage system (Maggia)

Phase 2 - T2.4 (ex T2.5) activities

SCCER SoE

Key research directions (KDs) to be investigated with tools developed in Phase 1

KD1: *Increase of flexibility in hydropower operation – structural and operation requirements*

KD2: *Update of climate change impacts on HP production and required adaptation strategies*

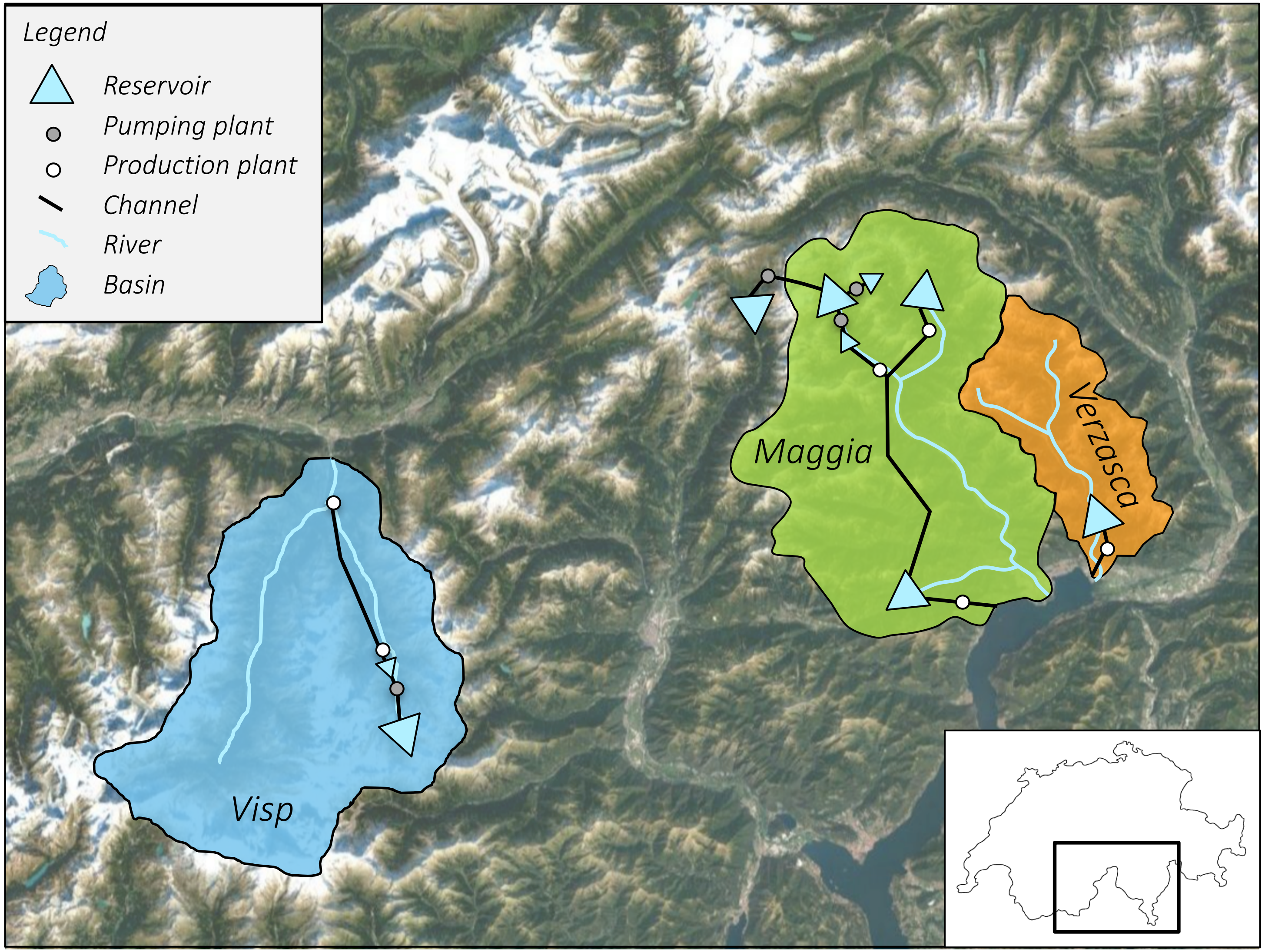
KD3: *Extreme natural events, hazards and risk of HP operation*

