Comparing land surface phenology with leafing and flowering observations from the PlantWatch citizen network

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Introduction

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Community and ecosystem responses to recent climate change

Gian-Reto Walther

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review article

Ecological responses to recent climate change

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There is now ample evidence of the ecological impacts of recent climate change, from polar terrestrial to tropical marine environments. The responses of both flora and fauna span an array of ecosystems and organizational hierarchies, from the species to the community levels. Despite continued uncertainty as to community and ecosystem trajectories under global change, our review exposes a coherent pattern of ecological change across systems. Although we are only at an early stage in the projected trends of global warming, ecological responses to recent climate change are already clearly visible.

Fingerprints of global warming on wild animals and plants

Terry L. Root*, Jeff T. Price†, Kimberly R. Hall‡, Stephen H. Schneider§,

NATURE | VOL 421 | 2 JANUARY 2003 | www.nature.com/nature

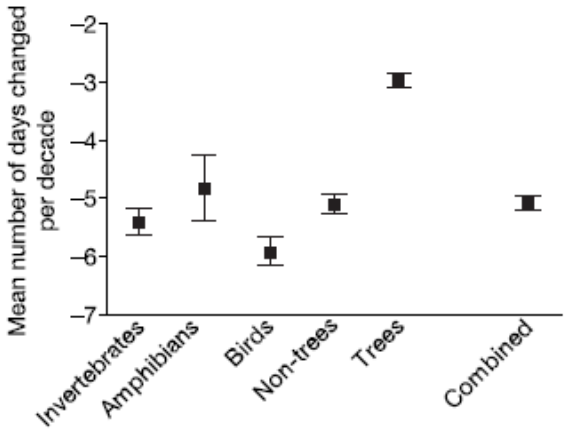

Figure 2 Means ± s.e.m. of days changed for the given groups of species. The 'Combined' category includes only those species tallied in the groups of species (that is, data for the one mammal, two fish and zooplankton are not included).

articles

A globally coherent fingerprint of climate change impacts across natural systems

Camille Parmesan* & Gary Yohe†

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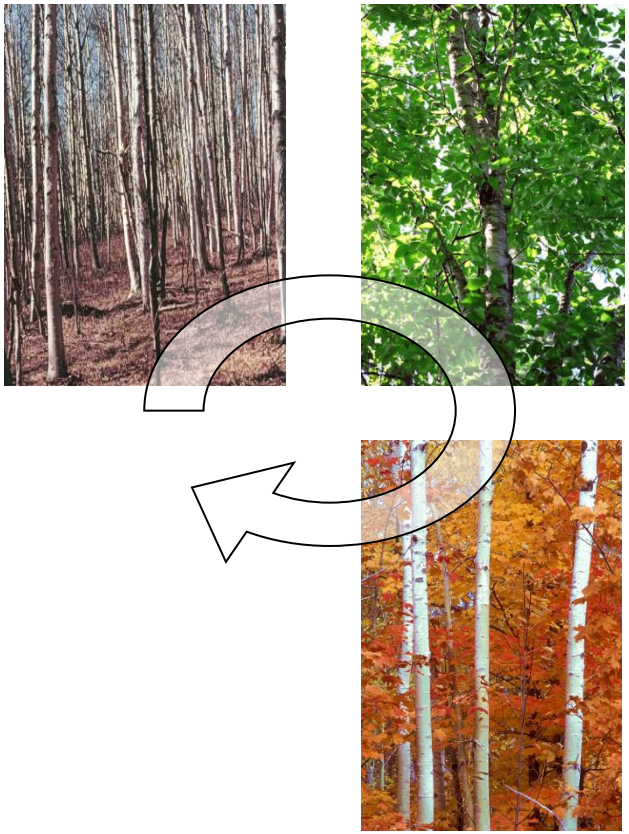
† *John E. Andrus Professor of Economics, Wesleyan University, 238 Public Affairs Center, Middletown, Connecticut 06459, USA*

Introduction

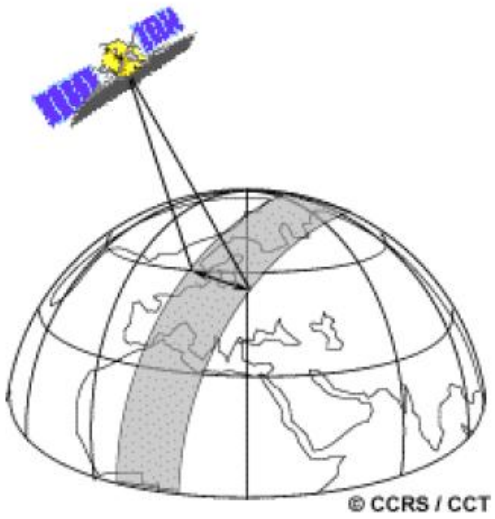
Seasonal variations.
Phenology.

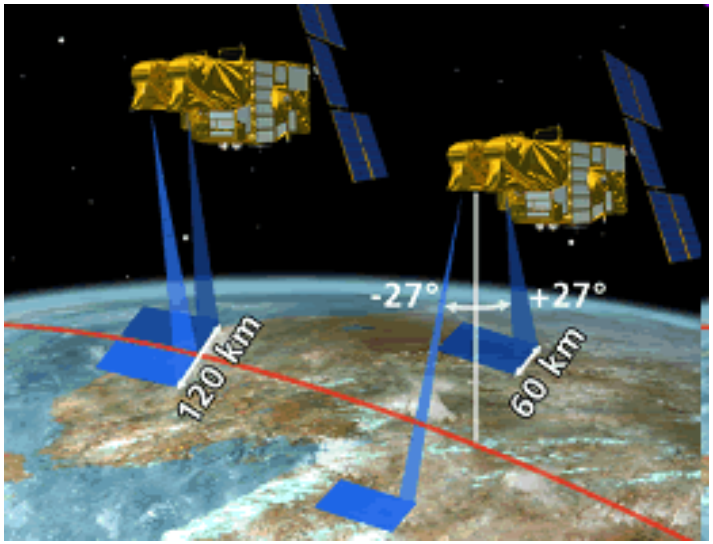


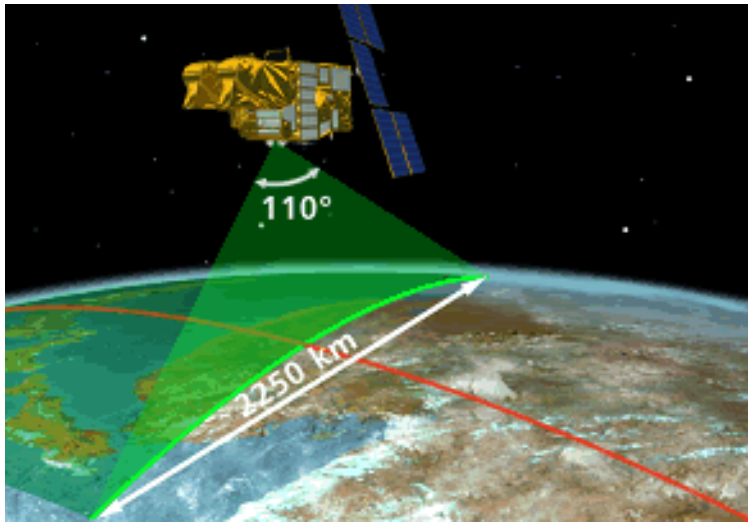
SPOT VEGETATION
1km

Timing of pixel greenup.

