



# Pavement Temperature Profile Prediction

## Temperature Estimate Model for Pavement Structures (TEMPS)

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# Pavement Temperature Profile Prediction

## ⑩ Improvement of the *Heat Transfer* model [Han et al., 2011 (TAMU)]

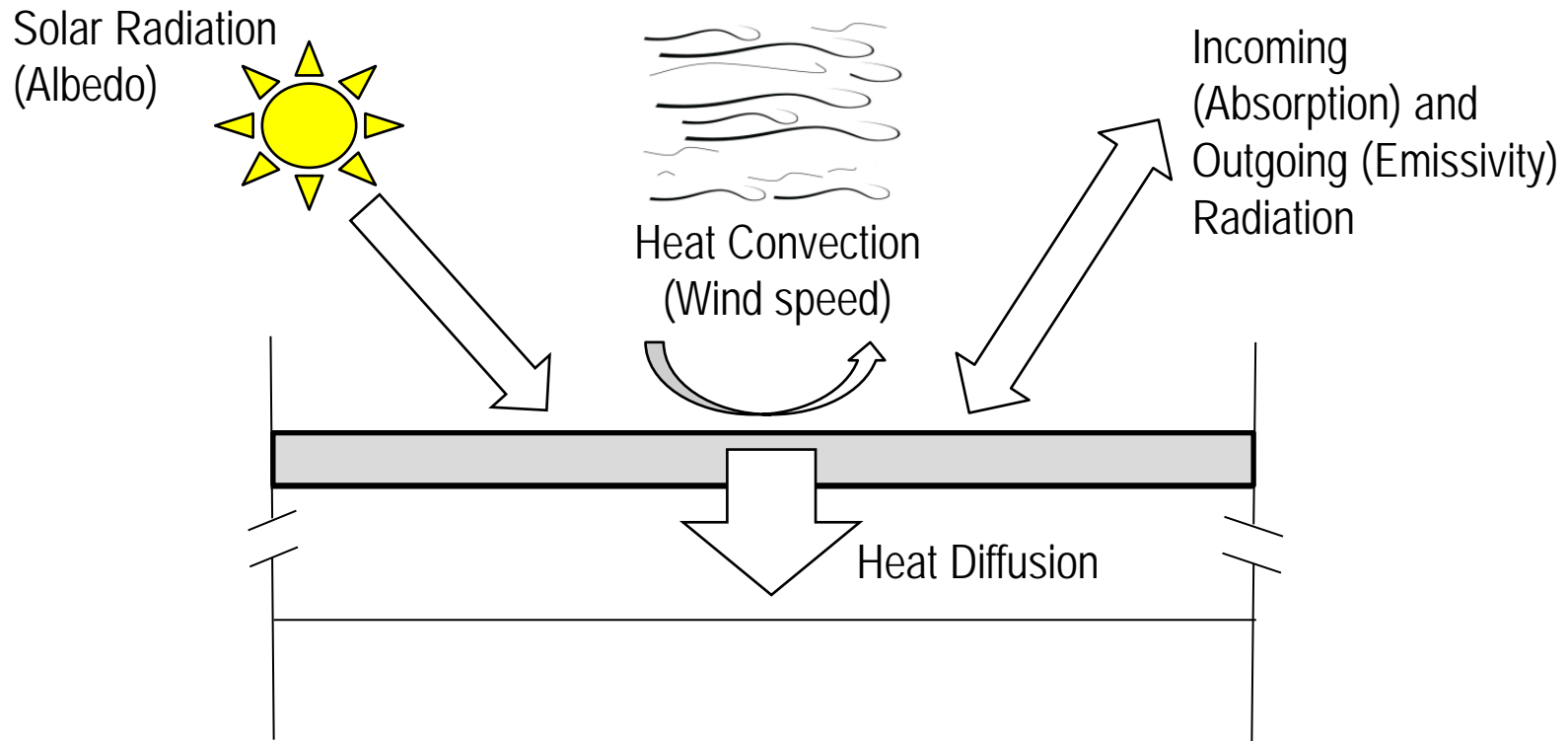
- Enhanced boundary conditions.
- Variable pavement surface radiation properties.

## ⑩ Application of Finite Control Volume method (FCV) with Implicit Scheme [Zia et al., 2014 (UNR)]

- Considering discontinuity in pavement layers' material.
- Improving the time efficiency of calculation.

