RISØ

Aggregation of satellite remote sensing-based land cover roughness applied to meteorological modelling

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DENMARK

Contents

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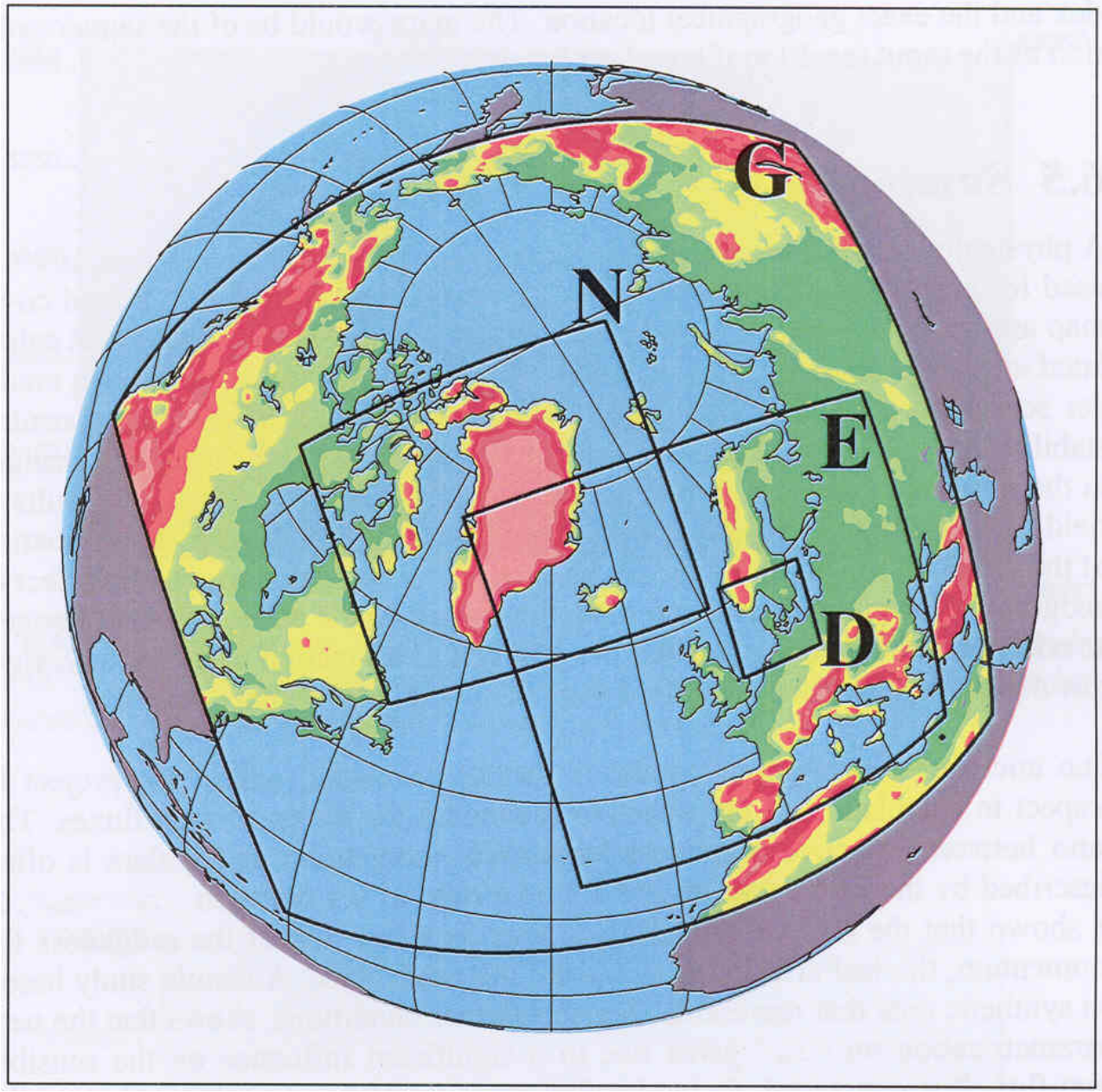
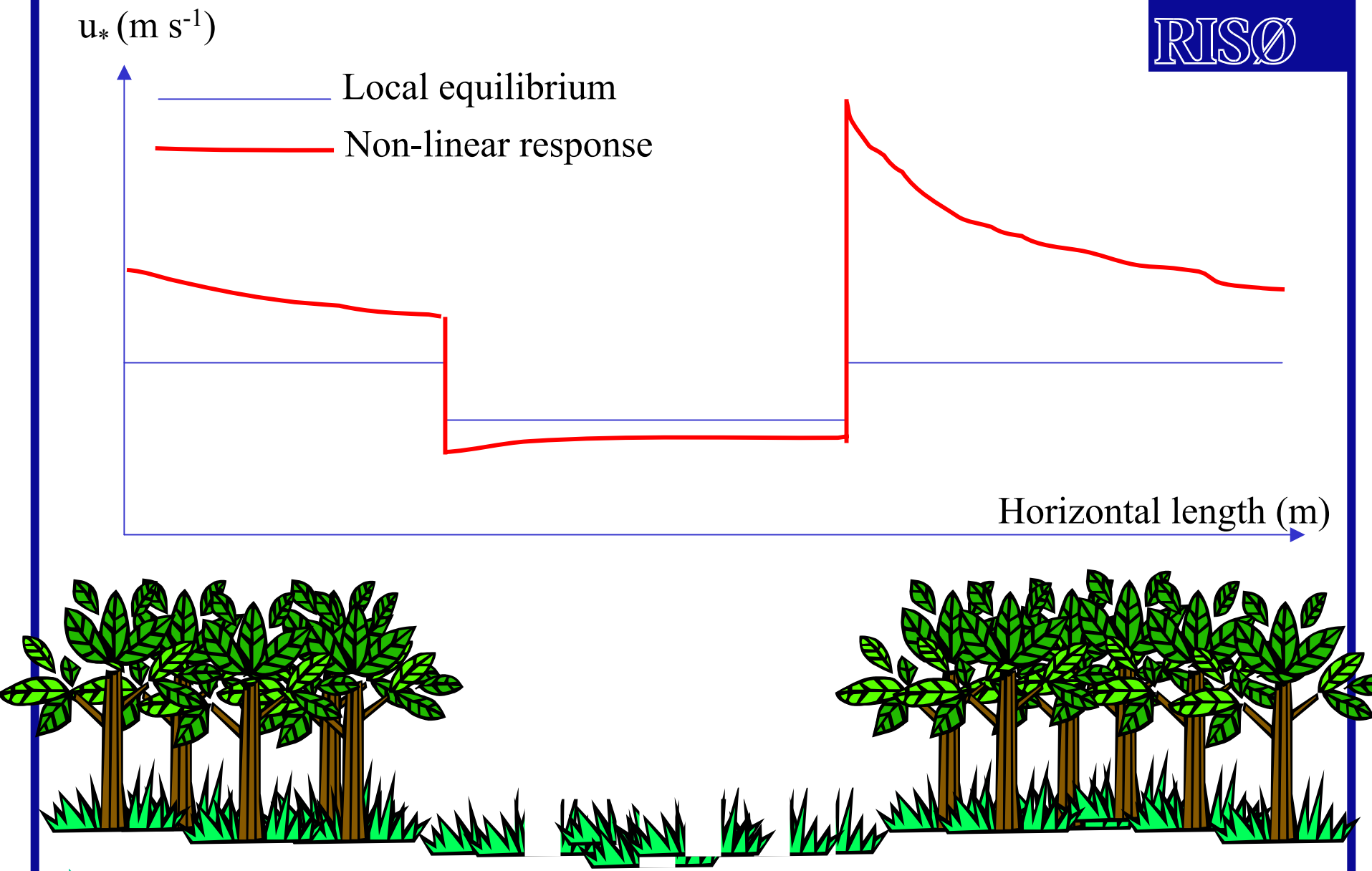
MOTIVATION

To improve weather forecasting and climate models by introducing aggregated roughness values for momentum and scalar surface fluxes.


