

PhD Course in Structural and Environmental
Health Monitoring and Management – SEHM²

Evaluation of PhD activity - Cycle XXXIII

Innovative techniques for remote sensing of hydrological-hydraulic variables

Candidate: *Molari Giada*
Cycle XXXIII

Supervisors:
Alessio Domeneghetti (main supervisor)
Attilio Castellarin (co-supervisor)



Introduction

Monate Lake case study

- Survey area
- Hydrological model (HyMOD)

Remote sensing techniques for hydraulic applications

- Satellite altimeters
- River bathymetry estimation
 - RiBEST tool
 - 2D hydraulic modelling
 - Data Assimilation approach on SRTM-based bathymetry
- Global investigation of river geomorphologic relationship

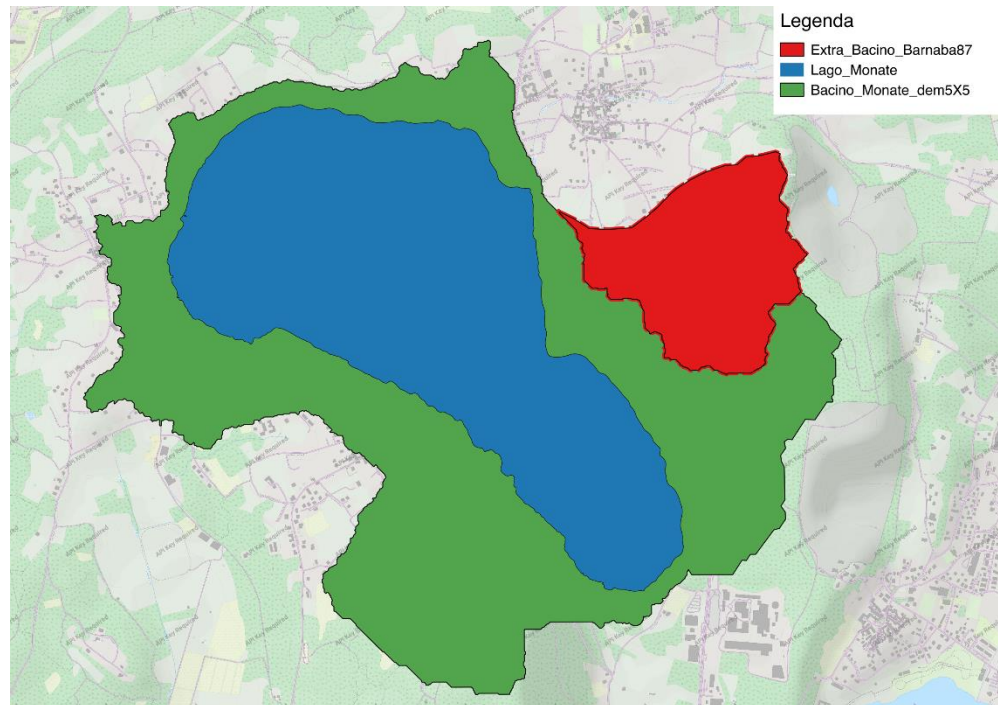





Monate case study

Survey area

The Monate Lake is a prealpine lake of glacial origin in Varese (Italy). Its surface is 2.6 km² and the Acquanegra torrent is its only emissary.

The peculiarity of this survey area is that topographical watershed does not coincide with the phreatic one. An additional ground watershed (red line) exists, situated between Monate Lake and Cava Faraona.



-  **Lake(2.6 km²)**
-  **Surface Watershed (3.25 km²)**
-  **Additional Groundwater Watershed (0.58 km²)**

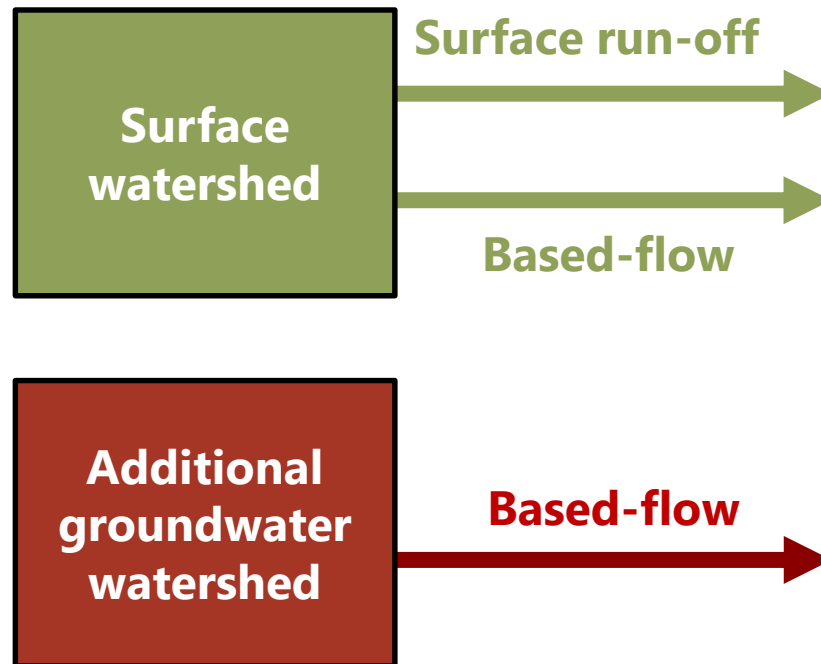


Monate case study

Hydrological model - HyMOD

HyMOD model is based on the theory of runoff yield under excess infiltration with typical conceptual hydrological components. The main characteristic is spatial variability of water storage capacity within the basin.

5 parameters: ***C_{max}, α , β , K_{quick}, K_{slow}***



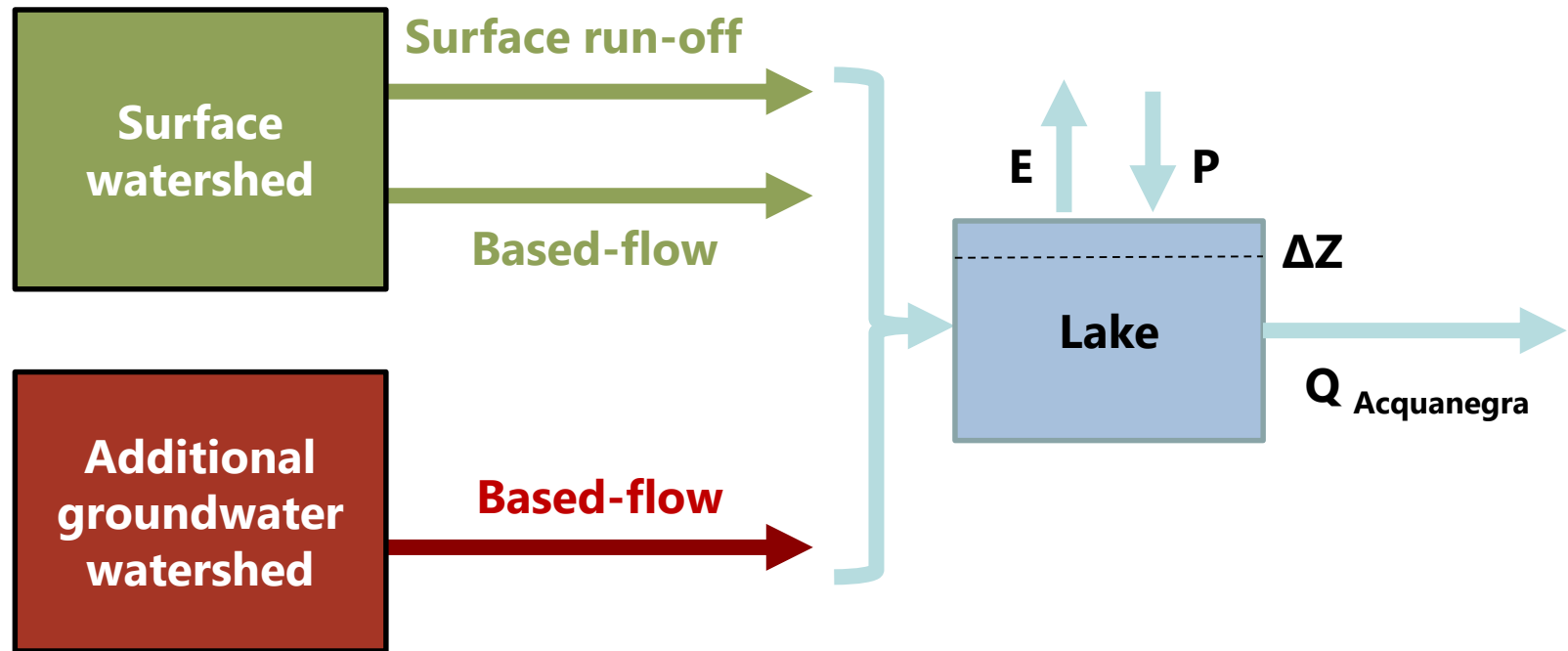


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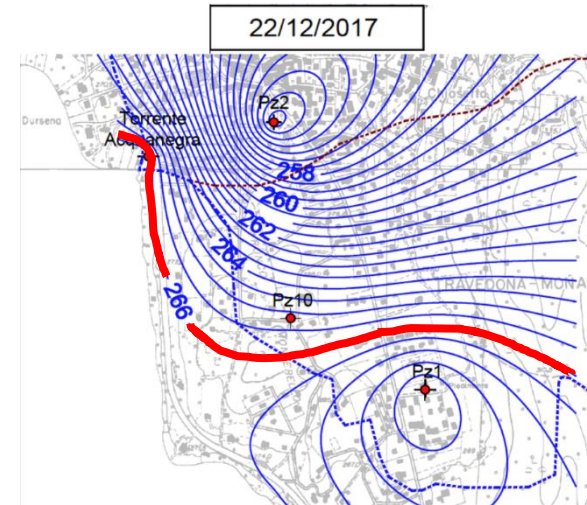
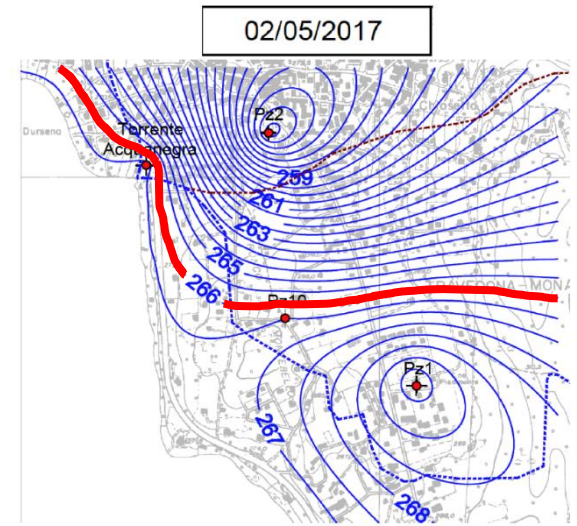
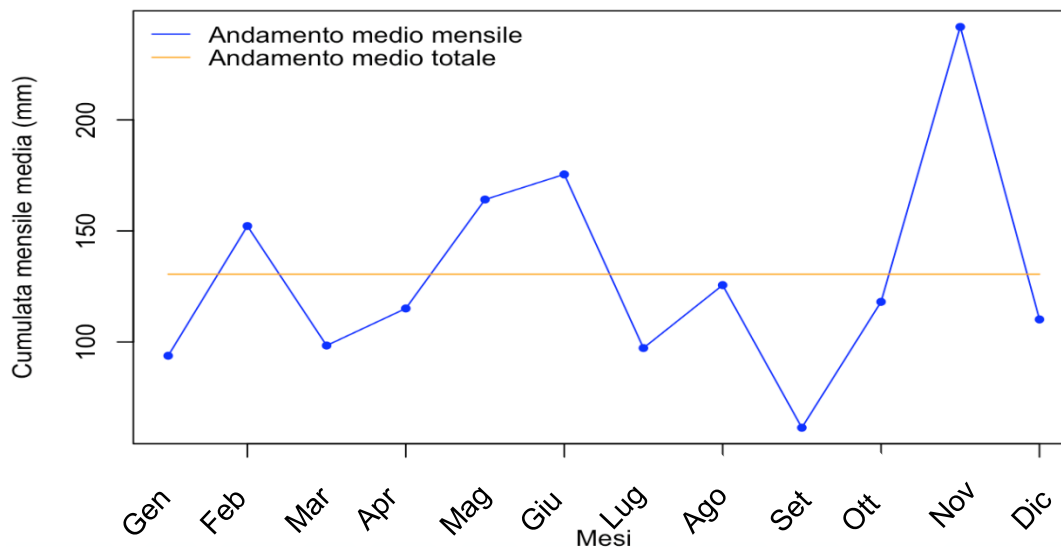
Monate case study

Groundwater watershed area variability

The displacement of the phreatic watershed highlights a seasonal variation of the edge of the groundwater watershed.

The area of the additional groundwater watershed is now considered as the sixth parameter of the HyMOD model.

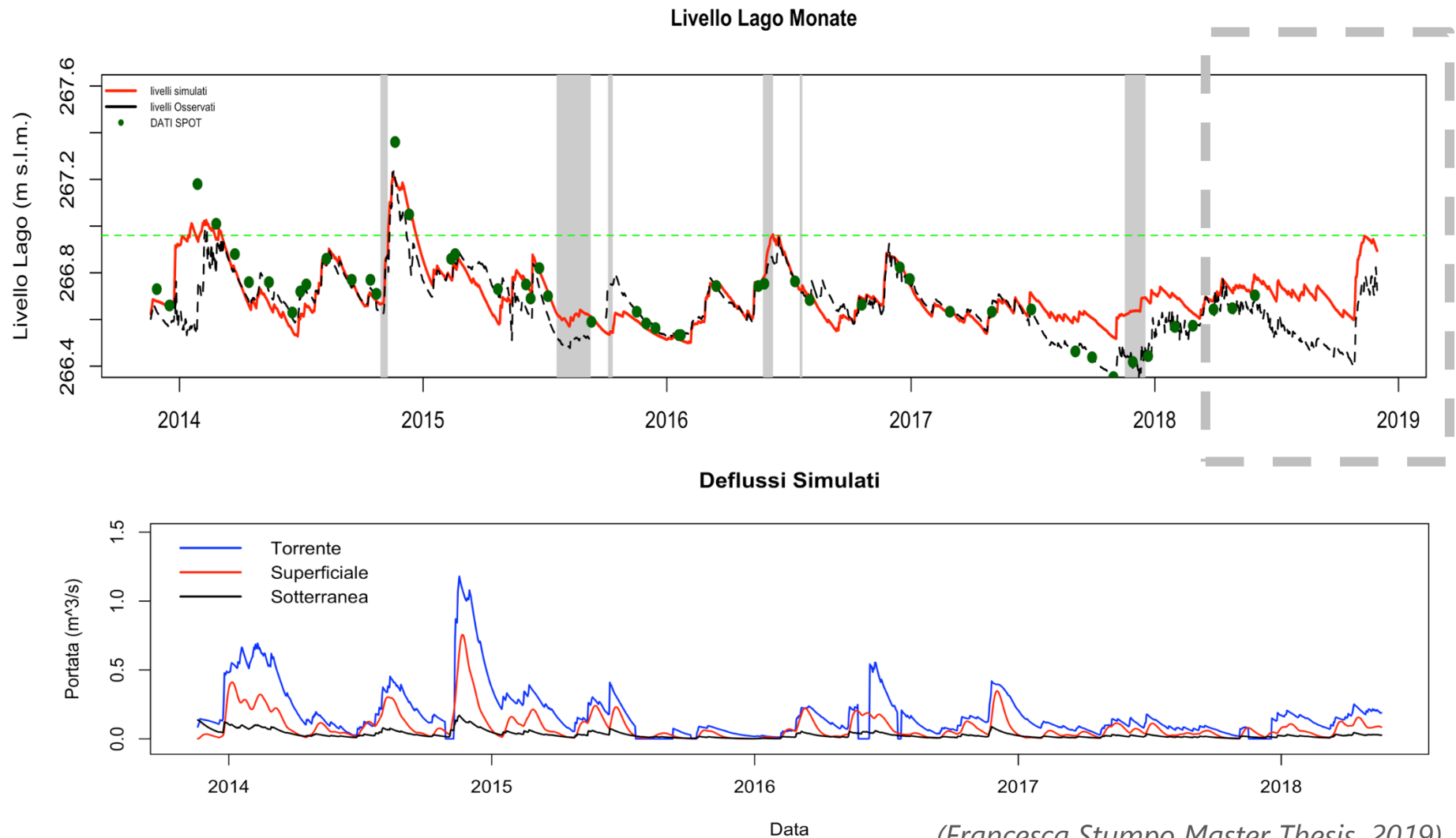
Andamento medio mensile 2013-2018





Monate case study

Hydrological model - HyMOD



(Francesca Stumpo Master Thesis, 2019)



