Annual Land Cover change using MODIS time series to improve emission inventories

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http://www.melodiesproject.eu/

MELODIES

"The MELODIES project will develop innovative and sustainable services, based upon Open Data, for users in research, government, industry and the general public in a broad range of societal and environmental benefit areas. Specifically, the project will develop eight new services which combine Earth Observation data with other open data sources to produce new information for the benefit of scientists, industry, government decision-makers, public service providers and citizens."

MELODIES WP3 – GHG Emissions

- Developing new land cover data to support UK GHG emissions inventory estimates
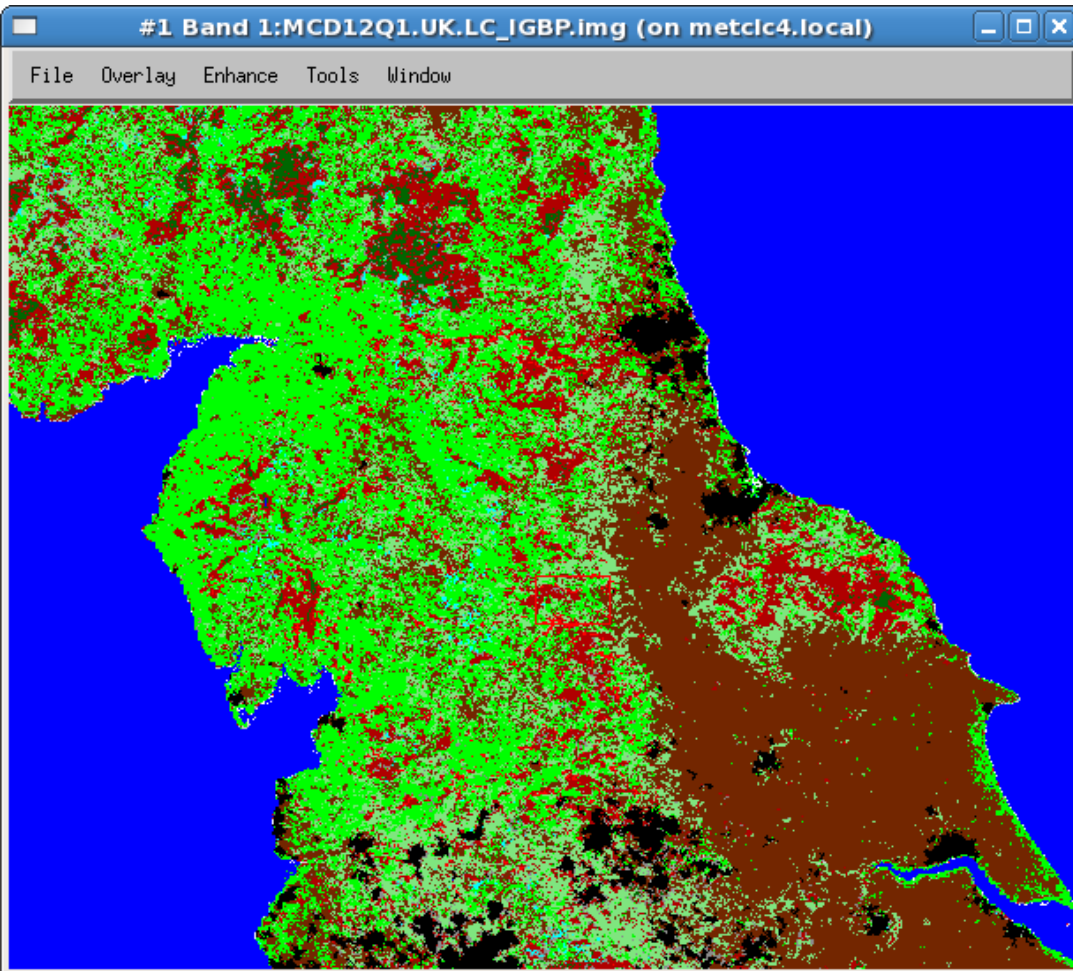- Objective is to improve representation of annual change in the data

3

Another land cover (LC) product…

- Global & continental LC products:
  - CORINE, 1990, 2006, 2012 (100m)
  - CCI LC map, 2000, 2005, 2010 (1km)
  - MODIS MCD12 LC, annual 2002-2012 (500m)
- Regional (UK):
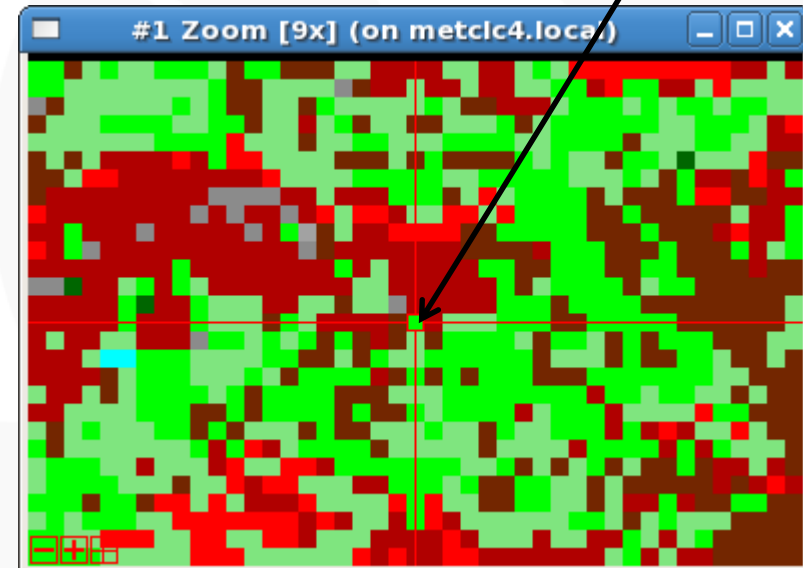 - Centre for Ecology and Hydrology (CEH) LC map, 2000, 2007 (25m)

