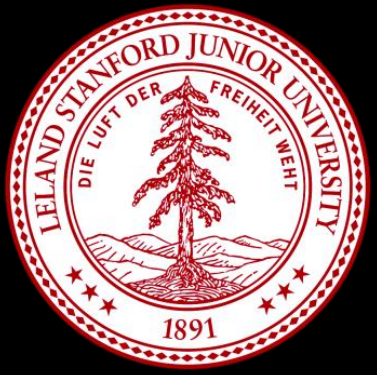

THE RAILS INSIDE THE SUN AND THE BUTTERFLIES THAT RIDE THEM

Andrés Muñoz-Jaramillo
www.solardynamo.org

Georgia State University
University of California - Berkeley
Stanford University

THE FOLLOWING **PREVIEW** HAS BEEN APPROVED FOR

APPROPRIATE AUDIENCES

BY THE MOTION PICTURE ASSOCIATION OF AMERICA, INC.

THE FILM ADVERTISED HAS BEEN RATED

www.filmratings.com

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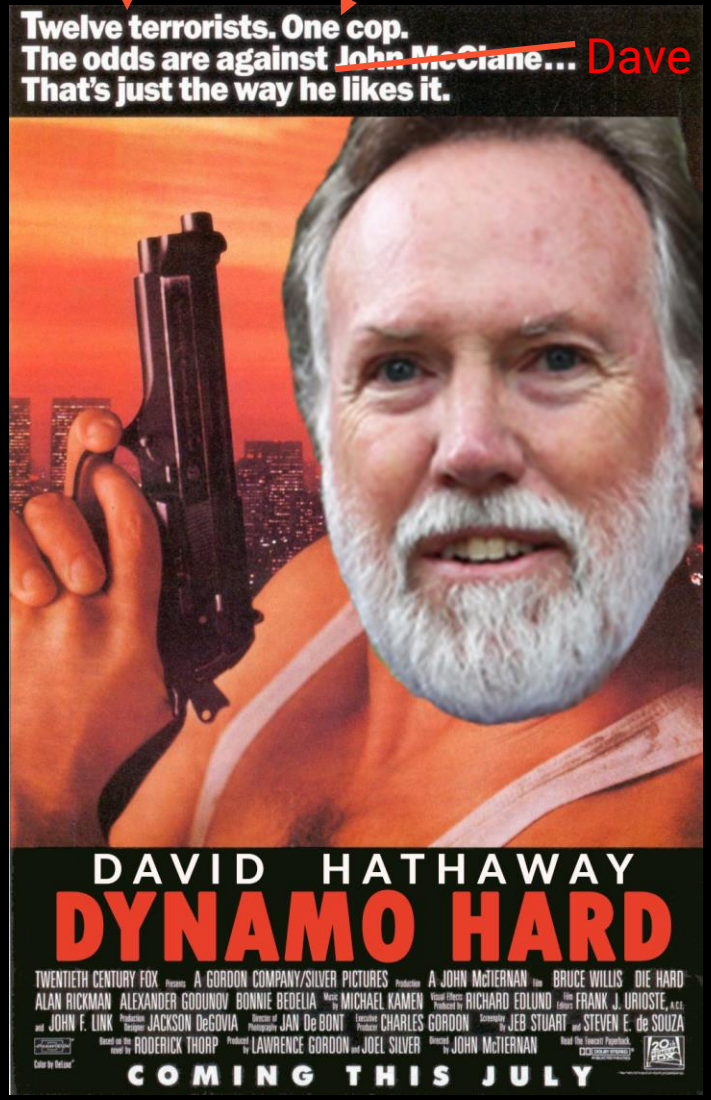
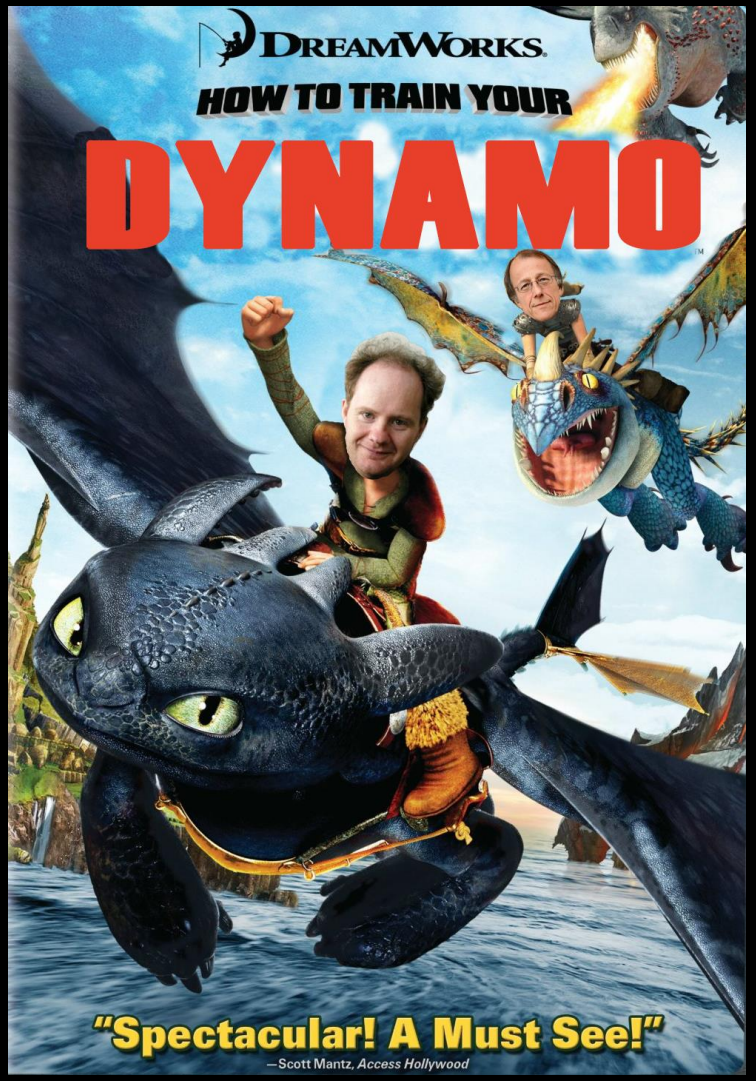
From the creators of

dynamo

observational

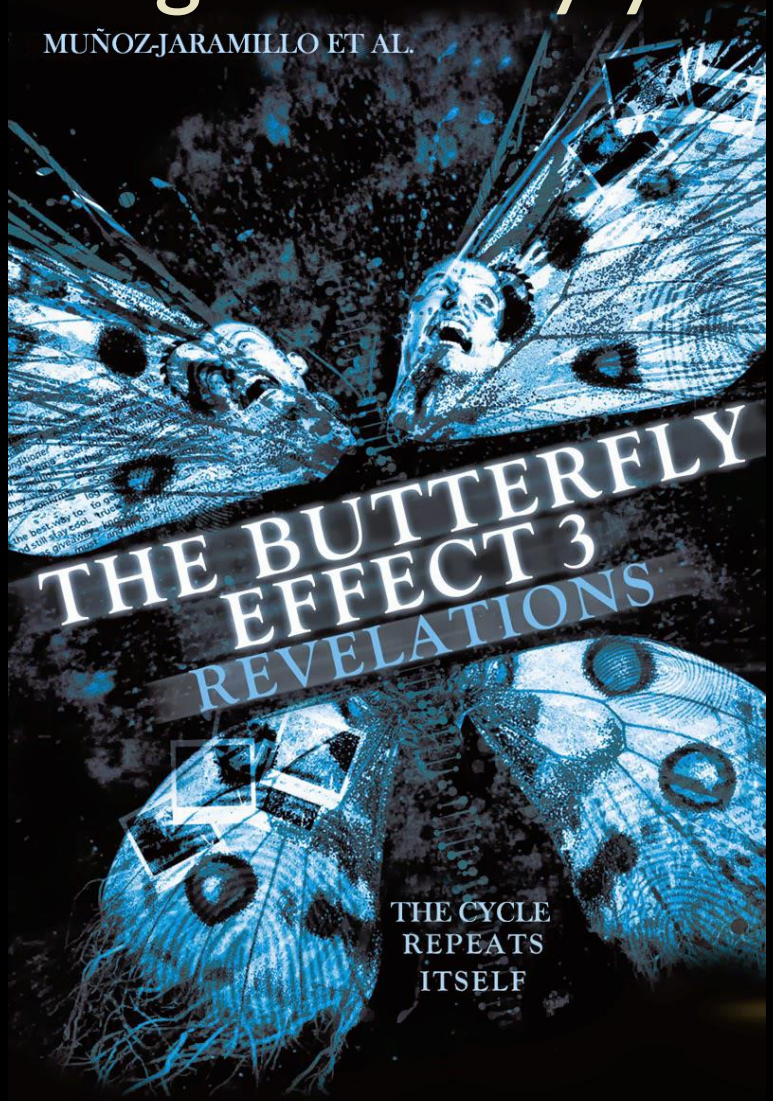


(Hathaway 2011)



(Cameron & Schüssler 2016)

Comes an action-packed psychological thriller that will change the way you see reality



(Muñoz-Jaramillo et al. in preparation)

A DEEPLY TOUCHING STORY BASED ON REAL OBSERVATIONS…

…of magnetic death*…

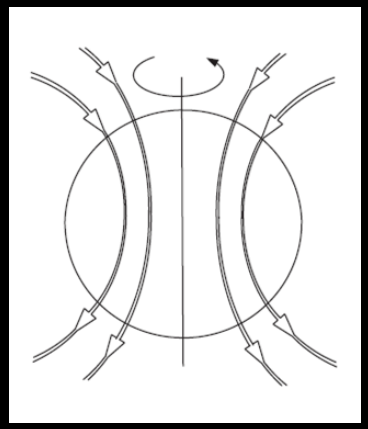
Poloidal

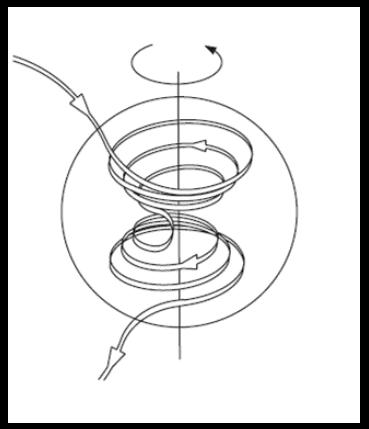
r - θ

Differential Rotation

Toroidal

ϕ





Credit: J. J. Love

* Transformation

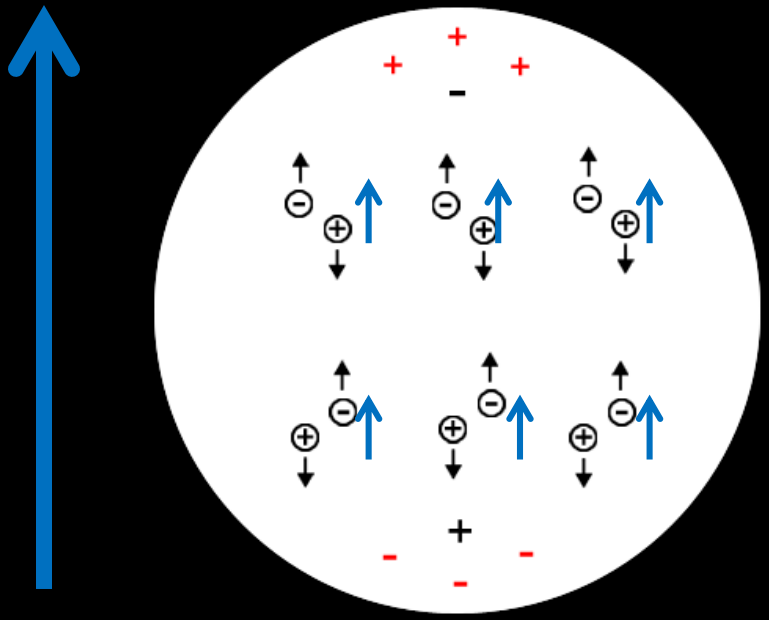
… and rebirth

Poloidal
r - θ

Differential
Rotation

Toroidal
ϕ

Emergence and Decay of
Tilted Active Regions



For decades, our heroes have civilly debated the nature of the solar cycle

It’s deep in the interior!

For decades, our heroes have civilly debated the nature of the solar cycle

No! It’s near the surface!

For decades, our heroes have civilly debated the nature of the solar cycle

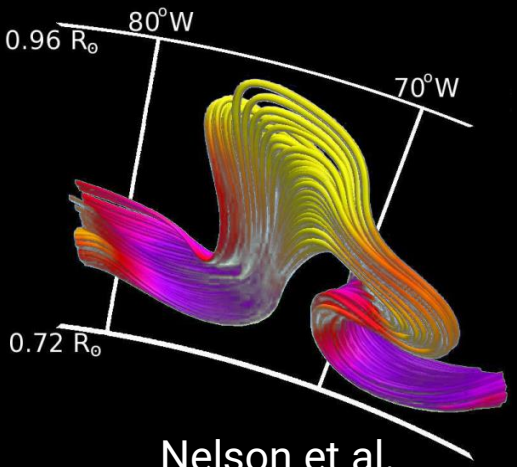
But new ways of looking at old data may provide the clues that we are missing

- Referencing sunspot properties to the strength of the cycle at a given time (activity level; Muñoz-Jaramillo et al 2015).
- Using latitude of the toroidal belts instead of time (Hathaway 2011; Ivanov & Miletsky 2014; Cameron & Schüssler 2016; this work).

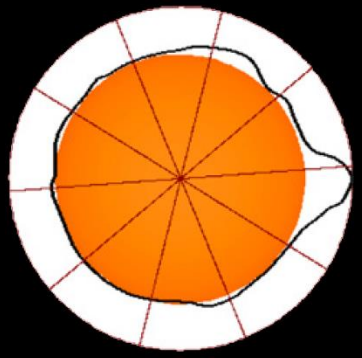
THE RAILS INSIDE THE SUN

(HATHAWAY 2011; IVANOV & MILETSKY 2014).

