A PRACTICLE INTRODUCTION TO THE SNOWPACK MODEL

How does it work?
How to use it?

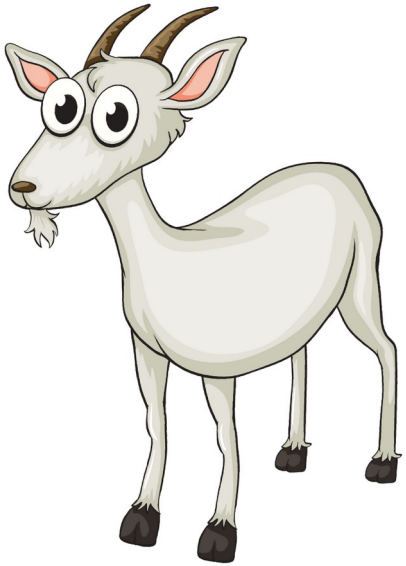
Physics and hydrology of snow

Laboratory of Cryospheric Sciences

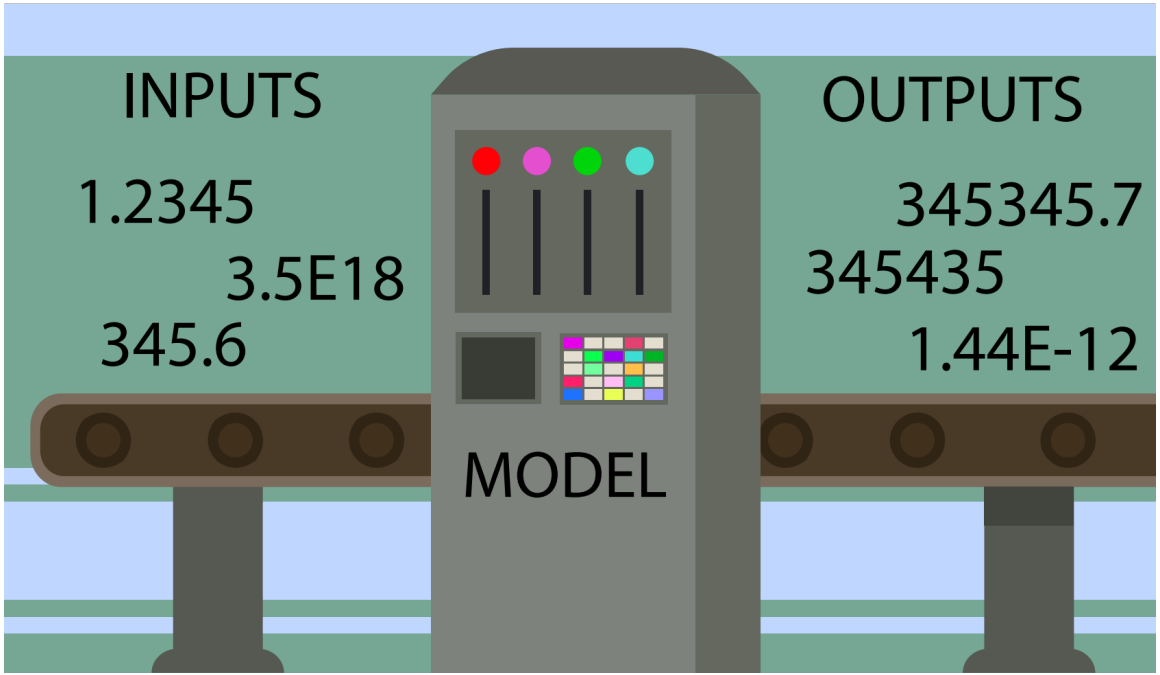
What is a Model ?

- It **Approximates** a phenomena
- It tries to **represent** (some aspects of) the observation

=?

