COMSOL CONFERENCE BOSTON 2012

Penetration of Moisture in a Solar-Panel Edge Seal

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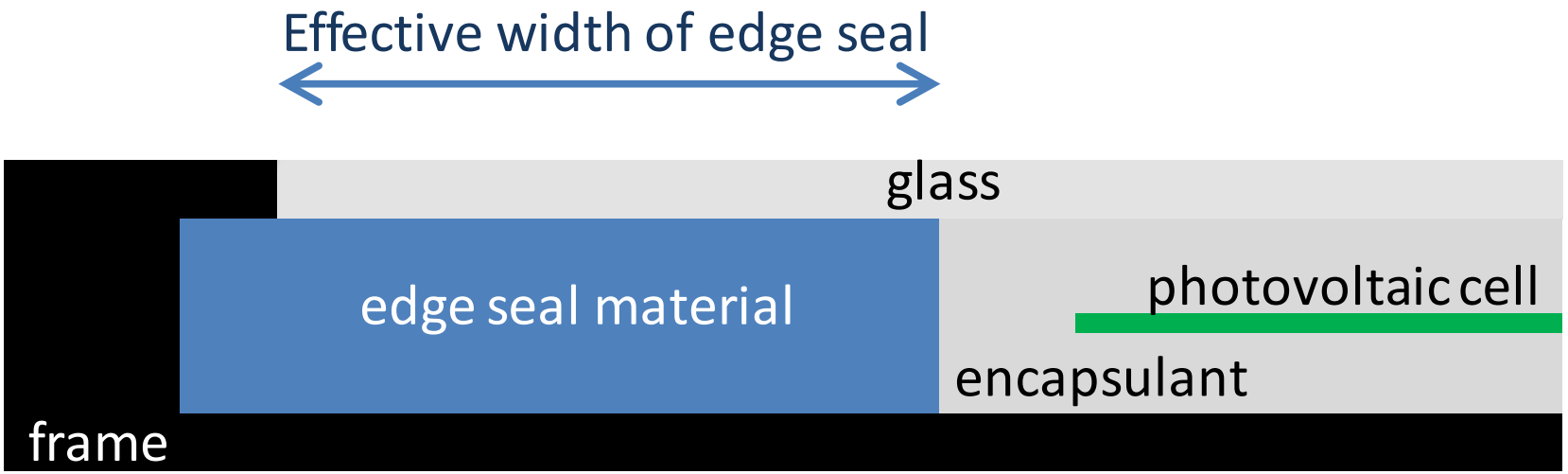
Excerpt from the Proceedings of the 2012 COMSOL Conference in Boston

Schematic view of edge seal

- not to scale!



Water Diffusion Model

- Stefan condition:

$$C_d \frac{\partial x_f}{\partial t} = -D \frac{\partial C}{\partial x}$$

- Stefan number:

$$St = \frac{C[x=0]}{C_d}$$

- Neumann solution:

$$C[x,t] = C[x=0,t]\left(1 - Erf\left[\frac{x}{2\sqrt{D\,t}}\right] / Erf[\lambda]\right)$$

$$x_f[t] = 2\,\lambda\,\sqrt{D\,t}$$

$$St = \lambda\,\sqrt{\pi}\;Exp\left[\lambda^2\right] Erf[\lambda]$$

- The constant, λ, depends on the Stefan number

Experimental Data

- Kempe *et al* * published experimental data on diffusion of water into an edge-seal configuration and fit the analytical model:

$$x_f[t] = 0.018\left(cm/\sqrt{hour}\right)\sqrt{t}$$

- On previous equations:

