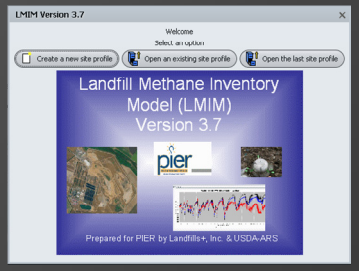
A NEW IPCC TIER 4 SITE-SPECIFIC MODEL FOR LANDFILL METHANE EMISSIONS INCLUSIVE OF SEASONAL METHANE OXIDATION



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Sixth Annual – 2009
Climate Change Symposium
The Future Is Now: Climate Change Mitigation, Impacts, and Adaptation Research

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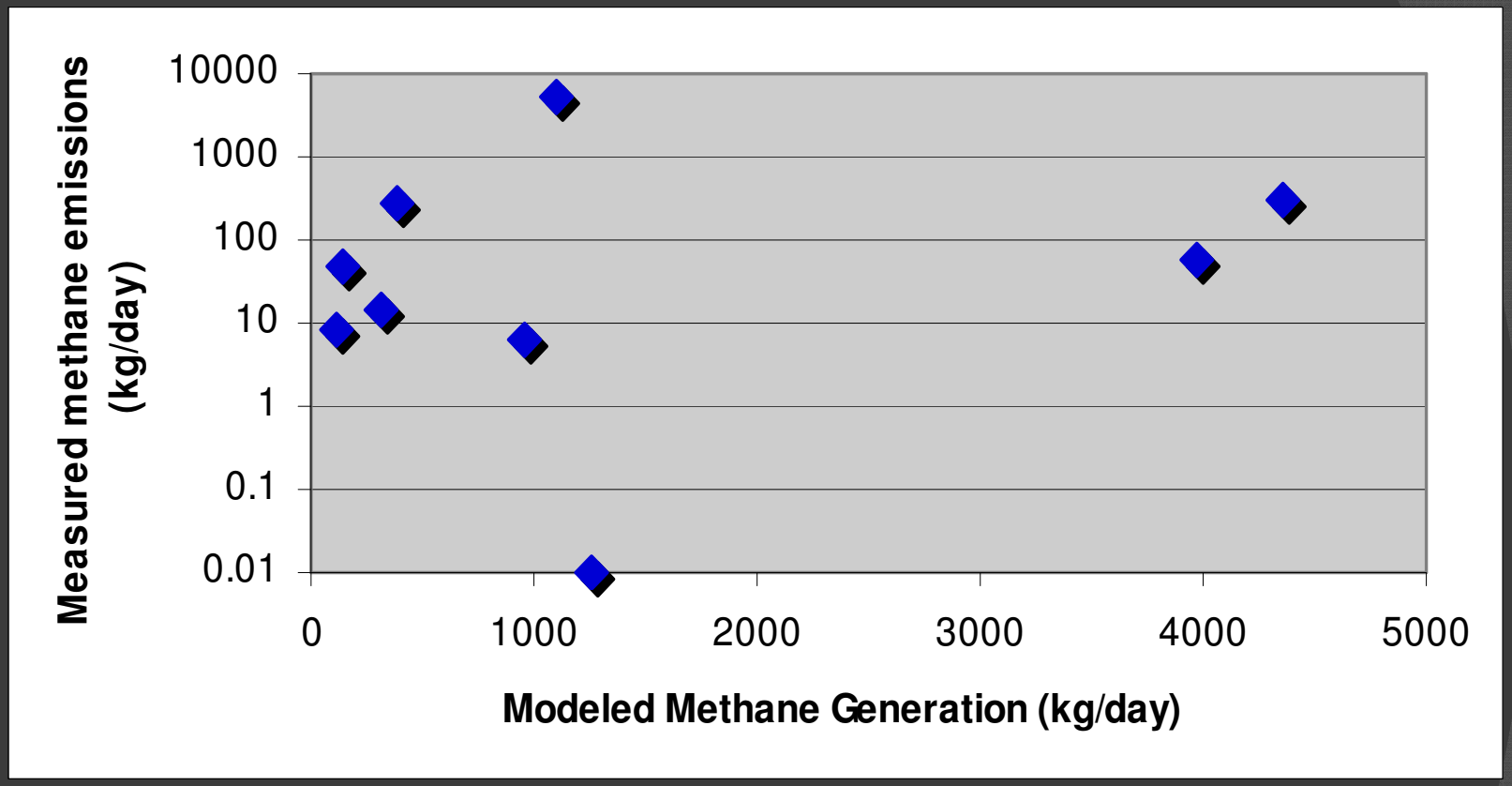
Why develop a new GHG inventory method for landfill methane emissions ?

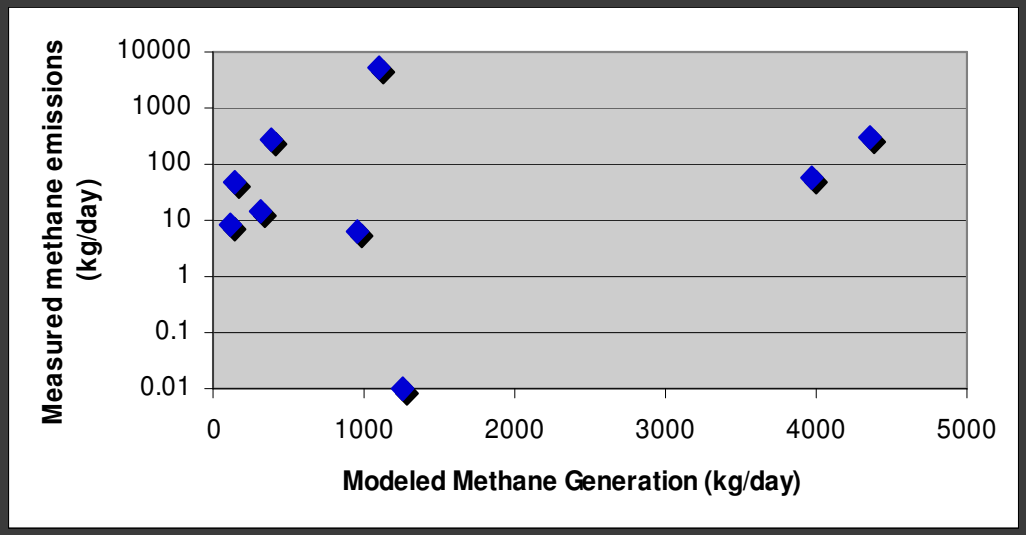
- Historical reliance on theoretical methane generation models for GHG inventory methods

Modeled landfill methane generation is not a very good predictor for landfill methane emissions...

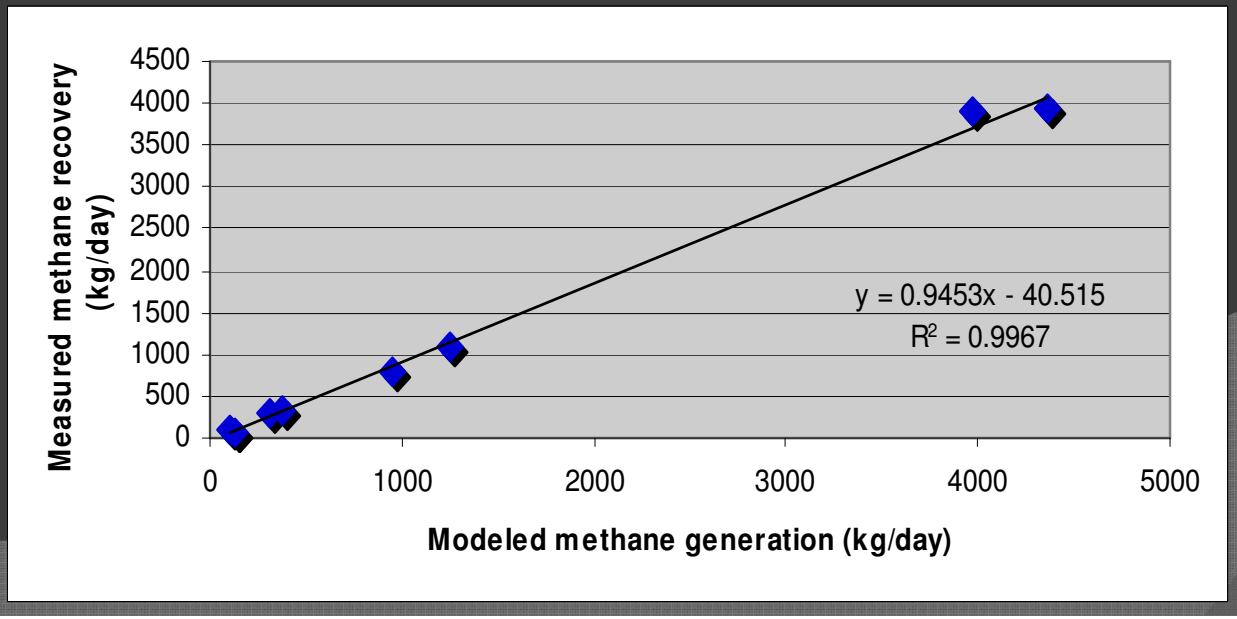


Data from a methane mass balance study at 7 different cells at three different French sites (Spokas et al., 2006)

Modeled landfill methane generation is not a very good predictor for landfill methane emissions...



However, the modeled generation is a good predictor for landfill methane recovery



Why develop a new GHG inventory method for landfill methane emissions ?

- Historical reliance on theoretical methane generation models for GHG inventory methods
- Recent field studies in several countries over the last 12 years Improved understanding of process dynamics/mechanisms
- Increased regulatory and market interest in improved methodologies
  - Especially in California (GHG inventory; AB 32; CCAR)
- IPCC guidelines includes site specific model development (Tier 4)

Intergovernmental Panel on Climate Change (IPCC)

National Inventory Guidelines for Landfill Methane Emissions

1996	*2006*
Tier 1: Mass Balance Simplified carbon (C) mass balance independent of time factor	Tier 1: FOD based on IPCC defaults for specified waste fractions: *Tier 1a*: multicomponent FOD based on waste composition *Tier 1b*: multicomponent FOD based on type of disposal site.
Tier 2: FOD ("First Order Decay") First order kinetic model based on methane generation potential (L_o) and kinetic constant (k).	Tier 2: FOD based on country specific model.

New Higher Tier Methods

THIS STUDY →

Tier 3: Use of "representative" whole landfill field measurements.
Scales up field measurements to national level.

Tier 4: Use of more complex site-specific methods with results summed for total national emissions.