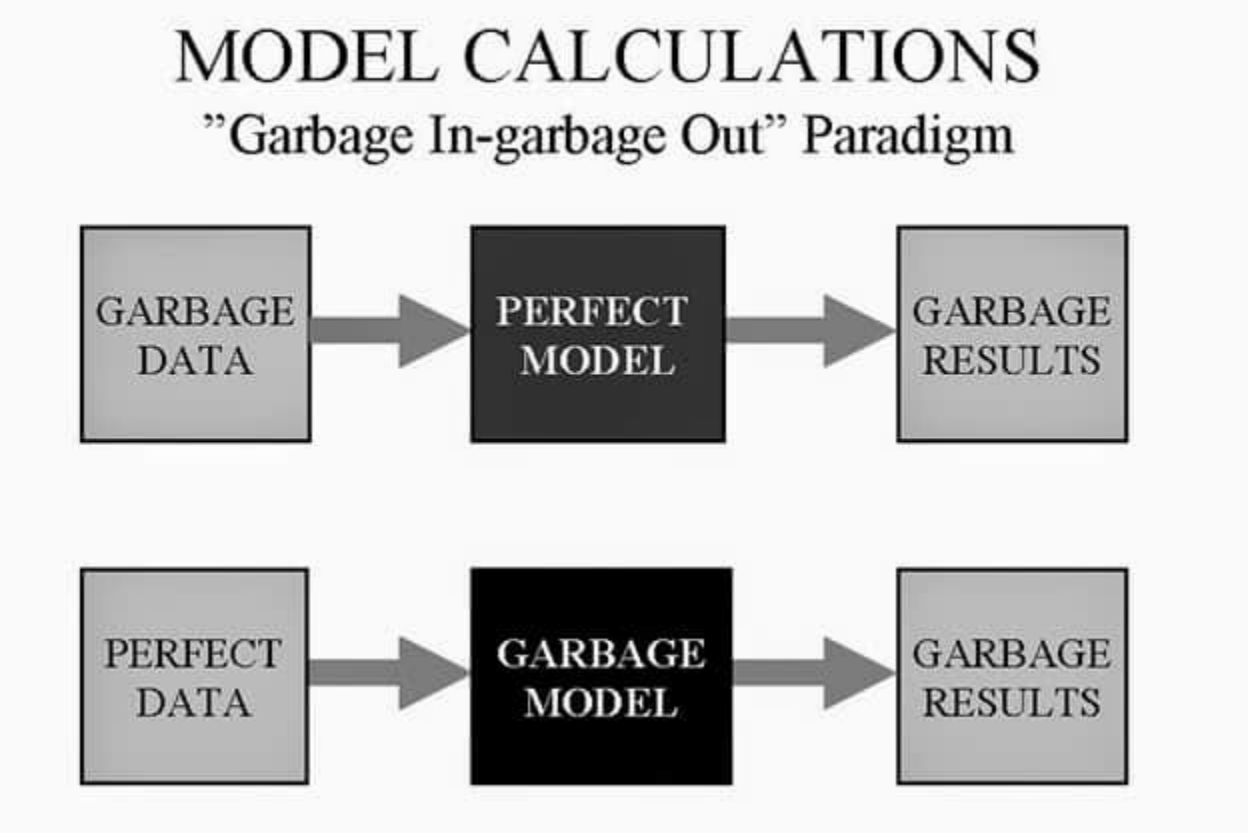


What is a Model ?



- It computes some **output** from the given **input;**
- It can be used as a **black box;**

What is a Model ?



How does SNOWPACK work?

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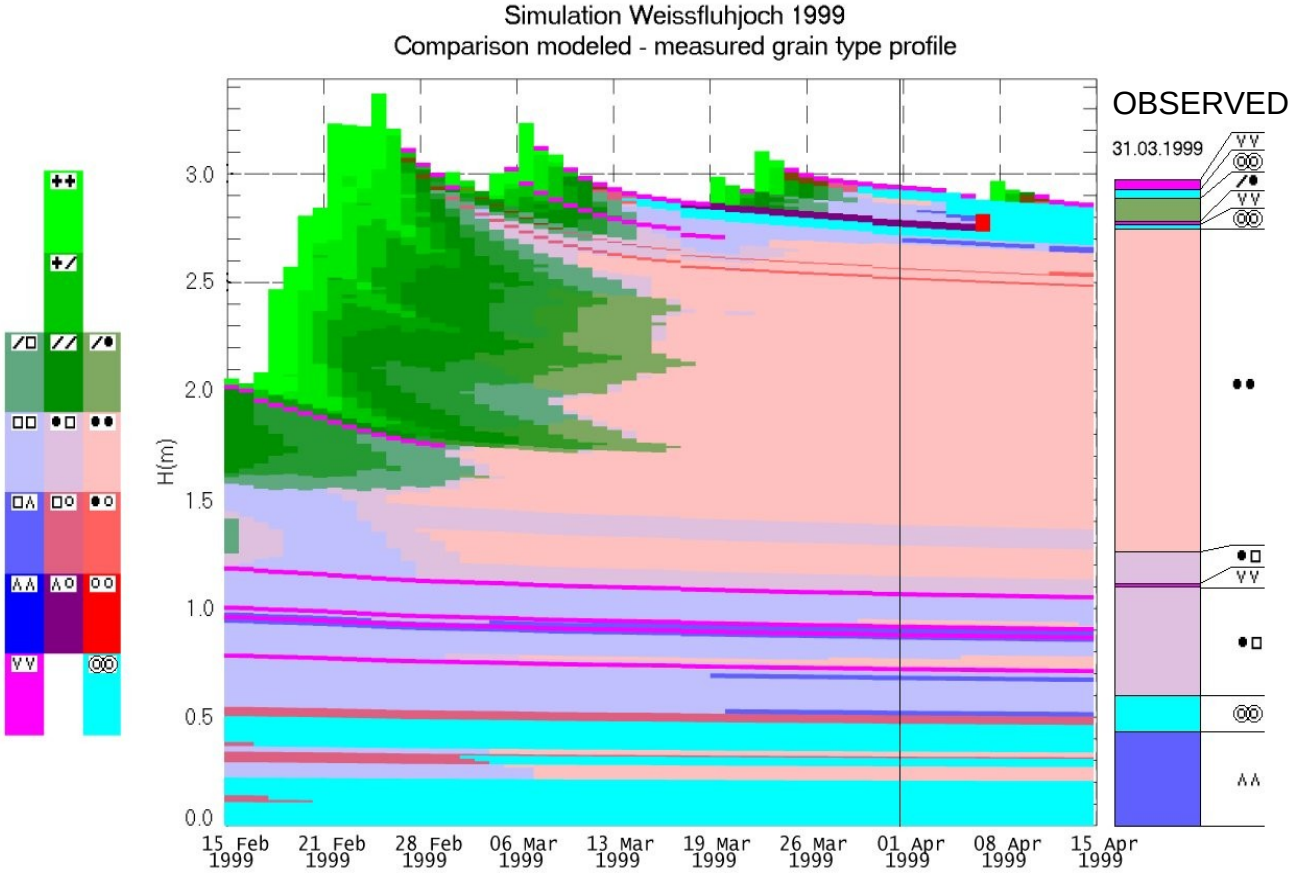


