COSMO for lake studies: use cases and criticalities in a scientific environment

Andrea Cimatoribus

Ecological Engineering Laboratory
École polythechnique fédérale de Lausanne

January 30, 2017

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A comprehensive framework for lakes modelling and monitoring

meteolakes.epfl.ch

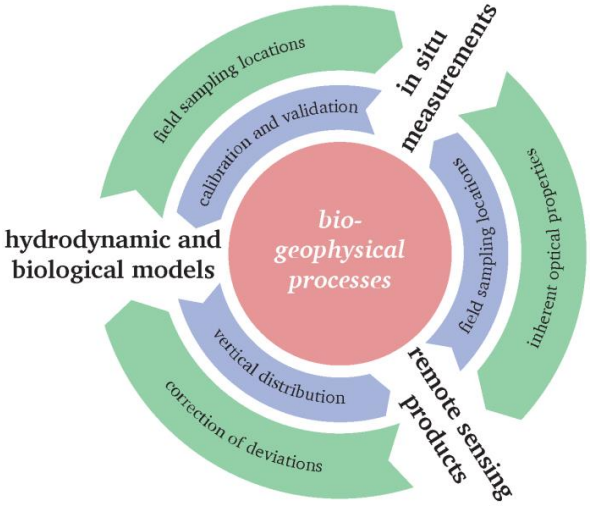
Theo Baracchini
A. J. Wüest, D. Bouffard
APHYS – EPFL

Introduction

CORESIM – ESA project

Provide a modelling framework tailored to inland waters:

- Operational in real-time
- With short-term forecasting
- Online, open to the public
- **Benefiting/applied to aquatic research**
  - By studying mesoscale processes (e.g. upwellings)
  - And assessing the variability of lake responses to climate change



Interlink of the 3 information sources

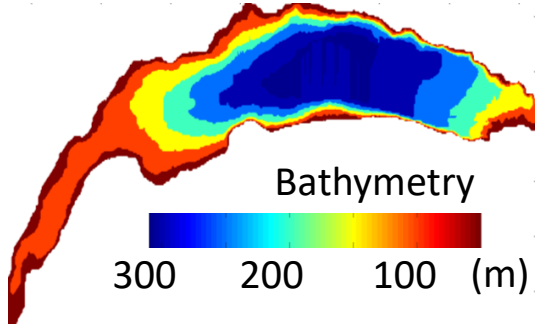
The current challenge is to combine those sources to provide timely, scientifically credible, and policy-relevant environmental information

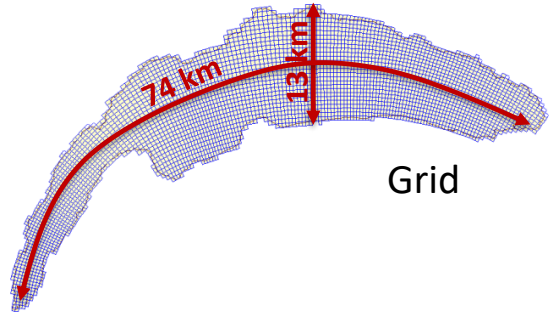
Background simulation

Model setup

Delft3D model set-up:

- Z-layer, 100 layers
- < 450m horizontal grid size
- 1 min simulation time step
- Calibrated and validated with in-situ and remote sensing
- Real time validation with AVHRR satellites and in-situ monitoring station



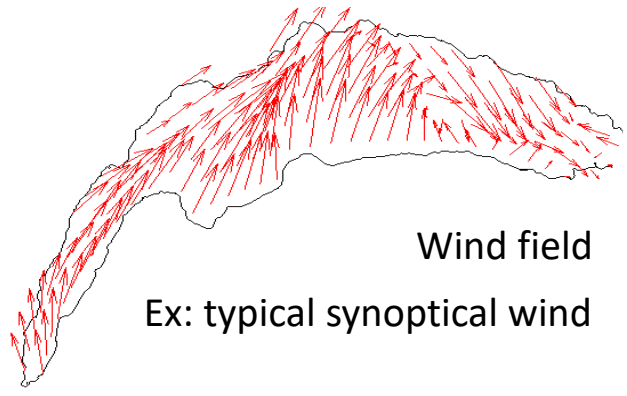


Background simulation

Space-time varying forcing

Meteorological forcing (MétéoSuisse's COSMO-1 & COSMO-E):

- 7 Variables
  - *Air temperature*
  - *Air pressure*
  - *Relative humidity*
  - *Cloud cover*
  - *Wind intensity*
  - *Wind direction*
  - *Solar radiations*



Wind field

Ex: typical synoptical wind

- On 1.1 km grid (COSMO-1) and 2.2 km (COSMO-E)
- Every hour

Real-time data collection

In-situ and meteo station

Buchillon station:

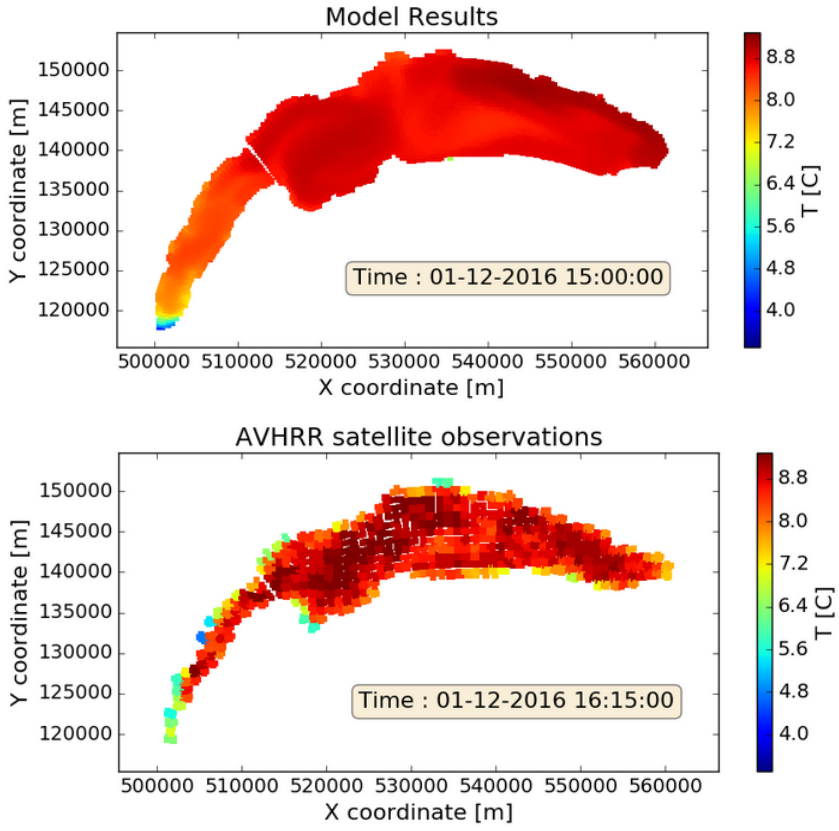
- 11 sensors
  - Air & water (skin + bulk) temperature
  - Wind direction & intensity
  - Solar radiations
  - ADCP (flow velocity)
  - …
- High frequency measurements (1/min)
- GPRS data uplink
- Openly available online

