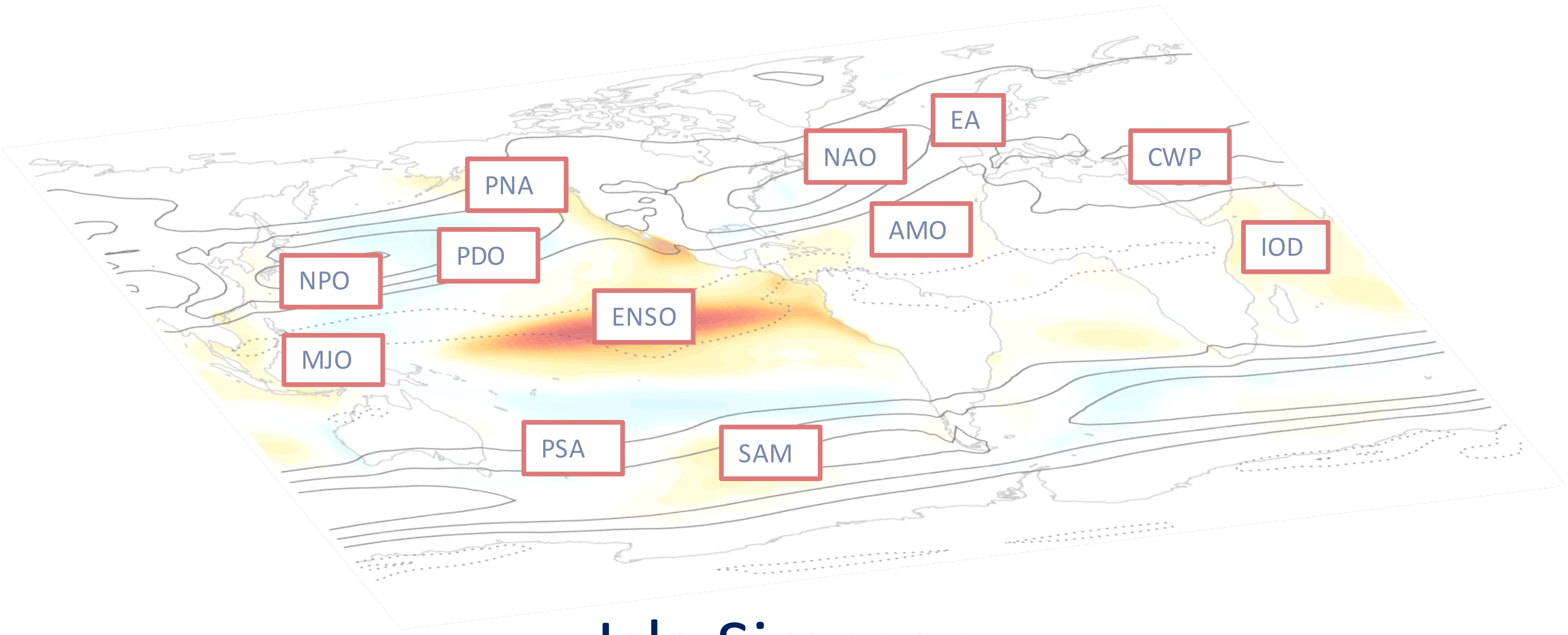
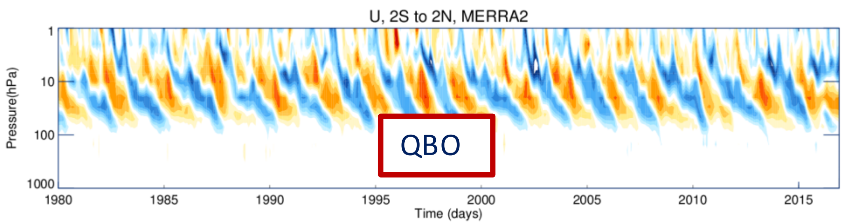
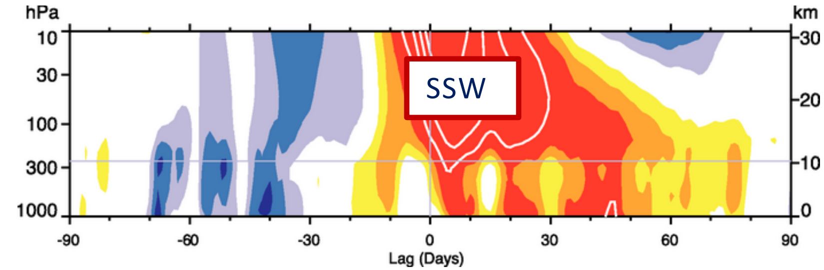
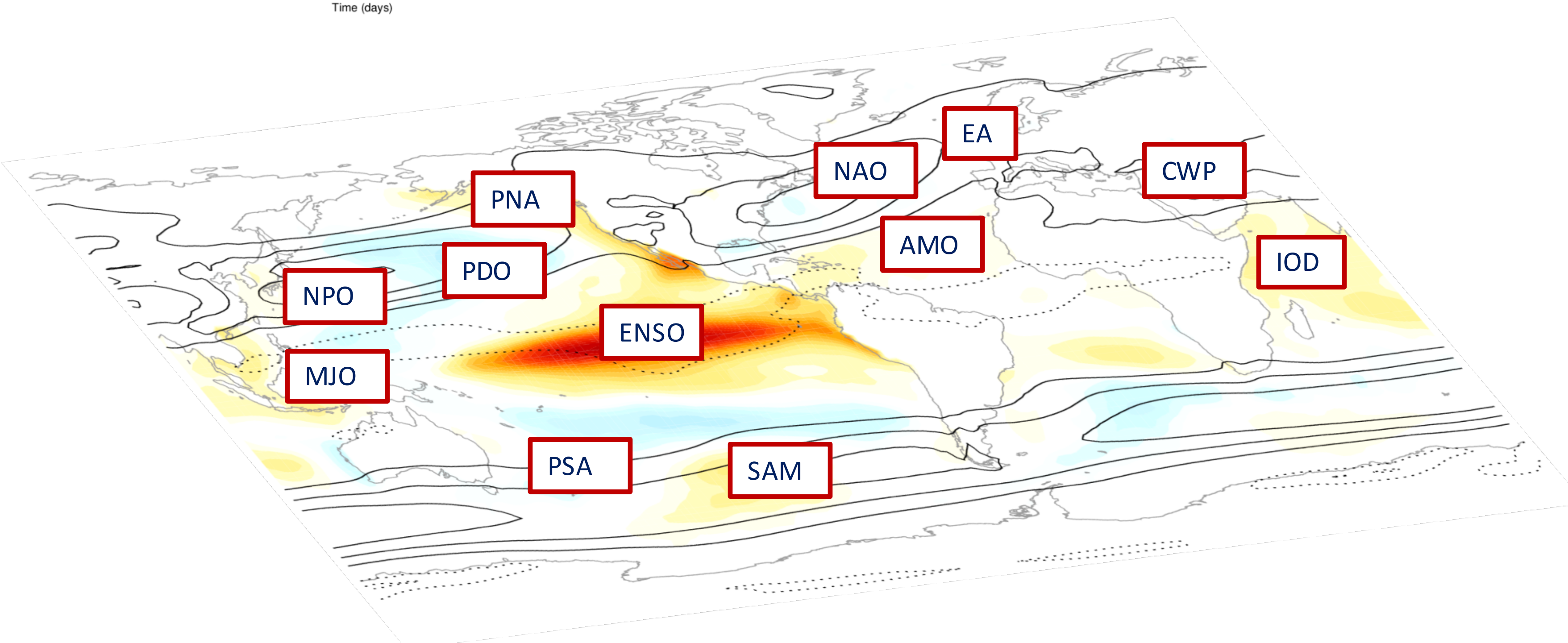
Modes of Variability



Isla Simpson
Climate and Global Dynamics Laboratory, NCAR


U, 2S to 2N, MERRA2
Pressure(hPa)
1
10
100
1000
1980
1985
1990
1995
2000
2005
2010
2015
Time (days)
QBO


hPa
km
10
30
100
300
1000
30
20
10
0
-90
-60
-30
0
30
60
90
Lag (Days)
SSW


EA
NAO
CWP
PNA
AMO
PDO
IOD
NPO
ENSO
MJO
PSA
SAM

Topics

- SAM (Southern Annular Mode)
- QBO (Quasi-Biennial Oscillation)
- North Atlantic Jet

Topics

- SAM (Southern Annular Mode)

  A case where we have a clear emergent constraint

  Although it may not be fully understood

- QBO (Quasi-Biennial Oscillation)

- North Atlantic Jet

Topics

- SAM (Southern Annular Mode)

  A case where we have a clear emergent constraint

  Although it may not be fully understood

- QBO (Quasi-Biennial Oscillation)

  New results from QBOi – models are all over the place

- North Atlantic Jet

Topics

- SAM (Southern Annular Mode)

  A case where we have a clear emergent constraint

  Although it may not be fully understood

- QBO (Quasi-Biennial Oscillation)

  New results from QBOi – models are all over the place

- North Atlantic Jet

  A case where we need to be careful with our observational uncertainty

Topics

- SAM (Southern Annular Mode)

  A case where we have a clear emergent constraint

  Although it may not be fully understood

- QBO (Quasi-Biennial Oscillation)

  New results from QBOi – models are all over the place

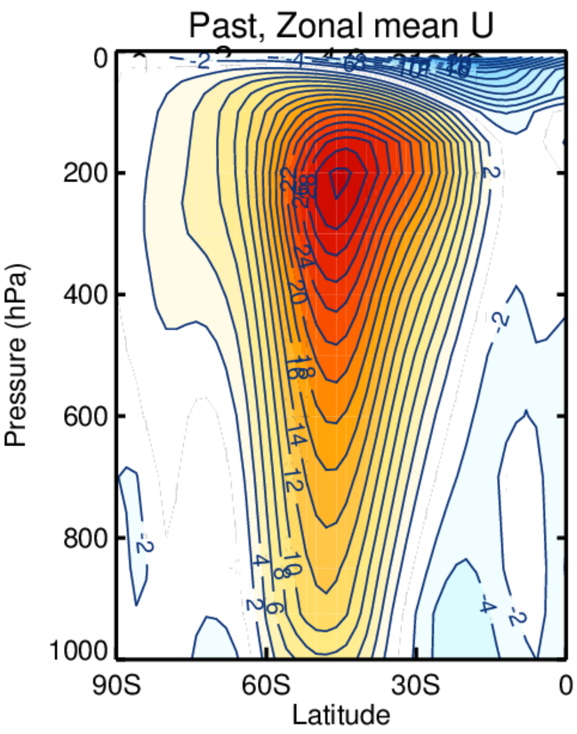
- North Atlantic Jet

  A case where we need to be careful with our observational uncertainty

The Southern Annular Mode

The Southern Annular Mode

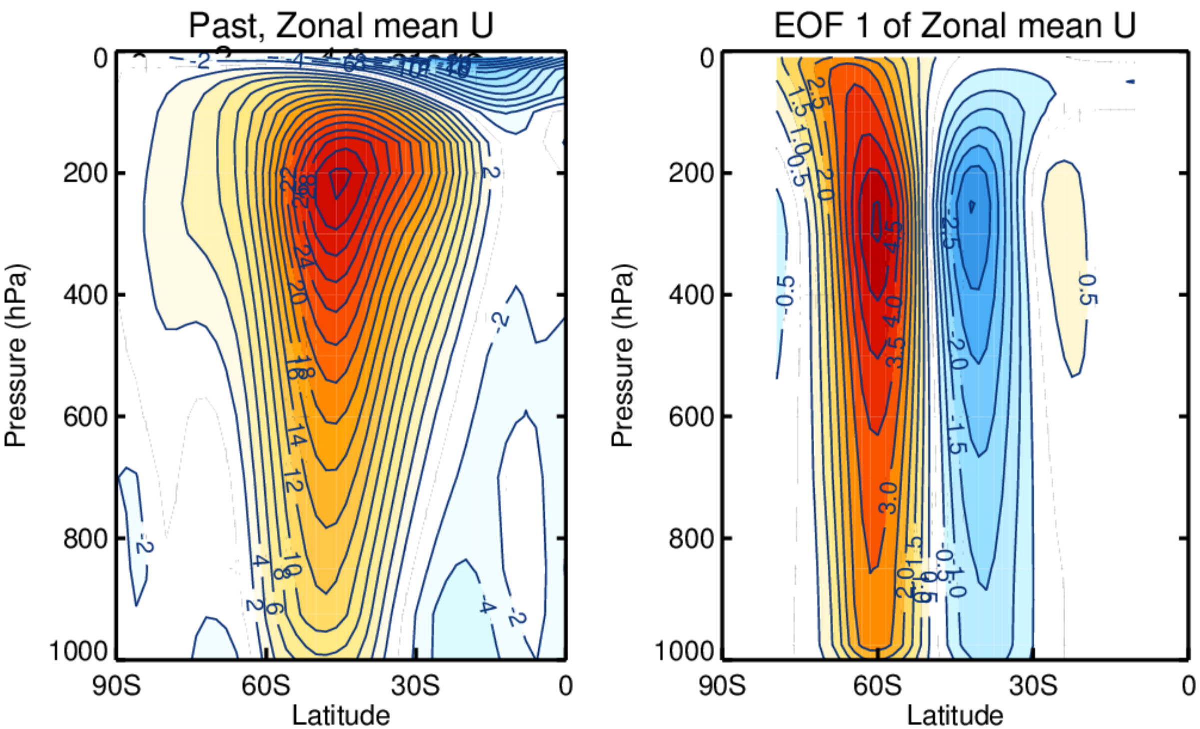
SAM = The dominant mode of variability in our SH jet stream



CMIP5 multi-model mean zonal mean zonal wind, (1979-2005, DJF)

