Thermal Simulations for Water Cherenkov detectors at High Altitude

TÉCNICO LISBOA

Filipe Mendes @ Department of Physics
Pedro Coelho @ Department of Mechanical Engineering
Ricardo Lordelo – MSc Student @ IST & Scholarship @ LIP

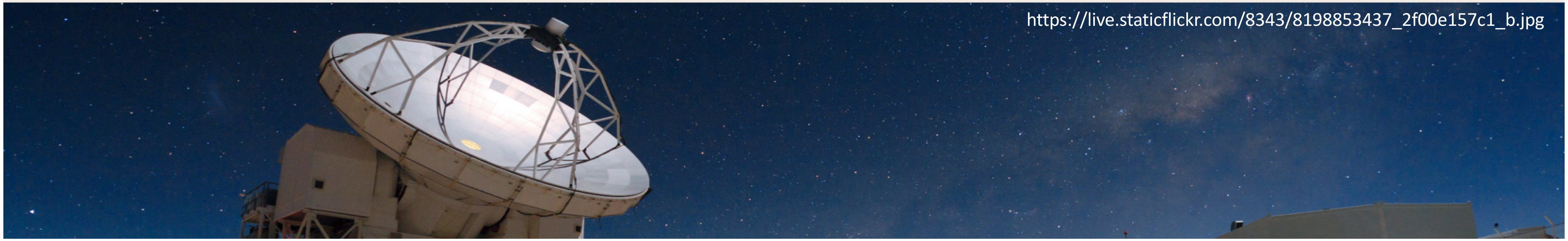
Wide field-of-view gamma-ray observatory in the Southern hemisphere Meeting
@LIP, 20th - 22nd May, 2019

Outline

1. Motivation
2. System
3. Physical Model
4. Some results
5. Next developments

1. Motivation

- Water tank detectors on extreme environment:
  - Long consecutive periods with negative temperatures according to APEX data
  - Strong winds according to APEX data
  - High altitude means higher solar irradiance but also high radiative losses to the sky



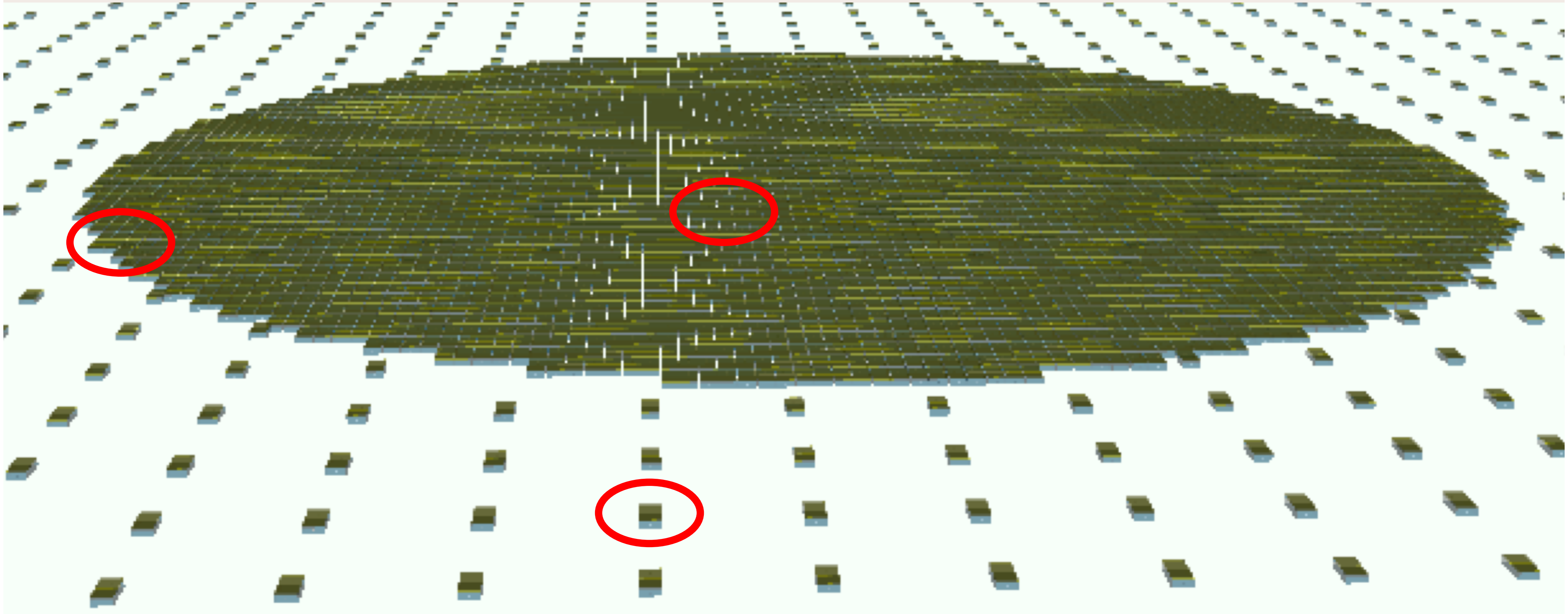
1. Motivation

- Partial or even full freezing is a possibility:
  - May be a problem to reconstruct signals
  - May lead to premature ageing of the detector
- Mitigation strategies are possible but it is important to know what is the “starting point” and their effect

2. System: a first case study

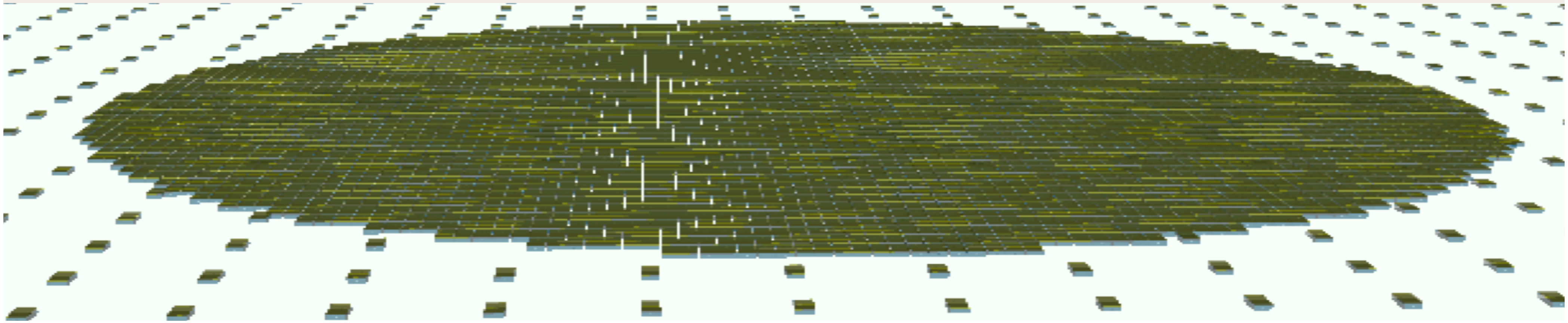
- Several possible detector configurations (components/dimensions)
- Several positions within the system (in line/isolated)

