# Mapping nectar flow phenology with satellites and Honey Bee hives to assess climate impacts.

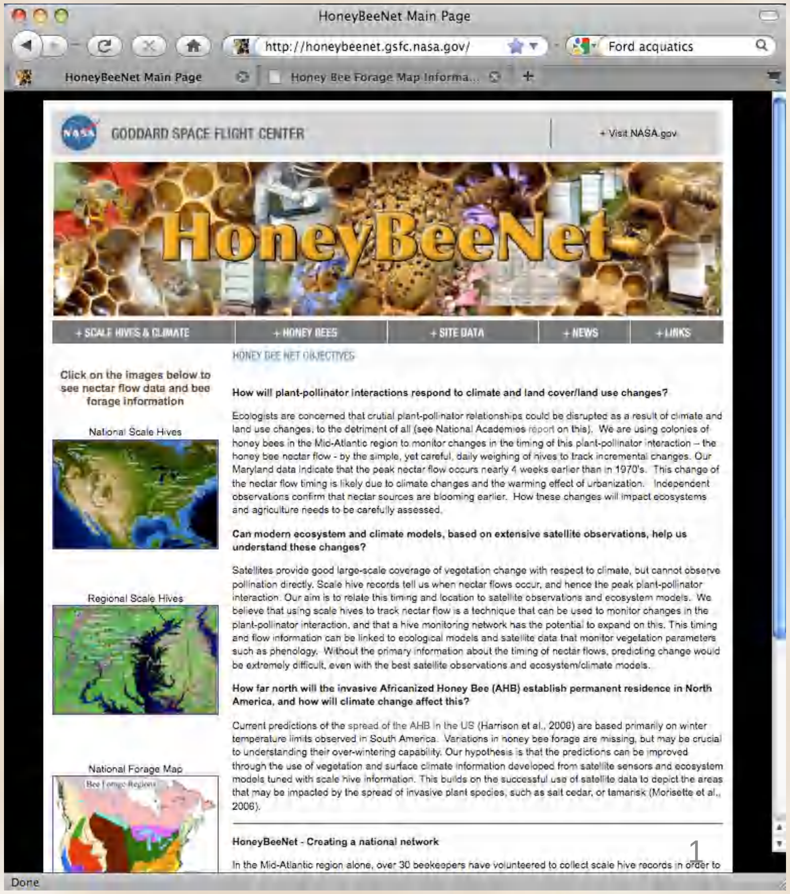
**Wayne Esaias**, J.E. Nickeson, B. Tan, P. Ma, J. Nightingale, R. Wolfe

NASA/Goddard Space Flight Center, Emeritus; Dept. Entomology, Univ. Maryland

http://honeybeenet.gsfc.nasa.gov

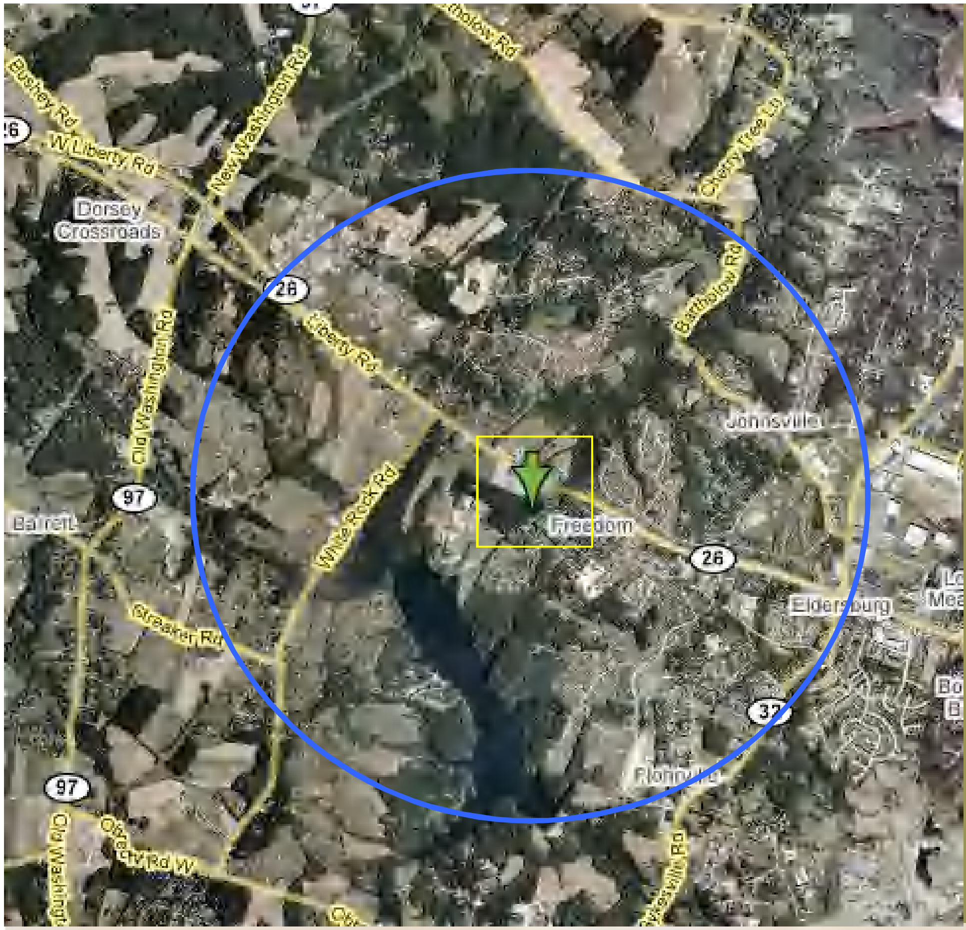
wayne.e.esaias@nasa.gov

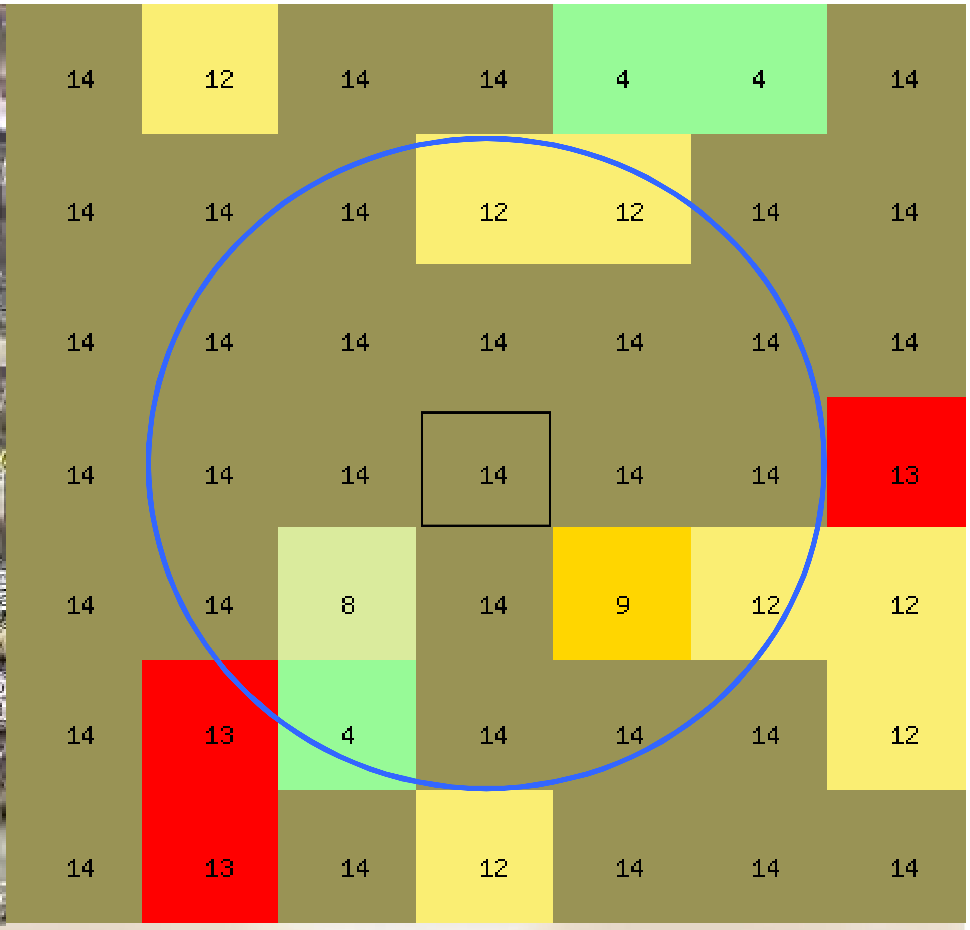
Or Google NASA Honey Bees



# Problem: How will climate change impact ecosystem pollination?

- ~$10^5$ Flowering plant species.
- ~$10^4$ Pollinating insect sp., many in decline.
- Dependencies, Areal Abundances, Trends, and Climate Response Functions of individuals or their partners are very poorly known.
- Our bees, ecosystems, and food depend on these interactions being successful.
- Little time for a species-by-species approach, we need to generalize in a smart way.




High Resolution 2-30 meter
Satellite Imagery

Only a few clear images per year
Cannot resolve blooming dynamics.

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

Daily-Weekly generic vegetation change,
carbon growth for Ecosystem Models, crops

Nectar plants are a small fraction of the signal.

Relationship Between Honey Bee Forage Phenology and
Satellite Vegetation Change
and Climate Modeling