The Southern Annular Mode

SAM = The dominant mode of variability in our SH jet stream

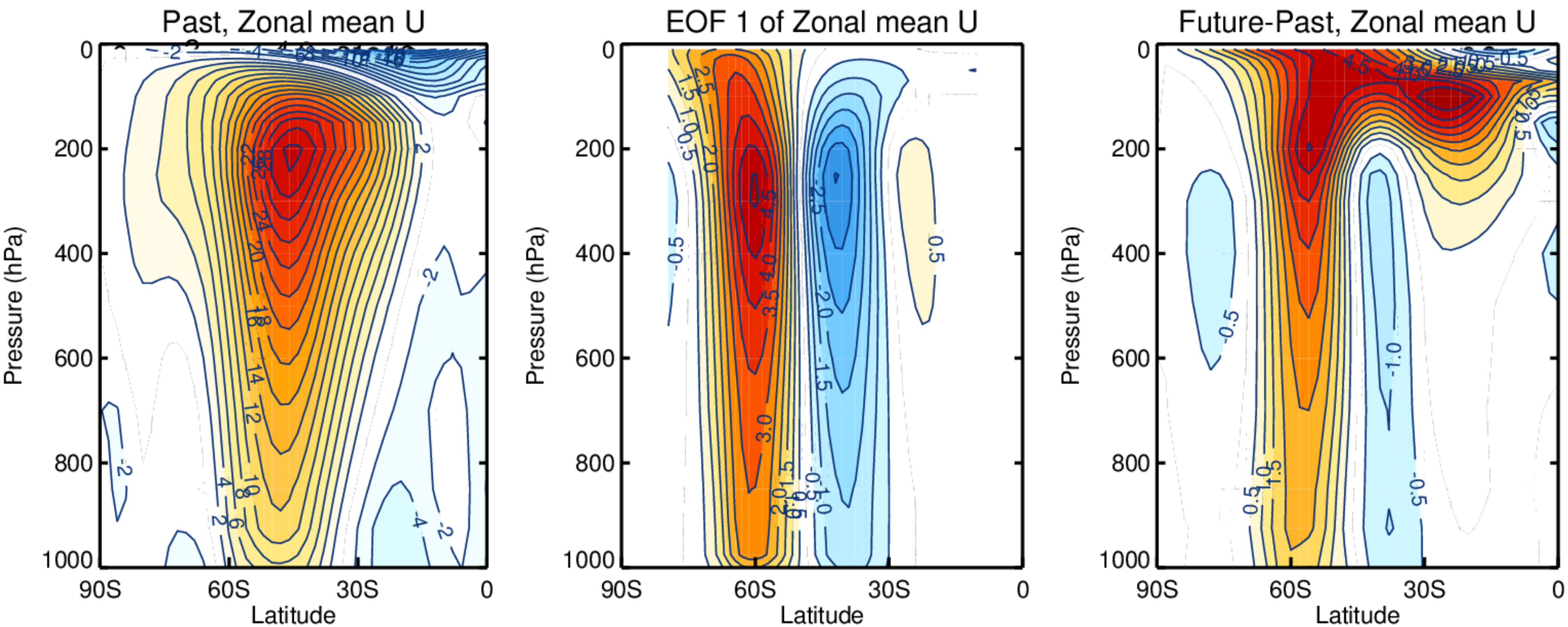


CMIP5 multi-model mean zonal mean zonal wind, (1979-2005, DJF)

1st EOF of daily zonal mean zonal wind variability

The Southern Annular Mode

SAM = The dominant mode of variability in our SH jet stream



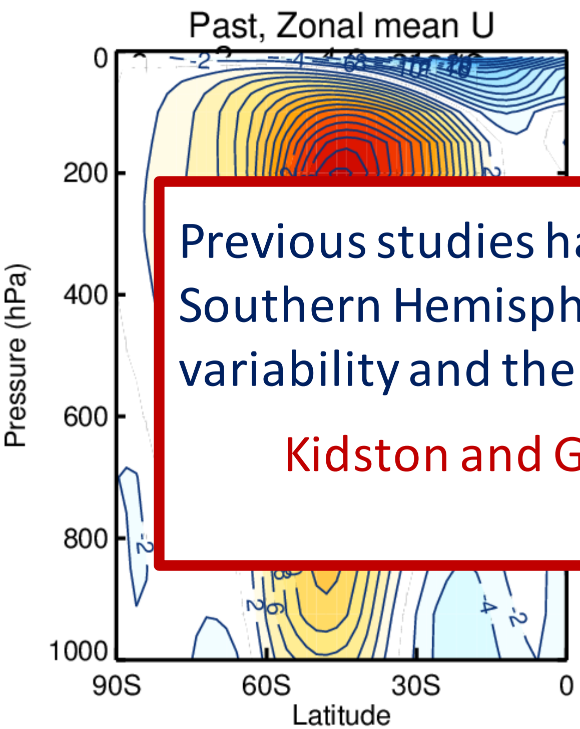
CMIP5 multi-model mean zonal mean zonal wind, (1979-2005, DJF)

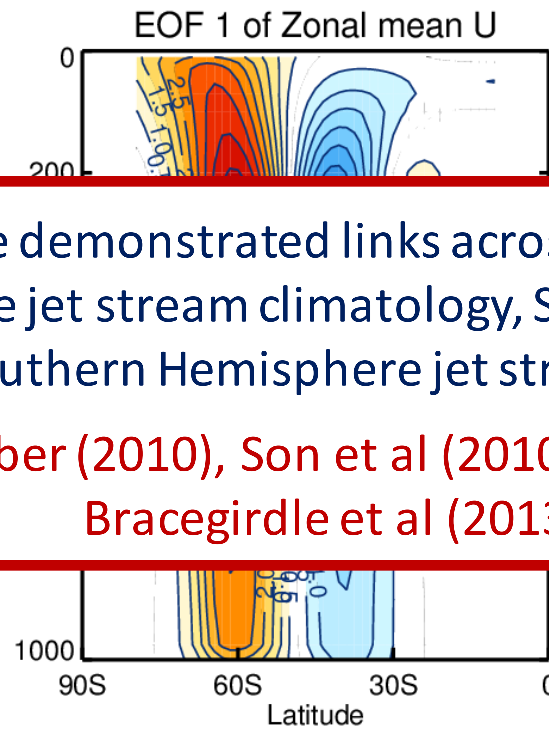
1st EOF of daily zonal mean zonal wind variability

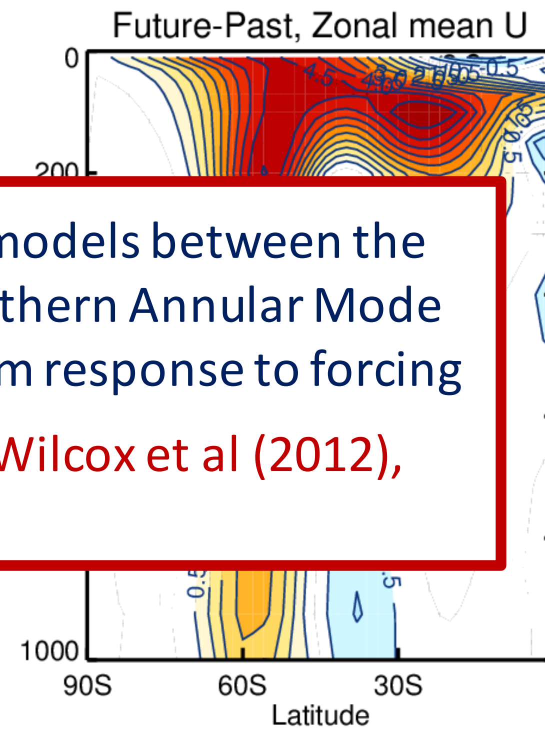
CMIP5 multi-model mean zonal mean zonal wind RCP8.5 response (2070-2099) - (1979-2005), DJF

The Southern Annular Mode

SAM = The dominant mode of variability in our SH jet stream







Previous studies have demonstrated links across models between the Southern Hemisphere jet stream climatology, Southern Annular Mode variability and the Southern Hemisphere jet stream response to forcing

Kidston and Gerber (2010), Son et al (2010), Wilcox et al (2012), Bracegirdle et al (2013)

CMIP5 multi-model mean zonal mean zonal wind, (1979-2005, DJF)

1st EOF of daily zonal mean zonal wind variability

CMIP5 multi-model mean zonal mean zonal wind RCP8.5 response (2070-2099) - (1979-2005), DJF