2. System: a first case study



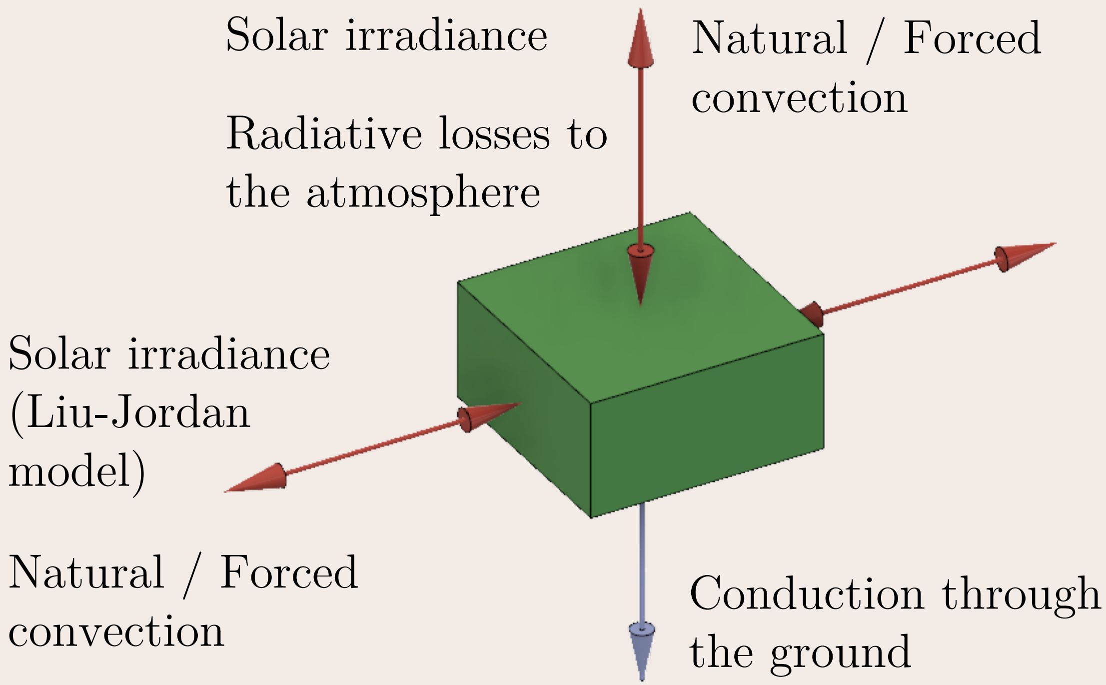
2. System: a first case study

- Several possible detector configurations (components/dimensions)
- Several positions within the system (in line/isolated)
- Each case has to be analyzed



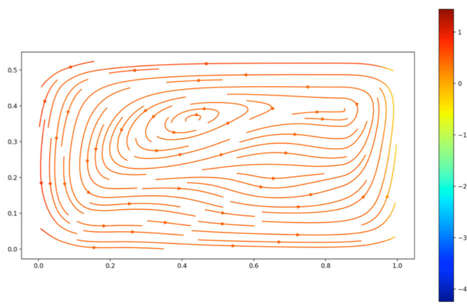
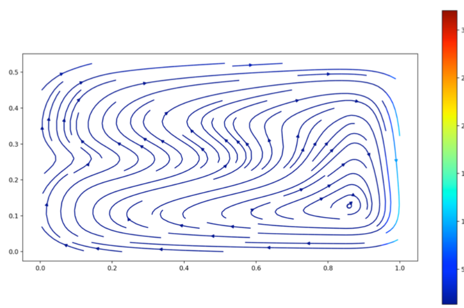
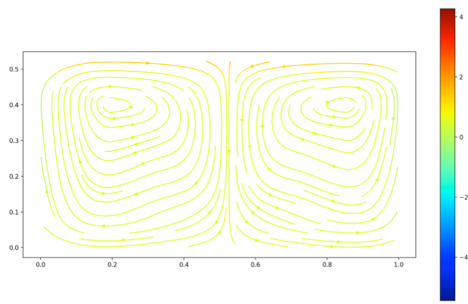
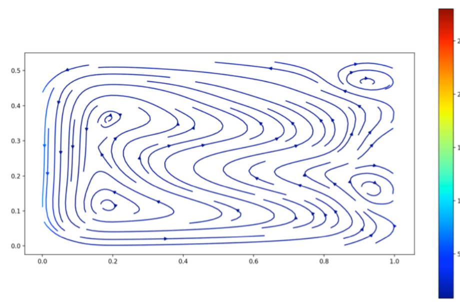
3. Physical Model: Heat transfer mechanisms

- With the surroundings



3. Physical Model: Heat transfer processes

- Inside
  - Conduction
  - Convection based on correlations
  - Convection solved with velocity field calculation (buoyancy driven flow)

3. Physical Model: Heat transfer processes

- Models for freezing and defrosting:
  - Literature on freezing or defrosting exist and may be used

Simulations of the water freezing process - numerical benchmarks

January 2003

Tomasz Michałek · Tomasz Kowalewski

A sharp-interface model coupling VOSET and IBM for simulations on melting and solidification