G
N
E
D

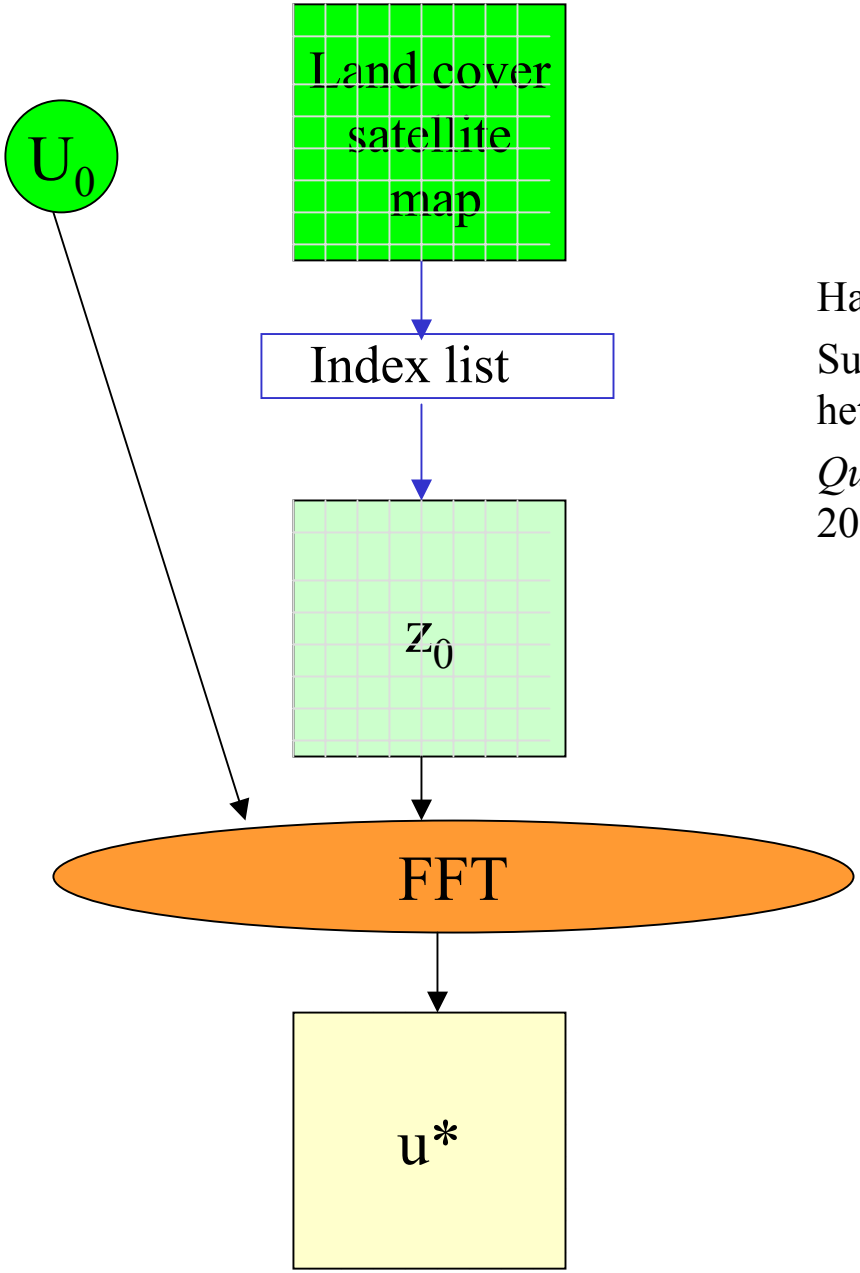

u_* (m s^{-1})
Local equilibrium
Non-linear response
Horizontal length (m)

Definition of aggregated friction velocity

$$< u_* > = \sqrt{\frac{1}{n_1 n_2} \sum_{x=1}^{n_1} \sum_{x=2}^{n_2} u_*^2(x, y)}$$

Definition of effective roughness

$$z_{0eff} = z / \exp\left(\frac{\kappa\, u(z)}{< u_* >}\right)$$



Hasager C.B. and N.O.Jensen, 1999

Surface-flux aggregation in heterogeneous terrain

Quart. J. Royal. Meteorol. Soc. **125**, 2075-2102

$$U\frac{\partial u}{\partial x} = K_x \frac{\partial^2 u}{\partial z^2}$$

Earth observation satellite data

Land cover types	(Landsat TM, SPOT)
Leaf area index	(Landsat TM)
Surface temperature	(Landsat TM)

Models

Microscale aggregation model	(Risø)
High Resolution Limited Area Model (HIRLAM)	(DMI)

Areal Information System (AIS) http://www.dmu.dk/ais

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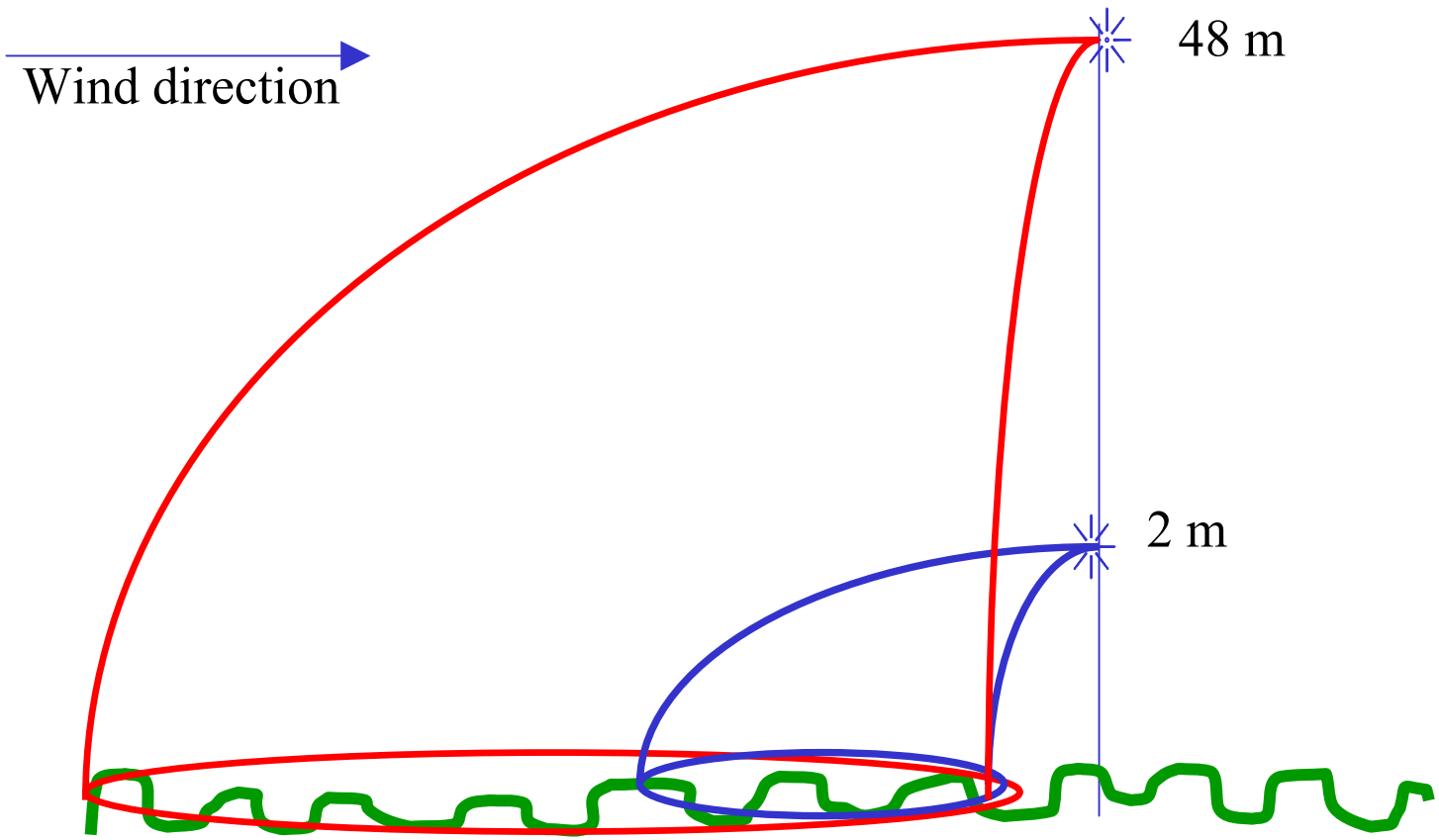
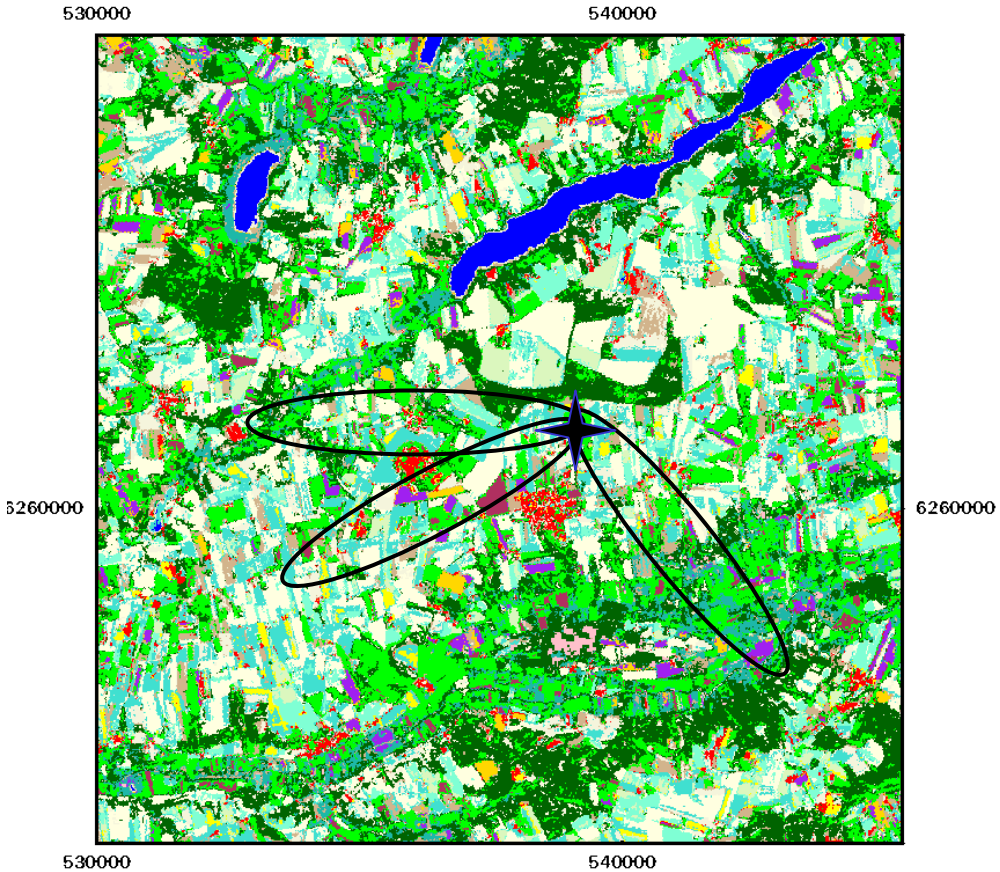
25 m pixel resolution