# Pavement Temperature Profile Prediction

## Heat Transfer Model Concept

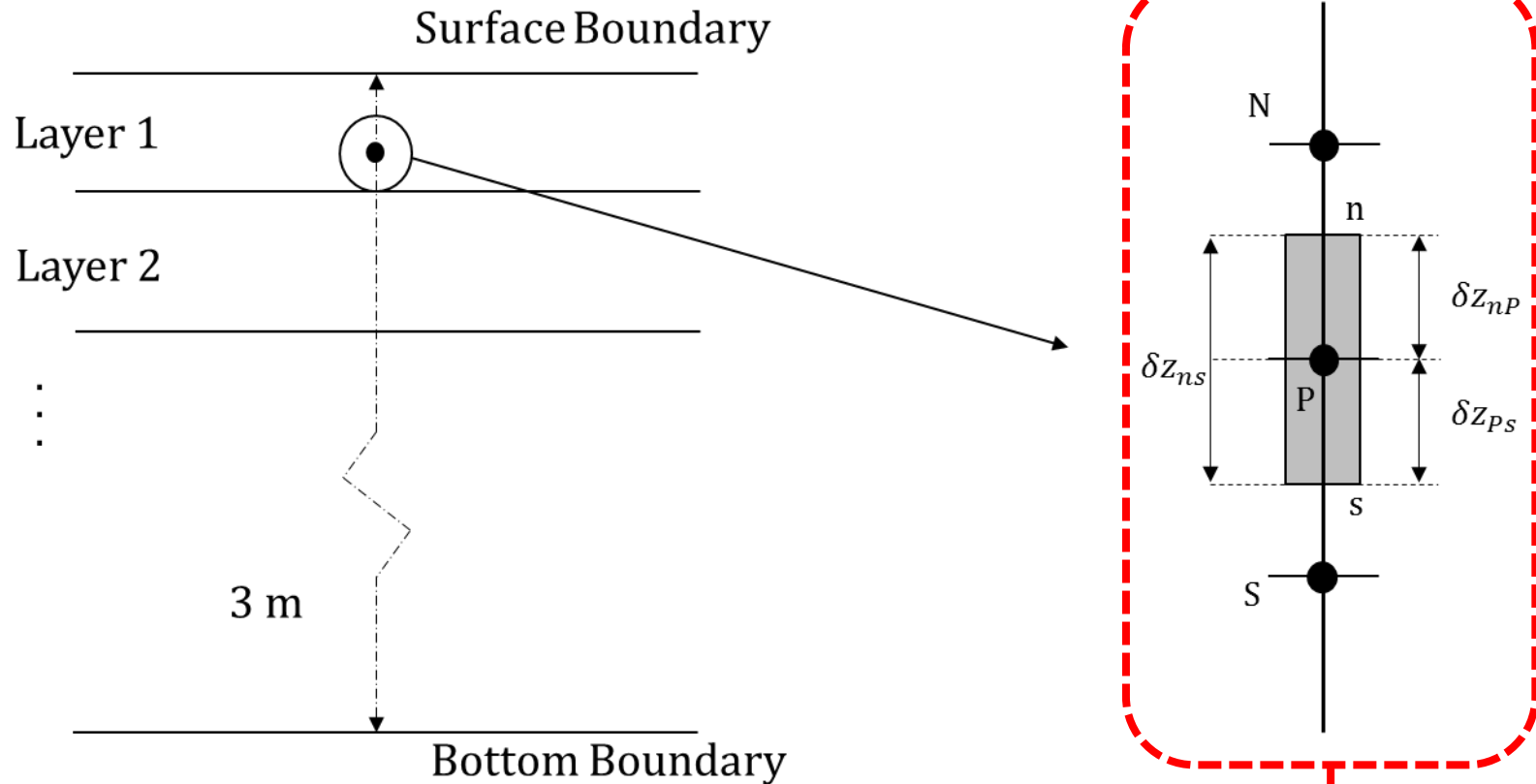


*Heat Transfer Balance Between Pavement Structure & Surrounding Environment*

$$\frac{\partial T}{\partial t} = \frac{\partial}{\partial z} \left( \alpha \times \frac{\partial T}{\partial z} \right), \quad \alpha = \frac{k}{\rho \cdot c}$$

