WindThrow 1.2

The aerodynmics ice throw toolbox, now with a (better) GUI

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Motivation

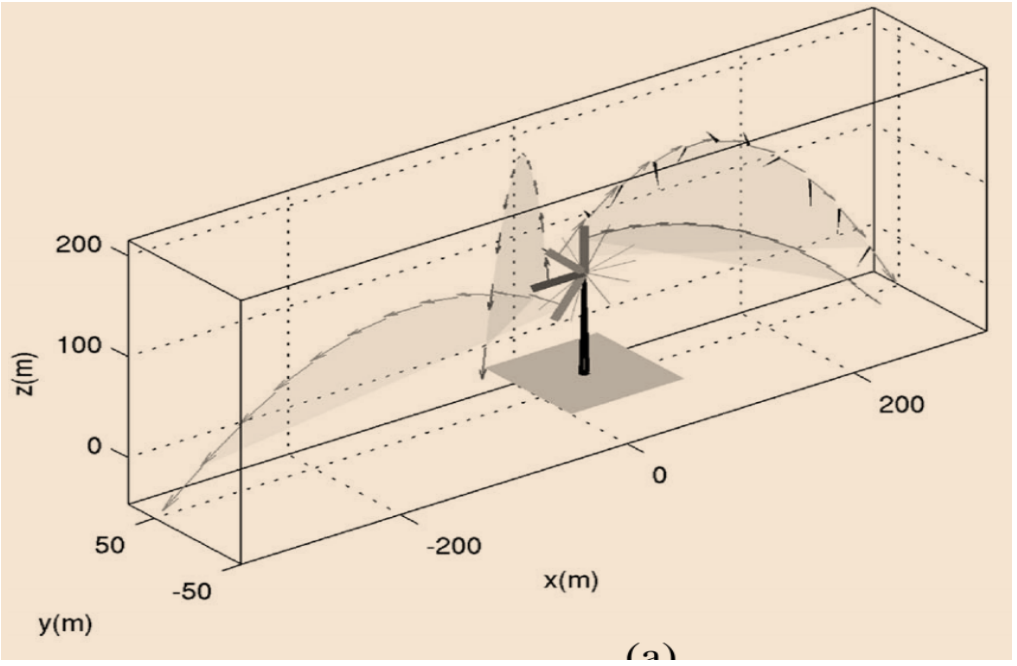
WECC: Known advantages, but …

- Increases in fatigue loads due to load imbalance
- Ice risks are much more significant than blade/fragment failure (Frequency blade failure 10 -3 /year; ice throw > 10/year)
- According to local legislations, the danger of getting hit by ice fragments needs to be assessed already during planning phase

https://www.eologix.com/en/hoarfrost-rime-ice-and-glaze-ice/

Ice throw calculation classification

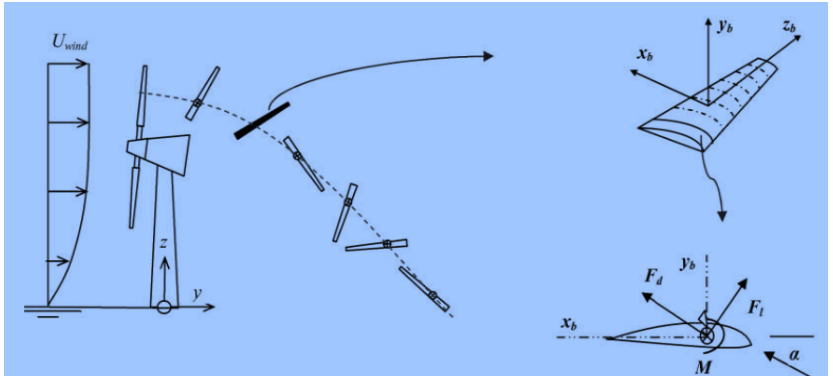
- Empirical formulas: e.g. d = 1.5 (D + H) for Ice throw
- Simple ballistic models (vacuum)
- More detailed aerodynamic models
- Higher fidelity tools and methods + AI (?)



