Scale hive network and satellites reveal shifts in nectar flows due to climate and land cover

Wayne Esaias, Robert Wolfe, Joanne Nightingale, Jaime Nickeson, Peter Ma
NASA Goddard Space Flight Center, Greenbelt, MD USA

Collaborators -
Jeff Pettis USDA ARS BBL
Jon Harrison Arizona State Univ.
Catherine Jarnevich Tom Stohlgren, Jeff Morisette USGS Ft. Collins

Mid Atlantic Apiculture Research and Extension Consortium (MAAREC)
Maryland State Beekeepers Association
Apiary Inspectors of America - Jerry Hayes, Fl Dept. Agric

NASA Earth Science Division “Decision Support” Program - Apply NASA Satellite and Science Results to National Needs (Invasive Species).
3 year Grant, began 3/08

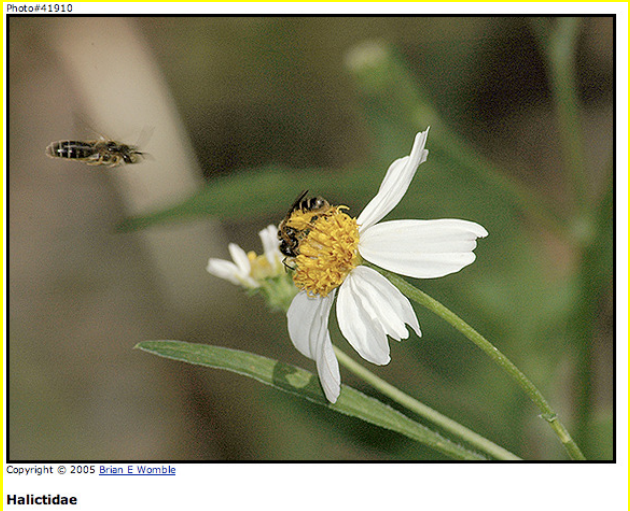
How is climate change affecting pollination?

Nectar Flow dates and quality are changing due to climate & land cover/land use changes.

We lack a good baseline of Nectar Flows to judge/predict climate change impacts.

Hive weight records can link satellite observations to plant-pollinator interactions and ecosystem climate change.

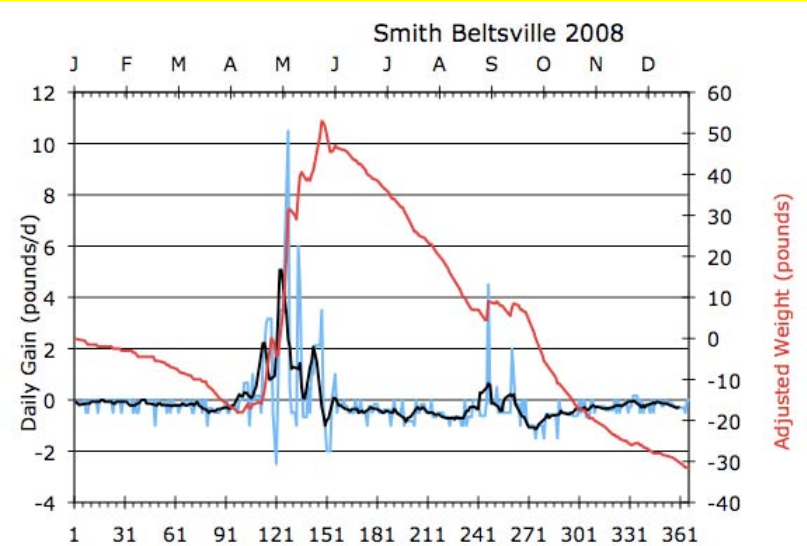
We are encouraging a network using ‘scale hives’ and satellite vegetation indexes, to begin to study impacts of climate change on plant-pollinator interaction, and honey bee health.



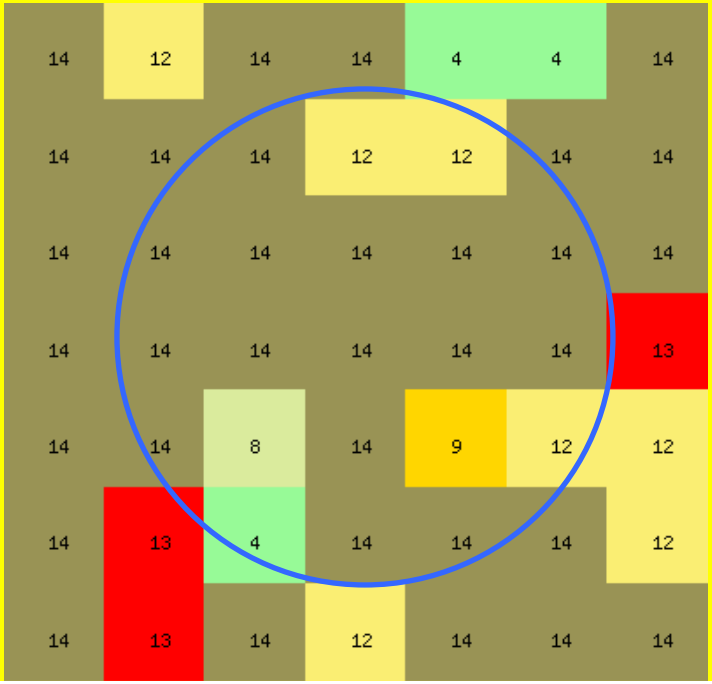
Nectar Flow from Scale Hives

- Daily Weight Change
  - -2 to + 25 lb/d
  - -1 to 10 kg/d
- Defines nectar flow & plant-pollinator interaction period