# Pavement Temperature Profile Prediction

## Numerical Computation: Finite Control Volume Method (FCVM)

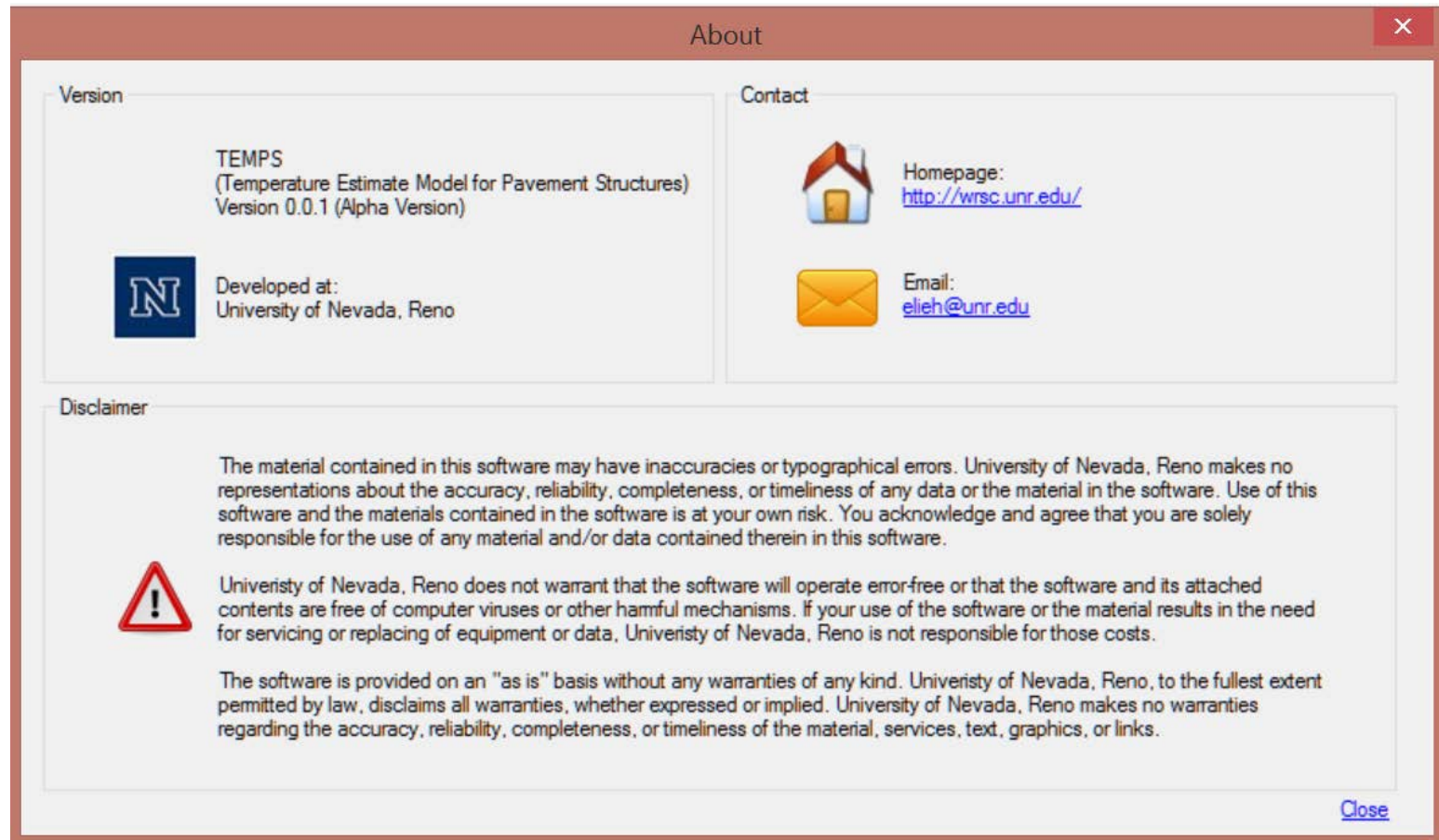


Energy Balance in Each of Control Elements

# Pavement Temperature Profile Prediction

## Standalone Software: TEMPS (Alpha Version)

### Temperature Estimate Model for Pavement Structures (TEMPS)

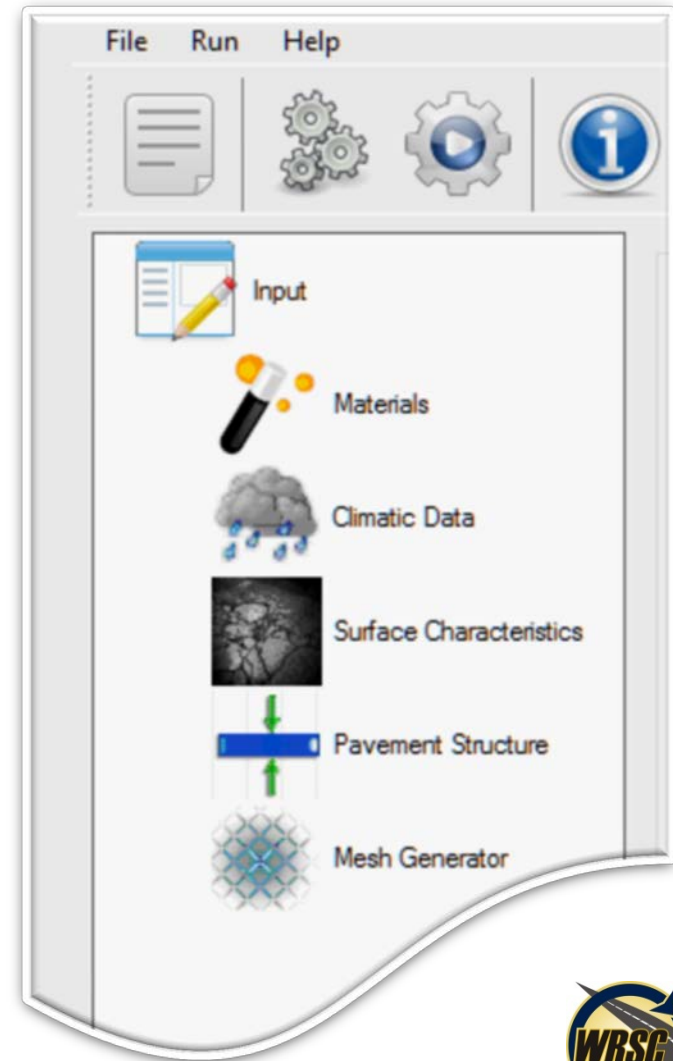


The screenshot shows the 'About' dialog box for the TEMPS software. The window title is 'About' with a close button (X) in the top right corner. The dialog is divided into three main sections: 'Version', 'Contact', and 'Disclaimer'.  
1. **Version:** Contains the text 'TEMPS (Temperature Estimate Model for Pavement Structures) Version 0.0.1 (Alpha Version)'. To the left is a blue square icon with a white letter 'N'. Below the text, it says 'Developed at: University of Nevada, Reno'.  
2. **Contact:** Contains a house icon next to 'Homepage: <http://wrsc.unr.edu/>' and an envelope icon next to 'Email: [elih@unr.edu](mailto:elih@unr.edu)'.  
3. **Disclaimer:** Contains a warning triangle icon (exclamation mark in a red triangle) and two paragraphs of text. The first paragraph states that the material may have inaccuracies and that the user assumes all risk. The second paragraph states that the University of Nevada, Reno does not warrant error-free operation or freedom from viruses, and is not responsible for costs of servicing or replacing equipment or data. The third paragraph states that the software is provided 'as is' without any warranties.

# Pavement Temperature Profile Prediction

## TEMPS – Input

- Materials
- Climatic Data
- Surface Characteristics
- Pavement Structure
- Mesh Generator



# Pavement Temperature Profile Prediction

## TEMPS – Materials

The screenshot shows the TEMPS software interface for material input. The window title is "Example-Montana - TEMPS". The menu bar includes "File", "Run", and "Help". The toolbar contains icons for a list, settings, play, and help. The left sidebar has icons for "Input", "Materials", "Climatic Data", "Surface Characteristics", "Pavement Structure", and "Mesh Generator".

The "Material" section contains the following input fields:

- Material Type: Material1
- Identifier Color: Brown
- Specific Heat Capacity (J/kg\*K): 1900
- Conductivity (W/m\*K): 1.00
- Density (kg/m³): 1500
- Description: (empty)

Control buttons include "Add" (green plus), "Delete" (orange X), "Insert" (green arrow down), "Up" (blue arrow up), and "Down" (blue arrow down).

Material Type	Identifier Color	Specific Heat Capacity (J/kg*K)	Conductivity (W/m*K)	Density (kg/m³)
Asphalt Mixture	Black	921	1.21	2250
Coarse Agg.	Silver	1900	1.00	1800
Fine Agg.	Brown	1900	1.00	1500

Logos for the University of North Dakota (N) and the Western Regional Superpave Center (WRSC) are visible in the bottom left corner of the software window.