Land cover type	Roughness
Water	0.001
Sand	0.03
Marsh	0.08
Grass heath	0.08
Permanent short grass	0.03
Grazing	0.08
Meadow	0.08
Bush/grass heath	1
Bush/heather	1
Bush/forest	1.8
Deciduous forest	1.8
Coniferous forest	1.8
Meadow	0.08
Agriculture	0.05
Discontinuous urban	0.5
Continuous urban	1.2
Beech forest	1.8
Young forest	1.8
Spruce plantation	1.8
Mixed forest	1.8
Mountain pine	1.8
Oak forest	1.8
Lark forest	1.8
Clearing	0.3
Sparse coniferous	1.8
Heather	0.08
Peat bog	0.08
Set-aside	0.08
Juniper heath	0.08
Heathland	0.08
Agriculture/grassland	0.05

Position of tall meteorology masts

Mast observations relate to a given footprint





Landsat TM 18-05-1998, Foulum

Scale

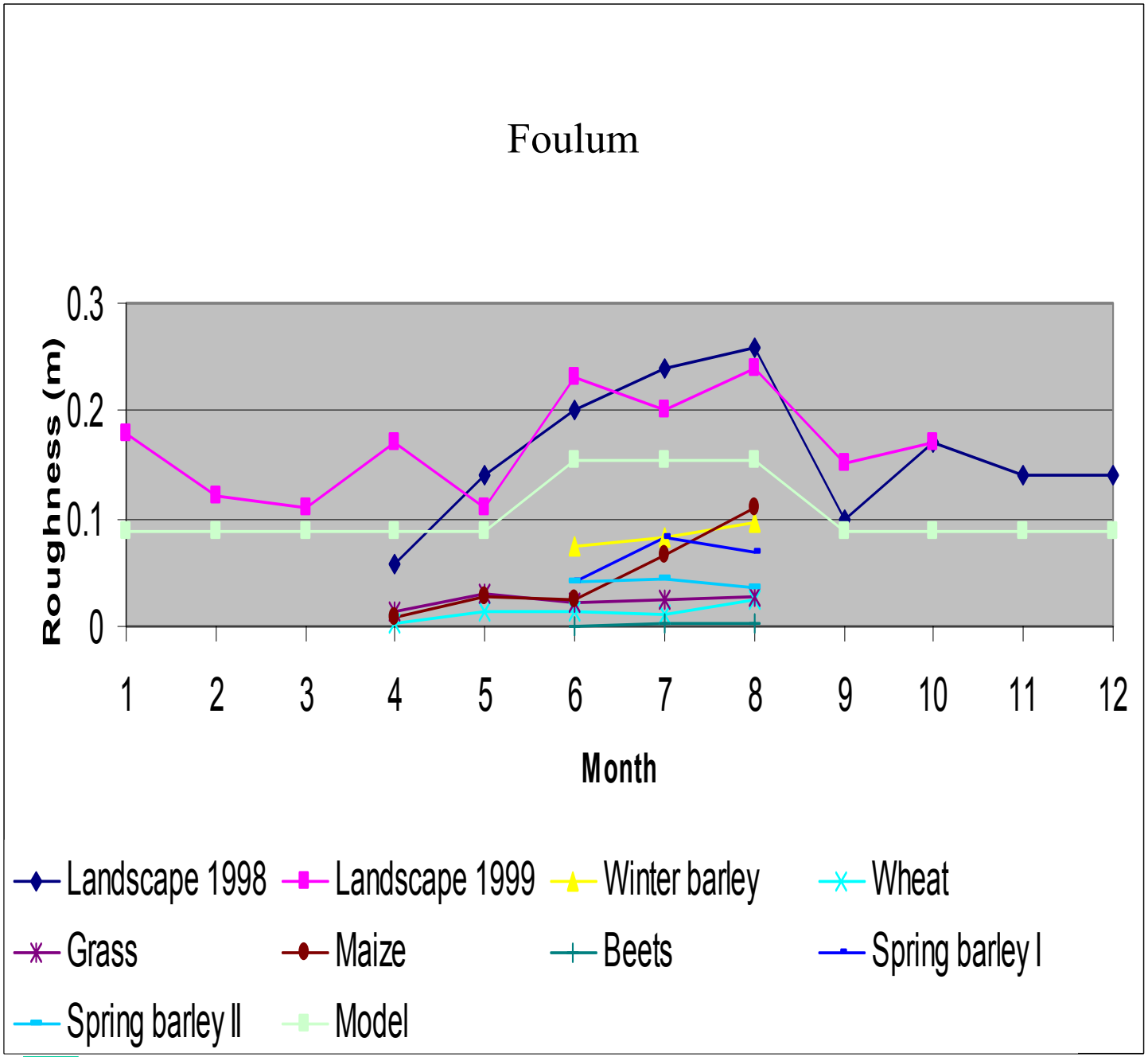
2 0 2 Kilometers

Cover type	Area (ha)	Cover type	Area (ha)
forest	4740	maize	233
grass	4257	beets	397
winterwheat	3847	clover	324
springbarley	2349	set-aside	946
winterbarley	1466	heather	82
springpeas	1445	bog	985
peas	1237	buildings	512
rape	331	lake	441

Landsat TM

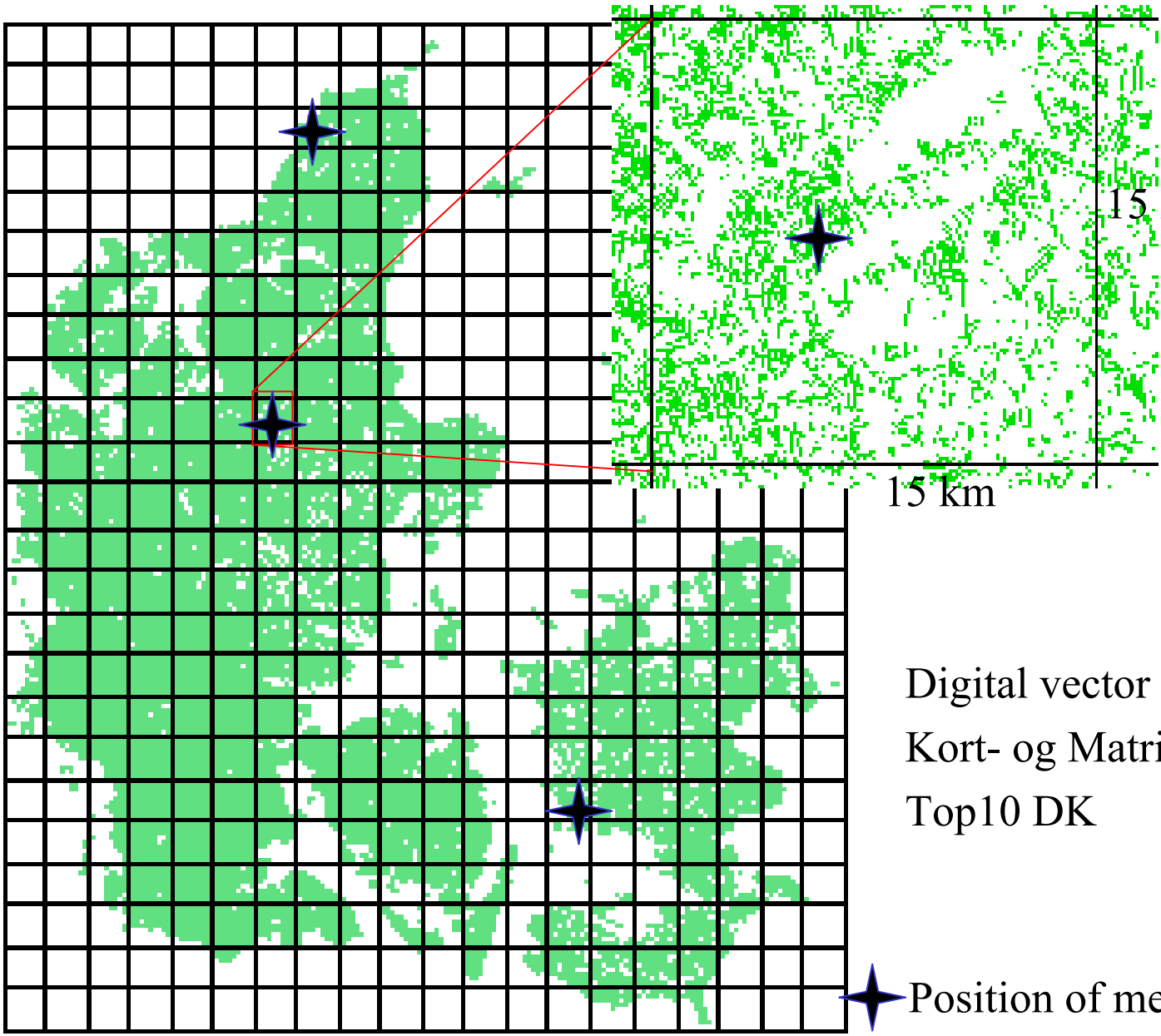
Land cover map

Position of 48 m tall meteorology mast



One 48.0 m tall mast

Seven short masts



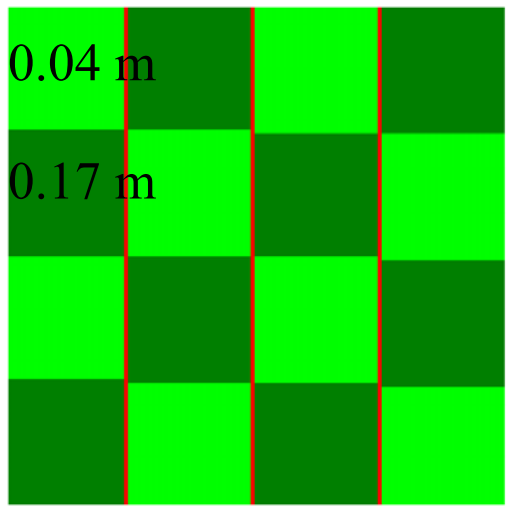
Digital vector map from
Kort- og Matrikelstyrelsen
Top10 DK

