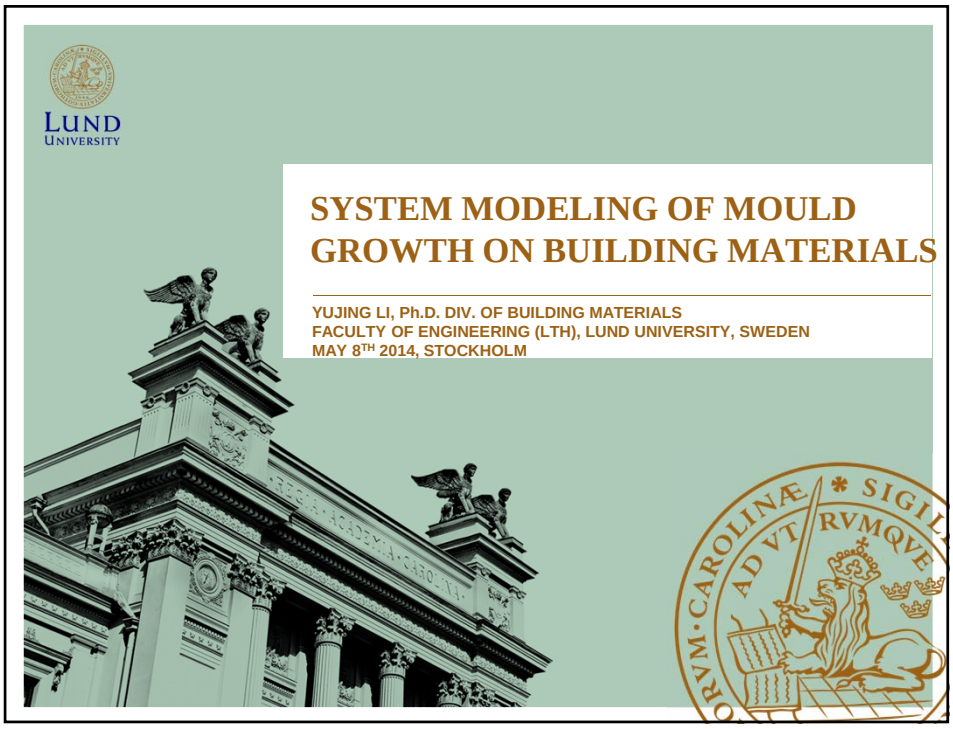


## Challenge

” ... varje material har en kritisk fuktnivå som inte får överskridas och om den inte kan redovisas så får materialets relativa fuktighet inte överstiga **75 %**...”

**- BBR (Boverket)**

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## Questions

- Only **critical level** matters?
  - **RH**
  - **Temperature**
  - **RH & temperature**
  - **Material ...**
- Exposure time
  - **How long?**
  - **Constant level vs. Changing conditions**
- **Long term** prediction?
- Practical **tool**?


## Previous models - What's missing

- The mechanism of the growth
- The mechanism of the decaying
- Other factors, e.g., the oxygen level etc.
- The connections between the biology and the material
- Etc.

## Major challenge

Modelling **HOW**

**MOULD** grown on

building **MATERIALS**

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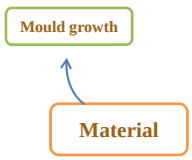
## Fundamentals behind: How does mould grow?

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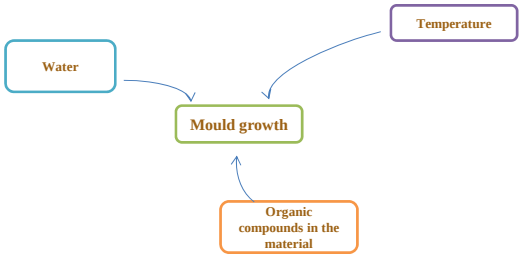
## Fundamentals behind: How does mould grow

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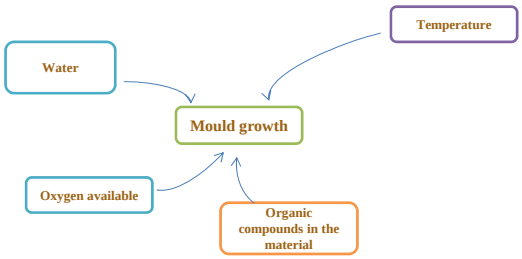
## Fundalmentals behind: How does mould grow

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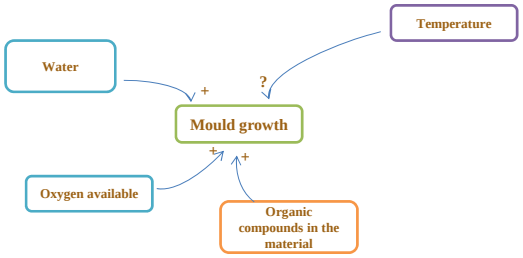
# A Causal Loop Diagram (CLD)

