# Web-based leaf water isoscapes in IsoMAP using raster modeling

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## Abstract

The oxygen isotope ratio of leaf water is an important driver of the δ18O of atmospheric O2 and CO2 and leaf water is also the medium in which photosynthesis occurs, affecting the isotopic composition (δ18O and δ2H) of all organic compounds produced by plants. Understanding what causes isotopic variation in leaf water is therefore of critical importance to the use of oxygen and hydrogen isotope ratios of plant materials to make inferences about a variety of processes in ecology, atmospheric science, and paleoecology, and others. Although understanding the spatial variation in leaf water isotopic composition is particularly important for drawing inferences from several proxies, modeling the spatial variation of leaf water isotopic variation has presented challenges. Here we describe a component of a new online portal (IsoMAP; http://isomap.org) that provides researchers with too ls to produce, utilize, and evaluate leaf water and other plant isoscapes. We believe that facilitating the use of plant isoscapes by a variety of researchers will enhance not only individual research efforts targeted at drawing inferences from plant hydrogen and oxygen isotope ratios, but produce a productive dialog and framework for plant physiologists interested in directly modeling the processes that drive isotopic variation in plants. IsoMAP is a web-based portal that provides users with free global access to a diverse set of tools for spatial isotopic data analysis, modeling and the generation of isoscapes. The IsoMAP plant modeling component implements three steady state models of leaf water isotope enrichment: the core “Craig-Gordon” model, a “Two-pool” model, and the “Péclet” model, giving user the opportunity for inter-model comparison completely within the web portal system. The model takes as input publicly-available climate grids and IsoMAP-generate d precipitation isotope grids in a common IsoMAP format to allow model execution by the user. In addition, the user can modify several model parameters (e.g., air temperature, leaf temperature, or stomatal conductance). In addition to providing a new tool for isoscapes-based research, IsoMAP is designed to generate dialog across disciplines and yield synergies as researchers use and compare various models and as we expand the models available to the IsoMAP user community.

## Steady-State Leaf Water Models

**Currently IsoMAP implements three steady state models of leaf water isotope enrichment – the “Craig-Gordon”, the “Two-pool” and the “Péclet” model giving user the opportunity for the inter-model comparison completely within the web portal system.**

### Craig Gordon

$$R_{wl} = \alpha * \left[ \alpha_k * R_{wx} * \left( \frac{e_i - e_s}{e_i} \right) + \alpha_{kb} * R_{wx} * \left( \frac{e_s - e_a}{e_i} \right) + R_a * \left( \frac{e_a}{e_i} \right) \right]$$

### 2-Pools

$$\delta_{wlB} = \delta_{wlE} * f_l + \delta_{wx} * (1 - f_l)$$

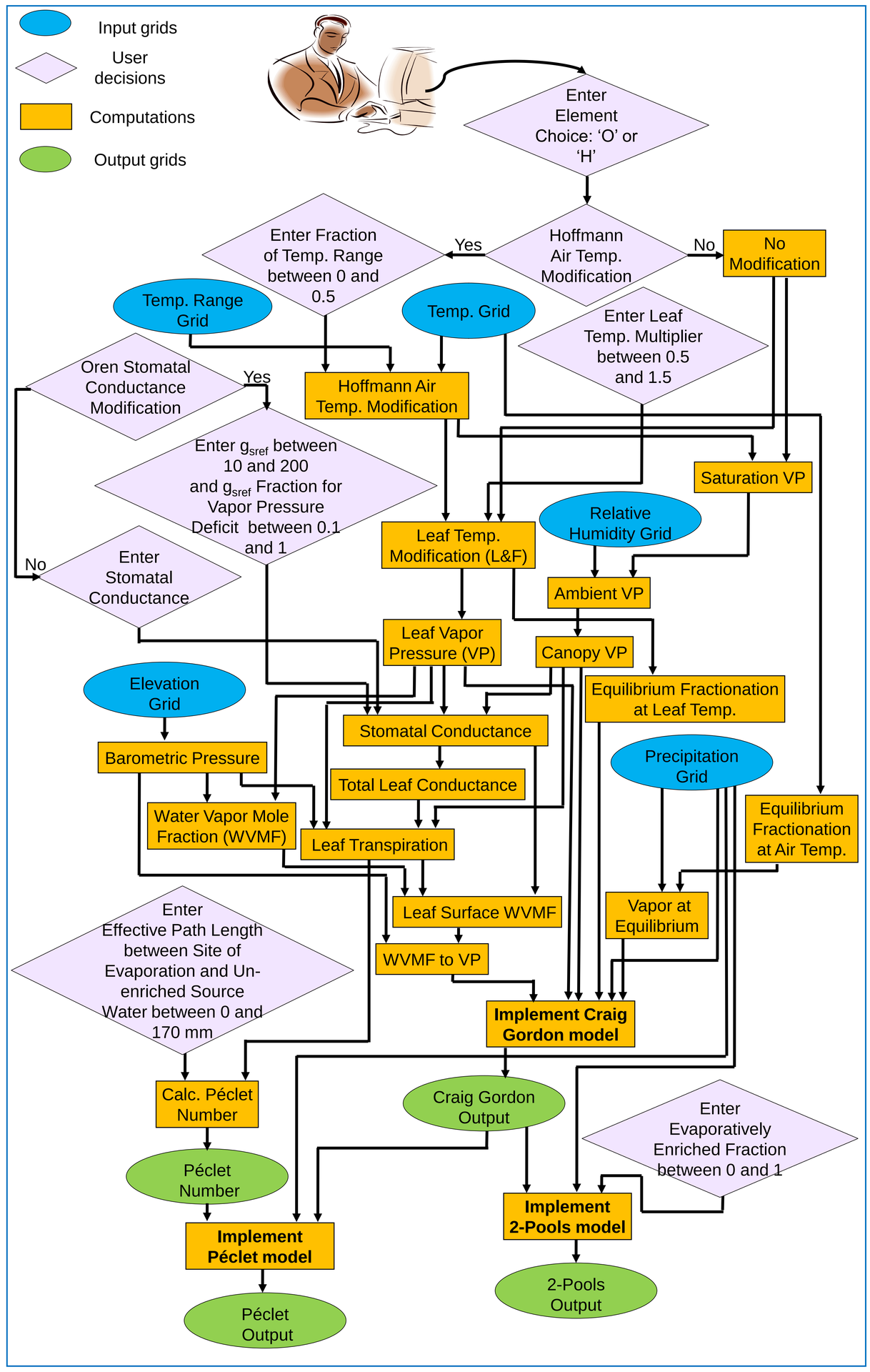
(Roden, et al.1999)