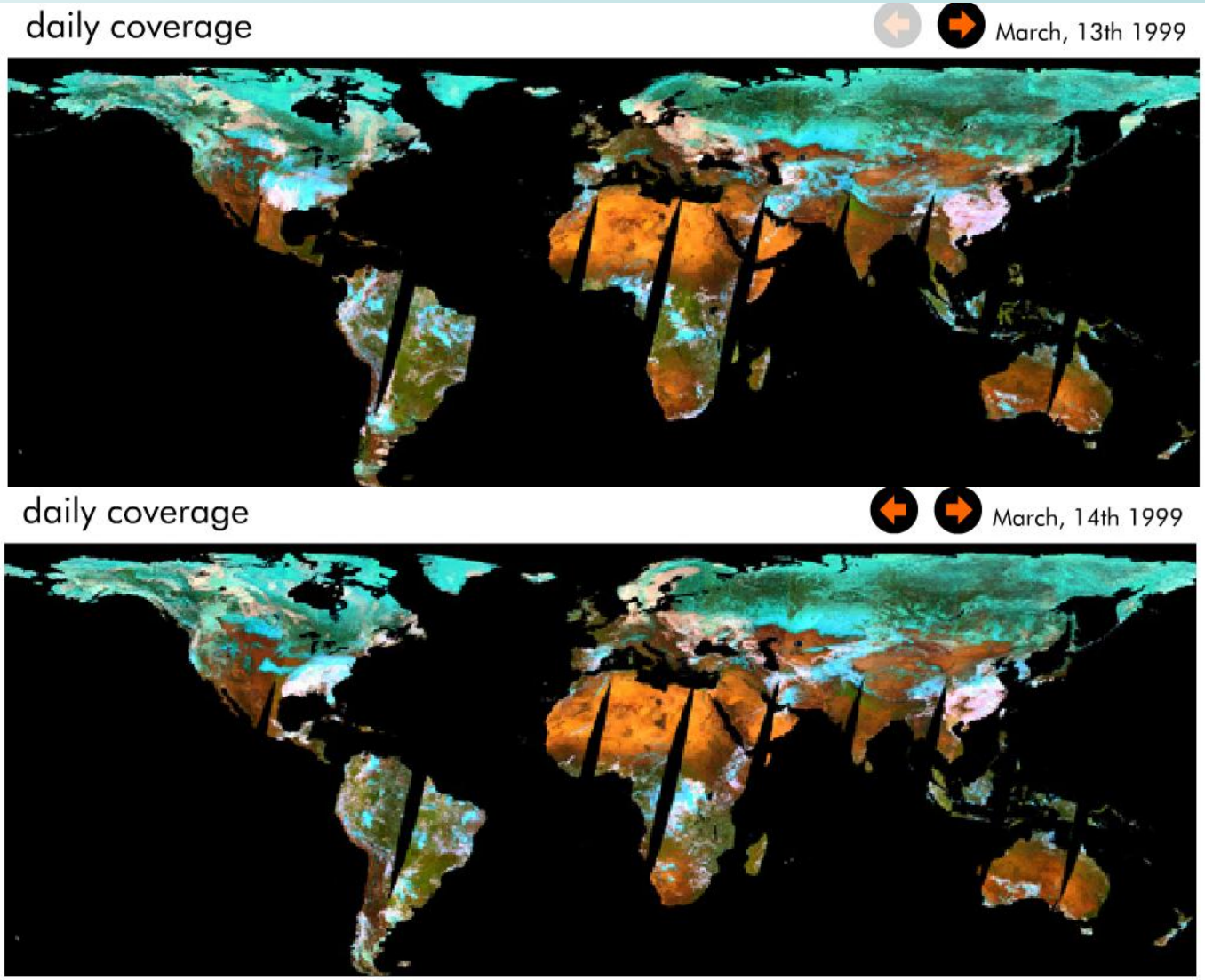
SPOT VEGETATION







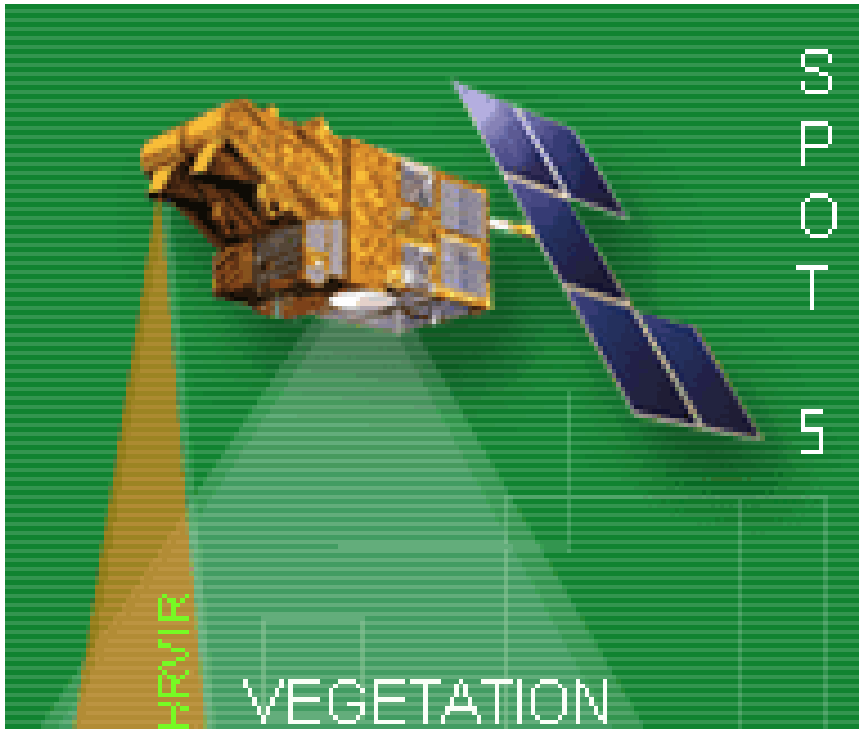
SPOT-VEGETATION



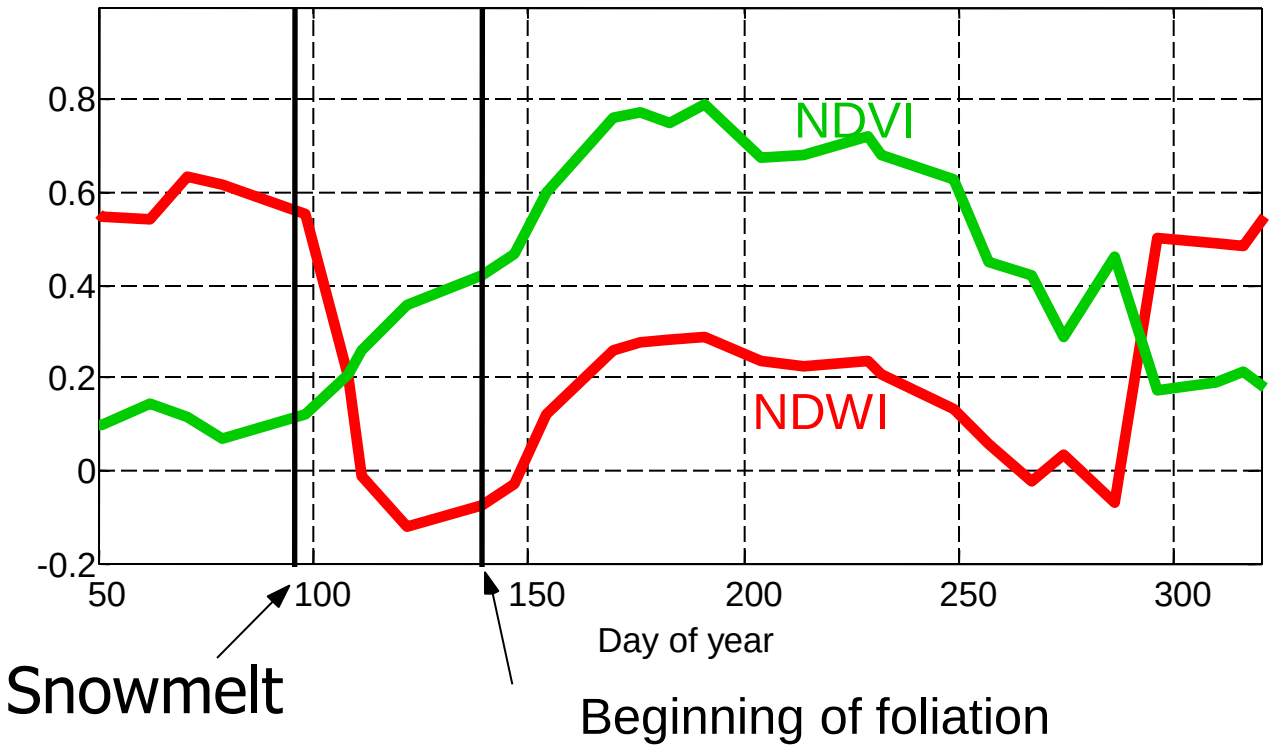
- http://spot5.cnes.fr/gb/systeme/310b.htm

SPOT VEGETATION

- SPOT-VEGETATION data.
- Resolution: 1km.
- S10 composite data: one measurement every ten days.
- Free on free.vgt.vito.be
- Available since 1998.
- **Middle infrared band (1.6µm)**



