Nye County Department
of Natural Resources and Federal Facilities

Status of Nye County Ventilation Studies

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Nuclear Waste Technical Review Board
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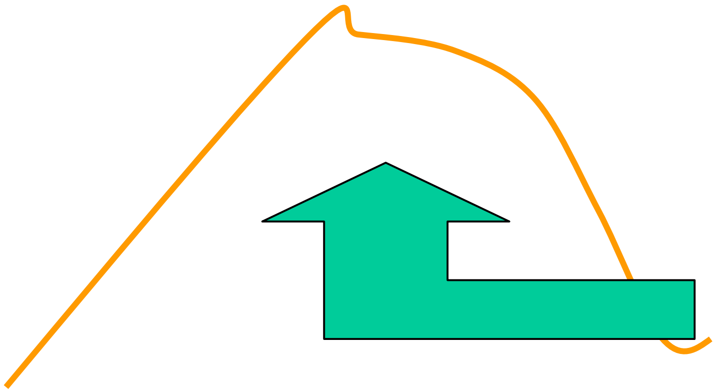
Outline

- Natural draft ventilation concept.
- MULTIFLUX code verification.
- Ventilation sensitivity study.
- Post-closure natural draft ventilation study.
  - An integrated thermo-hydraulic drift airflow model was prepared for 5000 years of pre- and post-closure.
  - Post closure natural ventilation will occur.
  - Cold-trap condensation is seen at the drift ends in the current design.
  - Design changes will be needed to eliminate condensation.

What do we mean by ventilation?

- Pre-closure ventilation and post-closure air infiltration.
- Concept:
  - Enhance natural breathing of mountain with rubble filled drifts or other means.
  - Permanent, flow driven by waste heat induced buoyancy.
  - Combine with more flexible pre-closure ventilation.
- Potential Advantages:
  - Smaller repository footprint.
  - Lower temperatures.
  - Dryer, less condensation.
  - Lower cost.
  - Lower corrosion.
  - Improved drift shadow.



MULTIFLUX

- Lawrence Livermore National Laboratory porous/fractured-media flow and transport software model (NUFT) as a module for simulating heat and moisture flows in the rock domain.
- Computational fluid dynamics (CFD) module for the simulation of transport processes in the airway system, including the waste packages.
- Modules coupled on the rock-air interface:
  - Heat and moisture flows are balanced at interface.
  - Temperature and vapor pressure equalized at each surface node.
- Developed by George Danko, University of Nevada, Reno.

Code Verification (Benchmarking)

- Analytical solution of transient heat transfer from drift to rock with heat conduction in rock.
- Boundary condition arbitrary function of time.
- Carslaw and Jaeger double integral solution.
- Integrate along drift to give two dimensional transient solution.
- Set parameters to maximize "action".
- Excellent agreement between model and analytical solution.
- NWRPO-2003-05 Coupled Hydrothermal-Ventilation Studies for Yucca Mountain Annual Report for April 2002 – March 2003, George Danko.

Sensitivity Study

- What factors and parameters are most important?
- Modify: ventilation rate, thermal conductivity (k), heat transfer coefficient (h), heat capacity (ρC_p).
- NWRPO-2003-05 Coupled Hydrothermal-Ventilation Studies for Yucca Mountain Annual Report for April 2002 – March 2003, George Danko.

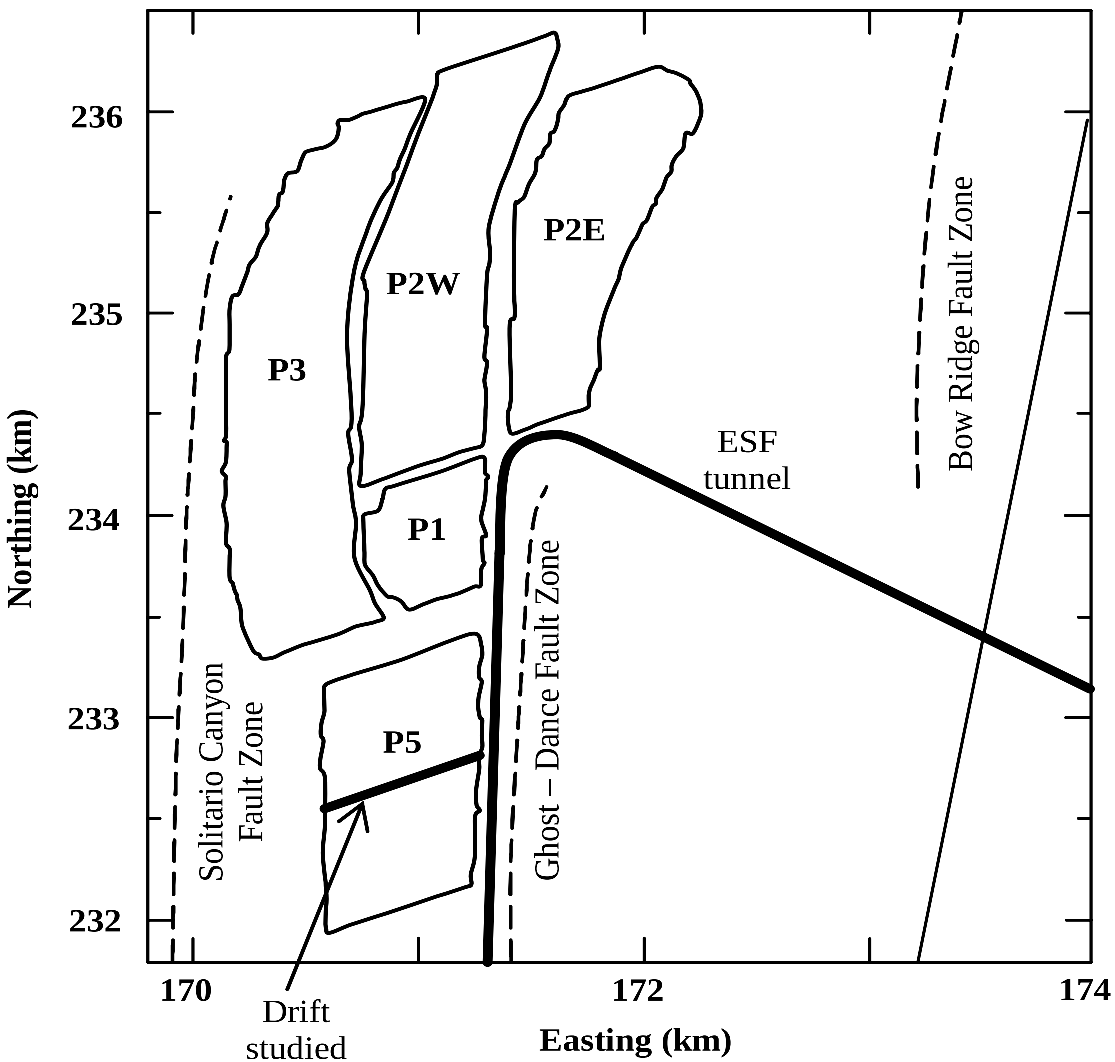
Sensitivity Study Conclusions

- Thermal loading does not change sensitivities.
- Ventilation rate:
  - Thermal conductivity and thermal diffusivity (density) important at low flow rates (lower than 5 kg/s ~ 0.25 m/s air velocity).
  - Heat transfer coefficient important at high flow rates (higher than 1 kg/s ~ 0.05 m/s air velocity).
- Thermal conductivity important and uncertain in lithophysal areas.

Post Closure Ventilation Simulation

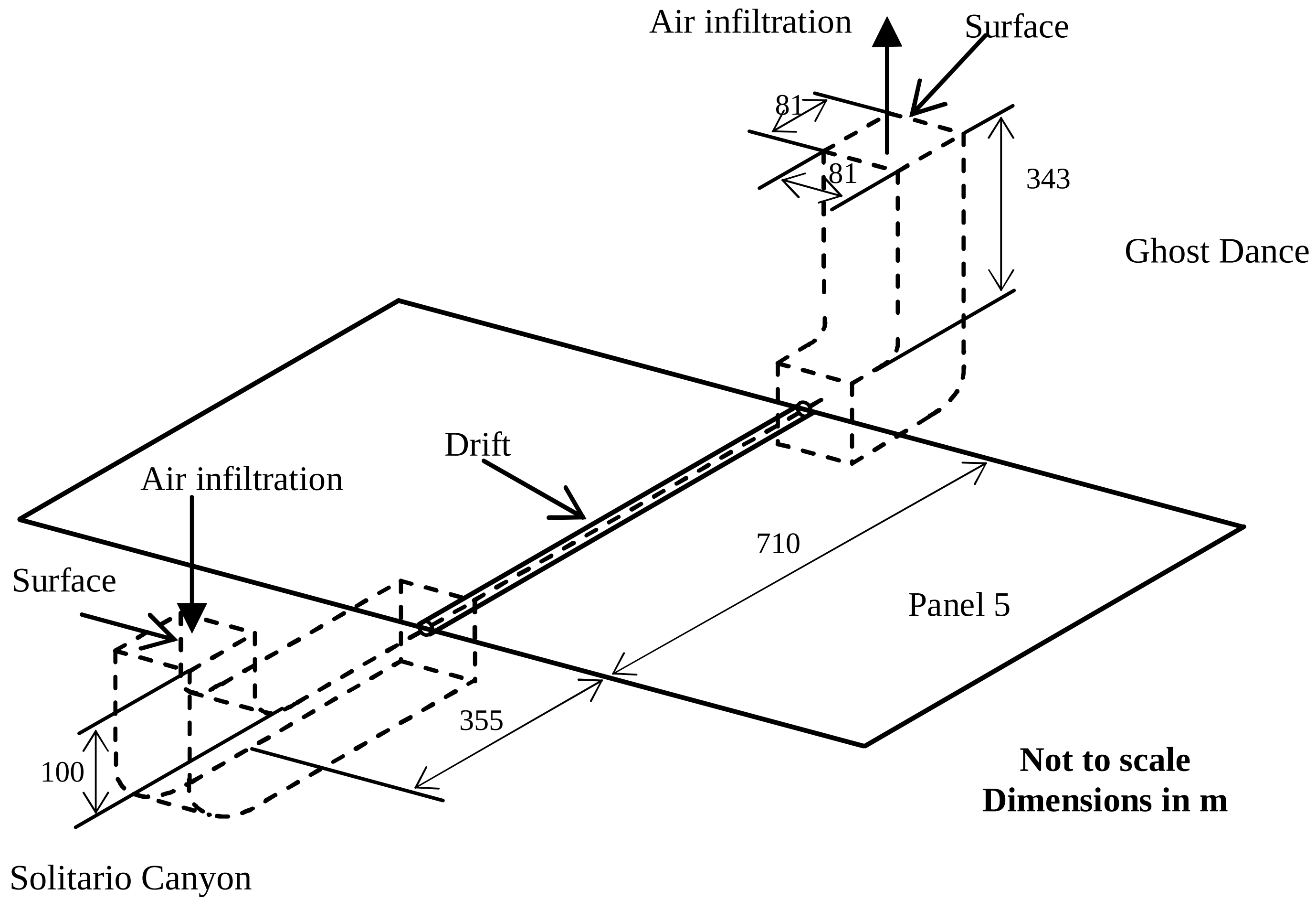
- Simulates current DOE “hot” repository design.
- U-Tube assumption for buoyancy flow:
  - Cold air goes down Solitario Canyon Fault zone.
  - Warm air goes up Ghost Dance Fault Zone.
  - Single drift.
- Flow rates centered on USGS (Gary LeCain) permeability.
- Results for a range of flow rates following 50 years of forced ventilation.
- Highest flow rates illustrate enhanced natural draft ventilation.

Repository

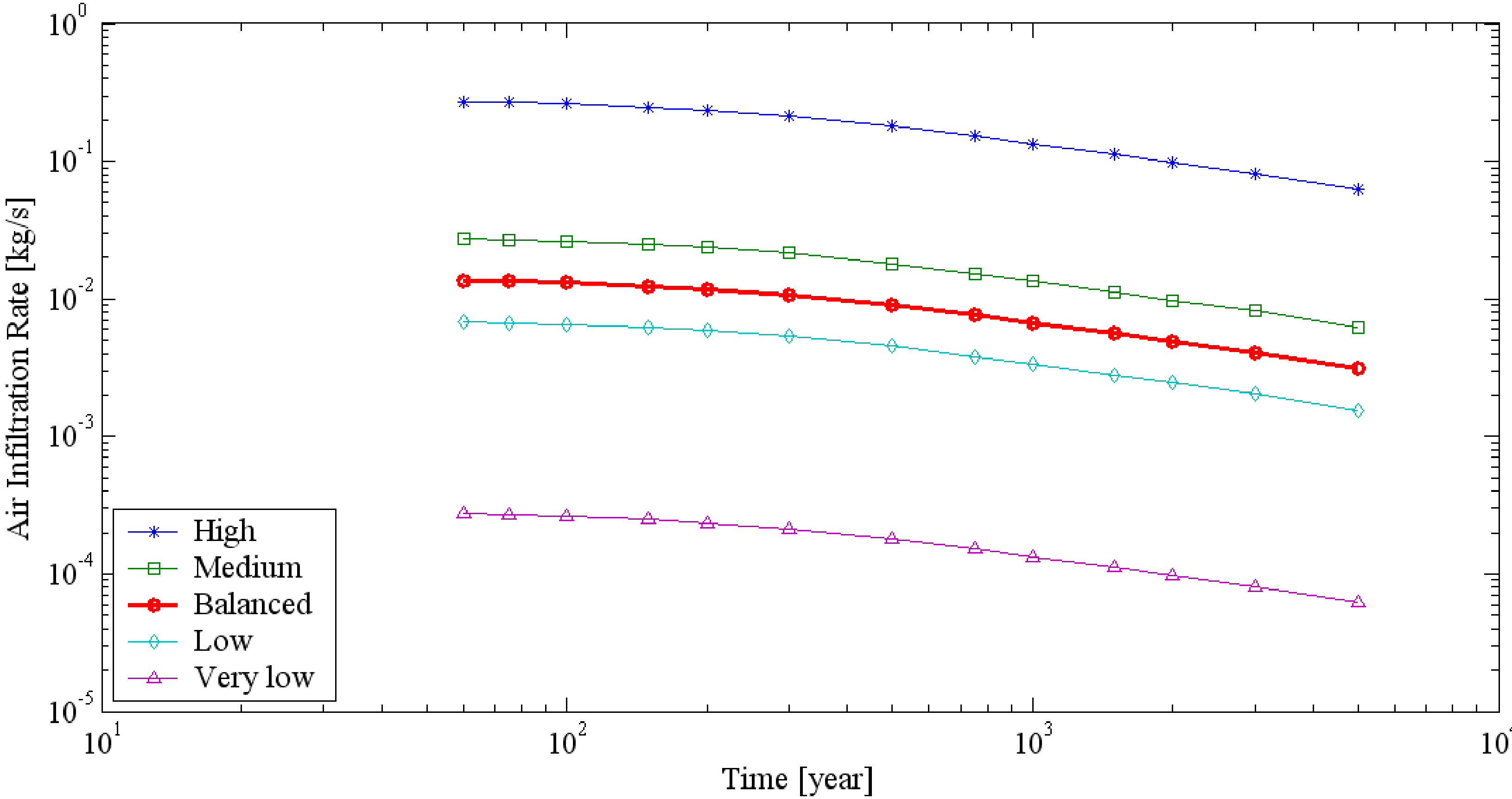


236
235
234
233
232
Northing (km)
170
172
174
Easting (km)
P3
P2W
P2E
P1
P5
ESF
tunnel
Solitario Canyon
Fault Zone
Ghost – Dance Fault Zone
Bow Ridge Fault Zone
Drift
studied