None of the above optimised for change
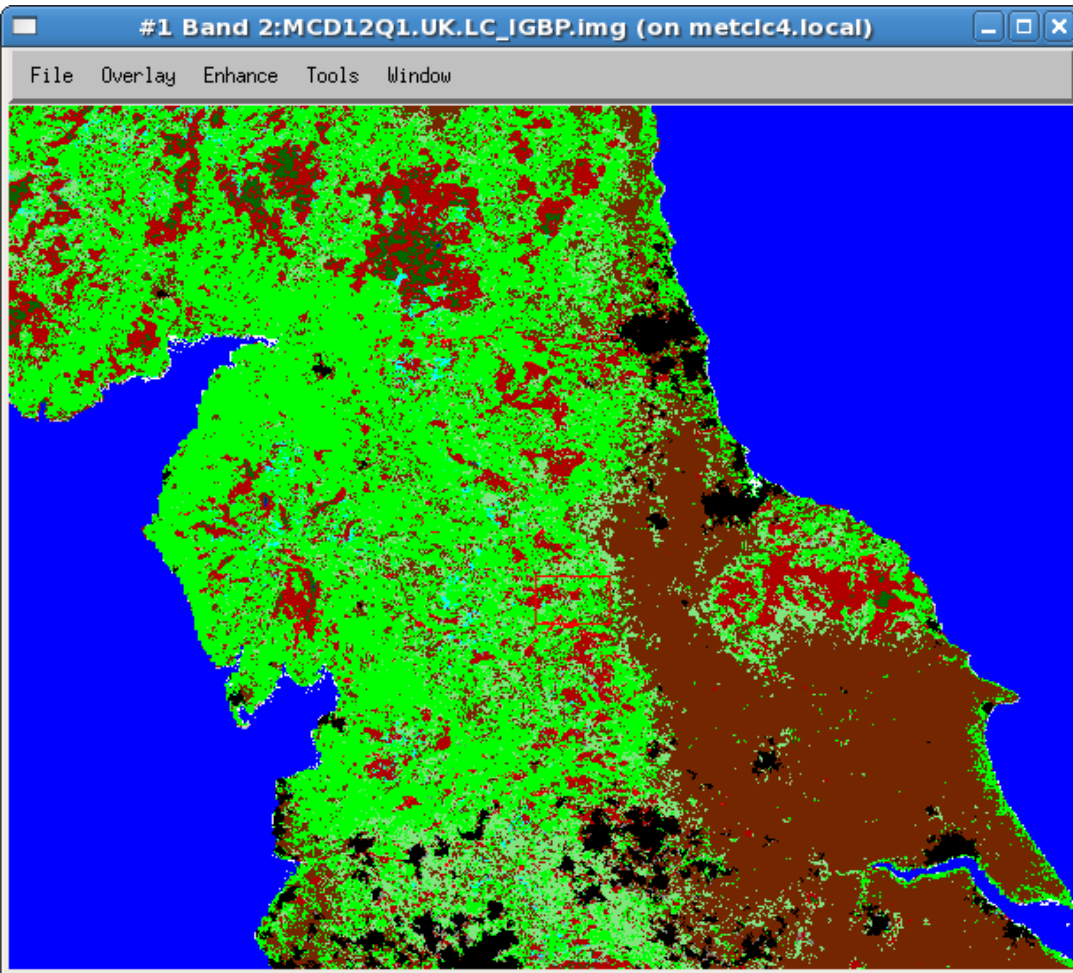
MODIS LC product over time - 2001