Examine Climate Trends in Hive Weight Change

Link to Satellite Vegetation Change in Eastern North America

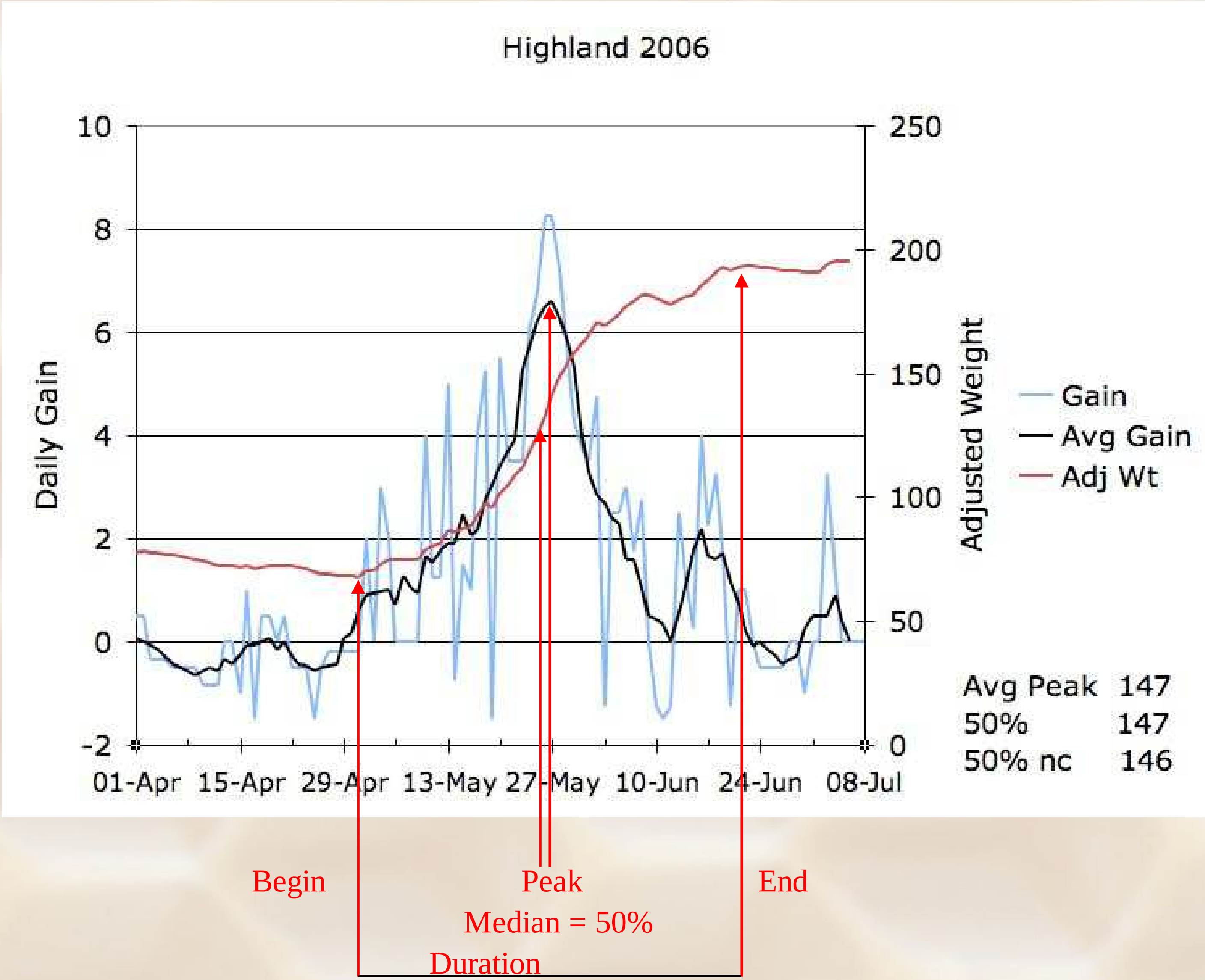

FAIRBANKS
74



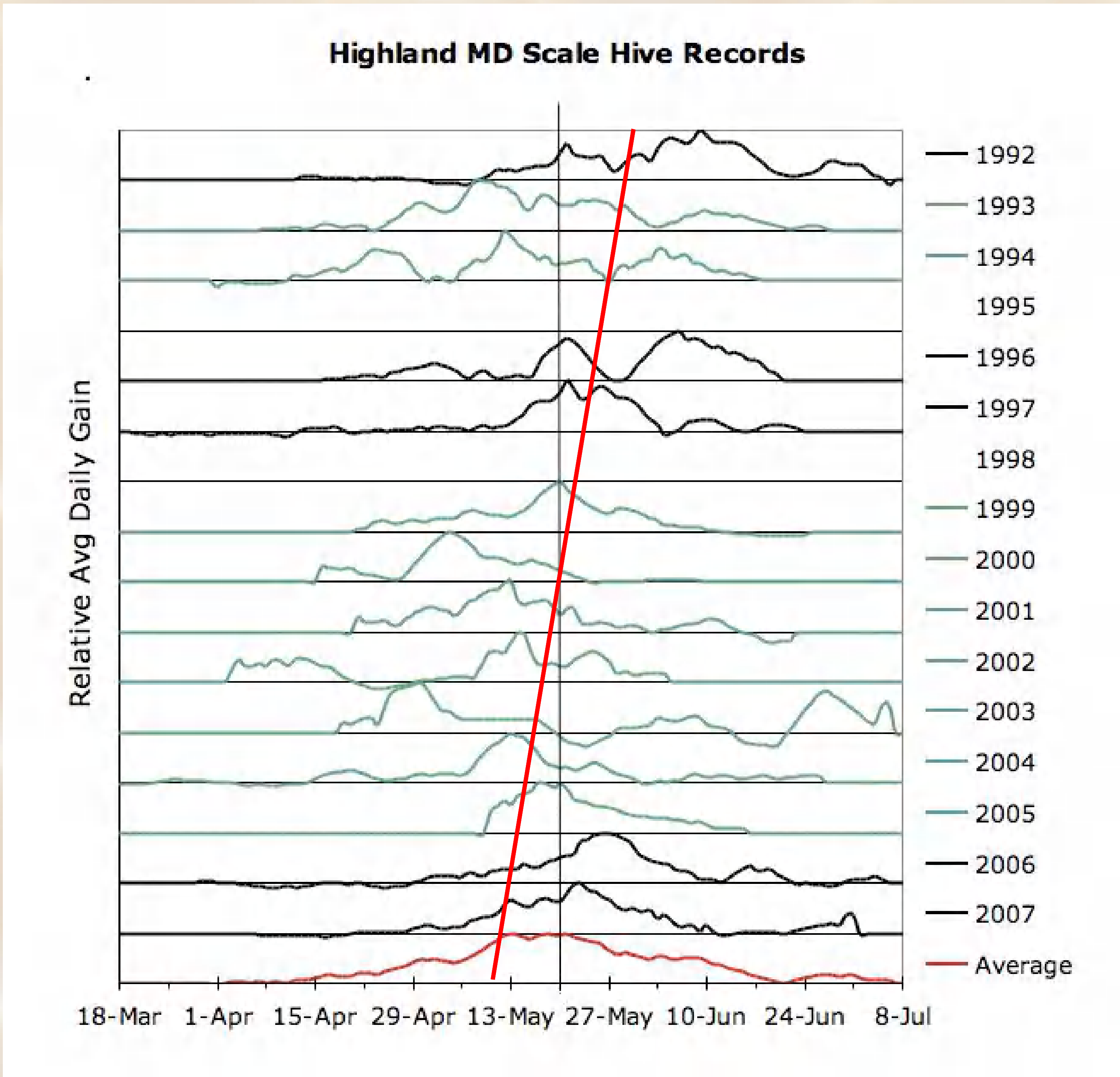
INDUSTRIAL

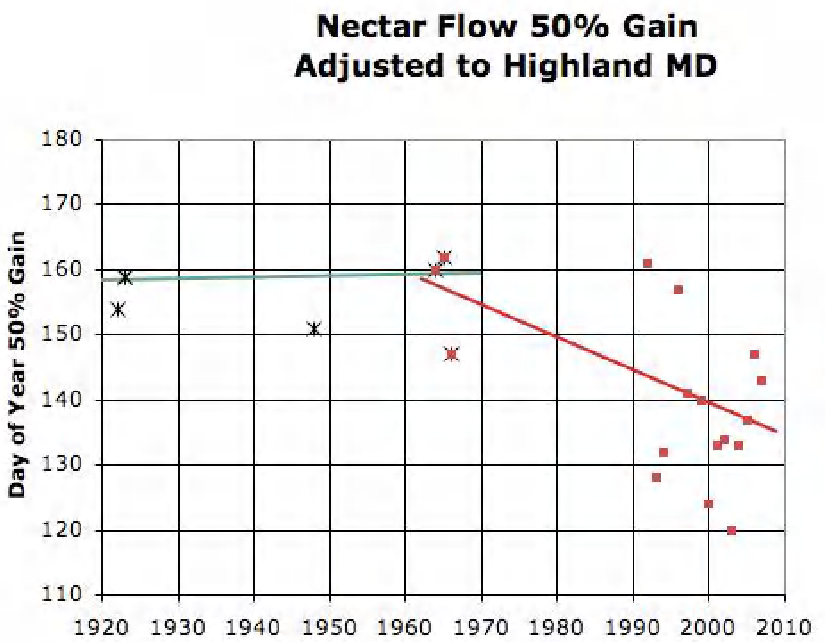


# Honey Bee Nectar Flow (HBNF) Metrics




Composite integral covering ~ 1000 hectares, of plants, pollinators, and environmental variables of successful interactions.


Highland MD Scale Hive Records
Relative Avg Daily Gain
18-Mar
1-Apr
15-Apr
29-Apr
13-May
27-May
10-Jun
24-Jun
8-Jul
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Average



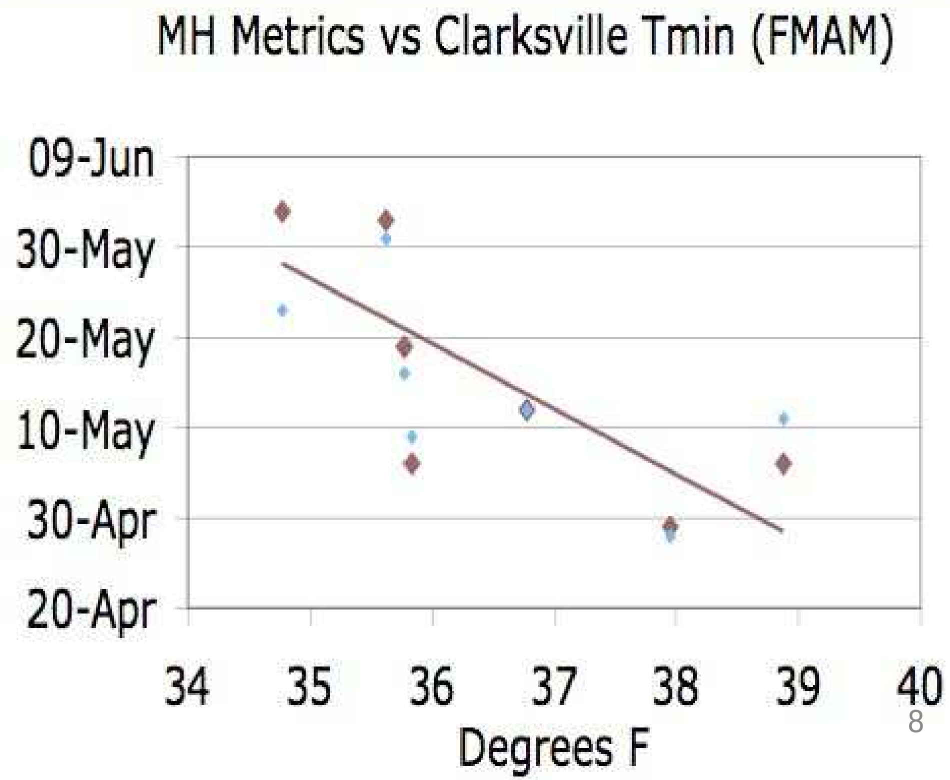

Nectar Flows have Advanced by 0.58 days per year since 1970 in Central MD

Similar Advance seen in Nectar Forage Plants Blooming Dates

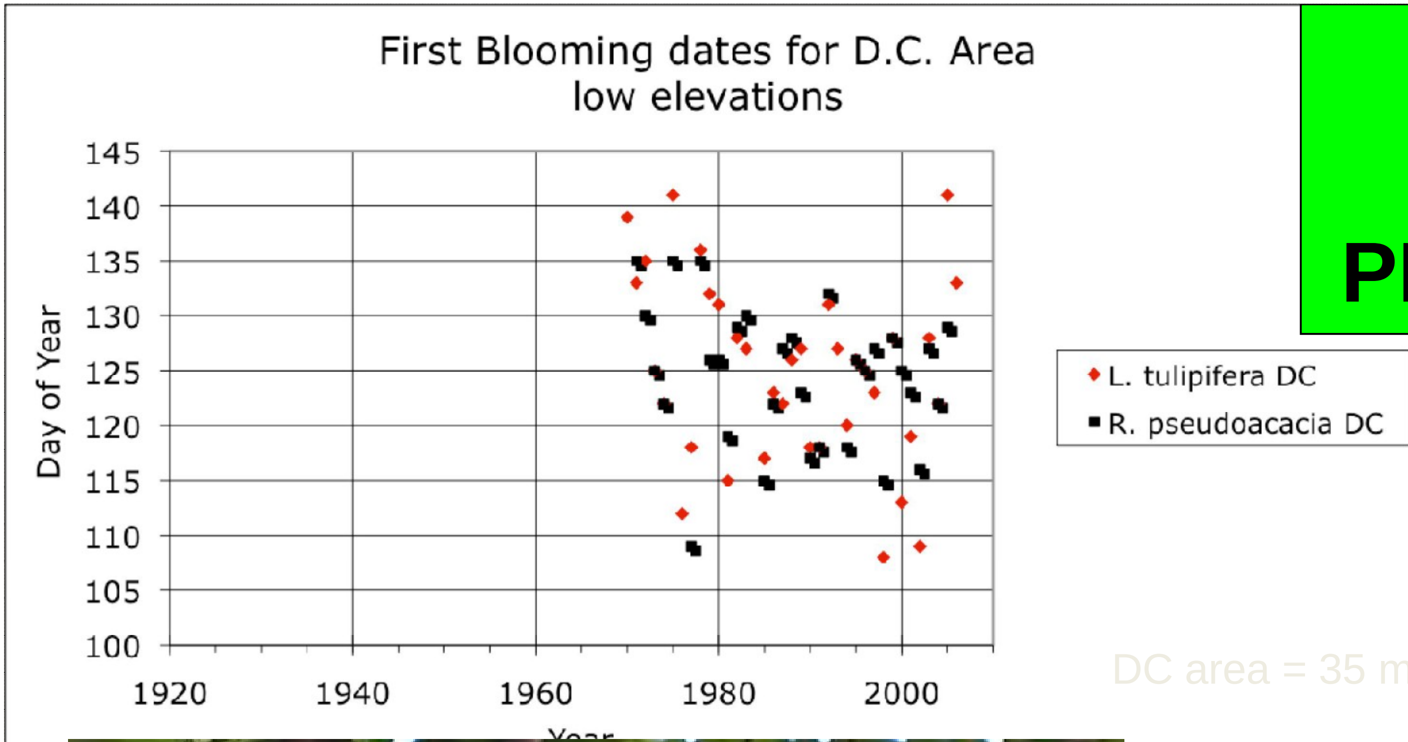
Warm Winter-Springs lead to earlier Nectar Flows in MD.

1 ° F of Warming ~ 1 Week Advance
1 ° C of Warming ~ 12 Day Advance
in the 1990-2010 epoch

No significant trend in NF duration.



