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XXVI FIG Congress 2018

6–11 May 2018

ISTANBUL



# A Deep Learning Method for Local Climate Zone Classification

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EMBRACING OUR SMART WORLD WHERE THE CONTINENTS CONNECT:
ENHANCING THE GEOSPATIAL MATURITY OF SOCIETIES

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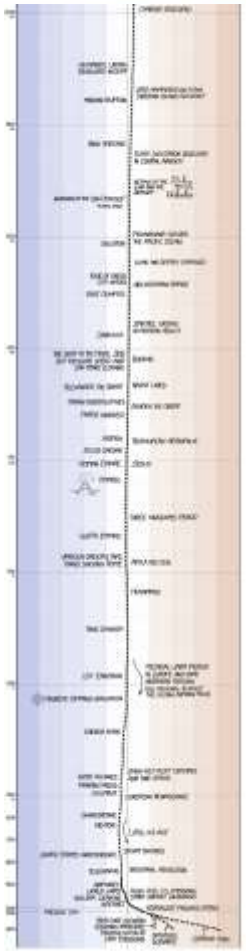
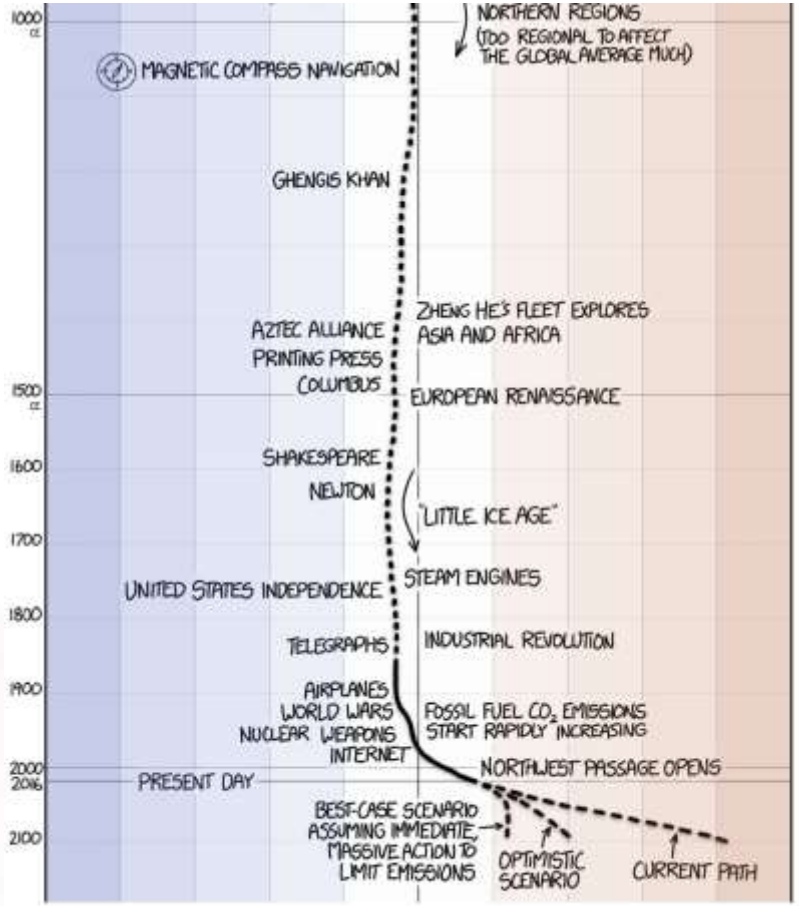


xkcd.com

# Anthropocene




# Urban Heat Islands

- Pavement, concrete, etc. cause  more intense UHI
- Local but has global effect.
- Urban- Semi-urban, Rural
- Global Human Settlement Layer (GHSL) LABEL project, imagery 1975-2014
- Local Climate Zones (LCZ), functional 17 classes, 1-10, A-G, lower resolution

GHSL-LABEL

| | Description | Source and Note |
|---|---|---|
| 1 | Other | GlobeCover |
| 2 | Ice and snow | GlobeCover |
| 3 | Bare soil and rocks | GlobeCover |
| 4 | Shrubs and grassland | GlobeCover |
| 5 | Mosaic croplands and forest | GlobeCover |
| 6 | Rain cropland | GlobeCover |
| 7 | Irrigated cropland | GlobeCover |
| 8 | Forest | GlobeCover |
| 9 | Occasionally Water/Land-Water | GlobeCover |
| 10 | Surface Water | GlobeCover |
| 11 | Roads | OSM |
| 12 | Highly reflecting roof | Filtering |
| 13 | Very light impervious | NDVI > 0.4 |
| 14 | Light impervious | 0.3 < NDVI ≤ 0.4 |
| 15 | Medium impervious | 0.2 < NDVI ≤ 0.3 |
| 16 | Low rise | NDVI ≤ 0.2; 3Dr ≤ 25 m |
| 17 | Medium rise | NDVI ≤ 0.2; 25 < 3Dr ≤ 50 m |
| 18 | High rise | NDVI ≤ 0.2; 50 < 3Dr ≤ 100 m |
| 19 | Very high rise | NDVI ≤ 0.2; 3Dr > 100 m |