2001

MODIS LC product over time - 2002

2002

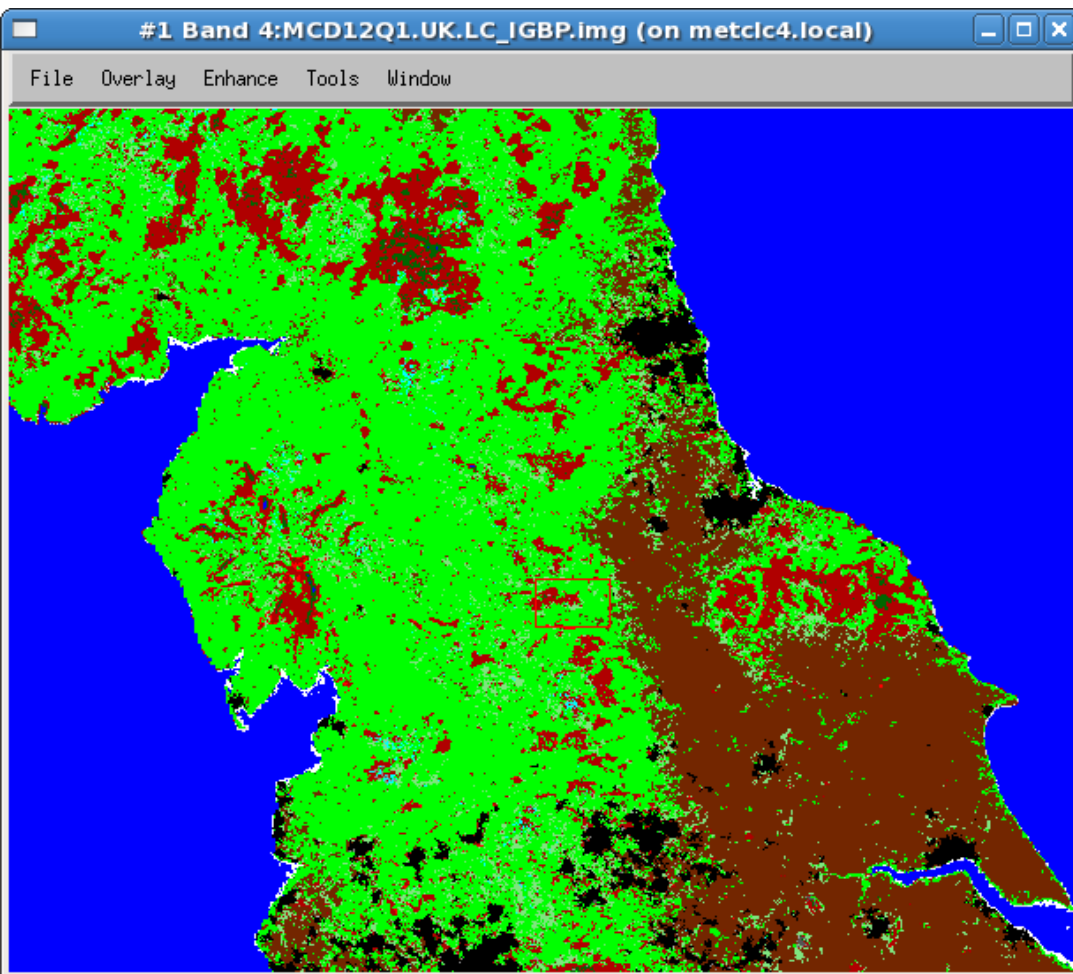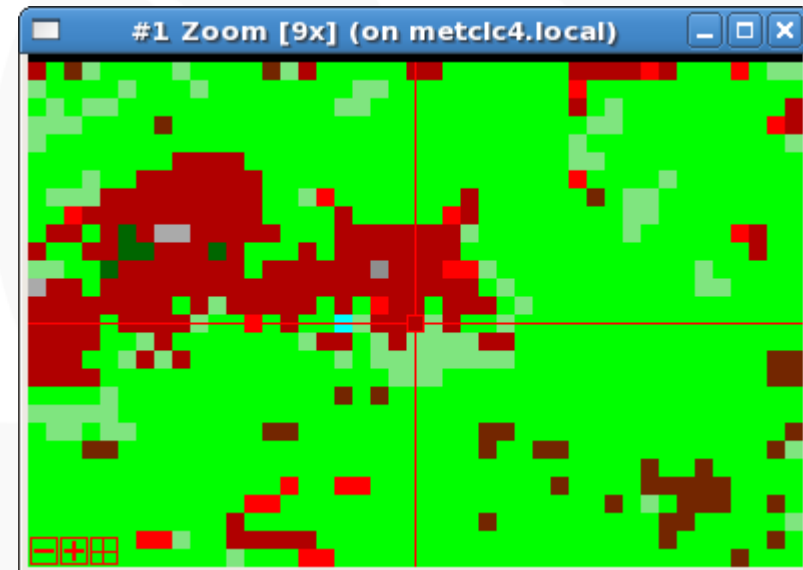| Value	Class
0	Water
1	Evergreen Needleleaf forest
2	Evergreen Broadleaf forest
3	Deciduous Needleleaf forest
4	Deciduous Broadleaf forest
5	Mixed forest
6	Closed shrublands
7	Open shrublands
8	Woody savannas
9	Savannas
10	Grasslands
11	Permanent wetlands
12	Croplands
13	Urban and built-up
14	Cropland/Natural vegetation mosaic
15	Snow and ice
16	Barren or sparsely vegetated
254	Unclassified
255	Fill Value

MODIS LC product over time - 2003

2003

MODIS LC product over time - 2004

2004

MODIS LC product over time - 2005

2005

MODIS LC product over time - 2006

2006

MODIS LC product over time - 2007

2007

Value	Class
0	Water
1	Evergreen Needleleaf forest
2	Evergreen Broadleaf forest
3	Deciduous Needleleaf forest
4	Deciduous Broadleaf forest
5	Mixed forest
6	Closed shrublands
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254	Unclassified
255	Fill Value