Natural Ventilation Flow System



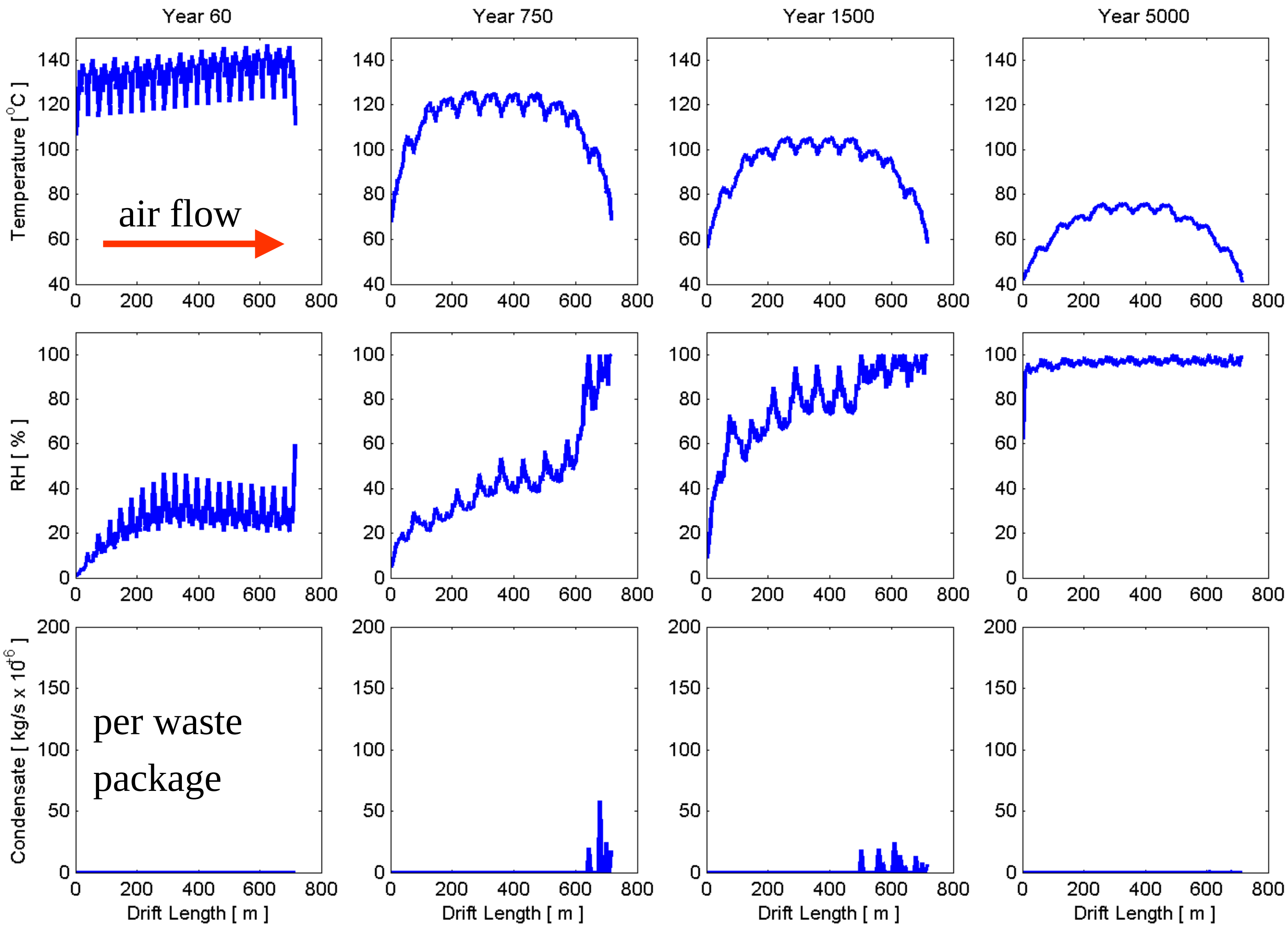
Infiltration Airflow Rates



Air Infiltration: Low

Location: WP

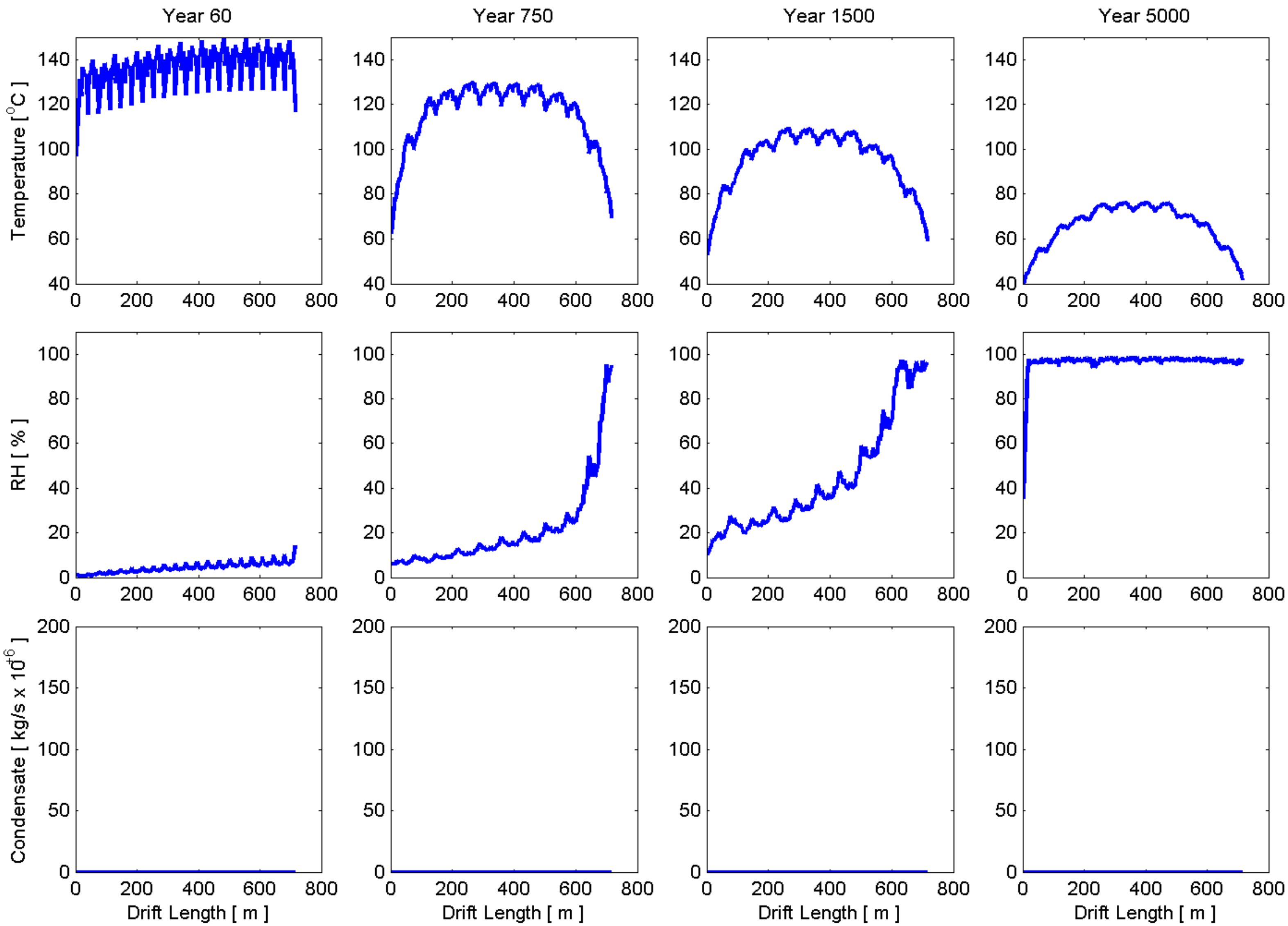
In-Drift Model: CFD-Convective



Air Infiltration: Low

Location: WP

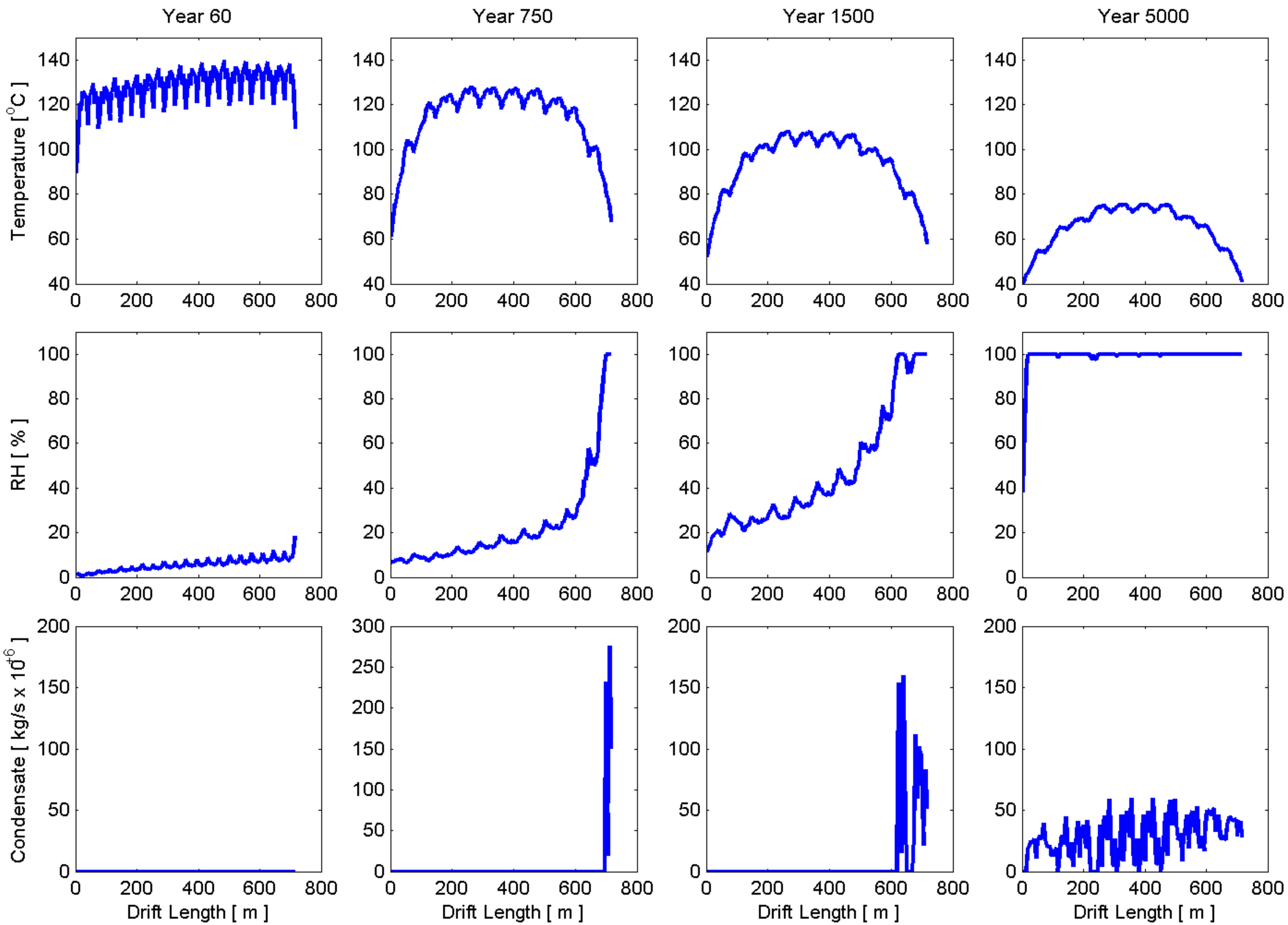
In-Drift Model: CFD-Diffusive (Porous Media Emulation)



Air Infiltration: Low

Location: Drift wall

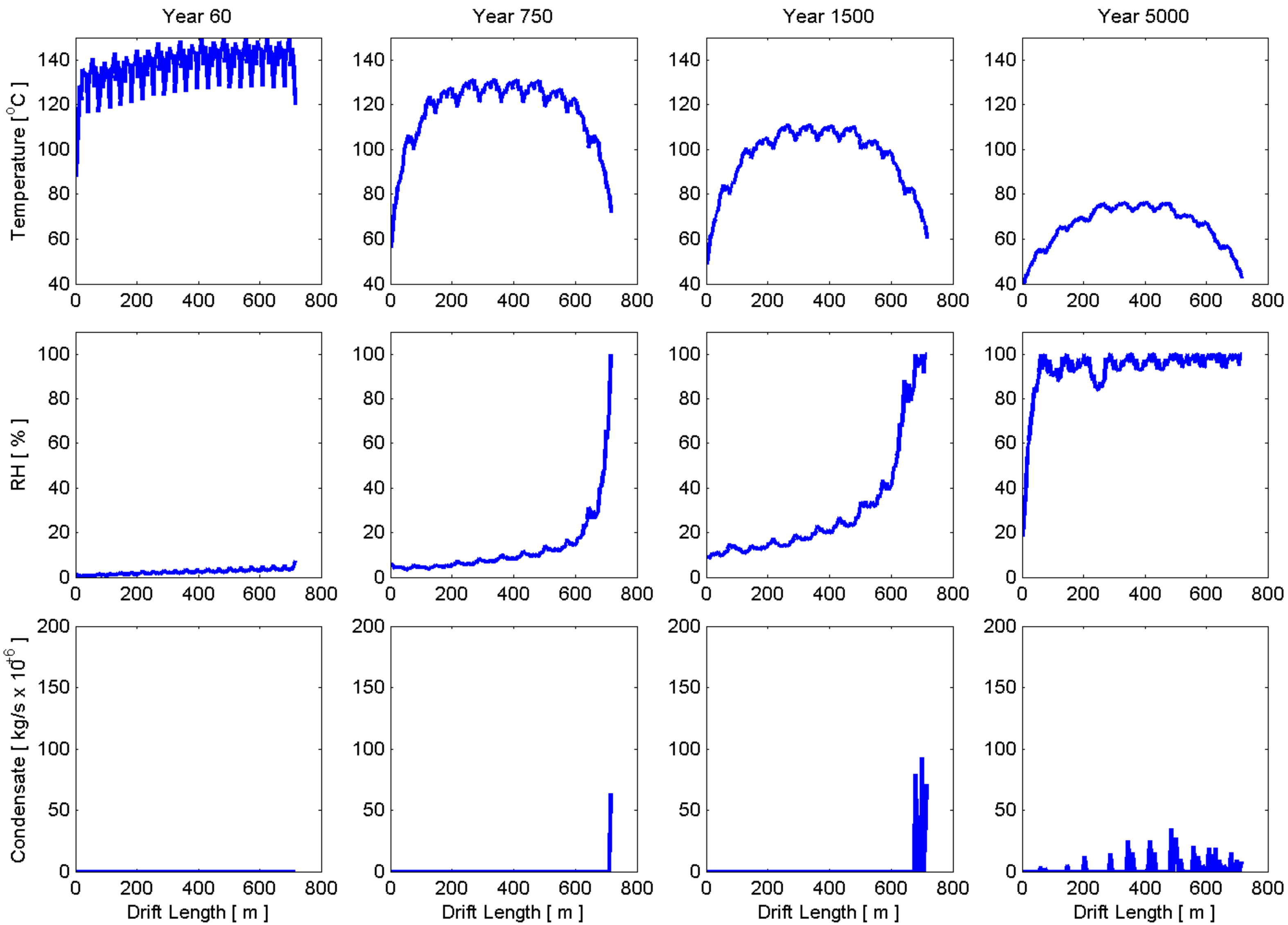
In-Drift Model: CFD-Convective



Air Infiltration: Balanced (best estimate of anticipated flow rate)

Location: WP

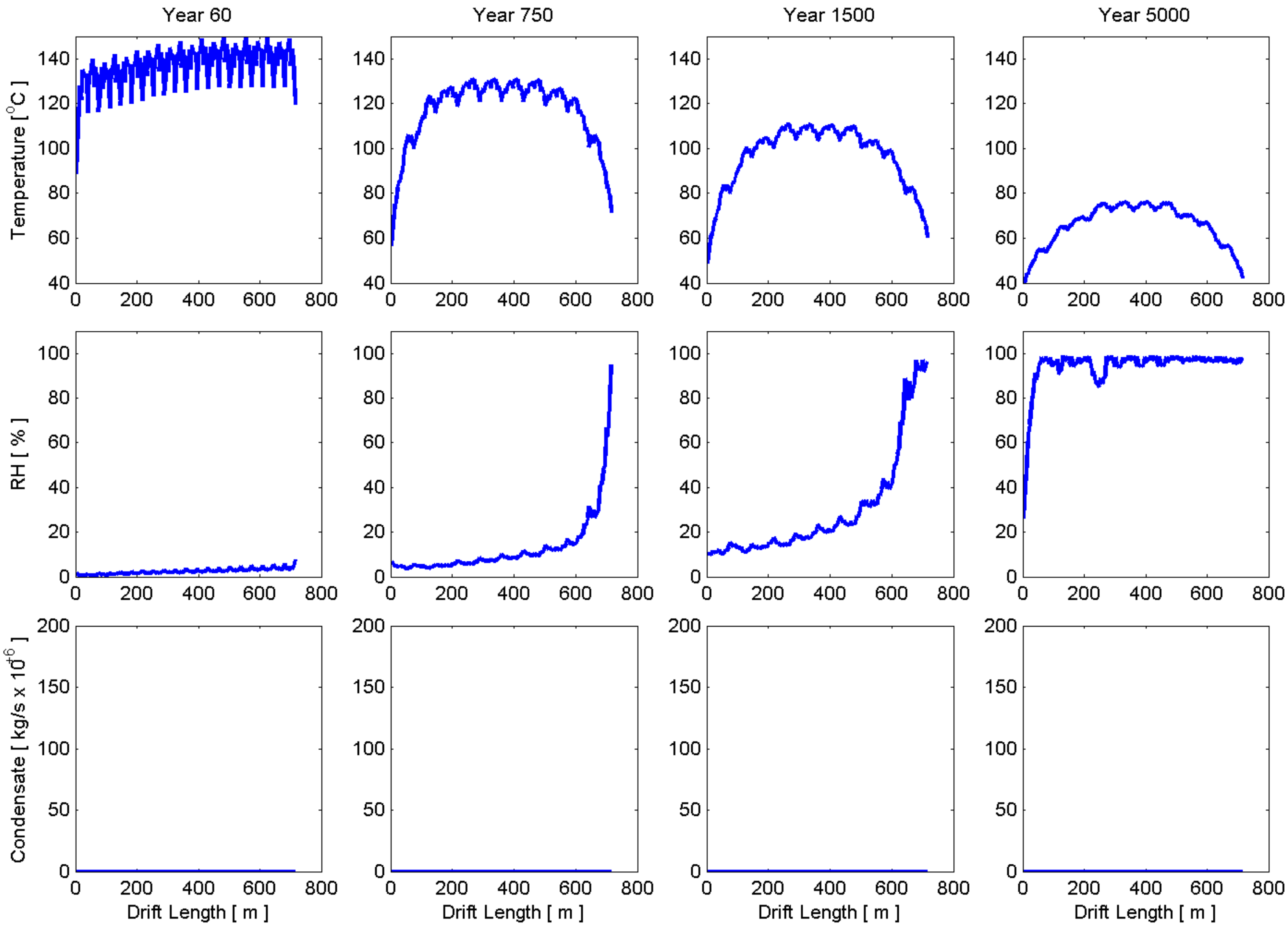
In-Drift Model: CFD-Convective



Air Infiltration: Balanced

Location: WP

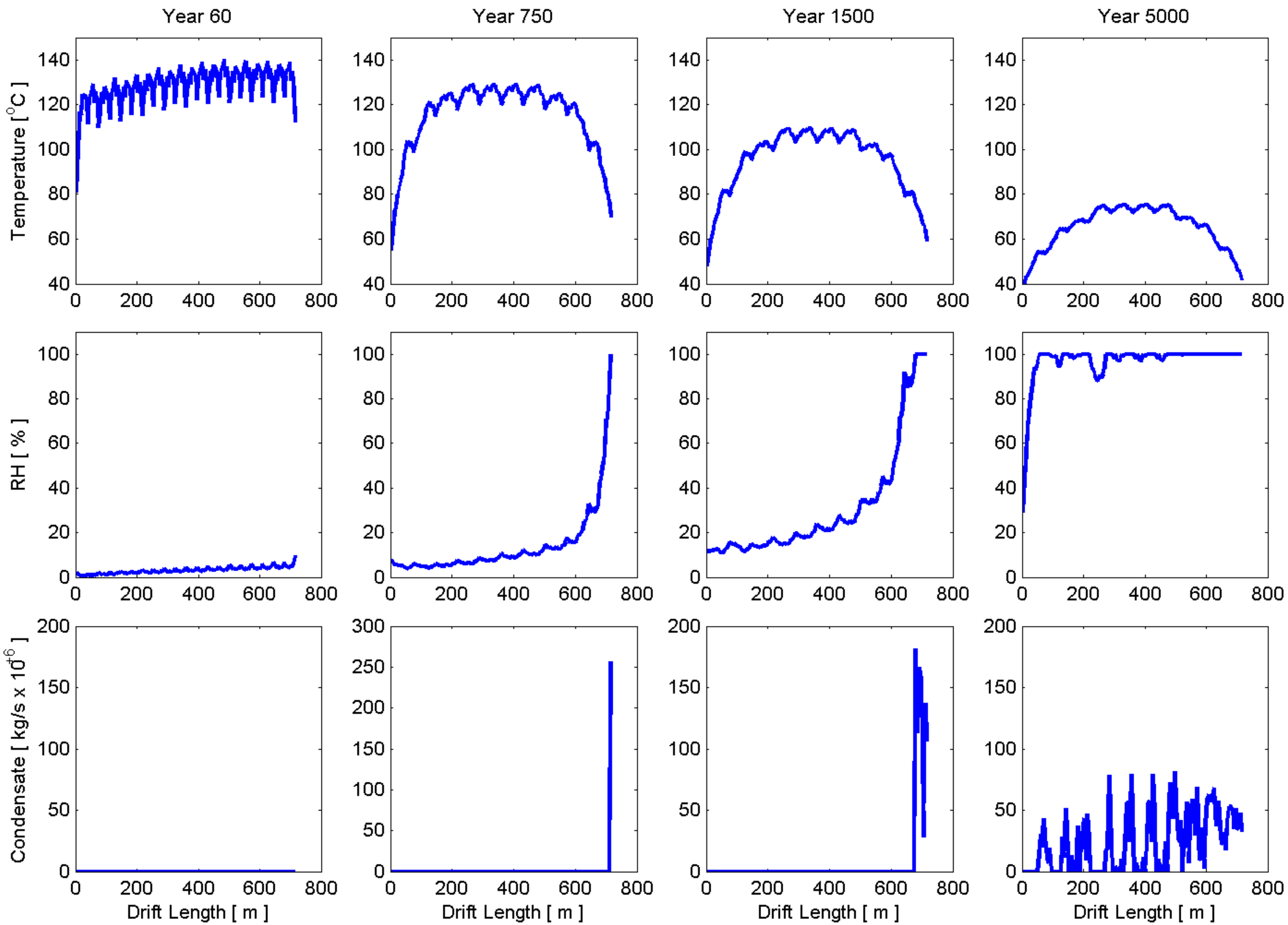
In-Drift Model: CFD-Diffusive (Porous Media Emulation)