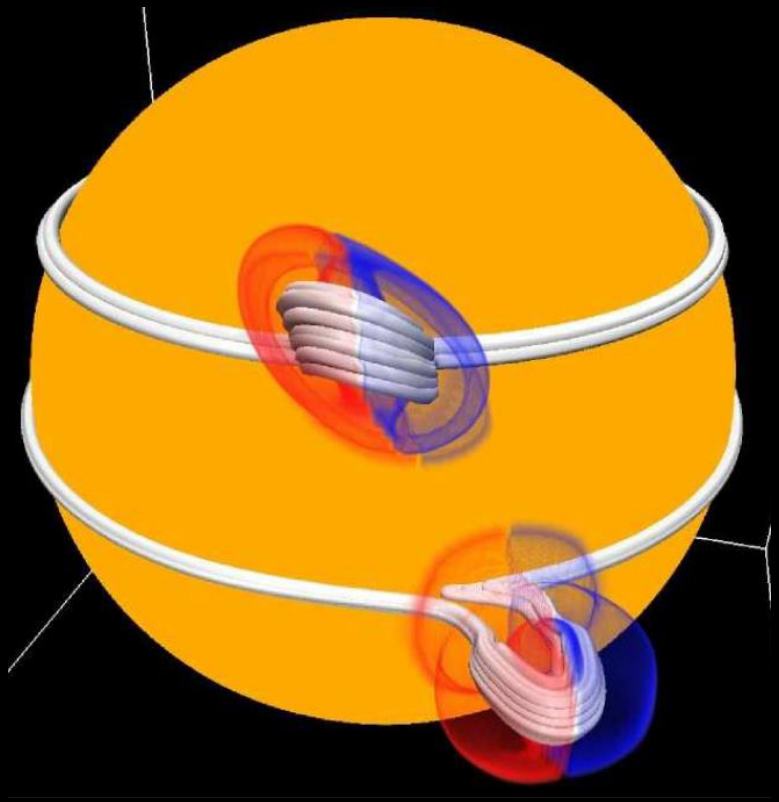
ACTIVE REGIONS AND THE TOROIDAL FIELD



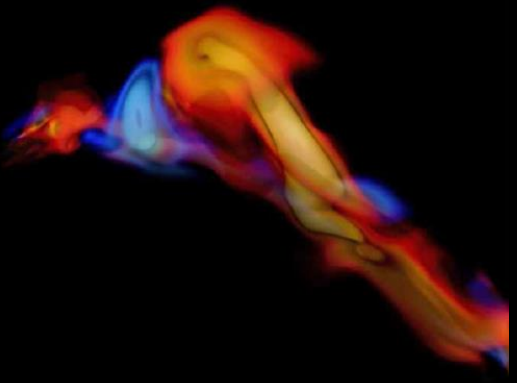
Nelson et al.
(2014)



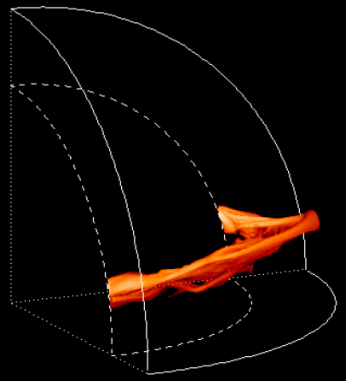
Weber, Fan, & Miesch
(2011)



Yeates & Muñoz-Jaramillo
(2013)

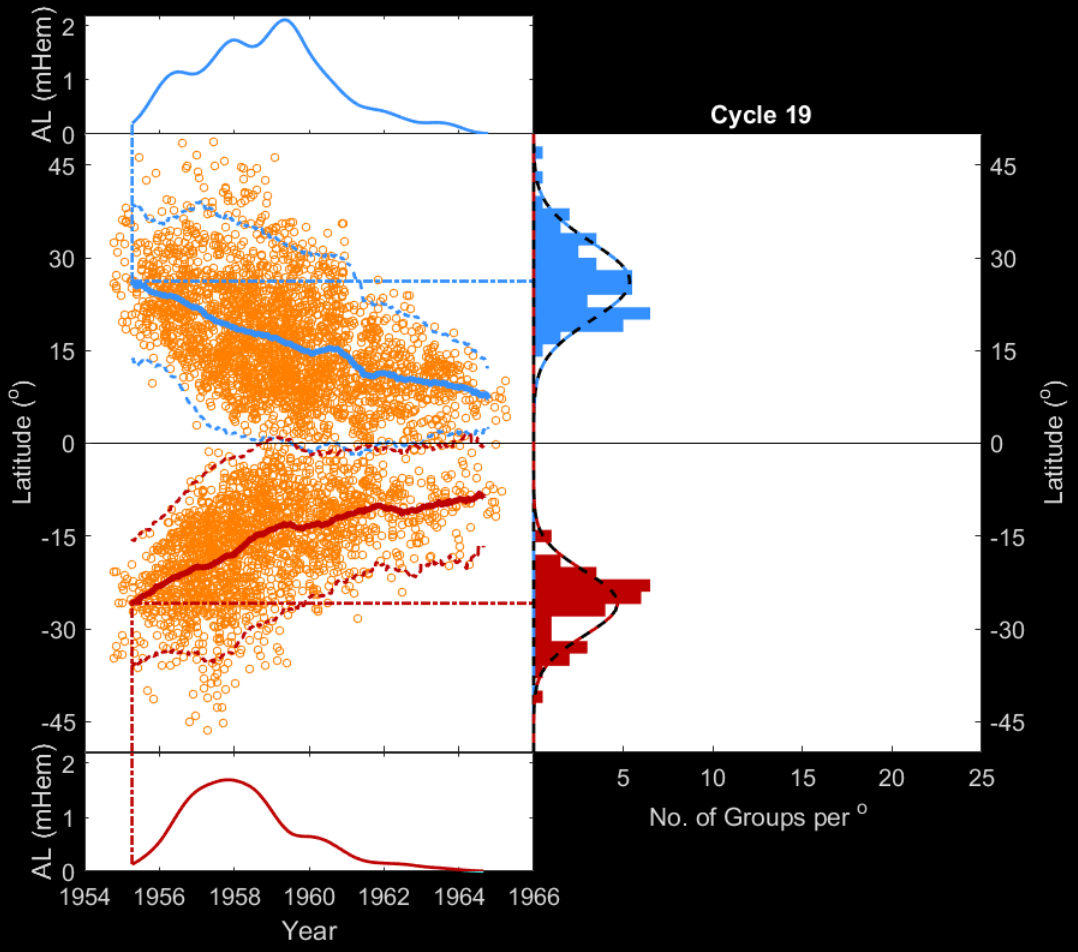


Jouve, Brun, & Aulanier
(2013)



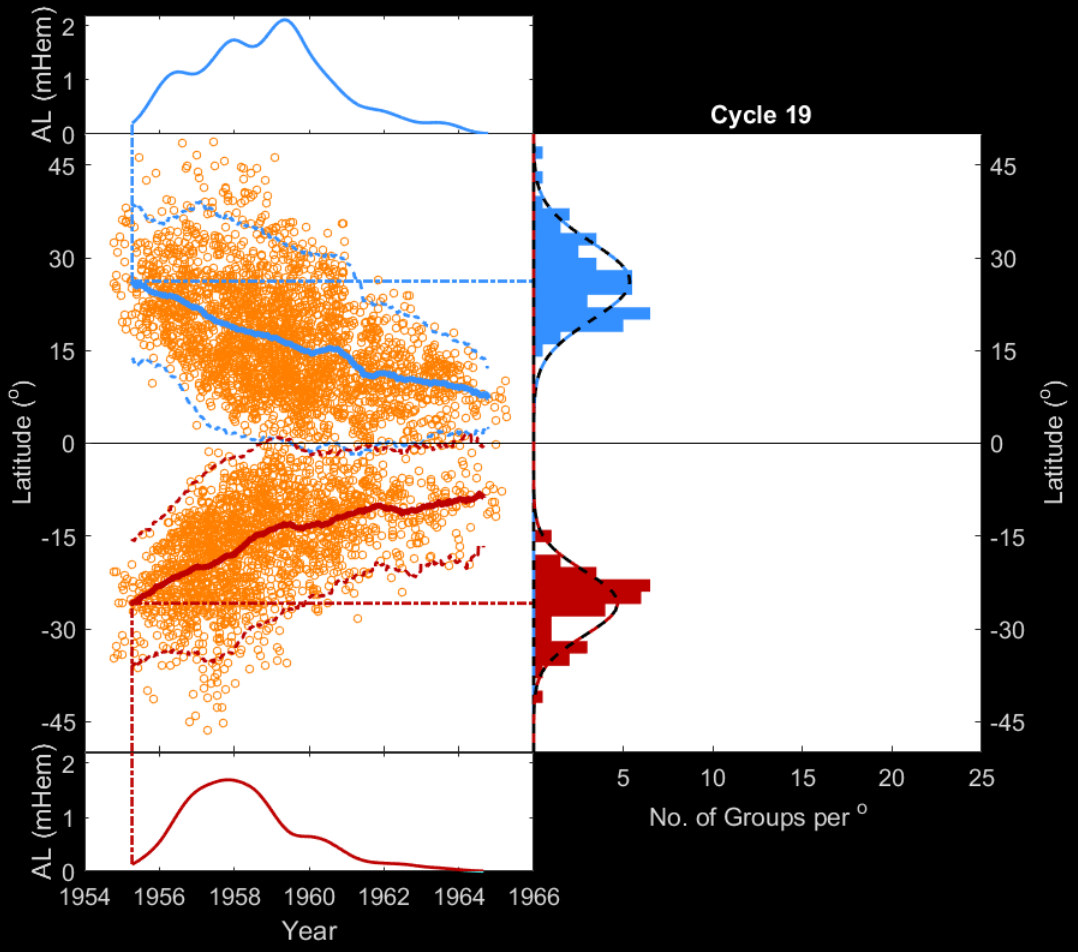
Fan
(2008)

CHARACTERIZATION OF THE BUTTERFLY WINGS



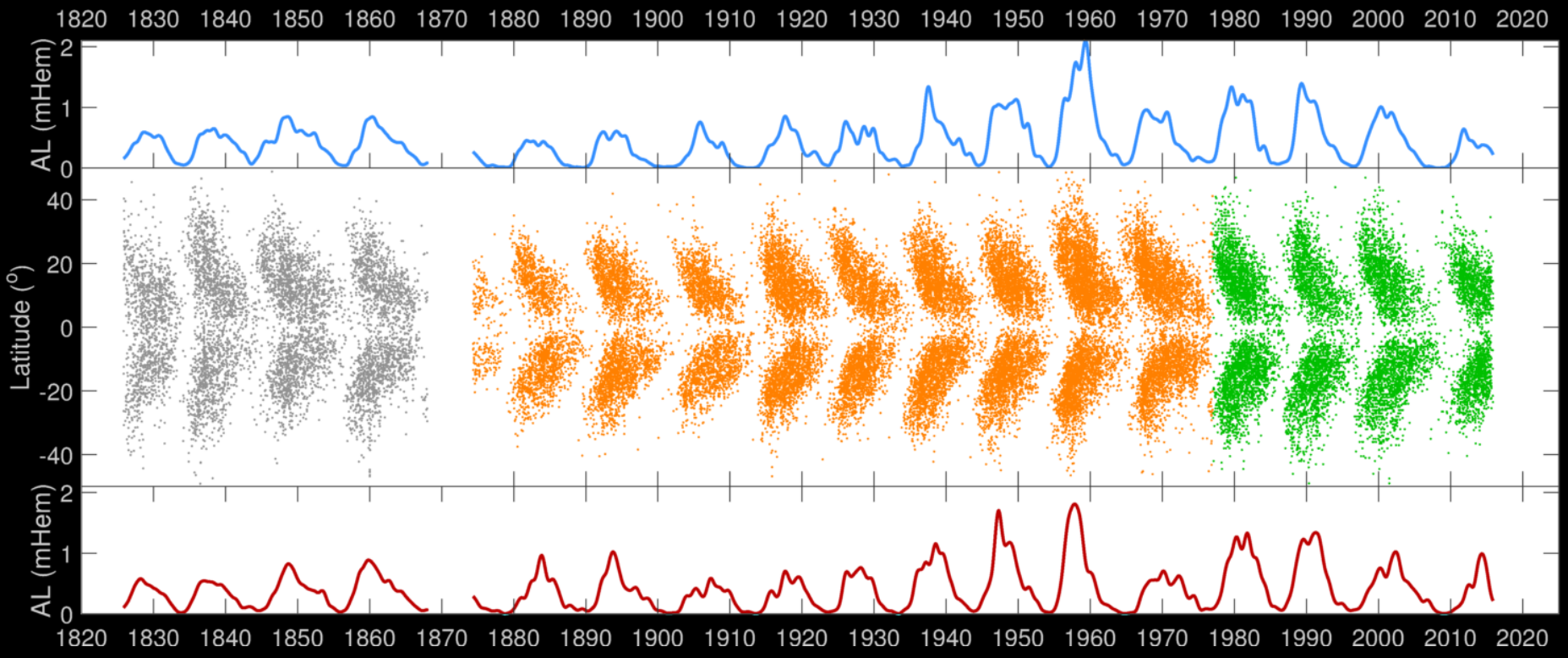
A Gaussian is fitted to the latitudinal distribution of all observed groups within a 24 month window

