NPP from Earth Observation

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Introduction

- Main methods:
  - Optical - based on rate/potential rate of photosynthesis
  - Structural - based on rate of growth
- Range of spatial scales
  - Canopy
  - Landscape/regional
  - Global
- RS of NPP often closely linked to field studies or modelling studies

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Basis of optical methods

Red & blue light absorbed by chlorophyll fuels photosynthesis

Green and IR light reflected

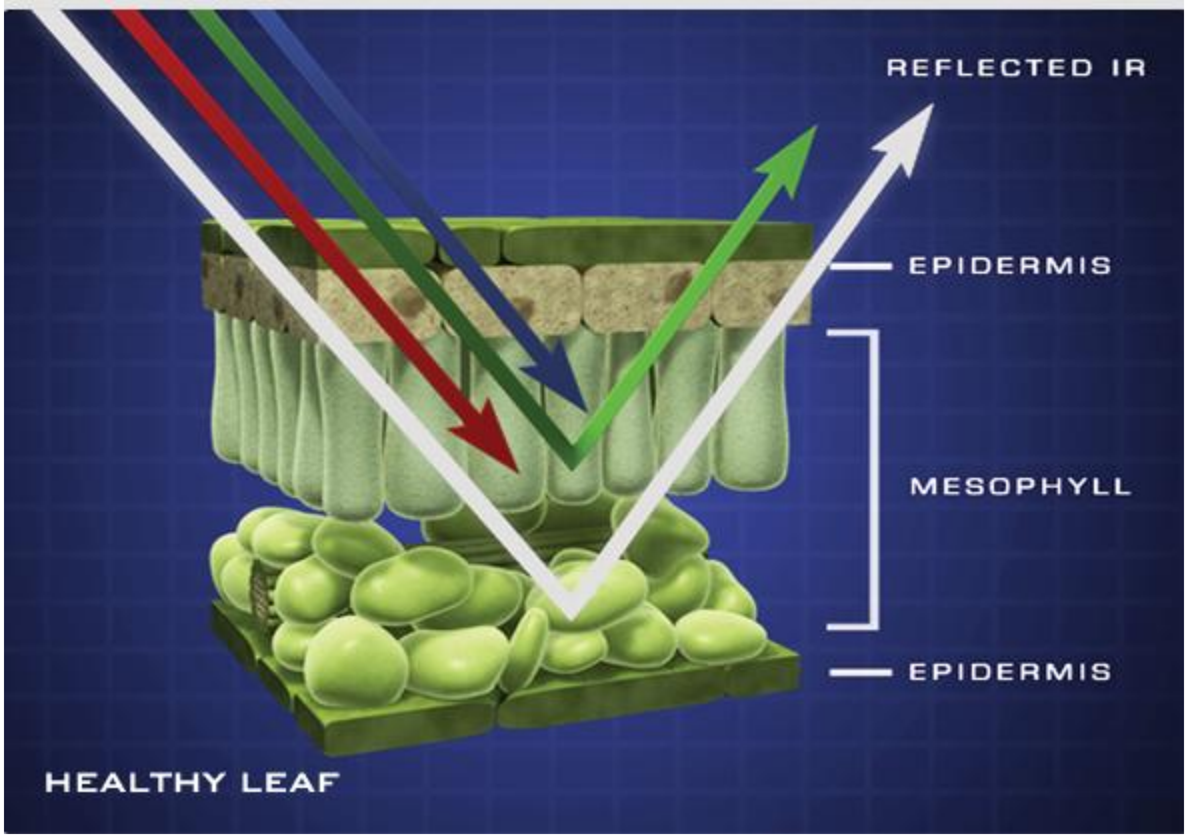

Figure from http://missionscience.nasa.gov/ems/08_nearinfraredwaves.html

Satellites measure light reflected at different wavelengths , so are sensitive to changes in light reflected at visible (red, green & blue) and NIR wavelengths

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OPTICAL METHODS

EO data	Satellite , Radiometer, Digital photo
Intermediate variable(s)	NDVI , FPAR (Fraction of photosynthetically active radiation), annual integral of growth curve (NDVI)
Estimate of NPP/NPP proxy	Physical model of NPP (e.g. MODIS global 1km NPP product), or empirical model (e.g. small-scale studies with field observations of NPP)

STRUCTURAL METHODS

EO data	Radar or lidar data
⇩	⇩
Intermediate variable(s)	Estimate canopy height/biomass/ stemwood volume
⇩	⇩
Estimate of NPP/NPP proxy	Use other data on growth rate to calibrate/model NPP, or Use repeat measurements to capture rate of growth

Optical methods

Standard formulation:

$NPP = \varepsilon * \sum(FPAR * PAR)$

ε is the radiation use efficiency (including plant respiration costs)