# NECTAR SOURCE PHENOLOGY

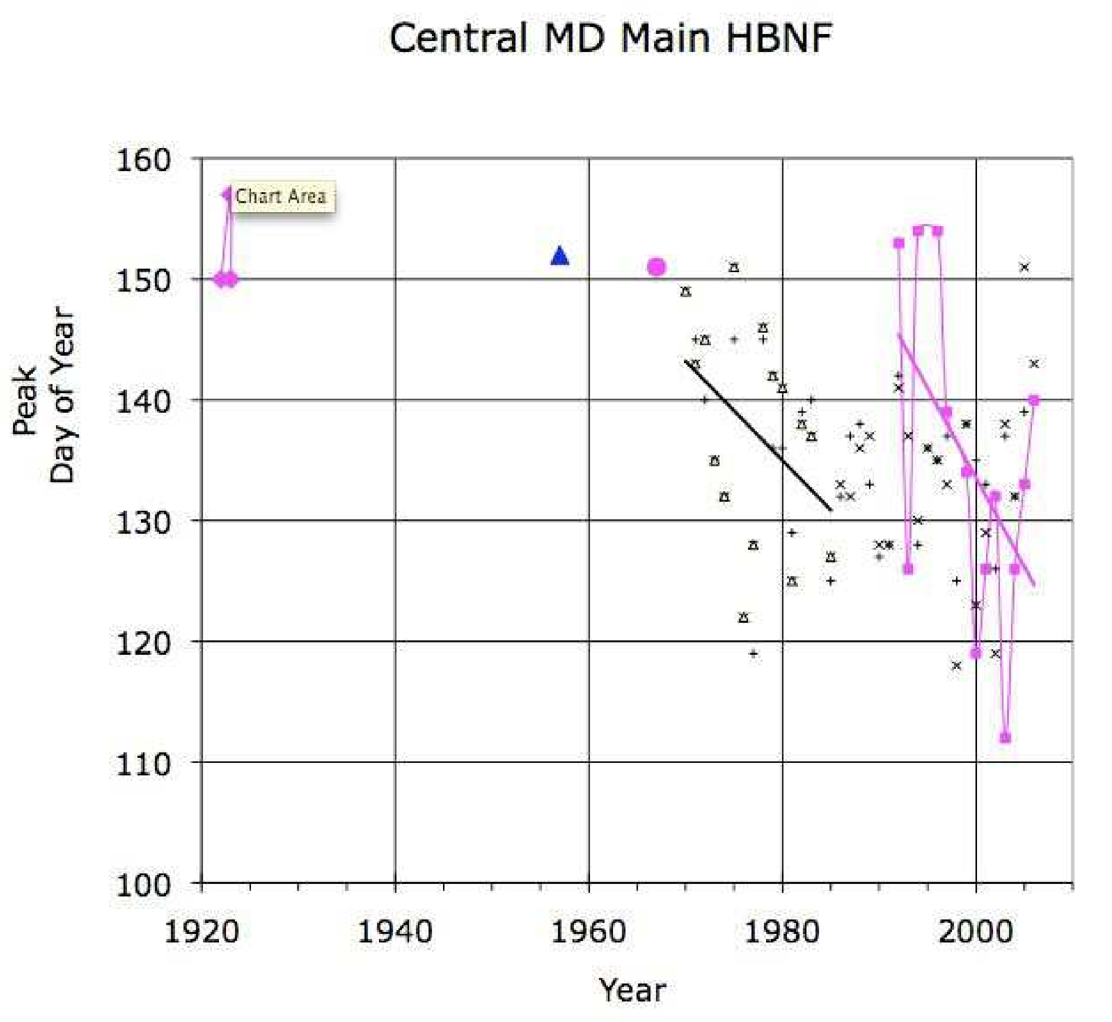


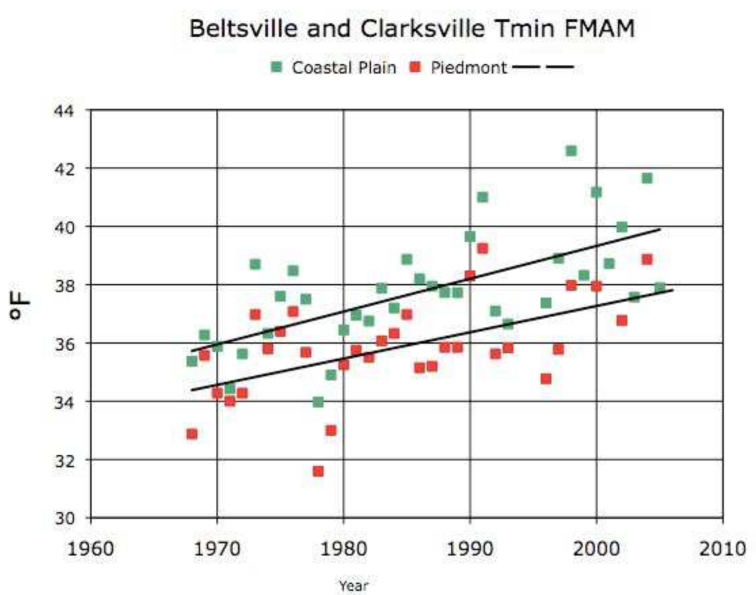

Abu-Asab, M. S., P. M. Peterson, S. G. Shetler, and S. S. Orli. 2001. Earlier plant flowering in spring as a response to global warming in the Washington, DC, area. Biodiversity and Conservation 10:597-612.

DC area = 35 miles

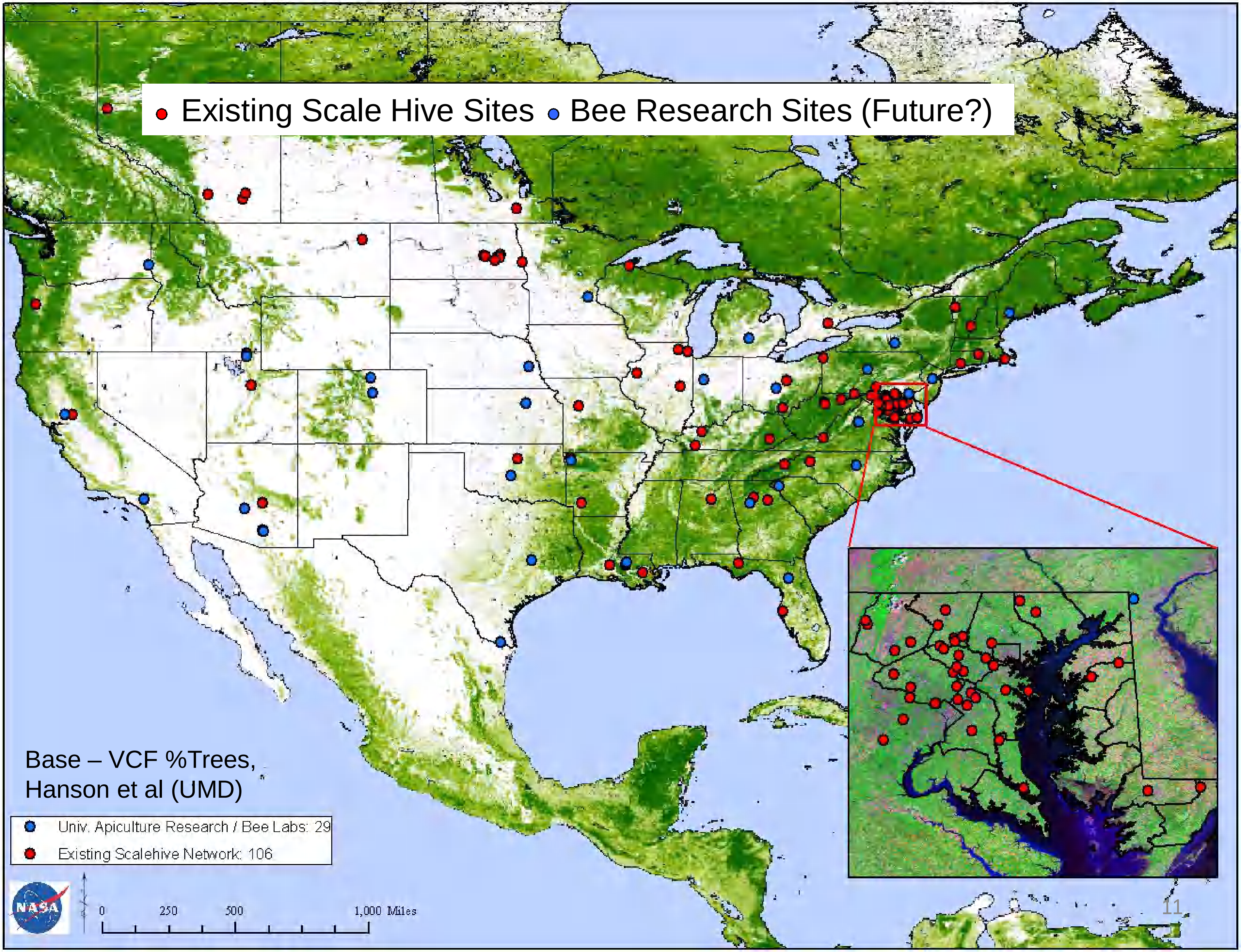
*Liriodendron tulipifera* Tulip Poplar

*Robinia pseudoacacia* Black Locust



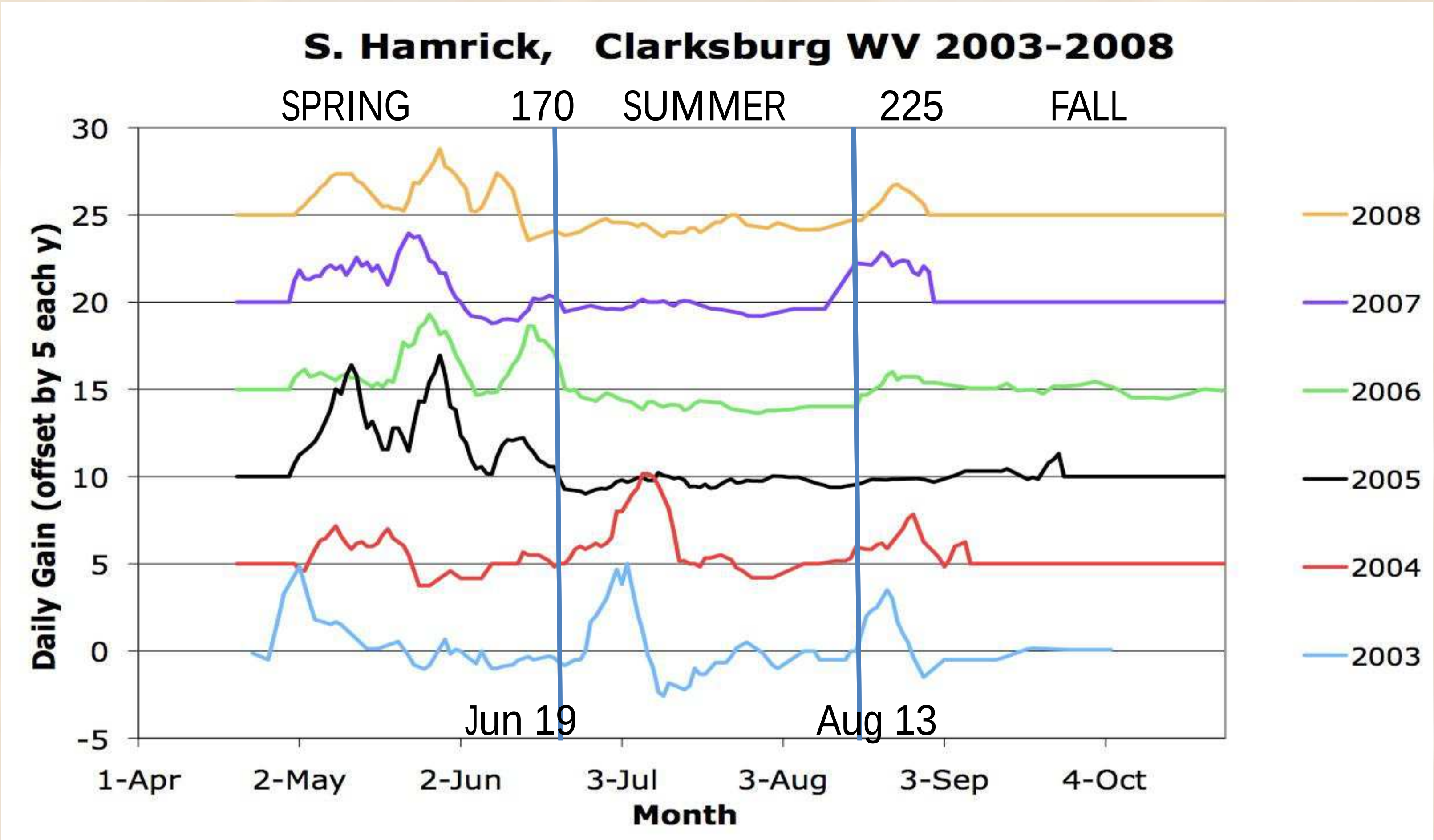

Apparent (15 yr) lag between advances in blooming in Washington DC and Nectar Flows in Central Maryland, is due to the (~15 yr) lag in Winter Tmins between the locations (elevation – 150 m difference).