- Metrics focus on phenology

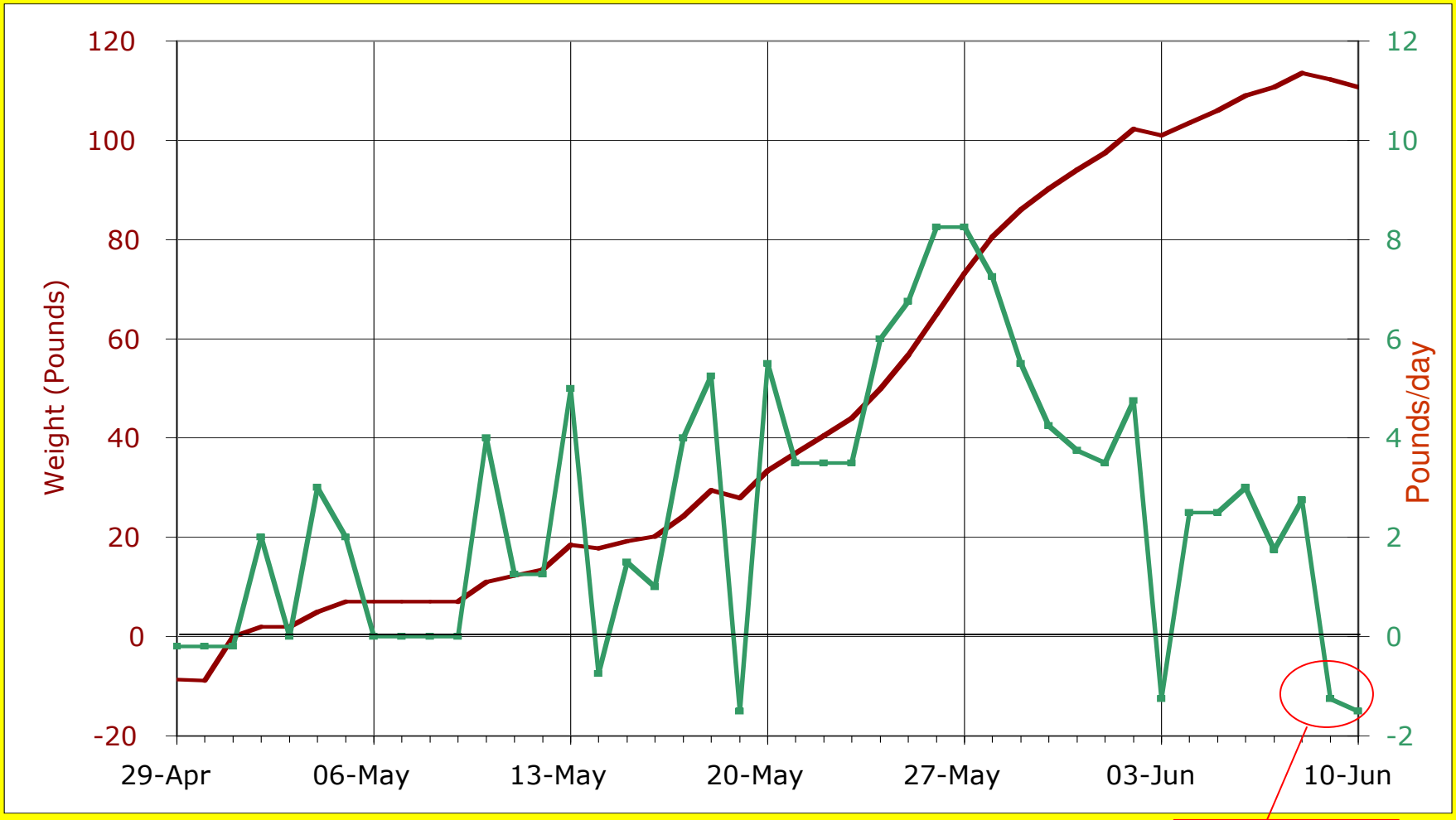


MODIS Vegetation Data vs. Scale Hive 2000 2006

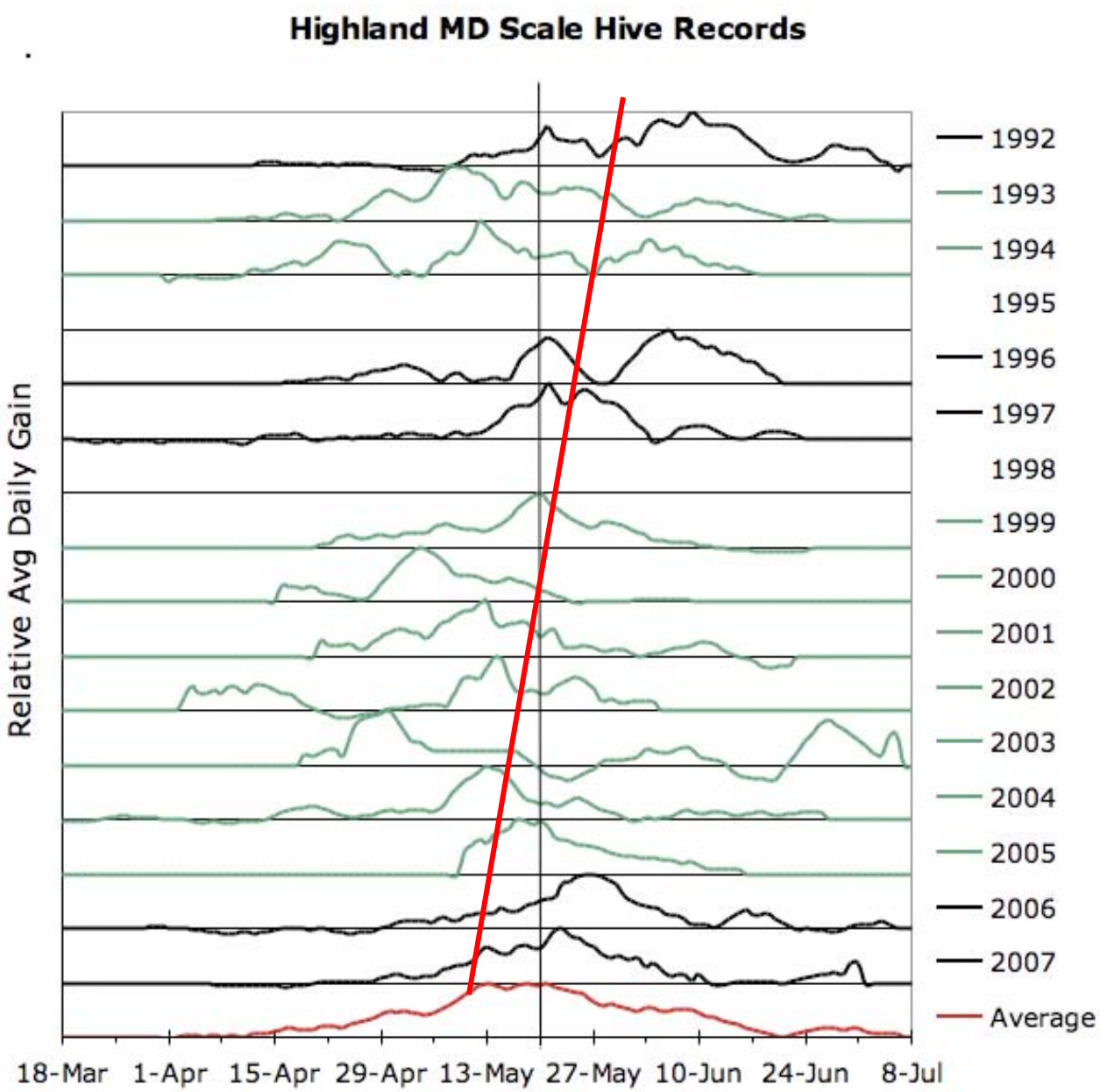


Pollinator-plant interaction, Howard County, MD

2006



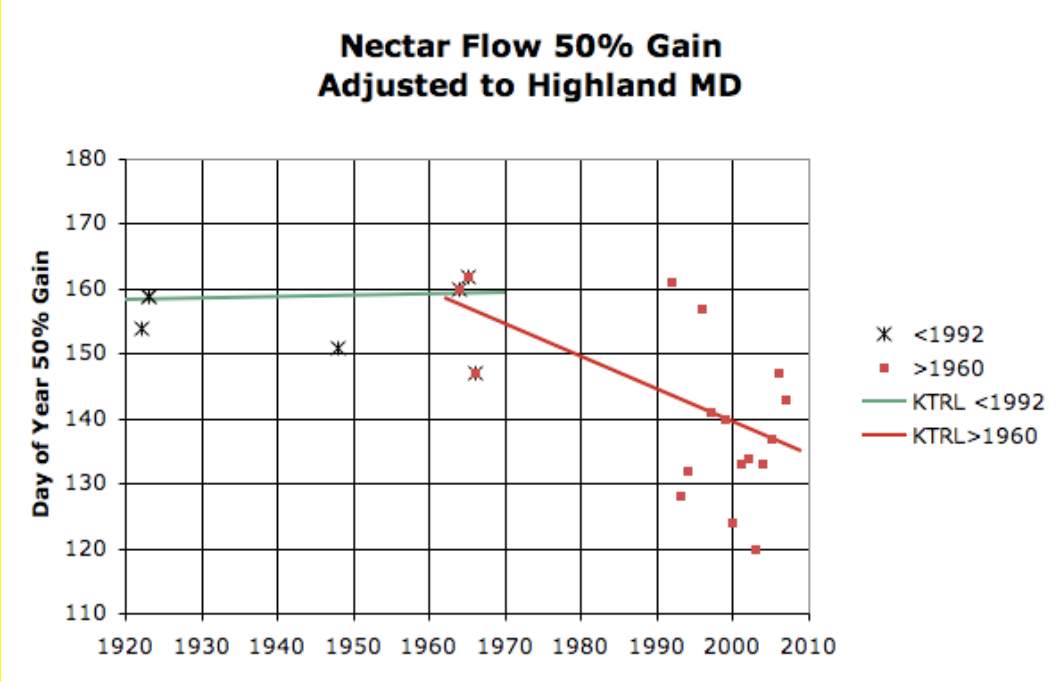
Beautiful clear days - but the nectar flow is over



A 17 year time series 1992-2009

Shows variations due to short term climate events

And an overall trend

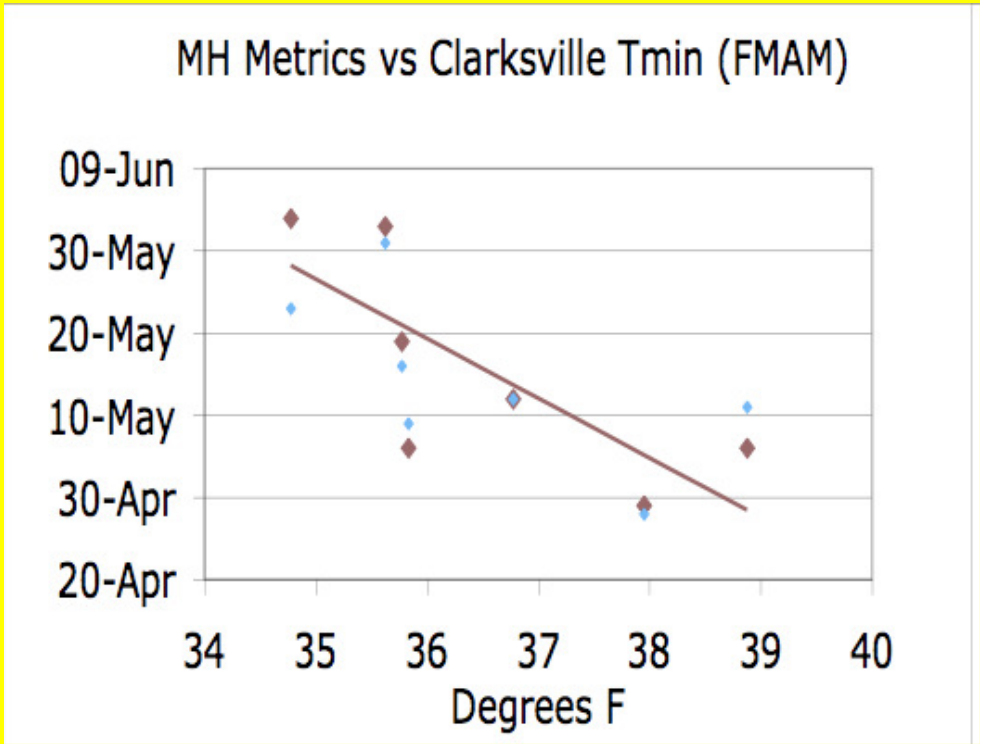


Nectar Flows have Advanced by 0.58 days per year since 1970 in Central MD (~27 days)

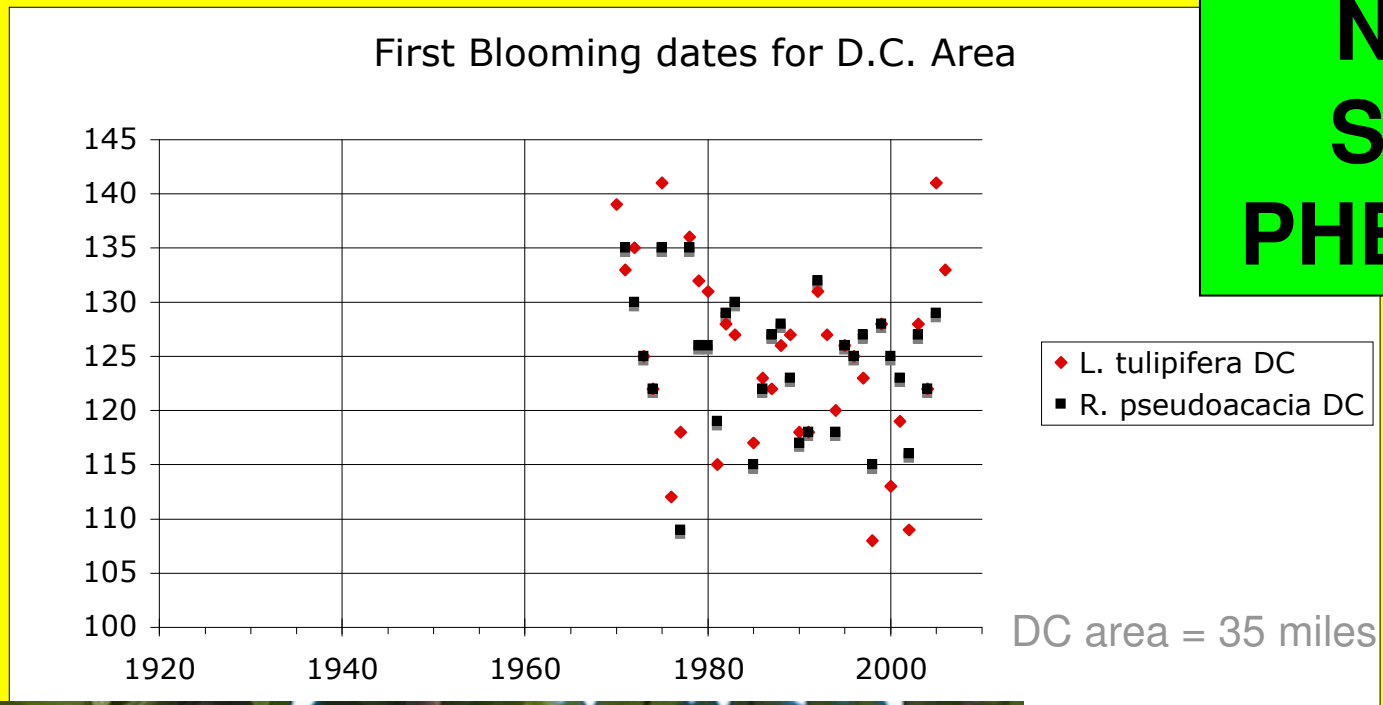
Similar Advance seen in Nectar Forage Plants Blooming Dates

Warm Winter-Springs lead to earlier Nectar Flows in MD.

1° F of Warming ~ 1 Week Advance
1° C of Warming ~ 12 Day Advance



NECTAR SOURCE PHENOLOGY

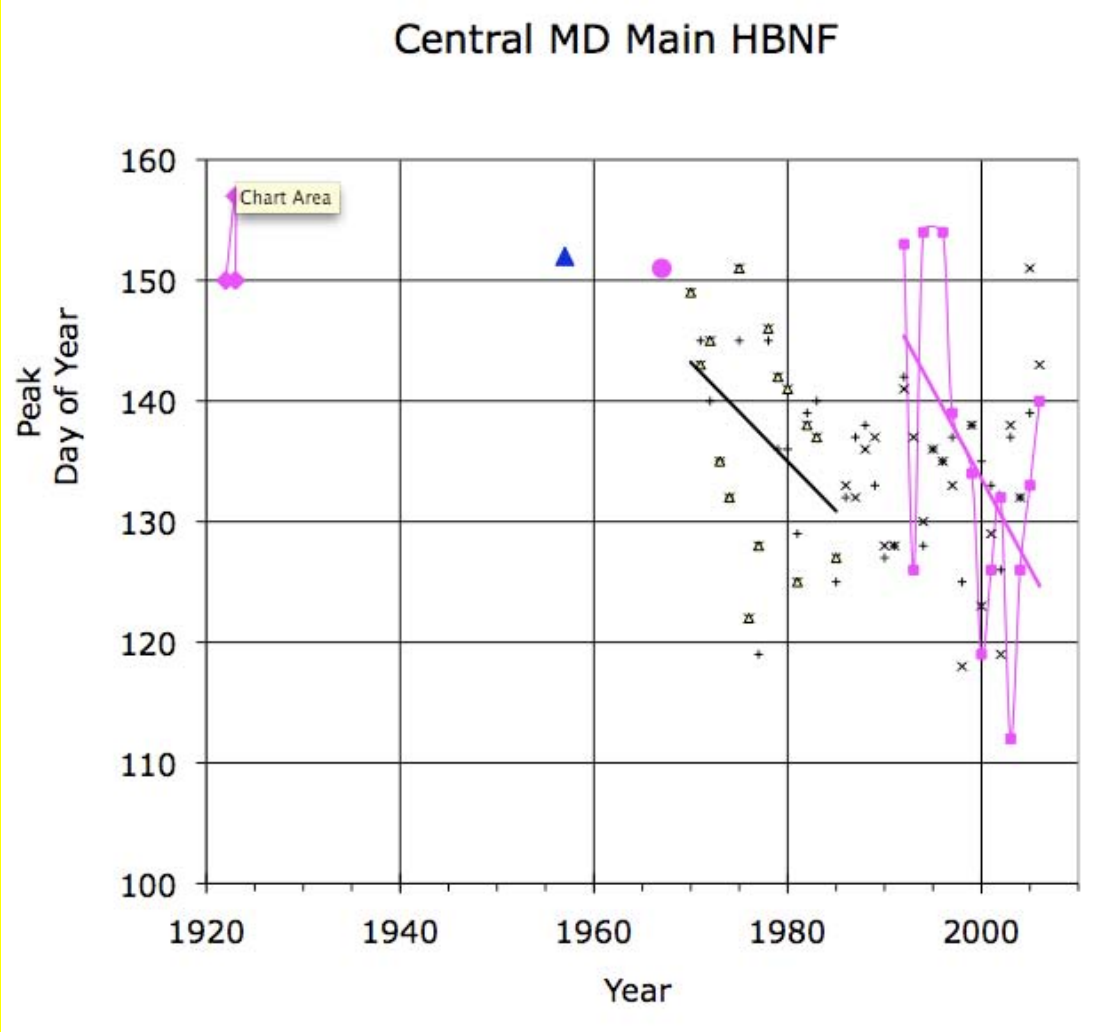


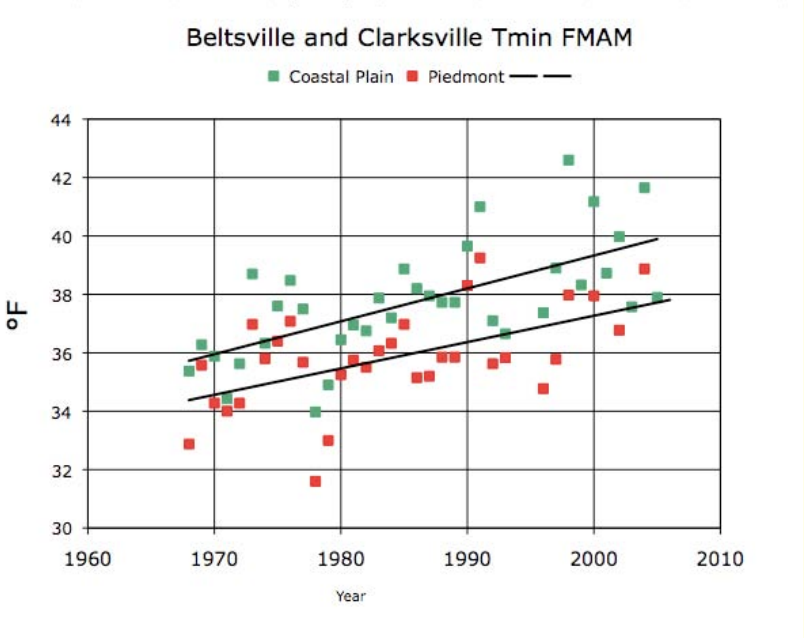
DC area = 35 miles

Abu-Asab, M. S., P. M. Peterson, S. G. Shetler, and S. S. Orli. 2001. Earlier plant flowering in spring as a response to global warming in the Washington, DC, area. Biodiversity and Conservation 10:597-612.