September 2018 · Computers & Fluids 178

DOI: 10.1016/j.compfluid.2018.08.027

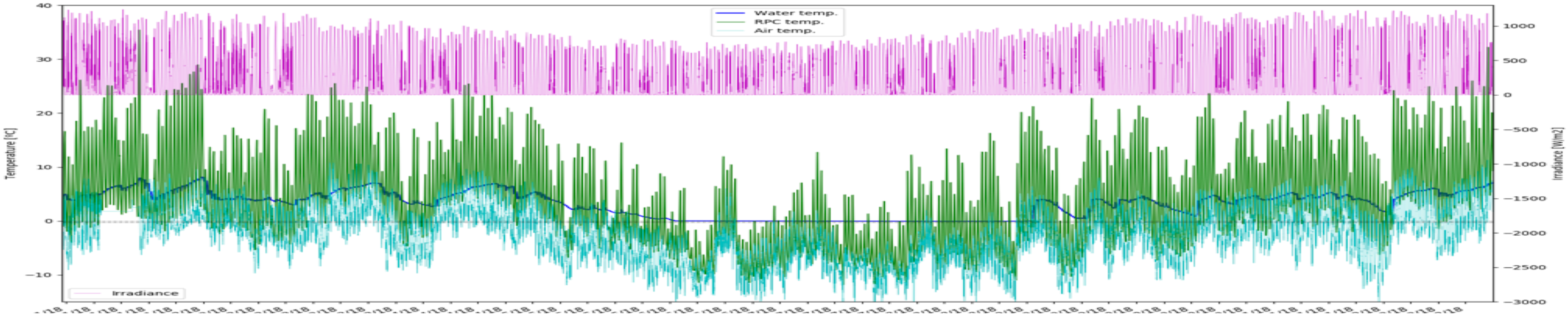
Kong Ling · Wen-Quan Tao

3. Physical Model: Heat transfer processes

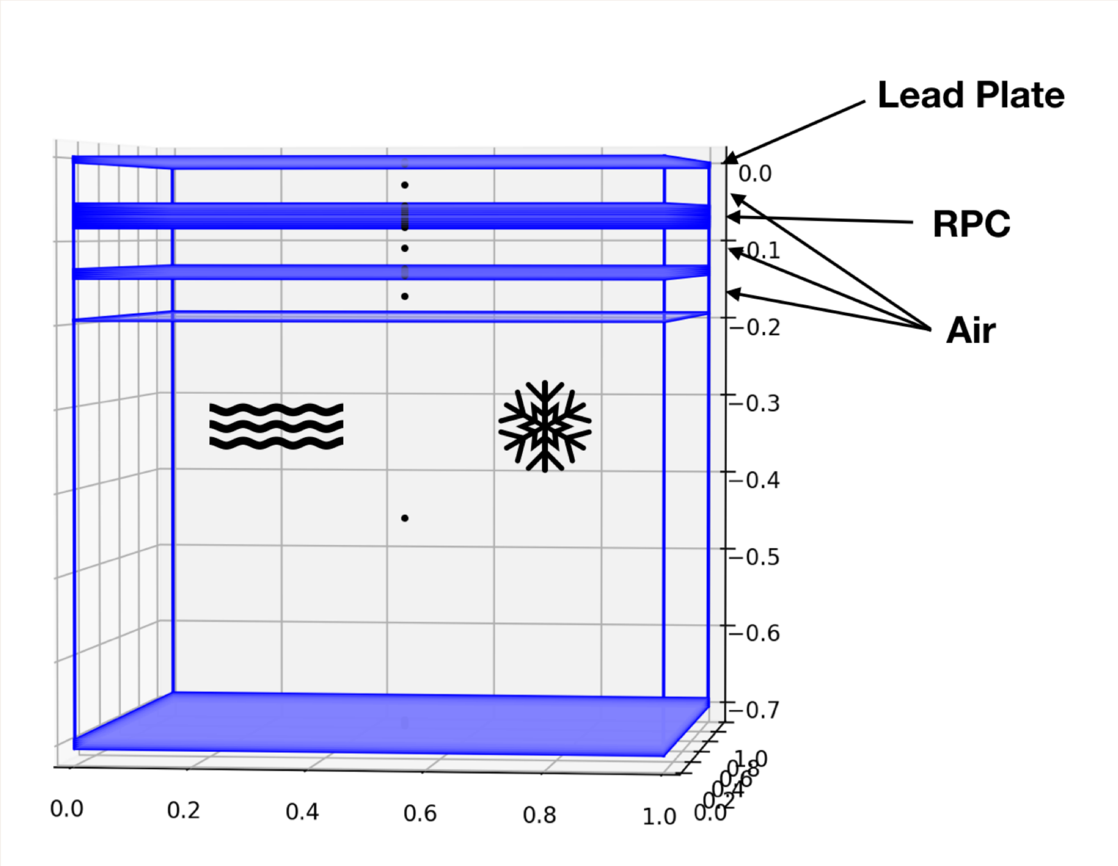
- Models for freezing and defrosting:
  - Literature on daily cycle of freezing/defrosting couldn't be found and this process is *a challenge*

3. Physical Model: Discretization

- 1D, 2D and 3D analysis, as needed
- Try to avoid "heavy calculations": simulations of 1 year with a time step of 1 min may take several days without powerful calculation tools