PAR is the photosynthetically active radiation,

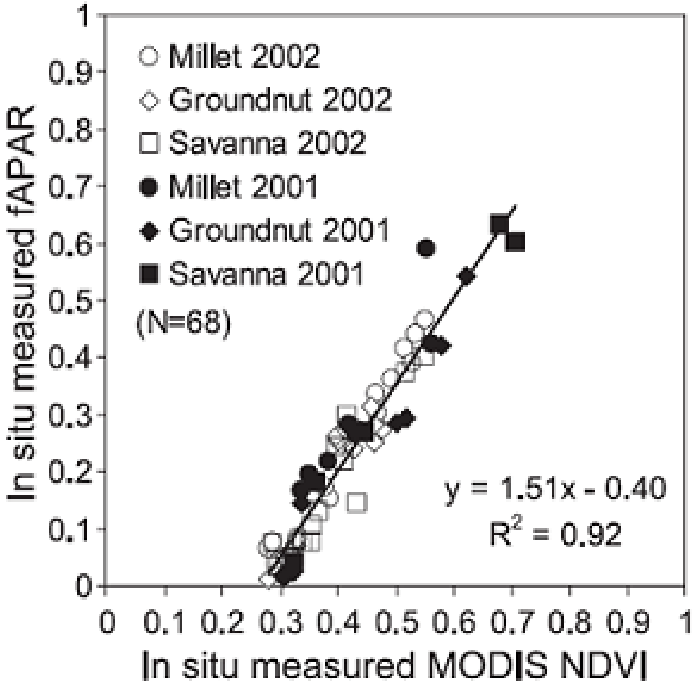
FPAR is the fraction of absorbed photosynthetically active radiation

FPAR is strongly correlated with NDVI

NDVI is a ratio derived from EO data, it quantifies vegetation greenness

EO-friendly version:

$\mathbf{NPP = \varepsilon * \sum(NDVI * PAR)}$



Fensholt et al., (2004)