MODIS LC product over time - 2008

2008

0 Water
1 Evergreen Needleleaf forest
2 Evergreen Broadleaf forest
3 Deciduous Needleleaf forest
4 Deciduous Broadleaf forest
5 Mixed forest
6 Closed shrublands
7 Open shrublands
8 Woody savannas
9 Savannas
10 Grasslands
11 Permanent wetlands
12 Croplands
13 Urban and built-up
14 Cropland/Natural vegetation mosaic
15 Snow and ice
16 Barren or sparsely vegetated
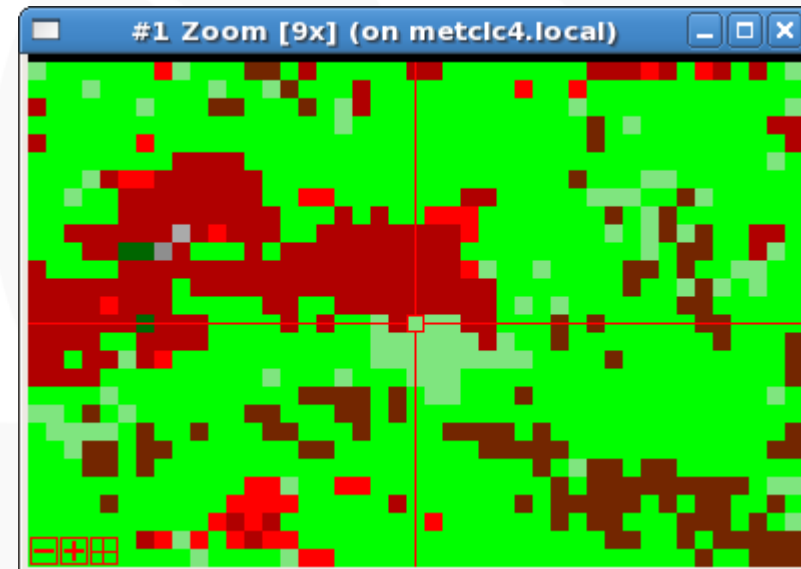254 Unclassified
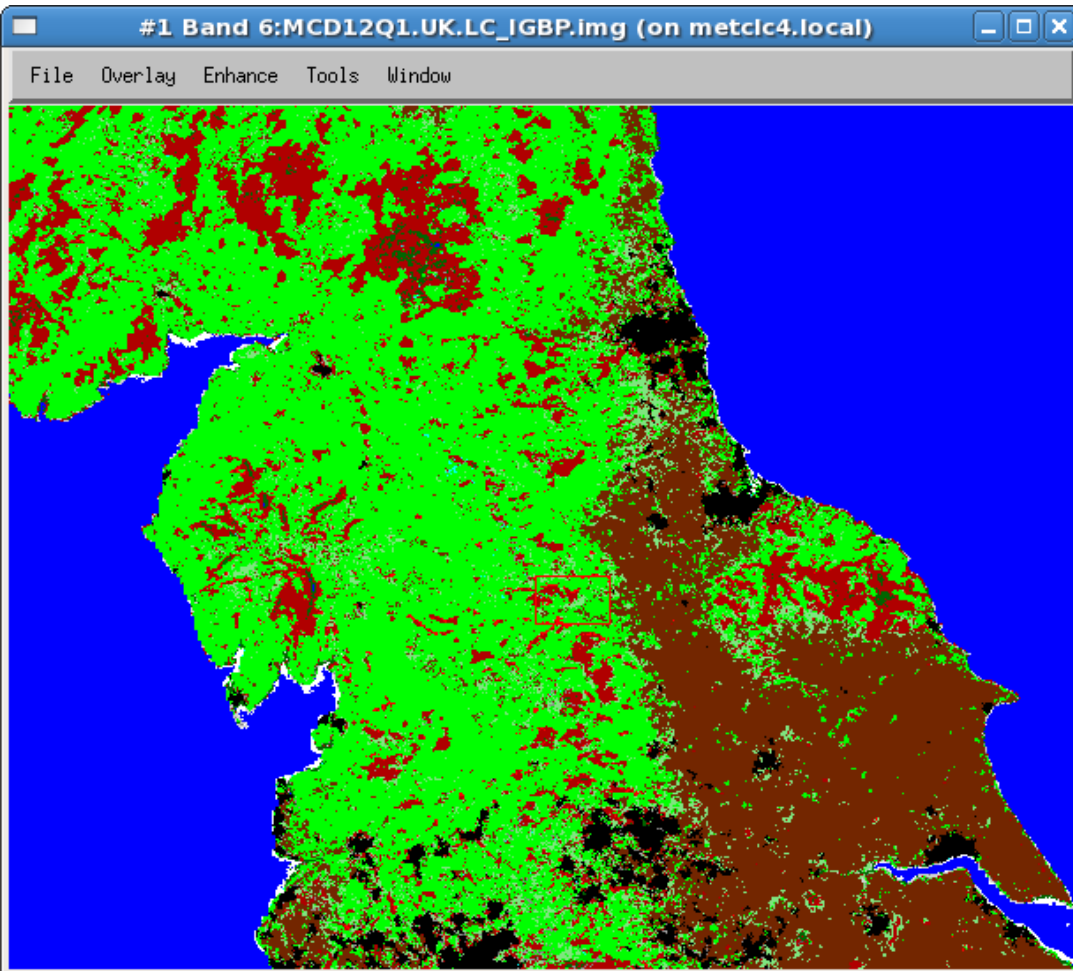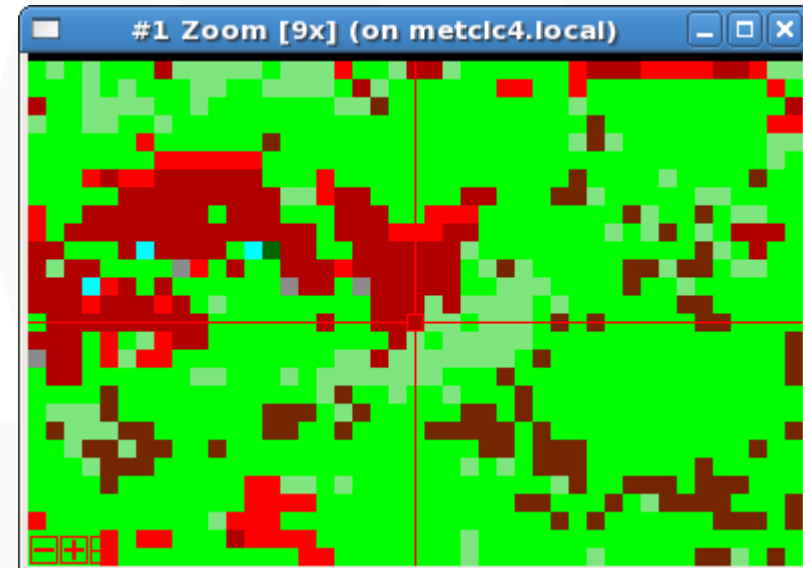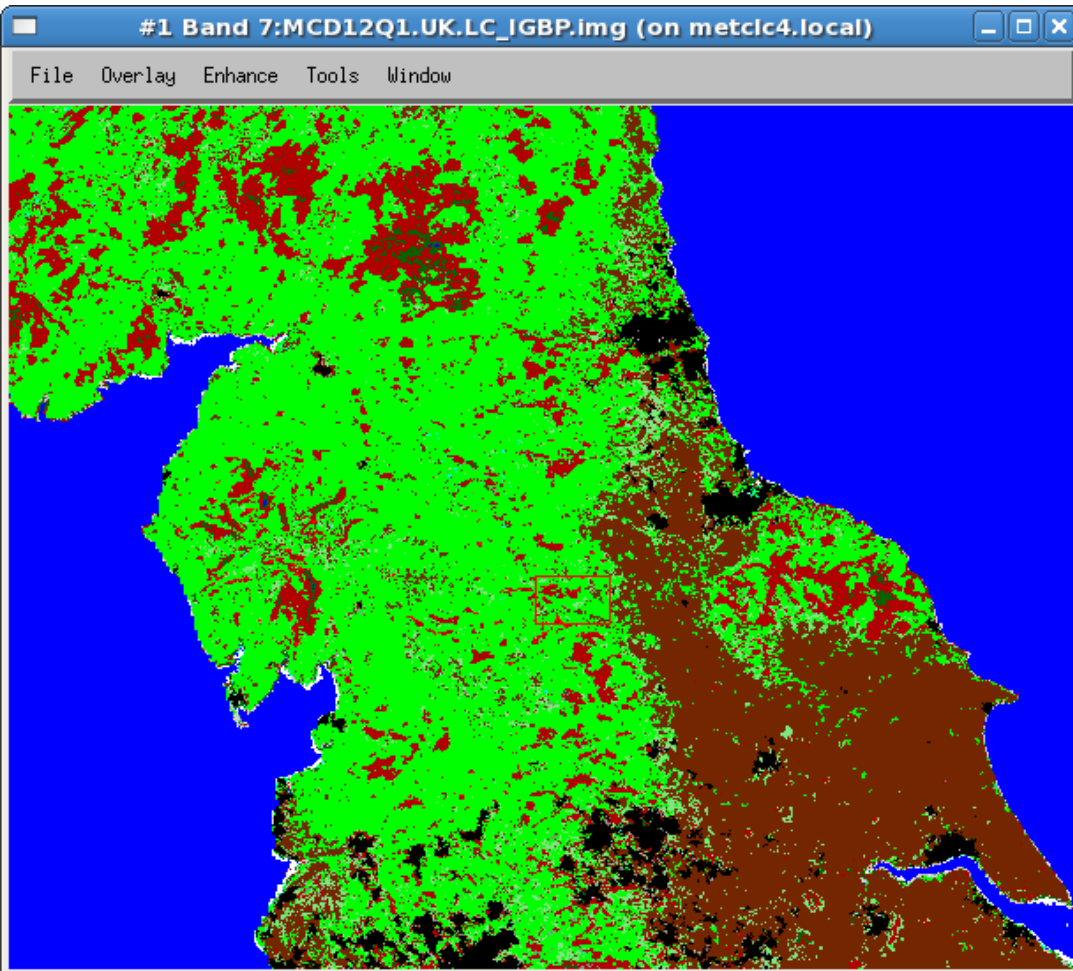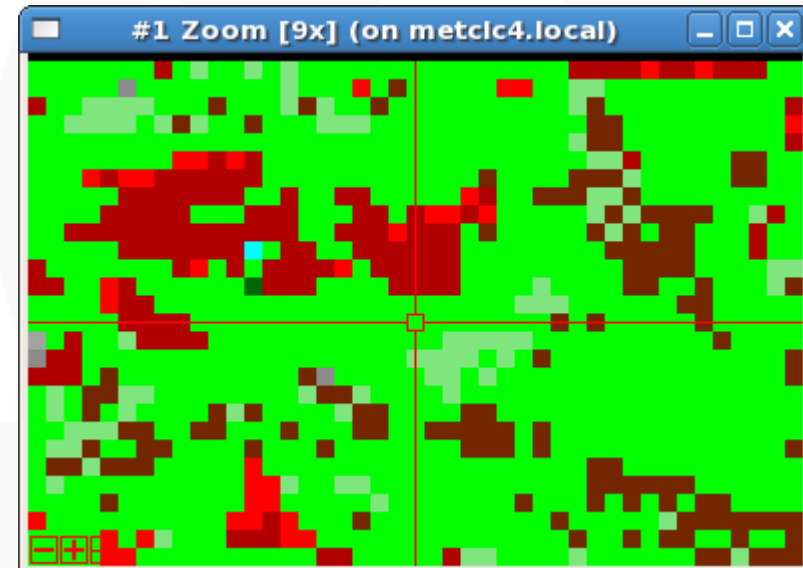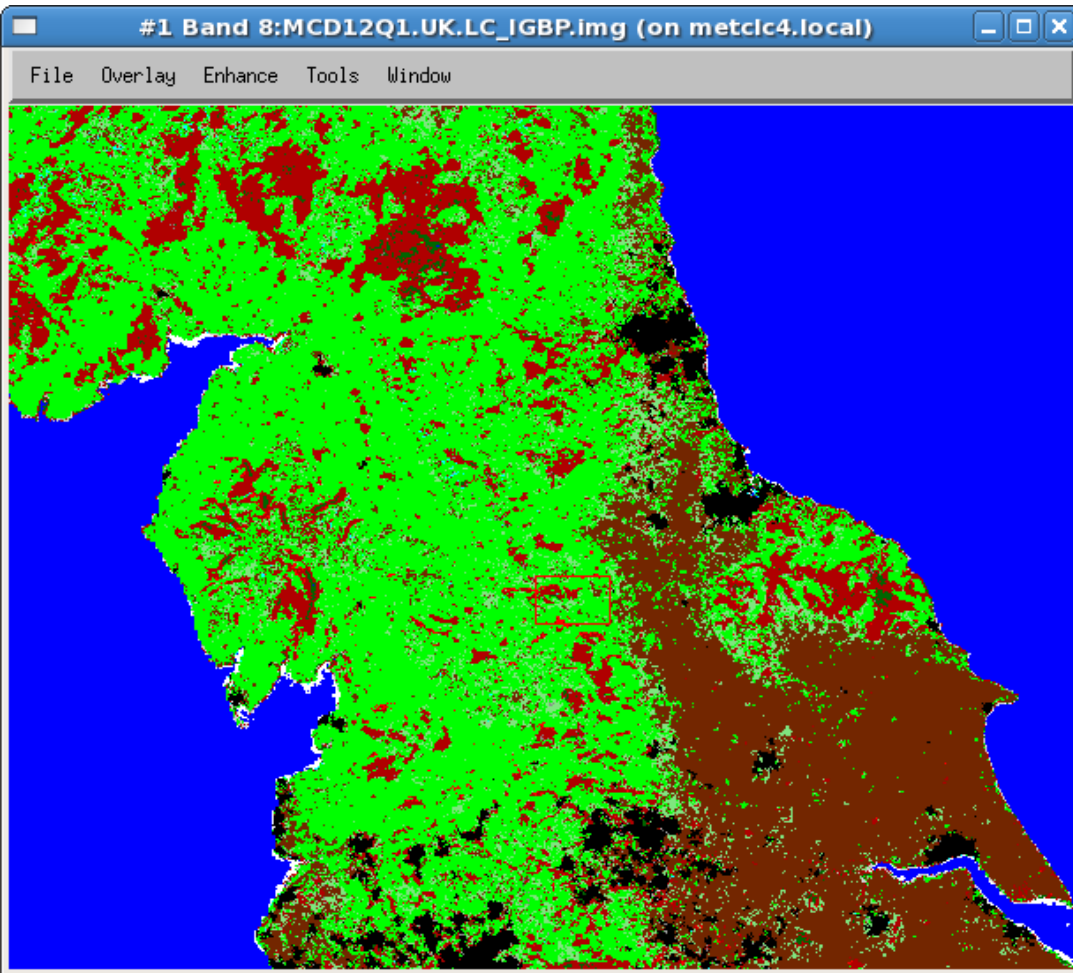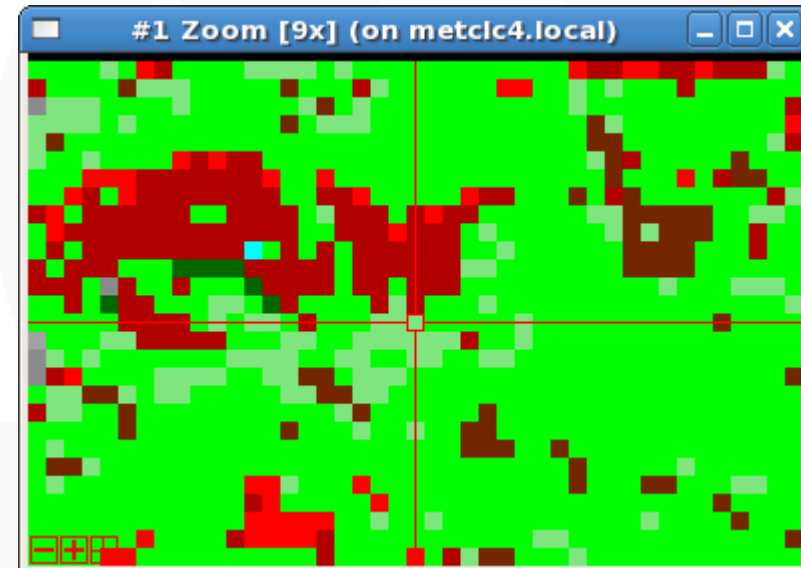255 Fill Value