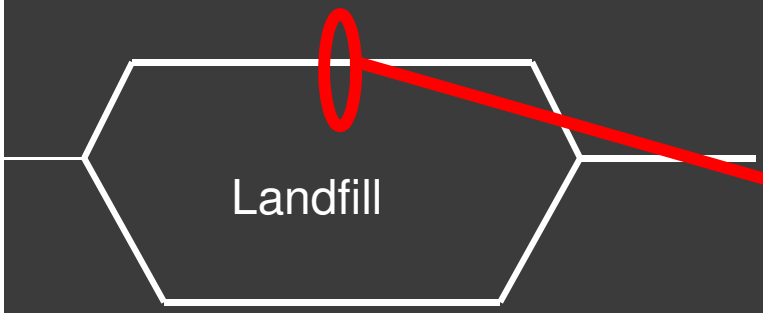
Project Goal

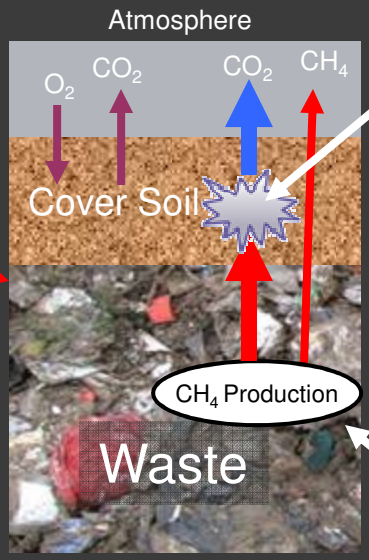
- Develop an improved GHG inventory methodology for landfill methane emissions in California based on a field-validated emissions model inclusive of seasonal methane oxidation

Primary consideration:

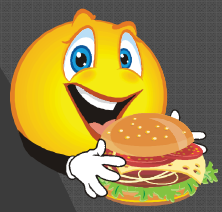
Balancing science-based methods with an appropriate level of detail for a regional GHG inventory

Closer look at soil methane oxidation





CH_4 Oxidation



Methanotrophic oxidation:
[aerobic] methane consumption in cover soils

Dependent on:

- Temperature
- Soil moisture

} Climate

- Oxygen presence

A very important consideration is methane oxidation in landfill cover soils => Reduction of landfill methane emissions by aerobic methanotrophic microorganisms:

Methanogenesis:
[anaerobic] methane production in waste (gas generation models)

- Balancing the methane oxidation *capacity* of cover soils vs. methane transport to and through the cover
- Current inventory methodologies allow either 10% or zero methane oxidation
  (10% based on Czepiel et al., 1996 for Nashua, NH landfill)
  However, recent studies have indicated that this percentage is higher (Chanton et al., 2009)
- Previous studies have observed that soil matric potential explains 53–87% of the temporal variation in CH_4 oxidation (Borken et al., 2003).

Creating a New Tier 4 GHG Inventory Methodology for California

- **Move focus to CH_4 EMISSIONS rather than CH_4 GENERATION**
- **Use of site-specific data for model implementation**
  - **Site location used to predict annual patterns for air temperature, precipitation and solar radiation**
  - **Coverage areas and characteristics of daily, intermediate, and final covers**
    - **Model currently handles up to 10 different cover types**
    - **Maximum depth of cover is 100 inches**
    - **12 USDA soil texture classes as well as 11 non-soil categories (sludge, wood chips, tires, etc.)**
  - **Presence or absence of gas recovery system**
- **Entry of site specific concentration gradients or model defaults**

Java Model Overview

Landfill Methane Inventory Model – LMIM

(1) Site Location, Cover, and Gas Recovery Information (interactive template)

(2) Environmental Simulation/Meteorology
air temperature, precipitation, solar radiation, evaporation

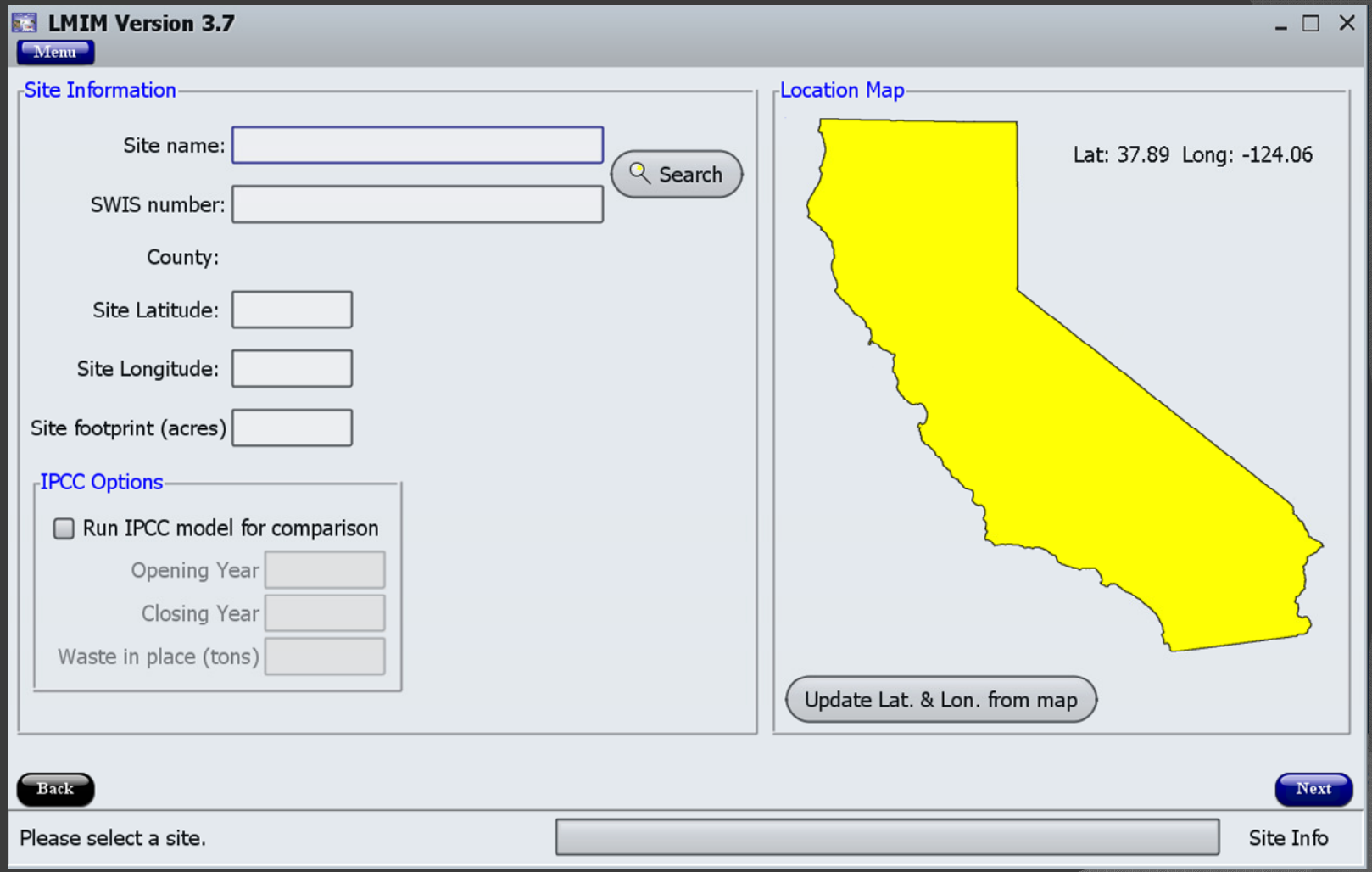
(3) Soil Microclimate Model
temperature and moisture (1D)

(4) CH_4 Emission/Oxidation Model
(1D diffusion)

Annual Methane Emission Estimate for Site

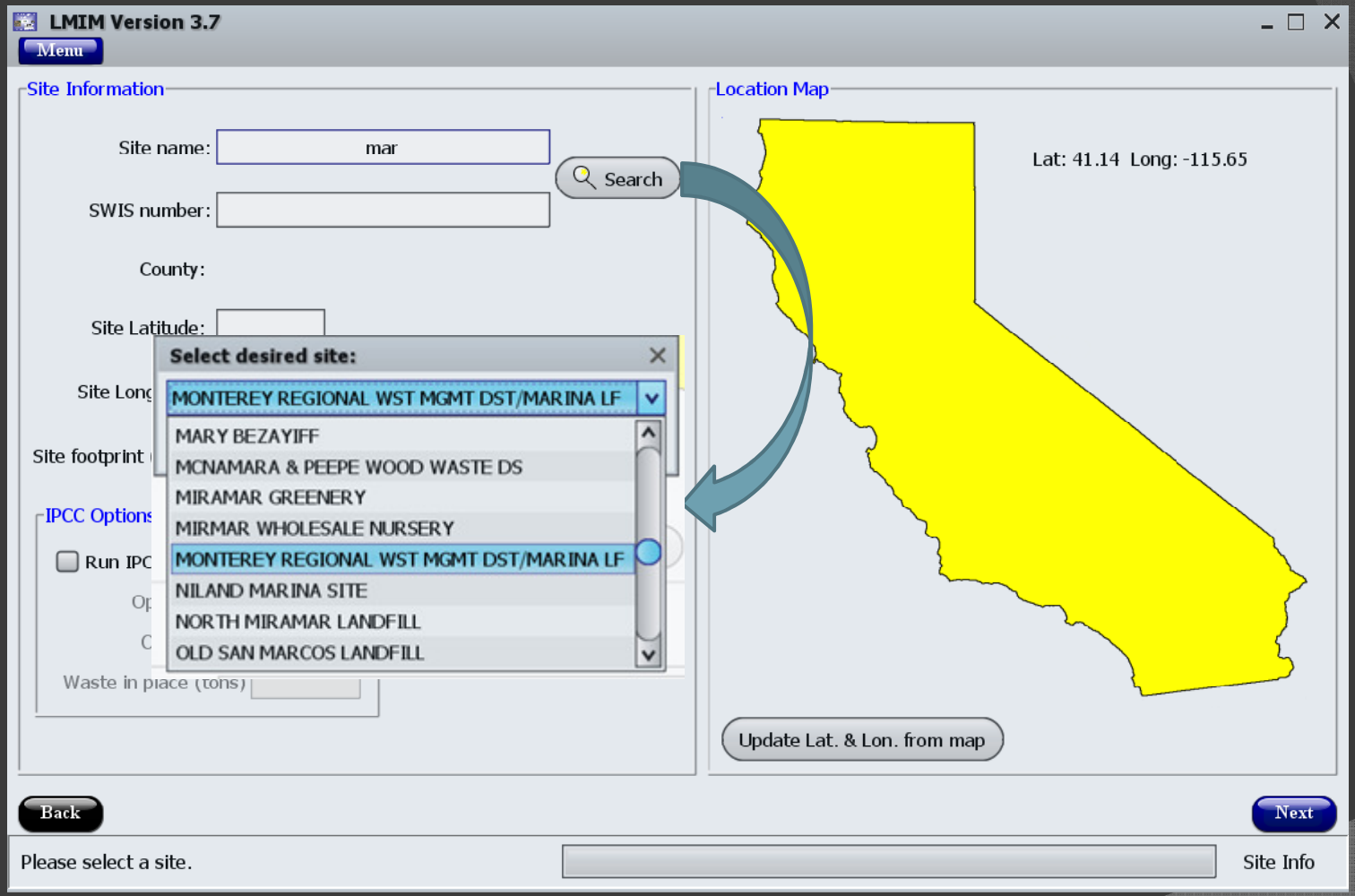
Field Validation and Supporting Laboratory Studies