Liriodendron tulipifera Tulip Poplar


Robinia pseudoacacia Black Locust





Apparent (15 yr) lag between advances in blooming in Washington DC and Nectar Flows in Central Maryland, is explained by the (15 yr) lag in Winter Tmins and urban warming.

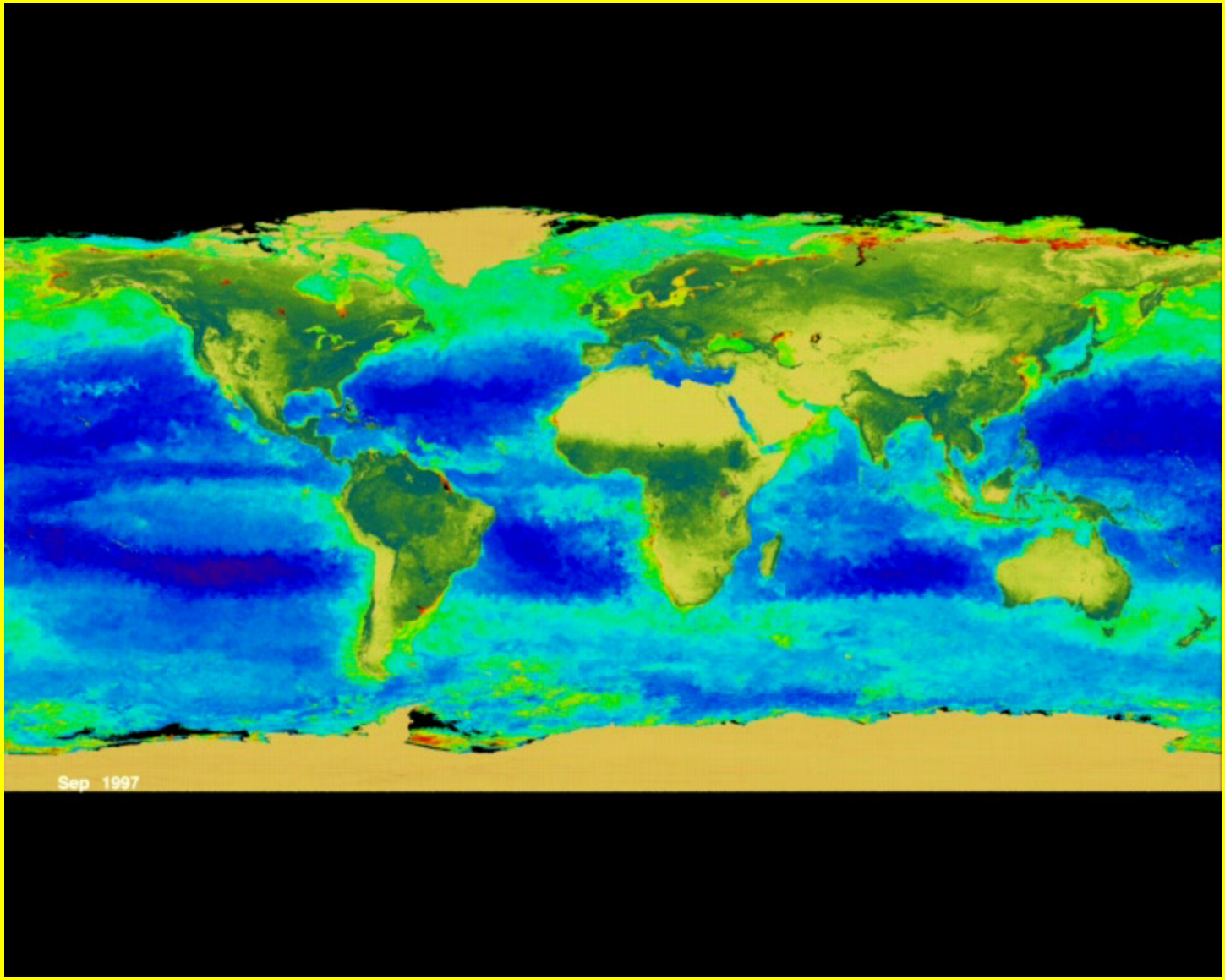
Impacts of earlier nectar flows in Maryland

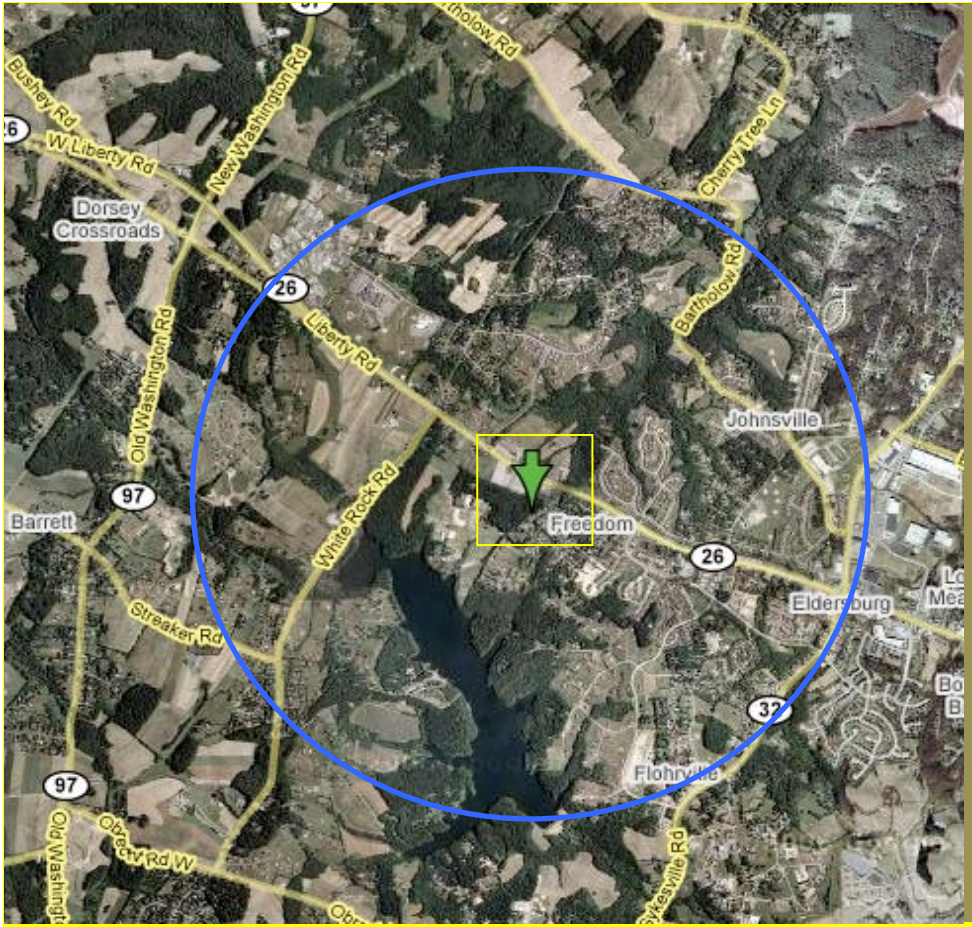
Harder for beekeepers to get colonies strong enough for good pollination and honey production.

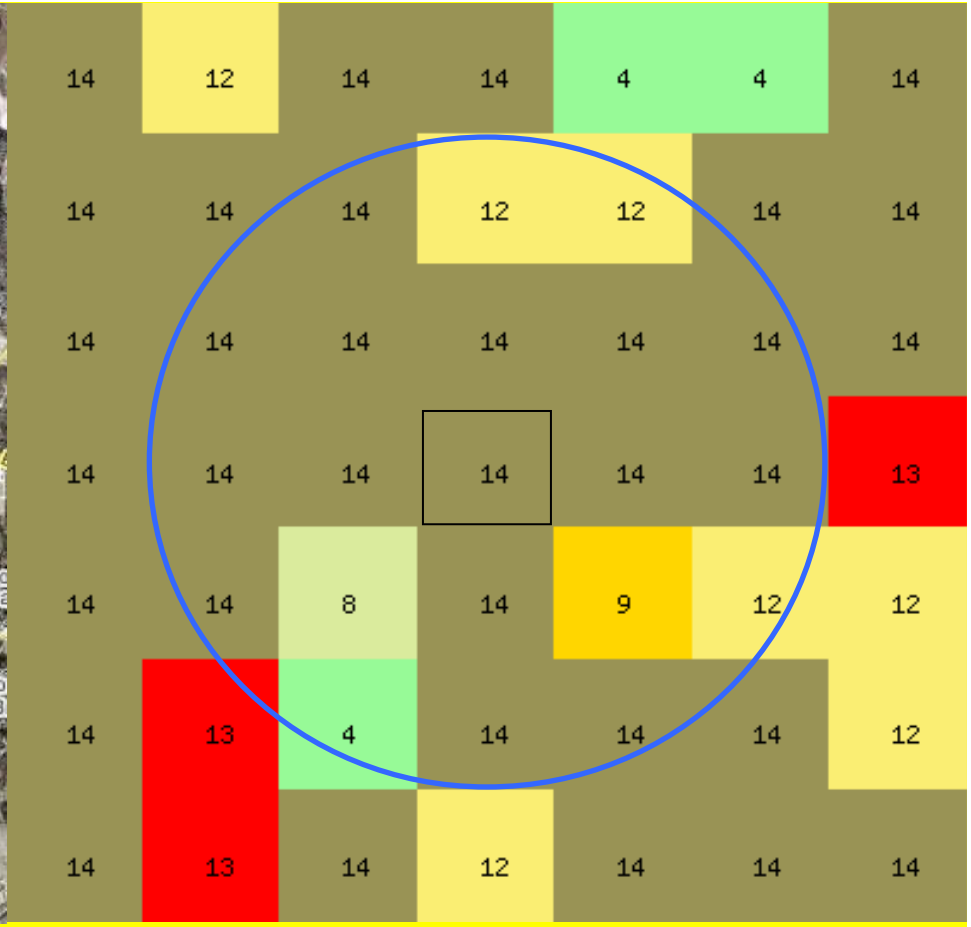
Growers are having a harder time getting bees for pollination in time. Crops suffer, costs increase.

Colonies must be fed in the fall.

