Methods to Reduce Fumigant Emissions

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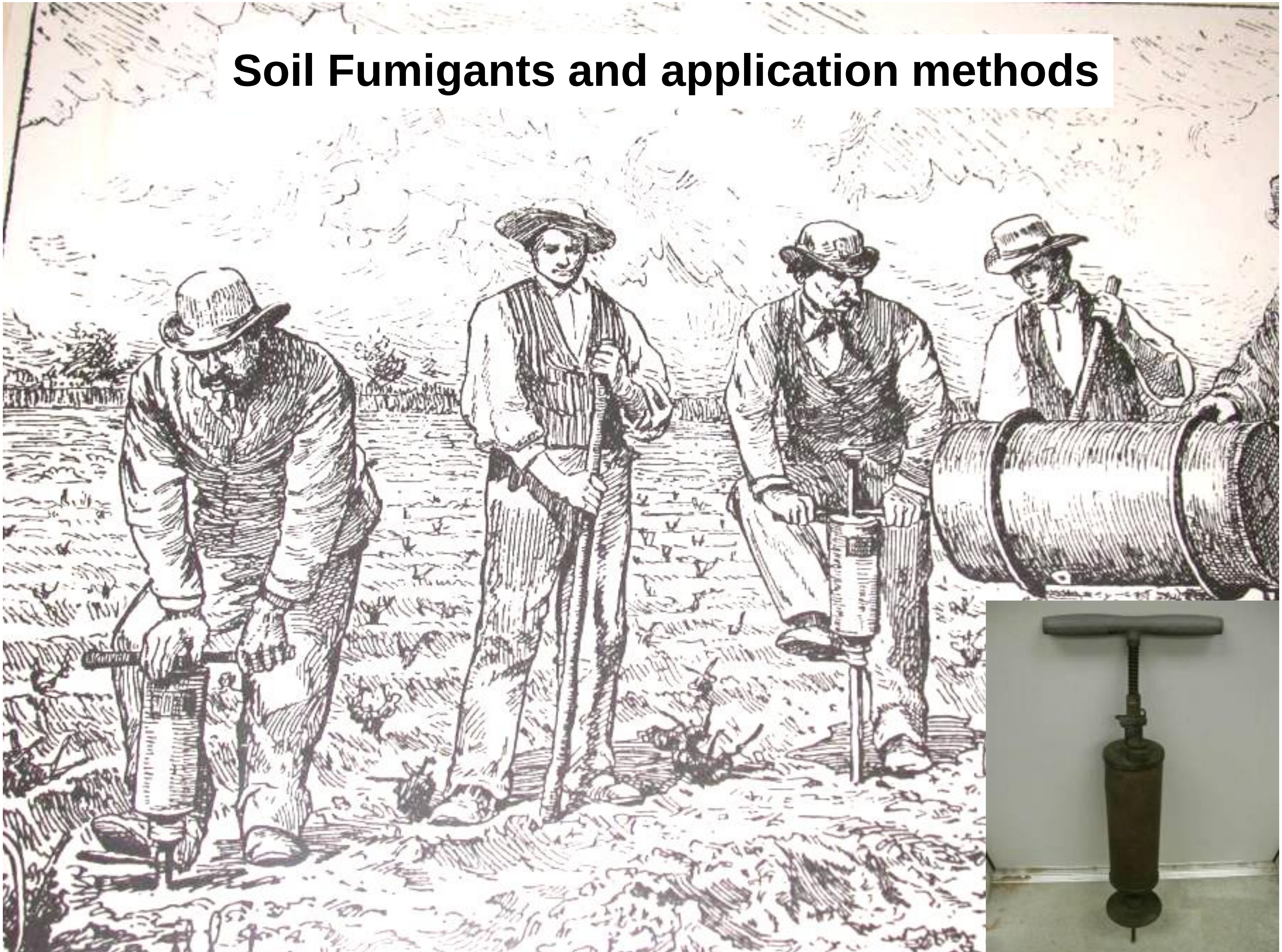
Soil Fumigants and application methods



Conventional Soil Fumigation (Acres, California 2007):

Methyl Bromide/Chloropicrin:	40,000
Telone/Chloropicrin:	17,000
Telone II:	37,000
Chloropicrin alone:	6,000
Metam sodium:	77,000

TOTAL: ~ 180,000 acres annually

Methyl Bromide Alternatives Research

Strawberry: Verticillium wilt

- **Pathogen is *Verticillium dahliae***
- **Survives in the soil as microsclerotia**
  - **These can survive for long periods of time in the soil**
- ***V. dahliae* has a broad host range**
- **Strawberry is very susceptible, 3-12 microsclerotia/g soil can cause significant losses.**
- **Symptom expression starts in the spring as the temperatures begin to warm up**


Macrophomina problems are increasing on fields treated consecutively via drip fumigation (***or low application rates***). Growers will need to rotate drip applications with broadcast treatments to keep these fields viable for crop production.
Macrophomina (Charcoal Rot)

Fusarium (Fusarium wilt)

Emission Reduction Methods

- **Application Methods:**
  - Deep injection
  - Subsurface drip fumigation
  - Local area treatment (strip or spot applications)
- **Surface Treatment:**
  - Plastic film (tarp) (impermeable film)
  - Irrigation (water treatment/seal)
  - Organic amendment (compost, manure, etc.)
  - Chemical treatment (e.g., K-thiosulfate)

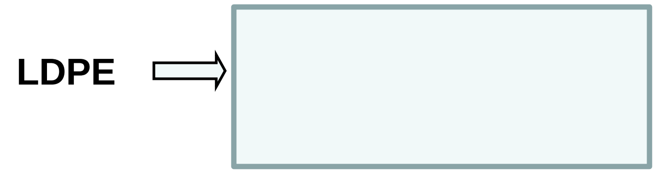
Use of "Plastic Mulch" or Tarp for Soil Fumigation

"Agricultural Film"

- Reduces/delays fumigant volatilization losses
  - Less emissions rates and smaller buffer zone
  - Less total fumigant emissions (total flux)
- Enhances the efficacy of reduced rates by keeping fumigants in soil for a longer time
- Maintains and possibly enhances yield by warming/cooling the soil, moisture, etc…

Agricultural Film Types

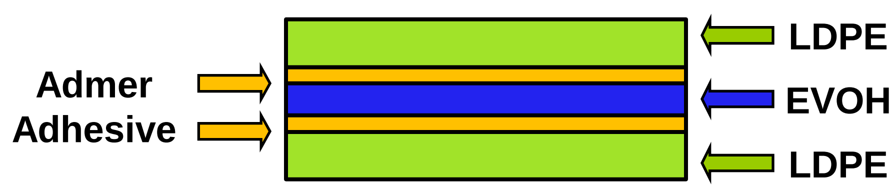
“Standard” polyethylene tarp (HDPE or LDPE)



