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Faculty Summit 2010

Network of environmental sensors in tropical rain forest

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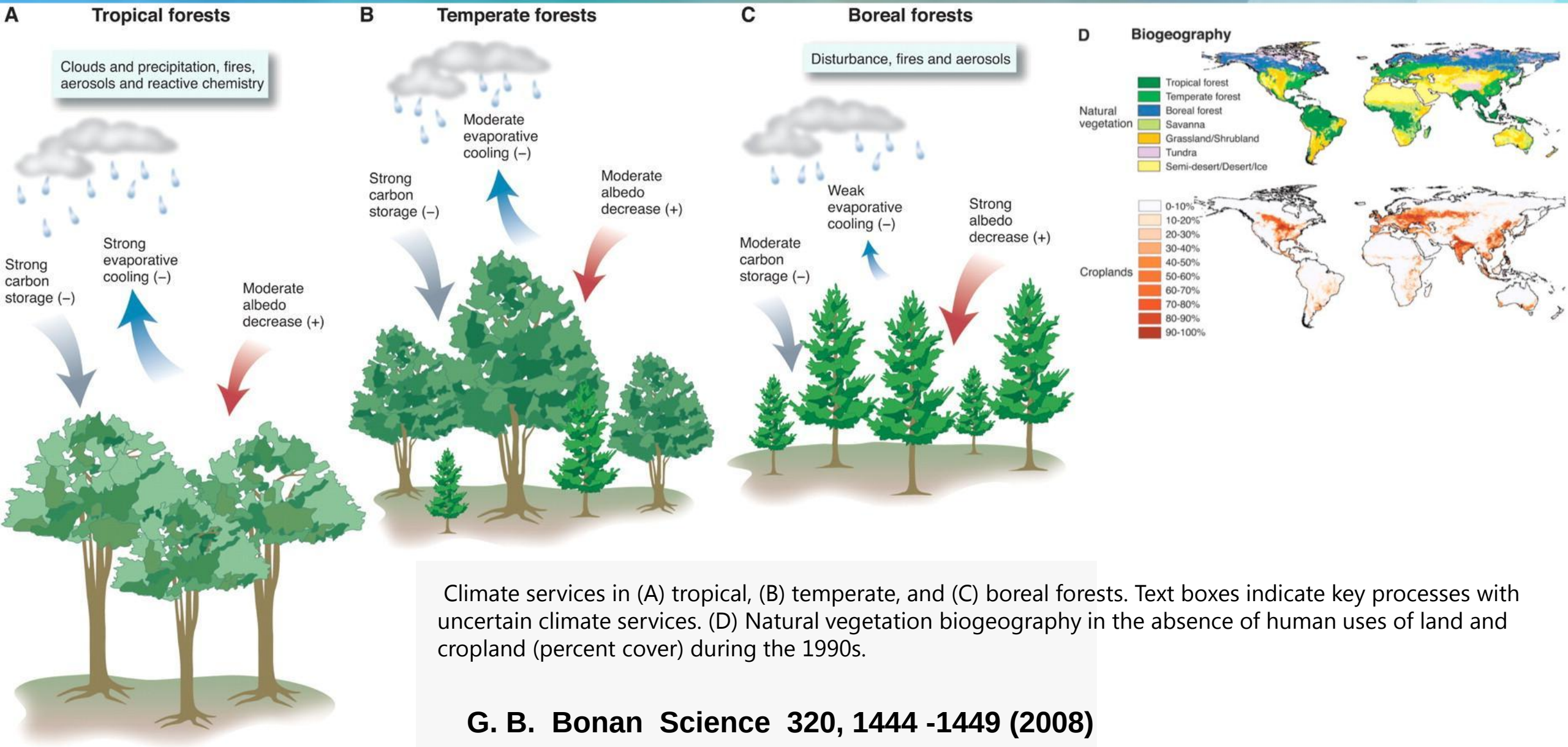
Climate services in forests



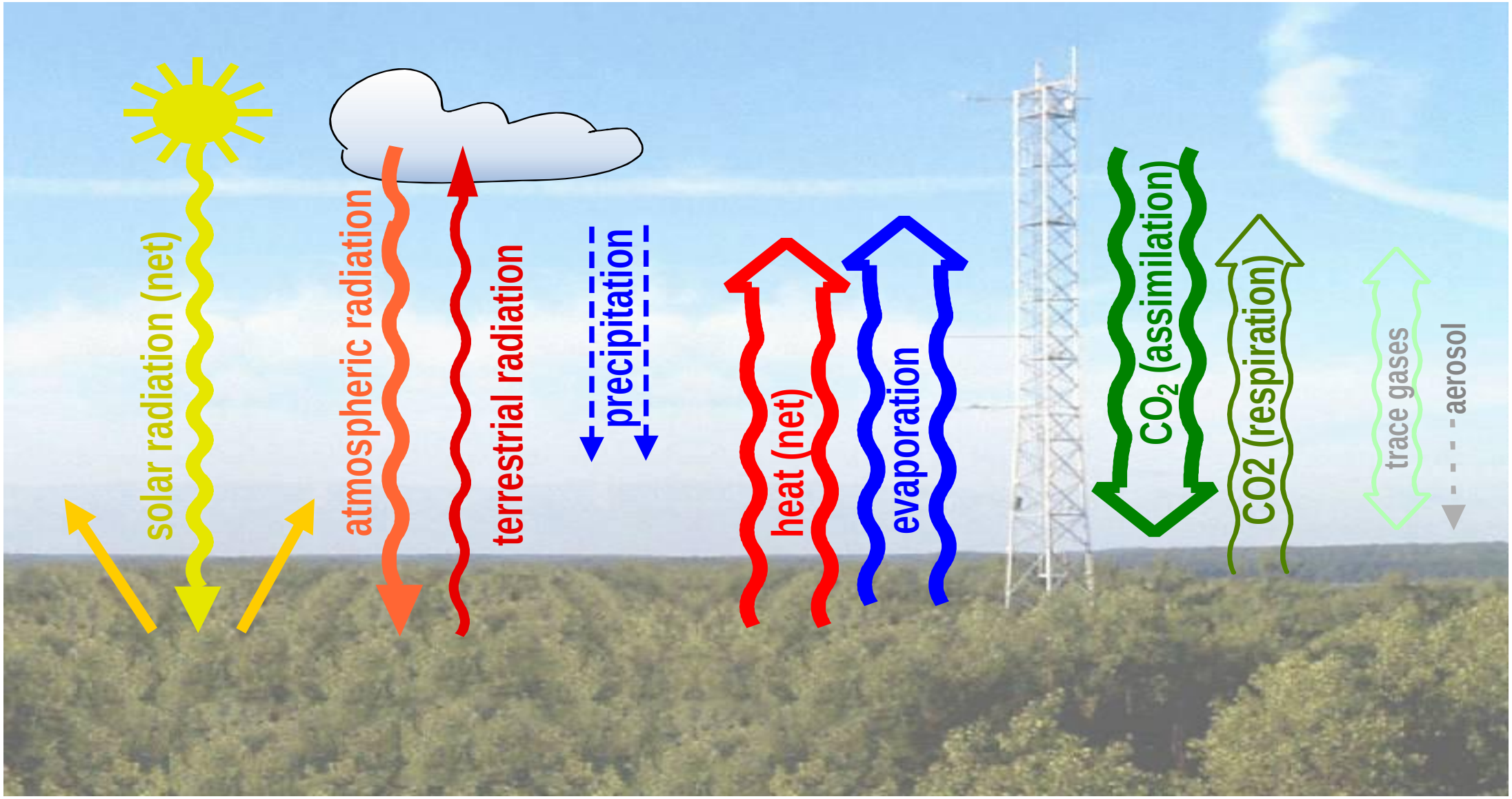
Climate services in (A) tropical, (B) temperate, and (C) boreal forests. Text boxes indicate key processes with uncertain climate services. (D) Natural vegetation biogeography in the absence of human uses of land and cropland (percent cover) during the 1990s.

G. B. Bonan Science 320, 1444 -1449 (2008)

Outline

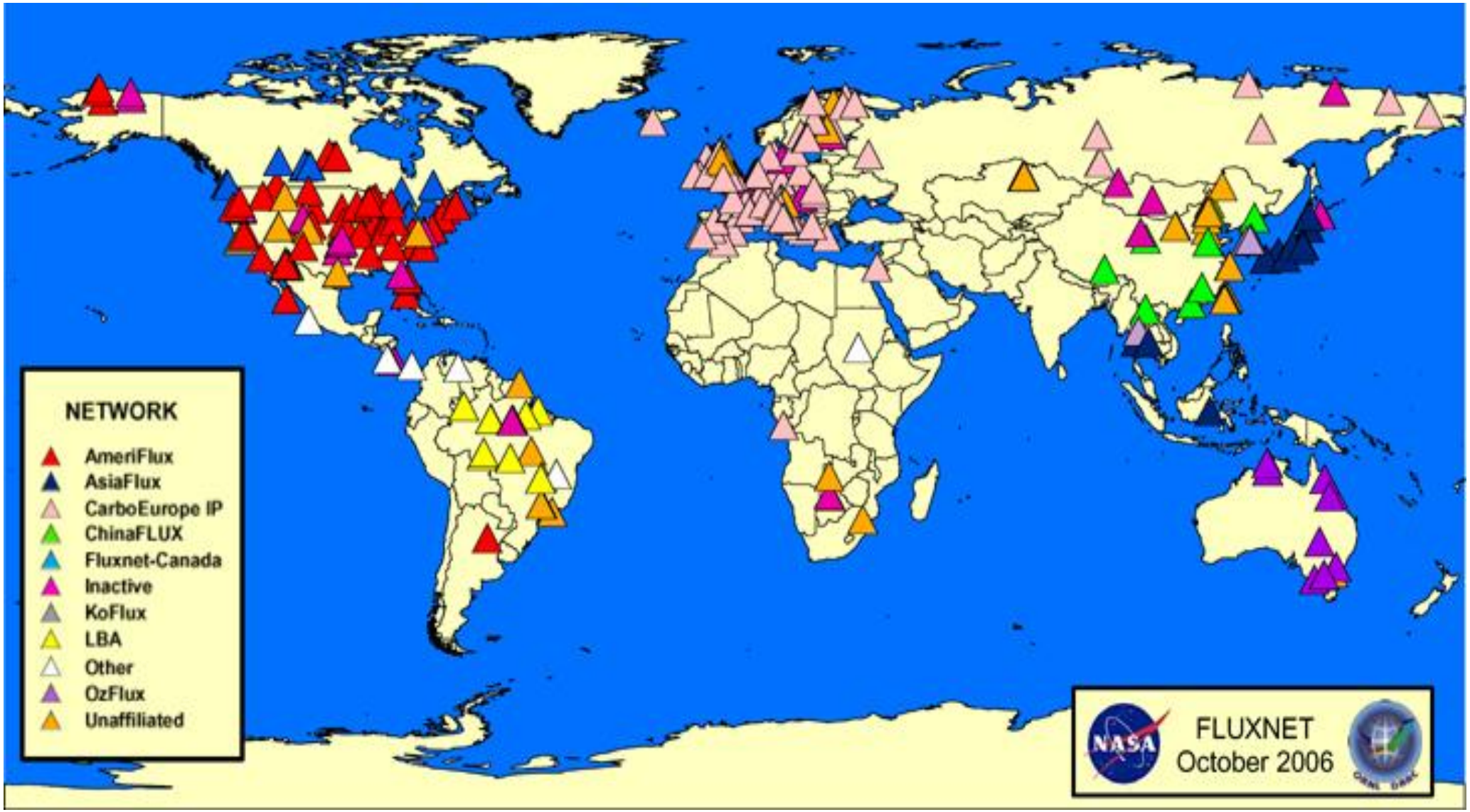
- Biosphere-Atmosphere Interactions
- Technical and Scientific challenges
  - Environmental conditions in the tropics
  - Heterogeneity of rainforests
- Development of integrated network of environmental sensors
- Results from the pilot study in Atlantic coastal forest in Brazil
- Future plans: deployment and expansion of network in Amazonia

