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beyond the sea® by Yves Parlier

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Kite as a Beam Modelling Approach: Assessment by Finite Element Analysis

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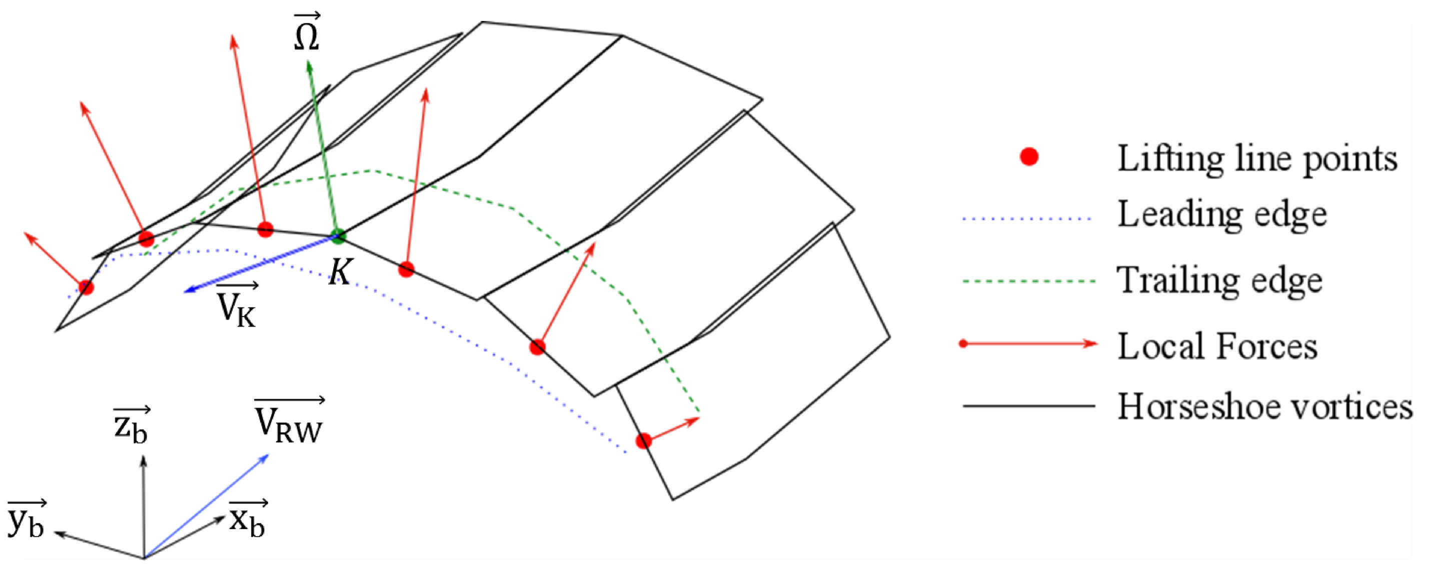
3D non-linear lifting line model [1]