SeaWiFS Biosphere Land Vegetation, Ocean Chlorophyll







High Resolution 2-30 meter
Satellite Imagery

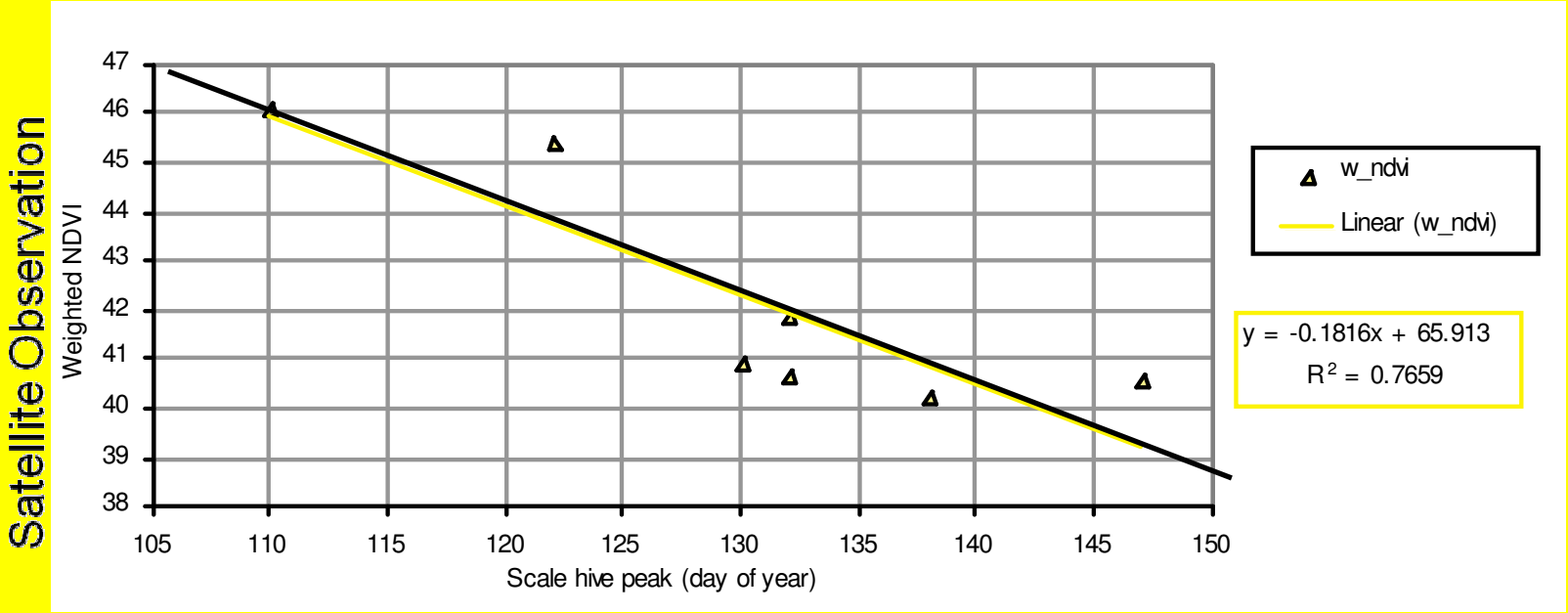
Only a few images per year
Cannot resolve nectar flows

1 km Resolution, Daily Coverage
Land Cover Change & Climate Models
<u>MODIS</u>

Weekly Vegetation change, Carbon growth
for Ecosystem Models, Crops.

But one cannot see blooming plants.

MODIS Vegetation Data and Maryland Nectar Flow 2001 - 2007

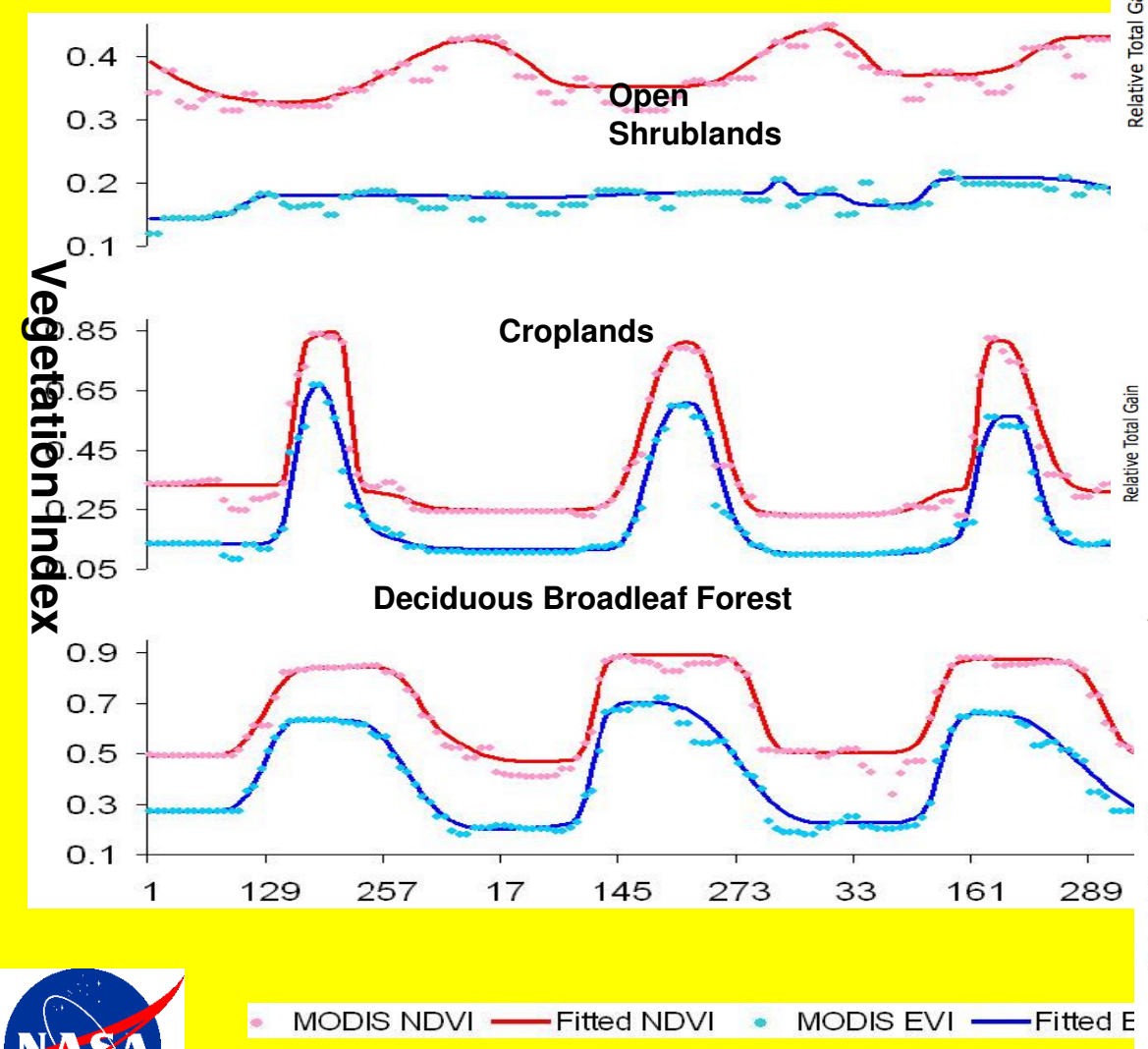


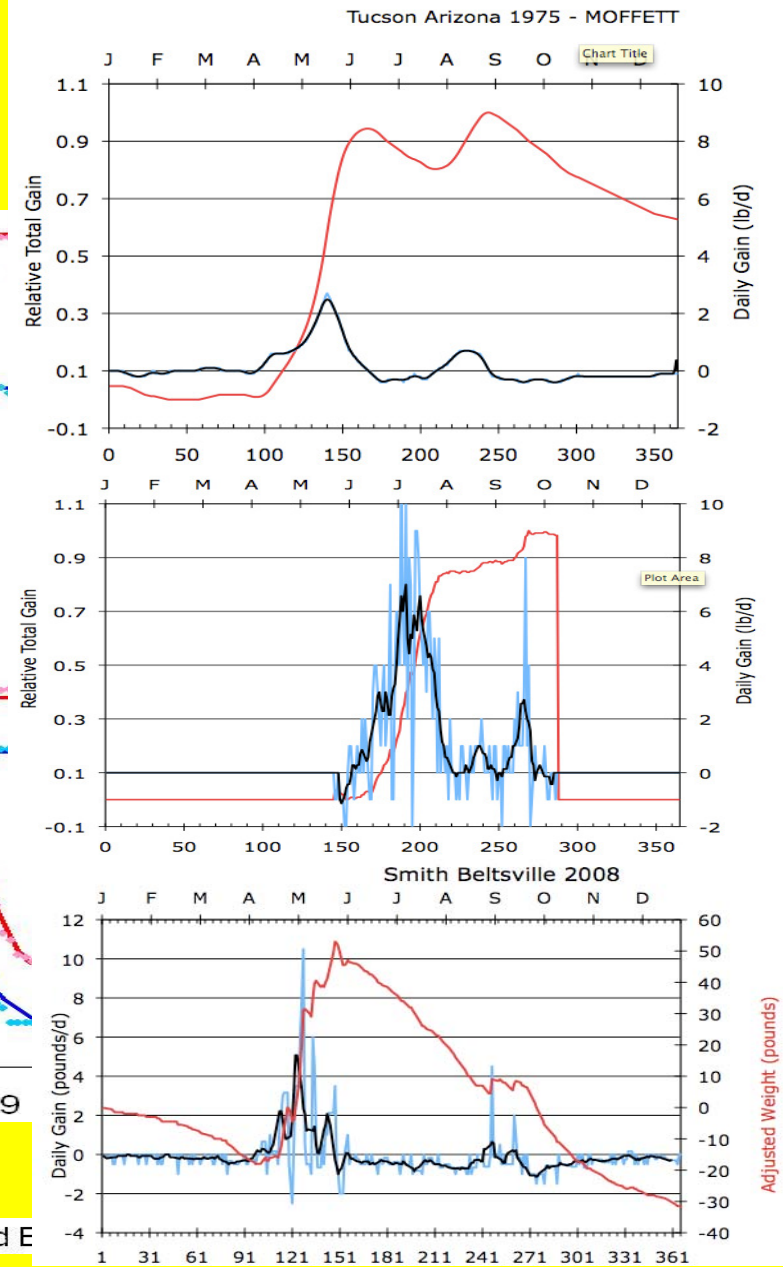
Scale Hive Peak

Satellite vegetation data correlate well with the date of the Honey Bee Nectar Flow in MD. Predictive, cumulative approach. Satellite index is calculated using data up to day 81 (Mar 15).

The relationship will be different in other regions, with different forage plants and climates.

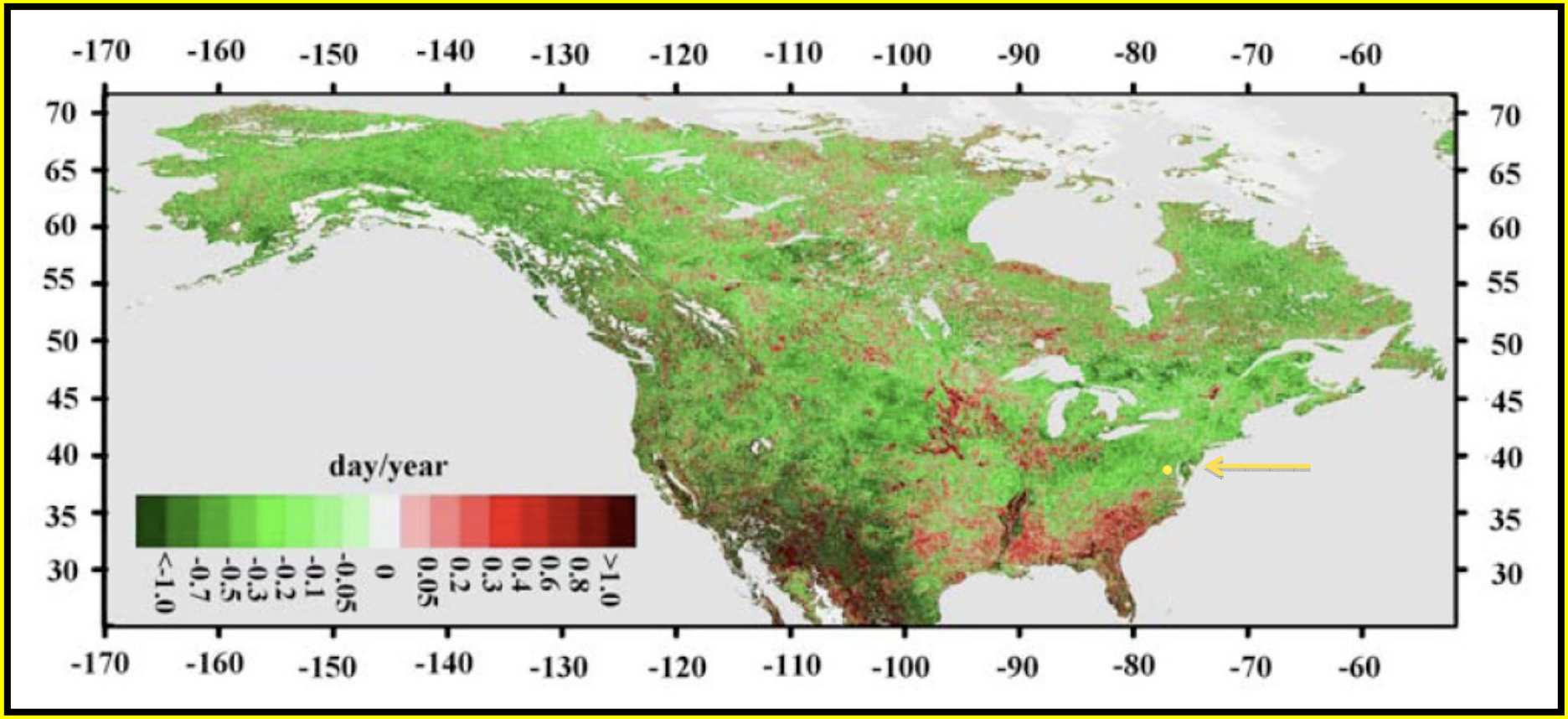
Sat and scales in different land cover types





Satellite Vegetation Trend - changes in onset of Spring green-up

1982 thru 2005 Green = Earlier Red = Later



Zhang et al. Geophysical Research Letters, vol. 34, L19405, doi:10.1029/2007GL031447, 2007