CHARACTERIZATION OF THE BUTTERFLY WINGS



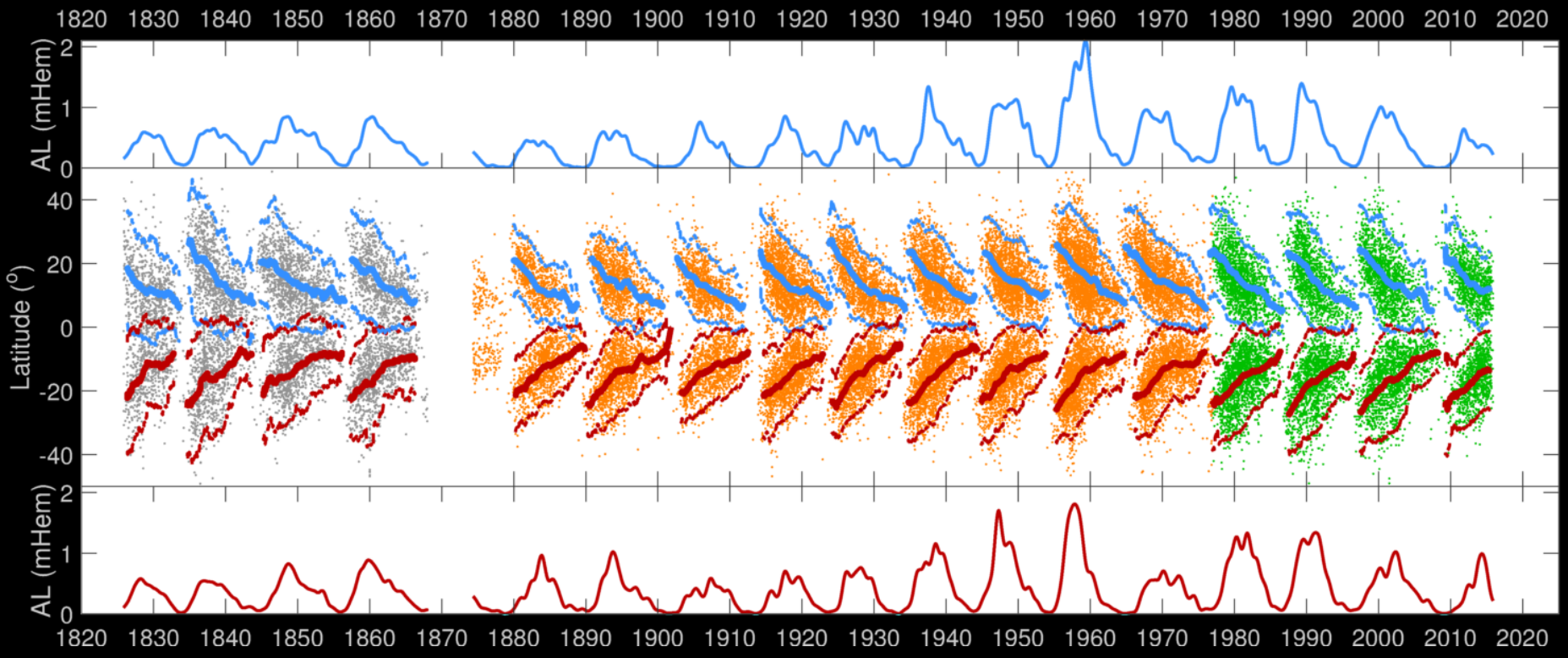
A Gaussian is fitted to the latitudinal distribution of all observed groups within a 24 month window

ALL HEMISPHERIC CYCLES FOLLOW DIFFERENT PARTS OF A UNIVERSAL PATH



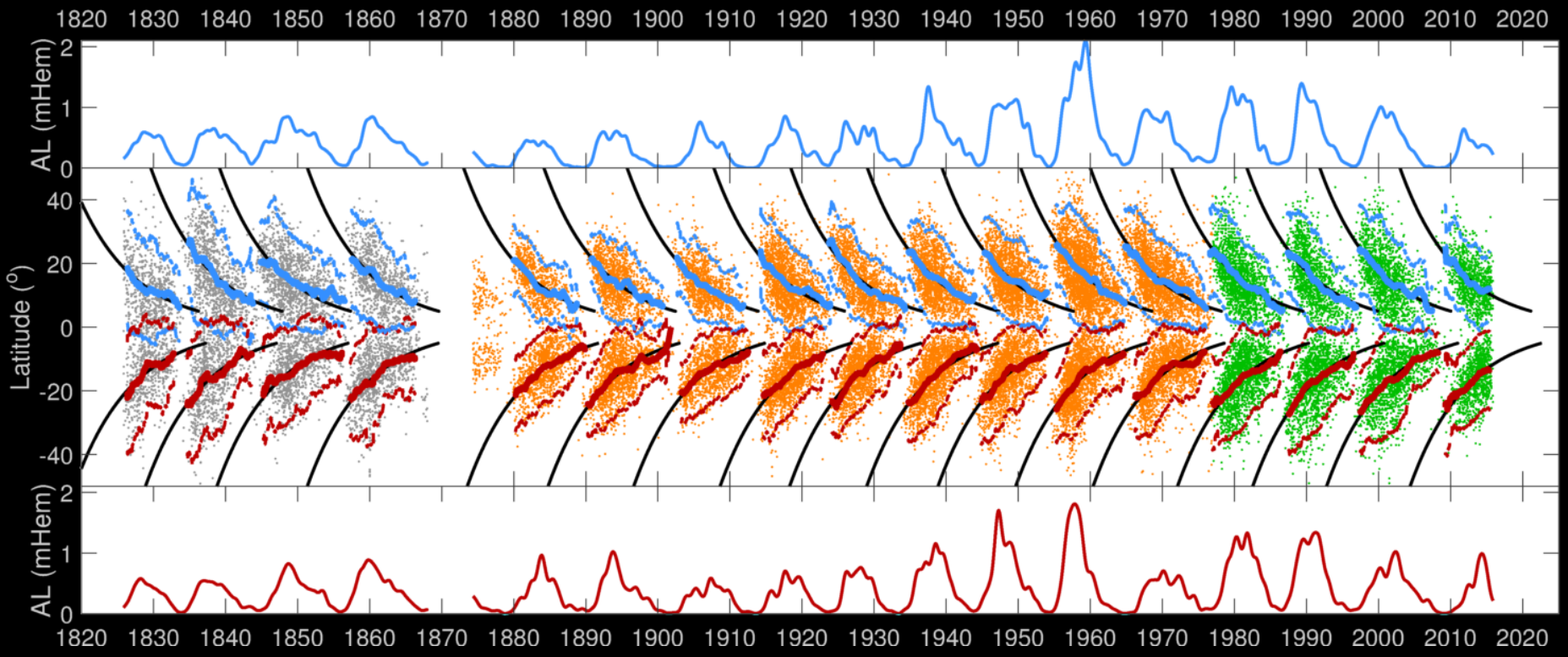
We use Schawbe's, RGO and KMAS data

ALL HEMISPHERIC CYCLES FOLLOW DIFFERENT PARTS OF A UNIVERSAL PATH



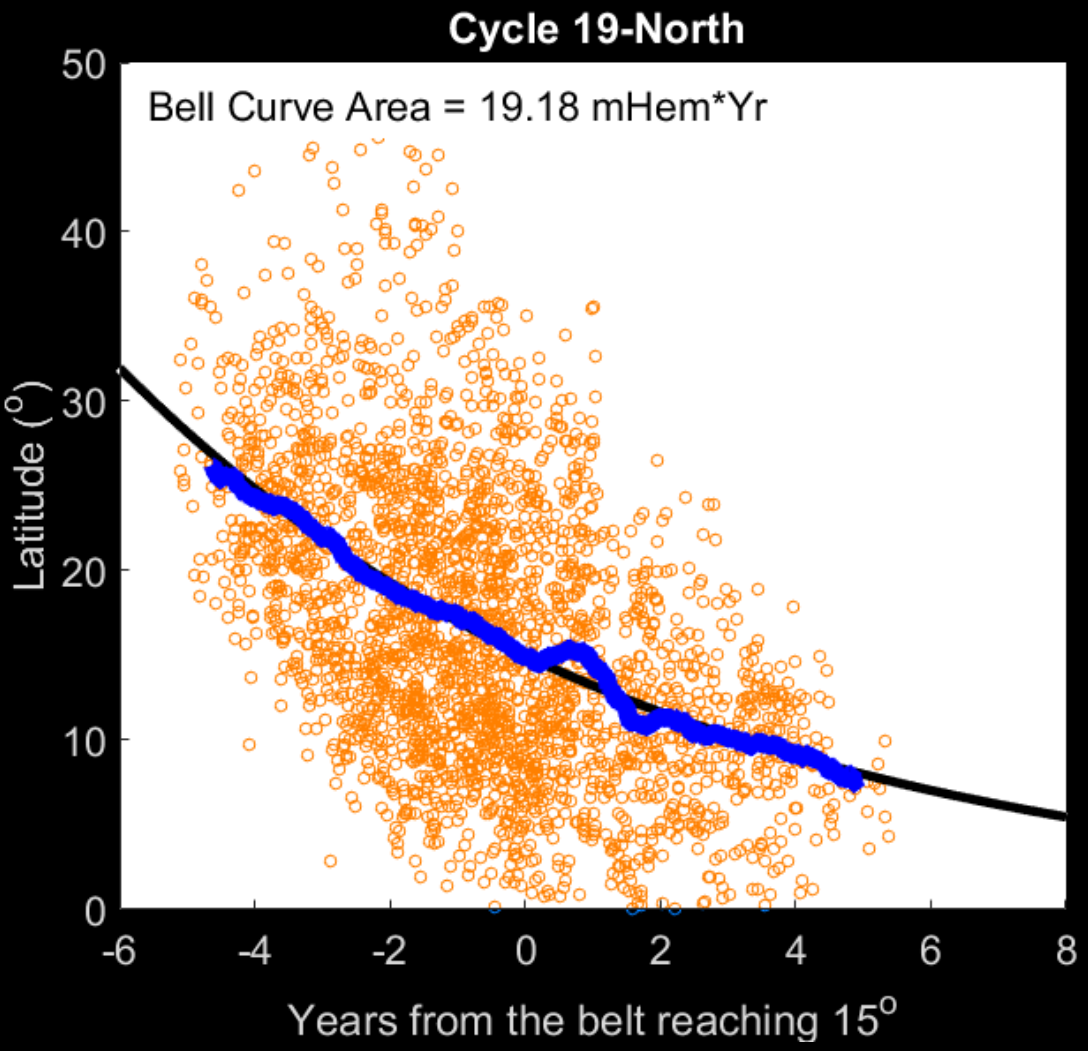
And calculate the path followed by the wing centroids and the width of the wings

ALL HEMISPHERIC CYCLES FOLLOW DIFFERENT PARTS OF A UNIVERSAL PATH

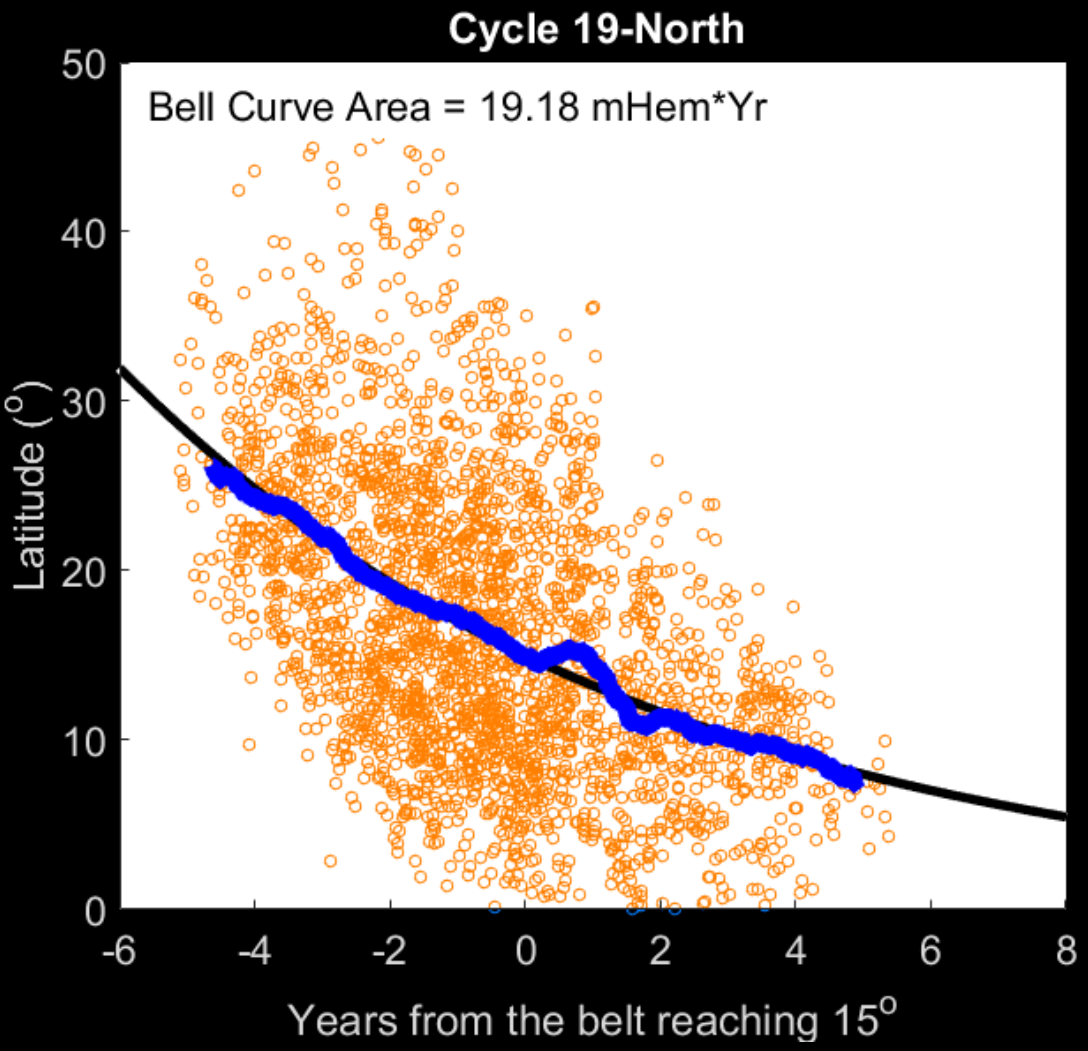


All paths can be fitted by the same function with only a difference in time-shift

