Joined-up planetary information: in the cloud and on devices.

Matthew J. Smith (Matthew.Smith@Microsoft.com, @JungleTeuch)

http://research.microsoft.com/science/tools
www.fetchclimate.org

Planetary Intelligence

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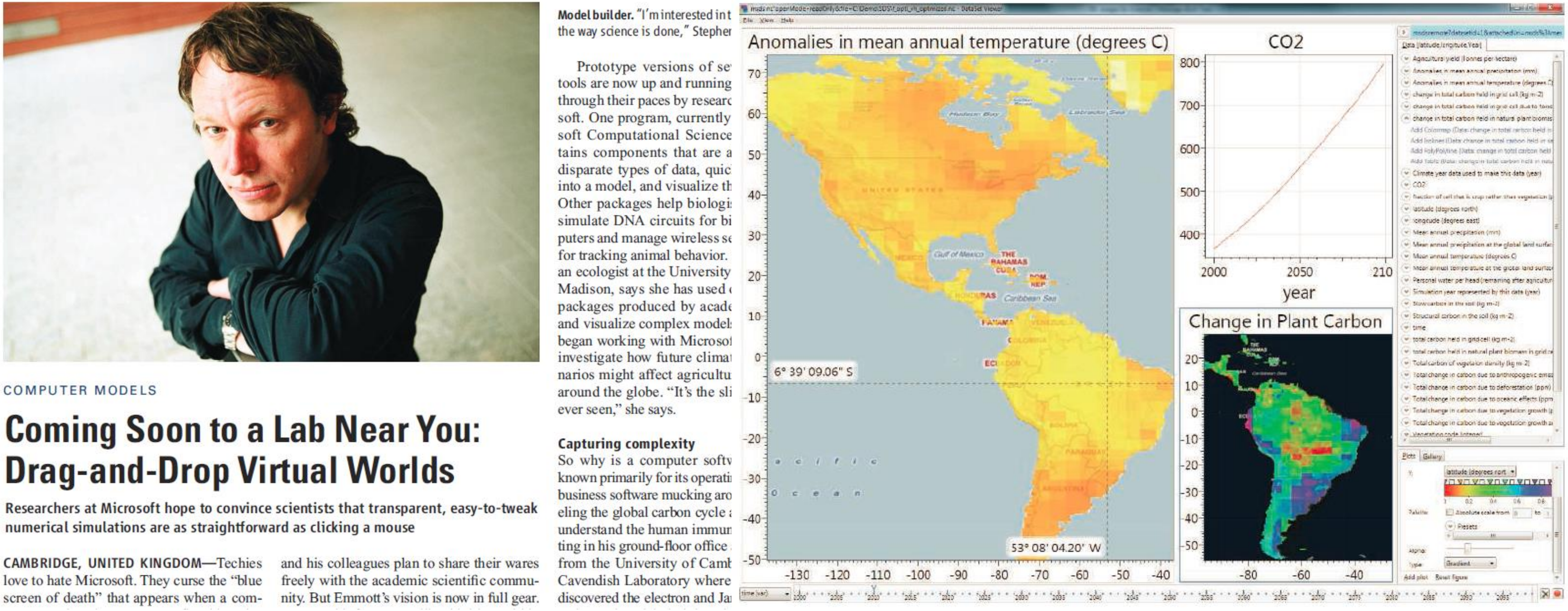

COMPUTER MODELS

Coming Soon to a Lab Near You: Drag-and-Drop Virtual Worlds

Researchers at Microsoft hope to convince scientists that transparent, easy-to-tweak numerical simulations are as straightforward as clicking a mouse

CAMBRIDGE, UNITED KINGDOM—Techies love to hate Microsoft. They curse the "blue screen of death" that appears when a com-

and his colleagues plan to share their wares freely with the academic scientific community. But Emmott's vision is now in full gear.

Model builder. "I'm interested in t
the way science is done," Stepher

Prototype versions of se
tools are now up and running
through their paces by researc
soft. One program, currently
soft Computational Science
tains components that are a
disparate types of data, quic
into a model, and visualize th
Other packages help biologi
simulate DNA circuits for bi
puters and manage wireless se
for tracking animal behavior.
an ecologist at the University
Madison, says she has used
packages produced by acade
and visualize complex model
began working with Microso
investigate how future clima
narios might affect agricultu
around the globe. "It's the sli
ever seen," she says.

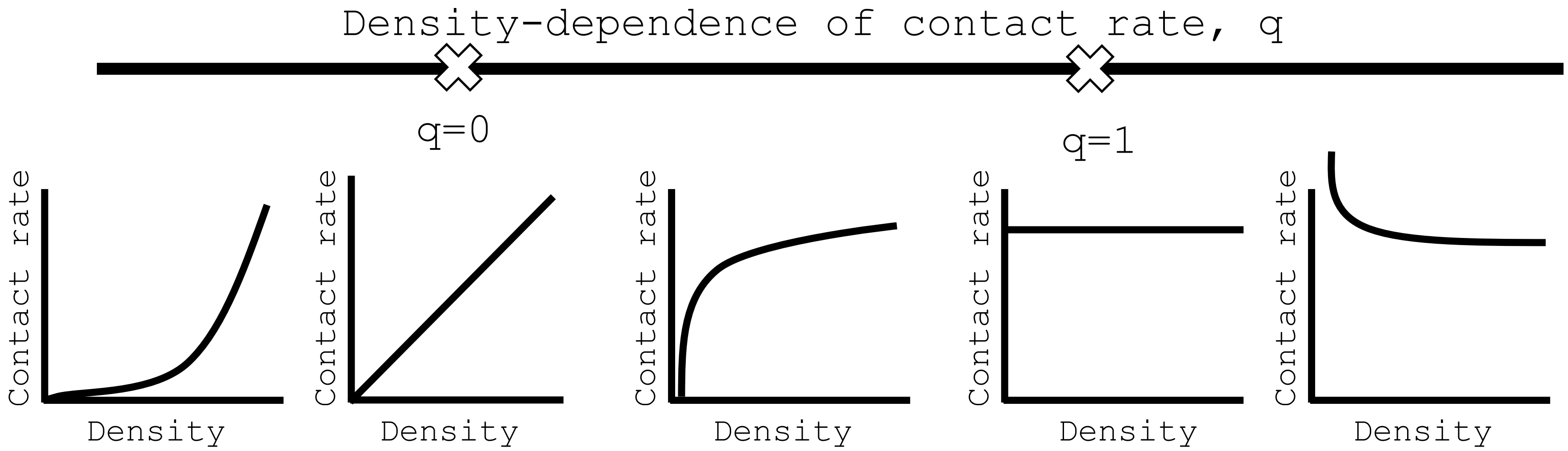
Capturing complexity
So why is a computer softw
known primarily for its operati
business software mucking aro
eling the global carbon cycle
understand the human immur
ting in his ground-floor office
from the University of Camb
Cavendish Laboratory where
discovered the electron and Ja

Model builder. "I'm interested in tools that change the way science is done," Stephen Emmott says.

But the Cambridge team's new software languages and models could bring such work—which now requires heavy lifting by highly specialized labs—within reach of a far broader audience. If so, their stock among scientists could be on the rise.

"The promise of the cloud is that every individual and organization has unlimited access to information."

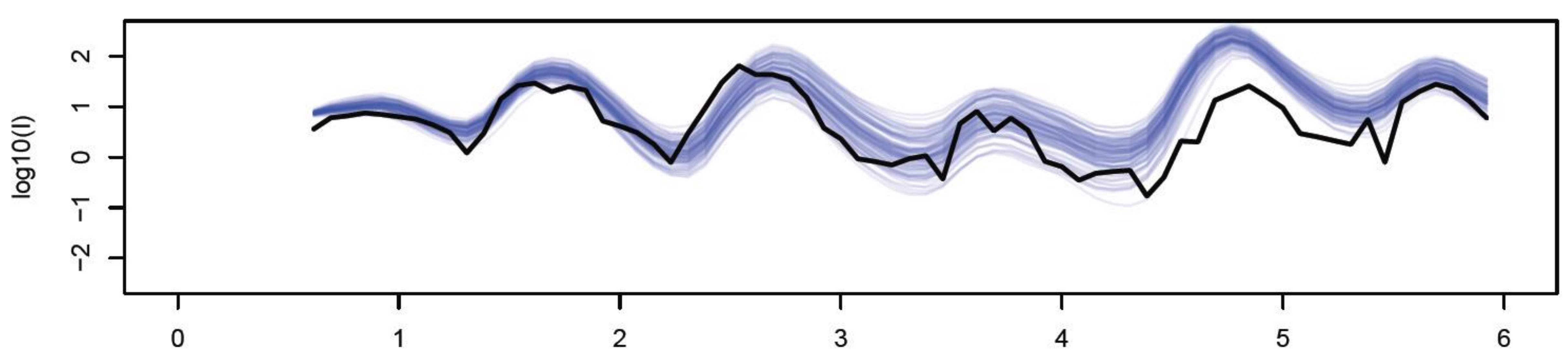
Satya Nadella, CEO of Microsoft

$$c = \kappa\left[\frac{N(t)^{(1-q)}}{A}\right]$$

$$\text{Infection rate} = \kappa\left[\frac{N(t)^{(1-q)}}{A}\right]\upsilon S(t)\left[\frac{I(t)}{N(t)}\right] = \frac{\beta_{qD}S(t)I(t)}{N(t)^q} = \frac{\beta K^q S(t)I(t)}{N(t)^q}$$

$$\frac{dI(t)}{dt} = \frac{\beta K^q S(t)I(t)}{N(t)^q} - M(1 + \alpha\sin(2\pi(t-\Delta)))I(t)$$


log10(I)
2
1
0
−1
−2
0
1
2
3
4
5
6

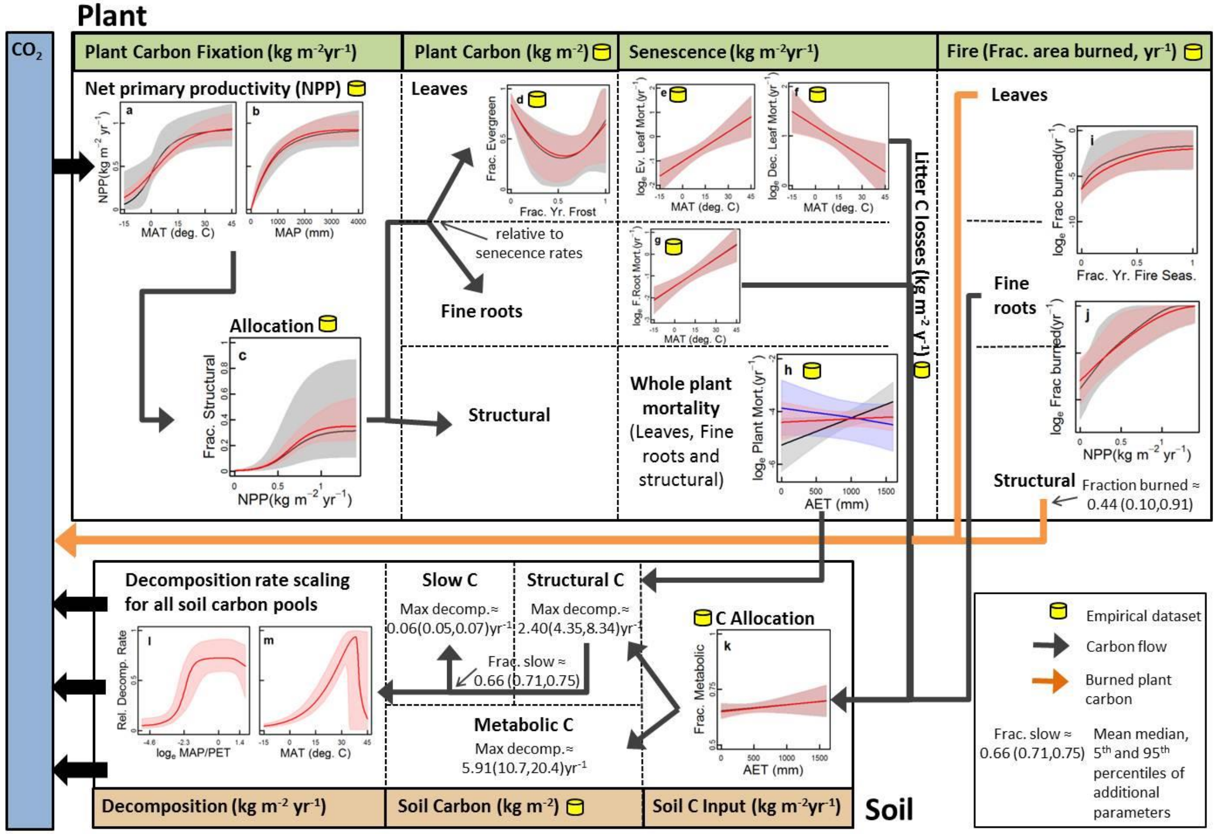
Biogeosciences, 10, 583–606, 2013
www.biogeosciences.net/10/583/2013/
doi:10.5194/bg-10-583-2013

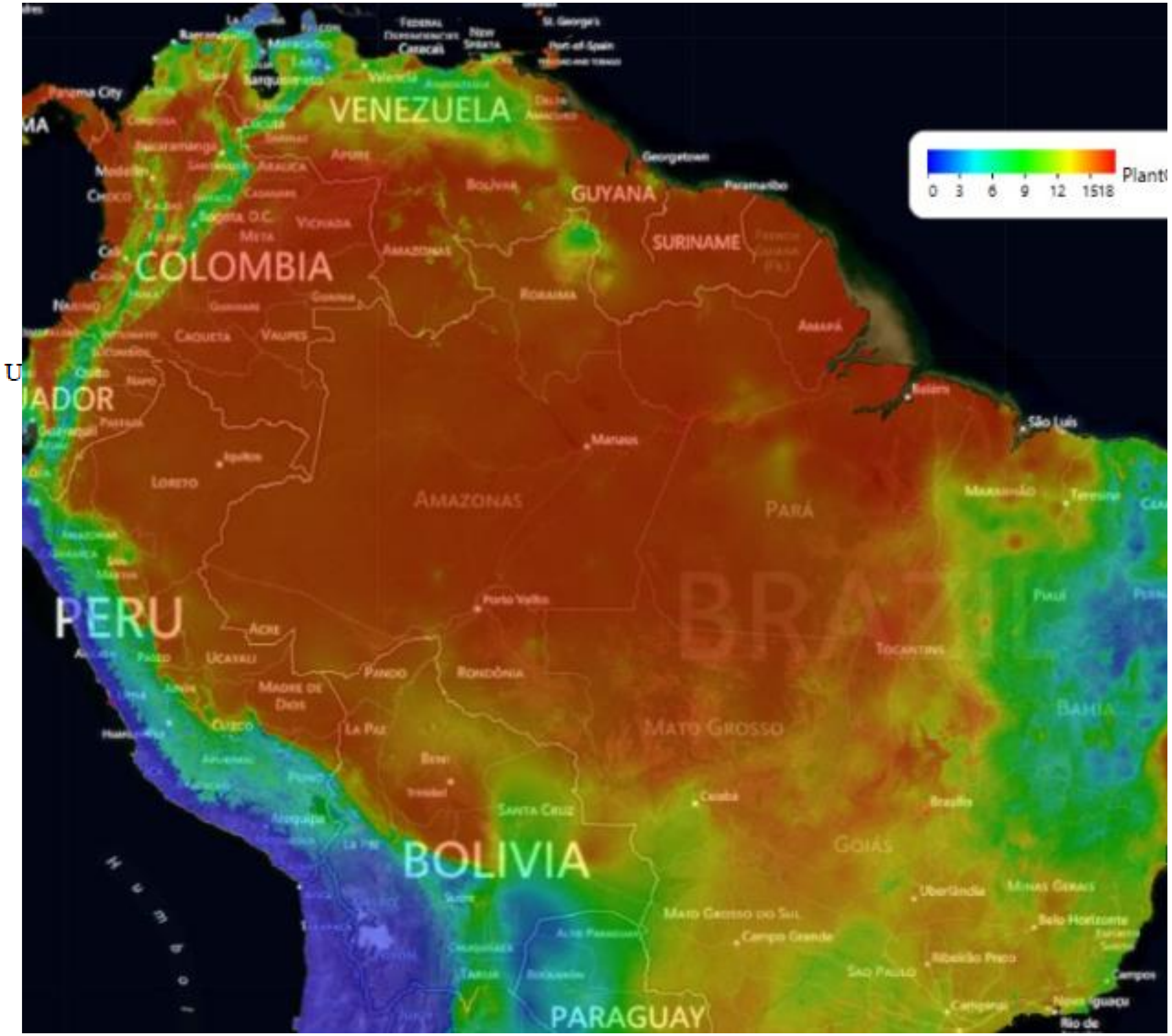
Biogeosciences

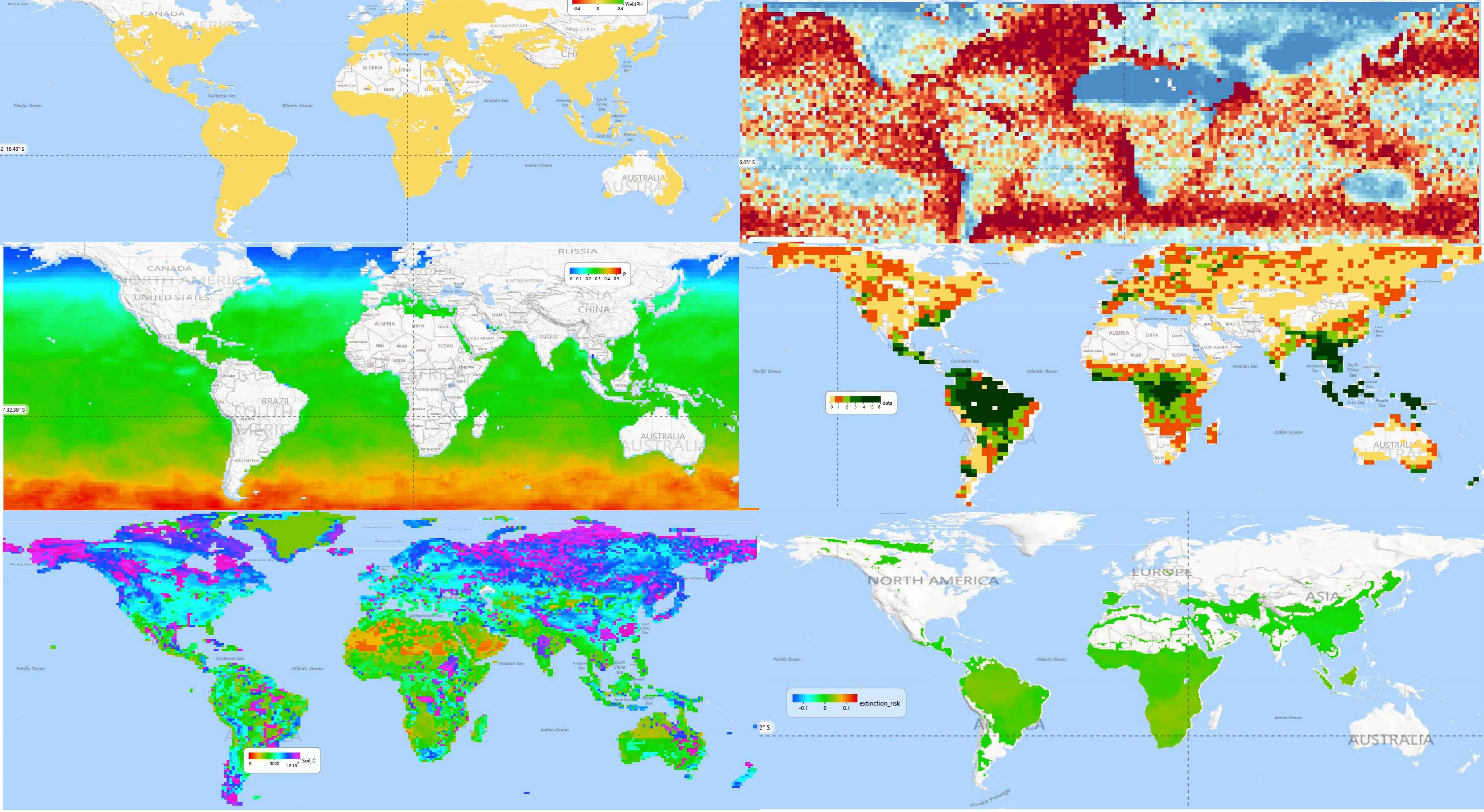
The climate dependence of the terrestrial carbon cycle, including parameter and structural uncertainties