For Highland, MD
Satellite -.575 days/year
Scale Hive -.58 days/year

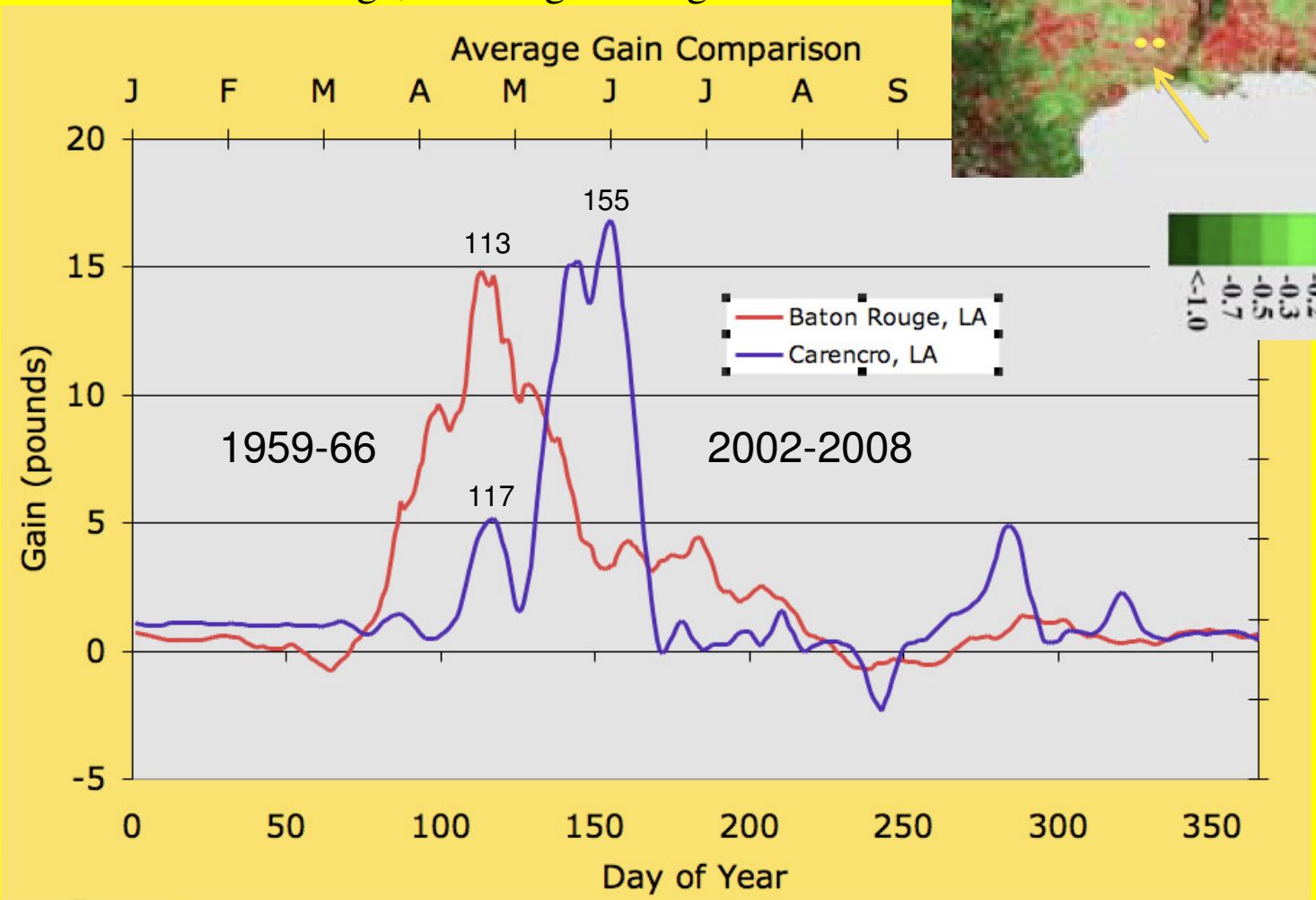
What is the relationship
In other regions?

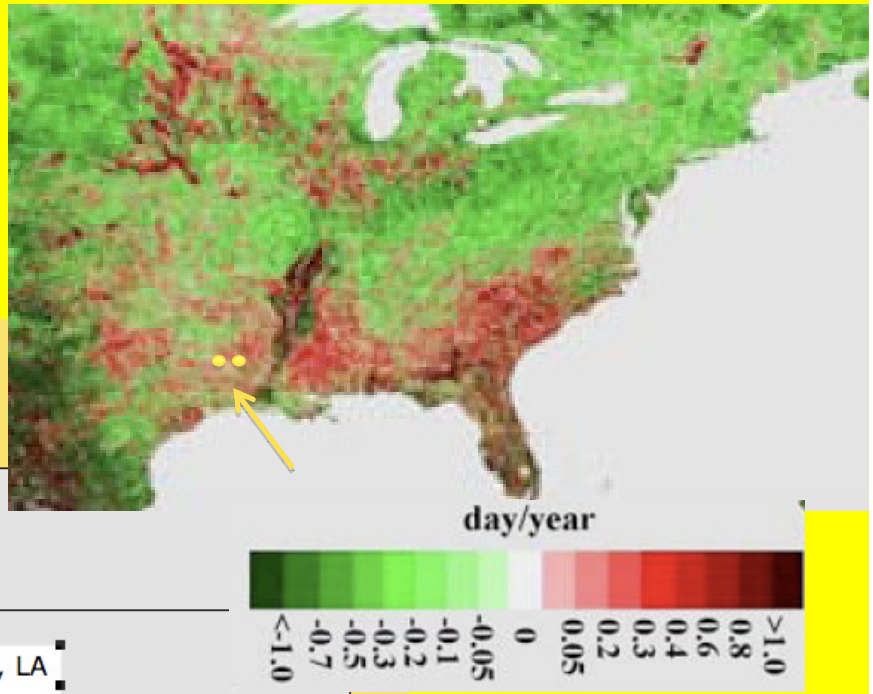
Changes in Louisiana

1960's – Baton Rouge – E. Oertel, ARS
2002-8 - Carencro – C. Harper

~40 miles, ~40 years > HBNF 42 days later

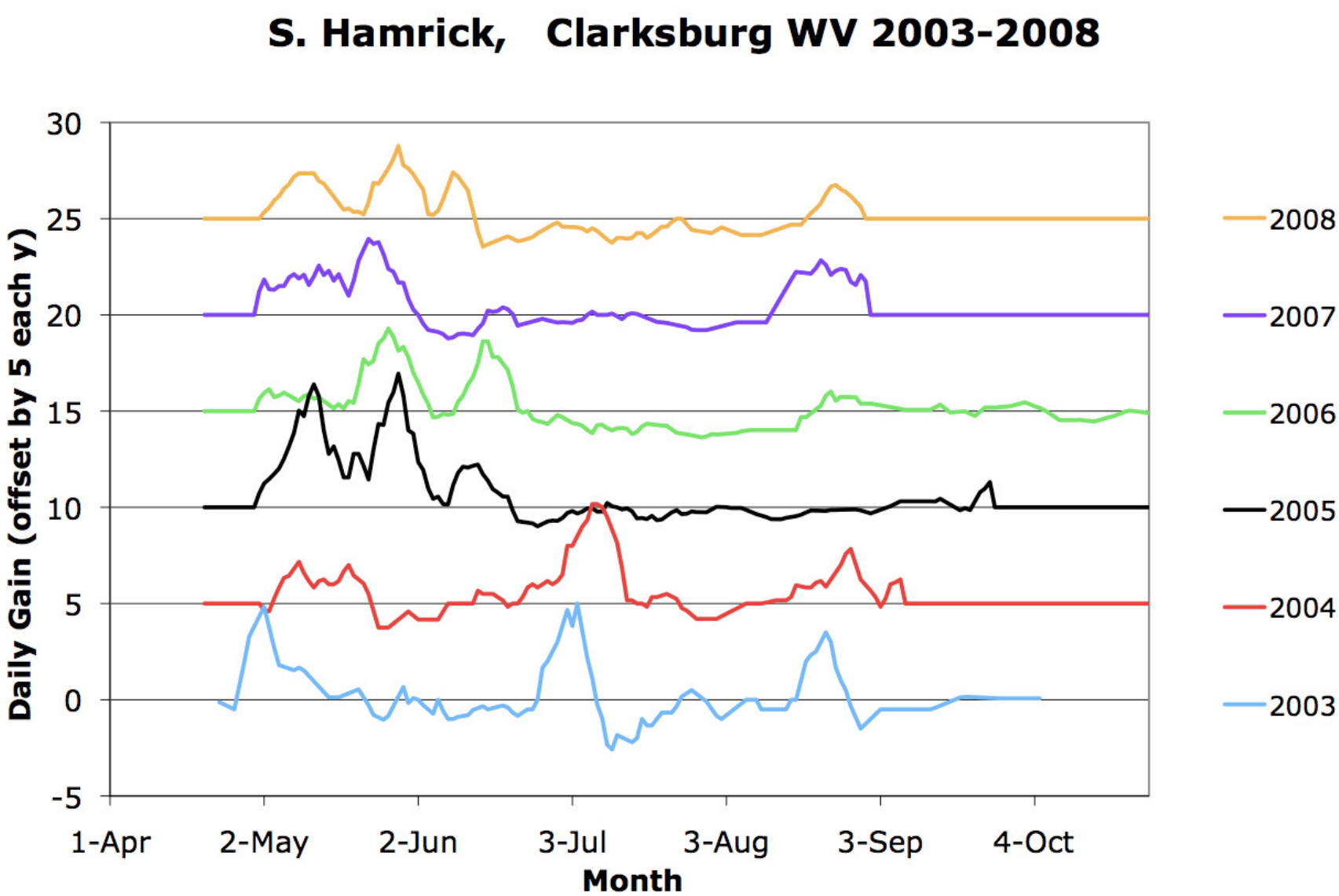
Climate Change, or Forage Change or Both?





Chinese Tallow
Triadica sebifera

This invasive has become a major source in LA and s.e. US, but Oertel did not mention it in his many works.

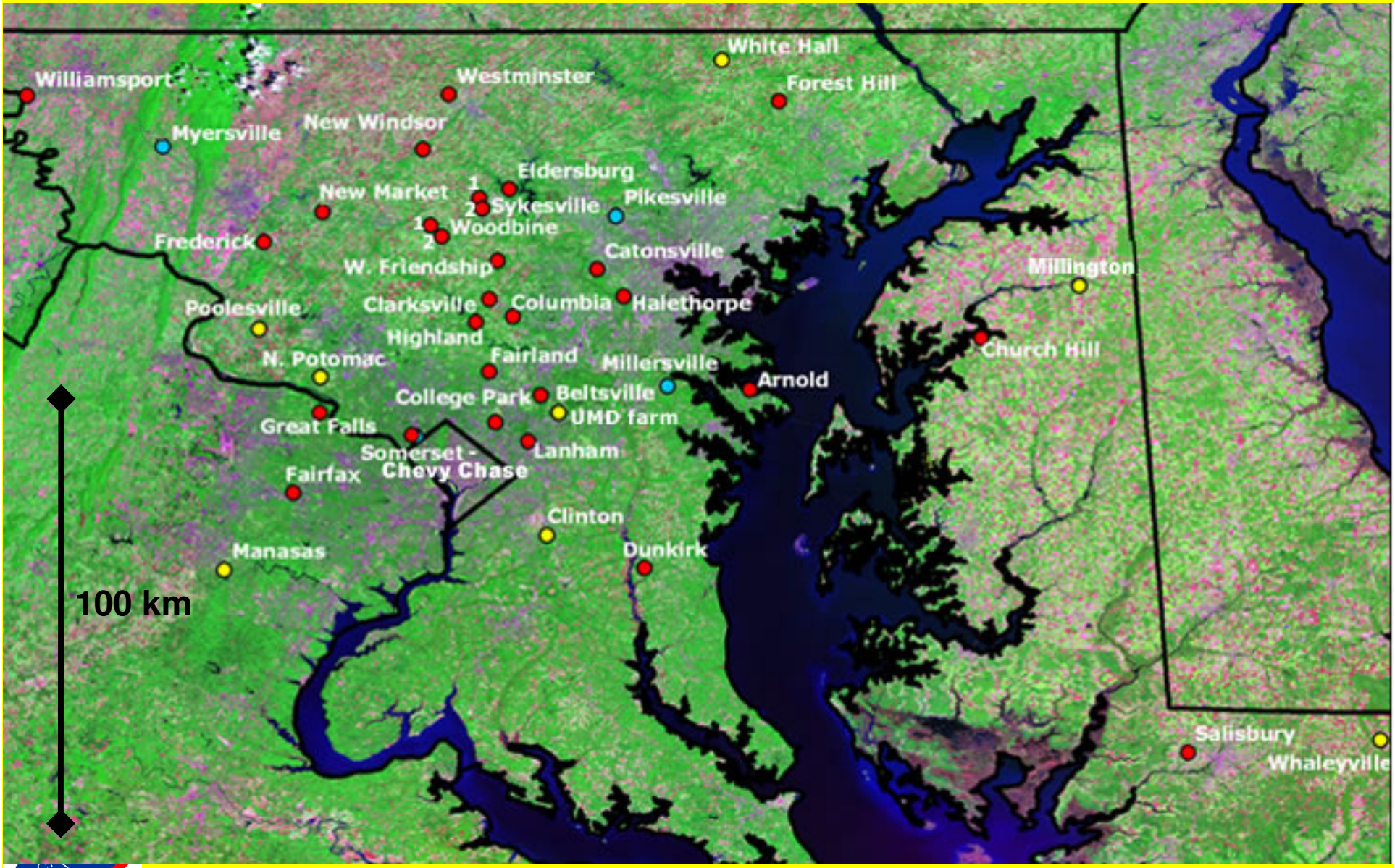

S. Hamrick, Clarksburg WV 2003-2008
Daily Gain (offset by 5 each y)
30
25
20
15
10
5
0
-5
1-Apr
2-May
2-Jun
3-Jul
3-Aug
3-Sep
4-Oct
Month
2008
2007
2006
2005
2004
2003