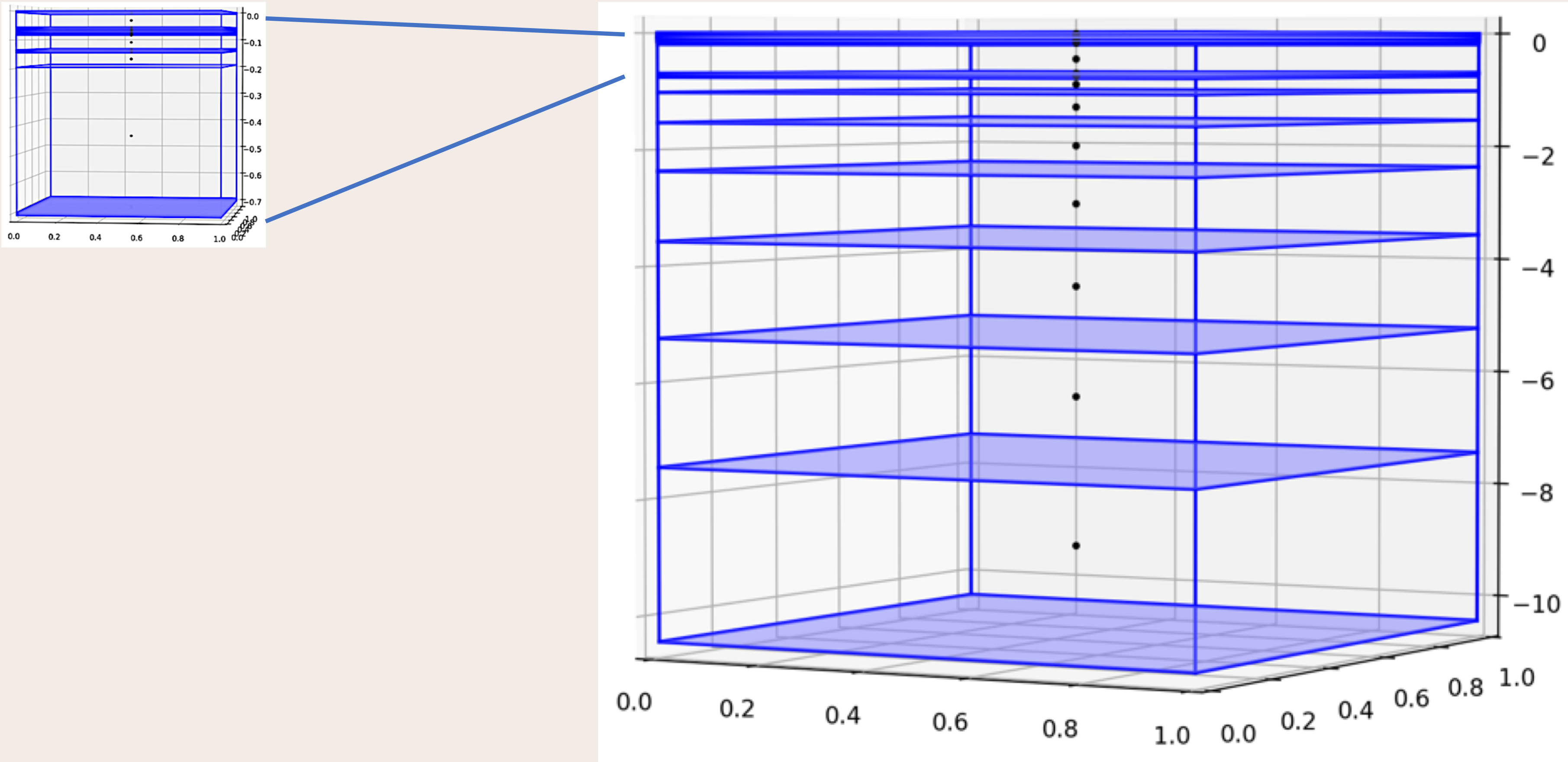


3. Physical Model: Discretization

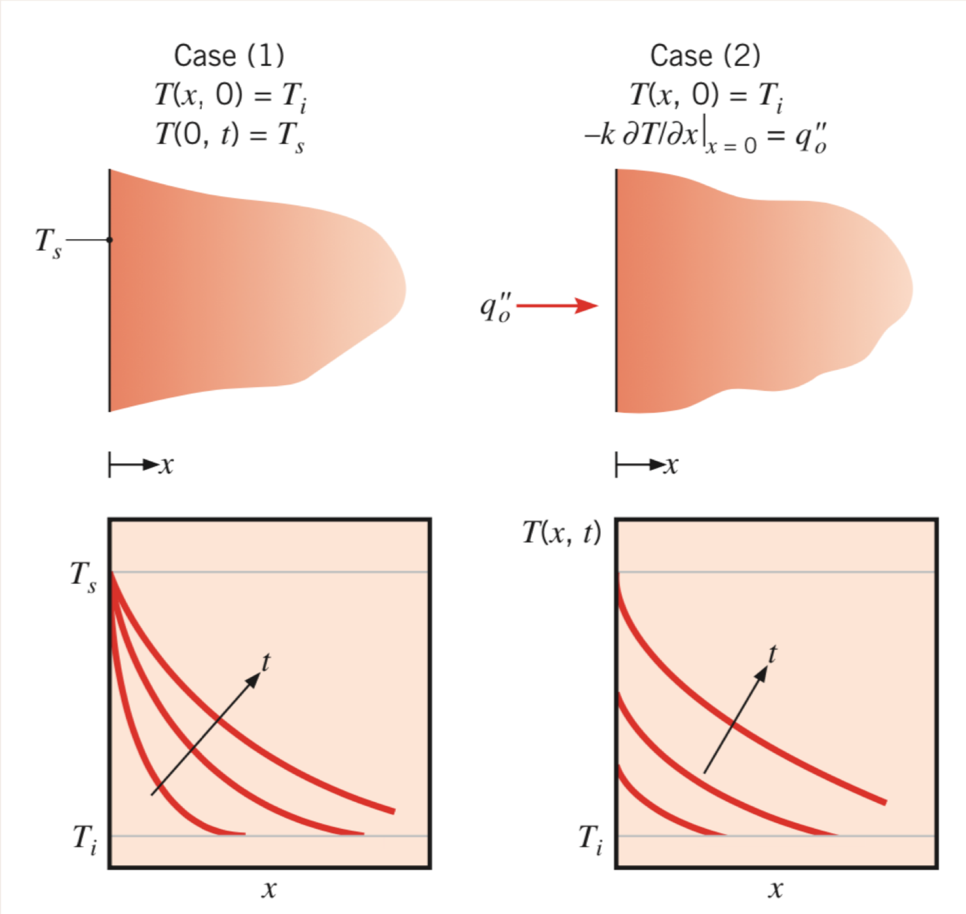


- Version with RPC on top:
  - 1 D
  - 72 nodes
  - 1 node per convective zone (including water tank)
  - (Adding/removing layers is easy to implement)