M. J. Smith, D. W. Purves, M. C. Vanderwel, V. Lyutsarev, and S. Emmott

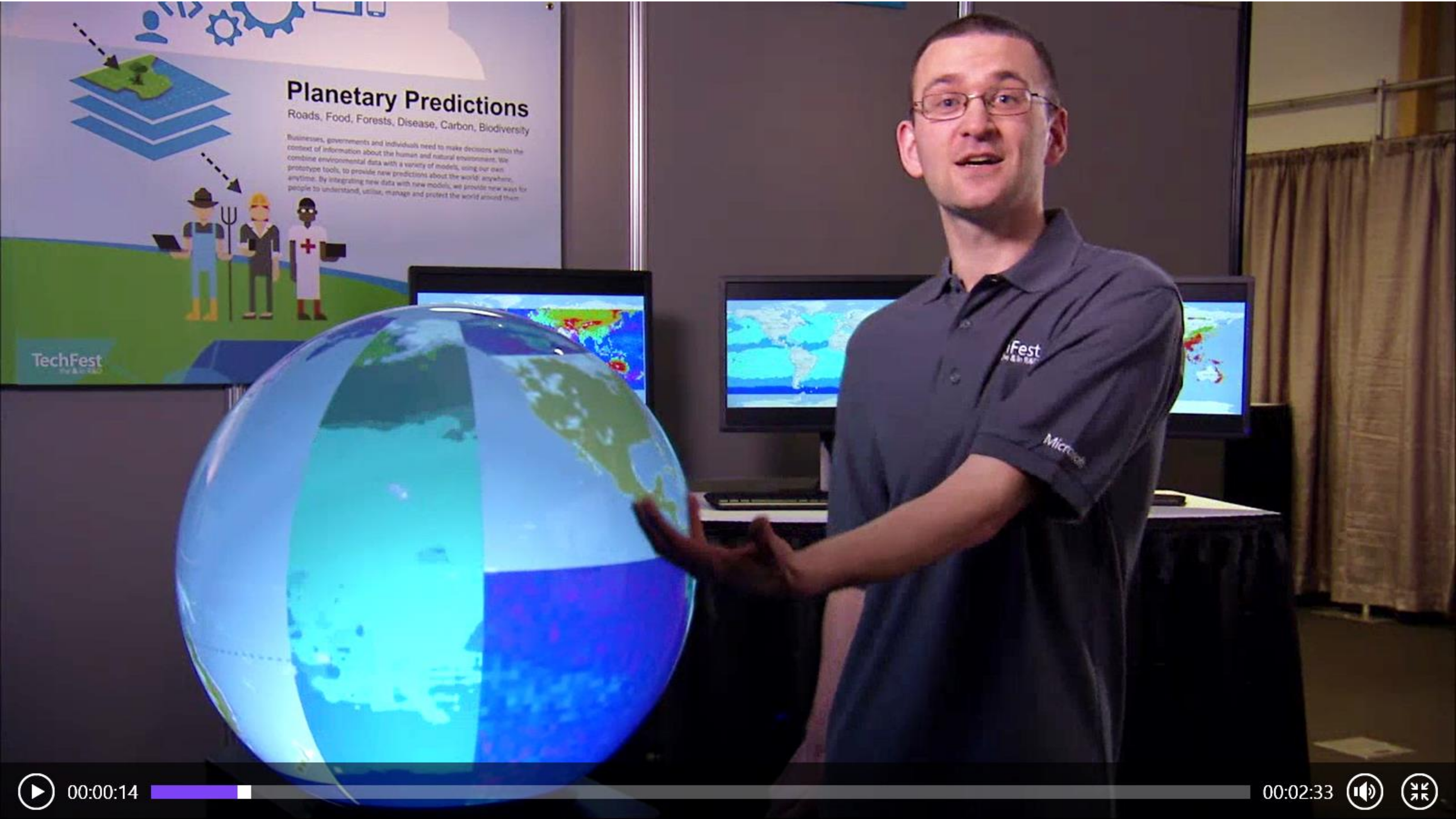
Computational Science Laboratory, Microsoft Research Cambridge, 21 Station Road, Cambridge, CB1 2FB, U



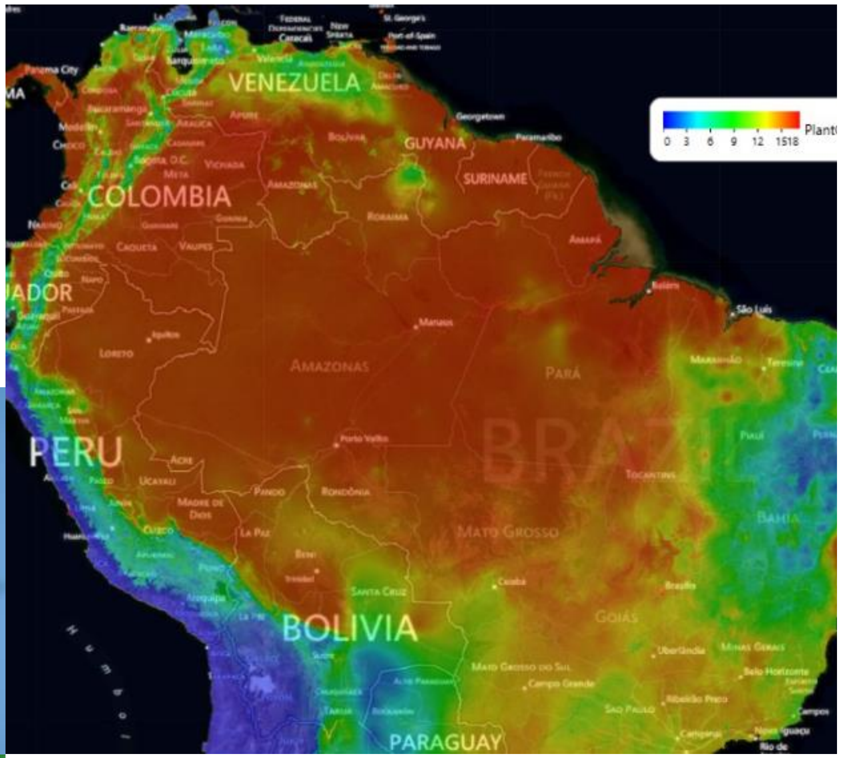




-0.4 0 0.4 YieldPH
0 0.1 0.2 0.3 0.4 0.5 p
0 1 2 3 4 5 6 data
0 9000 1.8·10⁴ Soil_C
-0.1 0 0.1 extinction_risk


Planetary Predictions
Roads, Food, Forests, Disease, Carbon, Biodiversity
TechFest
00:00:14
00:02:33


12
GTPA010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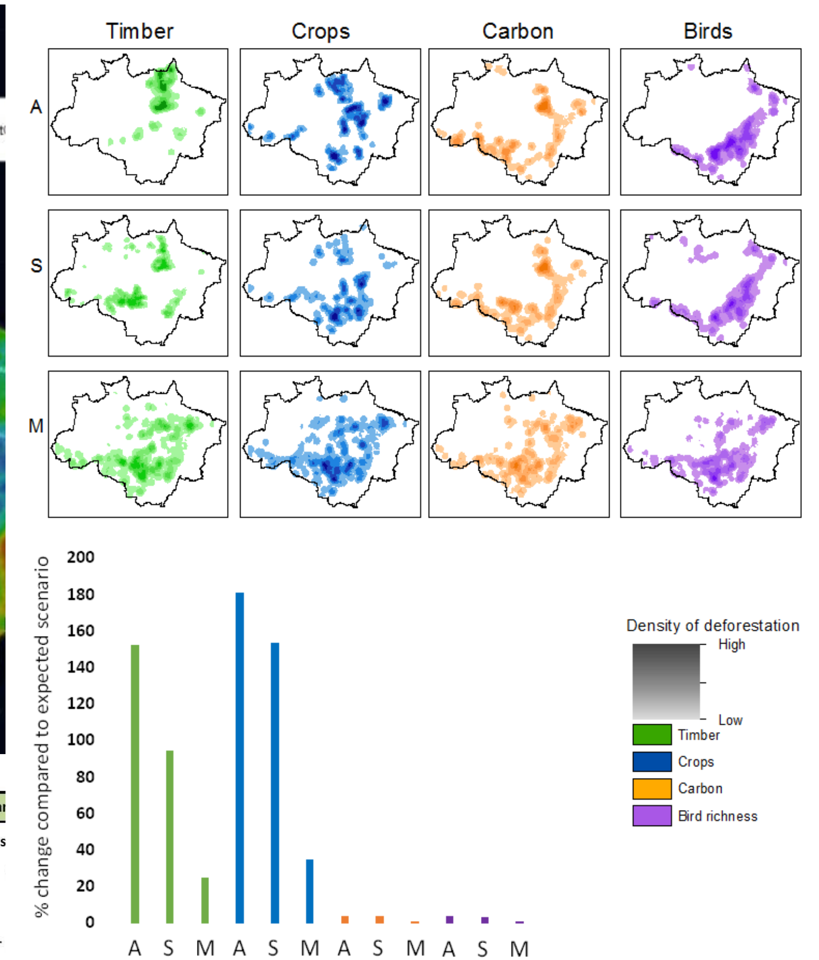
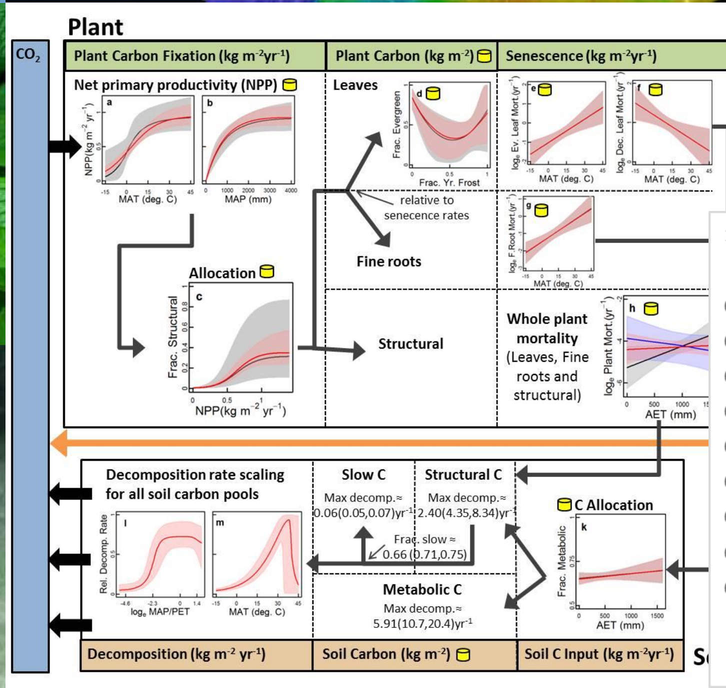
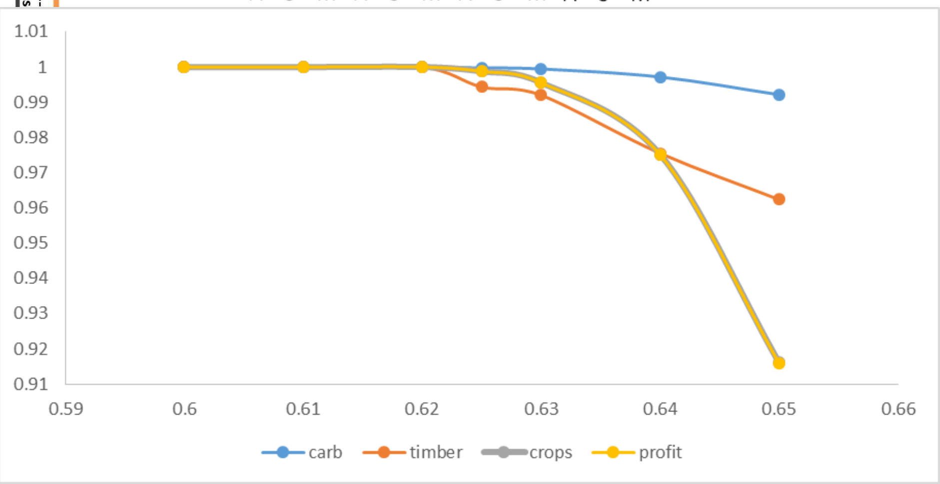
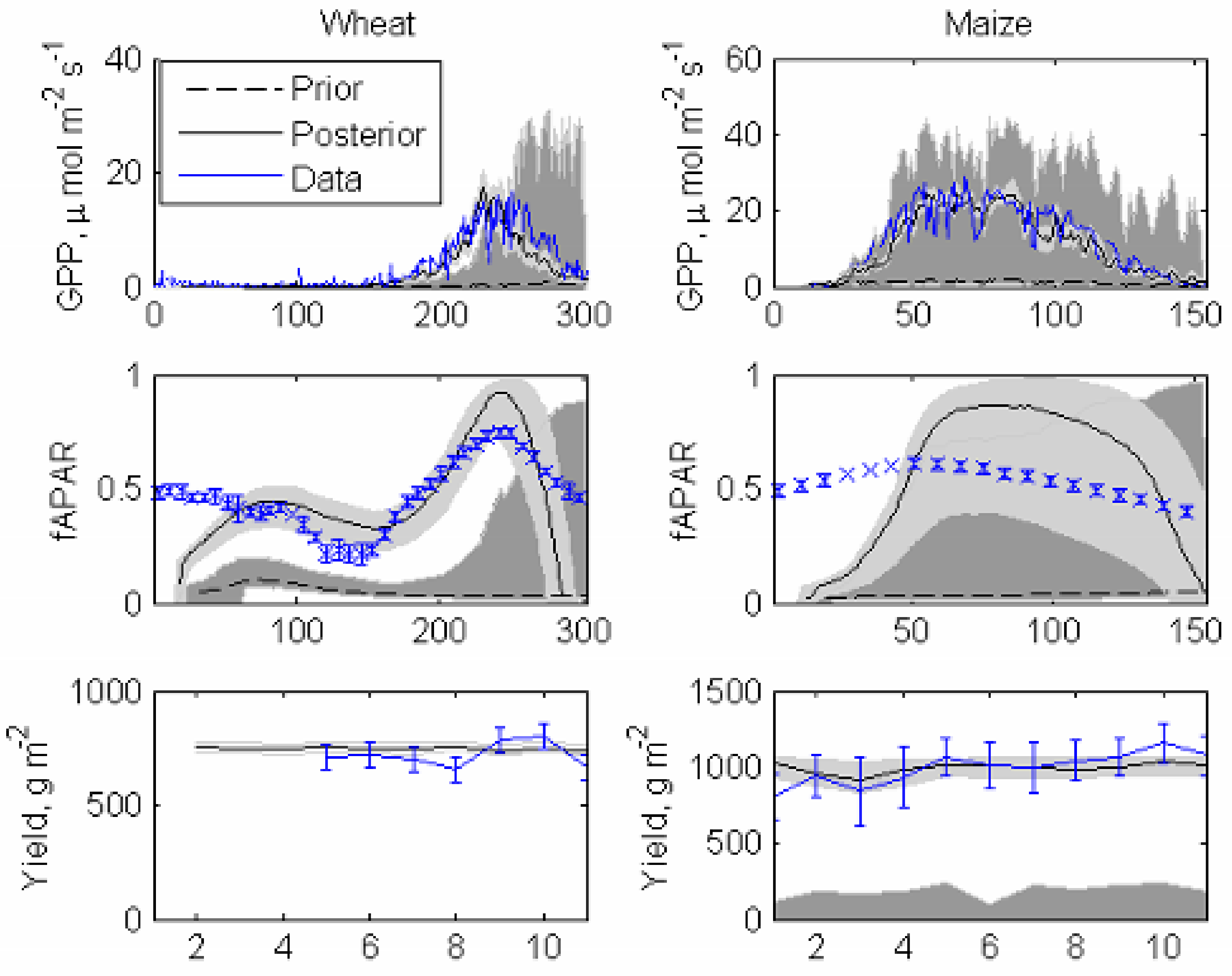
GUYANA
SURINAME
COLOMBIA
PERU
BRAZIL
BOLIVIA
PARAGUAY
0 3 6 9 12 1518