# Pavement Temperature Profile Prediction

## TEMPS – Climatic Data

Example-Montana - TEMPS

File Run Help

Input  
Materials  
Climatic Data  
Surface Characteristics  
Pavement Structure  
Mesh Generator

Climatic Data

Year	Day	Month	Hour	Air Temperature(°C)	Wind Speed(m/s)	Solar Radiation
2001	1	12	0	-1	19	0
2001	1	12	1	-1	16	0
2001	1	12	2	-1	15	0
2001	1	12	3	0	22	0
2001	1	12	4	-1	19	0
2001	1	12	5	-1	18	0
2001	1	12	6	0	21	0

Plot: Air Temperature  
Type: Line

X-Axis  
Start Date: Saturday, December 1, 2001  
End Date: Saturday, November 30, 2002

Y-Axis  
Minimum: 0

**Climatic Data Sources**

- 1. National Climate Data Center (NCDC)**  
The following website provides free hourly temperature data:  
<http://gis.ncdc.noaa.gov/>
- 2. National Solar Radiation Data Base (NSRDB)**  
The following website provides you with a good source for hourly air temperature, hourly solar radiation and hourly wind speed data which are available mostly for airports:  
[http://redc.nrel.gov/solar/old\\_data/nsrdb/](http://redc.nrel.gov/solar/old_data/nsrdb/)
- 3. Long Term Pavement Performance (LTPP)**  
The following website provides LTPP data, which are monitored on pavement sections in the United States over years:  
<http://www.infopave.com/>



# Pavement Temperature Profile Prediction

## TEMPS – Surface Characteristics

Example-Montana - TEMPS

File Run Help

Input  
Materials  
Climatic Data  
Surface Characteristics  
Pavement Structure  
Mesh Generator

Surface Characteristics

C. J. Glover's Suggested Values (May 2010)

LTPP Section: 30-8129

State: Montana

Parameter: Albedo

Summer Value: 0.2

Winter Value: 0.35

User-defined Values

Input Data Type: Monthly Values

Month: January

Albedo: 0.00

	January	February	March	April	May	June	July	August	September
Albedo	0	0	0	0	0	0	0	0	0
Emissivity	0	0	0	0	0	0	0	0	0
Albedo	0	0	0	0	0	0	0	0	0

# Pavement Temperature Profile Prediction

## TEMPS – Pavement Structure

Example-Montana - TEMPS

File Run Help

Input  
Materials  
Climatic Data  
Surface Characteristics  
Pavement Structure  
Mesh Generator

Pavement Structure

Layer Name:

Material Type:

Thickness (m):

Description:

+ Add    X Delete    ↓ Insert

Layer Name	Material Type	Thickness (m)	Start Depth (m)	End Depth (m)	Description
Asphalt	Asphalt Mixture	0.20	0	0.2	
Base	Coarse Agg.	0.25	0.2	0.45	
Subgrade	Fine Agg.	1	0.45	1.45	

Pavement Section

Pavement Surface

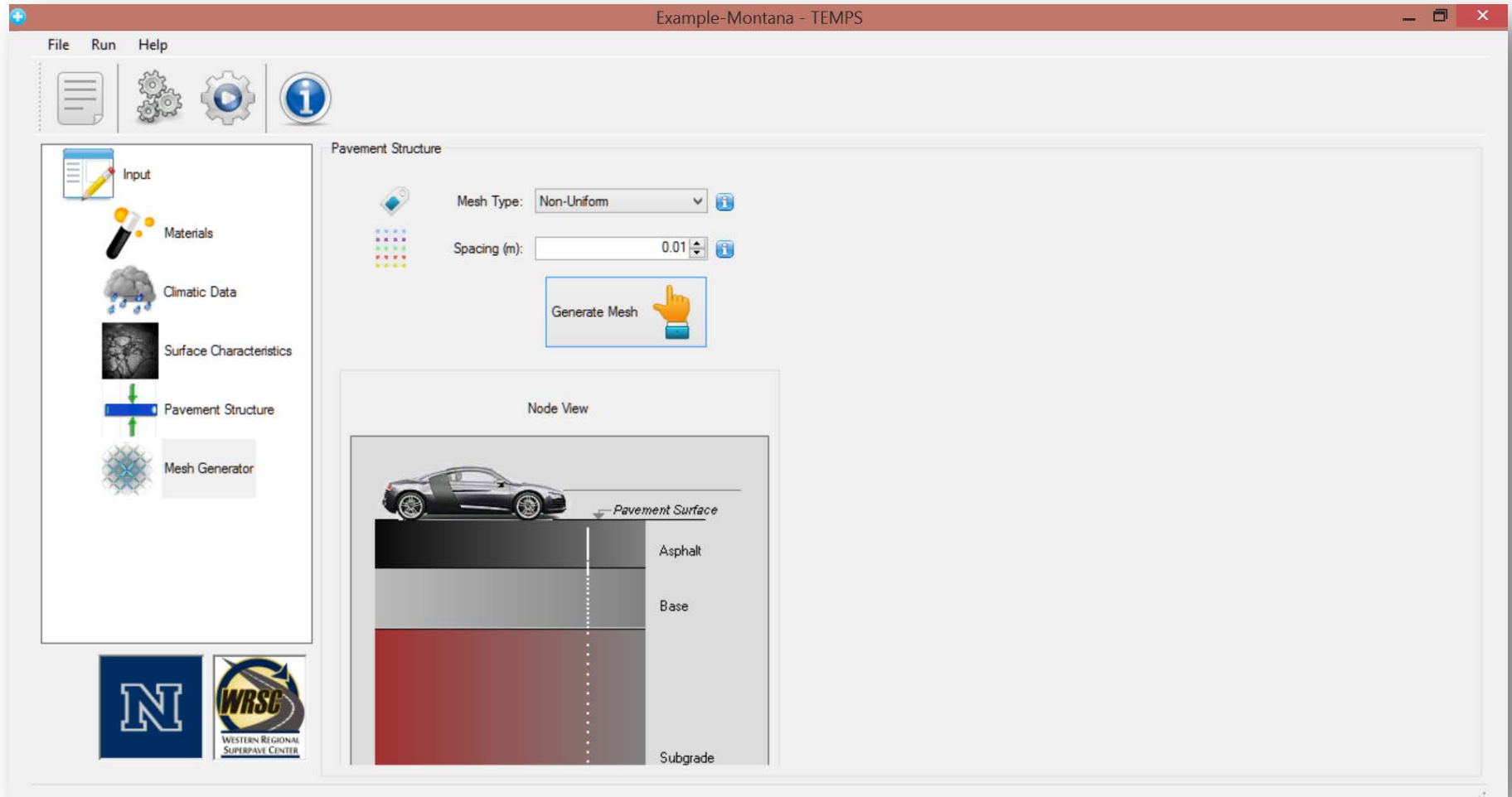
Asphalt

Base

Subgrade

# Pavement Temperature Profile Prediction

## TEMPS – Mesh Generator



# Pavement Temperature Profile Prediction

## TEMPS – Run Analysis

### Time Efficiency of Computation: Implicit Scheme

Run time for **1 years** analysis period  
(3.10 GHz proc. and 4.00 GB RAM)