$$2\lambda\sqrt{D} = 0.018\left[cm/hour\text{^}0.5\right]$$

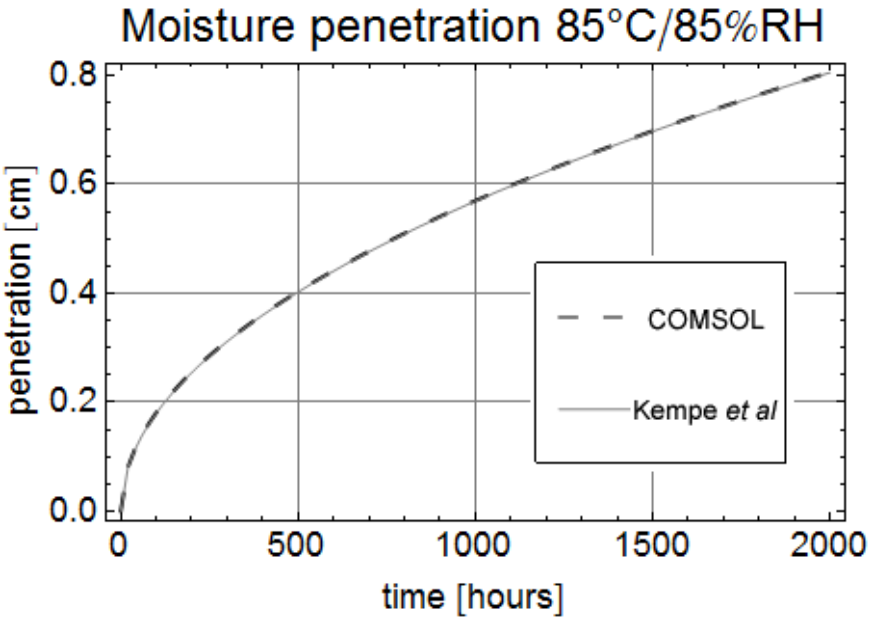
*** M. D. Kempe, A. A. Dameron, T. J. Moricone, M. O. Reese; "Evaluation and modeling of edge-seal materials for photovoltaic applications", *35th IEEE Photovoltaic Specialists Conference (PVSC)*, pp 256-261 (June 2010).**

Numerical Solution

- Rate of advancement of the moisture front:

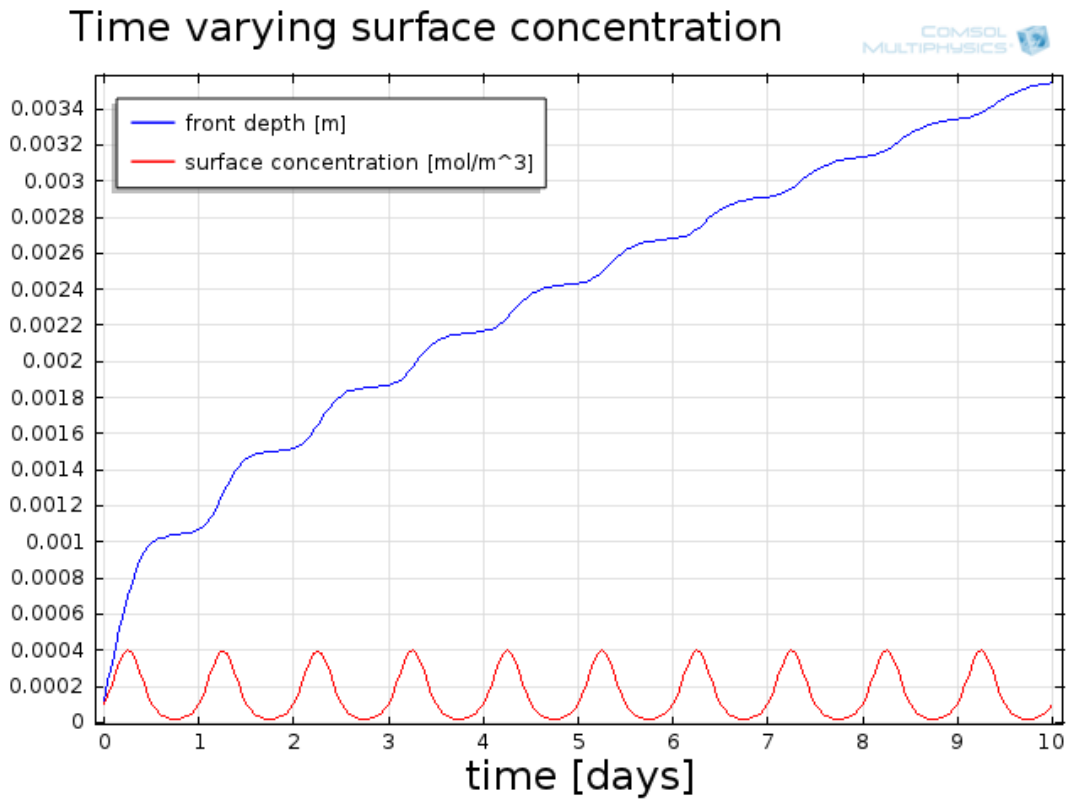
$$\frac{\partial x_f}{\partial t} = \frac{q\,[mole/(m\text{^}2*\sec)]}{C_d\,[mole/m\text{^}3]} = -\frac{D}{C_d}\frac{\partial C}{\partial x}$$