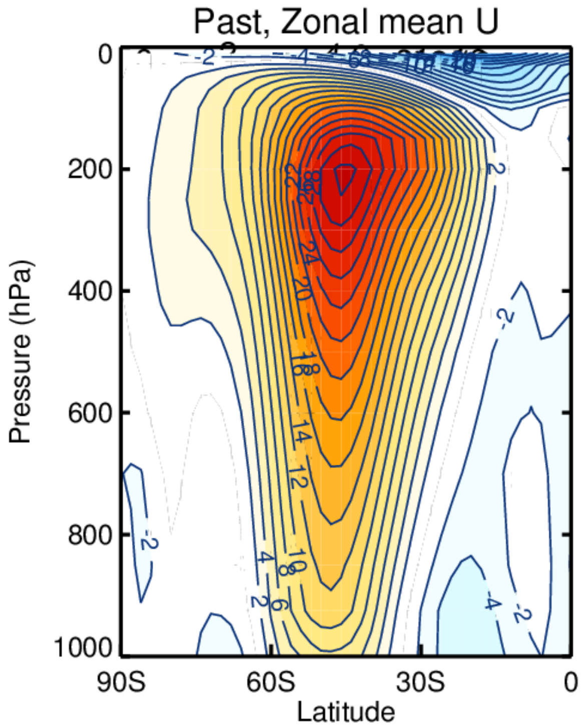
Three Parameters

Three Parameters

Jet Latitude $\square_o$

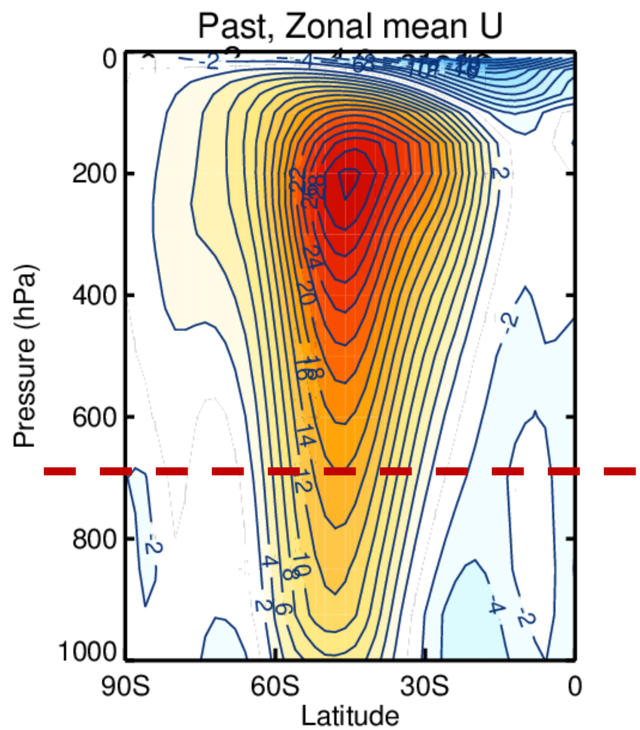
Three Parameters

Jet Latitude □$_o$



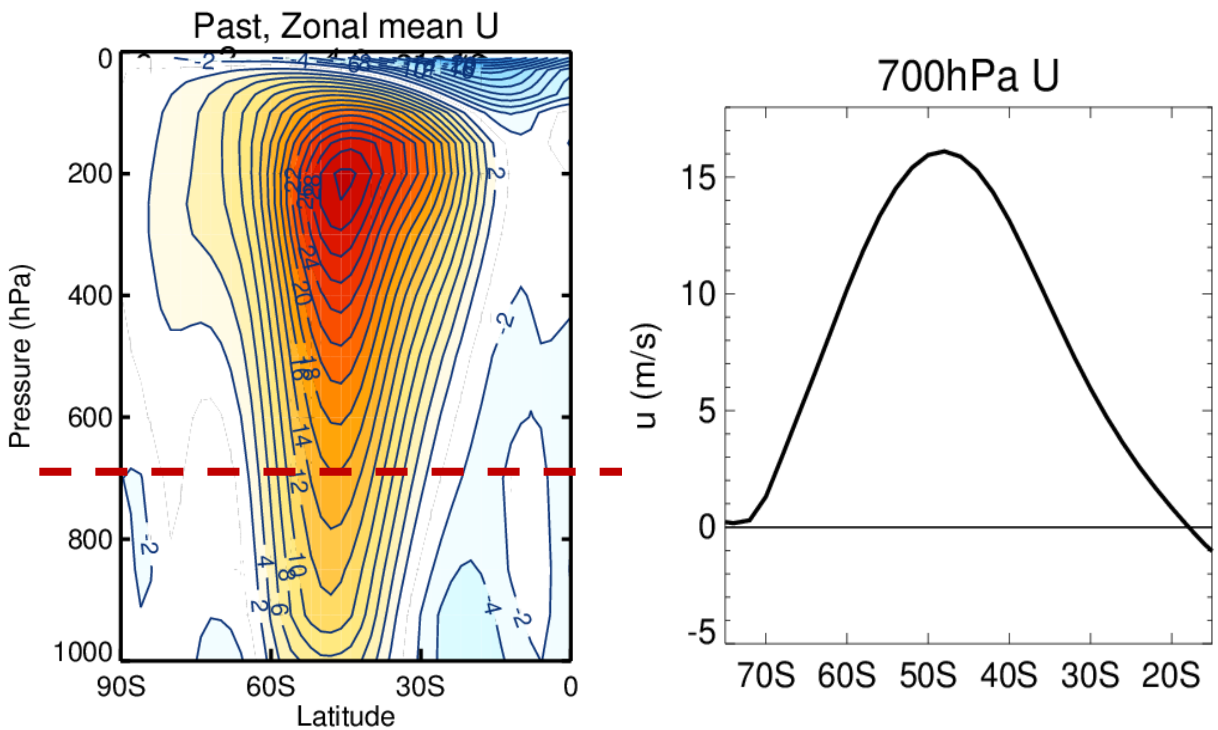
Three Parameters

Jet Latitude ϕ_o



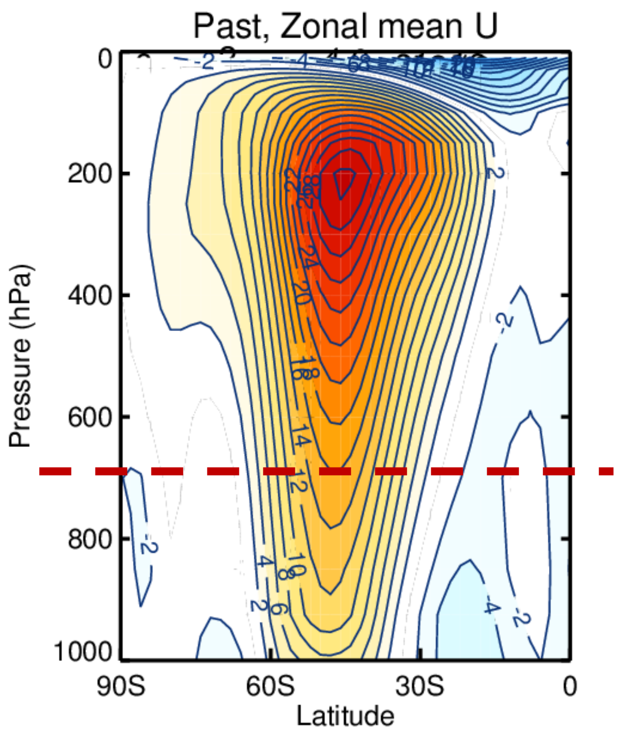
Three Parameters

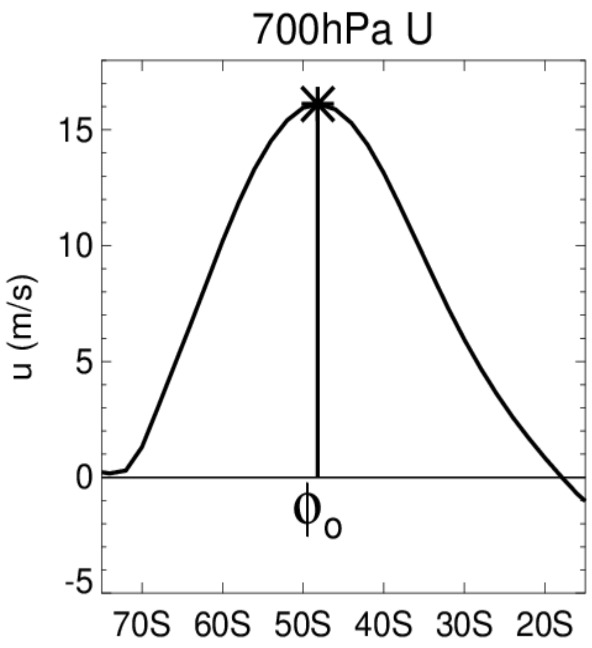
Jet Latitude □$_o$



Three Parameters

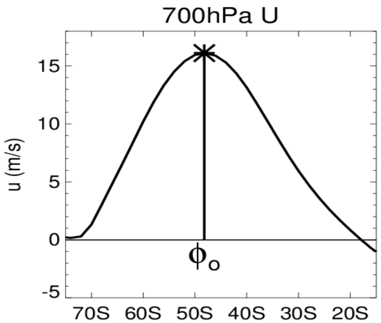
Jet Latitude ϕ_o

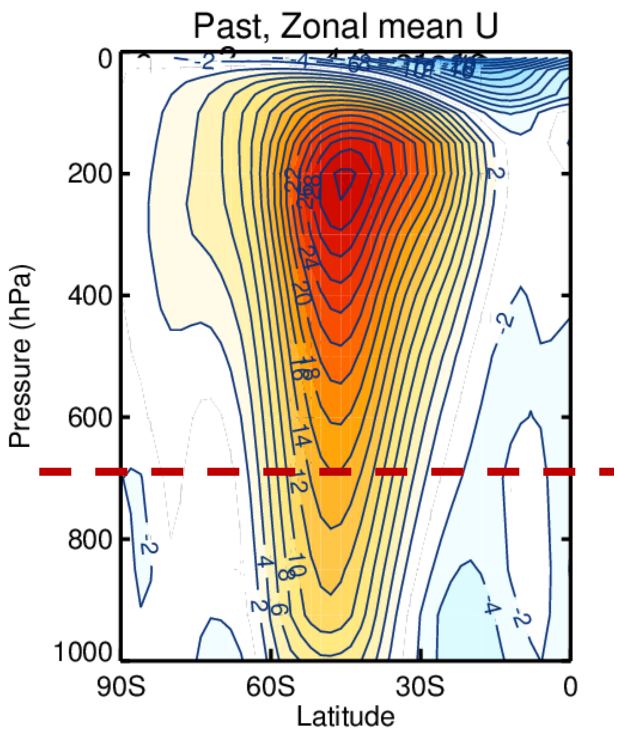


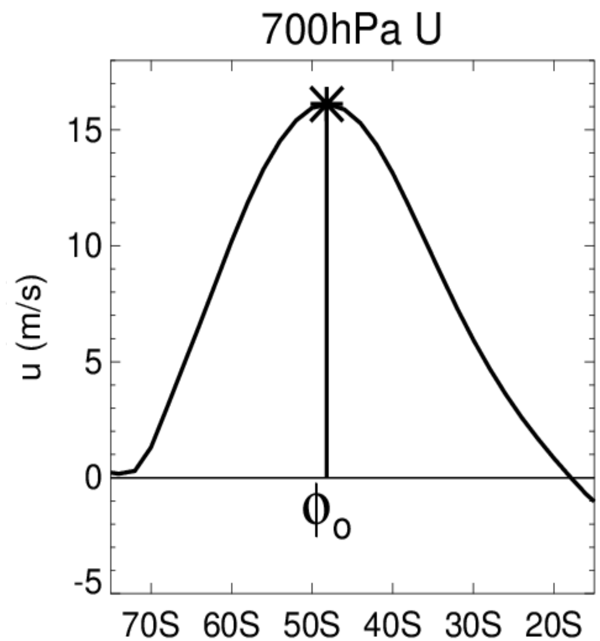


Three Parameters

Jet Latitude ϕ_o

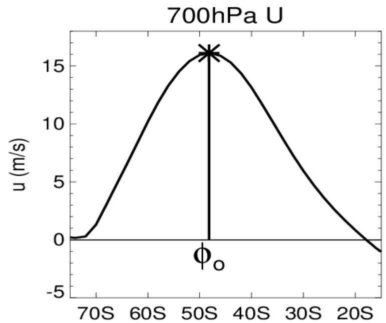




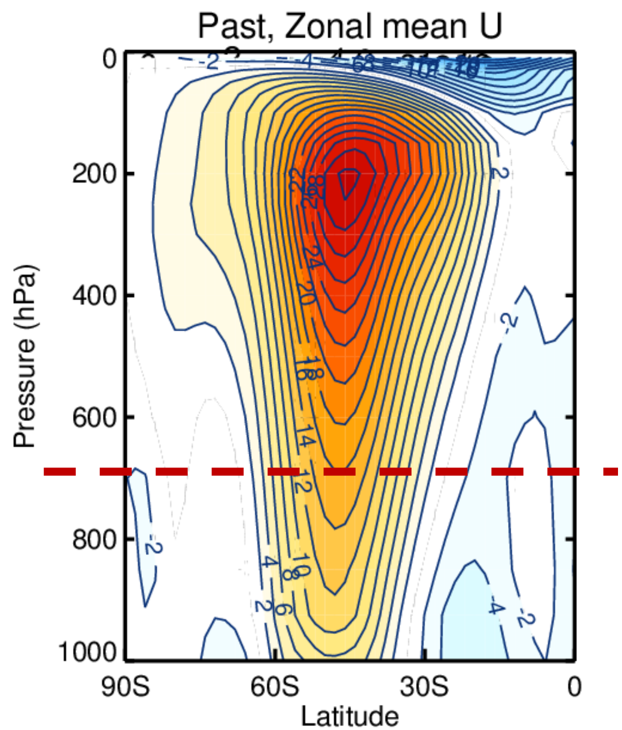


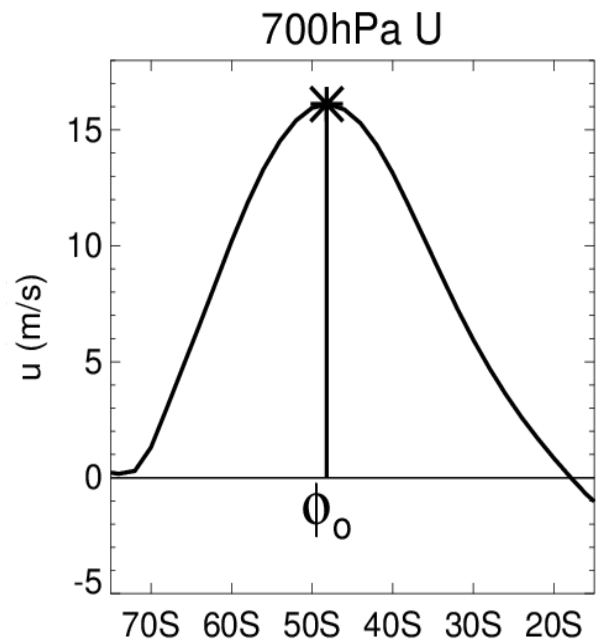
Three Parameters

Jet Latitude ϕ_o



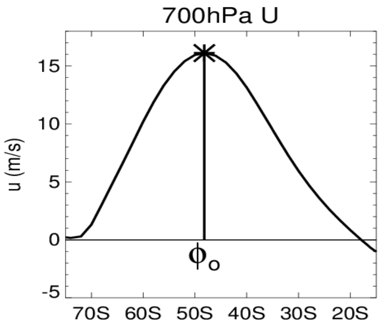
Jet Shift $\Delta\phi$



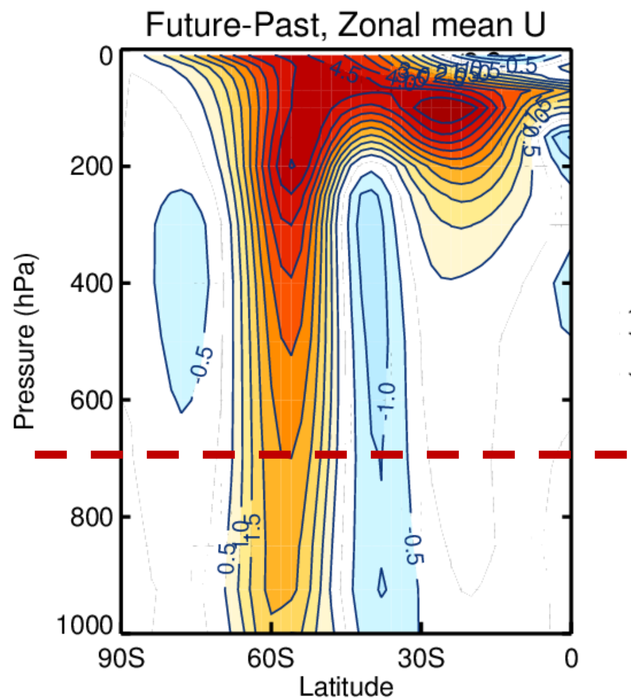


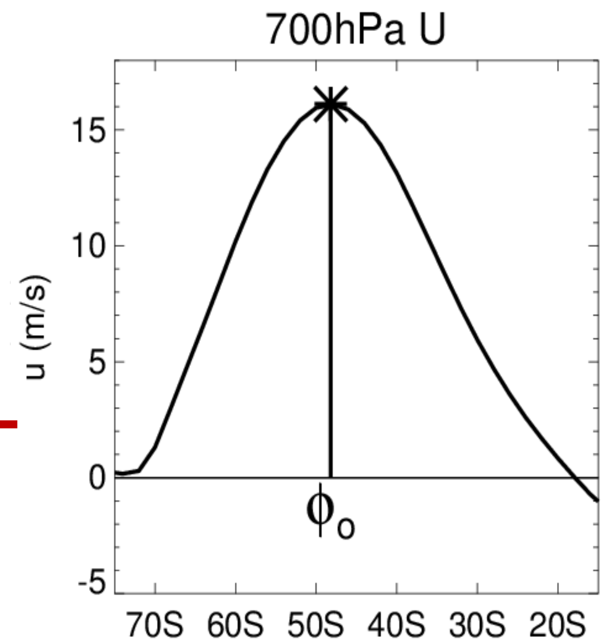
Three Parameters

Jet Latitude $\square_o$



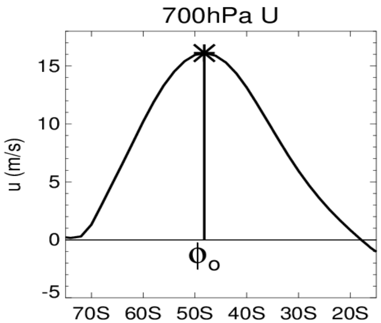
Jet Shift Δ□



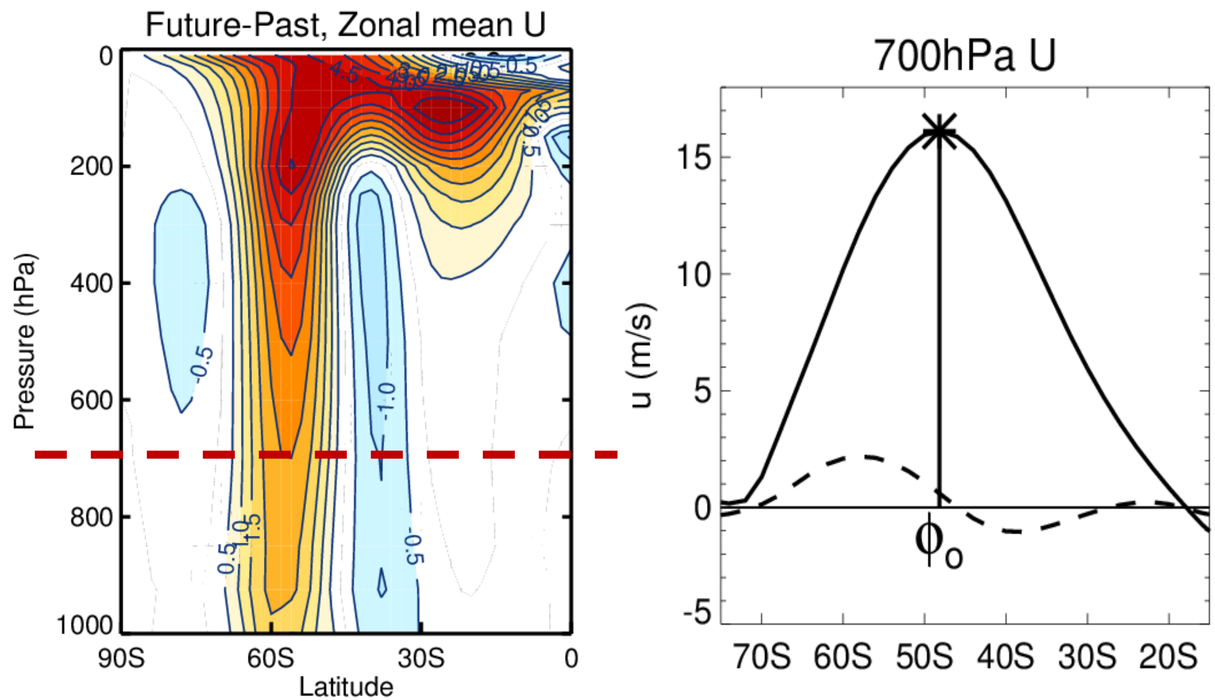


Three Parameters

Jet Latitude ϕ_o

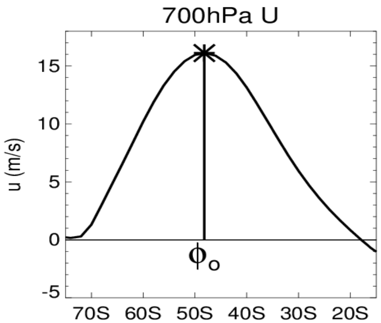


Jet Shift Δϕ

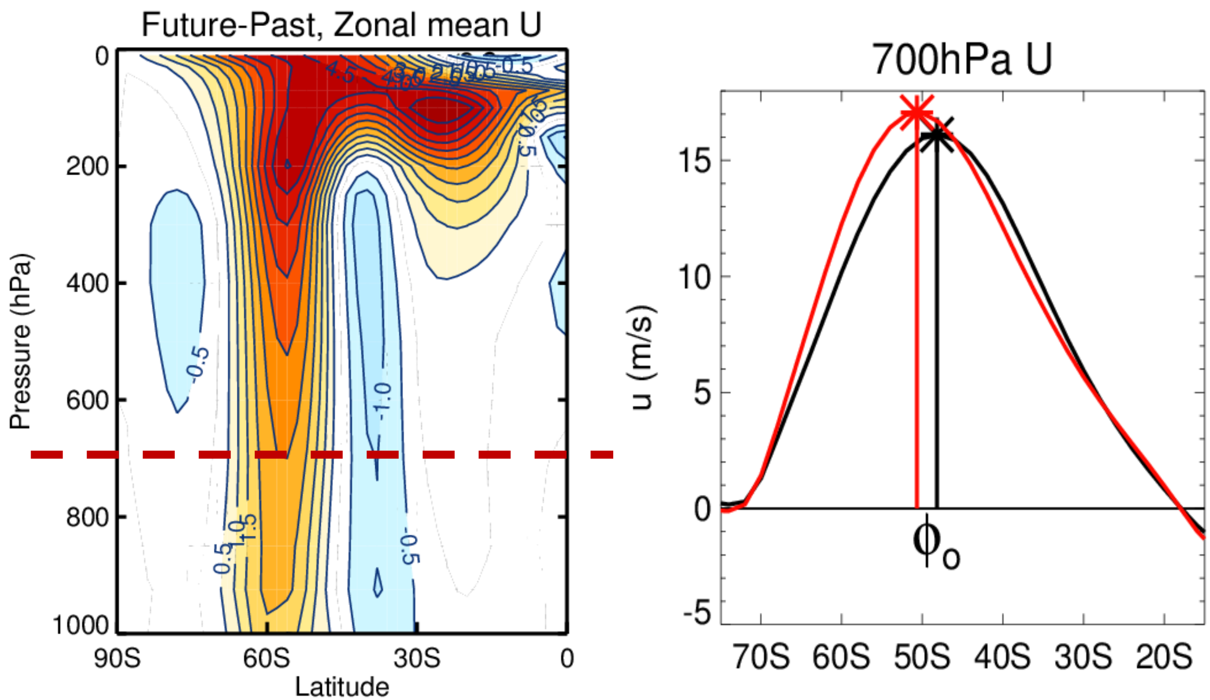


Three Parameters

Jet Latitude ϕ_o

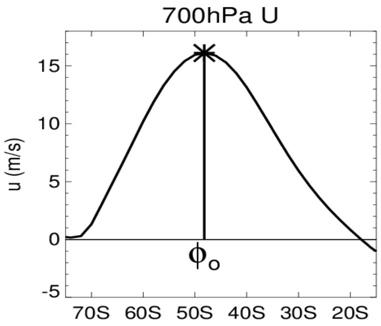


Jet Shift $\Delta\phi$

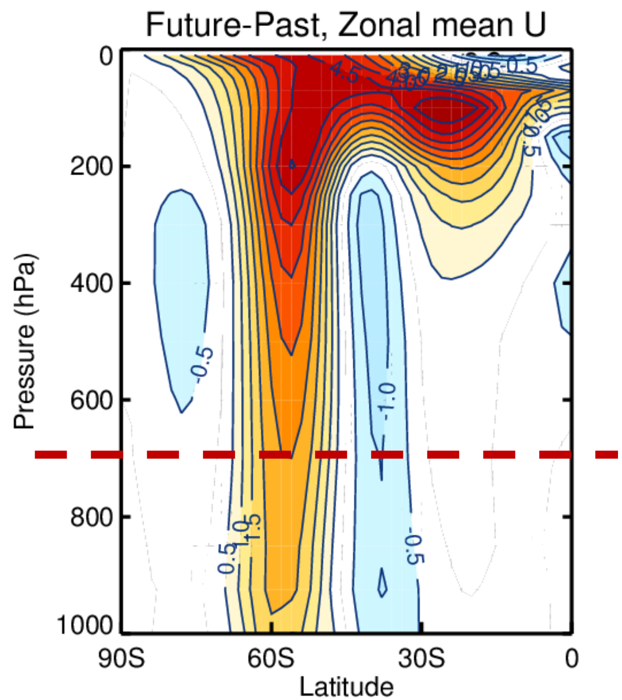


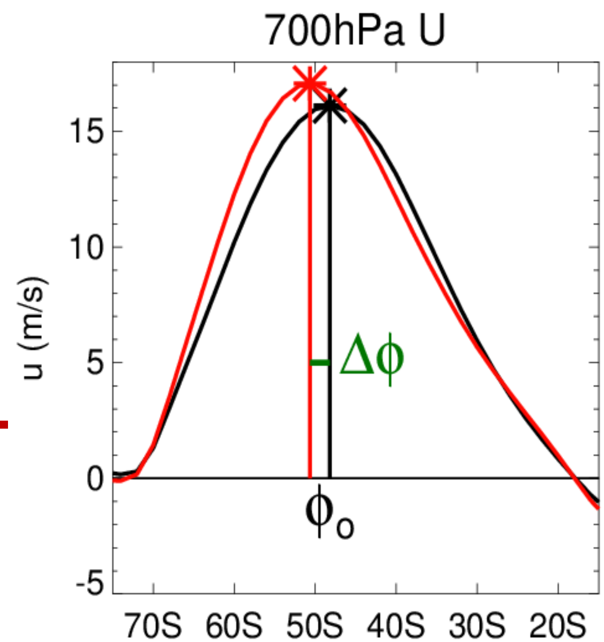
Three Parameters

Jet Latitude ϕ_o