http://honeybeenet.gsfc.nasa.gov

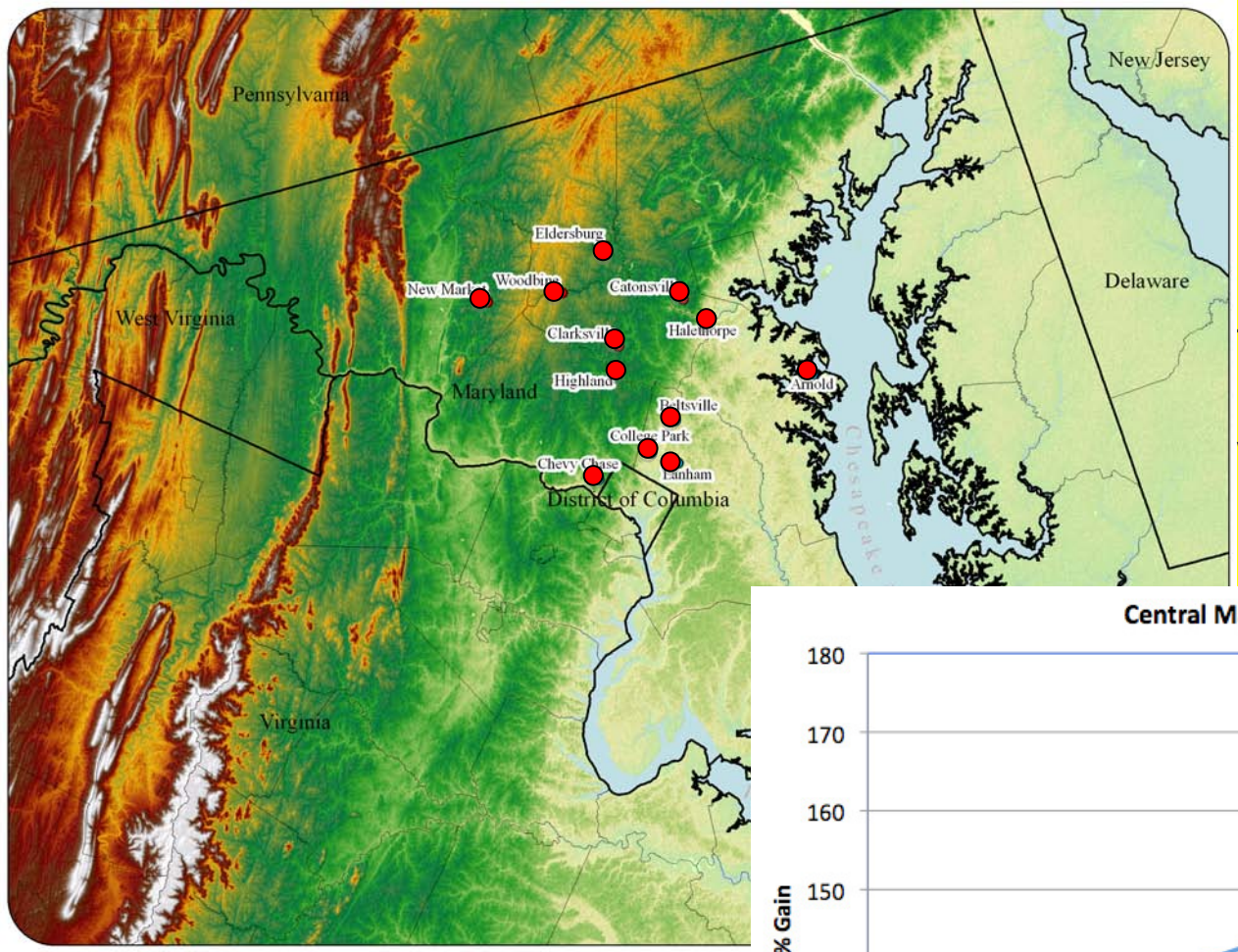
Archive Historic Data
Encourage Volunteers – Provide infrastructure & protocols
Data Base of Scale Hive Data & HBNF Metrics on the web
Provide satellite data for sites on the web
    Investigate Climate Change, Land Use/Land Cover
    Migration of the Africanized Bee


FAIRBANKS
74

Maryland – N. Virginia Scale Sites

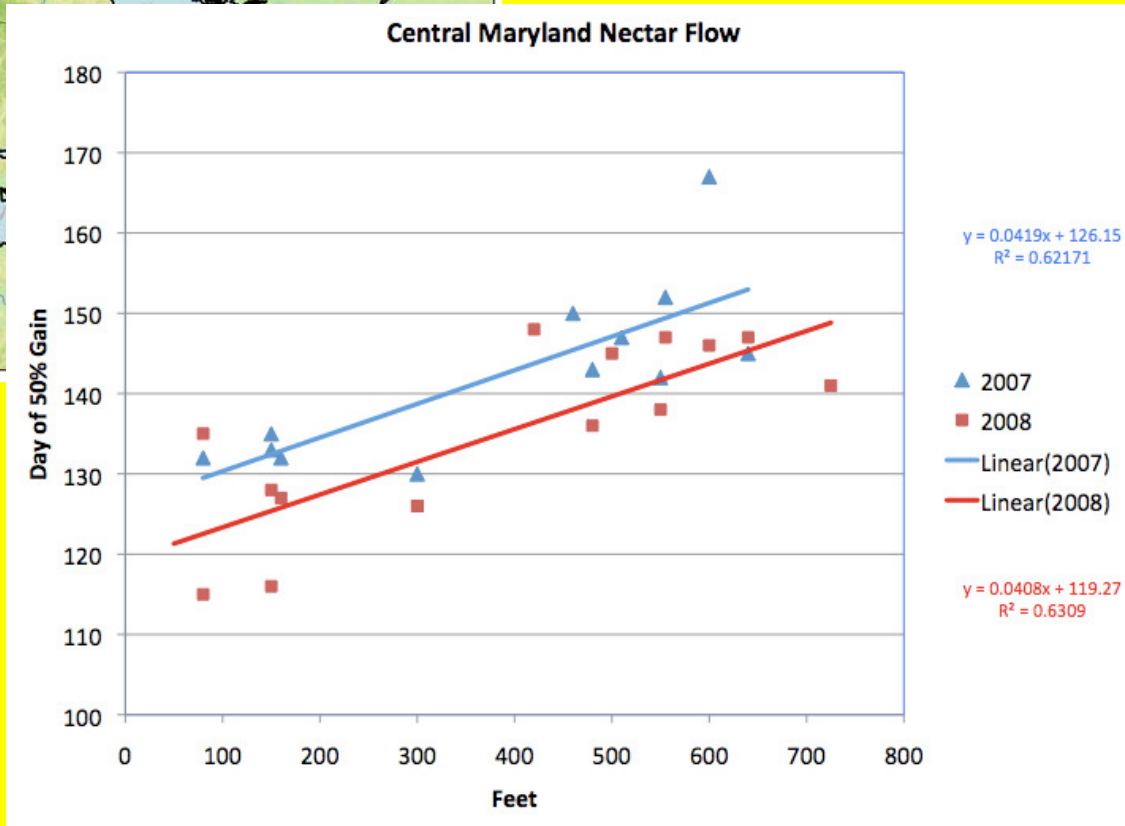


Blue – Historic Red – Current Yellow – New in 09

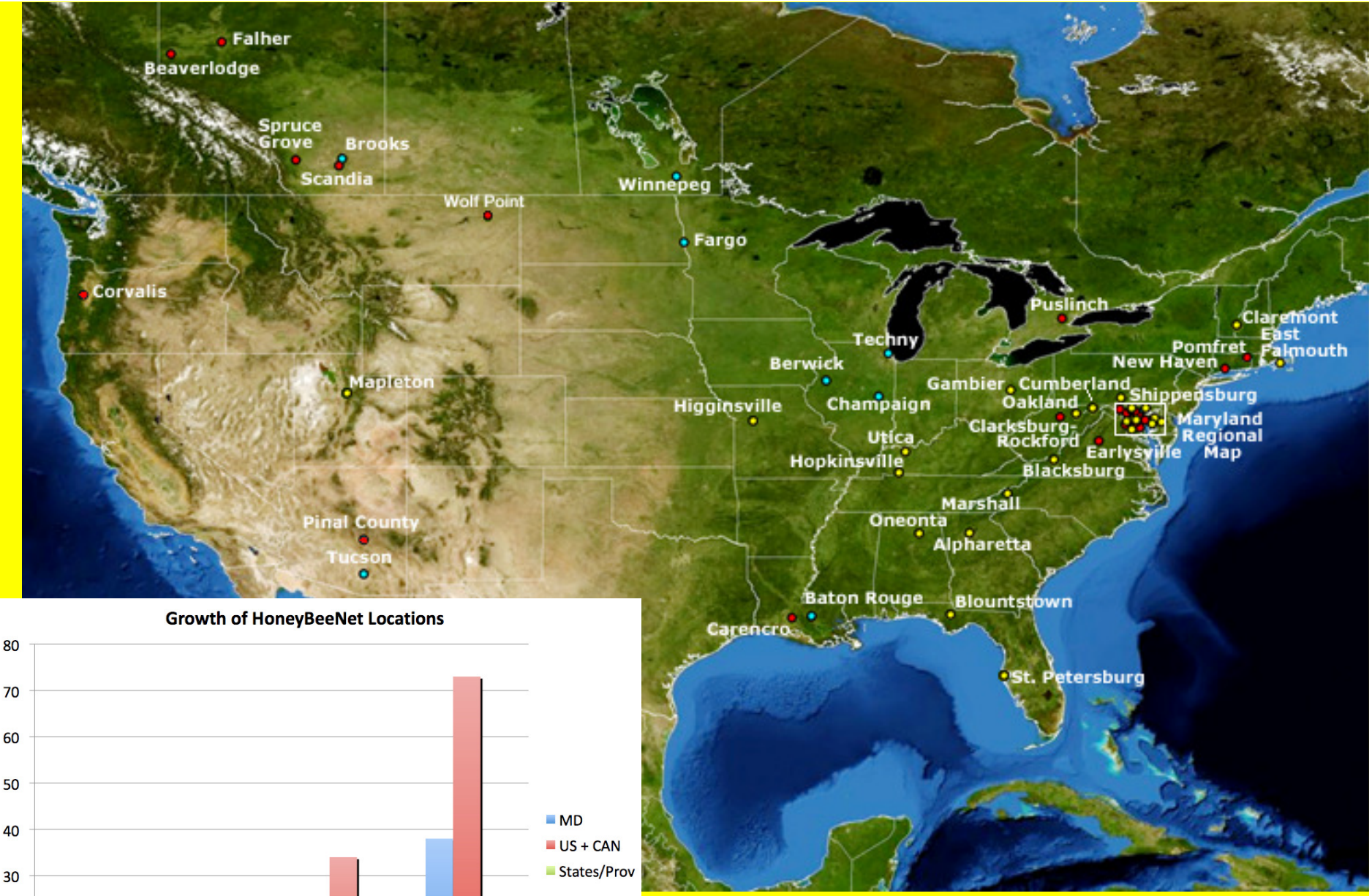


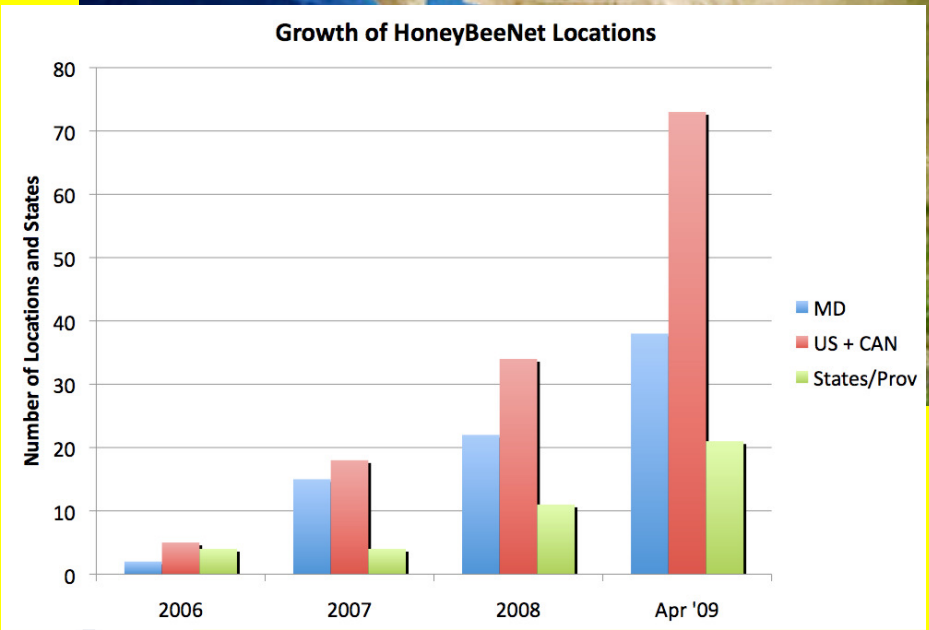
Nectar Flow date depends on late winter temperatures and hence on elevation.