Introduction

Monate Lake case study

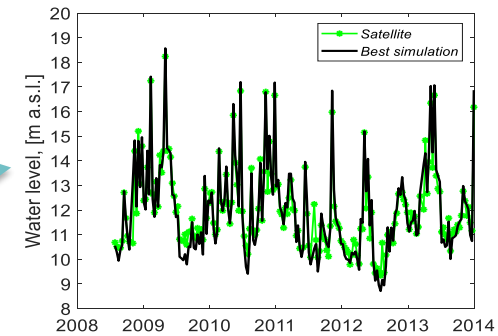
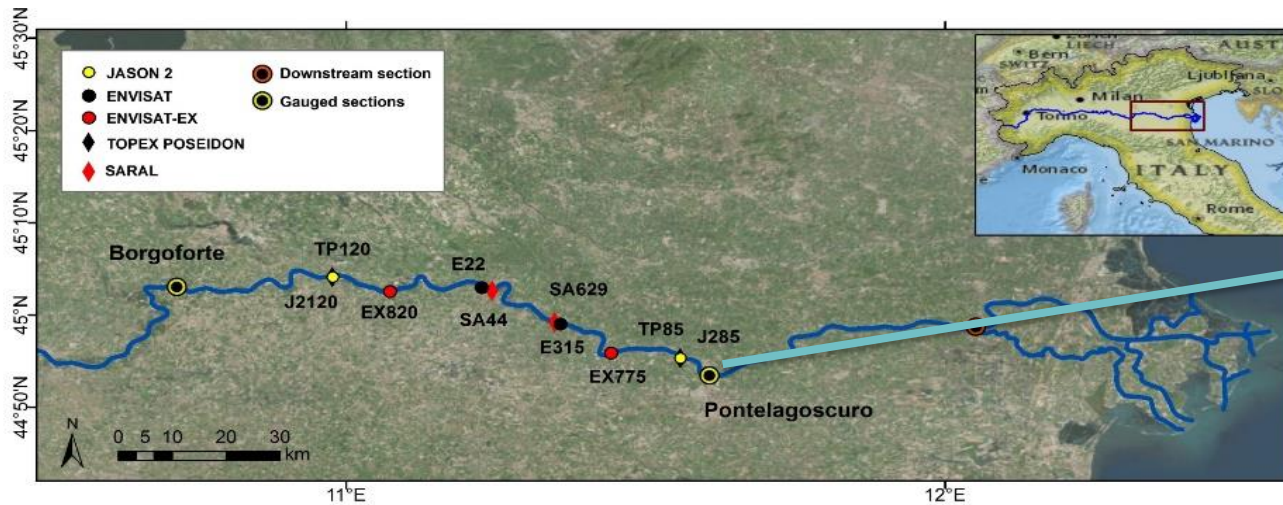
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Remote sensing techniques for hydraulic applications

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Satellite altimeters

Study aims



The goal of this study is to investigate the potential of satellite altimetry series for calibrating a quasi-2D model relative to the Po River (Italy). The remote sensed data are collected from different satellite missions (ENVISAT, ENVISAT extended SARAL/Altika, TOPEX/Poseidon, Jason-2 and Jason-3), relative to distinct periods of time between 1992 and 2019.

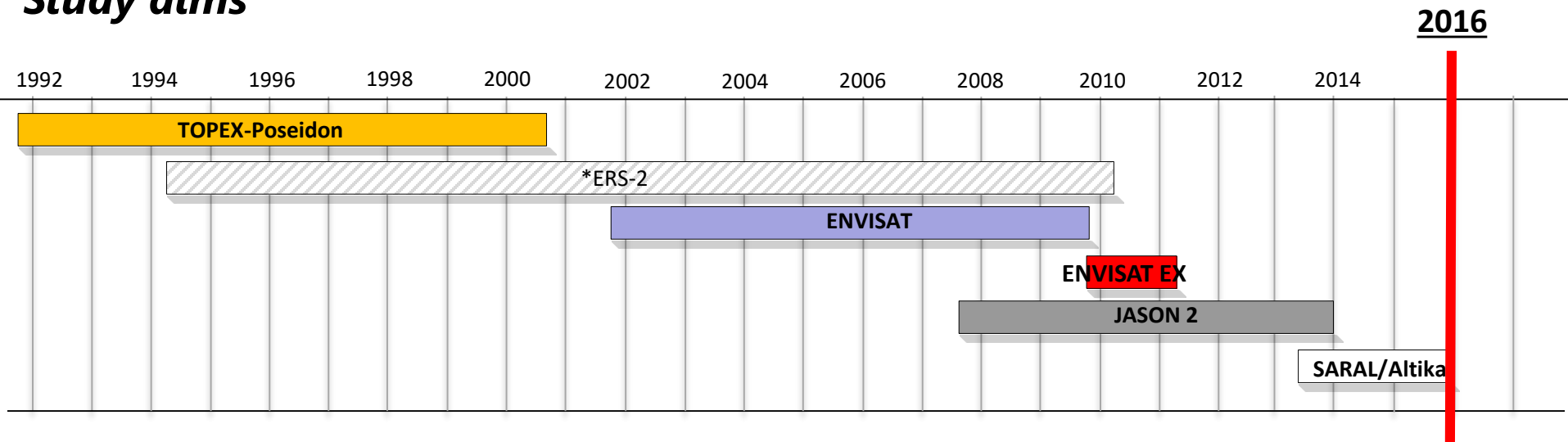
Aims:

- Comparison between data of **different satellite missions** (*Fig. 1*);
- Study of **satellite series length** effect on model hydraulic calibration (*Tab. 1*);
- Evaluation of **data uncertainty** on model accuracy;
- Estimation of **multi-mission series benefits** (*Fig. 2*).



Satellite altimeters

Study aims

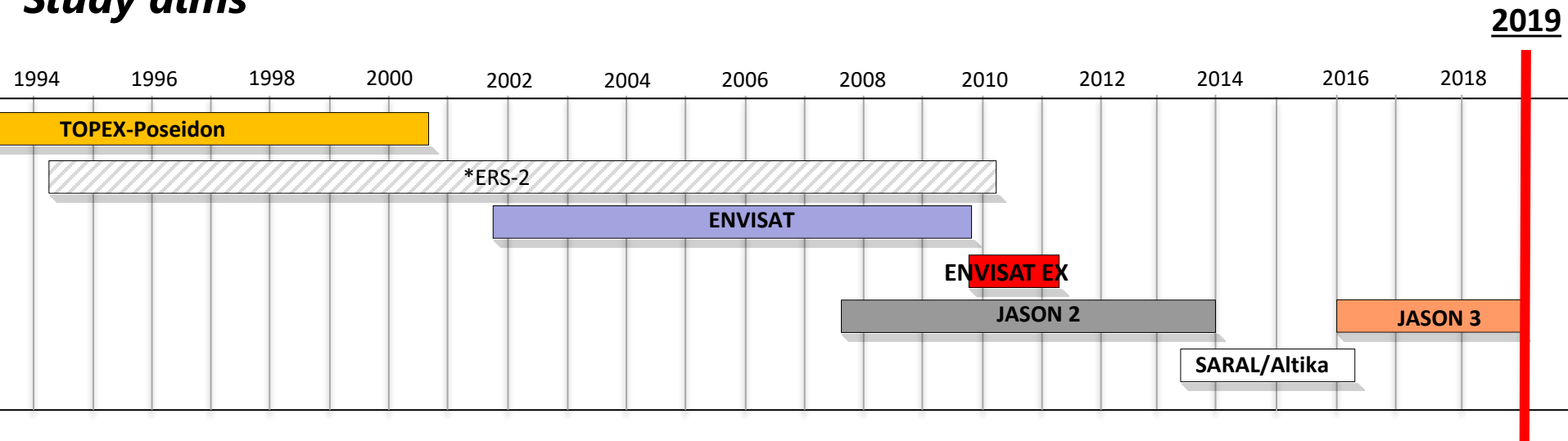


Mission	Observation period	Temporal resolution [day]
TOPEX/Poseidon (TP)	1992–2002	10
ENVISAT (E)	2002–2010	35
ENVISAT XT (EX)	2010–2012	35
SARAL/AltiKa (SA)	2013–2016	35
JASON 2 (J2)	2008–2015	10



Satellite altimeters

Study aims



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JASON 2 (J2)	2008–2015	10
JASON 3 (J3)	2016–2019	35



Satellite altimeters

Hydrological
Processes

Academic presentations and further activities

Ready for submission:

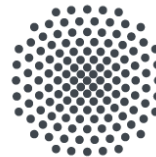
Satellite altimetry for hydraulic model calibration: single- vs. multi-mission series

*Alessio Domeneghetti⁽¹⁾, **Giada Molari⁽¹⁾**, Mohammad J. Tourian⁽²⁾, Angelica Tarpanelli⁽³⁾, Tommaso Moramarco⁽³⁾, Nico Sneeuw⁽²⁾, Armando Brath⁽¹⁾*

⁽¹⁾ School of Civil Engineering, Department DICAM, University of Bologna, Bologna, Italy

⁽²⁾ Institute of Geodesy, University of Stuttgart, Germany,

⁽³⁾ Research Institute for Geo-Hydrological Protection, National Research Council, Perugia, Italy



University of Stuttgart
Germany



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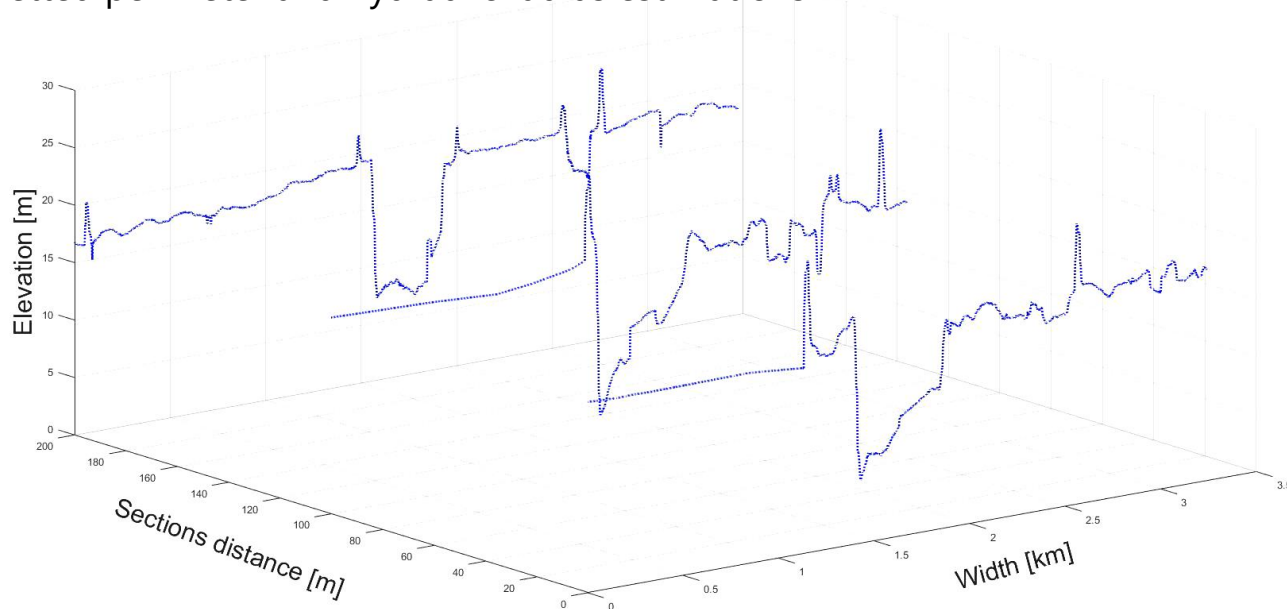
River bathymetry estimation

RiBEST (River Bathymetry Estimation From Satellite)

Development and testing of the RiBEST tool.

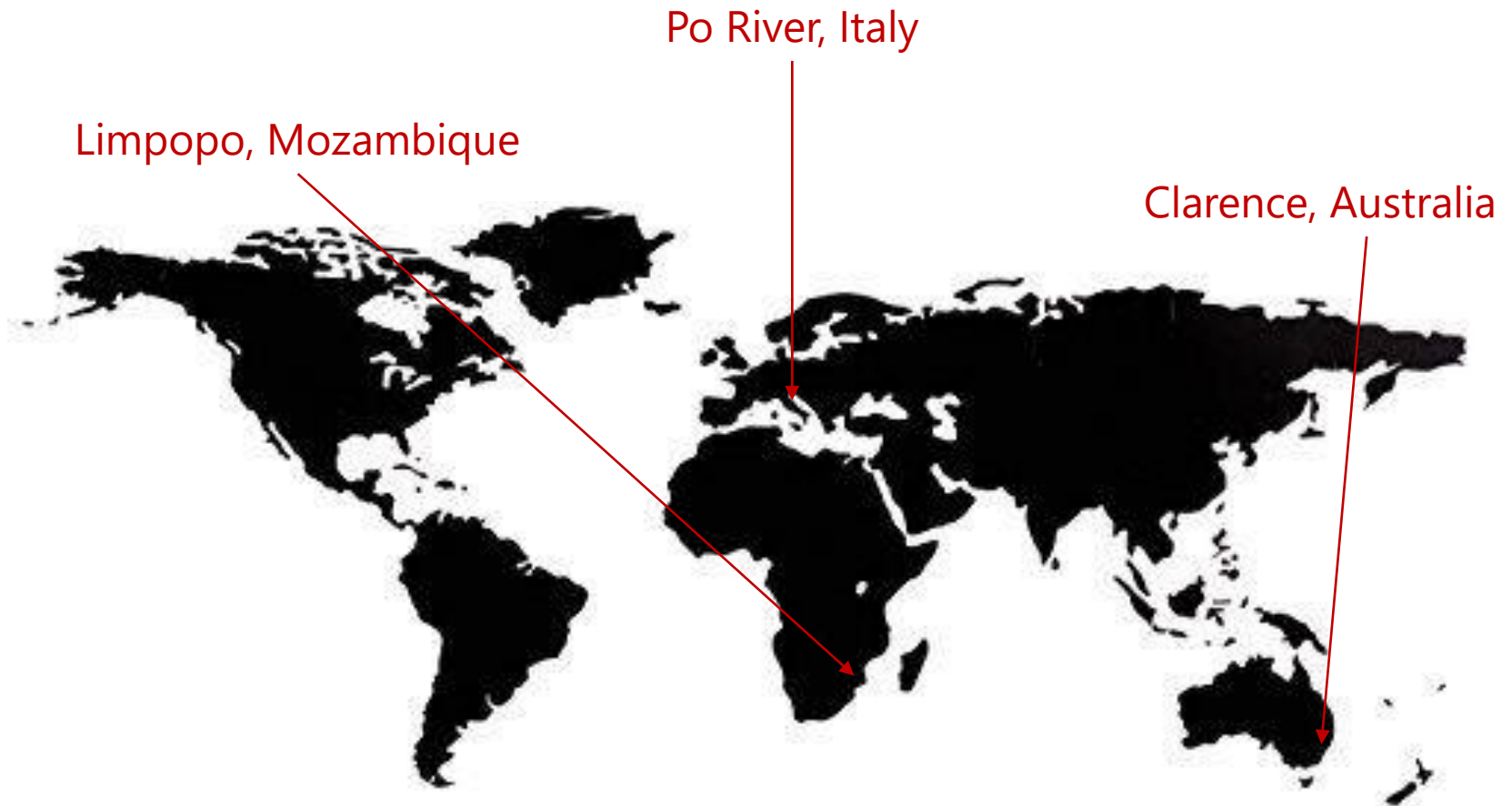
Based on a DEM and river centreline, RiBEST can automatically provide river geometry and hydraulic variables such as:

- River bathymetry
- Modified cross section geometry
- Flow area, wetted perimeter and hydraulic radius estimations