RS greenup

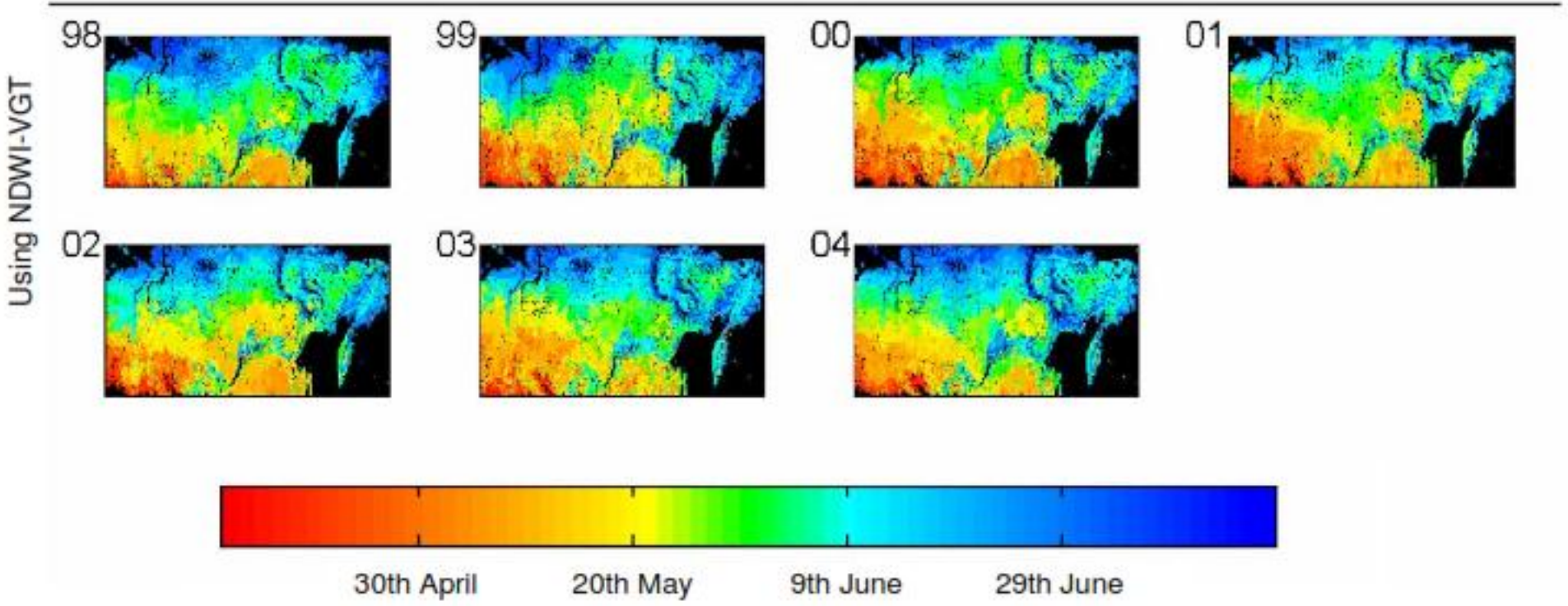


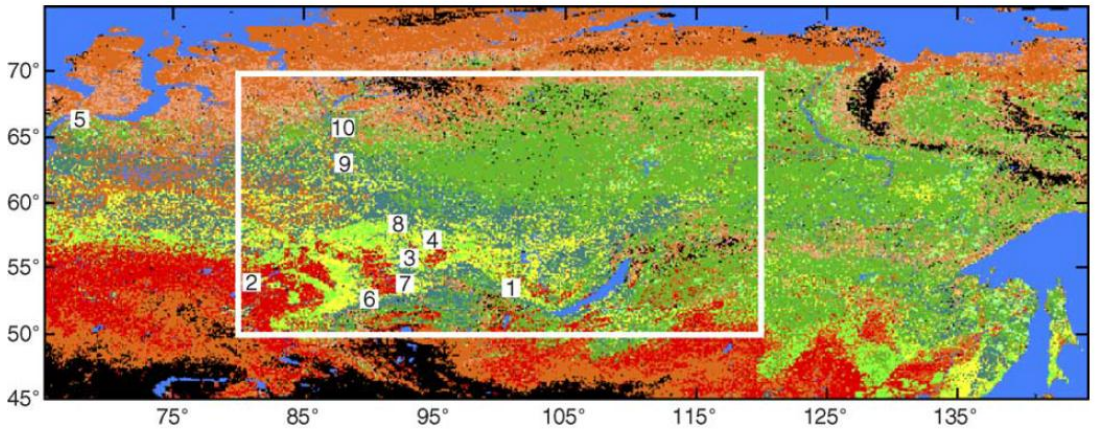
$$NDVI = \frac{NIR - R}{NIR + R}$$

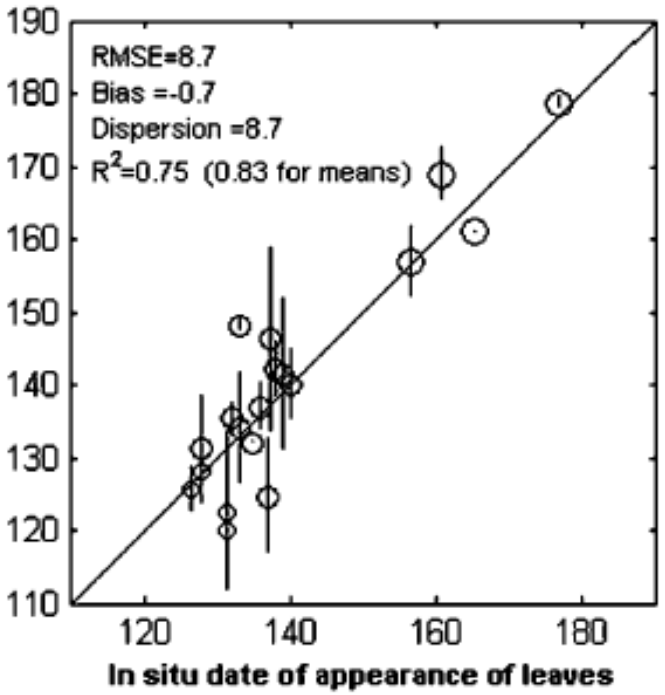
$$NDWI = \frac{NIR - MIR}{NIR + MIR}$$

(**Delbart, N.**, et al. (2005), Determination of phenological dates in boreal regions using Normalised Difference Water Index. *Remote Sensing of Environment, 97*, 26-38.)

RS greenup

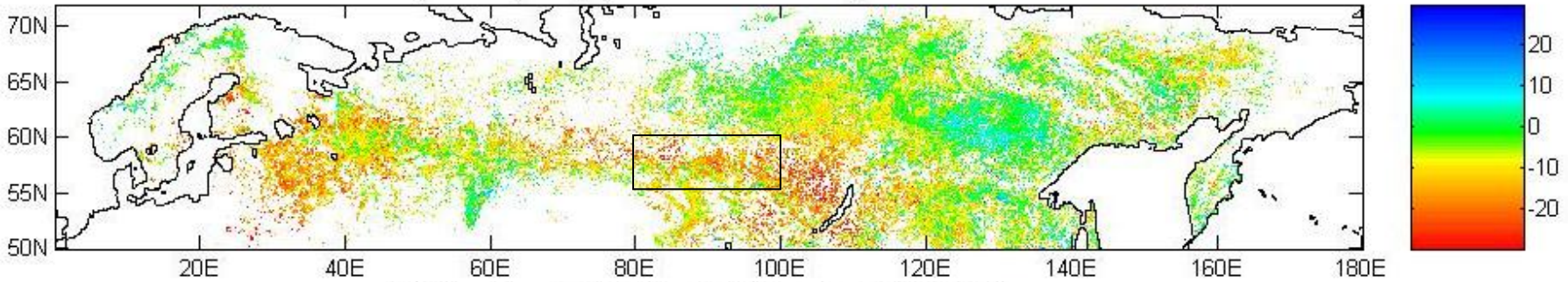

Using NDWI-VGT
98
99
00
01
02
03
04
30th April
20th May
9th June
29th June


70°
65°
60°
55°
50°
45°
75°
85°
95°
105°
115°
125°
135°
1
2
3
4
5
6
7
8
9
10

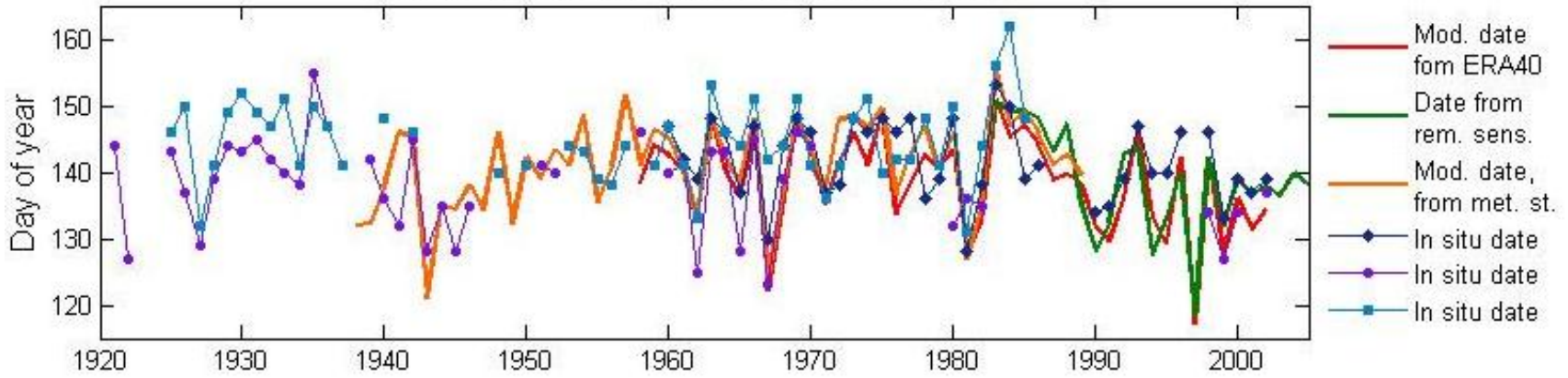

RMSE=8.7
Bias =-0.7
Dispersion =8.7
R²=0.75 (0.83 for means)
190
180
170
160
150
140
130
120
110
120
140
160
180
In situ date of appearance of leaves