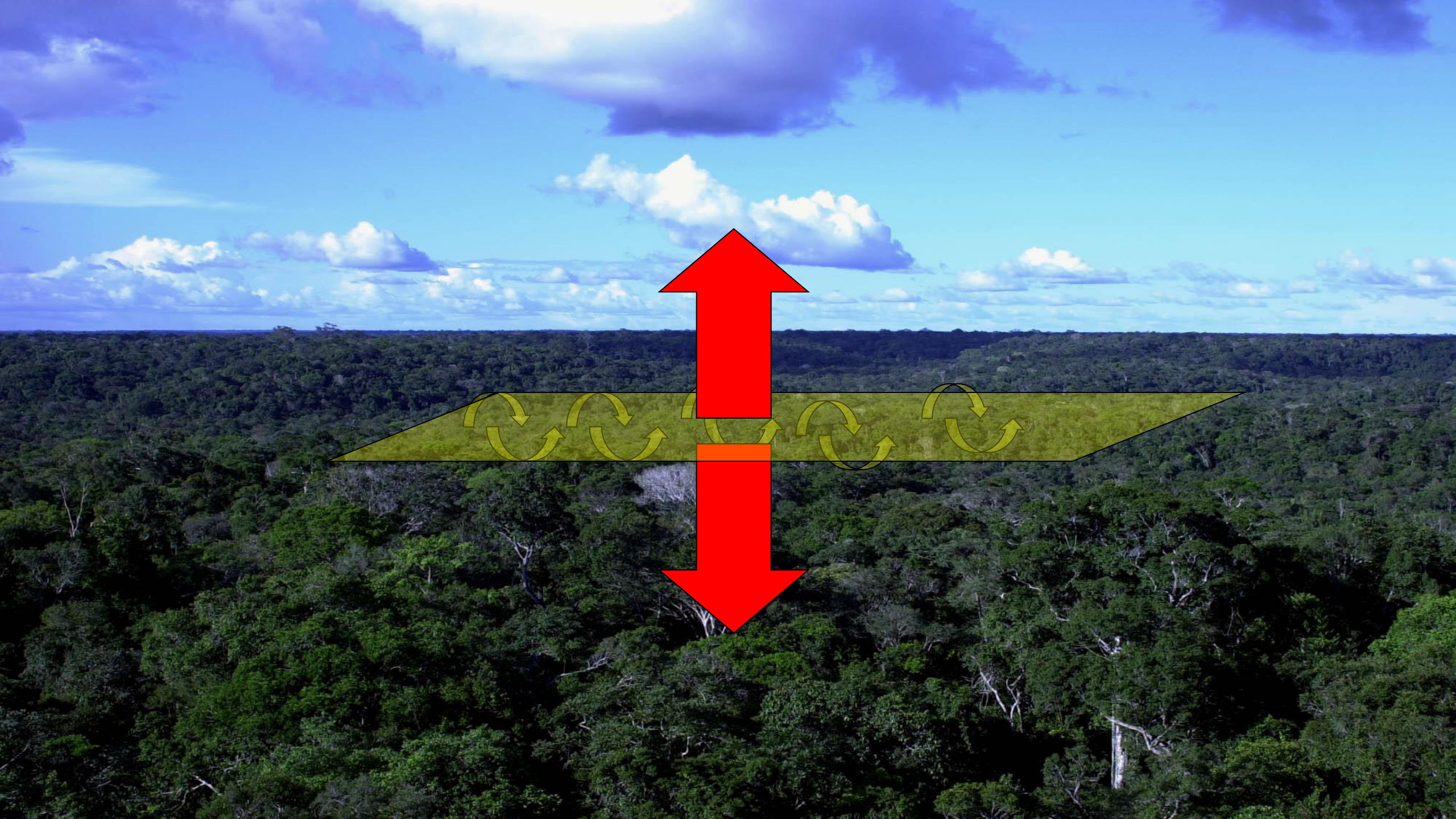
Biosphere – Climate Interactions



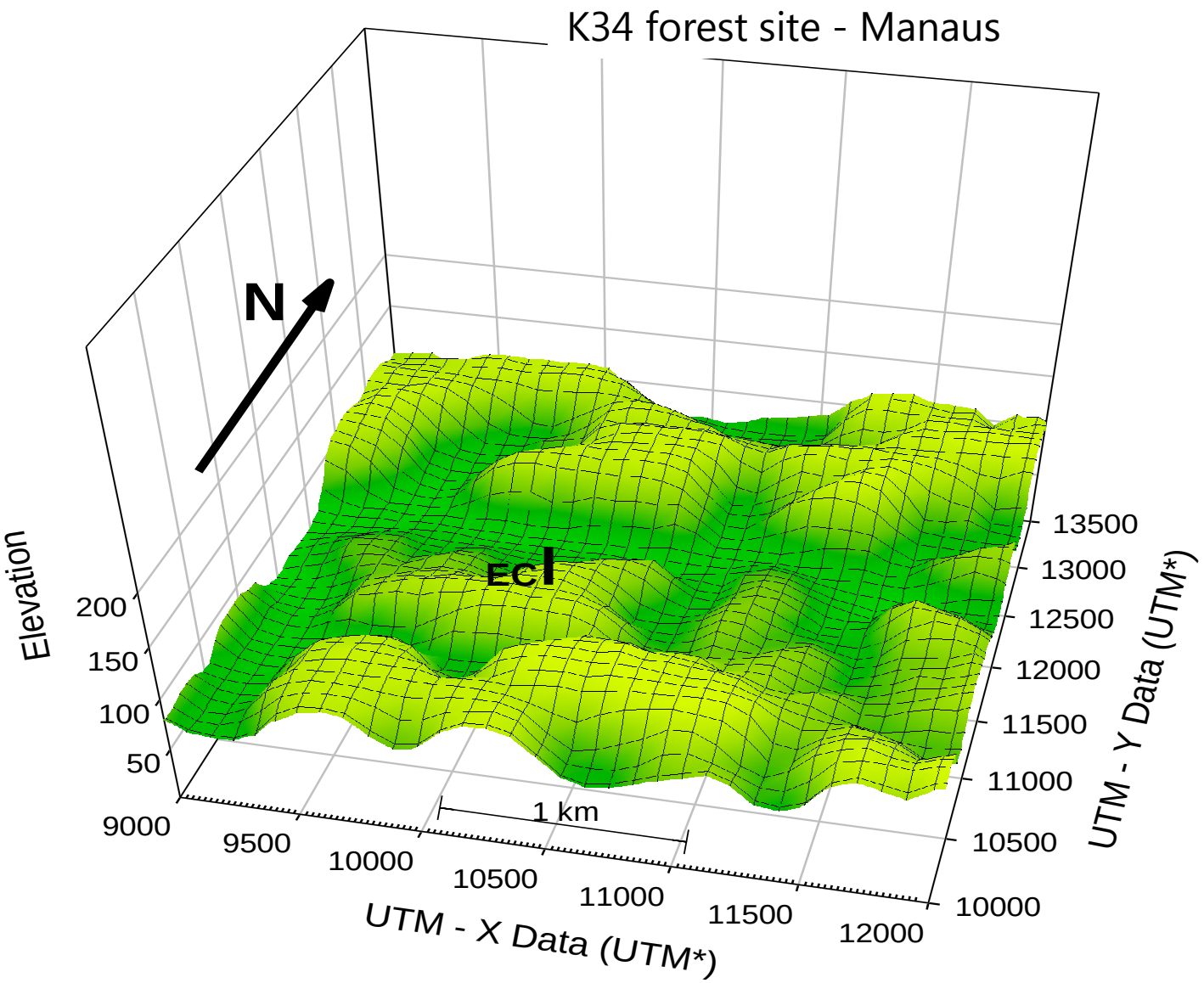
Flux tower measurements

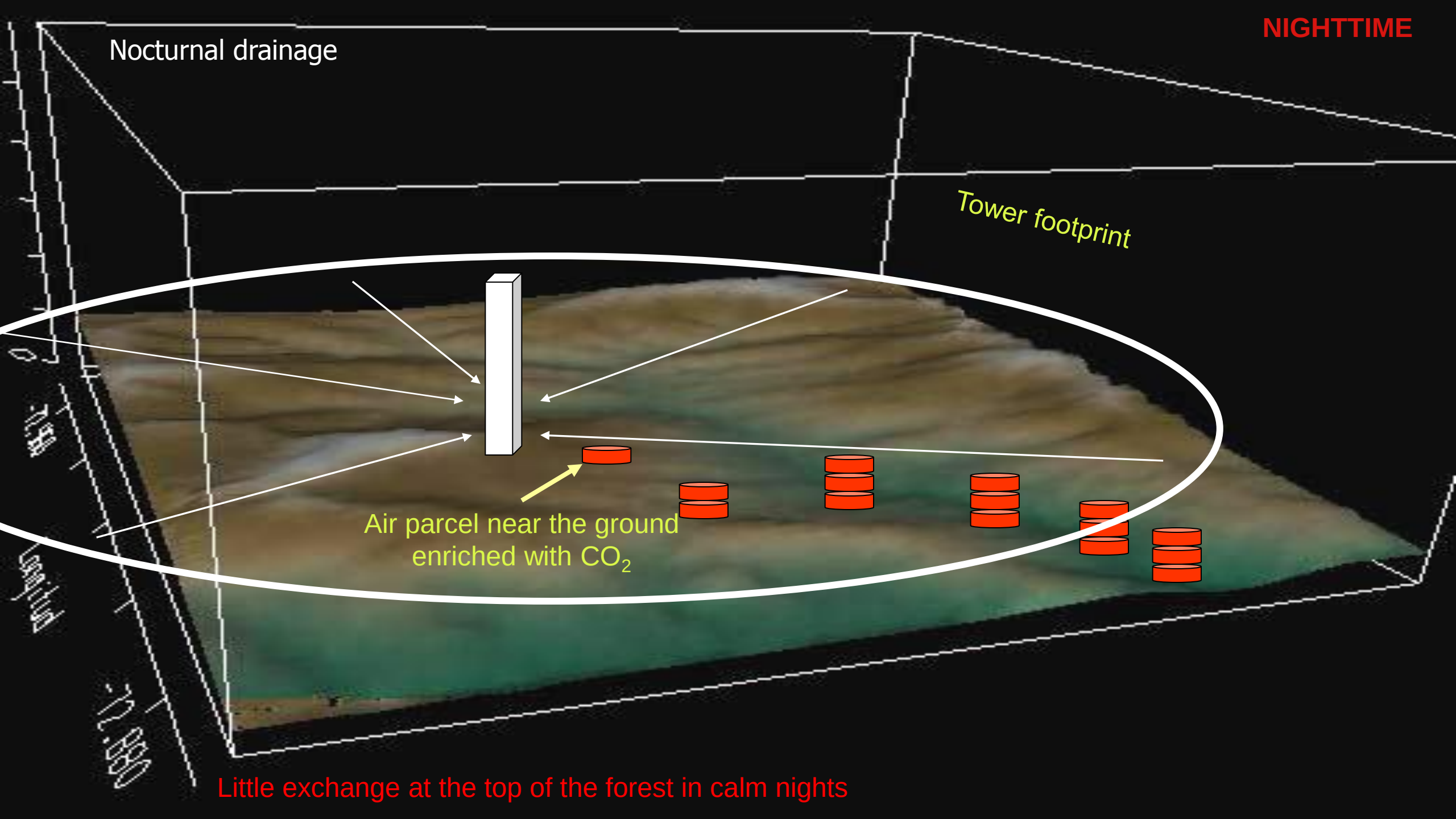
Worldwide network

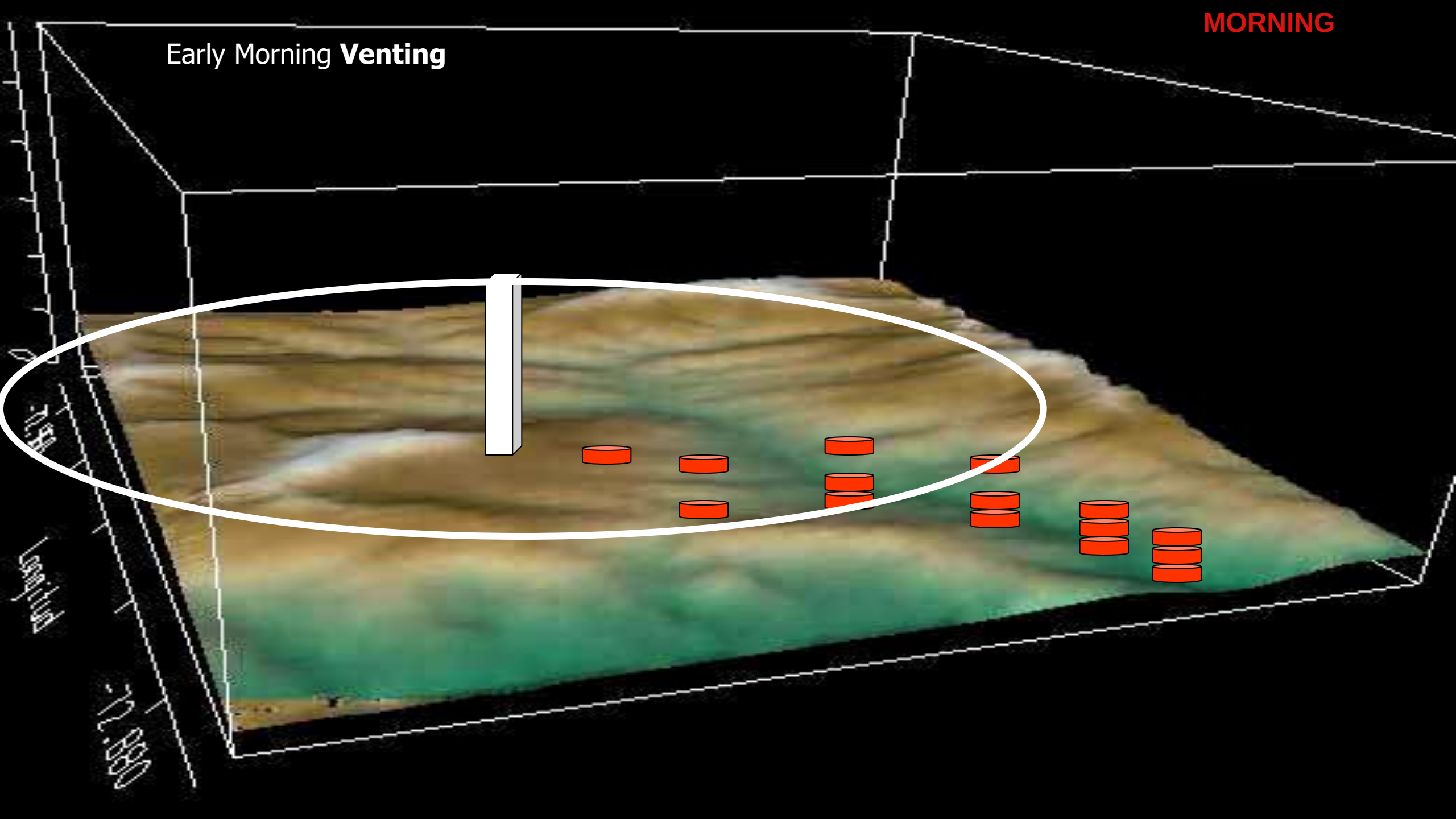


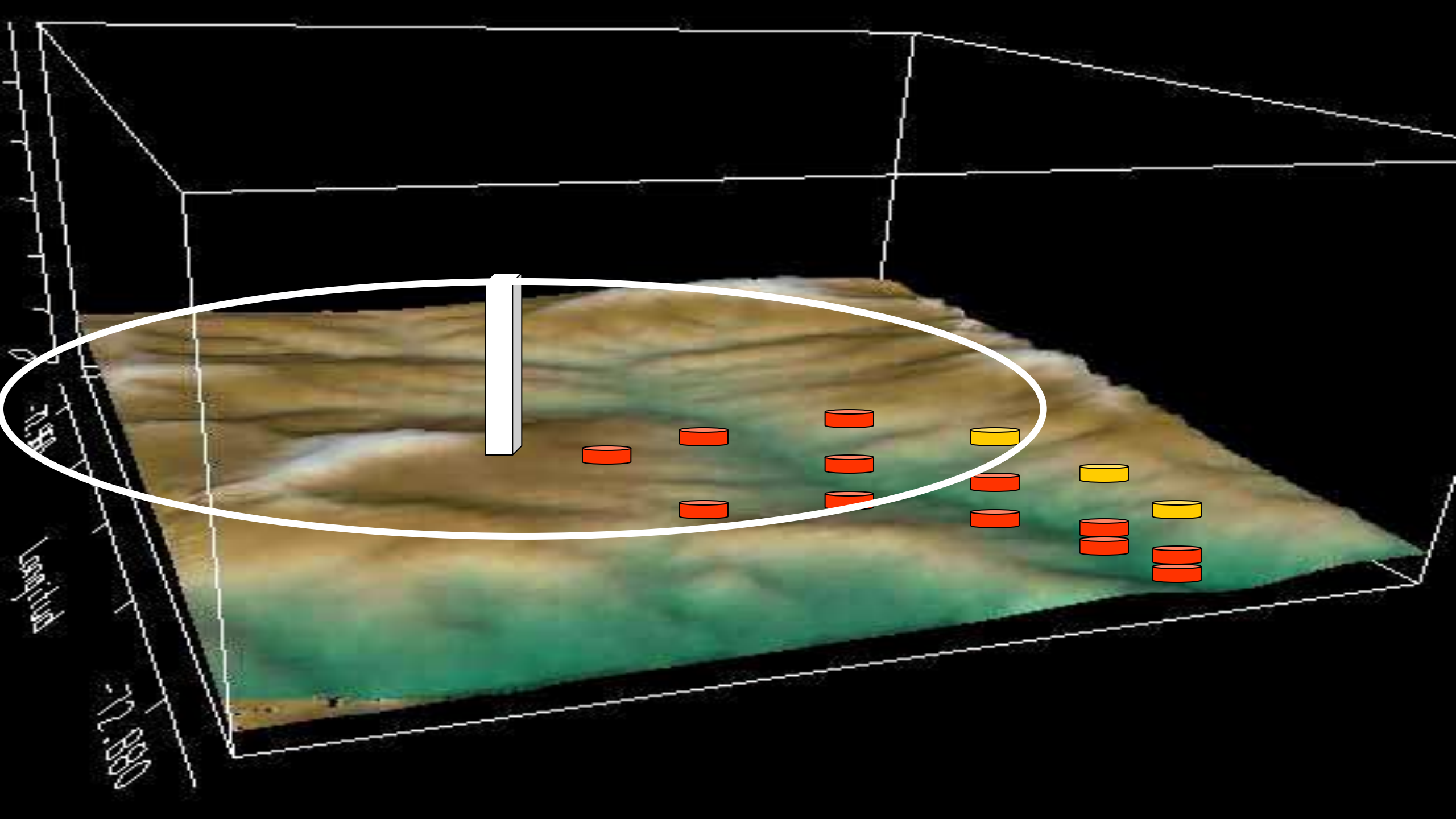


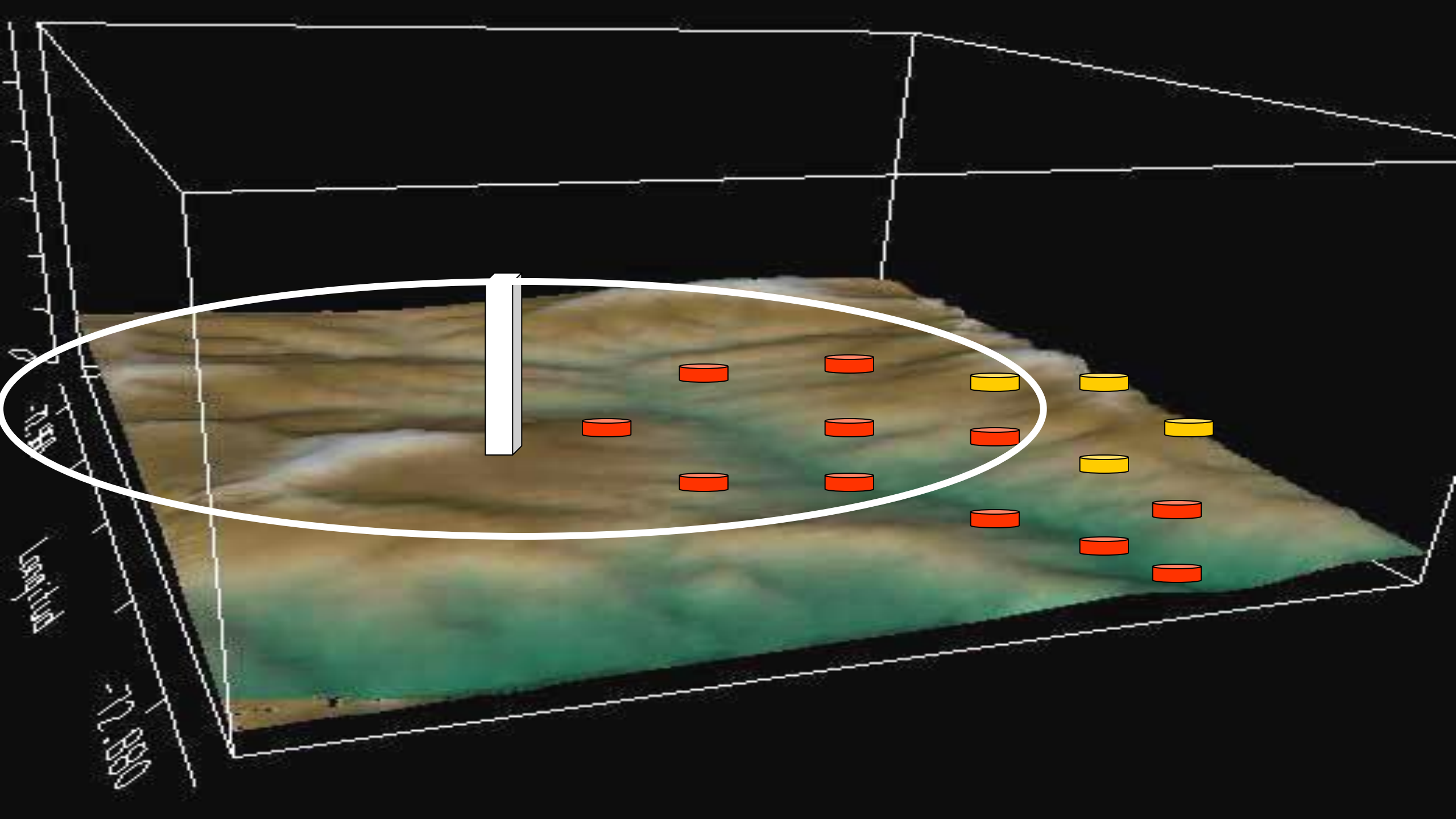
Sites are (almost) always complex

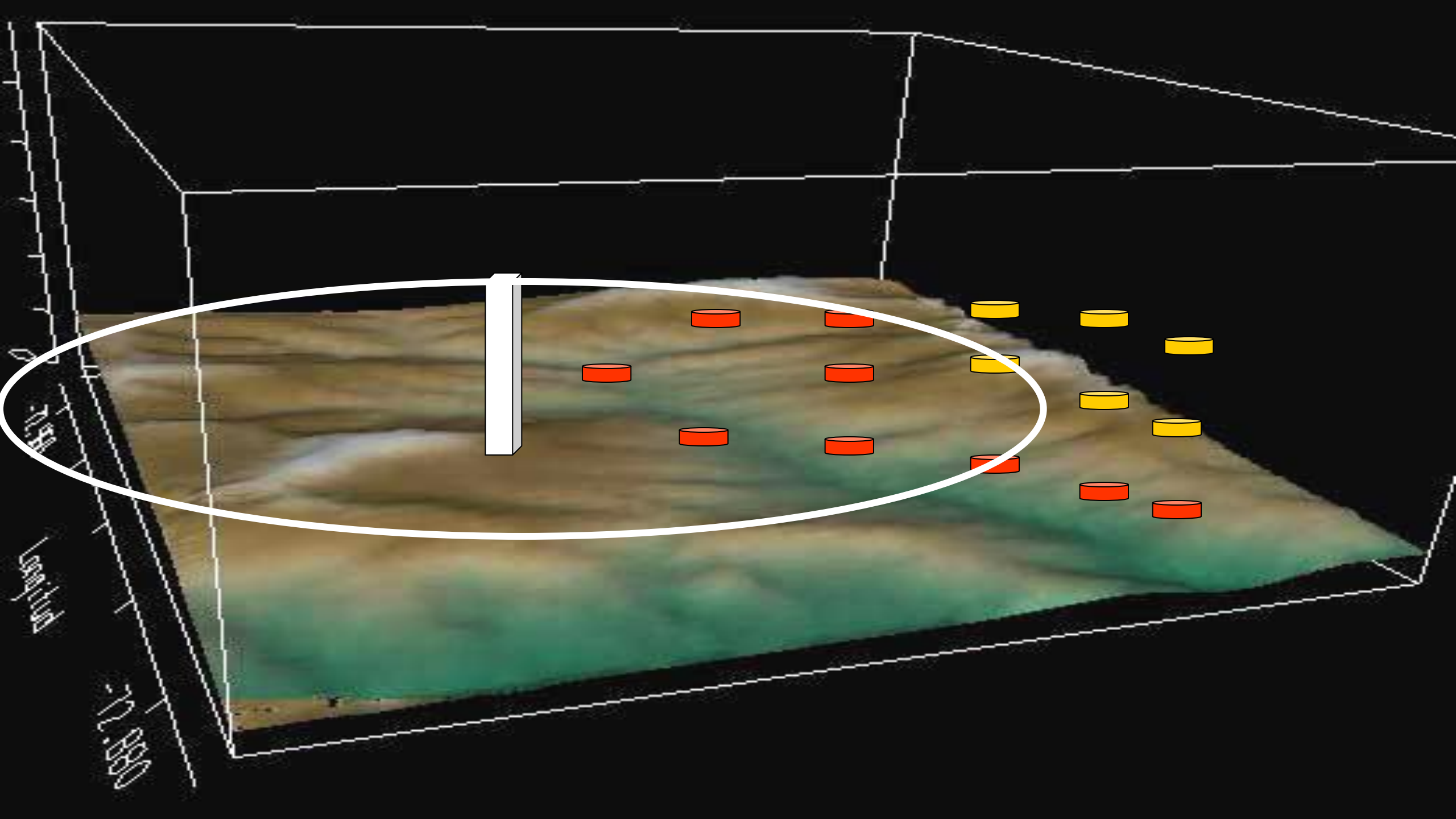


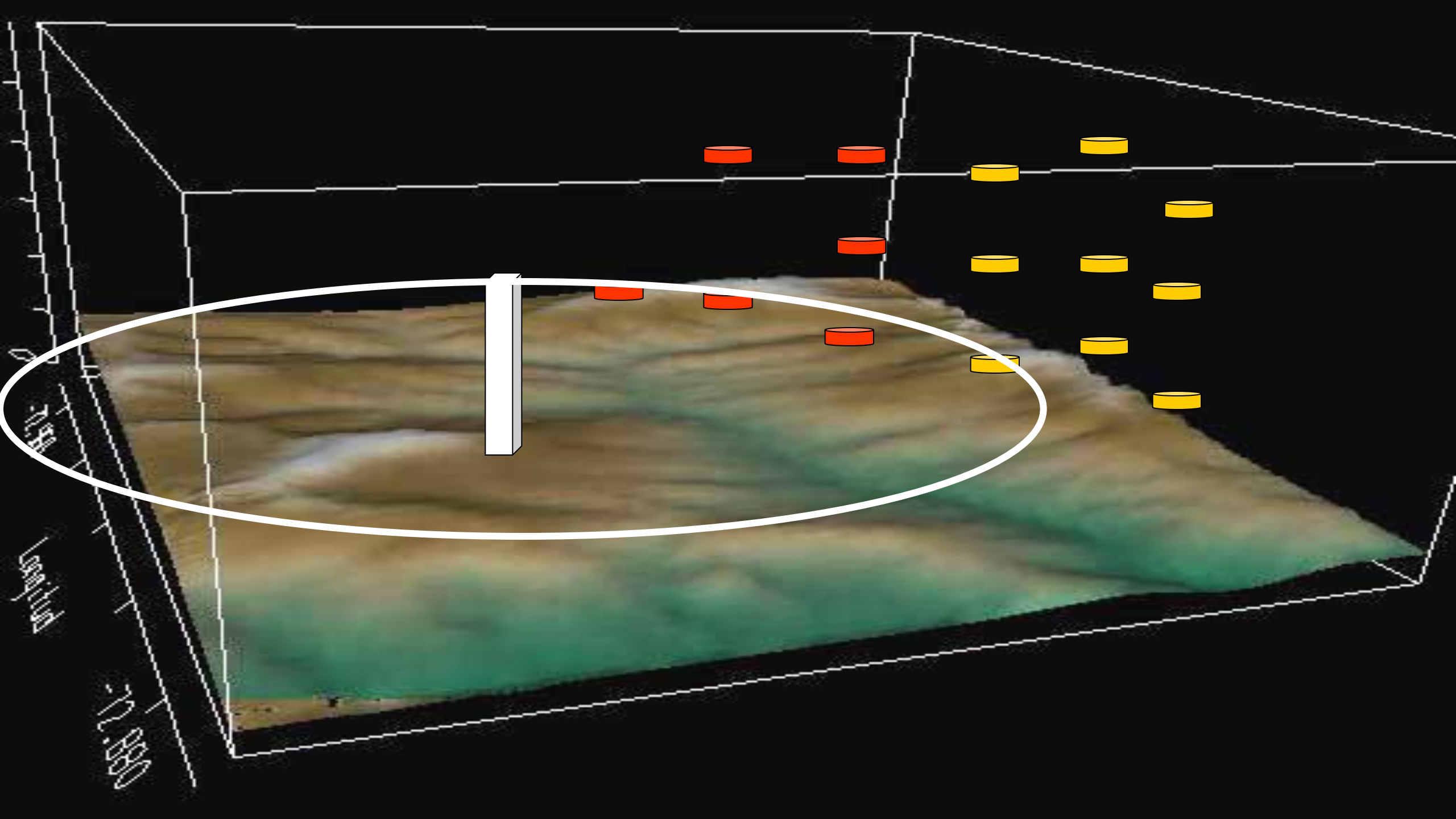

NIGHTTIME
Nocturnal drainage
Tower footprint
Air parcel near the ground
enriched with CO_2
Little exchange at the top of the forest in calm nights