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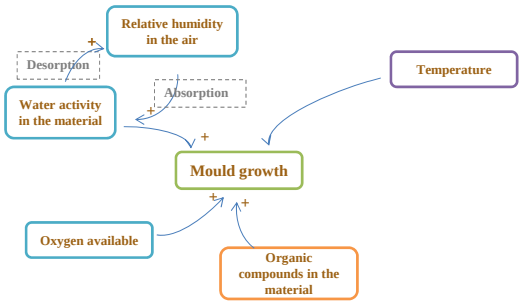
# A Causal Loop Diagram (CLD)

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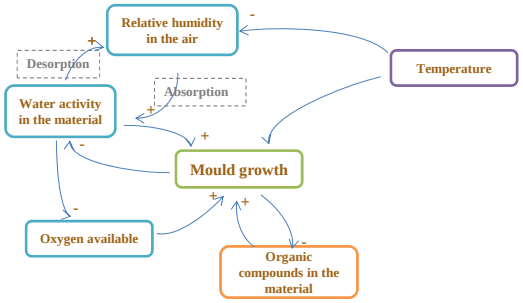
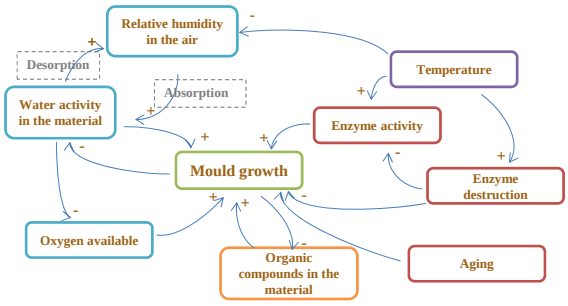
# A Causal Loop Diagram (CLD)





# A Causal Loop Diagram (CLD)




## Modelling...

Can we put **ALL** together?

**System analysis &**
**System dynamic modelling**

- Building Biology Group, LTH, Lund University
  *www.byggnadsmaterial.lth.se*
- Applied Systems Analysis & System Dynamics (ASASD) Group, Lund University
  *www.lth.se/asasd*

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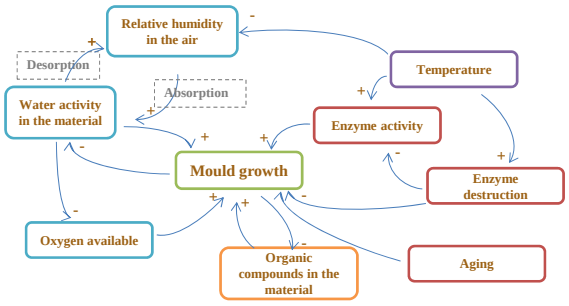


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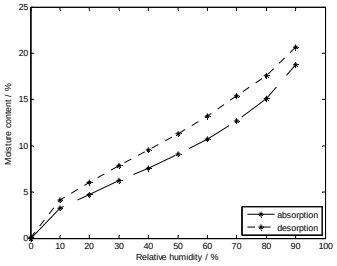
# Materal's moisture simulation

## Desorption and Adsorption

$$m_{wv,s} = \frac{hD}{R \times T}\left(P_{wv,w} - P_{wv,a}\right)$$

| | |
|---|---|
| $m_{wv,s}$: | water vapour mass flow rate (kg/m2s) |
| $h_D$: | diffusion coefficient |
| R: | gas constant |
| T: | temperature |
| $P_{wv,w}$: | water vapour pressure of the wood |
| $P_{wv,a}$: | water vapour pressure in the air |




*The sorption isotherm of wood (air dried spruce sapwood).*

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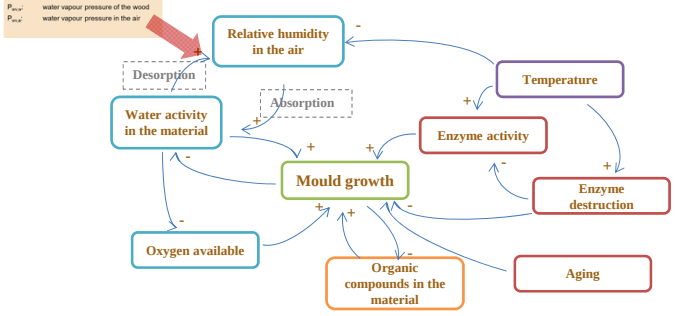
Desorption and Adsorption

$$m_{wv,s} = \frac{hD}{R \times T}\left(P_{wv,w} - P_{wv,a}\right)$$

$m_{wv,s}$: water vapour mass flow rate (kg/m2s)
$h_D$: diffusion coefficient
R: gas constant
T: temperature
$P_{wv,w}$: water vapour pressure of the wood
$P_{wv,a}$: water vapour pressure in the air