Phenology in Central Siberia, 1920-2005

a) Trend (in days) from remote sensing, 1982-2002



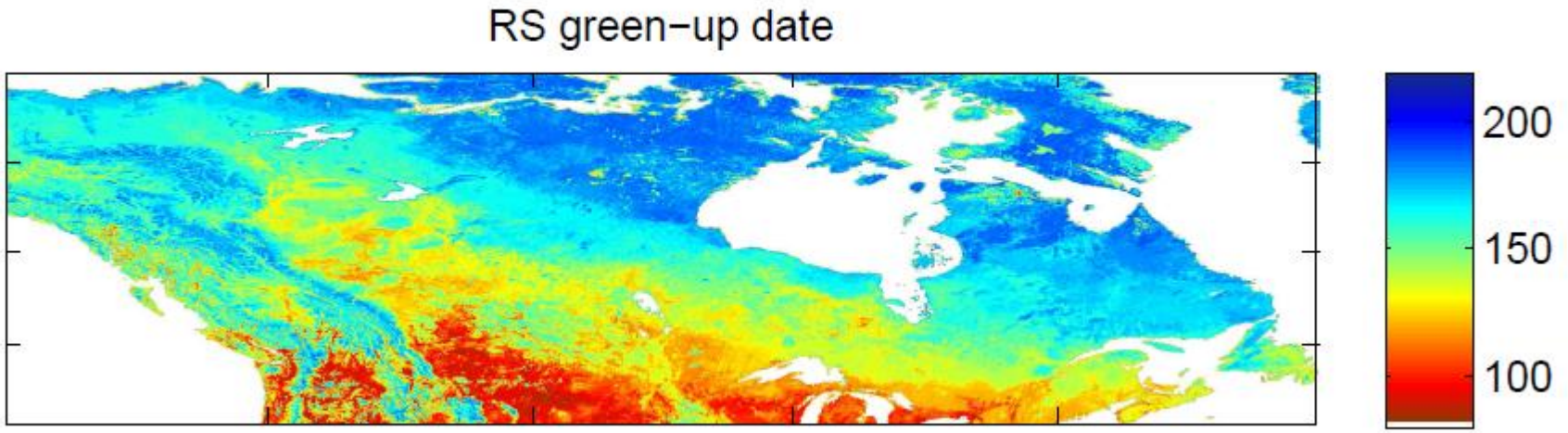
a) Date of leaf-out in Central Siberia, 1920-2005



Delbart, N., Picard, G., Le Toan, T., Kergoat, L., Quegan, S., Woodward, I, Dye, D., and Fedotova, V. (2008), Spring phenology in boreal Eurasia in a nearly century time-scale, *Global Change Biology*, 14, (3), 603-614.

This study

Objective : evaluate the remote sensing greenup product over Canada in 1998-2012.



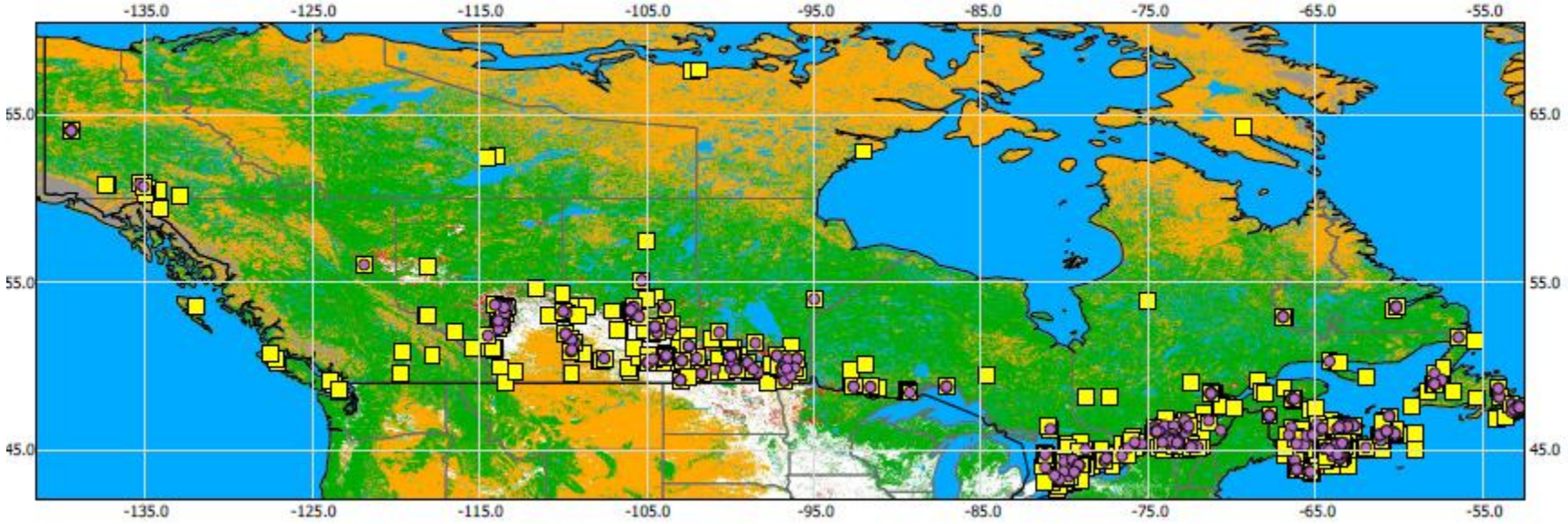
e.g. Year 2000.

PlantWatch

Citizen based science. Open-data.

Leafing date of 4 woody species.

Flowering date of 39 species (woody trees, shrub, herbaceous).



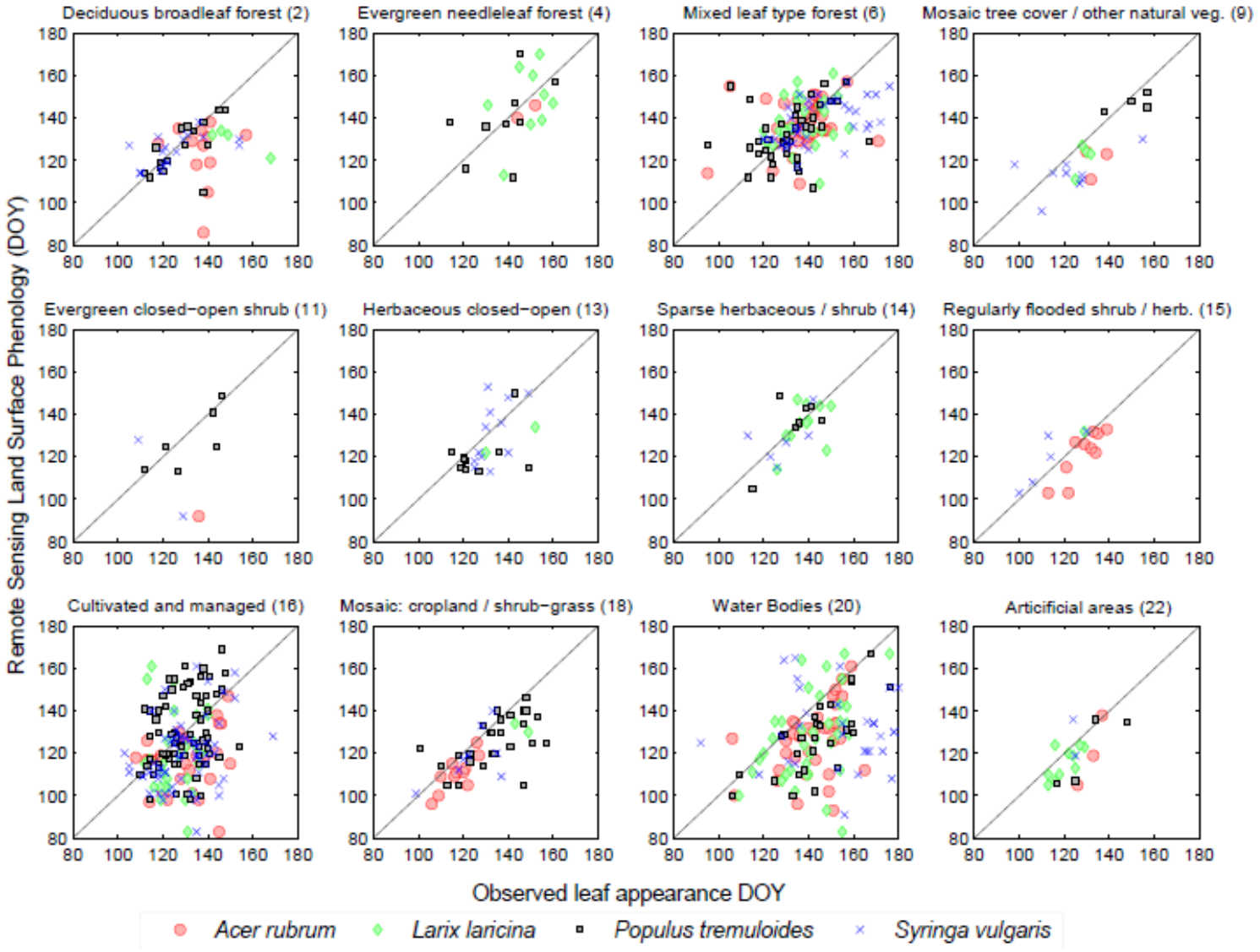
Beaubien, E.G., & Hamann, A (2011a). Plant phenology networks of citizen scientists: recommendations from two decades of experience in Canada, *International Journal of Biometeorology*, *55*, 833–841.

www.plantwatch.ca

Comparison methods

- Remote sensing greenup date tested over :
  - 3298 flowering observations,
  - 741 leafing observations.
- Three types of test :
  - « point test » : differences between RS and IS. -> spatial and temporal gradients are not differentiated.
  - Temporal variations at each point.
  - Temporal variations over large regions.