How do we get to these plots?

(Detailed results on Moodle!)

How does SNOWPACK work?

Representation of snow in SNOWPACK:

$$\theta_i + \theta_w + \theta_a = 1$$
$$\rho_s = \rho_i\theta_i + \rho_w\theta_w + \rho_a\theta_a$$

EQ.1) ENERGY: The bulk temperature equation:

$$\rho_s c_p \frac{\partial T_s}{\partial t} - \frac{\partial}{\partial z}(k_{eff}\frac{\partial T_s}{\partial z}) = [Q_{pc}] + [Q_{mm}] + Q_{sw}$$

EQ.2) MOMENTUM: The settlement equation:

$$\frac{\partial \sigma_s}{\partial z} + \rho_s g \cos\phi = 0$$

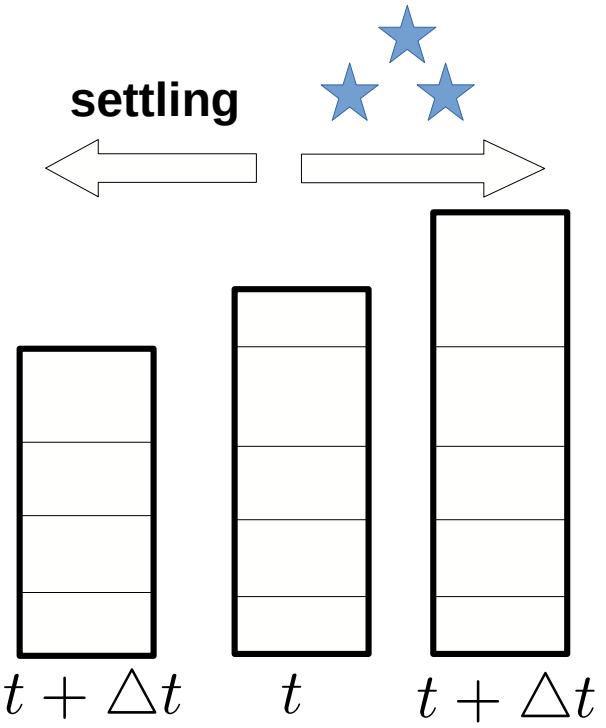
EQ.3) MASS: The water transport:

Simple bucket model

EQ.4) MASS: Vapor diffusion equation

(SNOWPACK papers on Moodle!)

Lagrangian coordinate system :



Numerical solver of differential equations

$$\rho_s c_p \frac{\partial T_s}{\partial t} - \frac{\partial}{\partial z}\left(k_{eff} \frac{\partial T_s}{\partial z}\right) = [Q_{pc}] + [Q_{mm}] + Q_{sw}$$

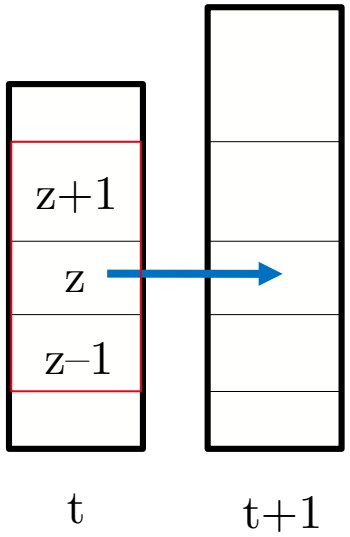
$$\frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial z^2}$$