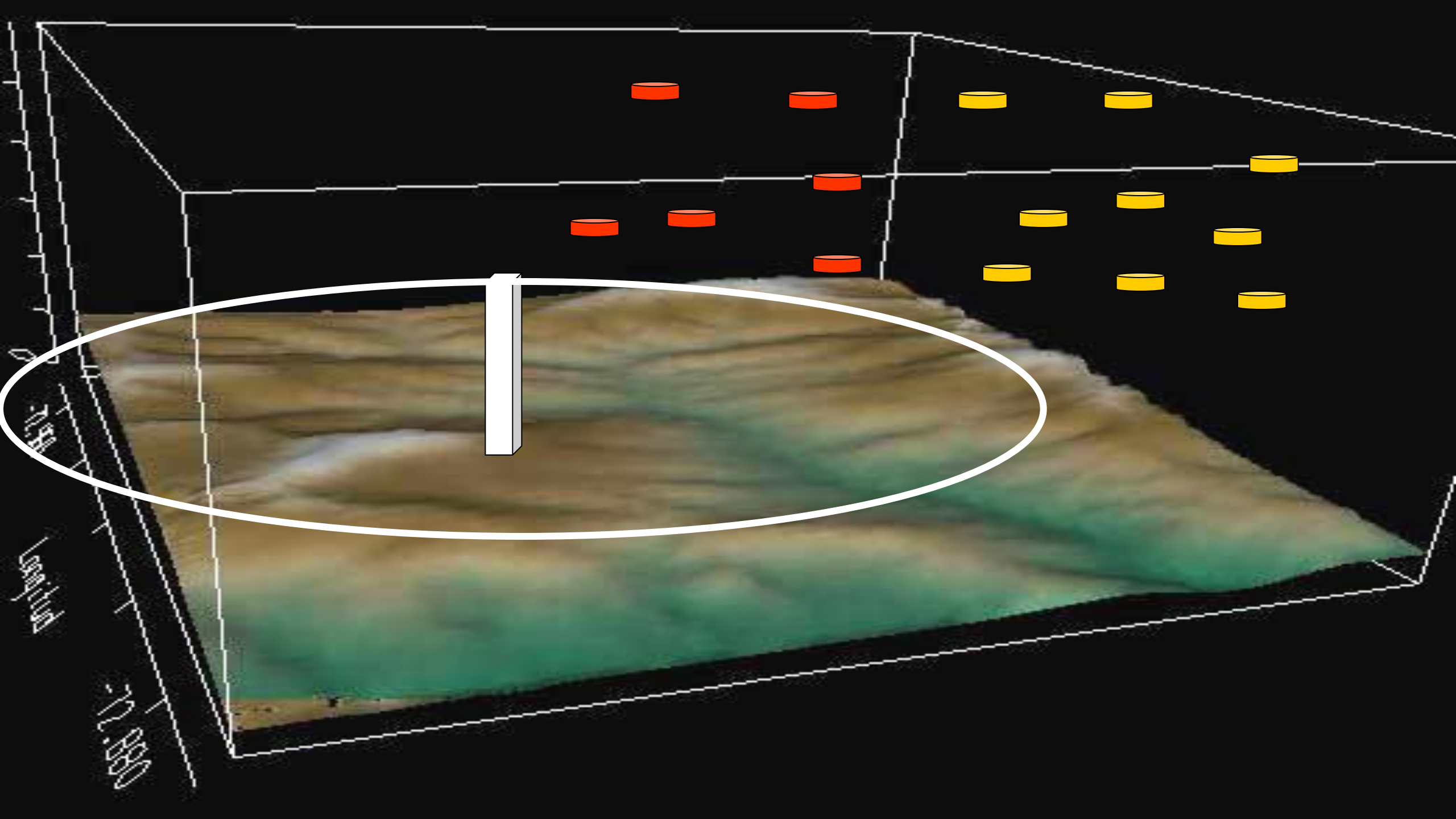

MORNING
Early Morning **Venting**

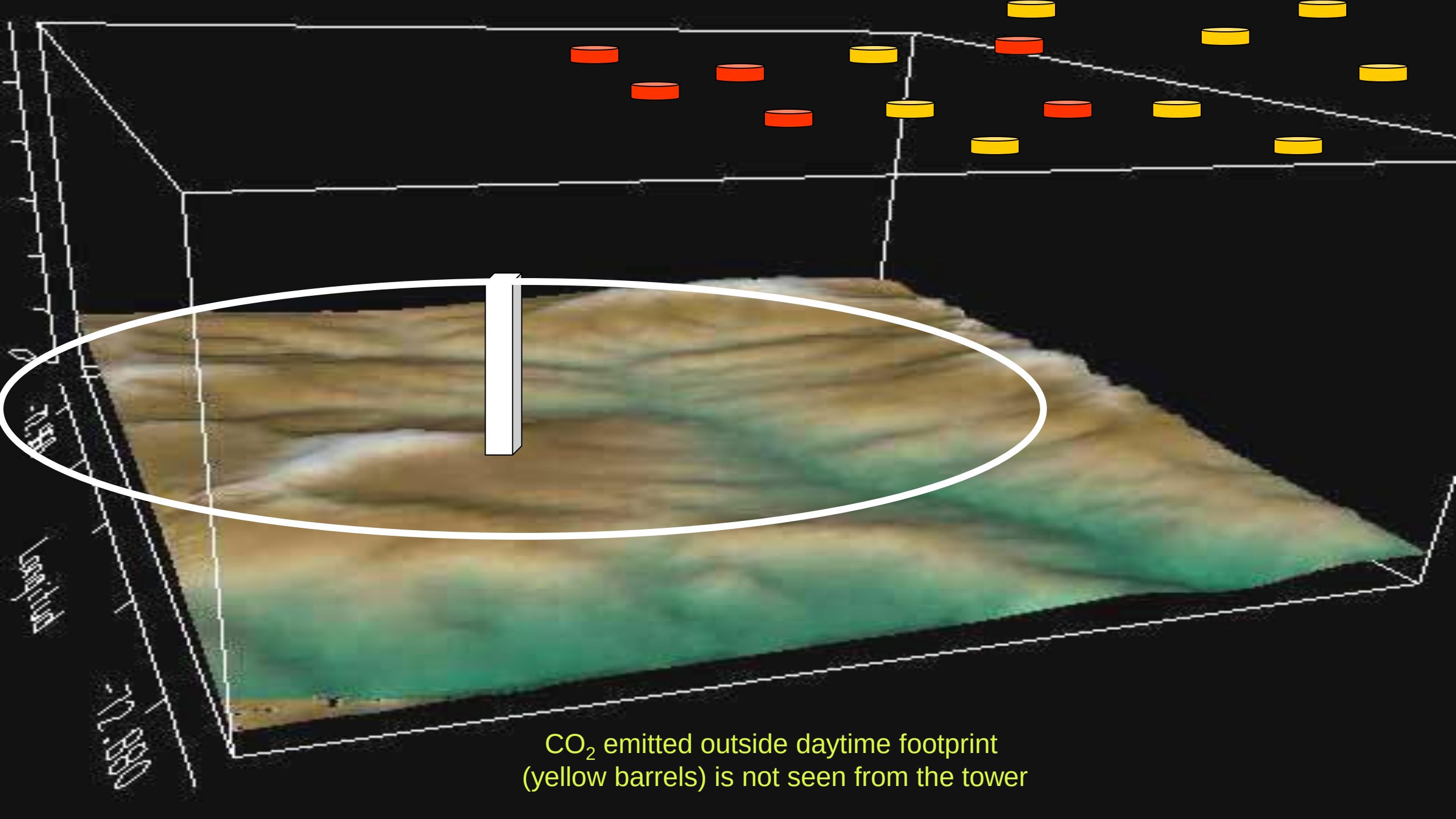




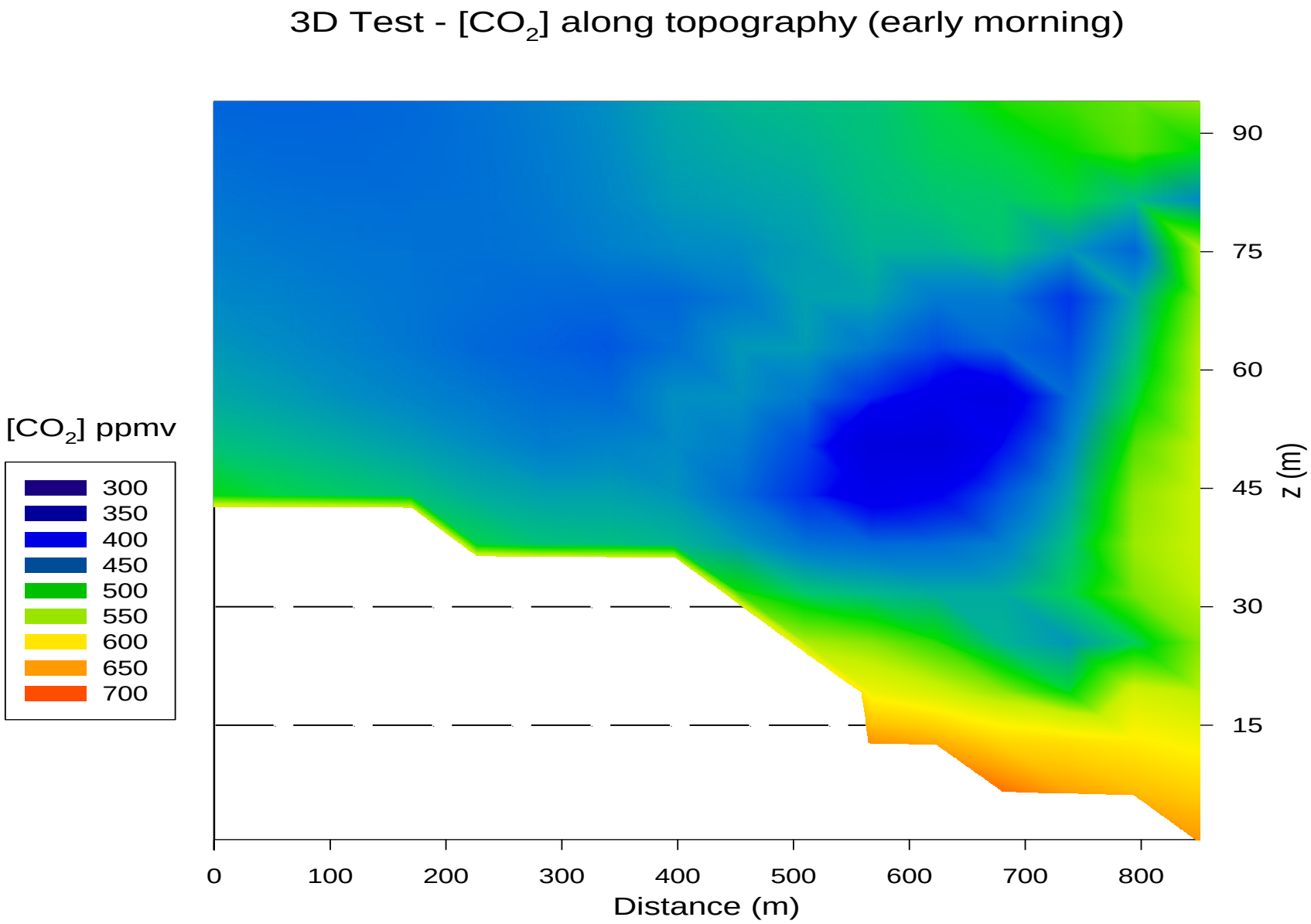


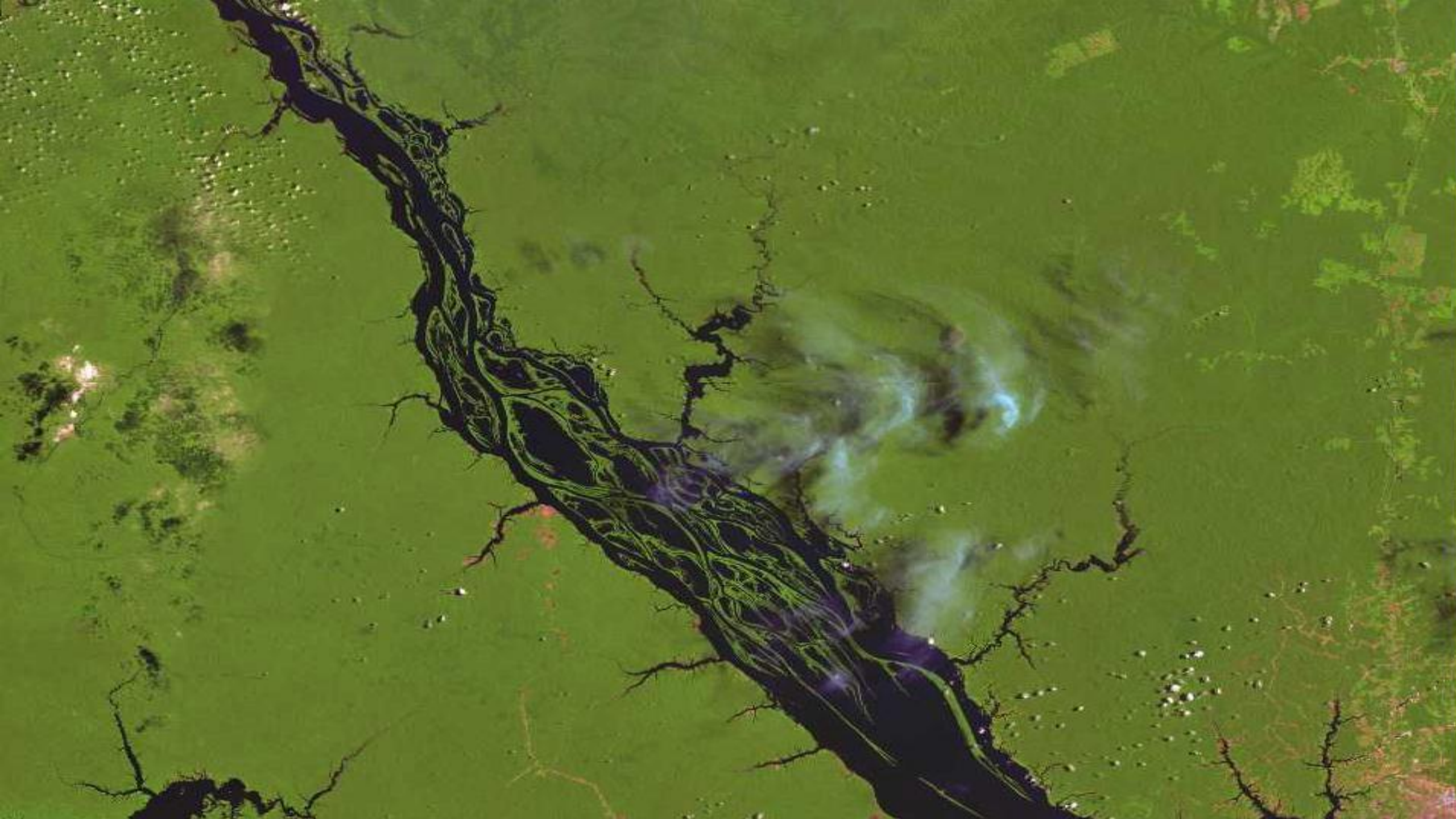


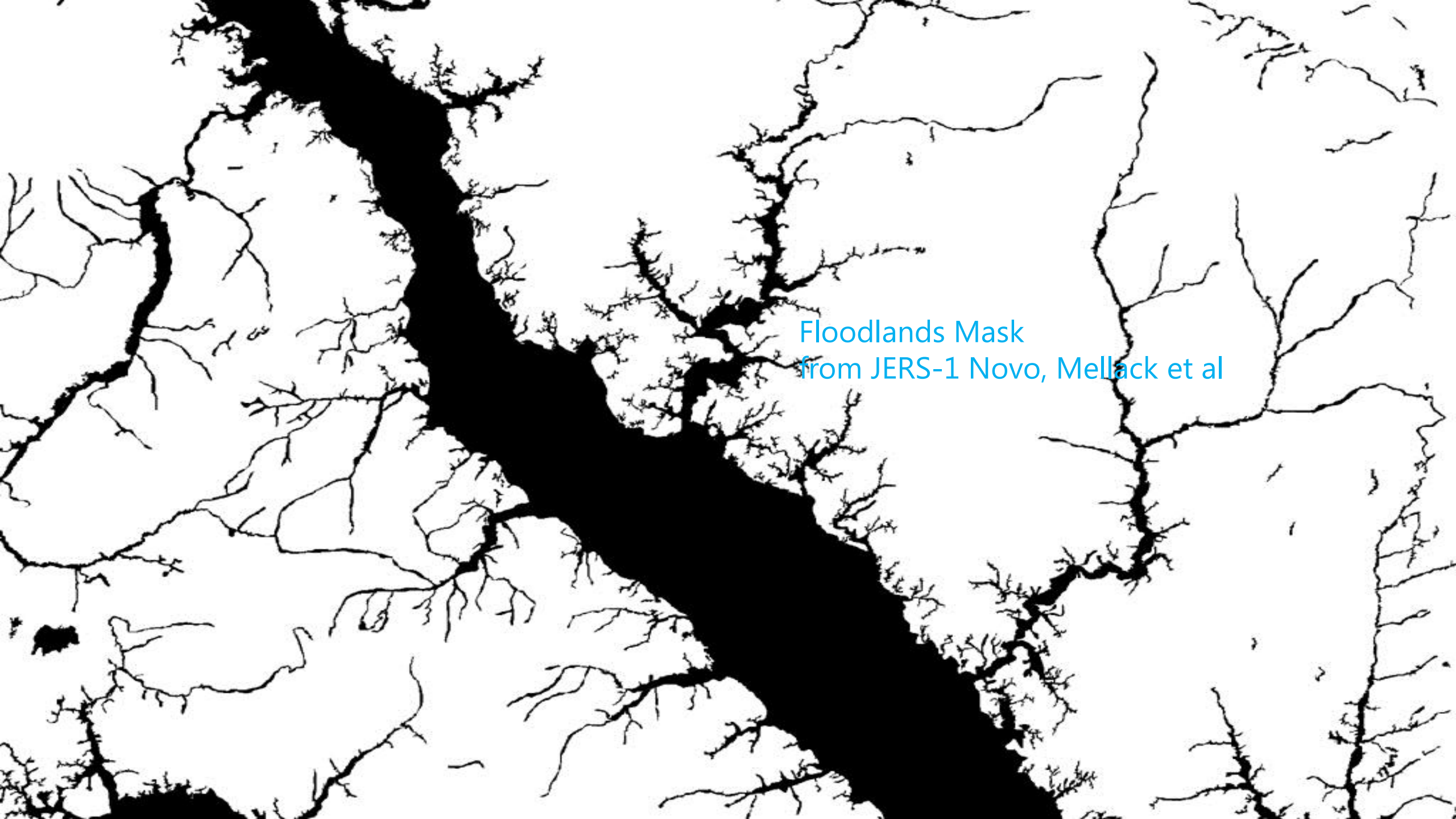


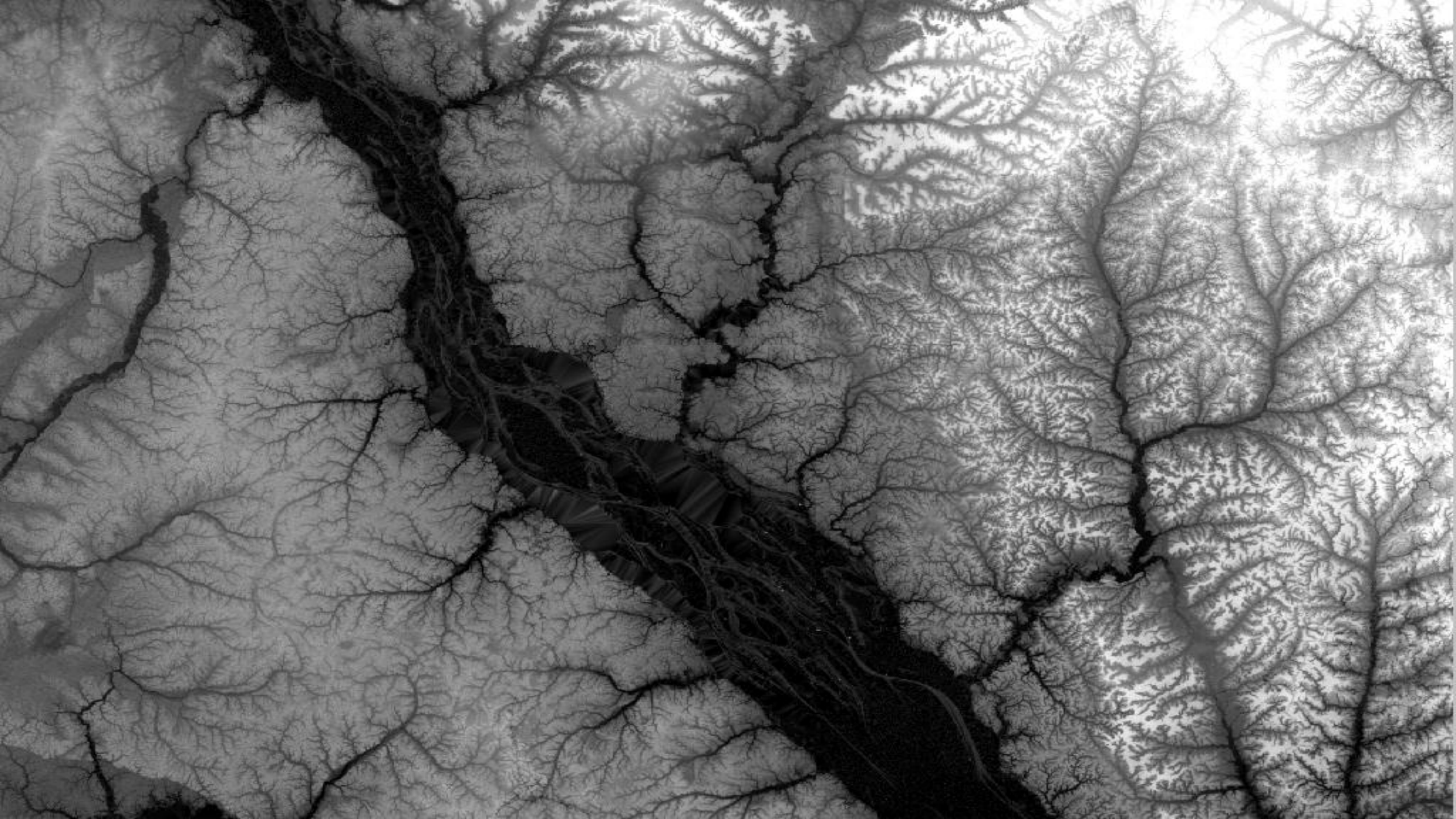

CO_2 emitted outside daytime footprint
(yellow barrels) is not seen from the tower

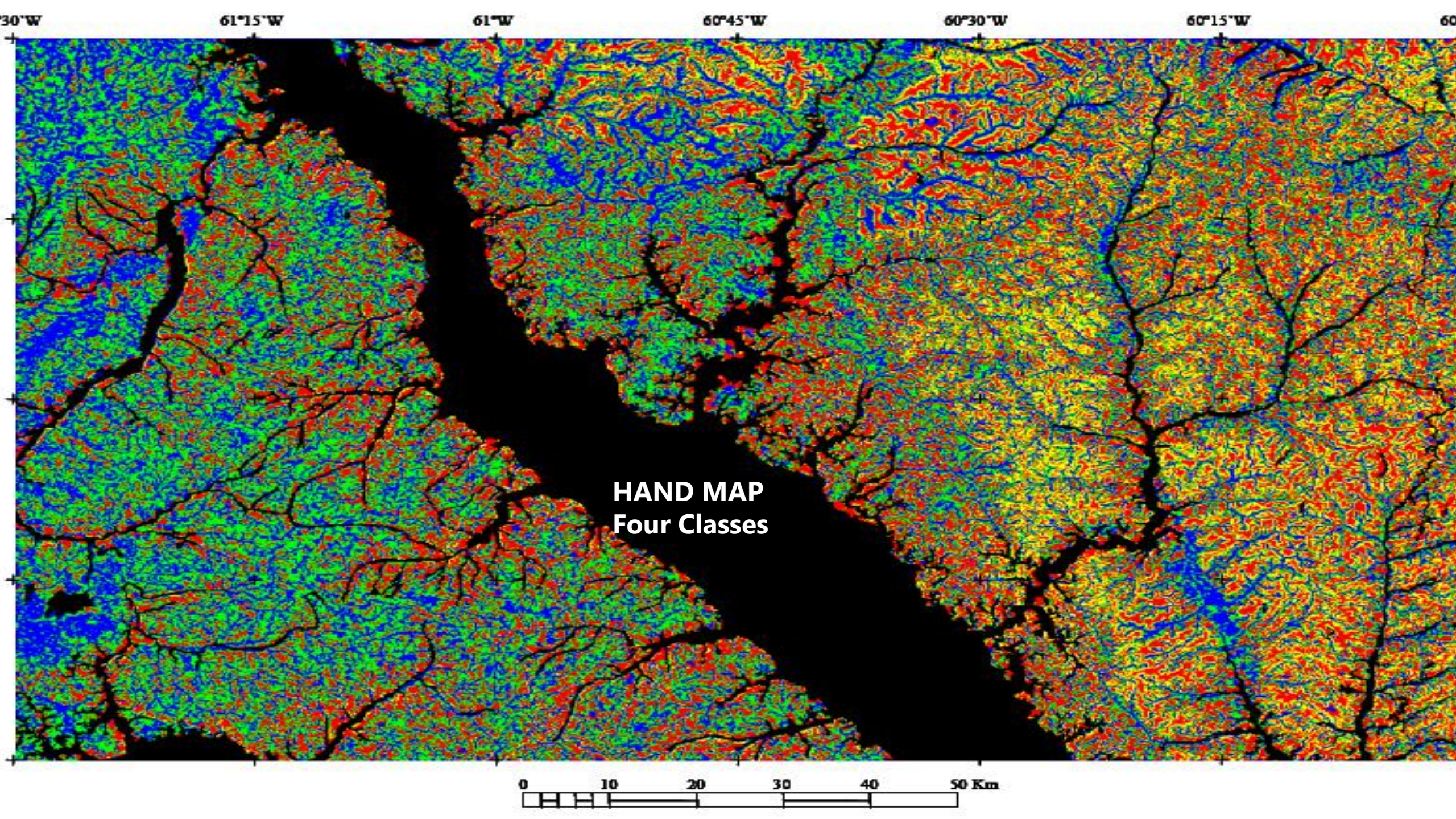
CO_2 concentrations along topography






Floodlands Mask
from JERS-1 Novo, Mellack et al

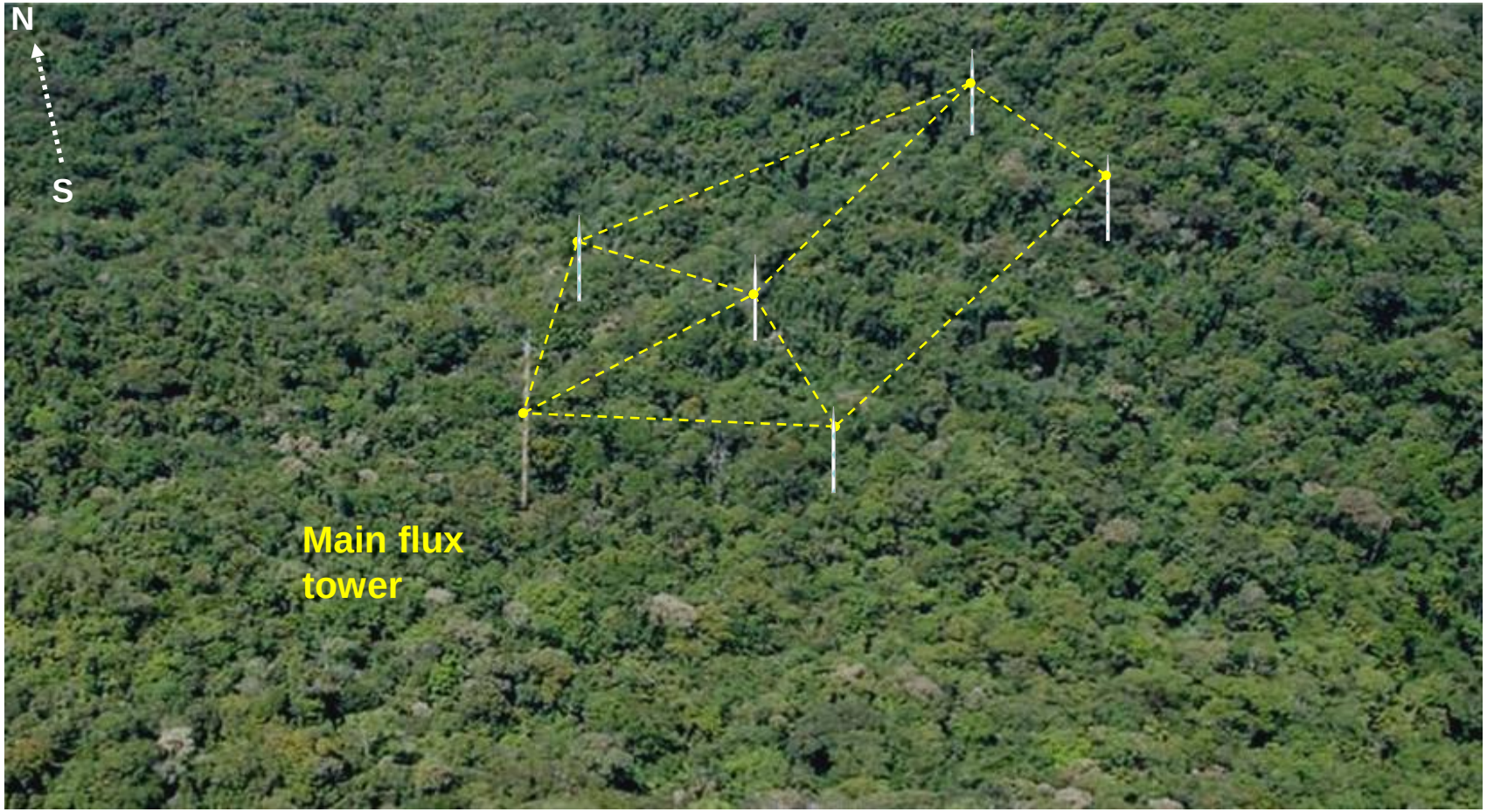



30°W
61°15'W
61°W
60°45'W
60°30'W
60°15'W
HAND MAP
Four Classes
0
10
20
30
40
50 Km

Challenge: understand the forest microclimate

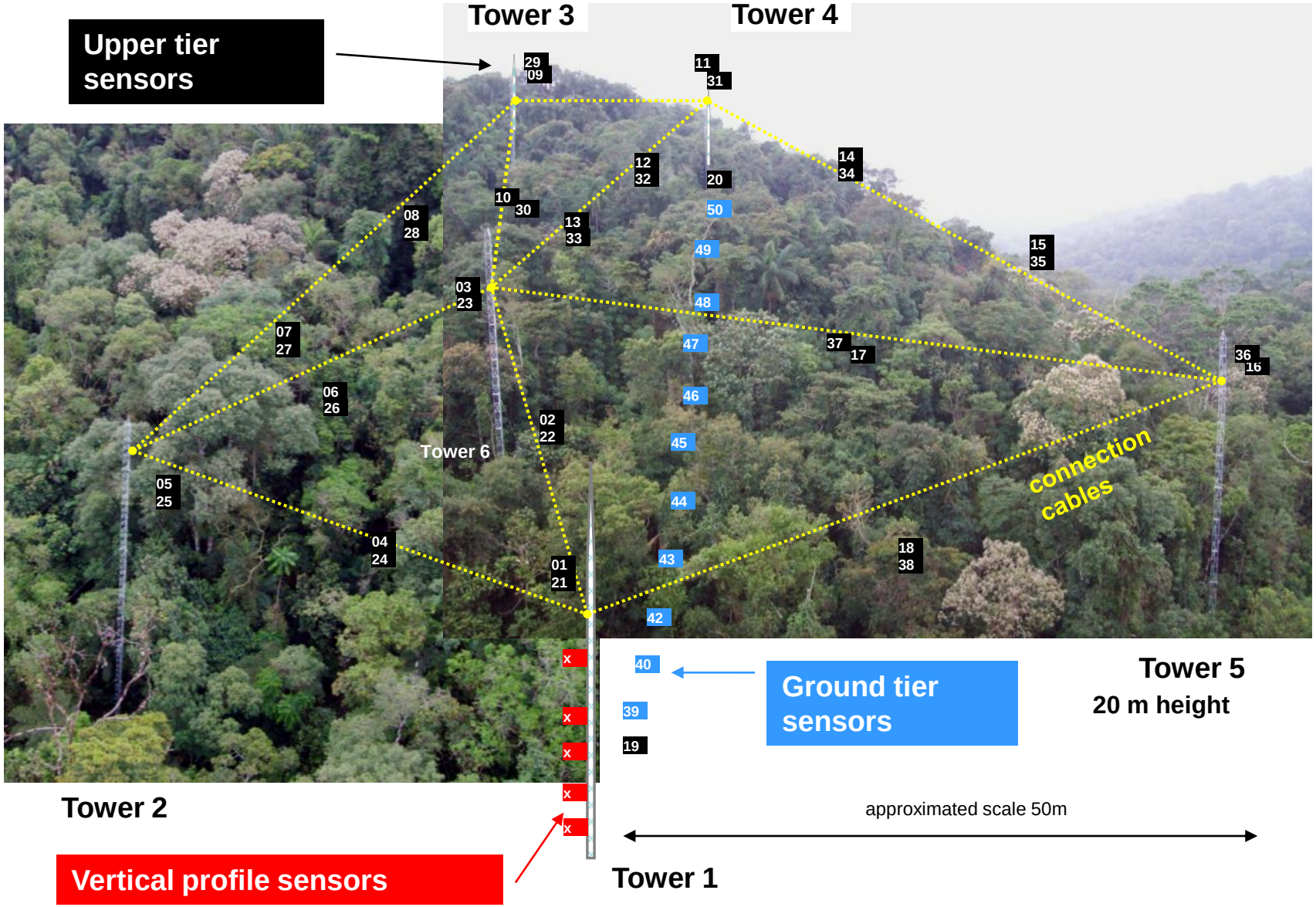
- Heterogeneity pose big challenge to our understanding
- Need an approach that recognizes the complexity of the spatial variability of the environmental variables
- Development of new systems for environmental monitoring
  - Ideally: measurements within an above the forest with high spatial and temporal resolutions
- Technical Challenges
  - Environmental conditions: high insulation, humidity; inaccessible areas; bugs, rodents, etc
  - Data quality assessment/ visualization tools

Pilot study in the Atlantic forest



Network in the Atlantic Forest, which includes five 25m towers linked by Kevlar cables. The network was placed east of the main tower, along an altitudinal transect of ~60m height. (Pilot Experiment)

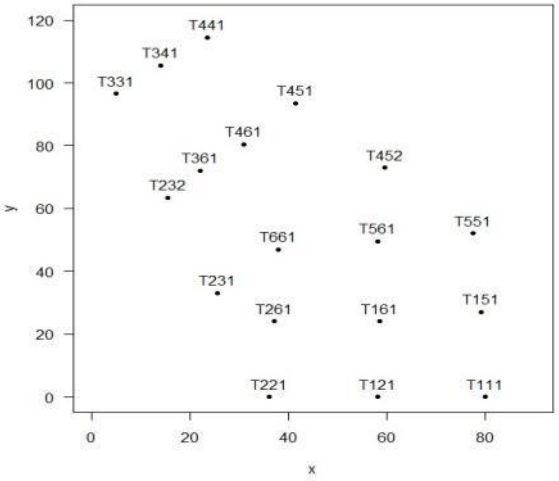
Geosensor network in the Atlantic forest : experimental design