Existing Scale Hive Sites
Bee Research Sites (Future?)
Base – VCF %Trees,
Hanson et al (UMD)
Univ. Apiculture Research / Bee Labs: 29
Existing Scalehive Network: 106
NASA
0
250
500
1,000 Miles

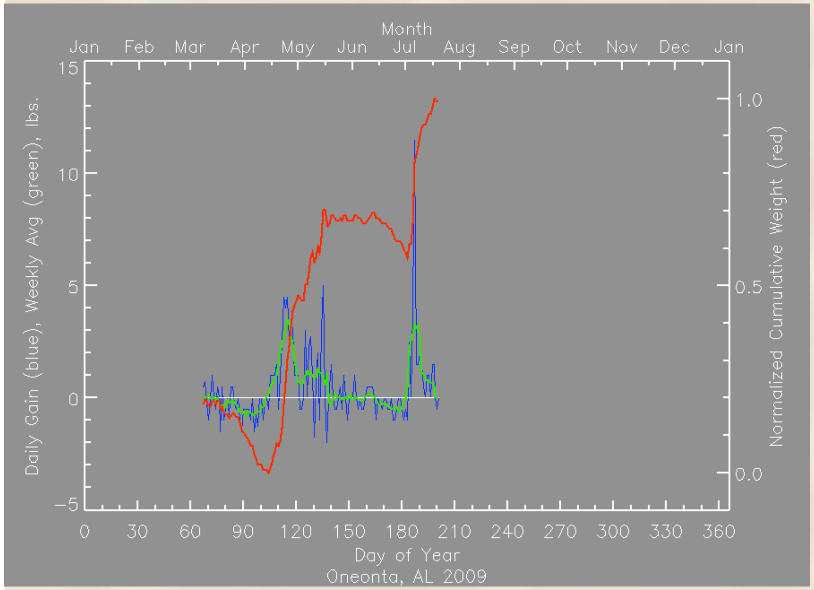
Seasonal breaks are consistent with Milum's analysis of Nectar Flows at Champaign-Urbana Illinois

(V.G. Milum 1956, J. Economic Entomology 49(6):735-738

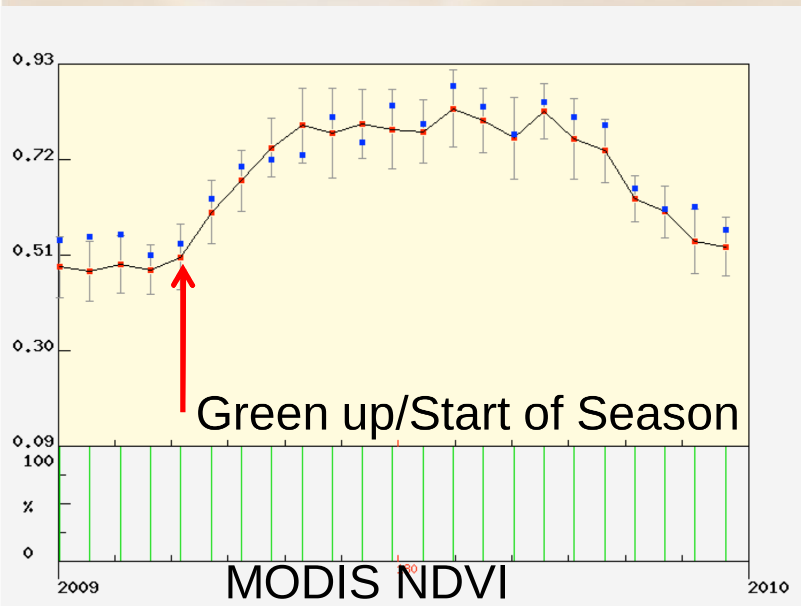



212 site-years of nectar flow data online as part of HoneyBeeNet and metrics for multiple seasons have been derived. This does not include some historic sites (~70 site yrs) for 282 site yrs.

# HBNF Metrics and Satellite Vegetation Phenology Metrics




Hive Record




| Scale Hive Metrics | Spring | MODIS NDVI Phenology | |
|---|---|---|---|
| Site_ID | AL001 | SiteID | AL001 |
| Location | Oneonta | Year | 2009 |
| ForageRegion | 11 | greenup | 54 |
| Start_Year | 2009 | browndown | 361 |
| Season | Spr | season length | 305 |
| QAcode | A.8.16.18.19 | base level | 4997 |
| Lat | 33.97072 | peak date | 191 |
| Lon | -86.50525 | peak value | 8364 |
| Elev_ft | 885 | amplitude | 3365 |
| 1st_day | 67 | greenup rate | 312 |
| Last_day | 170 | browndown rate | 203 |
| Num_days | 104 | large integral | 2834 |
| NF_begin_day | 105 | small integral | 845 |
| NF_end_day | 135 | annual max | 8246 |
| NFduration | 32 | annual min | 4900 |
| 25_percent_day | 113 | annual mean | 6830 |
| 50_percent_day | 117 | | |
| 75_percent_day | 127 | | |
| Max_dailyG_day | 135 | | |
| Max_avg_dailyG_day | 115 | | |
| Total_gain | 49.5 | | |
| Max_DG | 5 | | |
| Max_AvgDG | 3.5 | | |
| EarlySeasMin | -12.5 | | |
| FinalLoss | -2.5 | | |
| 50_pct_avgd | 0 | | |

Above is for all pixels,
8 day average
Also center pixel class

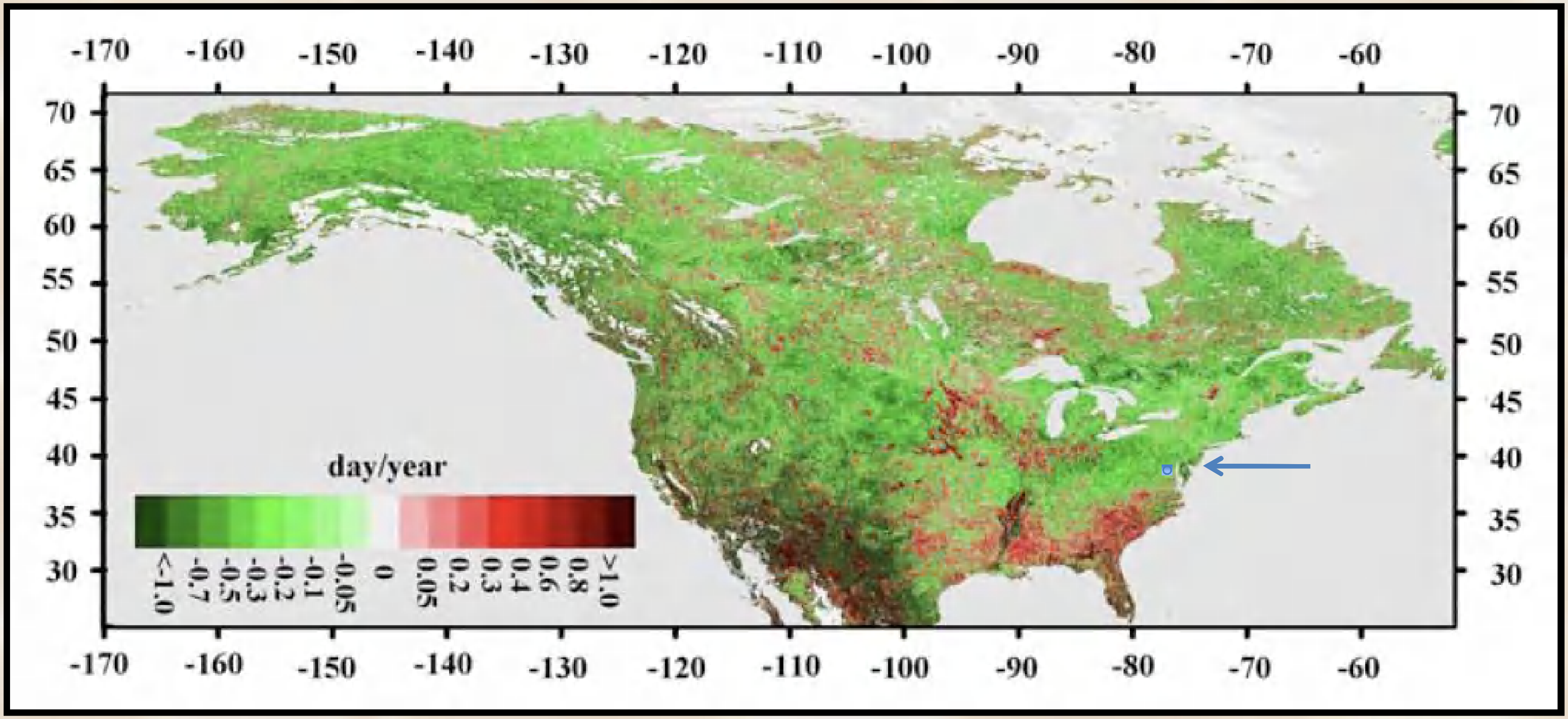
Linking Scale Hive Observations to Spatial Vegetation Data

AVHRR on NOAA  Satellites

MODIS sensor on NASA  Terra and  Aqua Satellites

## Satellite Vegetation Trends - changes in onset of Spring green-up

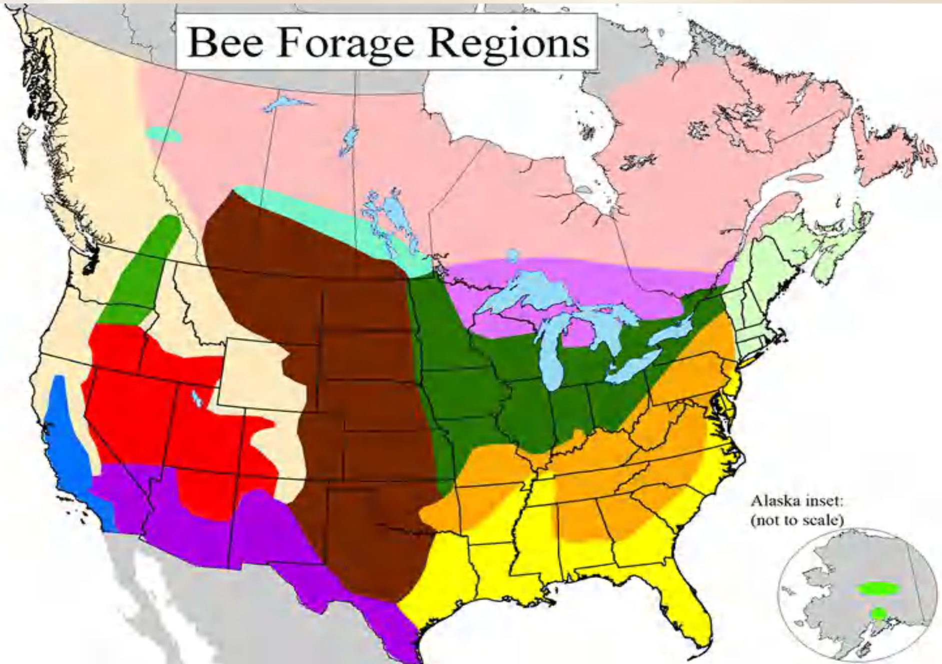
1982 thru 2005 Green = Earlier Red = Later

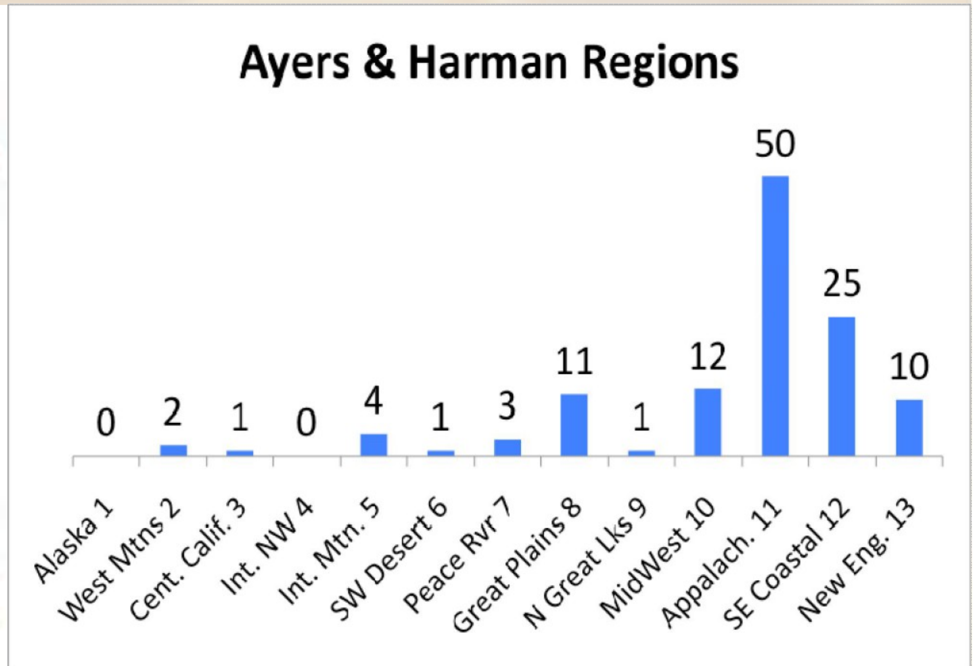



Zhang et al. Geophysical Research Letters, vol. 34, L19405, doi:10.1029/2007GL031447, 2007

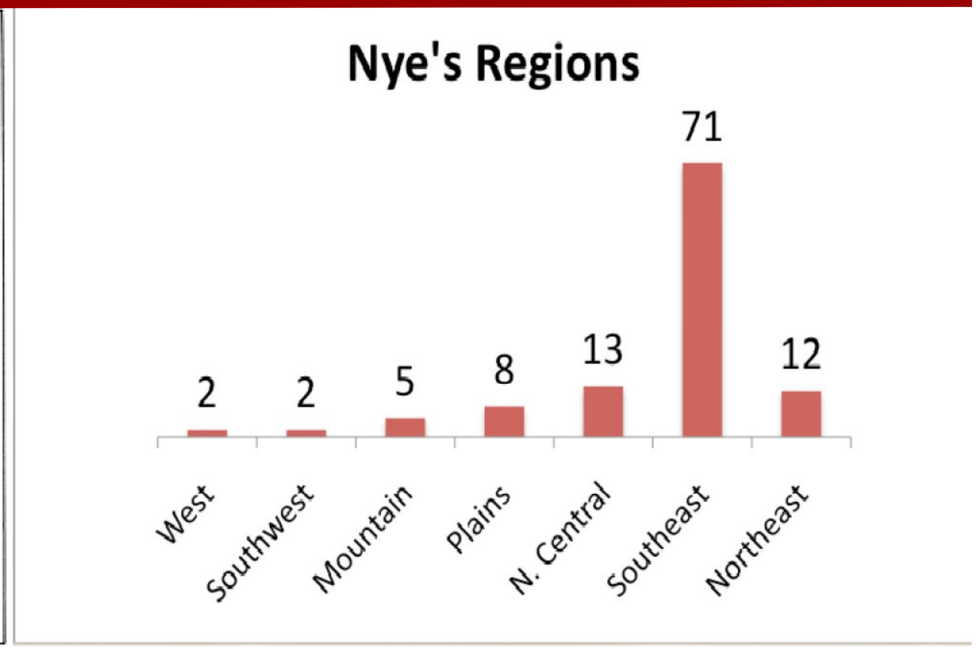
Trend For Highland, MD
Satellite ('82-'05) -.575 days/year
HBNF ('92 – '10) -.58 days/year

Spring Nectar Flows Are Highly Correlated with Greenup in Eastern US. This suggests the Zhang et al. map applies to Nectar Flows from NH to N. Florida, and west to the Ozarks.