Discretization: *intuitive* example of Finite Difference

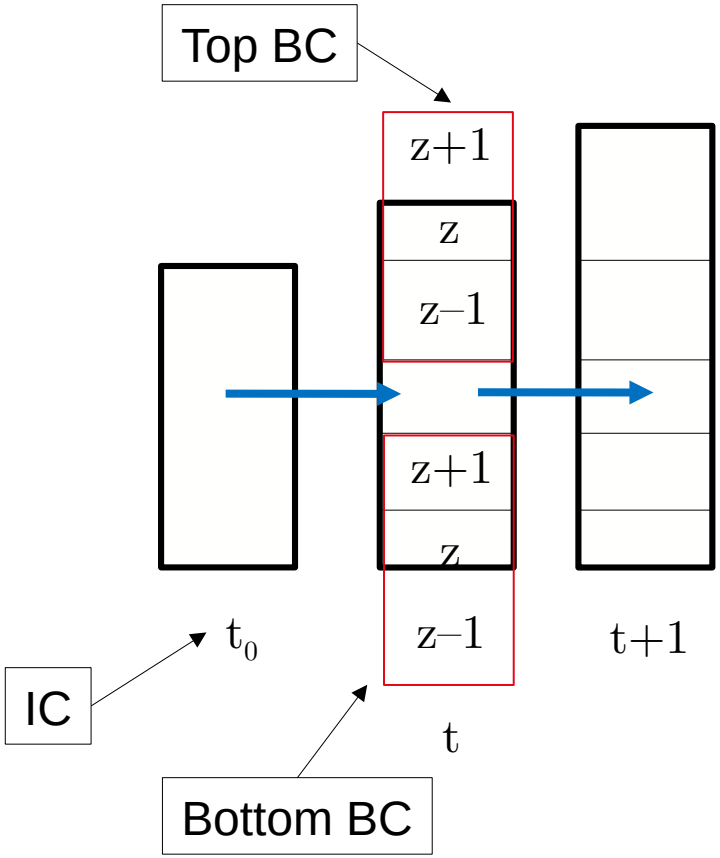
Explicit $$\frac{T_{z,t+1} - T_{z,t}}{\Delta t} = \frac{T_{z+1,t} - 2T_{z,t} + T_{z-1,t}}{\Delta z^2}$$

Implicit $$\frac{T_{z,t+1} - T_{z,t}}{\Delta t} = \frac{T_{z+1,t+1} - 2T_{z,t+1} + T_{z-1,t+1}}{\Delta z^2}$$

SNOWPACK *uses the Finite Element Method!*



Initial condition (IC) & Boundary condition (BC)



BCs in SNOWPACK

Energy (top/bottom):

- Fixed temperature → Dirichlet
- Fixed heat flux (top: energy balance) → Von Neumann

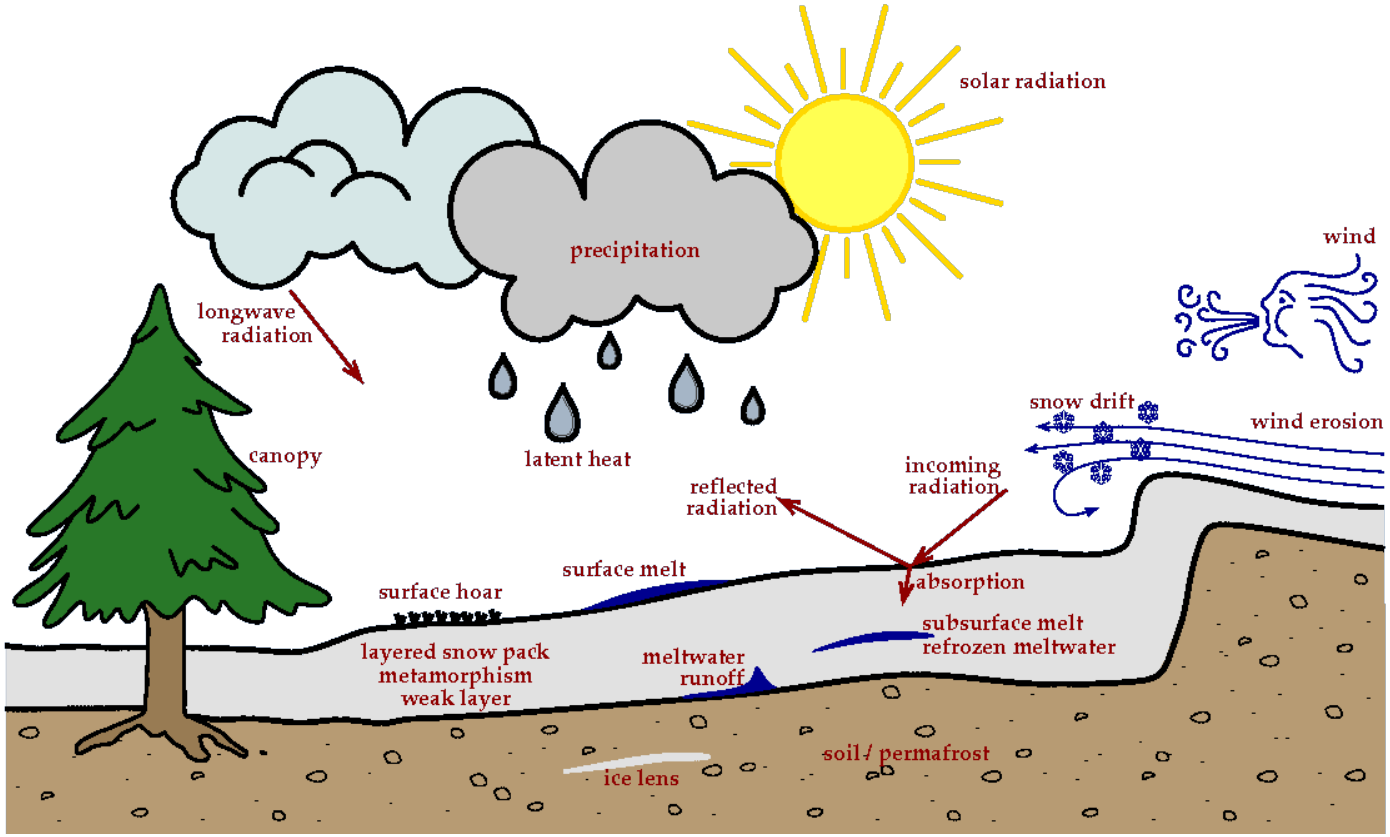
Mass (top):