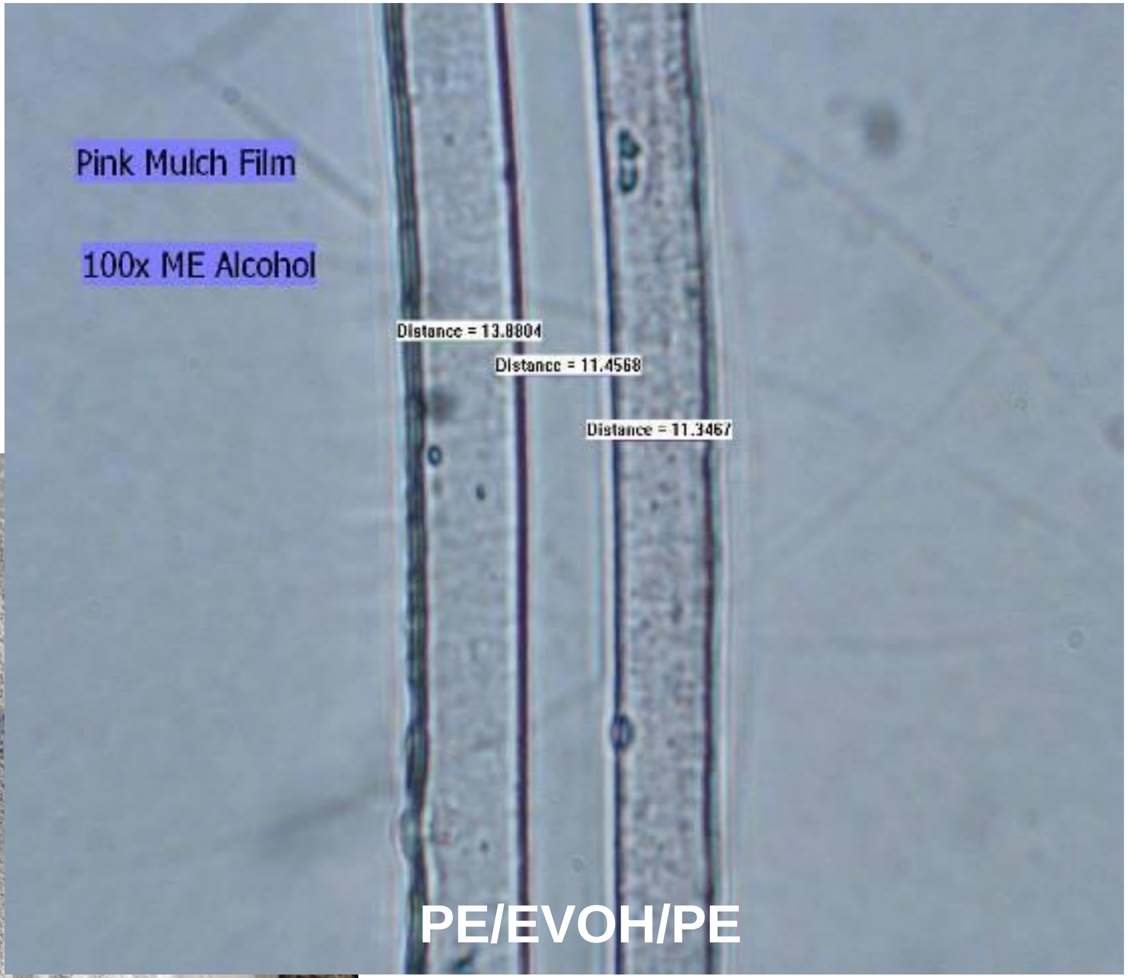
“Semi-impermeable” Tri-extruded LDPE

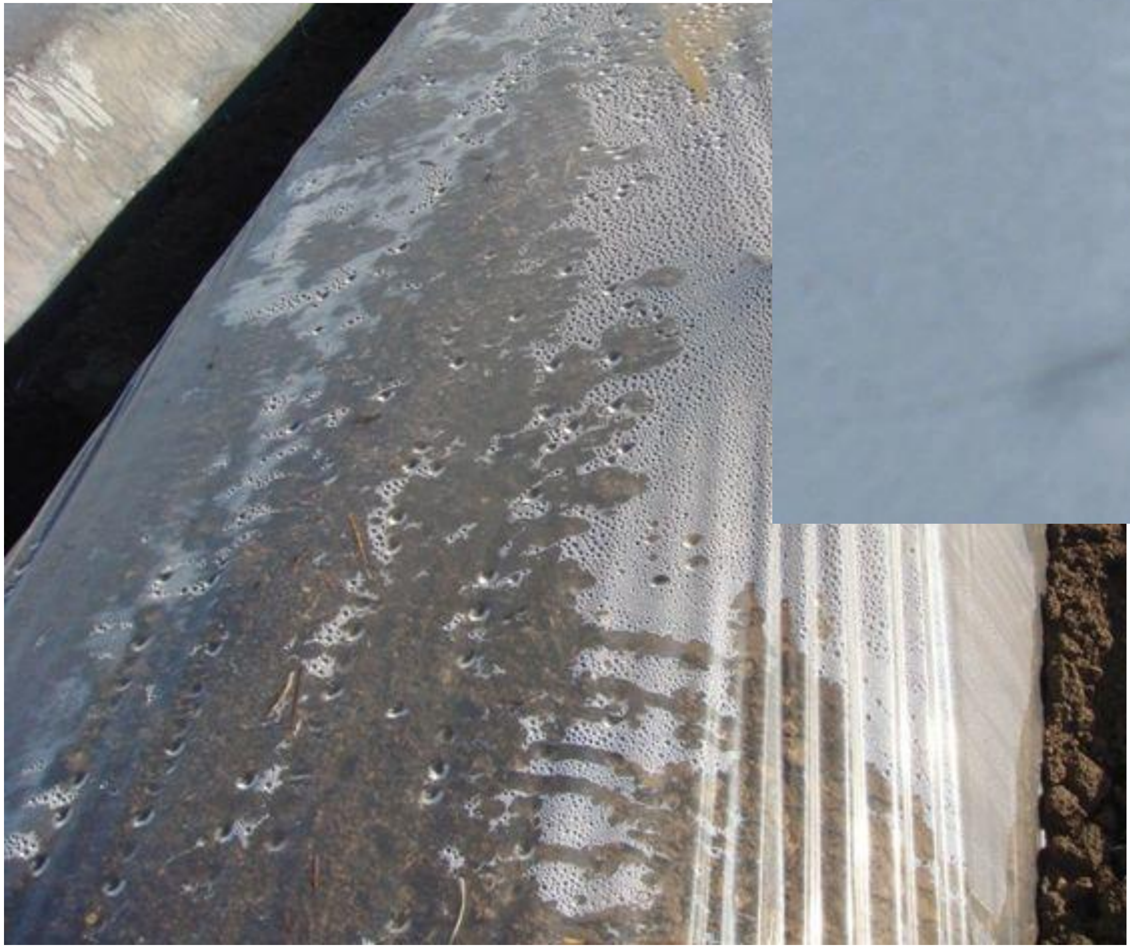
“Virtually impermeable (VIF)” LDPE + Nylon barrier

“Totally impermeable (TIF)” 5-layer EVOH resin barrier



5 layer TIF

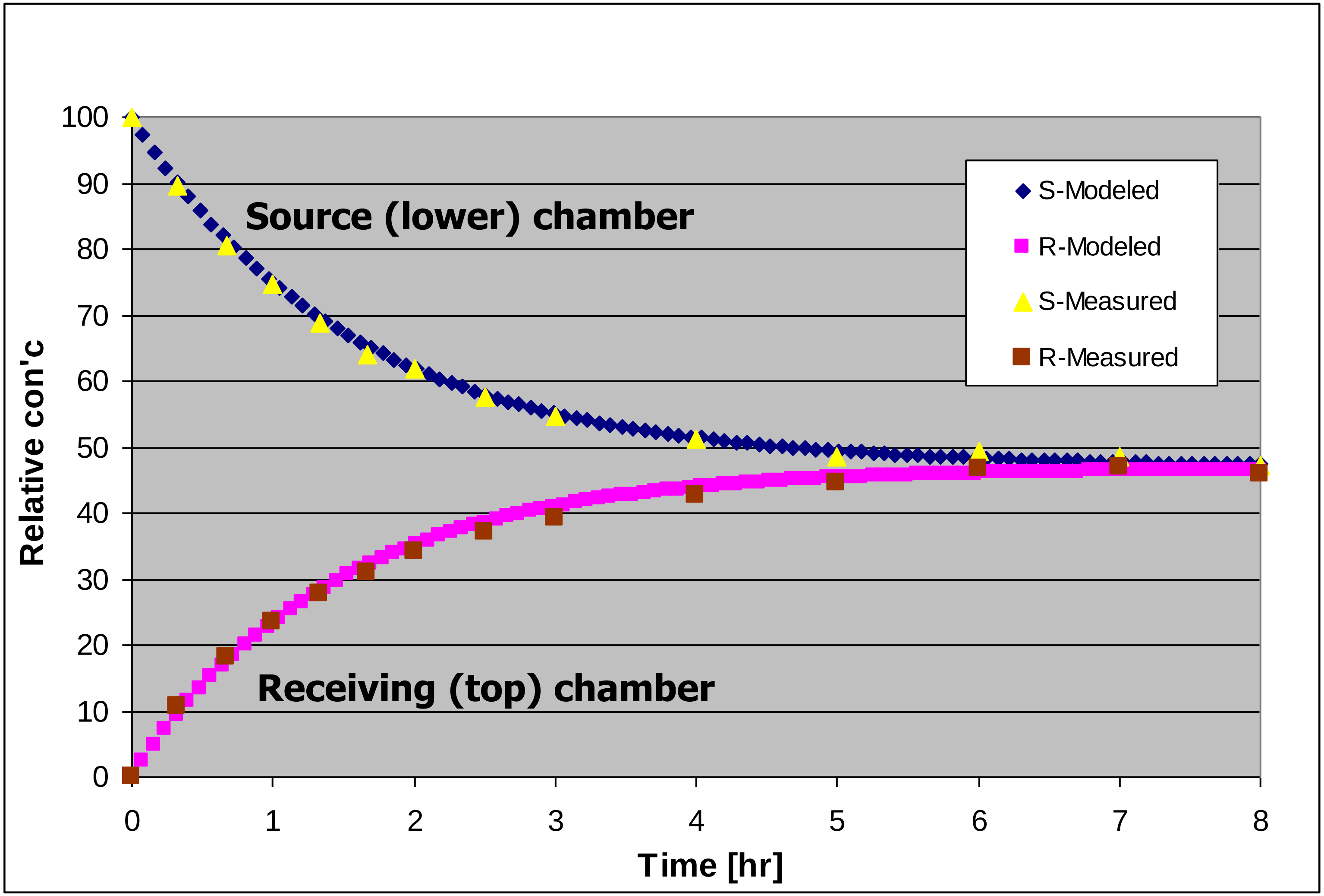

Pink Mulch Film
100x ME Alcohol
Distance = 13.8804
Distance = 11.4568
Distance = 11.3467
PE/EVOH/PE