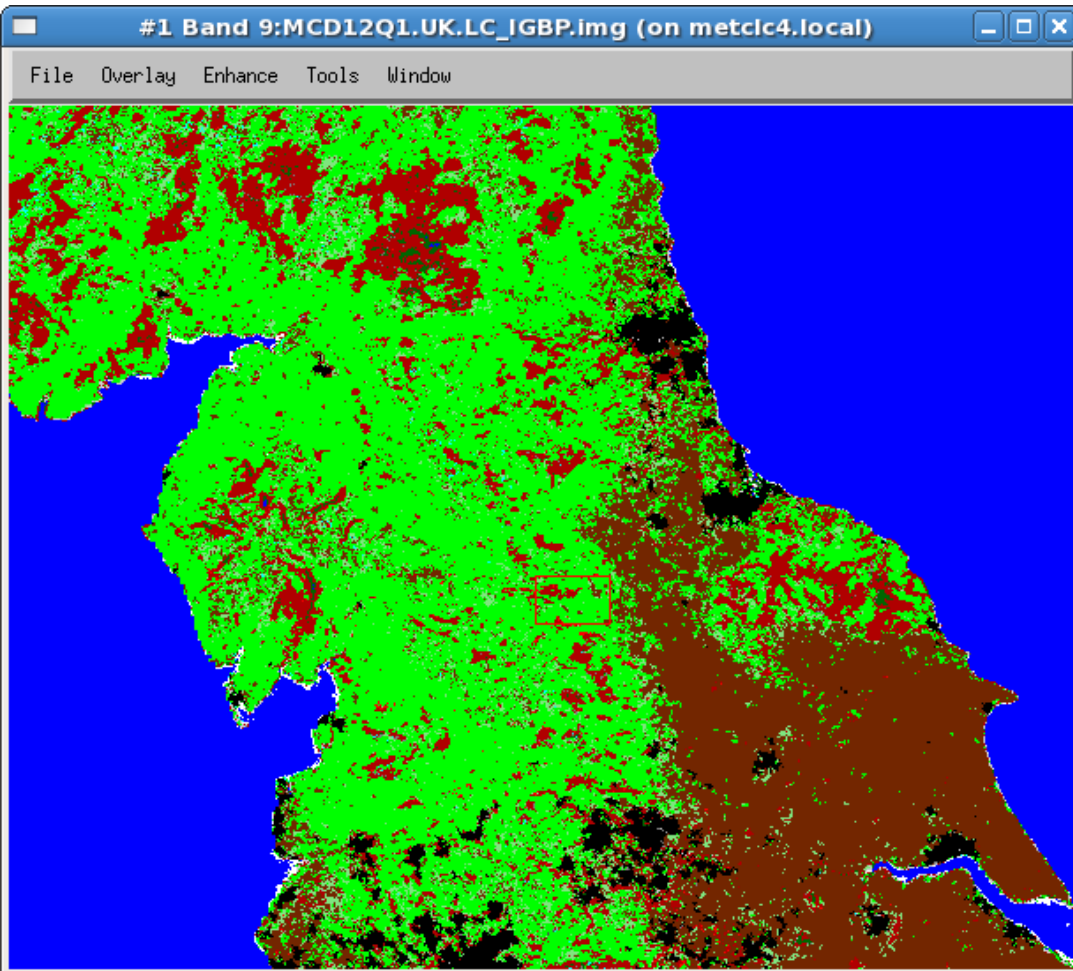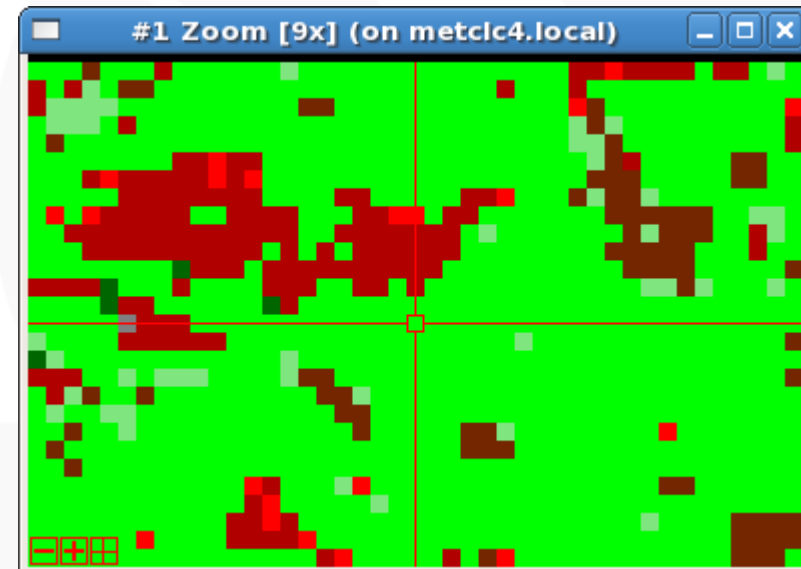# MODIS LC product over time - 2009