Timber
Crops
Carbon
Birds
A
S
M
% change compared to expected scenario
Density of deforestation
High
Low
Timber
Crops
Carbon
Bird richness


Plant
CO_2
Plant Carbon Fixation (kg m⁻²yr⁻¹)
Plant Carbon (kg m⁻²)
Senescence (kg m⁻²yr⁻¹)
Net primary productivity (NPP)
Leaves
Allocation
relative to senecence rates
Fine roots
Structural
Whole plant mortality (Leaves, Fine roots and structural)
Litter C loss
Decomposition rate scaling for all soil carbon pools
Slow C
Structural C
Metabolic C
C Allocation
Decomposition (kg m⁻² yr⁻¹)
Soil Carbon (kg m⁻²)
Soil C Input (kg m⁻²yr⁻¹)

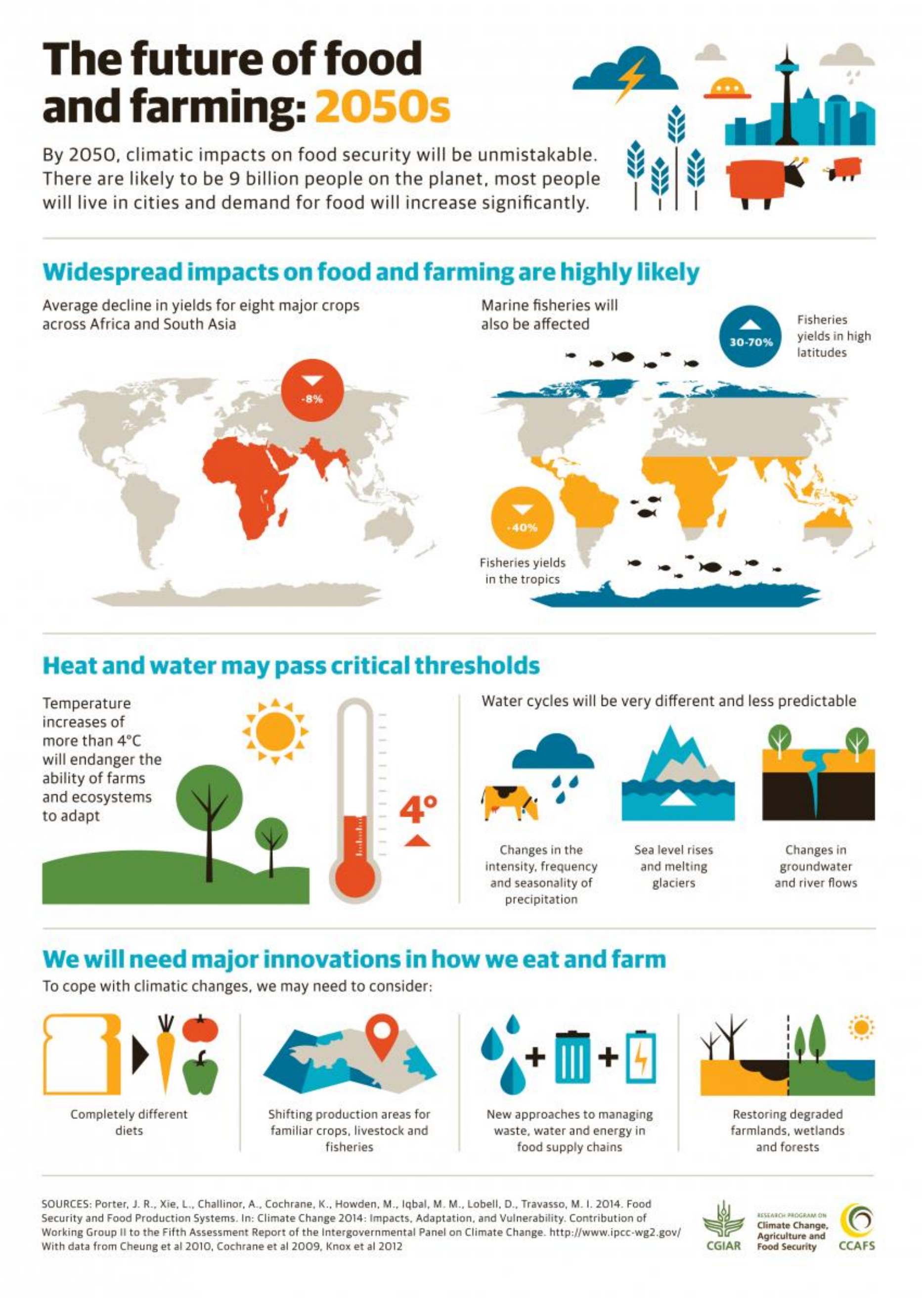

carb
timber
crops
profit



<- carbon flux
Eddy covariance data

<- greenness
MODIS – MOD15a product

<- county and
country level yield



The future of food and farming: 2050s
By 2050, climatic impacts on food security will be unmistakable. There are likely to be 9 billion people on the planet, most people will live in cities and demand for food will increase significantly.
Widespread impacts on food and farming are highly likely
Average decline in yields for eight major crops across Africa and South Asia
-8%
Marine fisheries will also be affected
30-70%
Fisheries yields in high latitudes
-40%
Fisheries yields in the tropics
Heat and water may pass critical thresholds
Temperature increases of more than 4°C will endanger the ability of farms and ecosystems to adapt
4°
Water cycles will be very different and less predictable
Changes in the intensity, frequency and seasonality of precipitation
Sea level rises and melting glaciers
Changes in groundwater and river flows
We will need major innovations in how we eat and farm
To cope with climatic changes, we may need to consider:
Completely different diets
Shifting production areas for familiar crops, livestock and fisheries
New approaches to managing waste, water and energy in food supply chains
Restoring degraded farmlands, wetlands and forests
SOURCES: Porter, J. R., Xie, L., Challinor, A., Cochrane, K., Howden, M., Iqbal, M. M., Lobell, D., Travasso, M. I. 2014. Food Security and Food Production Systems. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. http://www.ipcc-wg2.gov/
With data from Cheung et al 2010, Cochrane et al 2009, Knox et al 2012
CGIAR
Research Program on Climate Change, Agriculture and Food Security
CCAFS

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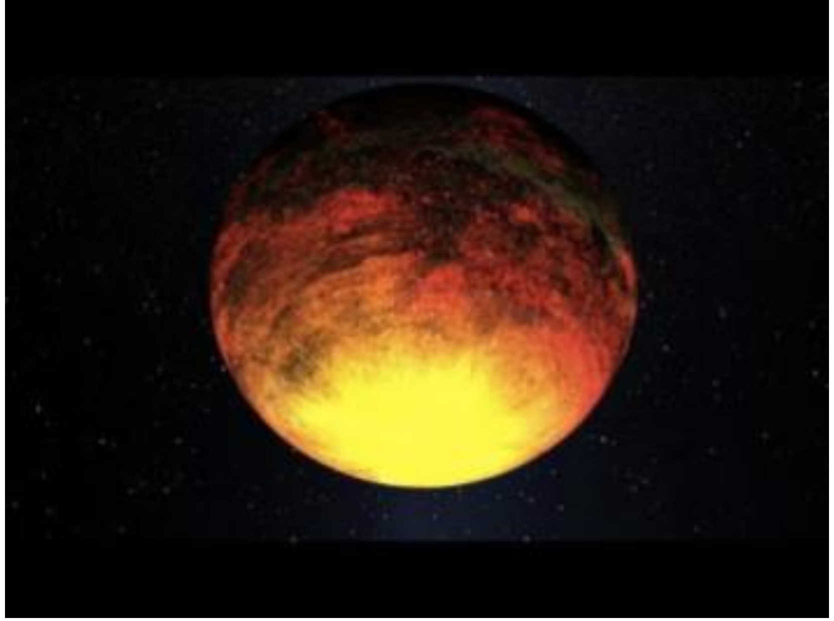
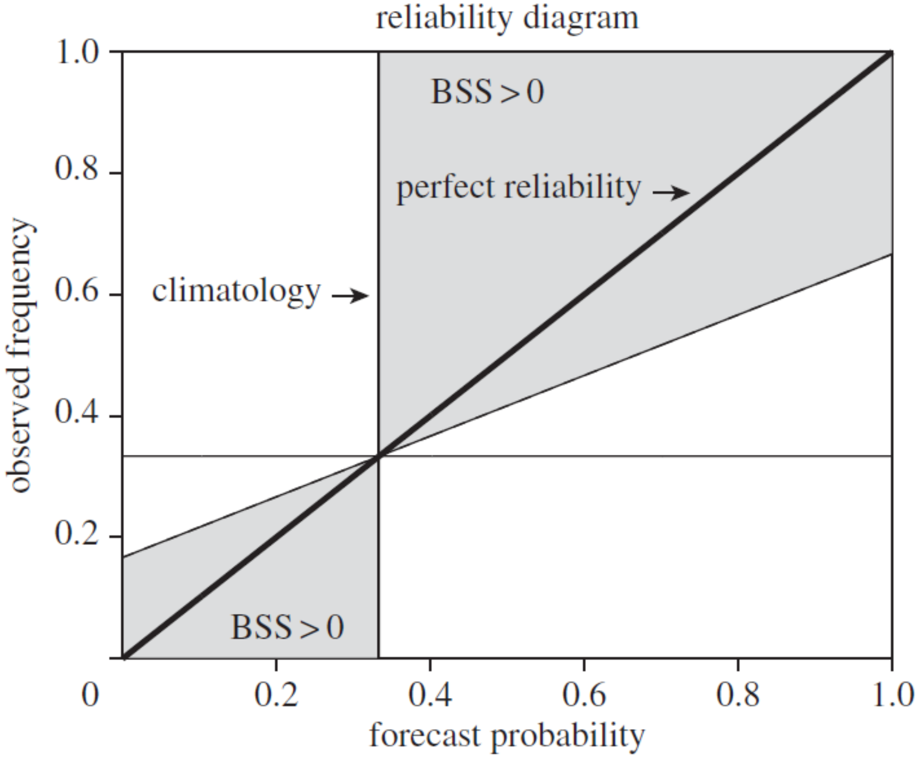
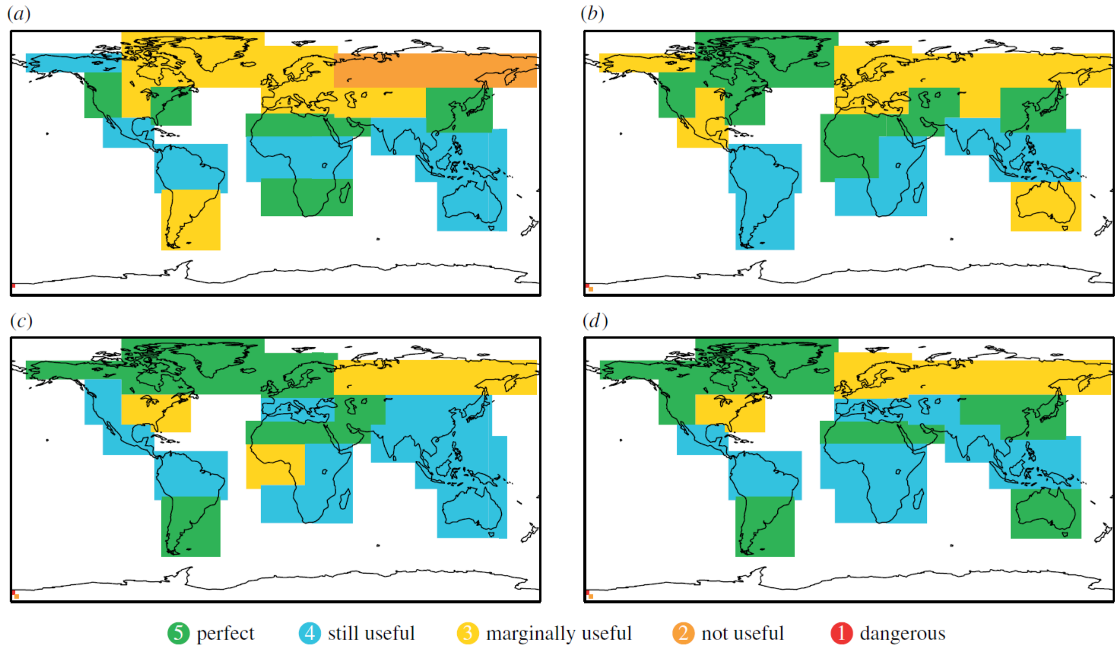
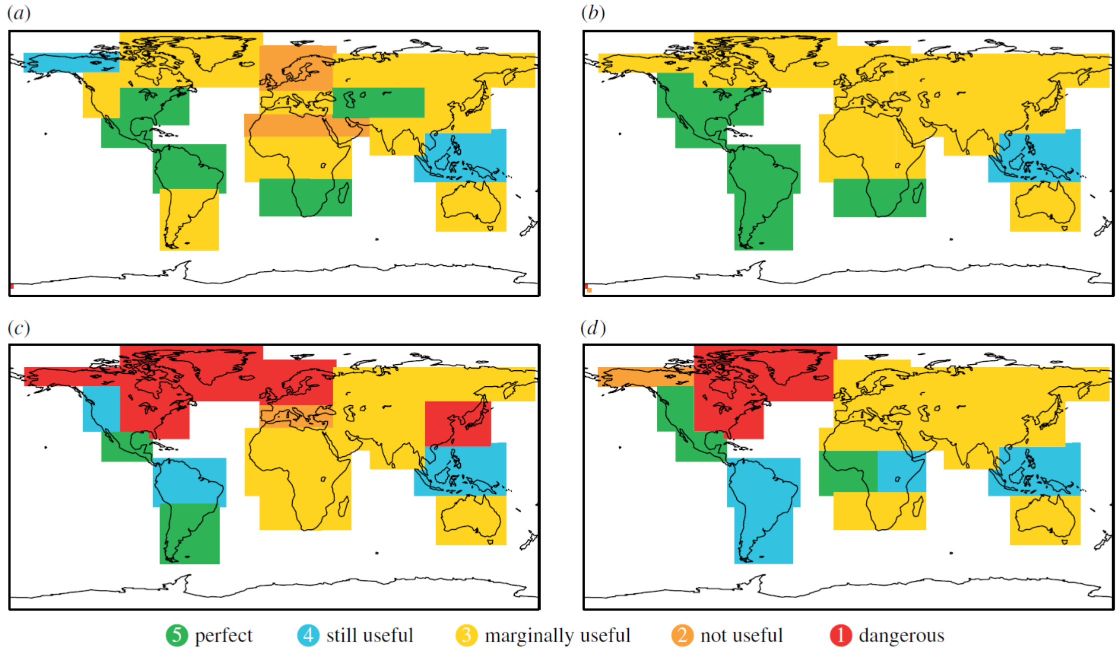






jure 4. Reliability of System 4 seasonal forecasts for 2 m temperature. (*a*) Cold DJF, (*b*) warm DJF, (*c*) cold JJA and (*d*) warm JJA.



jure 5. Reliability of System 4 seasonal forecasts for precipitation. (*a*) Dry DJF, (*b*) wet DJF, (*c*) dry JJA and (*d*) wet JJA.

6
7
8

"The promise of the cloud is that every individual and organization has unlimited access to information."