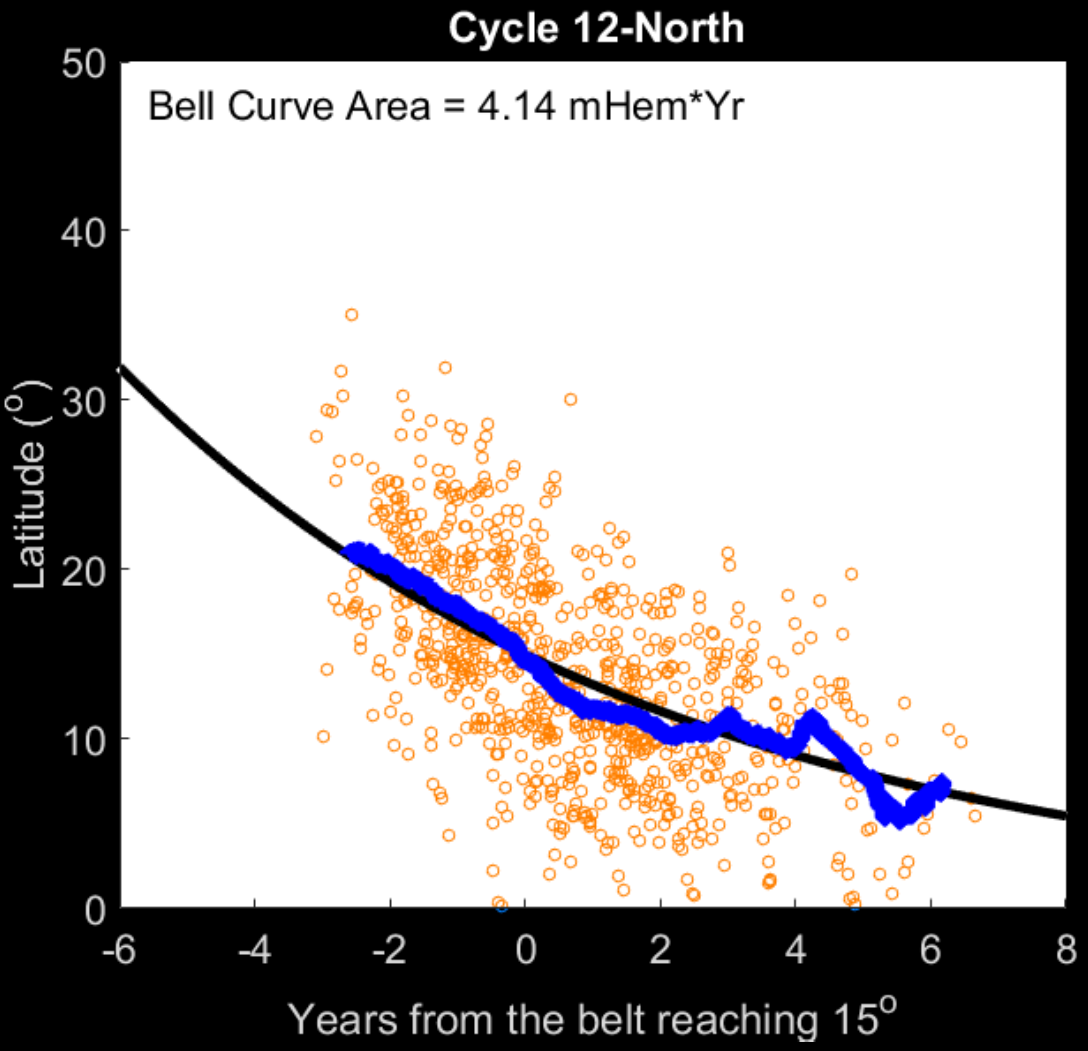
ALL HEMISPHERIC CYCLES FOLLOW DIFFERENT PARTS OF A UNIVERSAL PATH



ALL HEMISPHERIC CYCLES FOLLOW DIFFERENT PARTS OF A UNIVERSAL PATH

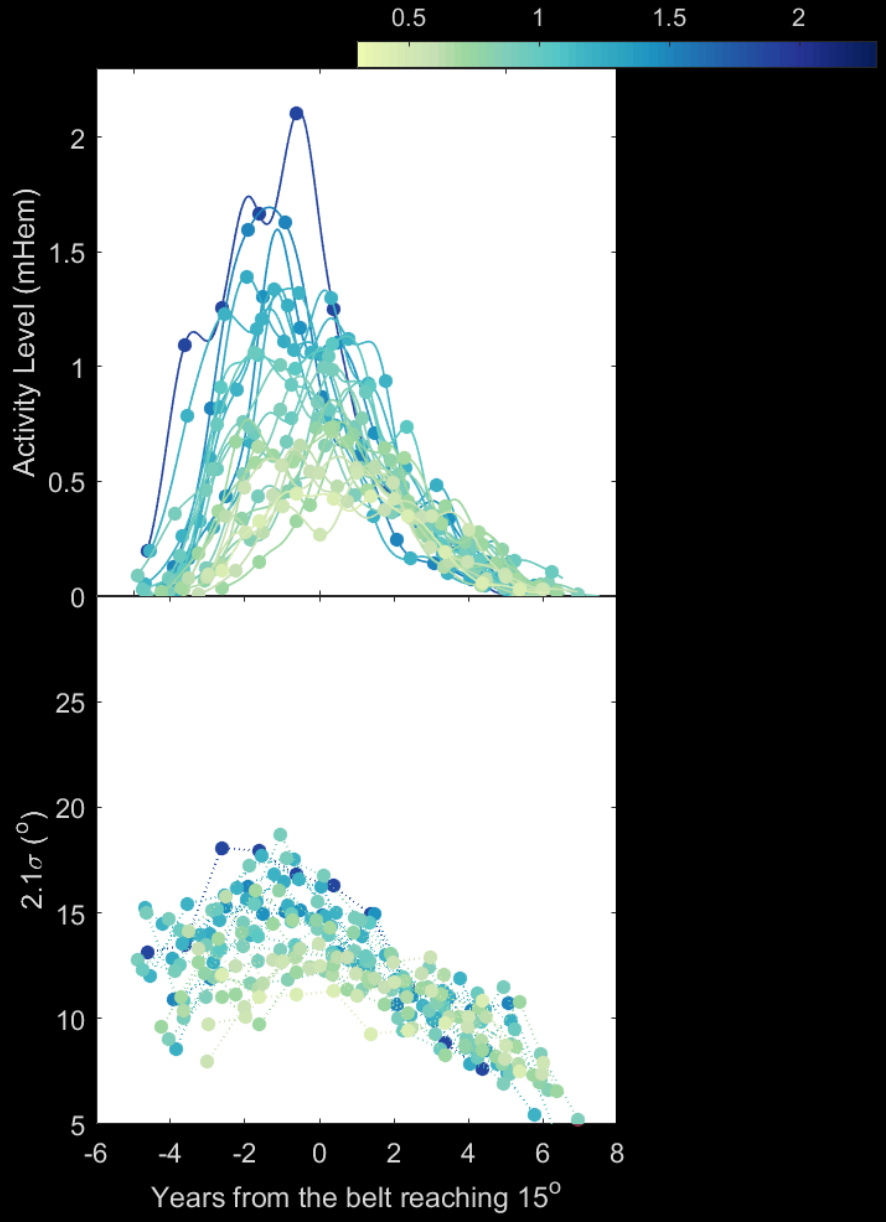


ALL HEMISPHERIC CYCLES FOLLOW DIFFERENT PARTS OF A UNIVERSAL PATH

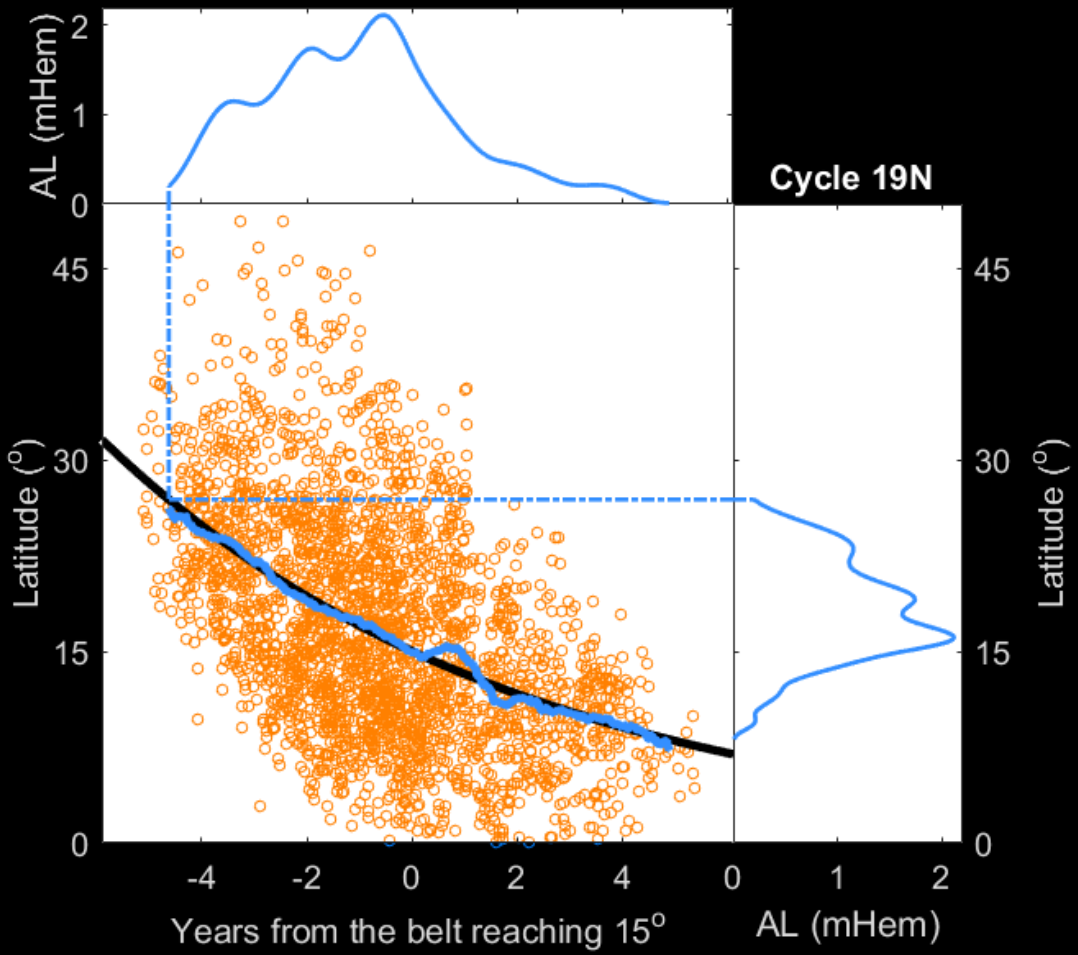


ALL CYCLES DECAY IN THE SAME WAY (CAMERON & SCHÜSSLER 2016).