Real-time data collection

Remote sensing validation

AVHRR satellite data:

- Up to 12 overpasses a day
- 1 km spatial resolution
- Downlink and processing (skin to bulk) at University of Bern
- Direct comparison with modelling results for validation
- Openly available online



Meteolakes

Future perspectives

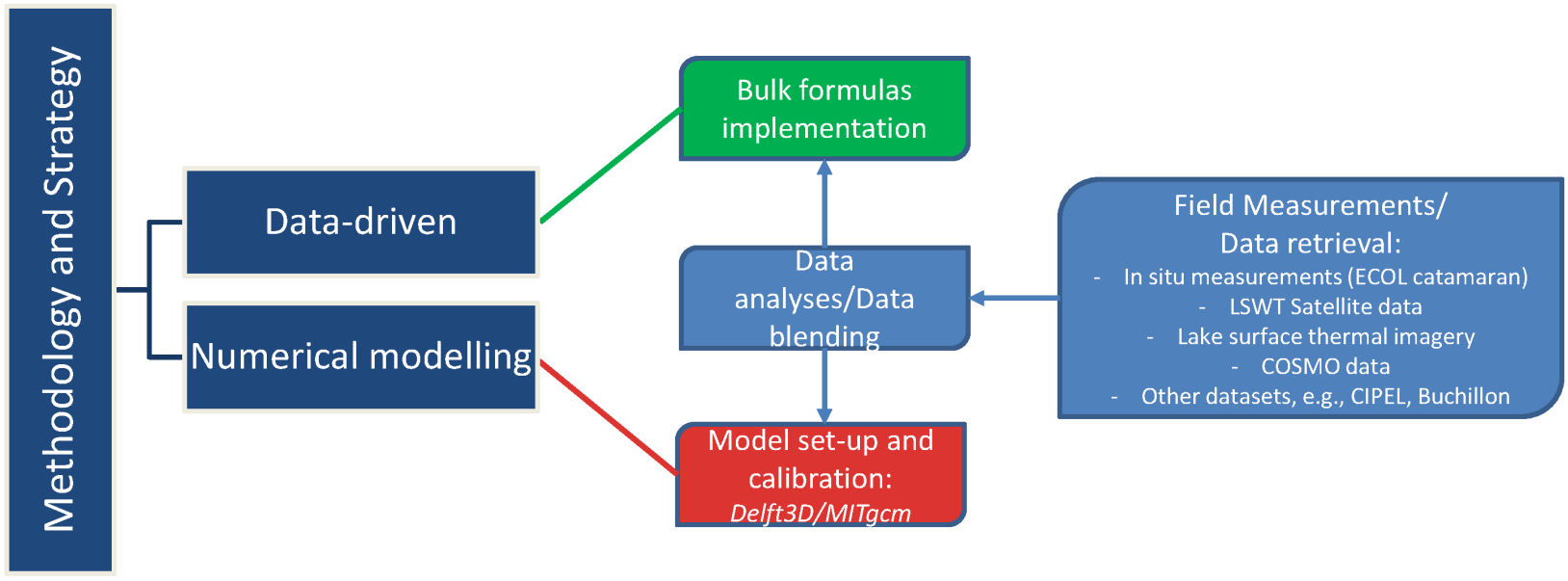
- Inclusion of BAFU river data (available Feb. 2017)
- Real-time data assimilation (DA)
  - Ensemble Kalman Filtering
  - AVHRR surface temperature DA
  - Forecasting uncertainties
- Water quality monitoring
  - Algae concentration, oxygen, plankton species, etc. (available summer 2017)
  - MERIS and Sentinel-2 satellite DA
- Implementation for other Swiss lakes

Air–water interaction in Lake Geneva

Abolfazl Irani Rahaghi
D. A. Berry, U. Lemmin
ECOL – EPFL

Scientific objectives

- **Characterizing the variability of surface heat flux and lake surface/near surface water temperature: large-scale, meso-scale and small-scale structures**
- **Understanding the physical phenomena underlying LSWT and SHF variability in a large lake**