Air Infiltration: Balanced

Location: Drift wall

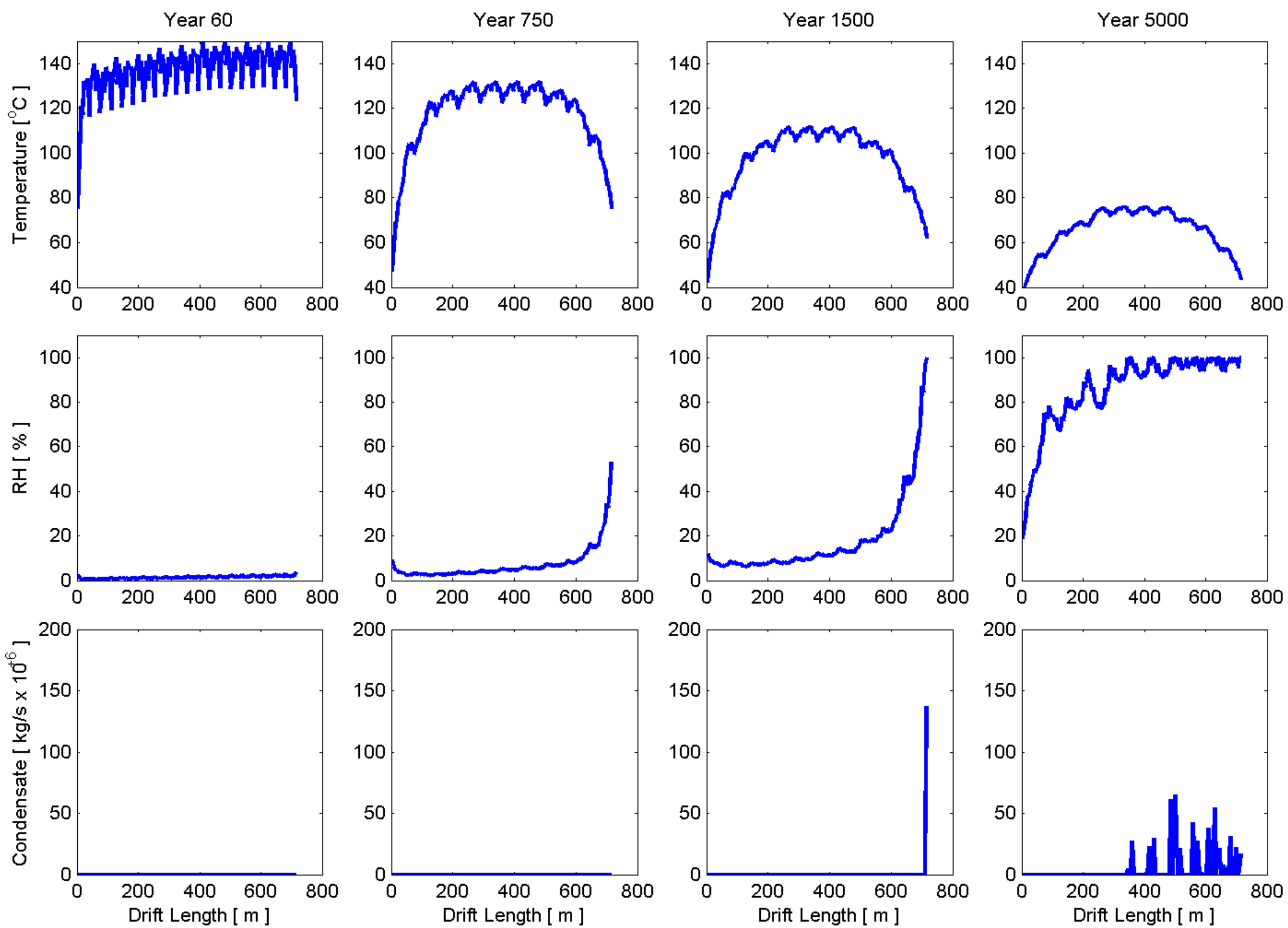
In-Drift Model: CFD-Convective



Air Infiltration: Medium

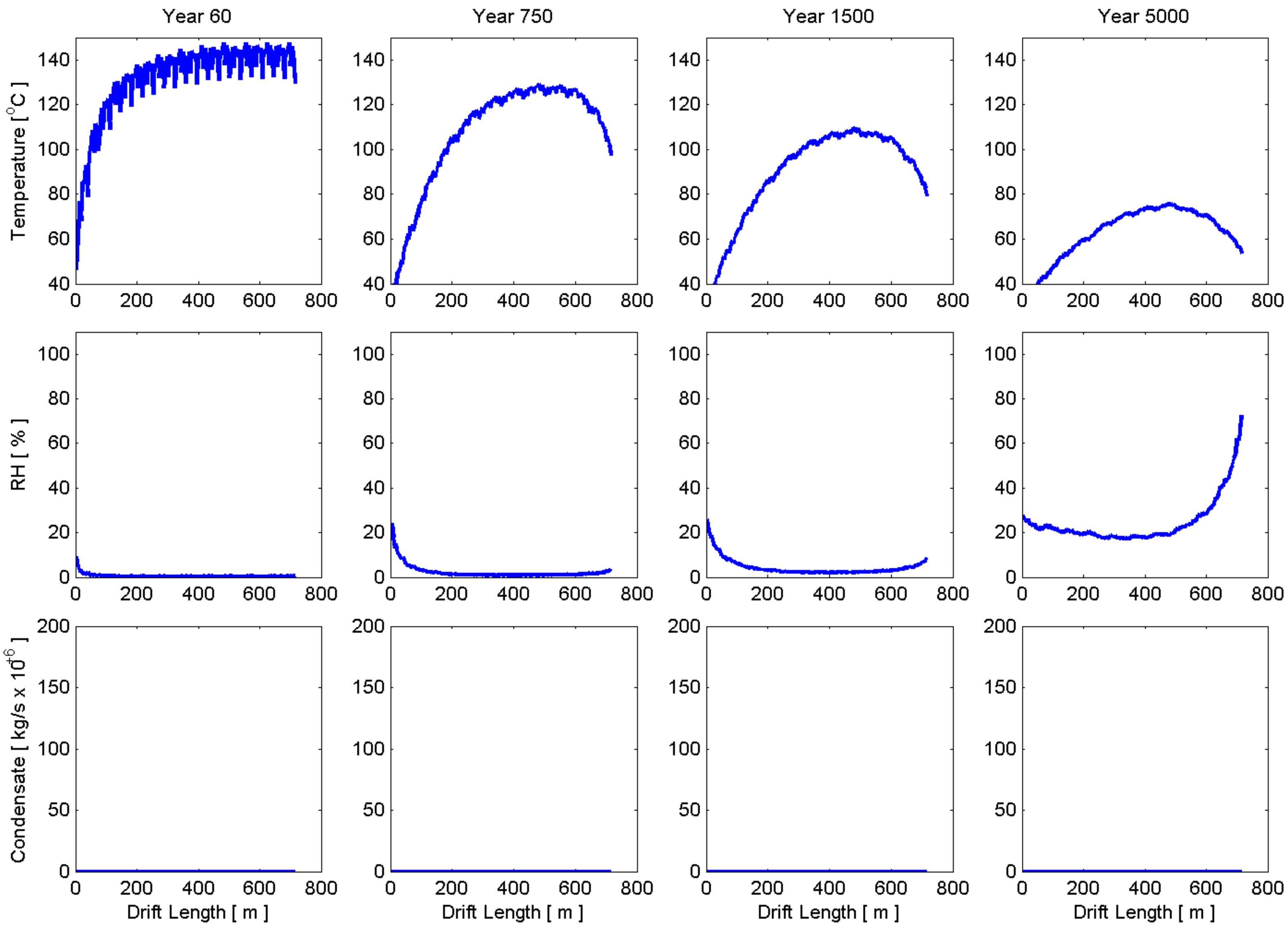
Location: WP

In-Drift Model: CFD-Convective



Air Infiltration: High

Location: WP In-Drift Model: CFD-Convective



Relative Humidity and Condensate Formation

- Condensation predicted on downstream drift wall and waste packages.
- Condensation disappears at higher flow rates.
- Condensation decreases with decreasing maximum temperatures.
- Refined convective air flow pattern required to see correct condensate formation.
- Best viewed as engineering design challenge.

Summary

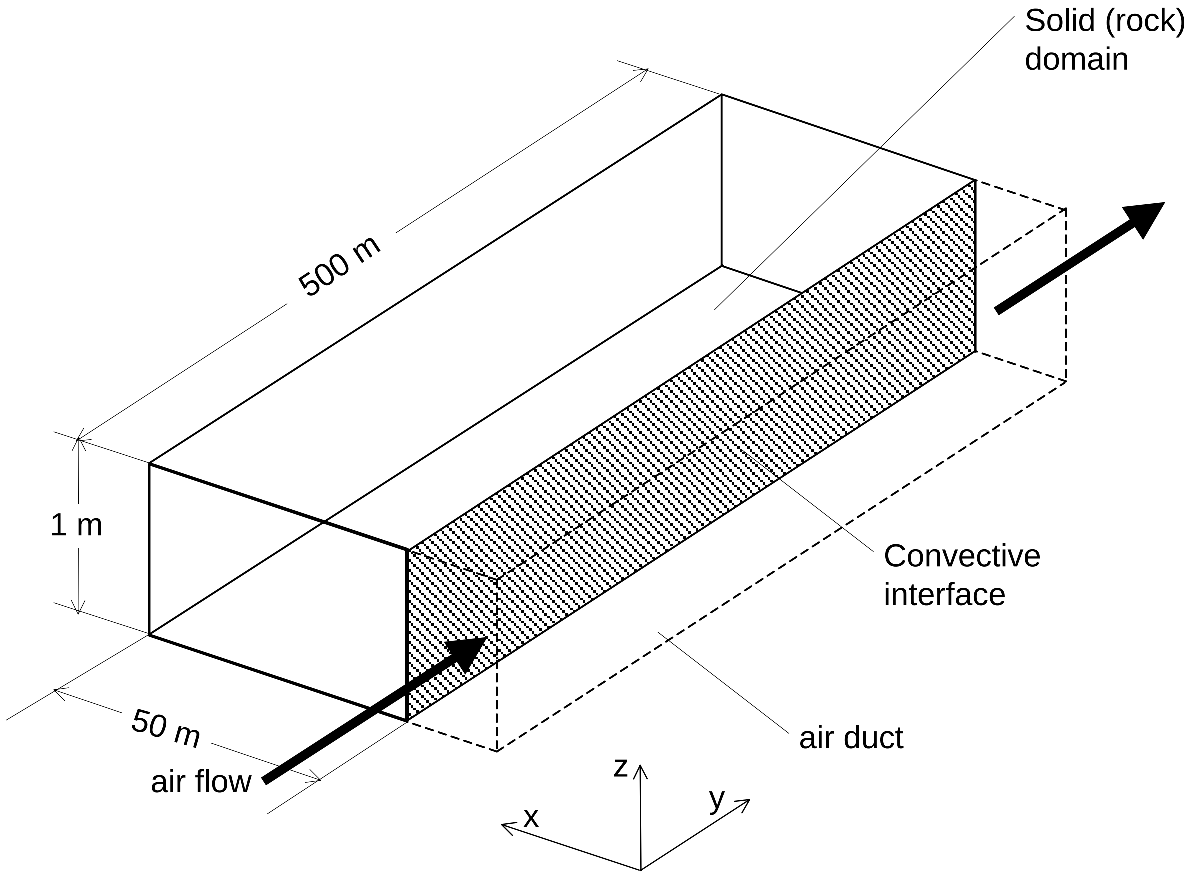
- Natural draft ventilation occurs with and without enhancement.
- Design changes will be needed to minimize condensation.
- Active and passive ventilation can be optimized to reduce condensation and lower average temperatures:
  - Run fans longer and/or faster?
  - Enhance natural ventilation?
  - Modify thermal loading?

Future Activities

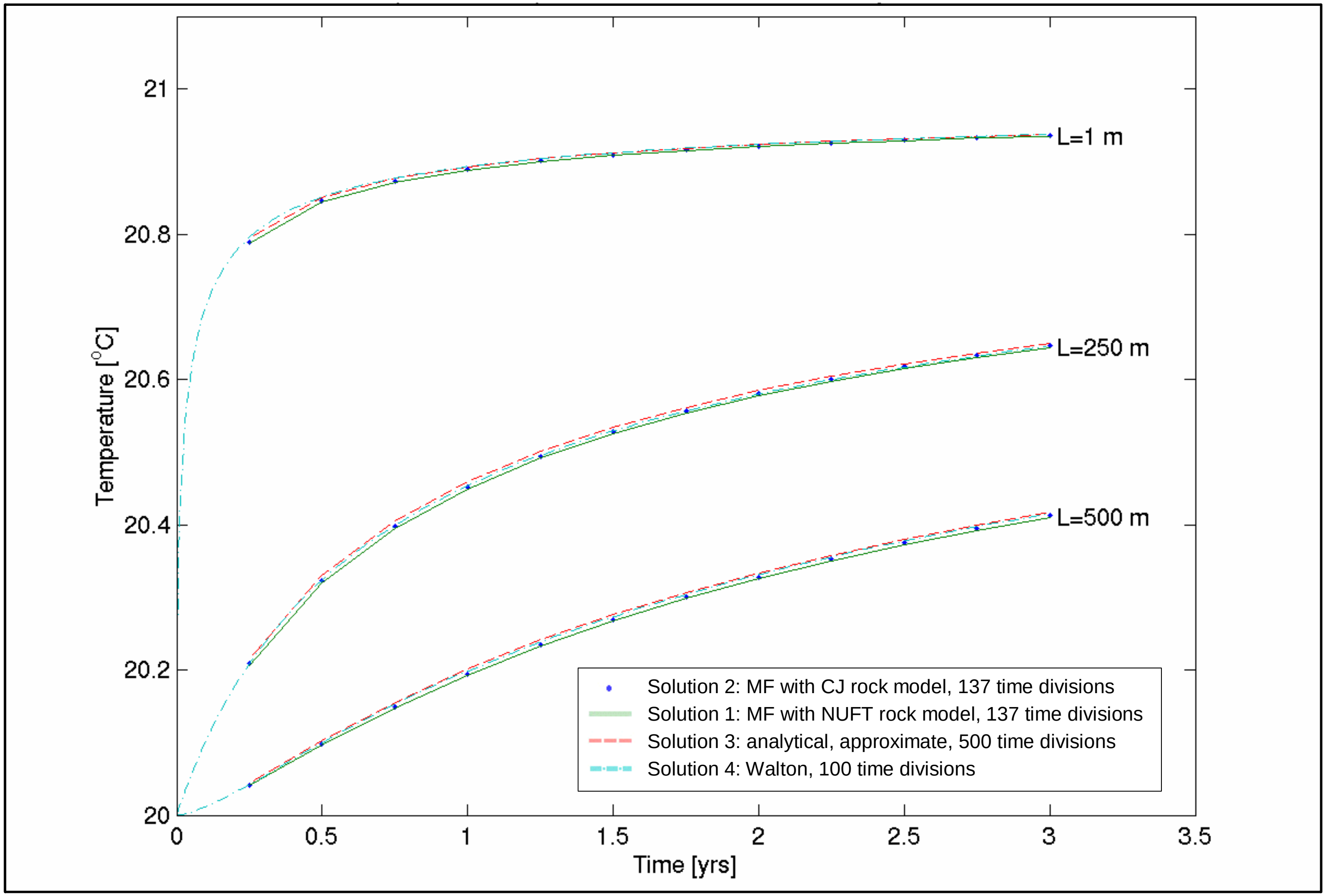
- We will continue to contribute subject to funding constraints, with Nye County and UNR cooperation.
- Future studies:
  - How to eliminate condensation?
  - Effects of partial roof collapse with air movement above rubble.
  - Effects of cold repository design.
  - Effects of barometric pressure pumping.
  - Will condensate at drift wall drip or imbibe into rock?
  - Can WPs be compartmentalized with alternative emplacement design?
  - We are open to suggestions.