Satya Nadella, CEO of Microsoft


Select geography
Fetch Climate
NORWAY
SWEDEN
FINLAND
UNITED KINGDOM
IRELAND
DENMARK
GERMANY
POLAND
UKRAINE
FRANCE
SPAIN
PORTUGAL
ITALY
ROMANIA
GREECE
TURKEY
KAZAKHSTAN
UZBEKISTAN
TURKMENISTAN
AFGHANISTAN
PAKISTAN
IRAN
IRAQ
SYRIA
SAUDI ARABIA
OMAN
YEMEN
EGYPT
LIBYA
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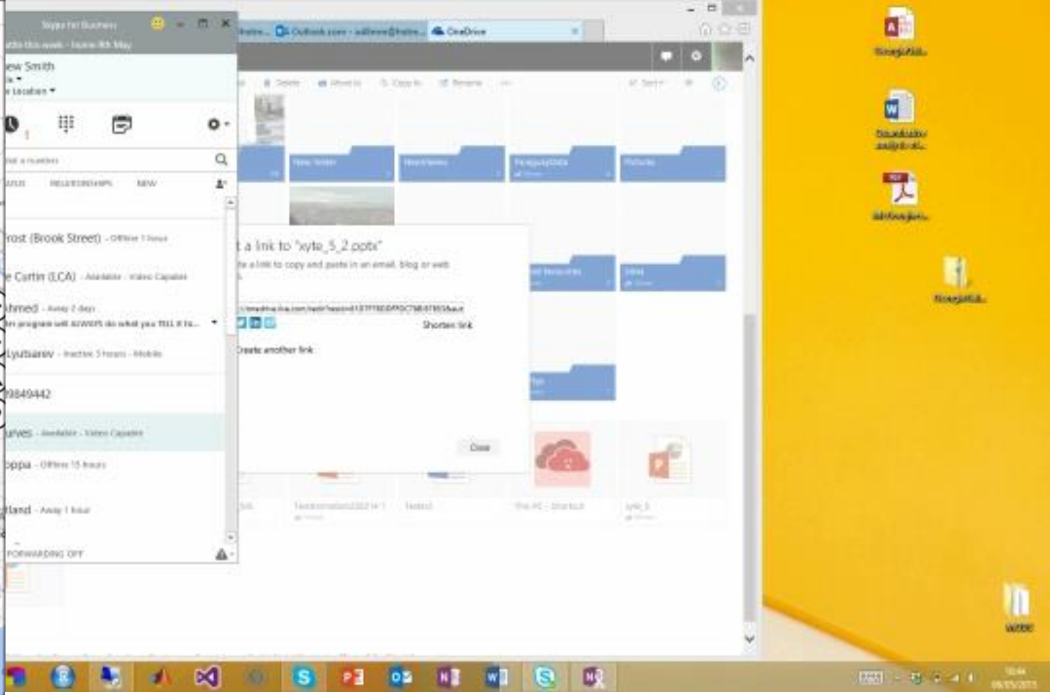
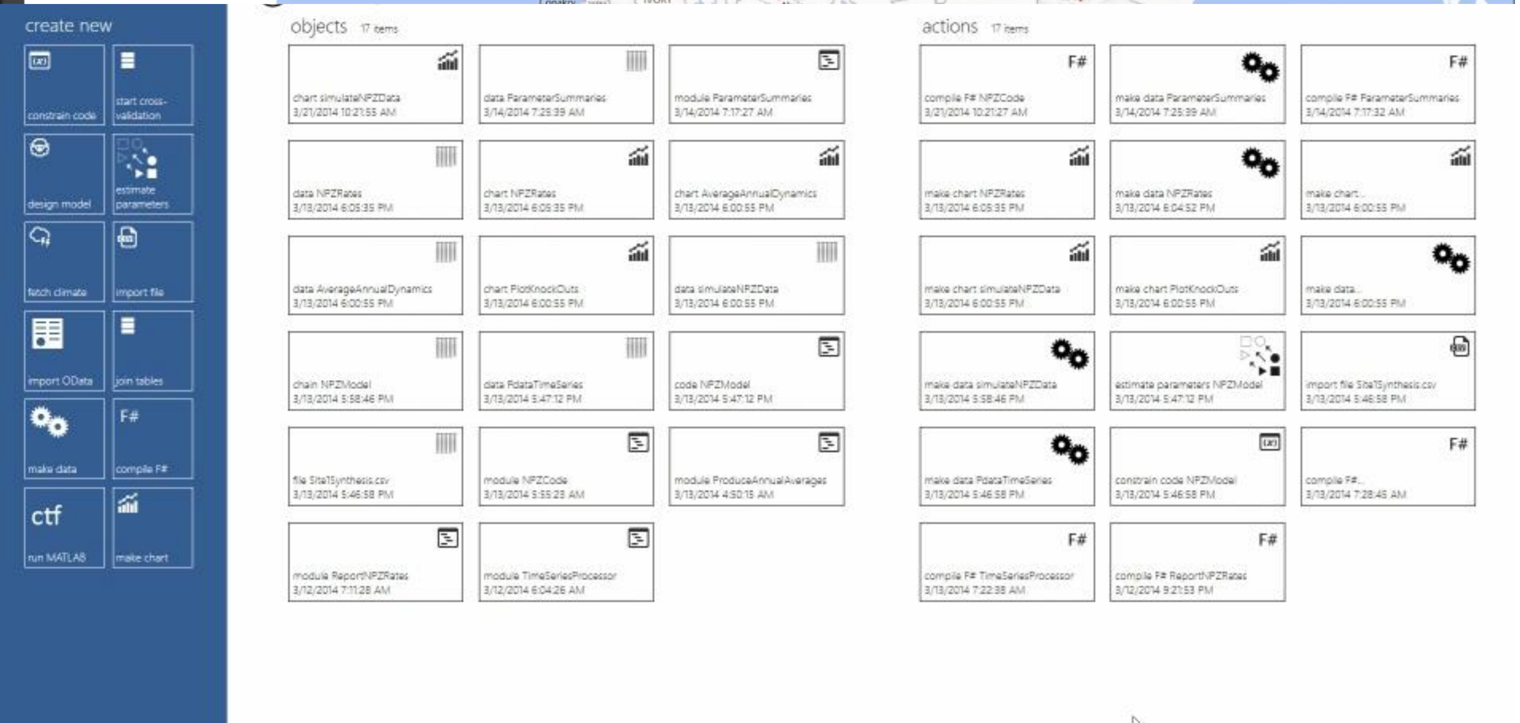
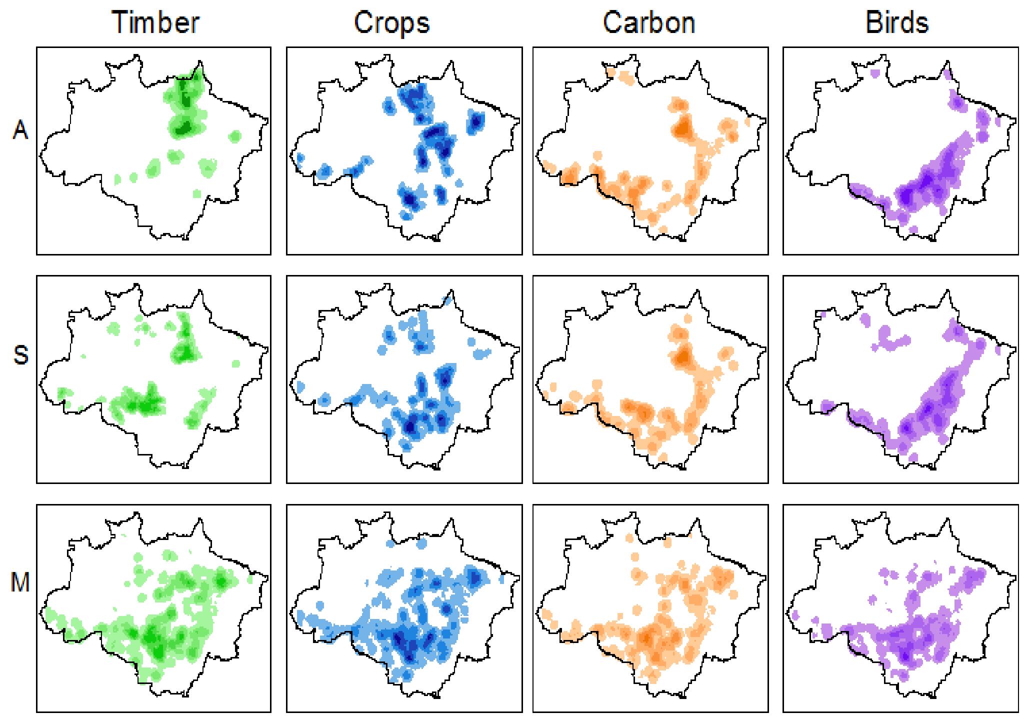
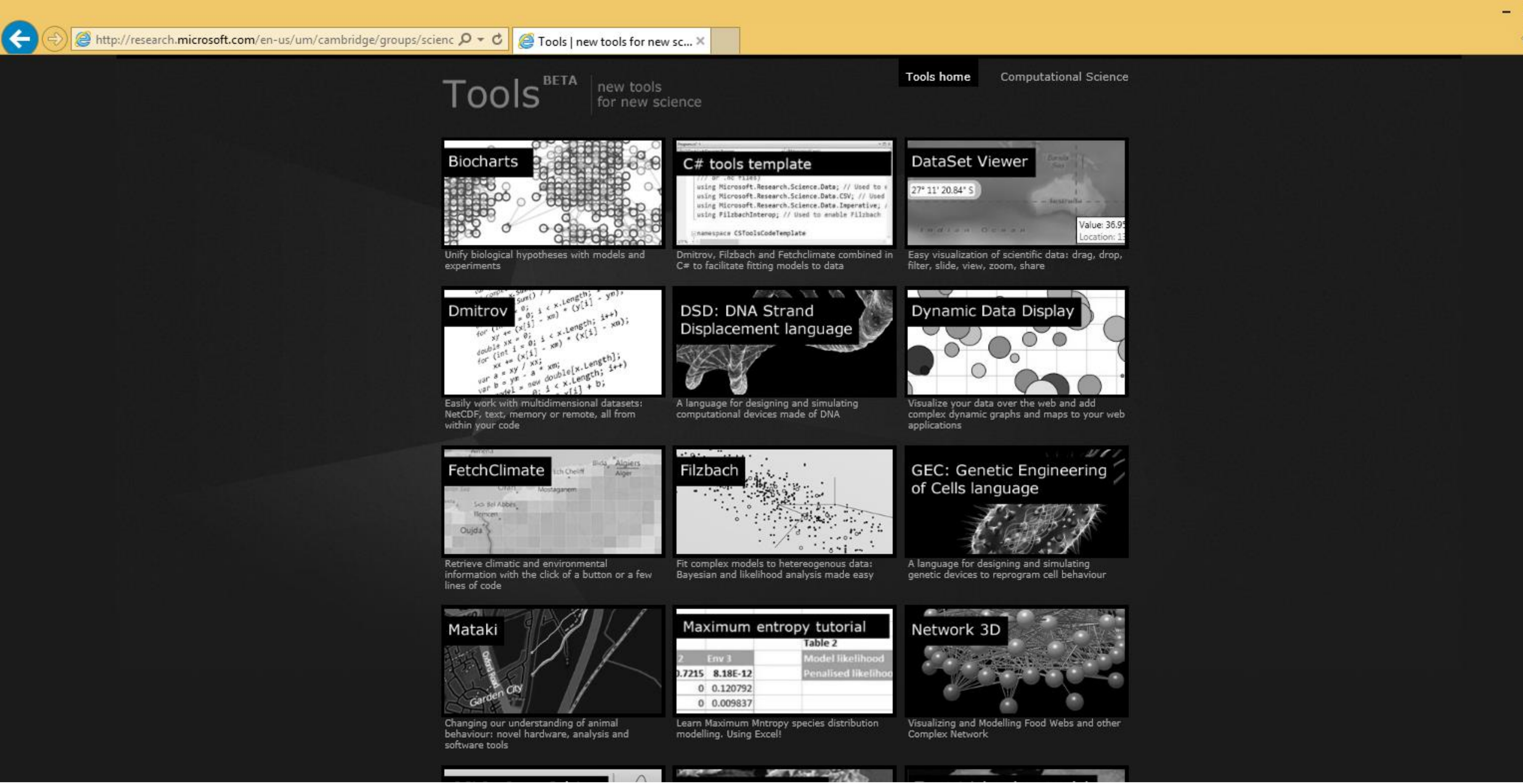
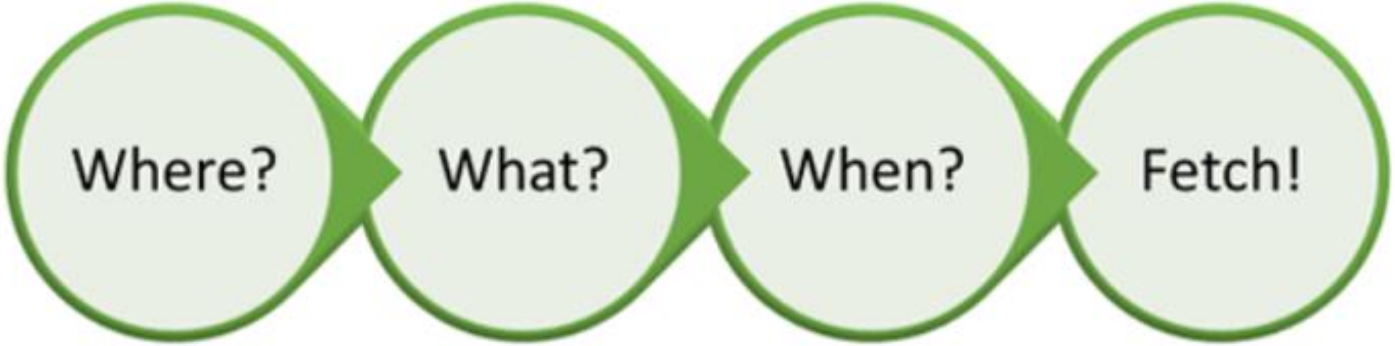
TUNISIA
MAURITANIA
MALI
NIGER
CHAD
SUDAN
NIGERIA
INDIA
Atlantic Ocean
Moscow
Stockholm
London
Paris
Berlin
Warsaw
Rome
Ankara
Tehran
Baghdad
Riyadh
Cairo
Algiers
Black Sea
Caspian Sea
Mediterranean Sea
Arabian Sea
250 miles


create new
constrain code
start cross-validation
design model
estimate parameters
fetch climate
import file
import OData
join tables
make data
compile F#
ctf
run MATLAB
make chart
objects
actions

Timber
Crops
Carbon
Birds
A
S
M



http://research.microsoft.com/science/tools

FetchClimate

Get environmental information in four easy steps



FetchClimate provides ready access to complex geographical data.

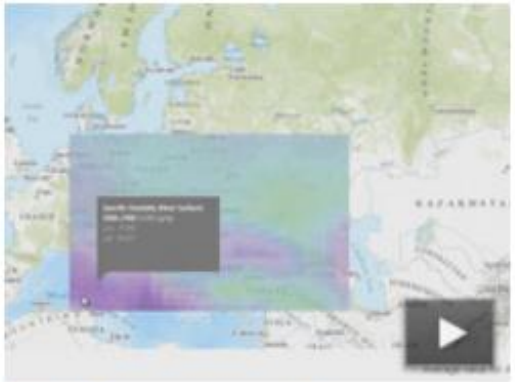
FetchClimate provides ready access to complex geographical information including, but not limited to, climatological information. On accessing the FetchClimate Azure web service, you simply need to perform four steps to find what you are looking for:

1. Draw the location on the Earth via points or grids (Where?)
2. Specify the data of interest (What?)
3. Set the timeframe, including future predictions, and a combination of averages over—or steps through—years, days, and hours (When?)
4. Fetch and view your results.

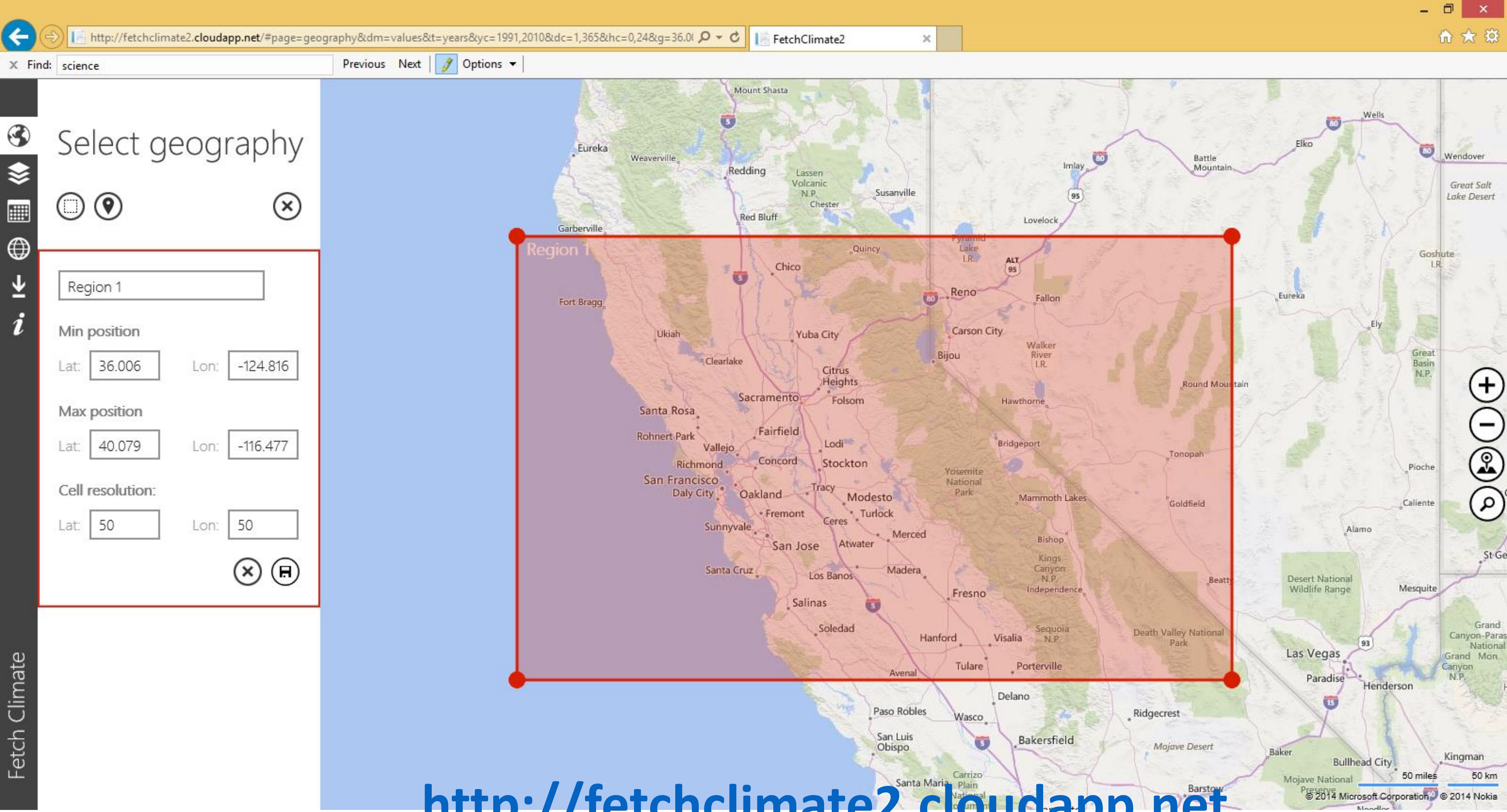
Related links

- Try FetchClimate online
- Download the FetchClimate user guide (PDF, 2.24 MB)
- Download the FetchClimate deployment guide (PDF, 1.16 MB)
- Deploy your own instance of FetchClimate on Microsoft Azure
- Visit the FetchClimate landing page
- Download the FetchClimate client
- Watch the latest tutorial video