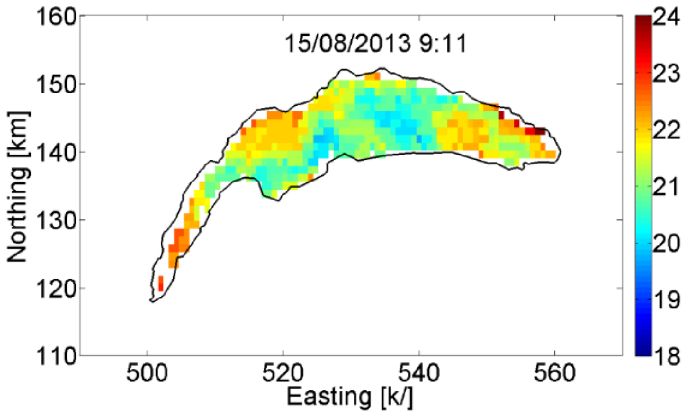


Large-scale long-term analysis

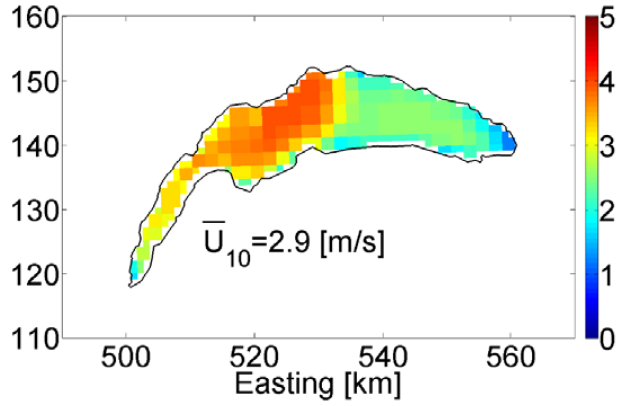
COSMO + satellite data

Calibration of bulk formulas

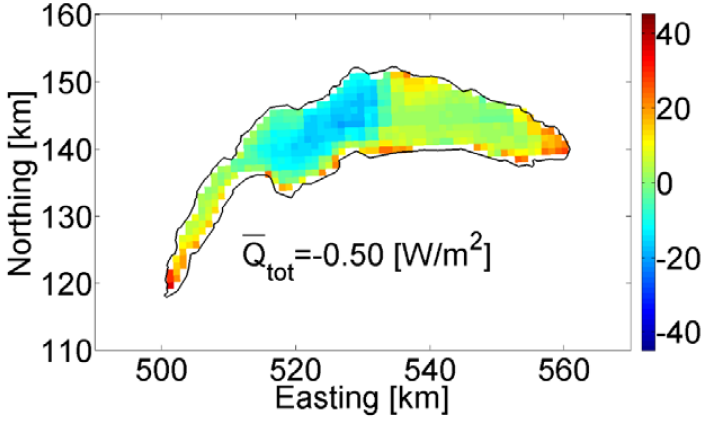
Surface heat flux terms

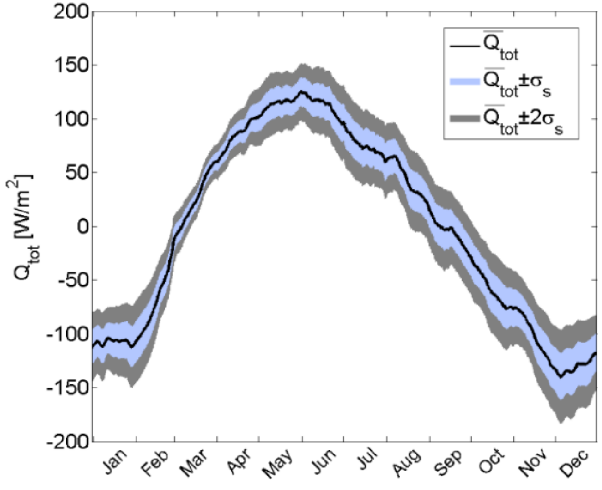


AVHRR satellite thermal images (a sample)



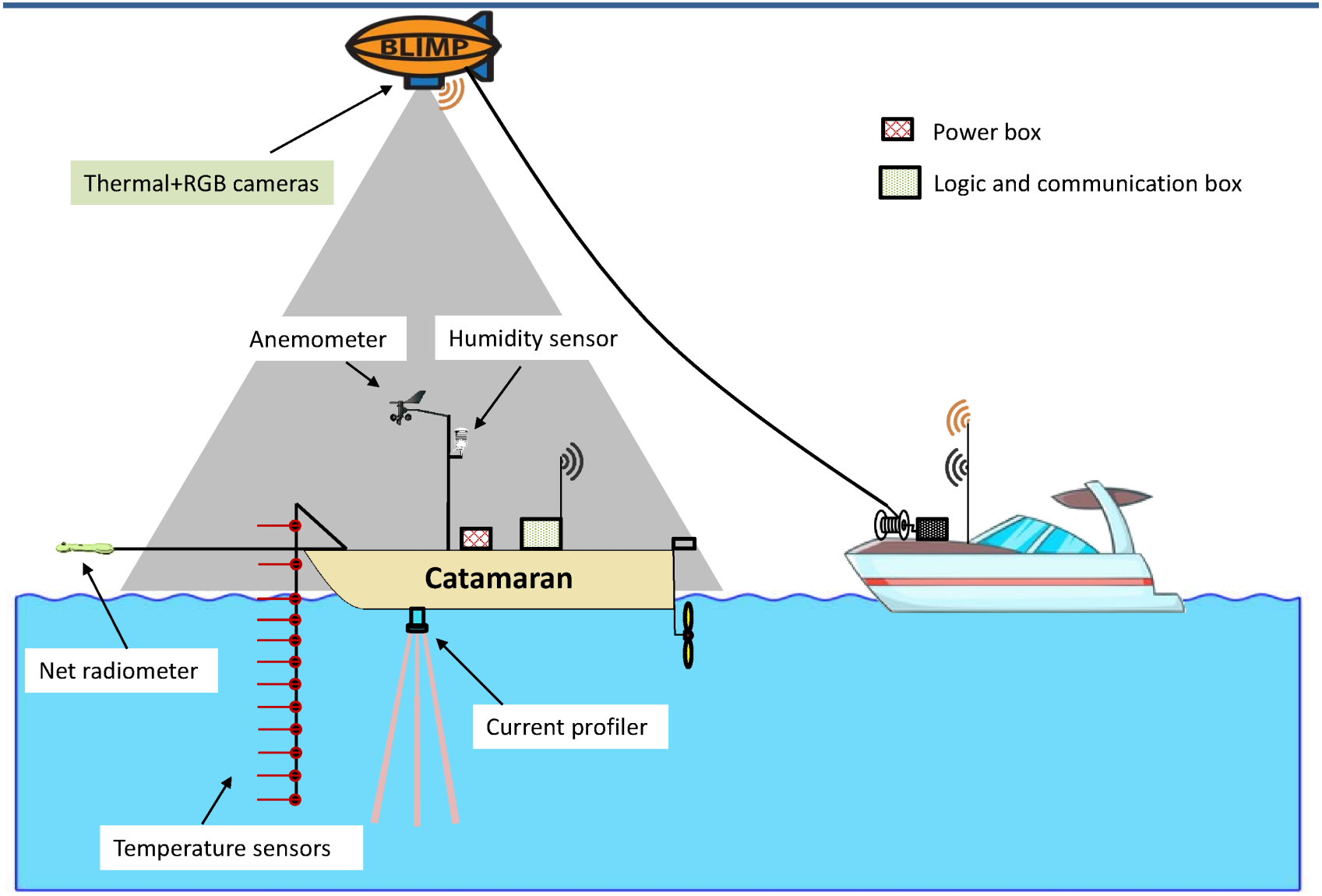
COSMO-2 meteorological data. The average U_{10} (m/s) map for September 2008-2014 is shown



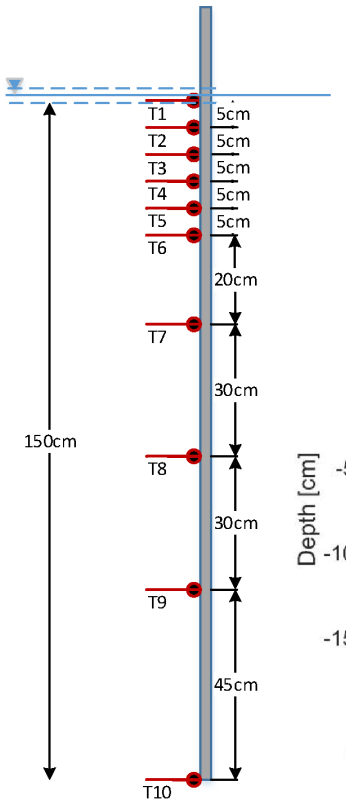


Sapatiotemporal average air-water surface heat flux (2009-2014)