Additional Support Material

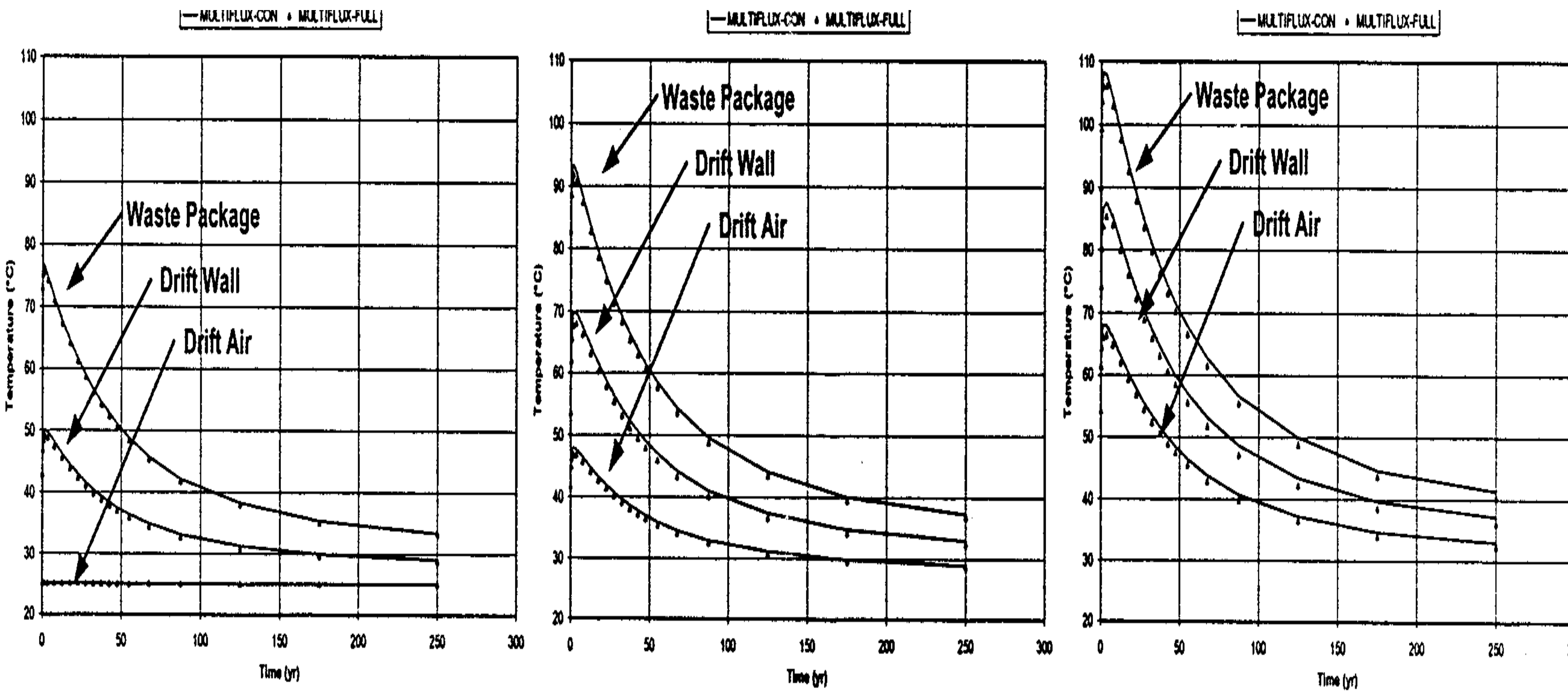
Benchmark Geometry



Wall Temperature Comparison



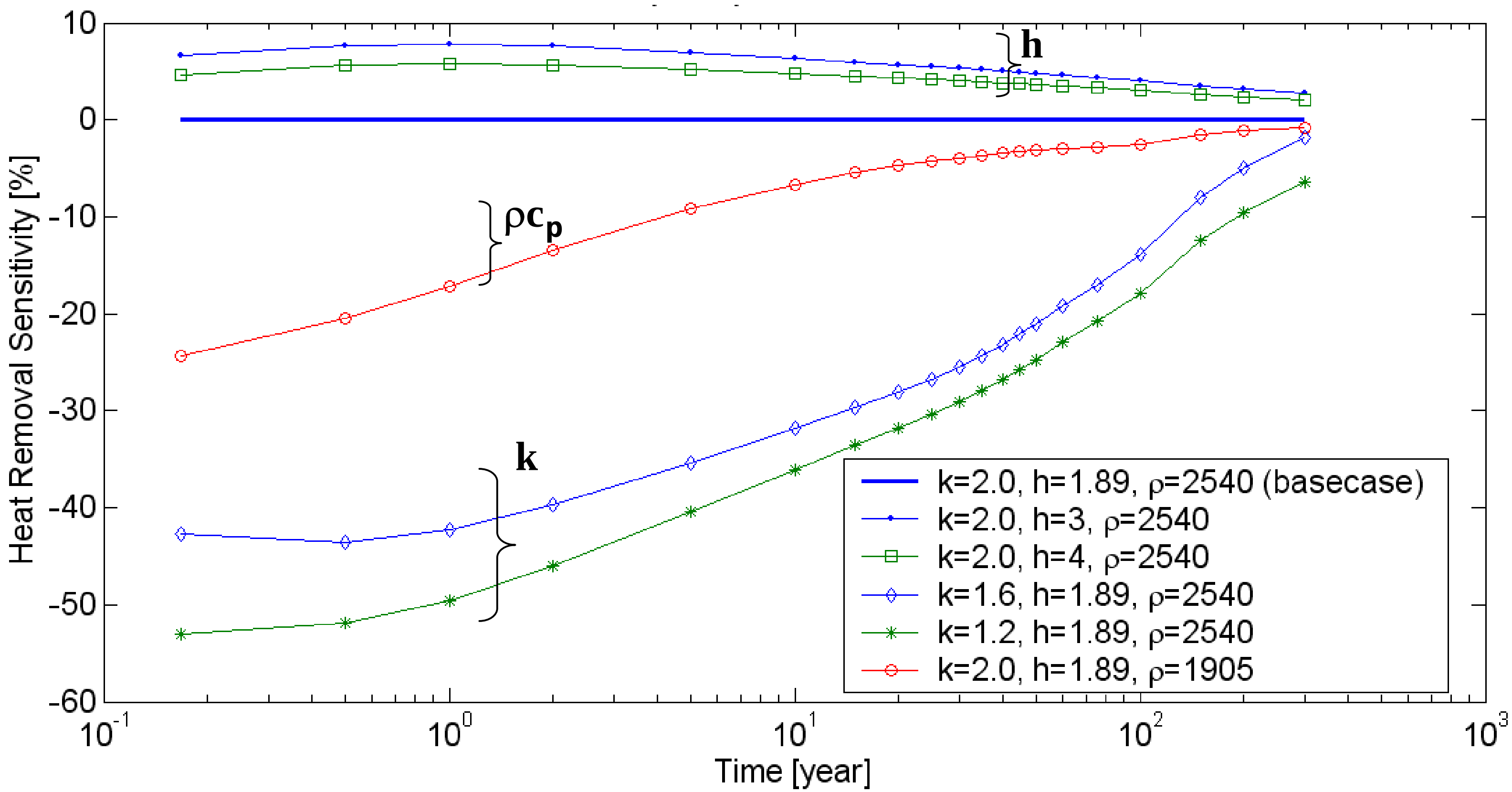
MULTIFLUX Compared with the ANSYS-based Ventilation Model (BSC)



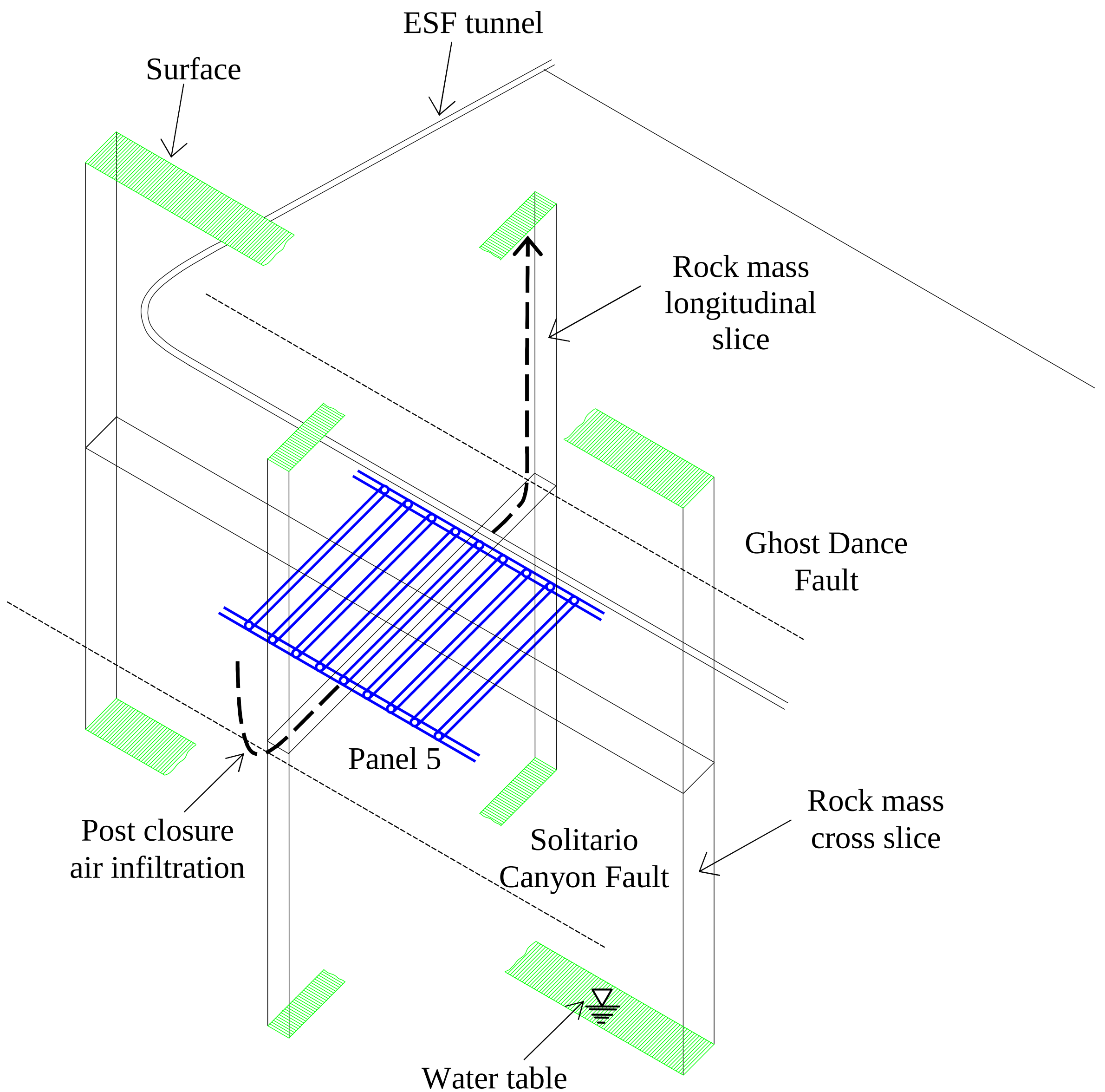
0 meters 300 meters 600 meters

Source: CAL-EBS-MD-000030 REV 01D, p. 76

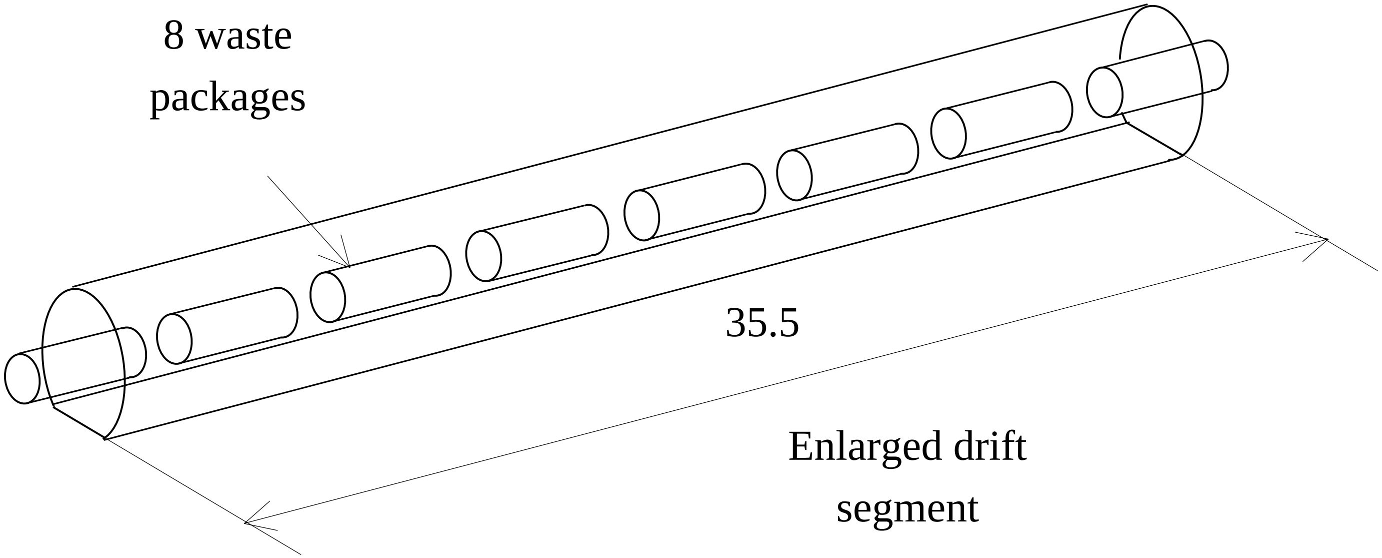
5 kg/s Air Flow Results



Panel 5 with the mountain-scale rockmass domain



Waste Package Emplacement Sequence



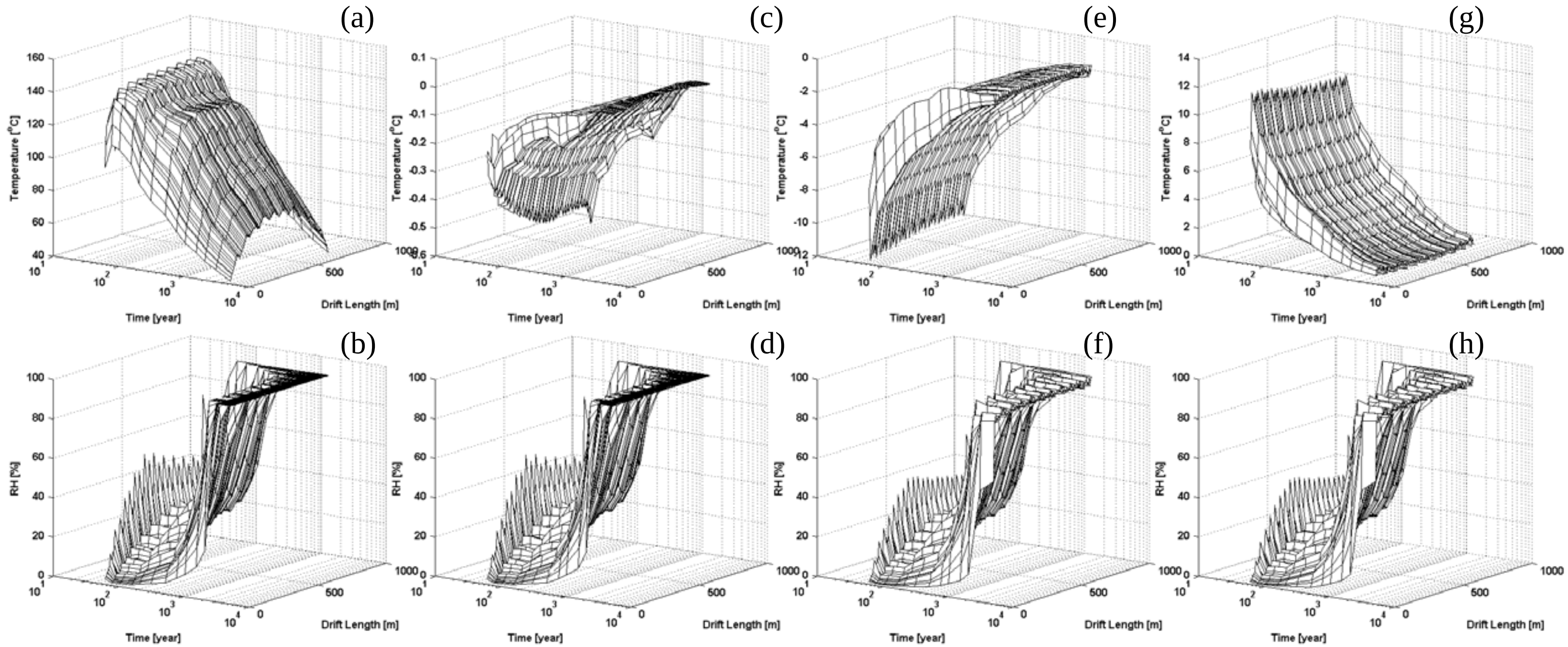
Air Infiltration: Very low

Temperatures, and Relative Humidities

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Convective



(a) Wall temperature; (b) Wall relative humidity; (c) Wall-air near wall temperature difference;
(d) Air near wall relative humidity; (e) Wall-air near WP temperature difference;
(f) Air near WP relative humidity; (g) WP-wall temperature difference; and
(h) WP relative humidity distributions in time and space

Air Infiltration: Low

Temperatures, and Relative Humidities

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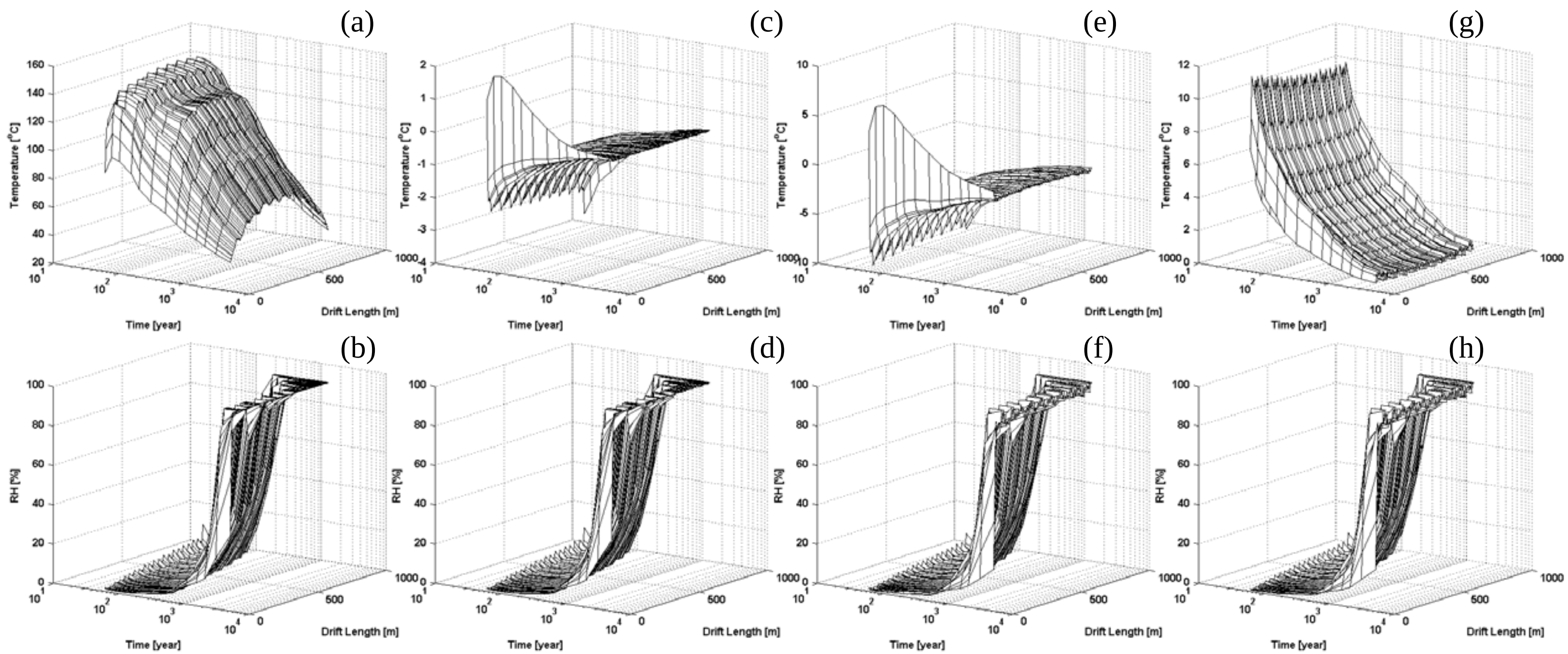