- Solved using COMSOL physics:
  - Transport of Diluted Species – for concentration
  - Deformed Geometry – for moisture front
- Comparison of COMSOL model and analytical model by Kempe *et al*:



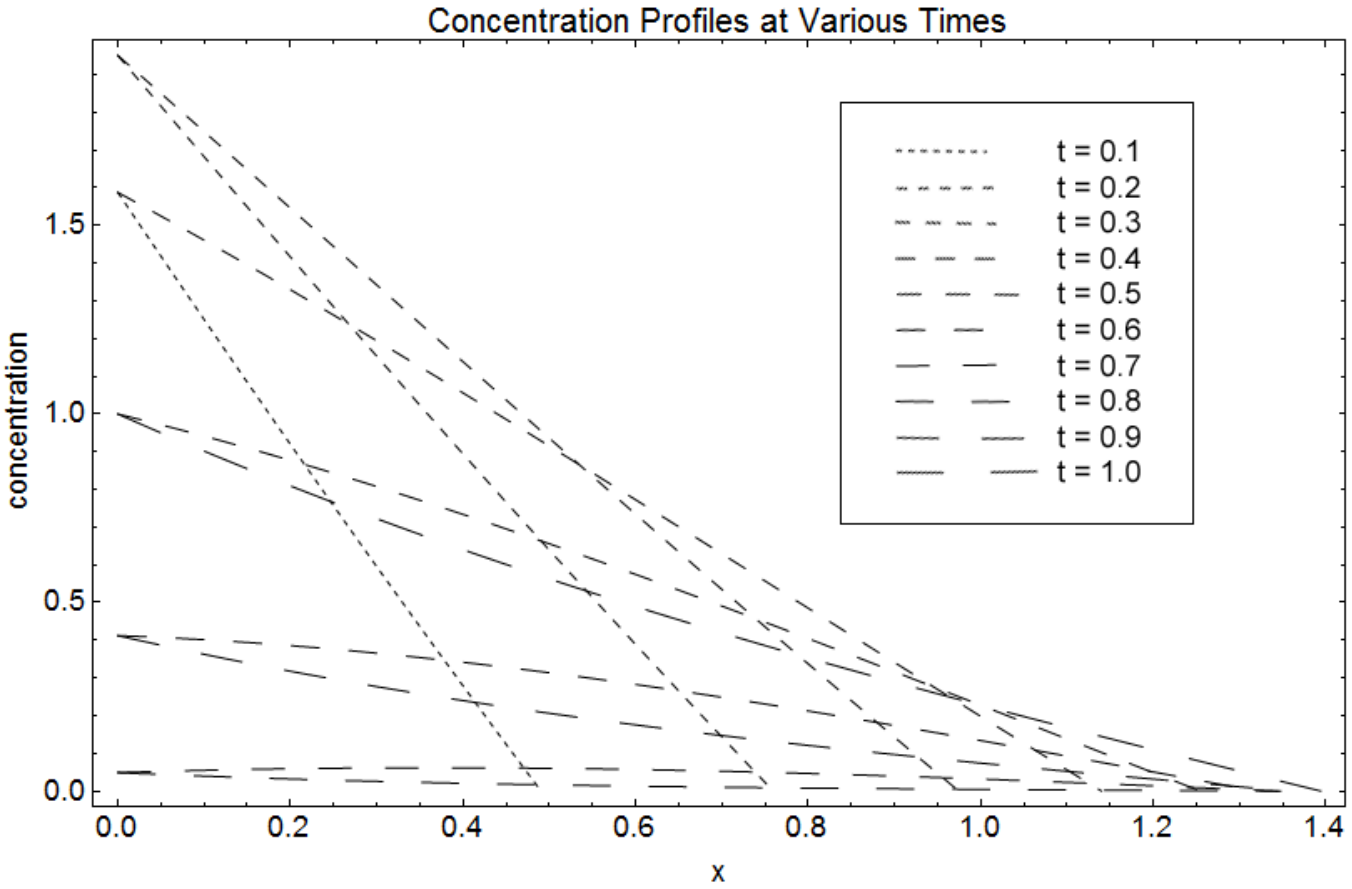
Penetration in varying conditions

- Temperature and humidity of the atmosphere change
- Solubility and diffusivity of water in the edge seal change with temperature



Concentration Profiles

- Concentration at surface varies, but the gradient at the moisture front is always negative