REFERENCED TO THE UNIVERSAL PATH, THE DECAYING PHASE OF ALL CYCLES ALIGNS

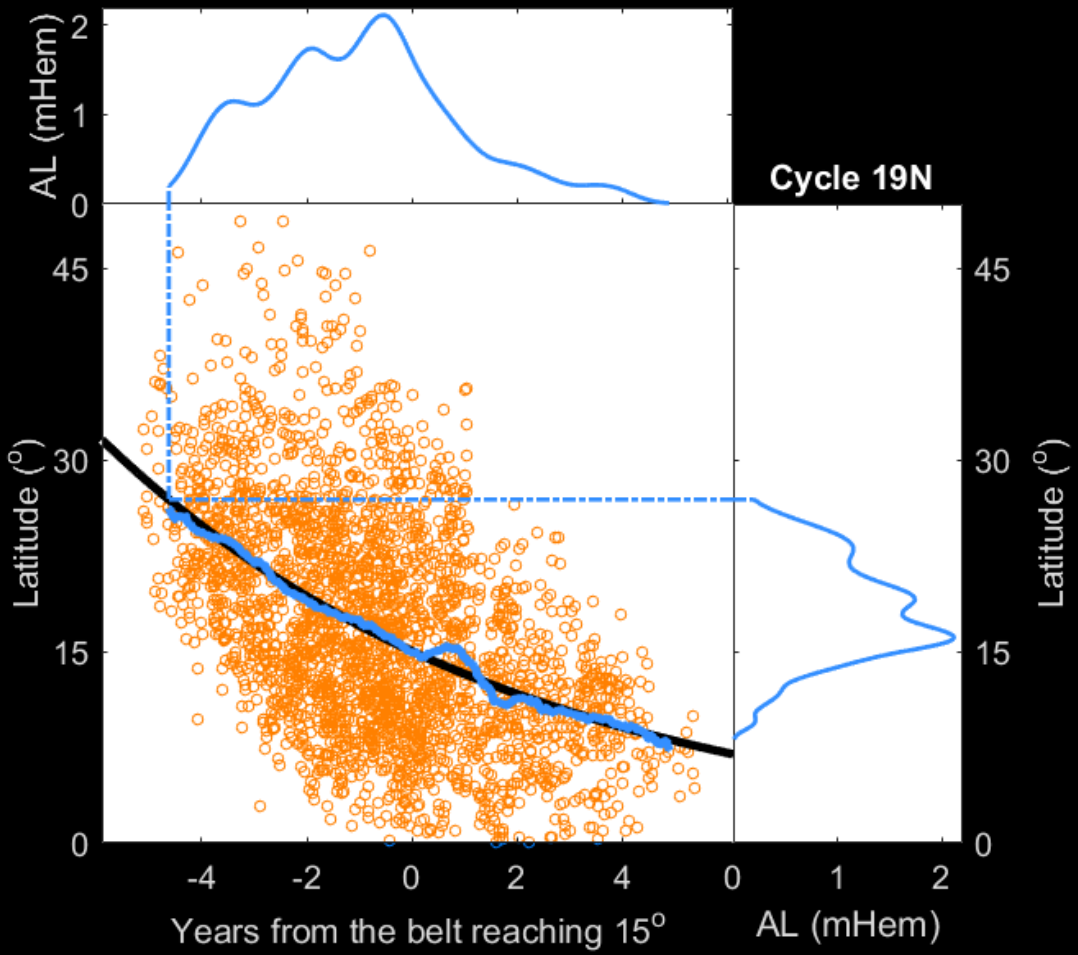


REMAPPING THE CYCLE TO LATITUDE



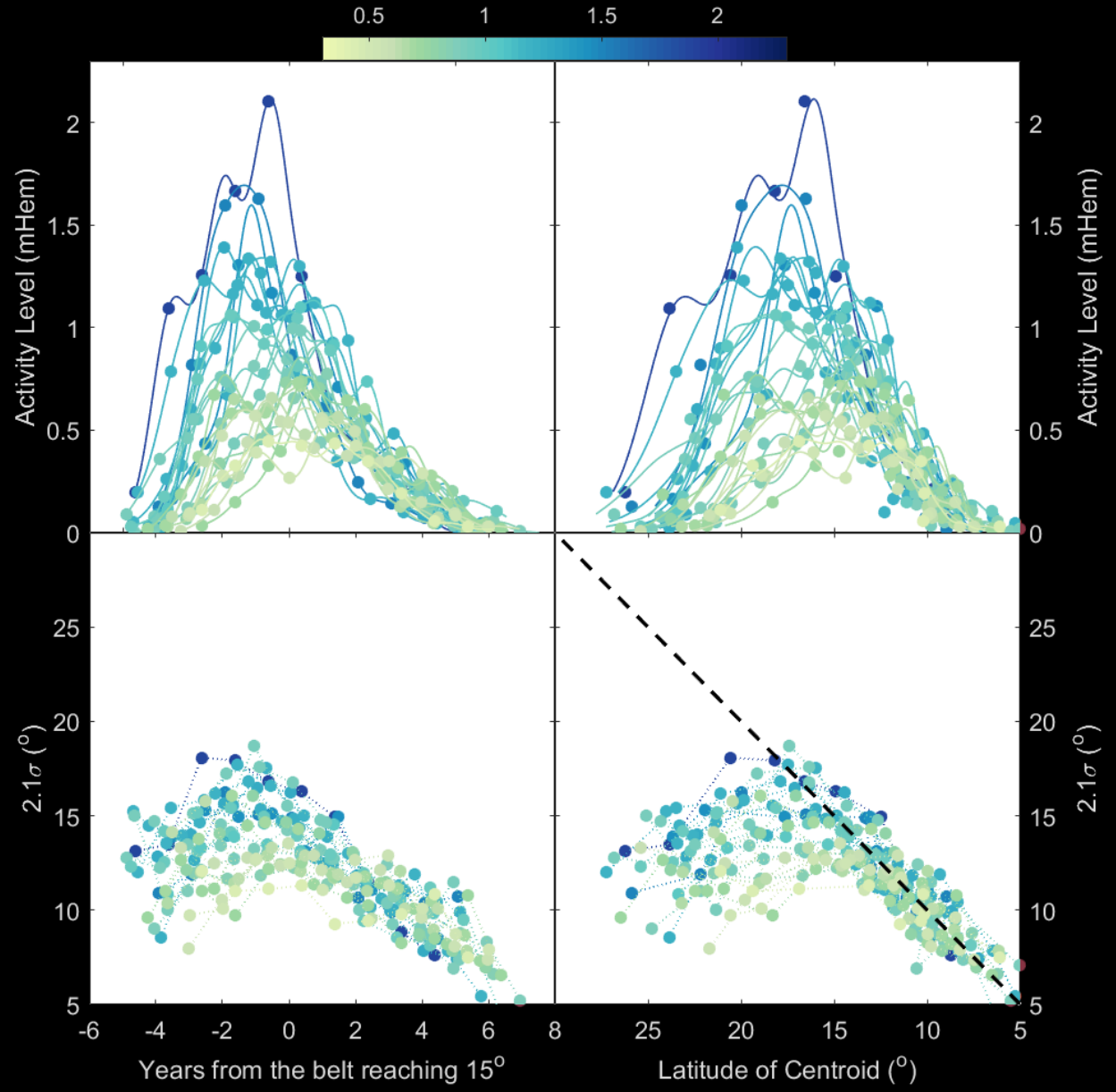
Latitude of centroid can be used as the independent variable instead of time

REMAPPING THE CYCLE TO LATITUDE

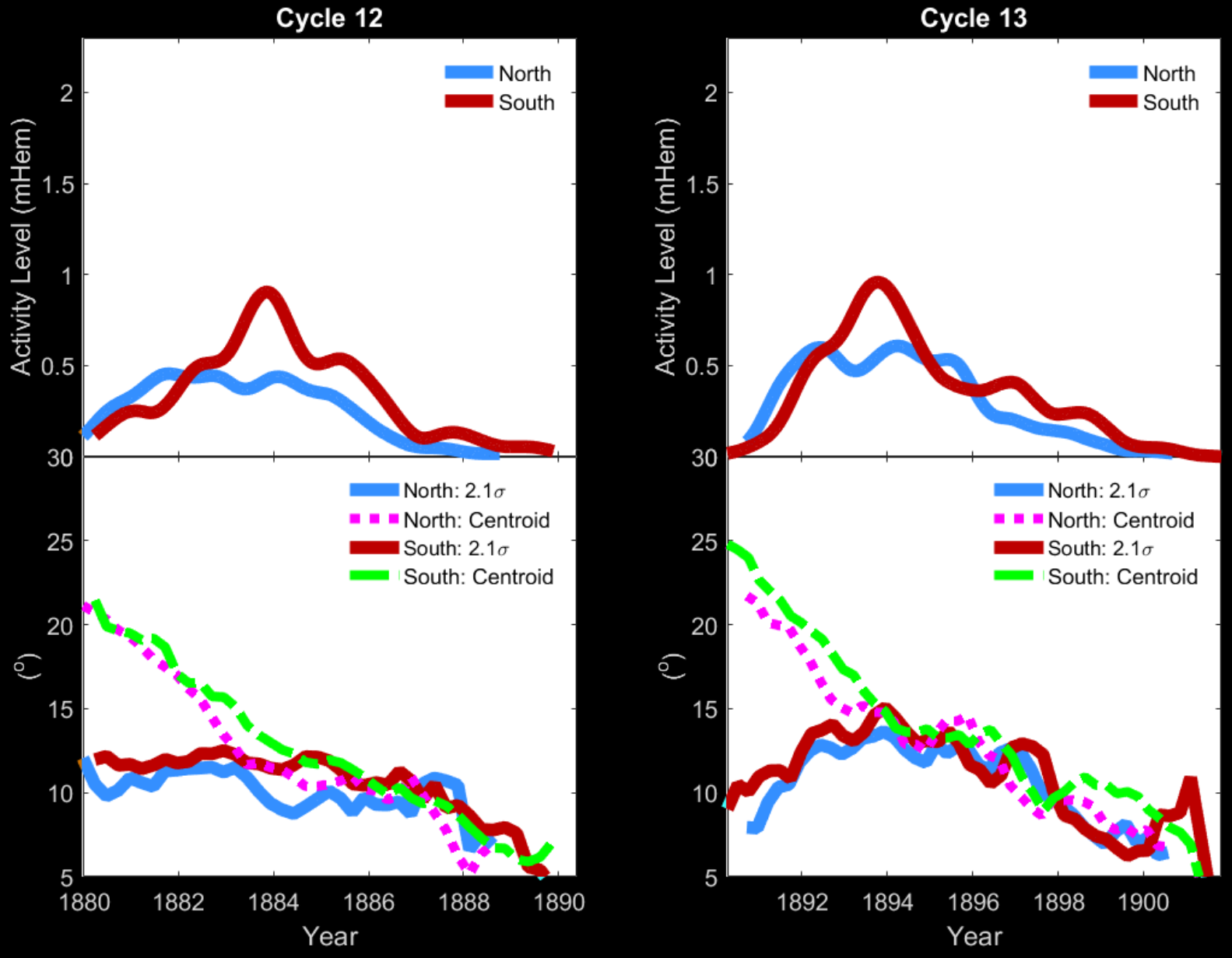


Latitude of centroid can be used as the independent variable instead of time

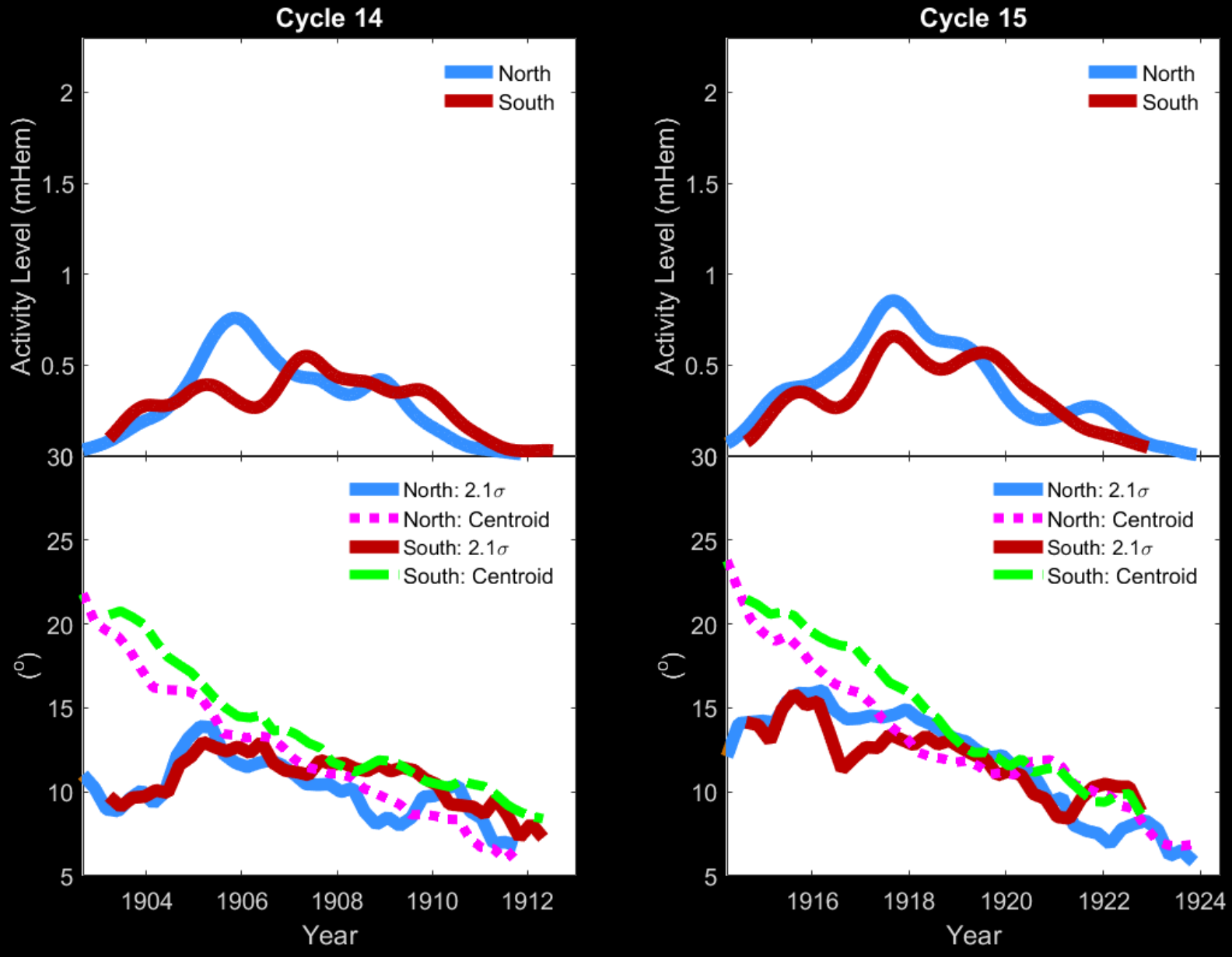
REFERENCED TO THE UNIVERSAL PATH, THE DECAYING PHASE OF ALL CYCLES ALIGNS



ALL CYCLES DECAY WHEN THEIR TOROIDAL BELTS TOUCH ACROSS THE EQUATOR



ALL CYCLES DECAY WHEN THEIR TOROIDAL BELTS TOUCH ACROSS THE EQUATOR



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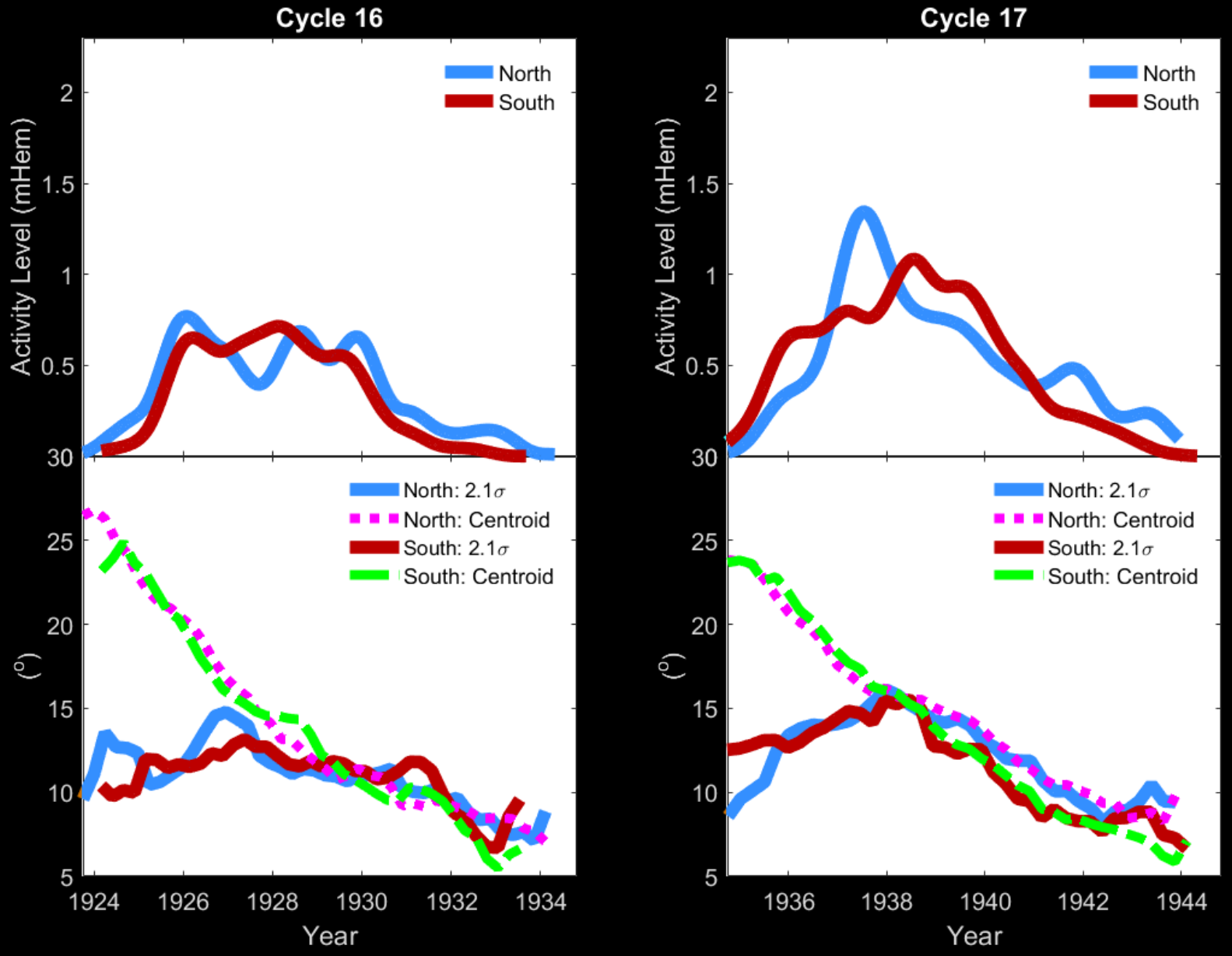