Position of meteorology masts

Sensitivity to hedges in checkerboard terrain

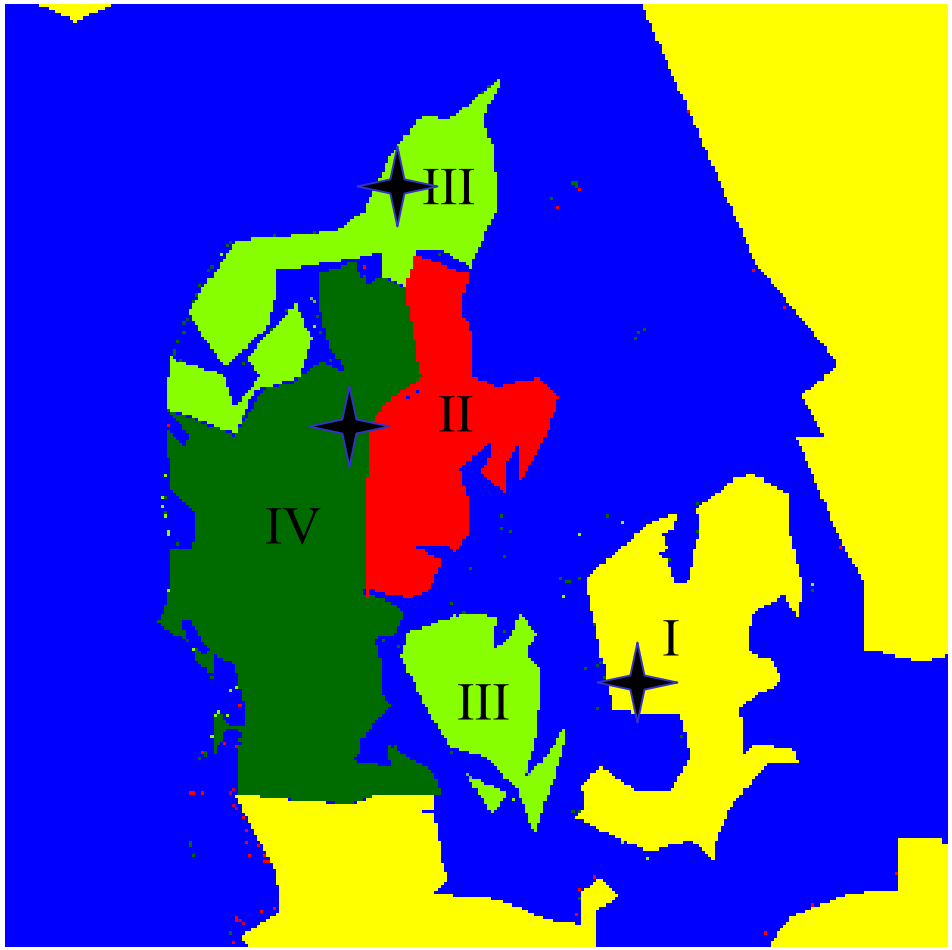
	Distance of hedges (m)	1	1.5	2
z0_eff	320	0.109	0.116	0.122
z0_eff	640	0.109	0.115	0.122
Added roughness	320	0.027	0.034	0.04
Added roughness	640	0.027	0.033	0.04

Synthetic data



Average log z_0 = 0.082 m

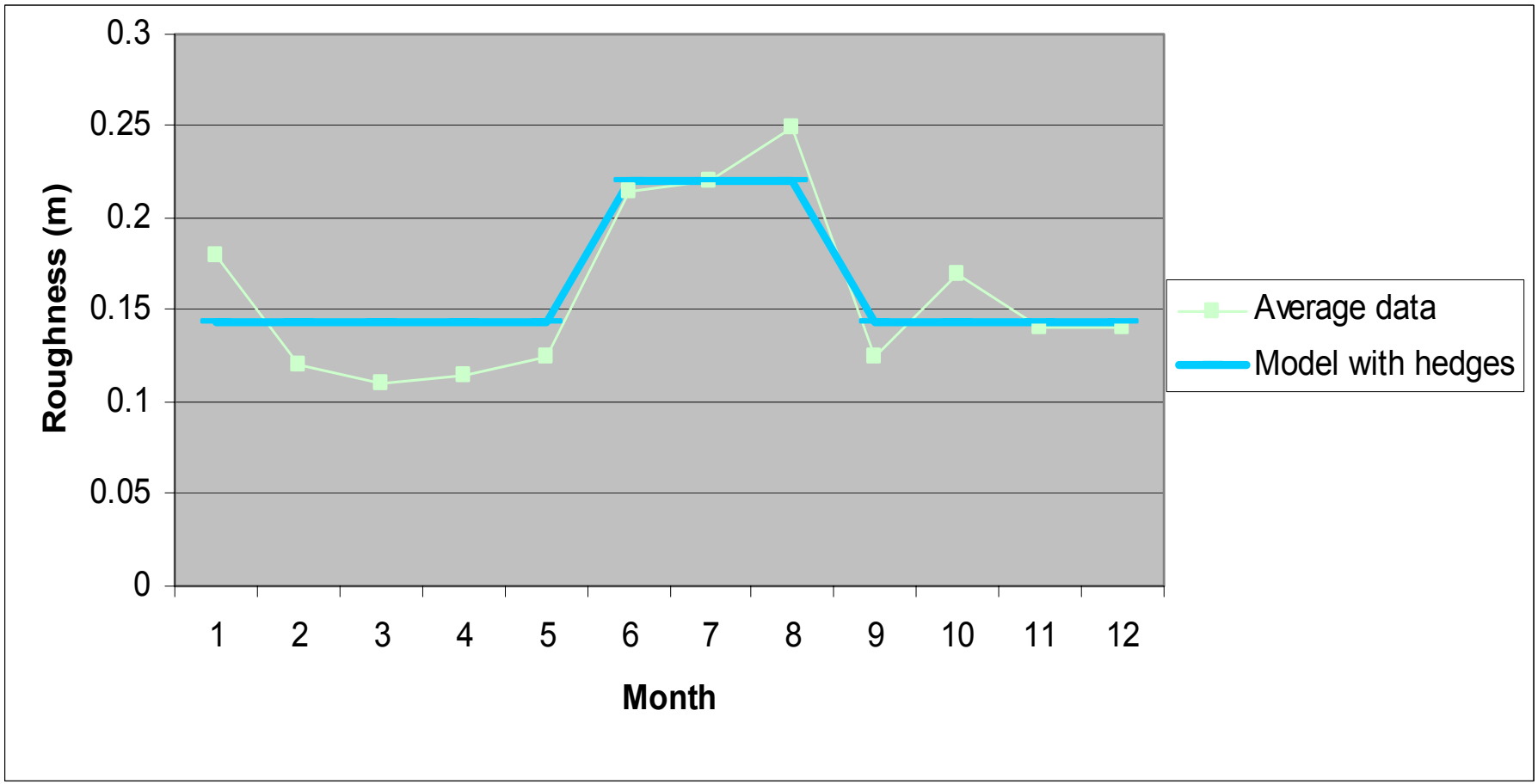
Regions of different hedge density in Denmark



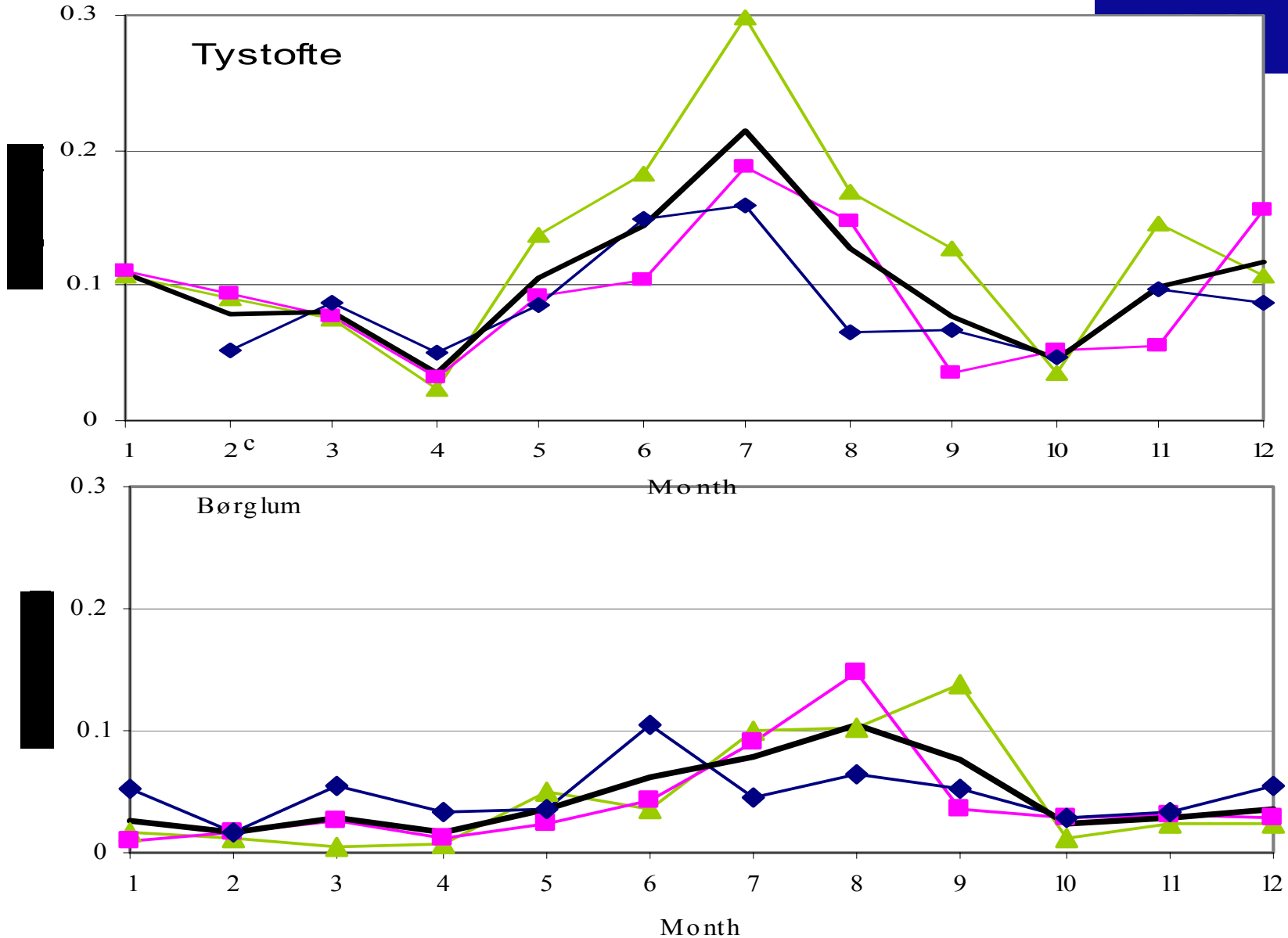
Region	Distance (m)	Roughness summer (m)	Roughness winter (m)
I	841	0.050	0.040
II	650	0.053	0.043
III	423	0.056	0.046
IV	296	0.060	0.050