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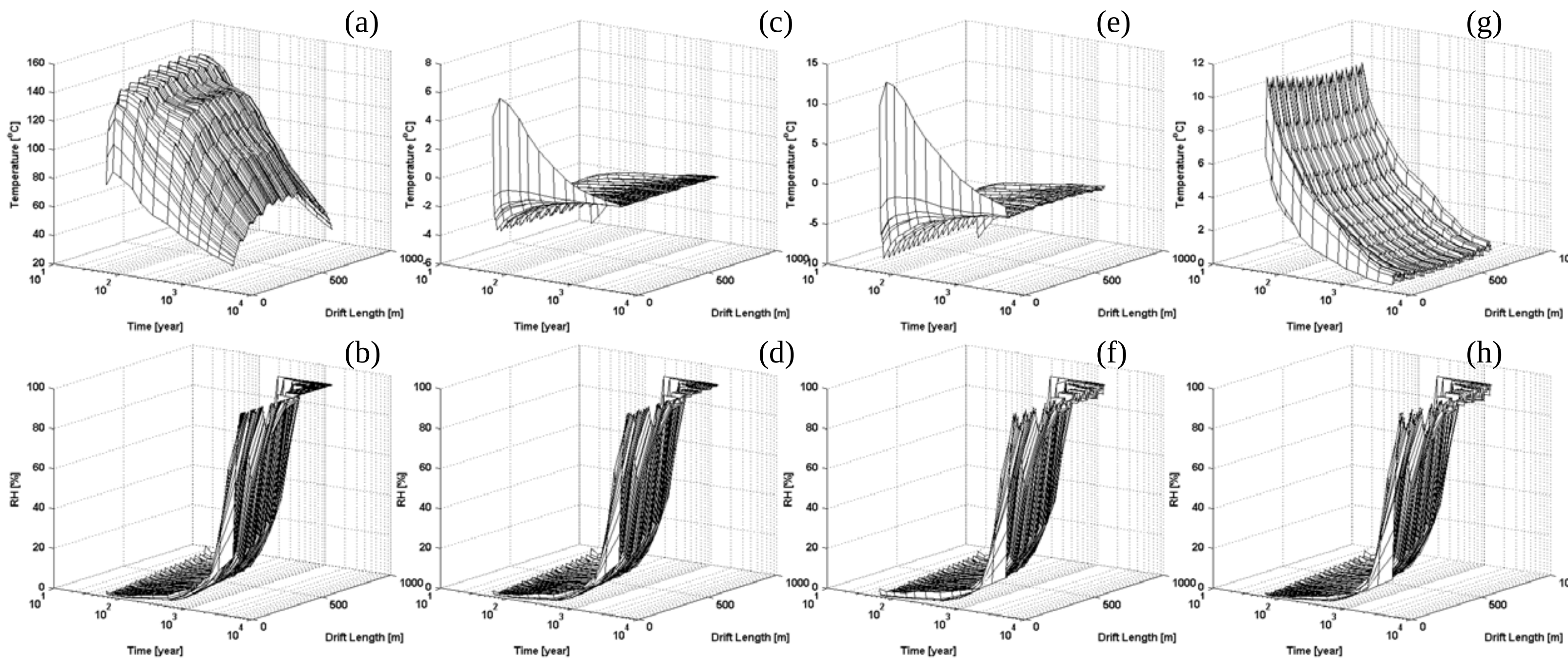
Air Infiltration: Balanced Temperatures, and Relative Humidities

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Convective



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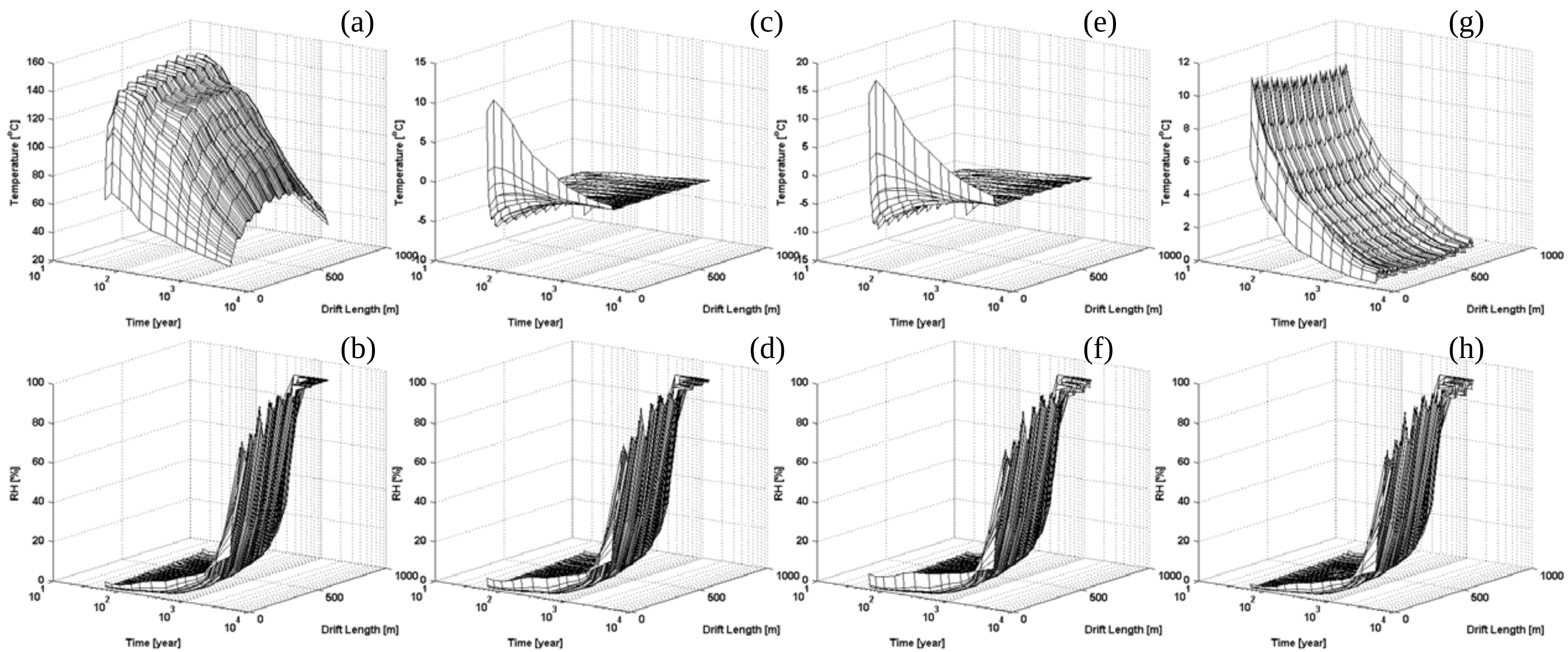
Air Infiltration: Medium

Temperatures, and Relative Humidities

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Convective



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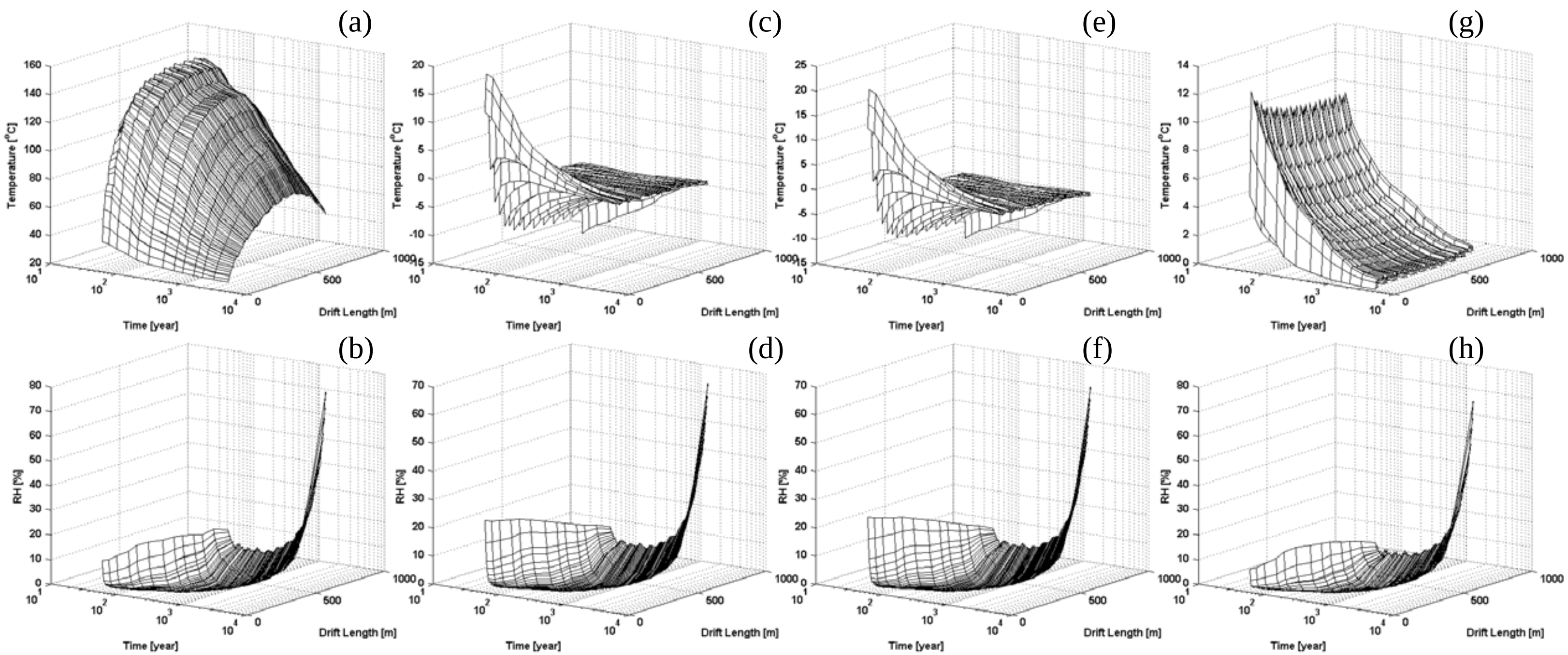
Air Infiltration: High Temperatures, and Relative Humidities

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Convective



(a) Wall temperature; (b) Wall relative humidity; (c) Wall-air near wall temperature difference; (d) Air near wall relative humidity; (e) Wall-air near WP temperature difference; (f) Air near WP relative humidity; (g) WP-wall temperature difference; and (h) WP relative humidity distributions in time and space

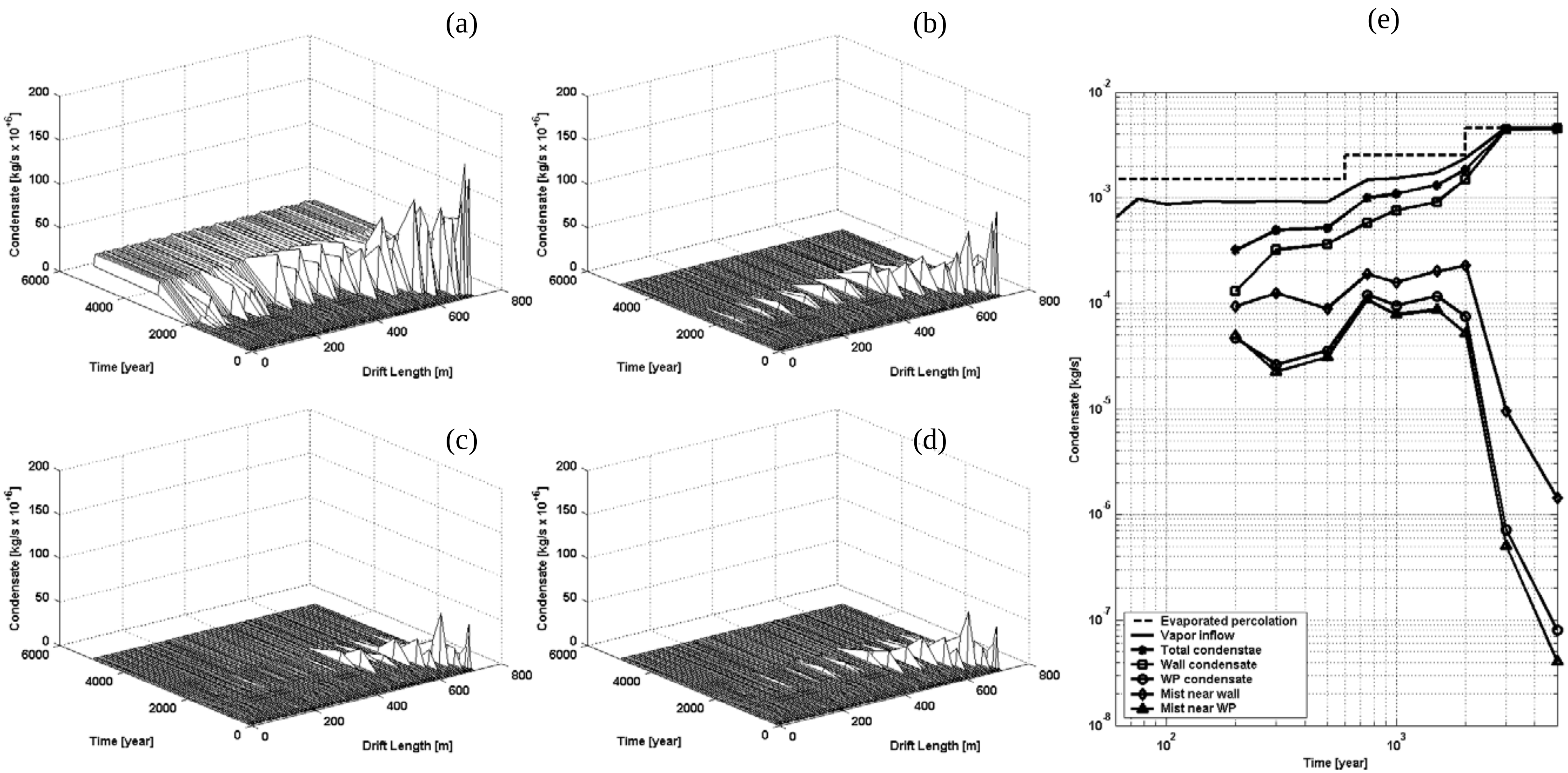
Air Infiltration: Very low

Parameter: Condensates

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Convective



(a) wall condensate, (b) WP condensate, (c) mist near wall,
(d) mist near WP, (e) condensate variation.

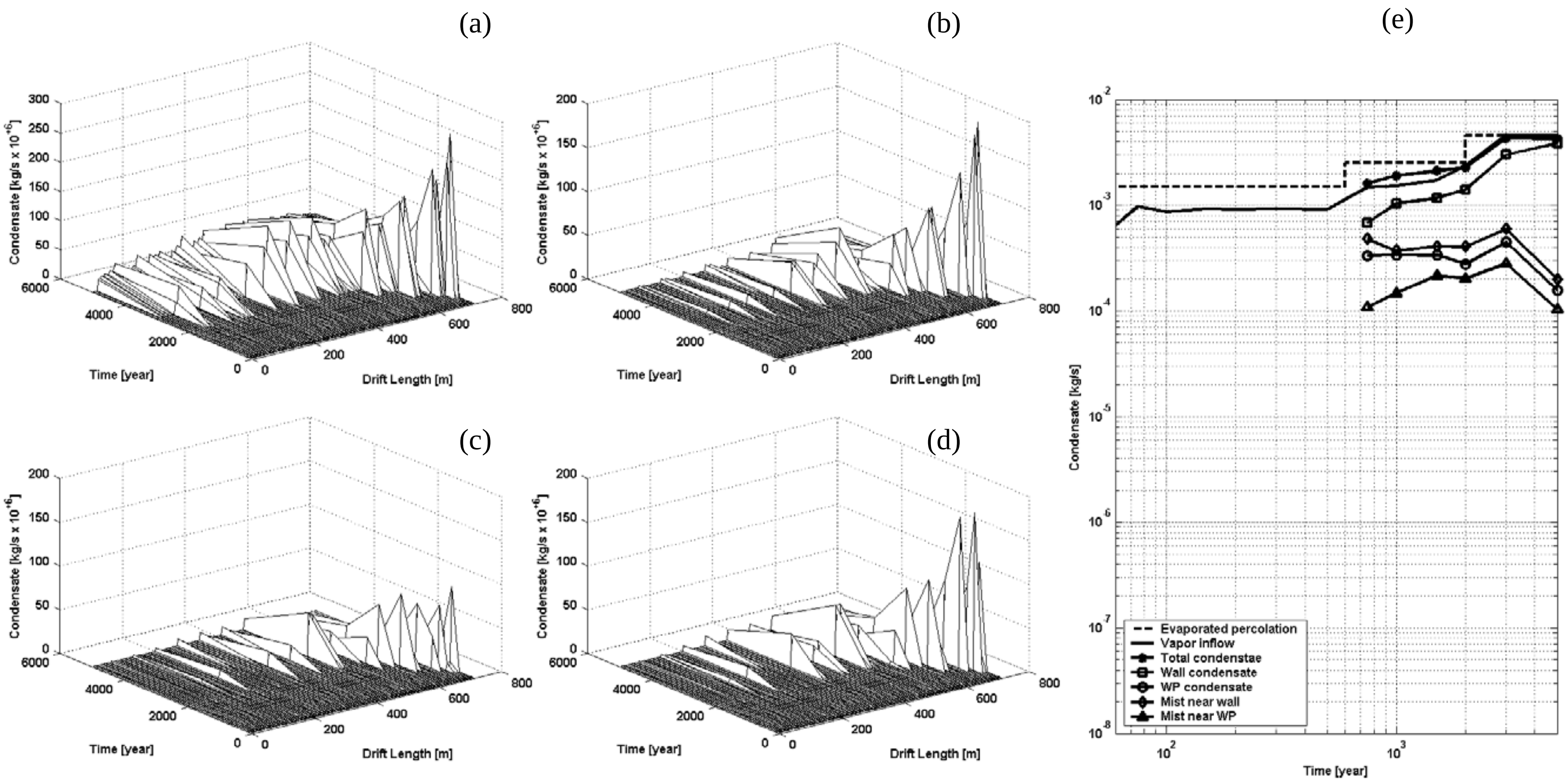
Air Infiltration: Low

Parameter: Condensates

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Convective



(a) wall condensate, (b) WP condensate, (c) mist near wall,
(d) mist near WP, (e) condensate variation.