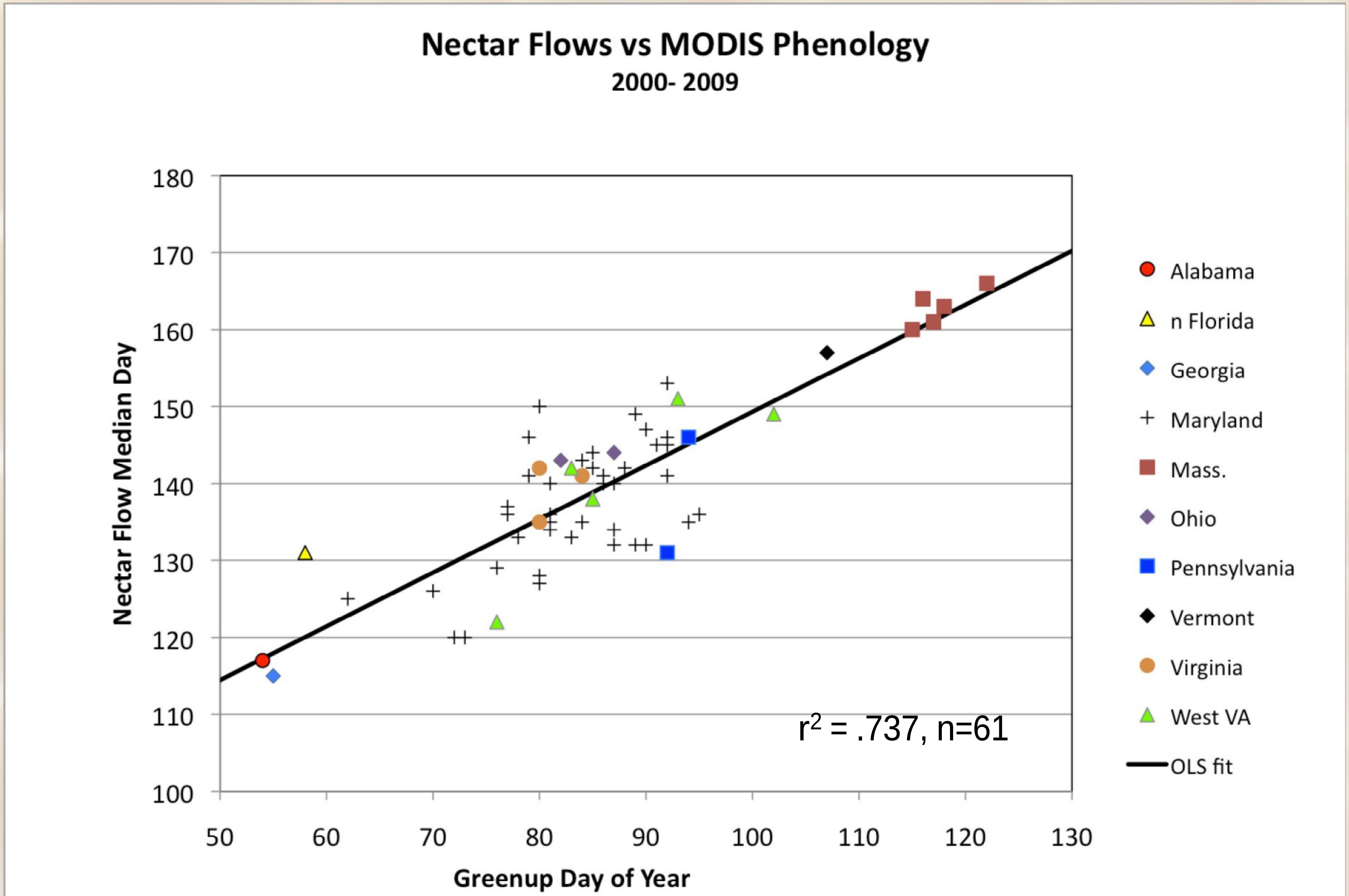


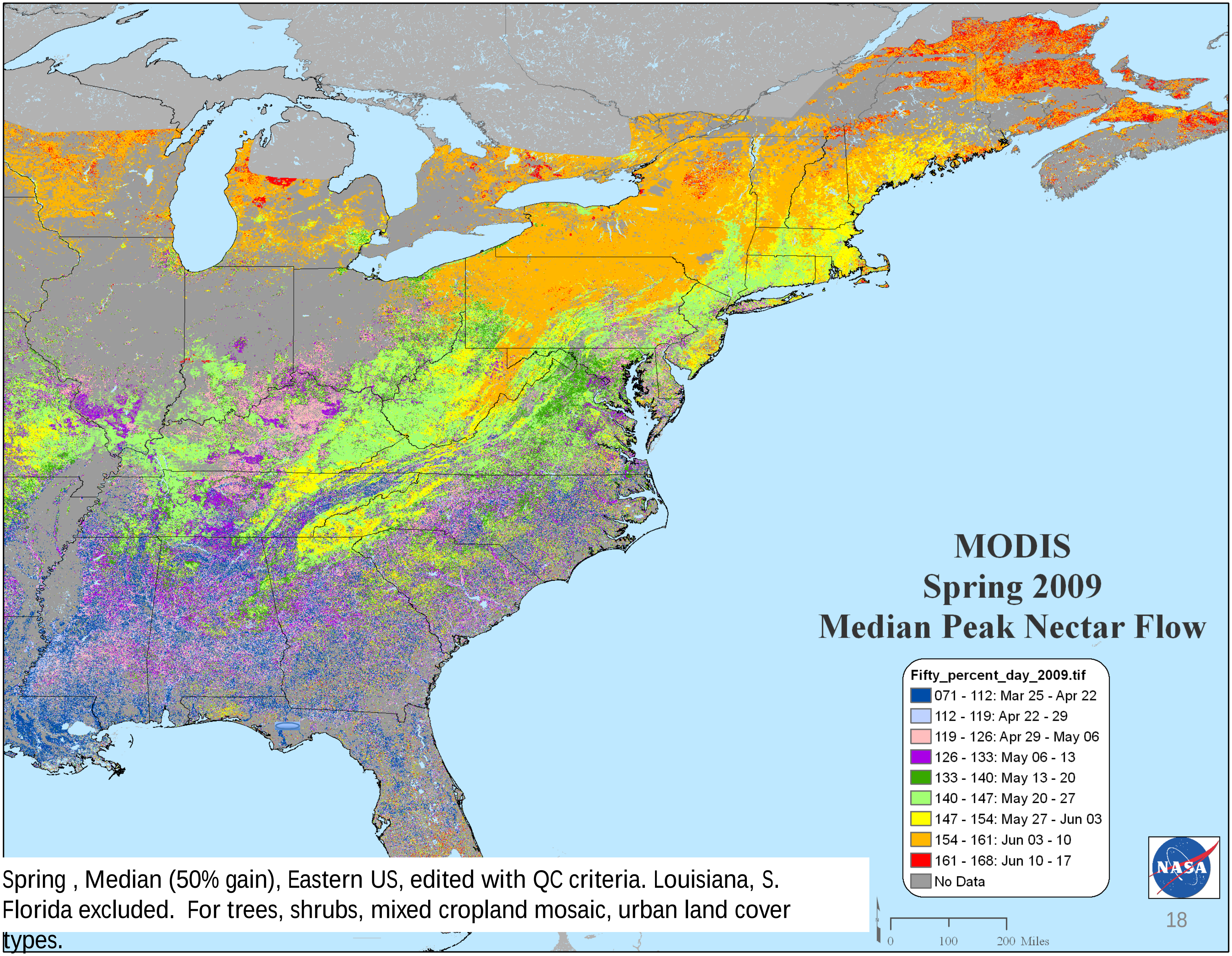





n > 120 Includes Current & Historic Sites




Spring , Median (50% gain), Eastern US, edited with QC criteria. Louisiana, S. Florida excluded. For trees, shrubs, mixed cropland mosaic, urban land cover types.

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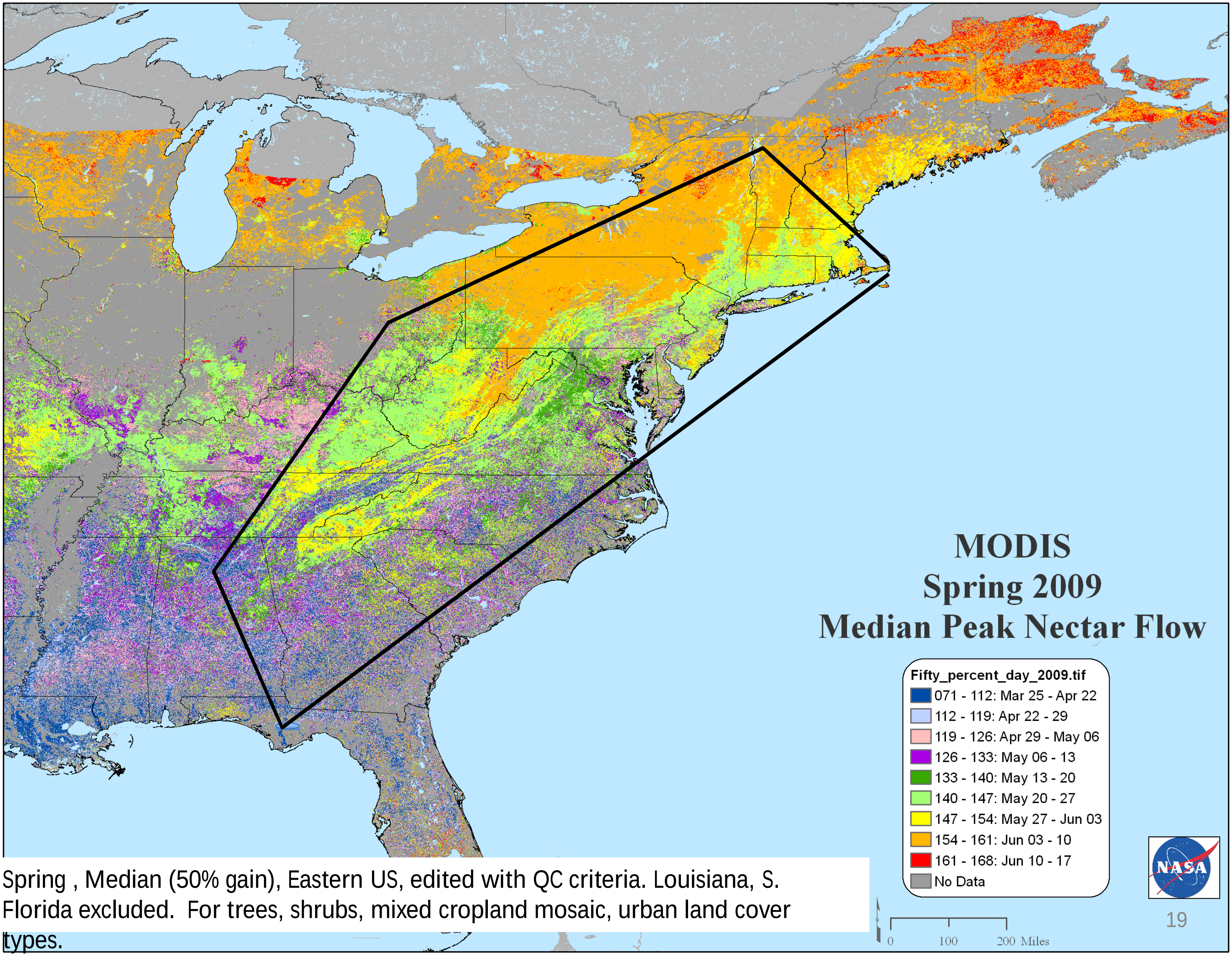