Position of meteorology masts

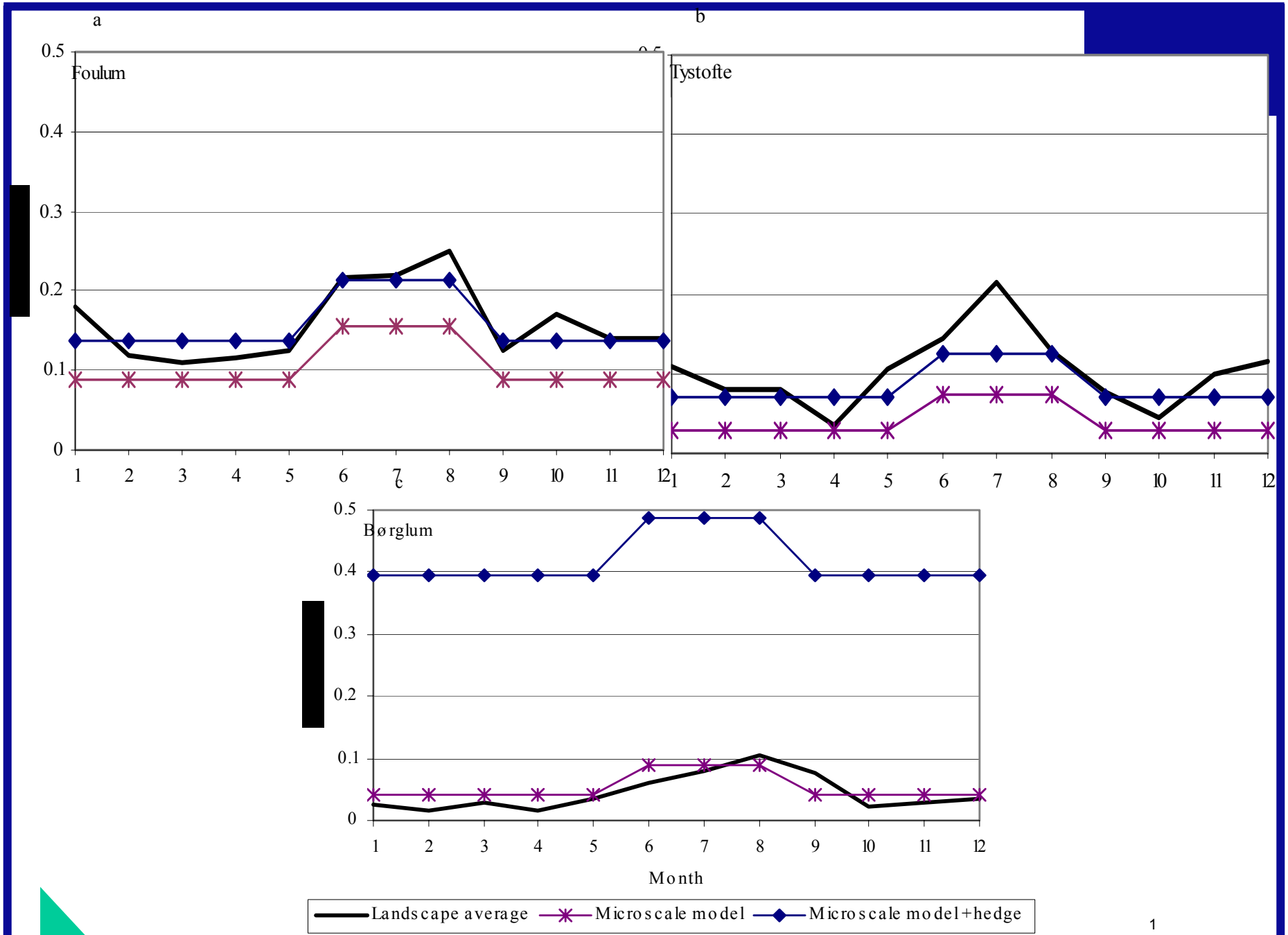
Foulum


0.3
0.25
0.2
0.15
0.1
0.05
0
Roughness (m)
1
2
3
4
5
6
7
8
9
10
11
12
Month
Average data
Model with hedges

b

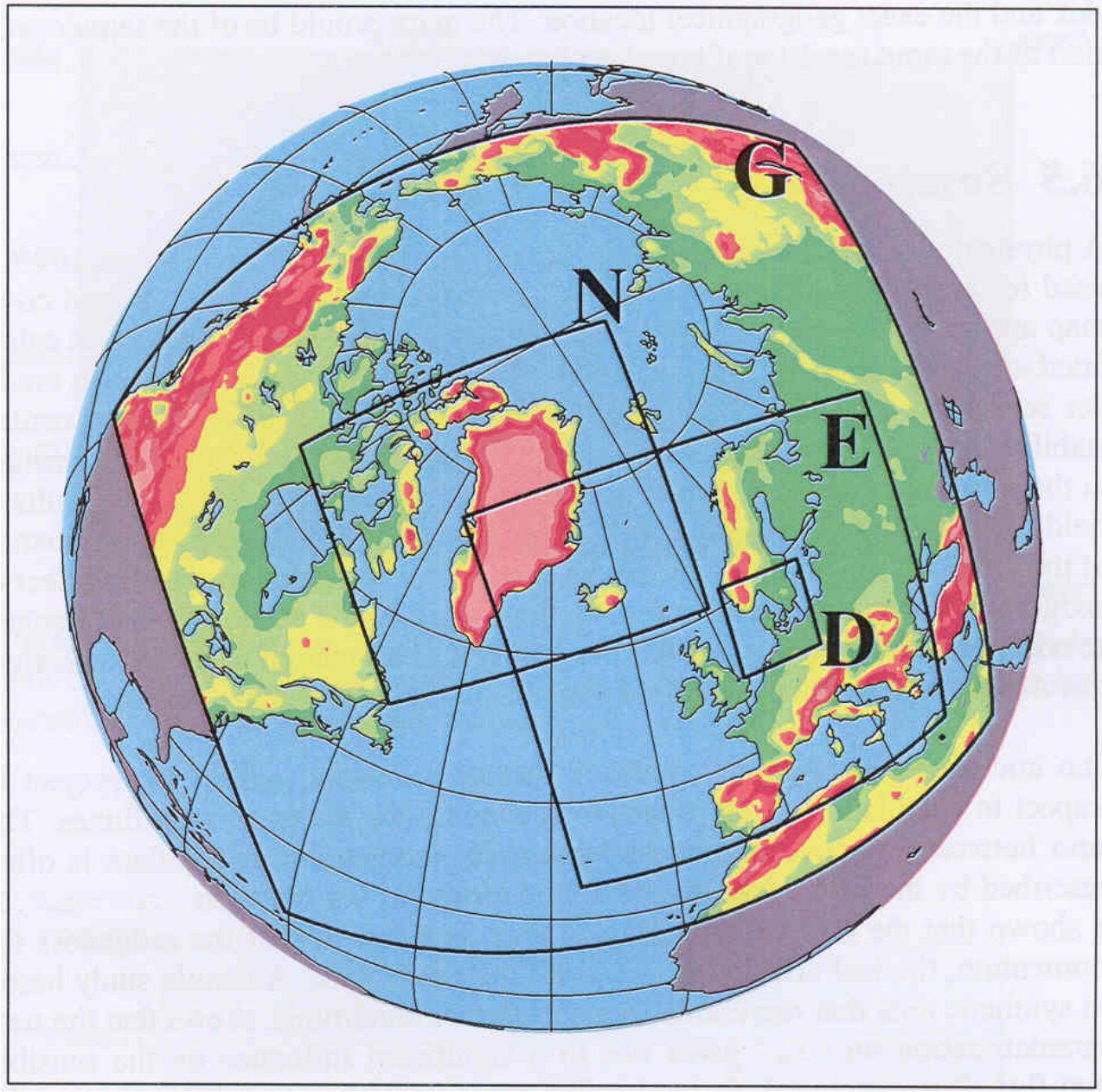

Tystofte
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
10
11
12
Month
Børglum
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
10
11
12
Month
Landscape 1998
Landscape 1999
Landscape 2000
Landscape average