windThrow's Ice throw model

- Blade element theory is used
  - Aerodynamic loads calculated on fragments and corresponding motions translated into a global coordinate system

Program SAVBAL(*ABL and turbine parameters, initial conditions*)
  Call initiate *! Evaluate initial position, orientation and velocities of fragment at t_0 in it's local coordinate*
  while $z_g \leq 0$ ***do*** *! main loop of the program, iteration until the body hits the ground*
    Call *trans1* $\vec{Y}^{old} \leftarrow [\mathbf{R}, \overline{og}_b, \vec{v}_b, \vec{\omega}_b]^{old}$ *! Arrange a set of 18 ODE's*
    Call *local velocity* $\vec{v}_{local} \leftarrow \mathbf{R}, \vec{v}_b, \vec{\omega}_b, \vec{v}_{wind}(h,t)$ *! Calculate relative velocities*
    Call *aerodynamics* $\vec{F}_{total}, \vec{M}_{total} \leftarrow \mathbf{R}(\alpha), \vec{v}_{local}, \vec{\omega}_b$ *! Calculate loads*
    Call *RungeKutta* $\vec{Y}^{new} \leftarrow [\vec{Y}, \vec{F}_{total}, \vec{M}_{total}]^{old}$ *! time integration*
    Call *Trans2* $[\mathbf{R}, \overline{og}_b, \vec{v}_b, \vec{\omega}_b]^{new} \leftarrow Y^{new}$ *! update new values*
  End while
End Program

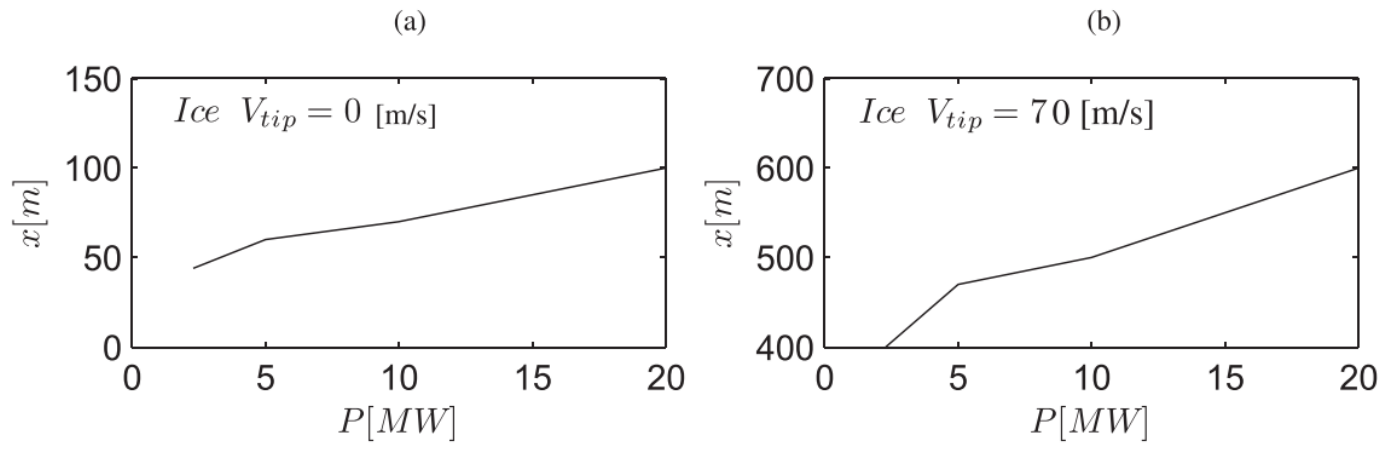


(Sarlak and Sørensen, WE, 2016)

Results of ice throw simulations

Table IV. Aspect ratios, reference chord length C_{ref} and detached mass m of the ice fragments ($\rho_{ice} = 0.7$ kg/m^3) used for throw simulation of turbines of different sizes.