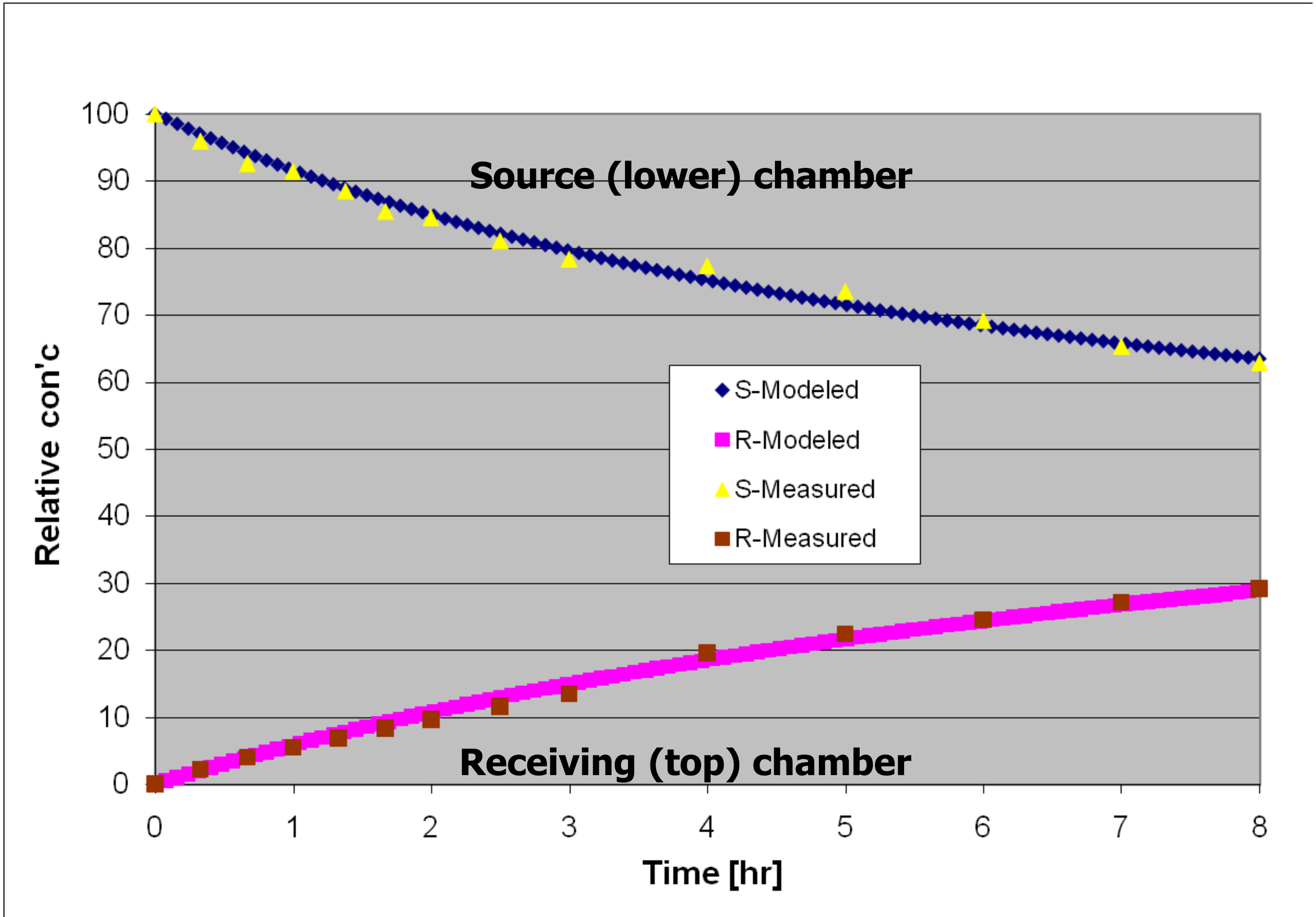
Plastic Permeability Measurement
Mass Transfer Coefficient

- Plastic film is mounted between two chambers
- Fumigant is applied to the lower chamber
- The cells are kept at a known temperature

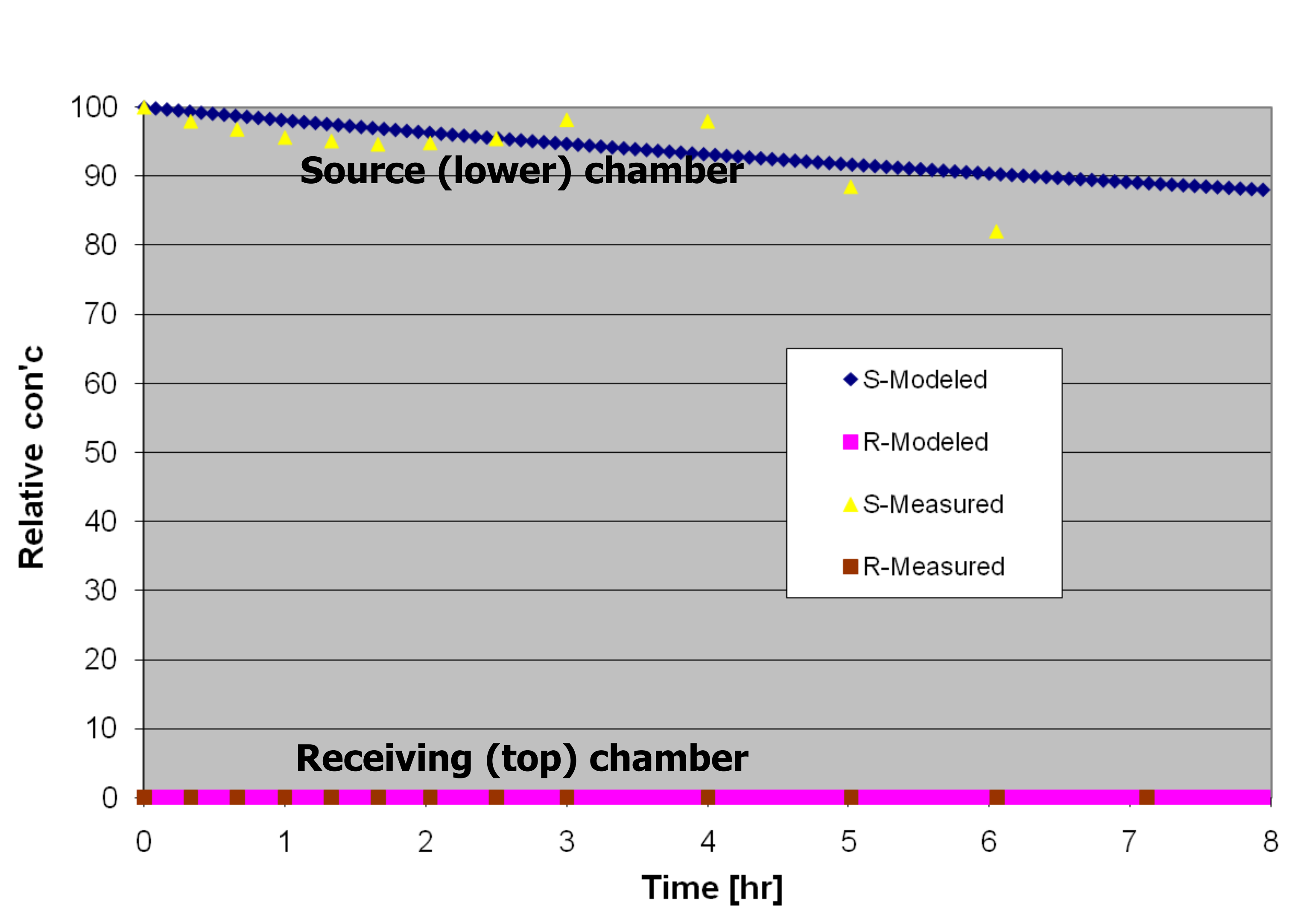
Diffusion of MB through standard LDPE



Diffusion of MB through metalized film



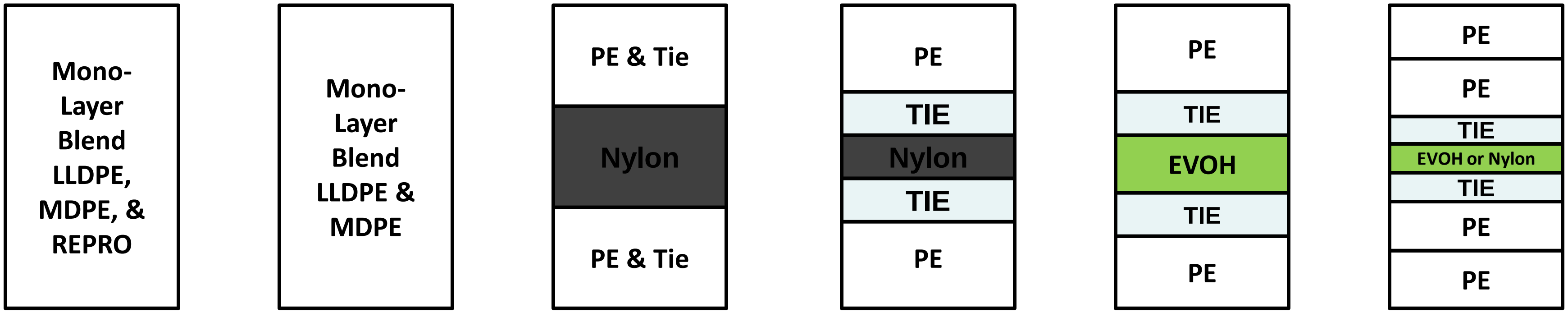
Diffusion of MB through Bromostop VIF



Mass Transfer Coefficients (cm/h) (Before and After Tarping)

Film type	Cis 1,3-D		Cis 1,3-D		Chloropicrin	
	Before	After	Before	After	Before	After
Pliant embossed, 1.25 mil	14.61	16.38	17.32	18.22	9.04	9.98
PolyPak Std, 1.5 mil	3.23	3.79	5.15	5.65	1.49	1.70
PolyPak SIF, 2.0 mil	1.42	1.53	1.51	1.71	0.67	1.71
Blockade, 1.25 mil	0.86	0.88	1.65	1.74	0.11	0.17
Bromostop VIF, 1.38 mil	0.07	0.27	0.09	0.42	0.02	0.18
Eval/Mitsui TIF, 1.38 mil	0.00	0.02	0.001	0.07	0.001	0.01

Various Film Structures



STD	STD	3-layer VIF	5-layer VIF	5-layer TIF	7-layer VIF or TIF
FUMIGANT BARRIER					
POOR	POOR	MEDIUM	MED/HIGH	MED/HIGH	HIGH
PHYSICAL PROPERTIES					
GOOD	HIGH	POOR	MEDIUM	POOR	HIGH