3. Physical Model: Discretization

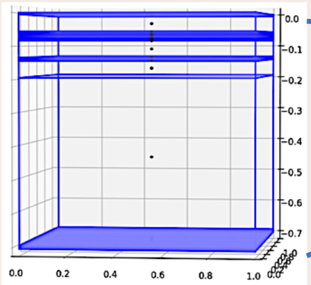


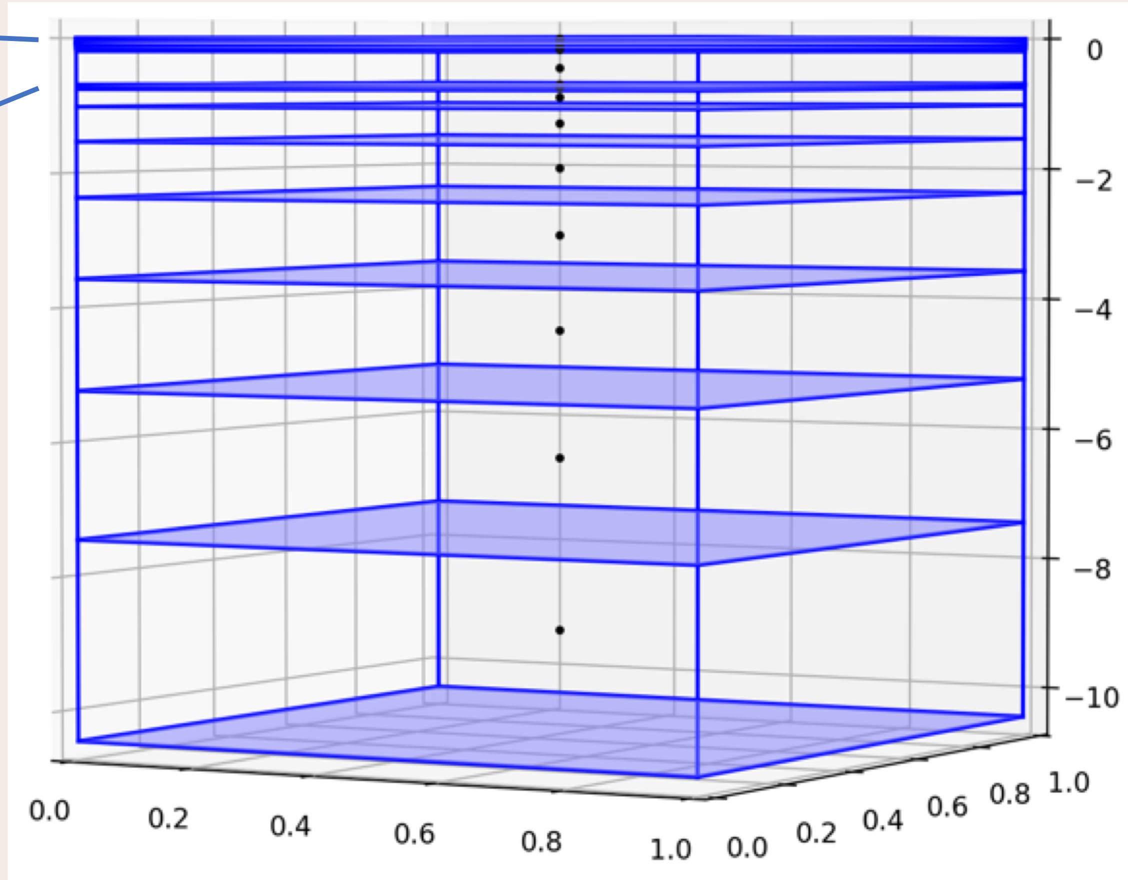
3. Physical Model: Discretization



Incropera, Frank P, and David P. DeWitt. Fundamentals of Heat and Mass Transfer. New York: J. Wiley, 2002

3. Physical Model: Discretization





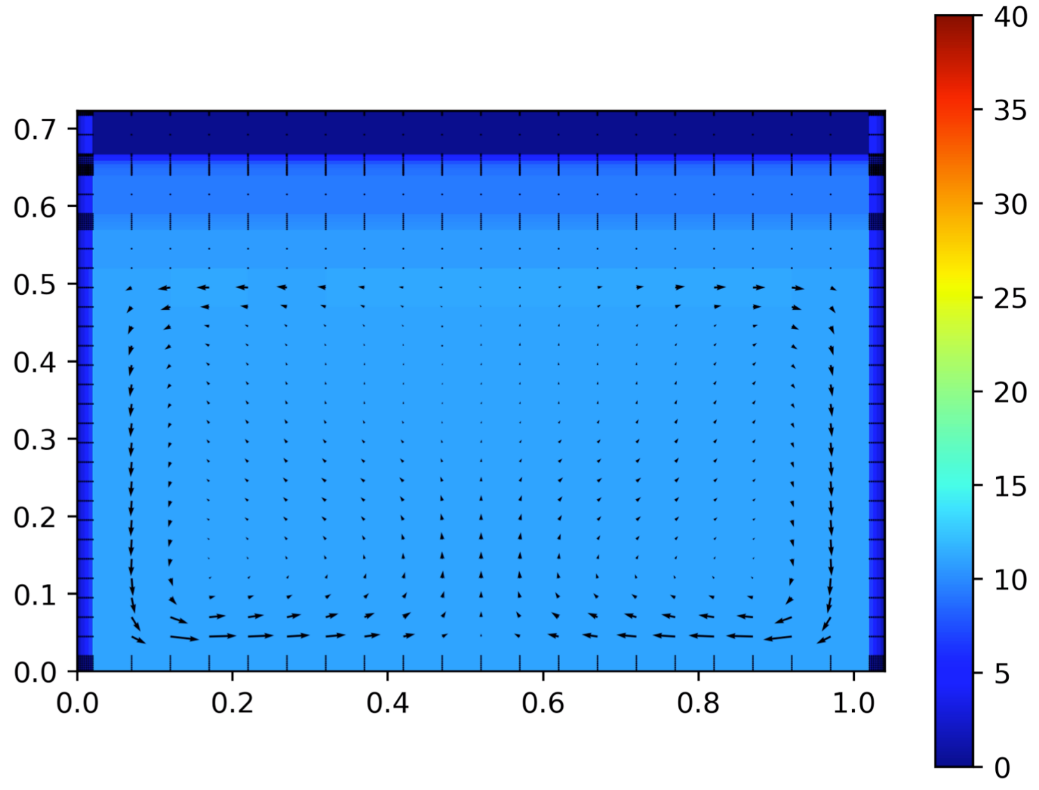
- For a semi-infinite solid, the heat flux will be zero at a certain distance from the surface: 10 m (8 Nodes)