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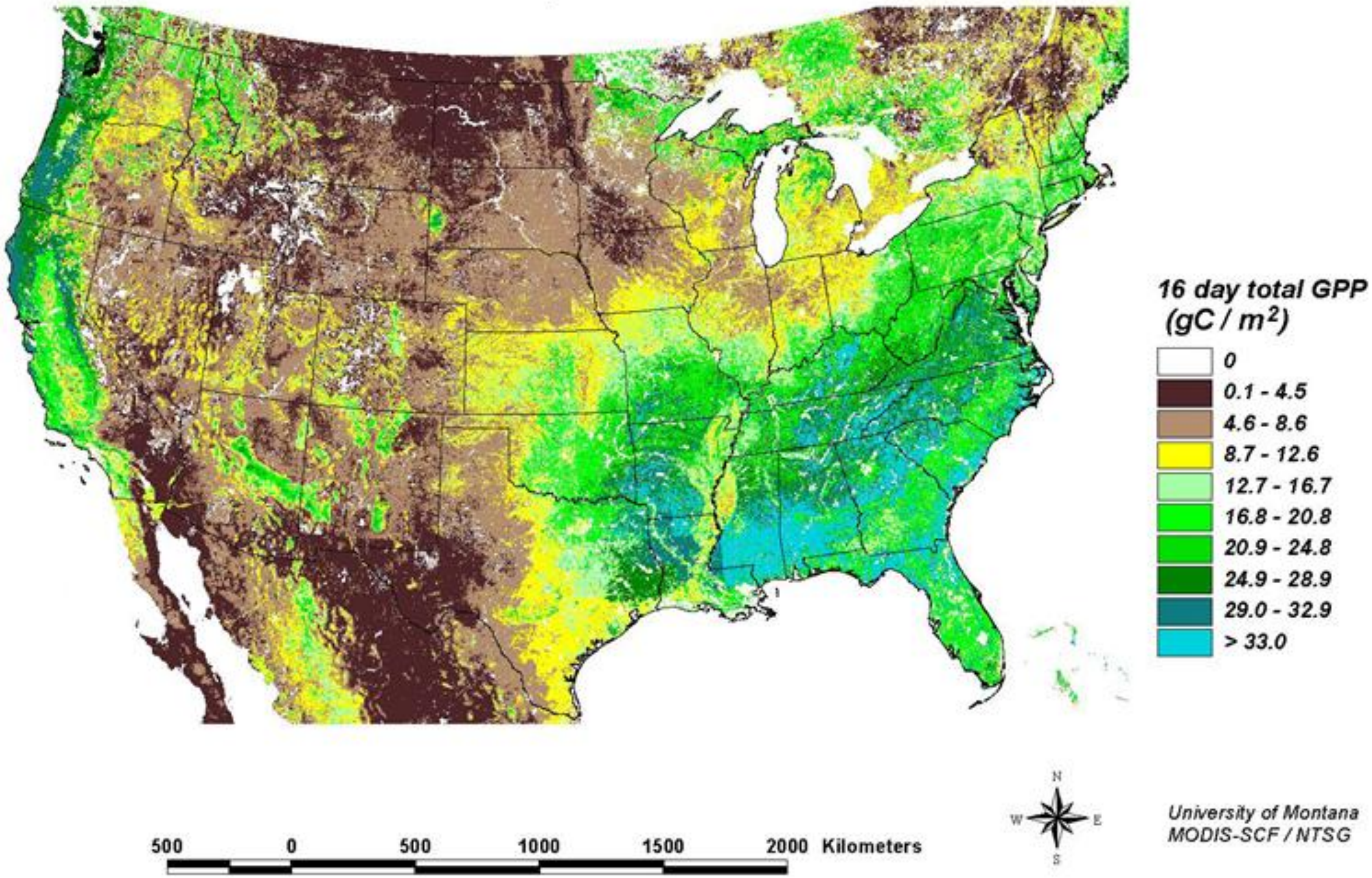
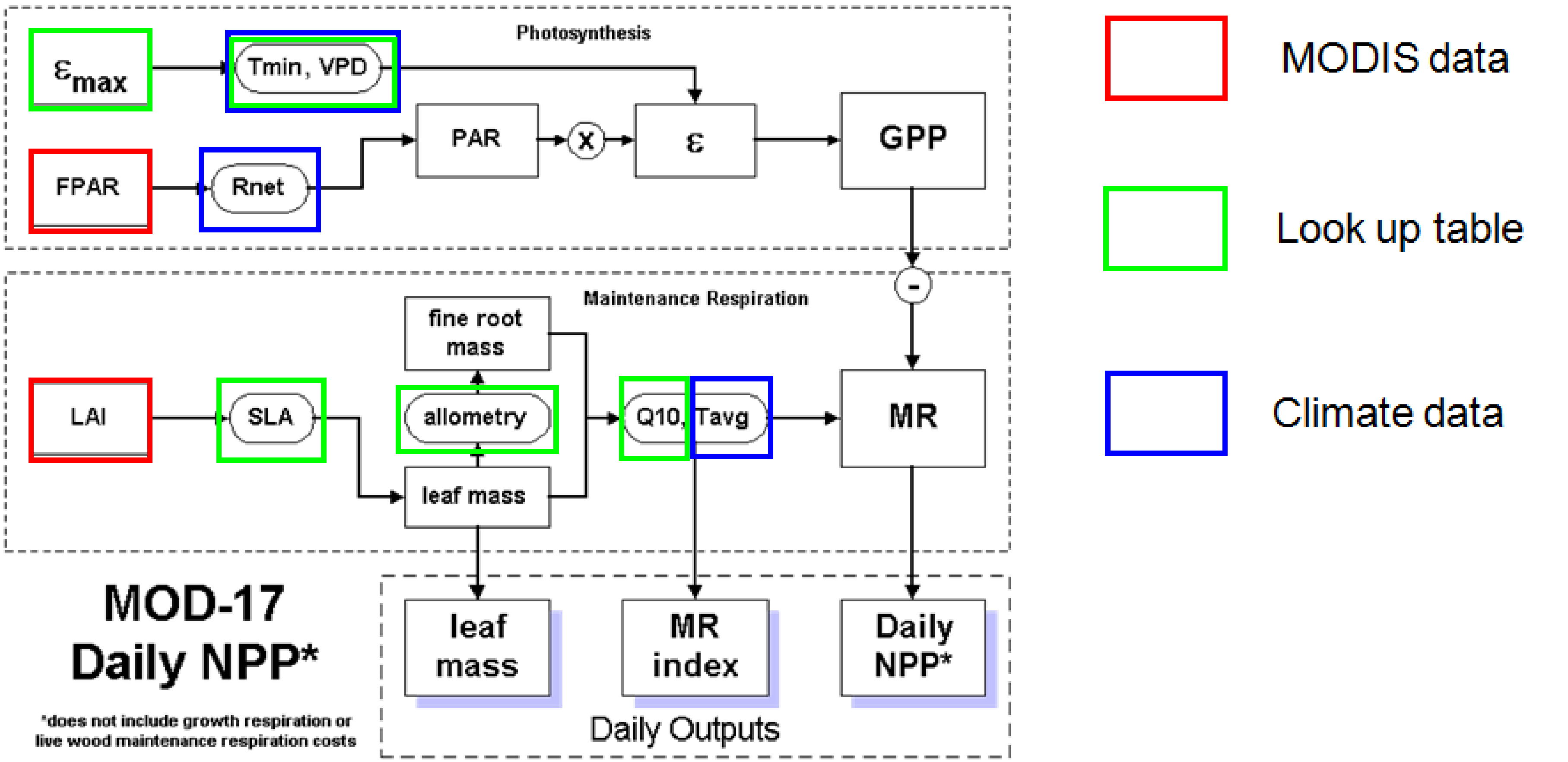
MODIS GPP/PSN product



http://visibleearth.nasa.gov/

MODIS GPP/PSN



http://www.ntsg.umt.edu/remote_sensing/netprimary/

GPP/PSN caveats

- Inherits errors from the LAI/fAPAR product
- Driven by climate data
- Uses a very simple model for efficiency
  - Linear ramps for VPD and temperature
- Driven by a generalised look-up table
  - Only 6 vegetation types for the whole globe