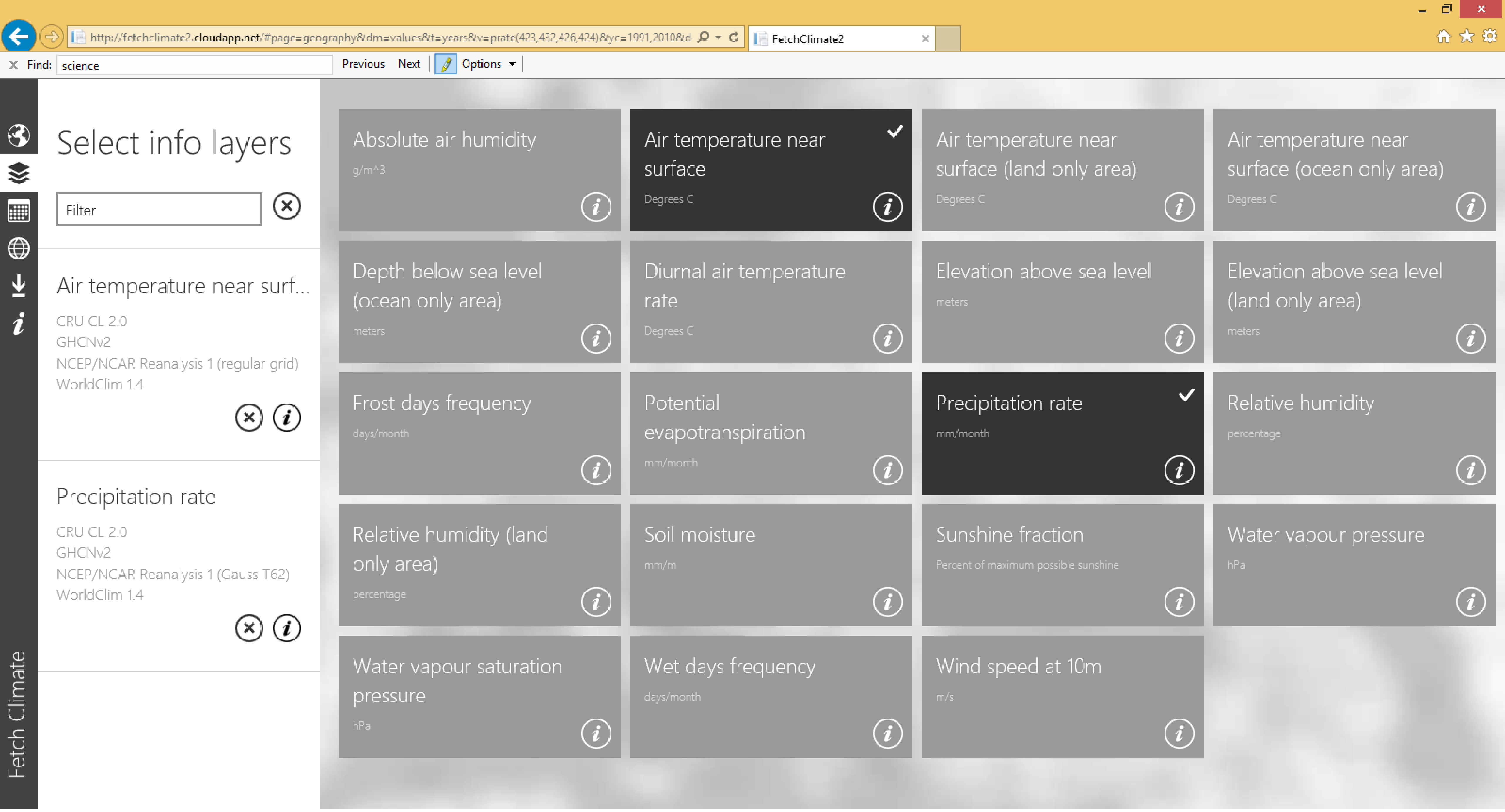
Videos



FetchClimate: a tutorial



http://fetchclimate2.cloudapp.net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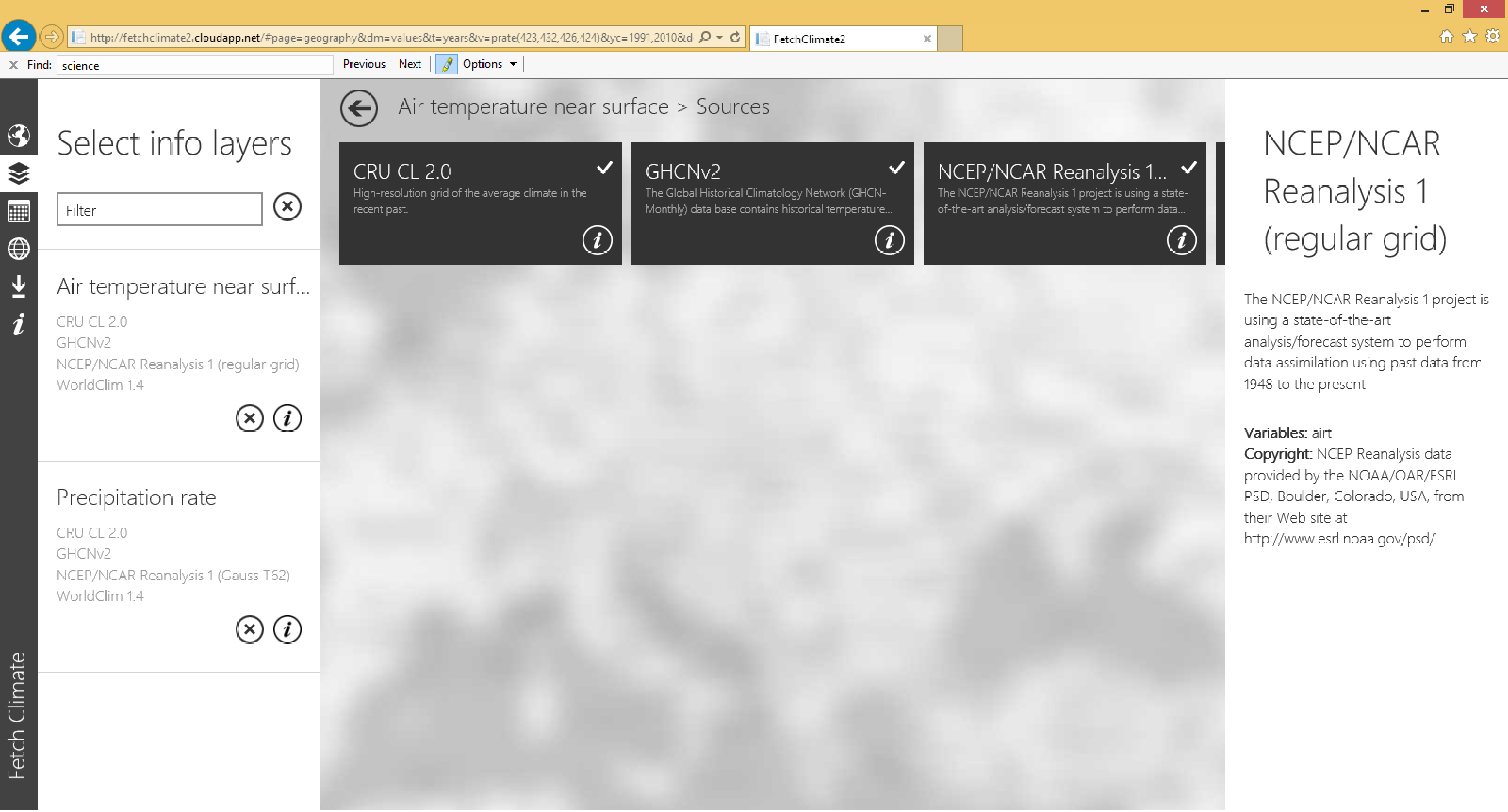
FetchClimate2
Find: science
Previous
Next
Options
Select info layers
Filter
Air temperature near surf...
CRU CL 2.0
GHCNv2
NCEP/NCAR Reanalysis 1 (regular grid)
WorldClim 1.4
Precipitation rate
CRU CL 2.0
GHCNv2
NCEP/NCAR Reanalysis 1 (Gauss T62)
WorldClim 1.4
Fetch Climate
Absolute air humidity
g/m^3
Air temperature near surface
Degrees C
Air temperature near surface (land only area)
Degrees C
Air temperature near surface (ocean only area)
Degrees C
Depth below sea level (ocean only area)
meters
Diurnal air temperature rate
Degrees C
Elevation above sea level
meters
Elevation above sea level (land only area)
meters
Frost days frequency
days/month
Potential evapotranspiration
mm/month
Precipitation rate
mm/month
Relative humidity
percentage
Relative humidity (land only area)
percentage
Soil moisture
mm/m
Sunshine fraction
Percent of maximum possible sunshine
Water vapour pressure
hPa
Water vapour saturation pressure
hPa
Wet days frequency
days/month
Wind speed at 10m
m/s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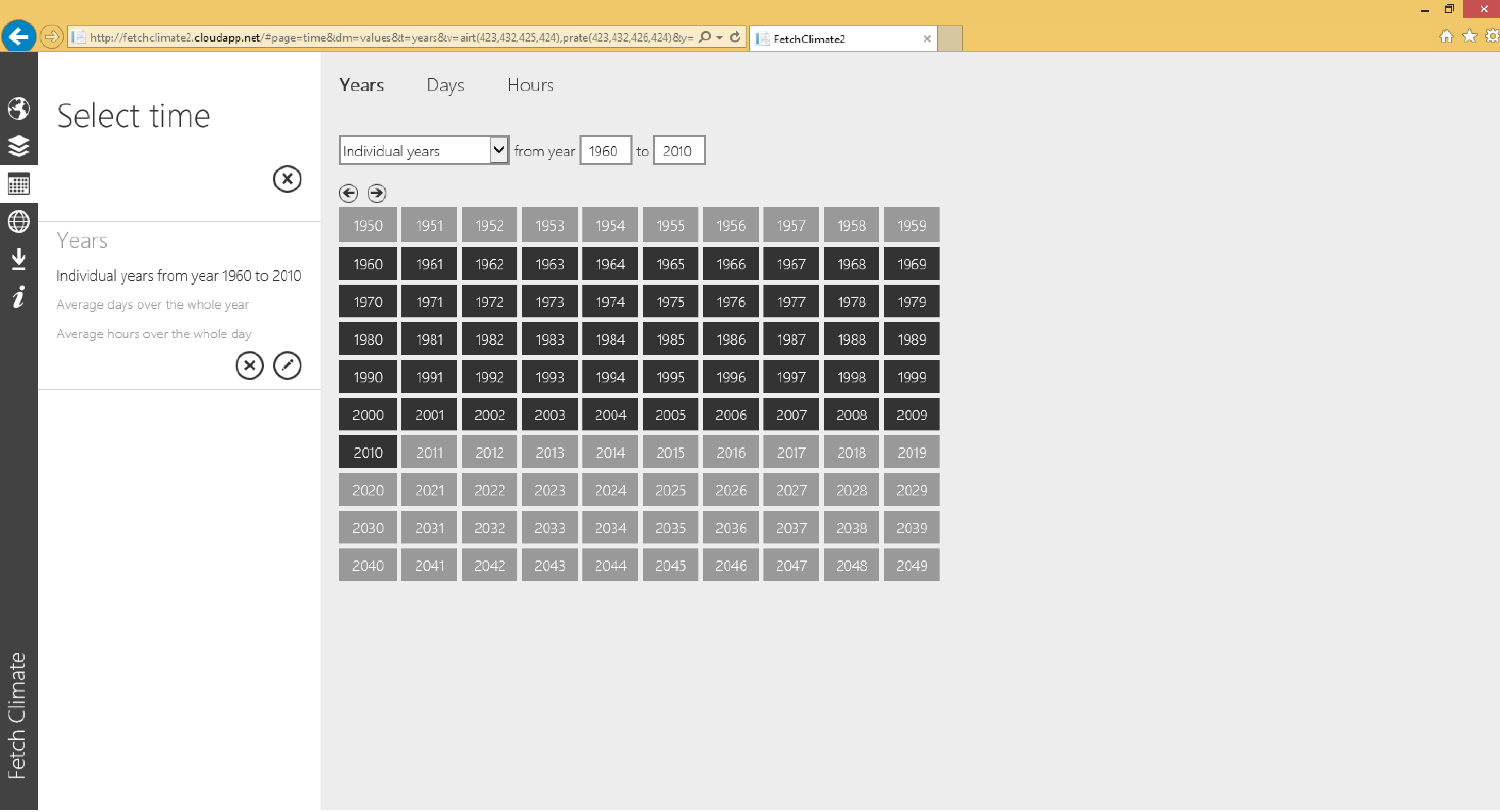
FetchClimate2
Find: science
Previous
Next
Options
Select info layers
Filter
Air temperature near surf...
CRU CL 2.0
GHCNv2
NCEP/NCAR Reanalysis 1 (regular grid)
WorldClim 1.4
Precipitation rate
CRU CL 2.0
GHCNv2
NCEP/NCAR Reanalysis 1 (Gauss T62)
WorldClim 1.4
Fetch Climate
Air temperature near surface > Sources
CRU CL 2.0
High-resolution grid of the average climate in the recent past.
GHCNv2
The Global Historical Climatology Network (GHCN-Monthly) data base contains historical temperature...
NCEP/NCAR Reanalysis 1...
The NCEP/NCAR Reanalysis 1 project is using a state-of-the-art analysis/forecast system to perform data...
NCEP/NCAR Reanalysis 1 (regular grid)
The NCEP/NCAR Reanalysis 1 project is using a state-of-the-art analysis/forecast system to perform data assimilation using past data from 1948 to the present
Variables: airt
Copyright: NCEP Reanalysis data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/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FetchClimate2
Select time
Years
Individual years from year 1960 to 2010
Average days over the whole year
Average hours over the whole day
Fetch Climate
Years
Days
Hours
Individual years
from year
1960
to
2010
1950 1951 1952 1953 1954 1955 1956 1957 1958 1959
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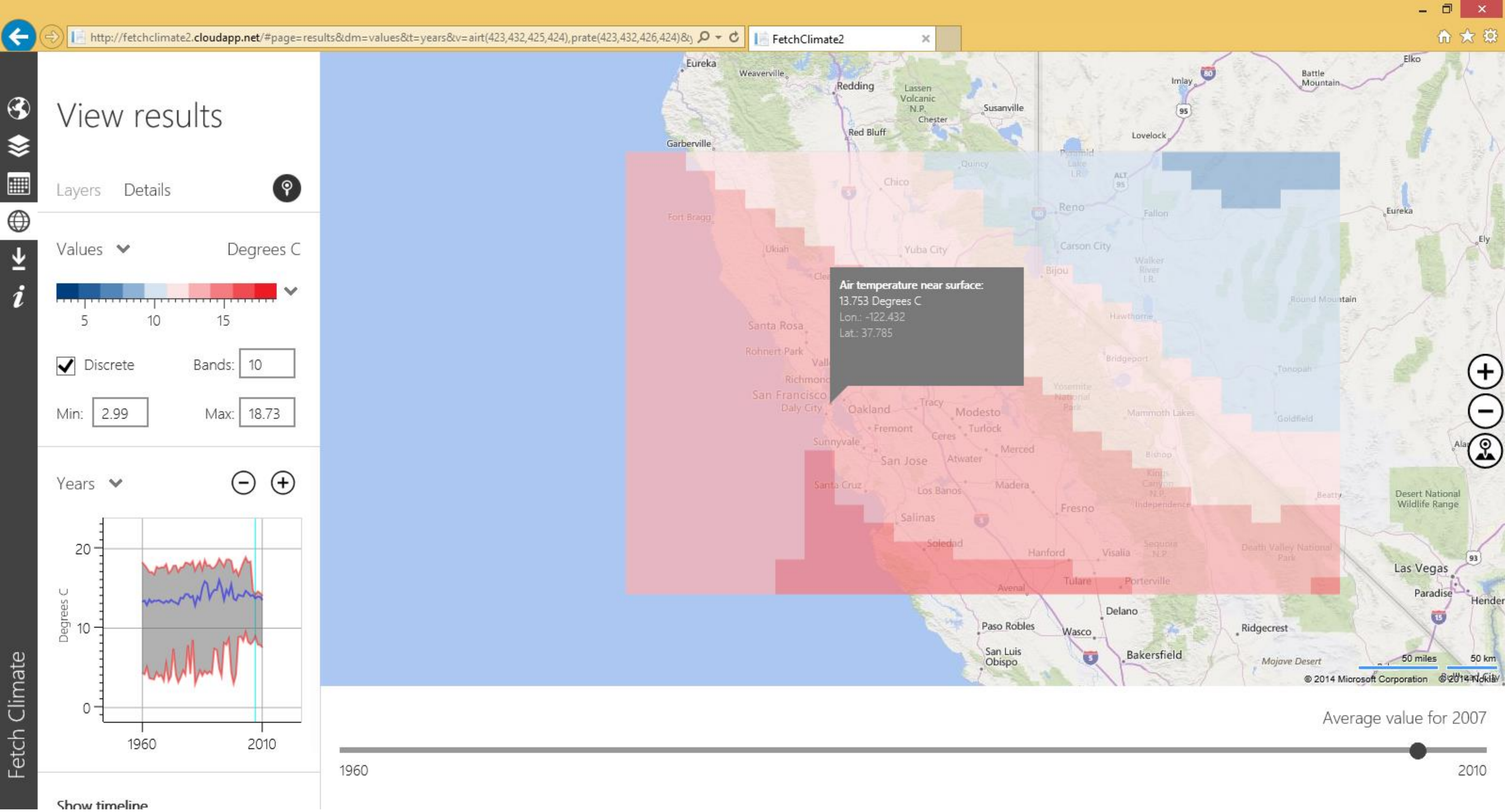
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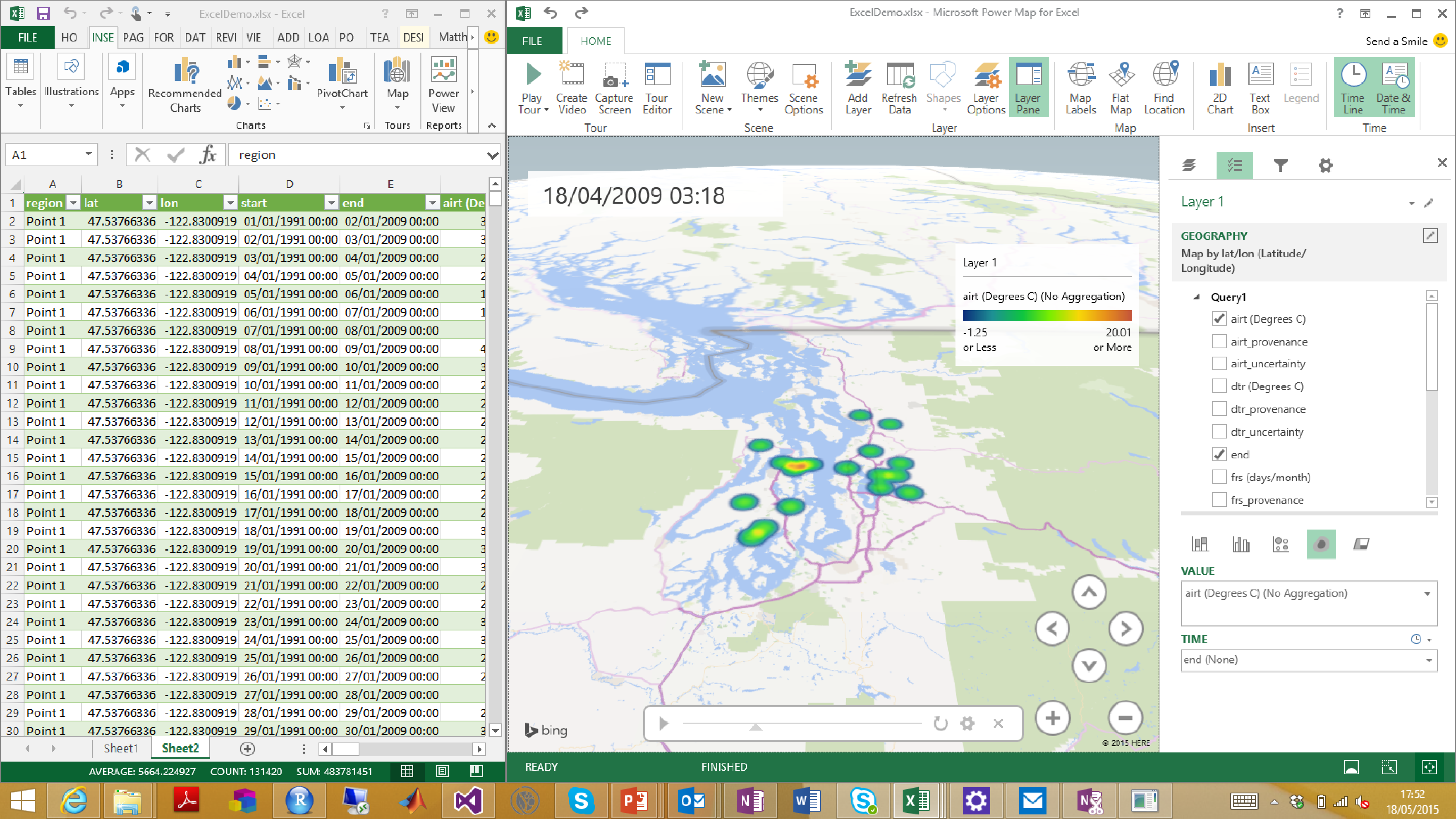
View results
Layers
Details
Values
Degrees C
5
10
15
Discrete
Bands:
10
Min:
2.99
Max:
18.73
Years
20
10
0
Degrees C
1960
2010
Show timeline
Fetch Climate
Air temperature near surface:
13.753 Degrees C
Lon.: -122.432
Lat.: 37.785
Average value for 2007
1960
2010
© 2014 Microsoft Corporation
© 2014 Nokia
50 miles
50 km

```
africaJulyTemp <- fcGrid(variable="airt",
   latitudeFrom=-35, latitudeTo=35, latitudeBy=1,
   longitudeFrom=-20,longitudeTo=60,longitudeBy=1,
   firstDay=182,lastDay=212, #July
   firstYear=1950,lastYear=2000)
```