2009

MODIS LC product over time - 2010

2010

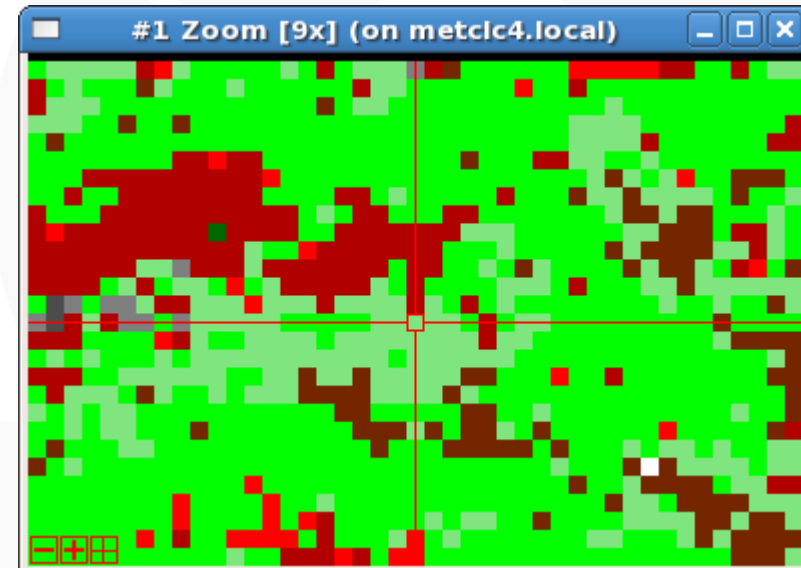| Value	Class
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MODIS LC product over time - 2011

2011

MODIS LC product over time - 2012

2012

Number of LC changes during 2001-2012

MELODIES approach

1. Careful processing of underlying data using semi-empirical BRDF models
   - Uses a climatological prior of surface reflectance to eliminate gaps and reduce noise
2. Post processing of classifications using a Bayesian model
   - Constrains probability of change based on national survey statistics
   - Not yet implemented in processing chain

Kernel driven BRDF model

$$\rho(\Omega, \Omega', \lambda) = \sum_{j=1}^{n} f_j(\lambda) K_j(\Omega, \Omega')$$

f   = kernel weight
K   = kernel value
n   = number of kernels

λ   = wavelength
ρ   = BRF
Ω   = view geometry
Ω' = illumination geometry

Kernel driven BRF model

surface bi-directional reflectance factor =

ISOTROPIC + **VOLUMETRIC** + **GEOMETRIC**

Constrained formulation

- Classic least squares solution:

$$f = (K^T C^{-1} K)^{-1} K^T C^{-1} \rho$$

- With prior estimate of f (f*):