LMIM

- 

Site Properties → Waste Information → Cover Editor → Weather Simulator

LMIM



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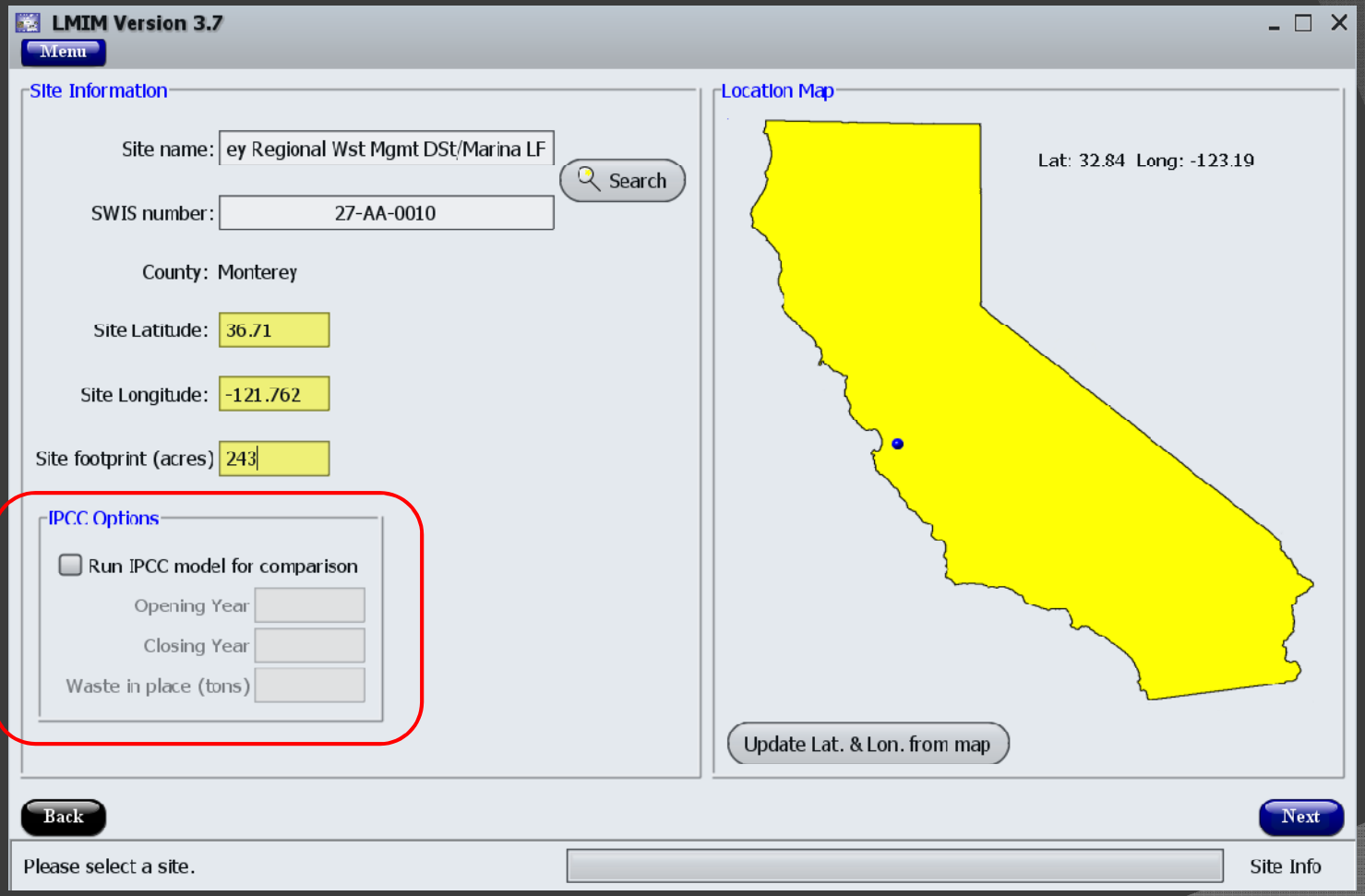

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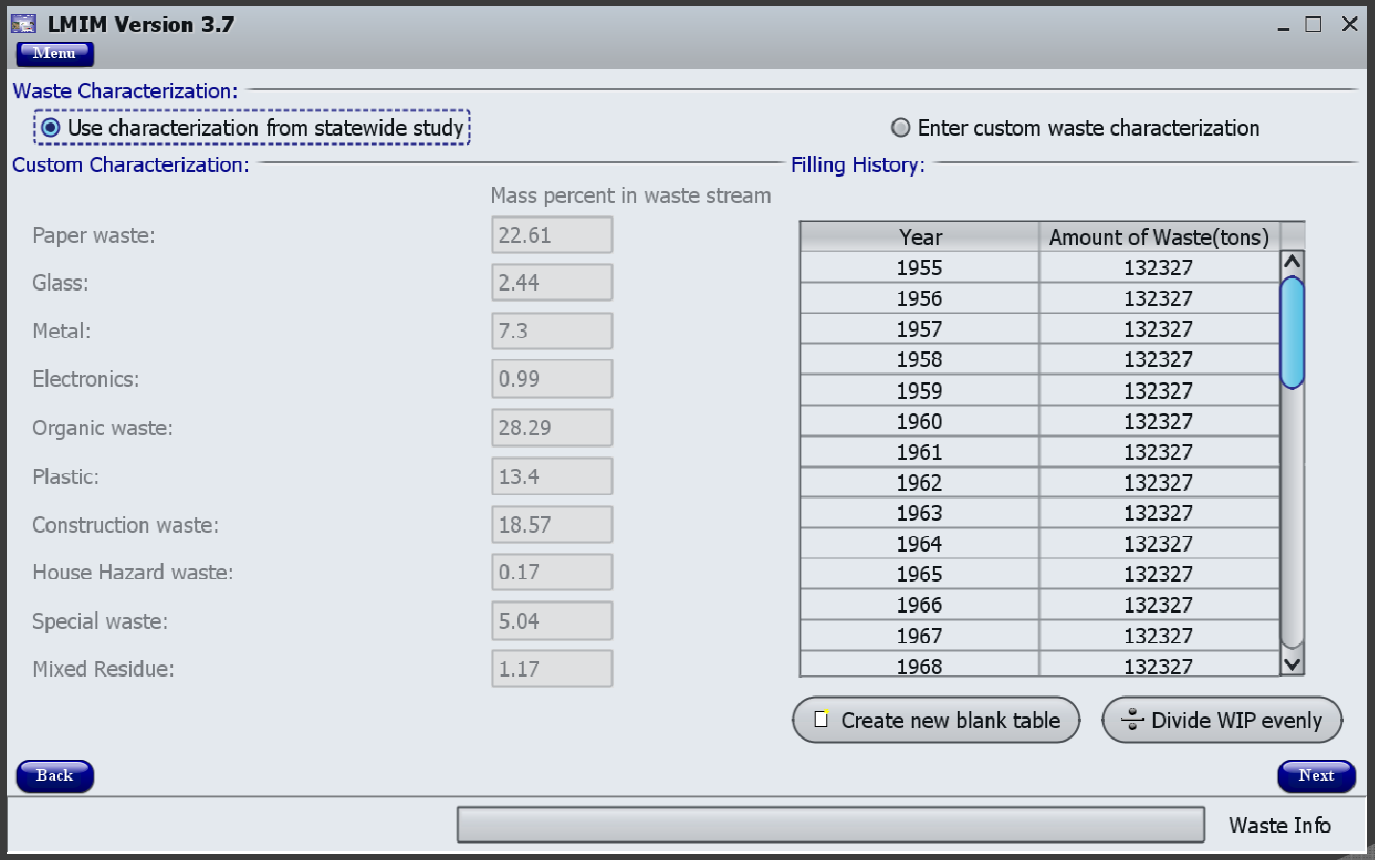

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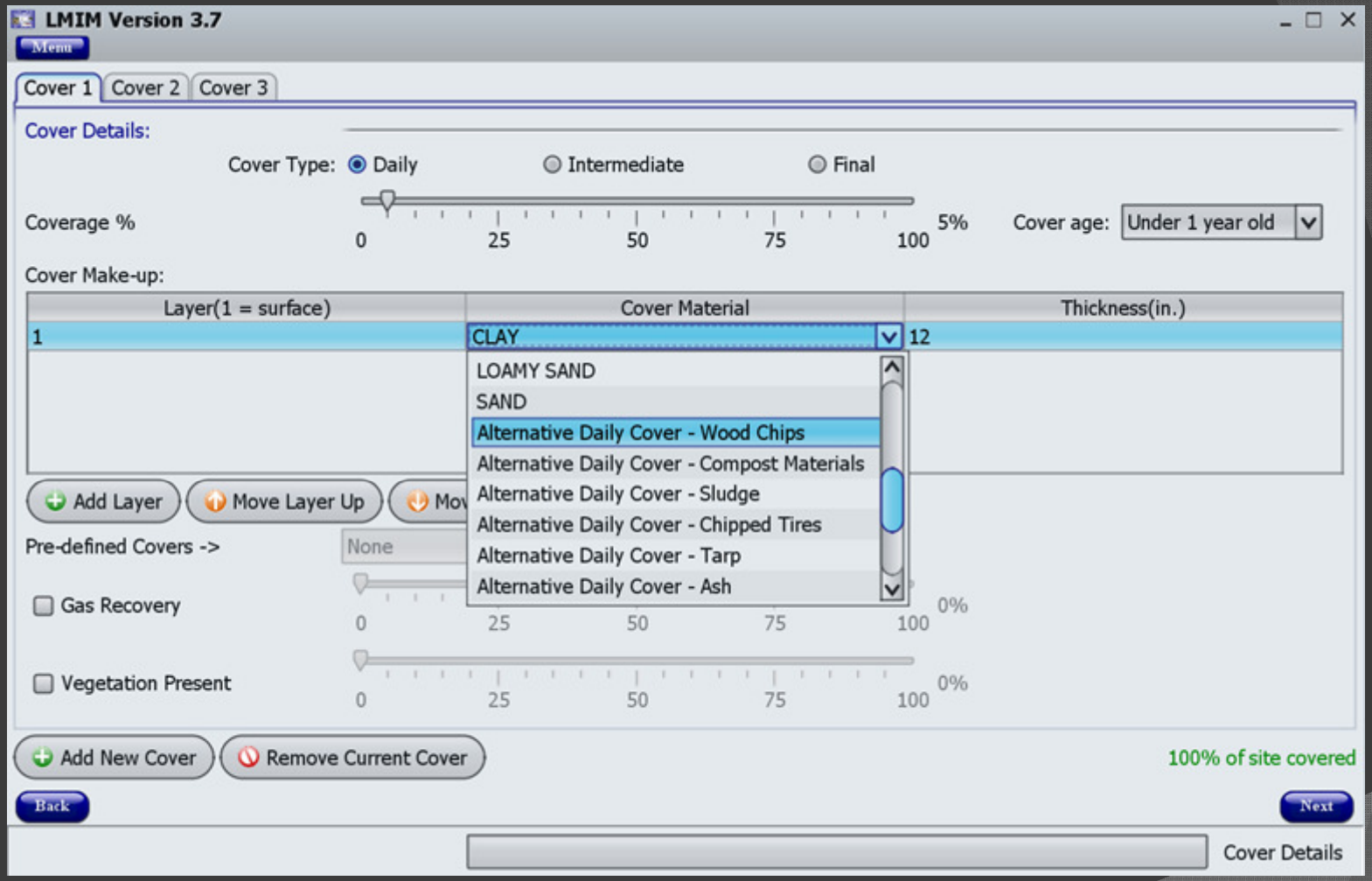

