**IMRAD Scribble MSc thesis**

**Introduction**

* Climate influences phenology
* Climate change will cause shifts in phenology (expectation: lower effect from temperature, maybe at the cost of moisture?)
* Unclear how/why/what/where
  + Climatic controls will play a huge role
* Phenology can be both observed and modelled
  + So can climatic controls
* Chance to test models over past years
  + If they correspond: set basis for future models
  + Analyse how climatic controls influenced phenology in the past 30 years
* Research questions:
  + See how well modelled LAI and measured LAI correspond
  + See how climatic controls changed over the last 30 years (regional differences?)
  + See how climatic controls and leaf growth/senescence correspond

**Materials & Methods**

* ***Materials:*** 
  + LAIre – Modelled LAI
  + LAI3g – Measured LAI
* ***Methods***
  + Making the two datasets comparable (spatial, temporal resolution differs)
  + Extracting Phenological Parameters
    - *Short overview: How does it work*
    - *Smoothing Datasets*
    - *Extracting Parameters (MP, MI methods)*
  + Comparing LAIre to LAI3g
    - *Raw bimonthly (correlations)*
    - *Phenological Parameters*
    - *Decadal changes*
  + Analyzing Climatic Controls
    - *Dominating controls by year*
      * *Extract changes over the last 30 years*
    - *Decadal changes bimonthly*
  + Connecting Climatic Controls to Phenology
    - *Extracting climatic controls prior to SOS/EOS (1 month)*
    - *Find dominating controls for growing/senescence season*
      * *Global correlation cc-LAI*
      * *Dominating control during that time*
      * *extract changes over 30 years*
    - Correlate shift in Phenology (days per decade) to change rate of climatic controls (change rate per decade)

**Results**

* ***LAIre to LAI3g***
  + Raw bimonthly results
  + SOS, EOS, GSL results
* ***Climatic Controls***
  + Dominating Controls (map of significant changes over last 30 years)
  + Significant changes bimonthly (maps or statistical measures?)
* ***Climatic Controls (CC) compared to Phenology***
  + CC to LAI correlation
  + Dominating CC by year (map)
  + Changes for dominating CC (maps)
  + Correlate shift in Phenology (days per decade) to change rate of climatic controls (change rate per decade)

**Analysis**

* ***LAIre to LAI3g***
  + Good correlation for raw data (-> Rest of analysis has a point)
  + Mixed results for SOS, EOS, GSL (expected due to global correlations, i.e. tropics where no clear start/end of seasons can be observed skew results. Regionally good correlations observed
  + …
* ***Climatic Controls***
  + Shifts in Dominating controls especially at the border of land surface types (i.e. border of Sahara desert)
  + … (closer look at affected areas)
  + Interesting intra-yearly shifts in certain areas
  + … (closer look at affected areas)
* ***Climatic Controls compared to Phenology***
  + Surprisingly strong CC to LAI correlations globally.
    - *Temperature increasingly positive correlation -> indication that influence of Temperature GOES DOWN as T is high enough to send control towards 1 (“saturation effect)*
    - *Moisture going DOWN (also effect of higher T -> less moisture?) BUT: very very tiny effect. -> might be seeing things where there are none.*
    - *Generally: Very hard to interpret properly, very hard to actually say anything (T-control of 1 -> no more influence; will yield high correlation nonetheless. Maybe only correlate with pixels where CC <1?*
  + Dominating CC by year:
    - *Discuss regional changes*
  + Dominating CC during SOS/EOS
    - *Interesting NHEM/SHEM differences*
      * *i.e. NHEM sees more changes for EOS (-> Irene’s findings?)*
    - *regional differences*
  + Correlation/regression/trend of change rates (CC-at-parameter decadal change to SOS/EOS/GSL change

**Discussion**

* What can be said:
  + Modelled LAI can be used for predictions due to its good correlation with measured LAI
    - Question: How useful are comparisons of modelled LAI with modelled CCs if both are based on the same model…
  + Climatic Controls have definitely shifted over the past 30 years, for some areas (esp. border-areas of biomes) especially in crucial phases of growing season
    - Influence on Phenology definitely there
* Challenges:
  + Getting quantitative results
  + Climatic Controls model questionable
  + ALL models rely heavily on MODIS data to model them. source of possible systematic error
  + Very coarse resolution used, possible errors due to resizing/averaging too much over different land cover types -> results still useful/applicable for lower resolution?