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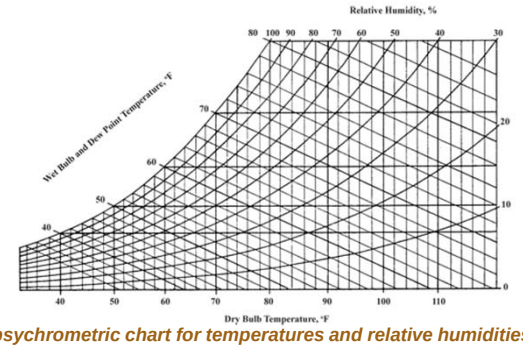
# Relative humidity and temperature

$$P_{wv,s} = (1.0007 + 3.46 \times 10^{-6} \times P_a) \times 6.1121 \times e^{\frac{17.502 \times T}{240.97+T}}$$




***Simplified psychrometric chart for temperatures and relative humidities.***
*Source: University of Nebraska 2008, http://www.ianrpubs.unl.edu/pages/publicationD.jsp?publicationId=1000*

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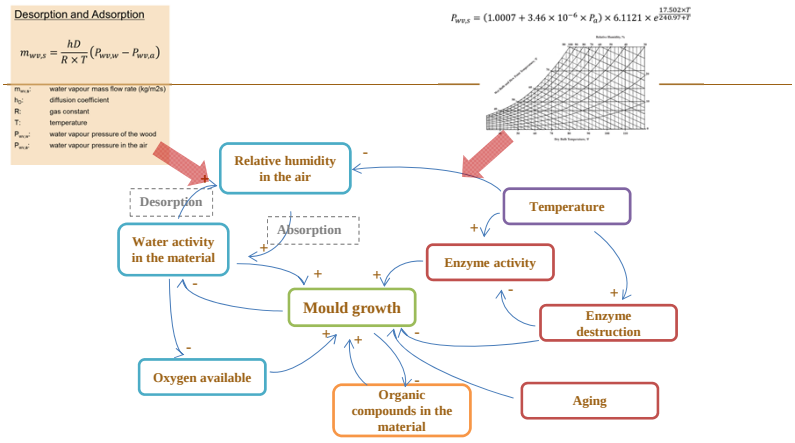


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# Mould growth factors

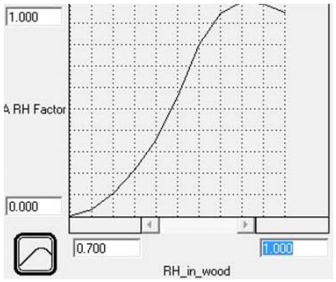


**Fig. 3. The factor by relative humidity on mould activity.** (Ayerst 1969)

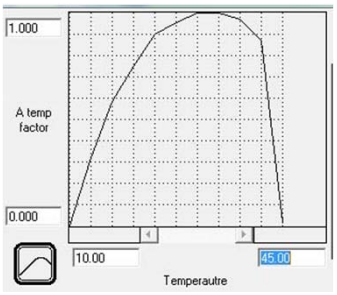


***Fig. 4. The temperature factor*** (Ayerst 1969)

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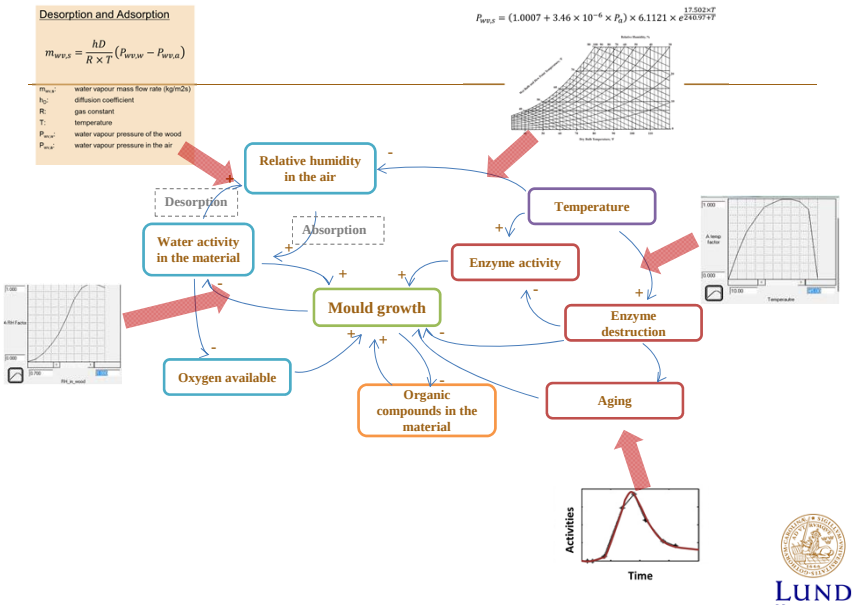