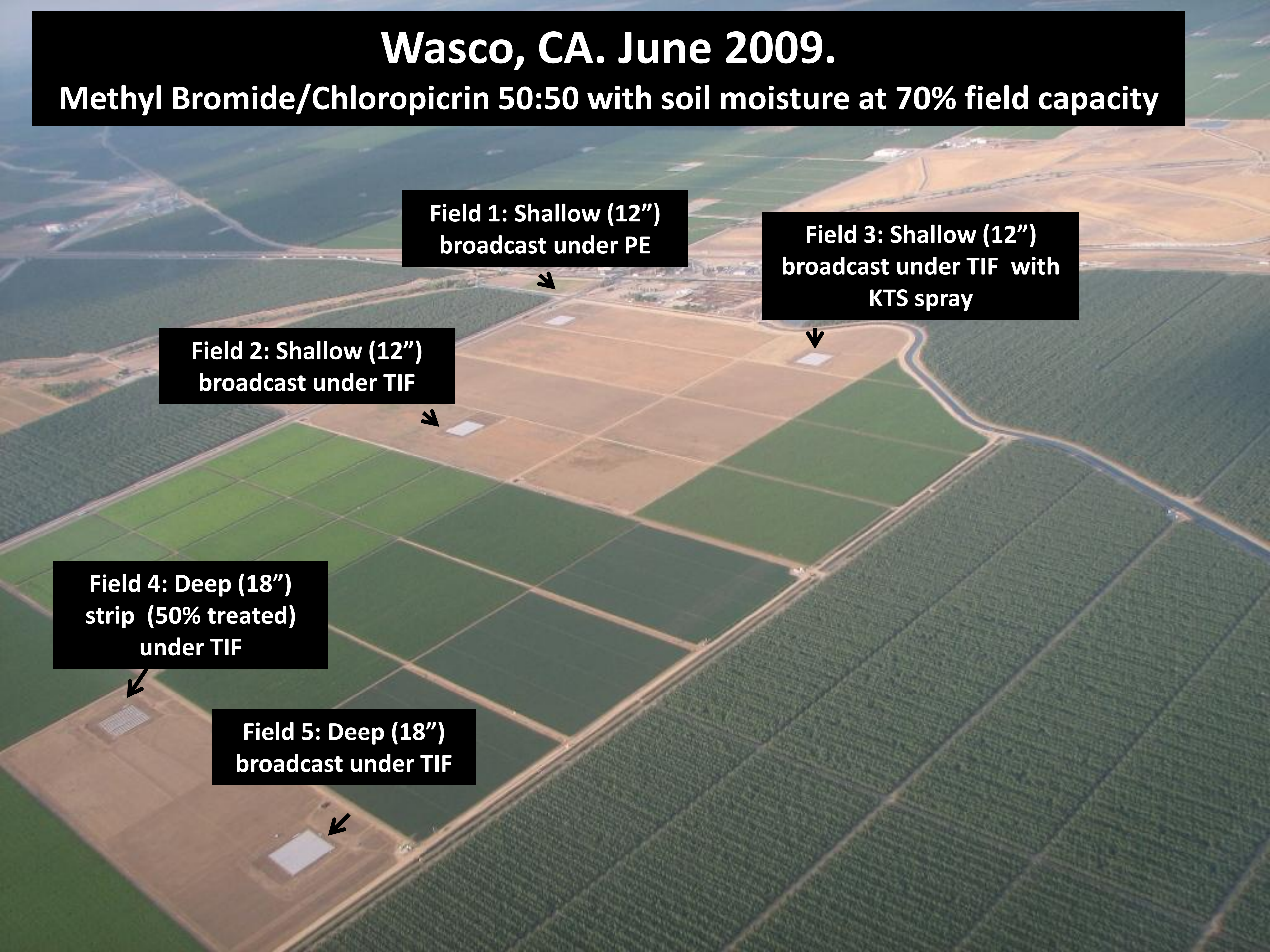
http://www.cdpr.ca.gov/docs/registration/mei_pdfs/tarp_list_approved.pdf

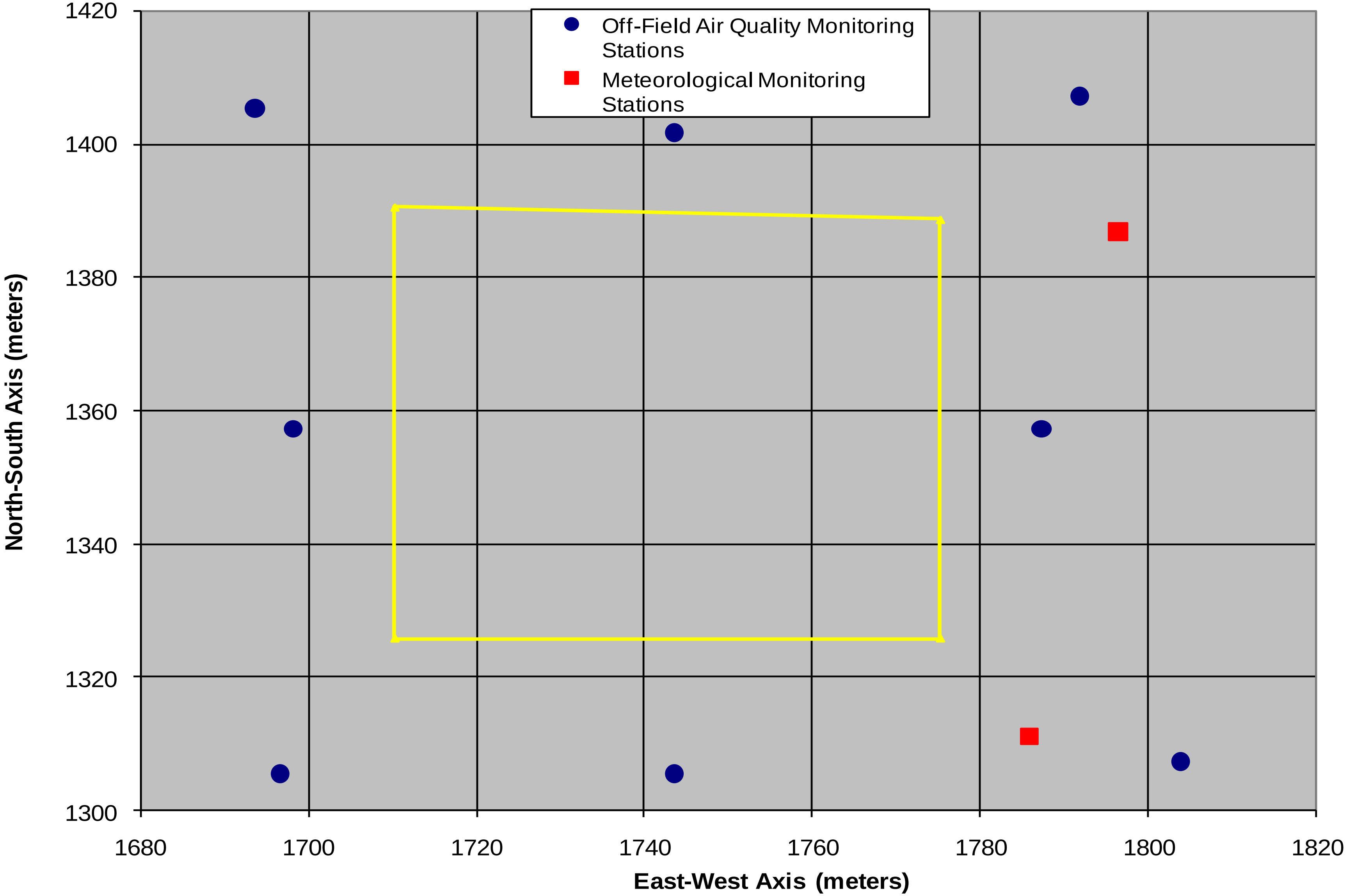
Approved Tarps for Products Containing Midas

Manufacturer	Trade Name	Tarp Thickness (mil)
Cadillac	Cadillac VIF	1.25
Filmtech	Grozone VIF	1.15
Ginegar	Ozgard (black) VIF	1.25
IPG	Bromostop VIF	1.30
Klerks	Hytibar VIF	1.30
Olefina	Guardian VIF	1.20
Pliant	Blockade VIF	1.25
Raven	VaporSafe TIF	1.00