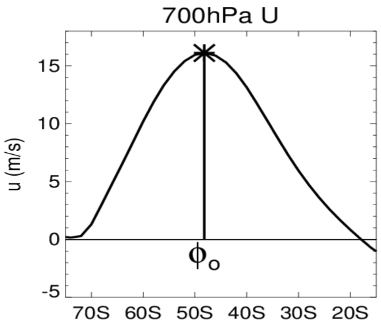
Jet Shift $\Delta\phi$



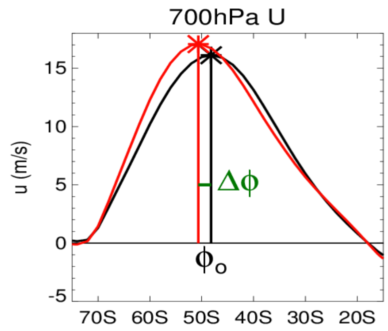


Three Parameters

Jet Latitude ϕ_o

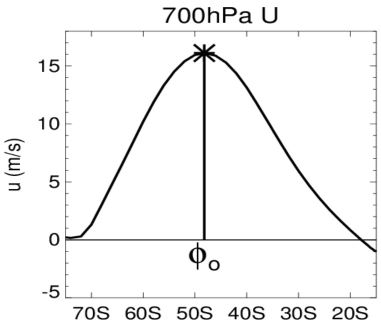


Jet Shift $\Delta\phi$

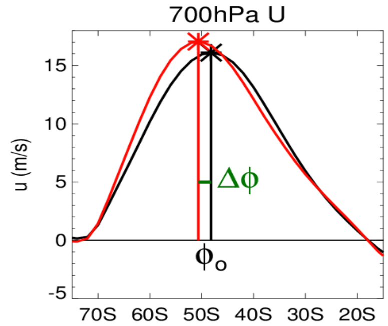


Three Parameters

Jet Latitude ϕ_o



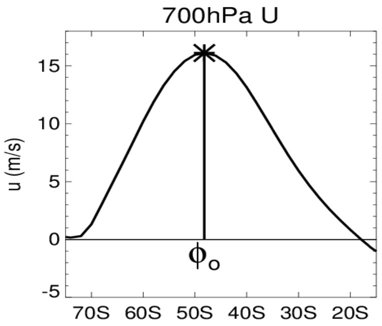
Jet Shift $\Delta\phi$



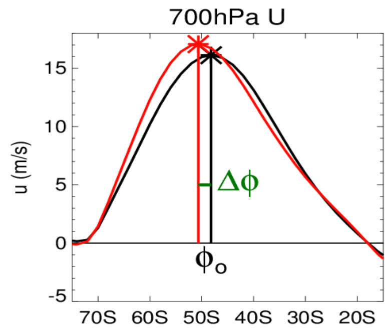
Annular mode timescale

Three Parameters

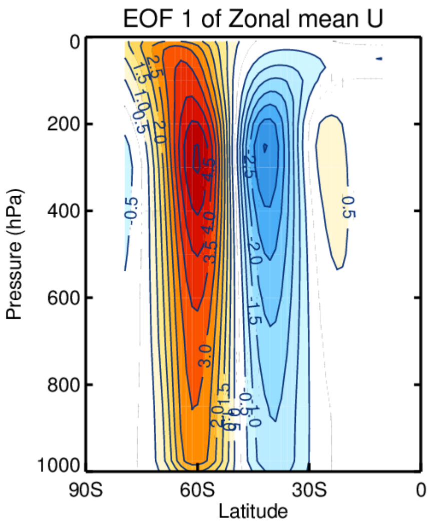
Jet Latitude ϕ_o



Jet Shift $\Delta\phi$

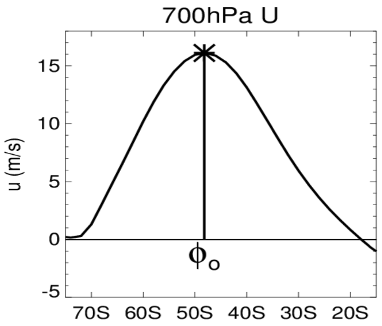


Annular mode timescale

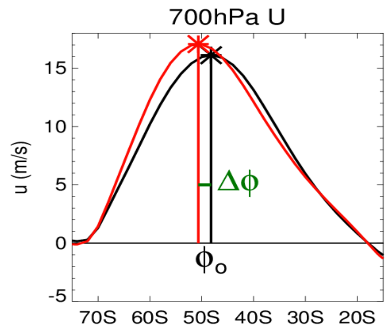


Three Parameters

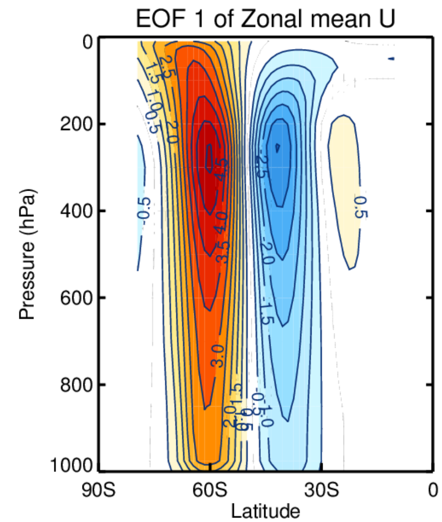
Jet Latitude ϕ_o



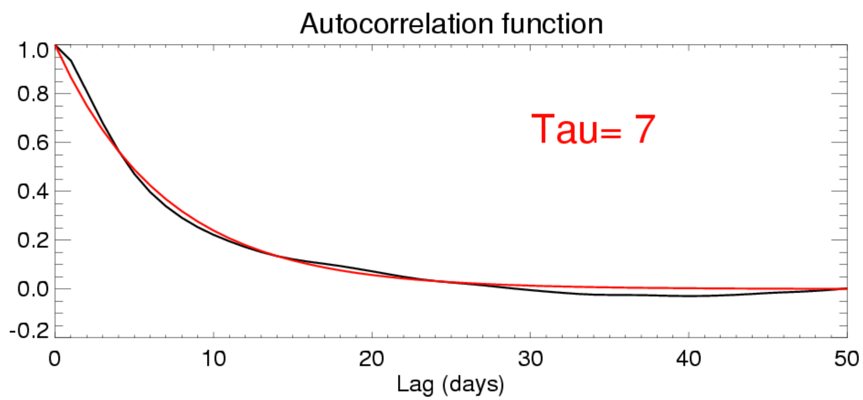
Jet Shift $\Delta\phi$



Annular mode timescale

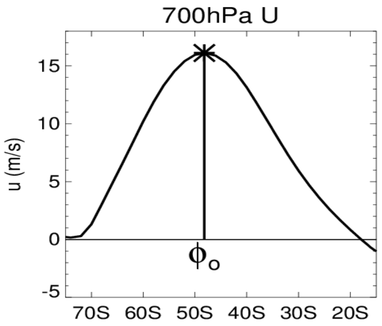


e-folding timescale of the autocorrelation function of the SAM time series

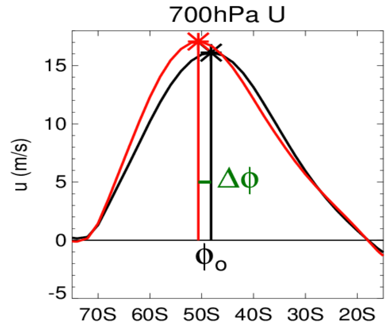


Three Parameters

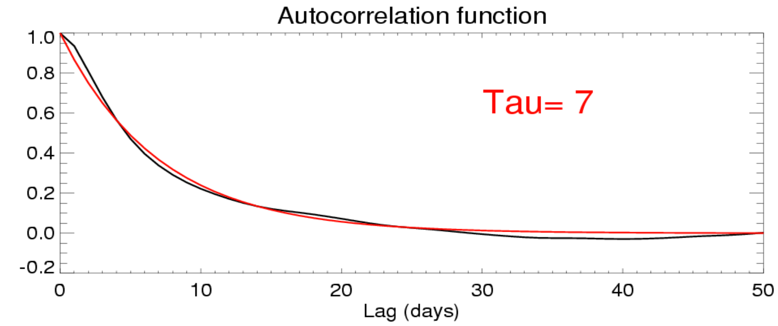
Jet Latitude □$_o$



Jet Shift Δ□

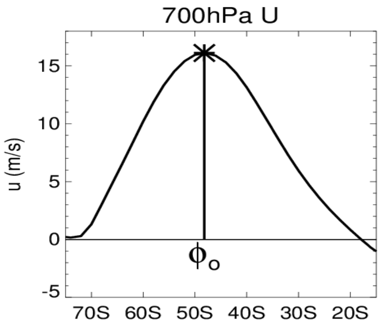


Annular mode timescale

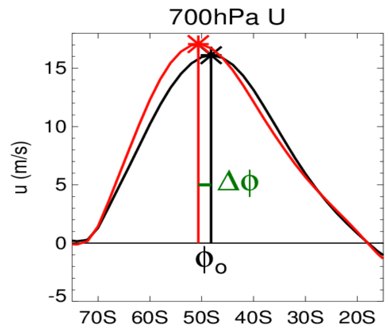


Three Parameters

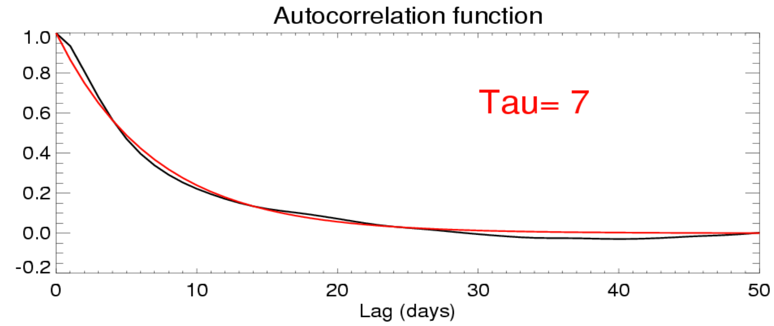
Jet Latitude ϕ_o



Jet Shift $\Delta\phi$



Annular mode timescale



GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L09708, doi:10.1029/2010GL042873, 2010