Total 52 motes =

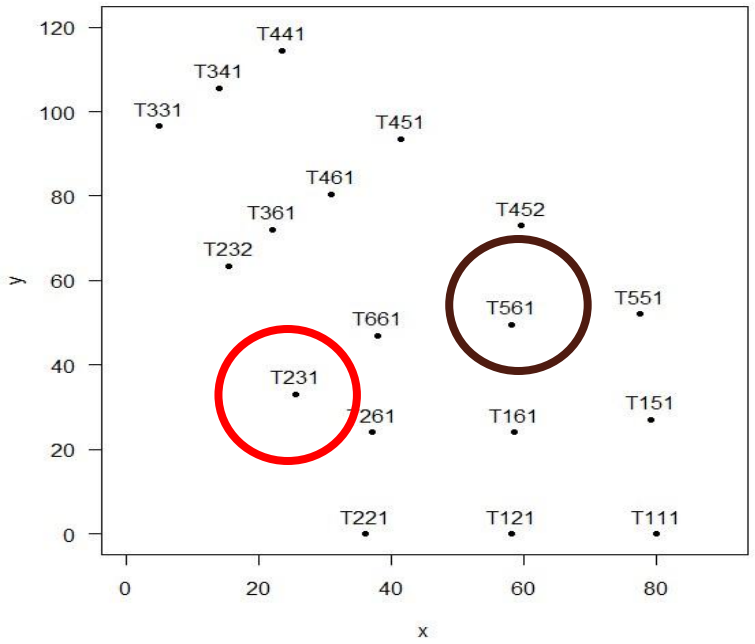
156 thermometers

52 hygrometers

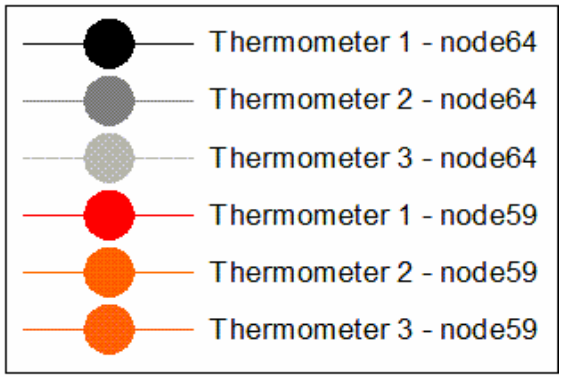


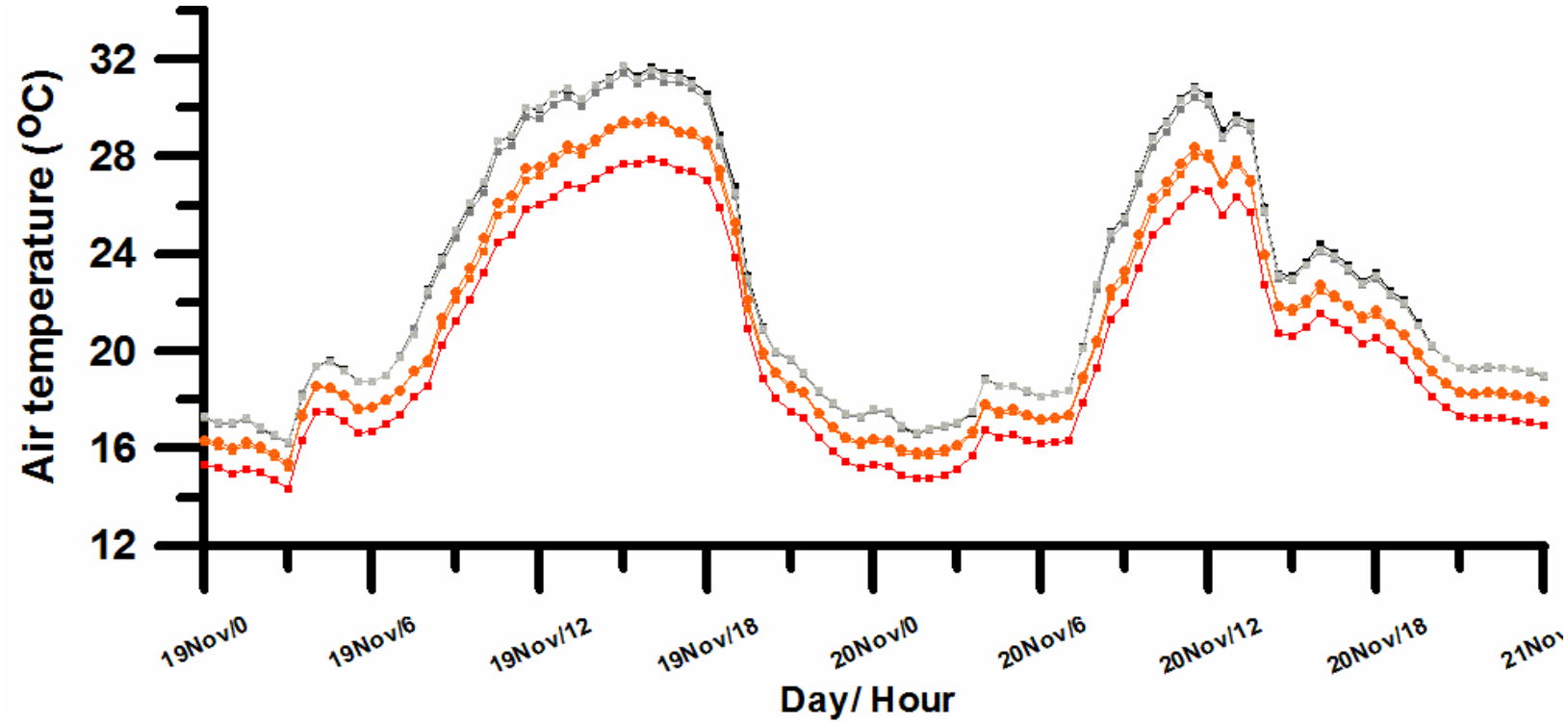
Upper tier design with 18 nodes

Spatial variability at 25 m height

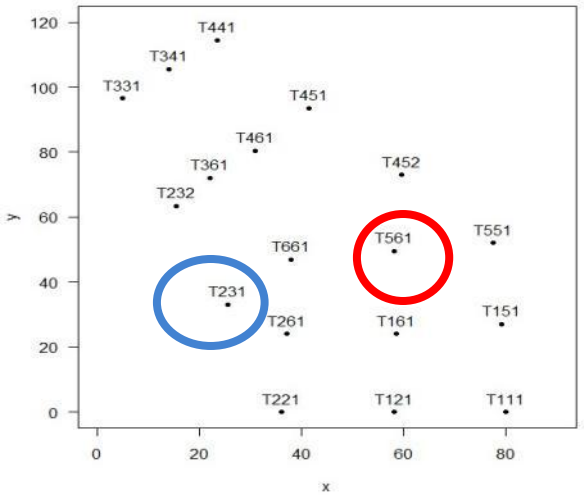


Sampling area : ~ 80 m x 120 m
18 nodes
Each node with 1 or 2 motes

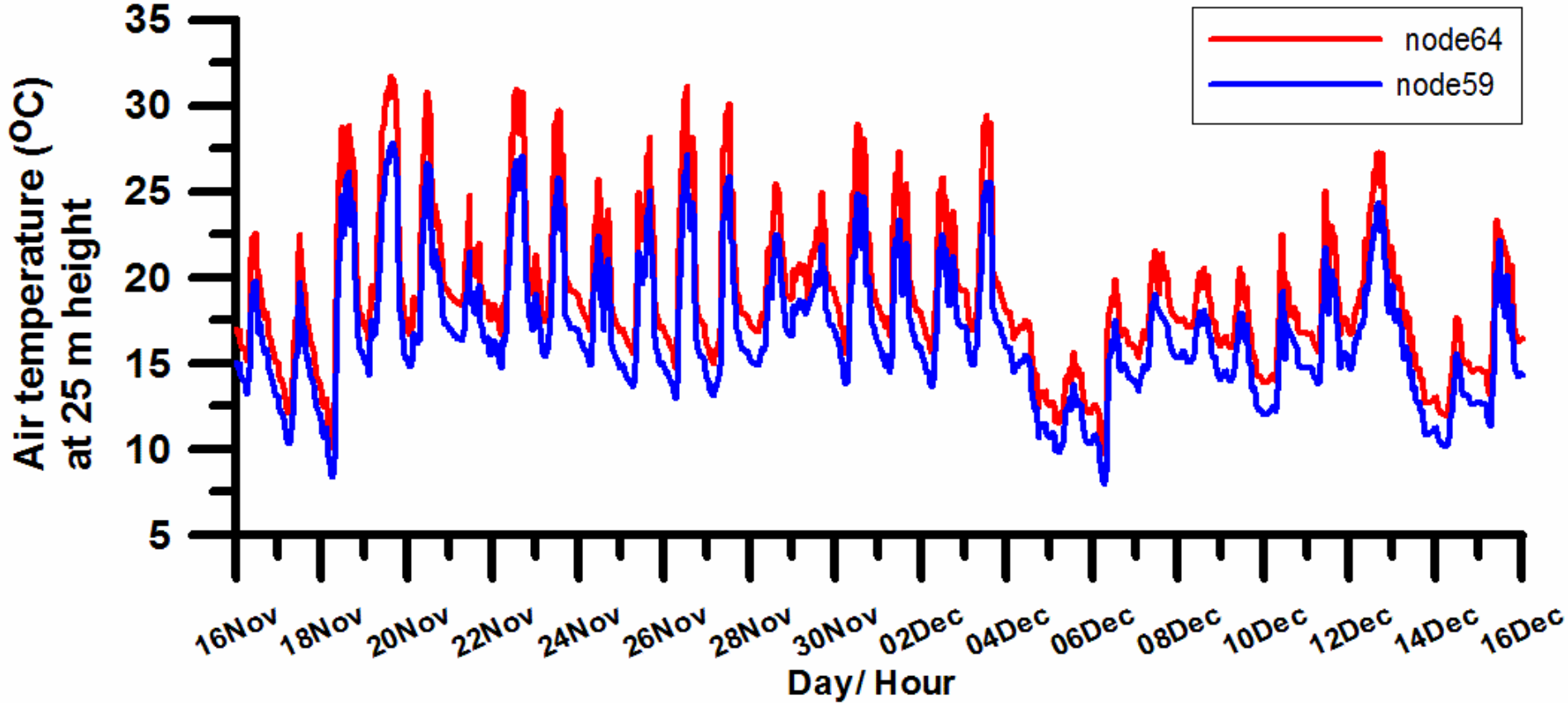




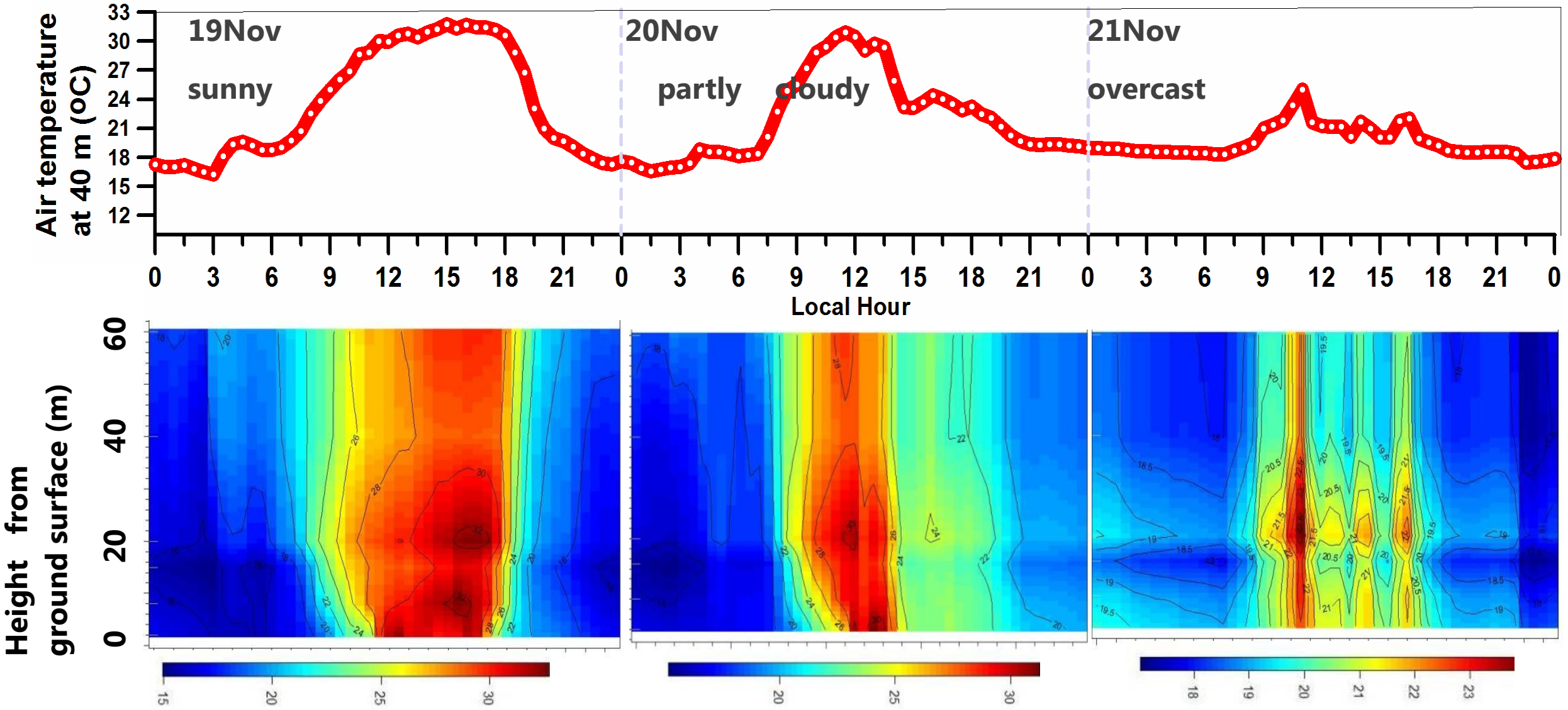
Spatial variability at 25 m height



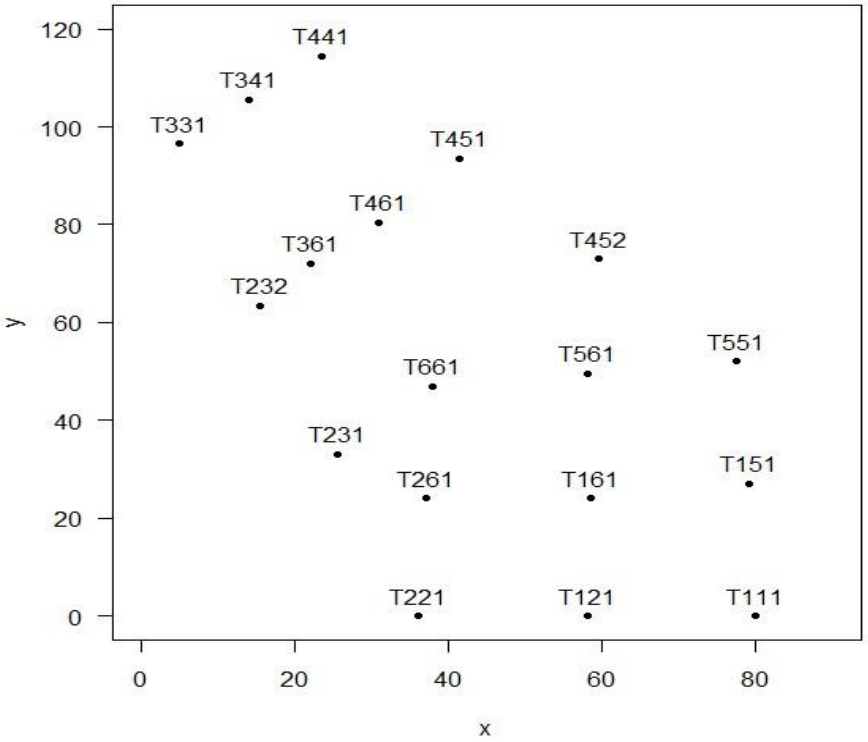
Period of measurements: 16Nov-18Dec 2009



Vertical variation of the temperature



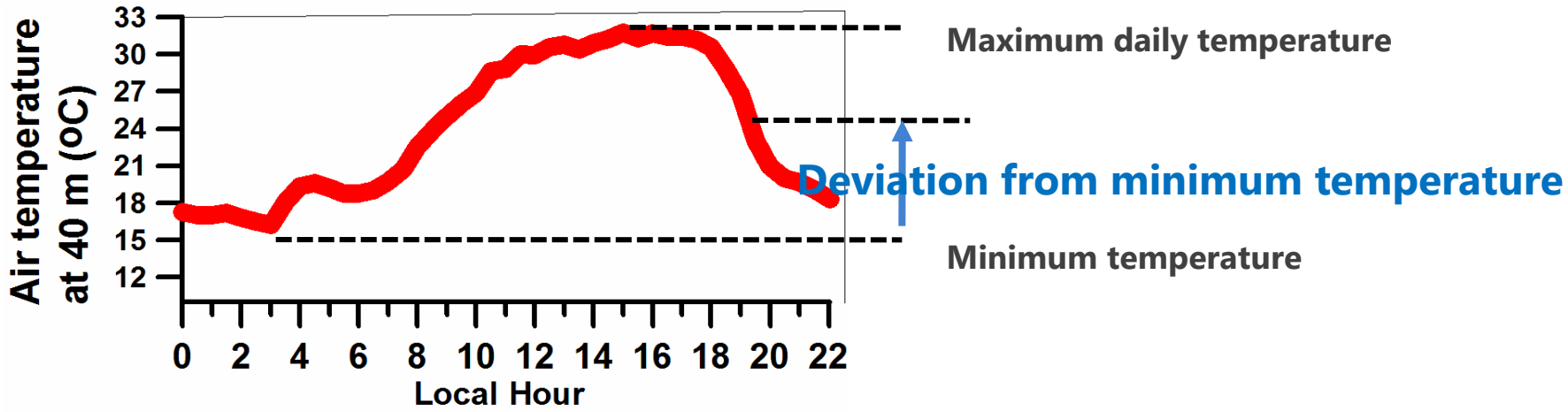
Visualization of spatial variability at 25 m height

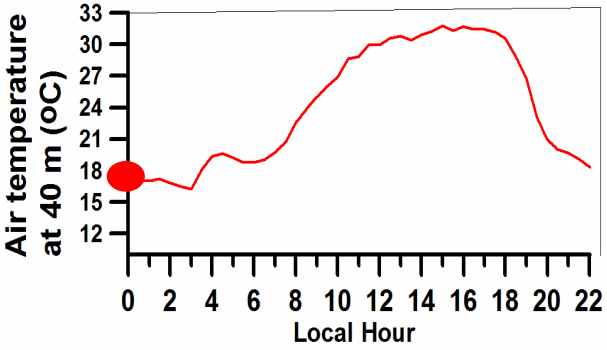


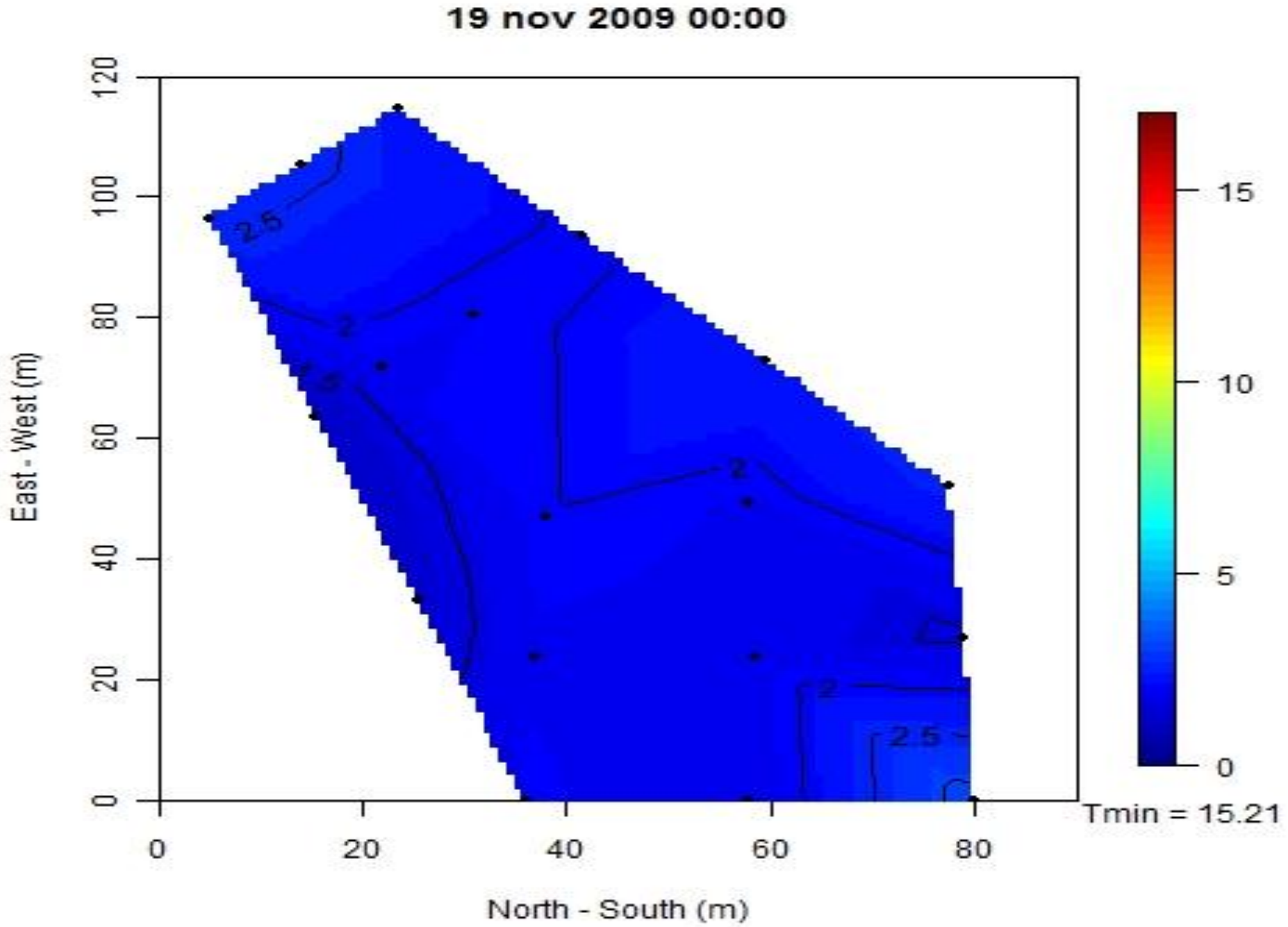
Node	Location	Nome	X (m)	Y (m)
6	Tower 3-4	T341	14	105,5
7/60	Tower 2-3	T232	15,5	63,5
8	Tower 1-5	T151	79	27
9	Tower 3-6	T361	22	72
13	Tower 1-2	T121	58	0
27/30	Tower 4	T441	23,5	114,5
29/50	Tower 2	T221	36	0
40/41	Tower 3	T331	5	96,5
42/69	Tower 5	T551	77,5	52
44/47	Tower 1	T111	80	0
46	Tower 6	T661	38	47
51/52	Tower 1-6	T161	58,5	24
56/58	Tower 4-5	T451	41,5	93,5
57/63	Tower 4-5	T452	59,5	73
59/61	Tower 2-3	T231	25,5	33
62/66	Tower 4-6	T461	31	80,5
64	Tower 5-6	T561	58	49,5
65	Tower 2-6	T261	37	24

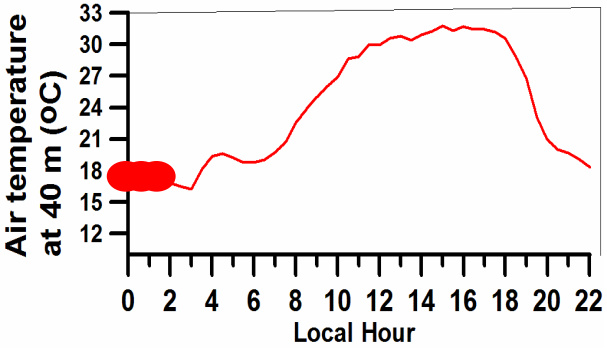
Node temperature value assigned: median of all thermometers each node

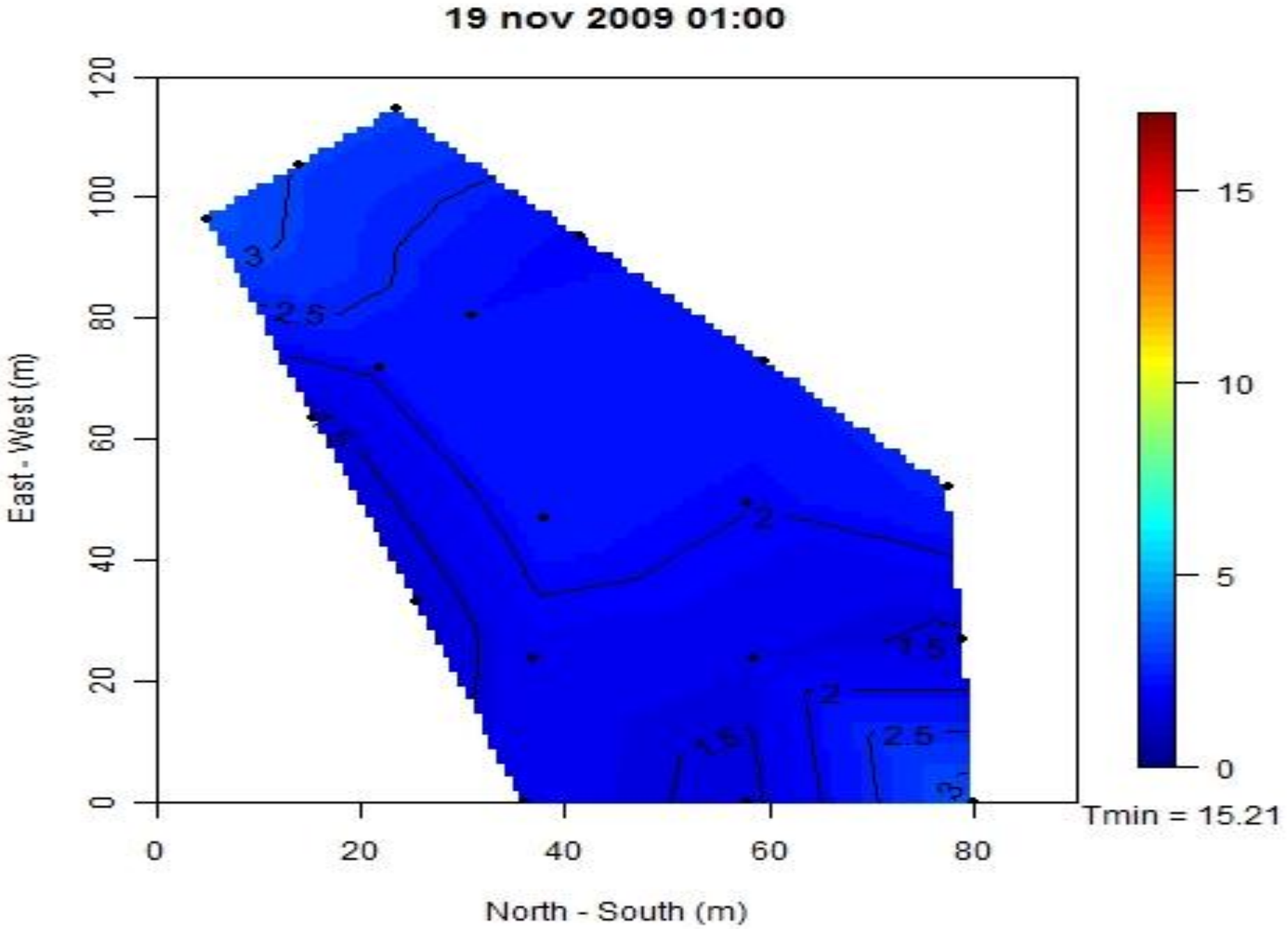
Visualization: deviation from minimum temperature