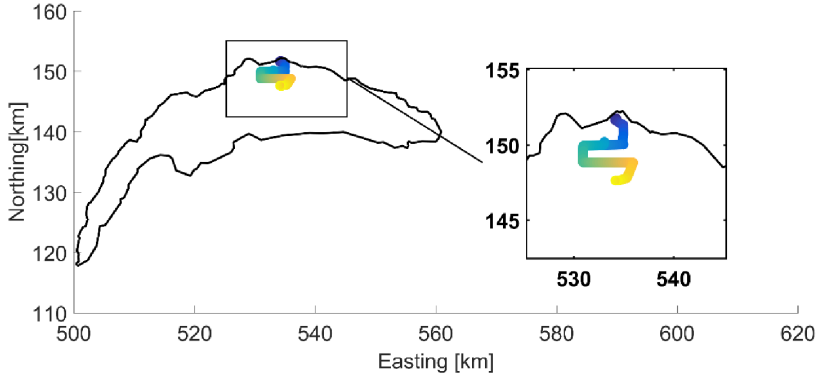
Meso-scale/small-scale platform: Catamaran/BLIMP/LIMONAD

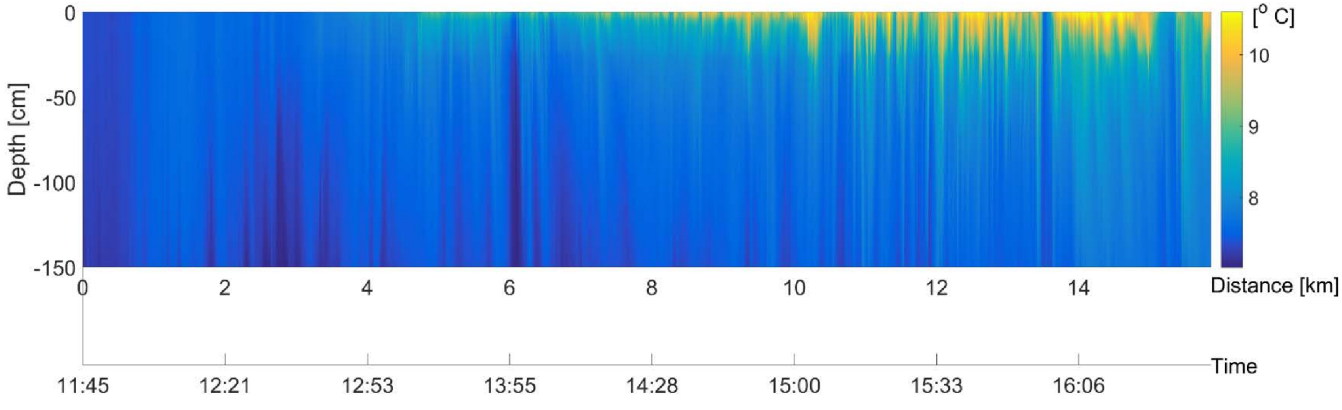


Catamaran trajectory and raw temperature data, 18/03/2016



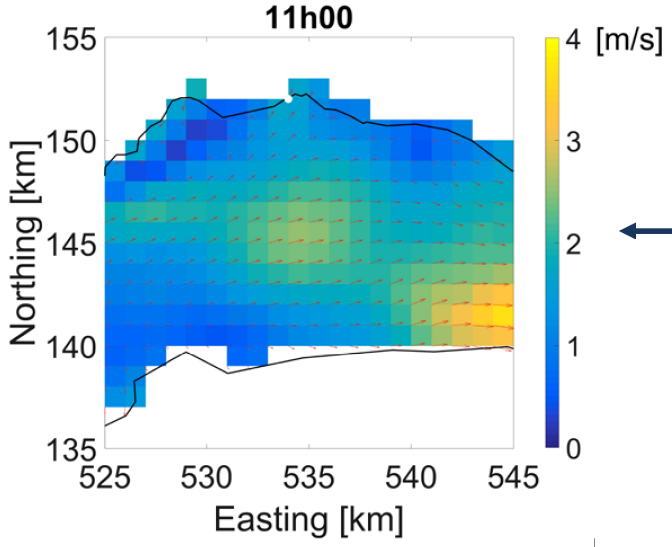
Thermistor mast





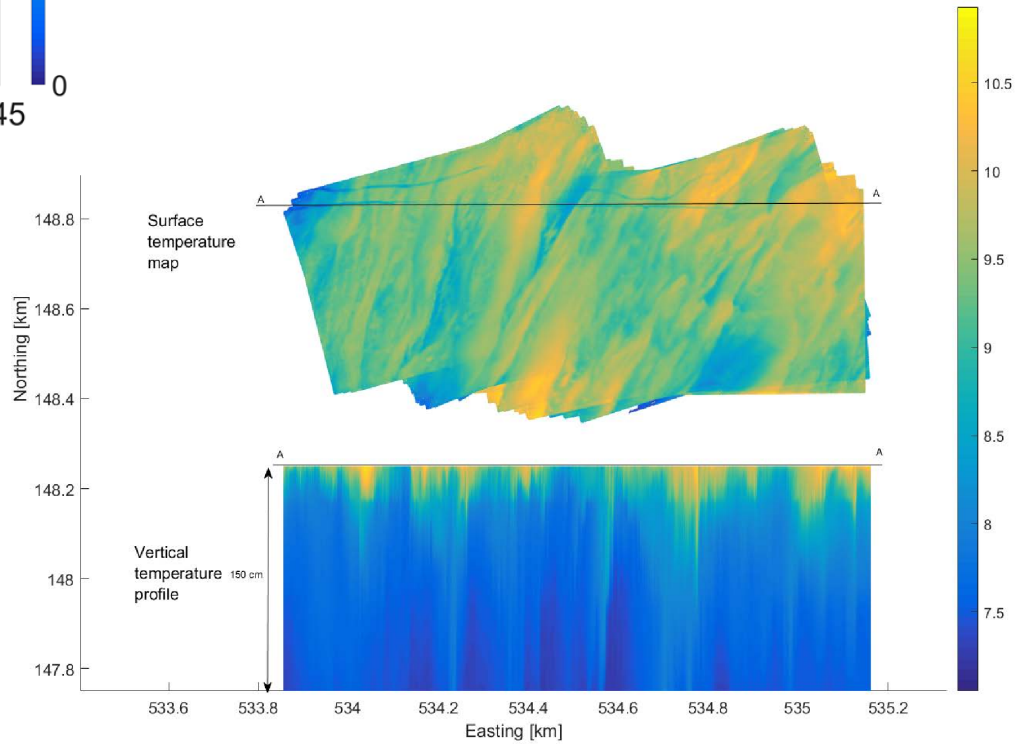
- **Please note the lack of uniformity in the time axis!**

An example of meso-scale thermal structures



COSMO-2 wind field (U_{10})

Stitched BLIMP thermal images + in situ Catamaran temperature data



Perspectives

- High resolution (both spatial and temporal) reliable meteorological data are helpful for meso-scale structure interpretation, e.g., the streaks over lake

- ECOL data acquisition platform can be used for uncertainty evaluation in over-water results of COSMO model?