MY INTEREST IN NPP

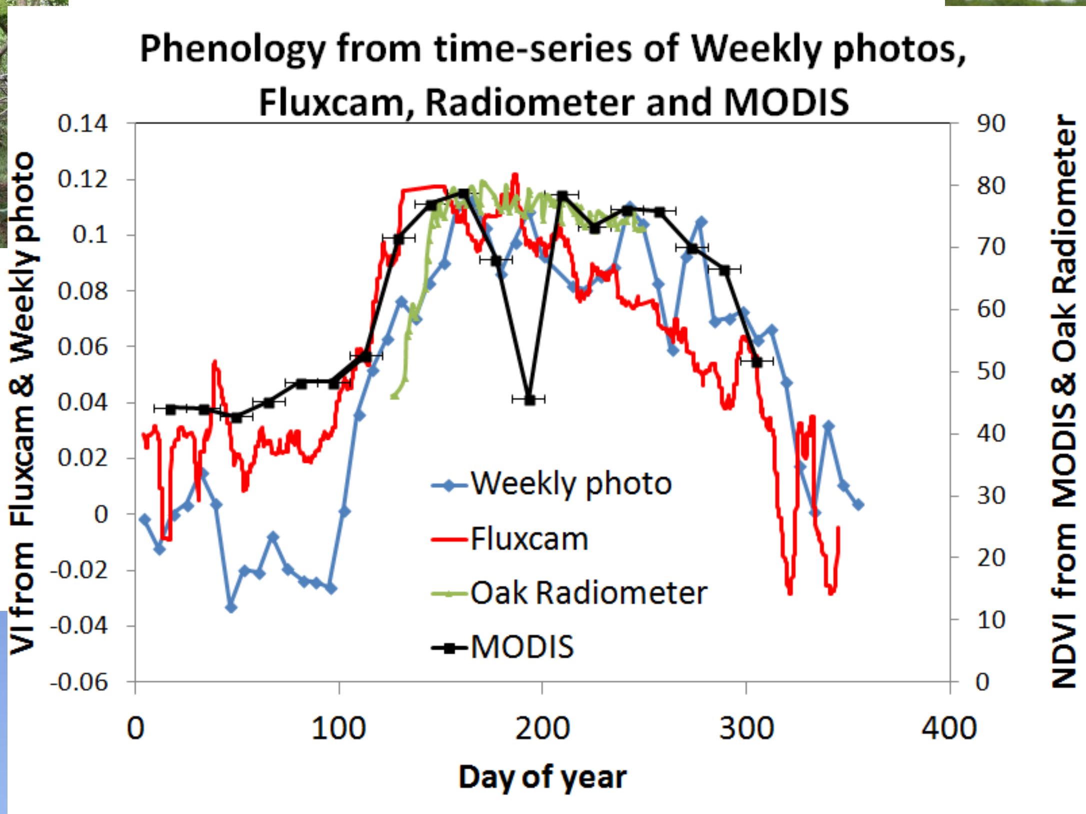
- Better characterisation of the land surface, especially:
  - use of NPP/NPP proxies to quantify ecosystem functioning
  - use of NPP/NPP proxies as an early indicator of vegetation stress/degradation
  - explore links between NPP & biodiversity

- Canopy-level daily digital camera data sets
  - Wytham (deciduous woodland)
  - Moor House (upland heather/grassland)
  - Both data sets enable production of vegetation growth curves (greenness curves)

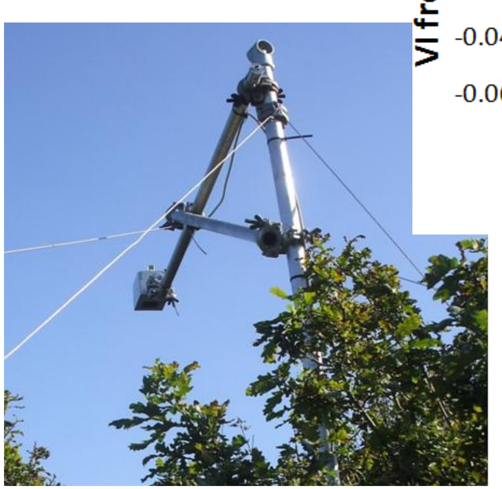
- Landscape level - Fusion of MODIS (*high temporal resolution, low spatial resolution*) & Landsat (*low temporal resolution, high spatial resolution*) to create reconstructed/synthetic time-series images to better estimate annual NDVI