### Péclet

$$\wp = \frac{LE}{CD} \qquad \Delta_L = \frac{\Delta_e \left(1 - e^{-\wp}\right)}{\wp}$$

(Barbour, et al. 2004)

## Leaf Water Models Generation & Implementation Process




## Hoffmann Air Temperature Modification

$$T_{new} = T_{mean} + \left(x * T_{mdr}\right)$$

$T_{new}$ is the new air temperature, $T_{mean}$ is the mean monthly air temperature, $T_{mdr}$ is the monthly mean of the daily air temperature range, and x is a user input for fraction of temperature range fitted between 0.05 and 0.14 by Hoffmann et al.

Hoffmann, et al. 2004

## Leaf Temperature Modification (L&F)

$$T_{leaf} = T_{new} * \left(1 + \frac{y}{100}\right)$$

$T_{leaf}$ is the leaf temperature and y is a user input for leaf temperature multiplier. $T_{leaf}$ is assumed to be y% warmer than the air temperature.

Lloyd, Farquhar 1994

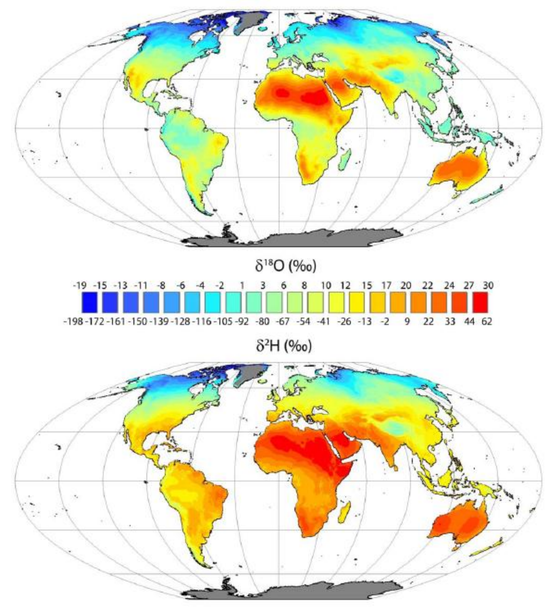
## Stomatal Conductance

$$g_s = g_{sref} - m * \ln D \qquad m = z * g_{sref}$$

$g_s$ is the stomatal conductance, $g_{sref}$ is the reference stomatal conductance at D=1 kPa, D is vapor pressure deficit, and z is the user input for $g_{sref}$ fraction for vapor pressure deficit slope. $g_s$ generally declines with increasing D, apparently in response to changes in leaf water content.

Oren, et al. 1999

## Leaf Water Isoscapes




Global mean annual average leaf water $\delta^{18}O$ and $\delta^{2}H$ isoscapes for the sites of evaporation within leaves.

West, et al. 2008

## IsoMAP – 3 Tier Architecture

**IsoMAP is a web-based cyber infrastructure that allows users a free and global access to a diverse set of web-based tools for isotopic data analysis, modeling and prediction. IsoMAP supports 3 tier architecture:**

**Frontend -** ***provides users with an ability to identify, explore, and select spatiotemporal domains, data, and models, and to specify parameters for model execution. It also handles the display of end results to the users and provides them with an ability to manipulate the results through web-GIS interface or download the results to the local computer.***

**Middle layer aka Common Modeling Interface (CMI) -** ***serves as a link of communication between the front-end user interface and the back-end data and computation functions.CMI is a scalable and modular workflow management system that facilitates selection, processing, and provisioning of data products needed by IsoMAP-hosted models, and provides an extensible framework supporting the addition of new data and models. Addition of new model content will only require the addition of new model code and metadata to the CMI libraries.***

**Backend -** ***performs all the computations tasks and implements the leaf water models depending upon the selections made by the user at the front end.***

## Process flow in IsoMAP




## References

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Barbour MM, Roden JS, Farquhar GD, Ehleringer JR (2004) Expressing leaf water and cellulose oxygen isotope ratios as enrichment above source water reveals evidence of a Pe´clet effect. Oecologia 138: 426–435.

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