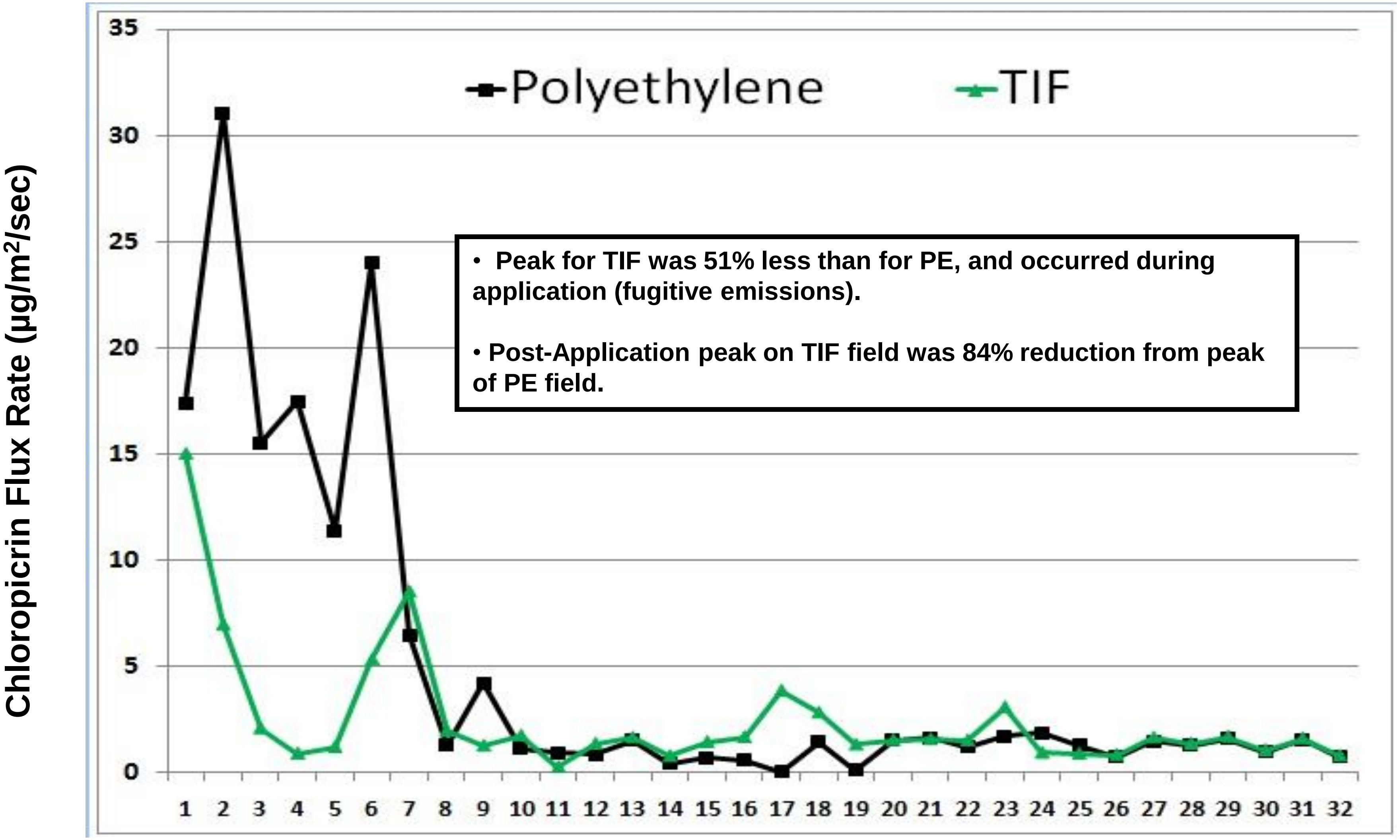
Concerns about using retentive films:

- **Does retentive film (TIF and VIF) reduce fumigant volatilization losses (flux rate and total mass loss) from agricultural fields?**
- **Does retentive tarp improve fumigant distribution (vertical/horizontal) in soil?**
- **Does retentive tarp enhance the efficacy of lower fumigant application rates? *(concentration x time)***


Wasco, CA. June 2009.
Methyl Bromide/Chloropicrin 50:50 with soil moisture at 70% field capacity
Field 1: Shallow (12”) broadcast under PE
Field 3: Shallow (12”) broadcast under TIF with KTS spray
Field 2: Shallow (12”) broadcast under TIF
Field 4: Deep (18”) strip (50% treated) under TIF
Field 5: Deep (18”) broadcast under TIF



Field layout showing locations of the monitoring stations

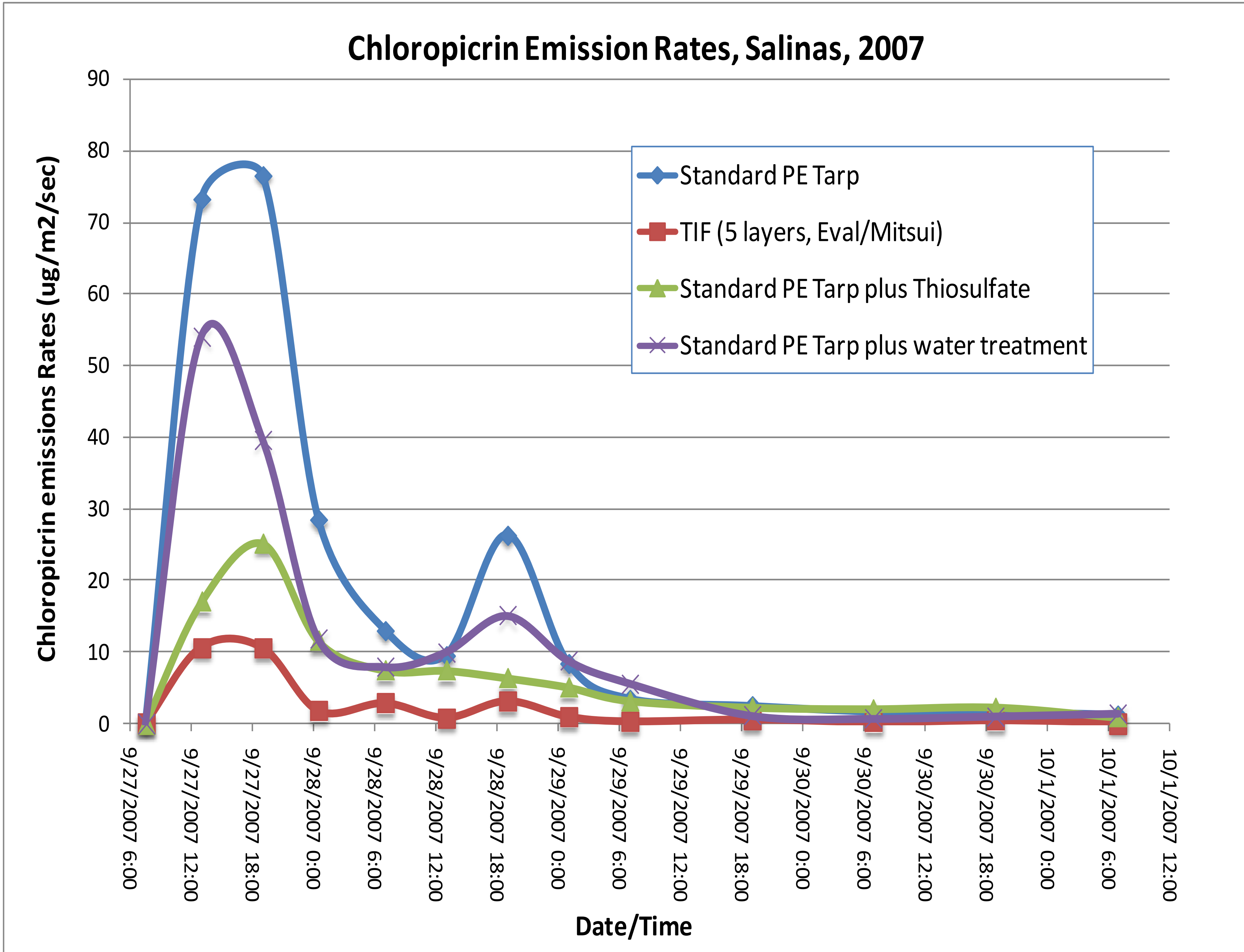


Chloropicrin Flux Rate (µg/m²/sec)
Polyethylene
TIF
• Peak for TIF was 51% less than for PE, and occurred during application (fugitive emissions).
• Post-Application peak on TIF field was 84% reduction from peak of PE field.
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

Chloropicrin Drip Studies

Emission reduction with TIF and potassium thiosulfate

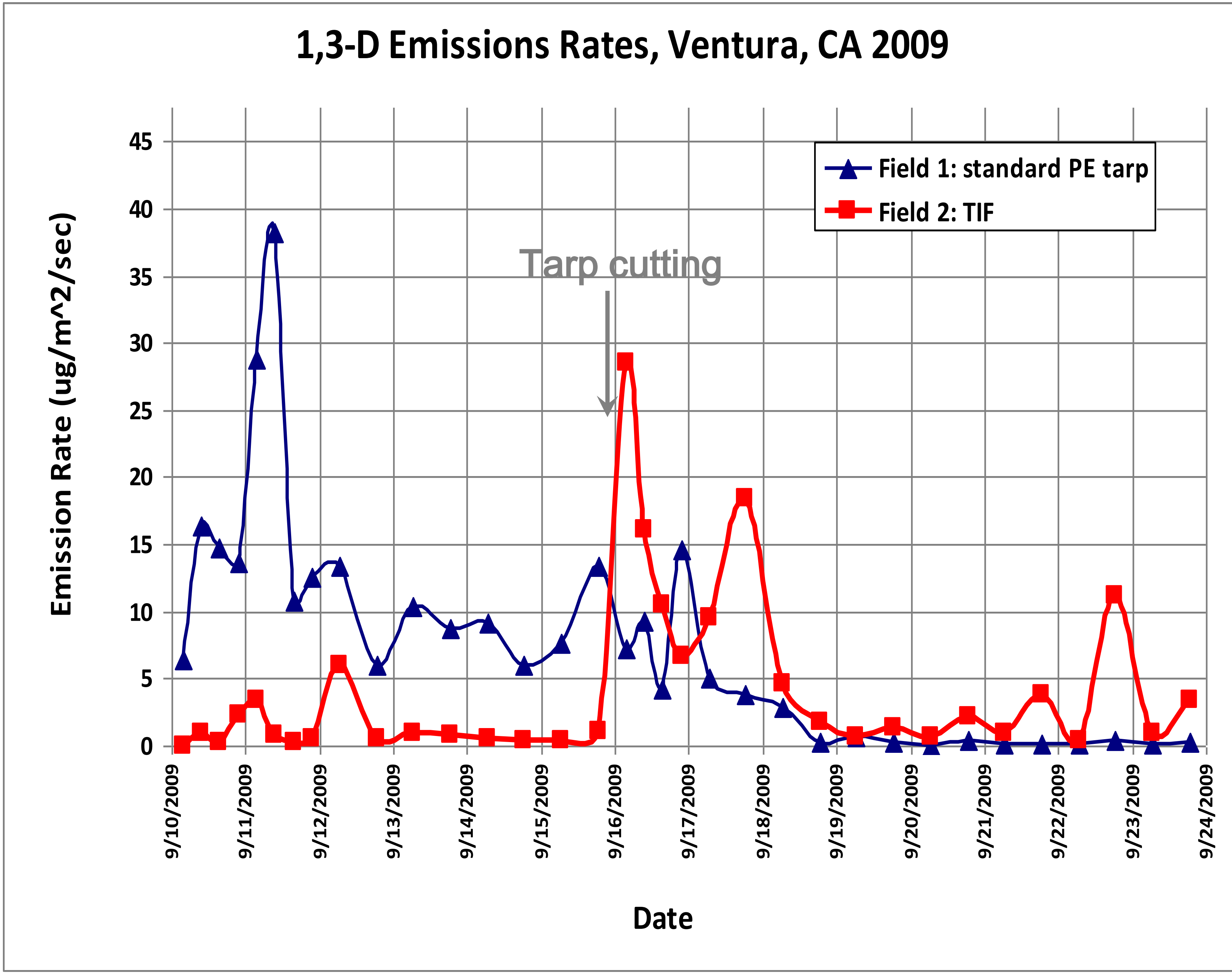
Field #	Tarp material	Water seal	Potassium Thiosulfate
1	Standard LDPE	No	No
2	TIF (Eval/Mitsui)	No	No
3	Standard LDPE	Yes	Yes
4	Standard LDPE	Yes	No