Weekly photos

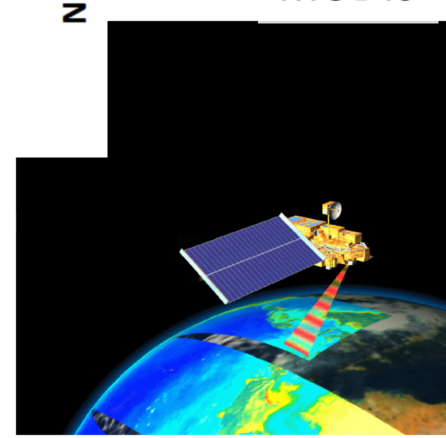
Fluxcam



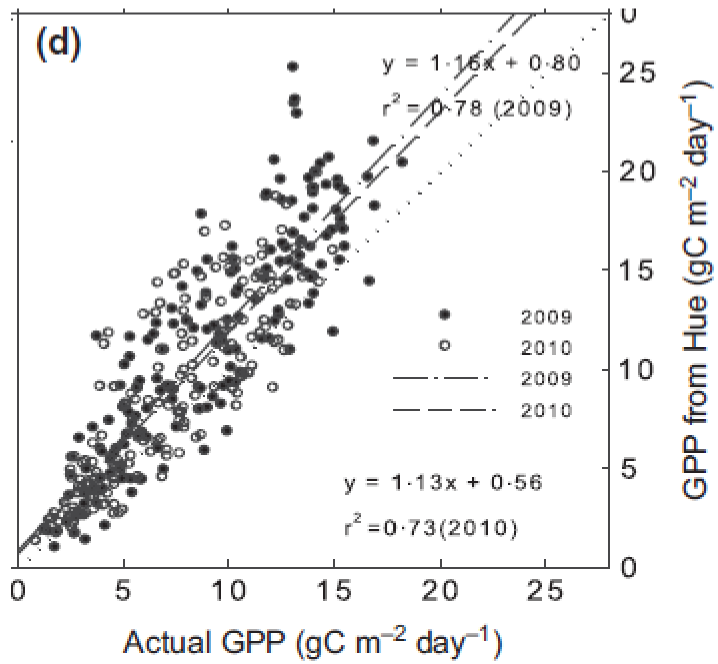
Radiometer



MODIS



Relationship between digital camera data and GPP



Digital camera data

Flux tower measurements

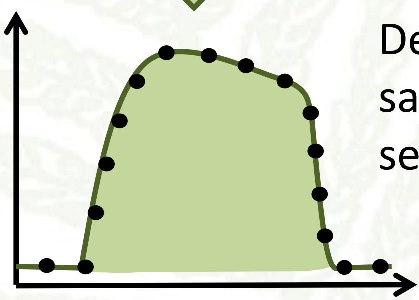
Mizunuma et al., (2013) Functional Ecology, 27, 196–207

NPP FROM FUSION OF MODIS AND LANDSAT

Need sufficient EO data to accurately characterise the vegetation dynamics

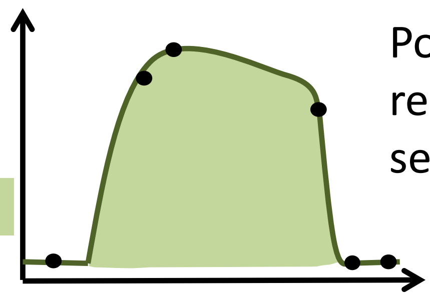
In practice a compromise between:

Frequent data @ coarse spatial resolution (500m-1km pixel size)



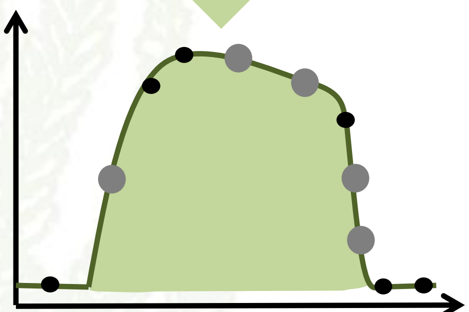
Densely sampled time series

Irregular, infrequent data @ high spatial resolution (~30m pixel size)