Leafing date



Poor results over agricutural pixels or dominated by water.

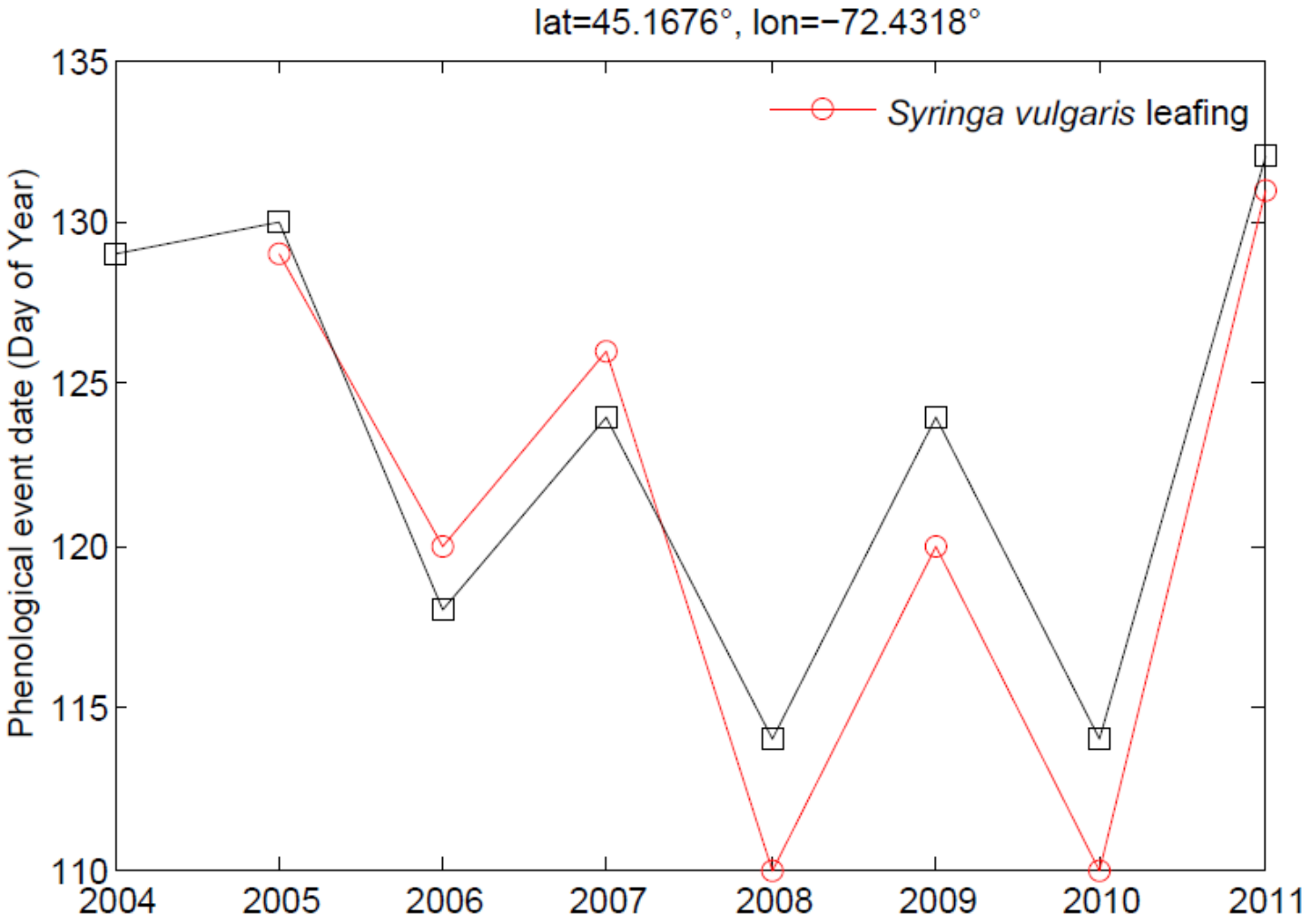
	N	Average lag (days)	RMSE (days)	RMSEu (days)	RMSEs (days)	r
Populus tremuloides	133	-3.18	13.61	11.46	7.35	0.51**
Larix laricina	80	-3.89	13.54	11.73	6.77	0.50**
Acer rubrum	86	-5.64	15.02	13.00	7.53	0.49**
Syringa vulgaris	104	-5.67	15.65	10.60	11.51	0.70**

Flowering date

	N	Average lag (days)	RMSE (days)	RMSEu (days)	RMSEs (days)	r	
Acer rubrum	157	10,8	17,9	12,5	12,8	0,45	**
Achillea millefolium	80	-3,9	13,5	11,7	6,8	0,50	**
Amelanchier	226	-10,5	18,7	14,0	12,4	0,49	**
Anemone patens	127	14,9	21,4	12,3	17,5	0,36	**
Arctostaphylos uva-ursi	59	-4,1	13,7	12,8	4,9	0,65	**
Clintonia borealis	172	-18,4	22,8	12,3	19,2	0,63	**
Cornus canadensis	238	-22,5	26,9	13,4	23,4	0,35	**
Dryas integrifolia/D.octopetala	19	-11,1	15,9	10,8	11,6	0,90	**
Elaeagnus commutata	22	-32,0	33,5	9,8	32,0	0,57	*
Epigaea repens	78	13,9	21,8	12,7	17,7	0,02	
Forsythia suspensa	48	4,9	13,4	12,2	5,6	0,48	*
Fragaria virginiana/F. vesca	297	-6,8	16,7	13,8	9,4	0,41	**
Galium boreale	22	-46,3	47,6	10,0	46,6	0,46	*
Houstonia caerulea	21	-1,3	18,7	16,9	7,9	-0,09	
Larix laricina	89	5,9	16,4	13,5	9,4	0,31	*
Linnaea borealis	21	-31,9	35,6	13,7	32,9	0,31	
Lupinus arcticus	20	-11,5	27,3	6,1	26,7	-0,48	*
Maianthemum stellatum	24	-20,2	22,3	9,5	20,2	0,63	*
Myrica gale	24	7,3	20,2	15,5	12,9	0,14	
Populus tremuloides	175	15,0	21,6	11,9	18,0	0,44	**

- Remote sensing greenup correlates with :
  - Leafing date of the four tested species
  - Flowering date of many species, even with large bias.
- However, agreement is lower than in previous studies over Siberia. (Delbart et al. 2005, 2008).

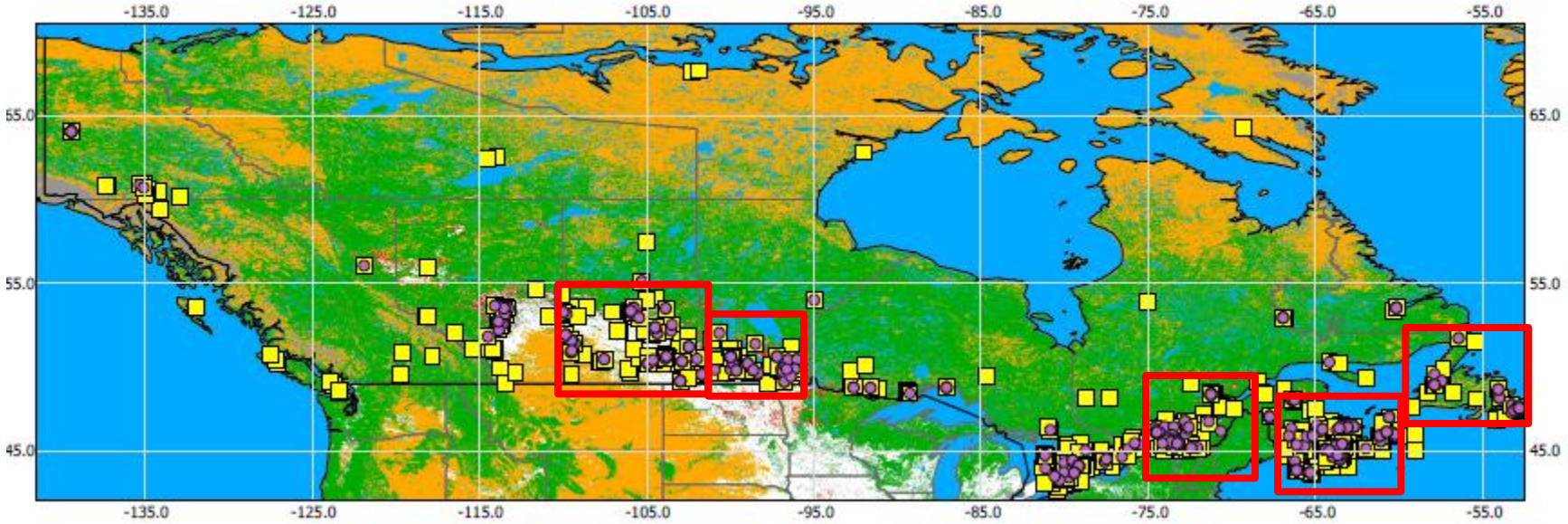
Temporal variations



Temporal variations

- However, not all series correlate that well :
  - Series longer than 10 years : siginificant ($p<0.05$) correlation for 8 out of 18 series.
  - But less correlation for shorter series (e.g. 26 out of 131 for longer than 5 years series.)
- Two effects, that cannot be separated :
  - Incompletness of in situ time series,
  - RS cannot follow robustly interannual variations at local scale, for various reasons :
    - Pixel size, mosaic of landscape within the pixel,
    - Noise in input reflectance data,
    - ...