3. Physical Model: Discretization

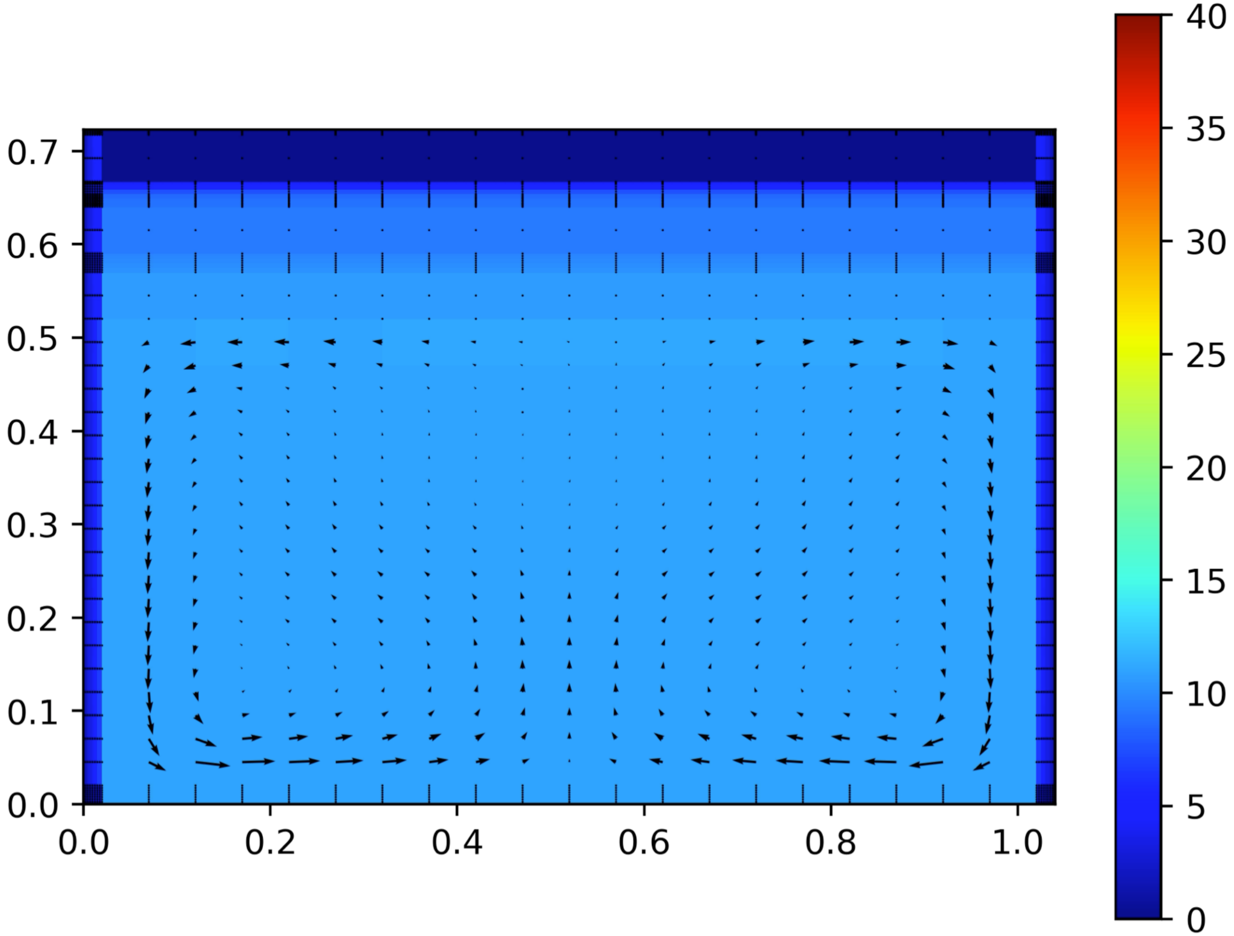
- Solving the convective velocity field in the water tank may be needed:
  - 2D or 3D discretization
  - Will it better describe the thermal behavior of the system? (more time consuming)
  - It is necessary to simulate in detail the freezing and the defrosting processes