ExcelDemo.xlsx - Excel
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Tables Illustrations Apps Recommended Charts PivotChart Map Power View
Charts Tours Reports
A1 region
region lat lon start end airt (De
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Point 1 47.53766336 -122.8300919 23/01/1991 00:00 24/01/2009 00:00
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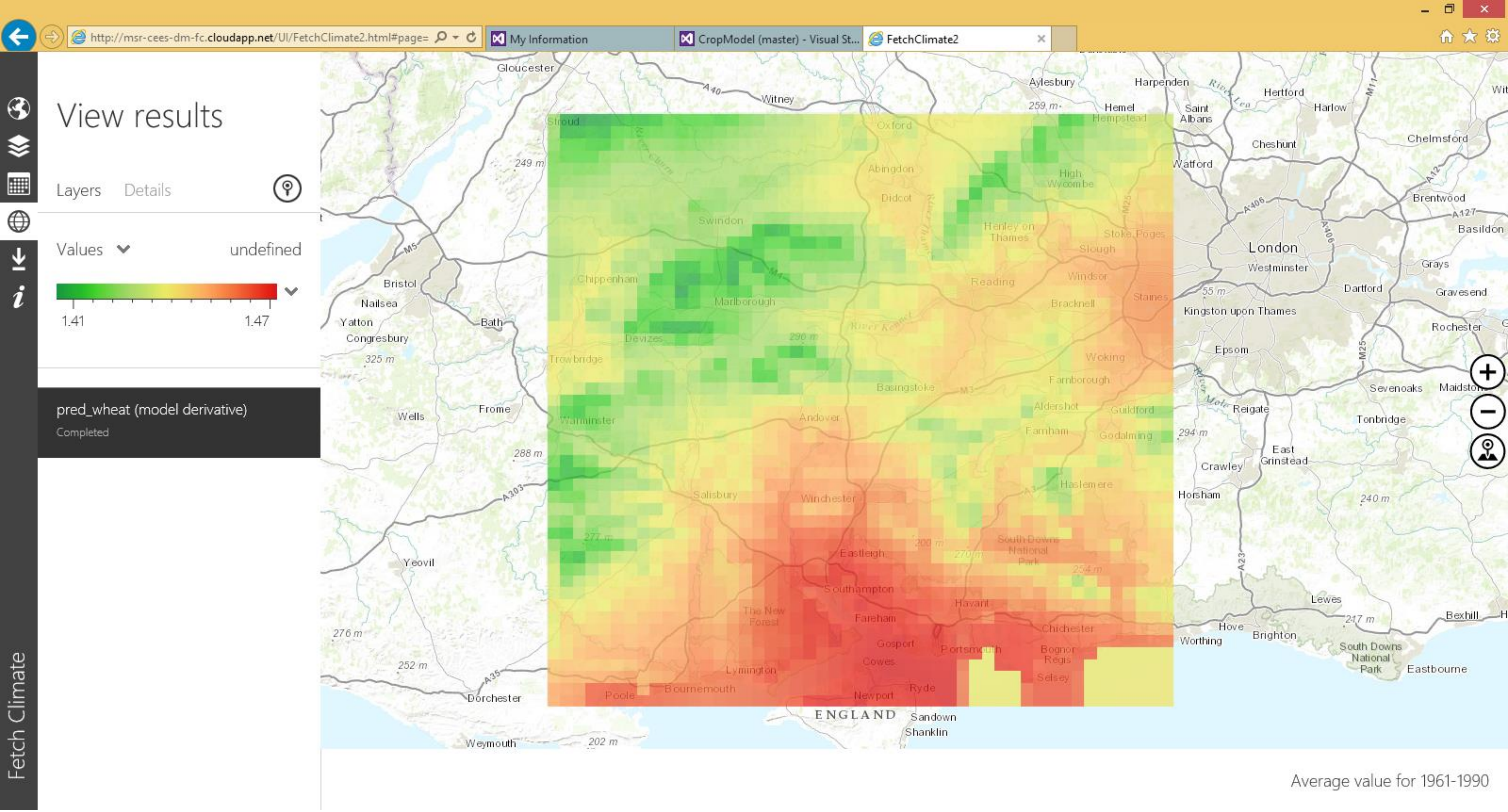
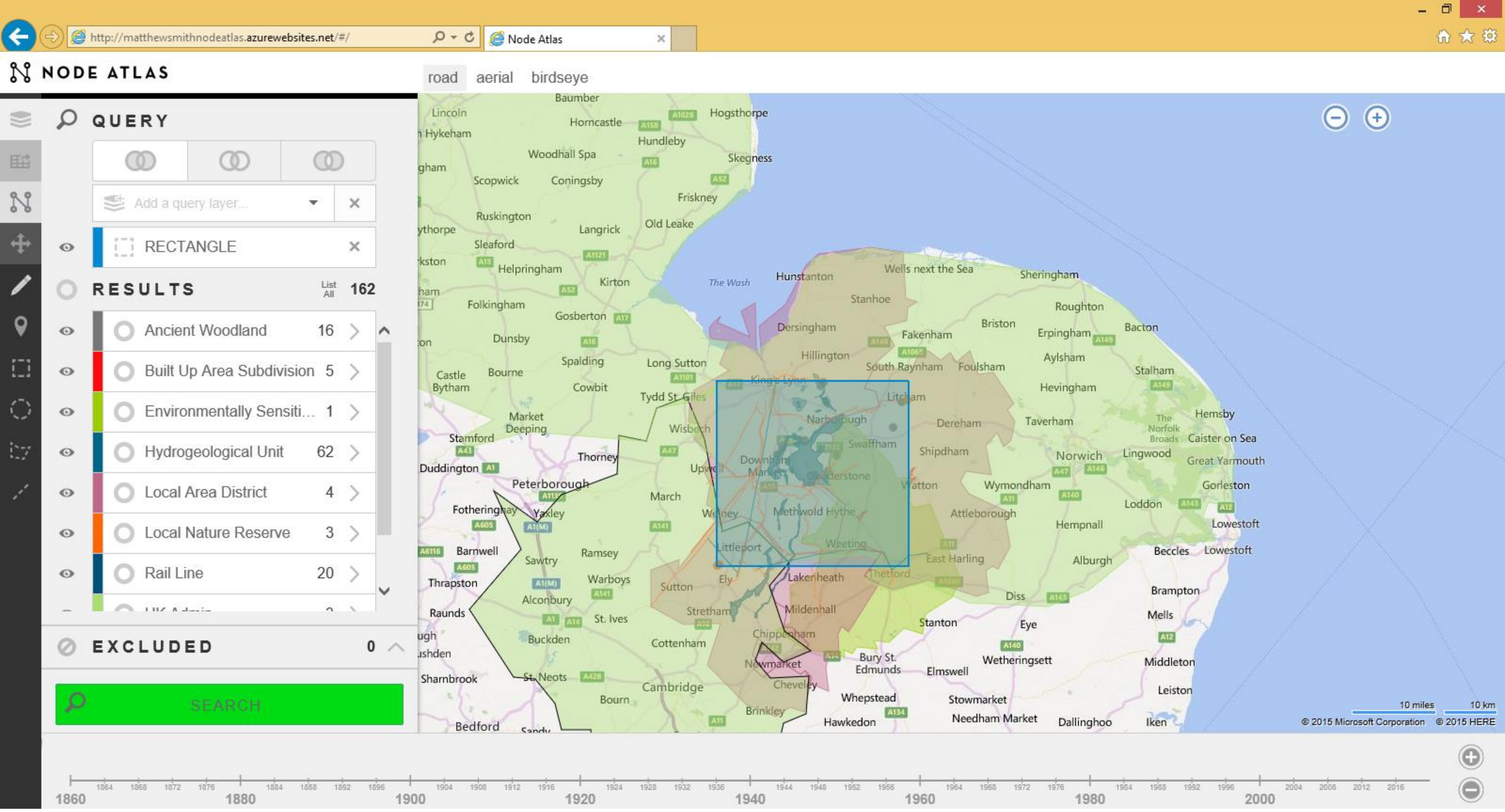
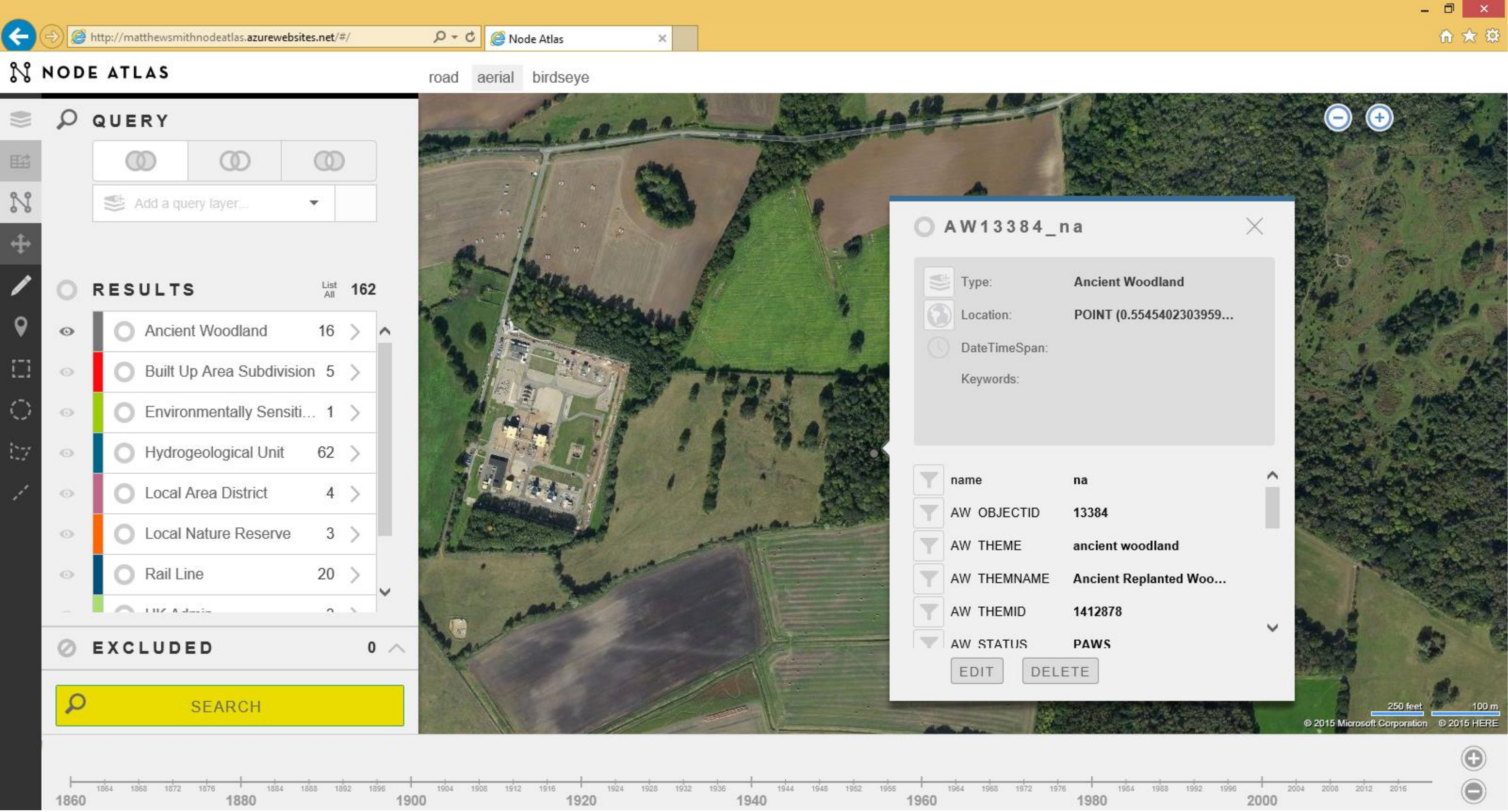
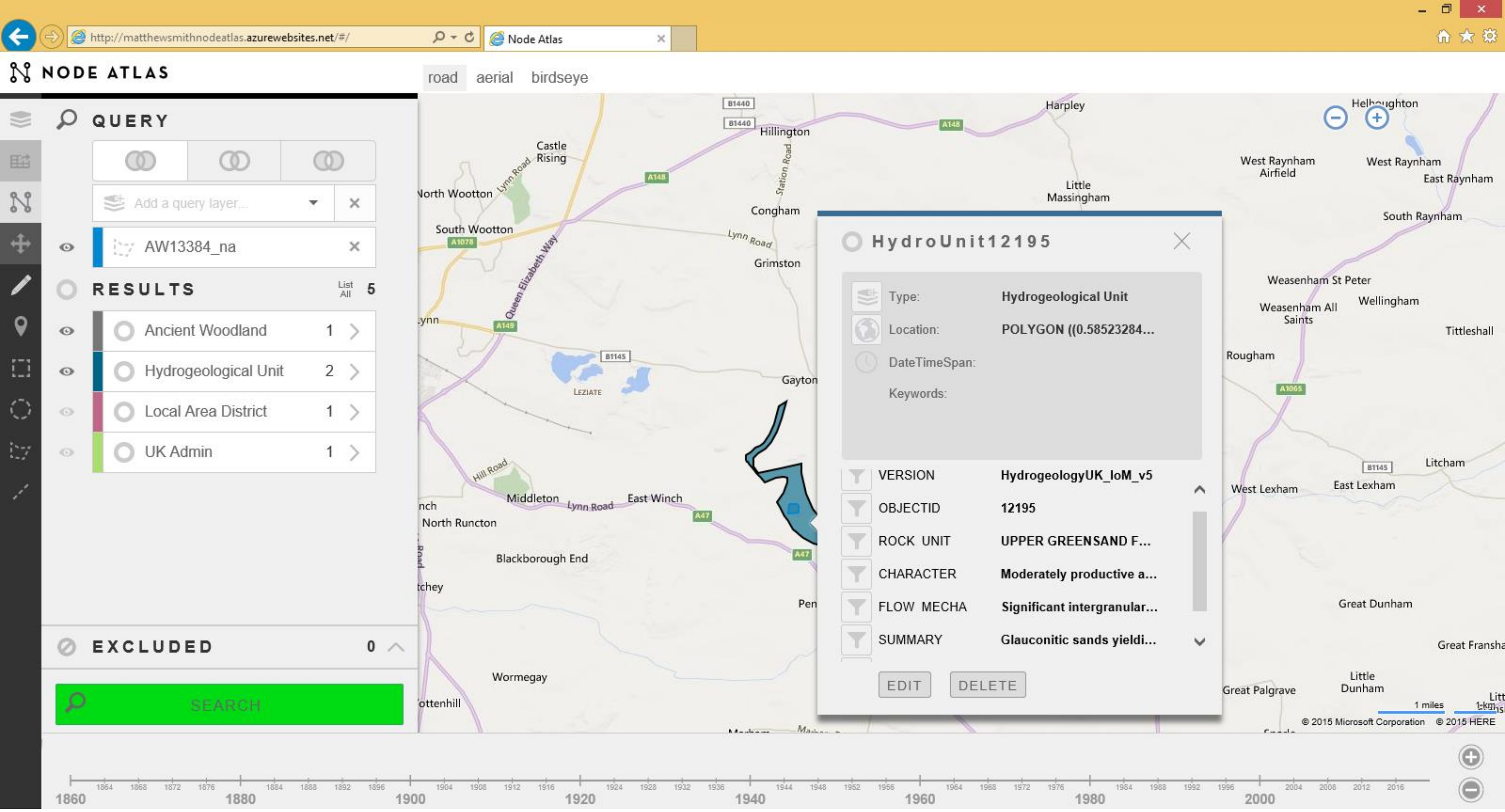
Point 1 47.53766336 -122.8300919 27/01/1991 00:00 28/01/2009 00:00
Point 1 47.53766336 -122.8300919 28/01/1991 00:00 29/01/2009 00:00
Point 1 47.53766336 -122.8300919 29/01/1991 00:00 30/01/2009 00:00
Sheet1 Sheet2
AVERAGE: 5664.224927 COUNT: 131420 SUM: 483781451
ExcelDemo.xlsx - Microsoft Power Map for Excel
FILE HOME Send a Smile
Play Tour Create Video Capture Screen Tour Editor New Scene Themes Scene Options Add Layer Refresh Data Shapes Layer Options Layer Pane Map Labels Flat Map Find Location 2D Chart Text Box Legend Time Line Date & Time
Tour Scene Layer Map Insert Time
18/04/2009 03:18
Layer 1
airt (Degrees C) (No Aggregation)
-1.25 or Less
20.01 or More
bing
© 2015 HERE
Layer 1
GEOGRAPHY
Map by lat/lon (Latitude/ Longitude)
Query1
airt (Degrees C)
airt_provenance
airt_uncertainty
dtr (Degrees C)
dtr_provenance
dtr_uncertainty
end
frs (days/month)
frs_provenance
VALUE
airt (Degrees C) (No Aggregation)
TIME
end (None)
READY FINISHED
17:52
18/05/2015