Poorly resolved time-series

Merge

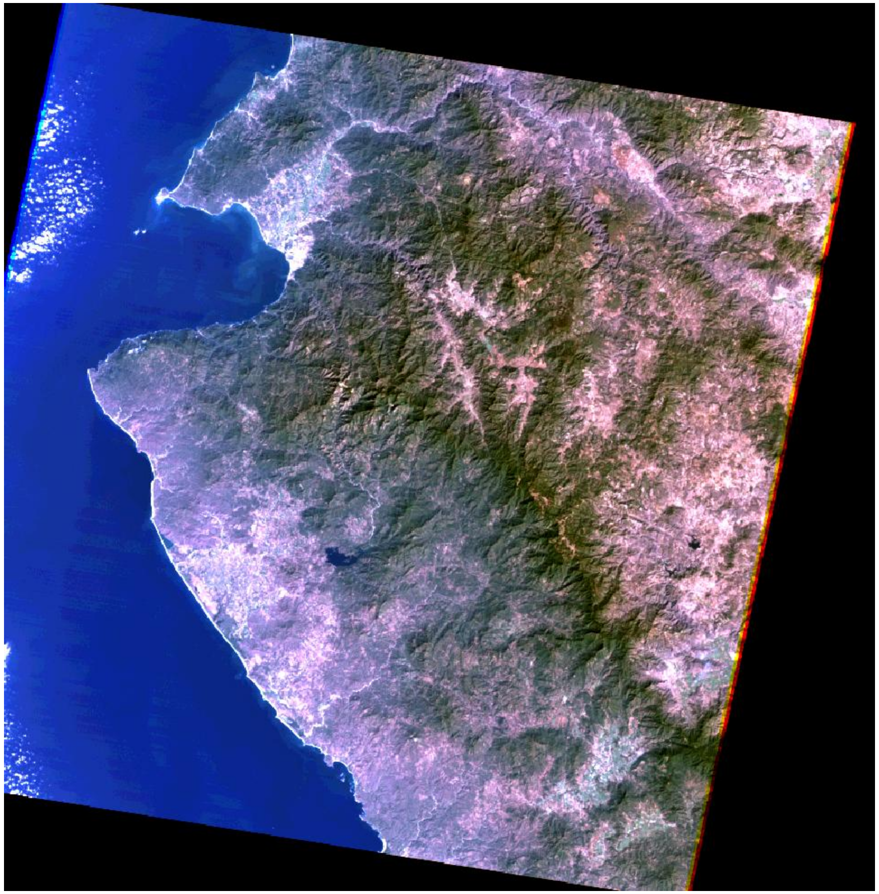


Merge coarse & fine spatial resolution data to create additional fine resolution time points

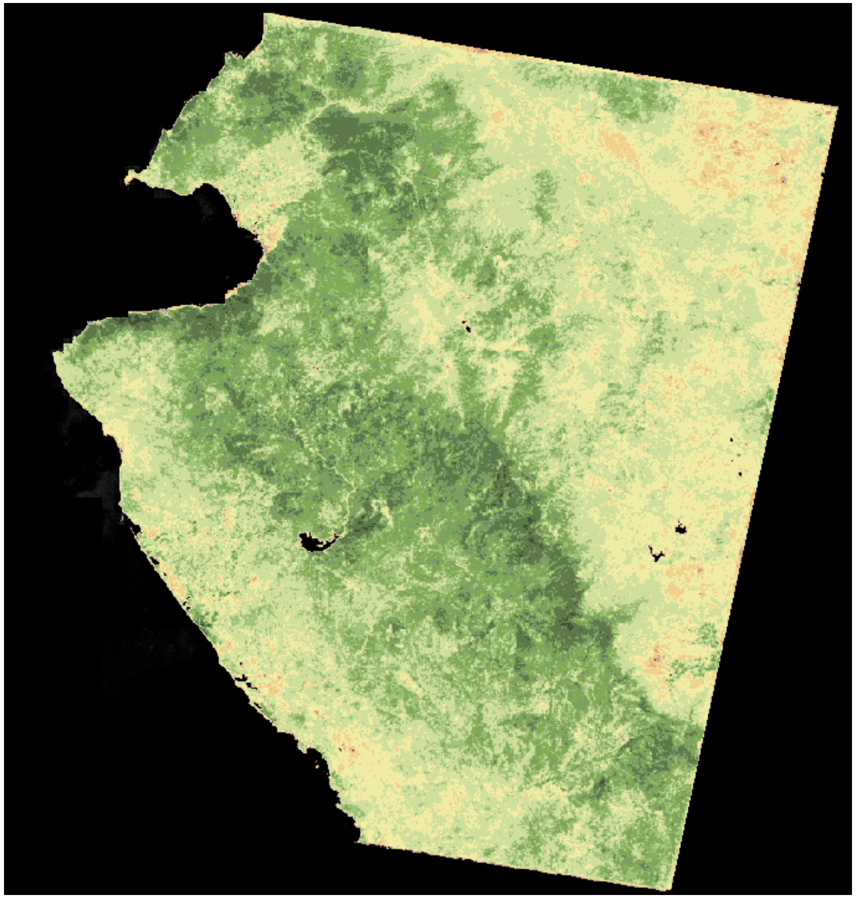
- High resolution images
- Merged images