Chloropicrin Emission Rates, Salinas, 2007
Chloropicrin emissions Rates (ug/m2/sec)
90
80
70
60
50
40
30
20
10
0
Standard PE Tarp
TIF (5 layers, Eval/Mitsui)
Standard PE Tarp plus Thiosulfate
Standard PE Tarp plus water treatment
9/27/2007 6:00
9/27/2007 12:00
9/27/2007 18:00
9/28/2007 0:00
9/28/2007 6:00
9/28/2007 12:00
9/28/2007 18:00
9/29/2007 0:00
9/29/2007 6:00
9/29/2007 12:00
9/29/2007 18:00
9/30/2007 0:00
9/30/2007 6:00
9/30/2007 12:00
9/30/2007 18:00
10/1/2007 0:00
10/1/2007 6:00
10/1/2007 12:00
Date/Time

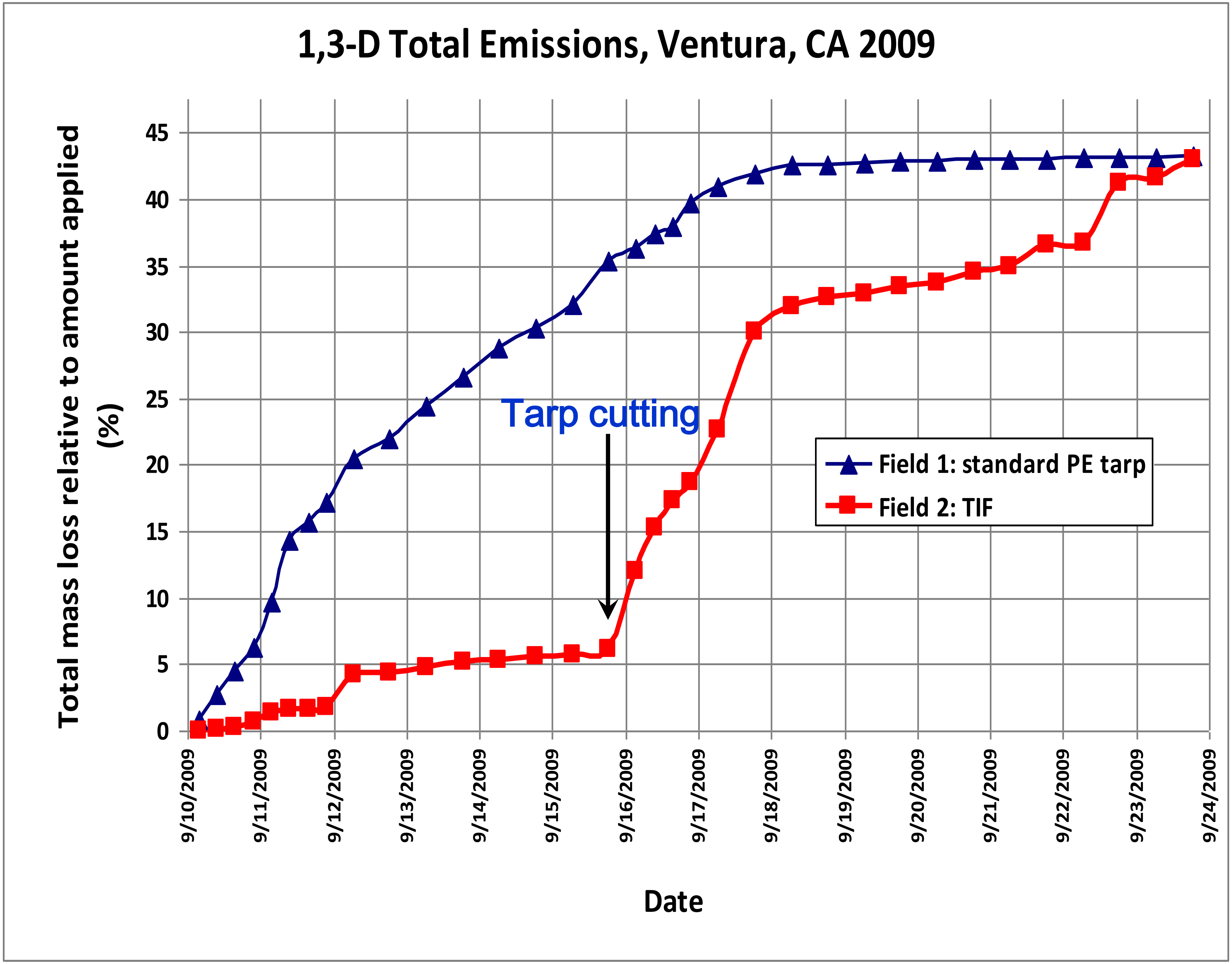
Waiting period before tarp cutting and removal

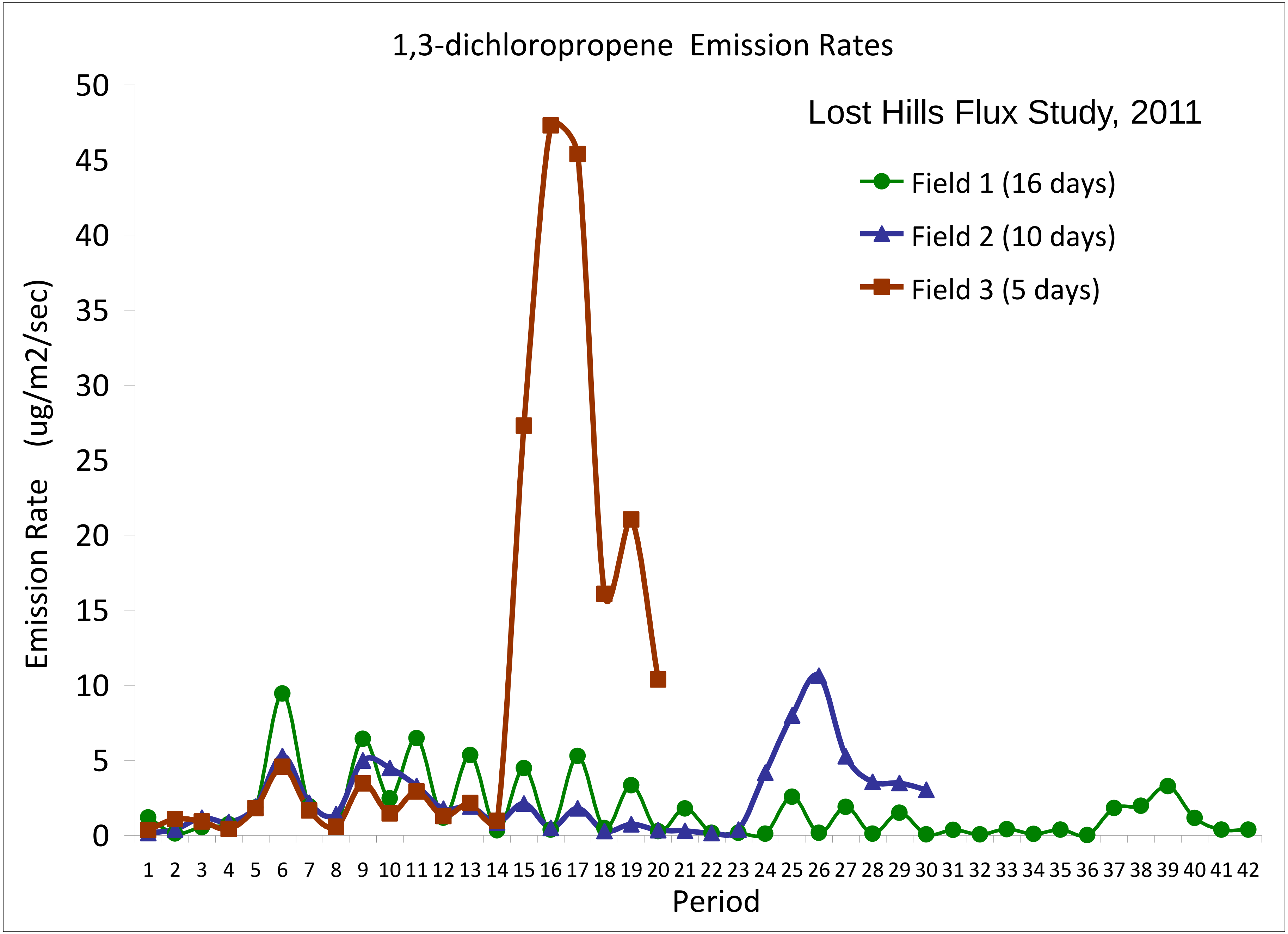
1,3-Dichloropropene and Chloropicrin Retention under Standard Tarp (PE) and Totally Impermeable Film (TIF)