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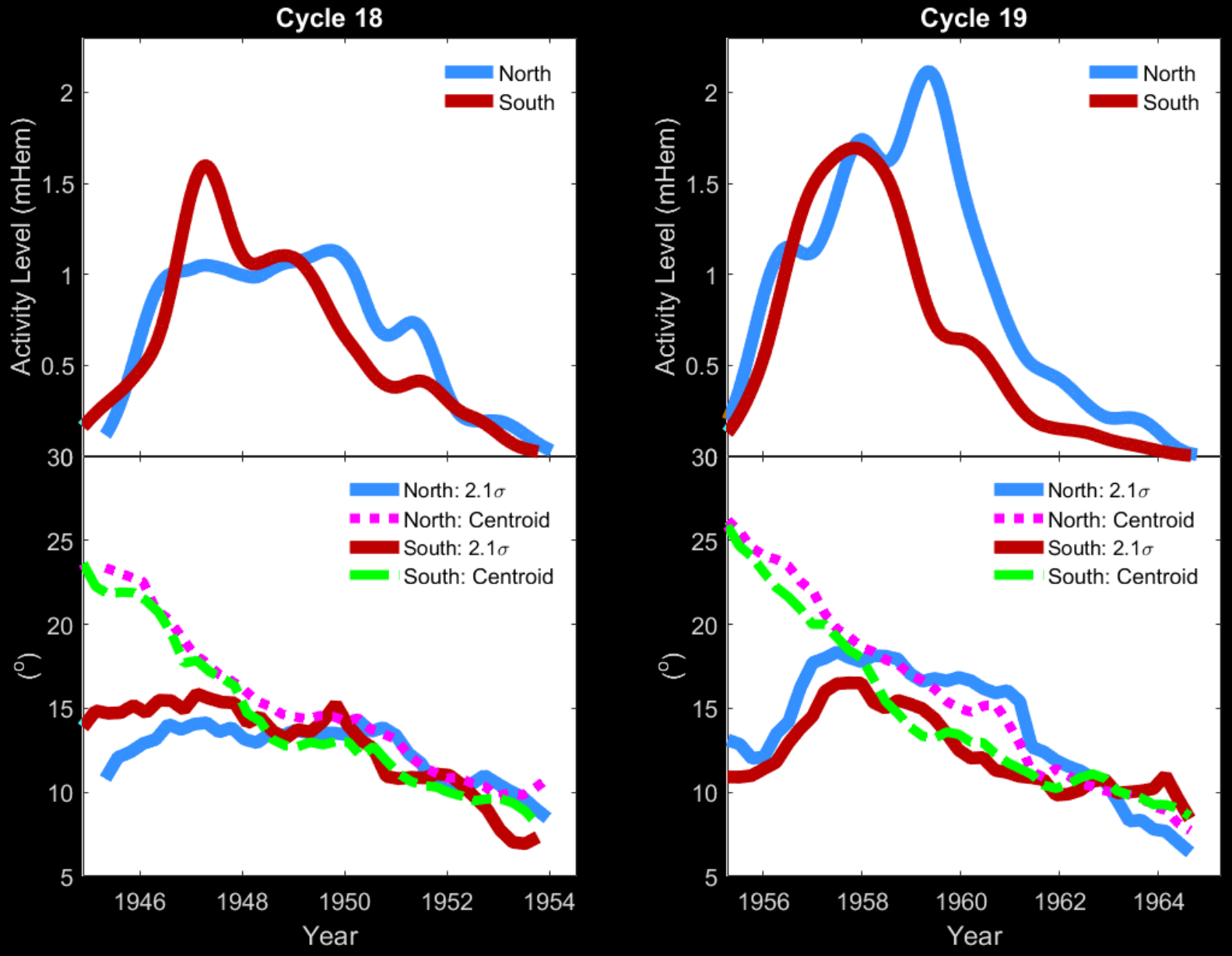
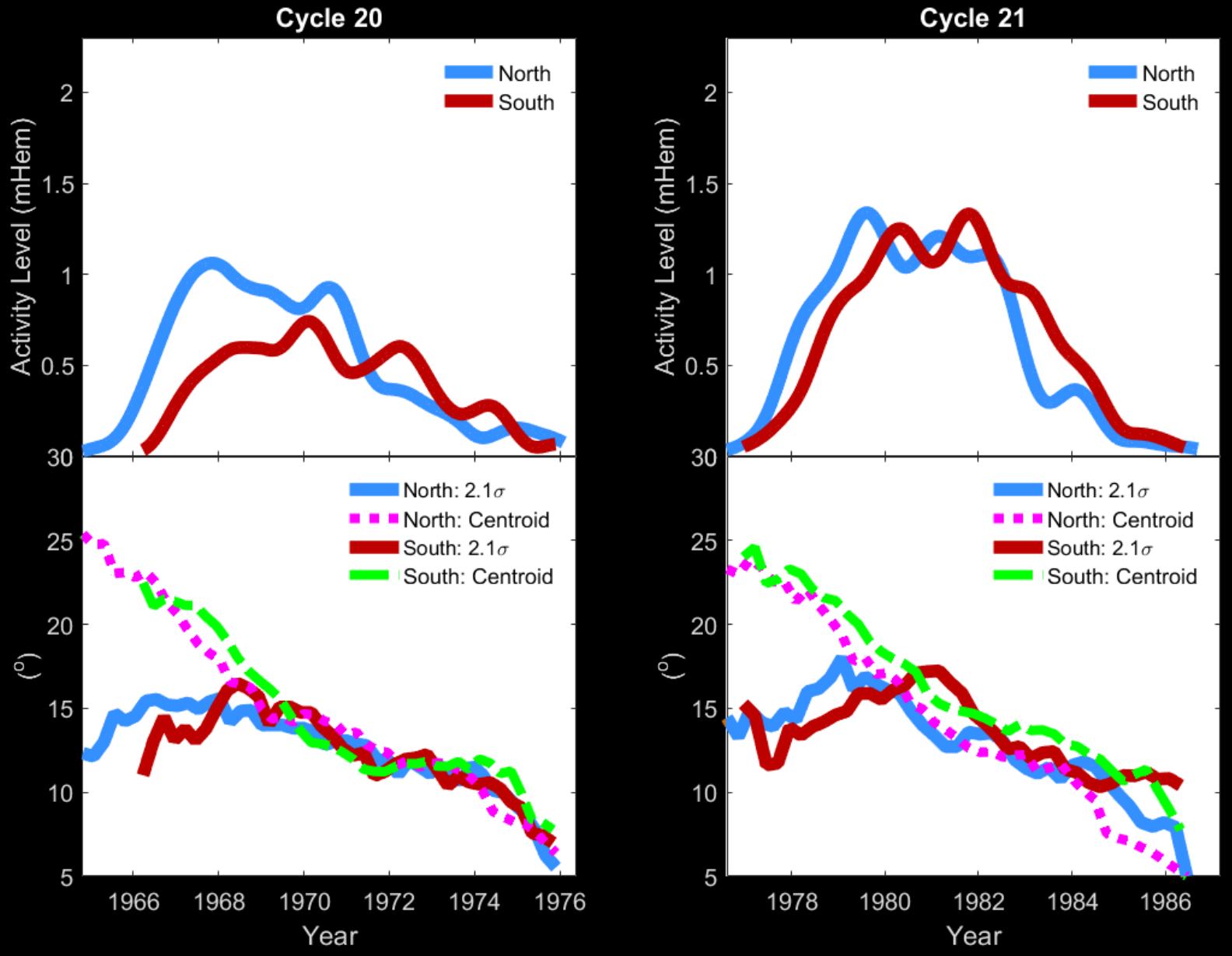
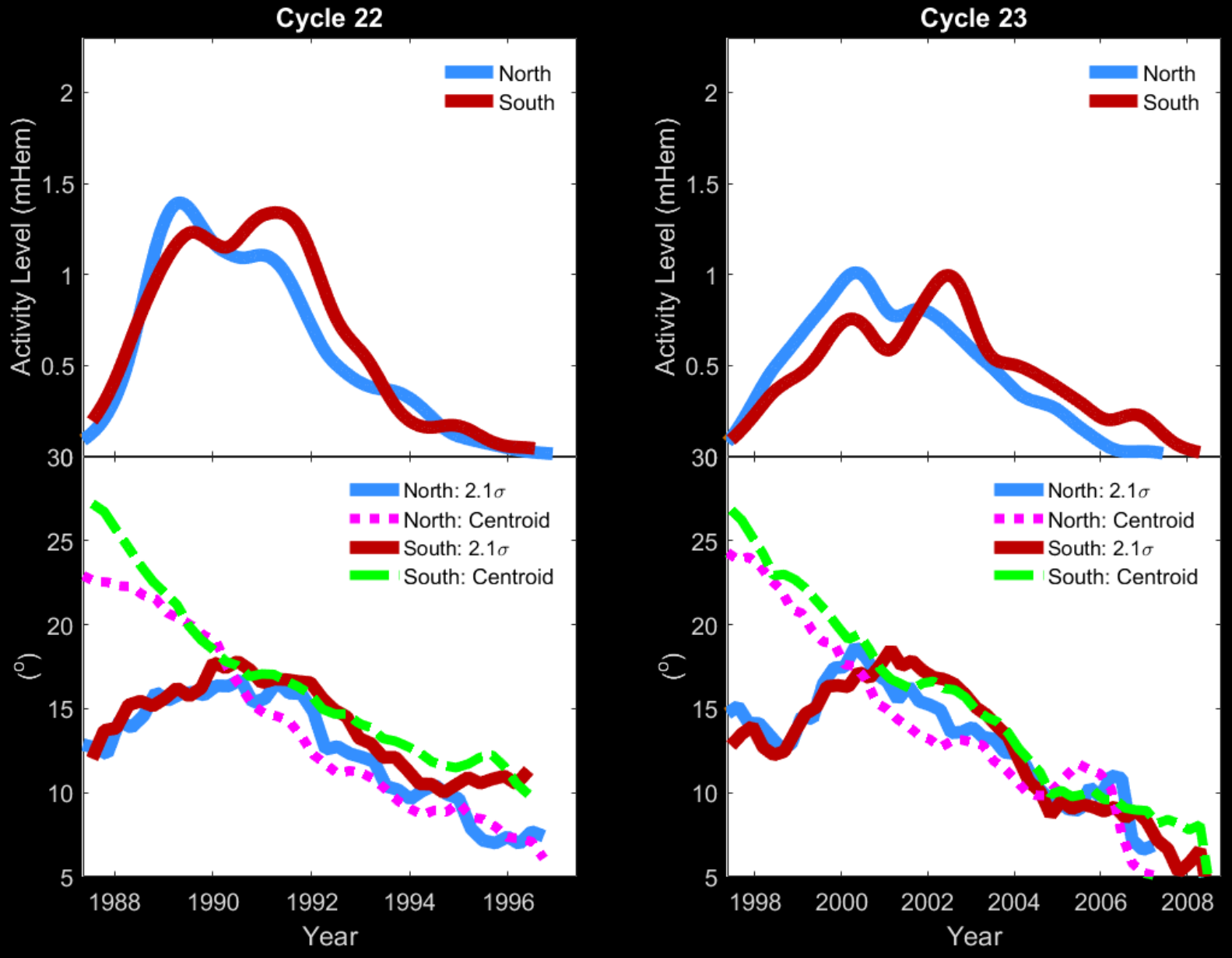


ALL CYCLES DECAY WHEN THEIR TOROIDAL BELTS TOUCH ACROSS THE EQUATOR



ALL CYCLES DECAY WHEN THEIR TOROIDAL BELTS TOUCH ACROSS THE EQUATOR



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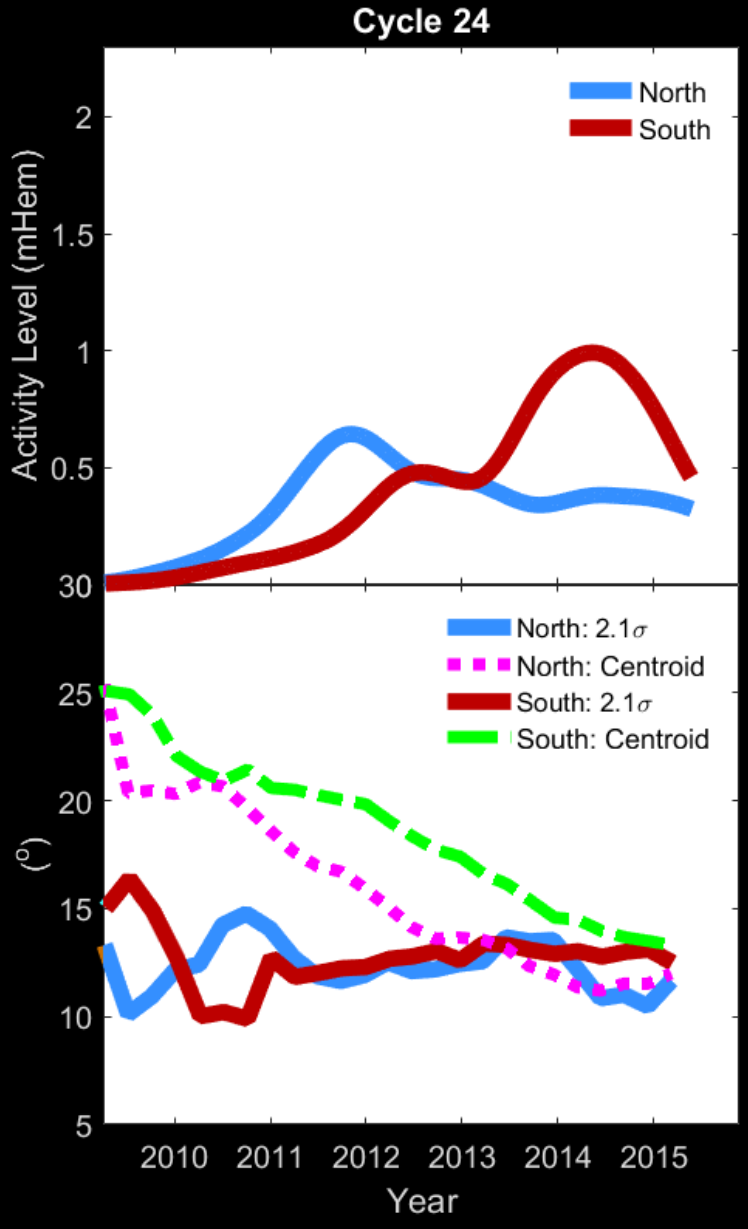
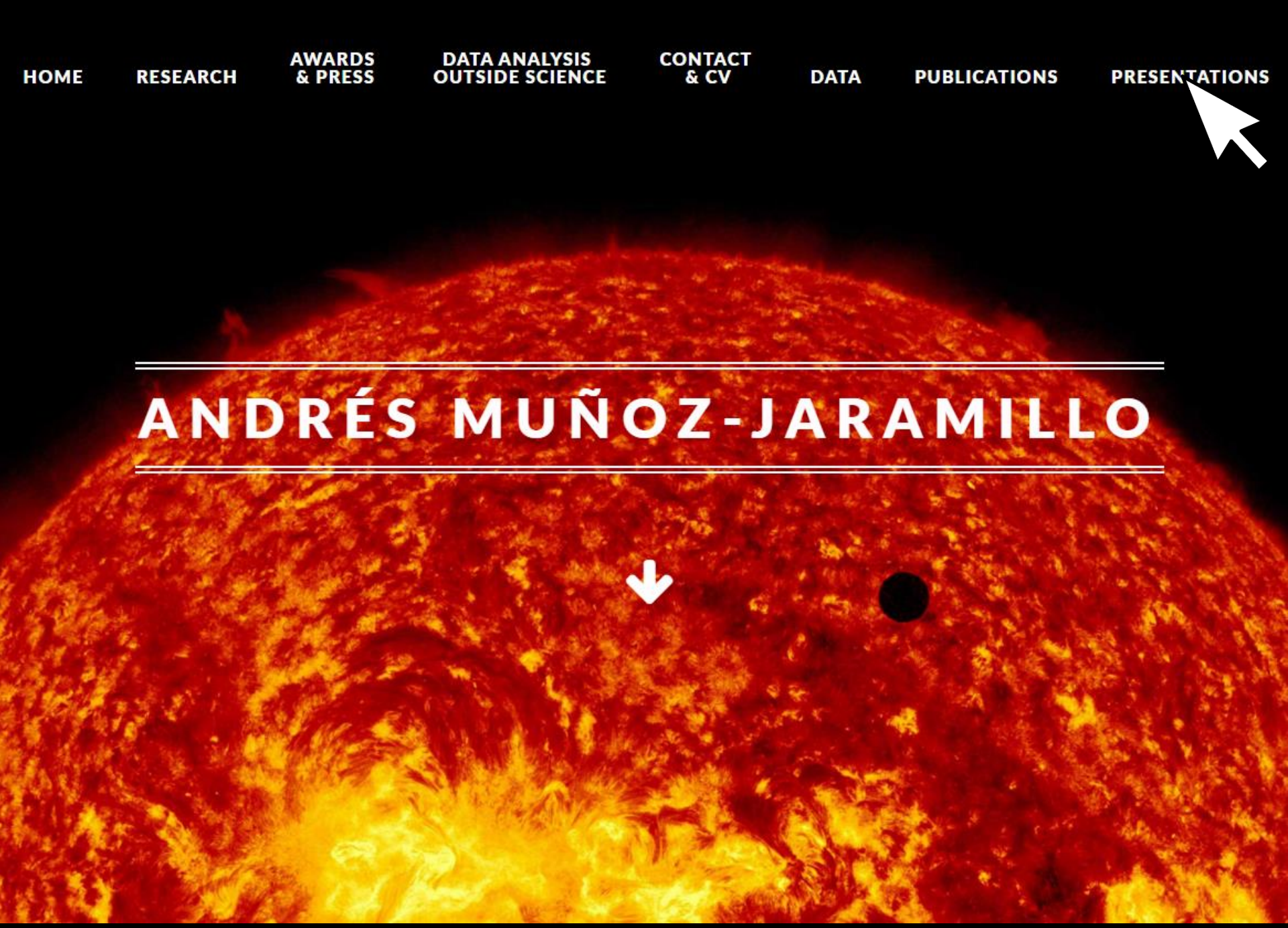