- Fixed snow height → Enforced snow height
- Precipitation

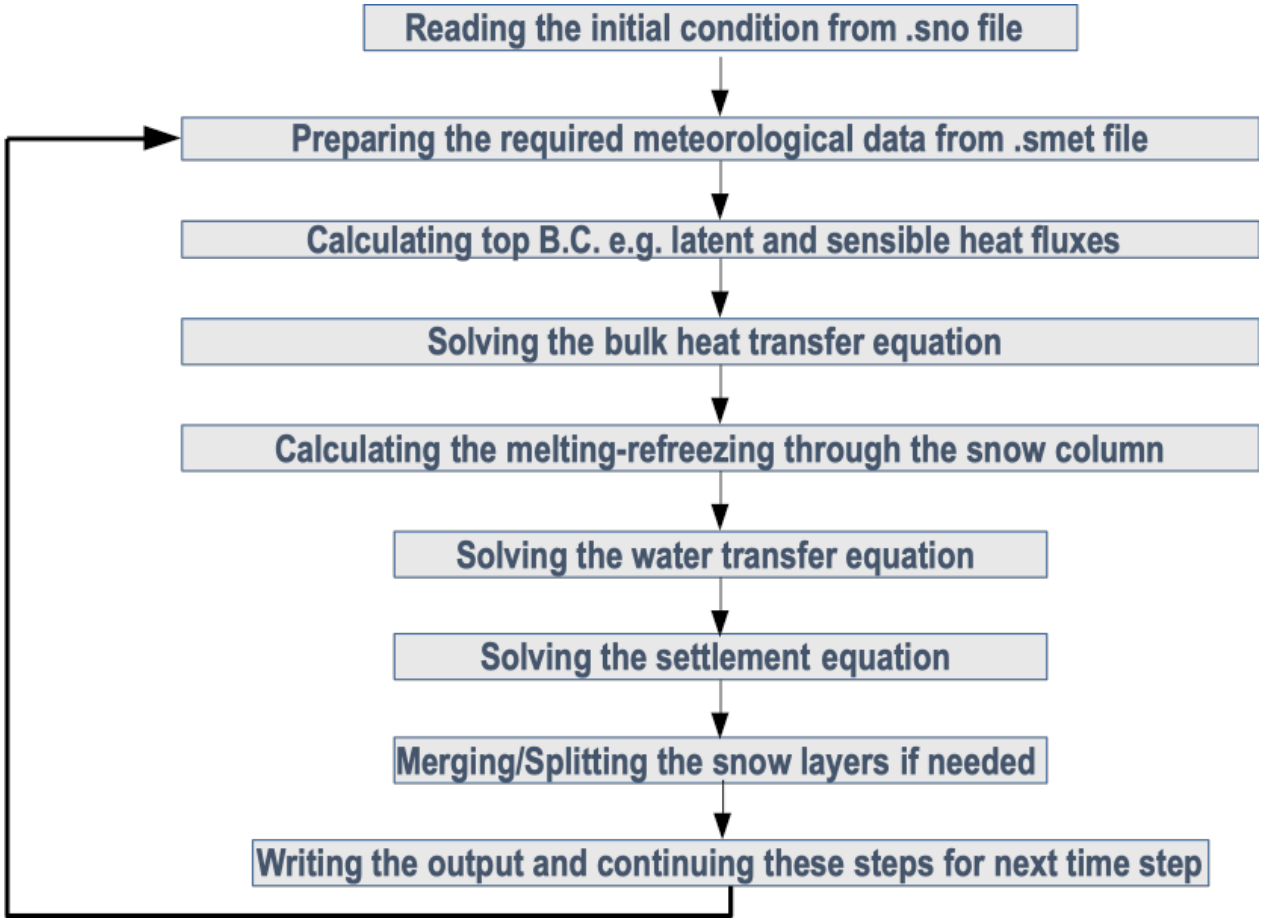
Mass (bottom):