3. Physical Model: Discretization

- Velocity field,
  2D heat flux,
  100 nodes
  1 day in 48s
  from 0h to 24h



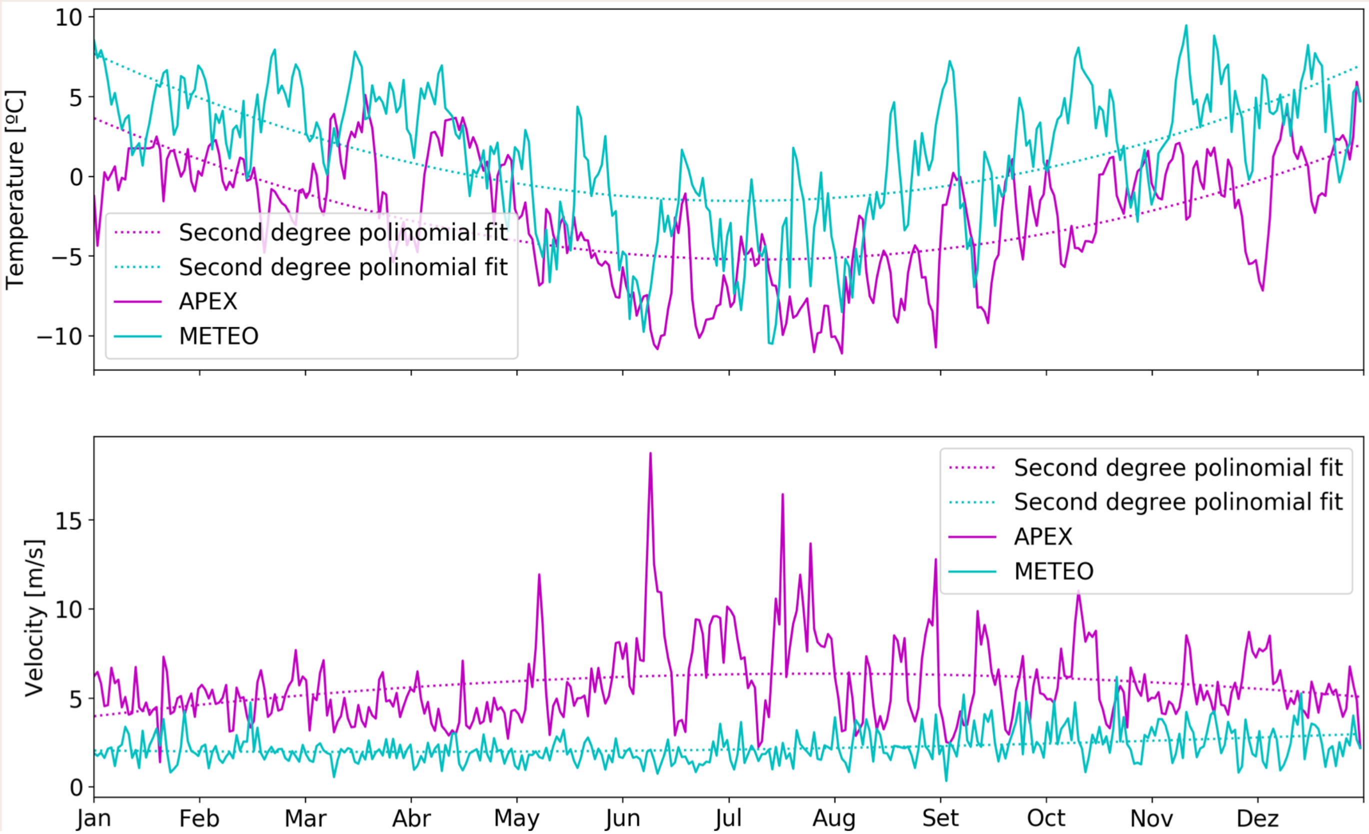
Animation



3. Physical Model: Weather data

- The nearest weather data source, the APEX site:
    - Incomplete: temperature and wind velocity
- Typical Meteorological Years (TMY):
    - Can be obtained for long term averages
    - Obtained from satellite data and ground weather meteorological stations but interpolated – large uncertainties

3. Physical Model: Weather data



APEX clearly presents lower temperatures (~4℃) and higher wind velocities than TMY

3. Physical Model: Weather data

- And an important question arises: are we interested in the TMY or in a representative extreme year?
  - Scarce literature, “just ideas” - *a challenge*

Rethinking the TMY: Is the 'Typical' Meteorological Year Best for Building Performance Simulation?

December 2015

Conference: Building Simulation 2015 · At: Hyderabad, India

Project: A new generation of weather data for building performance simulation – TMY, XMY and beyond