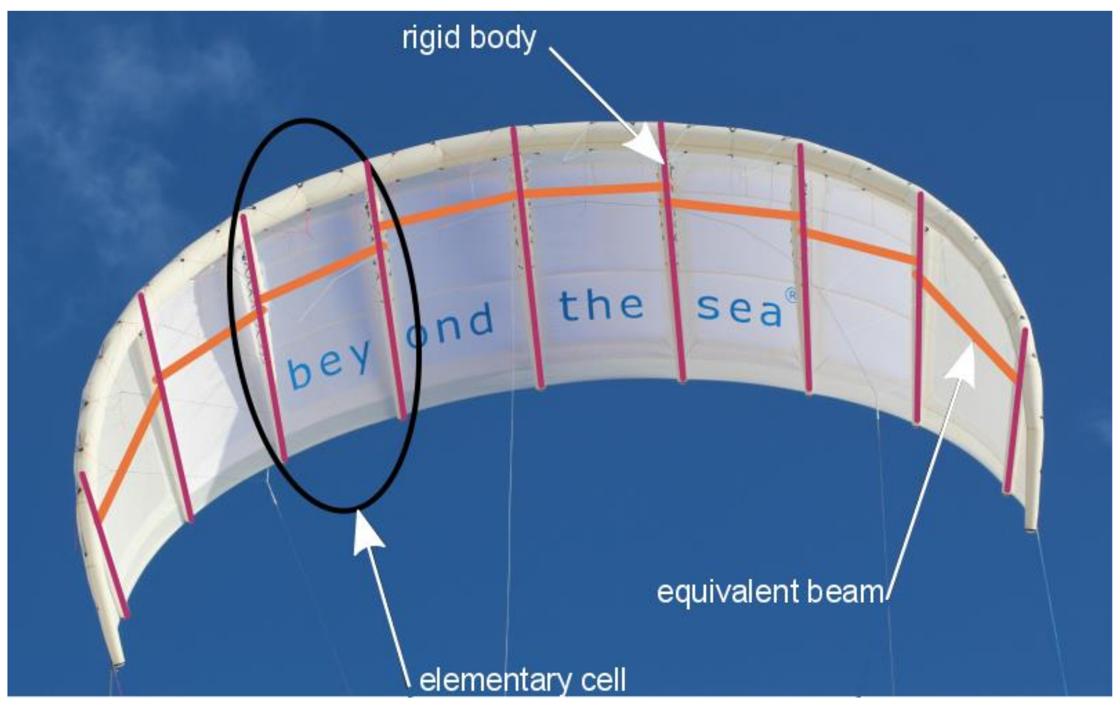


Example of a low discretised lifting line model

- Prandtl lifting line theory adapted to wings with variable dihedral and sweep angles. Finite wing and its wake represented by a set of horseshoe vortices of different strengths Γ
- Inclusion of the non-linearity of the lift coefficient