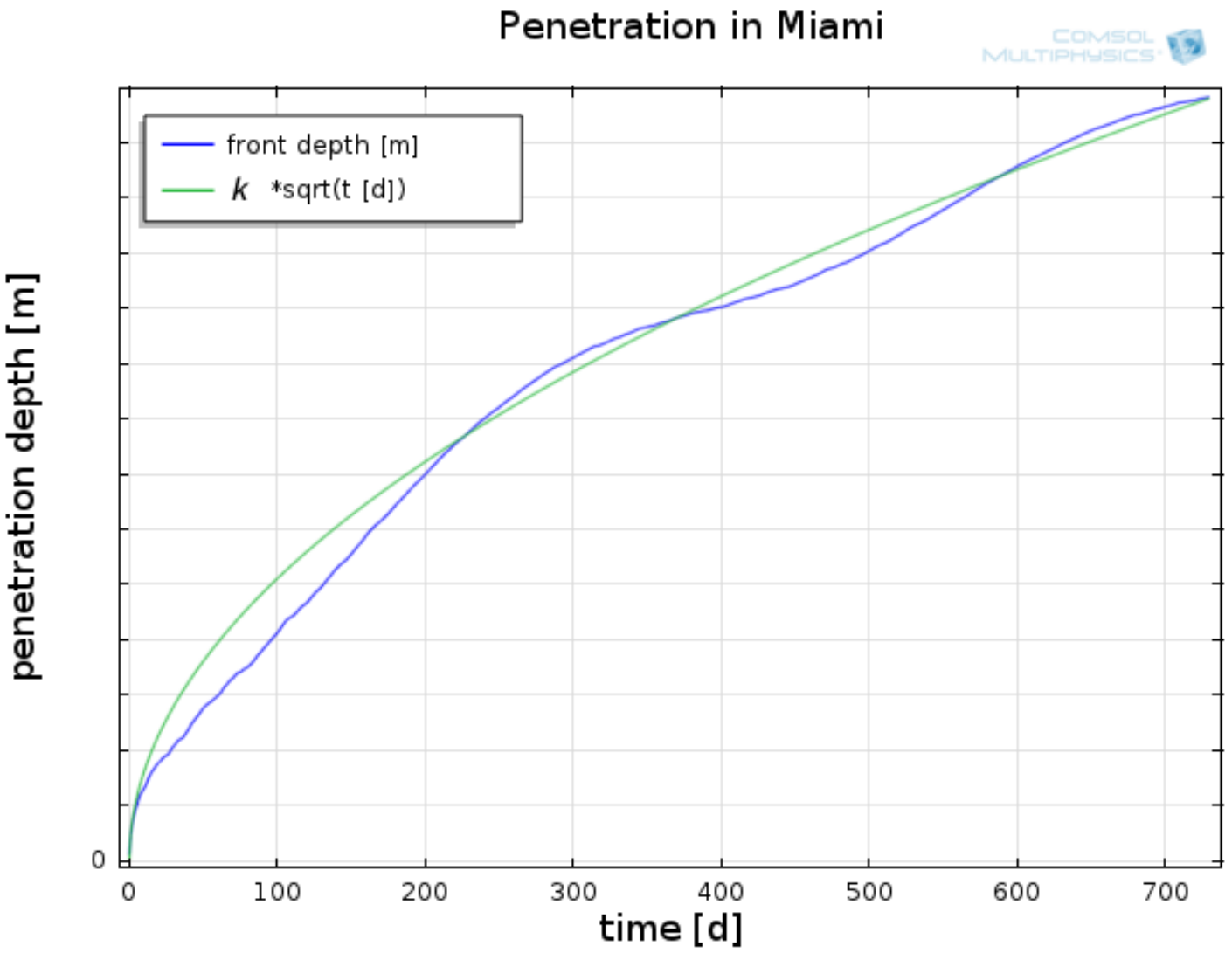


Weather Data

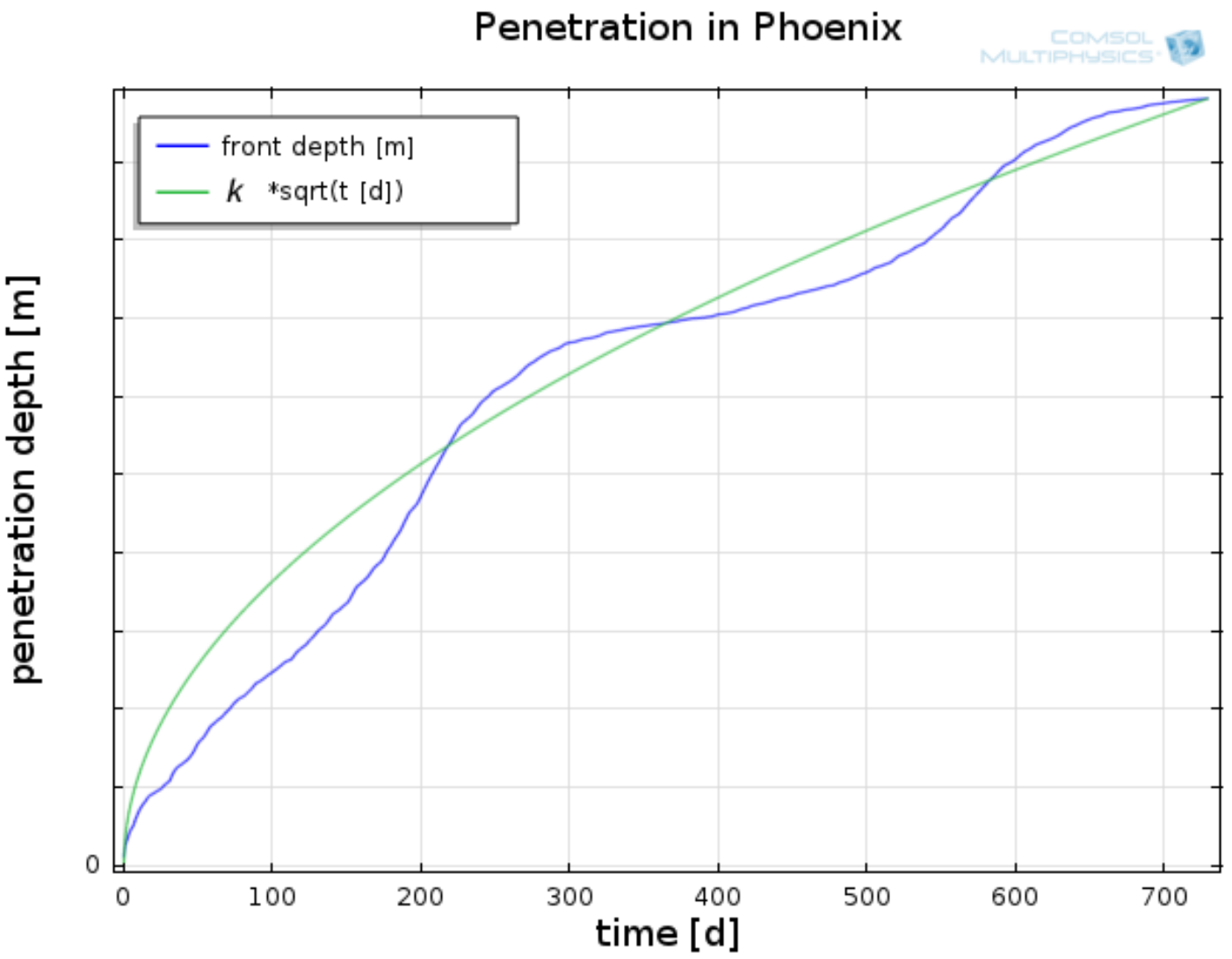
- "Typical meteorological Year" data (TMY) are available from NREL**,
  - Miami international airport file 722020
  - Phoenix Sky Harbor International Airport file 722780
- Thermal model from King *et al* *** was directly employed with coefficients for a glass-cell-polymer sheet with an insulated back to obtain module temperatures based on meteorological data for Ground Horizontal Irradiance (GHI), wind speed and ambient temperature [11].
- A COMSOL Interpolation function used for temperature and humidity data
- COMSOL Analytical functions for surface concentration and for the moisture diffusivity of the edge seal material

****Typical Metrological Year data, National Renewable Energy Laboratory: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/**
***** D. L. King, W. E. Boyson, J. A. Kratochvil; "Photovoltaic array performance model", Sandia Report SAND2004-3535 (December 2004).**

Prediction for Miami



Prediction for Phoenix



Conclusions

- The COMSOL numerical model of the edge seal moisture front matches the known analytical solution.
- Model can be used to make predictions
  - with varying temperature and humidity of specific locations
  - and variable permeability and solubility.
- This work confirms the work of Kempe *et al*:
  - in real weather conditions a 1 centimeter length of the edge seal studied will provide protection for 20 years in the locations considered.
- The model can also be used to optimize the edge-seal design.