A simple mechanistic model of higher plant gas exchanges in a reduced gravity environment

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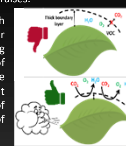
CONTEXT

This study was done in the frame of the ESA Micro-Ecological Life-Support System Alterative (MELiSSA) project, which envisions to grow higher plants and micro-algae in space for food, water, and oxygen production. But, in weightlessness and, more generally, in reduced gravity environments, gas exchanges at the leaf surface are impaired and leaf surface temperature raises.

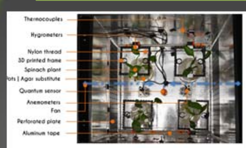
Although normal plant growth can be ensured with adequate ventilation, the use of higher plants for sustaining humans outside of Earth requires being able to predict their behavior for a wide range of parameters, including low ventilation settings. The development of a mechanistic model of plant growth allows a thorough multiple-scale study of plant growth mechanisms for a broad spectrum of parameters, as well as identifying knowledge gaps.

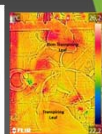


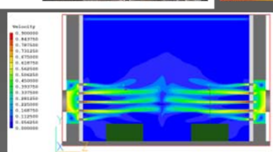
OBJECTIVES

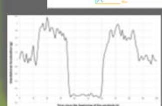
- Expand initial MELiSSA plant growth model by including gravity as a parameter;
- Couple initial model based on plant mass balance to the plant energy balance and introduce a new variable of the model: the leaf surface temperature;
- Characterize gas exchanges mechanisms at the leaf surface;
- Fine-tune the definition of boundary layer, conductance, and free convection velocity;
- Validate the model in various gravity levels and ventilation settings in a parabolic flight experiment.

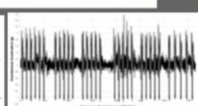
PARBOLIC FLIGHT EXPERIMENT



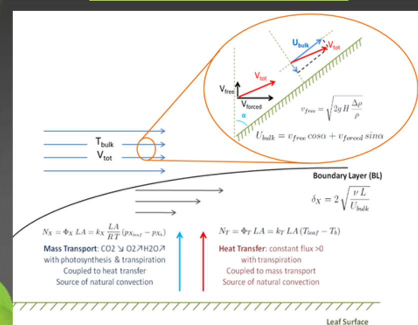




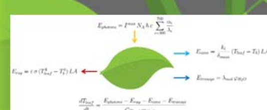




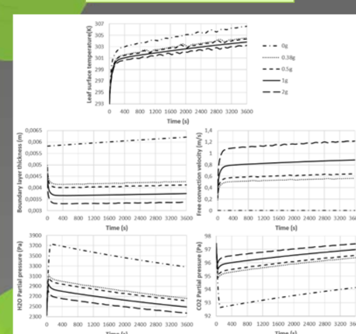
GAS EXCHANGES EQUATIONS



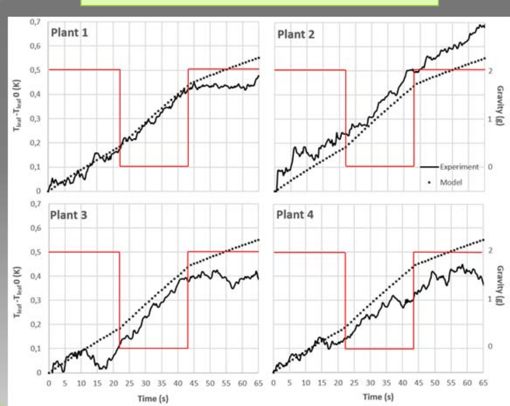
ENERGY BALANCE



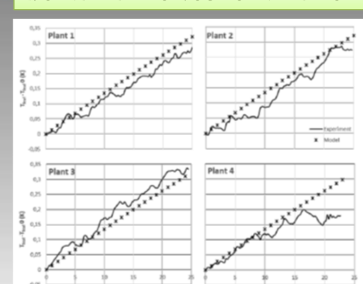
SENSITIVITY ANALYSIS



MODEL VALIDATON: WHOLE PARABOLA



MODEL VALIDATON: 0G NO VENTILATION



CONCLUSIONS AND FUTURE WORK

- The model was validated in the case without ventilation, on a whole parabola, including phases at 2g an 0g, for the short-term evolution of leaf temperature.
- Additional data acquisition and a better definition of boundary layer exchanges are necessary to validate the model in the case with ventilation and in partial g levels.
- Further development shall include long-term validation on biomass and water production and will necessitate the inclusion of respiration
- The boundary layer of a whole plant or a canopy will differ from a simple addition of in general making it possible to predict their growth on Earth for higher temperatures and CO_2 levels.