IMPLICATIONS FOR THE SOLAR DYNAMO

- The solar cycle is operating in a highly diffusive regime (in agreement with mixing-length estimates; Cameron & Schüssler 2016).
- We need to revise the role that the meridional flow as a critical ingredient of the solar dynamo.

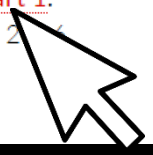


ANDRÉS MUÑOZ-JARAMILLO

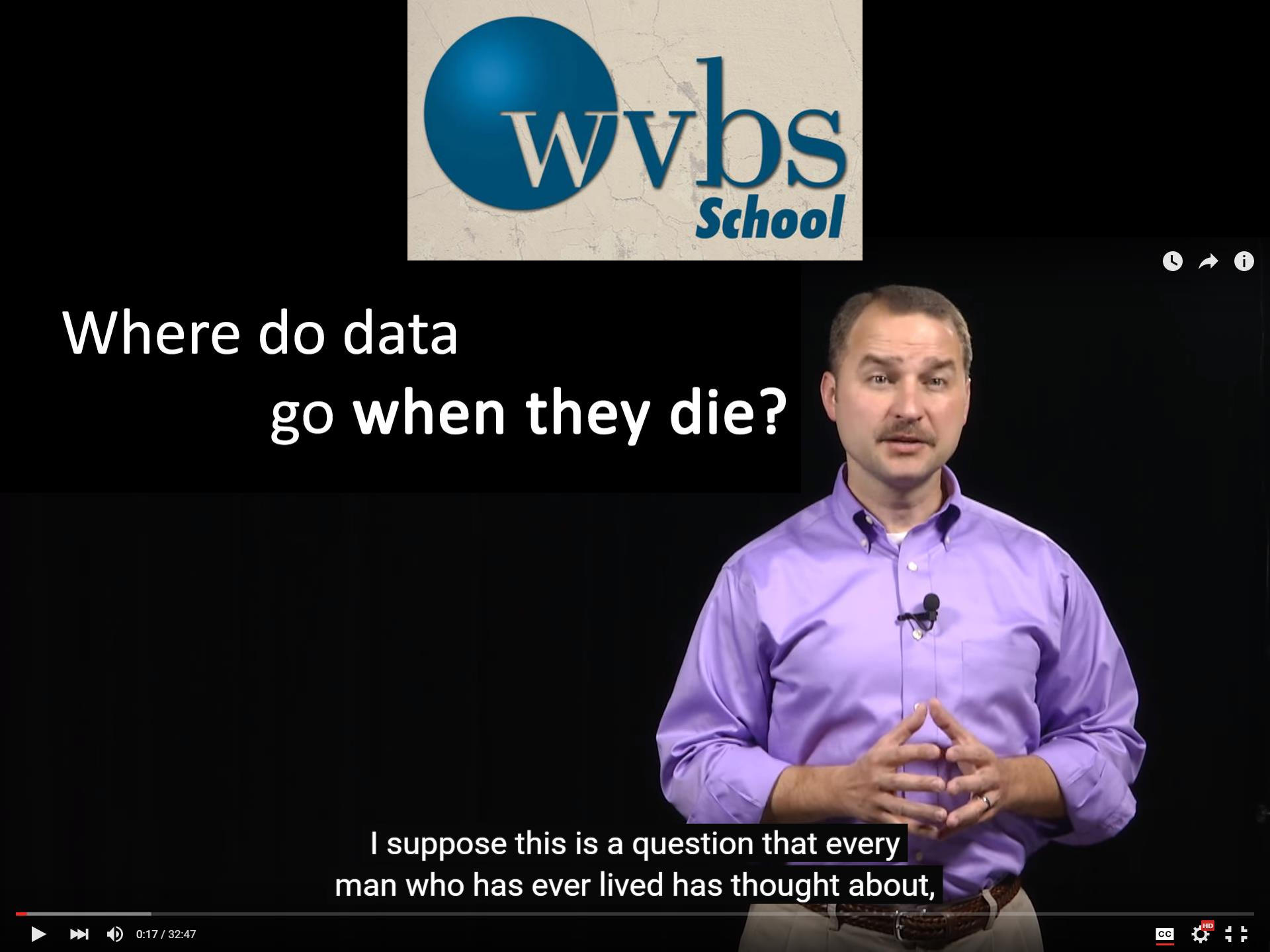
RESEARCH SEMINARS

The Rails Inside the Sun and the Butterflies that Ride Them.

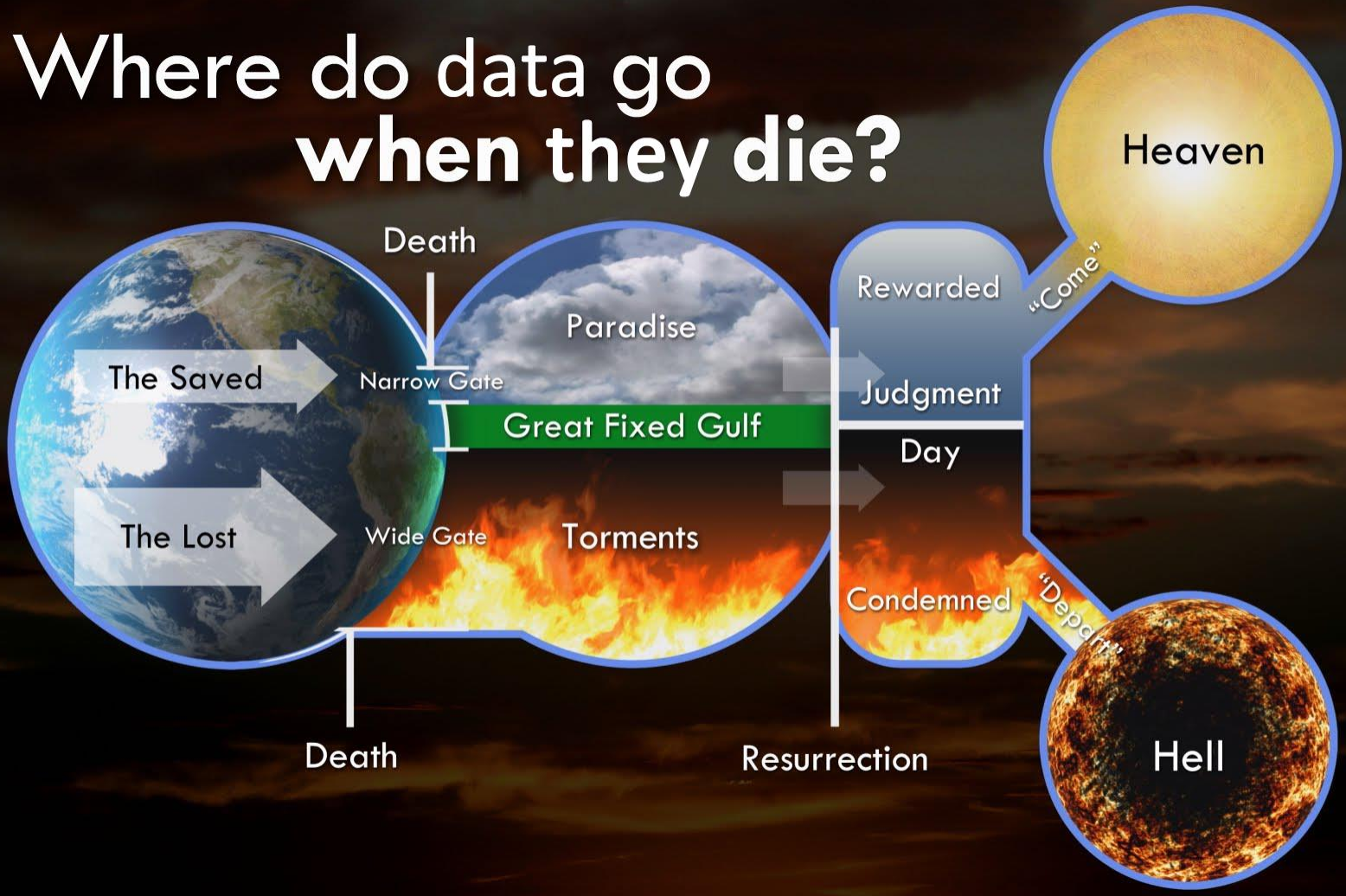
- Seminar at the High Altitude Observatory, Boulder, CO, USA, March 2015. **Video Available:** Part 1.
- Seminar of the Solar & Astrophysics Laboratory, Lockheed Martin, Palo Alto, CA, USA, January 2
- Stanford Solar Group Meeting, Palo Alto, CA, USA, January 2016.



WHERE DO DATA GO WHEN THEY DIE?

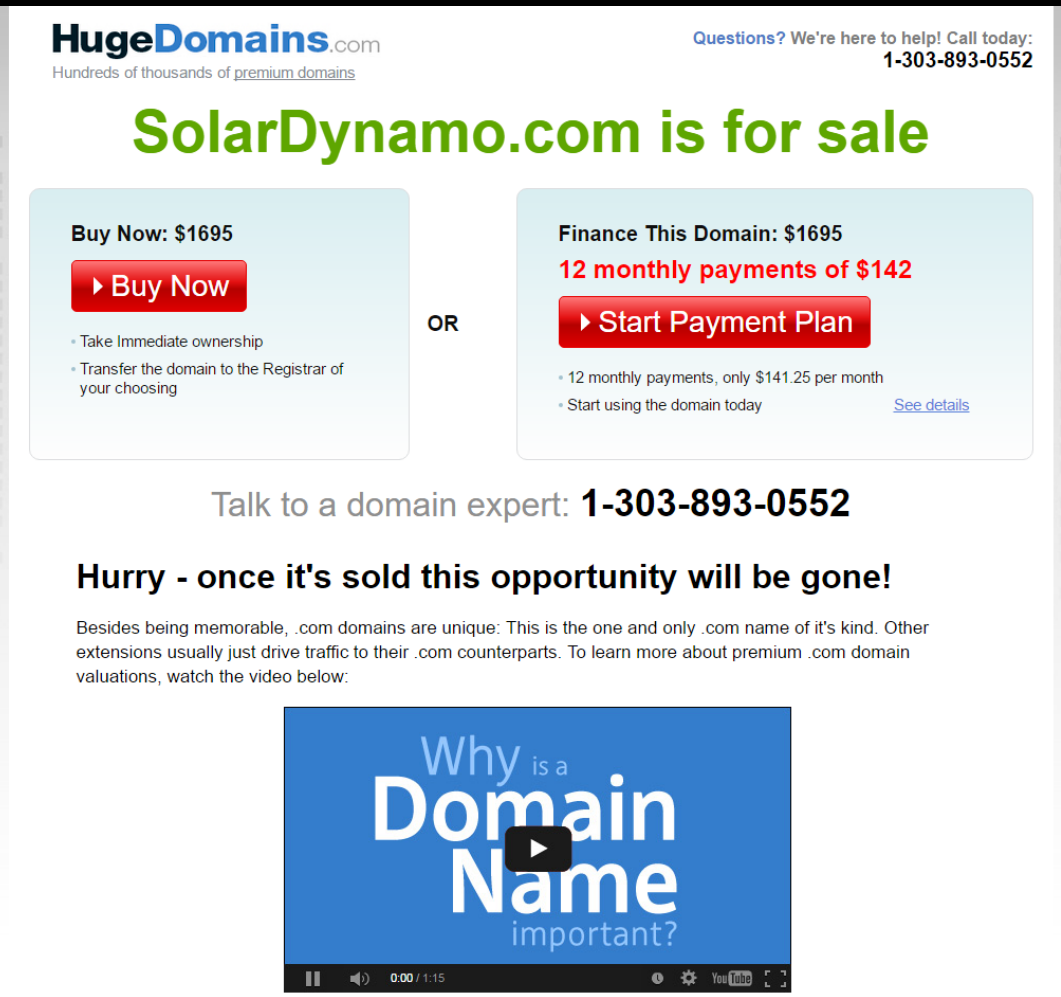

wvbs
School
Where do data
go when they die?
I suppose this is a question that every
man who has ever lived has thought about,
0:17 / 32:47

Where do data go **when they die?**



HOW TO ATTAIN DATA SALVATION?