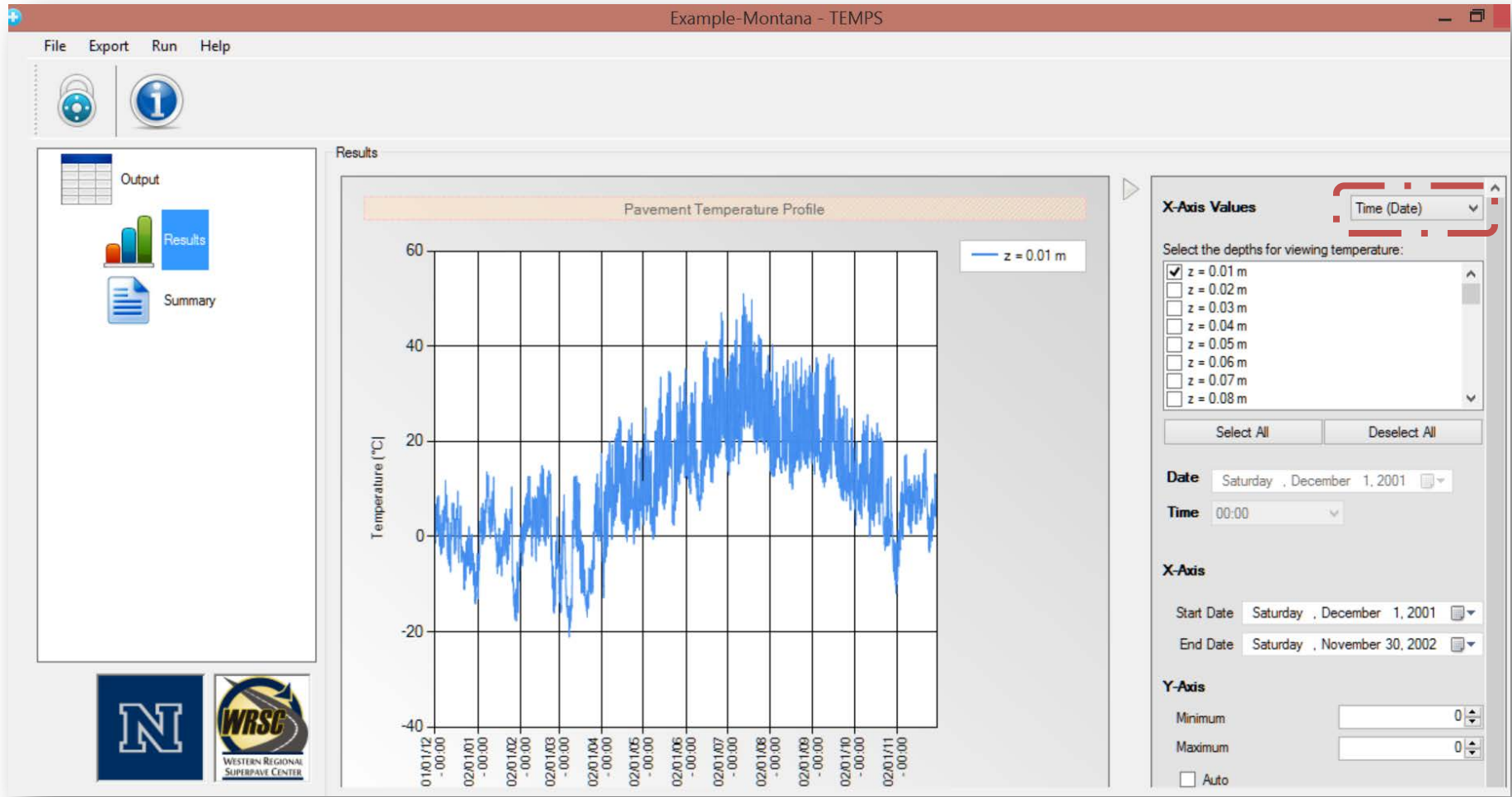
< 10 seconds using 1 hour time step\*



\* Note: 1 hour time step was chosen without jeopardizing the model accuracy for prediction.