EXAMPLE OUTPUT DATA

Landsat image

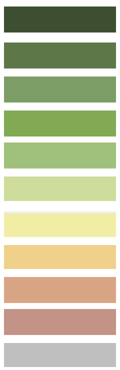


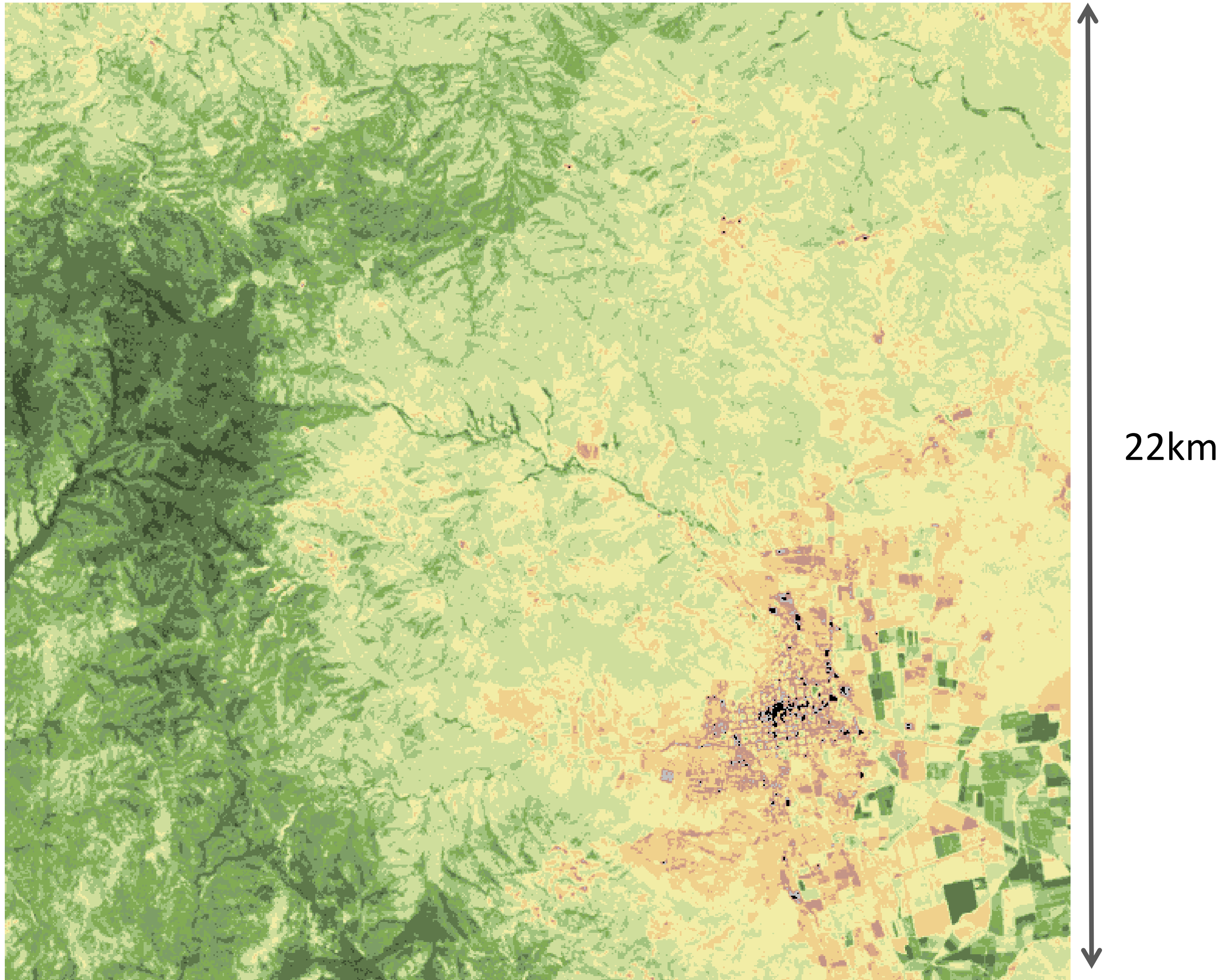
Integral of NDVI map for 2001 (proxy for NPP/GPP)



Coastal region of Jalisco, Mexico

CLOSER VIEW





- 30m pixels
- needs calibrating to convert to standard GPP/NPP units

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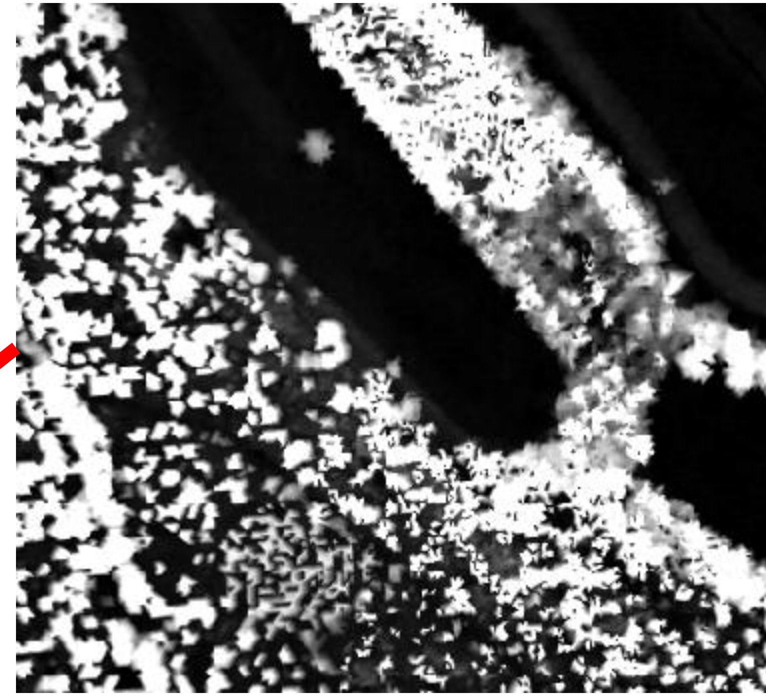
Structural methods

Lidar-derived canopy height map of Thetford



Repeat data gives growth rate, but need field data or existing empirical relationships to link tree height/tree height change with biomass/carbon