I’m a responsible data owner, I keep them on my personal webpage!



Ah, but my webpage is institutional, that's not going to happen to me

REACHING ENLIGHTEMENT THANKS TO THE ApJ/AAS

- The answer is on the 6th line of the 6th section of the latest AAS LaTeX template (version 6).

- https://github.com/AASJournals/Tutorials/tree/master/Repositories

- There are three online repositories that the AAS recommends:
  - https://zenodo.org/ (CERN)
  - https://figshare.com/ (Private)
  - https://dataverse.harvard.edu/ (Harvard)

REACHING ENLIGHTEMENT THANKS TO THE ApJ/AAS

1. They assign each database a unique DOI identifier.
2. They have contingency plans for migrating databases to another repository should their operation ends.

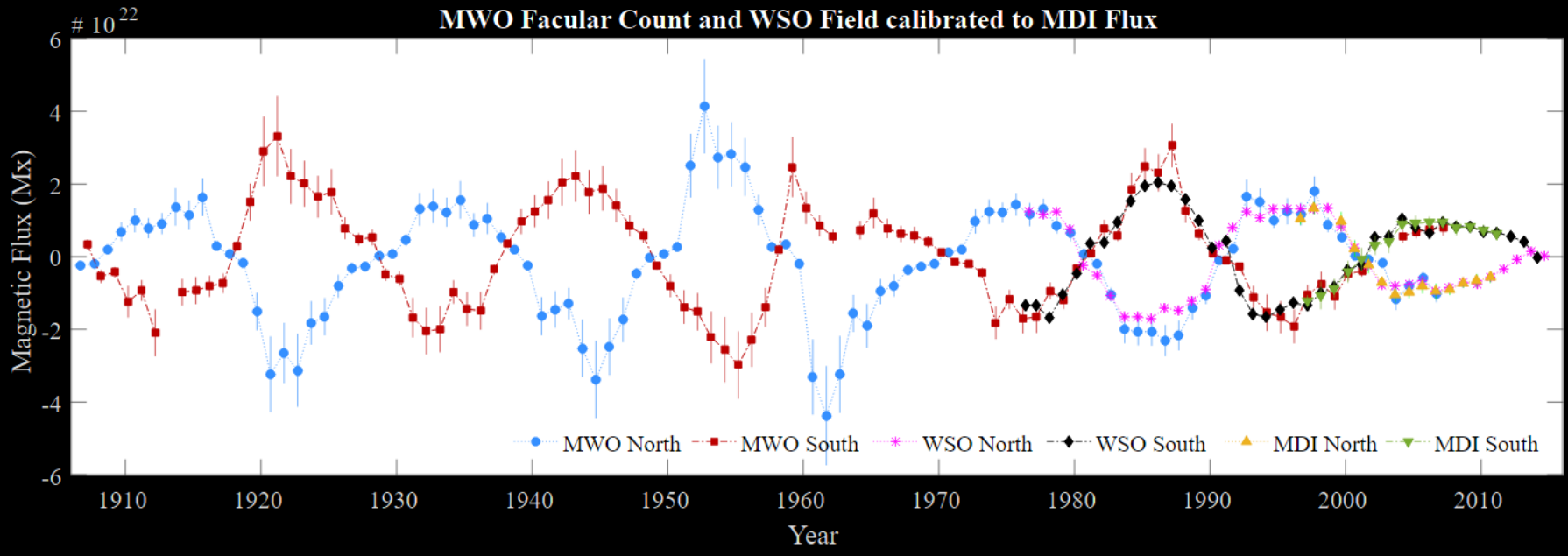
- There are three online repositories that the AAS recommends:
  - https://zenodo.org/ (CERN)
  - https://figshare.com/ (Private)
  - https://dataverse.harvard.edu/ (Harvard)

THE SOLAR DYNAMO DATAVERSE

A century of Calibrated Polar Faculae

Muñoz-Jaramillo et al. (2012)

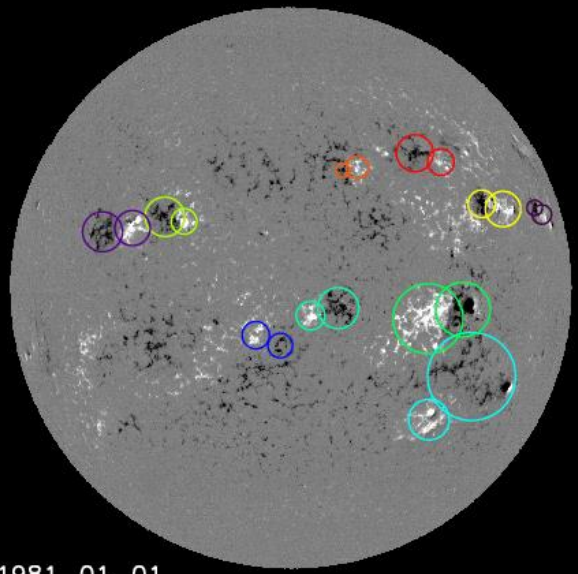
The most direct proxy we have for the evolution of the polar magnetic fields.



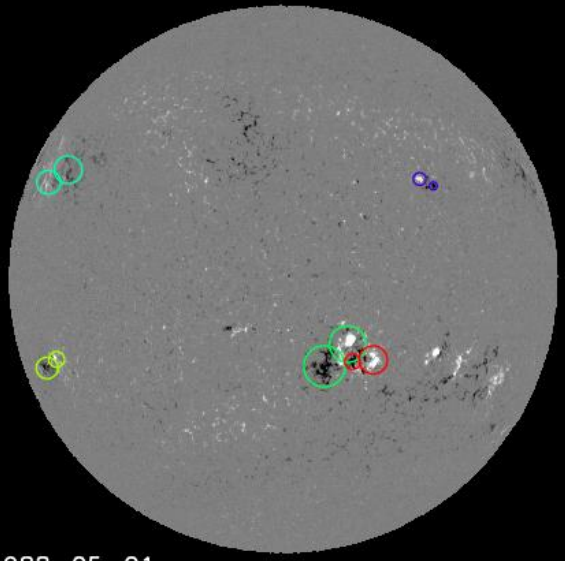
40 years of homogeneous bipolar active regions

Muñoz-Jaramillo et al. WIP

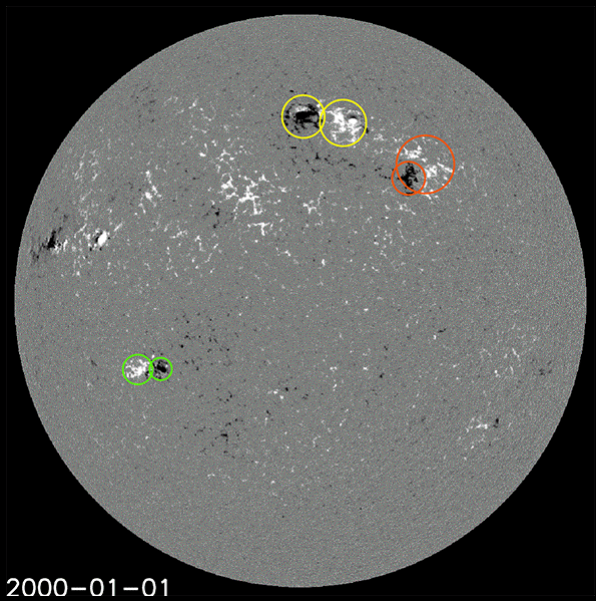
Cycle 21



Cycle 22



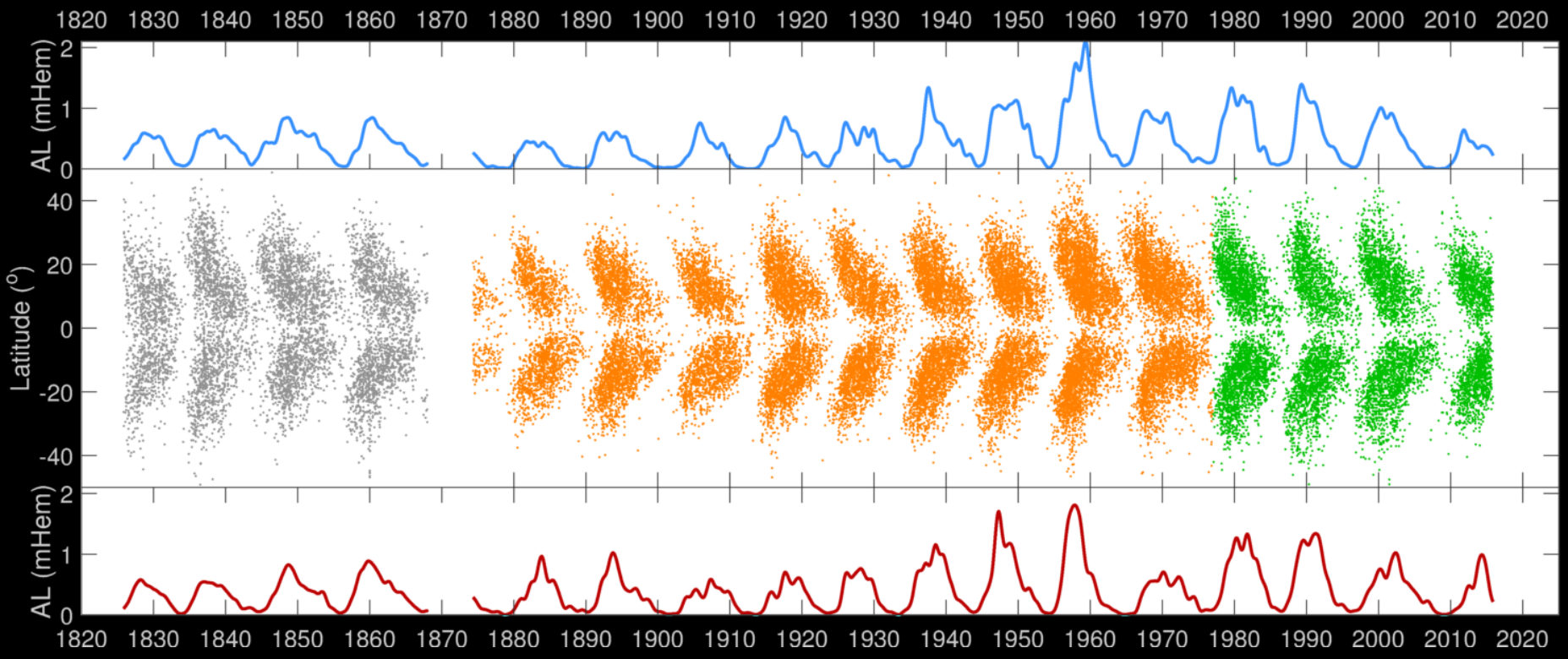
Cycle 23



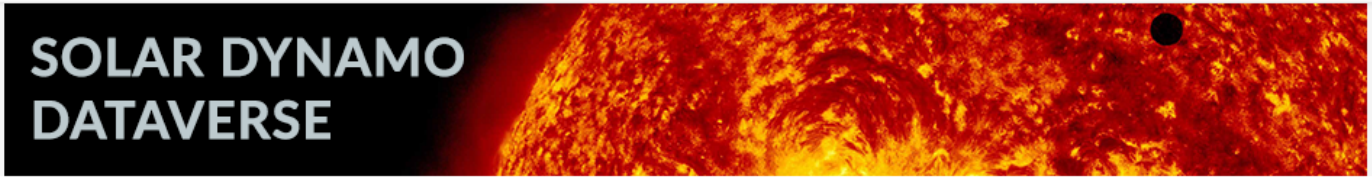
- MDI and KPVT-512 channel done 6,885 unique objects detected and tracked. HMI is being processed.

MORE THAN JUST MY DATA

A homogeneous composite of sunspot group data



Schawbe's, RGO and KMAS data



Solar Dynamo Dataverse (Georgia State University)

A collective of databases and data products tailored to understanding and predicting the solar cycle.

A collective of databases and data products tailored to understanding and predicting the solar cycle. Emphasis is placed on long-term variability and surface magnetic fields.

Search this dataverse... Find Advanced Search

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Dataverse Category
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Publication Date
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Subject
Astronomy and Astrophysics (4)

Author Name
Andrés Muñoz-Jaramillo (1)
Anthony R. Yeates (1)
Neil Sheeley, Jr. (1)

1 to 4 of 4 Results

Sort

Bipolar magnetic regions determined from NSO synoptic carrington maps
Mar 30, 2016 - Magnetic Catalogs Dataverse

Anthony R. Yeates, 2016, "Bipolar magnetic regions determined from NSO synoptic carrington maps", http://dx.doi.org/10.7910/DVN/Y5CXM8, Harvard Dataverse, V1

Database of bipolar magnetic regions (BMRs) determined from NSO synoptic carrington maps of the Sun's photosperic line-of-sight magnetic flux between carrington rotations cr1911 and cr2146 inclusive. The attached plots summarize the dataset. In the data file itself, the columns a...

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Catalogs of solar magnetic features (i.e. bipolar magnetic regions, ephemeral regions, magnetic elements, etc.).

MWO polar faculae count calibrated to WSO polar fields and SOHO/MDI polar flux
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Andrés Muñoz-Jaramillo; Neil Sheeley, Jr., 2016, "MWO polar faculae count calibrated to WSO polar fields and SOHO/MDI polar flux", http://dx.doi.org/10.7910/DVN/KF96B2, Harvard Dataverse, V2

Faculae counted by hand on the best 5 images during the periods of maximum pole coverage (August 15-September 15 for the North pole and February 15-March 15 for the South pole) and averaged. Standard deviation has been turned into standard error by dividing it by sqrt(5). Years w...

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