Regional tests

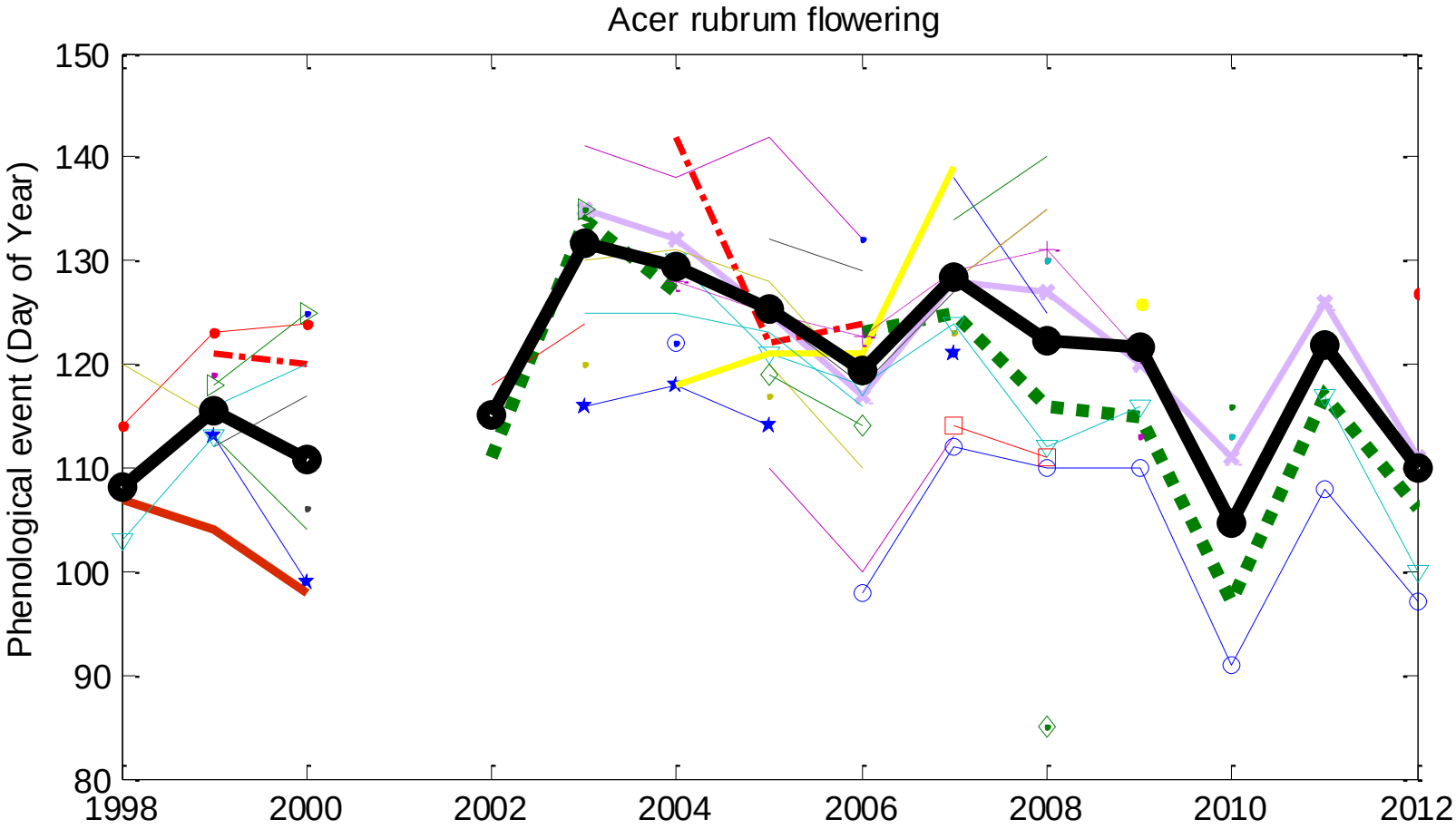


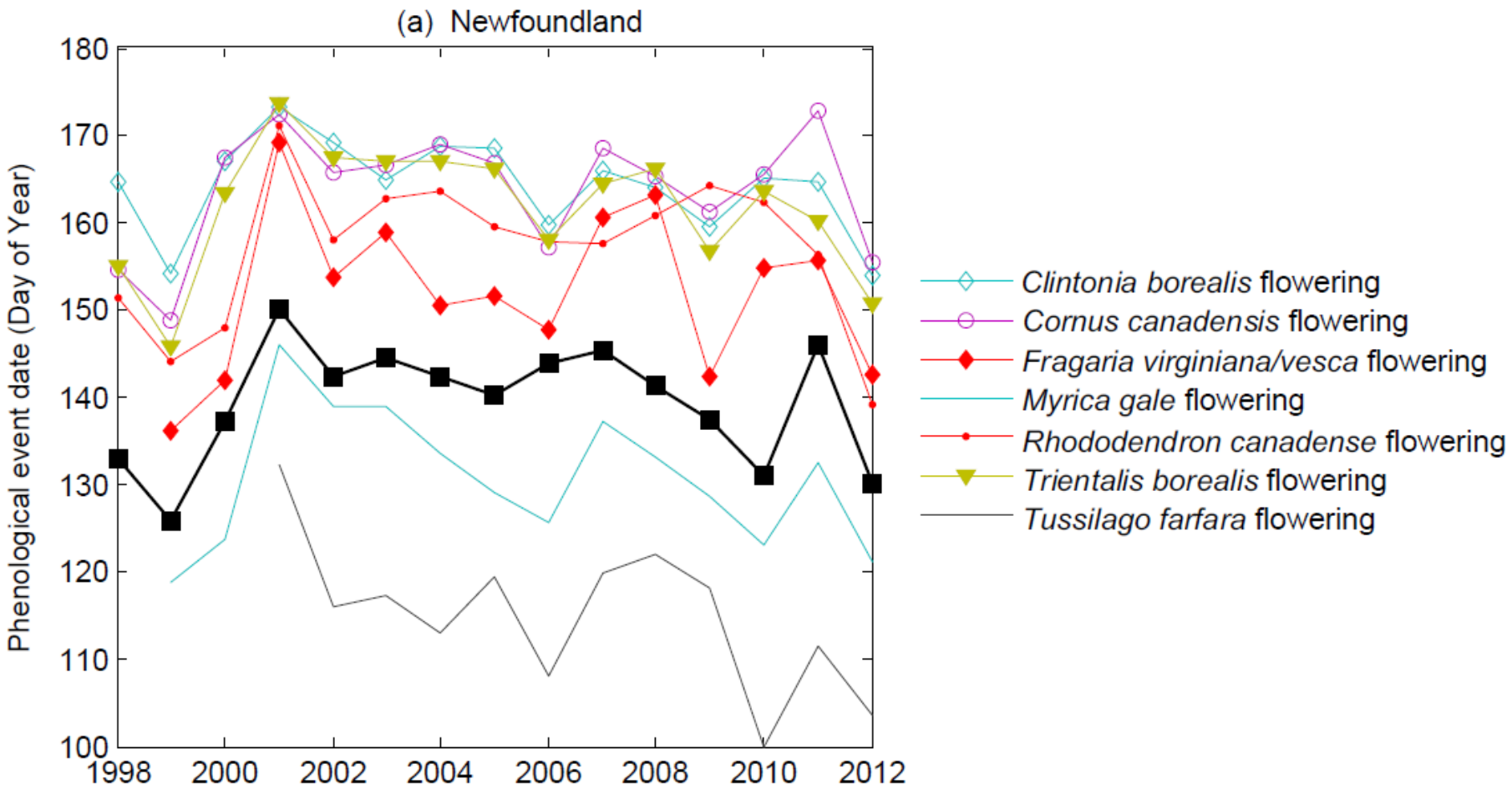
Aggregating ground observations

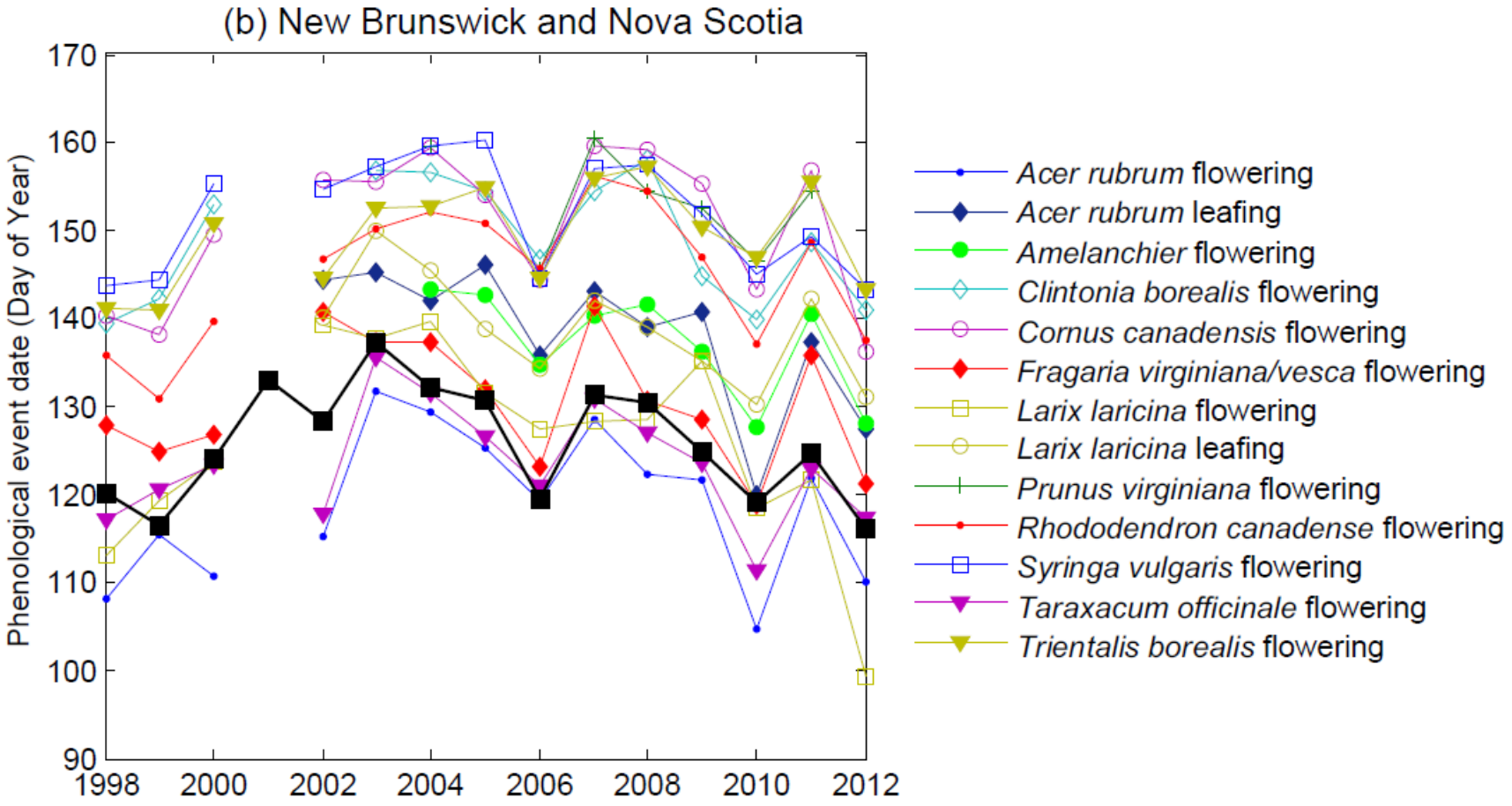
Example, Acer rubrum flowering, New Brunswick / Nova Scotia region.