KD4: *Design of new projects under uncertainties*

KD5: *Reservoir sedimentation and sustainable use of storage HP*

Case studies (exemplary) for KDs investigation by means of the integrated framework

SCCER SoE

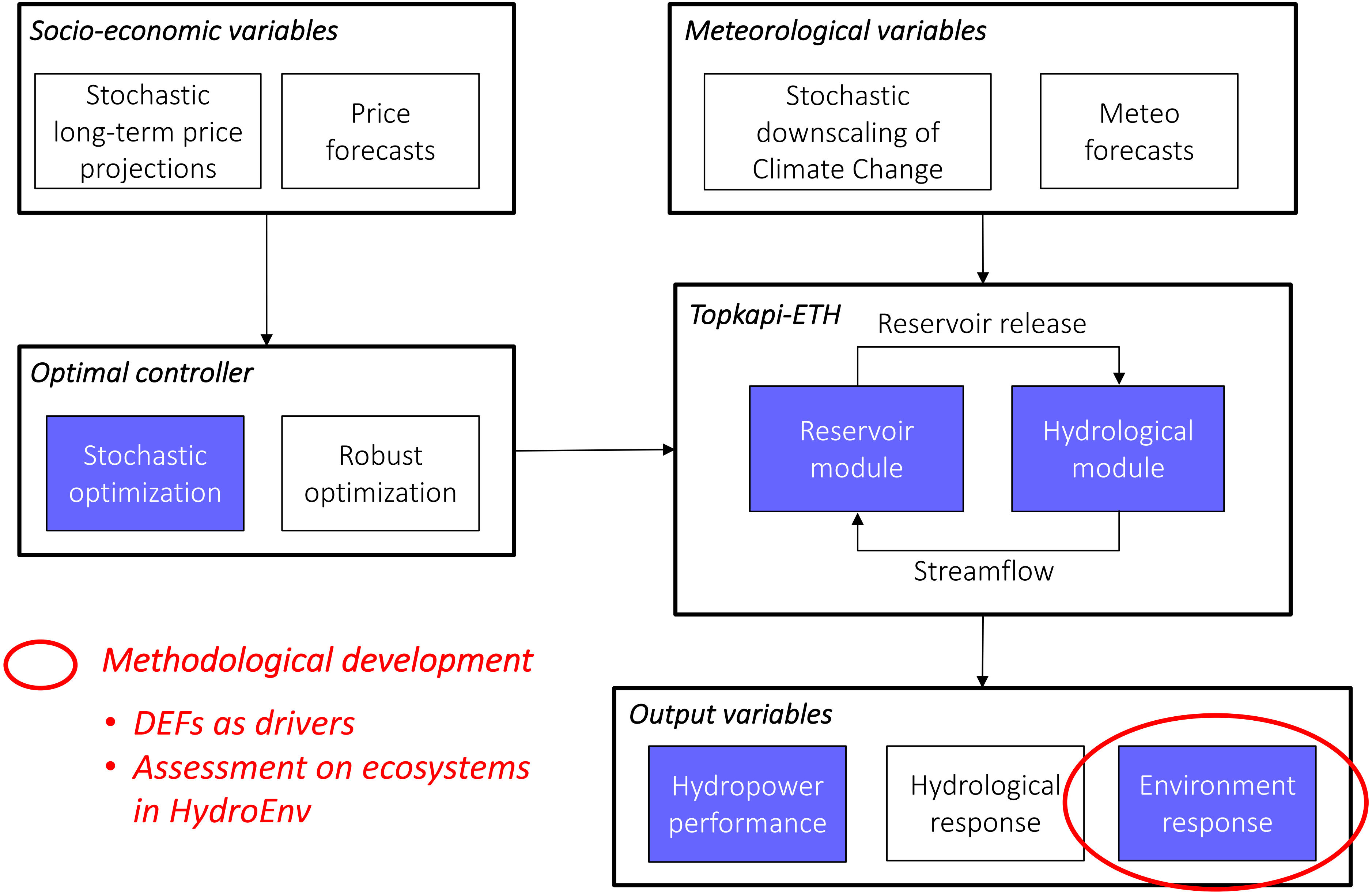


Planned numerical experiments (selection)

1. Effects of HP operation strategies on ecosystems (KD5, effects of new release strategies, e.g. DEFs → NFP70 HydroEnv).
2. Development of a robust planning and management approach in planning new infrastructures or upgrading existing ones (KD4).
3. Develop a real time operation framework to integrate forecasts of price and flows on different time scales into the design of HP reservoir operation strategies (KD1).