	2.3 MW		5 MW		10 MW		20 MW	
Cases – AR	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)
$AR = 1$		0.18		0.43		0.97		2.16
$AR = 2$	0.1	0.36	0.15	0.87	0.2	1.95	0.3	4.33
$AR = 3$		0.54		1.31		2.94		6.49



Maximum throw distances obtained for the ice throw in (a) standstill operation, i.e., $V_{tip} = 0$ m/s and (b) normal operating condition, i.e., $V_{tip} = 70$ m/s as a function of turbines power.

(Sarlak and Sørensen, WE, 2016)

New user interface and capabilities

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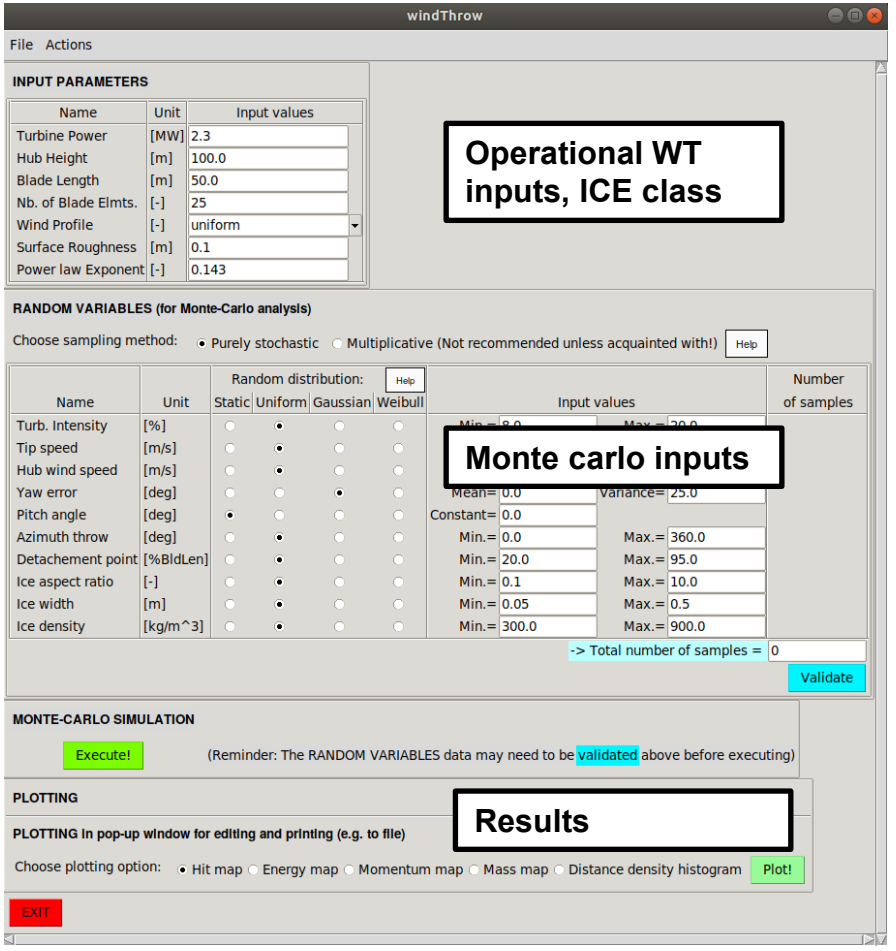
User friendliness

- Integration of other throw models
- Integration of guidelines and datasets
- Complex terrain
- Turbulence
- …



Old interface!