Drury B. Crawley · Linda Lawrie

ELSEVIER

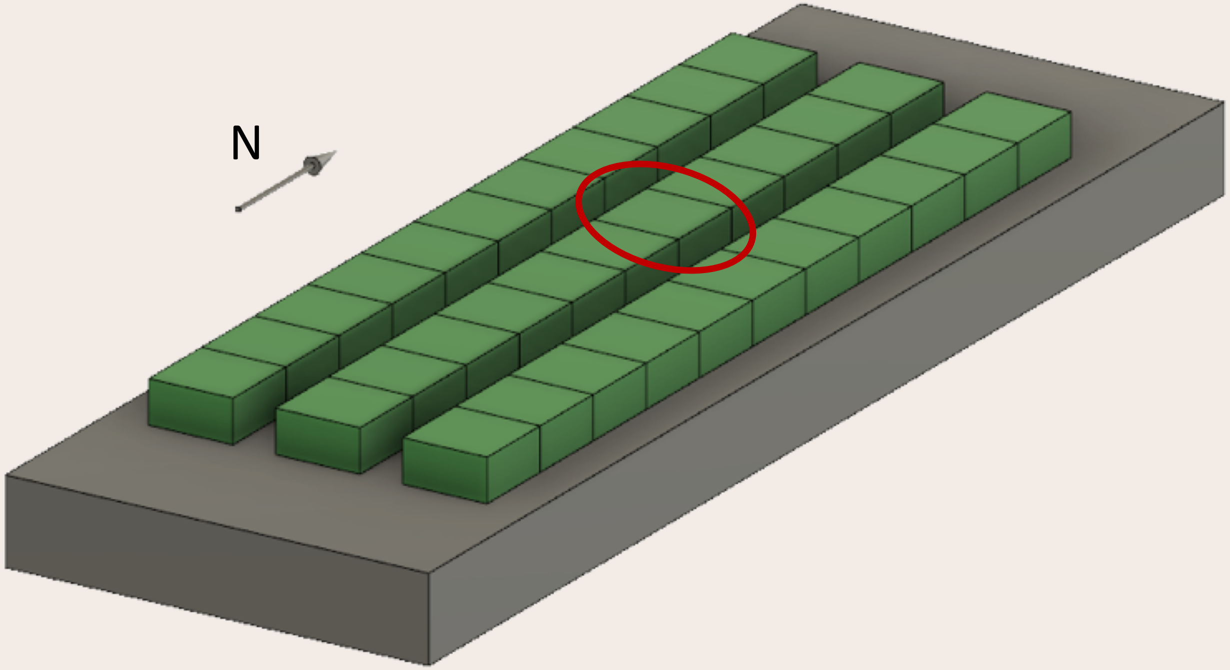
Energy Procedia

Volume 69, May 2015, Pages 1958-1969

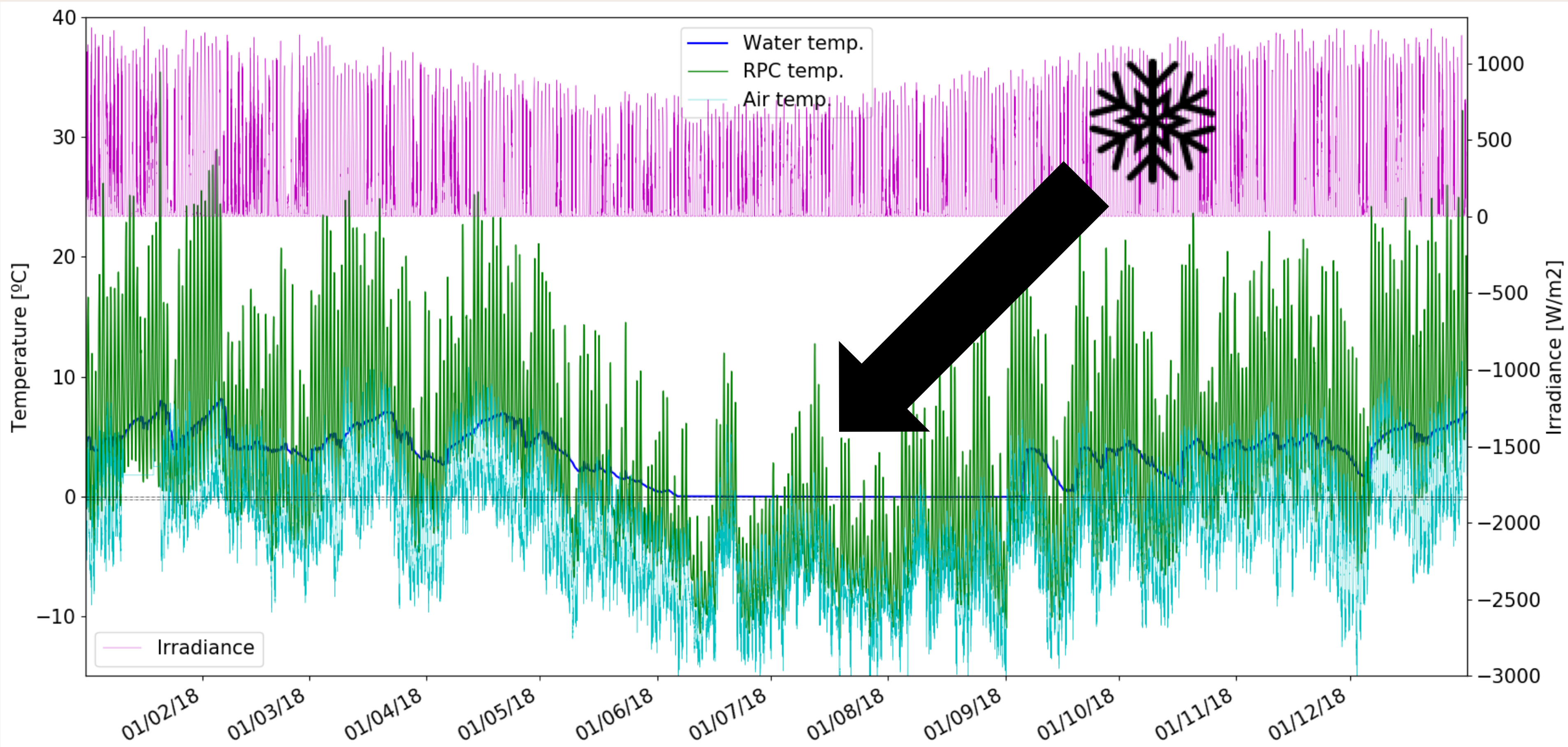
Typical Meteorological Year Data: SolarGIS Approach ☆

T. Cebecauer, M. Suri

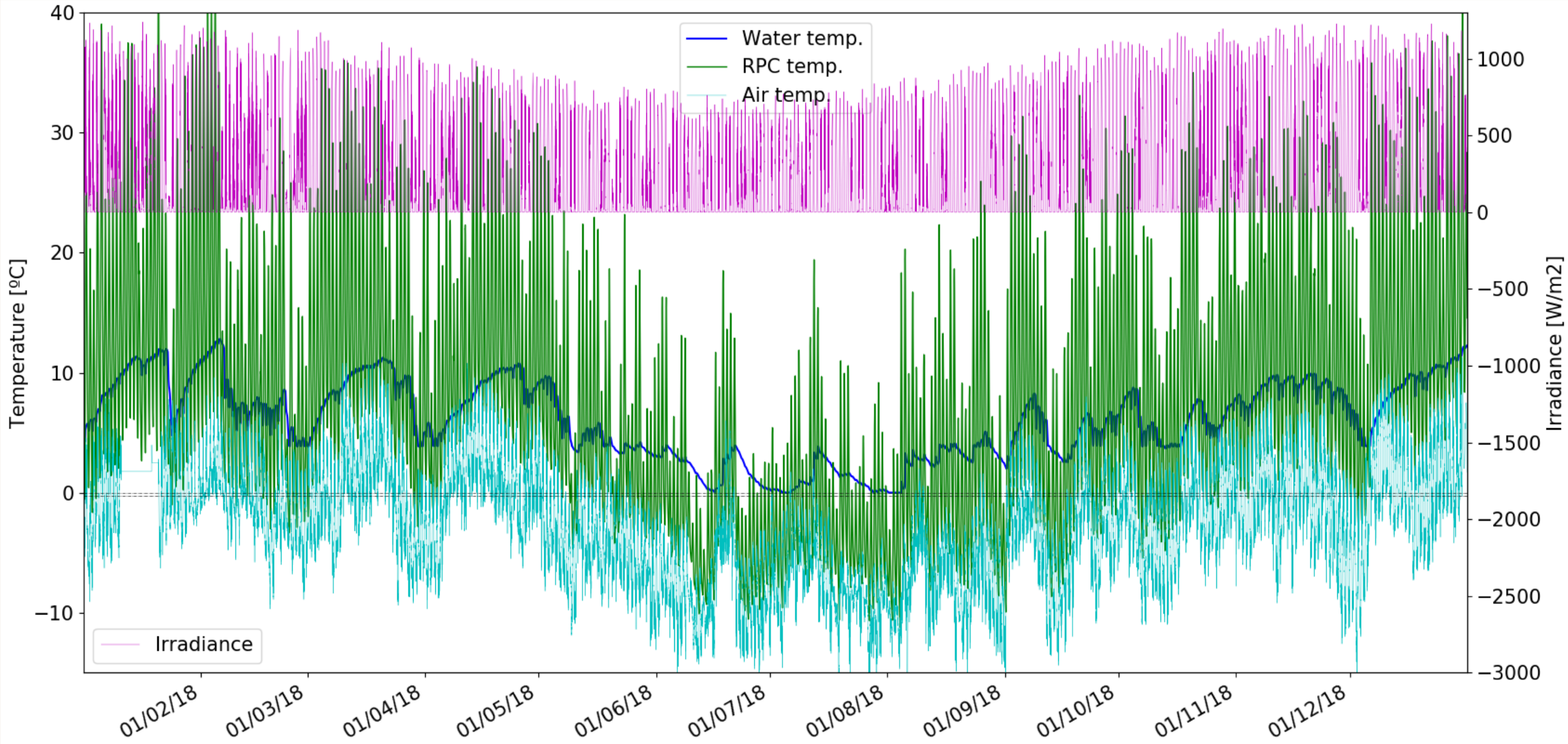
4. Some results



4. Some results: module without side insulation



4. Some results: module with side insulation (6 cm)



5. Next developments

- Model:
  - 3D conduction and convection for isolated module analysis
  - 2D and 3D phase change model for freezing and defrosting of the water
- Weather:
  - Definition of an extreme year model

5. Next developments

- First analysis:
  - Impact of the dimensions of the tanks
  - Mitigation strategies

Thank you