Elevation explains most of the variability in Maryland HBNF dates. Surrogate for winter/spring Temperature.



HBNF occurred 9 days earlier in 2008 vs 2007. 2 week gradient across elevation is the same.


Falher
Beaverlodge
Spruce Grove
Brooks
Scandia
Wolf Point
Winnepeg
Fargo
Corvalis
Mapleton
Pinal County
Tucson
Puslinch
Claremont
East Falmouth
Pomfret
New Haven
Techny
Berwick
Gambier
Cumberland
Oakland
Shippensburg
Higginsville
Champaign
Clarksburg-Rockford
Maryland Regional Map
Utica
Earlysville
Hopkinsville
Blacksburg
Marshall
Oneonta
Alpharetta
Baton Rouge
Blountstown
Carencro
St. Petersburg


Growth of HoneyBeeNet Locations
Number of Locations and States
0
10
20
30
40
50
60
70
80
2006
2007
2008
Apr '09
MD
US + CAN
States/Prov

Satellite Vegetation Metrics MODIS, AVHRR, (MERIS)

- 0.25, 1, 5 km, 8 and 16 day periods, global
- NDVI, EVI, LAI, Productivity
- TimeSat fits to annual time series
- 15 parameters – start, end, peak of season, integrals, ranges, length of season, (dearth)
- 17 Land Cover types

Comparisons with Scale Data underway on regional basis (bee forage, ecoregions).

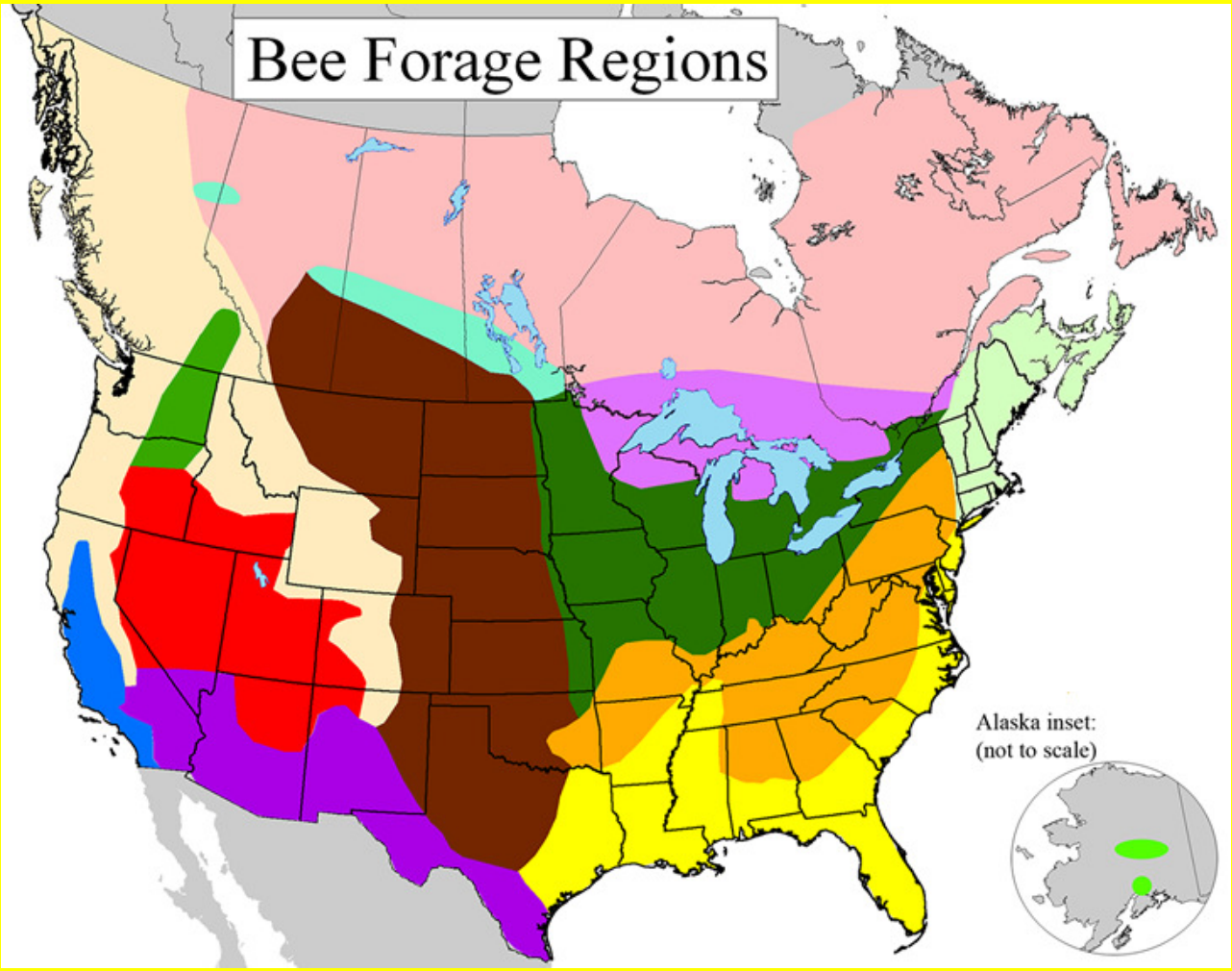
Metrics Derived from Scale Hive Records

Site Information – Site ID, Contact info. , Location (privacy protected)

Begin Day - Min of Adjusted Weight+1
End Day - Max of Adjusted Weight
Duration
Day of Percentile Cumulative Gain – 25, **50**, 75
Day of Max Daily Gain
Day of Max 7 day average Gain
Total Gain
Max Daily Gain
Max Avg Gain
Quality Assessment (A-C, 18 conditions)

Annual and Seasonal (Spring, Summer, Fall)

Original Notes, Blooming information is preserved



Derived from Ayers & Harman, 1992, The Hive and the Honey Bee.

14 Different Regions

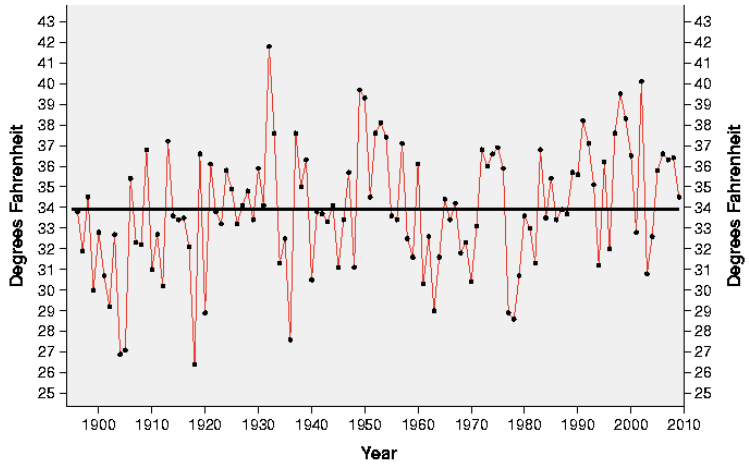
119 divisions (state/province x region)

Blooming months for 264 taxonomic groupings.

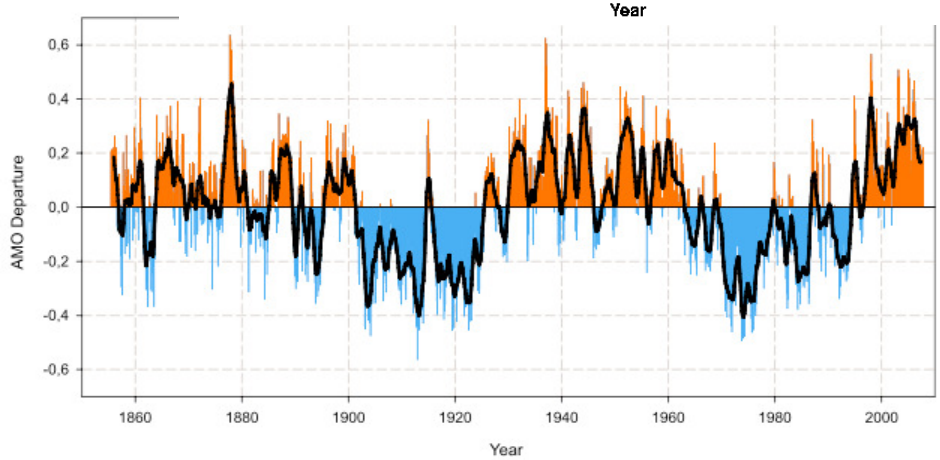
Ranking of nectar sources per division

Click on an area to get a listing of nectar plants and blooming period

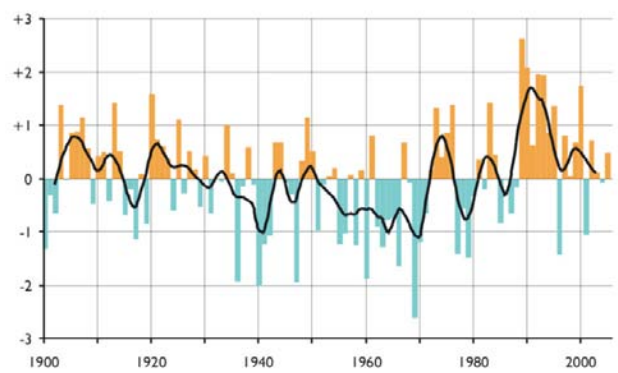
East US Winter Temperature Changes are related to Short Term Climate Cycles



Maryland Winter Temps
(Dec Jan Feb)



Atlantic Multidecadal Oscillation
(N. A. Sea Surface Temp Anomalies)



North Atlantic Oscillation
(Iceland – Azores Atmos. Pressure)

Summary

Scale Hive Records provide very useful information to the beekeeper, and show the response of the plant-pollinator interaction to short term (years – decades) climate events.

Nectar Flows can change dramatically in response to regional climate change. They exhibit temporal trends similar to bulk vegetation metrics.

This provides a framework for linking pollinator impact studies to the major climate/ecosystem climate impact efforts underway.

A continental / global network is feasible and essential for studying impacts of climate change on Honey Bees and Pollinators.

To get direct benefit from climate studies, Beekeepers can help by telling the climatologists and ecologists when nectar flows occur.

Regional networks can provide a baseline from which to judge climate - induced changes.

And a basis for management approaches to minimize, or take advantage of such changes.

This would benefit from a globally coordinated program. The sooner the better.