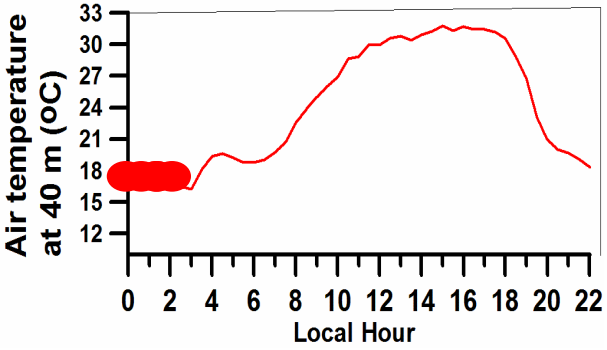


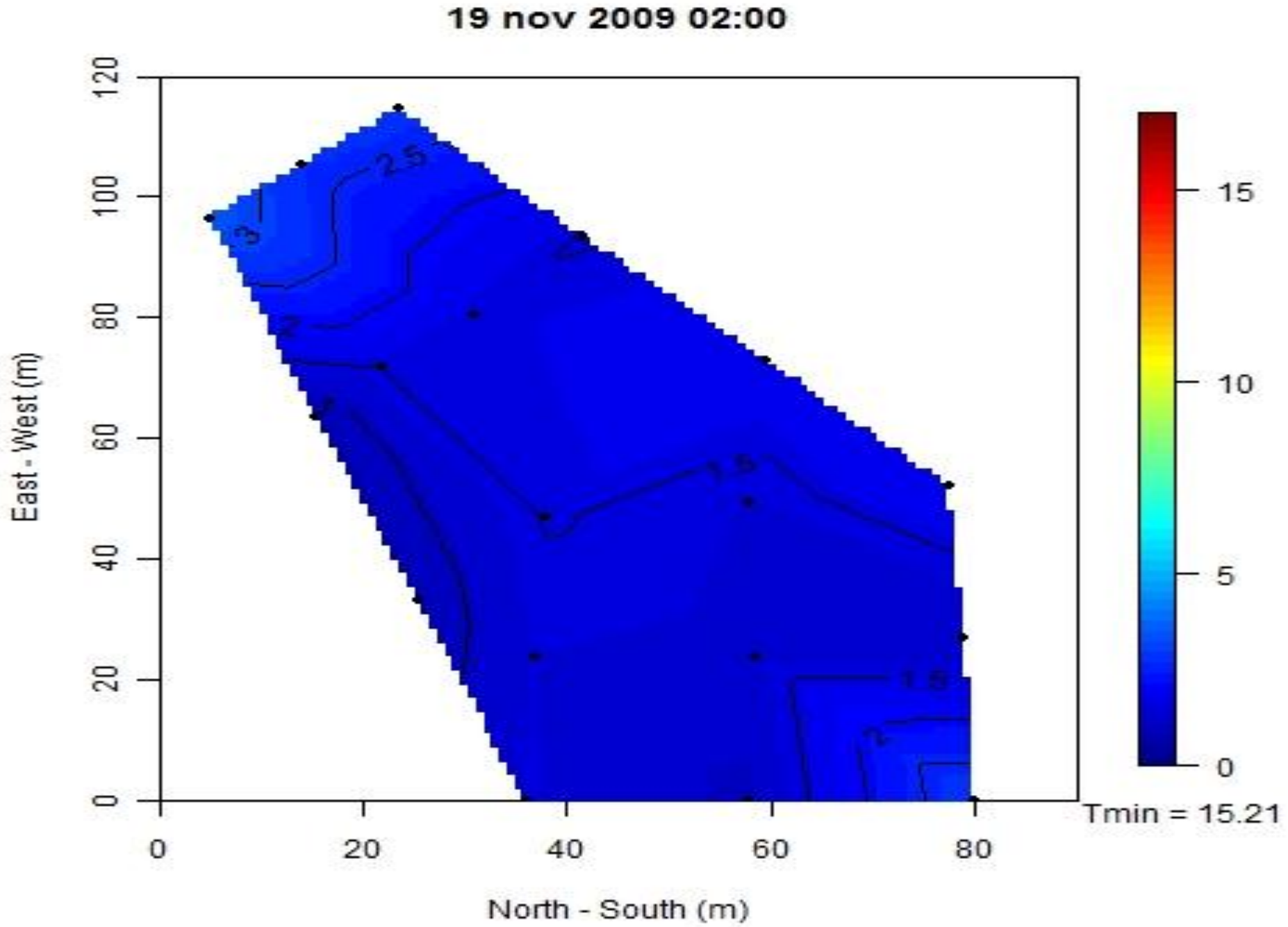

Air temperature at 40 m (oC)
33
30
27
24
21
18
15
12
0 2 4 6 8 10 12 14 16 18 20 22
Local Hour

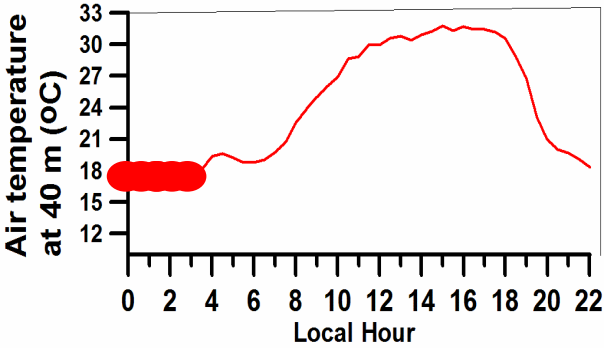

19 nov 2009 00:00
East - West (m)
0
20
40
60
80
100
120
North - South (m)
0
20
40
60
80
15
10
5
0
Tmin = 15.21

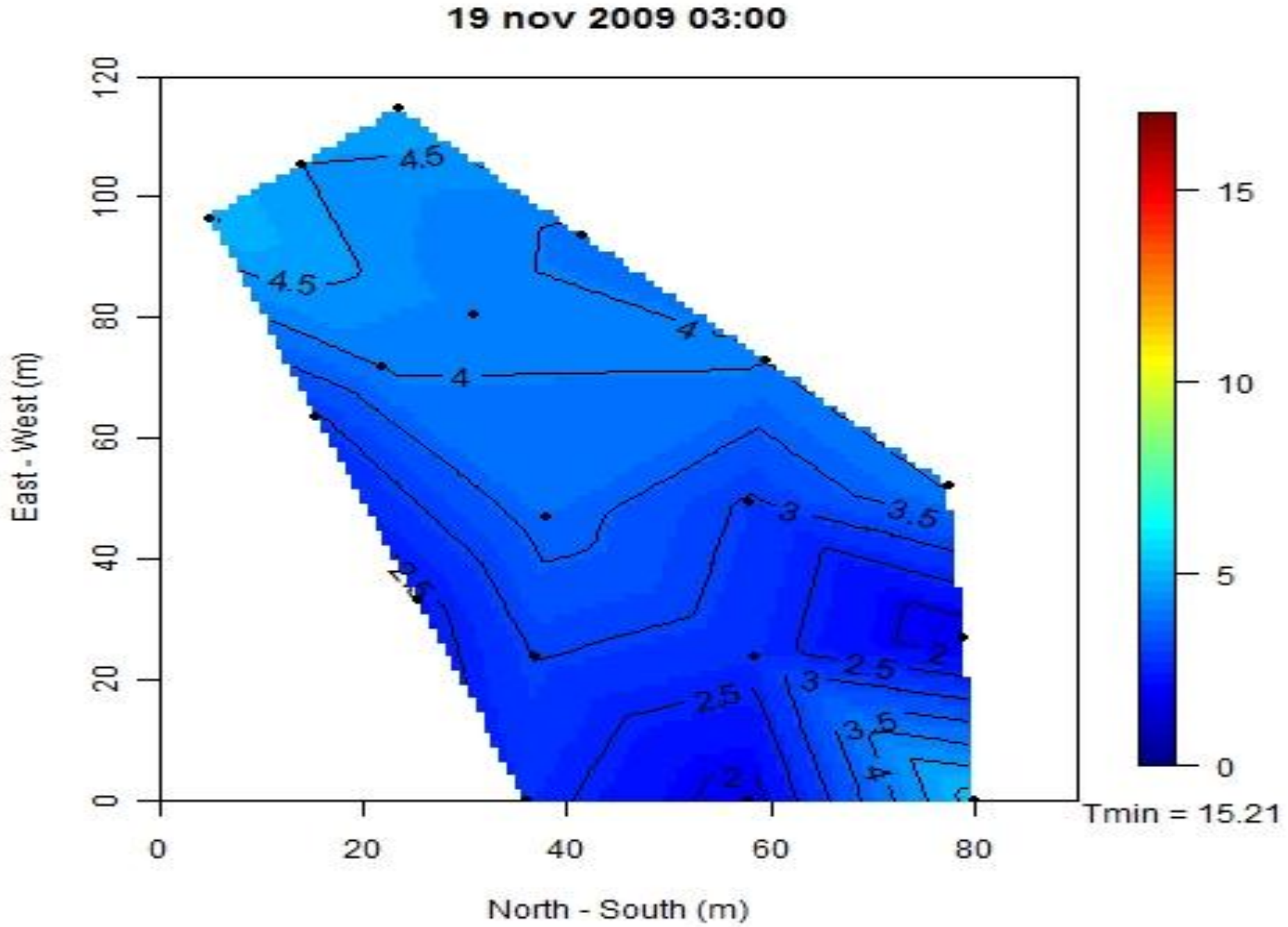

Air temperature at 40 m (oC)
33
30
27
24
21
18
15
12
0 2 4 6 8 10 12 14 16 18 20 22
Local Hour

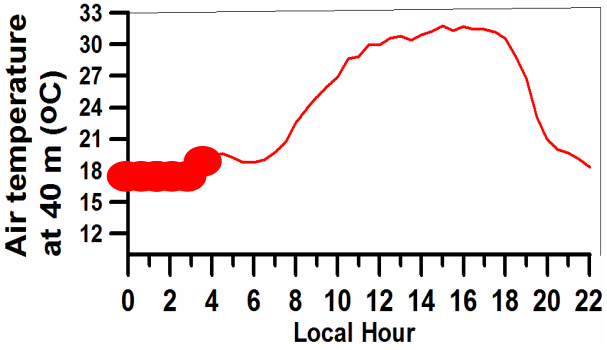

19 nov 2009 01:00
East - West (m)
0
20
40
60
80
100
120
North - South (m)
0
20
40
60
80
15
10
5
0
Tmin = 15.21

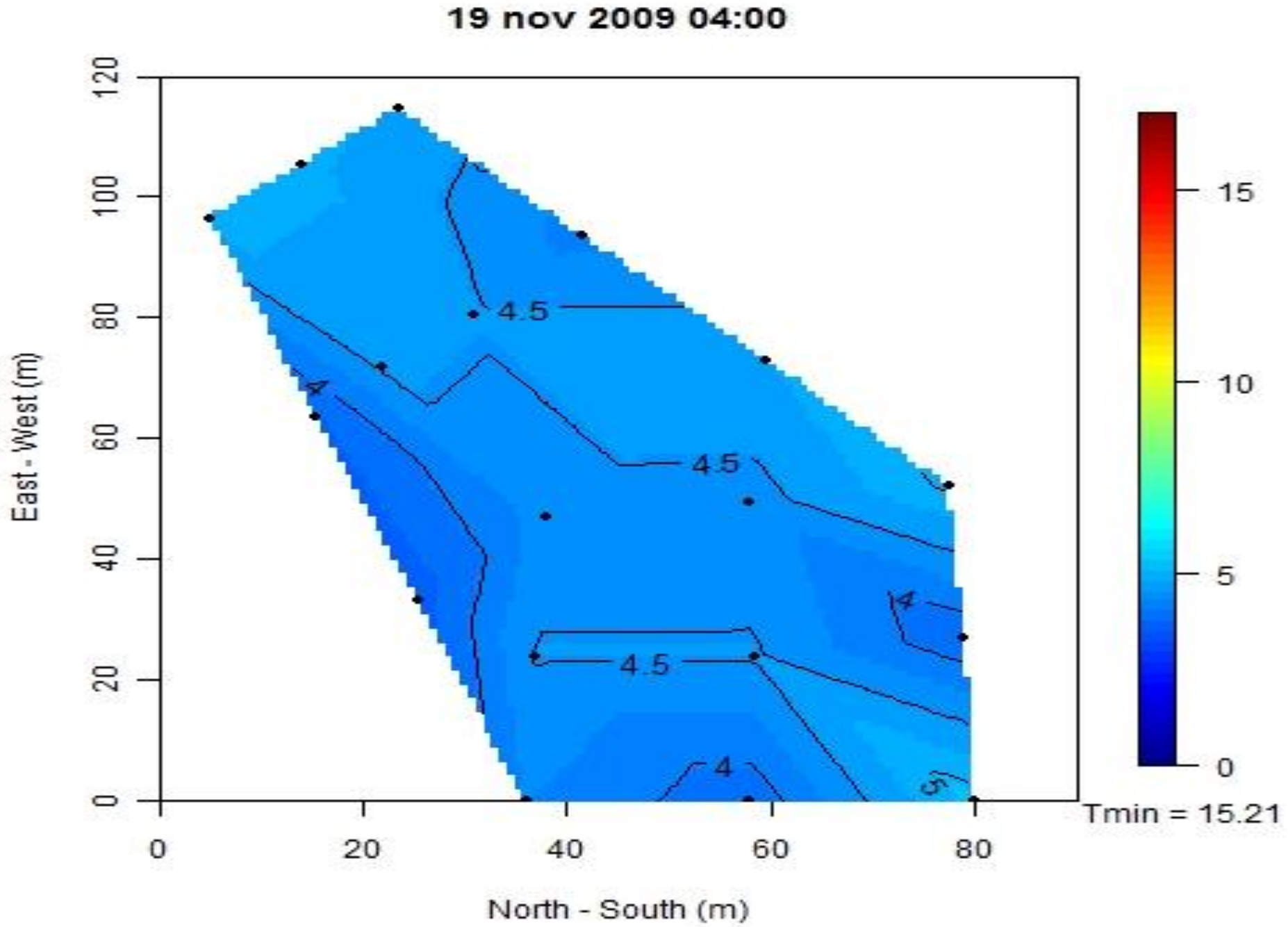

Air temperature at 40 m (oC)
33
30
27
24
21
18
15
12
0 2 4 6 8 10 12 14 16 18 20 22
Local Hour

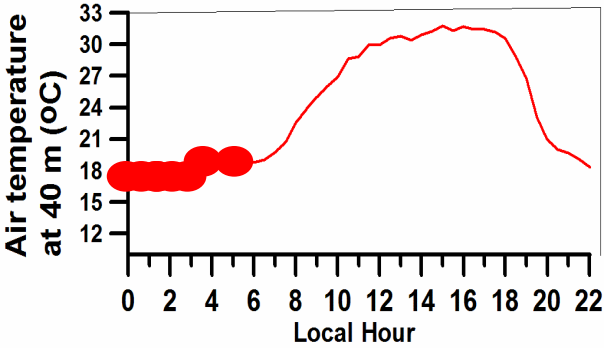

19 nov 2009 02:00
East - West (m)
0
20
40
60
80
100
120
0
20
40
60
80
North - South (m)
15
10
5
0
Tmin = 15.21

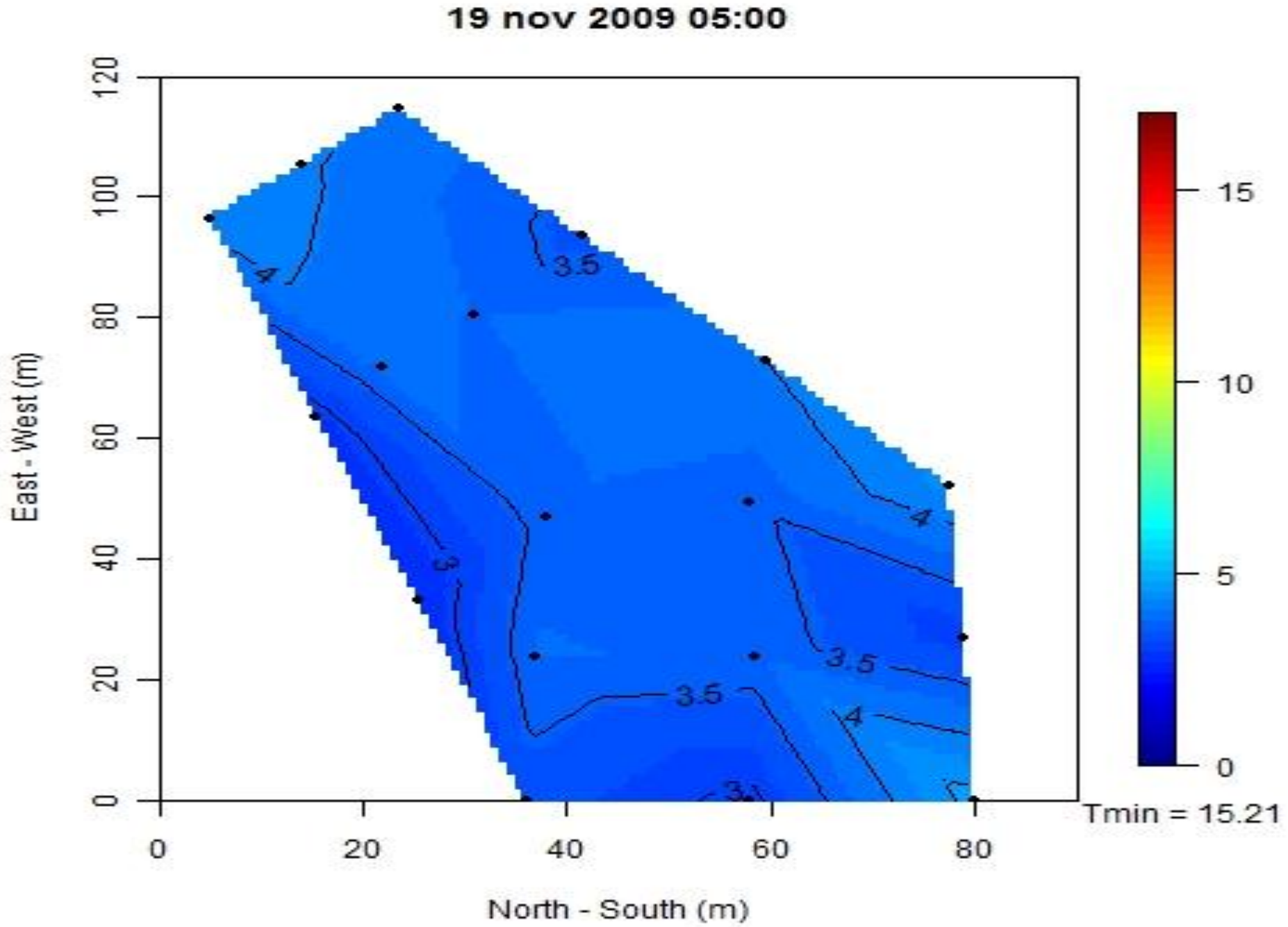

Air temperature at 40 m (oC)
33
30
27
24
21
18
15
12
0 2 4 6 8 10 12 14 16 18 20 22
Local Hour

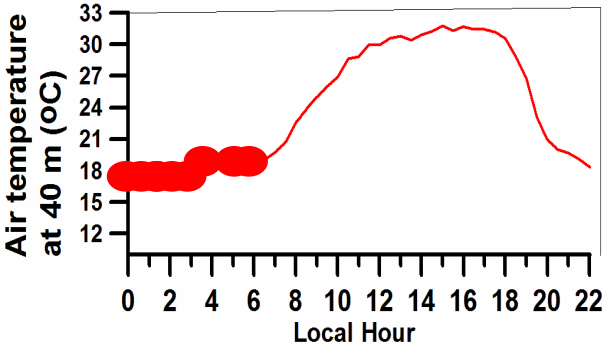

19 nov 2009 03:00
East - West (m)
0 20 40 60 80 100 120
North - South (m)
0 20 40 60 80
4.5
4
3.5
3
2.5
2
15
10
5
0
Tmin = 15.21

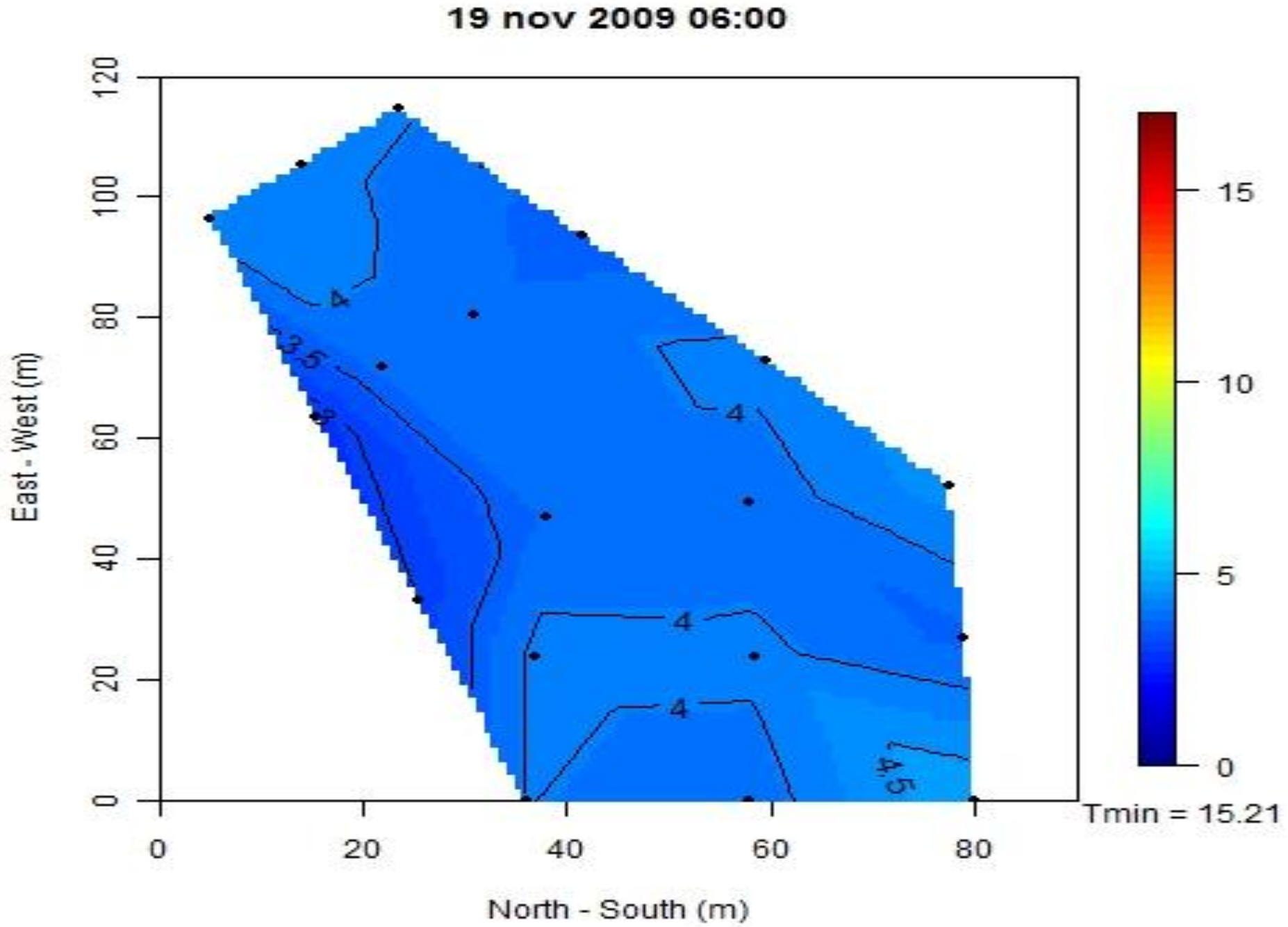

Air temperature at 40 m (oC)
33
30
27
24
21
18
15
12
0 2 4 6 8 10 12 14 16 18 20 22
Local Hour

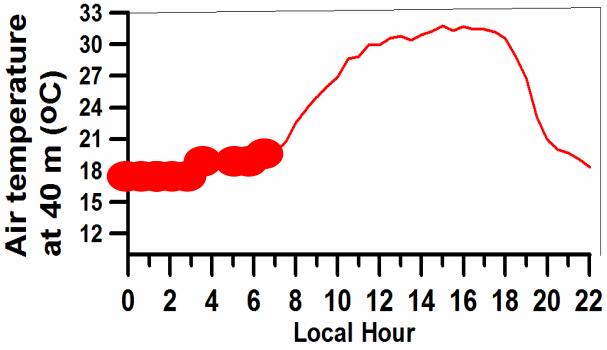

19 nov 2009 04:00
East - West (m)
0 20 40 60 80 100 120
North - South (m)
0 20 40 60 80
4.5
4
4.5
4.5
4
4
15
10
5
0
Tmin = 15.21


Air temperature at 40 m (oC)
33
30
27
24
21
18
15
12
0 2 4 6 8 10 12 14 16 18 20 22
Local Hour


19 nov 2009 05:00
East - West (m)
0 20 40 60 80 100 120
North - South (m)
0 20 40 60 80
4
3.5
3.5
4
3.5
4
15
10
5
0
Tmin = 15.21


Air temperature at 40 m (oC)
33
30
27
24
21
18
15
12
0 2 4 6 8 10 12 14 16 18 20 22
Local Hour


19 nov 2009 06:00
East - West (m)
0 20 40 60 80 100 120
North - South (m)
0 20 40 60 80
4
3.5
4
4
4
4.5
15
10
5
0
Tmin = 15.21