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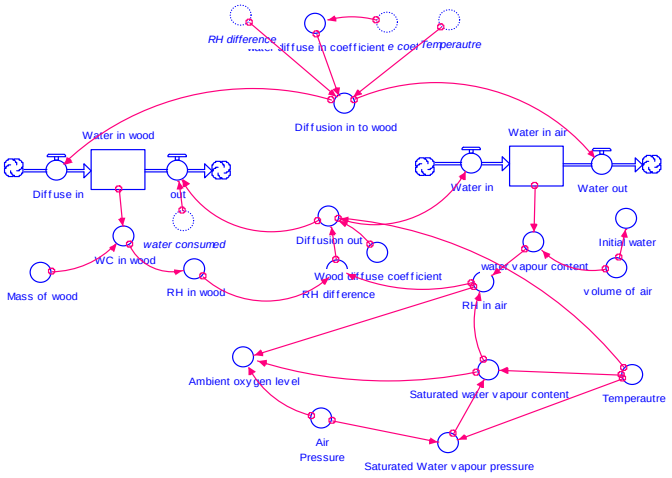
# Modelling: moisture – material properties




model of water vapour exchange between wood and air, STELLATM V 9.0 (isee systems, inc.)

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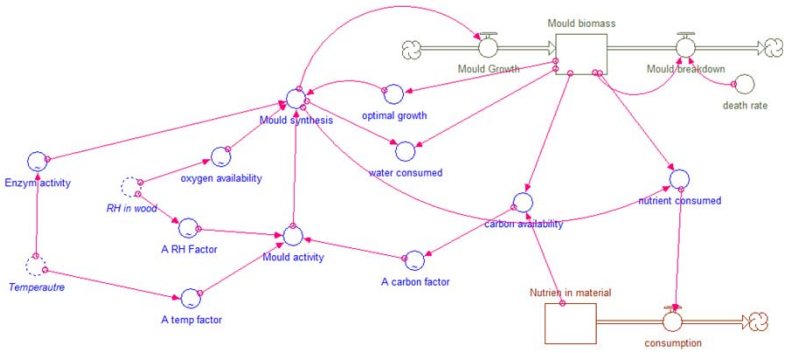
# Modelling: mould growing behaviour




model of mould growth with influencing factors, STELLATM V 9.0 (isee systems, inc.)

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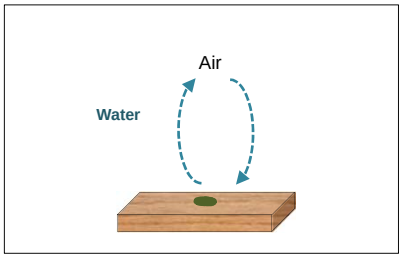
## Some simulaiton results – start with...

# Mould grown on wood in a closed environment

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## Results: Scenario 1 - drying

**Initial conditions:**

- **RH in the air: 70%**
- **Water content in wood: 0.3**
- **Temperature: 20° C (constant)**

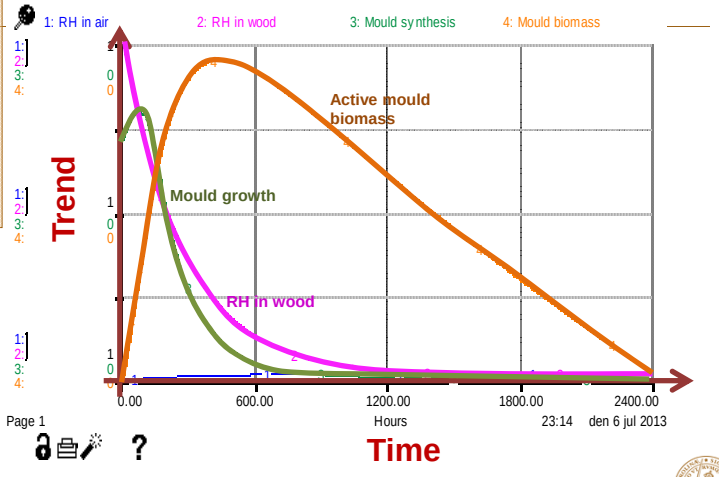


*Fig. 5-1. The development of mould growth on wood during wood drying*

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# Results: Scenario 1 - drying

**Initial conditions:**

- **RH in the air: 70%**
- **Water content in wood: 0.3**
- **Temperature: 20° C (constant)**