http://msr-cees-dm-fc.cloudapp.net/UI/FetchClimate2.html#page=
My Information
CropModel (master) - Visual St...
FetchClimate2
View results
Layers
Details
Values
undefined
1.41
1.47
pred_wheat (model derivative)
Completed
Fetch Climate
Average value for 1961-1990
ENGLAND
London
Oxford
Reading
Southampton
Swindon
Winchester
Salisbury
Basingstoke
Portsmouth
Bristol
Bath
Brighton


http://matthewsmithnodeatlas.azurewebsites.net/#/
Node Atlas
NODE ATLAS
road
aerial
birdseye
QUERY
Add a query layer...
RECTANGLE
RESULTS
List All
162
Ancient Woodland 16
Built Up Area Subdivision 5
Environmentally Sensiti... 1
Hydrogeological Unit 62
Local Area District 4
Local Nature Reserve 3
Rail Line 20
EXCLUDED 0
SEARCH
10 miles
10 km
© 2015 Microsoft Corporation © 2015 HERE
1860
1880
1900
1920
1940
1960
1980
2000


http://matthewsmithnodeatlas.azurewebsites.net/#/
Node Atlas
NODE ATLAS
road
aerial
birdseye
QUERY
Add a query layer...
RESULTS
List All
162
Ancient Woodland 16
Built Up Area Subdivision 5
Environmentally Sensiti... 1
Hydrogeological Unit 62
Local Area District 4
Local Nature Reserve 3
Rail Line 20
EXCLUDED 0
SEARCH
AW13384_na
Type: Ancient Woodland
Location: POINT (0.5545402303959...
DateTimeSpan:
Keywords:
name na
AW OBJECTID 13384
AW THEME ancient woodland
AW THEMNAME Ancient Replanted Woo...
AW THEMID 1412878
AW STATUS PAWS
EDIT
DELETE
250 feet
100 m
© 2015 Microsoft Corporation © 2015 HERE
1860
1880
1900
1920
1940
1960
1980
2000



http://matthewsmithnodeatlas.azurewebsites.net/#/
Node Atlas
NODE ATLAS
road
aerial
birdseye
QUERY
Add a query layer...
AW13384_na
RESULTS
List All
5
Ancient Woodland 1
Hydrogeological Unit 2
Local Area District 1
UK Admin 1
EXCLUDED 0
SEARCH
HydroUnit12195
Type: Hydrogeological Unit
Location: POLYGON ((0.58523284...
DateTimeSpan:
Keywords:
VERSION HydrogeologyUK_IoM_v5
OBJECTID 12195
ROCK UNIT UPPER GREENSAND F...
CHARACTER Moderately productive a...
FLOW MECHA Significant intergranular...
SUMMARY Glauconitic sands yieldi...
EDIT
DELETE
Harpley
Hillington
Castle Rising
North Wootton
South Wootton
Congham
Grimston
Little Massingham
West Raynham Airfield
West Raynham
East Raynham
South Raynham
Helhoughton
Weasenham St Peter
Weasenham All Saints
Wellingham
Tittleshall
Rougham
Gayton
Leziate
Middleton
East Winch
North Runcton
Blackborough End
Wormegay
West Lexham
East Lexham
Litcham
Great Dunham
Great Palgrave
Little Dunham
© 2015 Microsoft Corporation © 2015 HERE
1860
1880
1900
1920
1940
1960
1980
2000

https://npzmodel.visualstudio.com/DefaultCollection/_git/CropModel - Altai

action

provenance

module
Crop_Model

23.05.2014 06:07:25

Working for sim but now trying to get to work for inference

unsaved work

<no comment>

...

compile F# Crop_Model

delete

search

home

metadata

action

```
type generalModelPars = {
                          sowDate:int // prescribed
                          harvDate:int // prescribed
                          n0:float // inferred
                          mSeed0:float // prescribed
                          r:float // target C:N ratio
                          rtot:float // inferred
                          theta:float /// Nitrogen uptake efficiency
                          lma:float // inferred
                          trans:float // inferred
                          germLim:float // inferred
                          tBGerm:float // inferred
                          mc:float
                          cFrac:float
                          fr:float
                          }

type farquarModelPars = {
                          pcO2:float // prescribed
                          v25:float // inferred
                          pSynthType:int //prescribed
                          }

type allocDumbModel = {
                         par1:float // prescribed
                         par2:float // prescribed
                         }

type site = {
                lat:float // prescribed
                lon:float // prescribed
                harvDate:int // prescribed
                sowDate:int // prescribed
                }
```

module
Crop_Model

code
Simulator

data
Simulation

chart
Simulation

code
Crop_Model

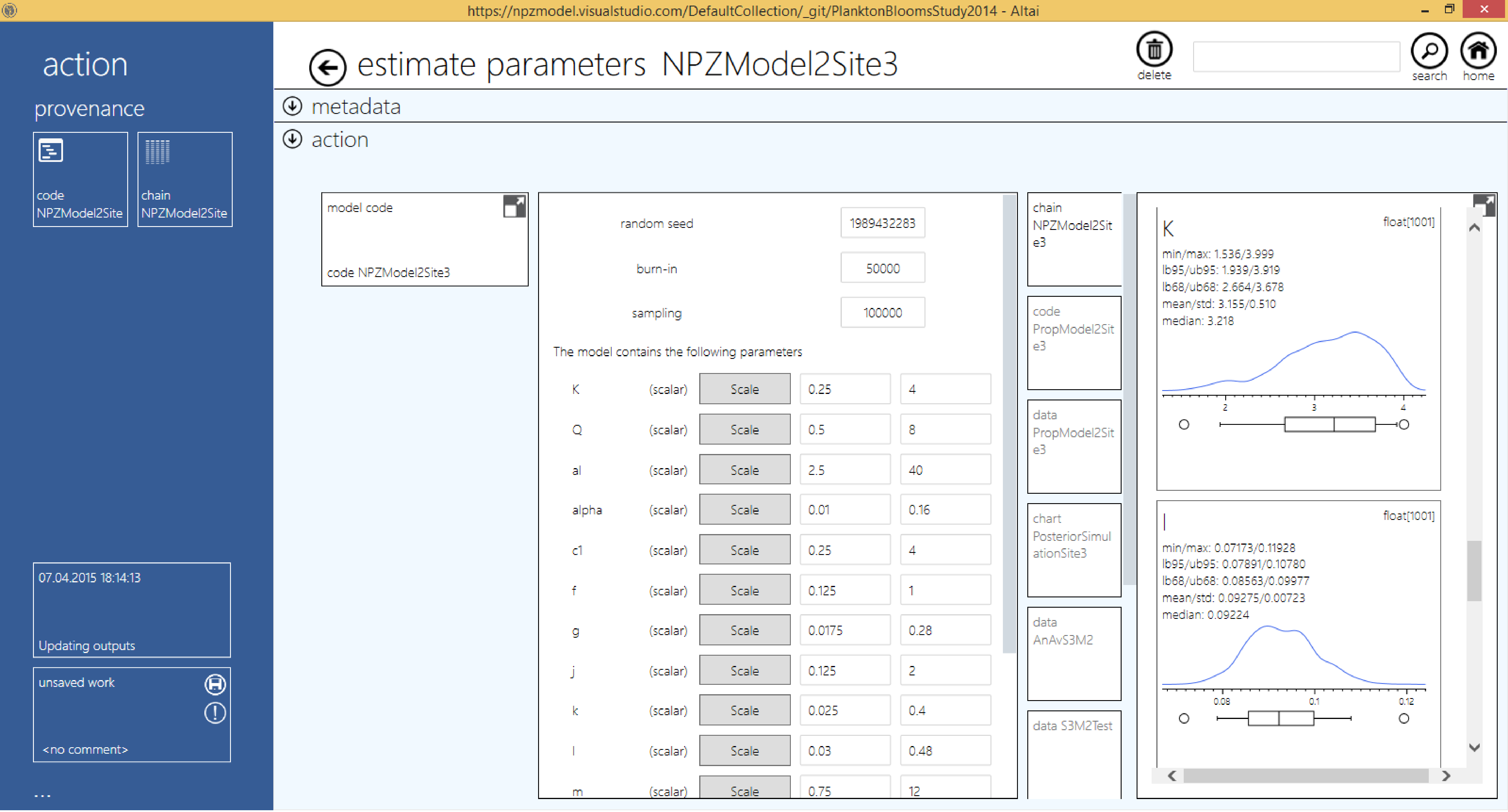
tand(r : float) : float

acosd(r : float) : float

cosd(r : float) : float

sind(r : float) : float

quadratic(a : float, b : float, c : float) : float[]


https://npzmodel.visualstudio.com/DefaultCollection/_git/PlanktonBloomsStudy2014 - Altai
action
provenance
code NPZModel2Site
chain NPZModel2Site
07.04.2015 18:14:13
Updating outputs
unsaved work
<no comment>
estimate parameters NPZModel2Site3
delete
search
home
metadata
action
model code
code NPZModel2Site3
random seed 1989432283
burn-in 50000
sampling 100000
The model contains the following parameters
K (scalar) Scale 0.25 4
Q (scalar) Scale 0.5 8
al (scalar) Scale 2.5 40
alpha (scalar) Scale 0.01 0.16
c1 (scalar) Scale 0.25 4
f (scalar) Scale 0.125 1
g (scalar) Scale 0.0175 0.28
j (scalar) Scale 0.125 2
k (scalar) Scale 0.025 0.4
l (scalar) Scale 0.03 0.48
m (scalar) Scale 0.75 12
chain NPZModel2Site3
code PropModel2Site3
data PropModel2Site3
chart PosteriorSimulationSite3
data AnAvS3M2
data S3M2Test
K float[1001]
min/max: 1.536/3.999
lb95/ub95: 1.939/3.919
lb68/ub68: 2.664/3.678
mean/std: 3.155/0.510
median: 3.218
2
3
4
l float[1001]
min/max: 0.07173/0.11928
lb95/ub95: 0.07891/0.10780
lb68/ub68: 0.08563/0.09977
mean/std: 0.09275/0.00723
median: 0.09224
0.08
0.1
0.12

http://npzmodel.visualstudio.com/DefaultCollection/_git/PlanktonBloomsStudy2014 - Altai