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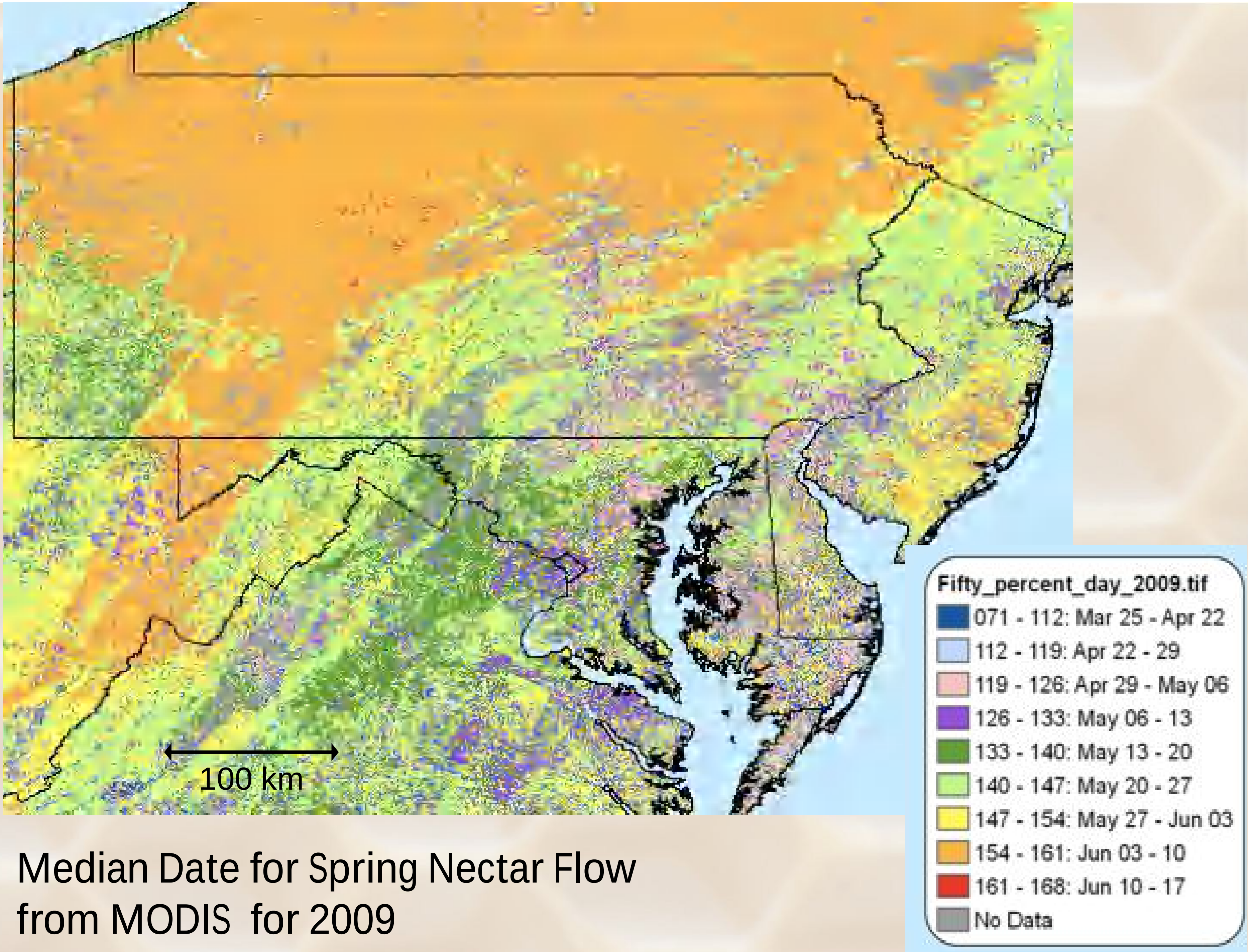
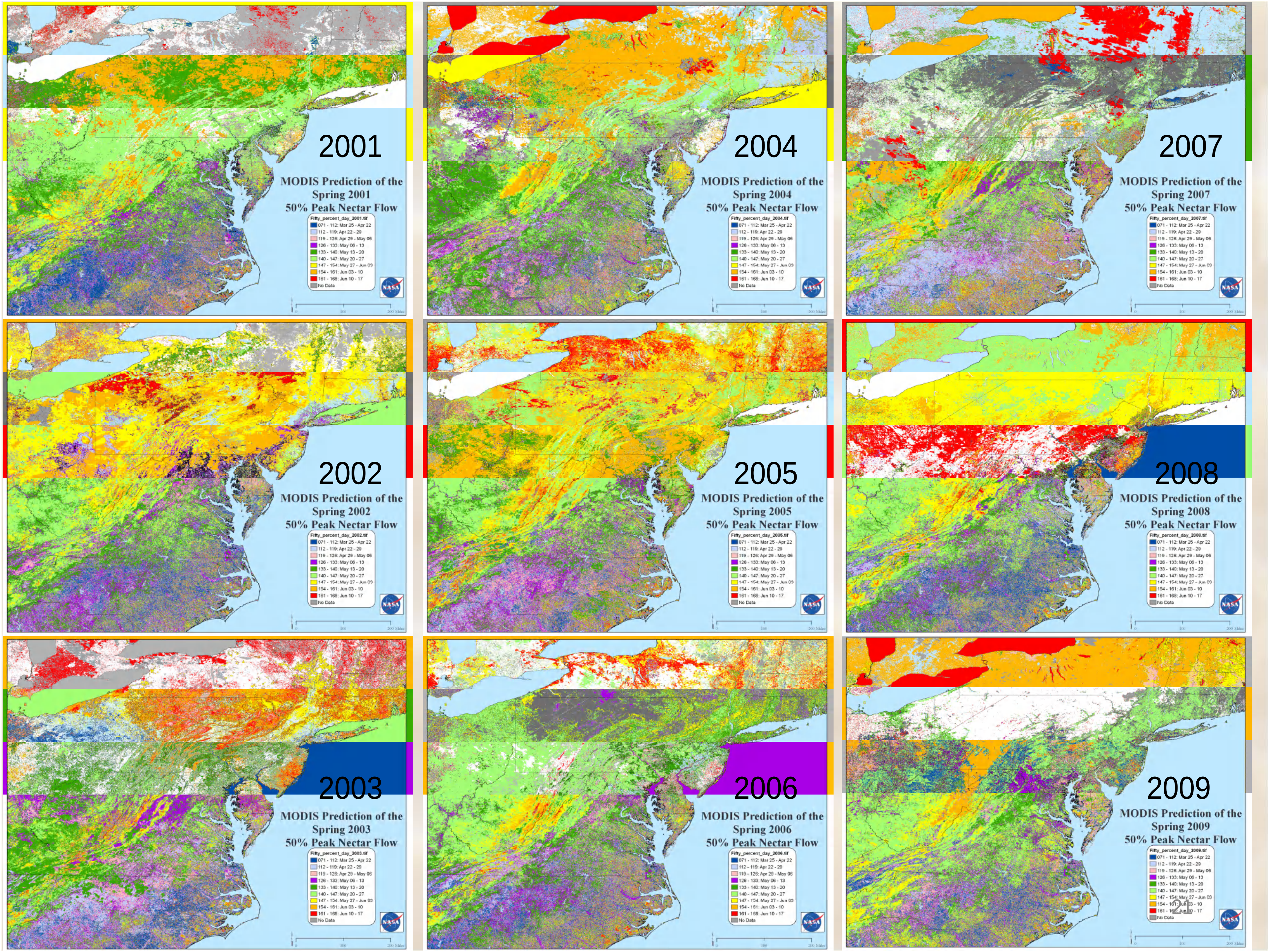



Median Date for Spring Nectar Flow
from MODIS for 2009


2001
MODIS Prediction of the
Spring 2001
50% Peak Nectar Flow
Fifty_percent_day_2001.tif
071 - 112: Mar 25 - Apr 22
112 - 119: Apr 22 - 29
119 - 126: Apr 29 - May 06
126 - 133: May 06 - 13
133 - 140: May 13 - 20
140 - 147: May 20 - 27
147 - 154: May 27 - Jun 03
154 - 161: Jun 03 - 10
161 - 168: Jun 10 - 17
No Data
NASA
2004
MODIS Prediction of the
Spring 2004
50% Peak Nectar Flow
Fifty_percent_day_2004.tif
2007
MODIS Prediction of the
Spring 2007
50% Peak Nectar Flow
Fifty_percent_day_2007.tif
2002
MODIS Prediction of the
Spring 2002
50% Peak Nectar Flow
Fifty_percent_day_2002.tif
2005
MODIS Prediction of the
Spring 2005
50% Peak Nectar Flow
Fifty_percent_day_2005.tif
2008
MODIS Prediction of the
Spring 2008
50% Peak Nectar Flow
Fifty_percent_day_2008.tif
2003
MODIS Prediction of the
Spring 2003
50% Peak Nectar Flow
Fifty_percent_day_2003.tif
2006
MODIS Prediction of the
Spring 2006
50% Peak Nectar Flow
Fifty_percent_day_2006.tif
2009
MODIS Prediction of the
Spring 2009
50% Peak Nectar Flow
Fifty_percent_day_2009.tif

# Colony Management Inferences Eastern N. A.

Nectar Flows have changed dramatically due to historical climate changes.

Spring and Fall Feeding are more important than ever.

One month advance in spring means 2 more months of high consumption rates
compared to “normal”, and total yield appears to have decreased.

Fall nectar flows are later, and may be very limited, but more data are needed.
Unfed colonies can starve in the late summer.
Increase in disease and absconding.
Poor ‘winter’ bee production.

When to super, when to harvest honey have changed – early by 1 month vs 1970.
Apiary size (colonies/km2) needs to be revisited.

Regional impacts can be very out of phase – Earlier in North, (later in South)
Impacts getting colonies ready for production in the North.
Impacts timeliness of replacement packages from the South US.

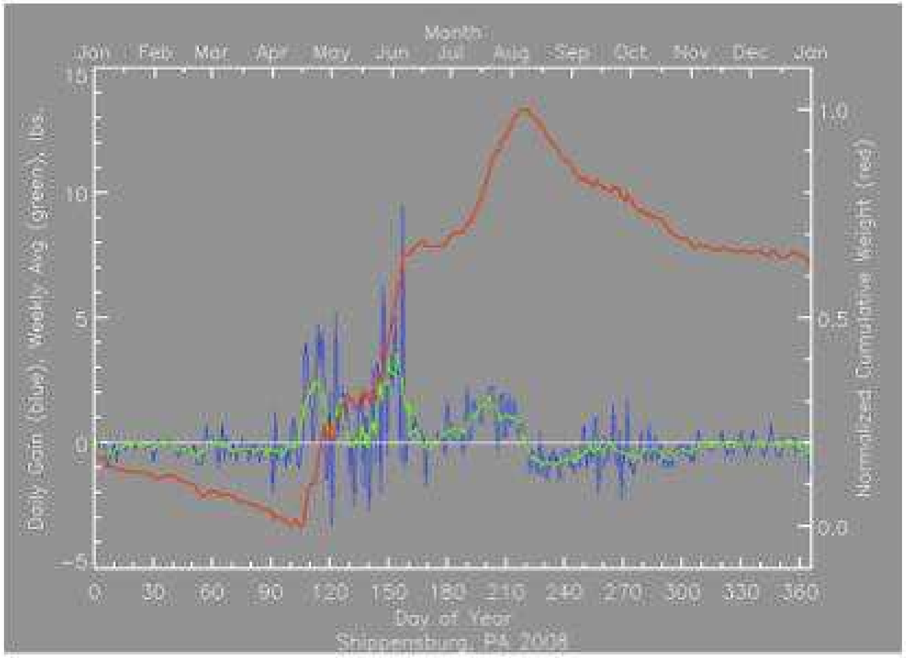
Relevant to chemical treatment timing, and crop pest spraying timing.