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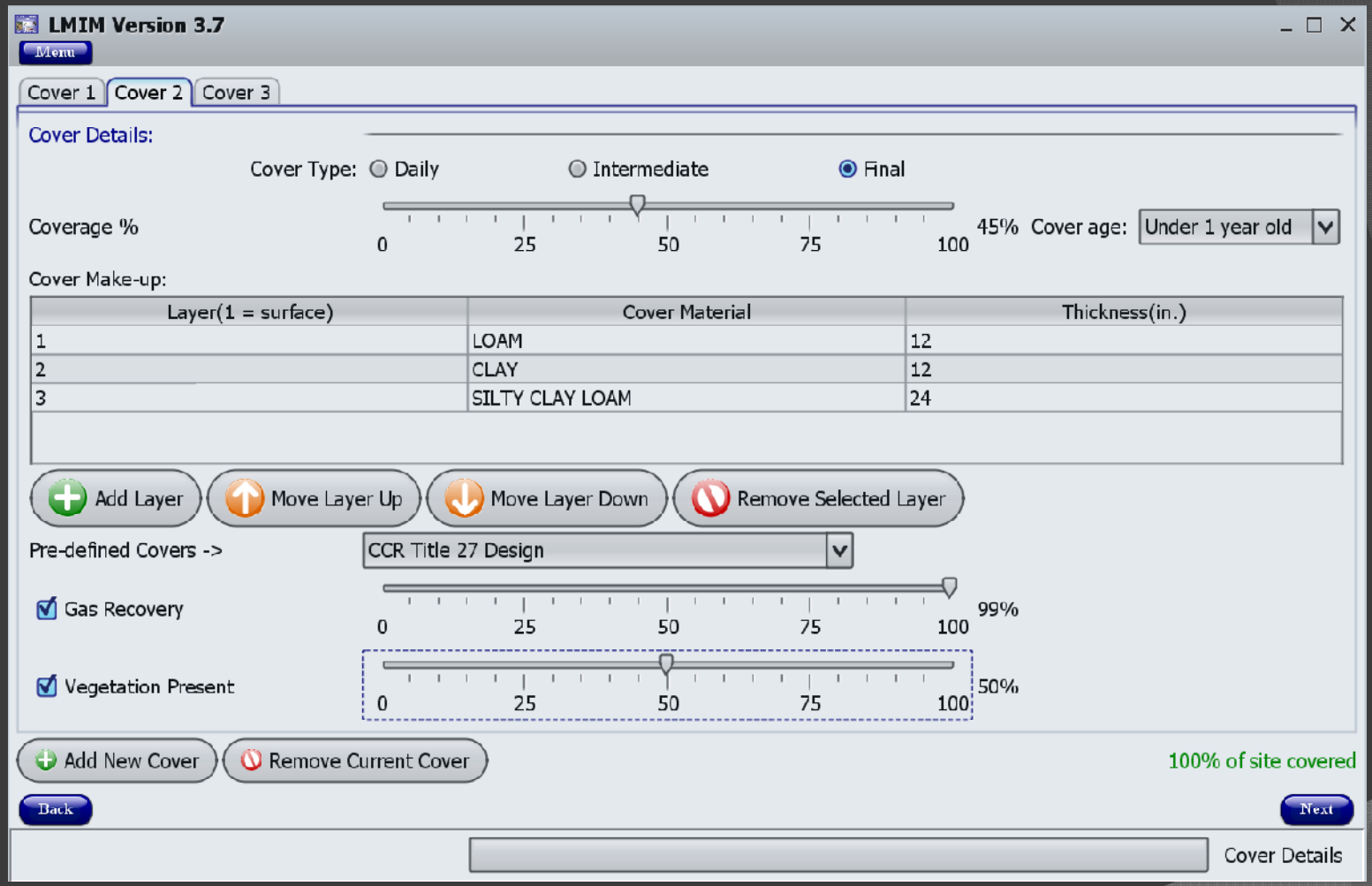

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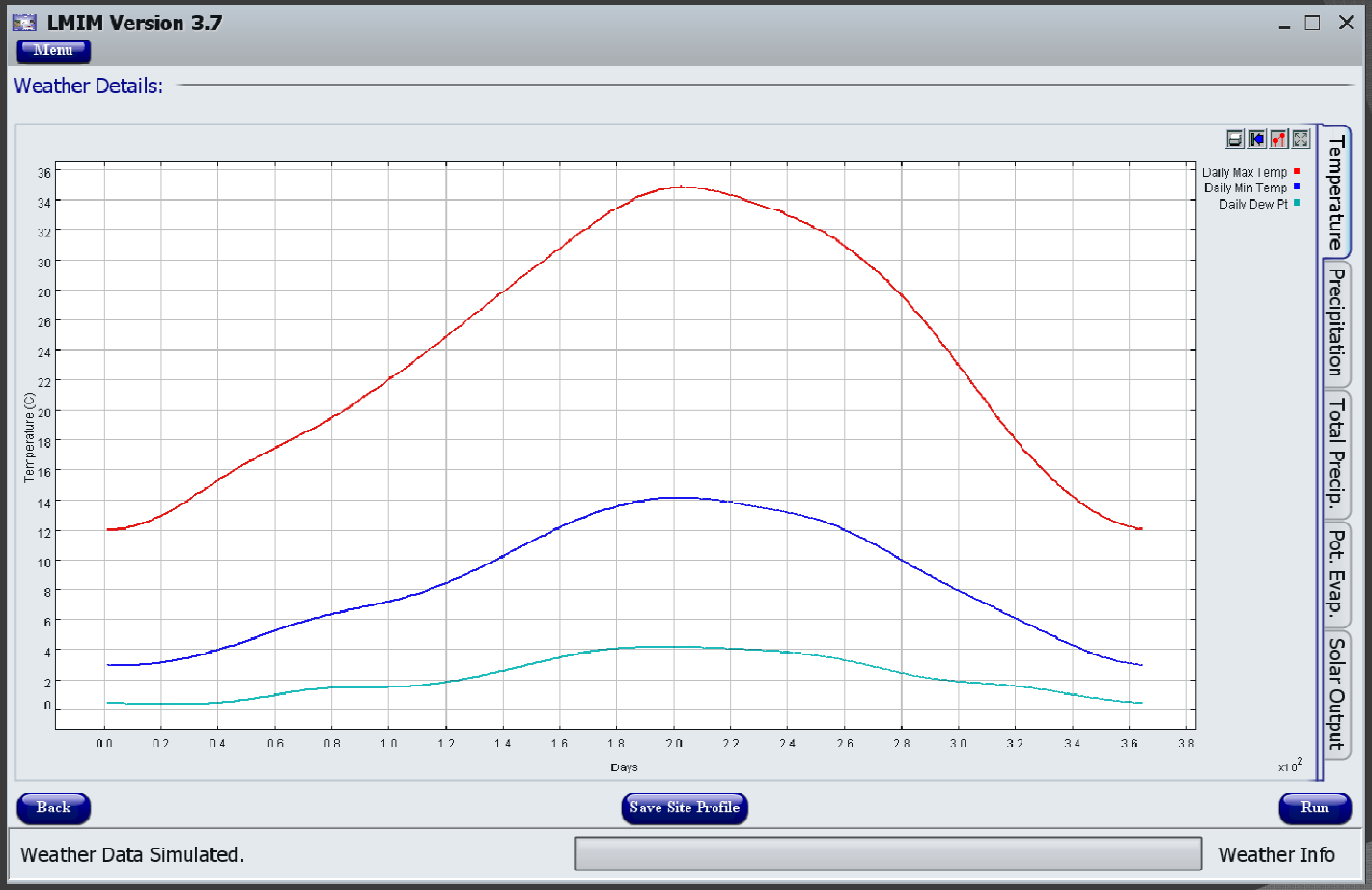

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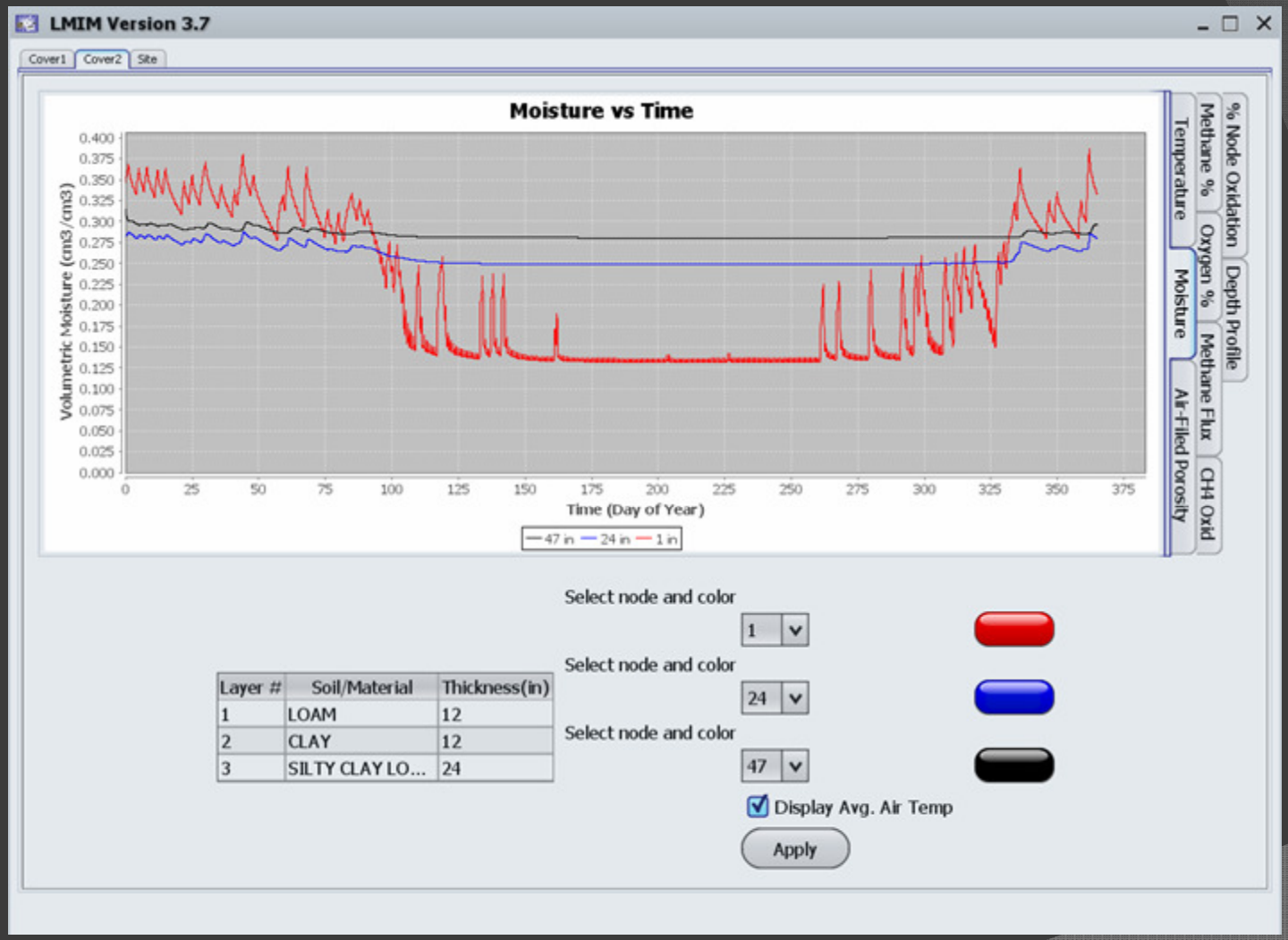


Site Properties → Waste Information → Cover Editor → Weather Simulator → Model Output

Field/Laboratory Validation of Method

- **Field validation over 2 annual cycles at:**
  - **coastal** — **Marina LF (Monterey)**
  - **semi-arid** — **Scholl Canyon LF (LA County)**

- **Additional field validation using recent WMX data at**
  - **Lancaster Landfill (Desert → Mojave)**
  - **Tri-Cities (Bay Area →Fremont/San Francisco Bay area)**
  - **Kirby Canyon (San Jose)**

Field Validation

- Process level studies of methane emission rates (mg $CH_4/m^2/day$) using static closed chambers at Marina and Scholl Canyon (855 fluxes)

- Stable carbon isotopic method of Chanton and Liptay (2000) for determination of fractional methane oxidation.