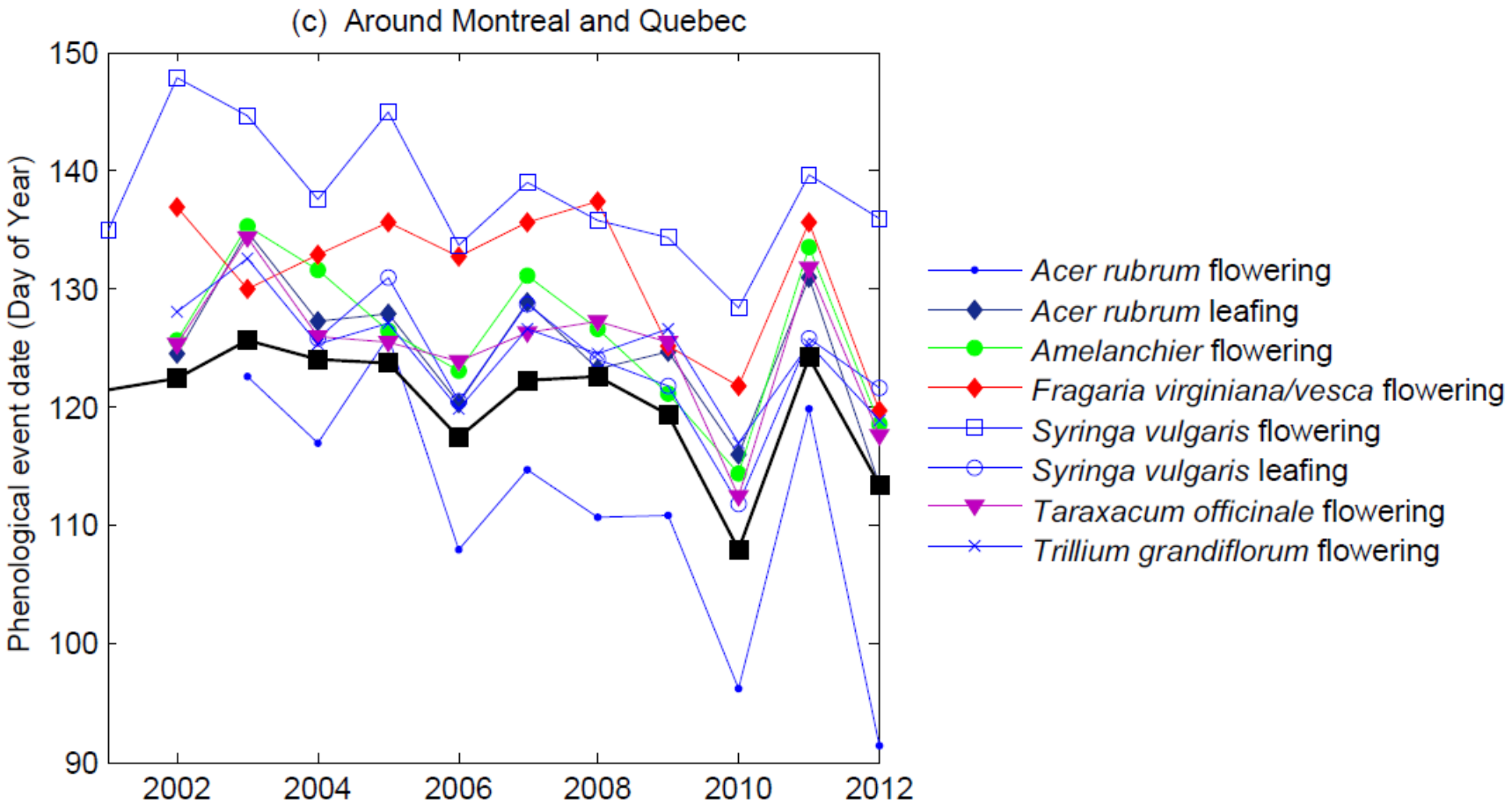
Issues : almost no series is complete + series are biased one to another.

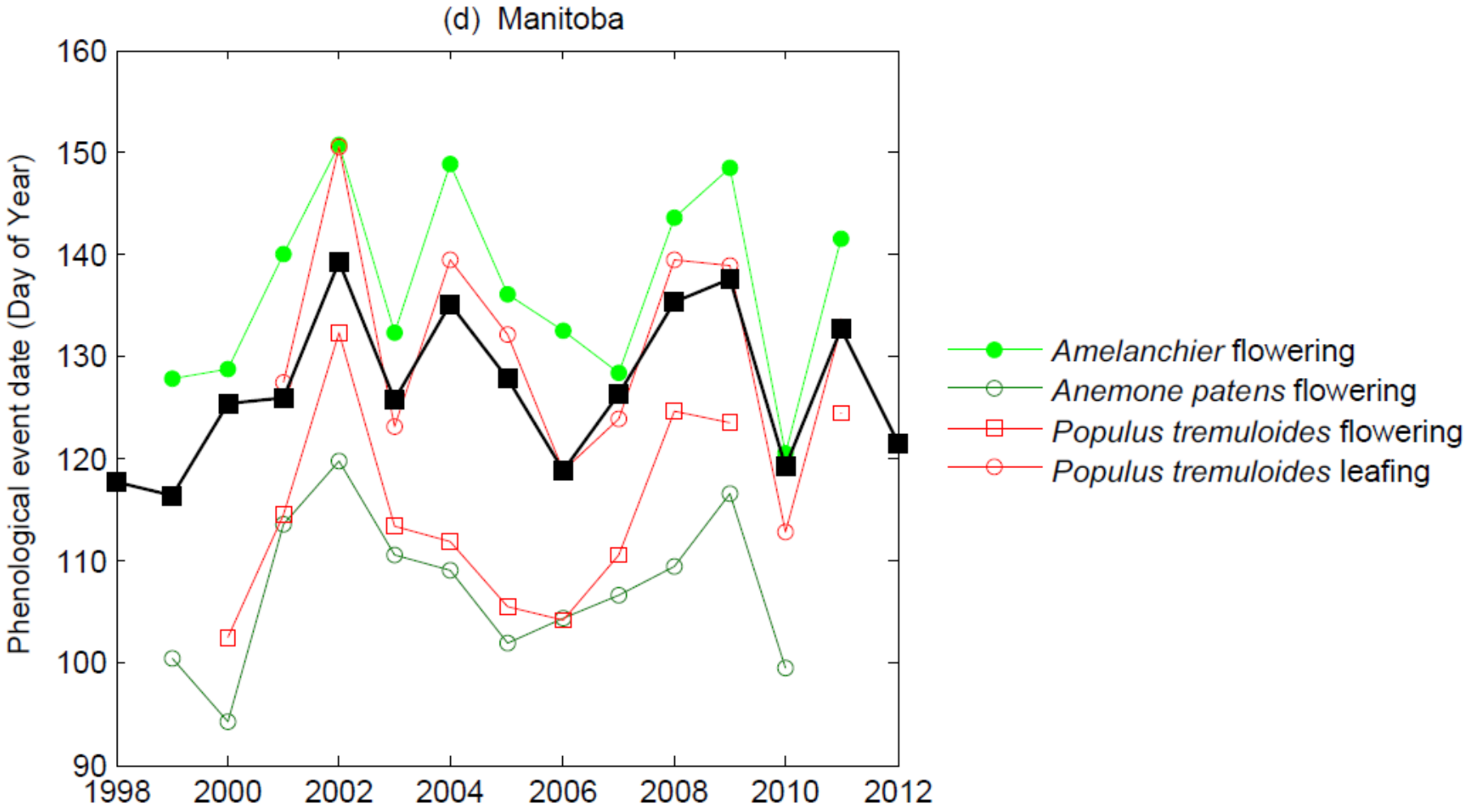
Aggregating procedure based on Häkkinen *et al.* 1995