Air temperature at 40 m (oC)
33
30
27
24
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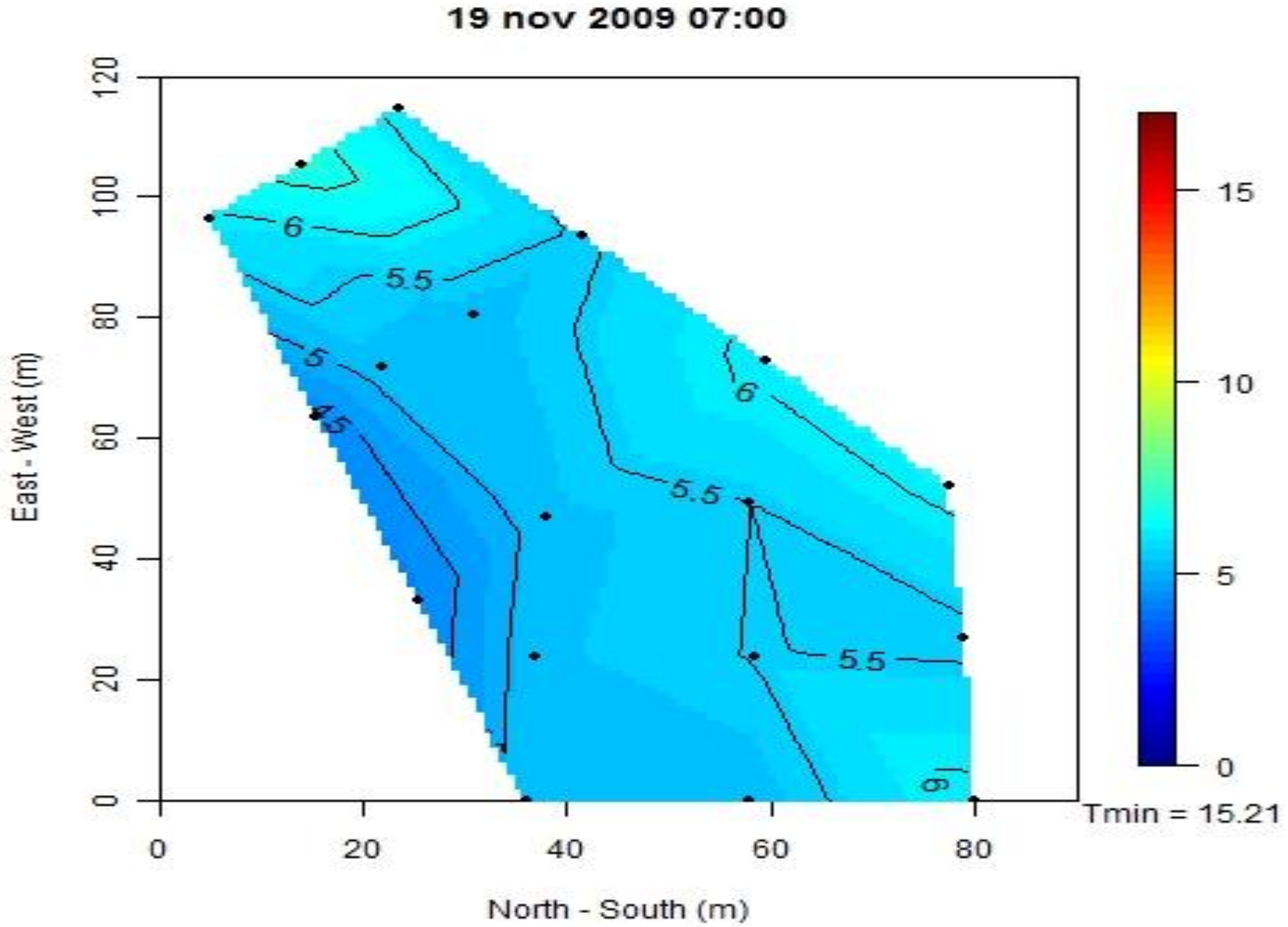
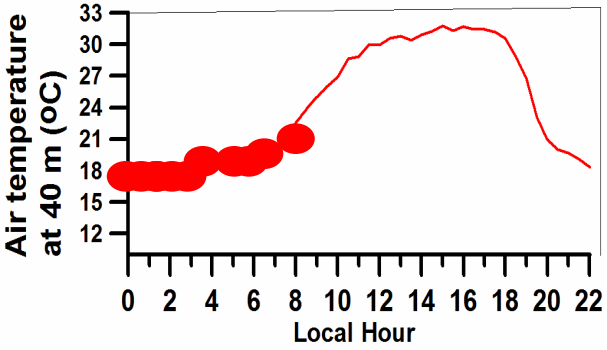
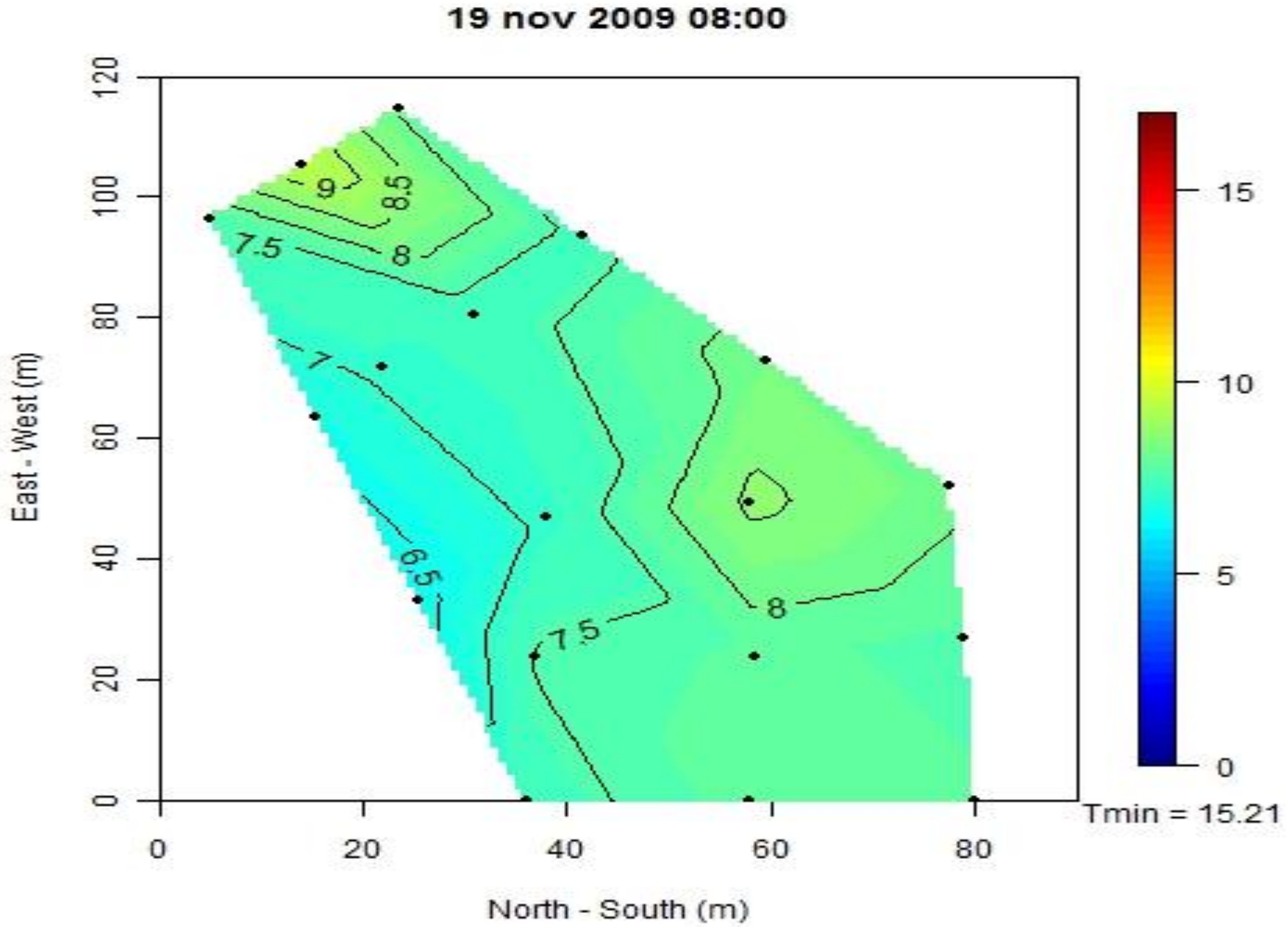
18
15
12
0 2 4 6 8 10 12 14 16 18 20 22
Local Hour


19 nov 2009 07:00
East - West (m)
0 20 40 60 80 100 120
North - South (m)
0 20 40 60 80
6
5.5
5
4.5
6
5.5
5.5
9
15
10
5
0
Tmin = 15.21


Air temperature at 40 m (oC)
33
30
27
24
21
18
15
12
0 2 4 6 8 10 12 14 16 18 20 22
Local Hour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North - South (m)
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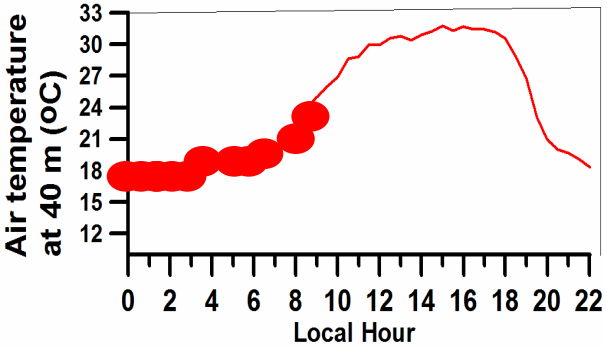
Air temperature at 40 m (oC)
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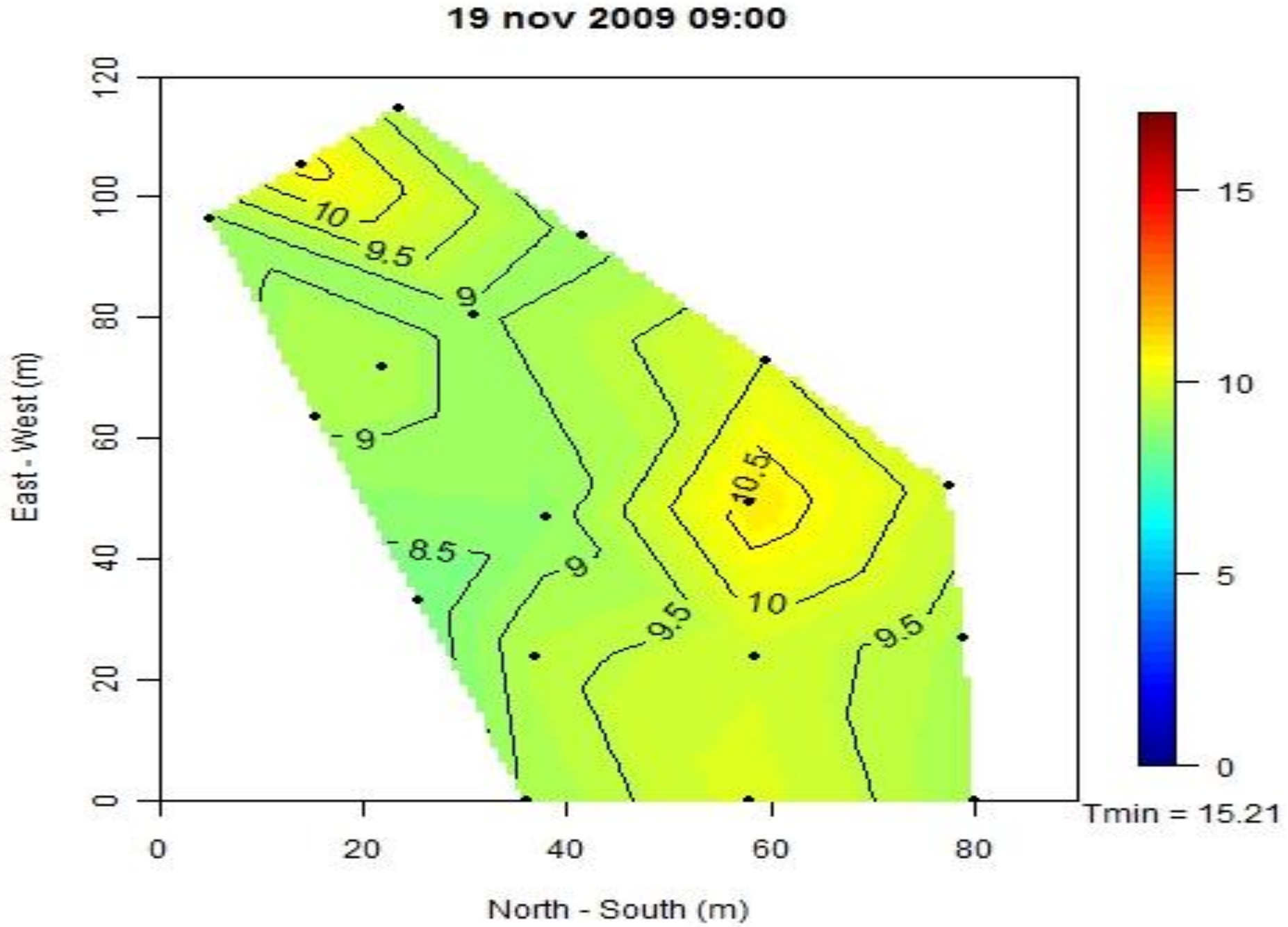
0 2 4 6 8 10 12 14 16 18 20 22
Local Hour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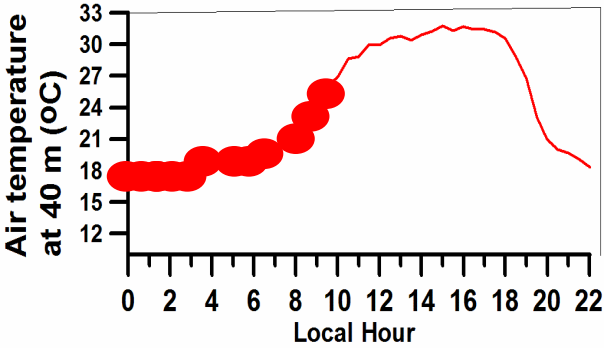
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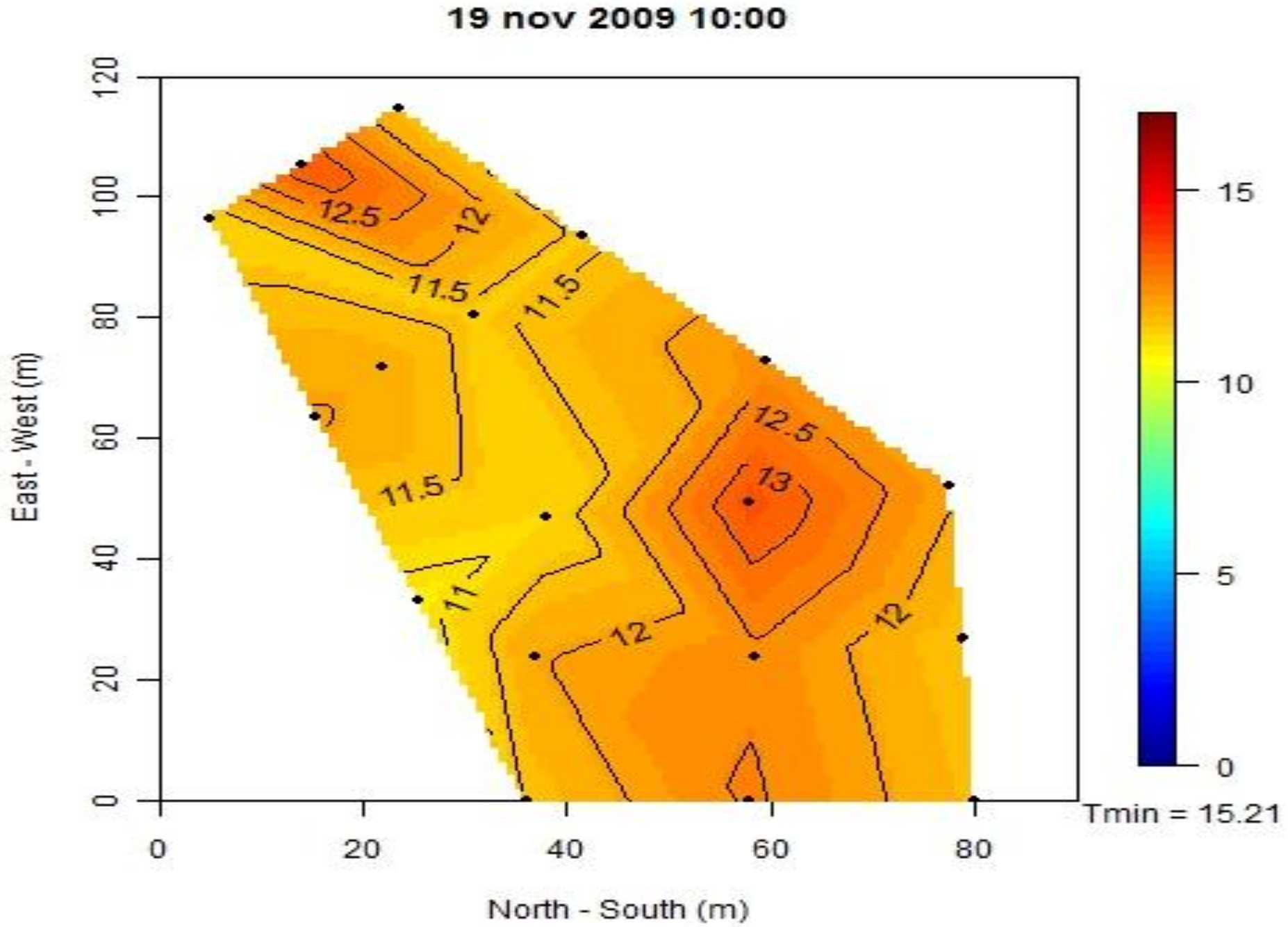
Local Hour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North - South (m)
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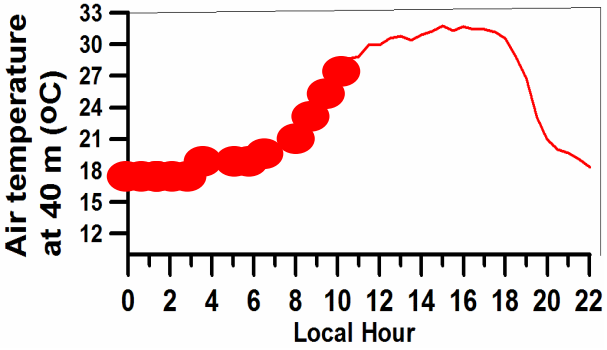
Air temperature at 40 m (oC)
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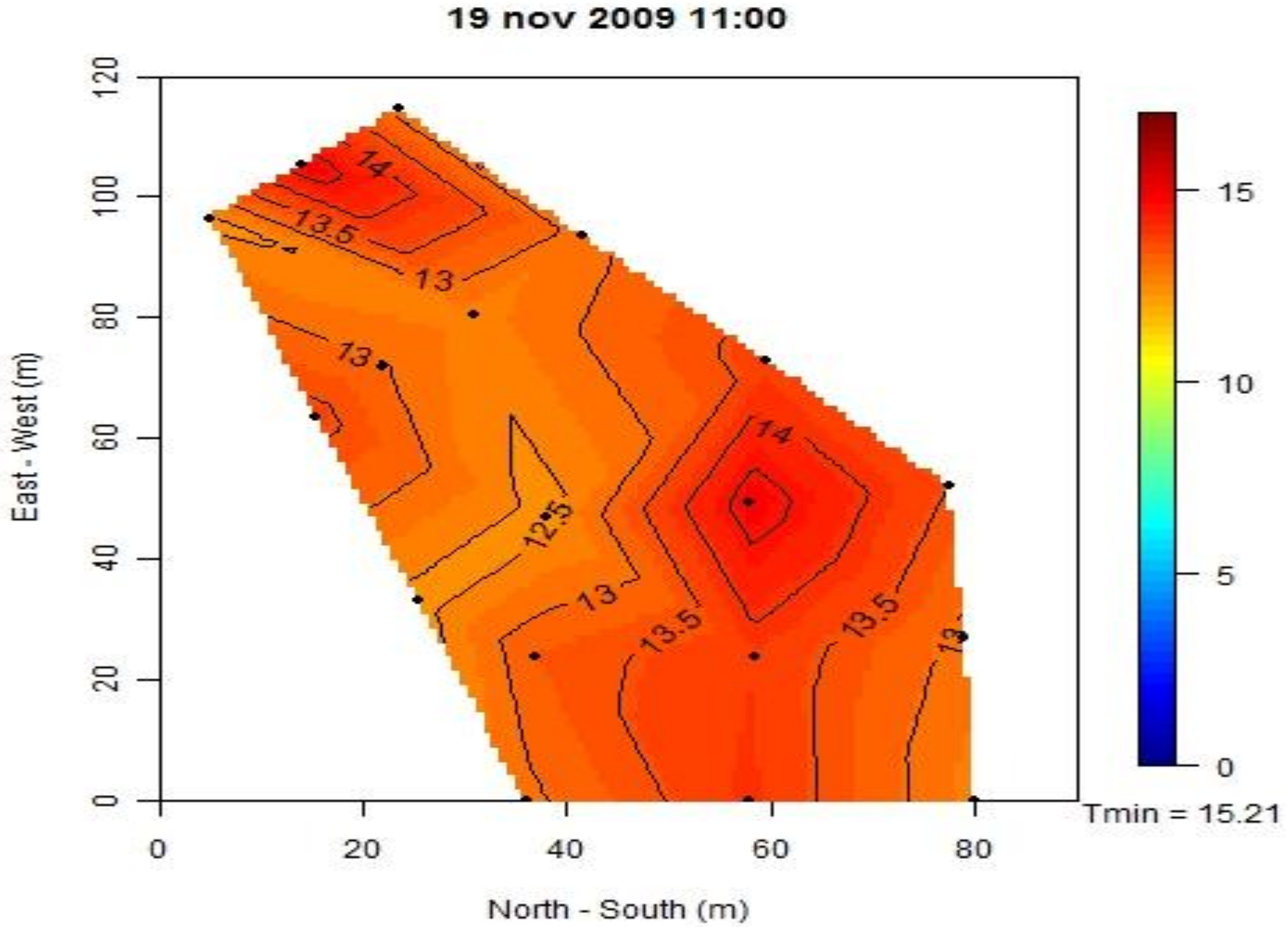
Local Hour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North - South (m)
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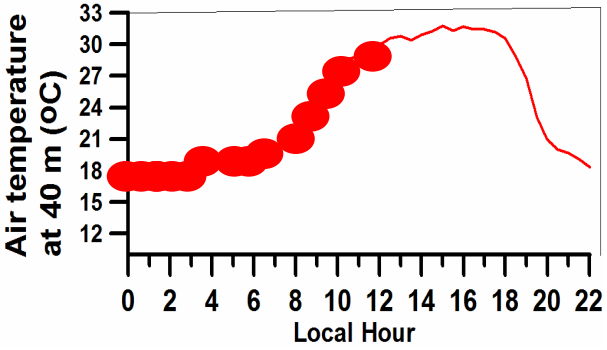
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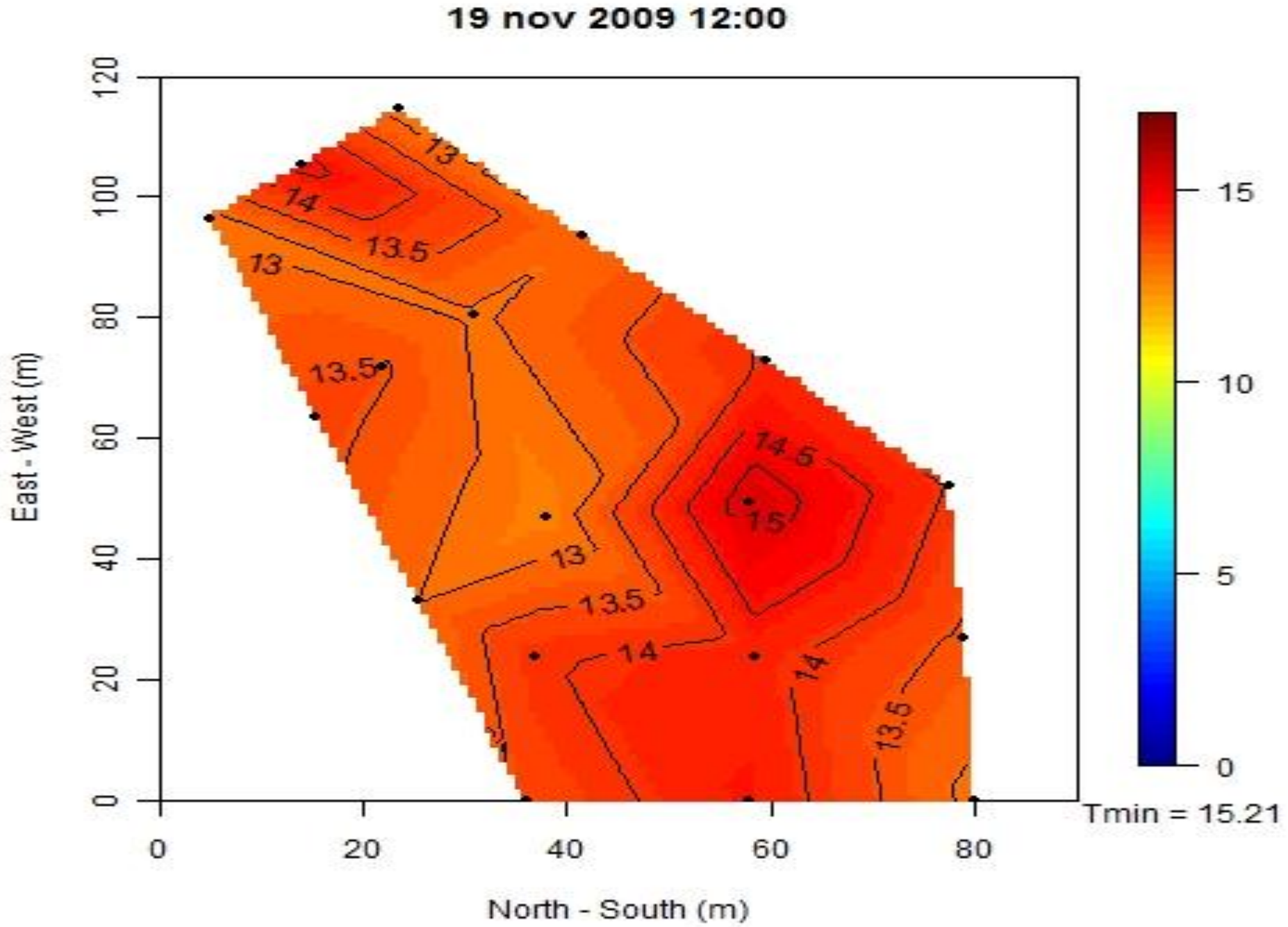
Local Hour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North - South (m)
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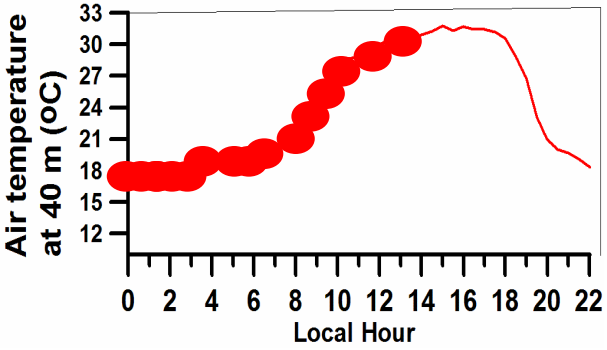
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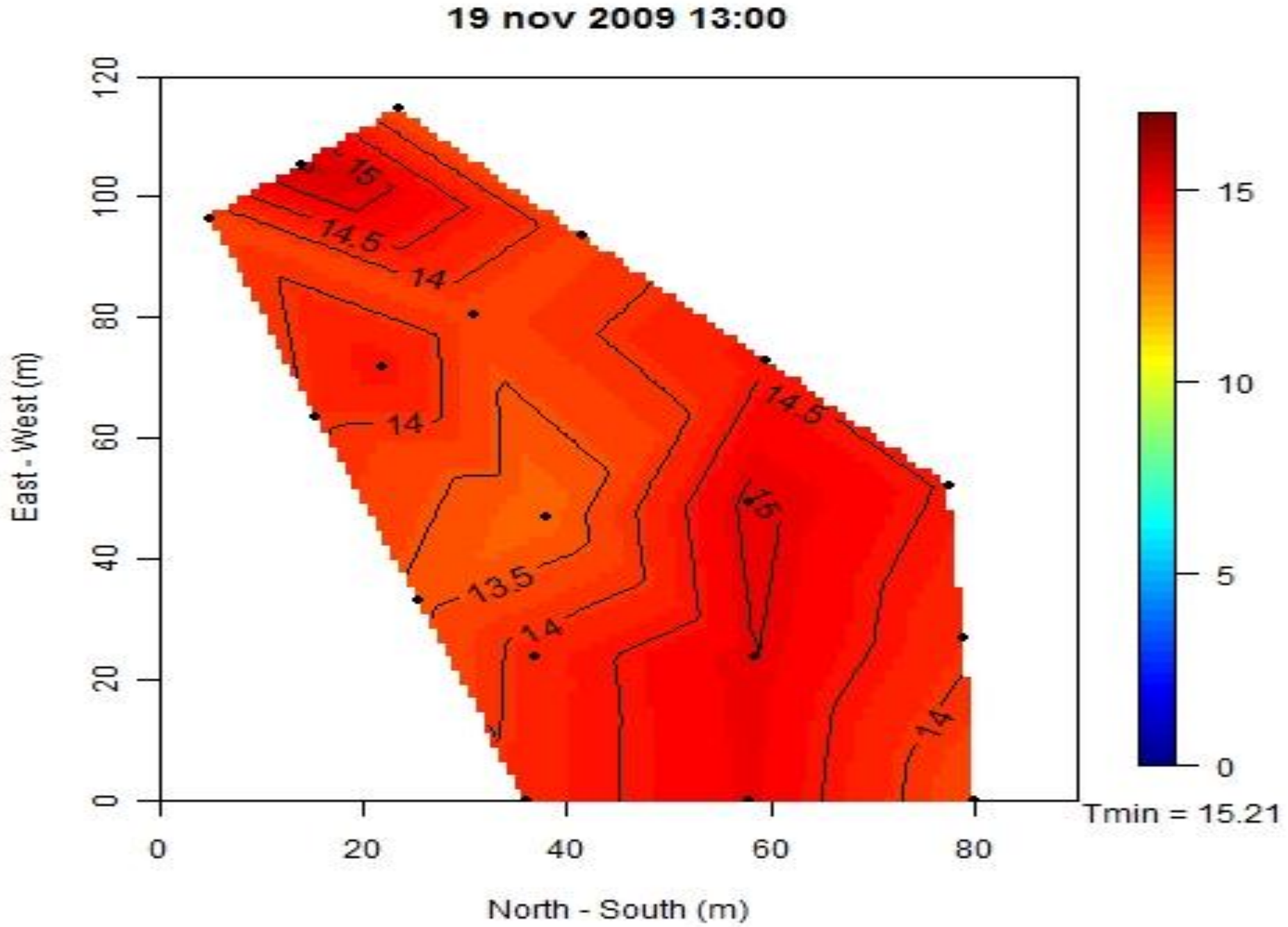
Local Hour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North - South (m)
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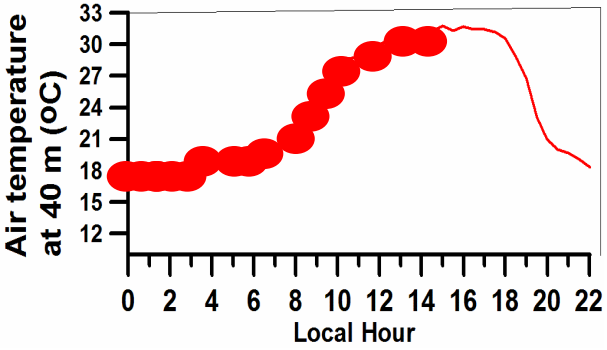
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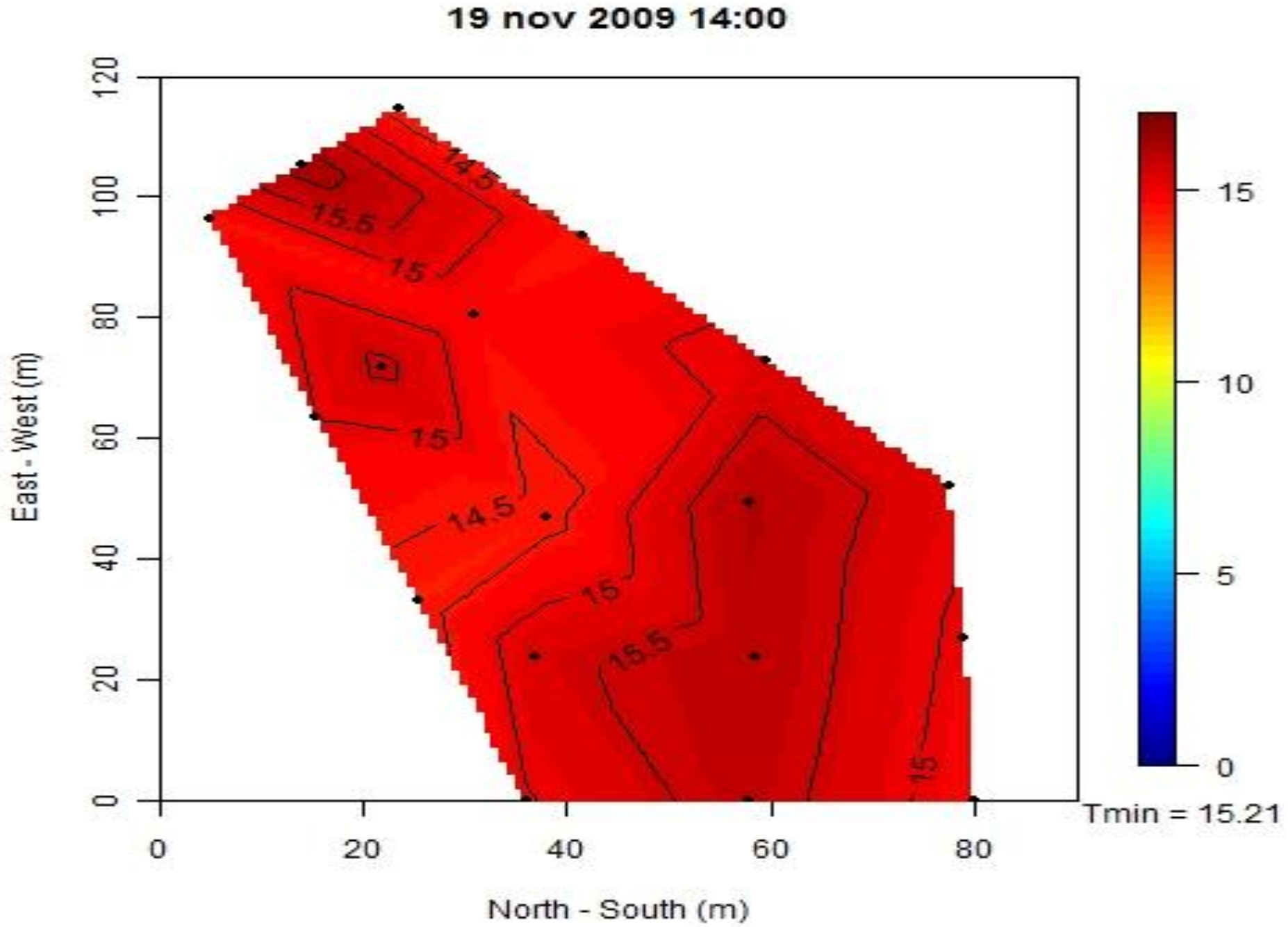
Local Hour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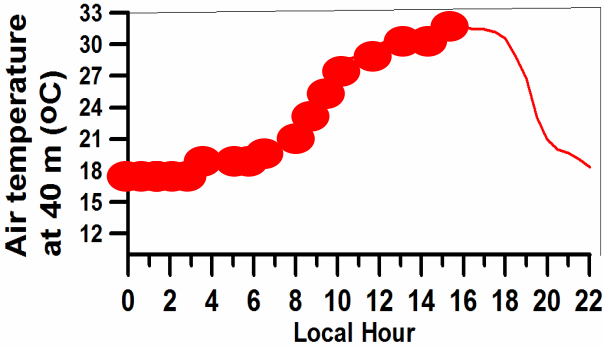
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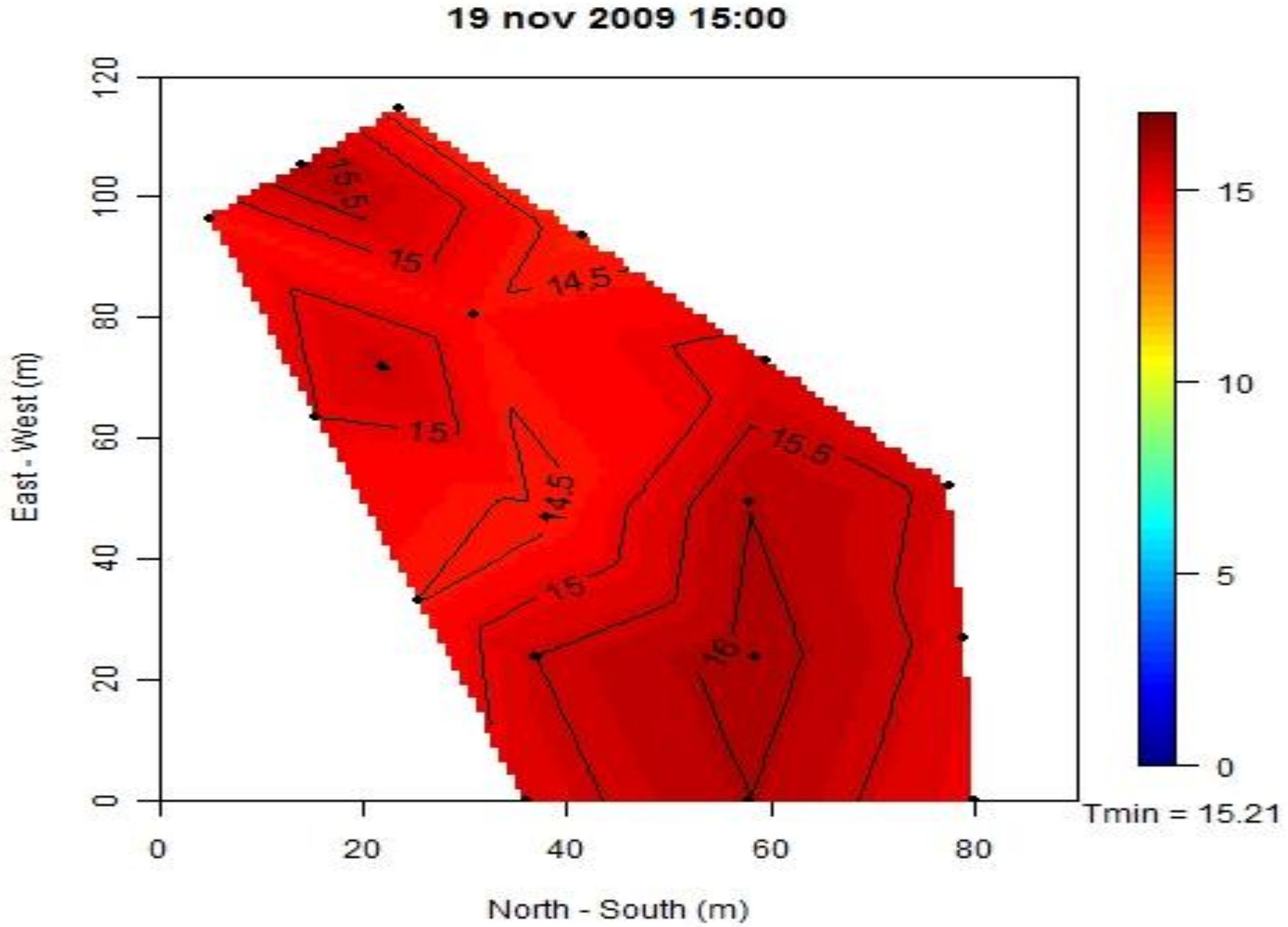
Local Hour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East - West (m)
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North - South (m)
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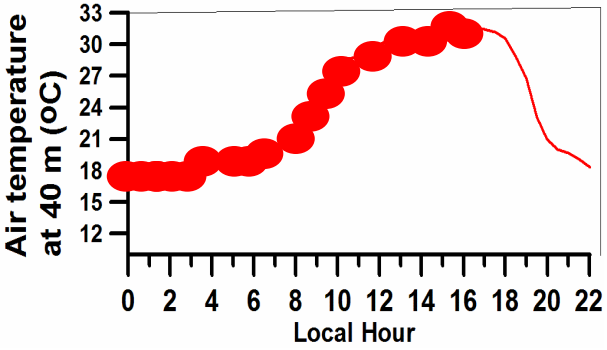
Tmin = 15.21