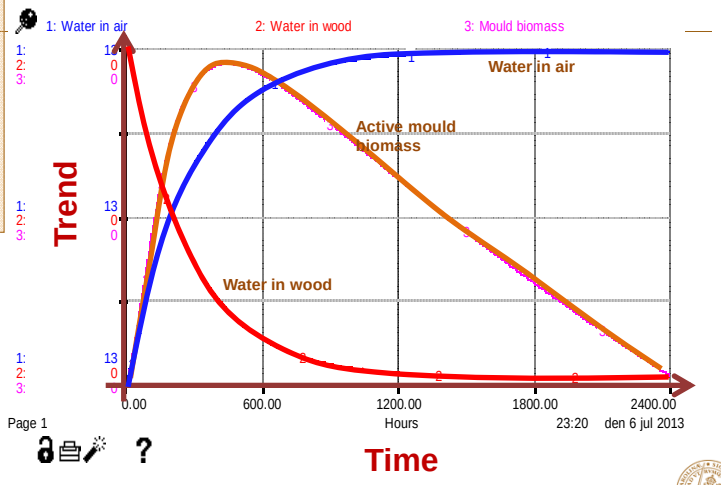


*Fig. 5-2. The development of mould growth with moisture content changes*

# Scenario 2 - wetting

**Initial conditions:**

- **RH in the air: 90%**
- **Water content in wood: 0.16**
- **Temperature: 20° C (constant)**

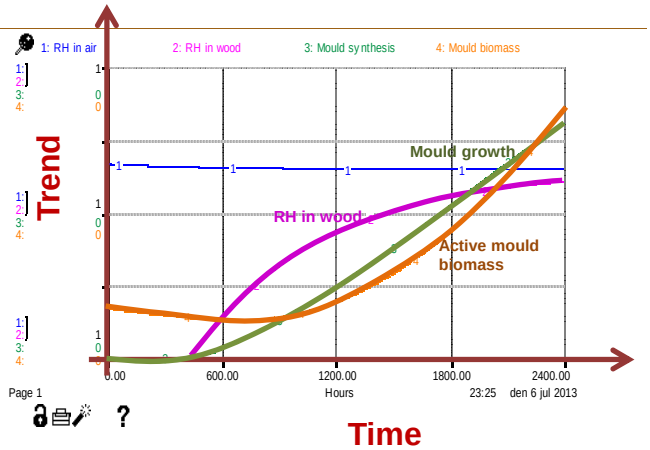


*Fig. 6. The development of mould growth on wood during wood wetting*

# Scenario 3 – fluctuating temperature

**Initial conditions:**

- **RH in the air: 70%**
- **Water content in the wood: 0.3**
- **Temperature varying between 20° C (noon time) and 10° C (night)**

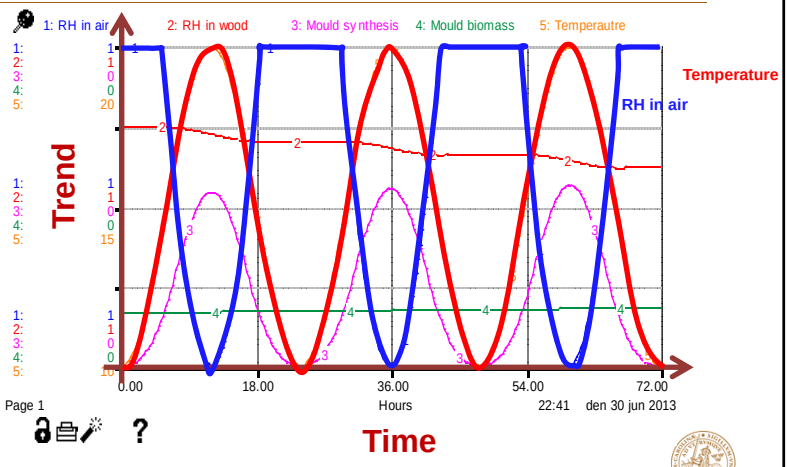


Fig. 5. The development of mould synthesis with varying temperature changes

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# Scenario 3 – fluctuating temperature

**Initial conditions:**

- **RH in the air: 70%**
- **Water content in the wood: 0.3**
- **Temperature varying between 20° C (noon time) and 10° C (night)**