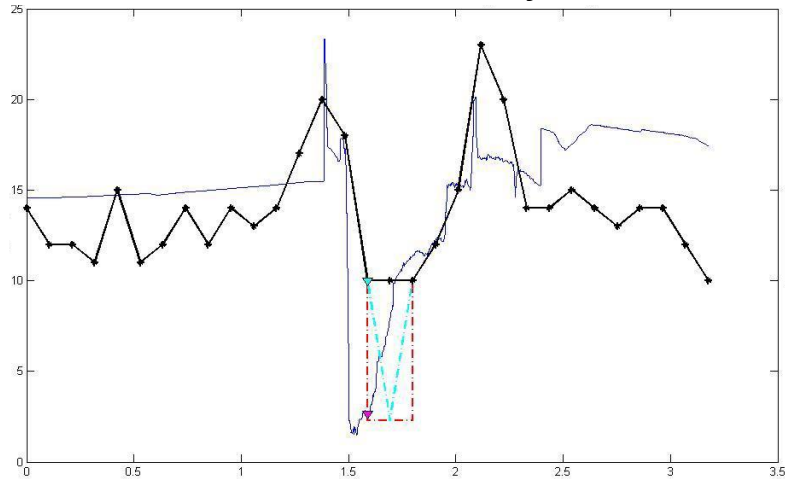
RiBEST tool



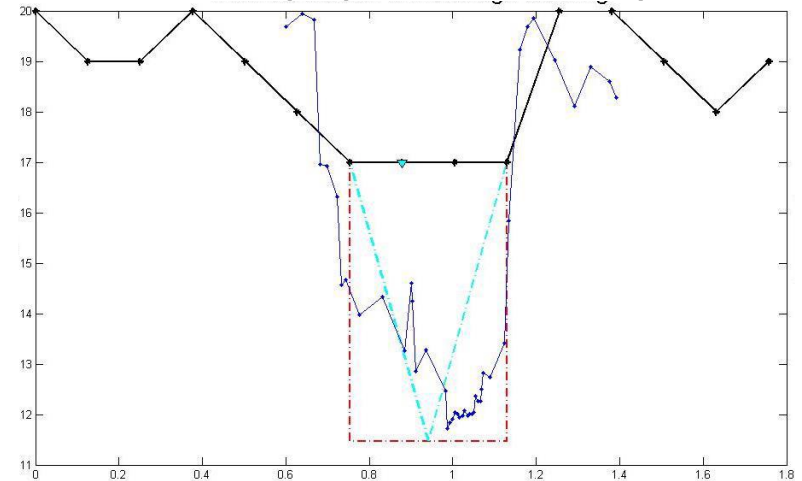


RiBEST tool

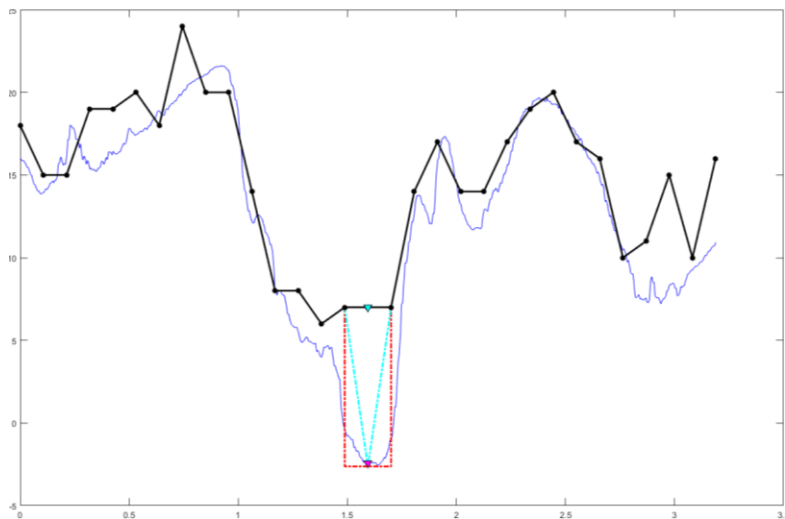
Po River, Italy



Limpopo, Mozambique



Clarence, Australia



- SRTM 30**
- Observed topography**
- RiBEST modification 1**
- RiBEST modification 2**



RiBEST tool

Further activities

Paper in preparation:

RiBEST – a tool for river bathymetry and hydraulic parameters estimation

Giada Molari⁽¹⁾, ***Stefania Grimaldi***⁽²⁾, ***Paolo Paron***⁽³⁾, ***Alessio Domeneghetti***⁽¹⁾

(1) School of Civil Engineering, Department DICAM, University of Bologna, Bologna, Italy

(2) Monash University, Melbourne, Australia

(3) IHE Delft Institute for Water Education, Hydroinformatics Chair, Delft, The Netherlands

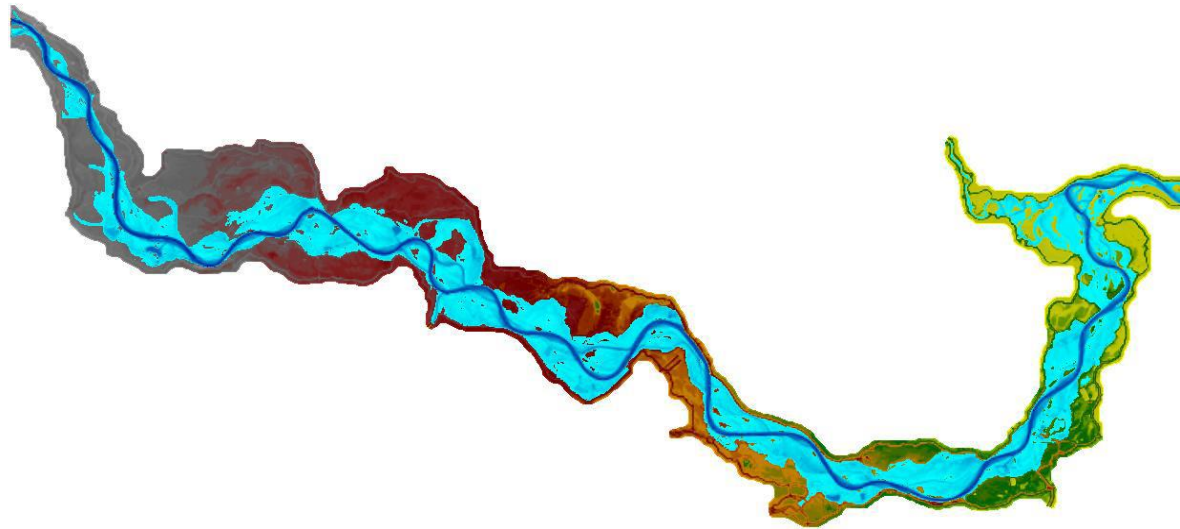


MONASH University



2D modelling application

The RiBEST application for 2D modelling is still ongoing in collaboration with IHE Delft, Netherlands, in order to assess how much the bathymetric information influences the accuracy of **2D** hydraulic models.



Po River : Cremona - Borgoforte

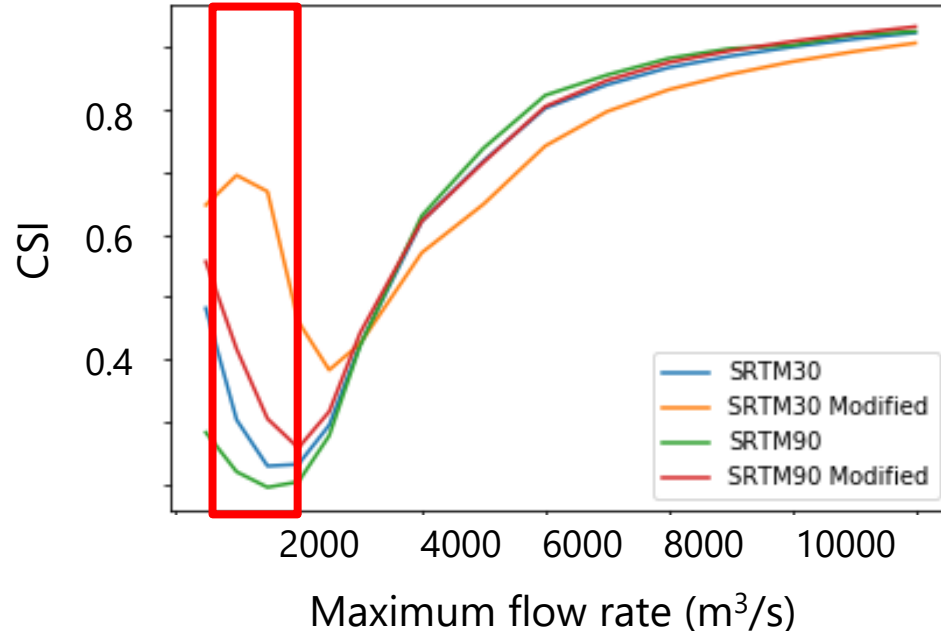


2D modelling application

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CSI (Critical Success Index) = hits / (hits + false alarms + misses)

Its range is 0 to 1, with a value of 1 indicating a perfect forecast





2D modelling application

Ready for submission:

Impact of micro topography and bathymetry modification on inundation modelling with different magnitudes based on SRTM data

*Hamounda Tarek⁽¹⁾, Maurizio Mazzoleni⁽¹⁾, **Giada Molari⁽³⁾**, Kun Yan⁽²⁾, Ioana Popescu⁽¹⁾, Alessio Domeneghetti⁽³⁾*

⁽¹⁾ IHE Delft Institute for Water Education, Hydroinformatics Chair, Delft, The Netherlands

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⁽³⁾ School of Civil Engineering, Department DICAM, University of Bologna, Bologna, Italy



United Nations
Educational, Scientific and
Cultural Organization



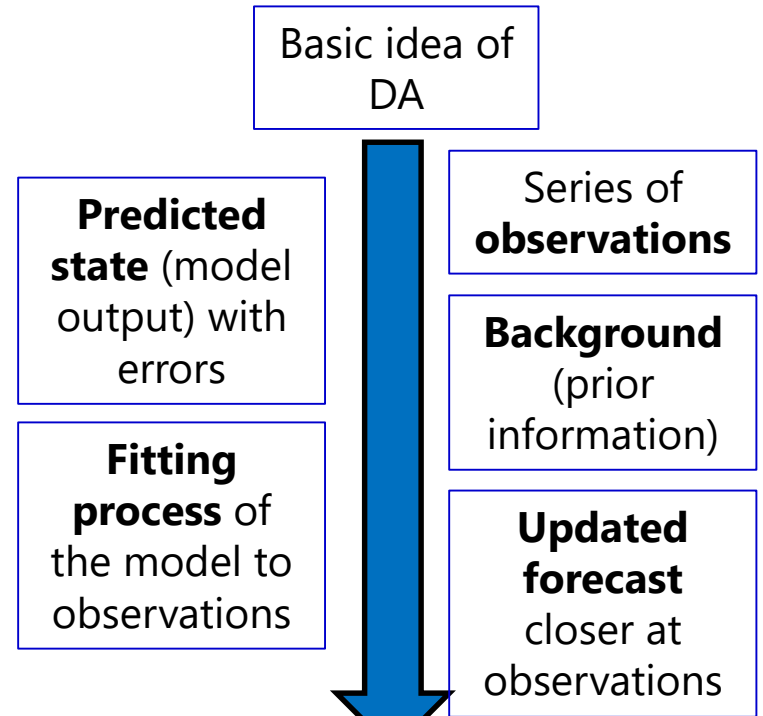
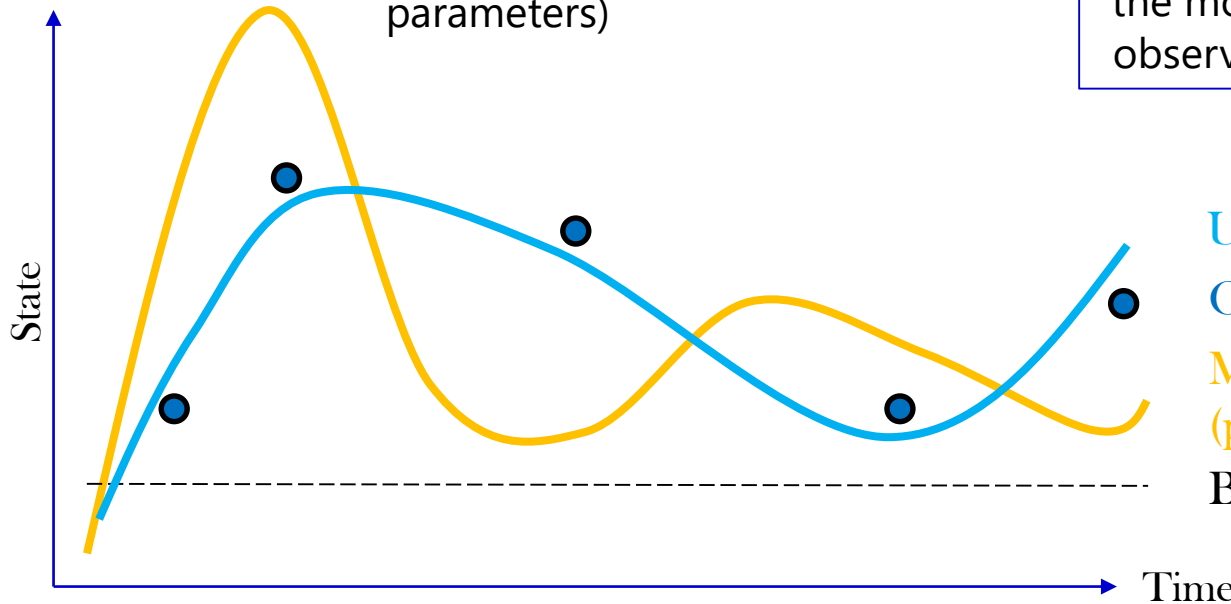
Institute for
Water Education
in partnership with UNESCO



Data assimilation

DA methods combine **observations** with **model output** with the objective of improving the latter. The object is to predict the state of a system, or its future, in the best possible way.

INVERSE PROBLEM :
from effects (model output) to causes (model parameters)

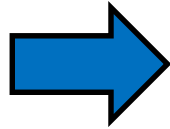


Updated forecast
Observation
Model output
(previous forecast)
Background



Data assimilation

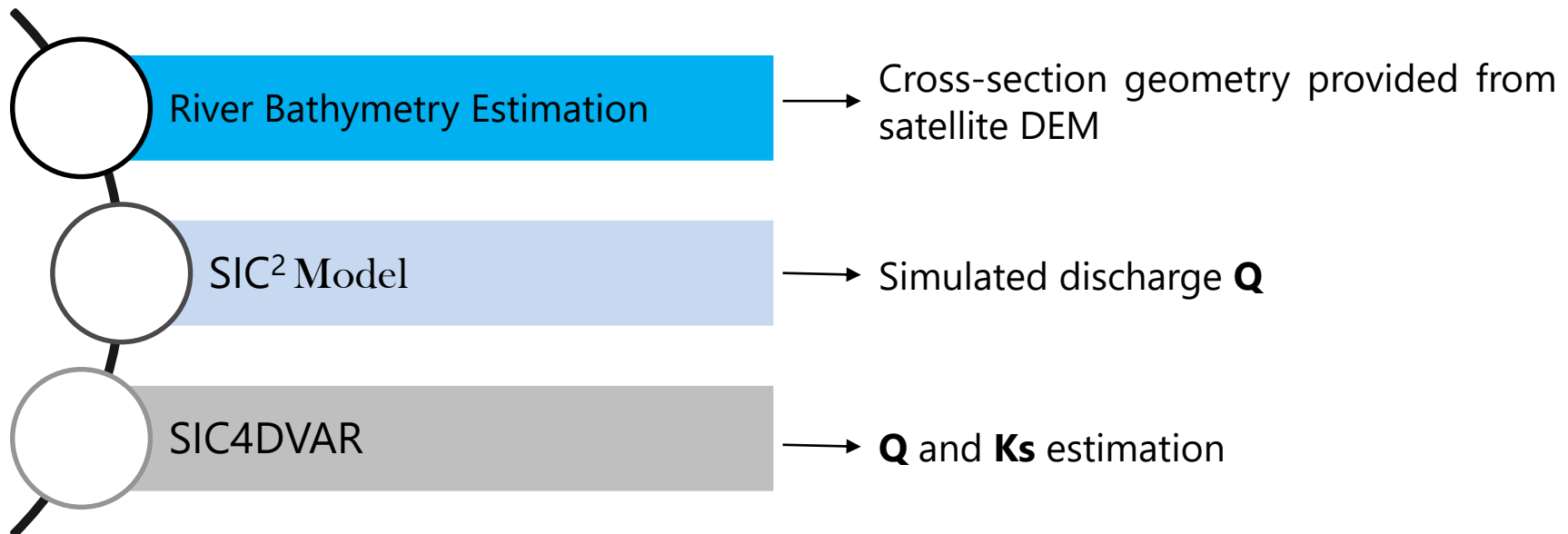
Fitting process of the model to observations



The comparison between model output and observations is performed by some form of **optimization**.

Among DA methods, variational DA has been the preferable approach in operational geophysical applications, for which the problem is formulated as an optimal control one. In particular **4DVAR** is adapted for nonlinear systems where heterogeneous variables are estimated simultaneously.