# Honey Bee Nectar Flow

- Mapping Nectar Flow Phenology is tractable on a continental scale using hive weight and satellite vegetation data.
- HBNF affected by Climate, Land Cover Change, plant succession.
- For Tree-dominated Eastern N.A., <u>robust,</u> <u>predictive</u> relationship with satellite greenup exists for the spring nectar flow.
  – For this region, findings of how vegetation responds to climate, derived from satellite-driven coupled models, are directly relevant to how HBNF phenology may change.
- Other regions, other seasons, other metrics and variables are open to investigation if hive weight data become available.
  – Many more questions are open for student projects.
- Mss in prep – Trends in hive data - NF phenology from MODIS

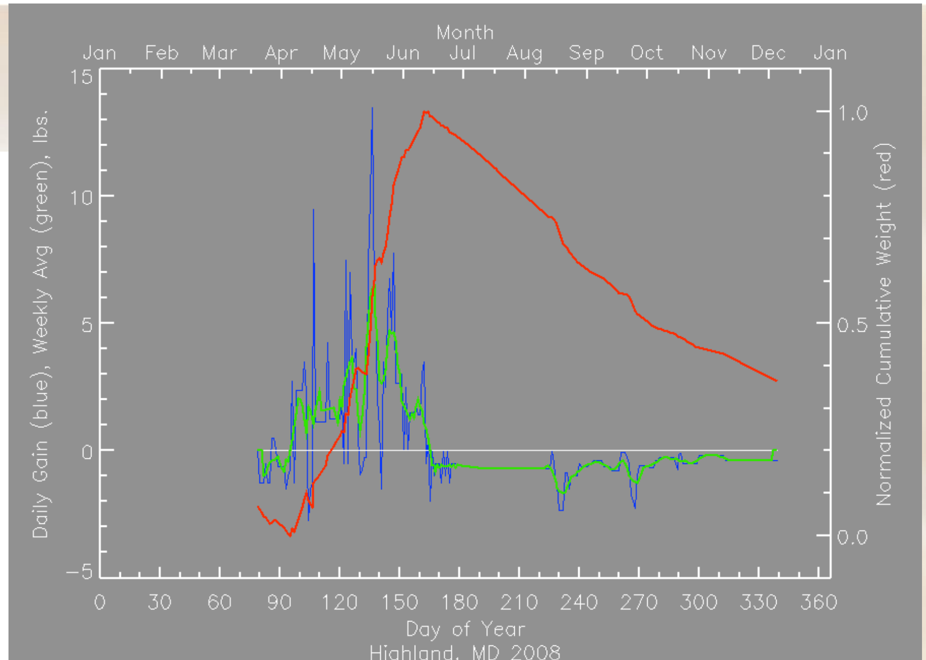
**Nectar Flow Data 2008**

Download Data File (comma delimited)

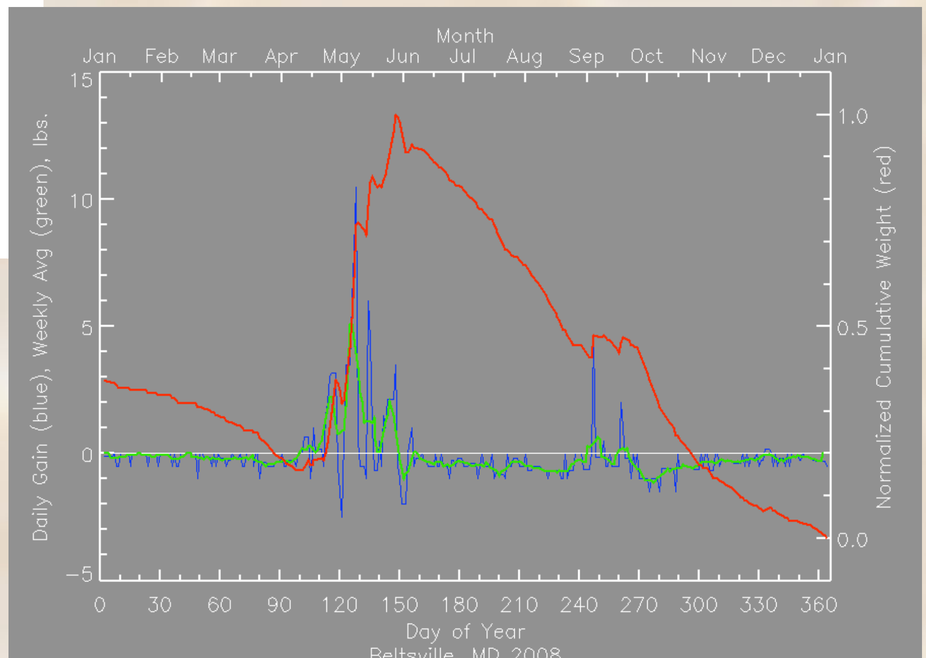



Shippensburg PA
Large excess at year end.

Does not include gains due to feeding syrup.




Highland MD smaller excess




Beltsville MD - annual deficit

# THANK YOU!

## ACKNOWLEDGEMENTS

Co-I's: NASA - Jaime Nickeson, Bin Tan, Pete Ma, R. Wolfe, J. Nightingale
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Arizona State Univ - Jon Harrison

Collaborators
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Dewey Caron
MAAREC (Dennis vanEngelsdorp, Maryann Frasier)
Maryland State Beekeepers Association
Bob Danka et al. Baton Rouge
Many Volunteers

NASA Earth Science Application Division "Decision Support" Program to Apply NASA Satellite and Science Results to National Needs (Invasive Species, Species Diversity)

# WHY IS THIS IMPORTANT ?

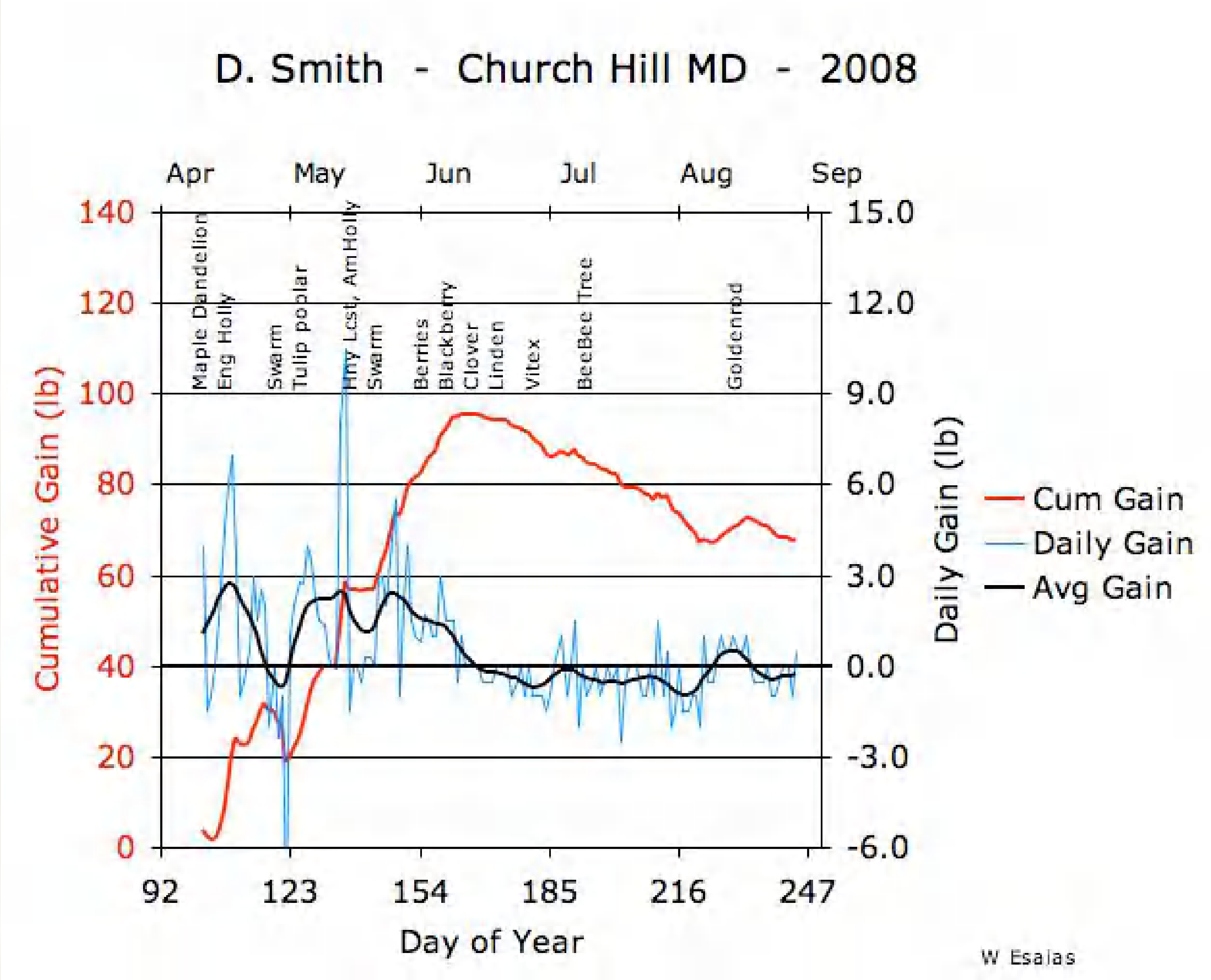
Develops a Linkage Between Pollinator Forage and Satellite Data (previously totally lacking on regional/national scale).

Nectar flow changes can be inferred from vegetation phenology changes in ecosystem/climate models

Baseline for Climate Impacts vs Plant-Pollinator Interactions for Future Comparisons . Preserves Historic Data.

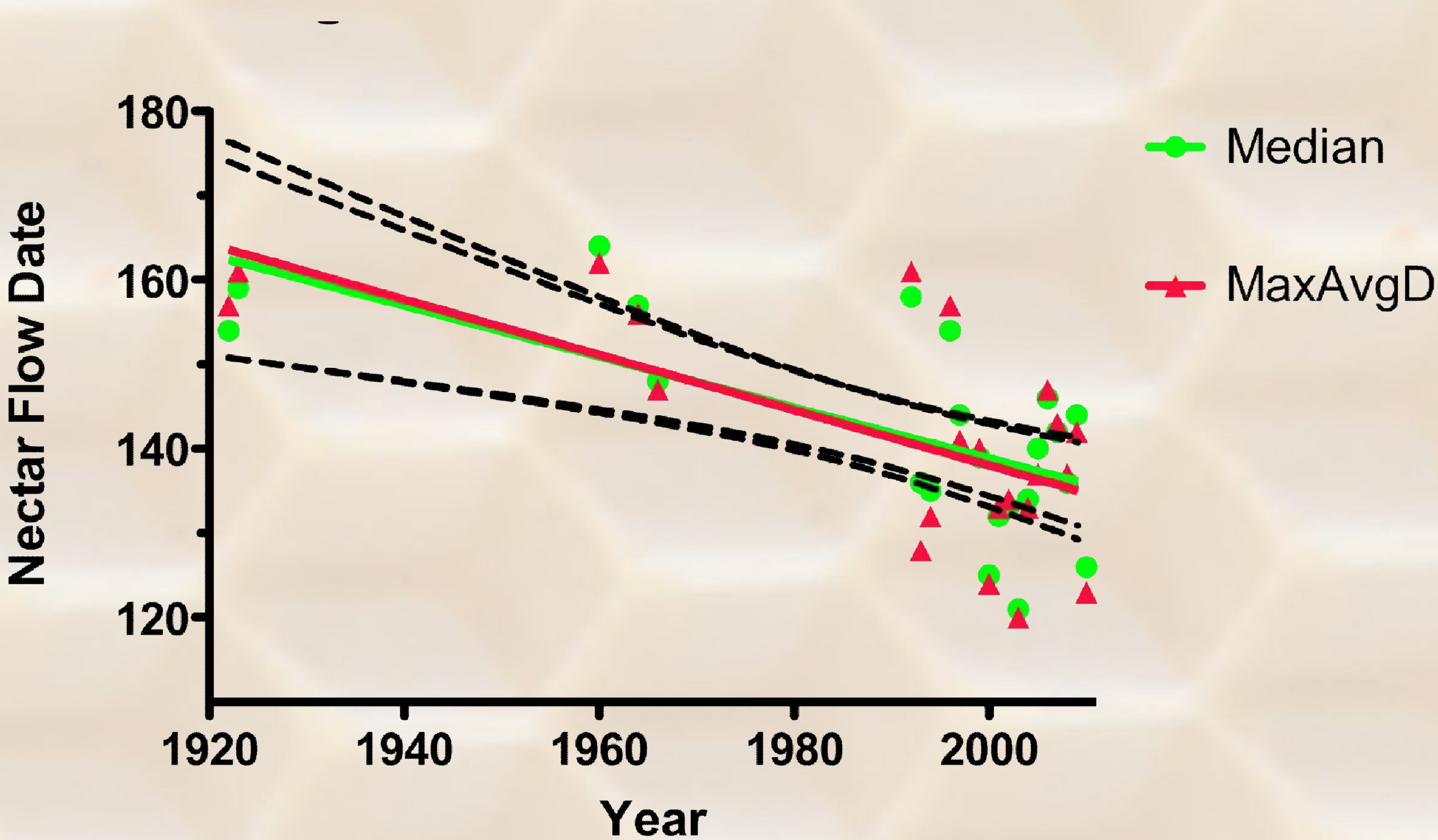
Honey Bee Nutrition is varying wildly, and regionally, due to climate variations, and will be impacted by future change, with added stress on colonies.

Provides basis for regional management practices and advice.