- Iterative solution:
  - Computation of the induced velocities with the Biot-Savart law
  - Computation of the circulation from the equivalence between local lift calculated from the Kutta formula and from the polar of the section

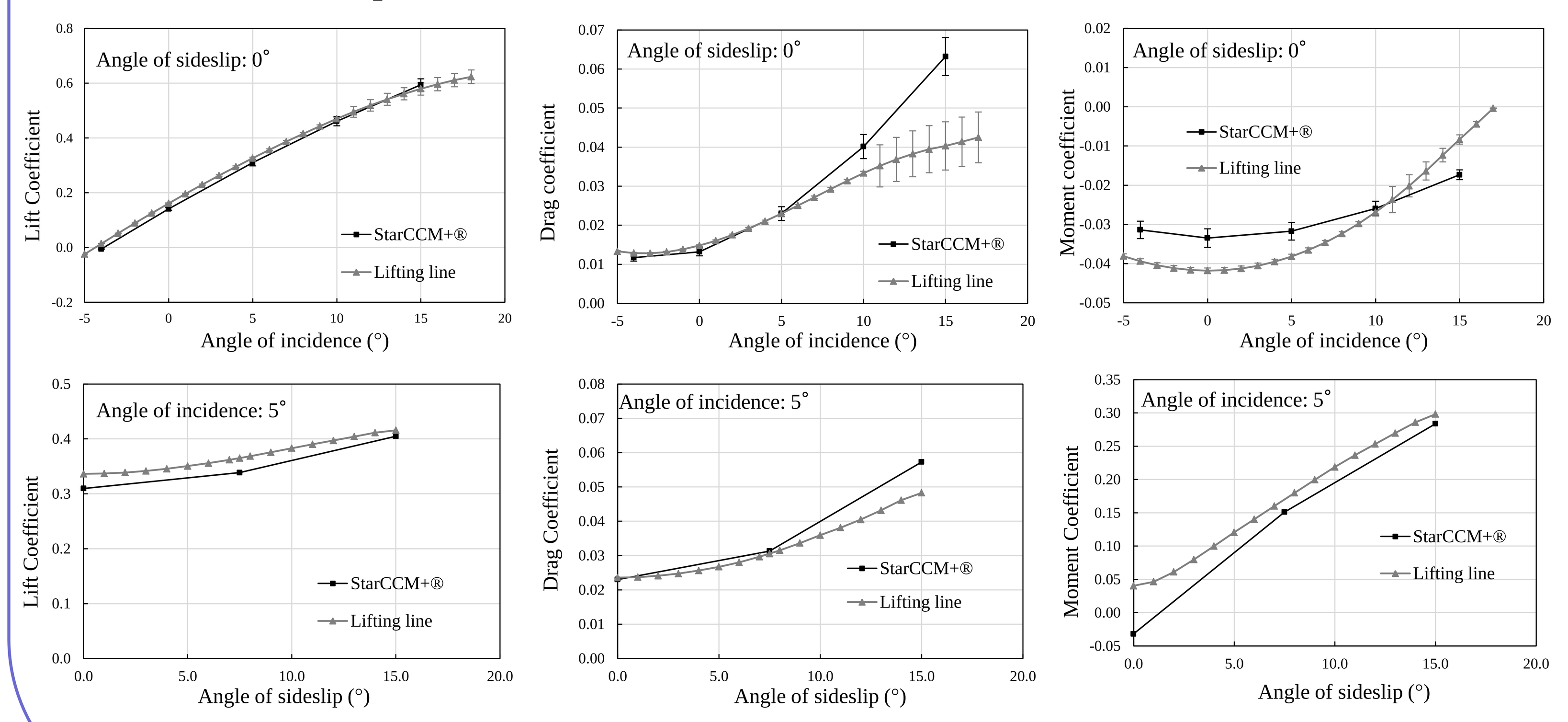
Kite as a Beam model [2]