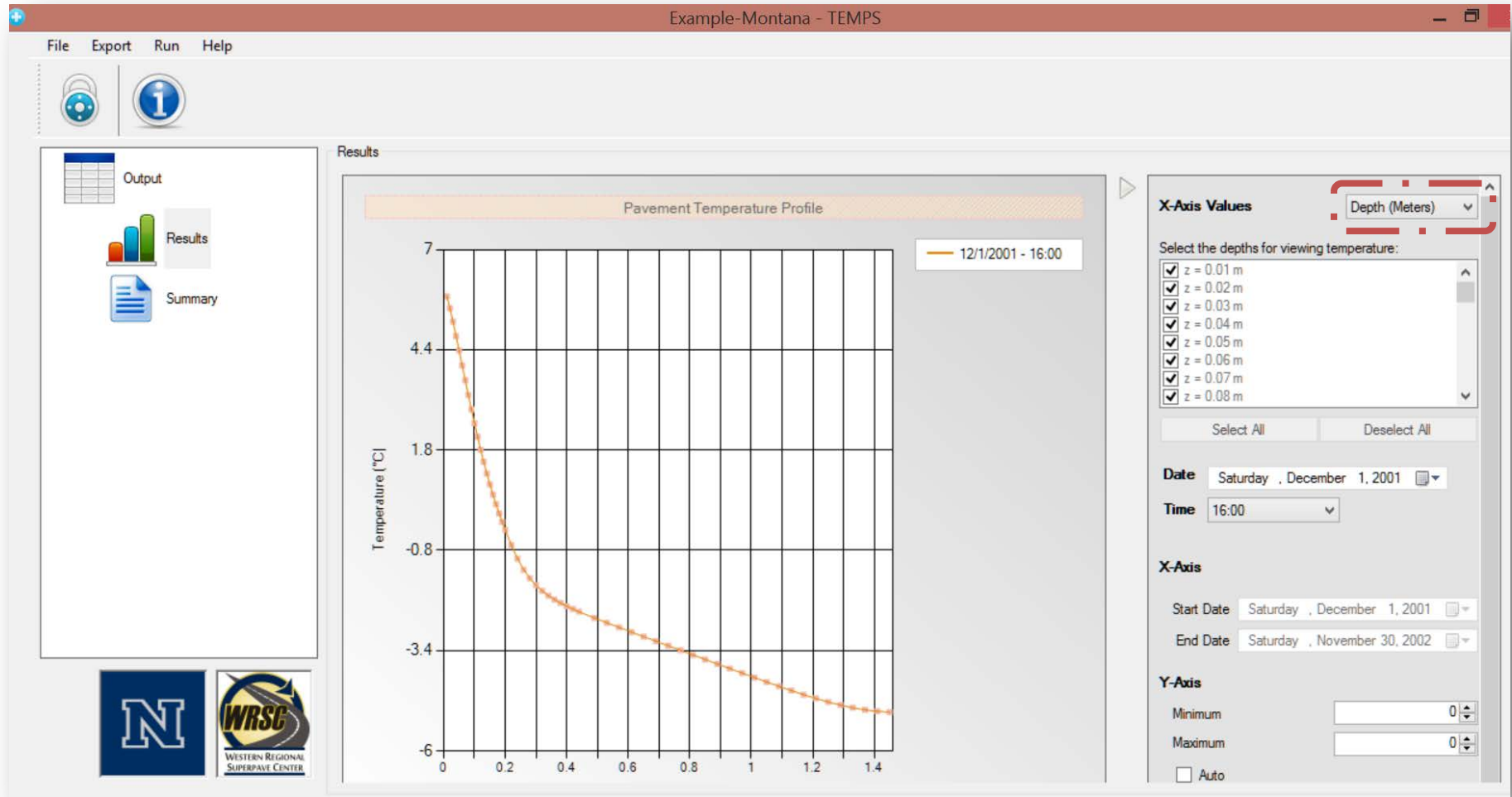
# Pavement Temperature Profile Prediction

## TEMPS – Output Results



# Pavement Temperature Profile Prediction

## TEMPS – Output Results



# Pavement Temperature Profile Prediction

## TEMPS – Output Summary

Example-Montana - TEMPS

File Export Run Help

Output Results Summary

Pavement Temperature Profile Summary



Date-Time ↓	Depth →	z = 0.01 m	z = 0.02 m	z = 0.03 m	z = 0.04 m	z = 0.05 m	z = 0.06 m	z = 0.07 m	z = 0.08 m	z = 0.09 m	z = 0.1 m
12/1/2001 - 0:00		-1.14°C	-1.17°C	-1.2°C	-1.23°C	-1.26°C	-1.29°C	-1.32°C	-1.35°C	-1.38°C	-1.41°C
12/1/2001 - 1:00		-1.39°C	-1.37°C	-1.36°C	-1.36°C	-1.36°C	-1.37°C	-1.39°C	-1.4°C	-1.42°C	-1.44°C
12/1/2001 - 2:00		-1.47°C	-1.46°C	-1.45°C	-1.44°C	-1.44°C	-1.44°C	-1.45°C	-1.46°C	-1.47°C	-1.49°C
12/1/2001 - 3:00		-1.29°C	-1.33°C	-1.36°C	-1.38°C	-1.4°C	-1.42°C	-1.44°C	-1.46°C	-1.48°C	-1.5°C
12/1/2001 - 4:00		-0.97°C	-1.06°C	-1.13°C	-1.2°C	-1.25°C	-1.3°C	-1.34°C	-1.38°C	-1.42°C	-1.45°C
12/1/2001 - 5:00		-1.14°C	-1.16°C	-1.19°C	-1.23°C	-1.26°C	-1.3°C	-1.33°C	-1.36°C	-1.4°C	-1.43°C
12/1/2001 - 6:00		-1.16°C	-1.19°C	-1.22°C	-1.24°C	-1.27°C	-1.3°C	-1.33°C	-1.36°C	-1.39°C	-1.42°C
12/1/2001 - 7:00		-0.91°C	-0.99°C	-1.06°C	-1.12°C	-1.17°C	-1.22°C	-1.27°C	-1.31°C	-1.35°C	-1.38°C
12/1/2001 - 8:00		-0.86°C	-0.93°C	-0.99°C	-1.05°C	-1.1°C	-1.16°C	-1.21°C	-1.25°C	-1.3°C	-1.34°C
12/1/2001 - 9:00		-0.57°C	-0.68°C	-0.78°C	-0.87°C	-0.95°C	-1.03°C	-1.09°C	-1.16°C	-1.21°C	-1.27°C
12/1/2001 - 10:00		0.53°C	0.23°C	-0.02°C	-0.24°C	-0.42°C	-0.58°C	-0.72°C	-0.84°C	-0.95°C	-1.05°C

General Summary Detailed Summary

Overall Minimum Pavement Temperature: -21.12°C Occured On: 3/8/2002 - 8:00, At the Depth of: 0.01 m

Overall Maximum Pavement Temperature: 51.04°C Occured On: 7/12/2002 - 16:00, At the Depth of: 0.01 m