- Intercomparison of bulk parameterization algorithm for air-water surface heat flux estimation (used in both COSMO model and ECOL research team)

- ECOL plane (LIMONAD) is functional now. We're looking forward to get more-frequent large-coverage thermal data.

Uses of COSMO

- Forcing field for hydrodynamic numerical model 
- Fill “missing data” (e.g. in bulk formula) 
- Interpretation of field observations 
- Weather prediction for field activities 

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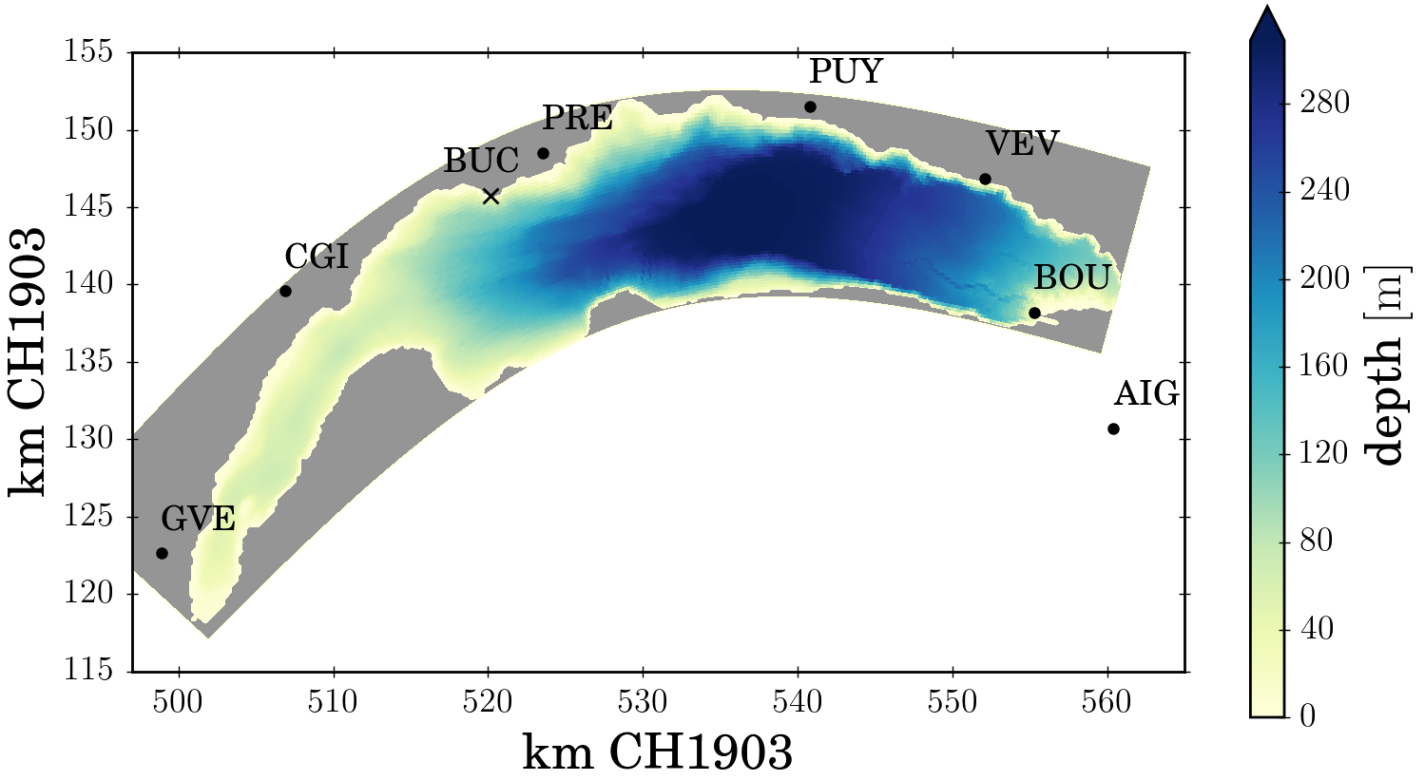
Validation of COSMO over lakes

How reliable are COSMO results over Lake Geneva?

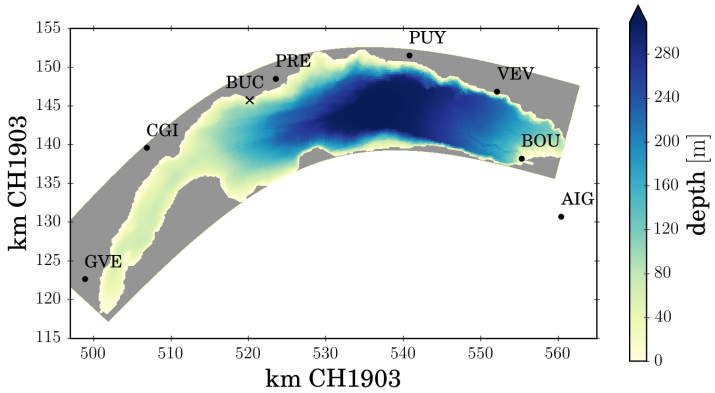


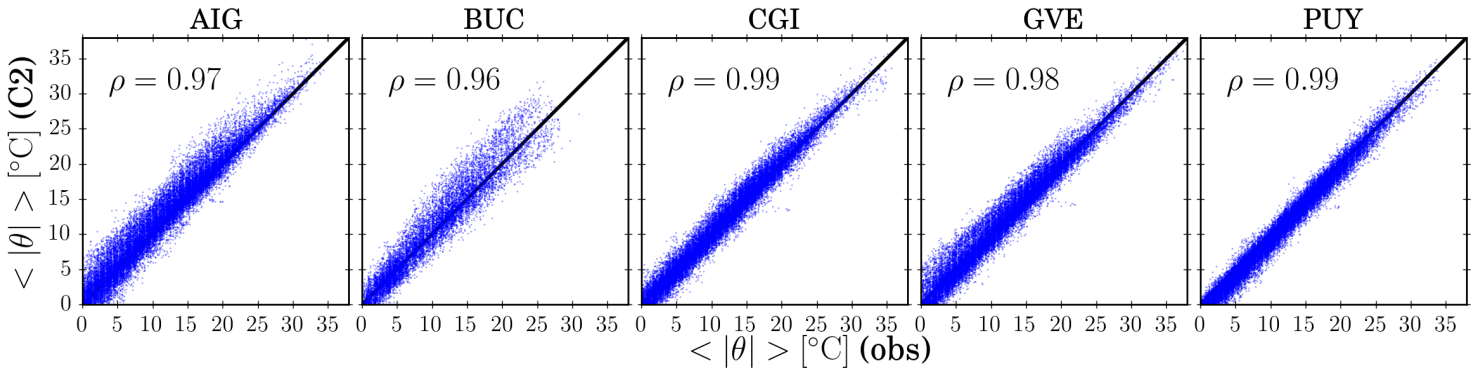
dots: MeteoSuisse stations, cross: EPFL station

Validation of COSMO over lakes

How reliable are COSMO results over Lake Geneva?