- Supporting data for each flux:
  5cm soil moisture (TDR), soil gas concentrations, soil temperature (RTD), GPS location, air temperature, continuous chamber temperatures, and continuous water vapor (in chamber)

- Other supporting field studies/data:
  continuous sub-surface CO_2 & pressure monitoring
  Differential pressure in chamber
  CO_2 & N_2O flux data

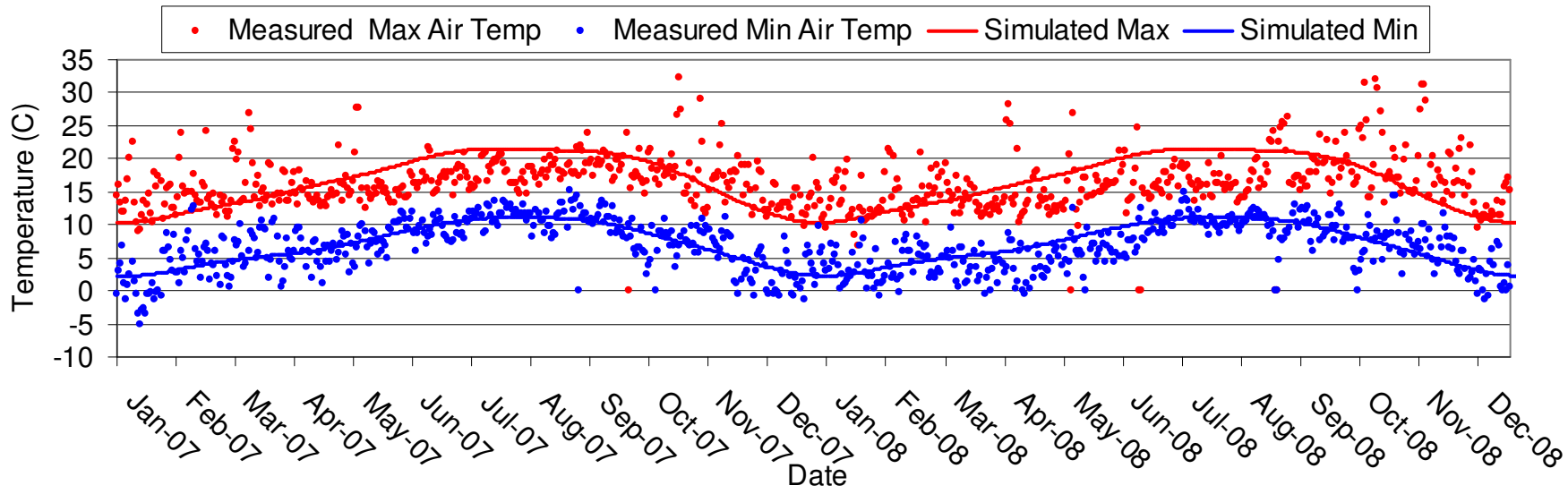
Model Comparisons:

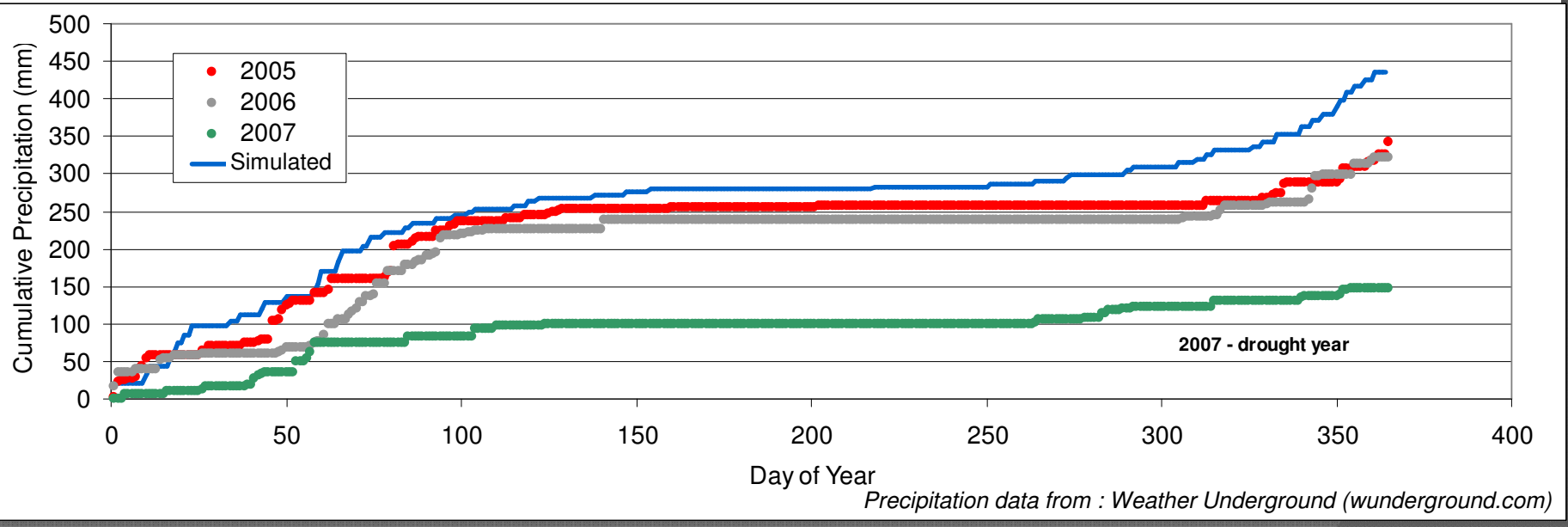
- Air temperature/Precipitation Predictions
- Modeled Soil Temperature
- Modeled Soil Moisture
  →Need to modify model to allow input of actual meteorological data
- Surface CH_4 Emission Comparison

Air Temperature/Precipitation Simulation

- Monterey, CA – Marina Landfill

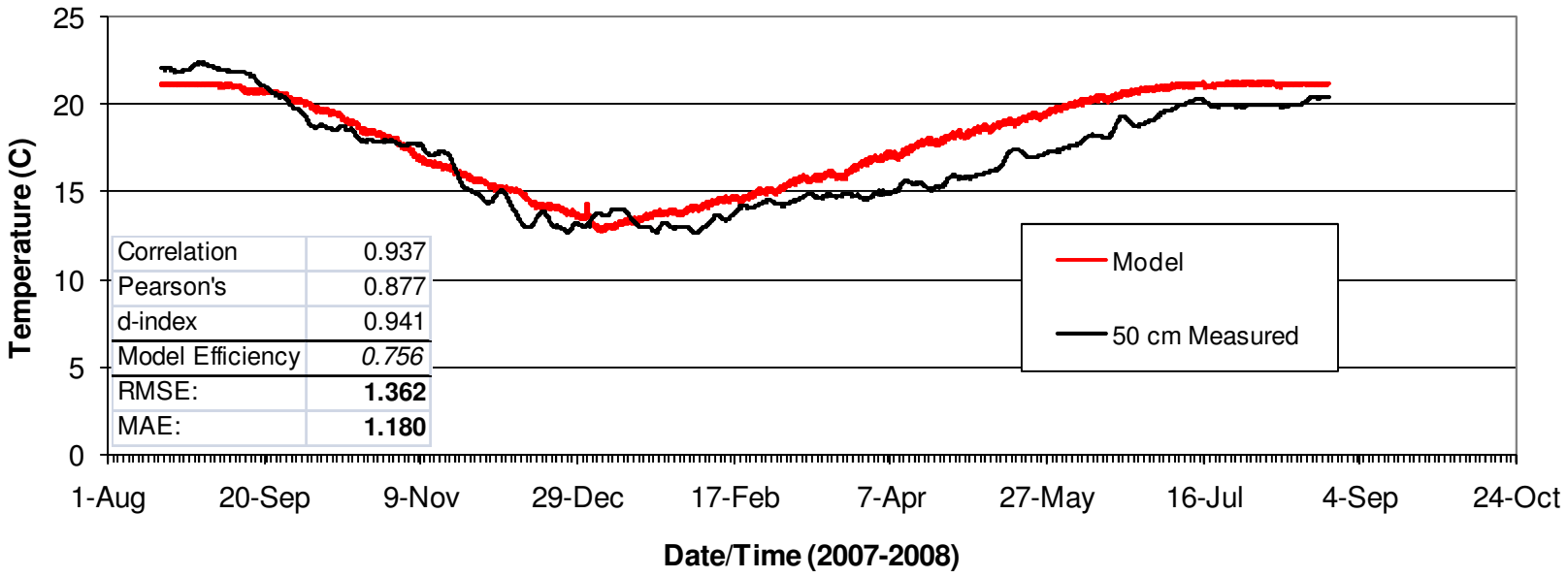
d-index	0.922
Model Efficiency	*0.619*
RMSE:	**0.478**
MAE:	**1.835**