- Runoff

The physics in SNOWPACK



SNOWPACK workflow : simplified



SNOWPACK summary

- Snow: modeled as a three-component (ice, water, air) porous material
- Energy, Mass, Momentum governing equations with the phase changes in the snowpack
- Required input variables:

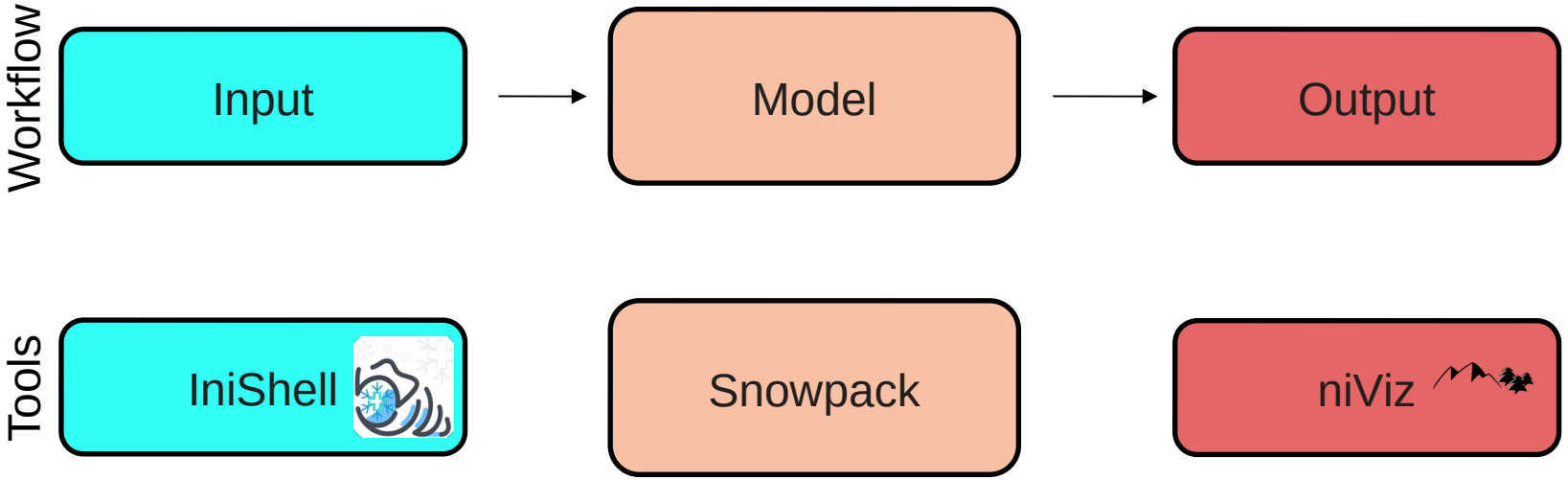
1. Air temperature (TA)
2. Relative humidity (RH)
3. Wind speed (VW)
4. Incoming shortwave radiation (ISWR) or Reflected shortwave radiation (RSWR)
5. Incoming long wave radiation (ILWR) or Surface temperature (TS)
6. Liquid precipitation (PSUM) or Measured snow depth (HS)

Reference: https://snowpack.slf.ch/

How to use SNOWPACK?

(Tutorial on Moodle!)

How to use SNOWPACK?



SNOWPACK variables list

Input | Model | Output

- TA: Temperature air
- P: Pressure
- TSS: Temperature snow surface
- TSG: Temperature surface ground
- ISWR / RSWR: Incoming/Reflected shortwave radiation
- ILWR / OLWR: Incoming/Outgoing longwave radiation
- PSUM: Precipitation
- RH: Relative humidity
- VW: Velocity wind
- DW: Direction wind

(List of main input/output abbreviations & units on Moodle!)