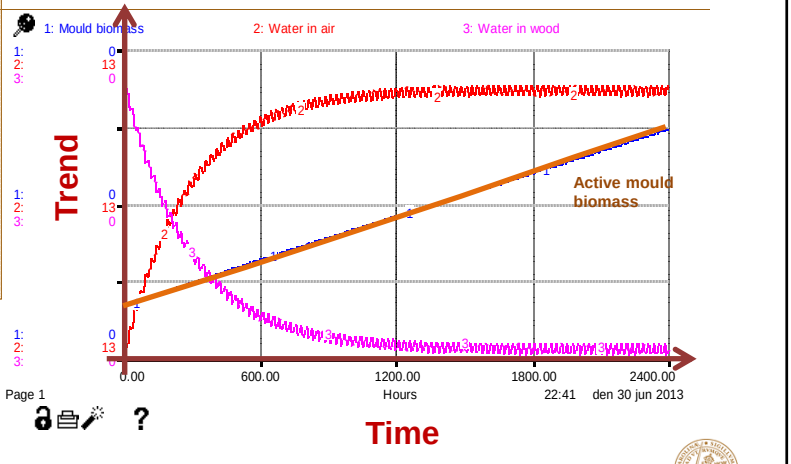


Fig. 6. The development of mould biomass with varying temperature changes

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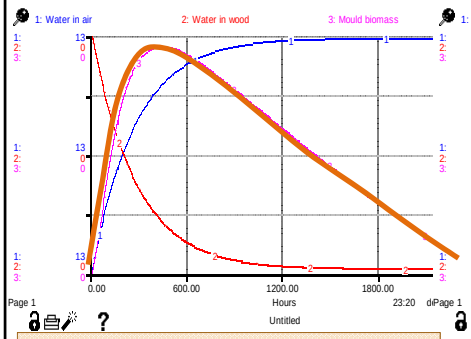
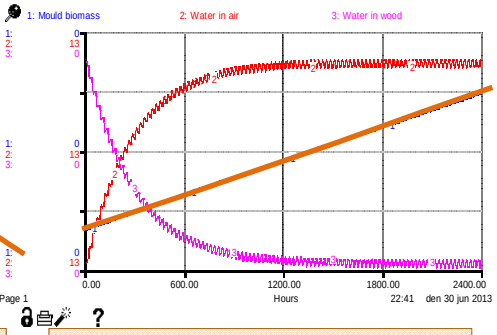



**Initial conditions:**

- **RH in the air: 70%**
- **Water content in wood: 0.3**
- **Temperature: 20° C (constant)**




**Initial conditions:**

- **RH in the air: 70%**
- **Water content in the wood: 0.3**
- **Temperaturevarying between 20° C (noon time) and 10° C (night)**

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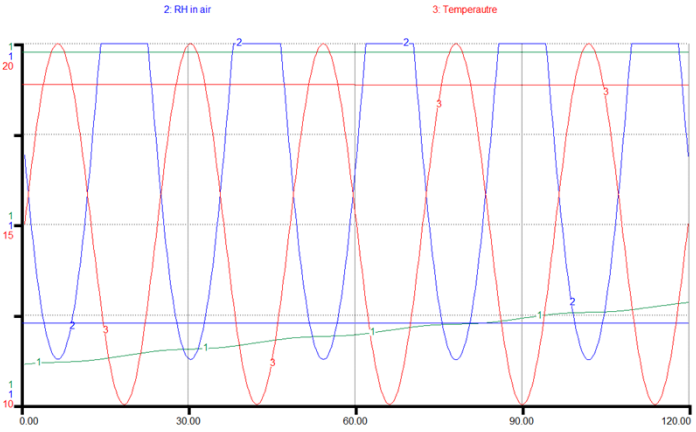
# Scenario 4 – longer period

**Initial conditions:**

- **RH in the air: 65%**
- **Water content in the wood: 0.16**
- **Temperature varying between 20° C (noon time) and 10° C (night)**