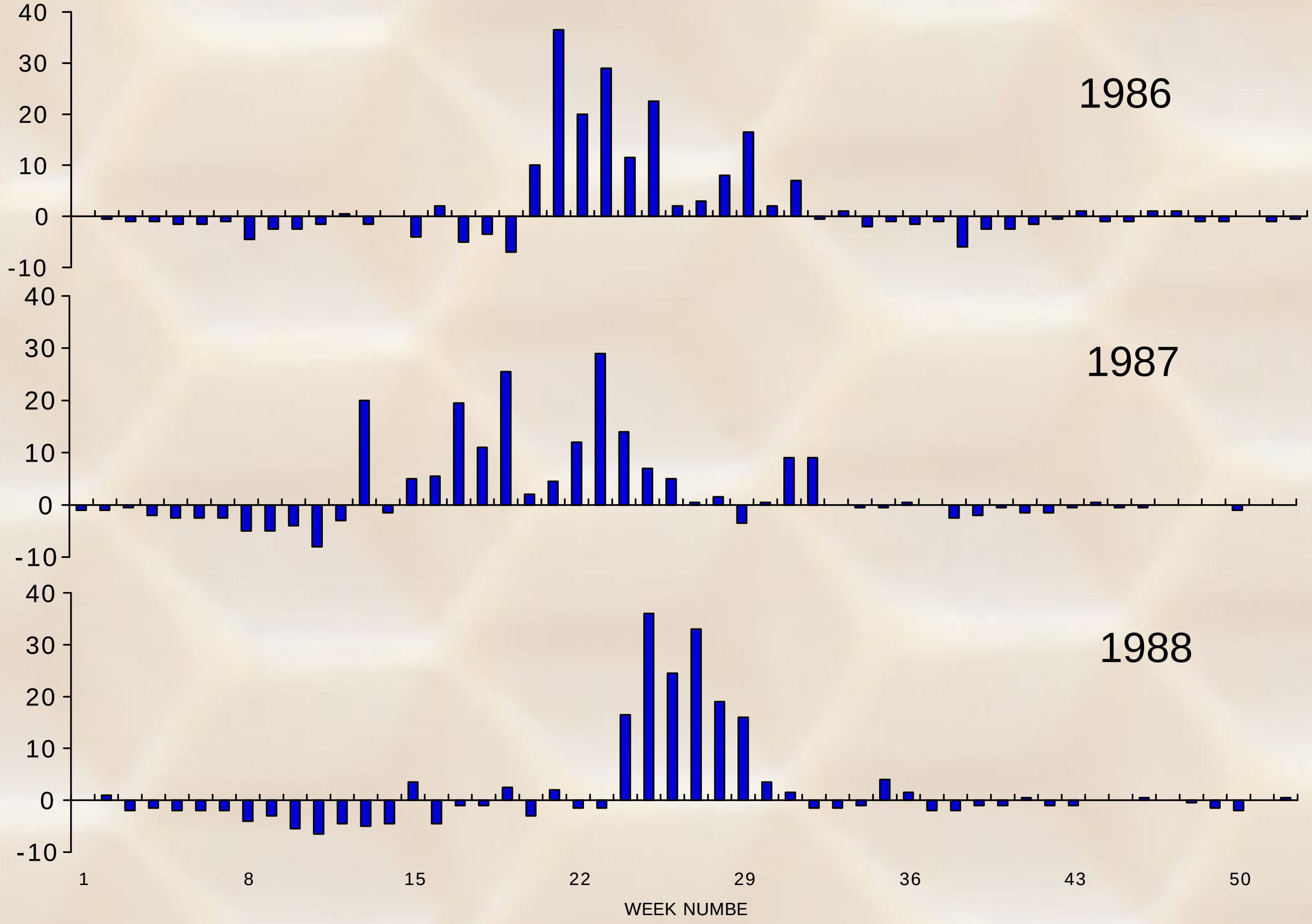

Documents the time course of successful interaction between a generalist pollinator and its multiple forage plants. Includes temp., precip., wind, colony health, forage species abundance and blooming phenology.

# Spring Nectar Flow Climate Trend in Central Maryland




Redone, including 2010 metrics & QA
Insignificant change from earlier version
The pooled slope equals -0.306 d/y
F=15.09, 14.68, n = 22, P =0.0009, 0.0010

Corvallis OR Scale Hive shows effects of El Nino




Maples

Blackberries

Data courtesy
M. Burgett

# A.V. Mitchener's Manitoba Scale Hive Network 1925 - 1954

J. Econ. Entom. 1955 **48**

Comparable HBN Metric

*October 1955* MITCHENER: NECTAR FLOWS IN MANITOBA 517

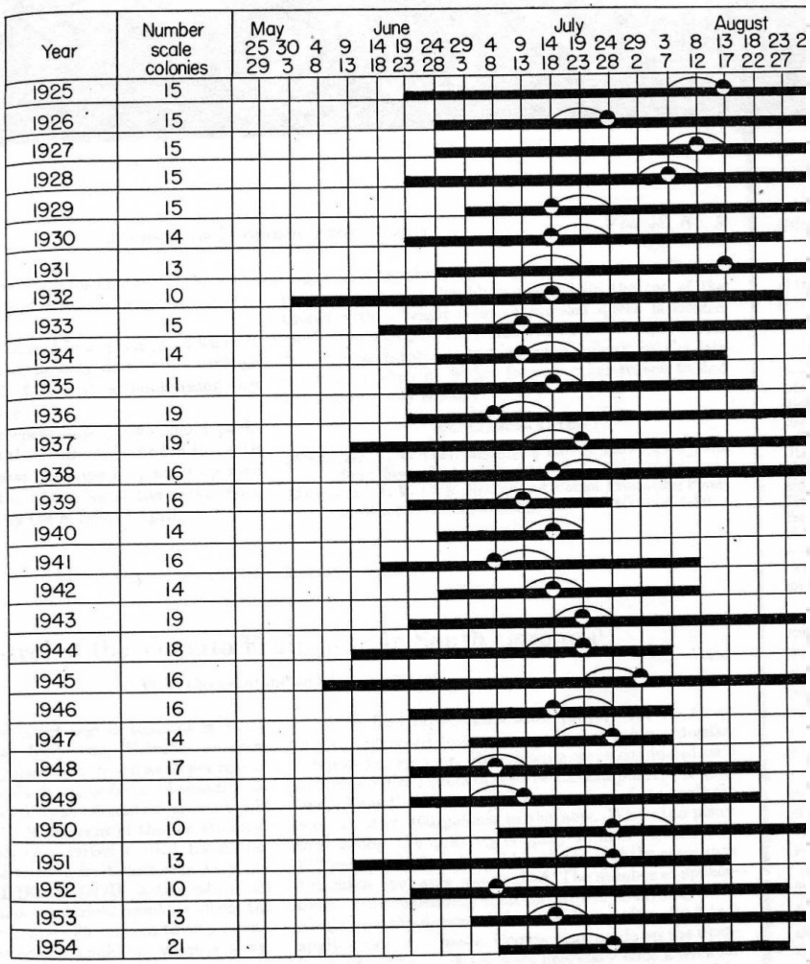
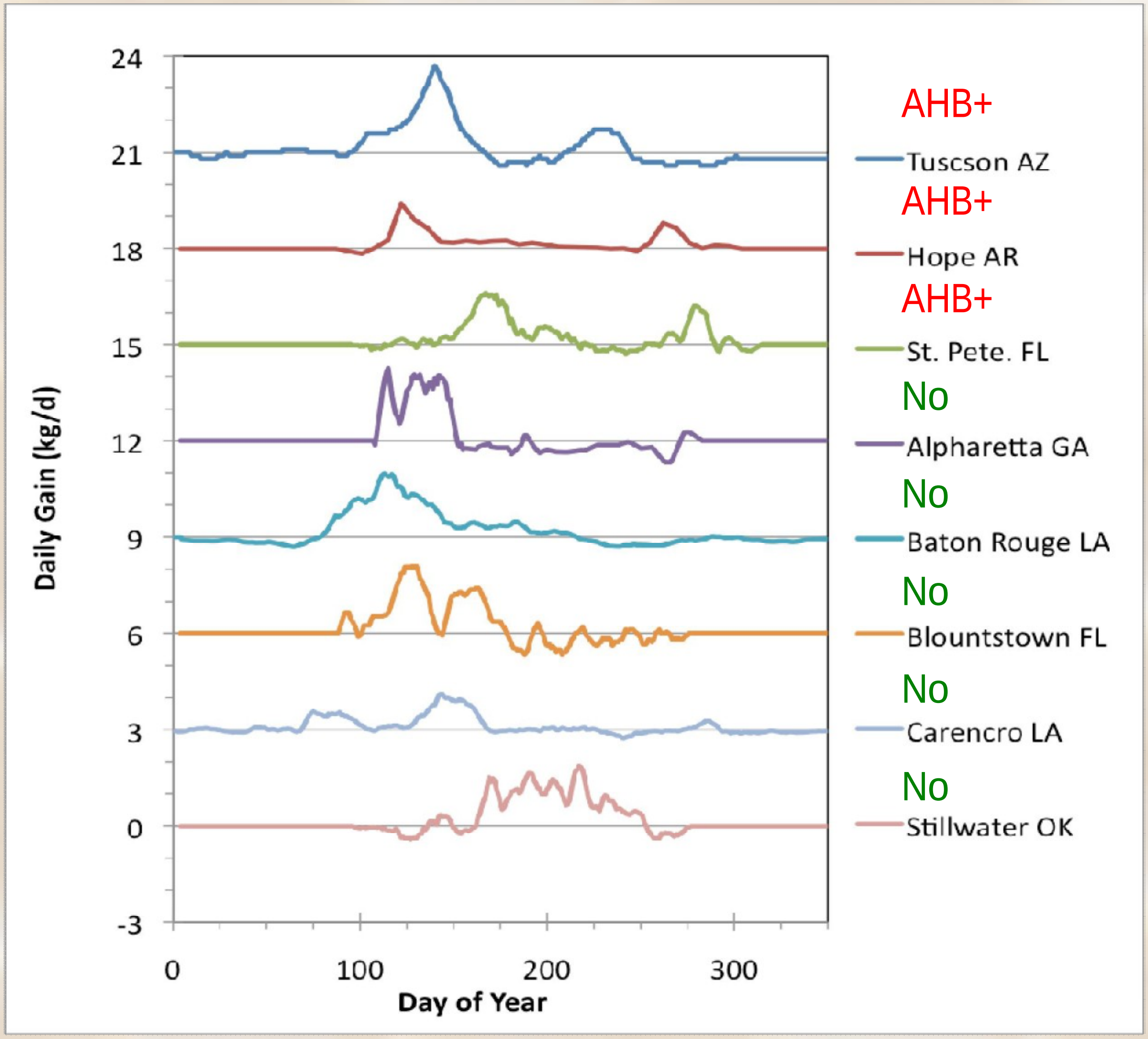



FIG. 3.—Nectar flows 1925–1954 are shown by bars during which the averaged scale colony gained 1 pound 5-day period. The circled points are the 5-day periods during which the peaks of the nectar flows were reach arcs cover the 15-day periods during which the averaged scale colony made the greatest gain.

| | NFbegD Begin | AvPeak/Mediar Av Peak | ~25% - 75% 15 day period | NFendD End | NF Dur Duration |
|---|---|---|---|---|---|
| 1925 | 19-Jun | 13-Aug | 3-Aug | 2-Sep | 75 |
| 1926 | 24-Jun | 24-Jul | 14-Jul | 28-Aug | 65 |
| 1927 | 24-Jun | 8-Aug | 3-Aug | 7-Sep | 75 |
| 1928 | 19-Jun | 3-Aug | 29-Jul | 2-Sep | 75 |
| 1929 | 29-Jun | 14-Jul | 14-Jul | 2-Sep | 65 |
| 1930 | 19-Jun | 14-Jul | 14-Jul | 23-Aug | 65 |
| 1931 | 24-Jun | 13-Aug | 9-Jul | 7-Sep | 75 |
| 1932 | 30-May | 14-Jul | 9-Jul | 23-Aug | 85 |
| 1933 | 14-Jun | 9-Jul | 4-Jul | 28-Aug | 75 |
| 1934 | 24-Jun | 9-Jul | 9-Jul | 13-Aug | 50 |
| 1935 | 19-Jun | 14-Jul | 9-Jul | 18-Aug | 60 |
| 1936 | 19-Jun | 4-Jul | 4-Jul | 7-Sep | 80 |
| 1937 | 9-Jun | 19-Jul | 9-Jul | 18-Aug | 70 |
| 1938 | 19-Jun | 14-Jul | 14-Jul | 28-Aug | 70 |
| 1939 | 19-Jun | 9-Jul | 4-Jul | 24-Jul | 35 |
| 1940 | 24-Jun | 14-Jul | 9-Jul | 19-Jul | 25 |
| 1941 | 14-Jun | 4-Jul | 4-Jul | 8-Aug | 55 |
| 1942 | 24-Jun | 14-Jul | 9-Jul | 8-Aug | 45 |
| 1943 | 19-Jun | 19-Jul | 14-Jul | 28-Aug | 70 |
| 1944 | 9-Jun | 19-Jul | 9-Jul | 3-Aug | 55 |
| 1945 | 4-Jun | 29-Jul | 19-Jul | 28-Aug | 85 |
| 1946 | 19-Jun | 14-Jul | 14-Jul | 3-Aug | 45 |
| 1947 | 29-Jun | 24-Jul | 14-Jul | 3-Aug | 35 |
| 1948 | 19-Jun | 4-Jul | 29-Jun | 18-Aug | 60 |
| 1949 | 19-Jun | 9-Jul | 29-Jun | 18-Aug | 60 |
| 1950 | 4-Jul | 24-Jul | 24-Jul | 2-Sep | 60 |
| 1951 | 9-Jun | 24-Jul | 14-Jul | 13-Aug | 65 |
| 1952 | 19-Jun | 4-Jul | 4-Jul | 23-Aug | 65 |
| 1953 | 29-Jun | 14-Jul | 9-Jul | 28-Aug | 60 |
| 1954 | 4-Jul | 24-Jul | 14-Jul | 23-Aug | 50 |
| | 19-Jun | 18-Jul | 12-Jul | 20-Aug | 61.83333 |
| | 30-May | | | | 61.83 |
| | 4-Jul | | | | 14.70886 |

# Why did the Africanized Bee go West from Texas, and not into Louisiana?




Not Climate, per se

**Starvation!**

Nectar Flows from the tree sources do not support its swarm survival!