1. Effects of HP operation strategies on ecosystem

SCCER SoE

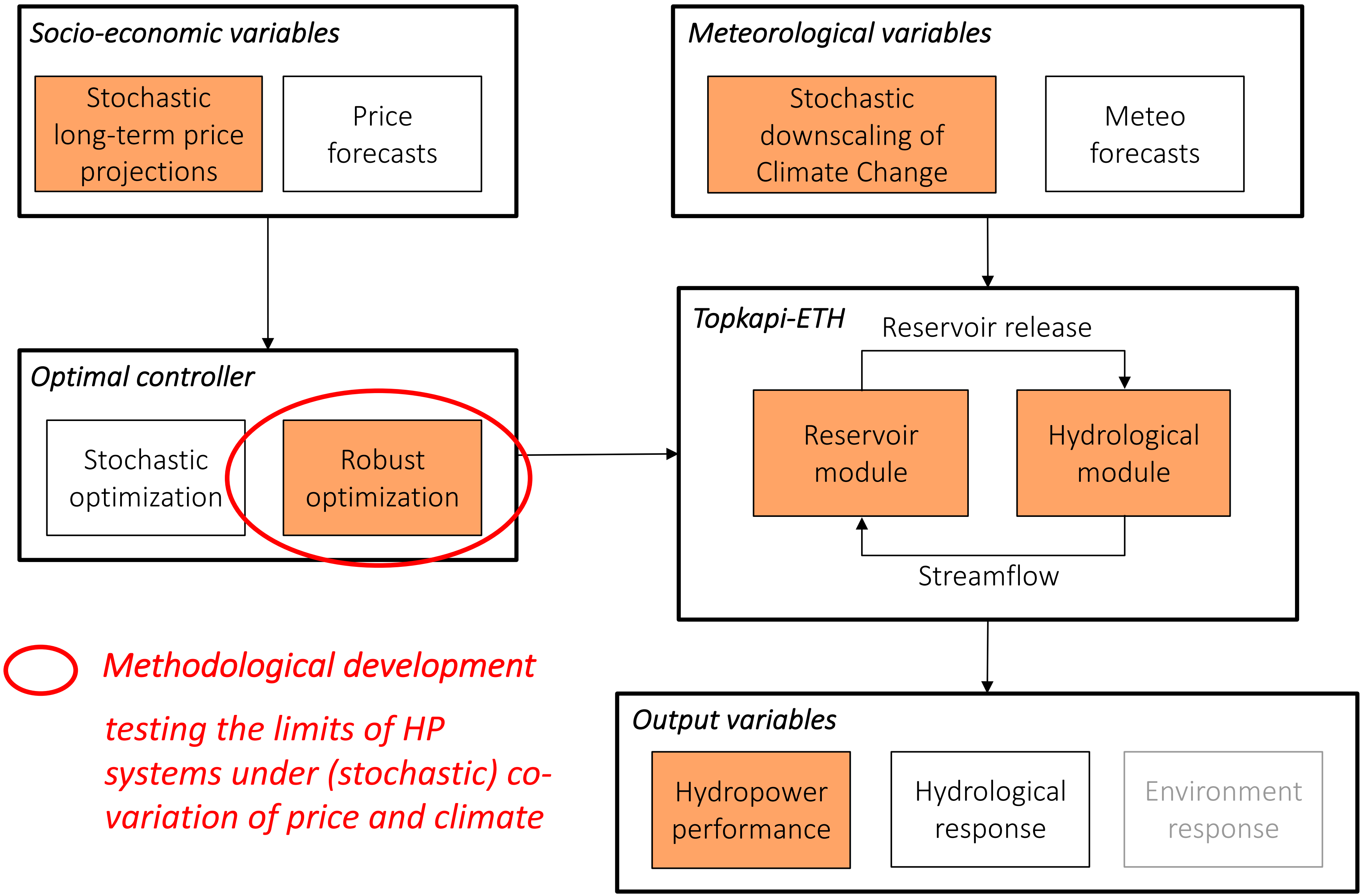


Methodological development

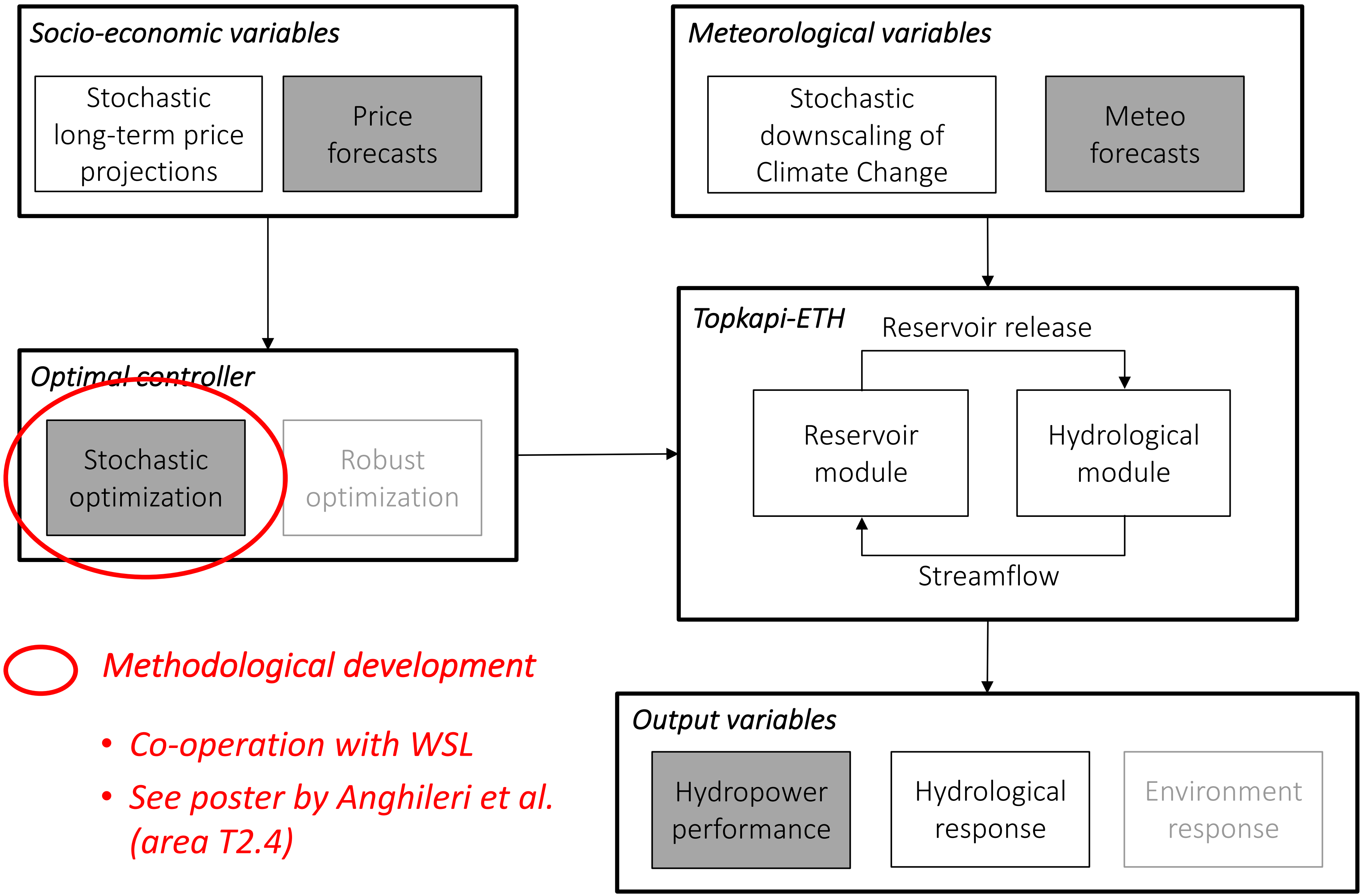
- *DEFs as drivers*
- *Assessment on ecosystems in HydroEnv*

2. Robust HP planning and management

SCCER SoE



3. Increase HP efficiency by use of forecasts



SCCER SoE

Thank you for your attention

Thanks to

KWM axpo Ofima

for their support