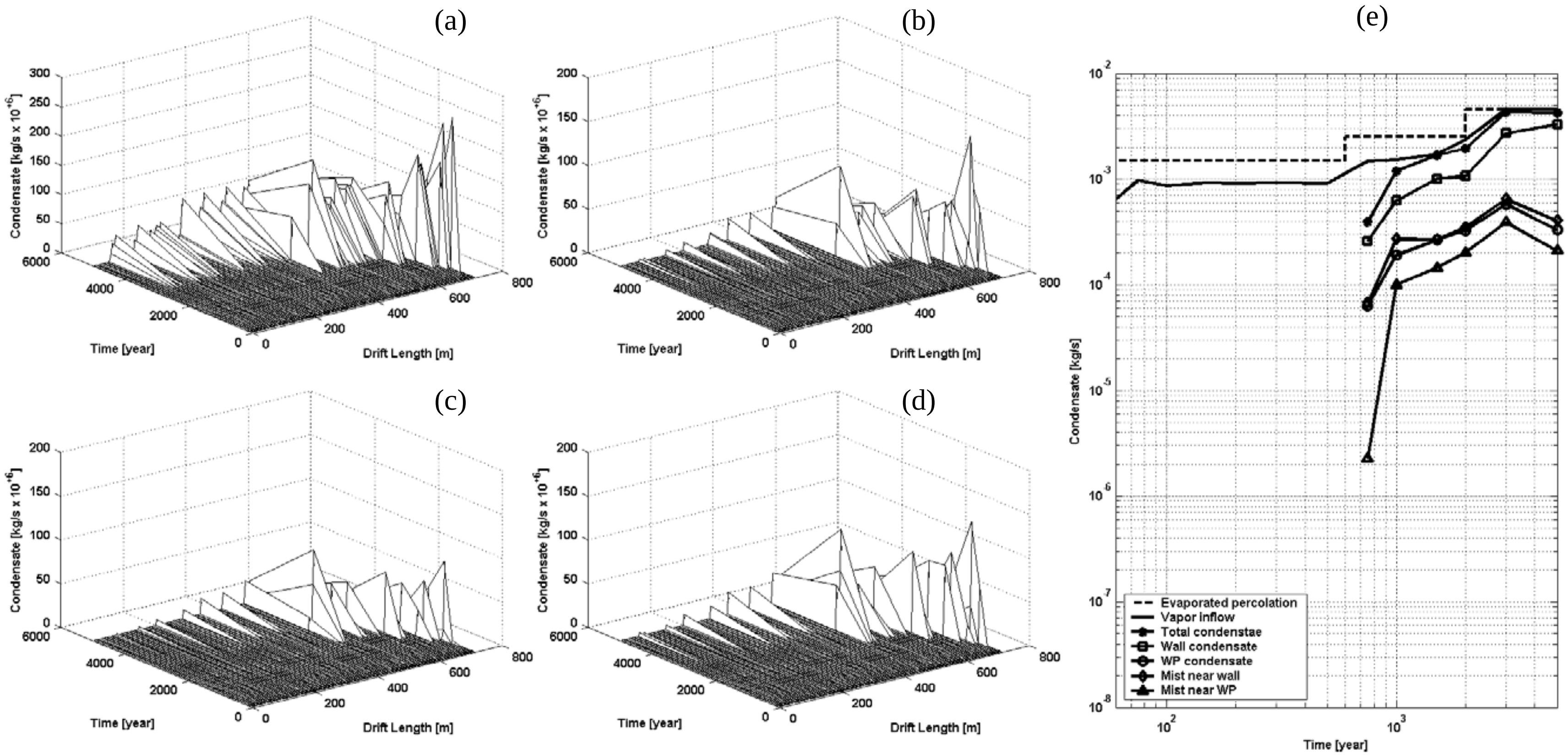
Air Infiltration: Balanced

Parameter: Condensates

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Convective



(a) wall condensate, (b) WP condensate, (c) mist near wall,
(d) mist near WP, (e) condensate variation.

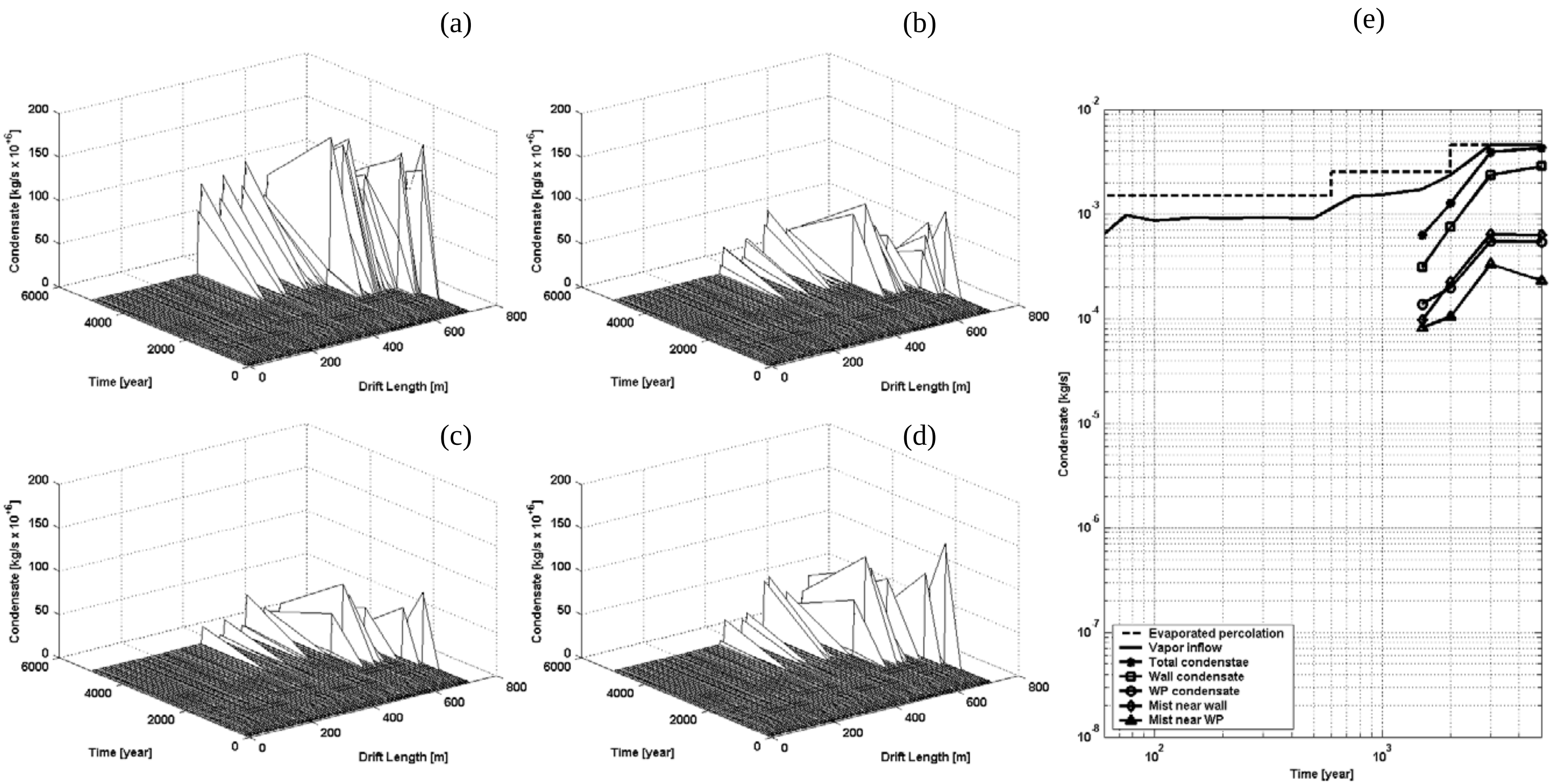
Air Infiltration: Medium

Parameter: Condensates

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Convective



(a) wall condensate, (b) WP condensate, (c) mist near wall,
(d) mist near WP, (e) condensate variation.

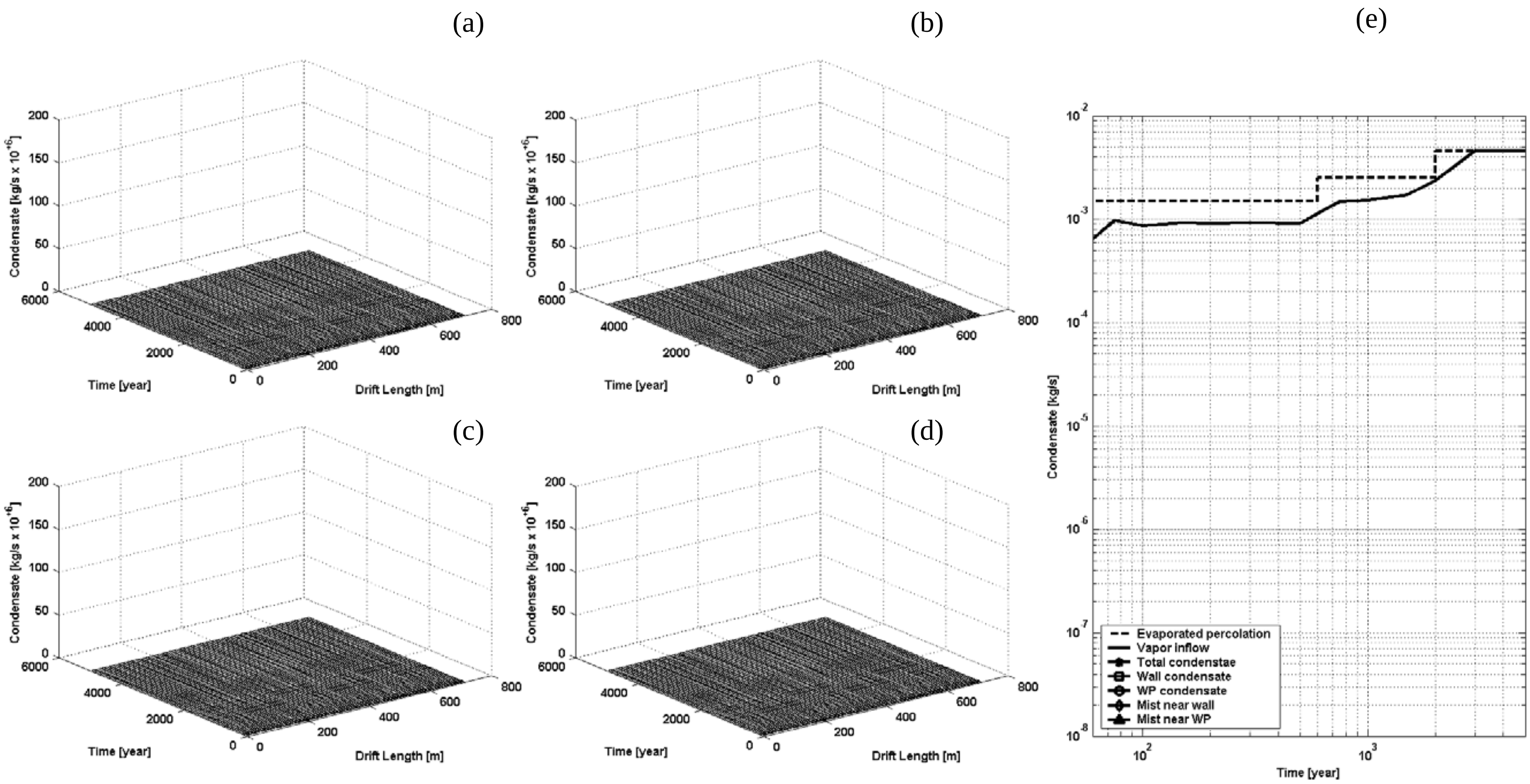
Air Infiltration: High

Parameter: Condensates

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Convective



(a) wall condensate, (b) WP condensate, (c) mist near wall,
(d) mist near WP, (e) condensate variation.

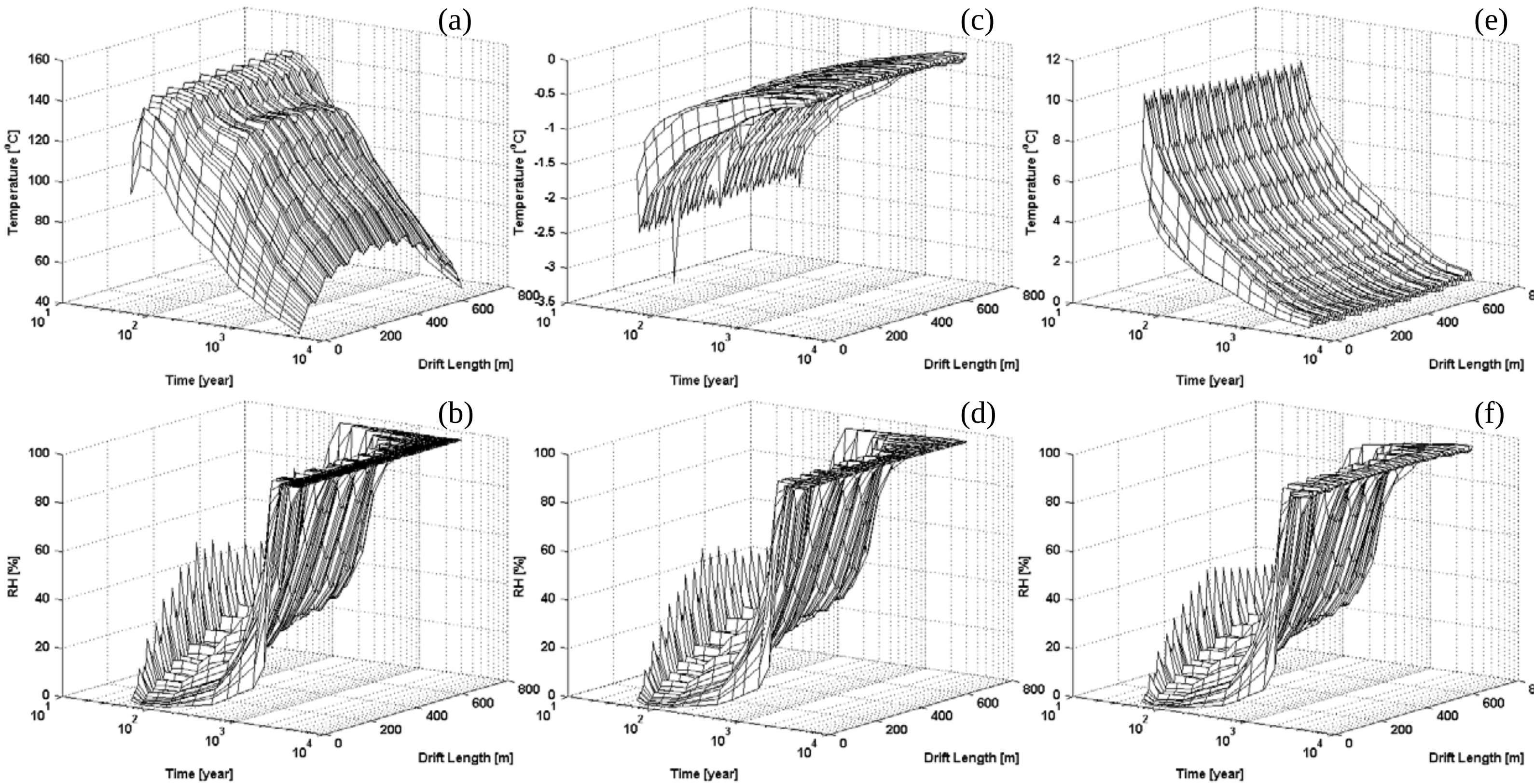
Air Infiltration: Very low

Temperatures, and Relative Humidities

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Diffusive (Porous Media Emulation)



(a) Wall temperature; (b) Wall relative humidity;
(c) Wall-air temperature difference; (d) Air relative humidity;
(e) WP-wall temperature difference; and (f) WP relative humidity distributions in time and space

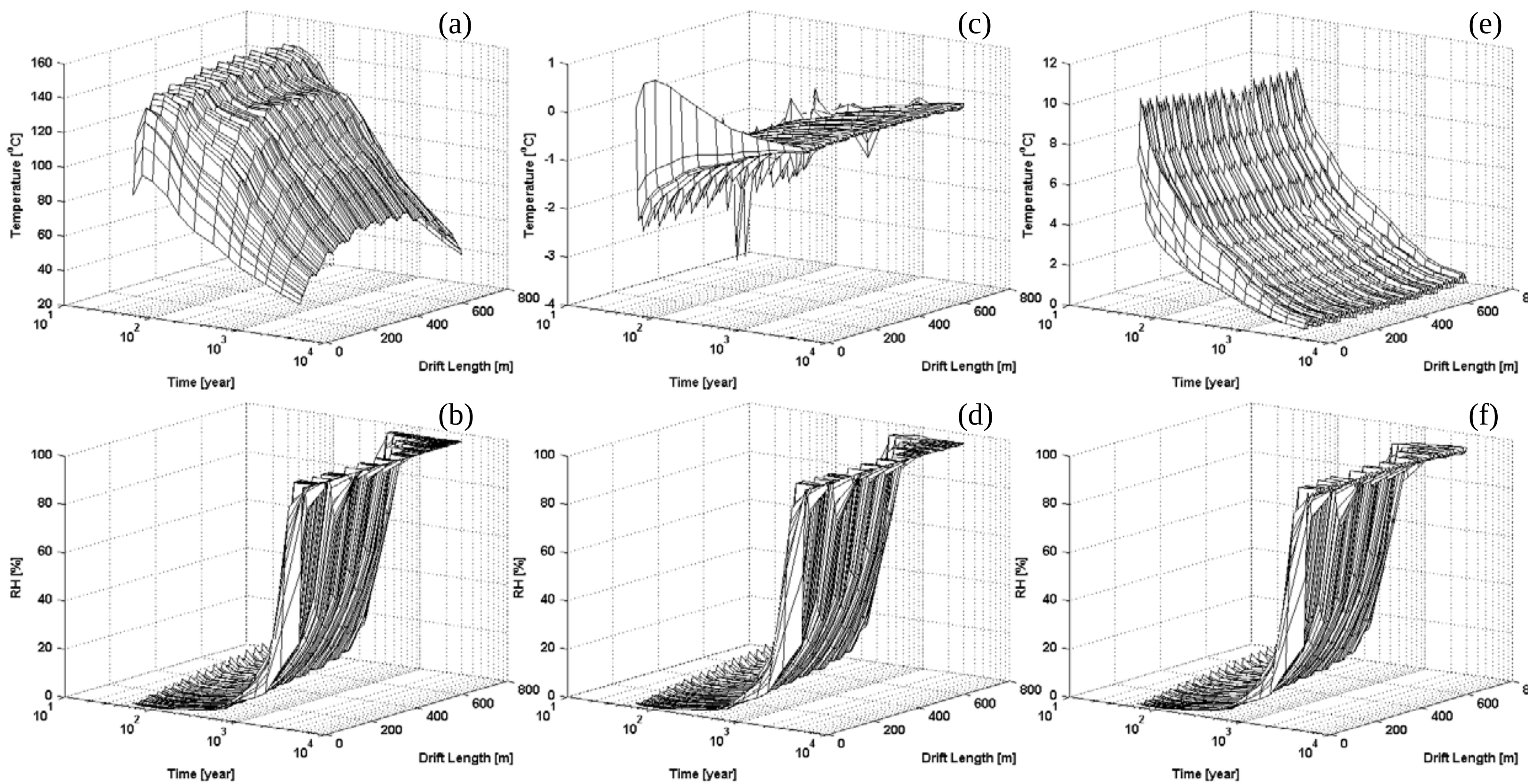
Air Infiltration: Low

Temperatures, and Relative Humidities

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Diffusive (Porous Media Emulation)