Pictures courtesy of Robert Danka, USDA Honey Bee Breeding, Genetics and Physiology Laboratory, Baton Rouge, LA

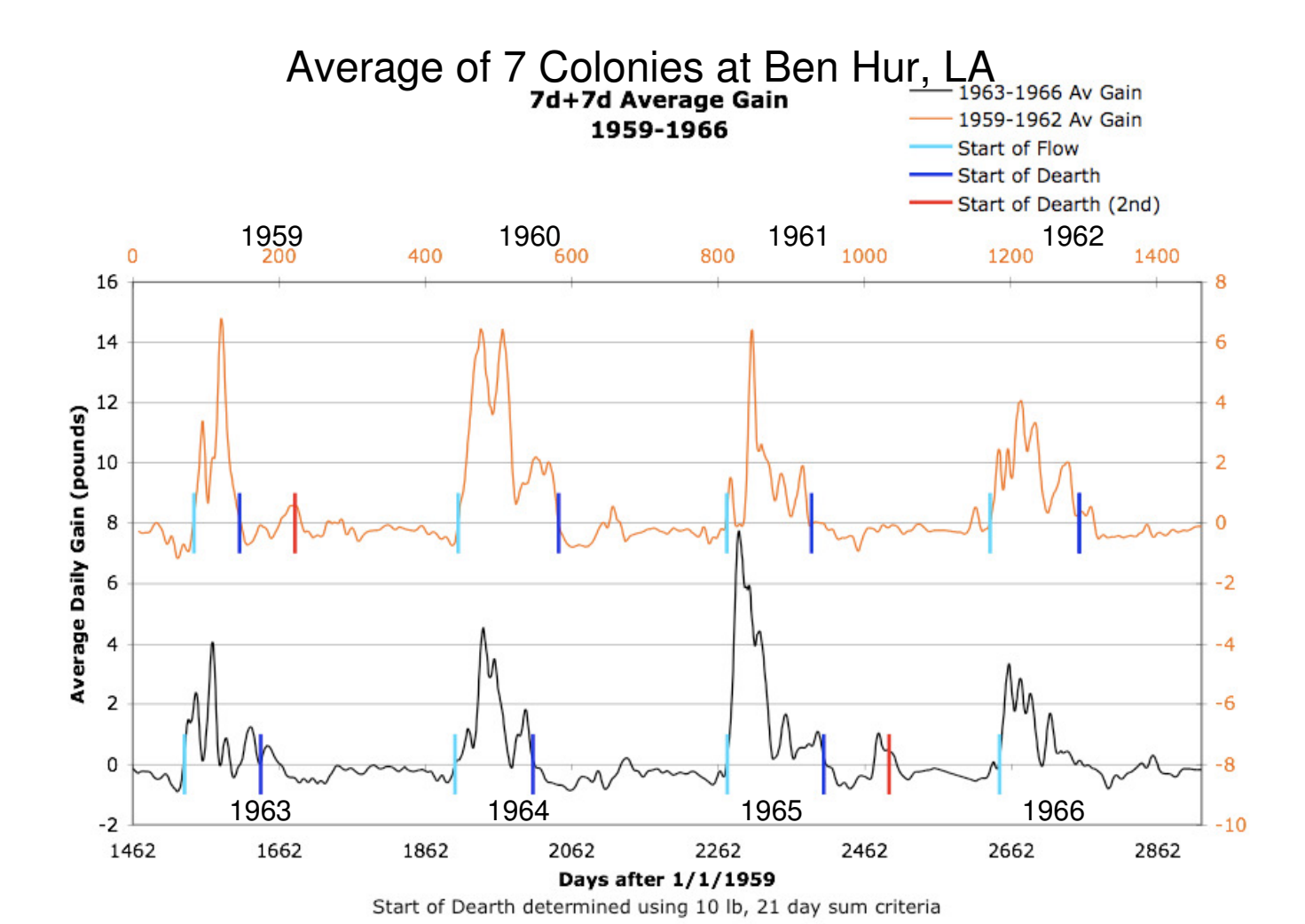
Baton Rouge, Louisiana

- Twenty-four years of monthly data.
- Eight years (1959-1966) of replicate, “daily” data from eight hives.

- Inter-hive variability
- Inter-annual variability

How representative is one hive

Inter-colony variation in HBNF dates is very small – a few days.



The within-year inter-colony variation (sd) of 50% points was <3 days.
The 50% point ranged from day 109 to 132.5 (23.5 days) 1959-66.
Dearth estimates based on 20 lb threshold.

Why scale hives?

Why not just blooming dates?

- Monitors plant – pollinator interaction
  - Blooming $\neq$ Pollination $\neq$ Nectar
  - Includes climate effects on nectar secretion, bee foraging
  - Includes plant species presence, abundance, & changes
- Honey Bee Nectar Flow (HBNF) & Dearths
- Bees sample a large area ~ 10's km^2
  - Equivalent to Climate Modeling Grids, Sat Climate/Veg data sets
- Robust measurement – large signal
- Relatively independent of colony size
- Much more useful to the beekeeper

Light or Dark?

Should we apply these coefficients to Global Warming Scenarios?

Short term (decades) ?

Maybe, within the same region, season (same flora)

Temperature impacts on blooming are not known for many species

Need to consider climate (rain) on bee foraging

Regional coefficients will be required – keyed to floral composition.

Longer term – tens of decades/centuries ?

Maybe not - Plant species succession/abundance becomes important

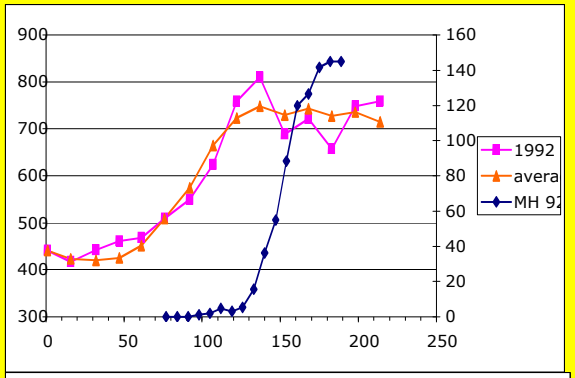
Climate models differ markedly at the regional level.

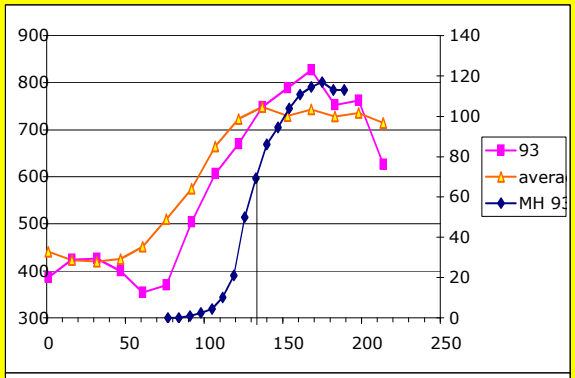
Applying Global Average forcing at the regional level is very risky.

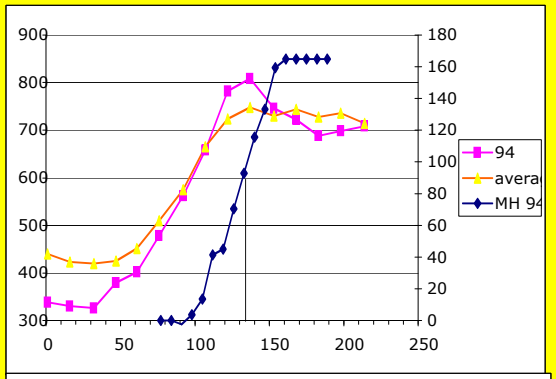
Poorer pollination of wild plants means less wildlife food and forage.

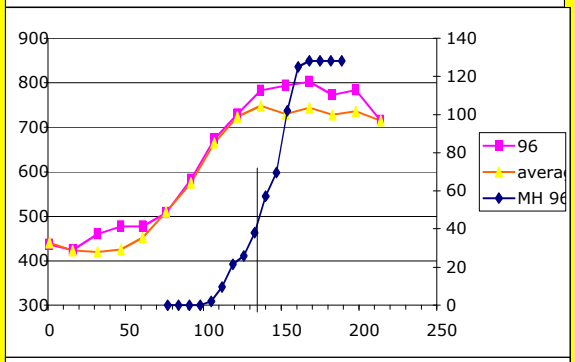
Migratory insects and birds (such as Ruby-throaded hummingbird, above) may arrive too late to take advantage of Maryland nectar.

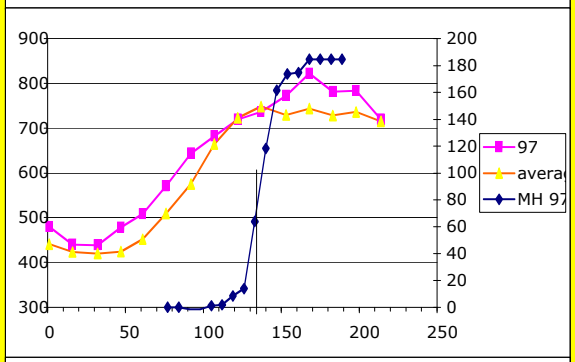
← Climate change may make the area more, or less, likely for the Africanized Honey Bee to establish resident populations.

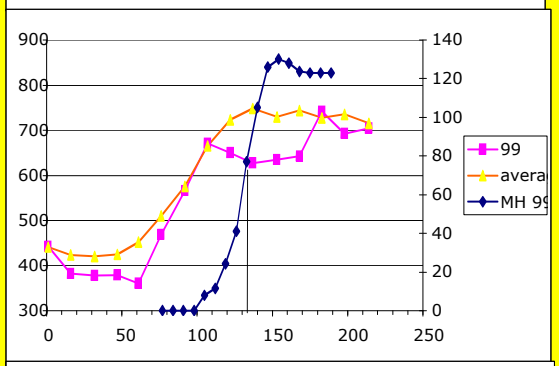

1992
avera
MH 9

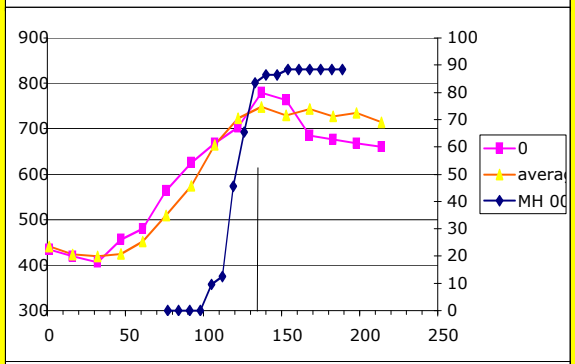

93
avera
MH 9

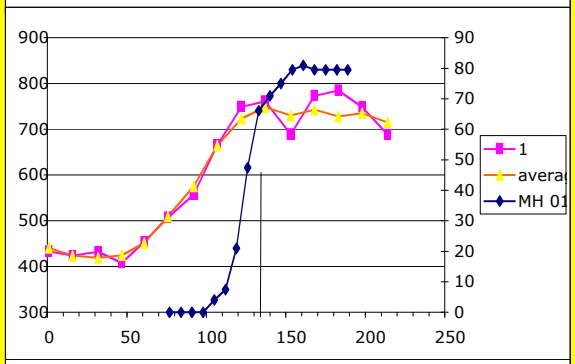

94
avera
MH 94

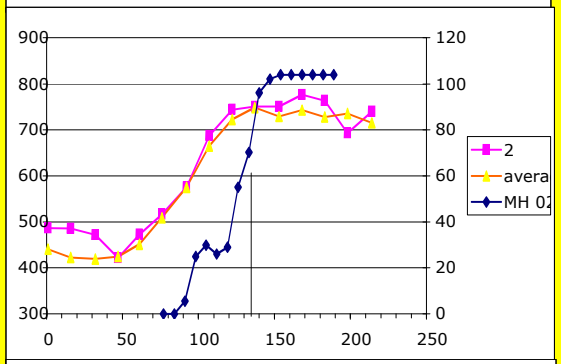

96
avera
MH 96

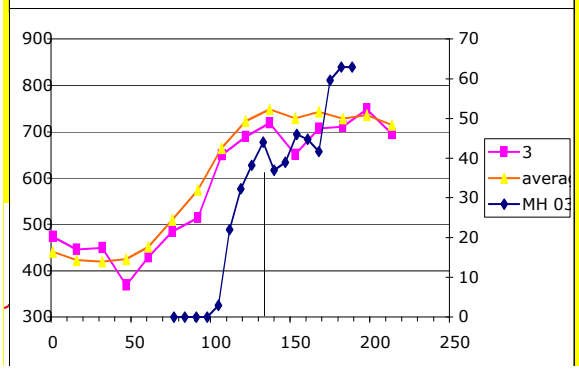

97
avera
MH 97

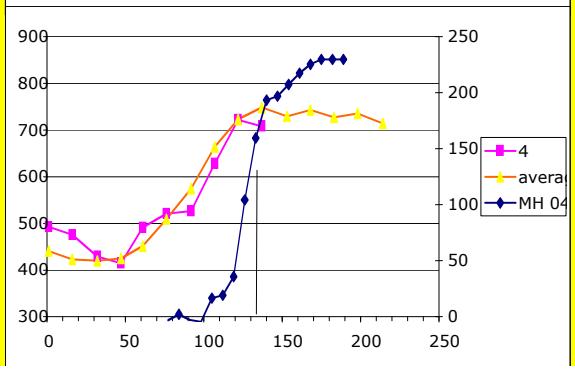

99
avera
MH 99

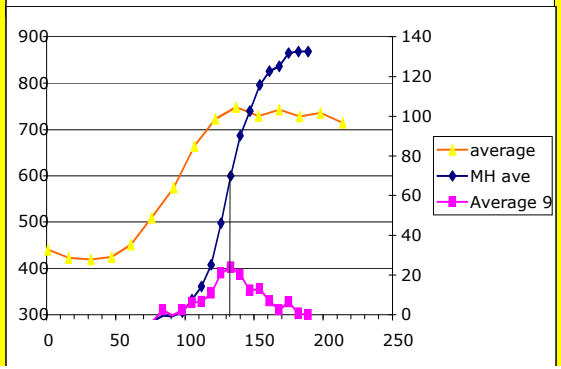

0
avera
MH 00


1
avera
MH 01


2
avera
MH 02


3
avera
MH 03


4
avera
MH 04


average
MH ave
Average 9