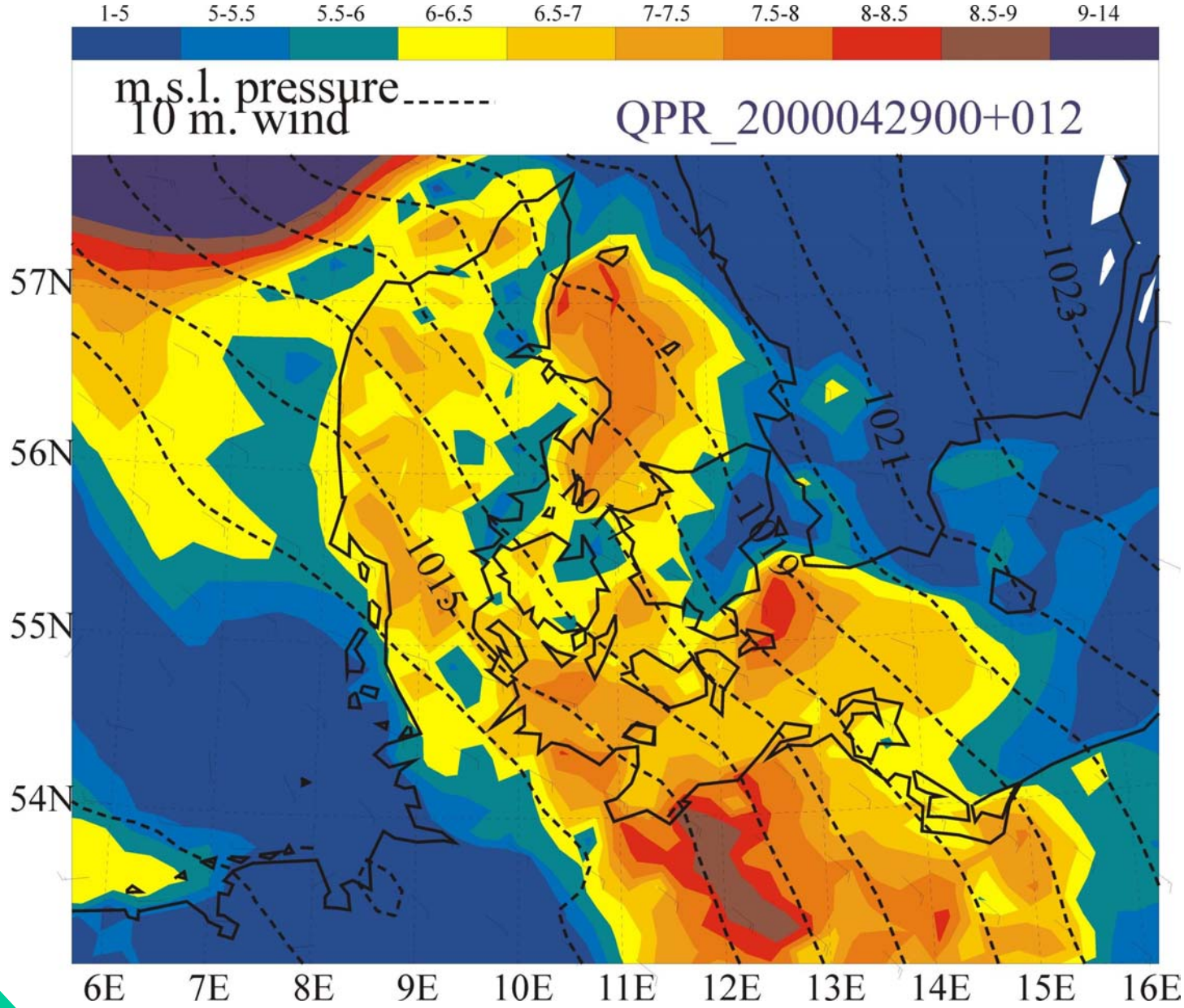
c


a
b
c
Foulum
Tystofte
Børglum
0.5
0.4
0.3
0.2
0.1
0
1 2 3 4 5 6 7 8 9 10 11 12
Month
Landscape average
Microscale model
Microscale model+hedge

Input to HIRLAM

Maps of aggregated roughness for momentum corrected for hedges in a 15 km by 15 km grid for summer and winter


G
N
E
D


1-5
5-5.5
5.5-6
6-6.5
6.5-7
7-7.5
7.5-8
8-8.5
8.5-9
9-14
m.s.l. pressure------
10 m. wind
QPR_2000042900+012
1023
1021
1019
1015
57N
56N
55N
54N
6E
7E
8E
9E
10E
11E
12E
13E
14E
15E
16E

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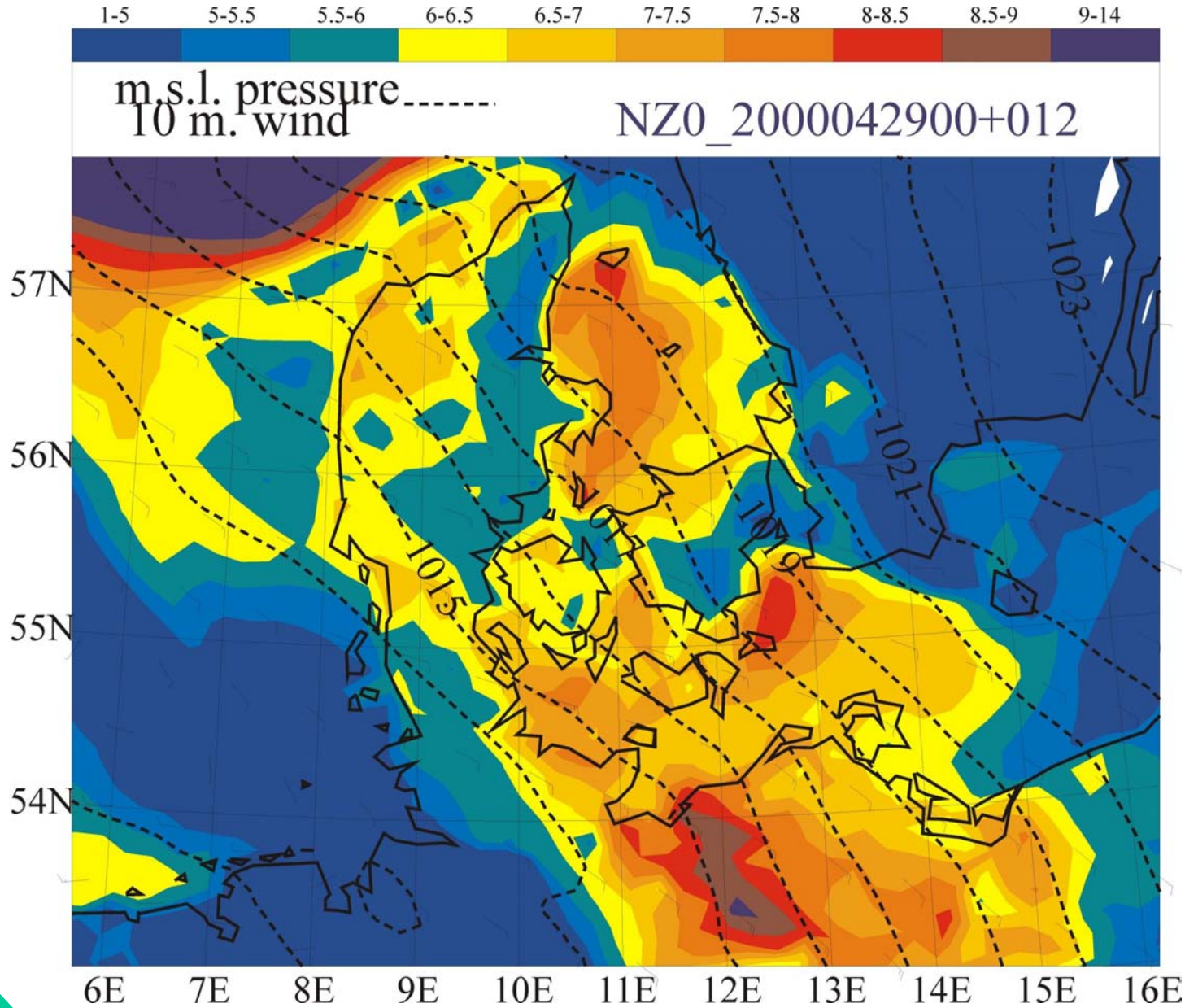
1-5
5-5.5
5.5-6
6-6.5
6.5-7
7-7.5
7.5-8
8-8.5
8.5-9
9-14
m.s.l. pressure
10 m. wind
NZ0_2000042900+012
1023
1021
1019
1017
1015
57N
56N
55N
54N
6E
7E
8E
9E
10E
11E
12E
13E
14E
15E
16E