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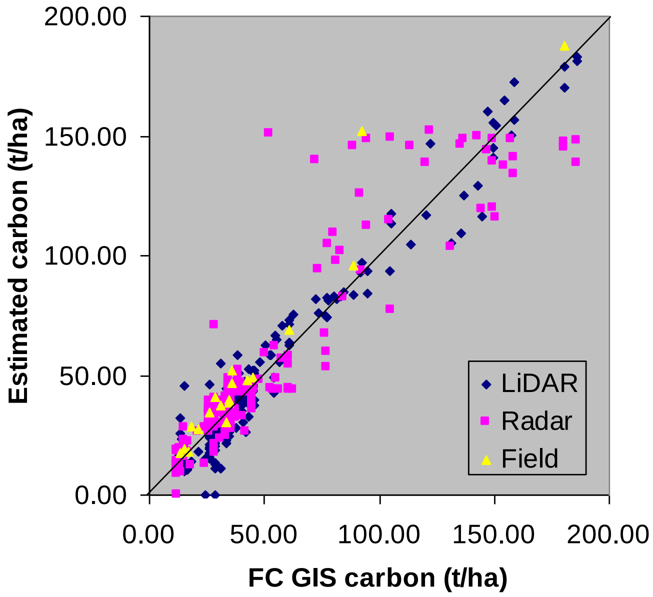
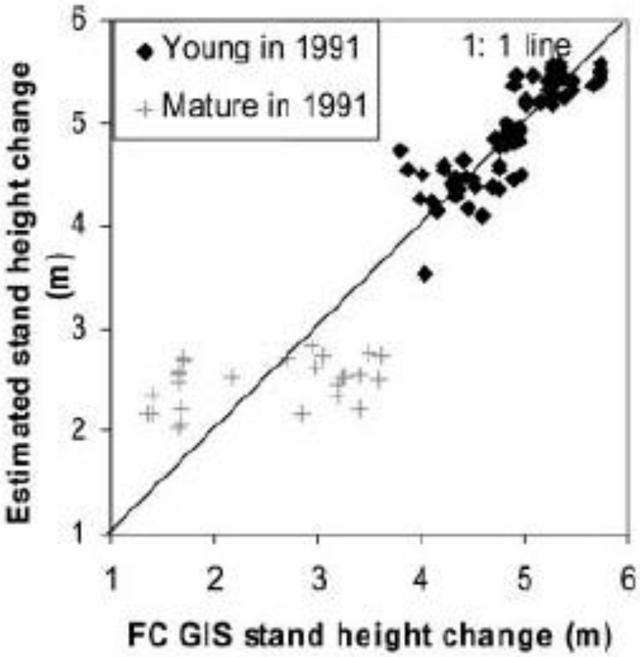
Carbon & stand height change estimates





LiDAR, radar & field measurements of aboveground carbon for Corsican pine stands, Thetford

RMSE: LiDAR: 10 t/ha

Radar: 15 t/ha (10t/ha below sat. pt. 29t/ha above)

Field: 16 t/ha

Radar estimates of stand growth between 1991 and 2000

Note results are for single-species, single-age plantation stands, with Forestry Commission data on yield & growth rates

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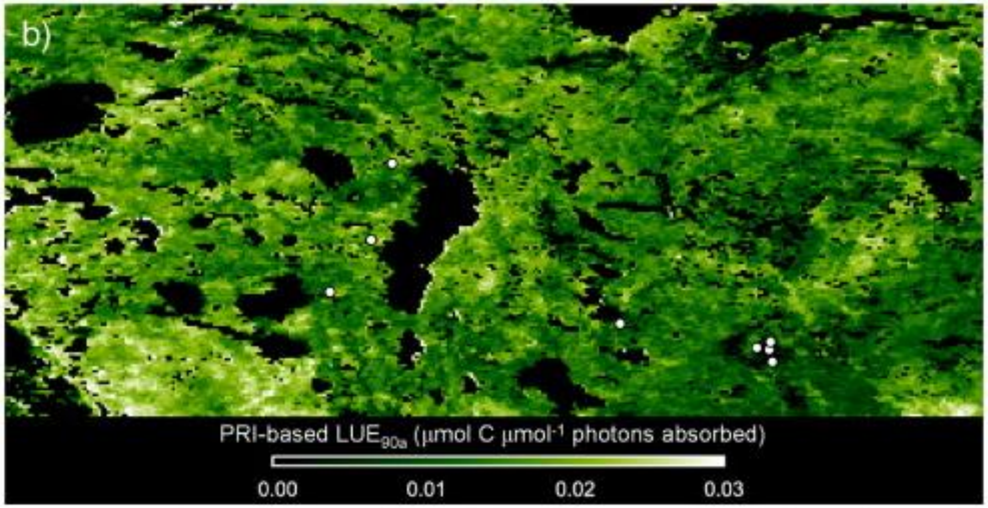
Current areas of Remote Sensing NPP research

- Scaling up ground measurements
- Scaling up flux tower measurements
- Validation/improvement of global products
- Quantifying yield in agriculture/forestry
- Determining the spatial + seasonal dynamics of vegetation growth/productivity
- Monitoring of LUE via vegetation indices (e.g. PRI) or fluorescence



Drolet et al., (2008)

Estimated LUE for area of Canadian boreal forest and shrubland derived from MODIS data and a Photochemical Reflectance Index (PRI)