SNOWPACK .smet file

Input | Model | Output

Contains meteorological forcing data

```
SMET 1.1 ASCII
[HEADER]
station_id = ATT2
station_name = Les_Attelas
latitude = 46.105286
longitude = 7.269906
altitude = 2550
easting = 586953
northing = 105990
epsg = 21781
nodata = -999
tz = 1
slope_angle = 0
slope_azi = 0
units_offset = 0 0 0 0 0 0 0 0 0 0 0 0
units_multiplier = 1 1 1 1 1 1 1 1 1 1 1 1
fields =timestamp TA RH TSG TSS HS VW DW VW_MAX RSWR PSUM ISWR
[DATA]
2016-09-30T00:00 277.45 0.758 278.25 273.45 0 0.4 225          3.7 0 0 0
2016-10-01T00:00 277.45 0.758 278.25 273.45 0 0.4 225          3.7 0 0 0
2016-10-01T01:00 277.15 0.777 278.15 273.55 0 0.7 205          3.9 0 0 0
```

Station information

Variables modification

Variables

Data

(.smet specification on Moodle!)

SNOWPACK .sno file

Contains initial profile and some parameters

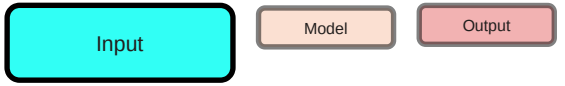
```
SMET 1.1 ASCII
[HEADER]
station_id       = ATT2
station_name     = Les_Attelas
[...]
nSoilLayerData   = 0
nSnowLayerData   = 0
SoilAlbedo       = 0.4
BareSoil_z0      = 0.200
CanopyHeight     = 0.00
CanopyLeafAreaIndex = 0.00
CanopyDirectThroughfall = 1.00
WindScalingFactor = 1.00
ErosionLevel     = 0
TimeCountDeltaHS = 0.000000
fields           = timestamp Layer_Thick  T  Vol_Frac_I  Vol_Frac_W  Vol_Frac_V  Vol_Frac_S Rho_S Conduc_S HeatCapac_S  rg  rb  dd  sp  mk mass_hoar ne CDot metamo
[DATA]
```

Location information

Soil and canopy parameters

Initial snow or soil layers

SNOWPACK .ini file



Contains the simulation configuration

Format: [section], key = value

Sections

[General]: General stuff, don't modify X

[Input]: Input files (see next slides) V

[Output]: Output setting (see next slides) V

[Snowpack]:Main snowpack settings (see next slides) V

[TechSnow]: Snowpack grooming module, not relevant for us X

[SnowpackAdvanced]: Advanced settings, don't touch! X

[Filters]: Filter meteo data, don't touch! X

[Interpolations1D / Generators]: Deal with missing data, interpolation, don't touch! X

SNOWPACK .ini file


```
[Input]

COORDSYS = CH1903
TIME_ZONE = +1

METEOPATH = ./input          ← You may need to adapt this path by clicking “Open path” and
                               navigate to <exercise_path>/input

STATION# = ATT2              ← Station number, no need to change for now

SNOWFILE# = ATT2.sno         ← May need to select the file manually from
                               <exercise_path>/input/MST96.sno (“Open file”)

[Output]
...
METEOPATH = ./output         ← You may need to adapt this path by clicking “Open path”
                               and navigate to <exercise_path>/output
...
EXPERIMENT = Snowpack_ex1    ← Change this parameter to name your output files !
...
```

SNOWPACK .ini file


```
[Snowpack]
...

ENFORCE_MEASURED_SNOW_HEIGHTS = TRUE

ATMOSPHERIC_STABILITY = MO_MICHLMAYR
CANOPY = FALSE
MEAS_TSS = TRUE
CHANGE_BC = TRUE


THRESH_CHANGE_BC = -1.0

SNP_SOIL = FALSE
```

← Use measured snow height or precipitation?

← Boundary layer stability

← Do we have canopy?

← Do we provide TSS?

← Dirichelet/Neumann boundary conditions (TRUE) or only Neumann (FALSE)?

← At which temperature should the BC be switched ?

← Do we have soil layers?

Setup .ini file via INIshell

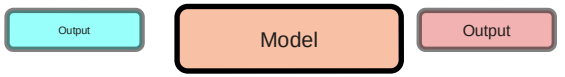
What is INIshell? 

- INIshell is a graphical user interface (GUI) that combines setting up, running and evaluating the model mostly over one interface
- It helps you to keep an overview of different simulation settings and outputs

How to set up a new simulation? (cf. tutorial)

1. Double click SNOWPACK in the white box and then open the .ini file
2. Change the parameter(s) you want
3. Change the experiment name in “OUTPUT” tab !
4. Save the .ini file !

Run SNOWPACK



How to launch the SNOWPACK simulation?