Temperature, COSMO2 vs. observations, year 2013

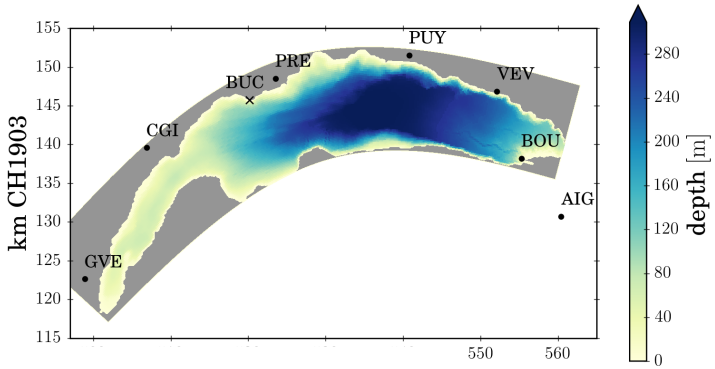


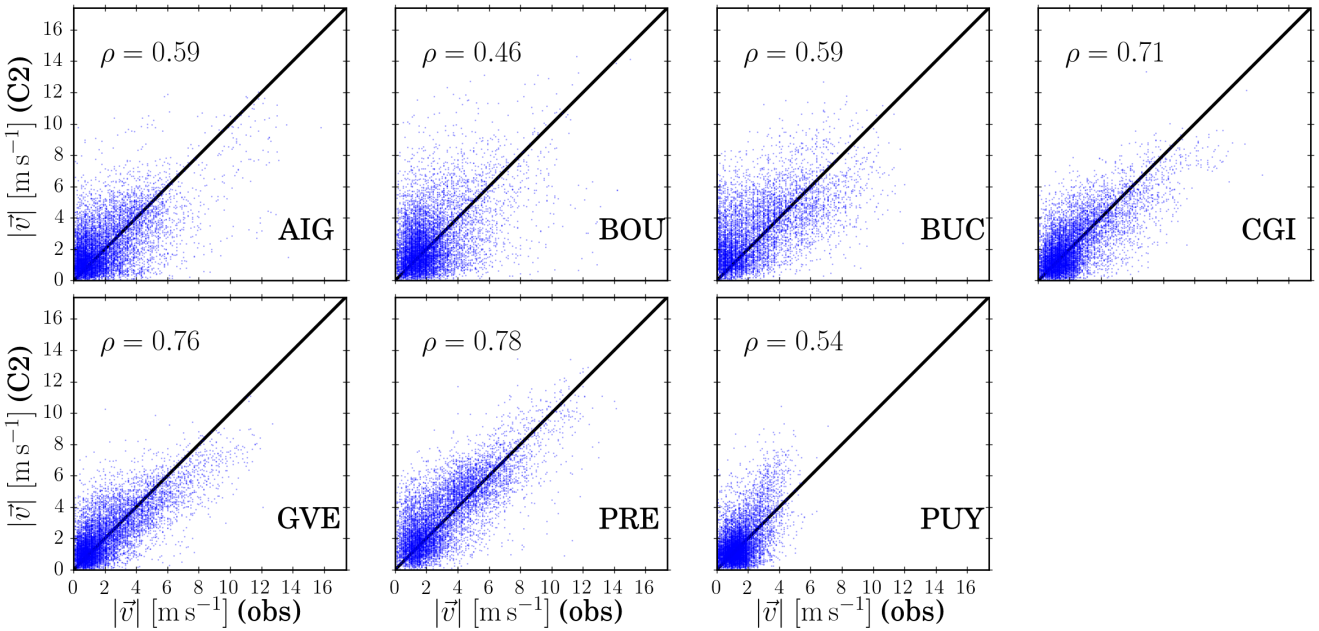


Validation of COSMO over lakes

How reliable are COSMO results over Lake Geneva?

Wind speed, COSMO2 vs. observations, year 2013





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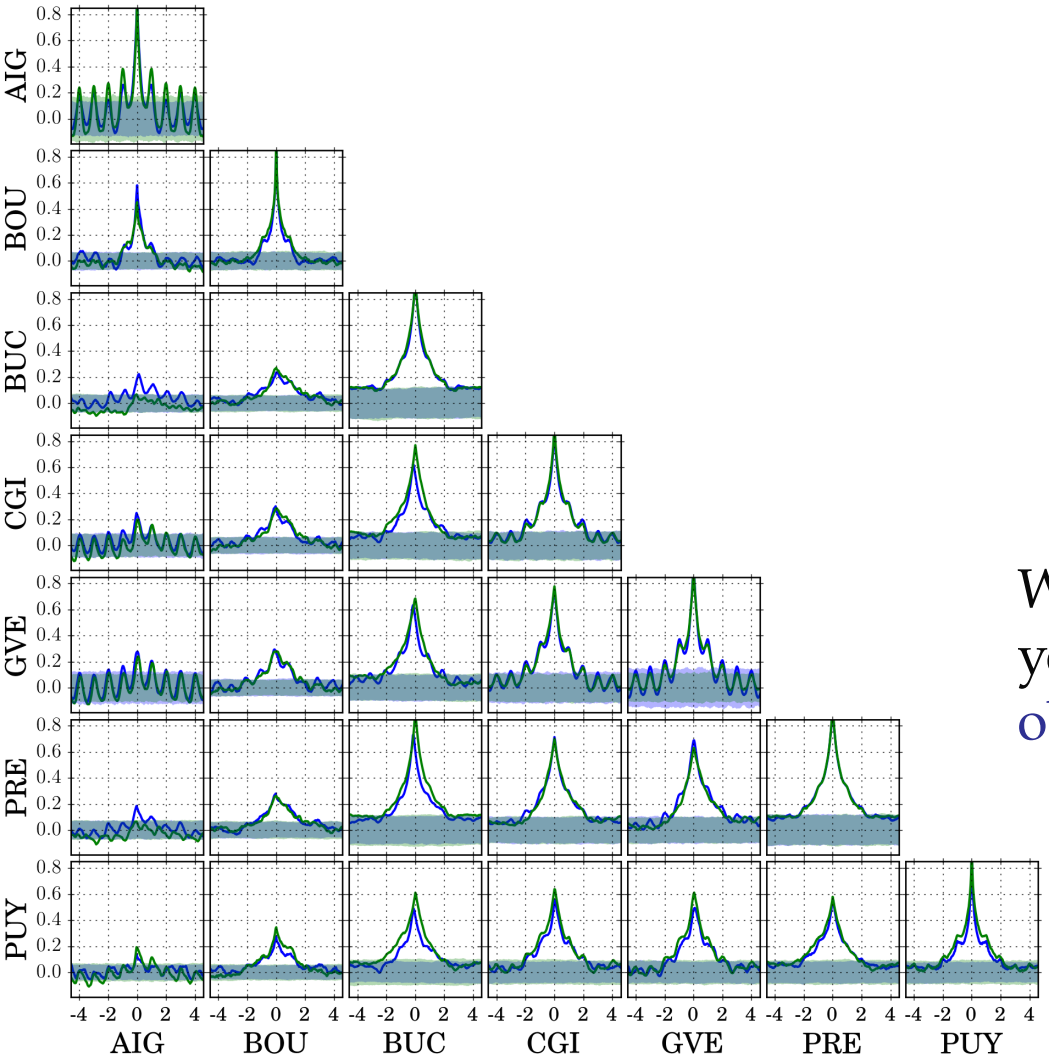
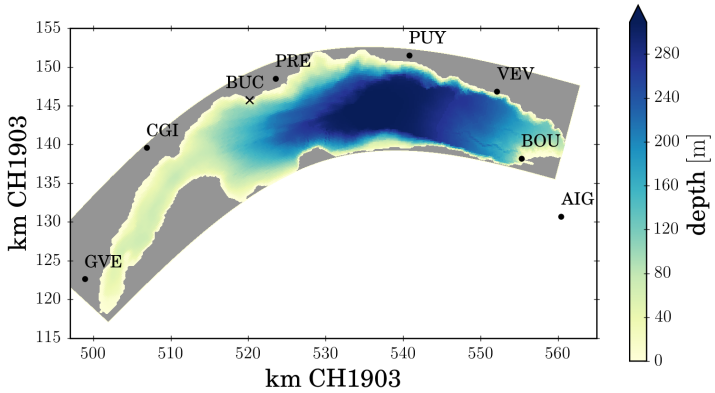