Click Here for Full Article

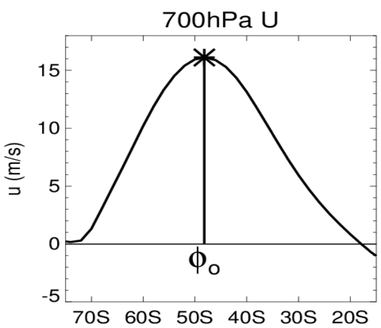
Intermodel variability of the poleward shift of the austral jet stream in the CMIP3 integrations linked to biases in 20th century climatology

J. Kidston[1] and E. P. Gerber[2]

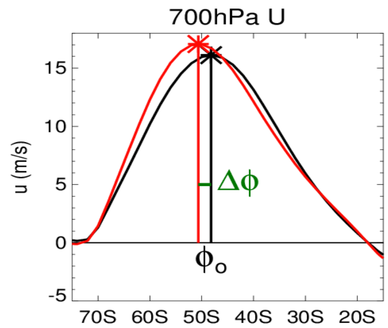
See also Son et al (2010) for CCMVal2 models

Three Parameters

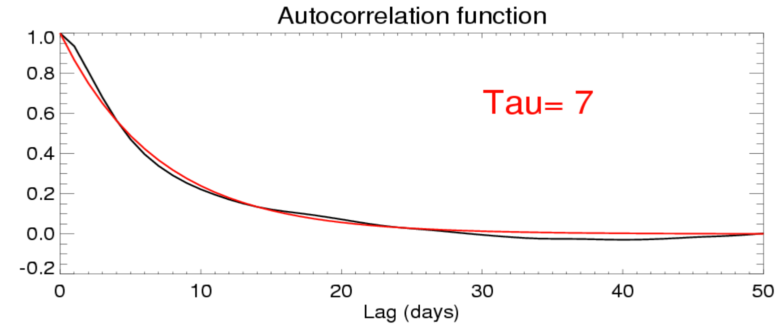
Jet Latitude ϕ_o



Jet Shift $\Delta\phi$



Annular mode timescale



GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L09708, doi:10.1029/2010GL042873, 2010

Click Here for Full Article

Intermodel variability of the poleward shift of the austral jet stream in the CMIP3 integrations linked to biases in 20th century climatology

J. Kidston[1] and E. P. Gerber[2]

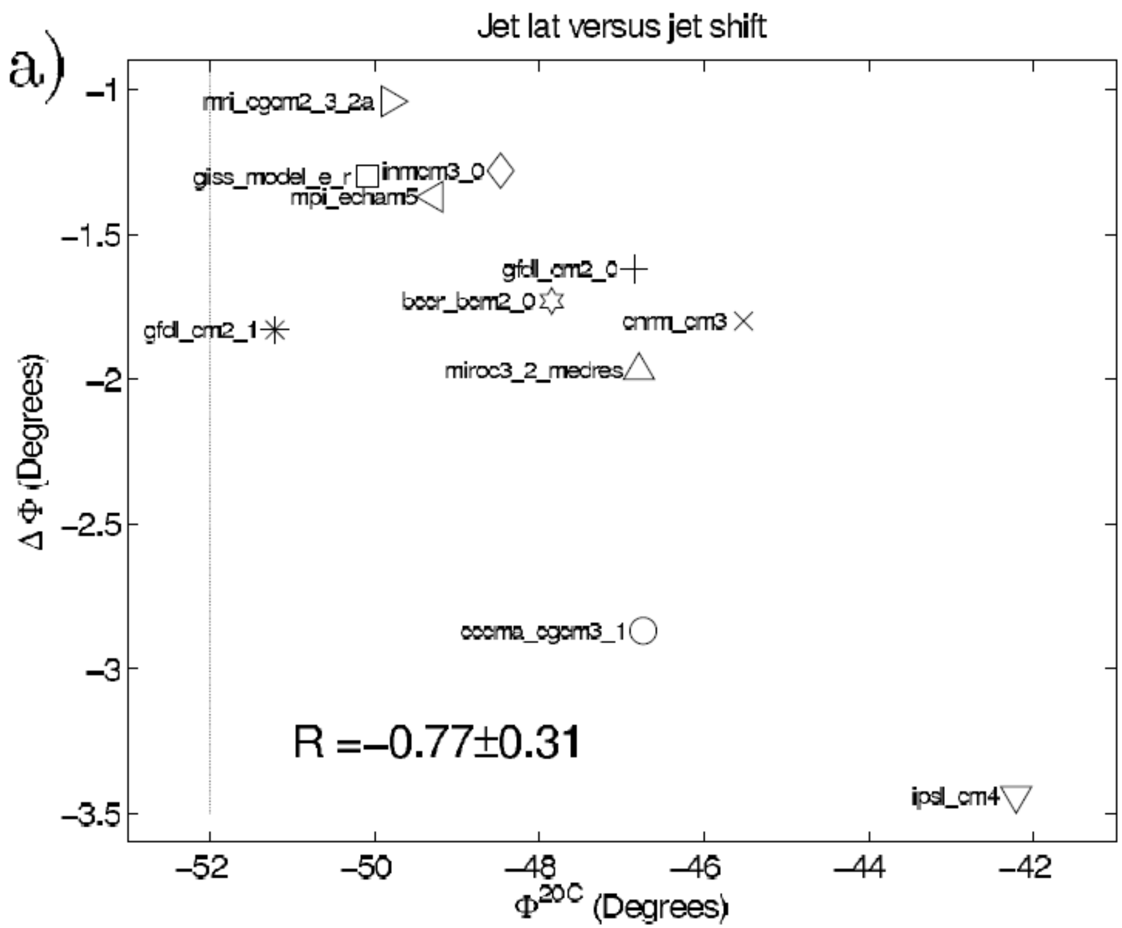
Focused on the annual mean

See also Son et al (2010) for CCMVal2 models

Jet Shift Δ□ vs Jet Latitude $□_o$

Poleward jet shift under A2 scenario

Jet Shift Δ□



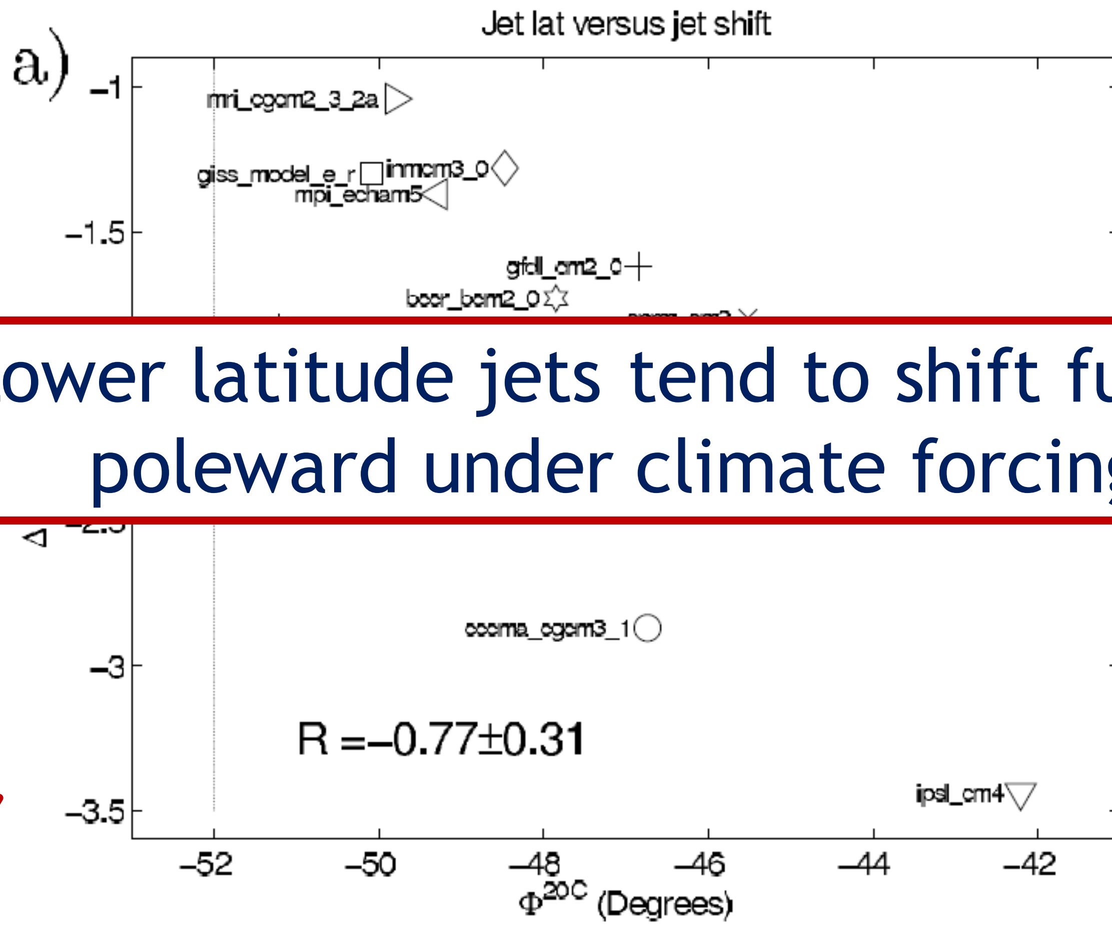
Jet Latitude $□_o$

Kidston and Gerber (2010)

Jet Shift Δ□ vs Jet Latitude $\square_o$

Poleward jet shift under A2 scenario

Jet Shift Δ□



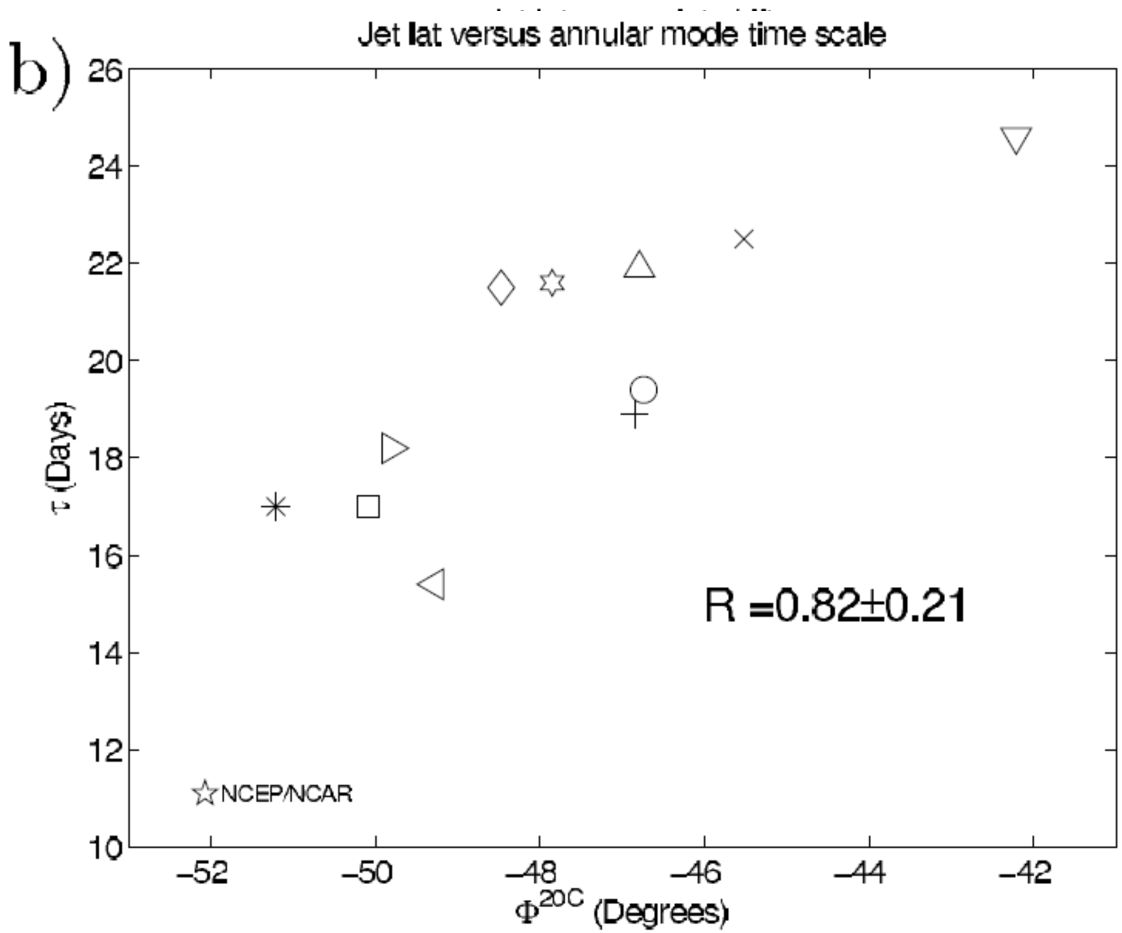
Lower latitude jets tend to shift further poleward under climate forcings

Jet Latitude $\square_o$

Kidston and Gerber (2010)