(a) Wall temperature; (b) Wall relative humidity;
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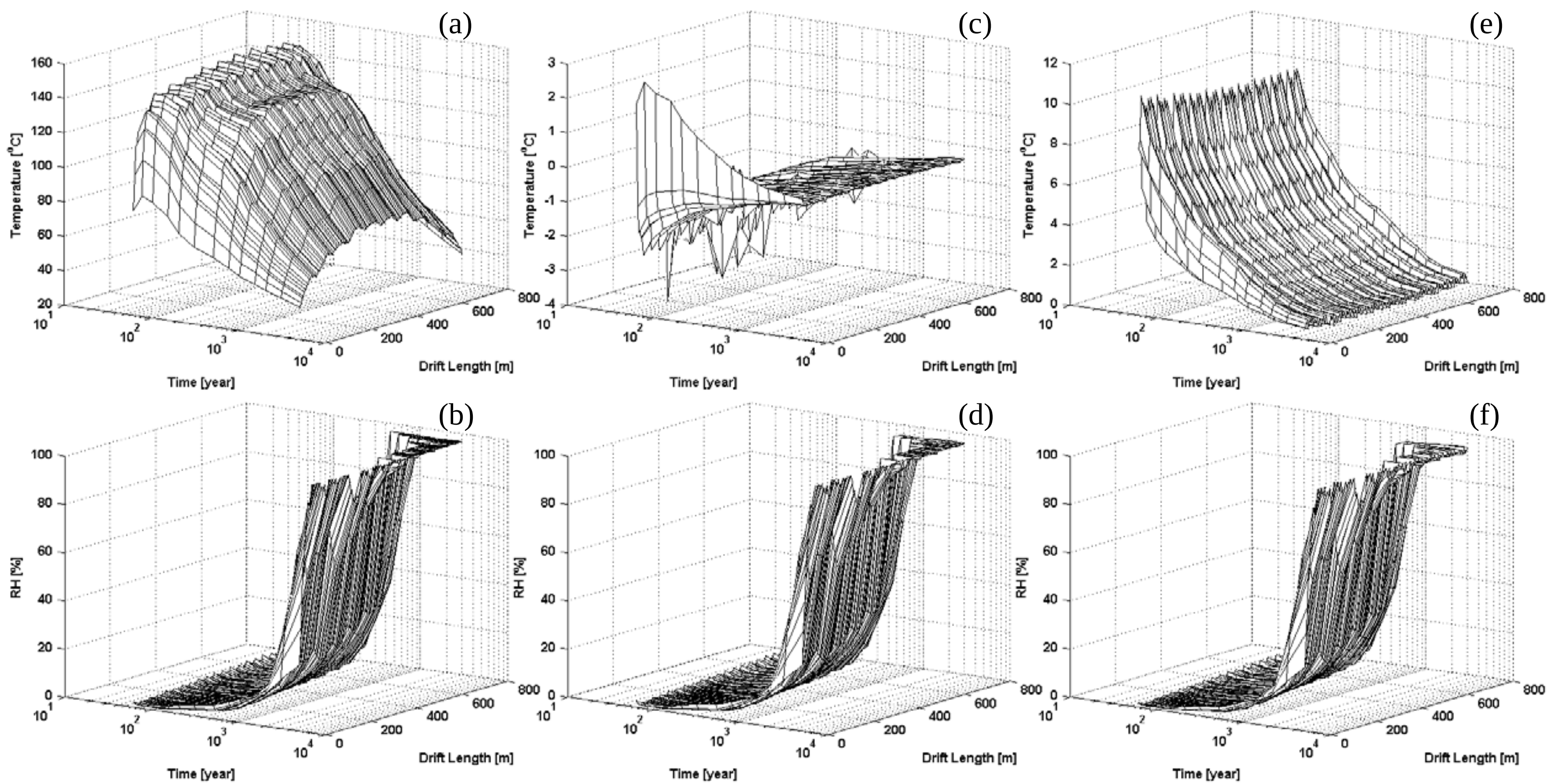
(e) WP-wall temperature difference; and (f) WP relative humidity distributions in time and space

Air Infiltration: Balanced Temperatures, and Relative Humidities

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Diffusive (Porous Media Emulation)



(a) Wall temperature; (b) Wall relative humidity;
(c) Wall-air temperature difference; (d) Air relative humidity;
(e) WP-wall temperature difference; and (f) WP relative humidity distributions in time and space

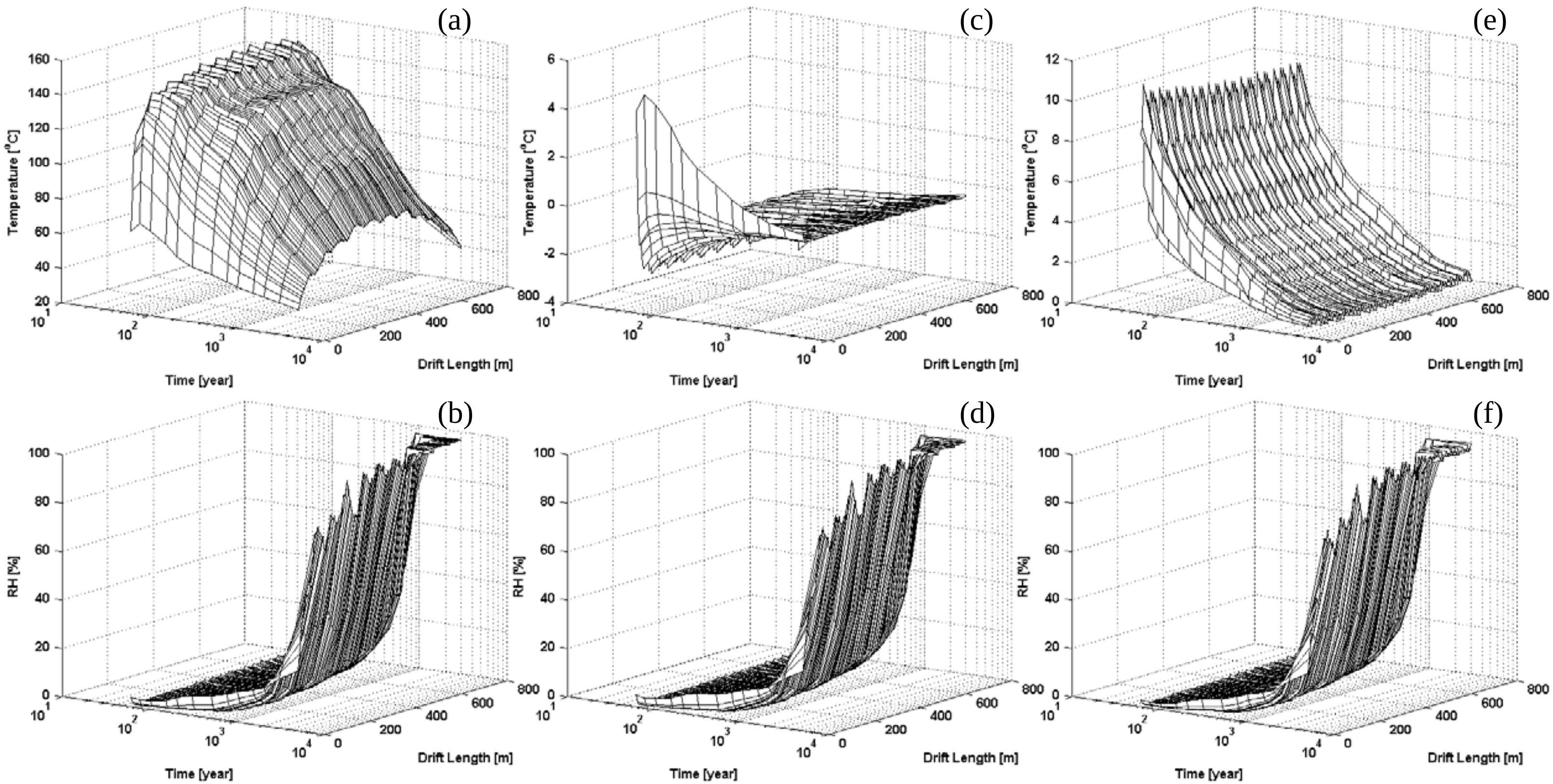
Air Infiltration: Medium

Temperatures, and Relative Humidities

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Diffusive (Porous Media Emulation)



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(e) WP-wall temperature difference; and (f) WP relative humidity distributions in time and space

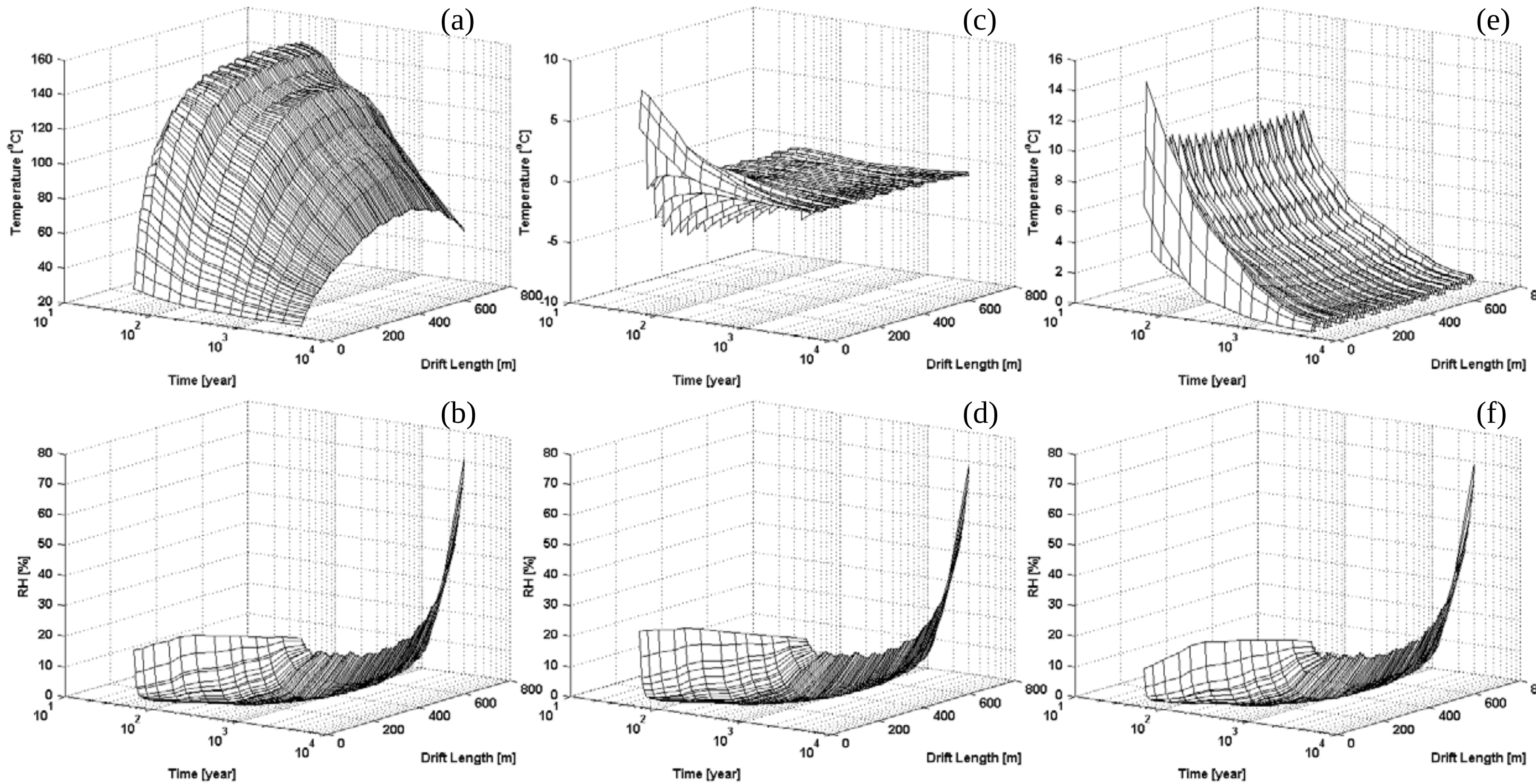
Air Infiltration: High

Temperatures, and Relative Humidities

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Diffusive (Porous Media Emulation)



(a) Wall temperature; (b) Wall relative humidity;
(c) Wall-air temperature difference; (d) Air relative humidity;
(e) WP-wall temperature difference; and (f) WP relative humidity distributions in time and space

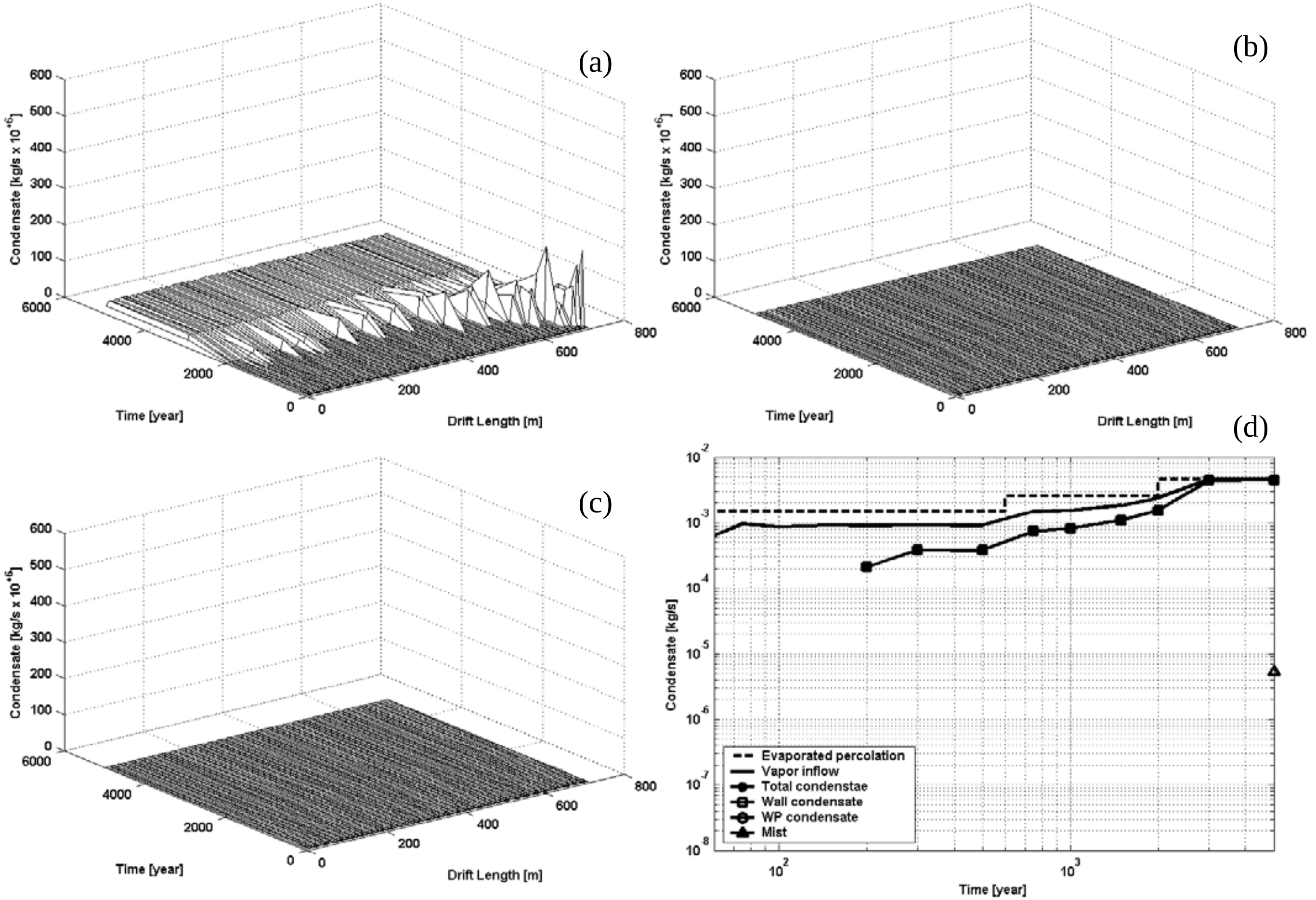
Air Infiltration: Very low

Parameter: Condensates

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Diffusive (Porous Media Emulation)



(a) wall condensate, (b) WP condensate, (c) mist
(d) condensate variation.