1. Navigate to SNOWPACK grey button on the lower left
2. Define **start date** and **end date**:
    - Both dates must be within the time period of the given .smet input file (but not the very first timestamp!)
3. Click “Run SNOWPACK”

SNOWPACK

- .ini file → Copy of the .ini file
- .sno file → Like input .sno file, but with the final state
- .smet file → All fluxes and 1D variables, same structure that the meteo file
- .pro file → Evolution of the state of the snowpack, all inner variables

SNOWPACK niViz

SNOWPAT
https://pypi.org/project/snowpat/

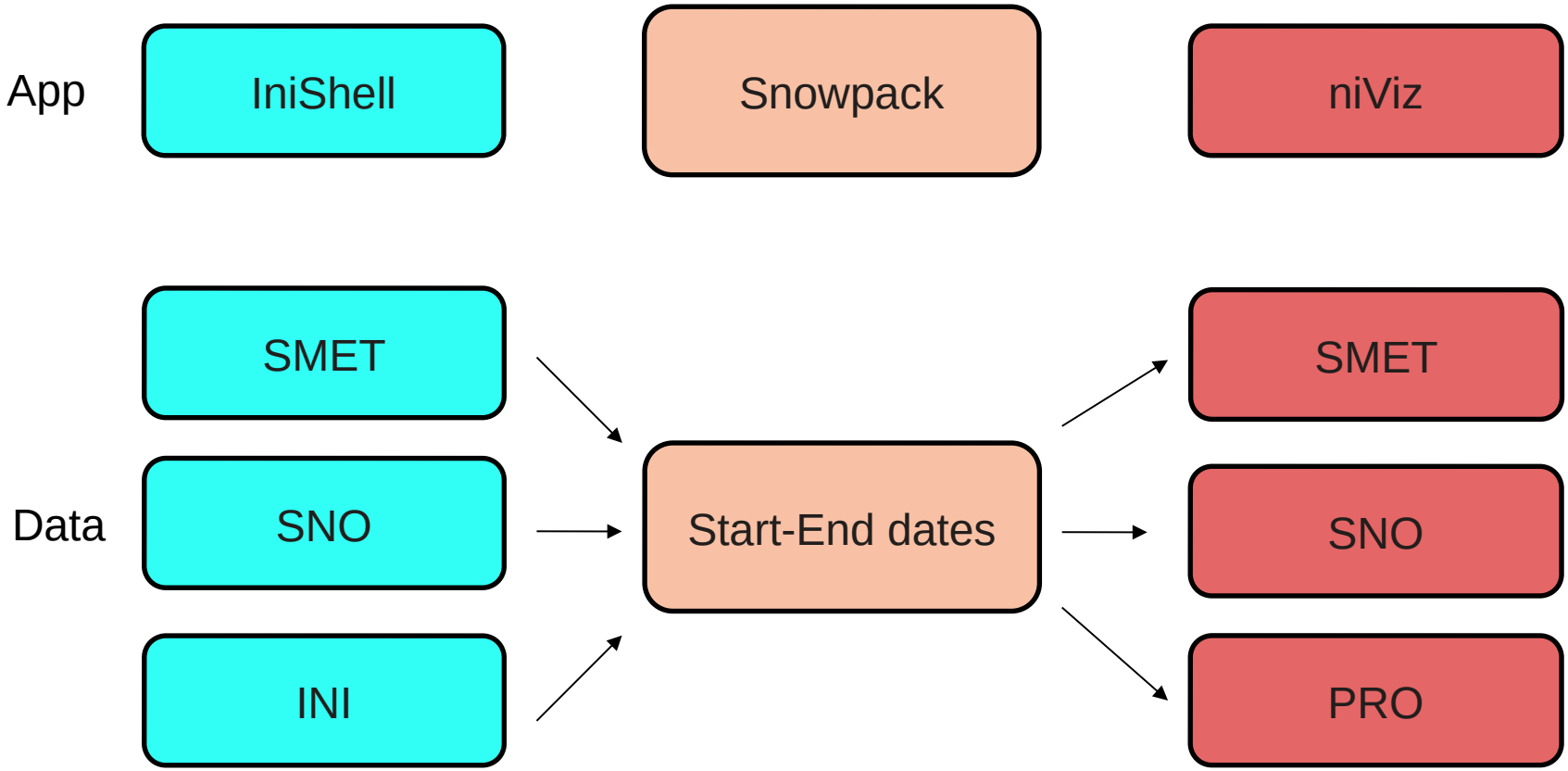
What is niViz?

- A visualization tool in a web browser (only visualization!)

How to use niViz?

- In INIshell, click on “Open niViz” or open https://run.niviz.org/
- Drag and drop the .pro and .smet files into niViz in the opened browser
- Look at the snow profile and play with the various parameters (use the menu button on the upper right part of the profile)
- Close the profiles and open the .smet files from the input and output
- Play with the various variables you can display to get familiar
  - Variable names on Moodle (cf. Additional Material)

Use SNOWPACK : summary



DEMO

cf. additional_material / SNOWPACK tutorial

Assignment 2

GR B3 30 (here) & GR C0 02
vdi.epfl.ch : ENAC-SSIE-WIN