Annular mode timescale vs Jet Latitude $\square_o$

Annular mode timescale

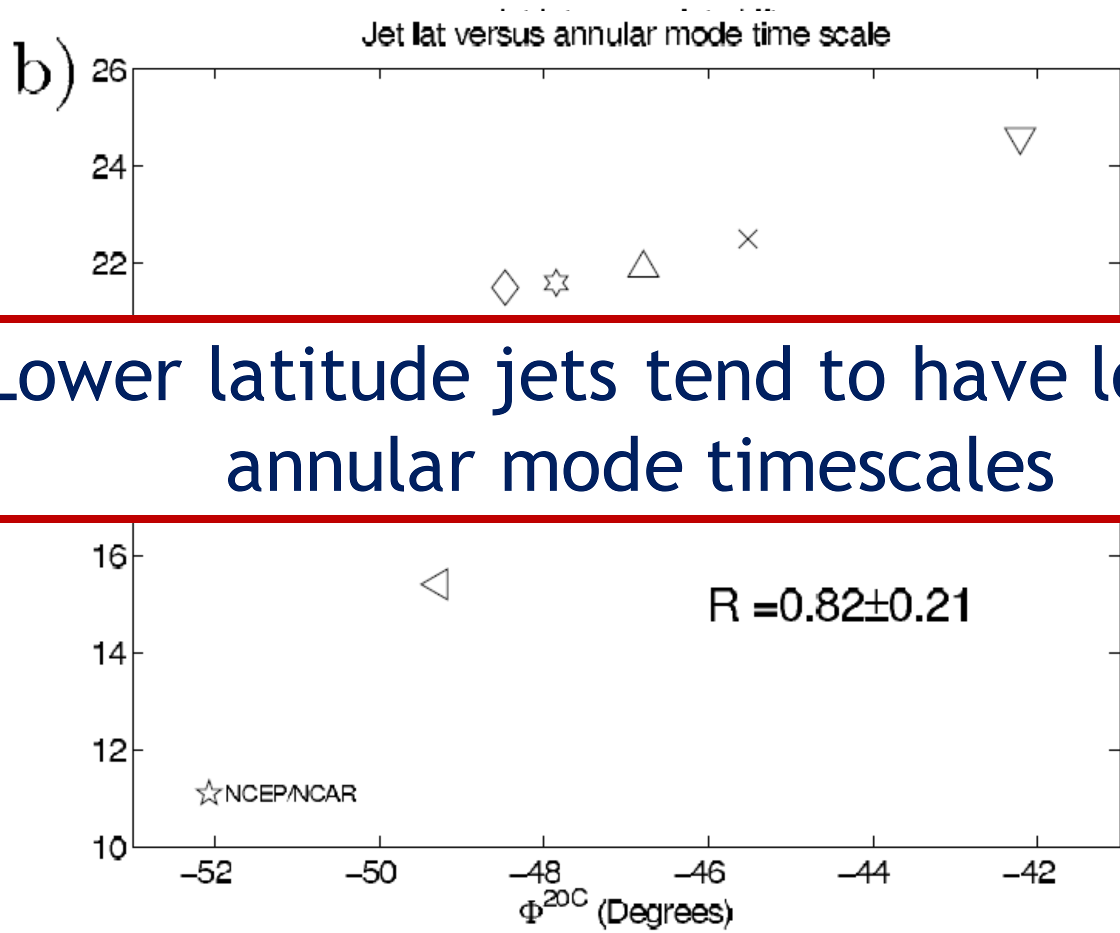


Jet Latitude $\square_o$

Kidston and Gerber (2010)

Annular mode timescale vs Jet Latitude □$_o$

Annular mode timescale



Lower latitude jets tend to have longer annular mode timescales

Jet Latitude □$_o$

Kidston and Gerber (2010)

Lower latitude jets:

(1) Shift further poleward under climate forcings

(2) Have longer annular mode timescales

Lower latitude jets:
(1) Shift further poleward under climate forcings
(2) Have longer annular mode timescales

How do these relationships look in CMIP5?

35 models

Historical (1979-2005)

RCP8.5 (2070-2099)

Simpson and Polvani (2016)
See also Wilcox et al (2012) for a smaller model subset

Lower latitude jets:
(1) Shift further poleward under climate forcings
(2) Have longer annular mode timescales

How do these relationships look in CMIP5?

35 models

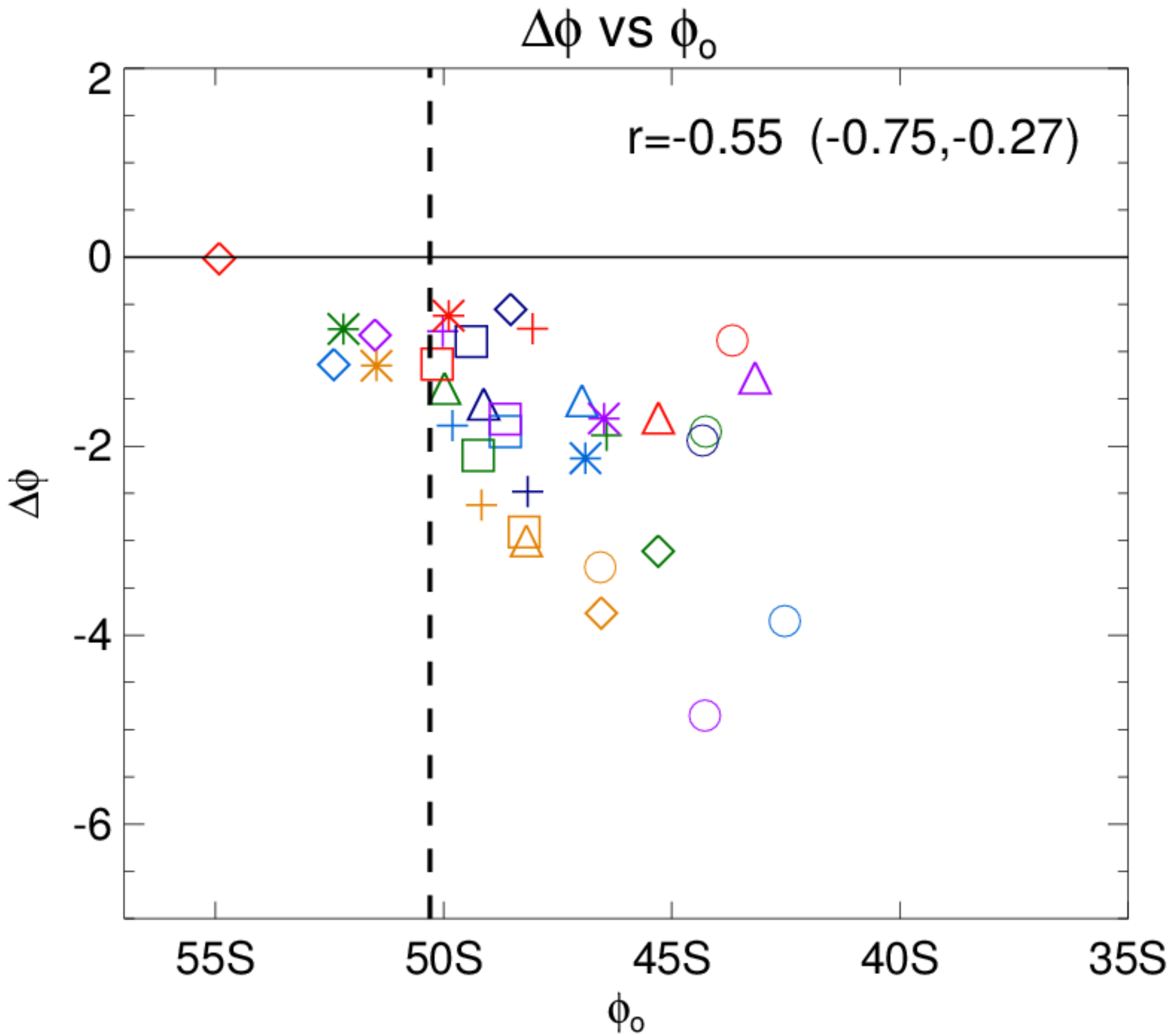
Historical (1979-2005)

RCP8.5 (2070-2099)

Simpson and Polvani (2016)

See also Wilcox et al (2012) for a smaller model subset

Jet Shift $\Delta\phi$ vs Jet Latitude ϕ_o

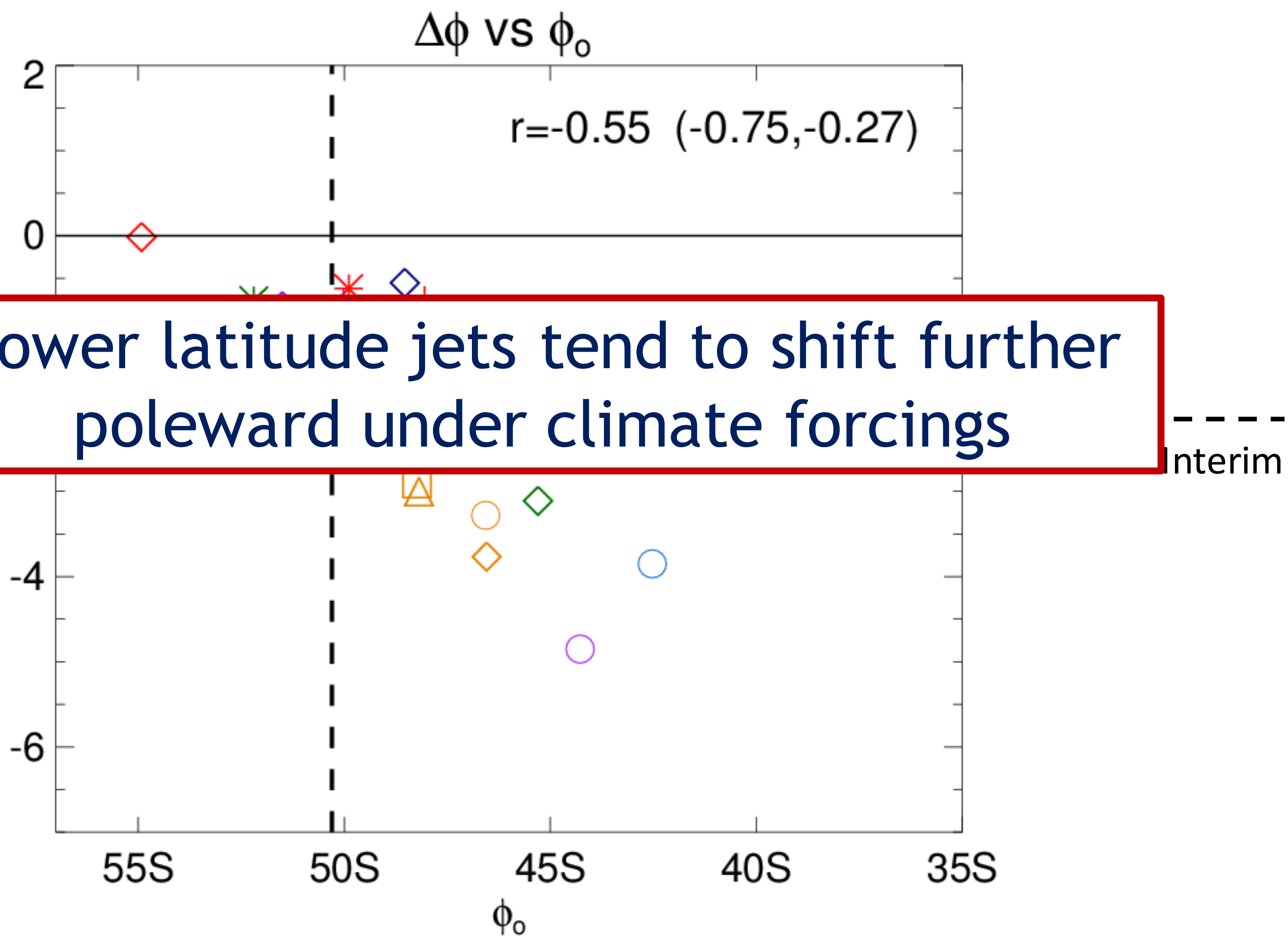


Jet Shift $\Delta\phi$

ERA-Interim

Jet Latitude ϕ_o

Jet Shift Δ□ vs Jet Latitude $\square_o$



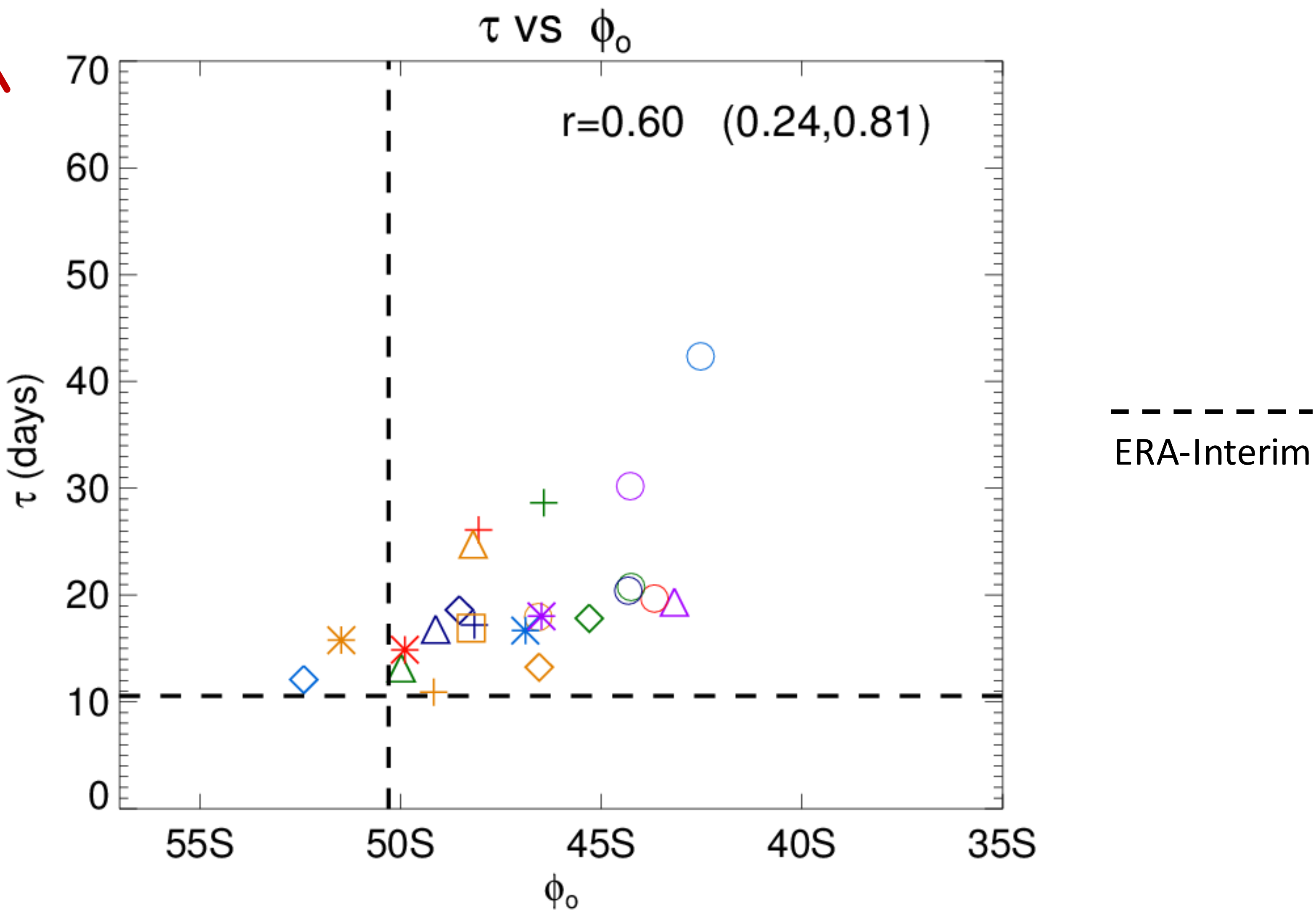
Lower latitude jets tend to shift further poleward under climate forcings