Object: Discharge estimation using 4DVAR approach and river bathymetry SRTM – based for the Po River (Italy)

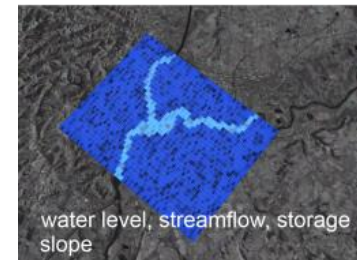
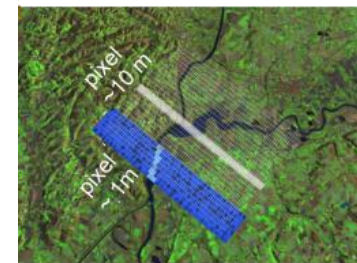




Data assimilation

SWOT

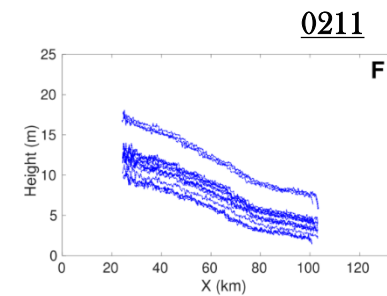
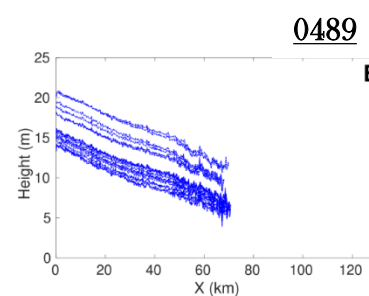
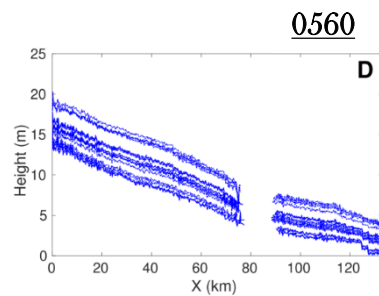
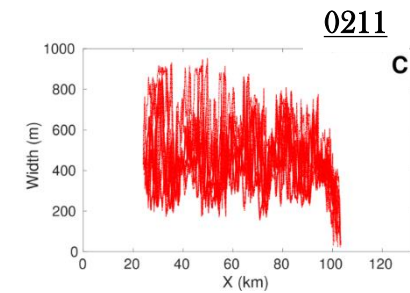
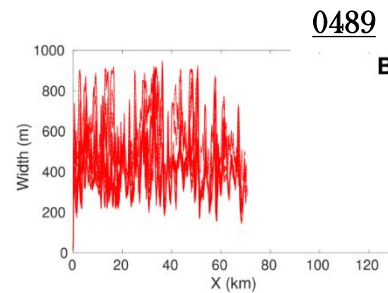
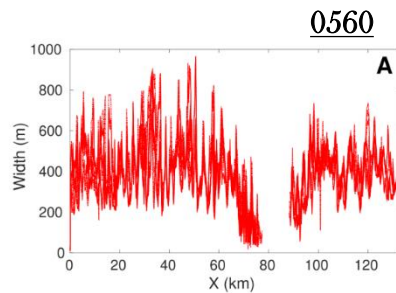
- First satellite mission dedicated to hydrology, river hydraulics and mesoscale oceanography
- Date of launch: September 2021
- **21** - day repeat
- Ka-band Radar Interferometer (KaRIn)
 - Cross-track resolution: 60 to 10 meters



Data assimilation

The SWOT Hydrology Simulator – Po River

- Reach : 133 km
- Nodes observations:
 - every 200 m
 - $\sigma \sim 2,5 m$
- Irregular sampling
- May 2008 – April 2009

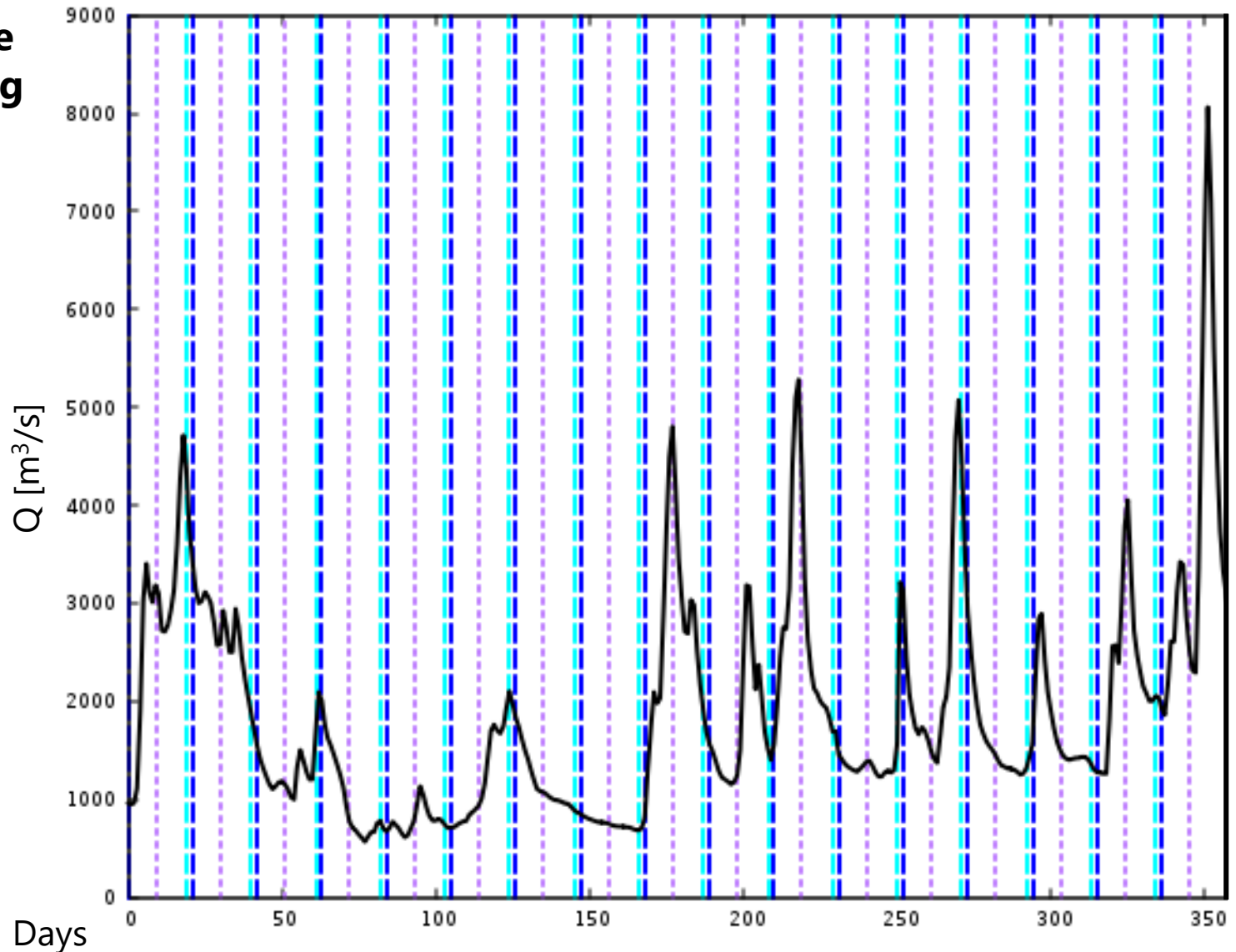




Data assimilation

River Discharge Estimation using SIC4VAR

- Reference
- Background
- Estimate

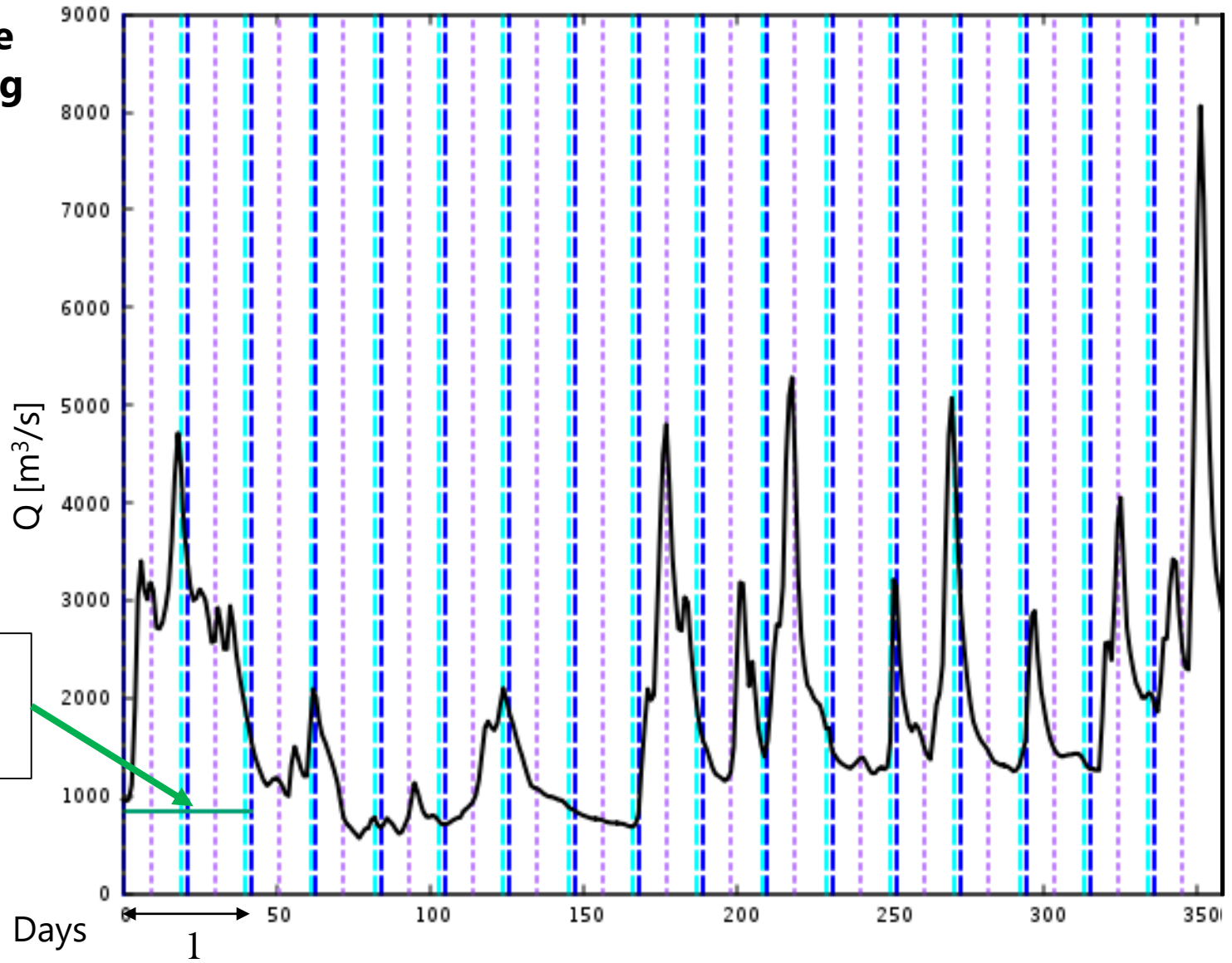




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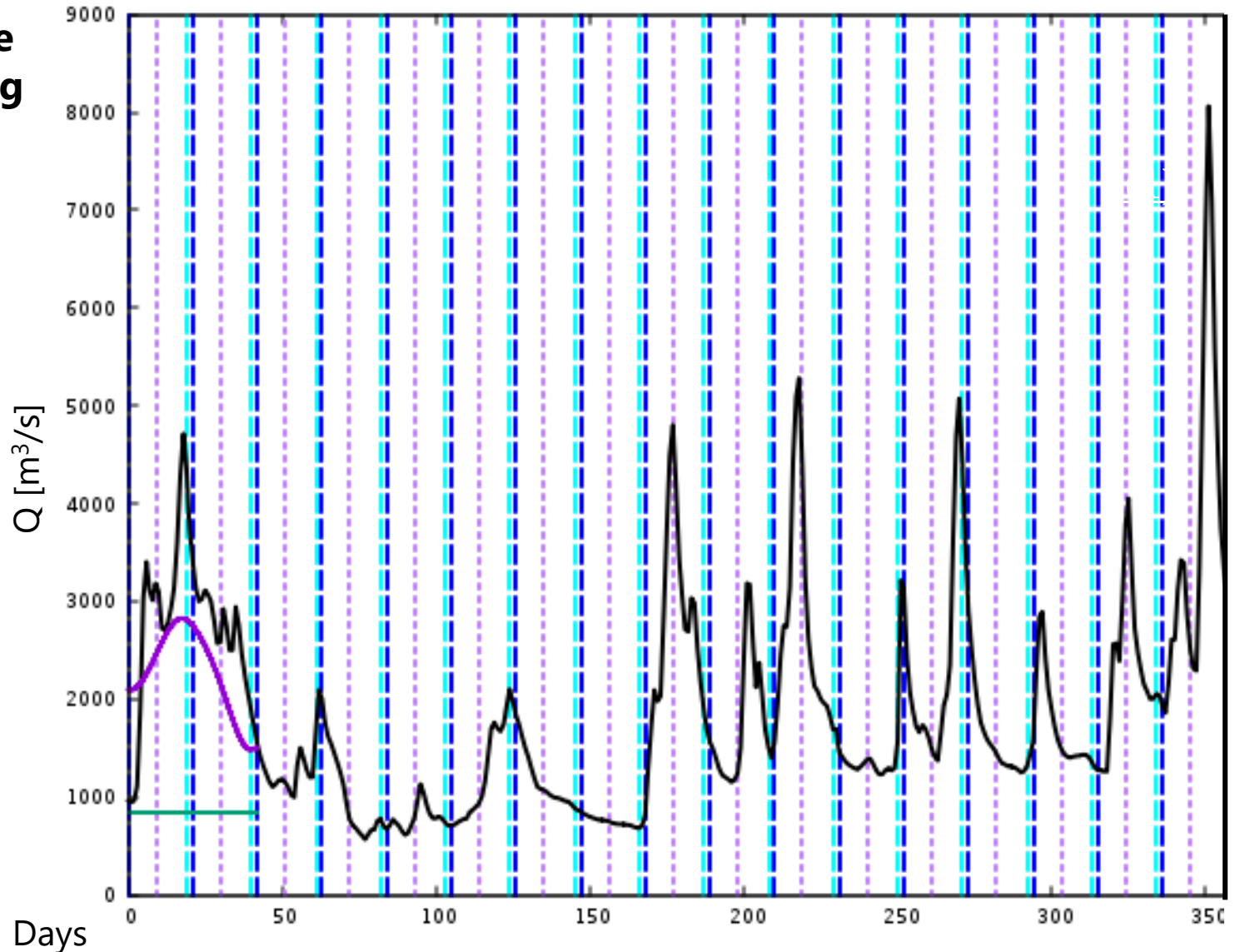
Q mean Water
Balance Model:
841 mc/s