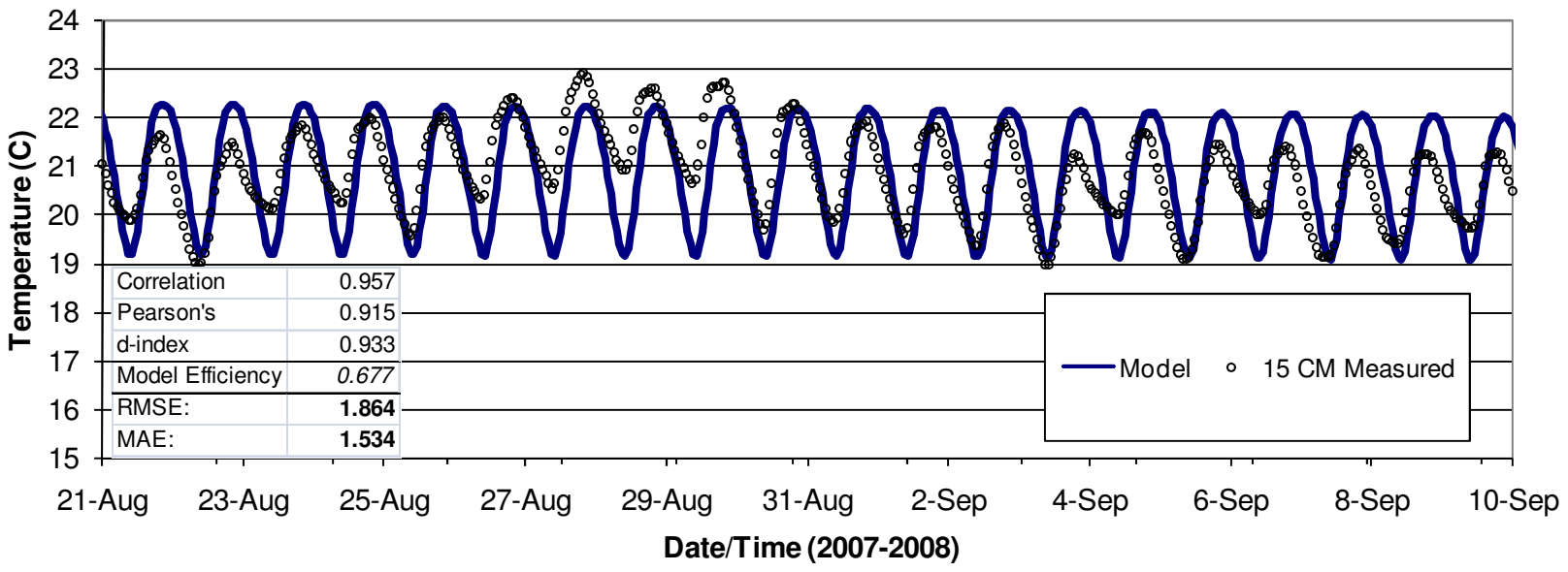




Precipitation data from : Weather Underground (wunderground.com)

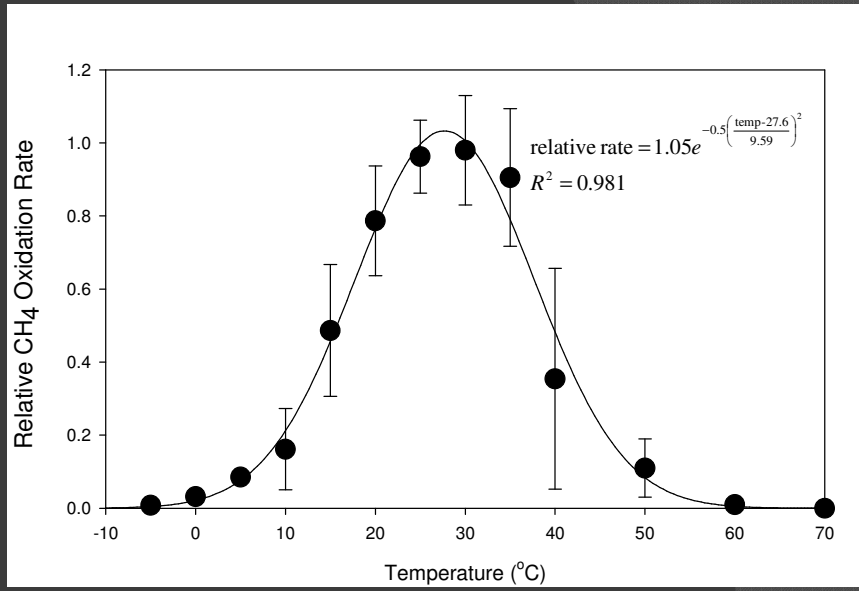
Marina Landfill Comparison
15 cm (intermediate cover) and 50 cm depth (final cover)

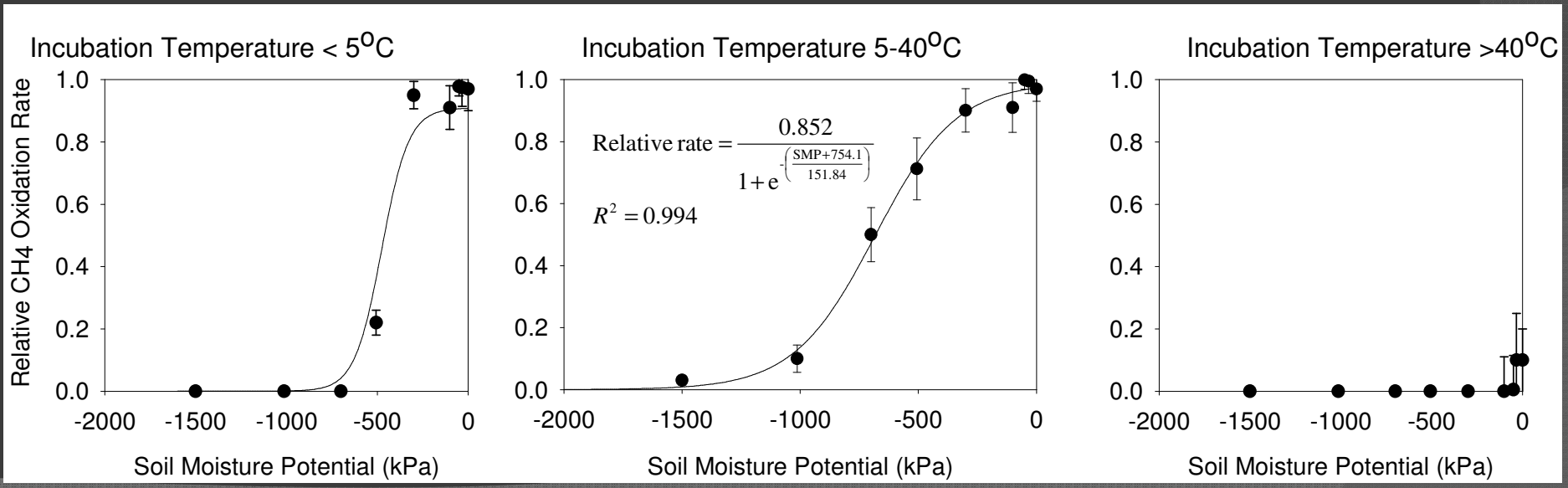




Laboratory Studies for Methane Oxidation Modeling

- A total of 2,112 soil incubations have been completed using Marina and Scholl Canyon cover soils
- Temperature range of 0-70 °C and moisture range from -15 bar to zero (saturated) soil moisture potential
- Isothermal and simulated diurnal fluctuations

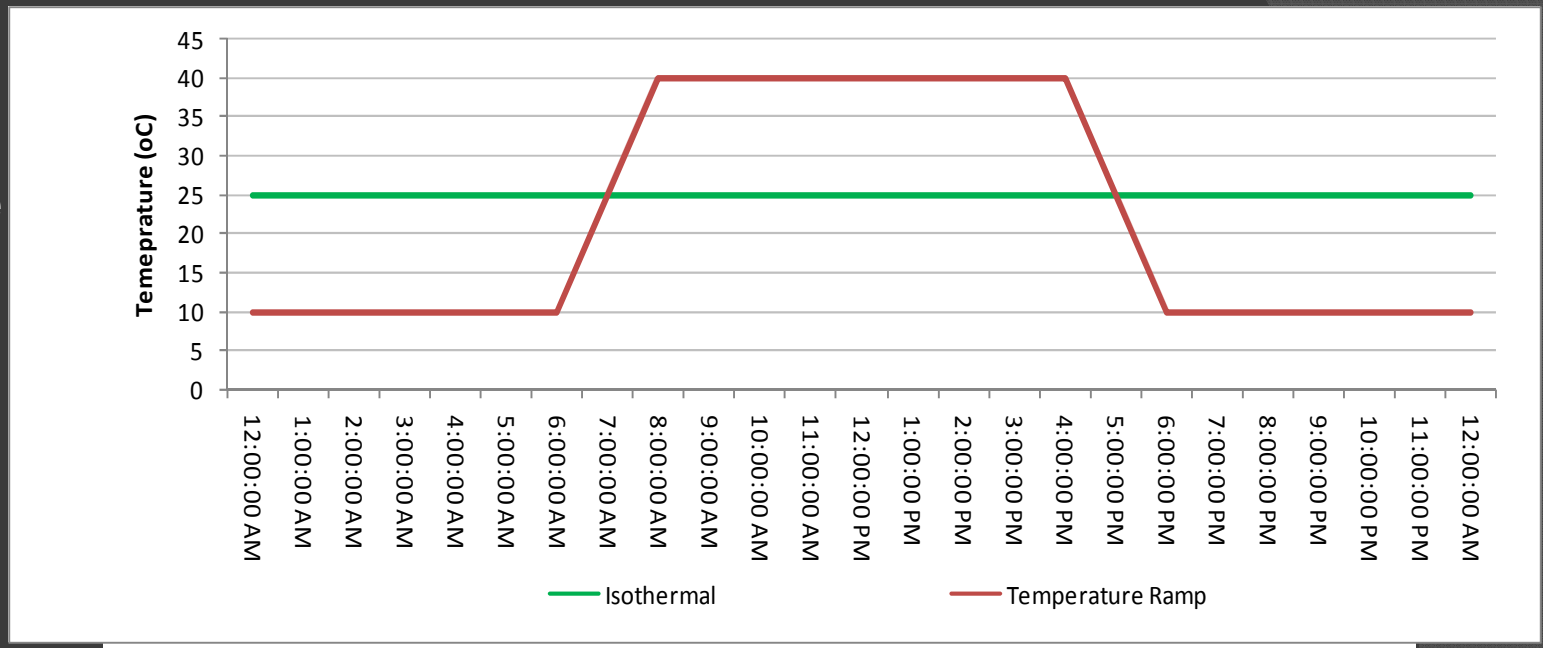




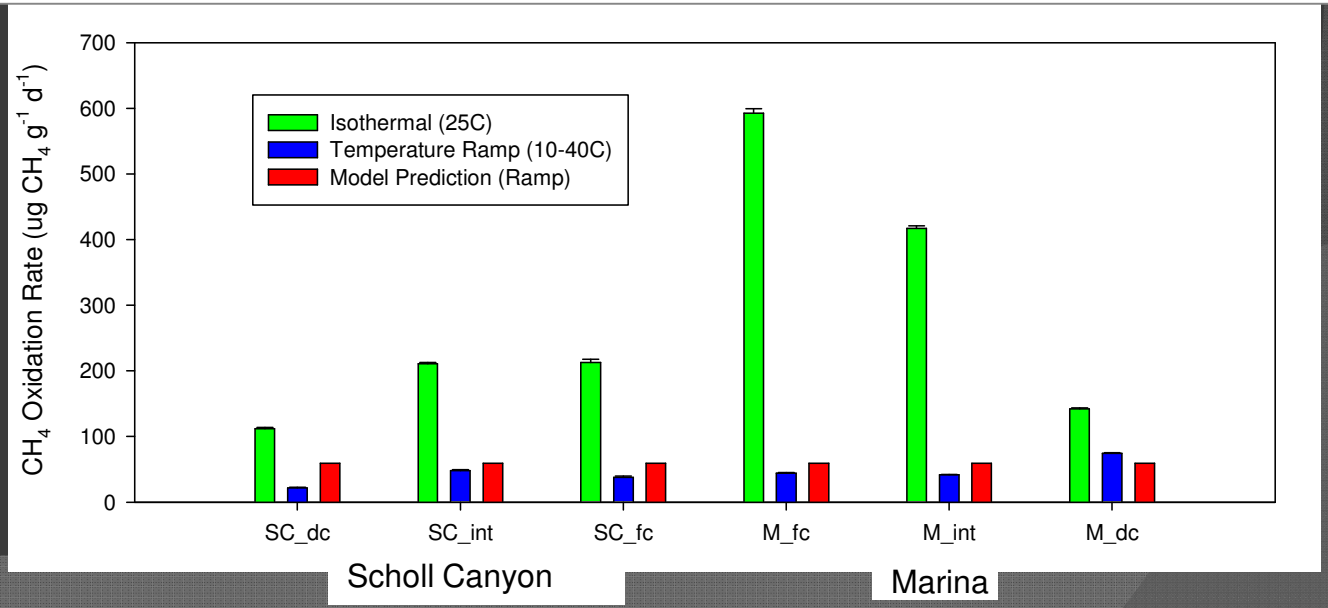
- **The soil moisture potential for 50% of the oxidation activity for the two validation sites ≈ -600 kPa; Threshold = -1200 kPa**