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INFO

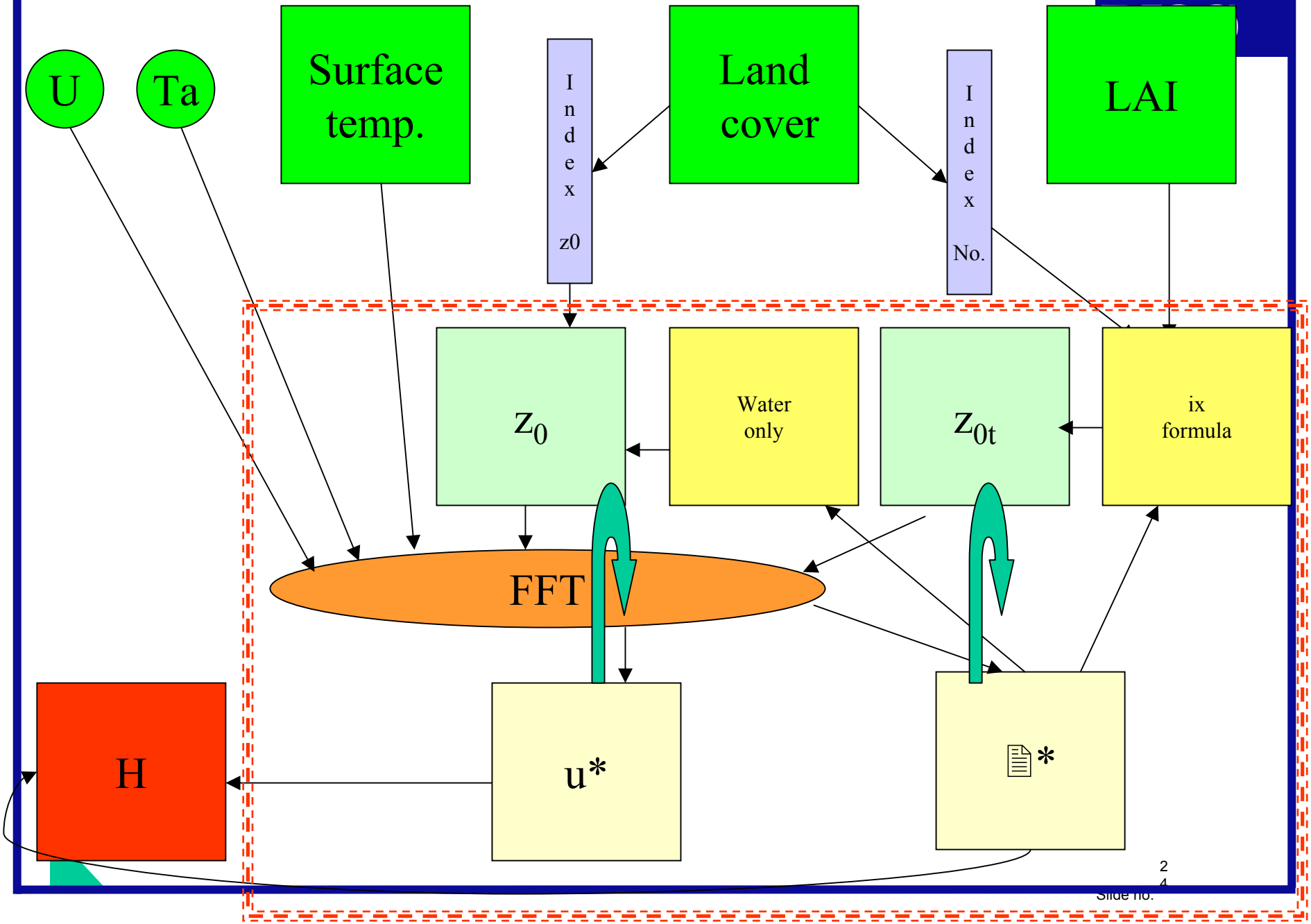
HIRLAM in spring has a bias of + 0.5 ms^{-1} over land and – 0.2 ms^{-1} over sea.

NEW RESULTS

The new roughness map improve wind speed in HIRLAM

FUTURE DEVELOPMENT ON z_0

Directional roughness for HIRLAM at higher resolution


U
Ta
Surface temp.
Index z0
Land cover
Index No.
LAI
z_0
Water only
z_{0t}
ix formula
FFT
H
u*
*

Ix-formula

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Vegetated land (include grass, grains, decidouos and conifer forest)

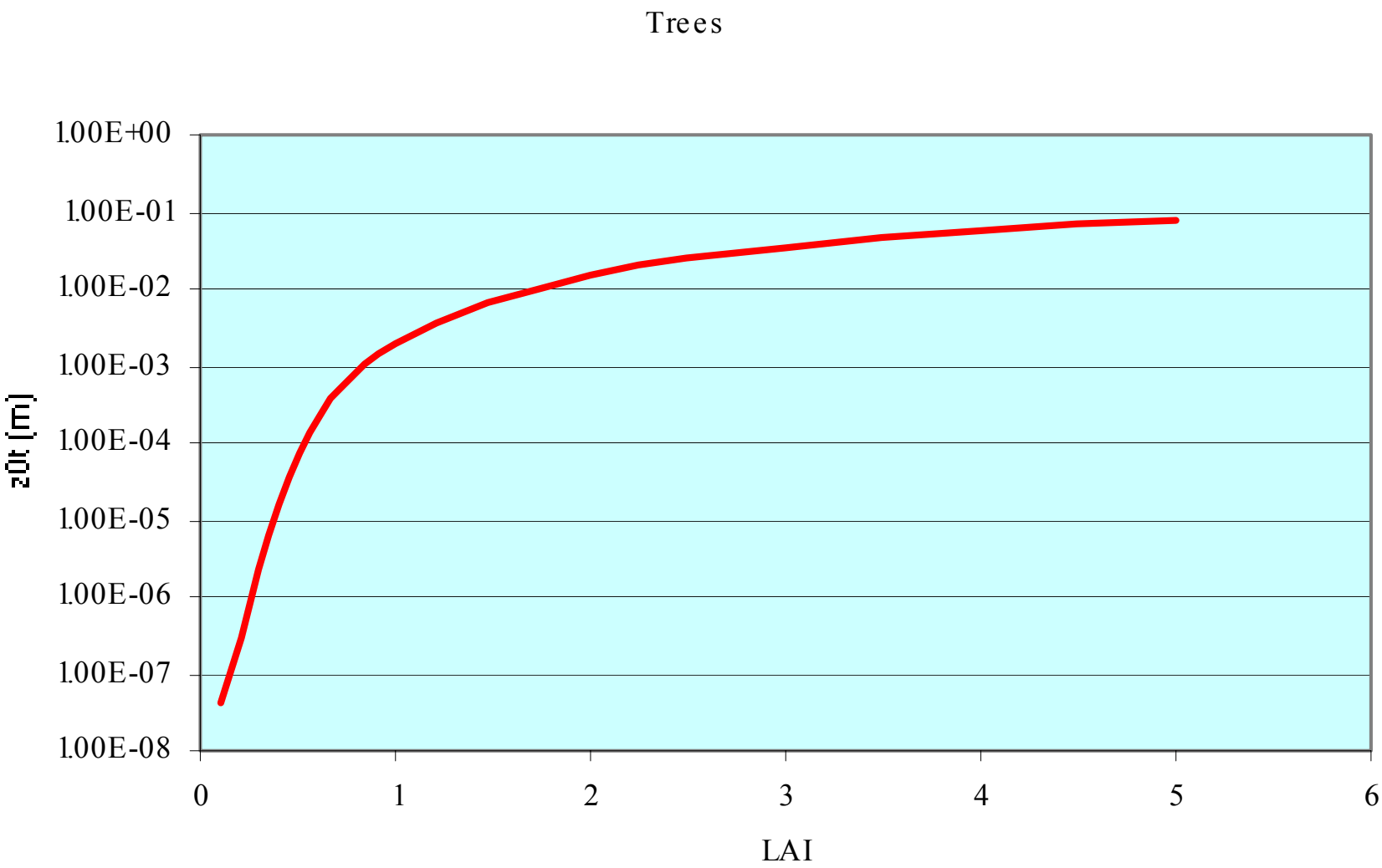
$$z_{ot} = \frac{z_o}{\exp\left(\frac{5.85}{LAI^{2/3}} u_*^{1/3}\right)}$$

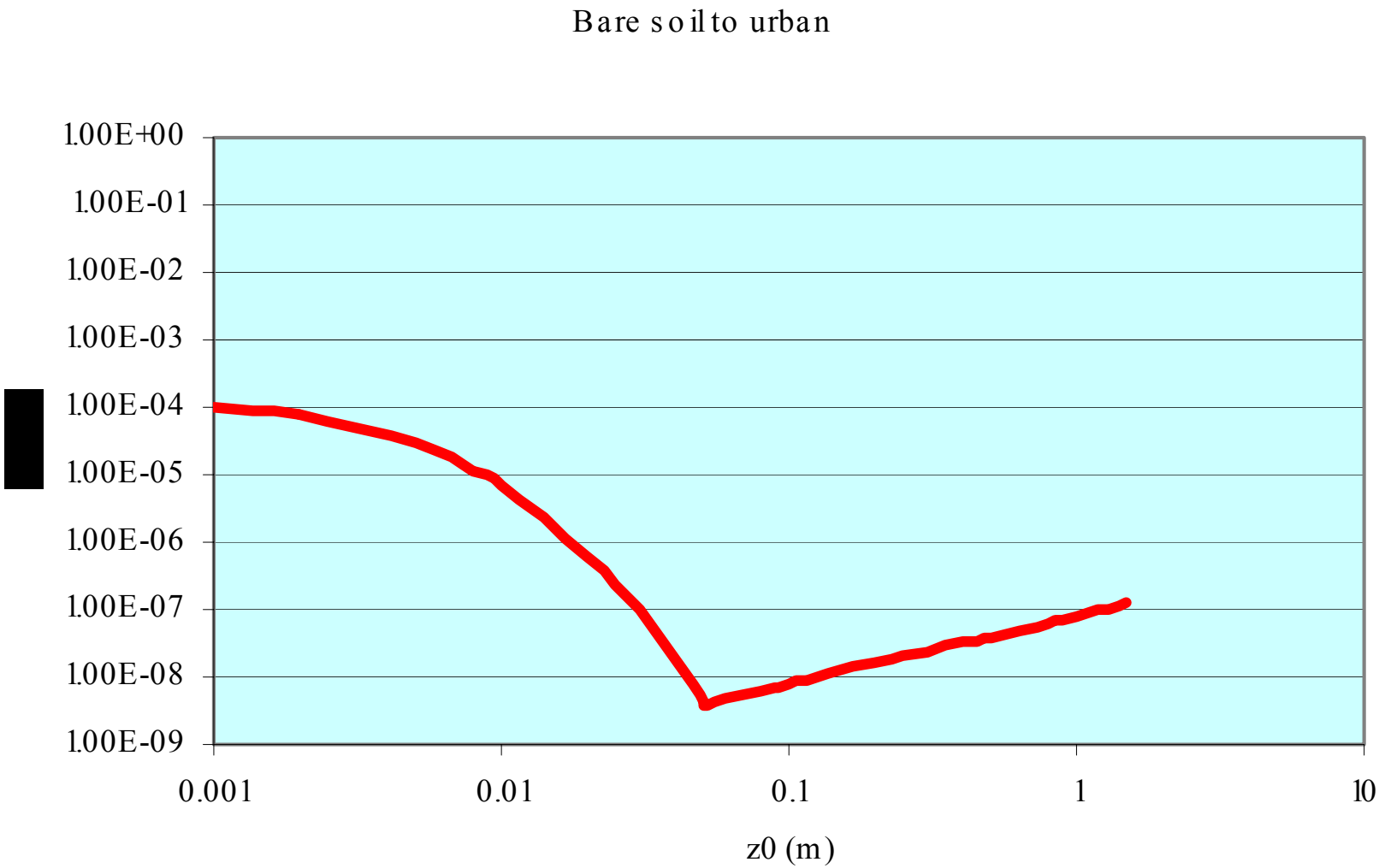
Bare land (include bare soil, ice, snow and urban areas)