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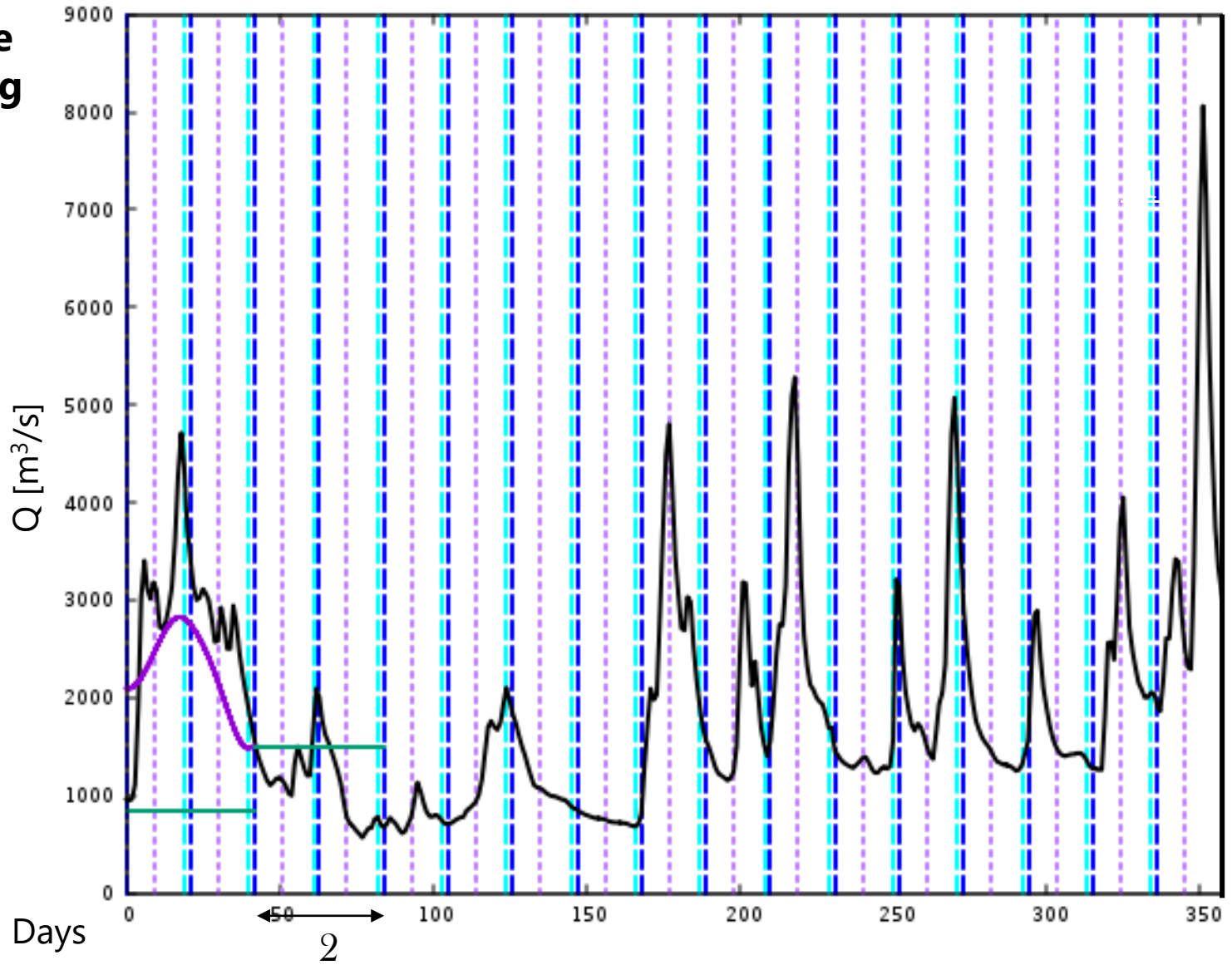




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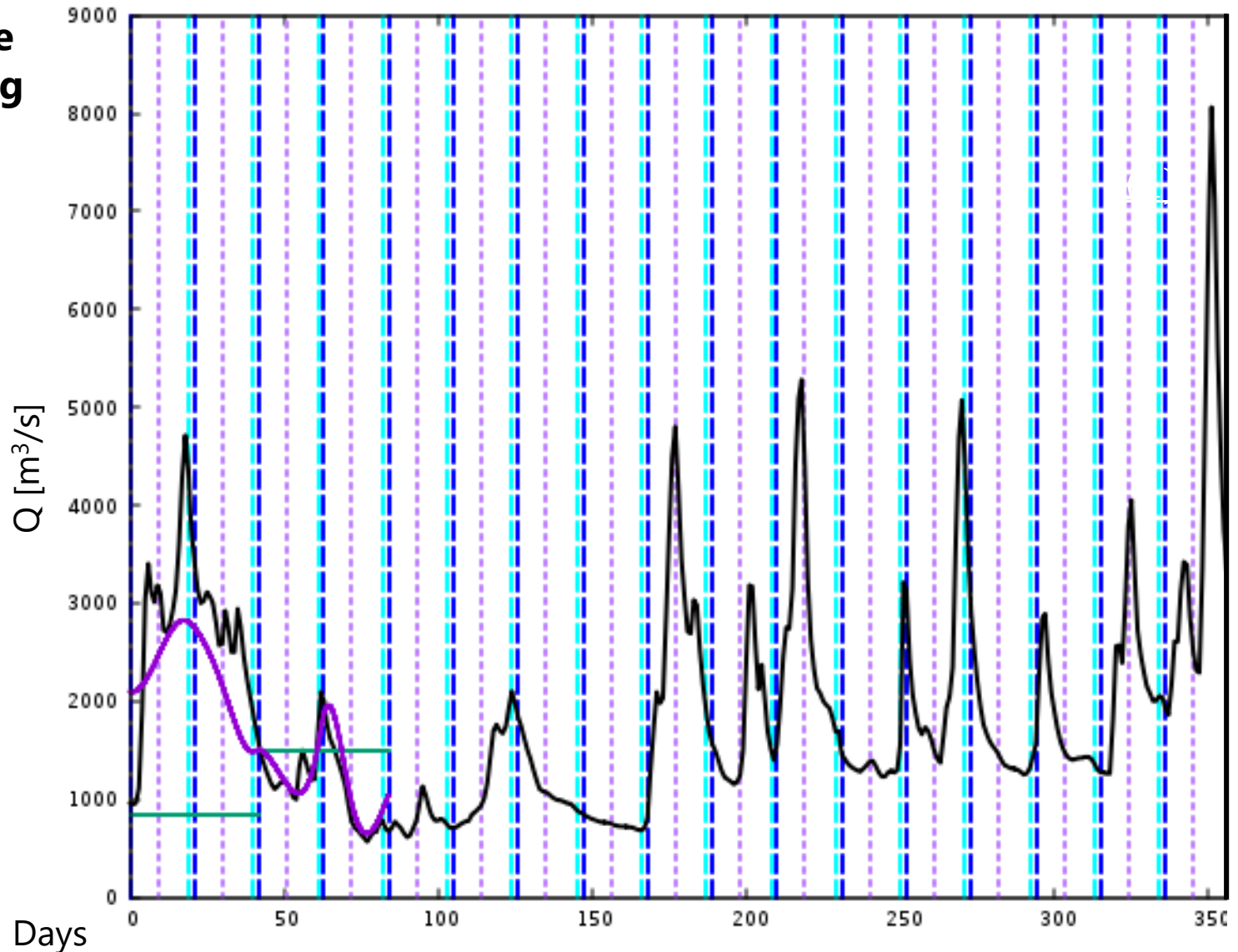




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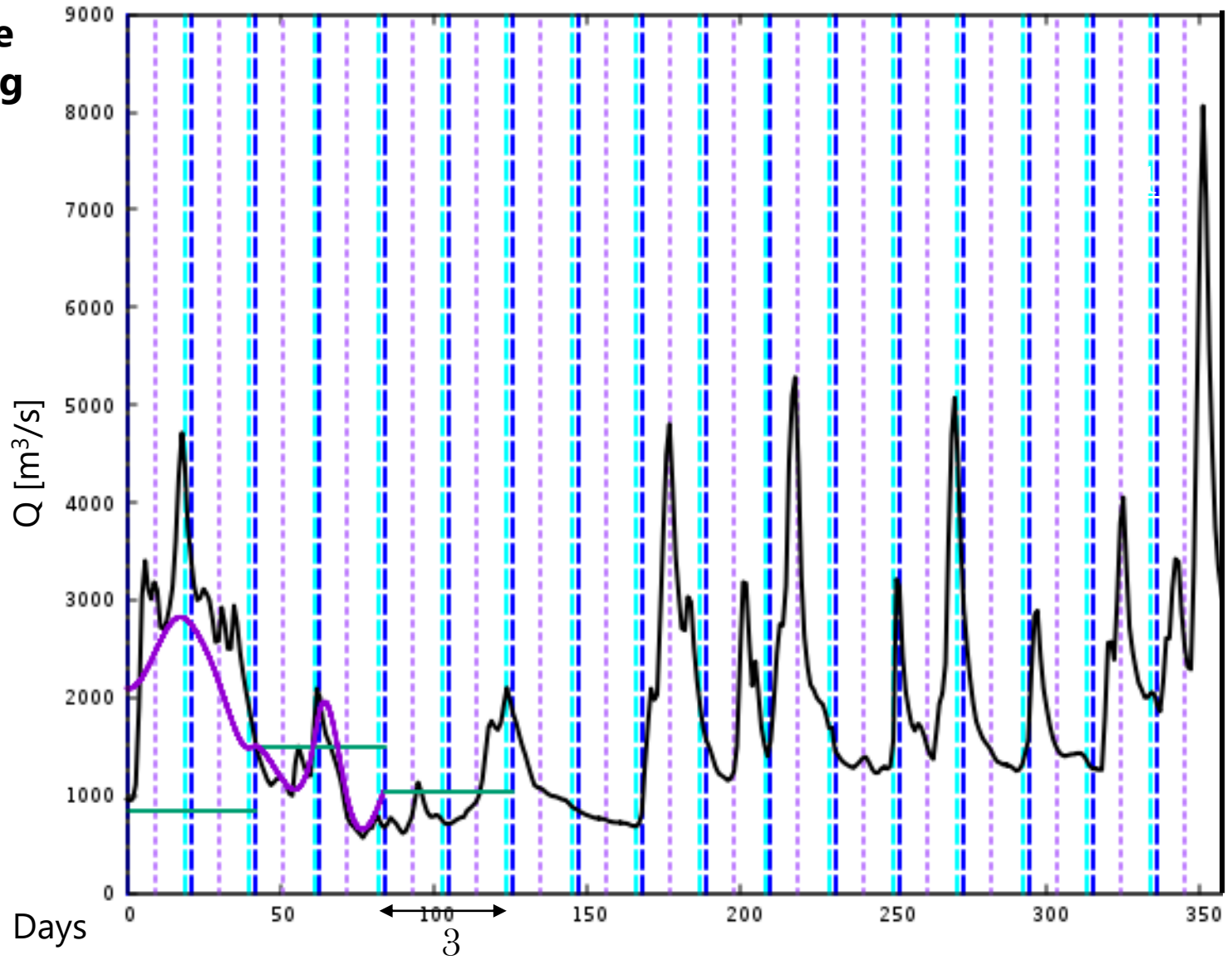




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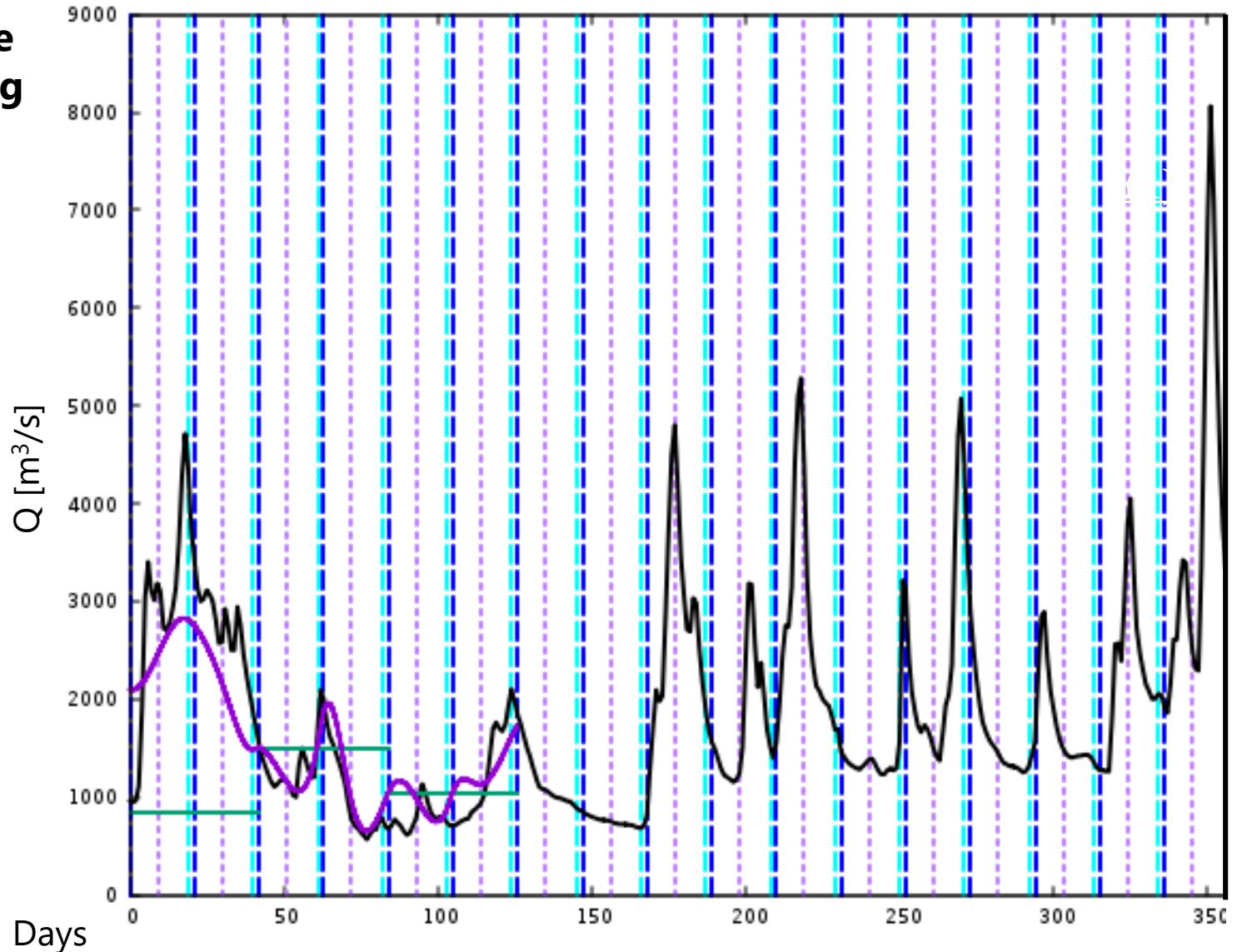




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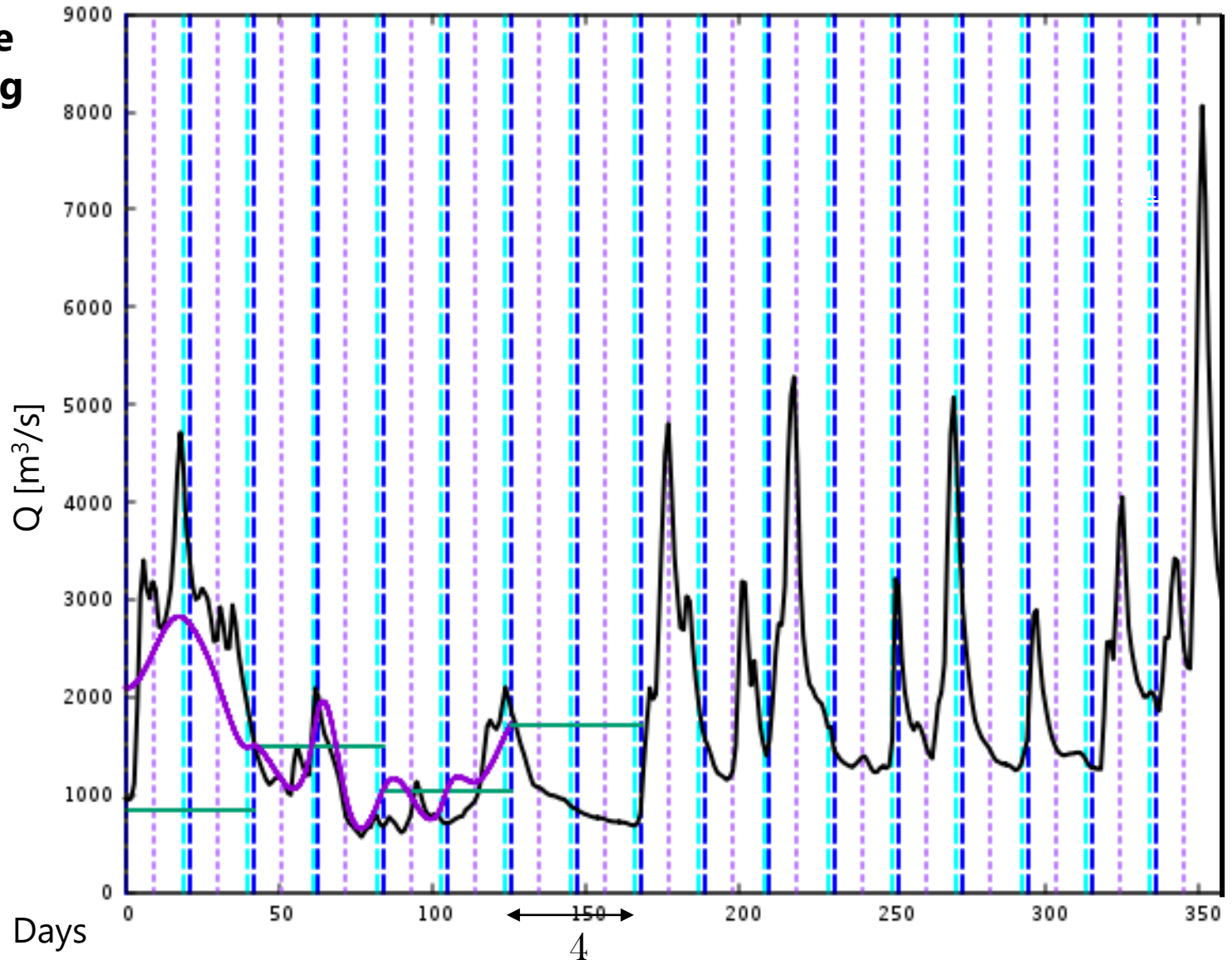