| Built types | Definition |
|---|---|
| 1. Compact high-rise  | Dense mix of tall buildings to tens of stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone, and glass construction materials. |
| 2. Compact midrise  | Dense mix of midrise buildings (3–9 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials. |
| 3. Compact low-rise  | Dense mix of low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials. |
| 4. Open high-rise  | Open arrangement of tall buildings to tens of stories. Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials. |
| 5. Open midrise  | Open arrangement of midrise buildings (3–9 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials. |
| 6. Open low-rise  | Open arrangement of low-rise buildings (1–3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick, stone, tile, and concrete construction materials. |
| 7. Lightweight low-rise  | Dense mix of single-story buildings. Few or no trees. Land cover mostly hard-packed. Lightweight construction materials (e.g., wood, thatch, corrugated metal). |
| 8. Large low-rise  | Open arrangement of large low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Steel, concrete, metal, and stone construction materials. |
| 9. Sparsely built  | Sparse arrangement of small or medium-sized buildings in a natural setting. Abundance of pervious land cover (low plants, scattered trees). |
| 10. Heavy industry  | Low-rise and midrise industrial structures (towers, tanks, stacks). Few or no trees. Land cover mostly paved or hard-packed. Metal, steel, and concrete construction materials. |

| Land cover types | Definition |
|---|---|
| A. Dense trees  | Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park. |
| B. Scattered trees  | Lightly wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park. |
| C. Bush, scrub  | Open arrangement of bushes, shrubs, and short, woody trees. Land cover mostly pervious (bare soil or sand). Zone function is natural scrubland or agriculture. |
| D. Low plants  | Featureless landscape of grass or herbaceous plants/crops. Few or no trees. Zone function is natural grassland, agriculture, or urban park. |
| E. Bare rock or paved  | Featureless landscape of rock or paved cover. Few or no trees or plants. Zone function is natural desert (rock) or urban transportation. |
| F. Bare soil or sand  | Featureless landscape of soil or sand cover. Few or no trees or plants. Zone function is natural desert or agriculture. |
| G. Water  | Large, open water bodies such as seas and lakes, or small bodies such as rivers, reservoirs, and lagoons. |
| **VARIABLE LAND COVER PROPERTIES** | |
| Variable or ephemeral land cover properties that change significantly with synoptic weather patterns, agricultural practices, and/or seasonal cycles. | |
| b. bare trees | Leafless deciduous trees (e.g., winter). Increased sky view factor. Reduced albedo. |
| s. snow cover | Snow cover >10 cm in depth. Low admittance. High albedo. |
| d. dry ground | Parched soil. Low admittance. Large Bowen ratio. Increased albedo. |
| w. wet ground | Waterlogged soil. High admittance. Small Bowen ratio. Reduced albedo. |