Impact of Diurnal Temperature Fluctuations

Same average daily temperature (25 °C)

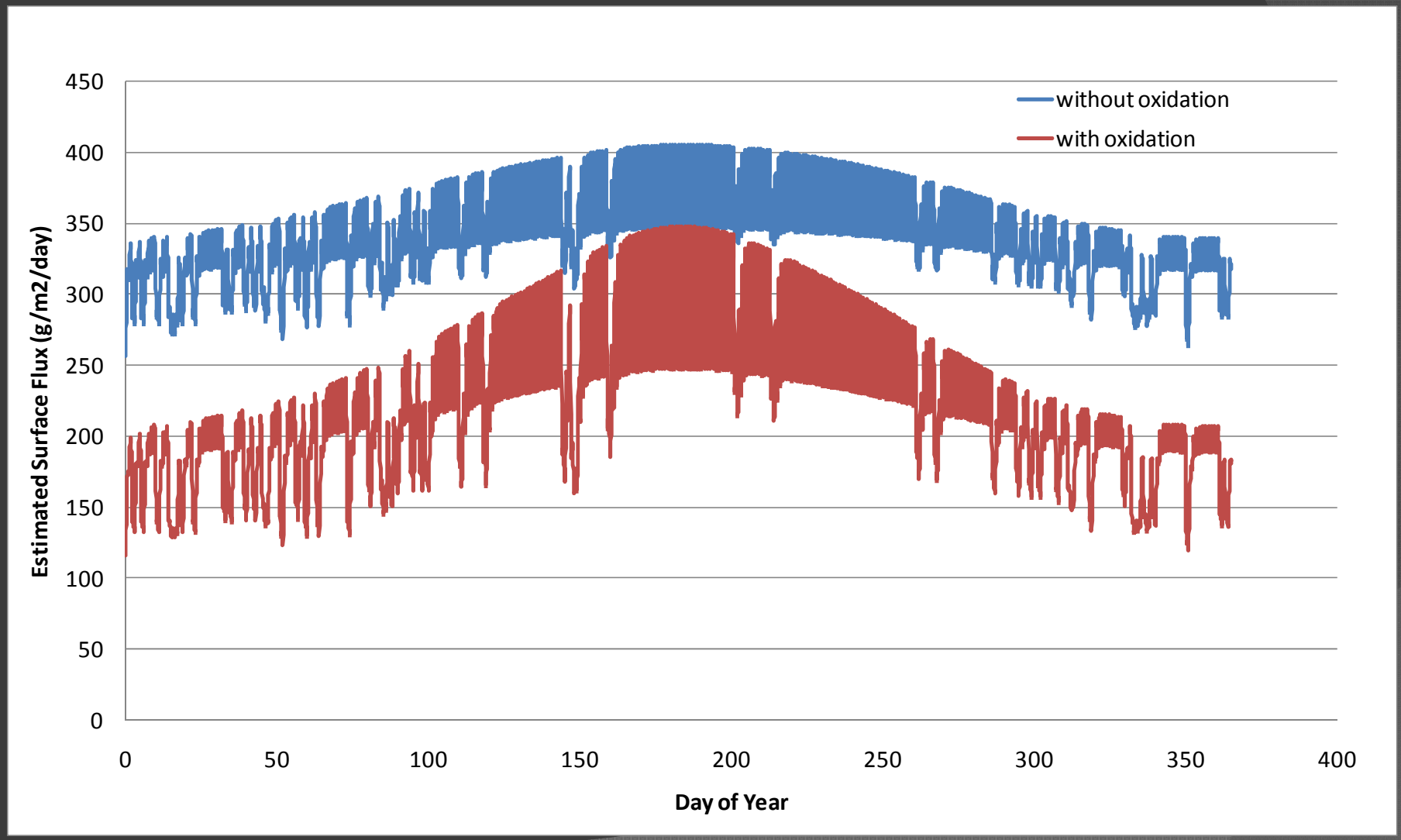


However – differences observed in net oxidation rates



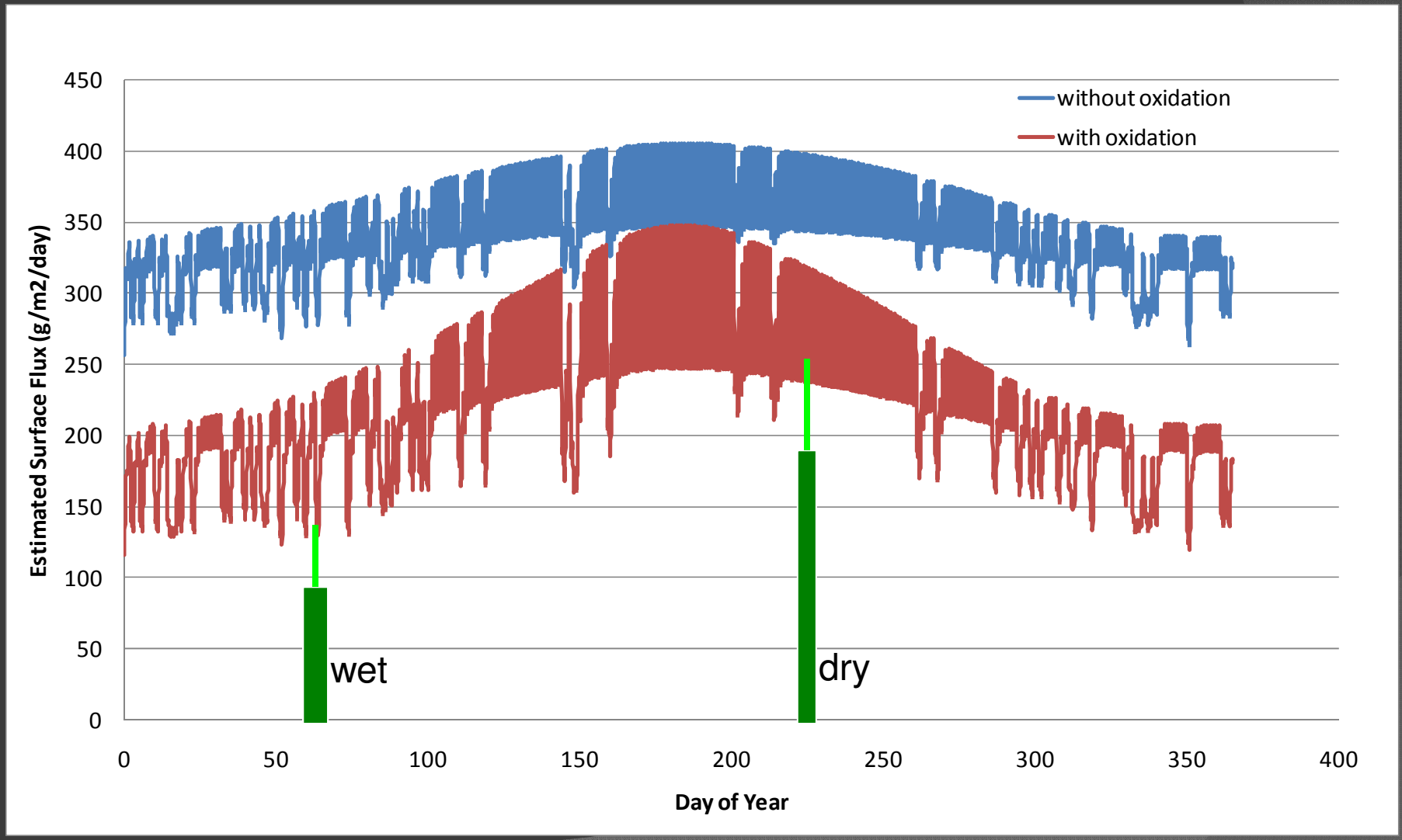
Model Results: Surface Emissions

Marina Intermediate Cover – with and without methane oxidation
30 cm (12” thick) Sandy Clay Loam