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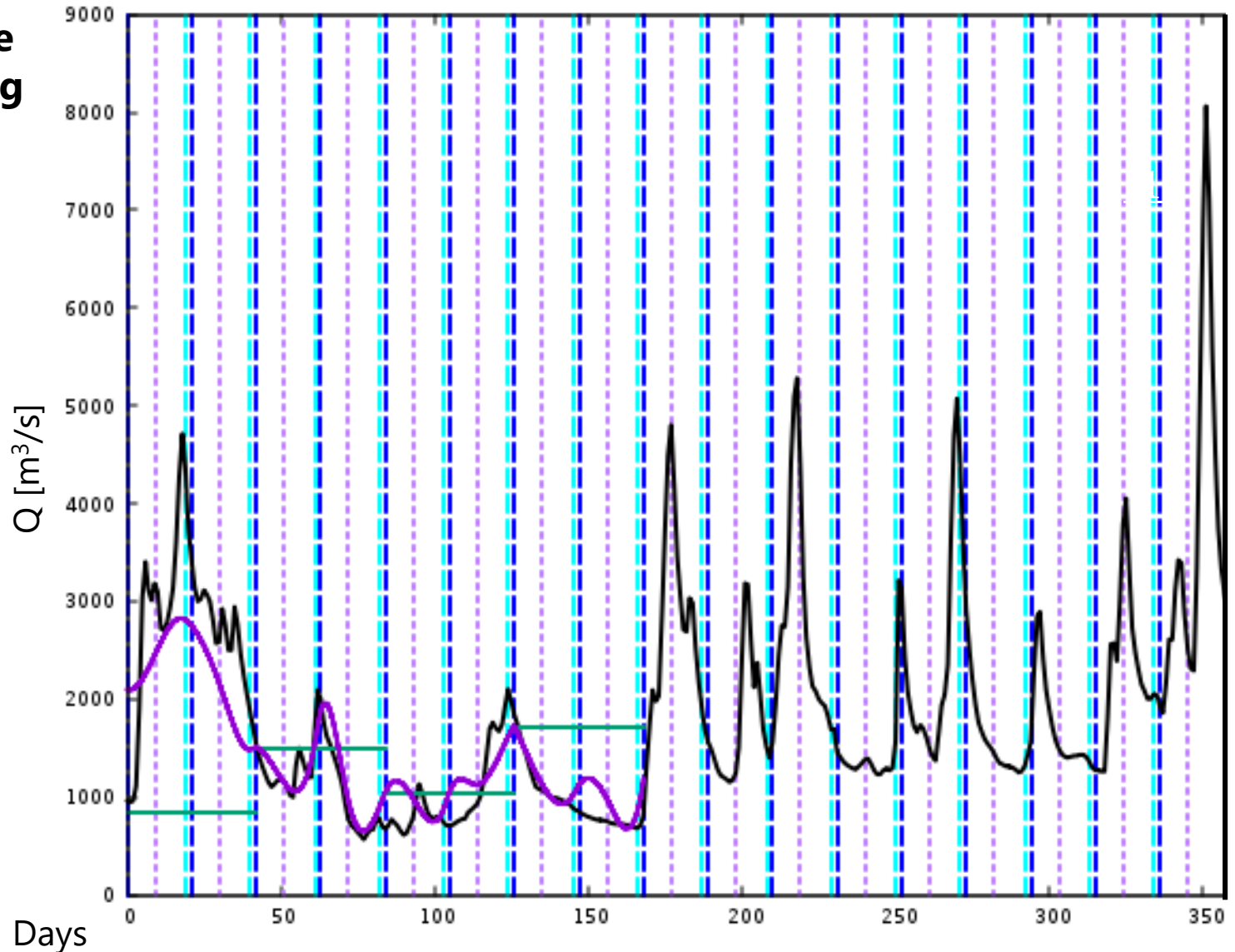




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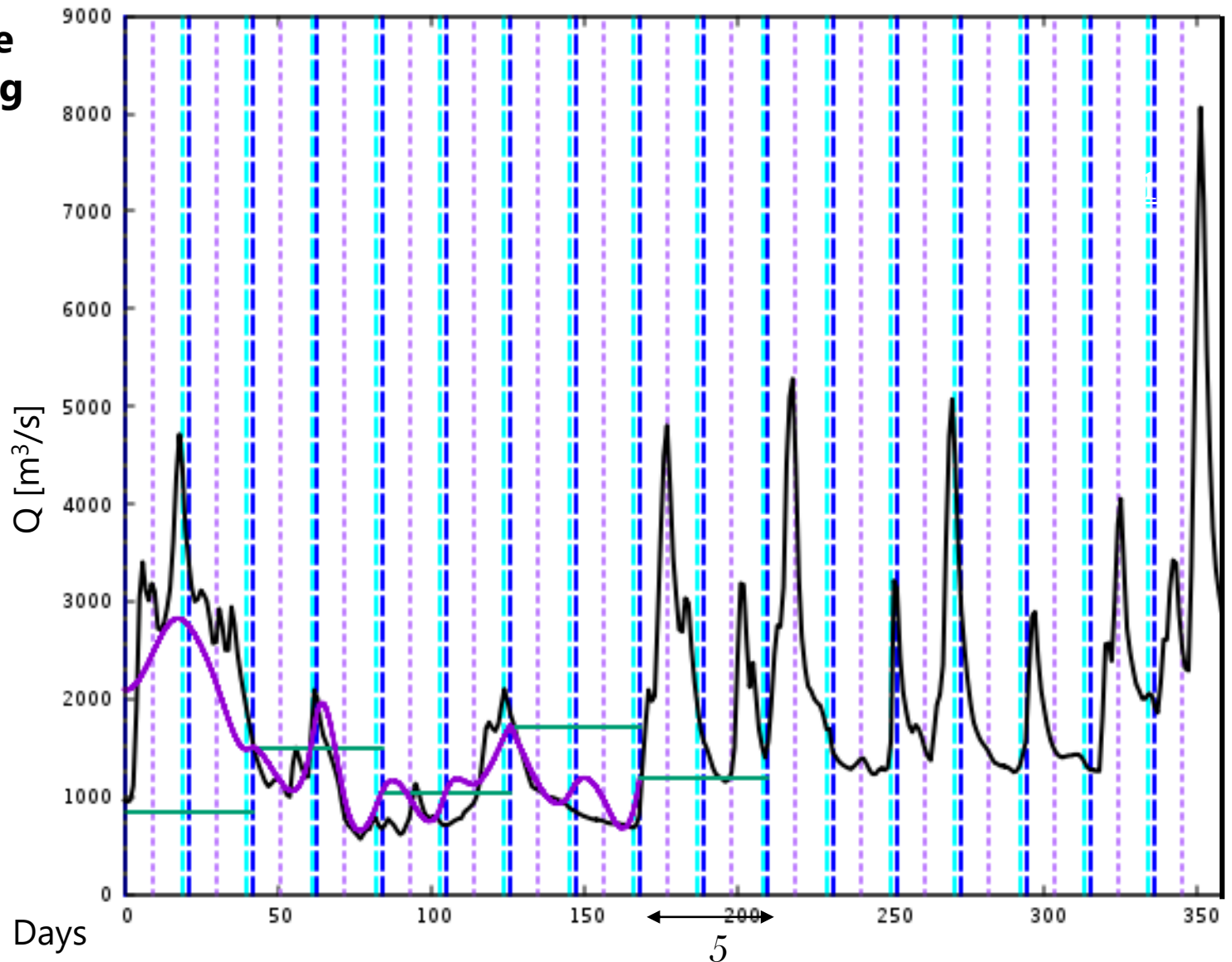




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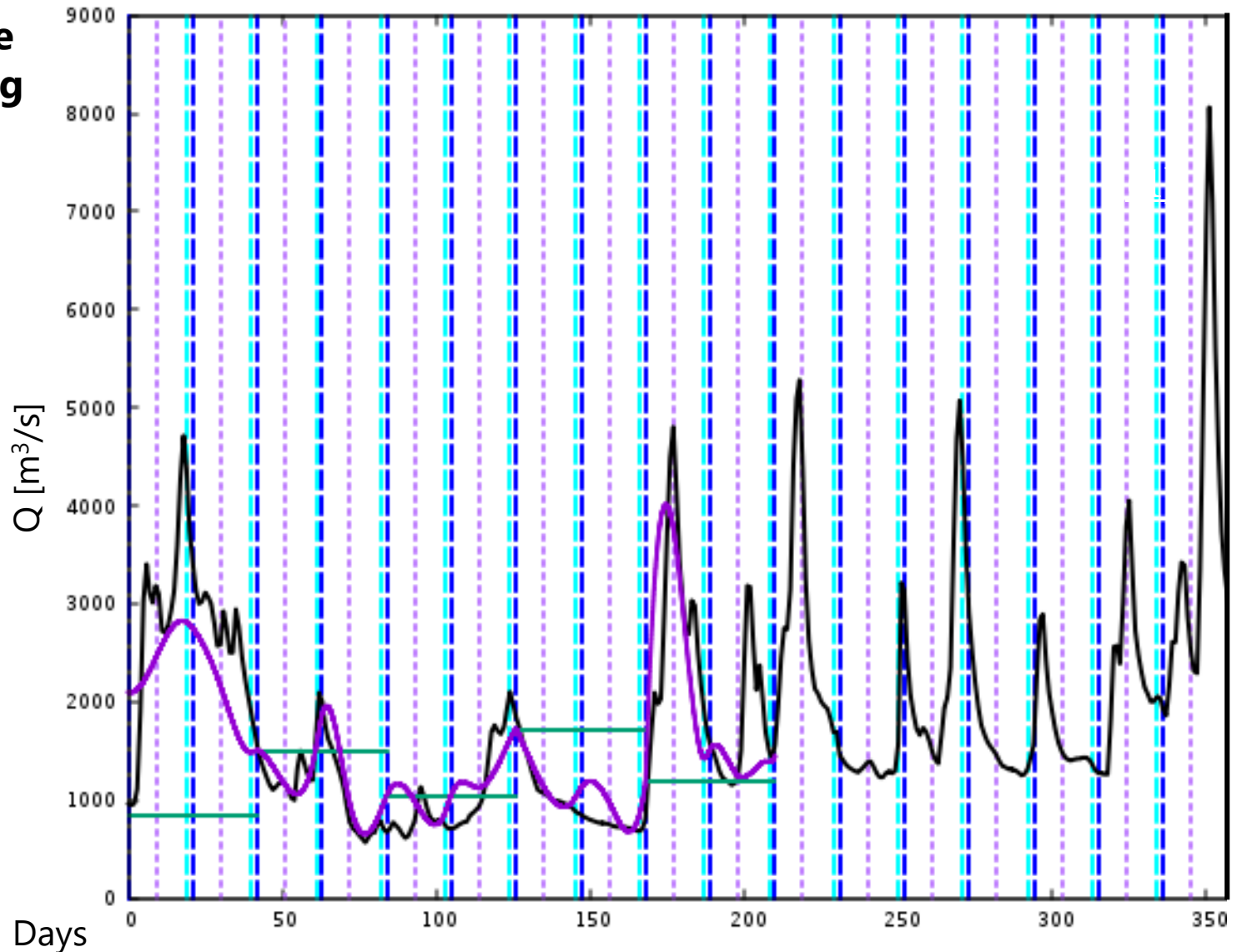




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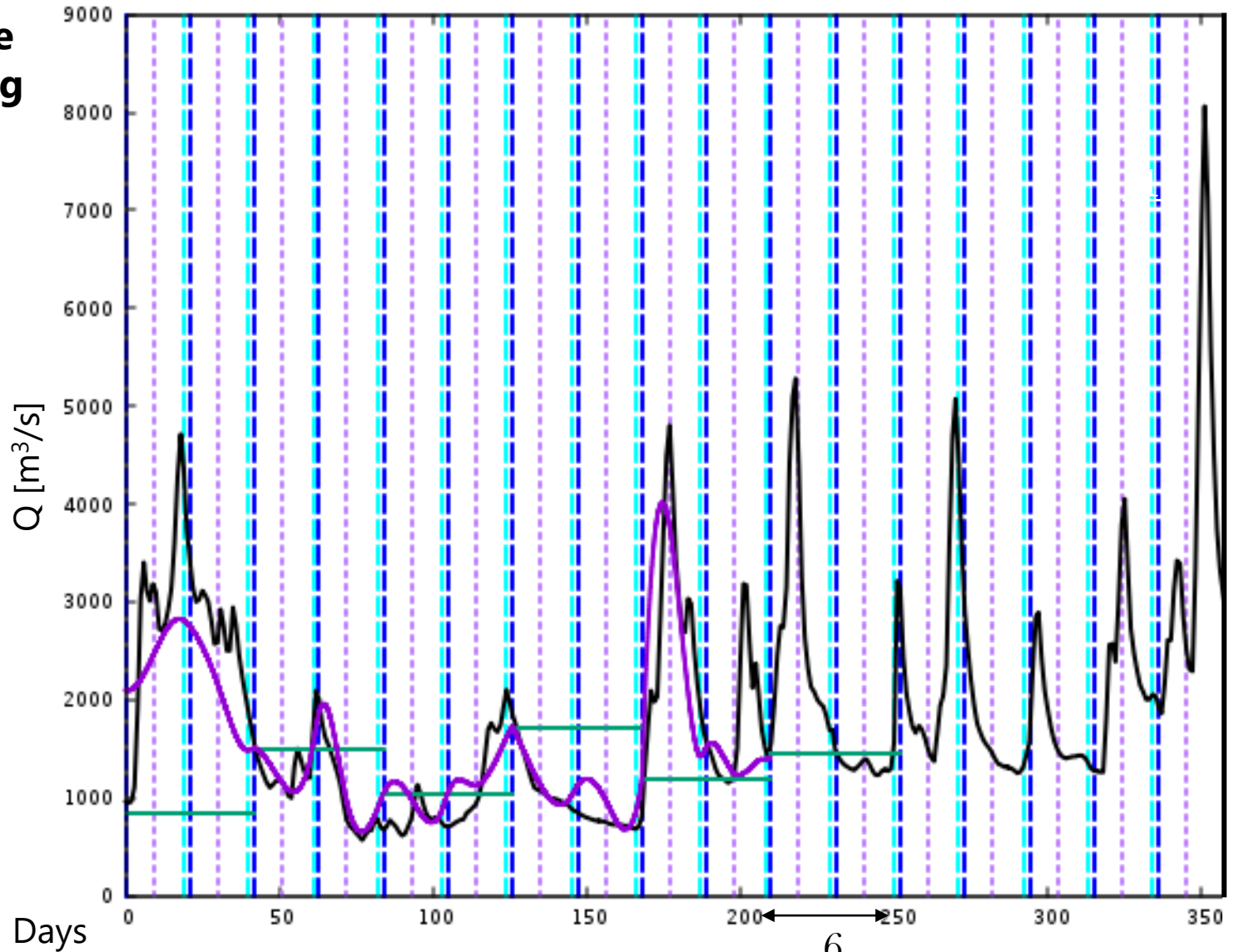