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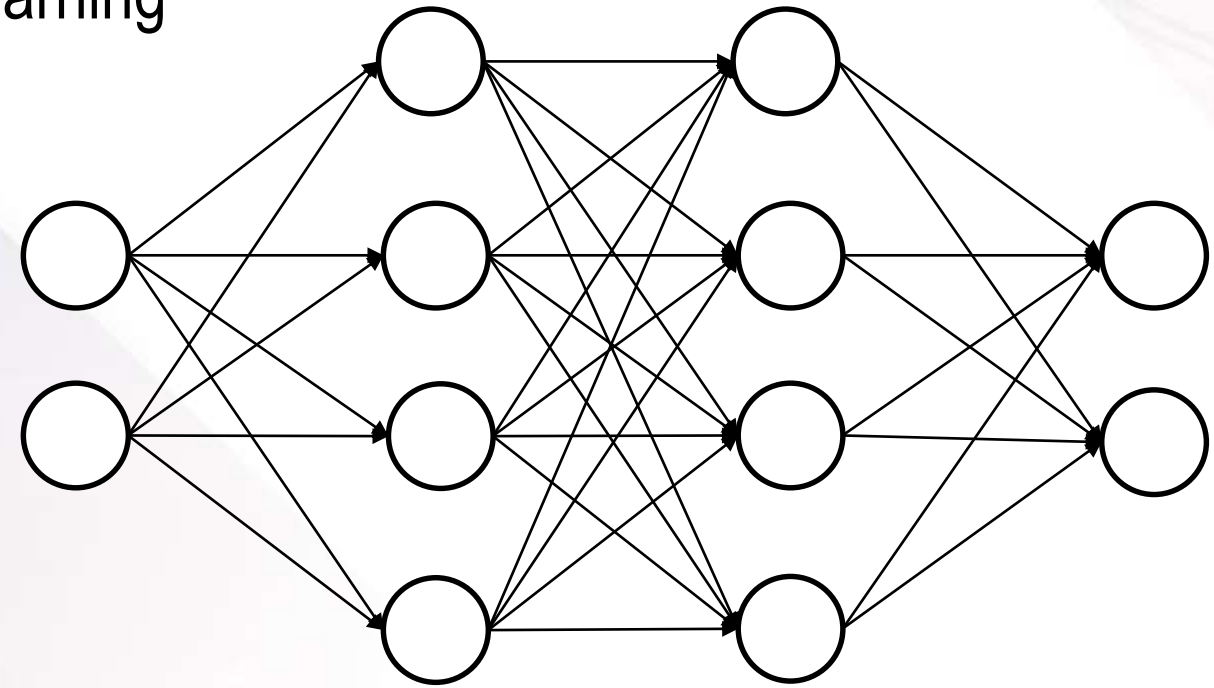
- LCZ 0 – 1 – 2
- LCZ 0 Cities are mapped using the Local Climate Zone (LCZ) scheme (Stewart and Oke, 2012)