Export General Summary

# Pavement Temperature Profile Prediction

## TEMPS – Output Summary

Example-Montana - TEMPS

File Export Run Help

Output

Results

Summary



Pavement Temperature Profile Summary

Date-Time ↓	Depth →	z = 0.01 m	z = 0.02 m	z = 0.03 m	z = 0.04 m	z = 0.05 m	z = 0.06 m	z = 0.07 m	z = 0.08 m	z = 0.09 m	z = 0.1 m
12/1/2001 - 0:00		-1.14°C	-1.17°C	-1.2°C	-1.23°C	-1.26°C	-1.29°C	-1.32°C	-1.35°C	-1.38°C	-1.41°C
12/1/2001 - 1:00		-1.39°C	-1.37°C	-1.36°C	-1.36°C	-1.36°C	-1.37°C	-1.39°C	-1.4°C	-1.42°C	-1.44°C
12/1/2001 - 2:00		-1.47°C	-1.46°C	-1.45°C	-1.44°C	-1.44°C	-1.44°C	-1.45°C	-1.46°C	-1.47°C	-1.49°C
12/1/2001 - 3:00		-1.29°C	-1.33°C	-1.36°C	-1.38°C	-1.4°C	-1.42°C	-1.44°C	-1.46°C	-1.48°C	-1.5°C
12/1/2001 - 4:00		-0.97°C	-1.06°C	-1.13°C	-1.2°C	-1.25°C	-1.3°C	-1.34°C	-1.38°C	-1.42°C	-1.45°C
12/1/2001 - 5:00		-1.14°C	-1.16°C	-1.19°C	-1.23°C	-1.26°C	-1.3°C	-1.33°C	-1.36°C	-1.4°C	-1.43°C
12/1/2001 - 6:00		-1.16°C	-1.19°C	-1.22°C	-1.24°C	-1.27°C	-1.3°C	-1.33°C	-1.36°C	-1.39°C	-1.42°C
12/1/2001 - 7:00		-0.91°C	-0.99°C	-1.06°C	-1.12°C	-1.17°C	-1.22°C	-1.27°C	-1.31°C	-1.35°C	-1.38°C
12/1/2001 - 8:00		-0.86°C	-0.93°C	-0.99°C	-1.05°C	-1.1°C	-1.16°C	-1.21°C	-1.25°C	-1.3°C	-1.34°C
12/1/2001 - 9:00		-0.57°C	-0.68°C	-0.78°C	-0.87°C	-0.95°C	-1.03°C	-1.09°C	-1.16°C	-1.21°C	-1.27°C
12/1/2001 - 10:00		0.53°C	0.23°C	-0.02°C	-0.24°C	-0.42°C	-0.58°C	-0.72°C	-0.84°C	-0.95°C	-1.05°C

General Summary Detailed Summary

Start Date Saturday, December 1, 2001 End Date Saturday, November 30, 2002 Depth z = 0.01 m Update Export

Date	Average Pavement Temperature (°C)	Minimum Pavement Temperature (°C)	Maximum Pavement Temperature (°C)	Pavement Temperature Standard Deviation (°C)
12/1/2001	1.64	-1.47	6.74	2.81
12/2/2001	3.77	1.23	8.16	2.39
12/3/2001	3.16	0.31	8.58	2.64
12/4/2001	0.25	-2.33	4.51	2.25
12/5/2001	-1.84	-3.79	2.79	1.93
12/6/2001	0.13	-3.01	5.49	2.75
12/7/2001	1.21	-2.21	6.39	2.75
12/8/2001	5.92	1.52	11.81	3.41
12/9/2001	4.1	-2.33	8.69	2.97

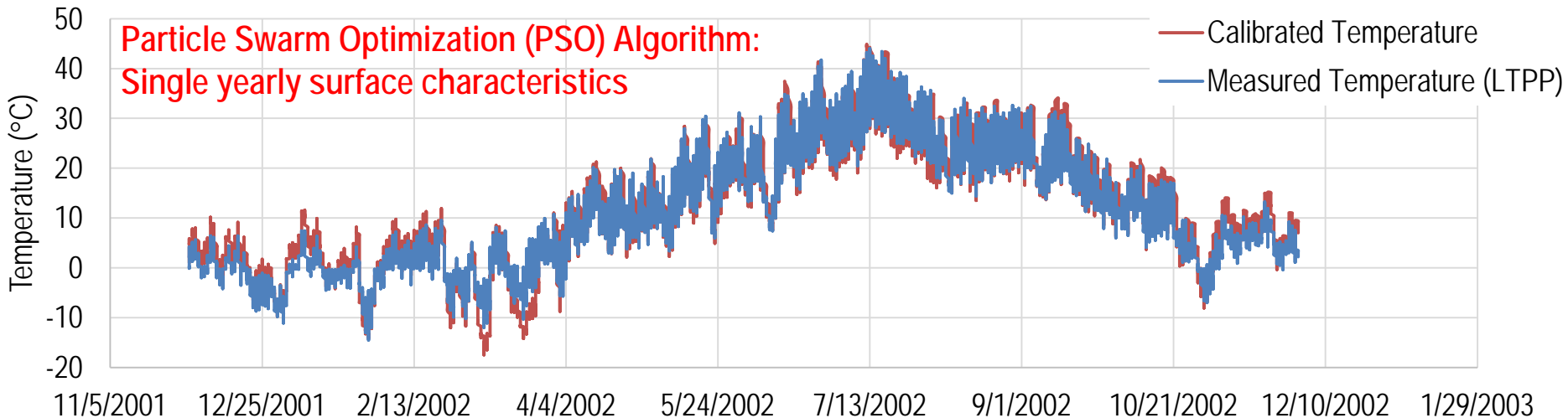
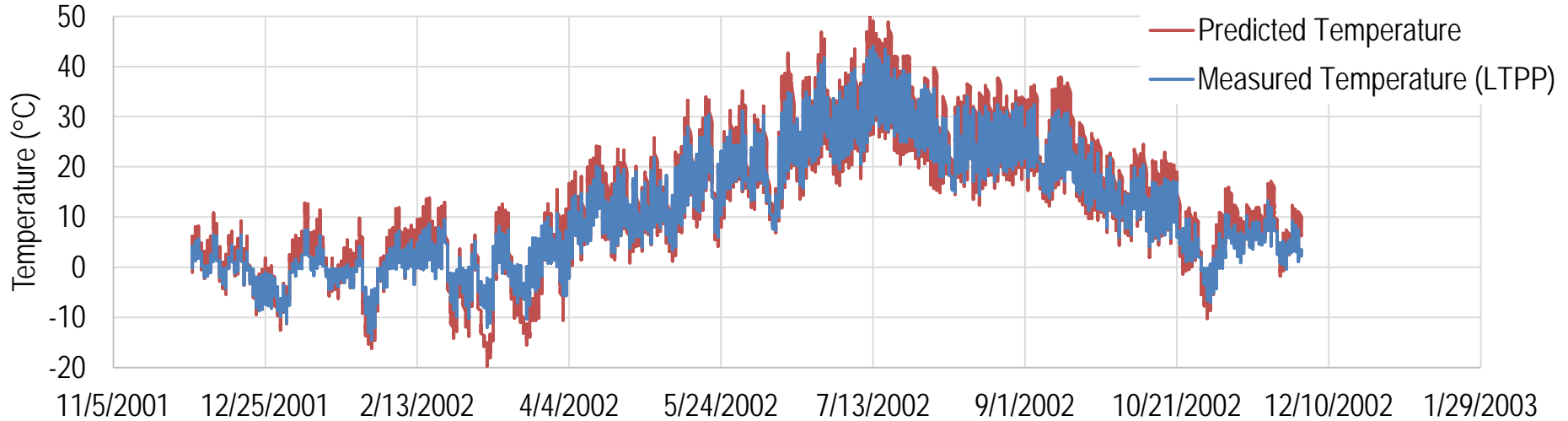
 