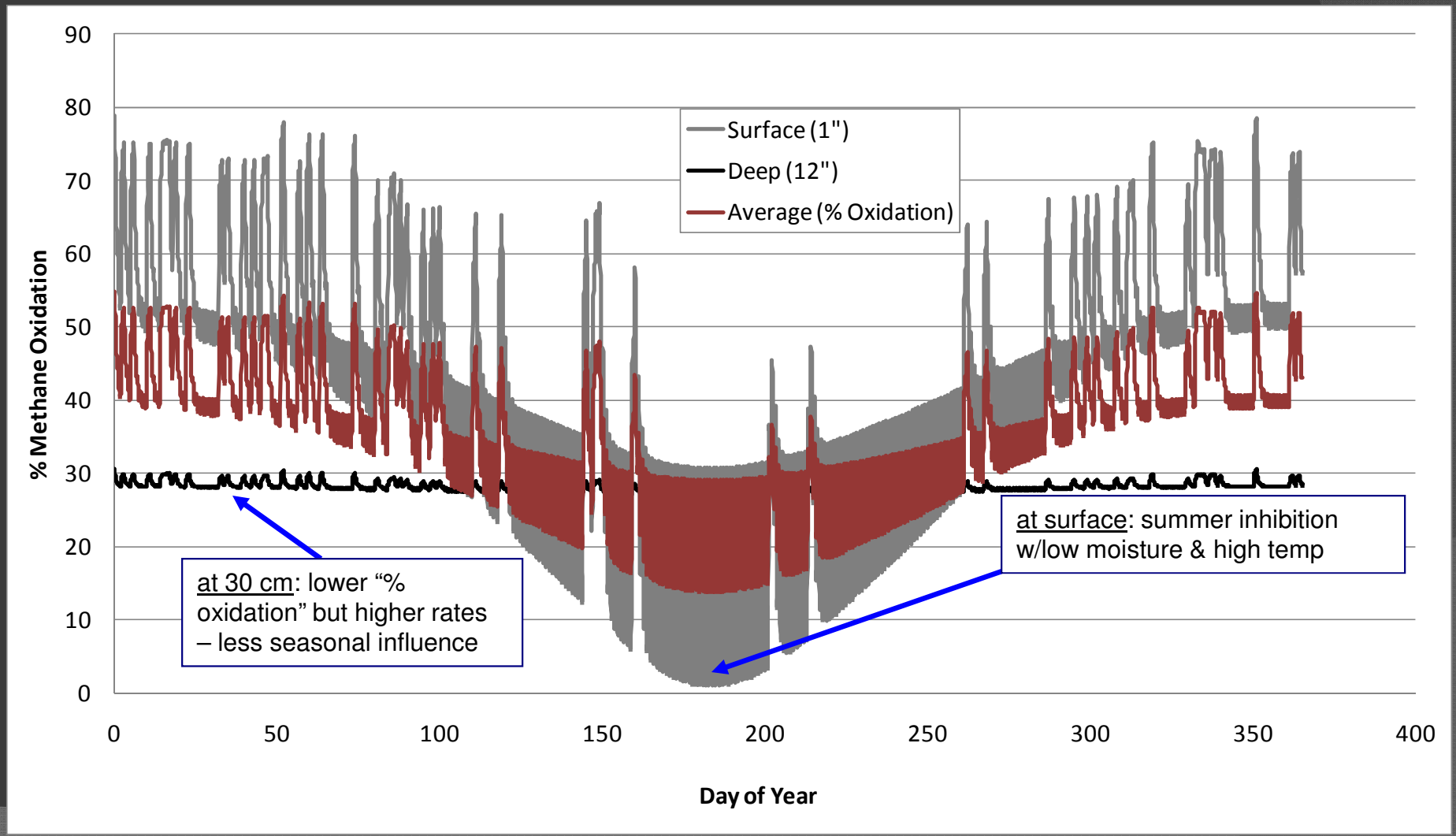


Model Results: Surface Emissions

Comparison to field data



Looking at % Methane Oxidation:

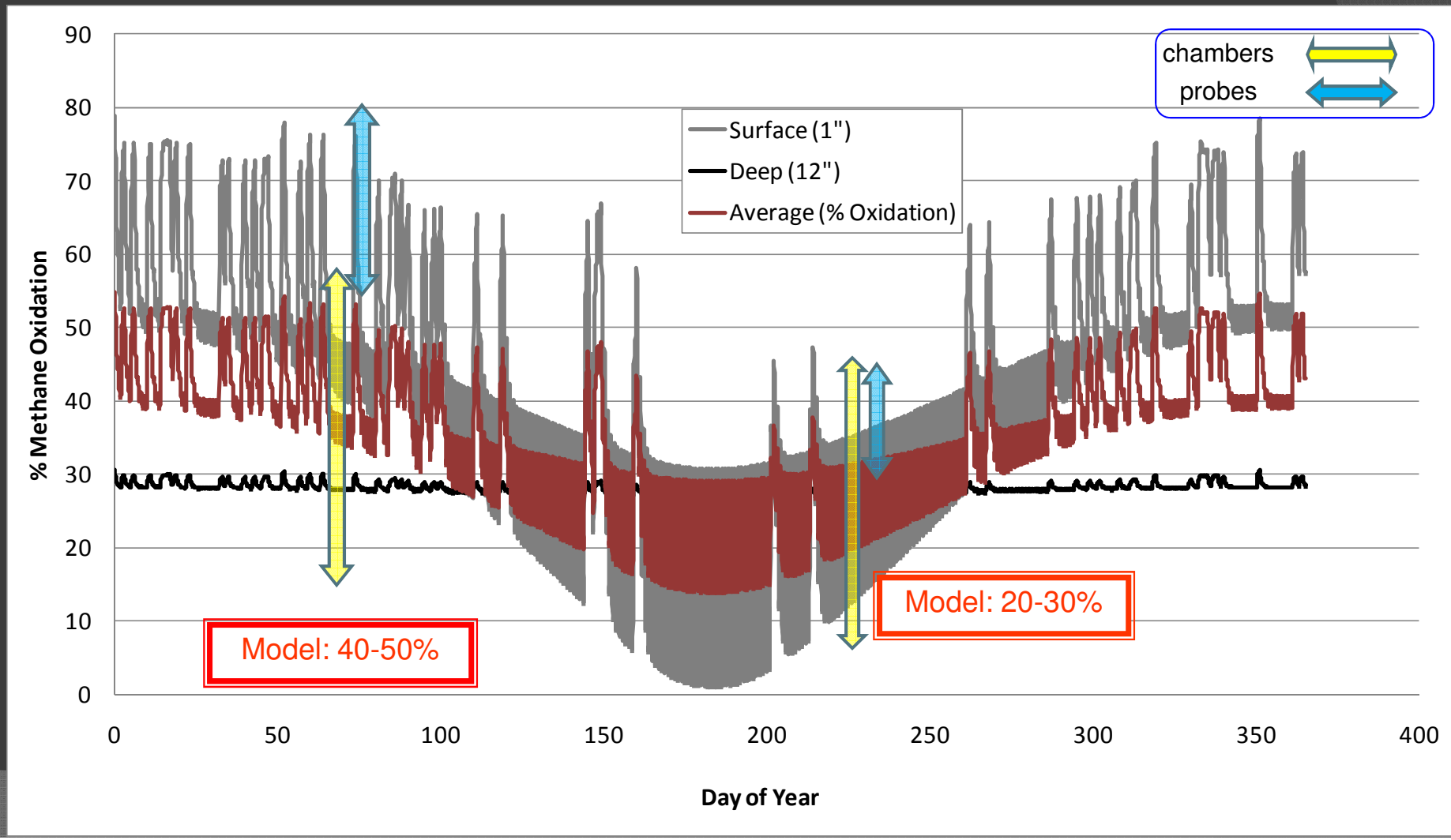


Comparison to Field Data:

Isotopic Analyses → Avg. CH_4 Oxidation Estimation

March (wet) Flux Chambers 10-53% Probes: 50-74%

August (dry) Flux Chambers 2-43% Probes: 25-40%



Summary and Conclusions:

Project is developing a new GHG Inventory Methodology for landfill methane focusing on the fate and transport of methane through the cover soils.

Based on:

- Expansion and integration of existing field-validated modeling approaches for meteorology and soil microclimate, including use of publicly-available climatic databases

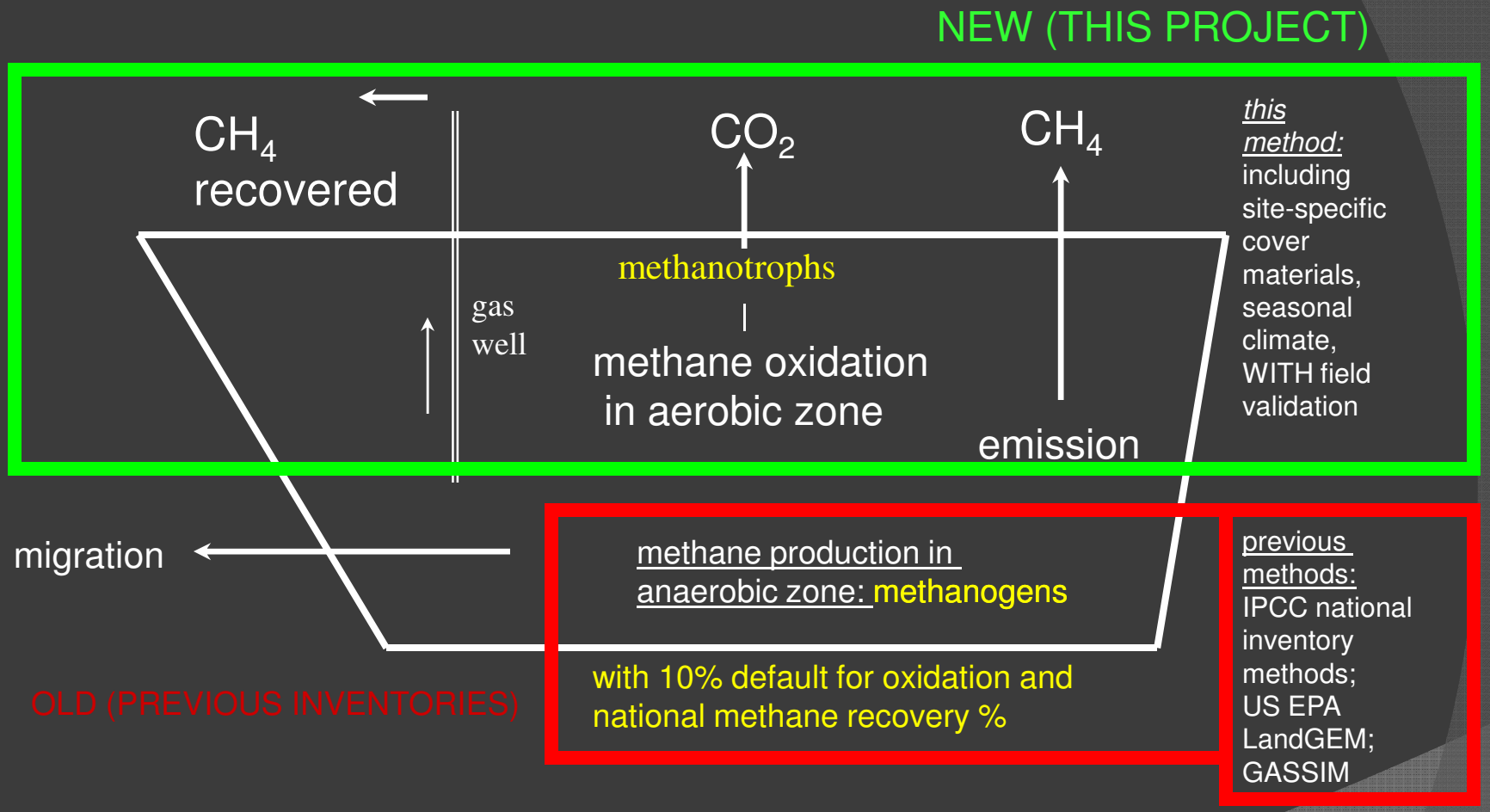
- Site specific data for cover soils and areas with gas recovery

- Modeling for methane emissions inclusive of seasonal methane oxidation in cover soils

- Model Validation:
  - Field validation over 2 annual cycles
  - Supporting laboratory incubation studies for methane oxidation

- Model is currently undergoing Beta testing… should be finalized early 2010

Summary and Conclusions:



"The difficulty lies, not in the new ideas, but in escaping the old ones…"

-John Maynard Keynes

Acknowledgments: CEC, CIWMB, ARB

Special thanks to the field sampling crew:
Chad Rollofson, Martin duSaire, and Dean Peterson

Field Validation Sites:
Scholl Canyon Landfill (Los Angeles County Sanitation Districts)
Marina Landfill (Monterey Bay Regional Waste Management Authority)

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