**Introduction**

*LAI3g:* based on GIMMS AVHRR NDVI3g (MODIS LAI used for training neural network)

*LAI-re:* MODIS dataset reanalysis by extending GSI Model (including Plant functional type (PFT) and elevation data; then: forward model FPAR, based on MODIS LAI on FPAR, )

-> both connected to MODIS LAI

-> any other LAI datasets to compare to? Something completely MODIS-independent?

Research Questions:

* How does the LAI-re compare to the LAI3g dataset? Do they differ/how? (any obvious over/under estimations?) \*Comparison LAI3g to MODIS?
* How do climatic controls (temperature, VPD) impact different PFTs/biomes/regions over time?
* (How) do changes in LSP depend on changes in climatic controls?

**Methods**

Problem orientated, not too technical

*Data Preprocessing*

First, all datasets had to be resampled to the same temporal and spatial resolution in order to be comparable. This means resampling the temporal resolution to bimonthly means to fit the LAI3g dataset, and resample the spatial resolution to 0.5 degrees to fit the LAIre dataset.

*Resample*all datasets to 0.5 degree resolution? (LAI-re resolution, coarsest dataset) Check for scaling effects..

*Test sites*: For LAI-Comparison: Landcover type (IGBP, like Zhu,2013)?

***Extraction of LSP indices***

*Smoothing*

In order to extract meaningful LSP indices from the remotely sensed LAI3g dataset, the data had to be smoothed to eliminate outliers due to cloud contamination. This was done using HANTS algorithm developed by de Wit et al. The algorithm works by applying a fast fourier transform to the measured values and extracting first, second and third order wavefunctions. Then it gets transformed back and compared with the original measurement.

*LSP Indices*

The most commonly used indices for LSP are the Start of Season (SoS), End of Season (EoS) and the Growing Season Length (GSL). There are several different ways of defining the onset of a growing season (SoS) (reed et al.). The end of the growing season is usually defined as the point at which the LAI-value goes below the LAI-values set as SoS again (see fig..)

In this thesis, two methods were used to define SoS, the Midpoint method and the Maximum increase method.

***LAI Comparison:***

The two LAI datasets were compared in several different ways. Firstly, a comparison between monthly mean LAI and standard deviation was made to test for systematic differences. Then, the extracted LSP indices were compared and their spatial difference was assessed by creating maps of difference (SOSLAIre-SOSLAI3g)

To compare the two datasets, LSP indices were extracted

- HANTS for smoothing

- Land Cover (p42. Validation good practices, Garonna) to mask water/other non-vegetation lc

- Extract metrics: Max-inflection and/or Midpoint method for LSP

***Changes in Climatic Controls***

Look at controls independently by creating maps, look at trend in time series by defined regions (same as LAI-regions?)

(mainly amount-of-daylight; or maybe test just to make sure?)

How: yearly averages? Monthly? Don’t know yet.

***Comparison***

Correlate changes in LSP-metric (GSL probably (or all 3)) to measured LAI3g; - Extract by PFT/Land Cover? Biome/Region -> seems more appropriate for global trend study.

**Results**

Expected:

*LAI*: generally GSL lengthening, Depending on location of course

*LAI3g-LAIre:* wouldn’t expect too many differences considering they use the same training data. NDVI limitations (3g) might influence it more than climatic controls (re)

*GSI-LAI*: slight rise in temperature, VPD?! No clue what to expect.

Comparison: generally slight rise of GSL with temperature; no trend with radiation (hours daylight stay the same), maybe something with VPD

**Analysis**

**Discussion**