$$f = (K^T C^{-1} K + \gamma^2 I)^{-1}(K^T C^{-1} \rho + \gamma^2 f^*)$$

Surface reflectance – temporal profiles
Broadleaved woodland - NIR

MELODIES LC 2007 classification

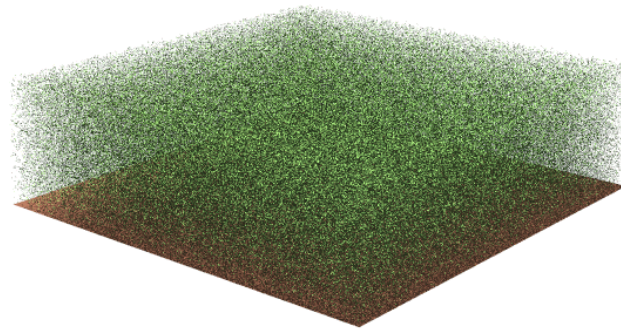|	
Broadleaved woodland	1
'Coniferous Woodland'	2
'Arable and Horticulture'	3
'Improved Grassland'	4
Rough grassland	5
'Neutral Grassland'	6
'Calcareous Grassland'	7
Acid grassland	8
'Fen, Marsh and Swamp'	9
Heather	10
Heather grassland	11
'Bog'	12
'Montane Habitats'	13
'Inland Rock'	14
Saltwater	15
Freshwater	16
'Supra-littoral Rock'	17
'Supra-littoral Sediment'	18
'Littoral Rock'	19
Littoral sediment	20
Saltmarsh	21
Urban	22
Suburban	23

Comparison with CEH LCM2007 map

MELODIES LC map 2007

CEH LC map 2007

Constraining change

- Have designed Bayesian approach to calculate the most likely change scenario

- Works across whole times series

- National change statistics provides prior
  - Easy to refine or change

- Support vector supplies probability of any scenario given the observations

LC change

- Real change matrices to be used as a prior (UK Greenhouse Gas Inventory, 1990 to 2012)

2005 to 2006

From To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2595	1	8	0	1	0	2607
Cropland	0	5822	52	0	0	0	5874
Grassland	3	99	13550	0	8	0	13660
Wetland	0	0	0	172	0	0	172
Settlement	1	5	10	0	1835	0	1851
Other Land	0	0	0	0	0	251	251
Total	2599	5927	13621	173	1844	251	24415

2006 to 2007

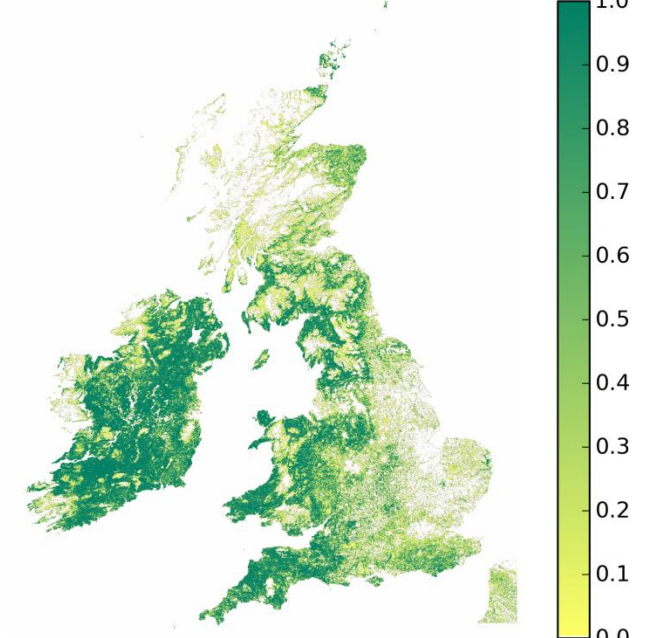| From To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2603	1	6	0	1	0	2612
Cropland	0	5769	52	0	0	0	5821
Grassland	2	99	13591	0	8	0	13700
Wetland	0	0	0	172	0	0	172
Settlement	1	5	10	0	1843	0	1859
Other Land	0	0	0	0	0	251	251
Total	2607	5874	13660	172	1852	251	24415

- Use per-pixel probabilities state vector for each year to estimate feasible changes constrained by the prior
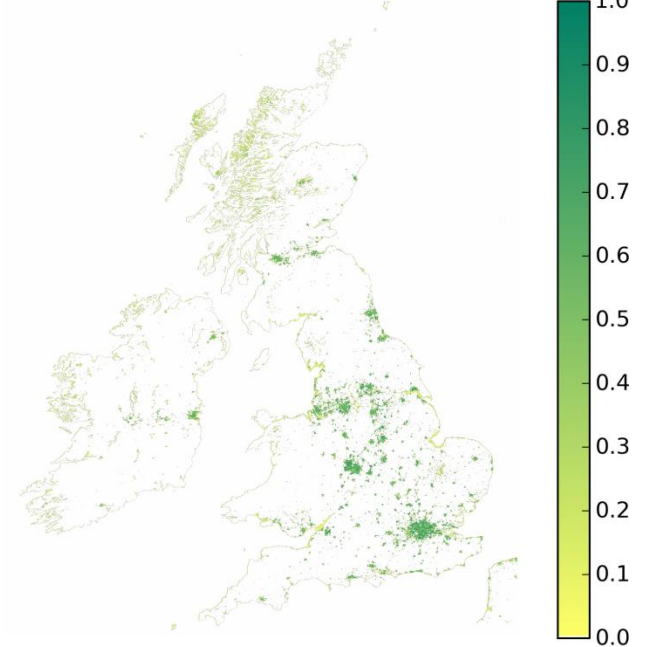
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Probability of LC

LC probability - Arable and Horticulture

LC probability - Improved Grassland

LC probability - Urban / Suburban

MELODIES LC – next 18 months

- 12 years of LC/LCC for the UK

- Full processing chain code will be available in the MELODIES GitHub repo

- Data portals to explore the LC datasets, LC product inter-comparison/translation
  - EAGLE

- Expansion of the service
  - Longer time series/EU wide