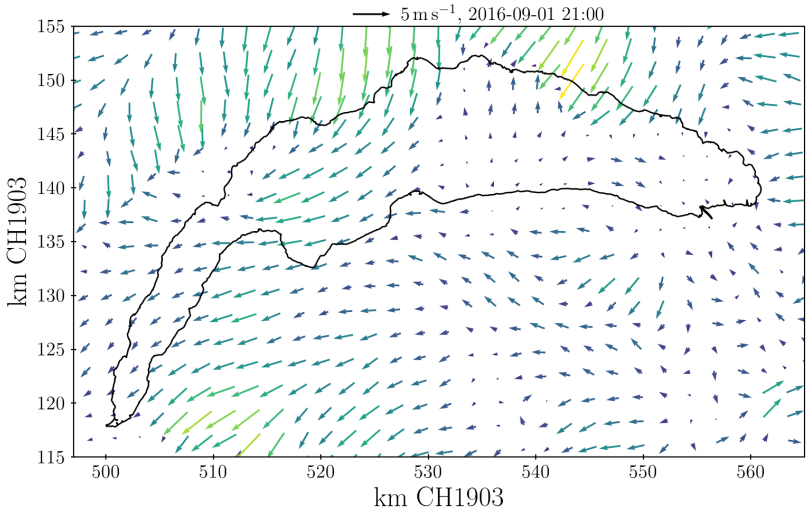


Wind speed xcorr,
year 2013,
observations, model

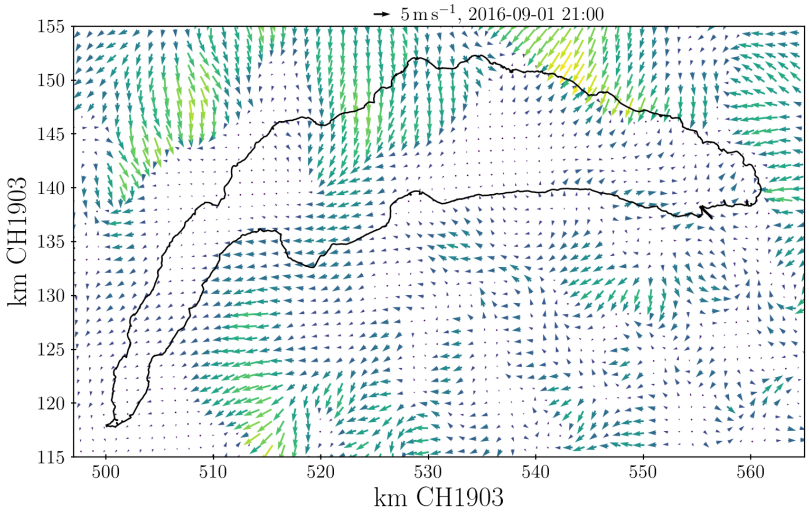
How important is resolution?

Is resolution (in space and time) important
in the forcing fields of a hydrodynamic model?

COSMO2



COSMO1

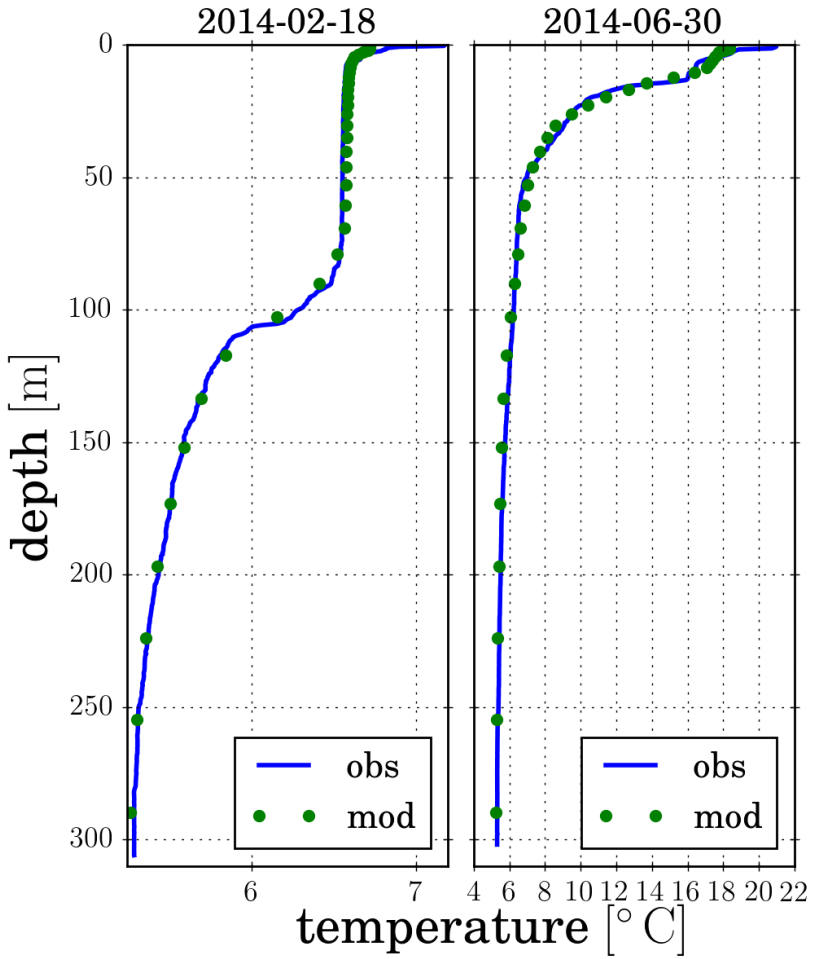


September 1, 2016, 21:00

How important is resolution?