# Pavement Temperature Profile Prediction

## TEMPS – Predicted versus Measured

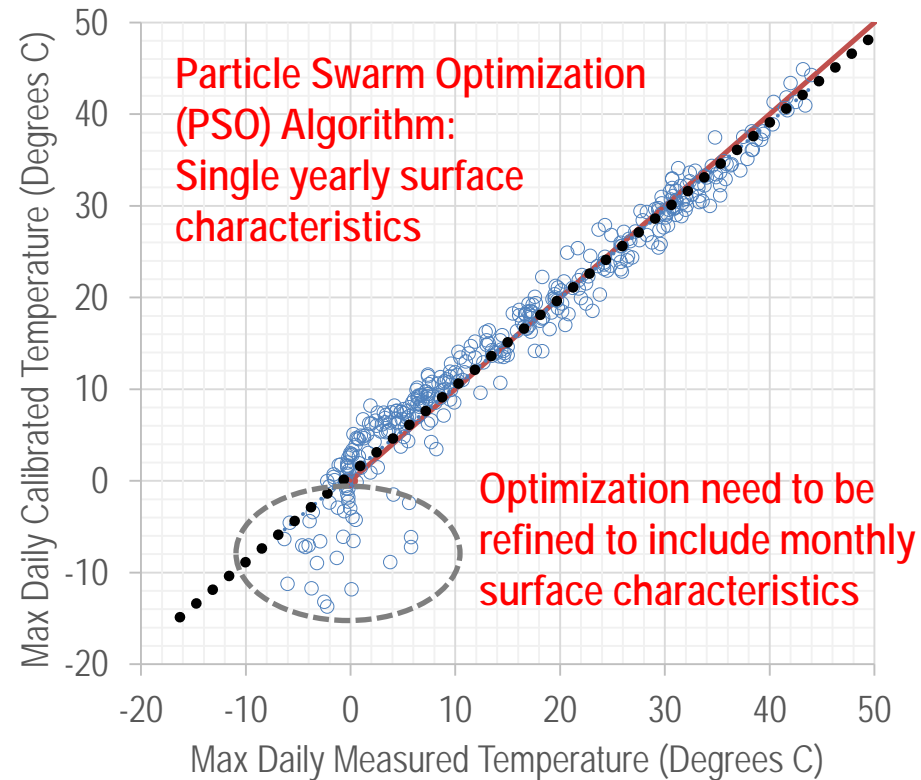
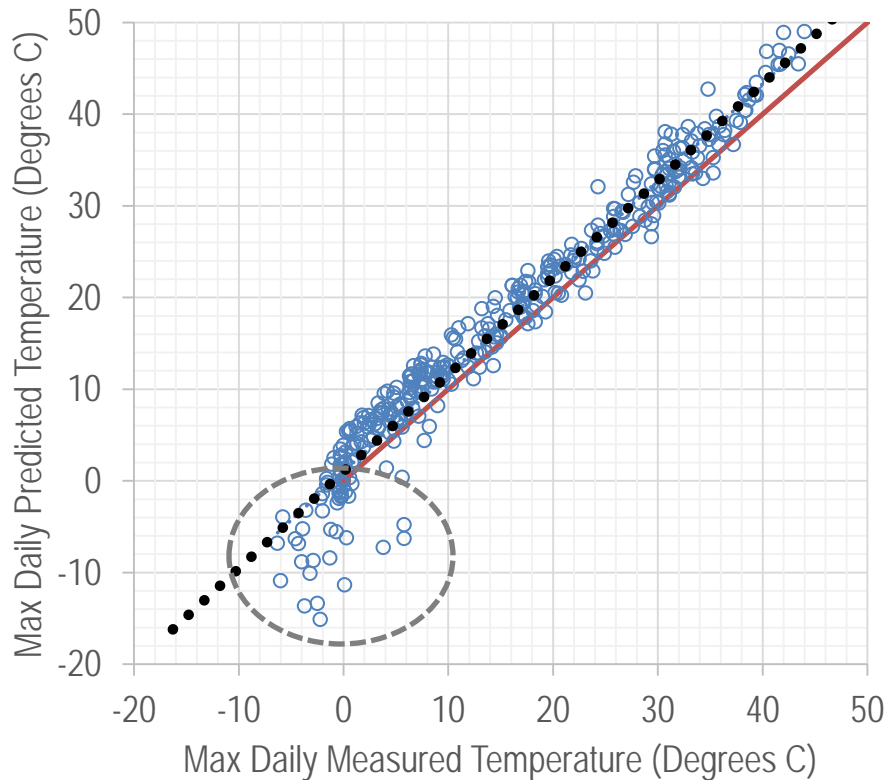
*Great Falls, MT at depth of 0.09 m (3.5 inch)*



# Pavement Temperature Profile Prediction

## TEMPS – Predicted versus Measured

*Great Falls, MT at depth of 0.09 m (3.5 inch)*



# TEMPS – Additional Improvements

- Optimize the surface characteristics for the US (Albedo, Emissivity, Absorption) using Particle Swarm Optimization (PSO) Algorithm
  - Monthly or seasonal values.
- Create/Include input files for LTPP SMP sections.
- Provide a summary of the average 7-day pavement temperature at various depths.
- Provide a summary of pavement cooling/warming rates

**Thank You!**