extra

provenance

make chart DemonstrateSit

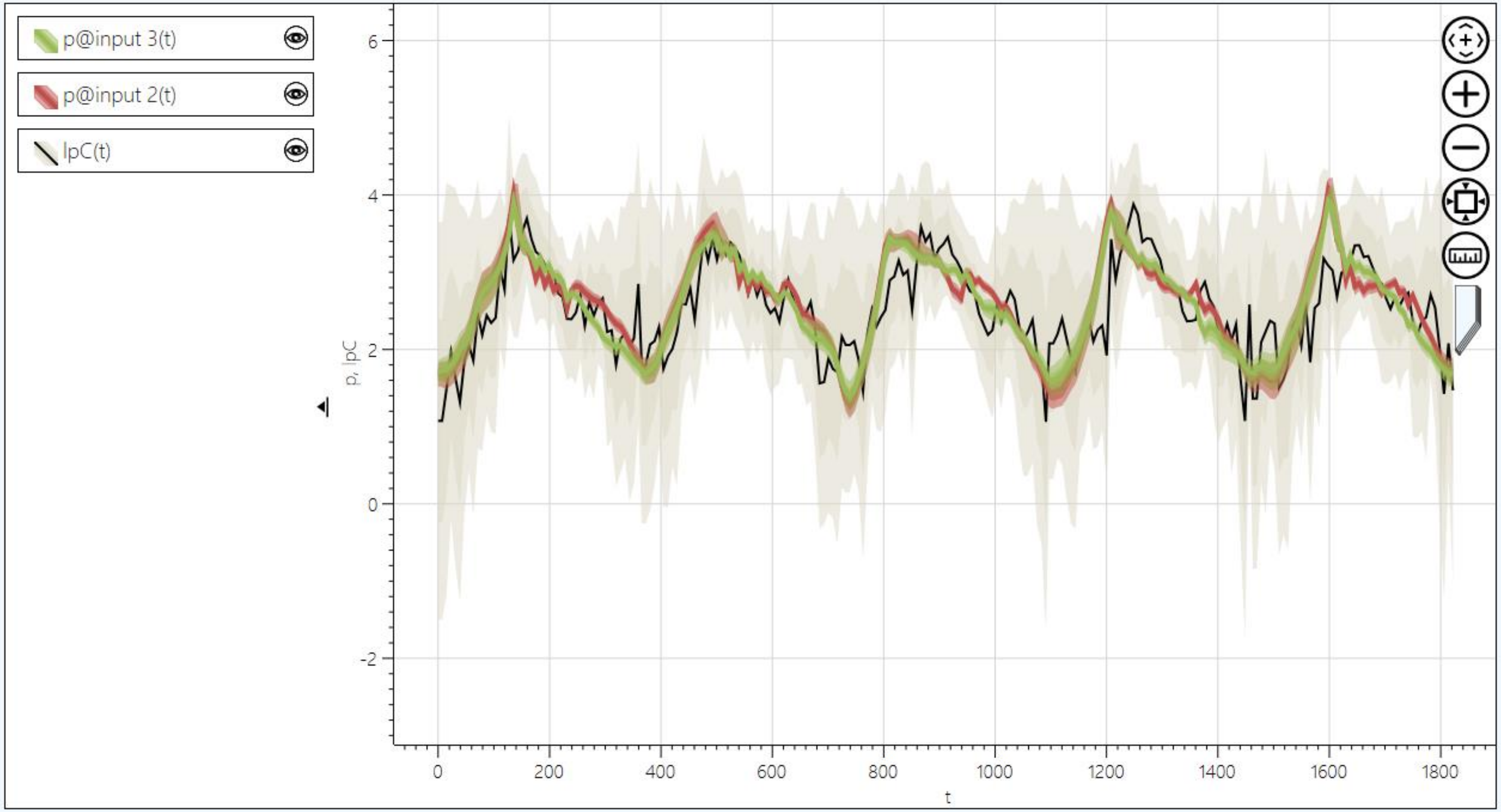
chart DemonstrateSite5Training

search

home

metadata

values



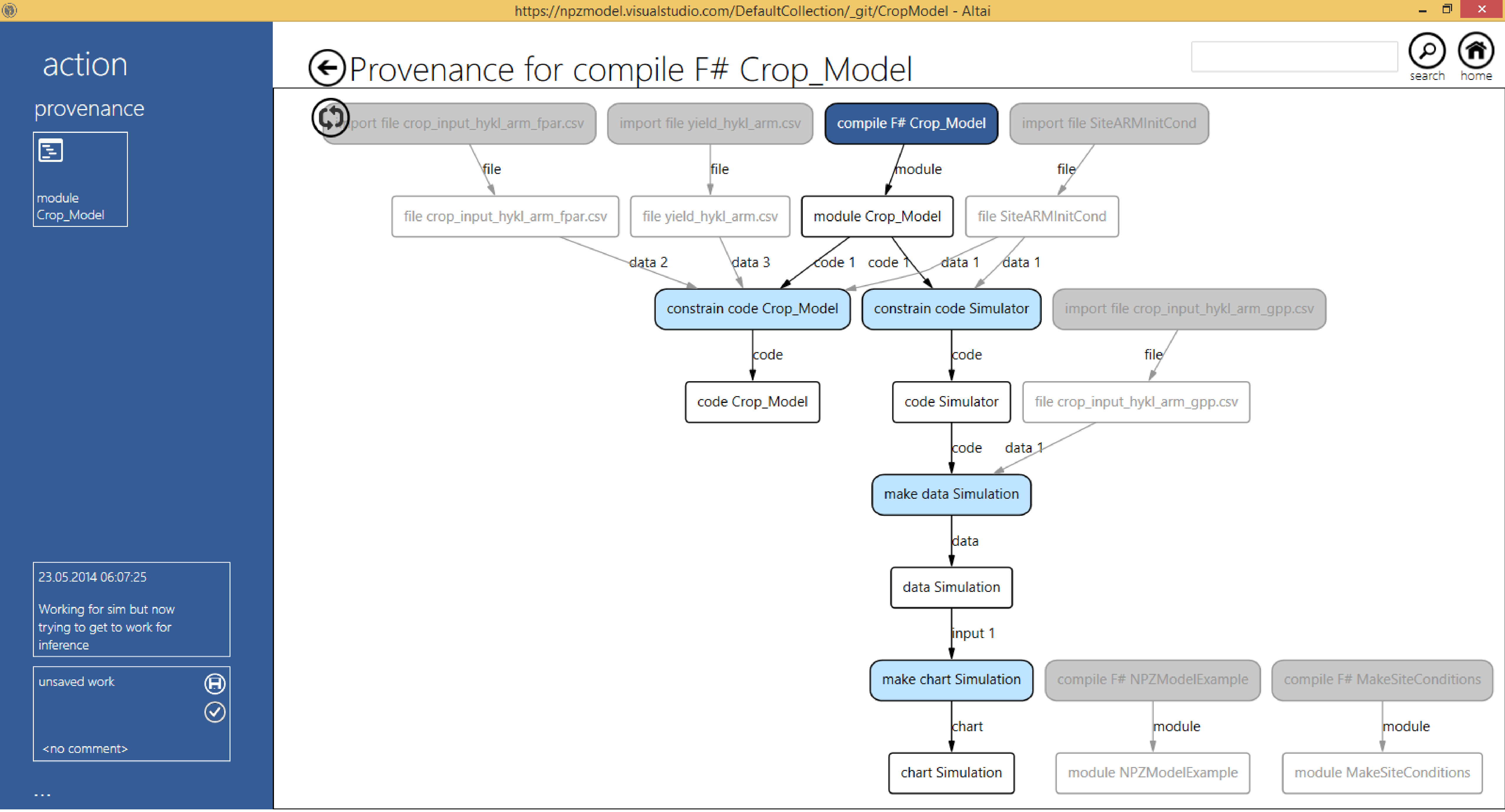
13.11.2014 13:31:00

Fixed aako 3

unsaved work

<no comment>

...


https://npzmodel.visualstudio.com/DefaultCollection/_git/CropModel - Altai
action
provenance
module Crop_Model
23.05.2014 06:07:25
Working for sim but now trying to get to work for inference
unsaved work
<no comment>
...
Provenance for compile F# Crop_Model
search
home
import file crop_input_hykl_arm_fpar.csv
import file yield_hykl_arm.csv
compile F# Crop_Model
import file SiteARMInitCond
file
file
module
file
file crop_input_hykl_arm_fpar.csv
file yield_hykl_arm.csv
module Crop_Model
file SiteARMInitCond
data 2
data 3
code 1
code 1
data 1
data 1
constrain code Crop_Model
constrain code Simulator
import file crop_input_hykl_arm_gpp.csv
code
code
file
code Crop_Model
code Simulator
file crop_input_hykl_arm_gpp.csv
code
data 1
make data Simulation
data
data Simulation
input 1
make chart Simulation
compile F# NPZModelExample
compile F# MakeSiteConditions
chart
module
module
chart Simulation
module NPZModelExample
module MakeSiteConditions

http://msr-cees-dm-fc.cloudapp.net/UI/FetchClimate2.html#page=

My Information | CropModel (master) - Visual St... | FetchClimate2

View results

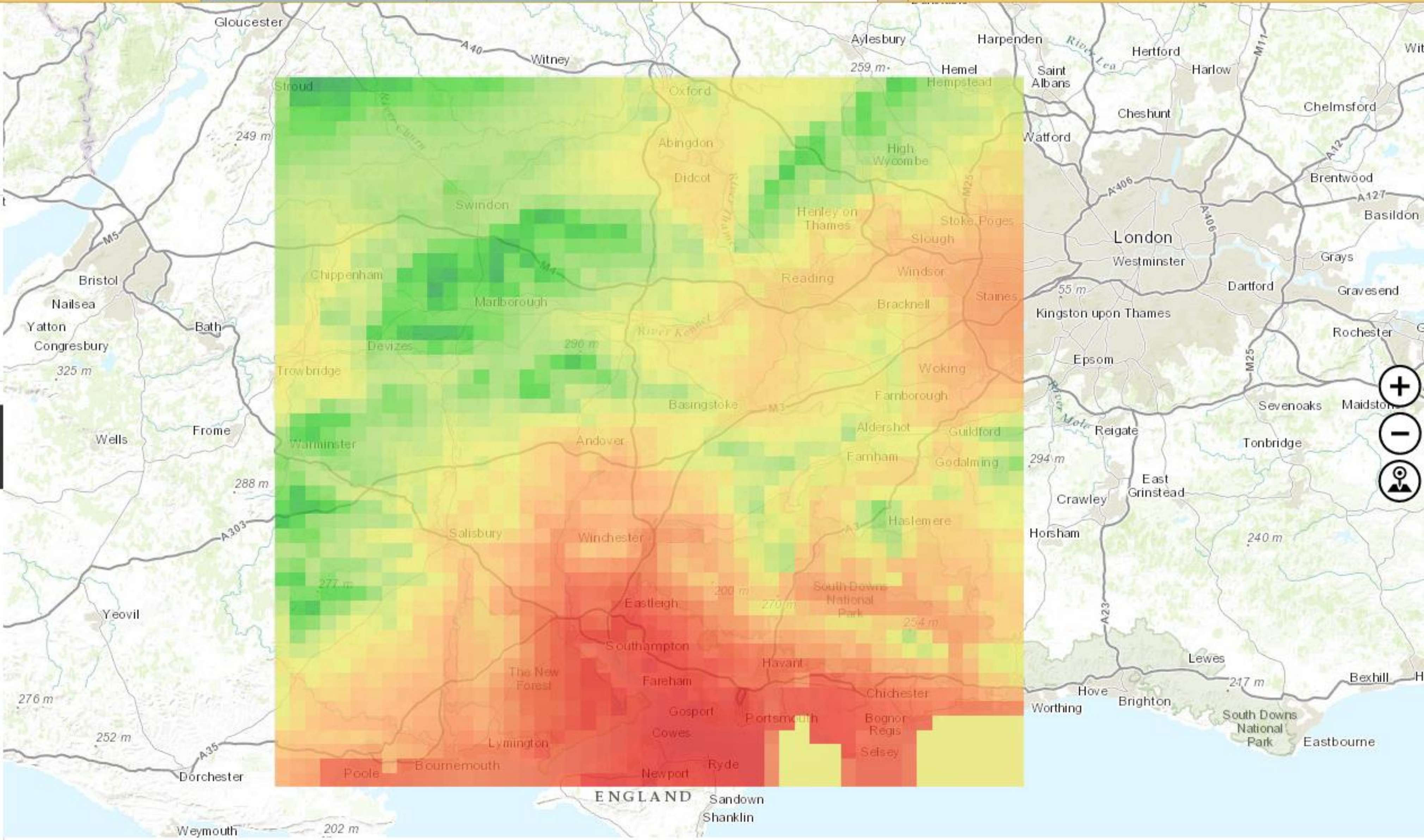
Layers Details

Values undefined

1.41 1.47

pred_wheat (model derivative)

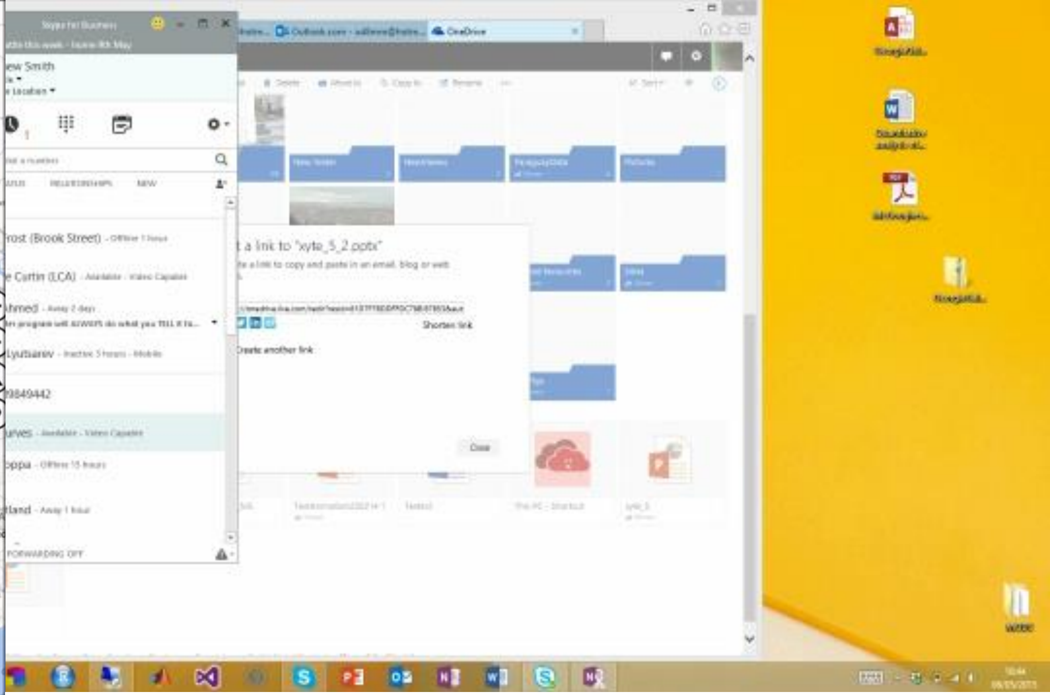
Completed

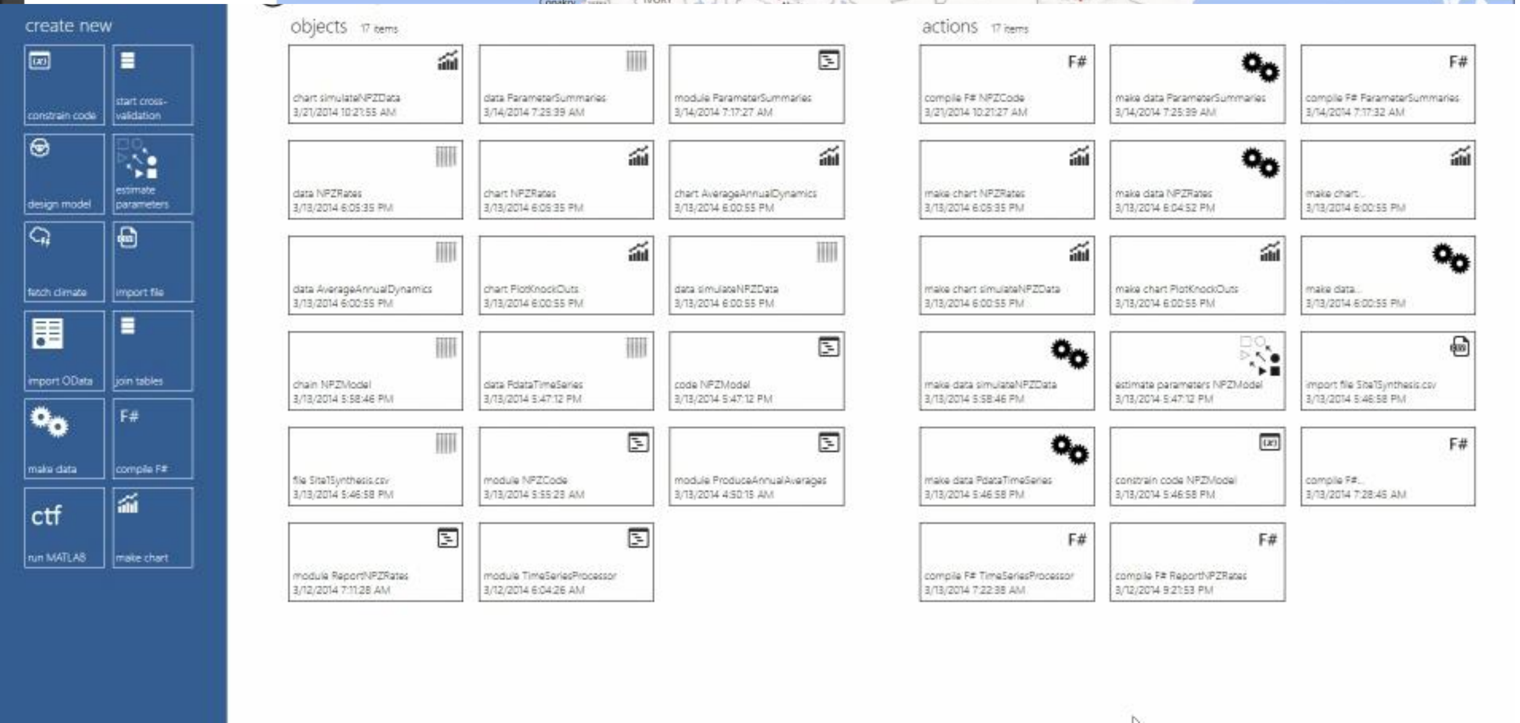


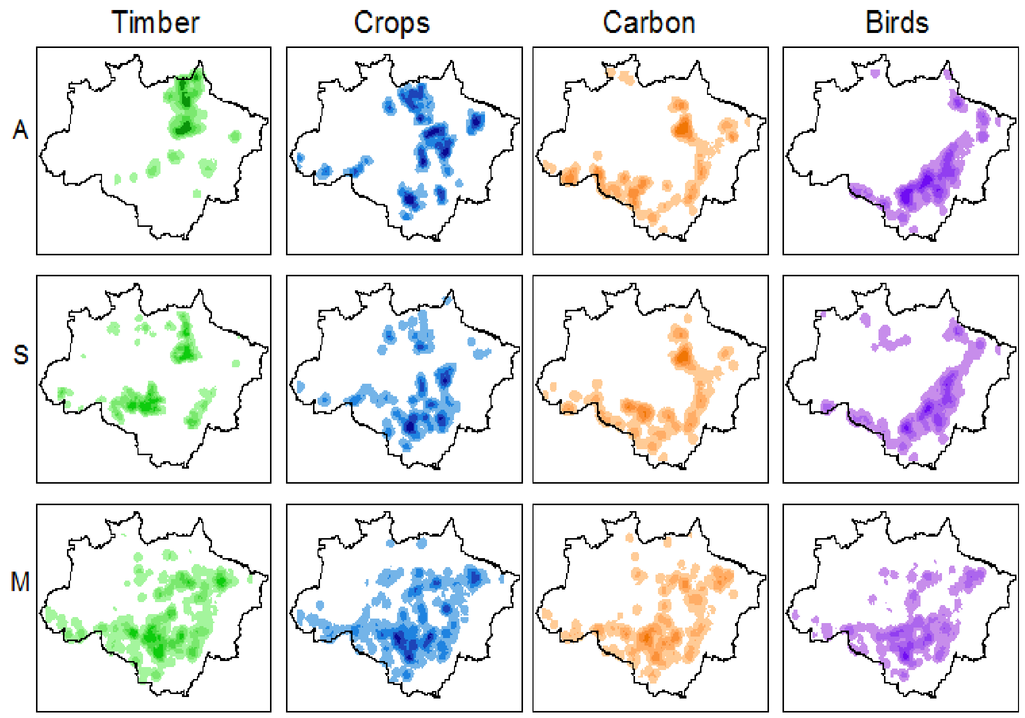
Fetch Climate

Average value for 1961-1990


Select geography
Fetch Climate
NORWAY
SWEDEN
FINLAND
DENMARK
UNITED KINGDOM
IRELAND
GERMANY
POLAND
BELARUS
UKRAINE
FRANCE
SPAIN
PORTUGAL
ITALY
ROMANIA
GREECE
TURKEY
KAZAKHSTAN
UZBEKISTAN
TURKMENISTAN
SYRIA
IRAQ
IRAN
AFGHANISTAN
PAKISTAN
INDIA
MOROCCO
ALGERIA
LIBYA
EGYPT
TUNISIA
SAUDI ARABIA
OMAN
YEMEN
SUDAN
CHAD
NIGER
MALI
MAURITANIA
NIGERIA
Atlantic Ocean
Mediterranean Sea
Black Sea
Arabian Sea
Moscow
Oslo
Stockholm
Helsinki
Copenhagen
London
Berlin
Warsaw
Paris
Rome
Madrid
Ankara
Tehran
Baghdad
Riyadh
Cairo
Khartoum
250 miles




create new
constrain code
start cross-validation
design model
estimate parameters
fetch climate
import file
import OData
join tables
make data
compile F#
run MATLAB
make chart
objects 17 items
actions 17 items


Timber
Crops
Carbon
Birds
A
S
M


"At our core, Microsoft is the productivity and platform company for the mobile-first and cloud-first world. We will reinvent productivity to empower every person and every organization on the planet to do more and achieve more."