- Kite considered as an assembly of elementary cells
- Cell composed of:
  - Portion of the inflatable leading edge: modelled as a beam
  - Two half inflatable battens: modelled as beams
  - Corresponding canopy: modelled as a shell
- Each elementary cell is replaced by an equivalent beam

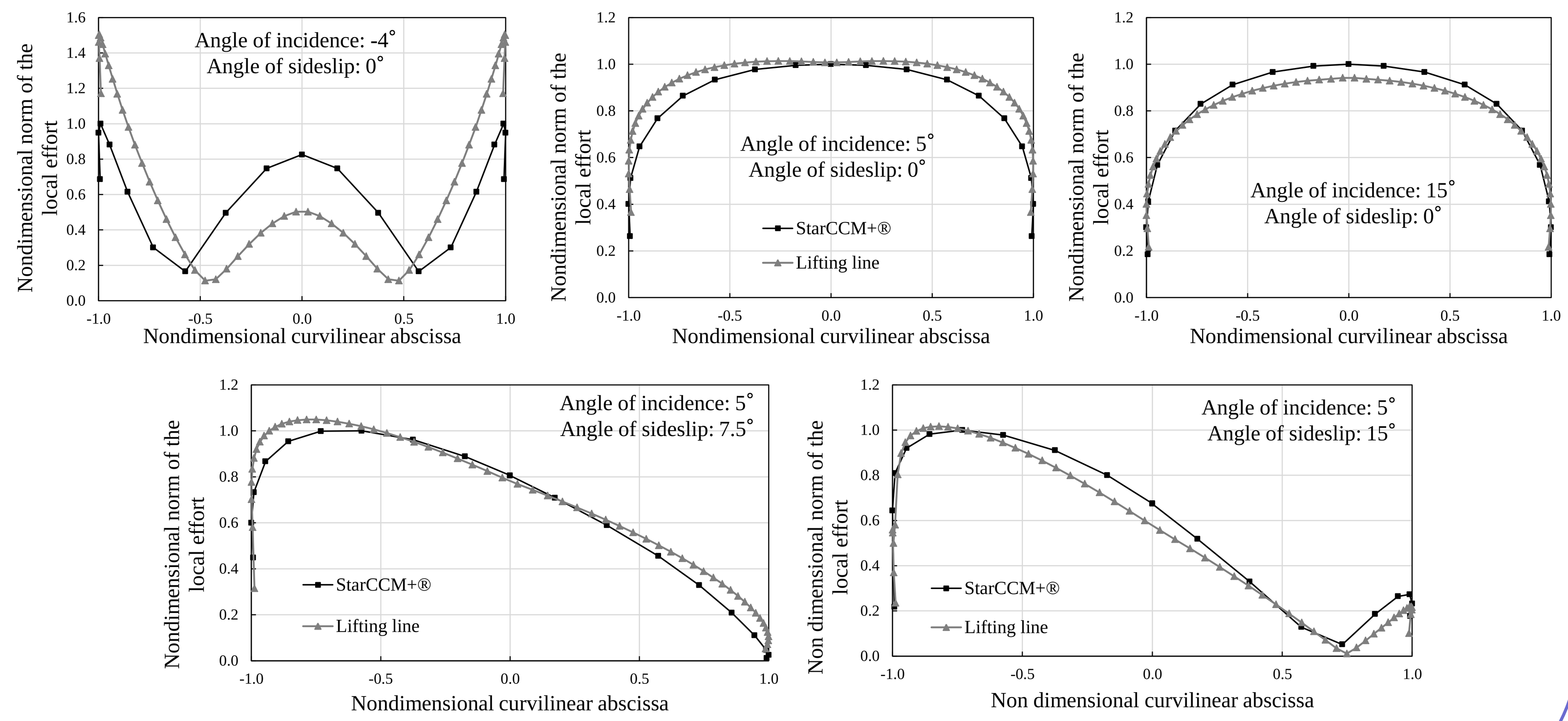


Comparison of the 3D non-linear lifting line method with 3D RANSE results (Star-CCM+®) [3]

- Semi-circular kite of radius $1.0m$ with a NACA2412 section
- Non-linear swept law
- Linear twist law, from 0° at root to 5° at tips
- Non-linear chord law from $1.0m$ at root to $0.1m$ at tips
- Computation time:
  - Lifting line: $0.5s$ with a standard PC
  - StarCCM+®: $40min$ with 8 cores



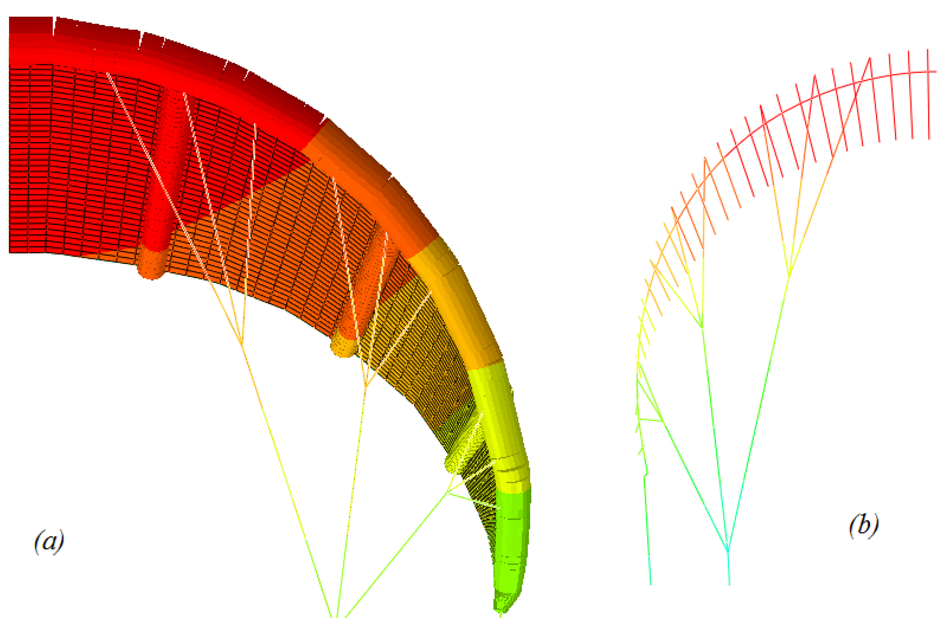
Kite 3D aerodynamic coefficients with respect to the angle of incidence (top) or the angle of sideslip (bottom)