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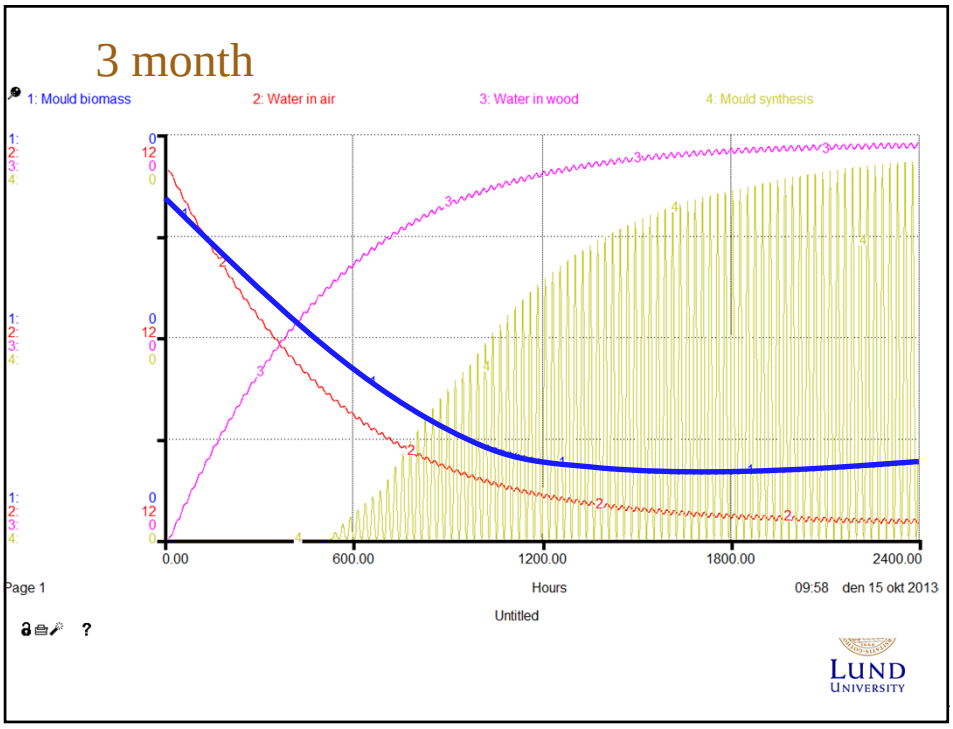
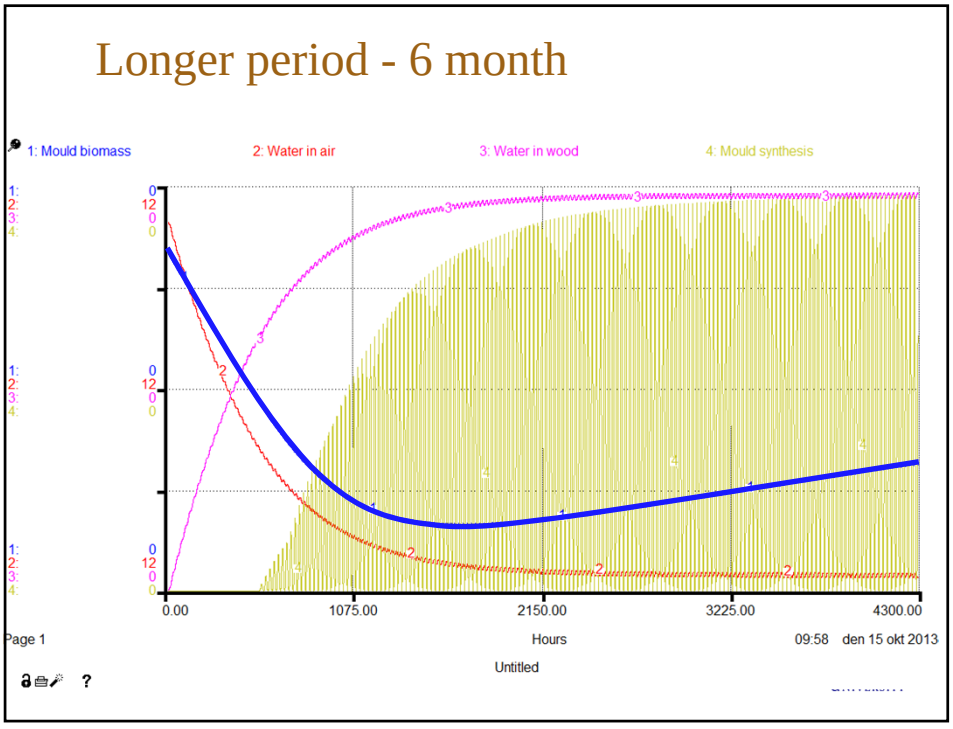
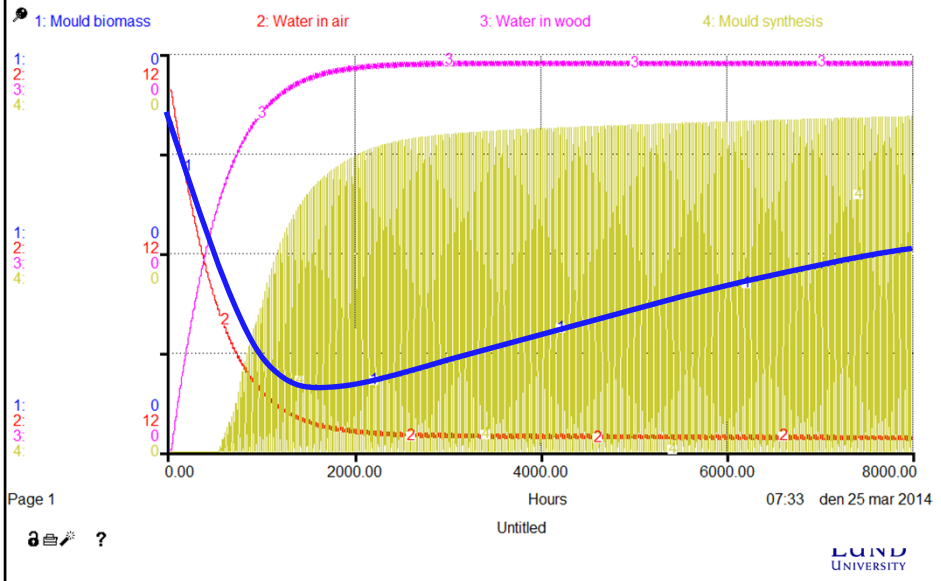
# 3 month