$$z_{0t} = \frac{z_0}{\exp(103\sqrt{z_0 u_*})}$$ for $z_0 < 0.05$ m

$$z_{0t} = \frac{z_0}{\exp(23\sqrt{u_*})}$$ for $z_0 \geq 0.05$ m

All quantities are in MKS units.


Trees
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
z0t (m)
0
1
2
3
4
5
6
LAI


Bare soil to urban
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
0.001
0.01
0.1
1
10
z0 (m)

$$kB^{-1} = \ln\left(\frac{< z_0 >}{< z_{0t} >}\right)$$

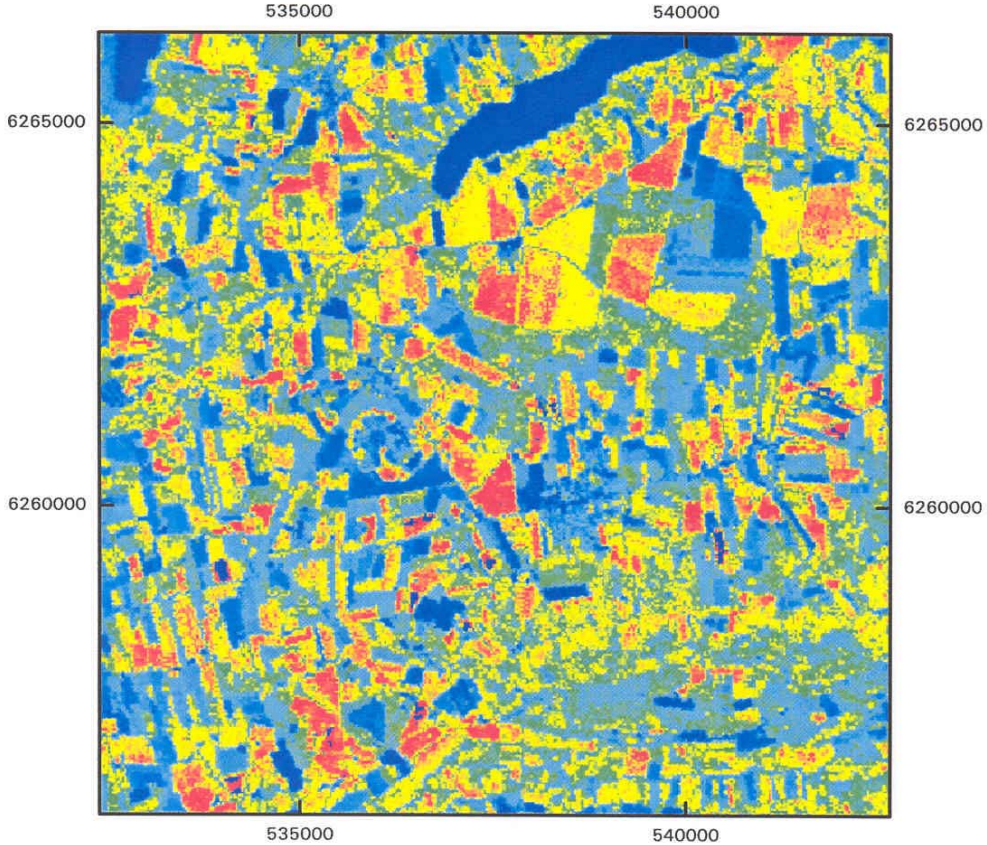
Results from synthetic checkerboard terrain case

	agriculture	forest	kB^{-1}
z_0 (m)	0.05	1.8	
LAI	1	1	6.5
LAI	3	3	4.5
LAI	5	5	3.0

	soil	bush	
z_0 (m)	0.01	0.5	
LAI	0	3	9.2

Typical assumptions 2.3 (or 0)

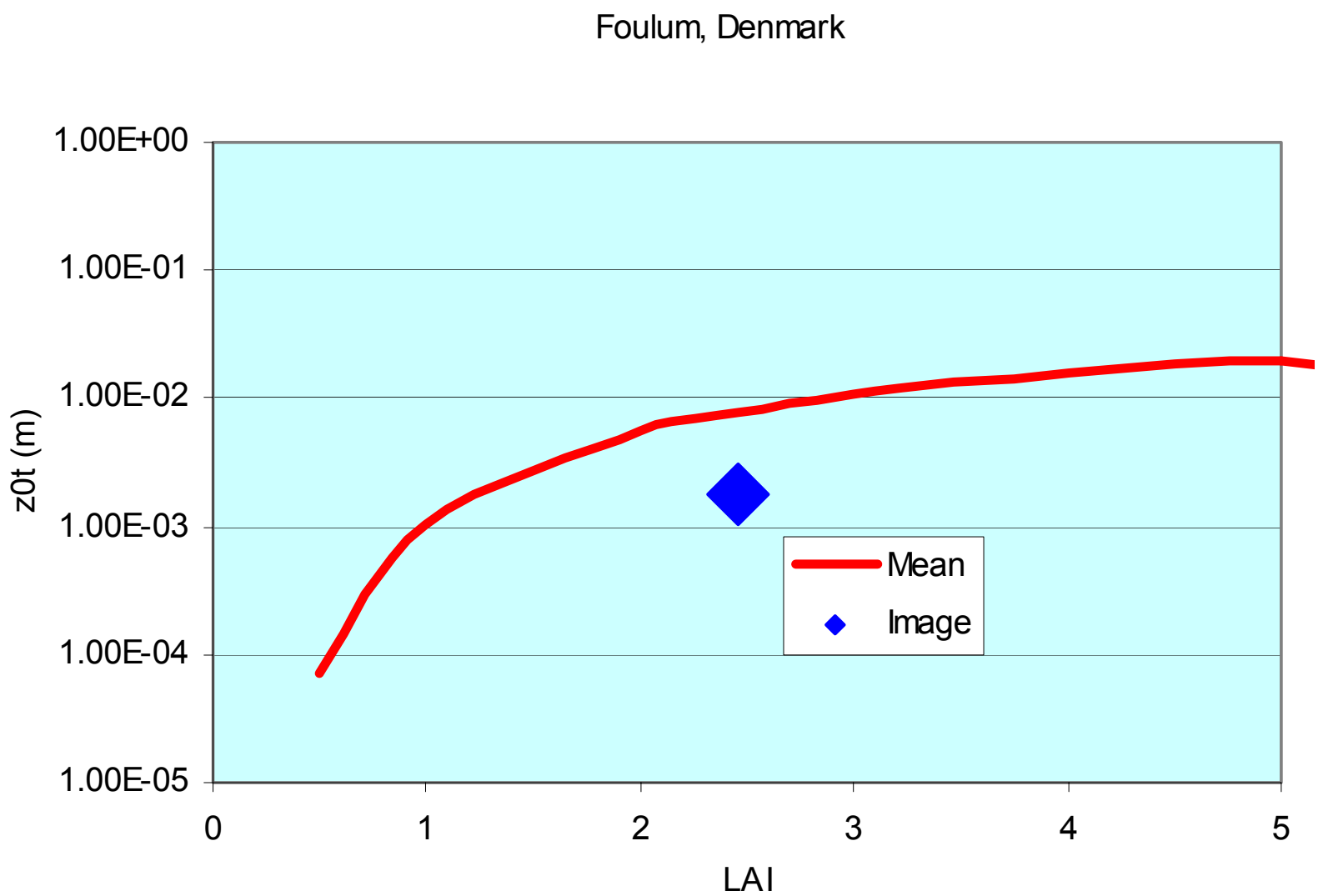
Foulum in Denmark from Landsat TM 28 April 1998



LAI

0
1
2
3
4
5
6

Leaf Area Index (LAI)
calculated from NDVI (Eva Bøgh)


Foulum, Denmark
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
z0t (m)
0
1
2
3
4
5
LAI
Mean
Image

CONCLUSIONS

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- An aggregation model for the roughness for momentum is used to calculate the grid-averaged roughness including hedges for Denmark.

- The new roughness maps are succesfully tested in the HIRLAM weather forecast model.

- An aggregation model for the roughness for scalars is developed that explicitely calculates kB^{-1} in heterogeneous terrain based on satellite maps of land cover type, surface temperature and LAI.

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Acknowledgements

SAT-MAP-CLIMATE project
EO-FLUX-BUDGET project