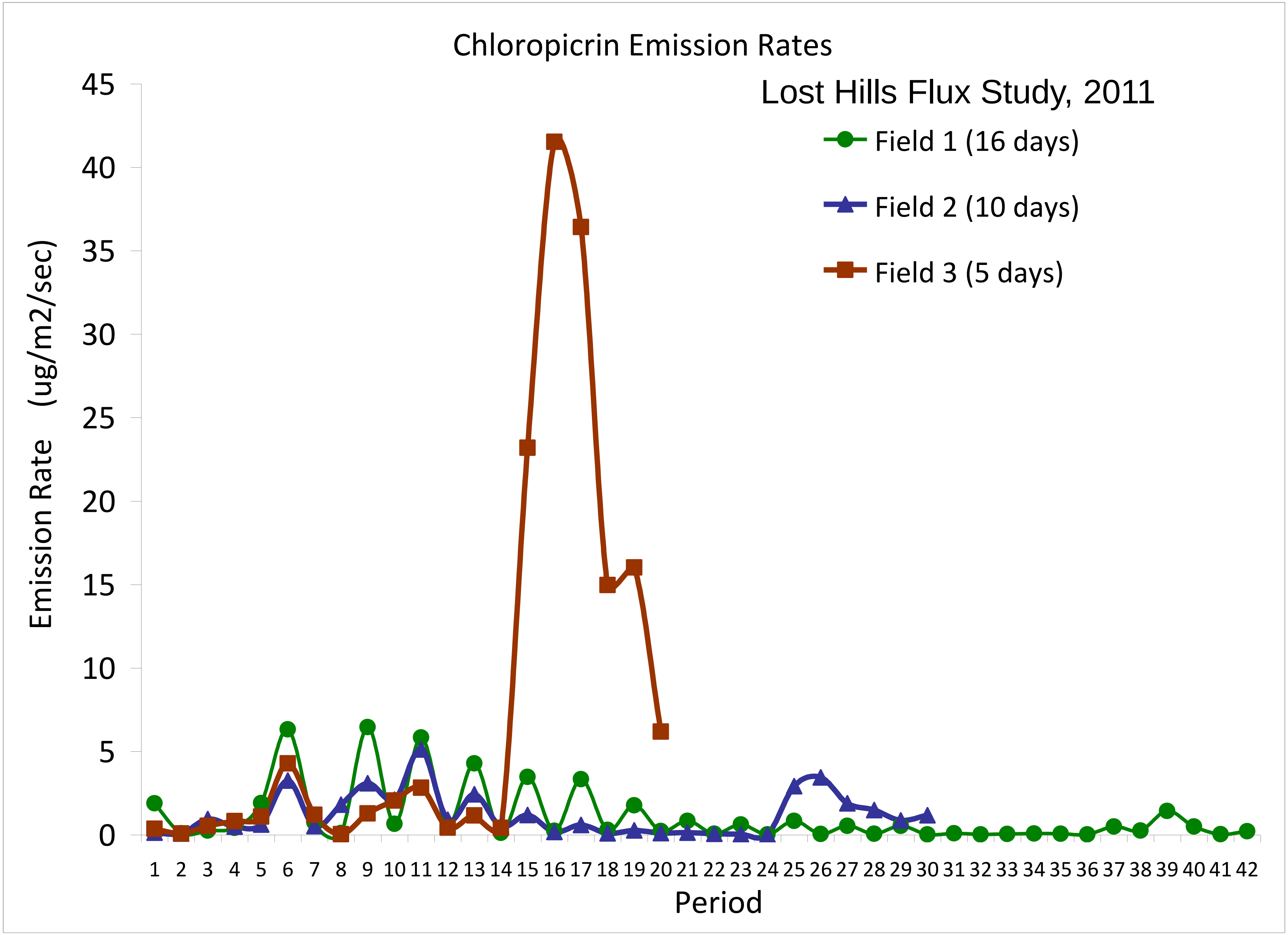
Chloropicrin and 1,3-Dichloropropene were shank injected at 12” under TIF and std PE

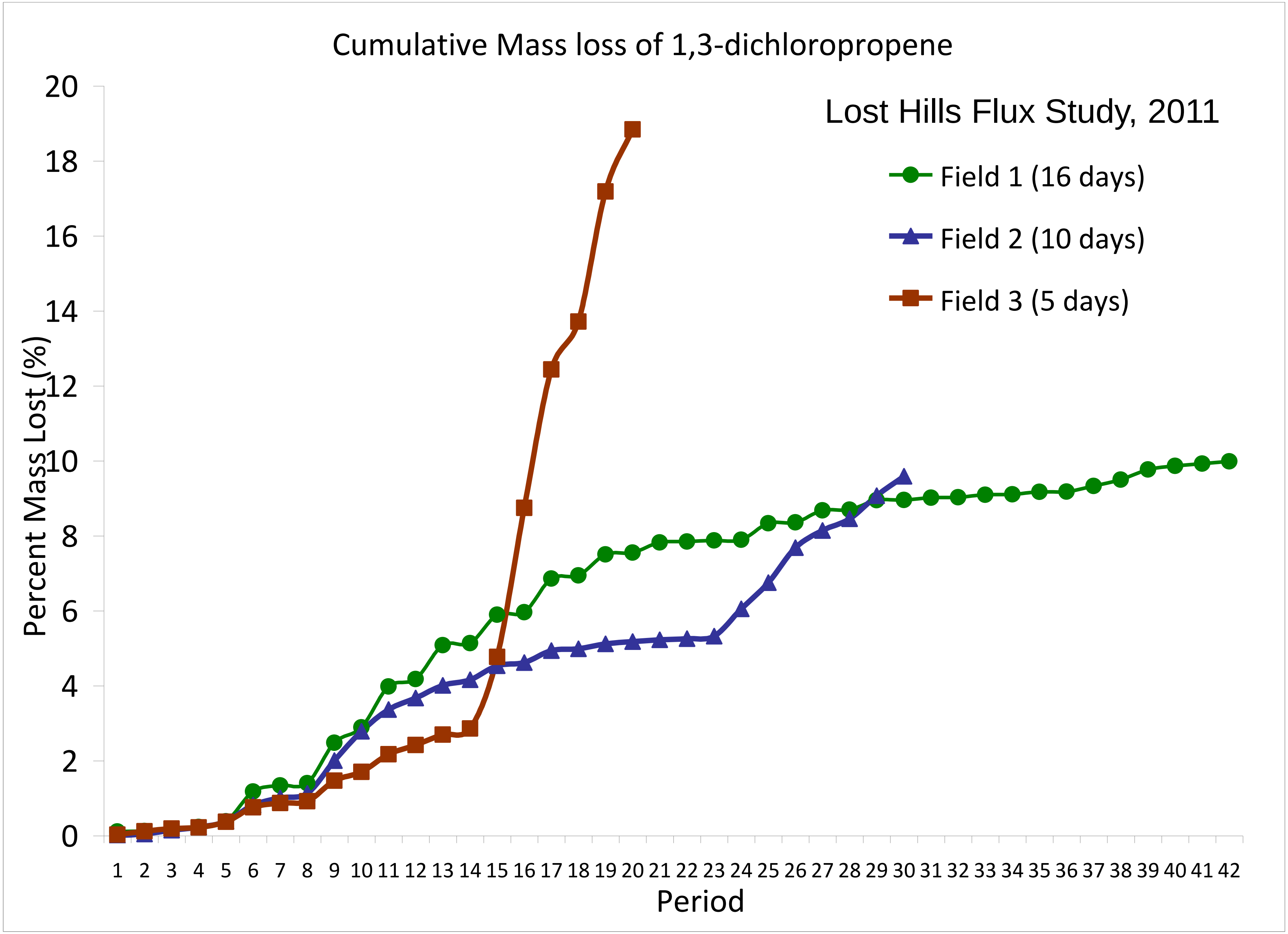


1,3-D Emissions Rates, Ventura, CA 2009
Emission Rate (ug/m^2/sec)
45
40
35
30
25
20
15
10
5
0
Field 1: standard PE tarp
Field 2: TIF
Tarp cutting
9/10/2009
9/11/2009
9/12/2009
9/13/2009
9/14/2009
9/15/2009
9/16/2009
9/17/2009
9/18/2009
9/19/2009
9/20/2009
9/21/2009
9/22/2009
9/23/2009
9/24/2009
Date