Is resolution (in space and time) important
in the forcing fields of a hydrodynamic model?

A hydrodynamic model (MITgcm) forced by hourly COSMO2 results is able to reproduce **observed** stratification.



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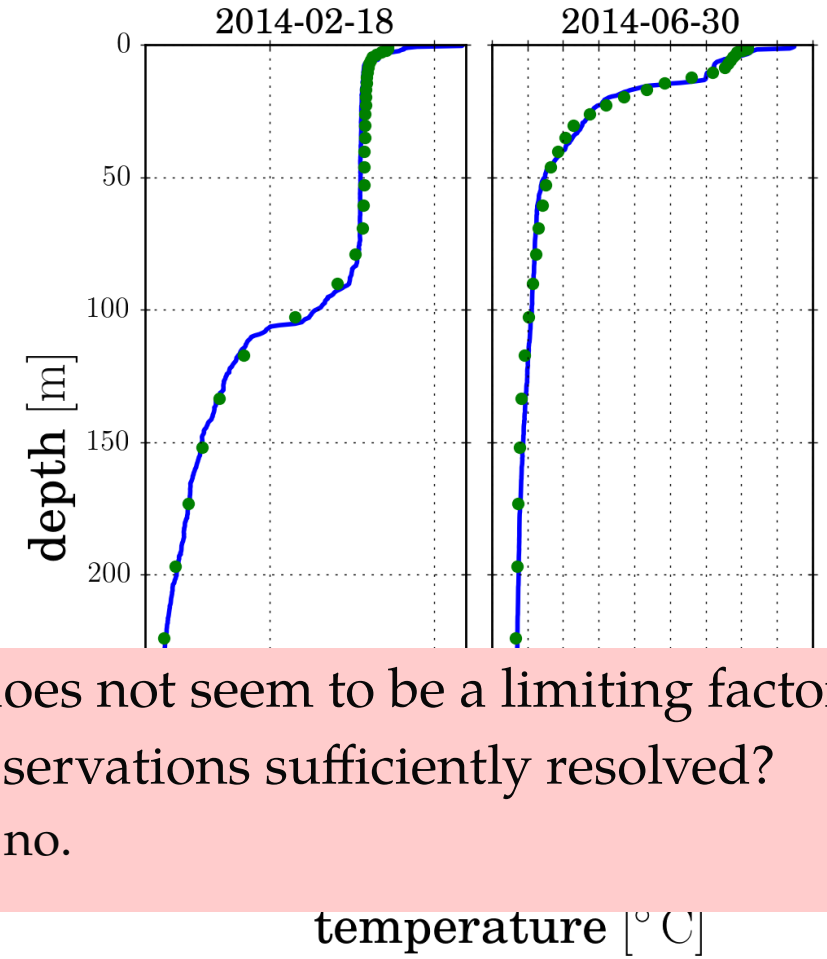

- Resolution does not seem to be a limiting factor…
- …but are observations sufficiently resolved?
  - Answer: no.

Possible issues of using COSMO for lake studies

- Lack of validation above water
- Over land, the temperature field seems very well constrained
  - I assume MeteoSuisse temperature measurements are assimilated in COSMO?
- For the wind field, the comparison between COSMO and observation is less clear
  - Is low correlation due to turbulence?
  - Patterns (x-corr) seem to be very well captured
- The resolution of COSMO results used ***seems*** a second order problem

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Validating COSMO over water

Main aims

- Know if/when/where COSMO results can be trusted
- Separate uncertainty in BC (COSMO) from other uncertainties
  - Model errors, parameterisations,...
- Suggest possible improvements to COSMO

Opportunities and issues

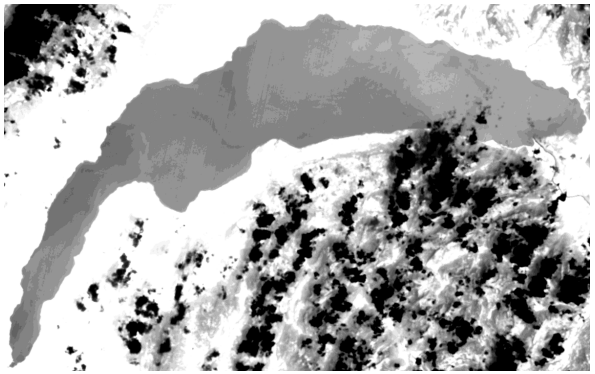
- EPFL near shore mast (Buchillon): operational
  - see `meteolakes.epfl.ch`
- Possibly soon a new platform in the north eastern part of the lake (AJ Wüest)
- No surface floating buoys are allowed in Lake Geneva
- Is validation in one lake relevant for other lakes?

Coupling between atmosphere and lake

Is there any advantage in a coupled atmosphere–lake model?

- A question only for large, deep lakes
- How important is air–water coupling in a lake?
  - How much heat can be stored and transported in the lake?
  - How does COSMO model interaction with lakes?
- Relevance for convection, both in the atmosphere and in the lake
- Broader scientific interest: lakes as natural laboratories for air–water interaction
- Study of small scale turbulent fluctuations at air–water interface

Summary



- COSMO in lake studies:
  - BC for hydrodynamic models
  - estimating air–water fluxes
  - planning of field campaigns
- Main issue: **unknown** reliability over water
  - Wind field in particular
- Is validation over water feasible?
- What can we learn by studying the coupled lake–atmosphere system?

Summary

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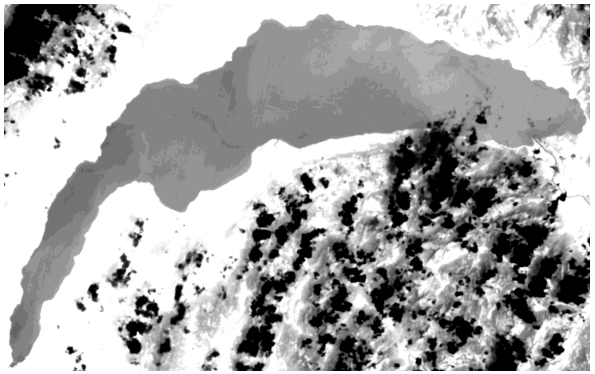

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Thank you!

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