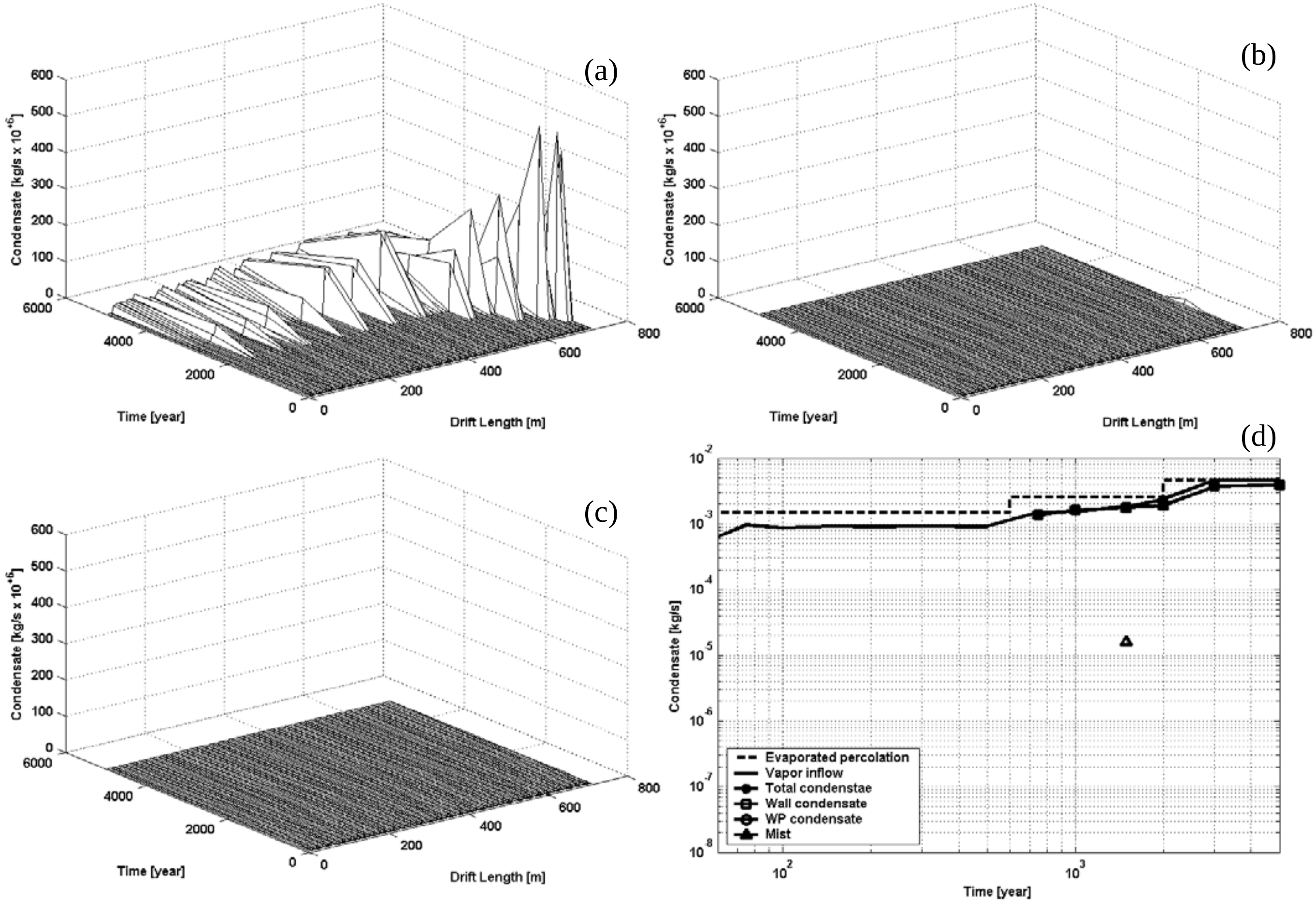
Air Infiltration: Low

Parameter: Condensates

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Diffusive (Porous Media Emulation)



(a) wall condensate, (b) WP condensate, (c) mist
(d) condensate variation.

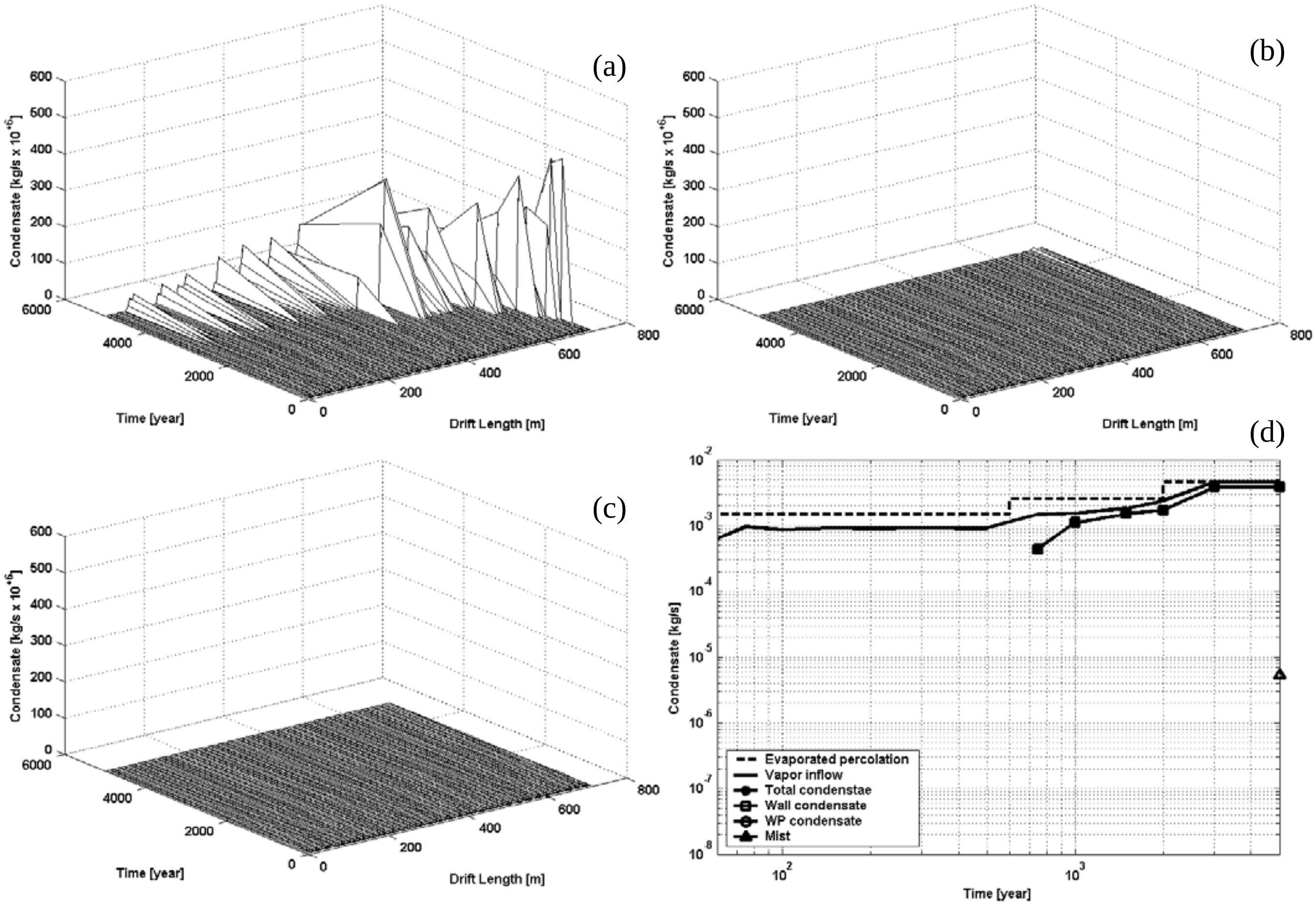
Air Infiltration: Balanced

Parameter: Condensates

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Diffusive (Porous Media Emulation)



(a) wall condensate, (b) WP condensate, (c) mist
(d) condensate variation.

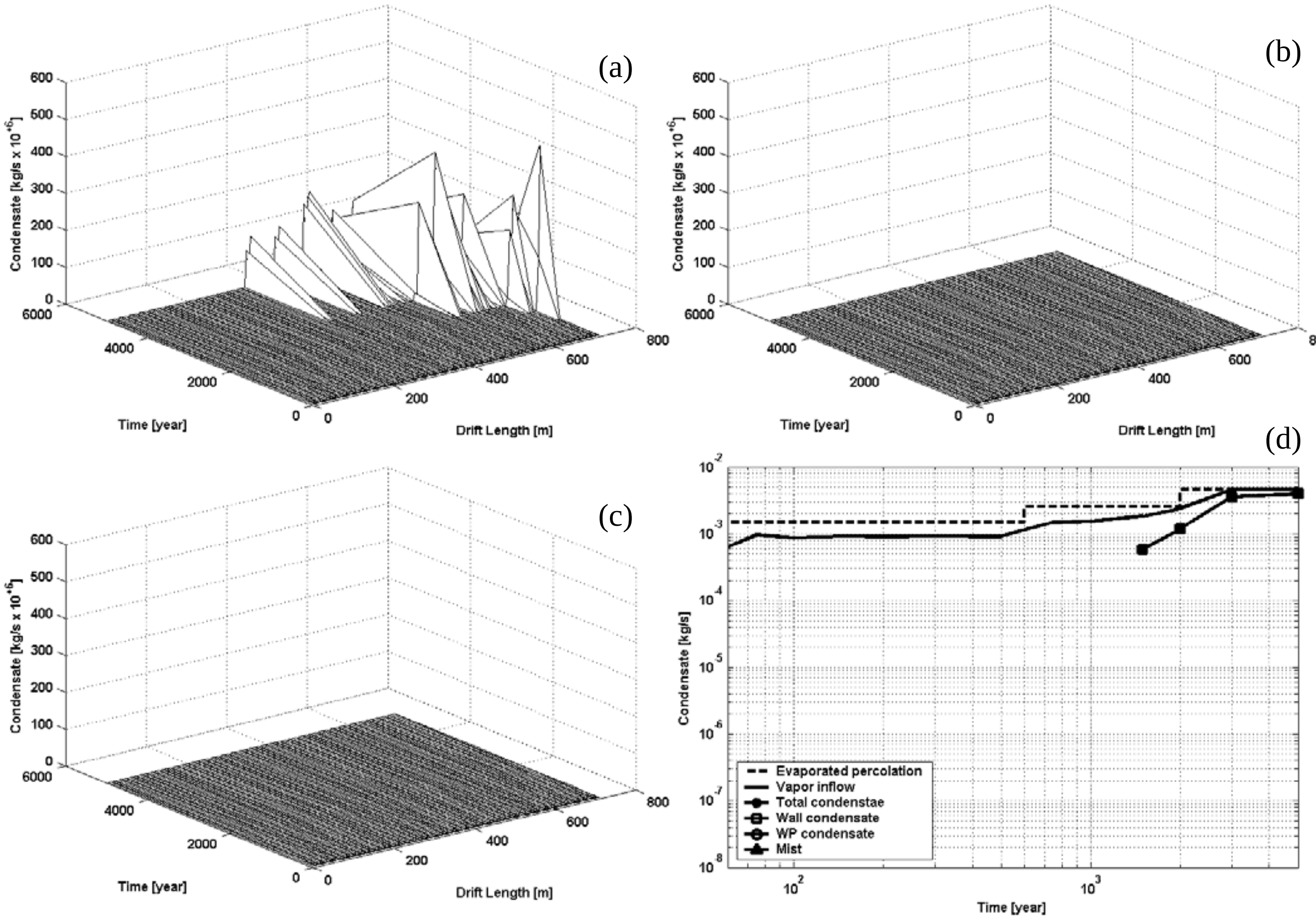
Air Infiltration: Medium

Parameter: Condensates

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Diffusive (Porous Media Emulation)



(a) wall condensate, (b) WP condensate, (c) mist
(d) condensate variation.

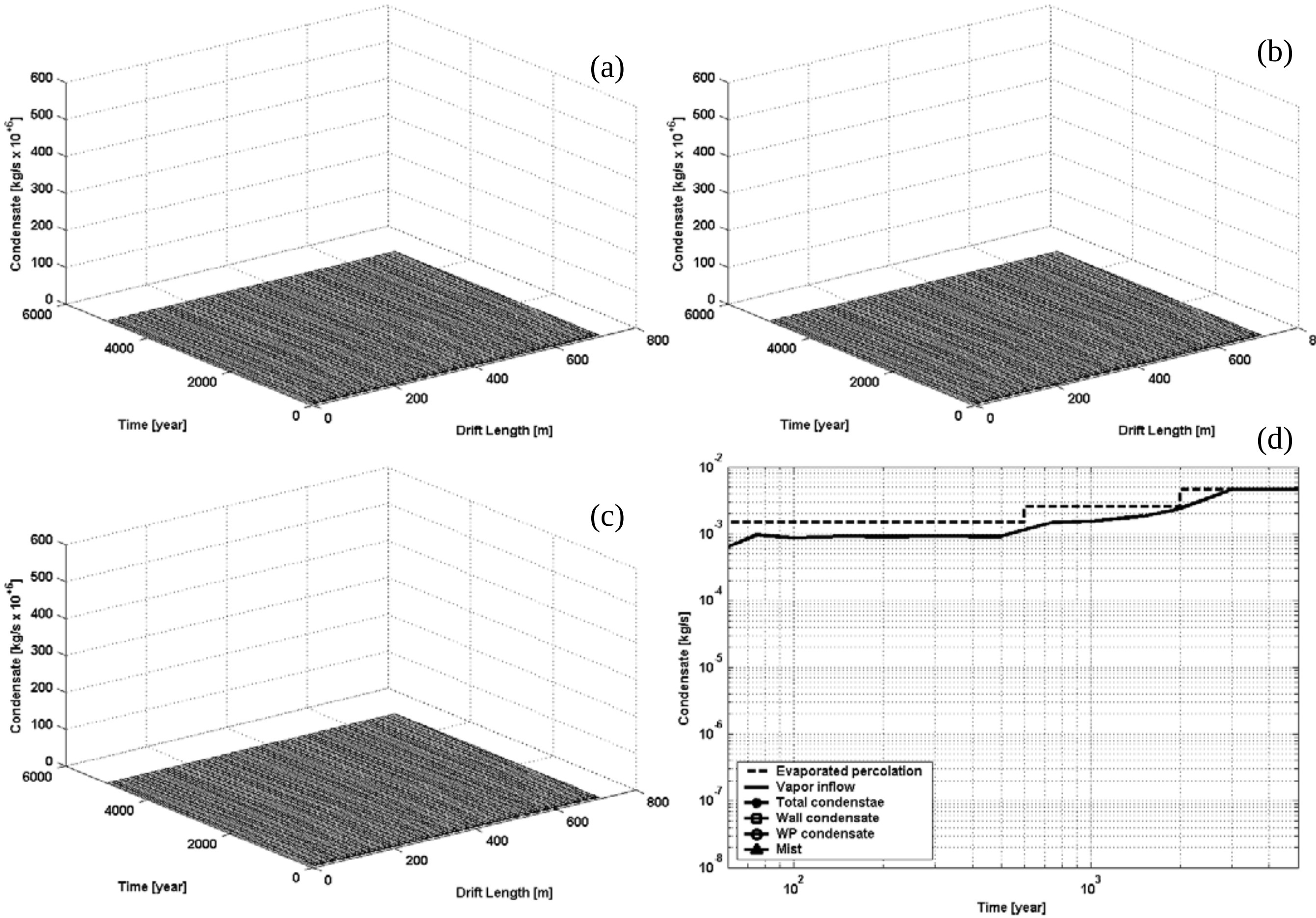
Air Infiltration: high

Parameter: Condensates

Thermal Model: NTCF-NUFT

Moisture Model: Robust-Approximate

In-Drift Model: CFD-Diffusive (Porous Media Emulation)



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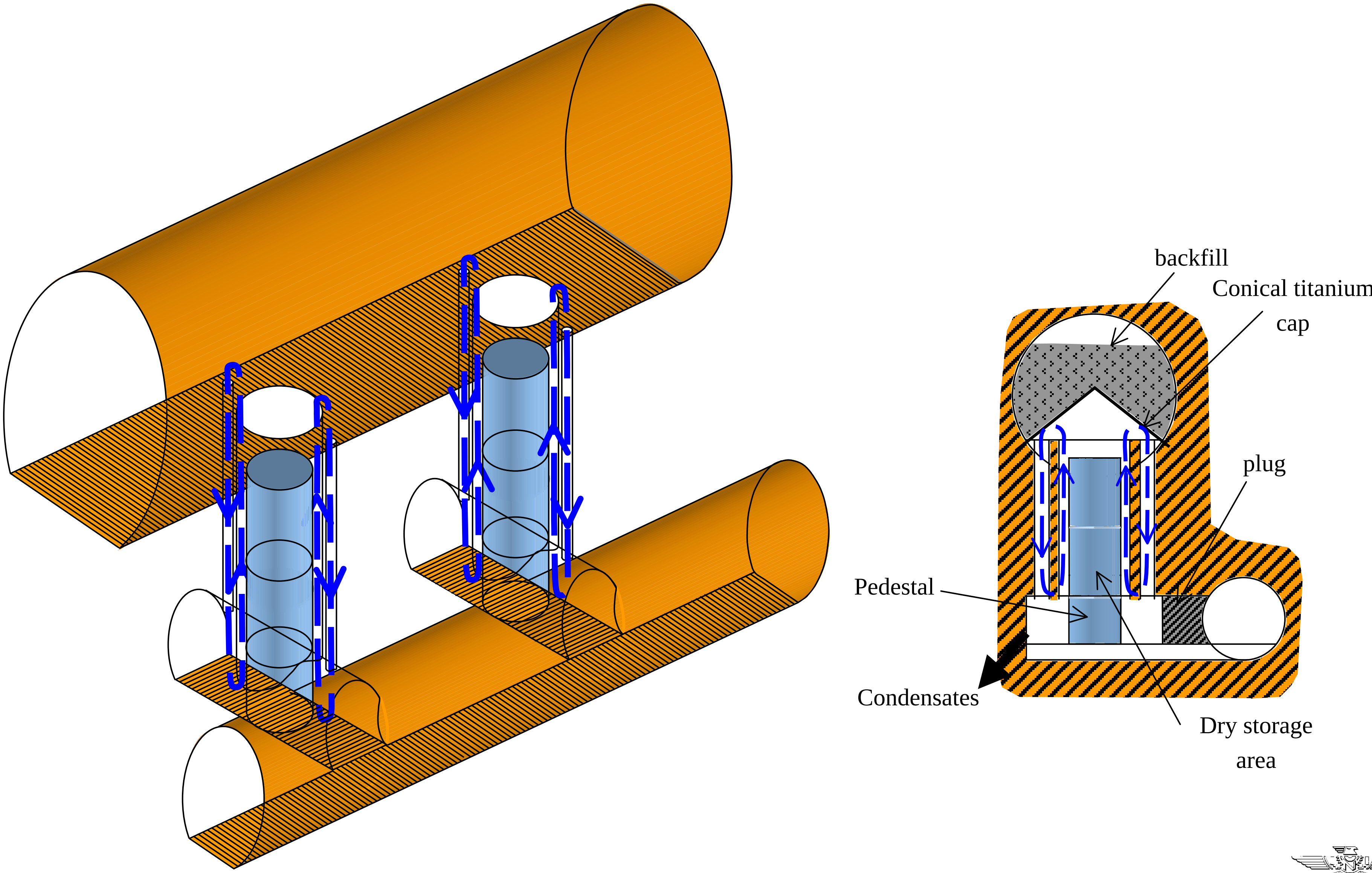
(d) condensate variation.

Alternative, Compartmentalized Waste Package Emplacement with Post-Closure Backfill and Air Cell Recirculation



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Not to scale