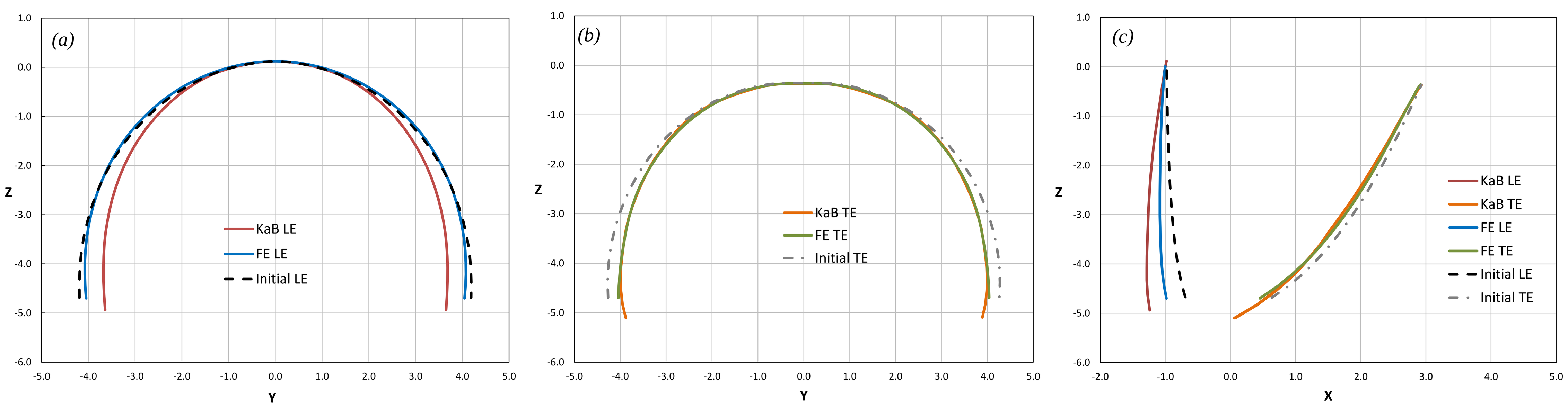
Nondimensional magnitude of the local aerodynamic force per unit length on a kite wing obtained via StarCCM+® (black square) and the lifting line method (grey triangle)

Comparison of the Kite as a Beam model with a Finite Element model [4]

- Fluid-Structure Interaction (FSI) on a $50m^2$ kite at 10° of incidence with an apparent wind of $25m/s$ and $75m$ of tether length. The anchor point of the tethers is a fixed point and the tethers and bridles system are represented by truss elements.
- Comparison between the Kite as a Beam model coupled with the 3D non-linear lifting line method and the Finite Element model coupled with a linear lifting line. The results of the two lifting line are sligthly different.
- Computation time: few minutes for the KaB FSI, few hours for the FE FSI



(a) **Complex Finite Element model with shell and beam elements,** *(b)* **Kite as a beam model. The color scale represents the displacement magnitude**



(a) **Front view of the leading edge (LE) of the kite, undeformed (initial), after convergence with the Kite as a Beam model (KaB), after convergence with the Finite Element model (FE).** *(b)* **Front view of the trailing edge (TE) of the kite, undeformed and after convergence with the Kite as a Beam model and the Finite Element model.** *(c)* **Side view of the leading and trailing edge of the kite, undeformed and after convergence of the two models.**

Acknowledgements :

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References :

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[3] *Duport C., Deberque M., Leroux J.-B., Roncin K., Jochum C.: Local results verification of a 3D non-linear lifting line method for Fluid-Structure interaction simulation on a towing kite for vessels. In: Proceedings of the 11th Symposium on High-Performance Marine Vehicles, Zevenwacht, South Africa, 11-13 Sep 2017.*

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