Code structure

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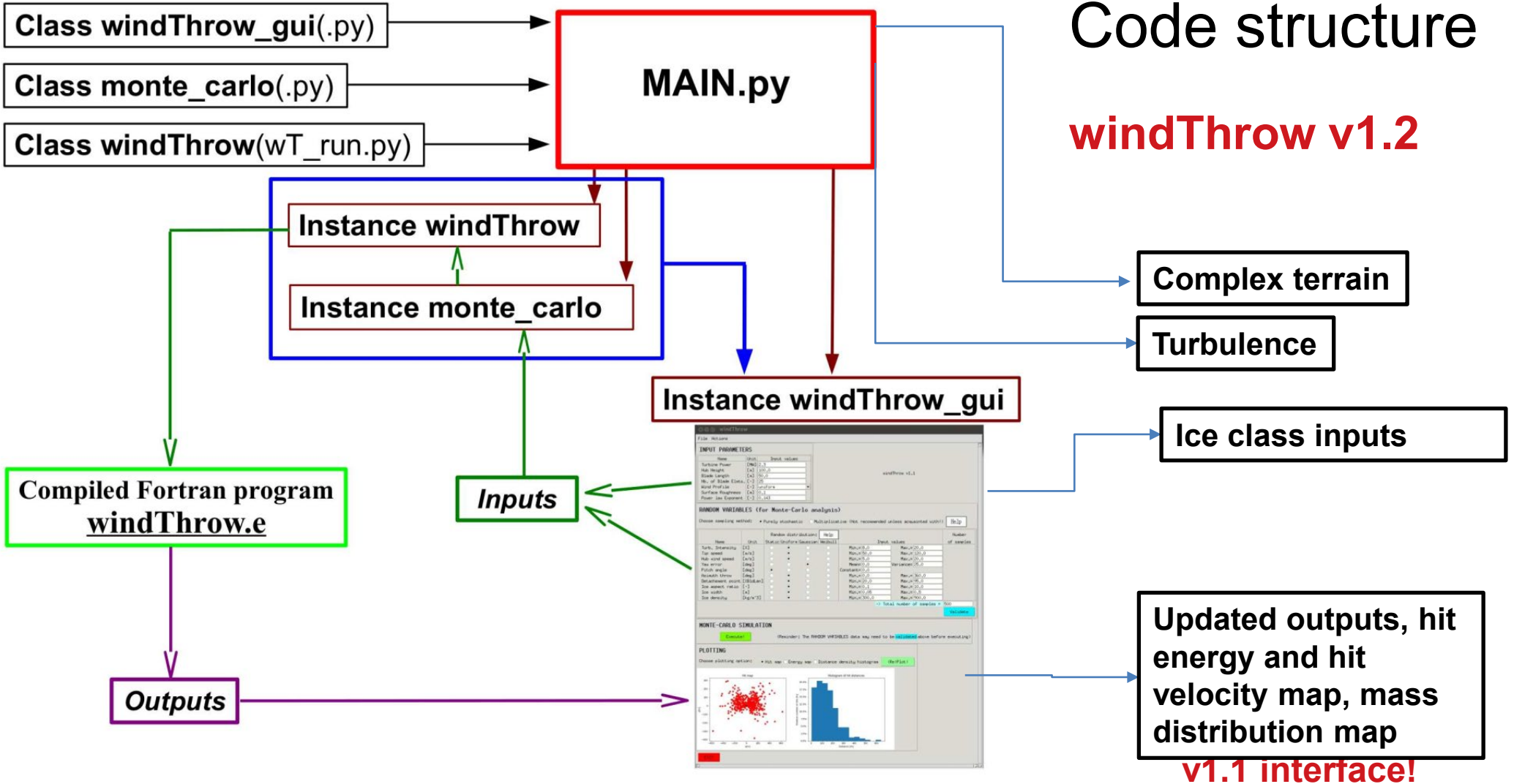

Closure:

- Since the last time,
  - New inflow turbulence, complex terrain, further software development was added to the previously developed massive computations (Monte-Carlo) and GUI

- In the future,
  - Ice risk and mitigation module
  - Improving the database and validation (AI is the next step)
  - Robustness and software development aspects

DTU

iea wind

Thank you for your attention!

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