- from forties % to sixties

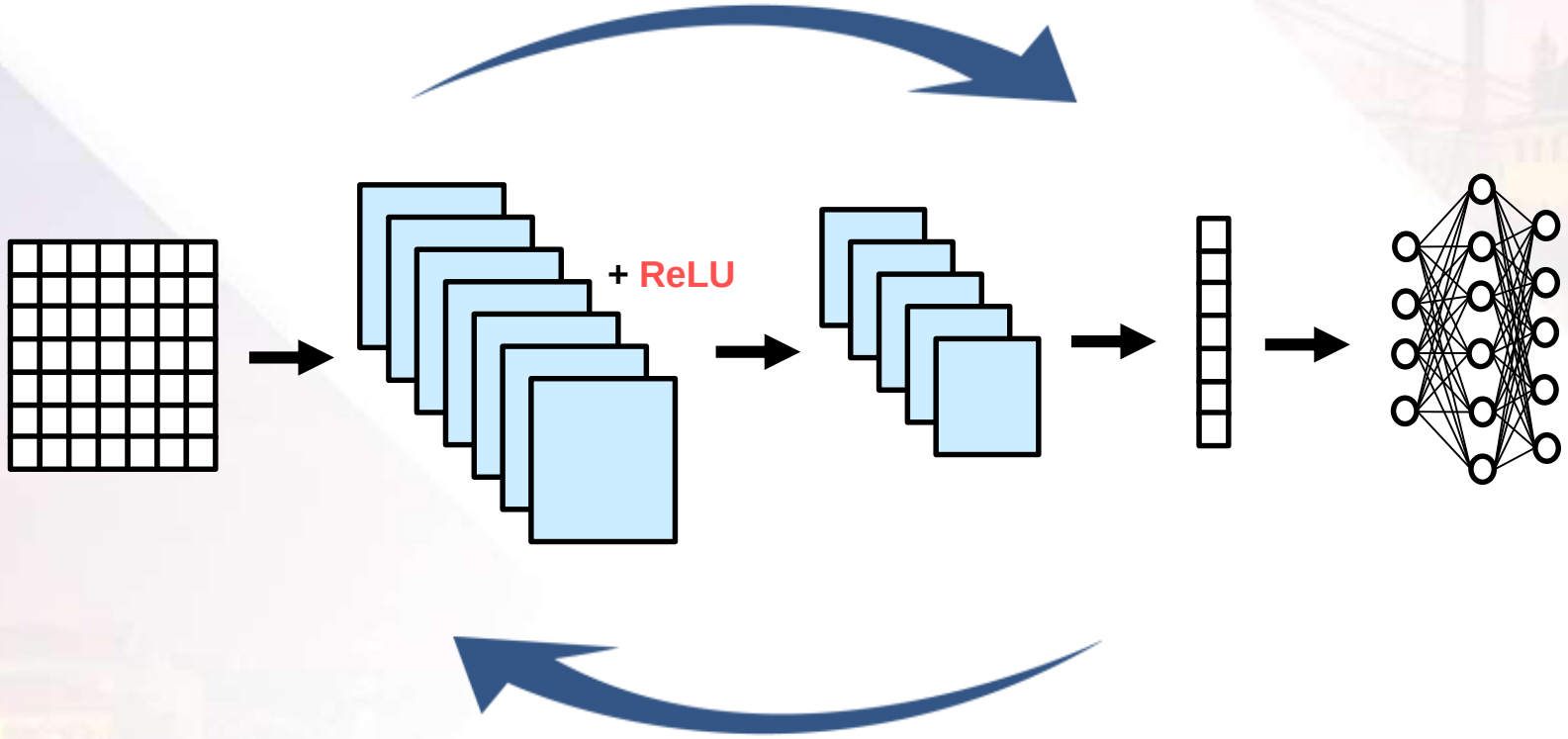
| | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 | Class 9 | Class 10 | Class 11 | Class 12 | Class 13 | Class 14 | Class 15 | Class 16 | Class 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class 1 | 98 | 42 | 61 | 49 | 23 | 17 | 0 | 146 | 0 | 65 | 3 | 12 | 9 | 77 | 11 | 29 | 9 |
| Class 2 | 59 | 3132 | 153 | 69 | 1042 | 750 | 0 | 987 | 0 | 173 | 9 | 193 | 1 | 42 | 249 | 3 | 78 |
| Class 3 | 0 | 50 | 845 | 0 | 9 | 90 | 0 | 343 | 47 | 13 | 0 | 0 | 0 | 158 | 97 | 0 | 0 |
| Class 4 | 7 | 240 | 9 | 1187 | 34 | 0 | 0 | 22 | 0 | 44 | 0 | 0 | 0 | 0 | 5 | 0 | 6 |
| Class 5 | 2 | 847 | 236 | 111 | 888 | 832 | 0 | 655 | 35 | 8 | 146 | 254 | 76 | 901 | 116 | 88 | 0 |
| Class 6 | 0 | 4 | 11 | 15 | 37 | 4806 | 0 | 67 | 0 | 3 | 5 | 109 | 0 | 223 | 0 | 0 | 0 |
| Class 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Class 8 | 59 | 260 | 72 | 204 | 43 | 109 | 0 | 7228 | 13 | 230 | 9 | 33 | 0 | 1 | 27 | 32 | 4 |
| Class 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 691 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Class 10 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 1 | 0 | 293 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Class 11 | 0 | 1 | 2 | 0 | 0 | 56 | 0 | 1 | 7 | 0 | 1900 | 865 | 125 | 395 | 0 | 0 | 0 |
| Class 12 | 0 | 0 | 6 | 4 | 0 | 311 | 0 | 1 | 23 | 0 | 44 | 1972 | 30 | 947 | 0 | 0 | 0 |
| Class 13 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 1 | 763 | 0 | 0 | 0 | 0 |
| Class 14 | 0 | 31 | 33 | 98 | 134 | 743 | 0 | 740 | 240 | 23 | 728 | 876 | 278 | 9753 | 111 | 63 | 3 |
| Class 15 | 10 | 4 | 7 | 5 | 0 | 289 | 0 | 626 | 3 | 9 | 0 | 0 | 0 | 132 | 479 | 4 | 0 |
| Class 16 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 162 | 0 |
| Class 17 | 7 | 281 | 12 | 528 | 45 | 139 | 0 | 362 | 13 | 59 | 86 | 198 | 2 | 200 | 9 | 10 | 4258 |

```
require 'mattorch'
require 'cunn'
require 'nn'
require 'optim'
require 'image'
require 'xlua'
local c = require 'trepl.colorize'
opt = lapp[[
   -b,--batchSize             (default 100)          batch size
   -r,--learningRate          (default 0.2)        learning rate
   --learningRateDecay        (default 1e-7)      learning rate decay
   --weightDecay              (default 0.0005)      weightDecay
   -m,--momentum              (default 0.9)         momentum
   --epoch_step               (default 3)          epoch step
    --model                   (default ConvNet)     model name
]]

classes = { '1', '2', '3', '4', '5', '6', '7', '8', '9', '10', '11', '12', '13', '14', '15', '16', '17'}

model=dofile('models/'..opt.model..'.lua')

model:cuda()

parameters,gradParameters = model:getParameters()


criterion = nn.CrossEntropyCriterion():cuda()

confusion = optim.ConfusionMatrix(#classes)

…
```

`Deep Learning



# `Convolutional Neural Networks



# Model steps for CNN type

nn.SpatialConvolutionMM
nn.Tanh
nn.SpatialMaxPooling
nn.SpatialConvolutionMM
nn.Tanh
nn.SpatialMaxPooling
nn.Reshape
nn.Linear
nn.Tanh
nn.Linear

Thank you