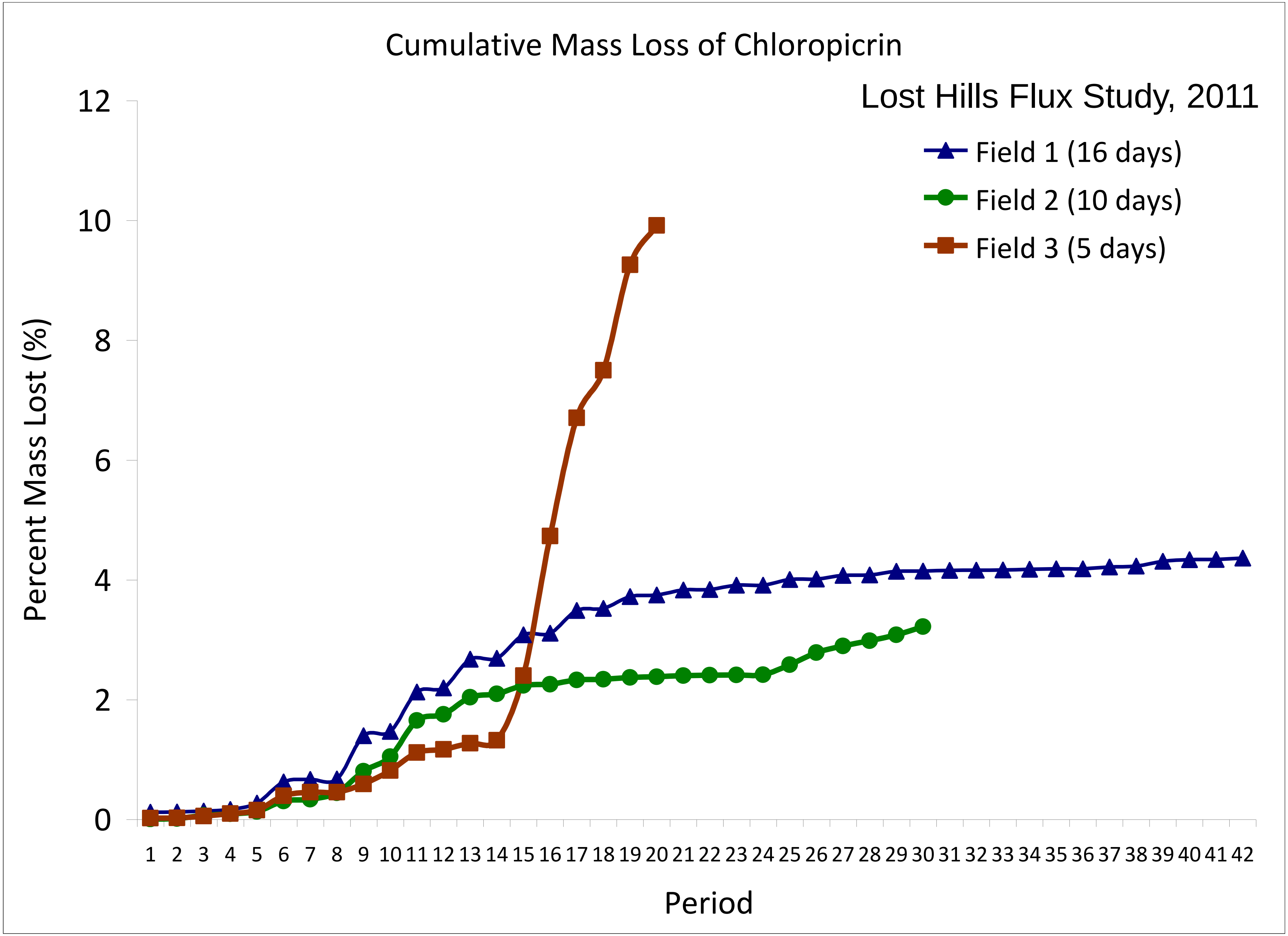

1,3-D Total Emissions, Ventura, CA 2009
Total mass loss relative to amount applied (%)
45
40
35
30
25
20
15
10
5
0
Tarp cutting
Field 1: standard PE tarp
Field 2: TIF
9/10/2009
9/11/2009
9/12/2009
9/13/2009
9/14/2009
9/15/2009
9/16/2009
9/17/2009
9/18/2009
9/19/2009
9/20/2009
9/21/2009
9/22/2009
9/23/2009
9/24/2009
Date


1,3-dichloropropene Emission Rates
Lost Hills Flux Study, 2011
Field 1 (16 days)
Field 2 (10 days)
Field 3 (5 days)
Emission Rate (ug/m2/sec)
0
5
10
15
20
25
30
35
40
45
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
Period


Chloropicrin Emission Rates
Lost Hills Flux Study, 2011
Field 1 (16 days)
Field 2 (10 days)
Field 3 (5 days)
Emission Rate (ug/m2/sec)
Period
0
5
10
15
20
25
30
35
40
45
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42

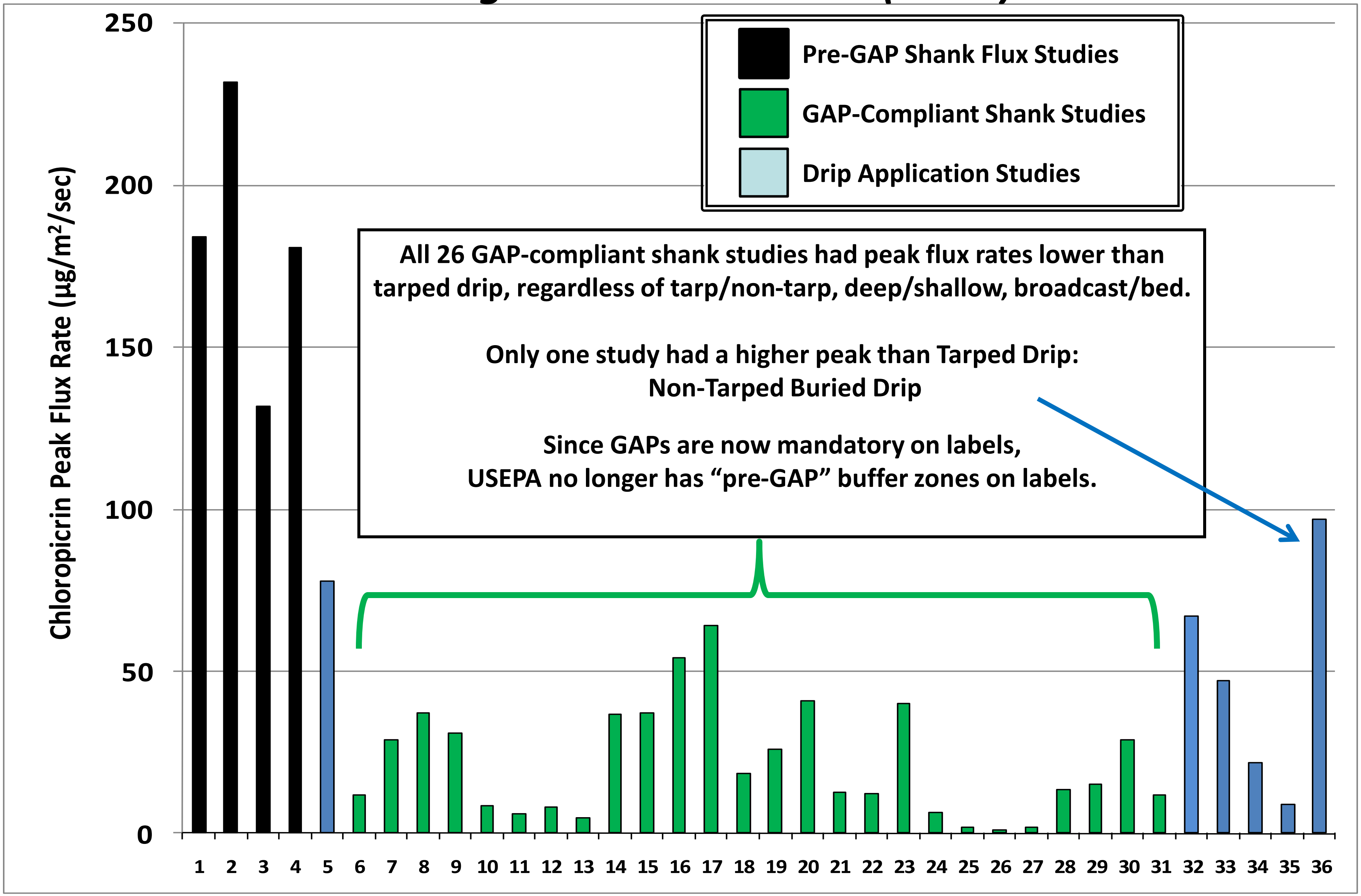


Cumulative Mass loss of 1,3-dichloropropene
Lost Hills Flux Study, 2011
Field 1 (16 days)
Field 2 (10 days)
Field 3 (5 days)
Percent Mass Lost (%)
Period
0
2
4
6
8
10
12
14
16
18
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42


Cumulative Mass Loss of Chloropicrin
Lost Hills Flux Study, 2011
Field 1 (16 days)
Field 2 (10 days)
Field 3 (5 days)
Percent Mass Lost (%)
0
2
4
6
8
10
12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
Period

Current Chloropicrin Field Volatility Dataset: 36 flux studies

Good Agricultural Practices (GAPs)



USEPA Buffers distances are subjectively large; want users to utilize emissions reduction strategies. Developed Buffer Zone Reduction Credits.

	% Reduction in Chloropicrin Buffer Zone
Condition	**Chloropicrin**
Use of specific high barrier tarp	20% (metalized films), 40% (nylon VIFs), or 60% (high-end VIFs and all TIFs)
Organic matter content	10% (OM ≥ 1% - 2%), 20% (OM >2 – 3%), 30% (OM > 3%)
Clay content > 27%	10%
Soil temp ≤ 50^{o}F (shank)	10%
Potassium thiosulfate	15%
Water seal	15%
Max reduction	**80%**

Summary

- ✓ **Low permeability tarps (TIF and VIF) can significantly reduce emissions as well as improve efficacy because it can retain high fumigant concentration under that tarp.**

- ✓ **Delayed tarp cutting will reduce peak flux and total emissions:**

  - **~10 days chloropicrin**

  - **~15 days 1,3-D (Telone)**

Acknowledgement

- California Strawberry Commission
- Cal-EPA (DPR)
- USEPA
- USDA-ARS, Area Wide Project
- Almond Board of California
- TriCal, Inc.

Thank you very much

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