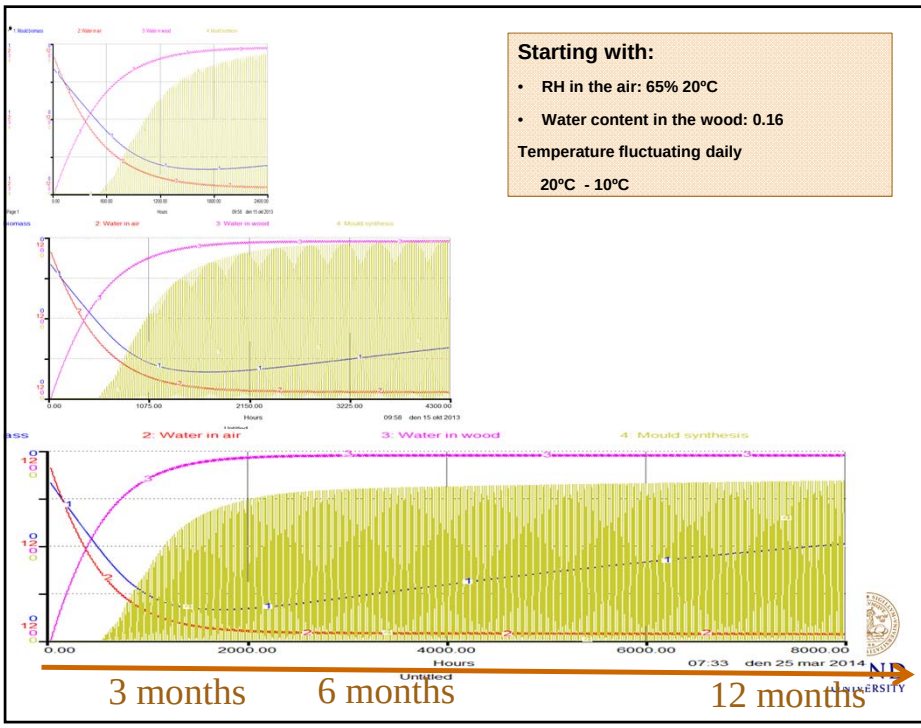



# Longer period - 6 month



# Even longer ~ 12 month



# Conclusion

- The temperature variation has significant impact on mould growth on materials
- it is called a conceptual model for the moment
- It is possible to combine the material properties and the mould behaviour into modelling

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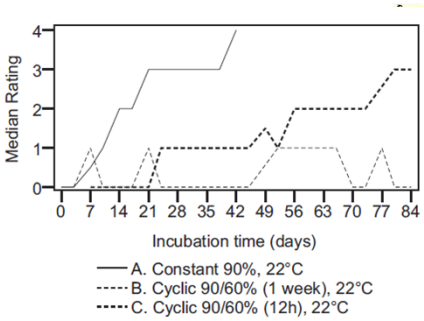
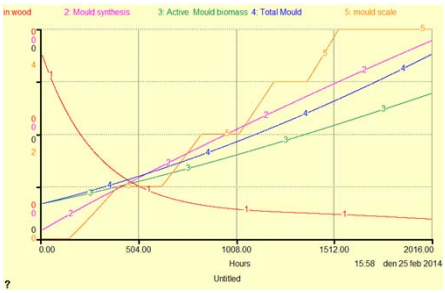
# A new M-Model project

(Comparing to Johansson et. al. 2013)

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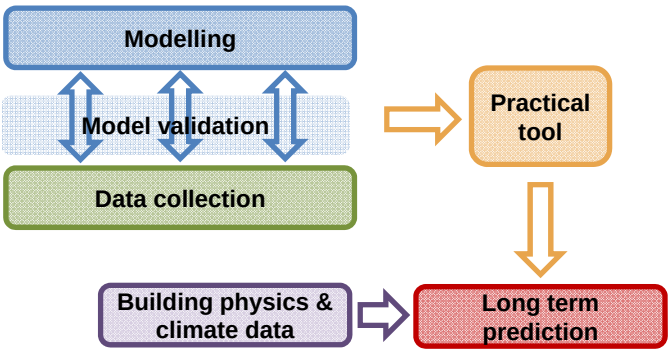
## The work flow of the new M-model

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## Acknowledgement

Forskningsrådet Formas
Formas främjar framstående forskning för hållbar utveckling

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Thank you for your attention!


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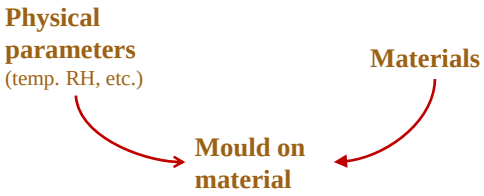
# Fundamentals behind

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