Air temperature at 40 m (oC)
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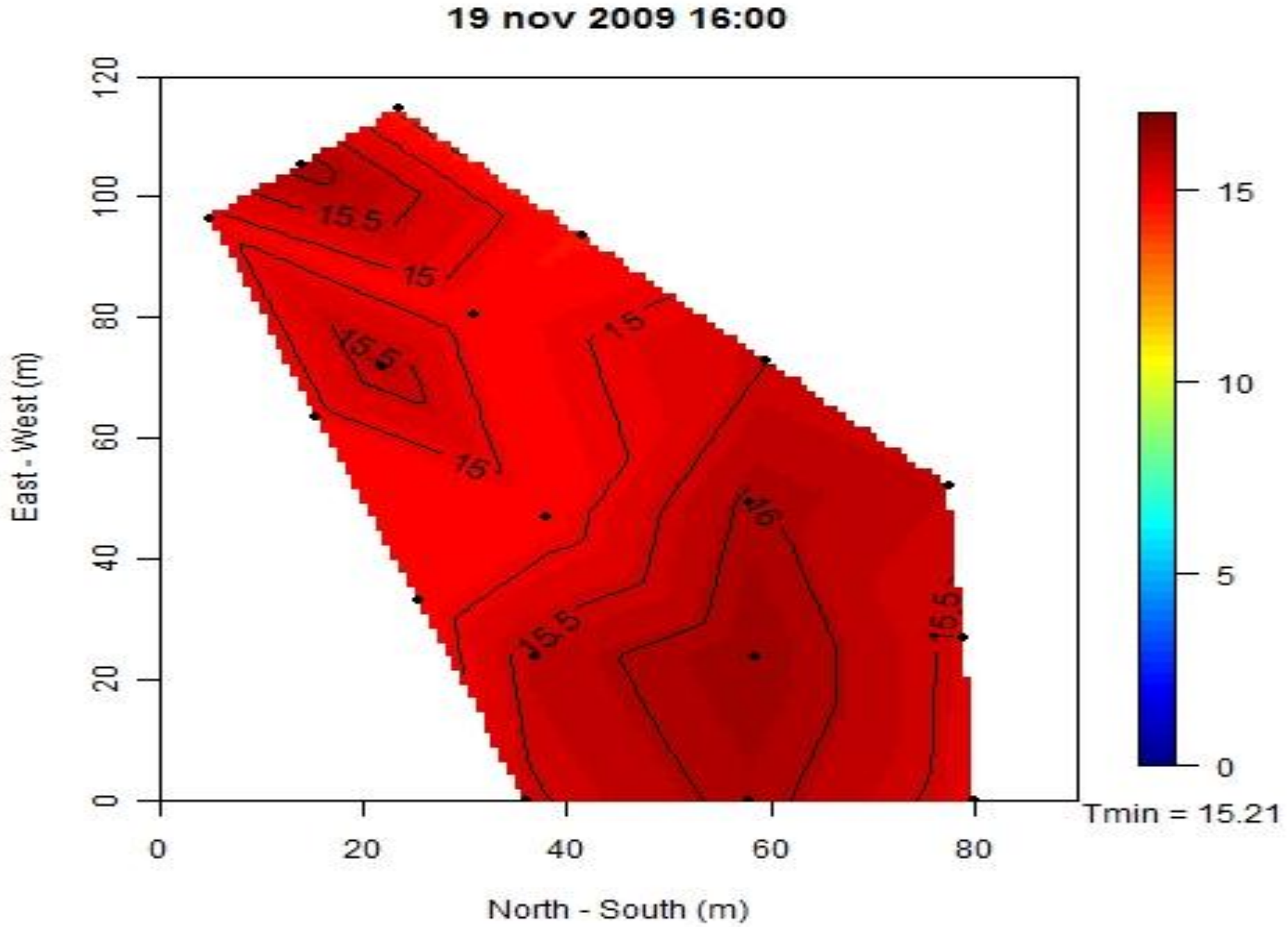
Local Hour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0 20 40 60 80
North - South (m)
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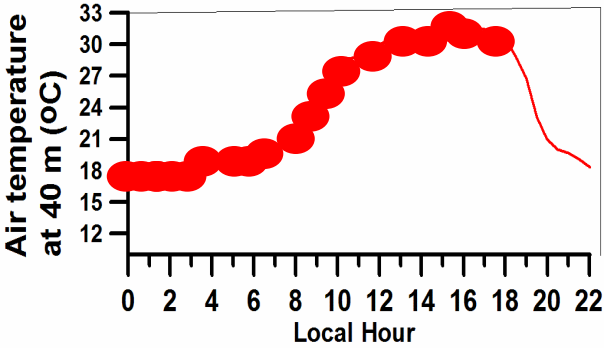
Tmin = 15.21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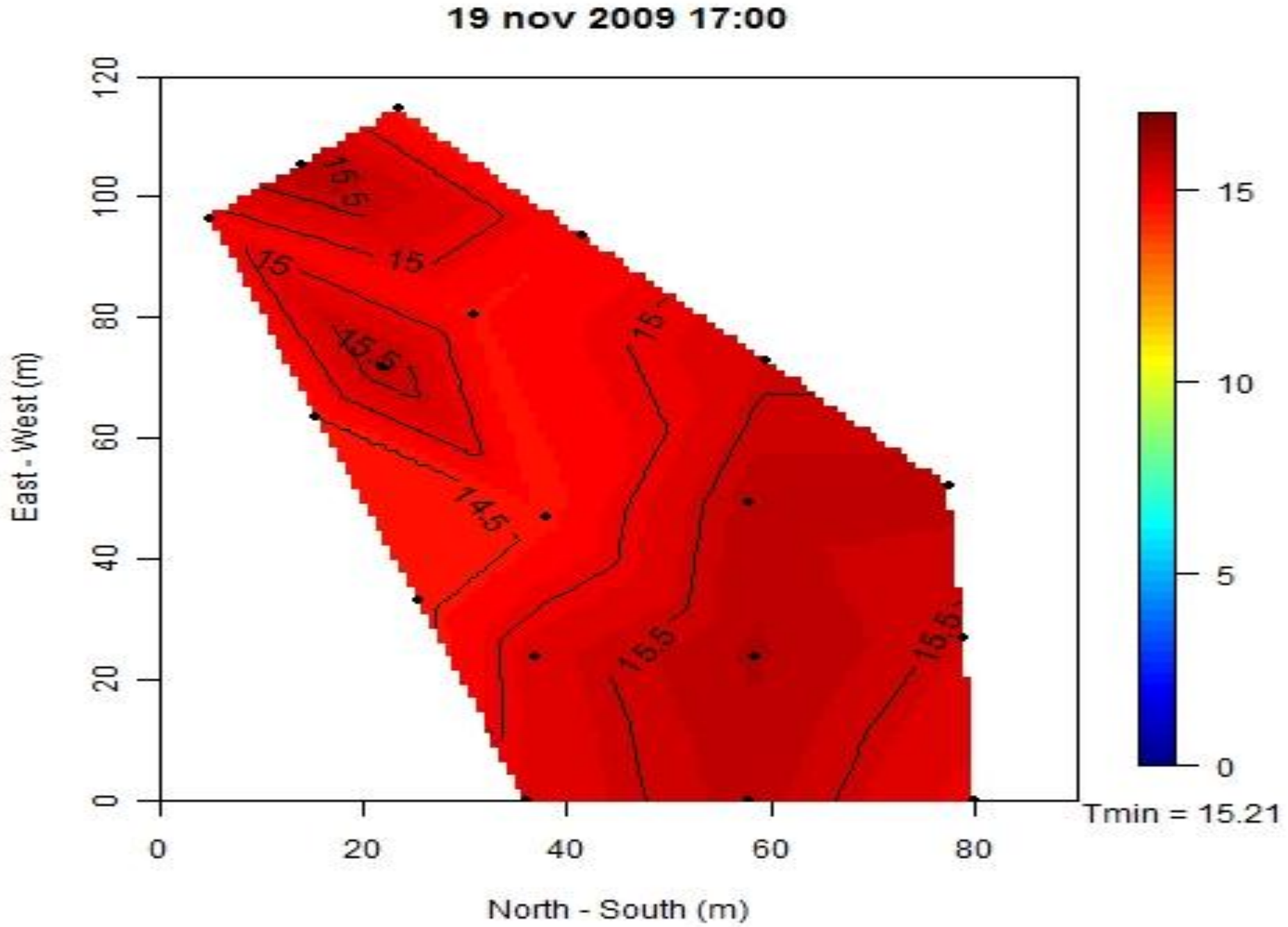
Local Hour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North - South (m)
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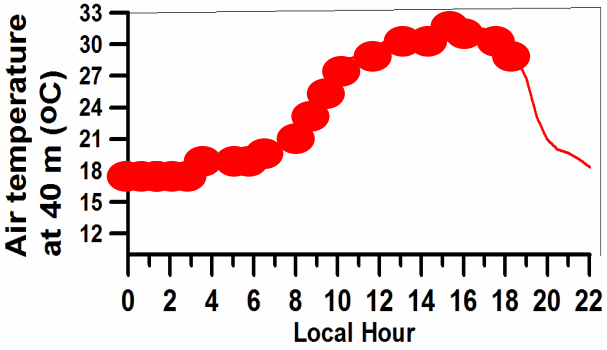
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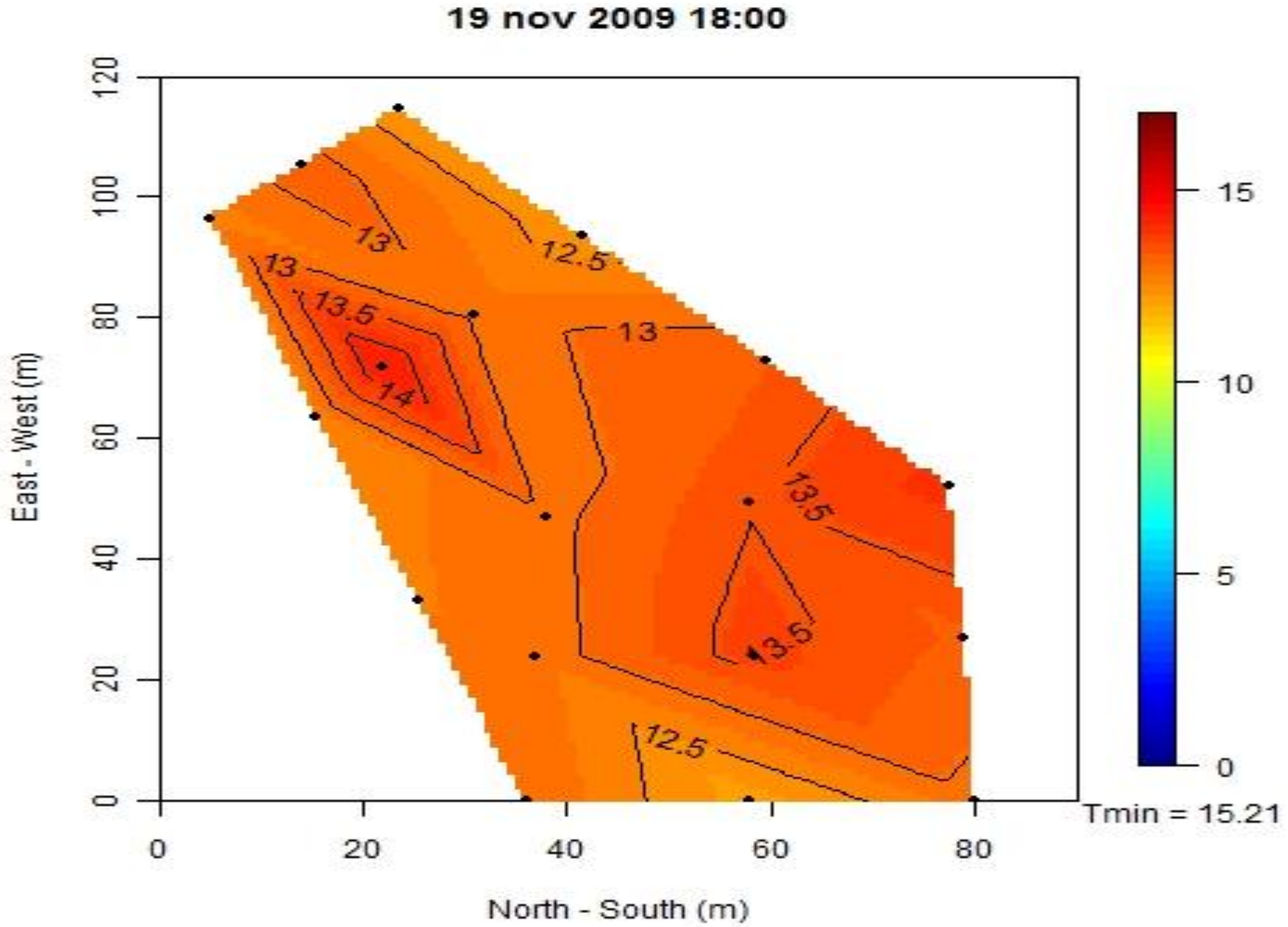
Local Hour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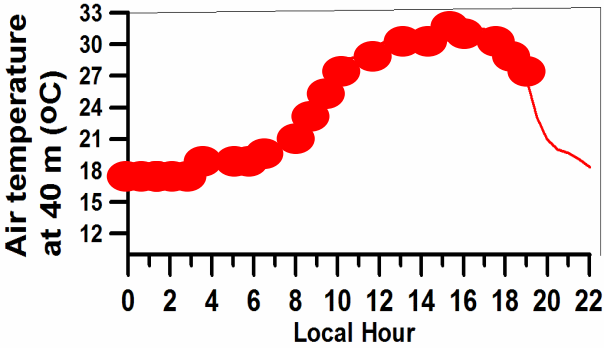
Air temperature at 40 m (oC)
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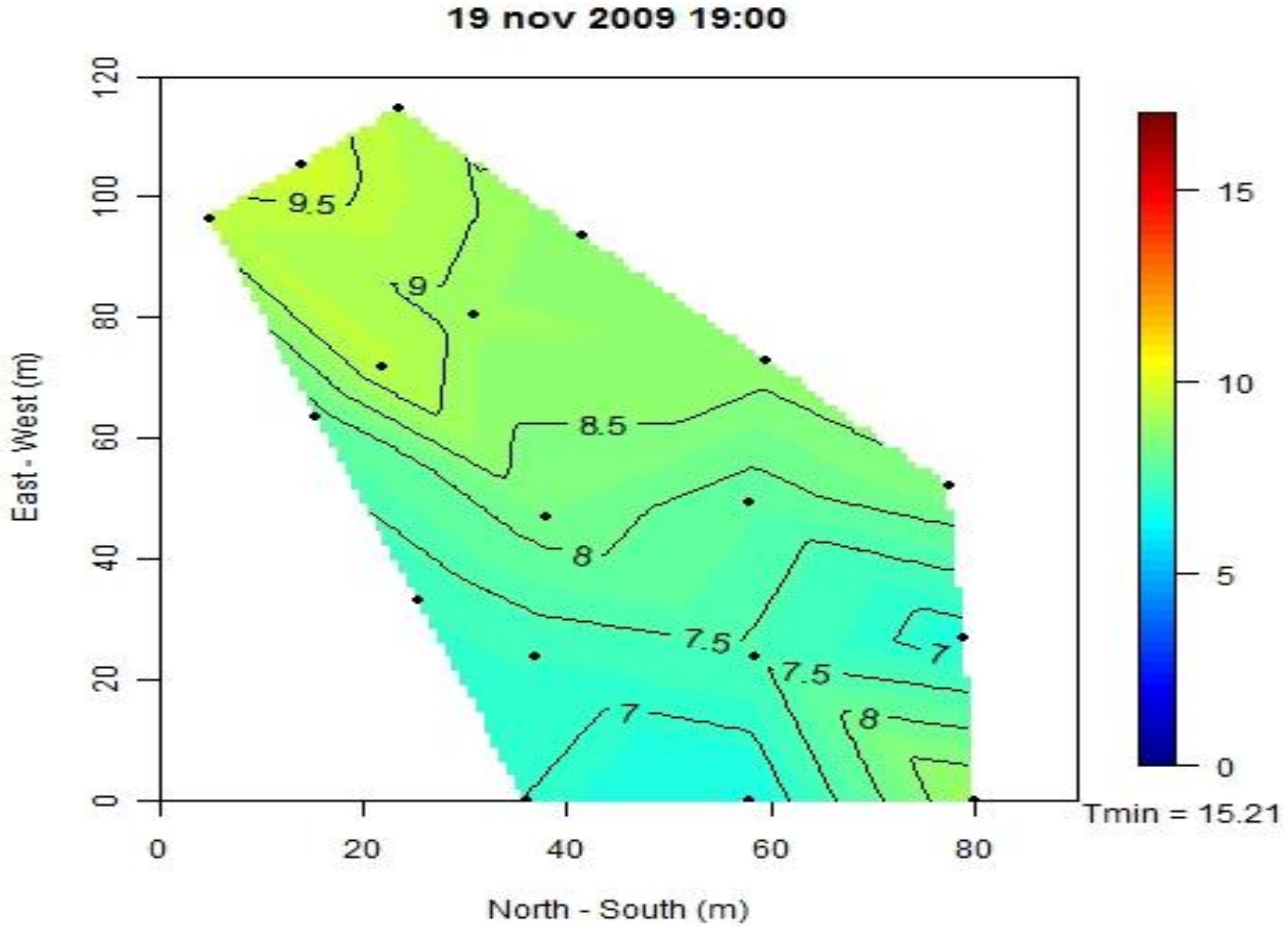
Local Hour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North - South (m)
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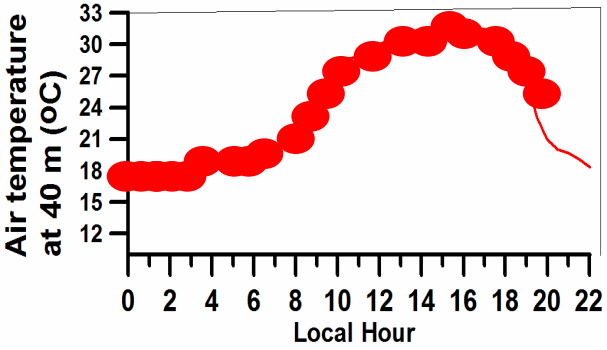
Air temperature at 40 m (oC)
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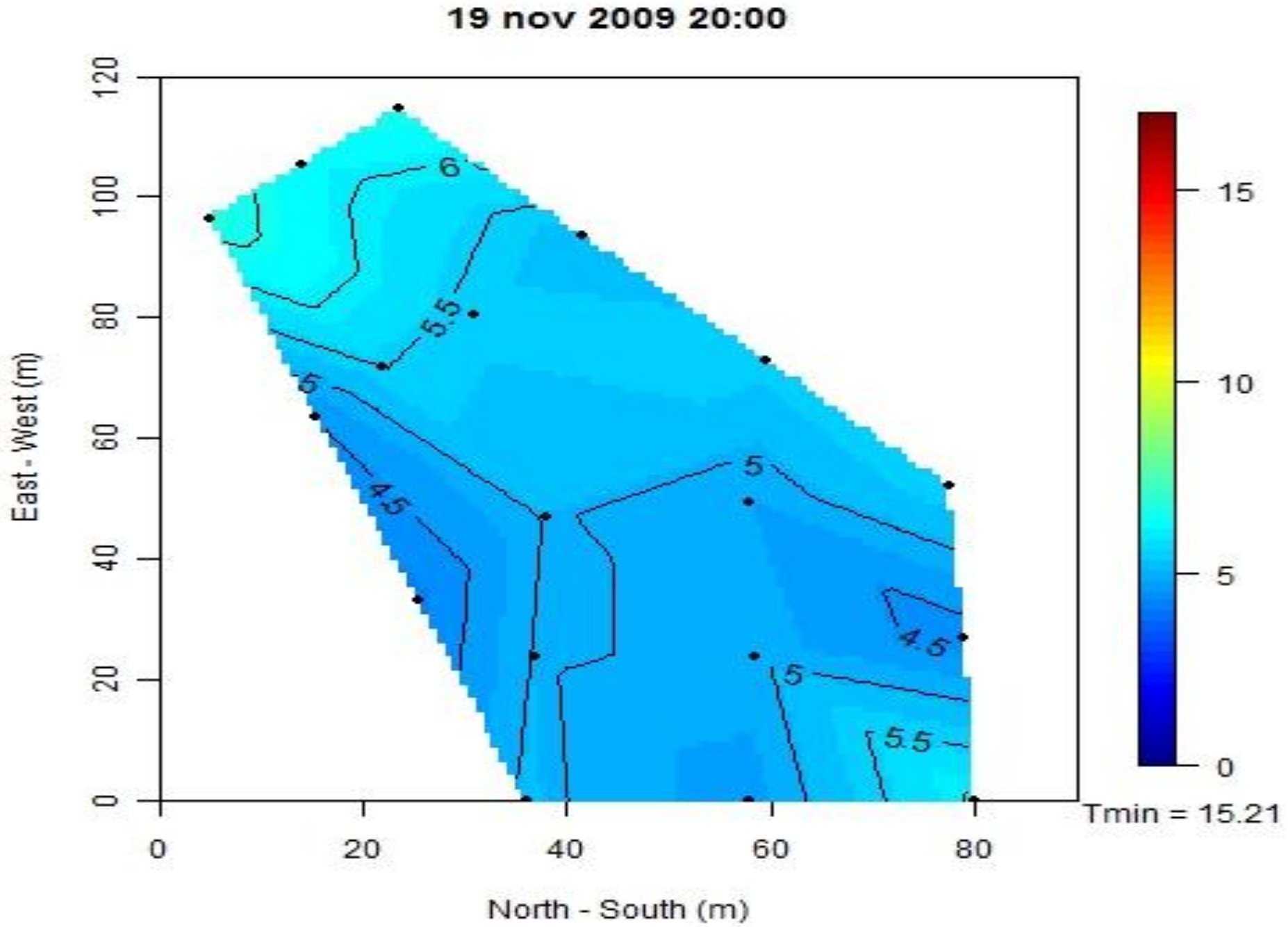
Local Hour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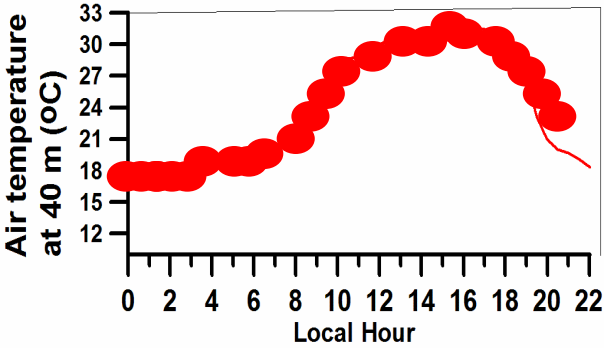
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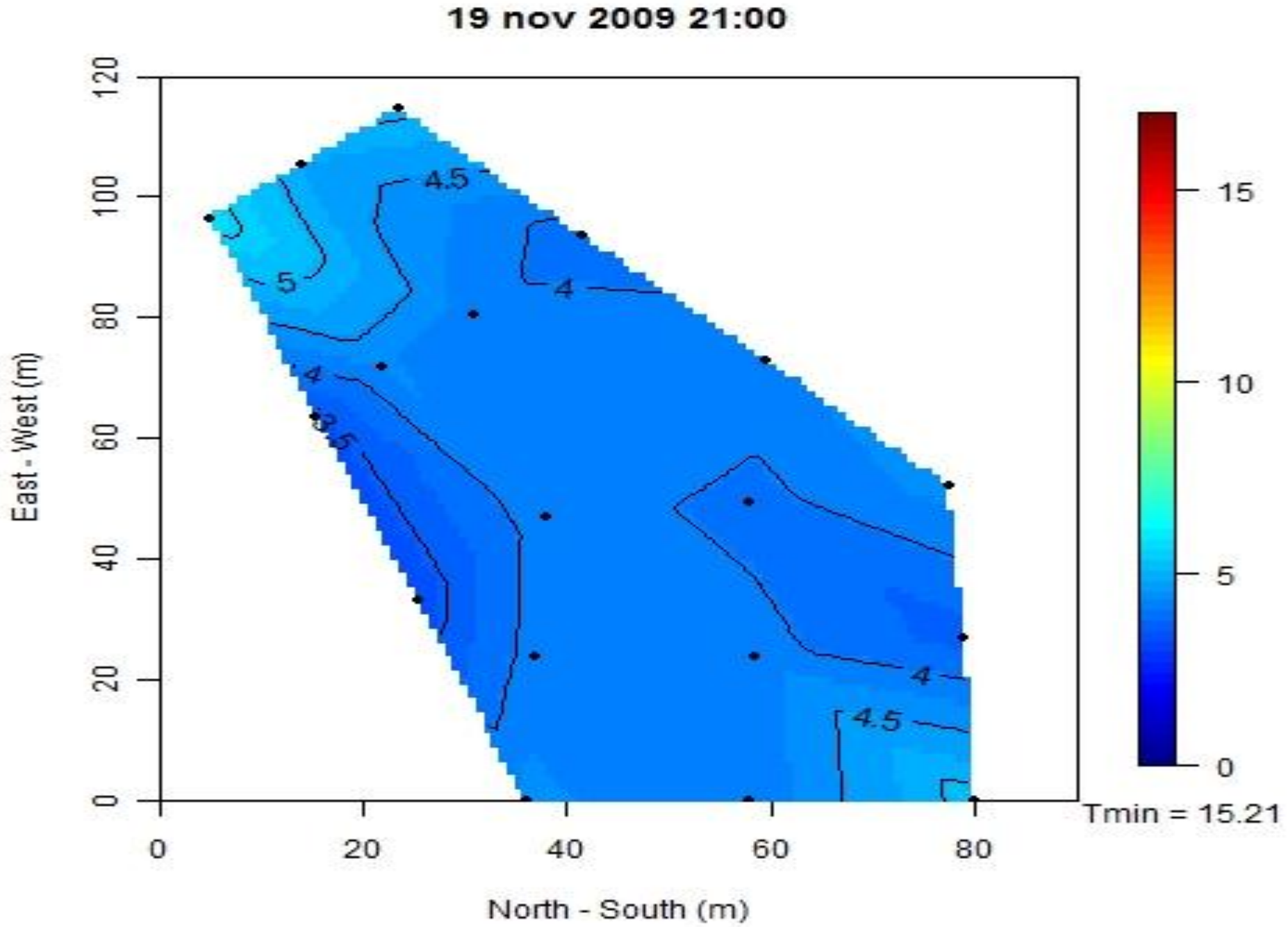
Local Hour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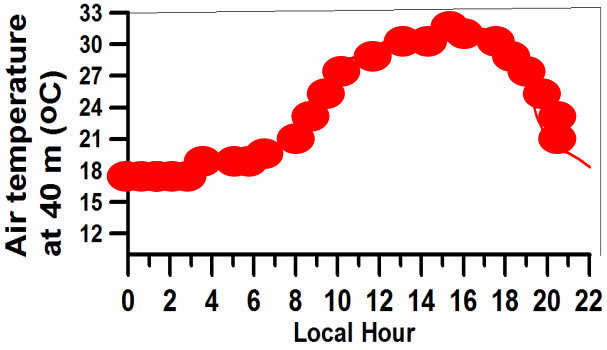
Air temperature at 40 m (oC)
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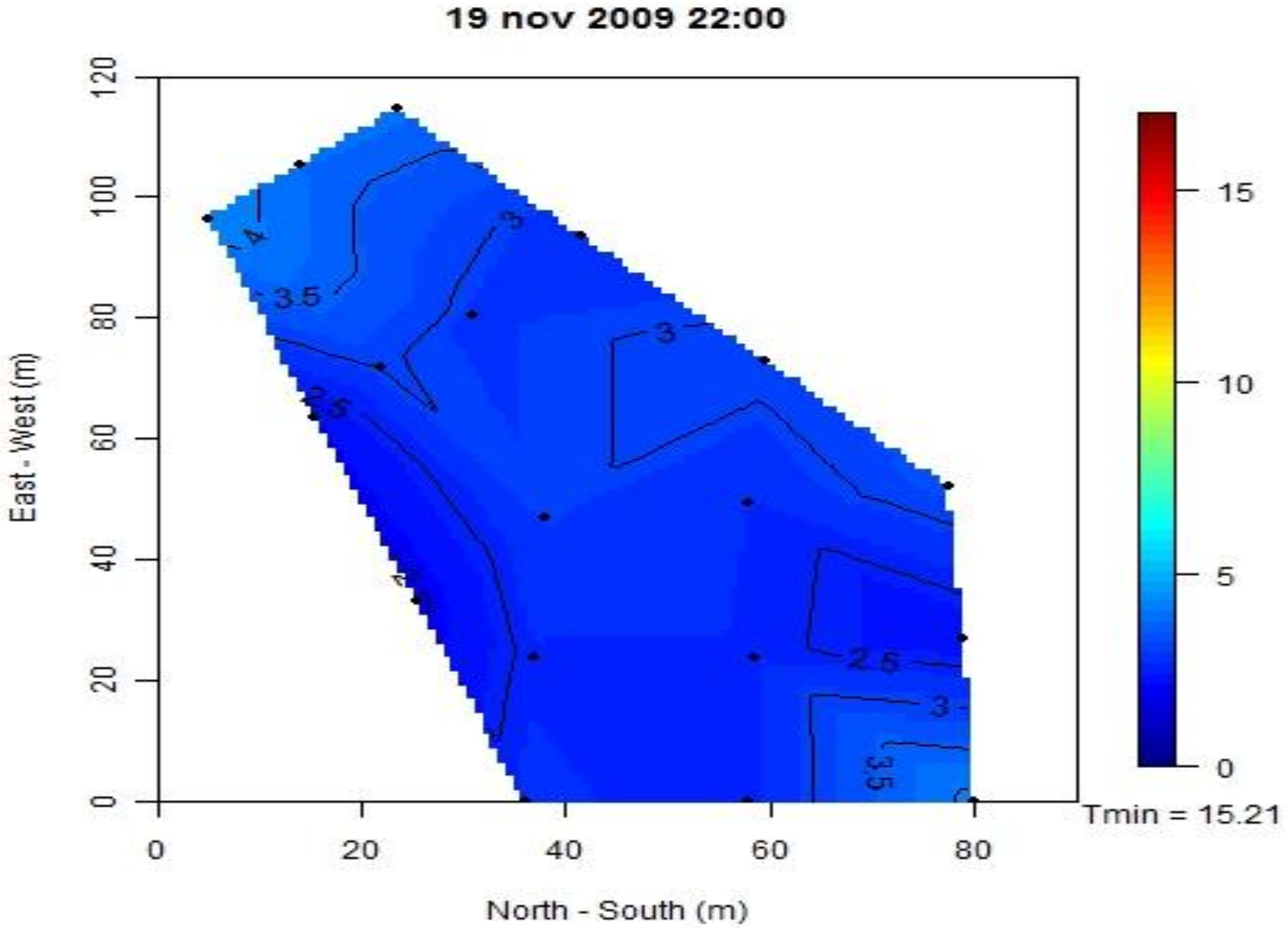
Local Hour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North - South (m)
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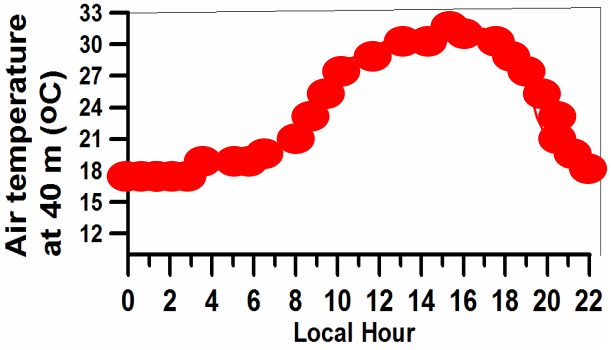
Air temperature at 40 m (oC)
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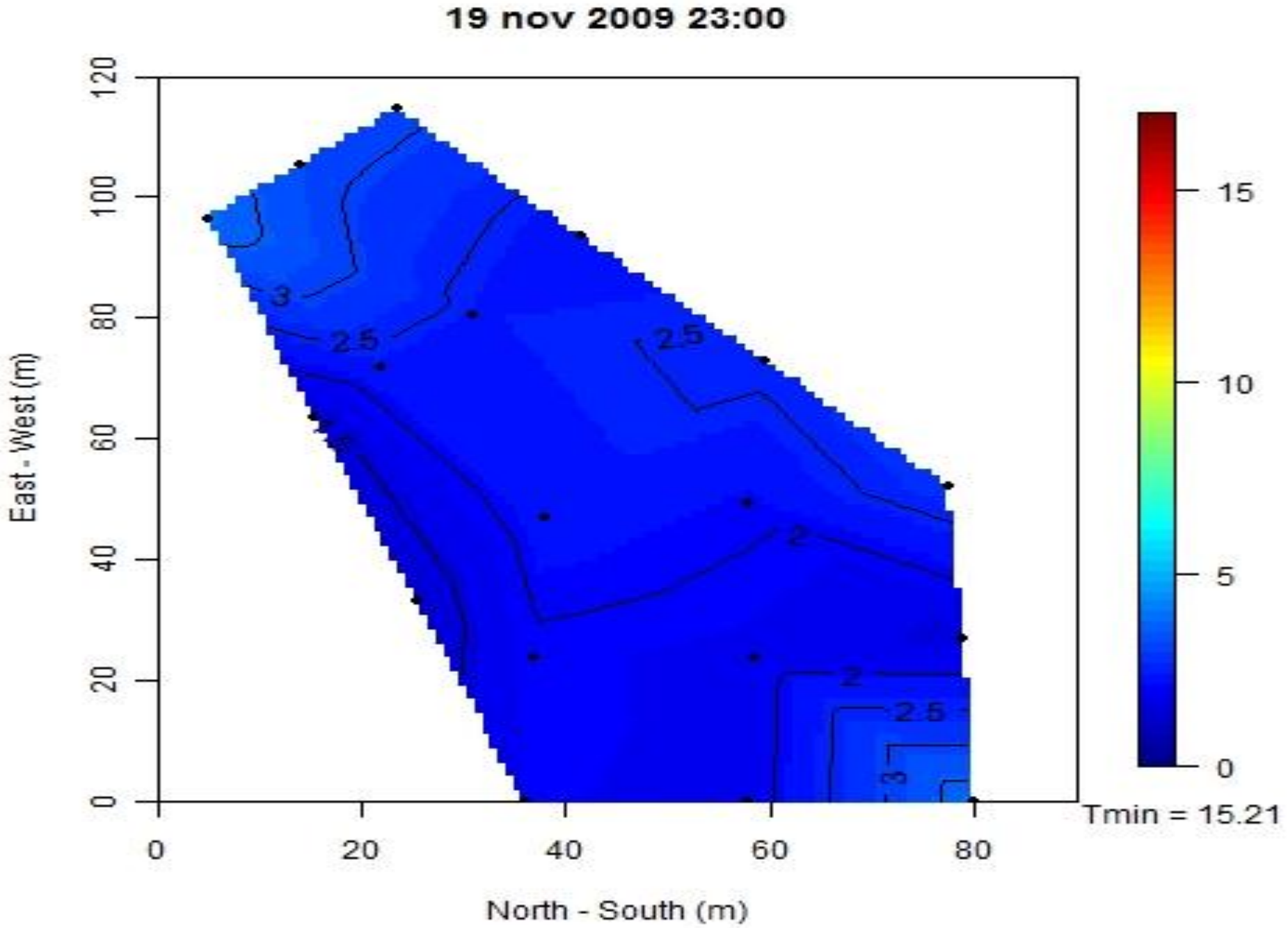
Local Hour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East - West (m)
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North - South (m)
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Tmin = 15.21