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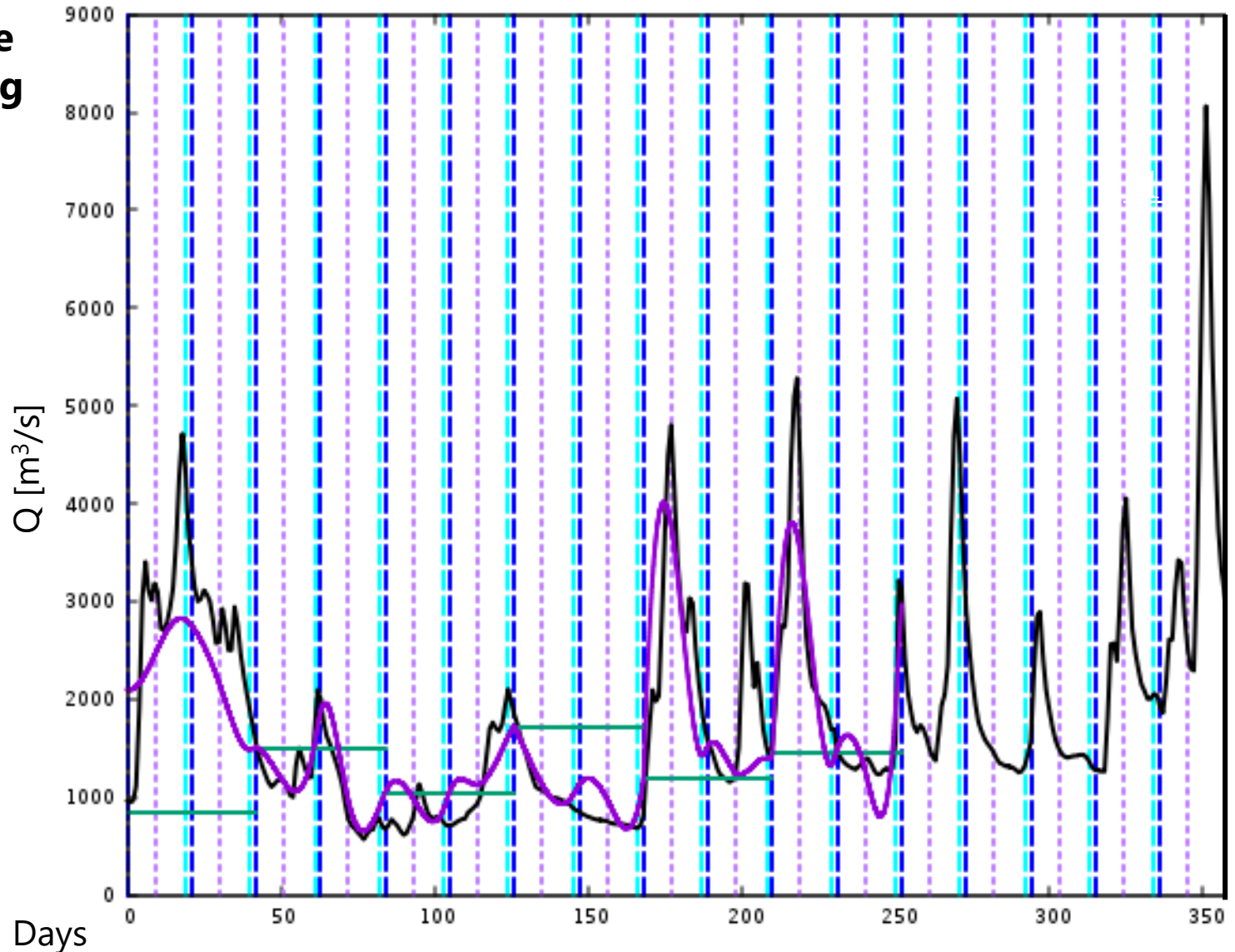




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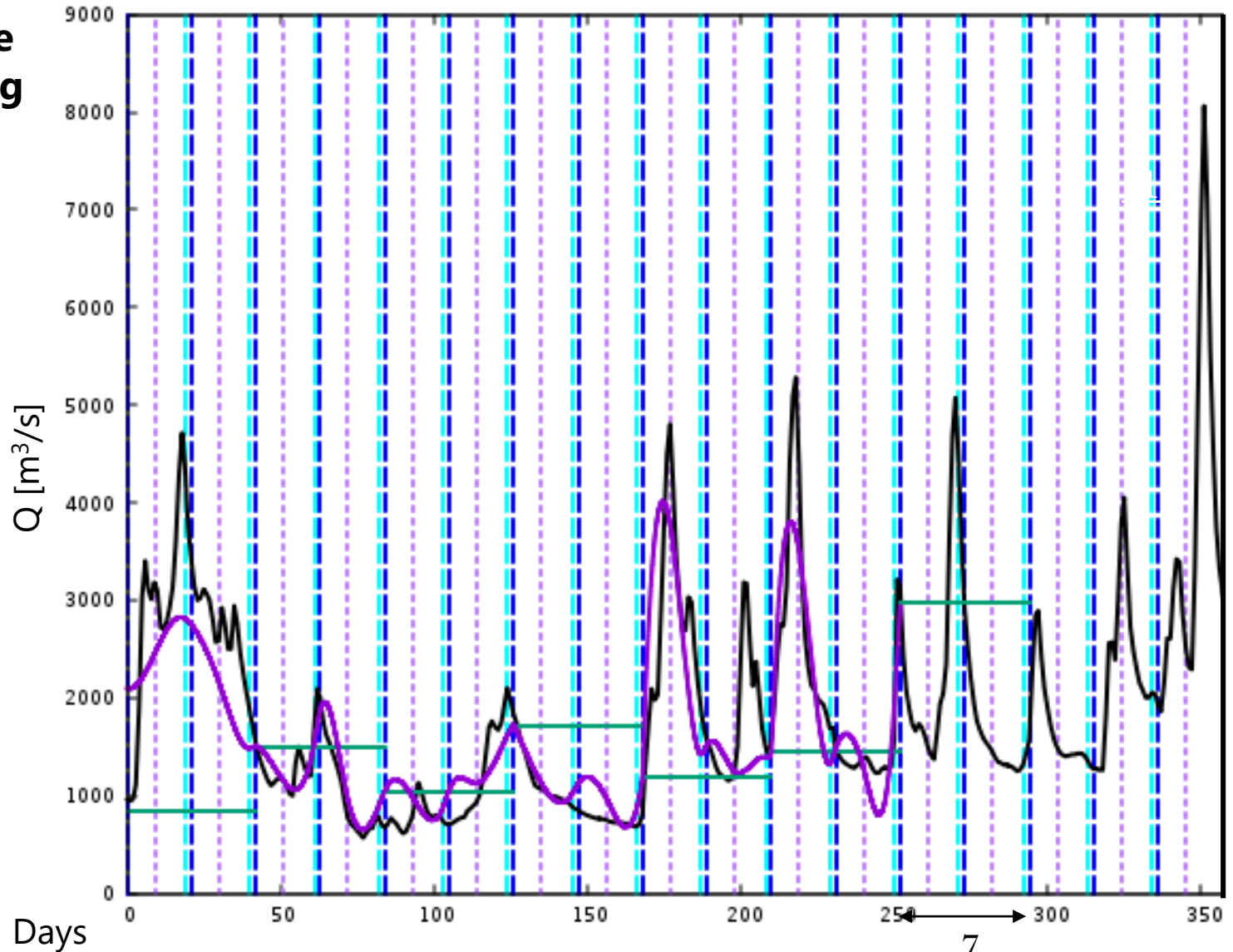




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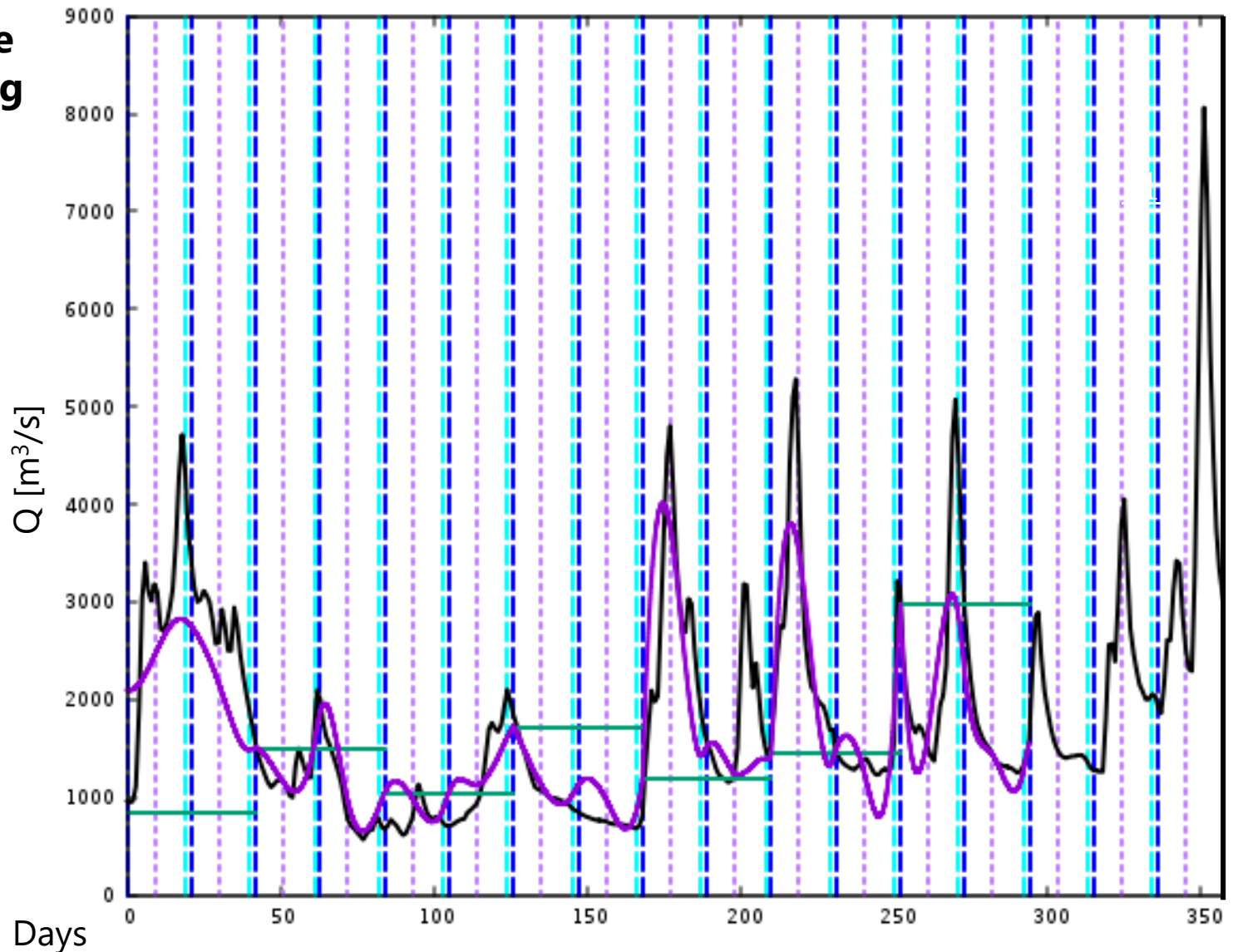




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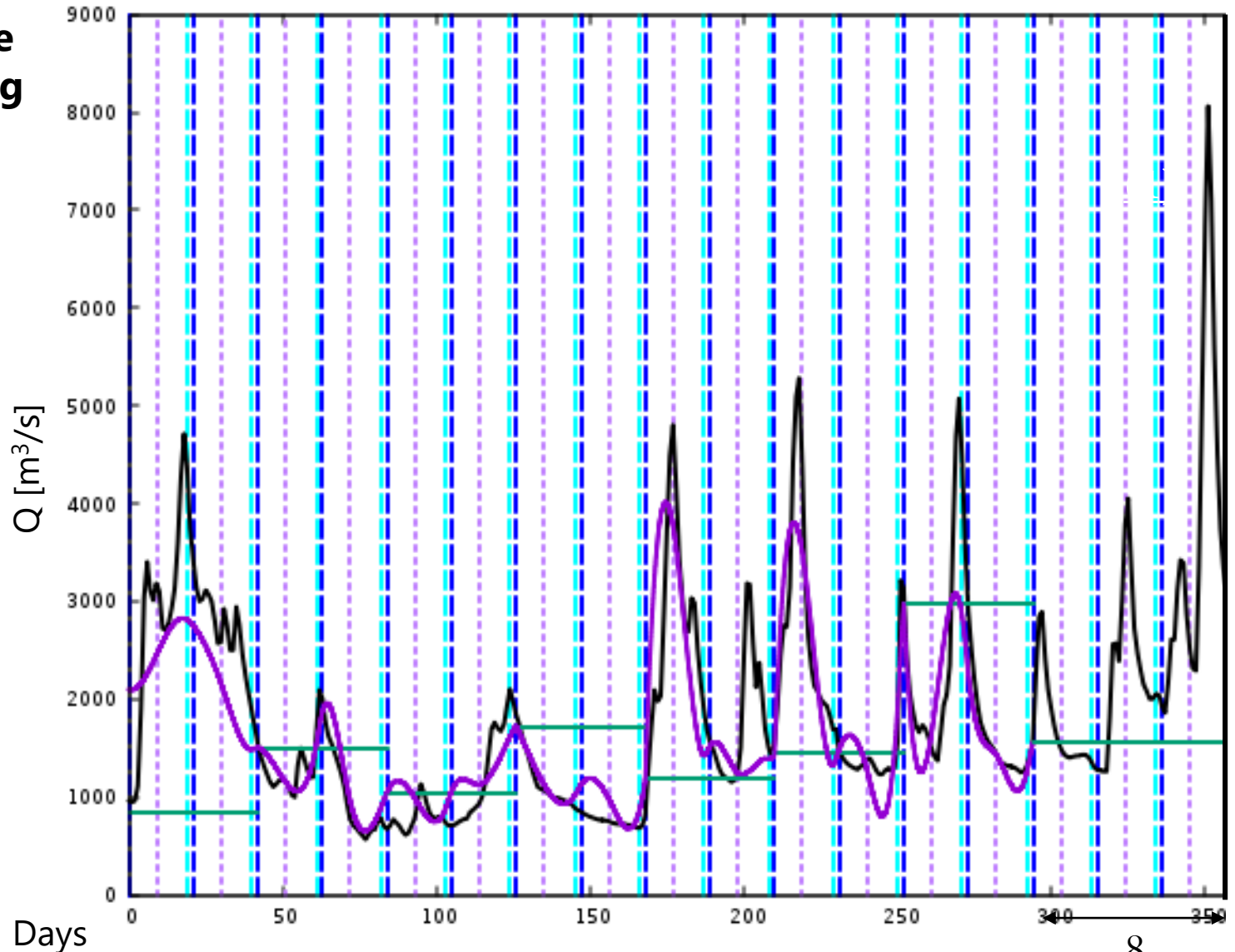




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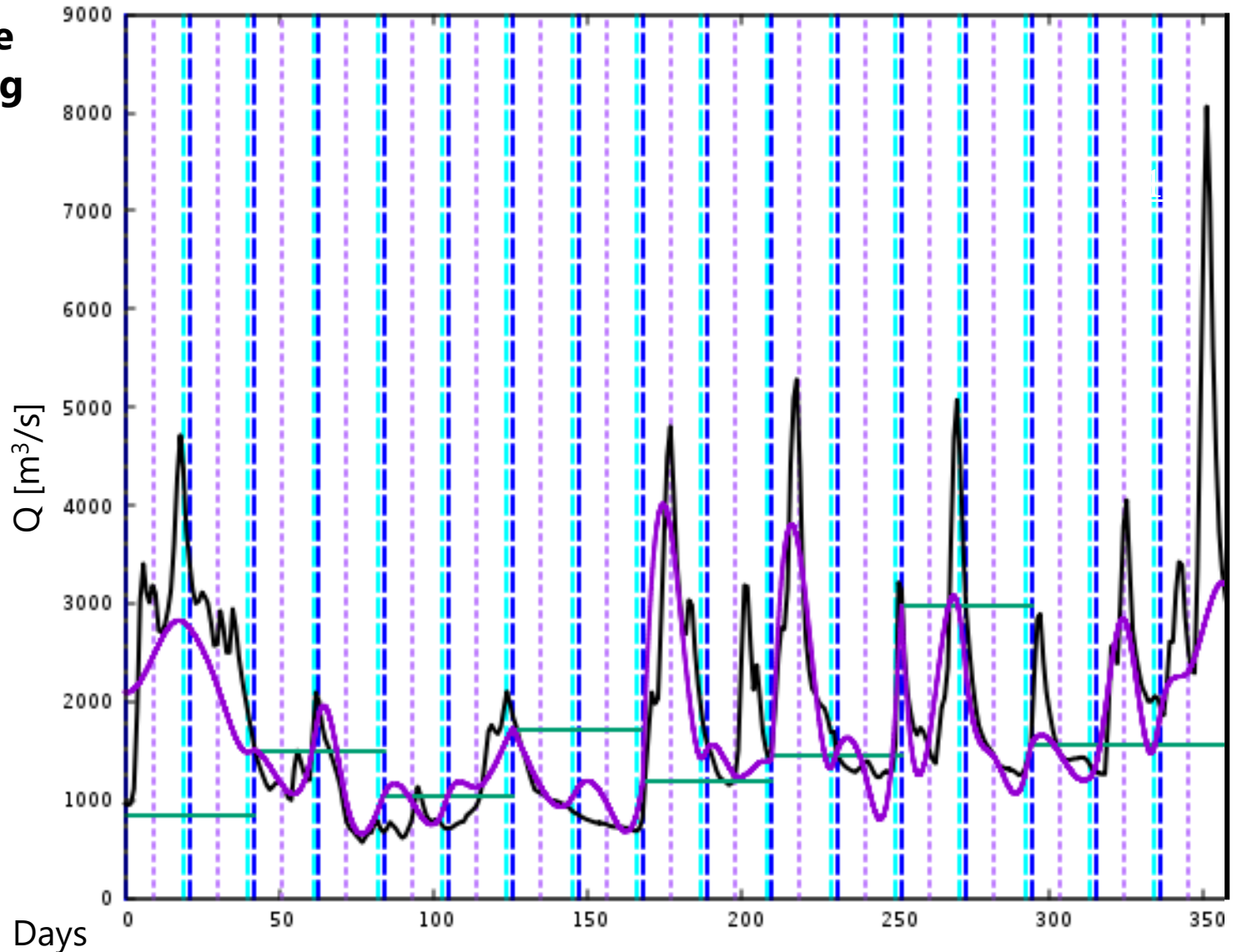