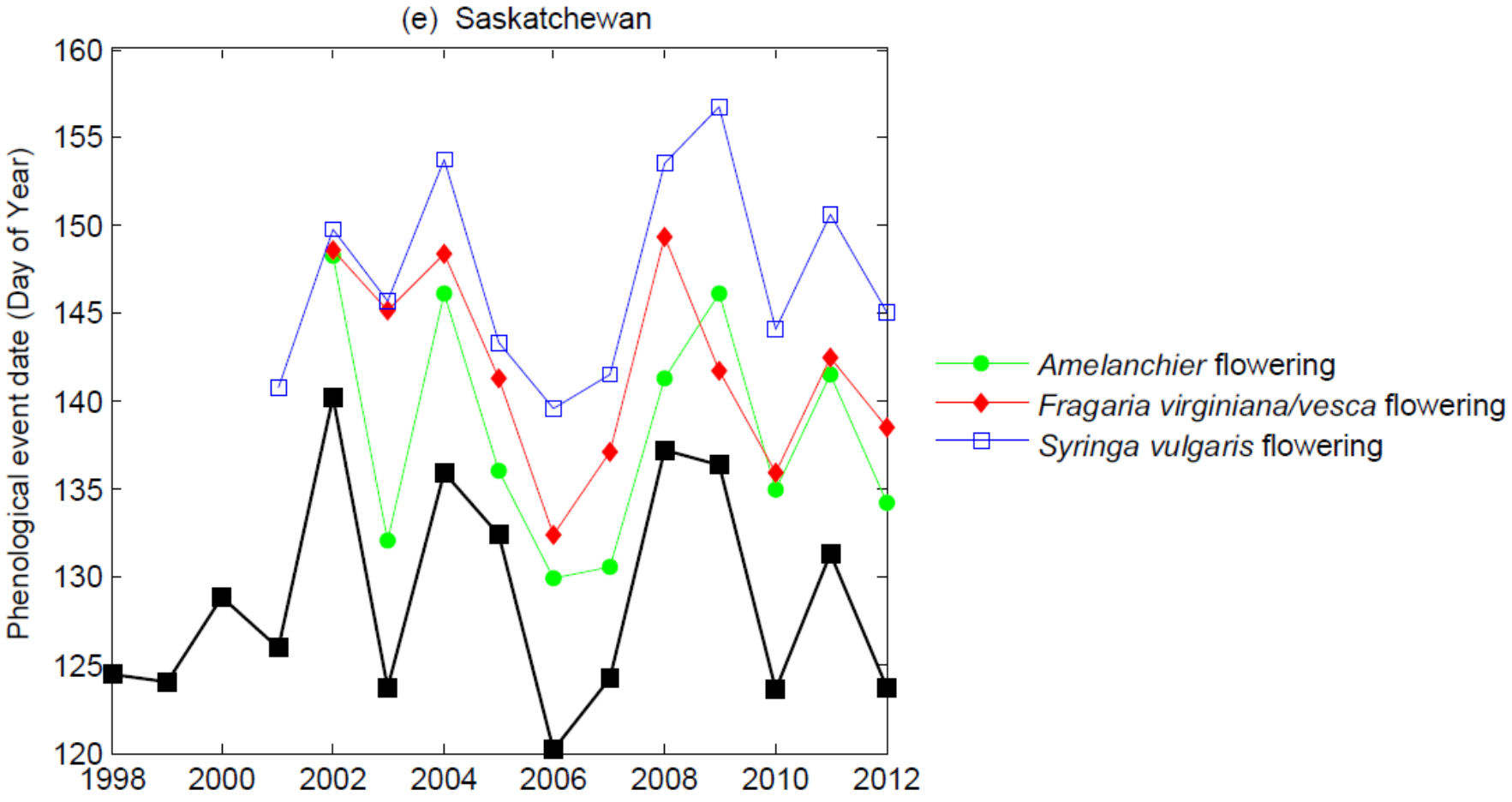



(a) Newfoundland
Phenological event date (Day of Year)
180
170
160
150
140
130
120
110
100
1998
2000
2002
2004
2006
2008
2010
2012
Clintonia borealis flowering
Cornus canadensis flowering
Fragaria virginiana/vesca flowering
Myrica gale flowering
Rhododendron canadense flowering
Trientalis borealis flowering
Tussilago farfara flowering


(b) New Brunswick and Nova Scotia
Phenological event date (Day of Year)
170
160
150
140
130
120
110
100
90
1998
2000
2002
2004
2006
2008
2010
2012
Acer rubrum flowering
Acer rubrum leafing
Amelanchier flowering
Clintonia borealis flowering
Cornus canadensis flowering
Fragaria virginiana/vesca flowering
Larix laricina flowering
Larix laricina leafing
Prunus virginiana flowering
Rhododendron canadense flowering
Syringa vulgaris flowering
Taraxacum officinale flowering
Trientalis borealis flowering


(c) Around Montreal and Quebec
Phenological event date (Day of Year)
150
140
130
120
110
100
90
2002
2004
2006
2008
2010
2012
Acer rubrum flowering
Acer rubrum leafing
Amelanchier flowering
Fragaria virginiana/vesca flowering
Syringa vulgaris flowering
Syringa vulgaris leafing
Taraxacum officinale flowering
Trillium grandiflorum flowering


(d) Manitoba
Phenological event date (Day of Year)
160
150
140
130
120
110
100
90
1998
2000
2002
2004
2006
2008
2010
2012
Amelanchier flowering
Anemone patens flowering
Populus tremuloides flowering
Populus tremuloides leafing


(e) Saskatchewan
Phenological event date (Day of Year)
160
155
150
145
140
135
130
125
120
1998
2000
2002
2004
2006
2008
2010
2012
Amelanchier flowering
Fragaria virginiana/vesca flowering
Syringa vulgaris flowering

	Newfoundland	New Brunswick / Nova Scotia	Montreal Quebec	Manitoba	Saskatchewan
Acer rubrum flowering	0	2	2		
Acer rubrum leafing	0	1	2		
Amelanchier flowering		2	2	2	
Anemone patens flowering				1	0
Clintonia borealis flowering	1	2			
Cornus canadensis flowering	2	2			
Elaeagnus commutata flowering					1
Epigaea repens flowering		1			
Forsythia suspensa flowering		0			
Fragaria virginiana/ vesca flowering	1	2	1		1
Galium boreale flowering					0
Houstonia caerulea flowering		0			
Larix laricina flowering	1	2			0
Larix laricina leafing	1	2	0		
Maianthemum stellatum flowering					0
Myrica gale flowering	2				
Populus tremuloides flowering		0	1	1	1
Populus tremuloides leafing		0		2	1
Prunus virginiana flowering		1			1
Rhododendron canadense flowering	1	2			
Rhododendron groenlandicum flowering	0	1			
Syringa vulgaris flowering	0	2	1	0	1
Syringa vulgaris leafing	0	0	1		1
Taraxacum officinale flowering	1	2	2	1	0
Trientalis borealis flowering	2	1			
Trillium grandiflorum flowering			2		
Tussilago farfara flowering	2	1			
Vaccinium vitis-idaea flowering	0	2			

Conclusion

- RS greenup correlates :
  - with obervations of leafing of woody species, with small bias.
  - With flowering, with bias depending on species.
- At the local (pixel) level, the interannual phenological variations are retrieved only sometimes.
- At the regional level, RS matches interannual phenological variations of leafing and flowering of a community of species.

Conclusion

- Issue : incompletness of ground observations series, which may lower the correlation.

- Citizen science -> only solution to provide massive data necessary to evaluate satelite products at a semi-continental scale.

- Seasonal signal : SENTINEL-2 (20m), PROBA-V (300m).