Results

1) Outstanding capacity of cooperation and expertise in only 1 year work with five institutions

- Preliminary analysis showed physically sounding data
- Detection of improvements (e.g. humidity measurement, sensor accuracy)

2) Foreseeing to monitor Amazonia

Wild environment with largest worldwide tropical forest, 20% world freshwater and an enormous biodiversity

Supportive on going projects:

Fapesp-MSR 2009-2011 : sensor and software development (INPE+ USP)

LBA/Fapesp Carbon Tracker 2009 – 2014 : regional multi-disciplinary data

Next steps: to adress which relevant questions to answer, partnerships, and how technology can help science and environment

Current efforts

FAPESP- Microsoft Research – Project # 2009/53154-0

DEVELOPMENT AND APPLICATION OF WIRELESS NETWORK OF GEOSENSORS FOR ENVIRONMENTAL MONITORING IN TROPICAL FORESTS

Geosensors

- Assembly of prototypes in Brazil
- New humidity sensors (materials engineering)
- Fault-tolerant, capable of almost-independent operation
- Low power consumption
- Wireless data transmission

Software infrastructure

- Data quality control (identification and removal of faults)
- Operational and science database
- Web-based, integrateable with other environmental data systems
- Visualization tools

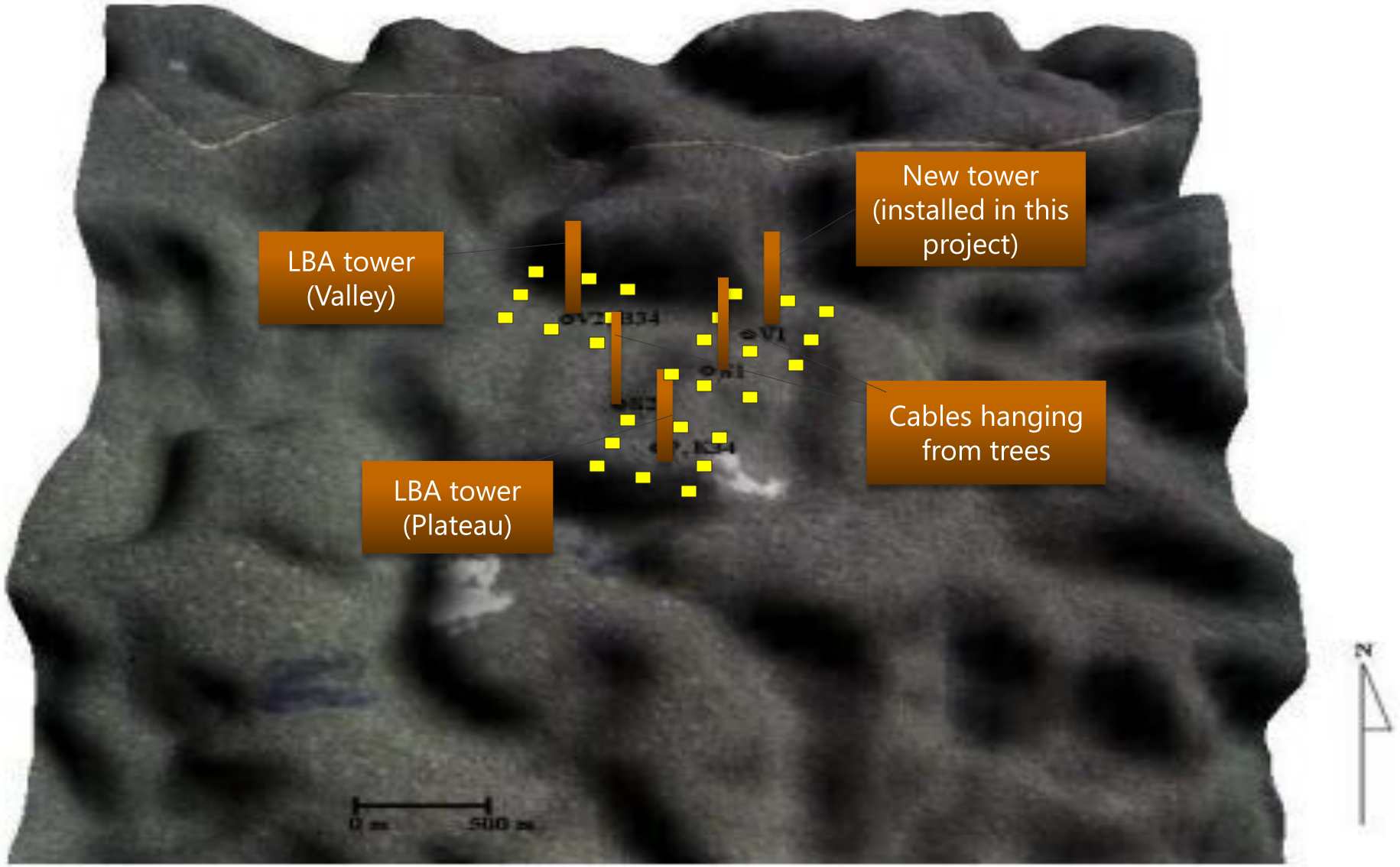
Application

- Study of spatial variability of temperature and humidity within the forest
- Reduction of uncertainties associated with the terrain's topography.
- Validation of theoretical biosphere models.

Software infrastructure development

- Data entry (from the sensor network): validation, metadata creation, data quality evaluation, etc.
- Science database.
- Science support:
  - Simple reports, subset extraction.
  - Visualization.
  - Spatiotemporal analysis (mining).
- Extensions:
  - Web services to provide access to the data.
  - Integration with other environmental databases.
  - Virtual Laboratories.
- Pilot for other environmental science databases.

Planned deployment in Amazonia



Partnership

CST
Centro de Ciência
do Sistema Terrestre

Microsoft®

JOHNS HOPKINS
UNIVERSITY

USP Universidade de São Paulo
BRASIL

Laboratório de Clima e
Biosfera – IAG / USP

Microsoft® Research
Faculty Summit 2010

Atlantic rainforest sensor networking

video

Microsoft® Research

Faculty Summit 2010