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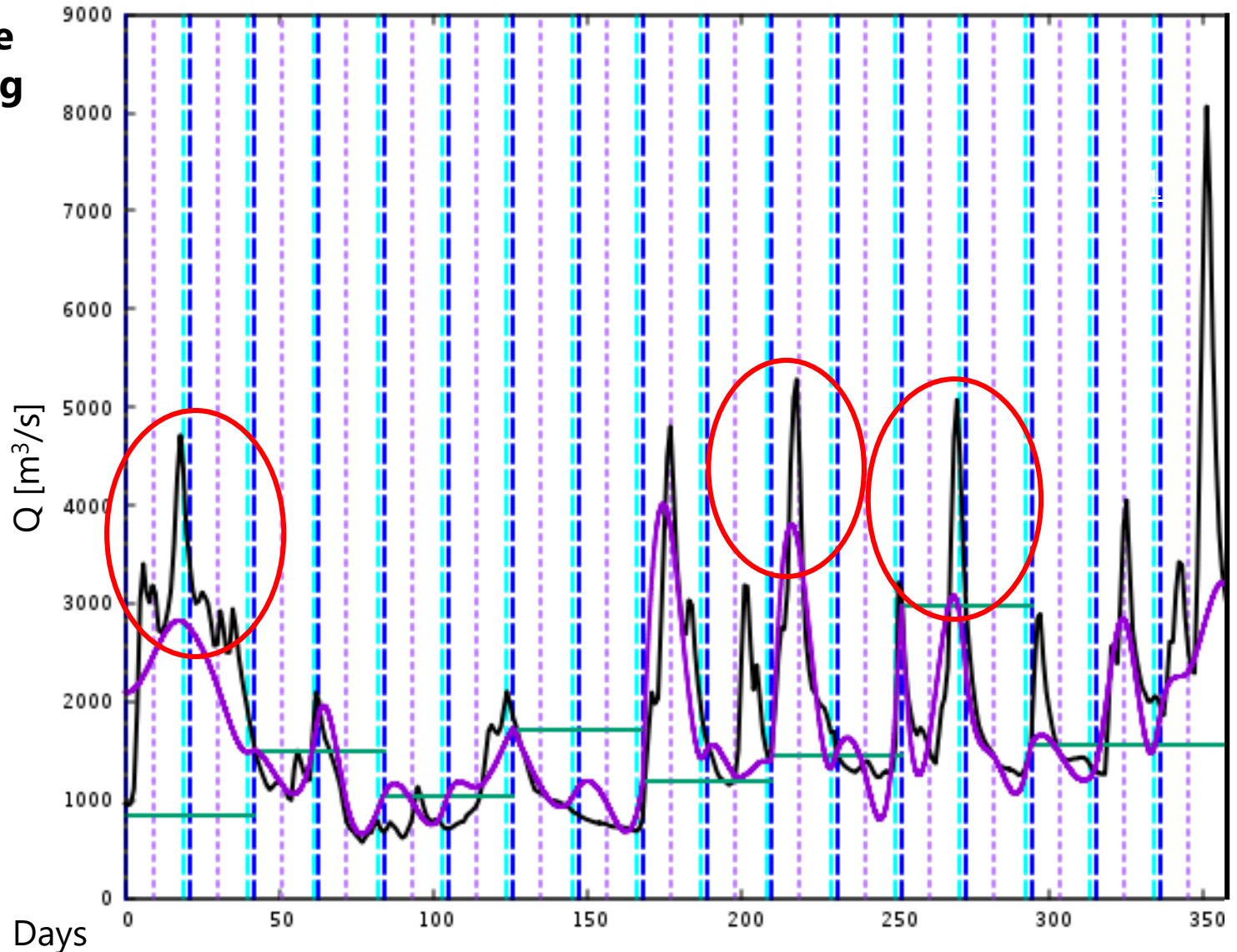




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Introduction

Monate Lake case study

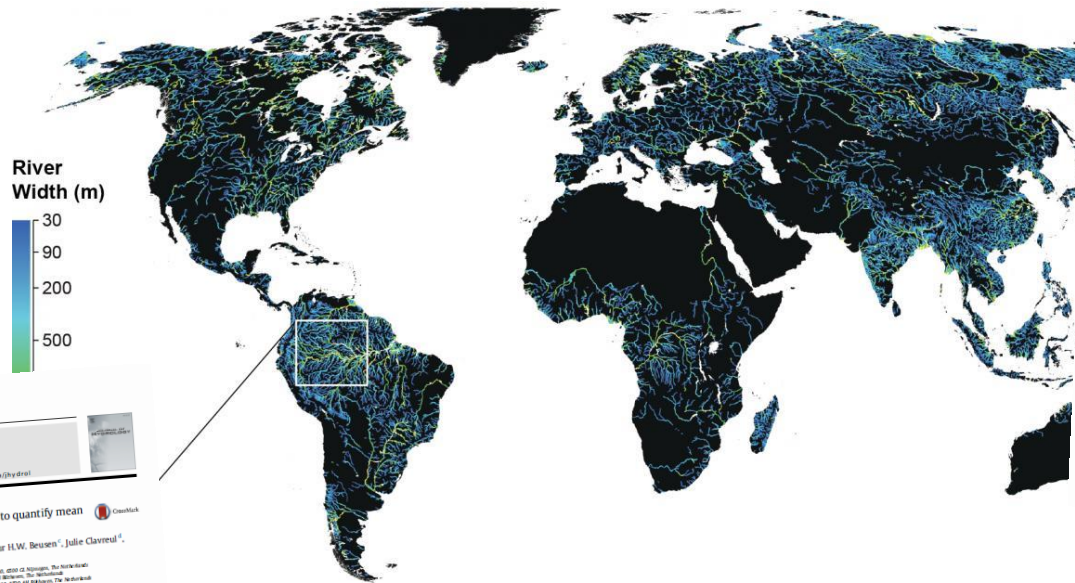
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River geomorphologic relationship



Journal of Hydrology 539 (2015) 103–119

Contents lists available at ScienceDirect
Journal of Hydrology

Efficient incorporation of channel cross-section geometry uncertainty into regional and global scale flood inundation models

Jeffrey C. Neal^{a,*}, Nicholas A. Odon^a, Mark A. Trigg^a, Jim E. Freer^a, Javier Garcia-Rodas^{b,c}, David C. Mason^d, Melissa Wood^e, Paul D. Bates^f

^a School of Civil and Environmental Engineering, University of Reading, Whiteknights, Reading, RG6 2AH, UK
^b Department of Geography and Institute of Hydrology, University of Reading, Whiteknights, Reading, RG6 2AH, UK
^c National Centre for Earth Information Science, University of Reading, Whiteknights, Reading, RG6 2AH, UK
^d School of Geography, Planning and Environmental Science, University of Reading, Whiteknights, Reading, RG6 2AH, UK
^e Department of Earth and Atmospheric Sciences, University of Reading, Whiteknights, Reading, RG6 2AH, UK

ARTICLE INFO
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KEYWORDS
Channel cross-section geometry
Flood inundation modeling
Uncertainty
Regional scale
Global scale

1. Introduction
Recently there has been substantial interest in simulating river discharge in regional and global scales. Most research has focused on the number of model runs required to quantify a given set of flow, flood and risk scenarios. There is currently no clear definition of what constitutes a large or small number of runs. The purpose of this paper is to assess that and to provide a framework that can be applied to similar systems that are not the focus of this paper. Some new progressions through the work have been made that are particularly interesting in terms of channel cross-section geometry and channel width.

ABSTRACT
This paper presents the challenge of representing structural differences in river channel cross-section geometry for regional and global scale flood inundation models. The River Cross-Section Geometry (RCSG) model is used to generate a set of channel cross-sections that are used to represent the uncertainty in channel cross-section geometry. The RCSG model is used to generate a set of channel cross-sections that are used to represent the uncertainty in channel cross-section geometry. The RCSG model is used to generate a set of channel cross-sections that are used to represent the uncertainty in channel cross-section geometry.

Journal of Hydrology 539 (2015) 479–491

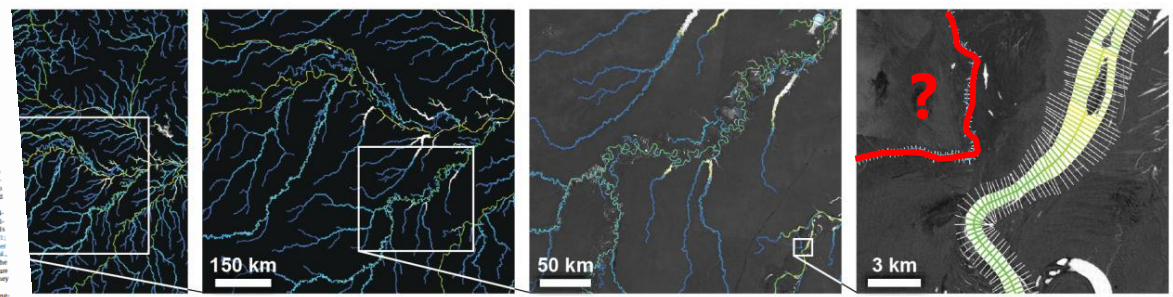
Contents lists available at ScienceDirect
Journal of Hydrology

Research papers
Developing and testing a global-scale regression model to quantify mean annual streamflow

Valerio Barbarossa^{a,*}, Mark A.J. Huijbregts^{b,c}, A. Jan Hendriks^b, Arthur H.W. Beusen^b, Julie Ciavutti^d, Henry King^e, Aalke M. Schipper^f

^a Institute of Environmental Sciences and Technology, Department of Environmental Science, 100 Bushy Park, Dublin 15, Ireland
^b MIRA – Maastricht Environmental Assessment Agency, Department of Hydrology, Soil and Land Use, 6001 SB, Maastricht, The Netherlands
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ABSTRACT
Quantifying mean annual flow of rivers (MAF) at ungauged sites is essential for assessments of global water supply, energy and water resources. MAF can be quantified with spatially explicit mean annual streamflow (MASF) models, which require time-consuming and data-intensive global-scale process-based models, which may be overly time-consuming and data-intensive for this purpose. An alternative approach is to use regression models based on observed data. In this paper, we developed a global-scale regression model to quantify MAF at ungauged sites. The model is based on a global-scale regression model, which requires time-consuming and data-intensive global-scale process-based models, which may be overly time-consuming and data-intensive for this purpose. An alternative approach is to use regression models based on observed data. In this paper, we developed a global-scale regression model to quantify MAF at ungauged sites. The model is based on a global-scale regression model, which requires time-consuming and data-intensive global-scale process-based models, which may be overly time-consuming and data-intensive for this purpose.

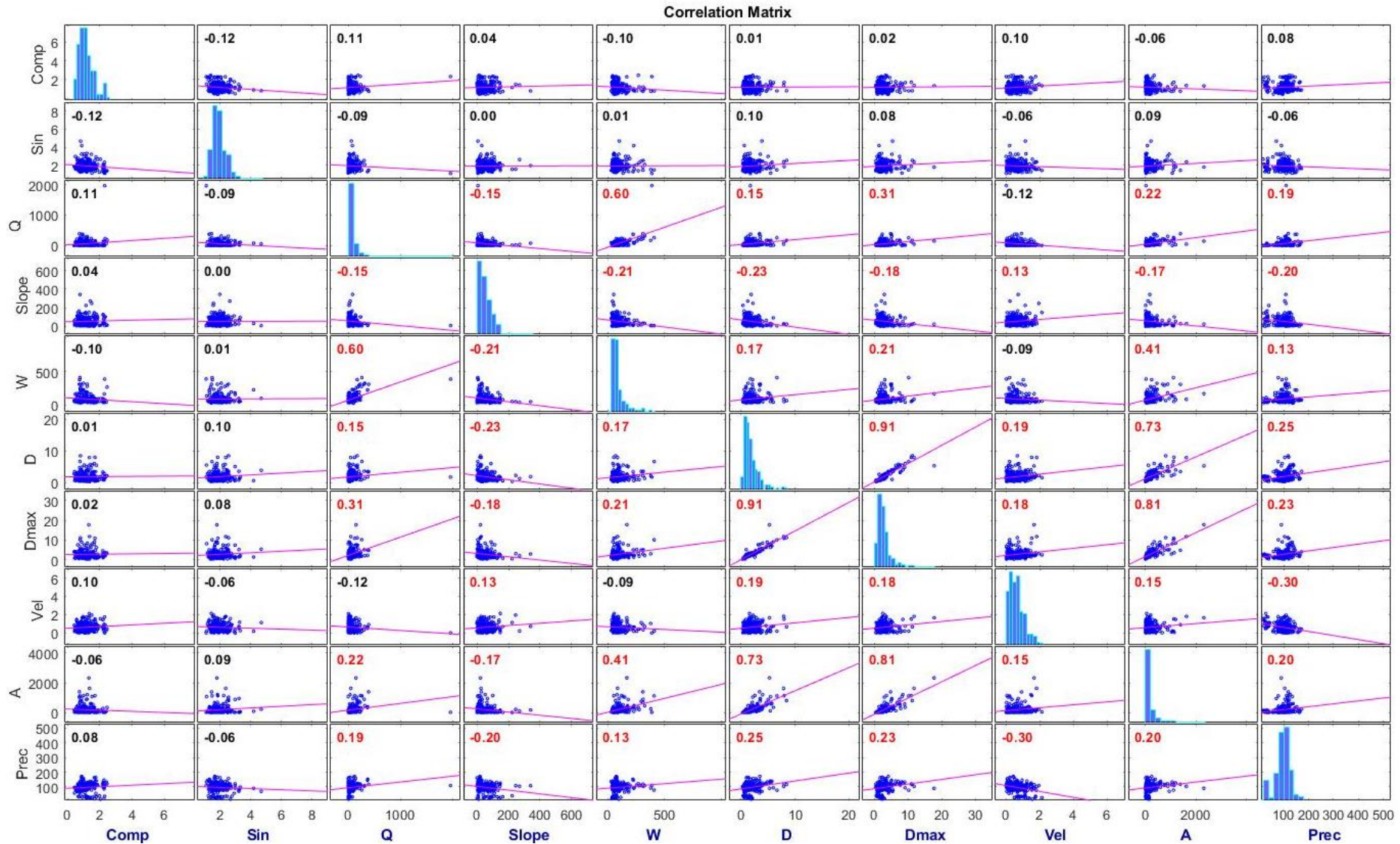


(Neal et al, 2014)

(Barbarossa et al, 2016)



River geomorphologic relationship





Courses and seminars attended

Period abroad: 14/01-18/04 2019, IRSTEA (Montpellier)

Advisor: Hind Oubanas

Courses taken from a master program

- *Introducing to algorithms and programming* – Proff. Simone Martini, Maurizio Gabrielli, 09/12.2019, UniBo, 6 ECTS
- *Calcolo Numerico* – Prof. Silvia Bonettini, 02/06.2019, UniMore, 9 ECTS
- *Fondamenti di Machine Learning* – Prof. Luca Zanni, 09/12.2019, UniMore, 6 ECTS
- *Ottimizzazione Numerica A* – Proff. Luca Zanni, Silvia Bonettini, 09/12.2019, UniMore, 6 ECTS

Other courses, seminars and workshops

- Seminar: *Catastrophe Modelling* – Laurent Marescot (RMS Zurich), Maurizio Savina (RMS Zurich), Cecilia Bittoni, 21.06.2019, UniBo, 3 hours.

National and international conferences:

- Conference: *European Geosciences Union (EGU) General Assembly 2019*, 07/12.04.2019, Vienna (Austria), 5 days.
- Conference: *Giornate dell'Idrologia 2019*, 16/18.09.2019, Bologna, 3 days.
- Conference: *Living the Planet Symposium*, 14/16.07.2019, Milan, 3 days.



Evaluation of PhD activity

Thanks for your attention

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