Jet Shift Δ□

Jet Latitude $\square_o$

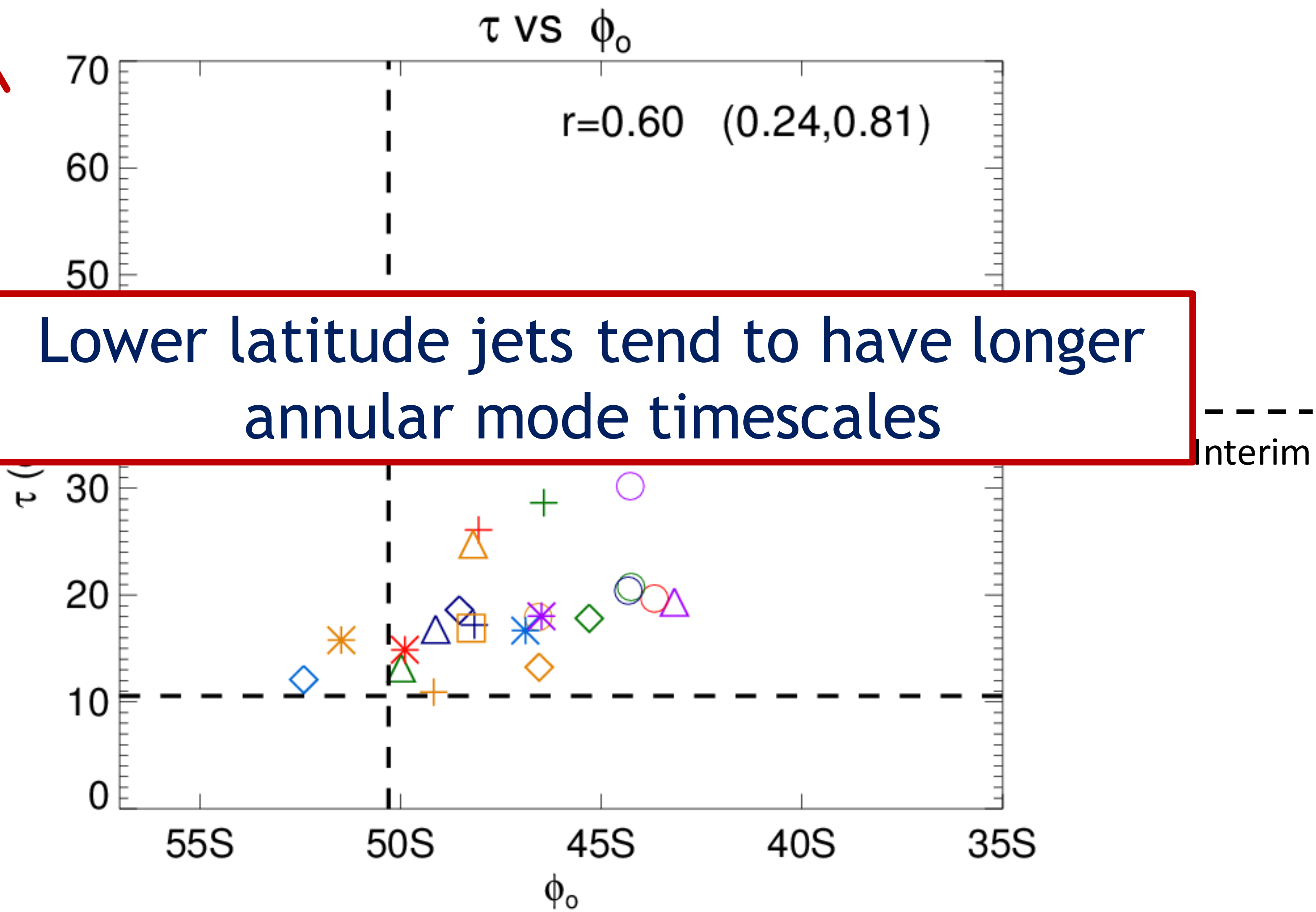
Annular mode timescale vs Jet Latitude ϕ_o

Annular mode timescale



Jet Latitude ϕ_o

Annular mode timescale vs Jet Latitude ϕ_o



Annular mode timescale

Lower latitude jets tend to have longer annular mode timescales

Jet Latitude ϕ_o

Lower latitude jets:

(1) Shift further poleward under climate forcings

(2) Have longer annular mode timescales

Lower latitude jets:

(1) Shift further poleward under climate forcings

(2) Have longer annular mode timescales

Could be used as an emergent constraint on the real world.

Lower latitude jets:

(1) Shift further poleward under climate forcings

(2) Have longer annular mode timescales

Could be used as an emergent constraint on the real world.

→ Real world is likely to shift less than many of the CMIP5 models since most models have an equatorward bias in the SH jet stream.

Lower latitude jets:

(1) Shift further poleward under climate forcings

(2) Have longer annular mode timescales

Previous interpretation of these relationships:

Lower latitude jets:
(1) Shift further poleward under climate forcings
(2) Have longer annular mode timescales

Previous interpretation of these relationships:

- Lower latitude jets, shift further poleward under climate forcings because of stronger eddy-mean flow feedbacks

Lower latitude jets:
(1) Shift further poleward under climate forcings
(2) Have longer annular mode timescales

Previous interpretation of these relationships:

- Lower latitude jets, shift further poleward under climate forcings because of stronger eddy-mean flow feedbacks
- Stronger eddy feedbacks inferred from the longer annular mode timescale Following the ideas of the Fluctuation-Dissipation theorem (Leith 1975)

Lower latitude jets:
(1) Shift further poleward under climate forcings
(2) Have longer annular mode timescales

Previous interpretation of these relationships:

- Lower latitude jets, shift further poleward under climate forcings because of stronger eddy-mean flow feedbacks

- Stronger eddy feedbacks inferred from the longer annular mode timescale Following the ideas of the Fluctuation-Dissipation theorem (Leith 1975)

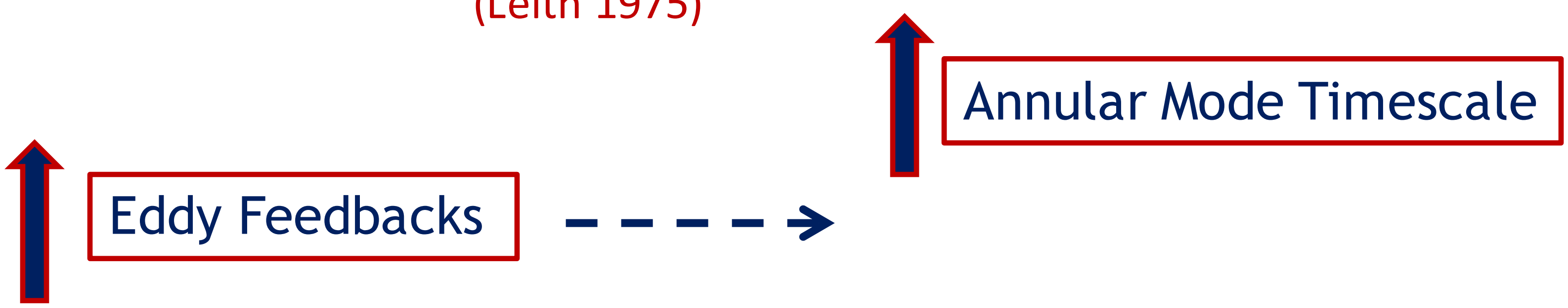
Eddy Feedbacks

Lower latitude jets:
(1) Shift further poleward under climate forcings
(2) Have longer annular mode timescales

Previous interpretation of these relationships:

- Lower latitude jets, shift further poleward under climate forcings because of stronger eddy-mean flow feedbacks

- Stronger eddy feedbacks inferred from the longer annular mode timescale Following the ideas of the Fluctuation-Dissipation theorem (Leith 1975)

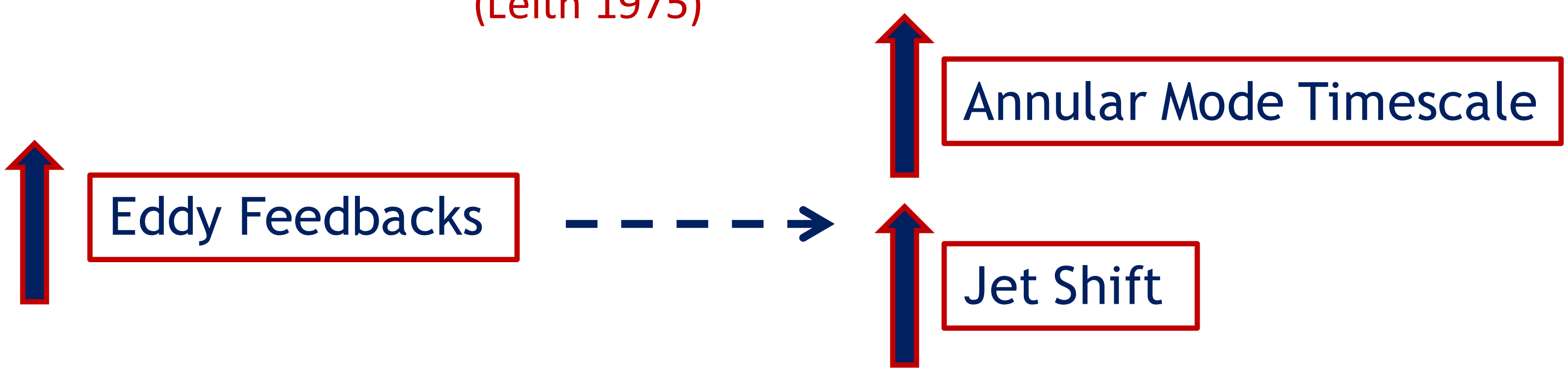


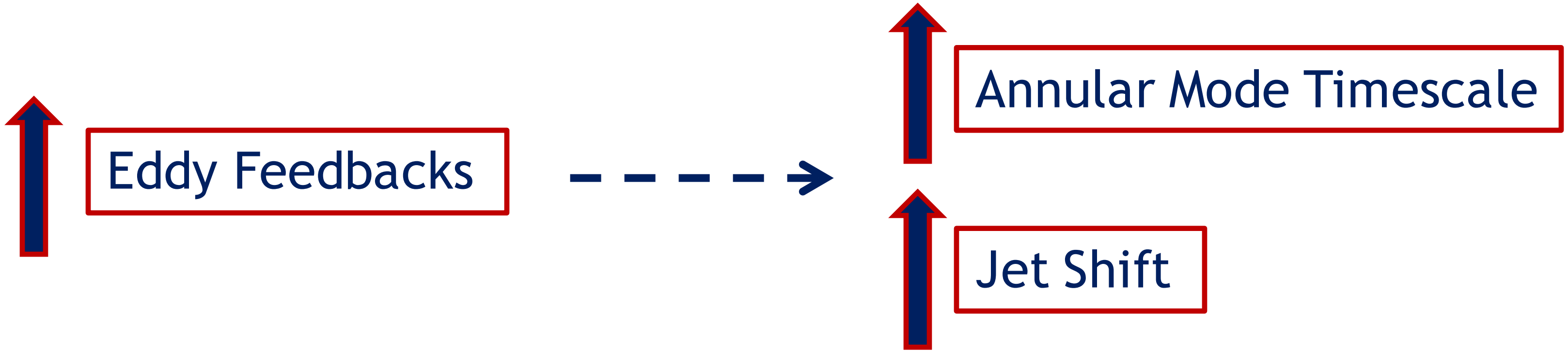
Lower latitude jets:
(1) Shift further poleward under climate forcings
(2) Have longer annular mode timescales

Previous interpretation of these relationships:

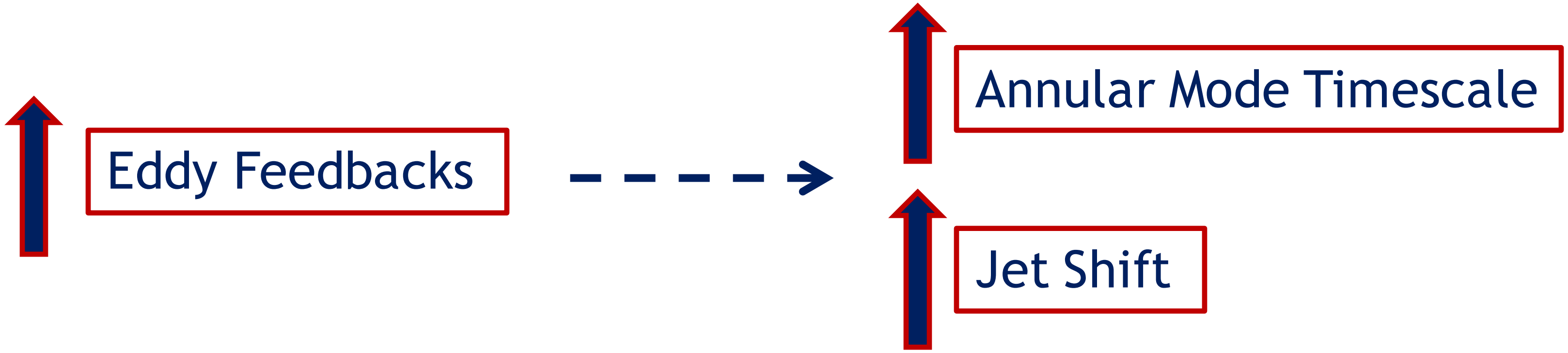
- Lower latitude jets, shift further poleward under climate forcings because of stronger eddy-mean flow feedbacks

- Stronger eddy feedbacks inferred from the longer annular mode timescale Following the ideas of the Fluctuation-Dissipation theorem (Leith 1975)

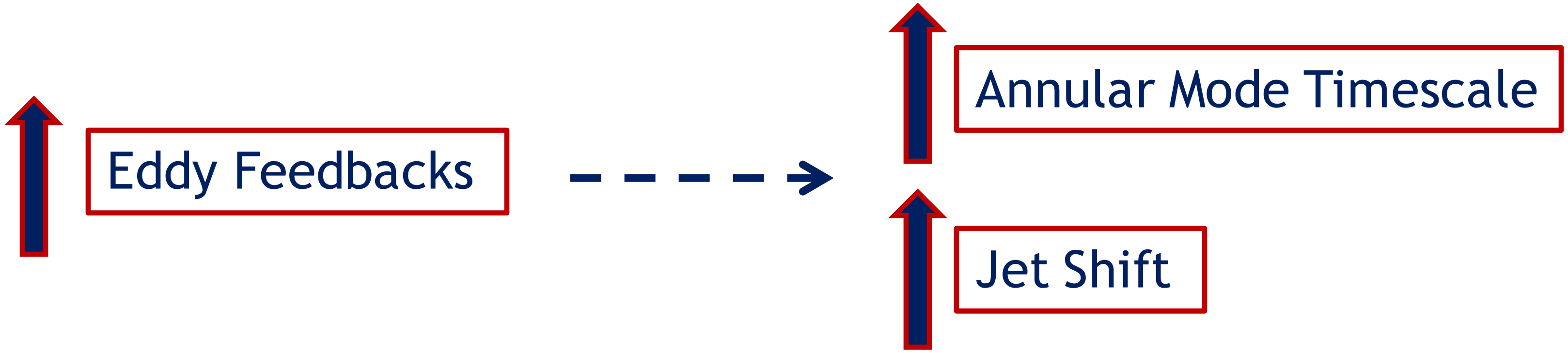




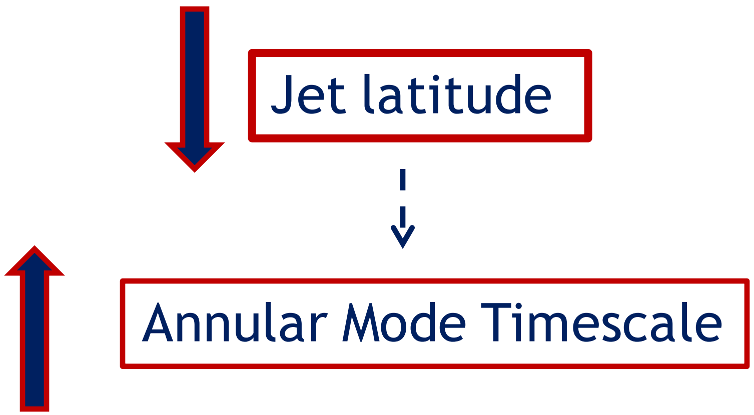
Line of reasoning:

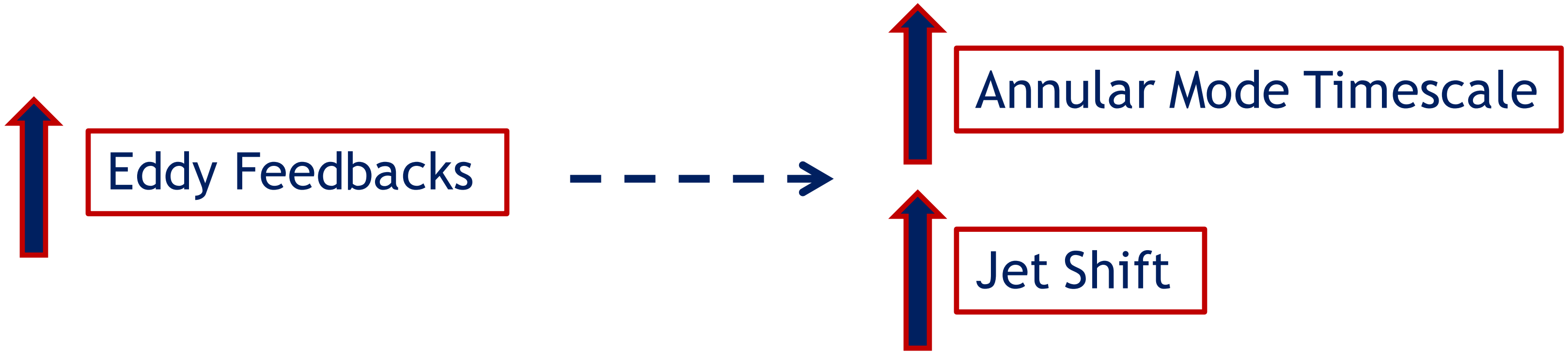


Line of reasoning:

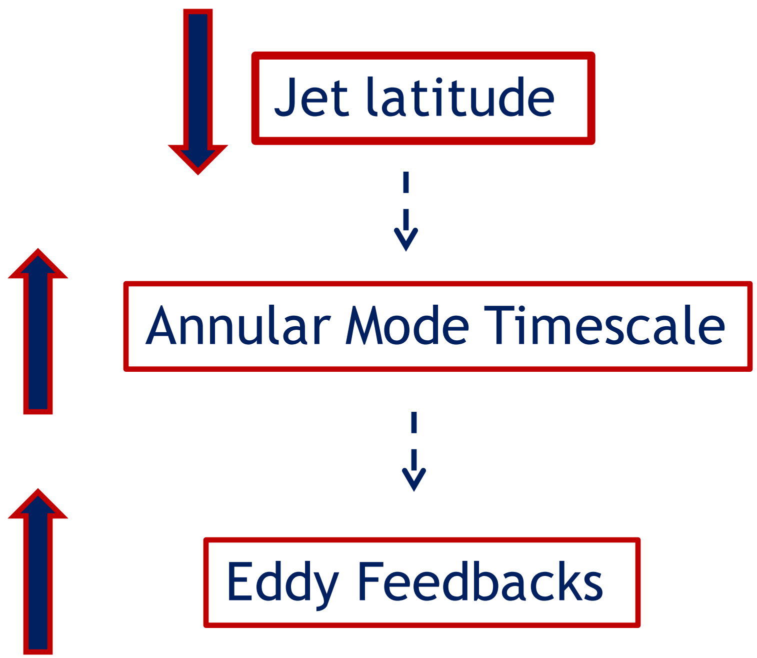


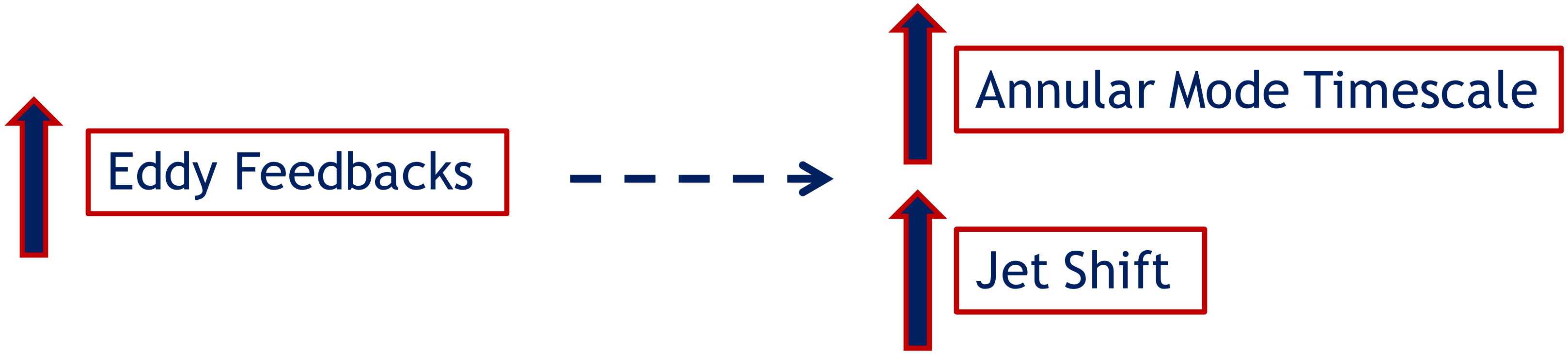
Line of reasoning:



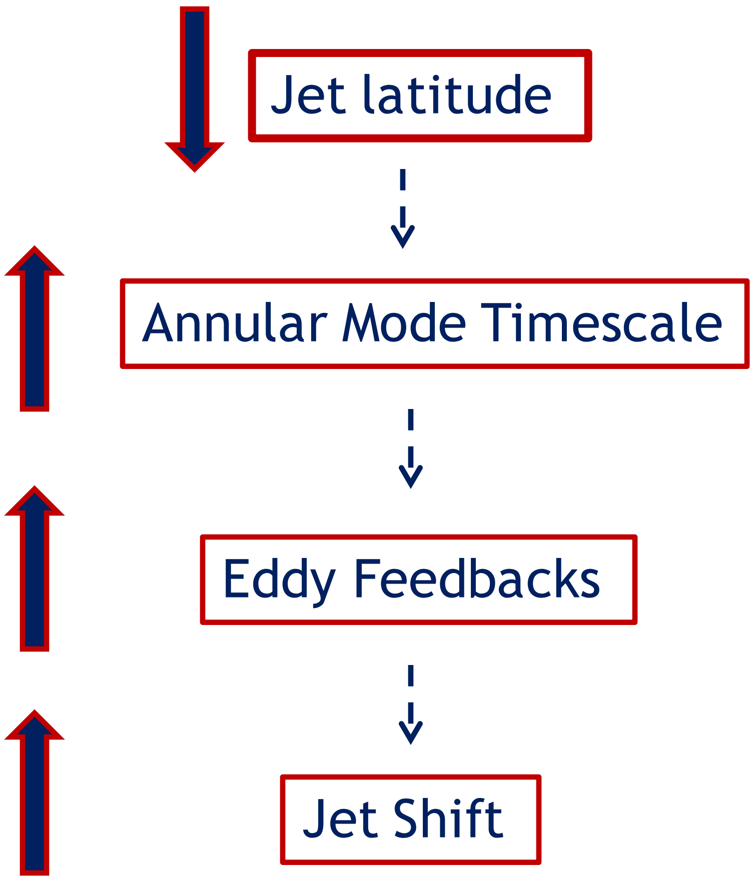


Line of reasoning:





Line of reasoning:



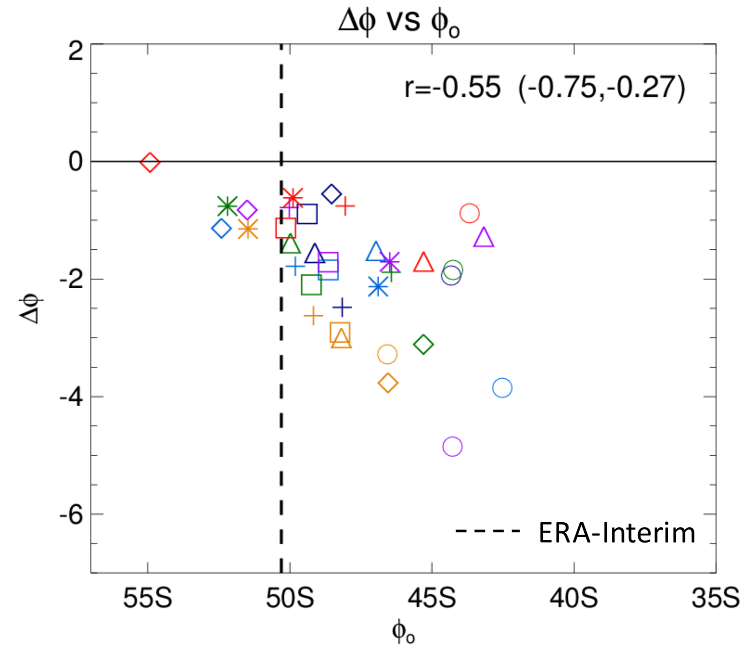
The seasonality of these relationships

Jet Shift Δ□

vs

Jet Latitude □$_o$

Annual Mean



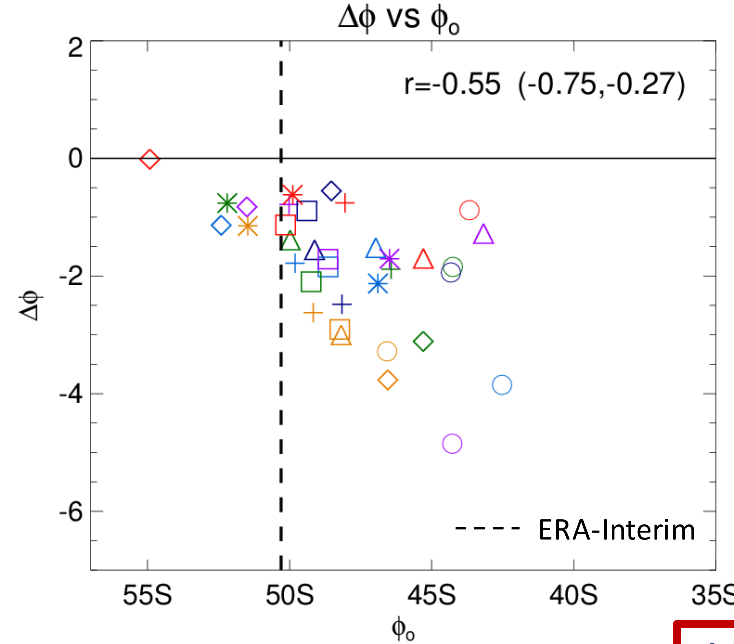
Simpson and Polvani 2016

Jet Shift Δ□

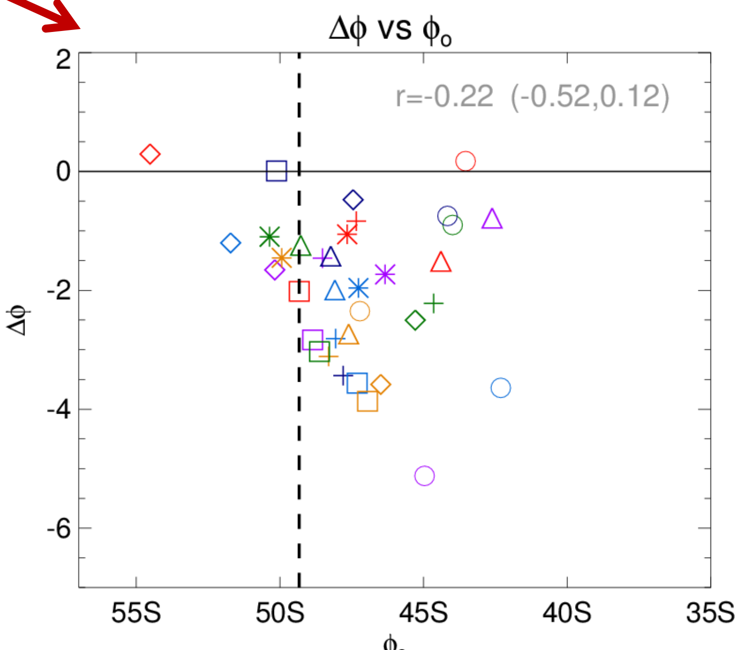
vs

Jet Latitude □$_o$

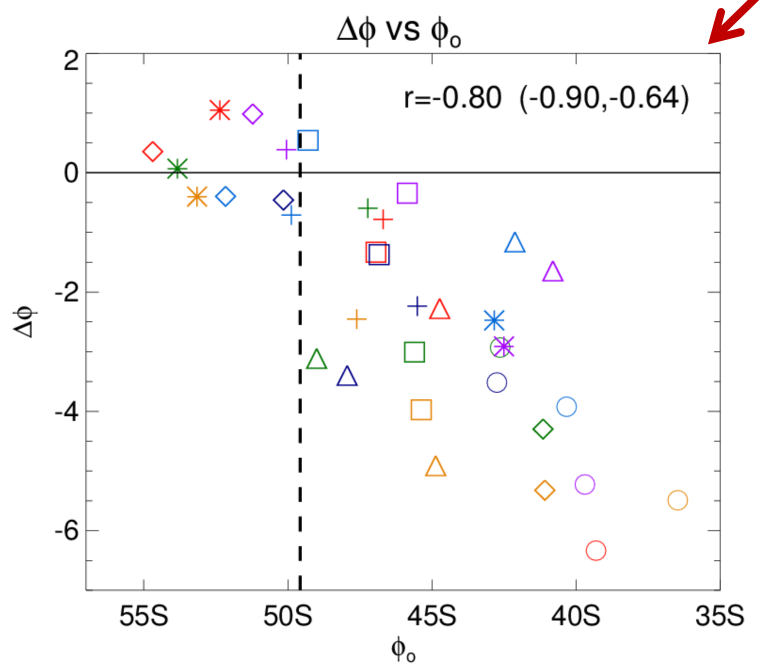
Annual Mean



DJF

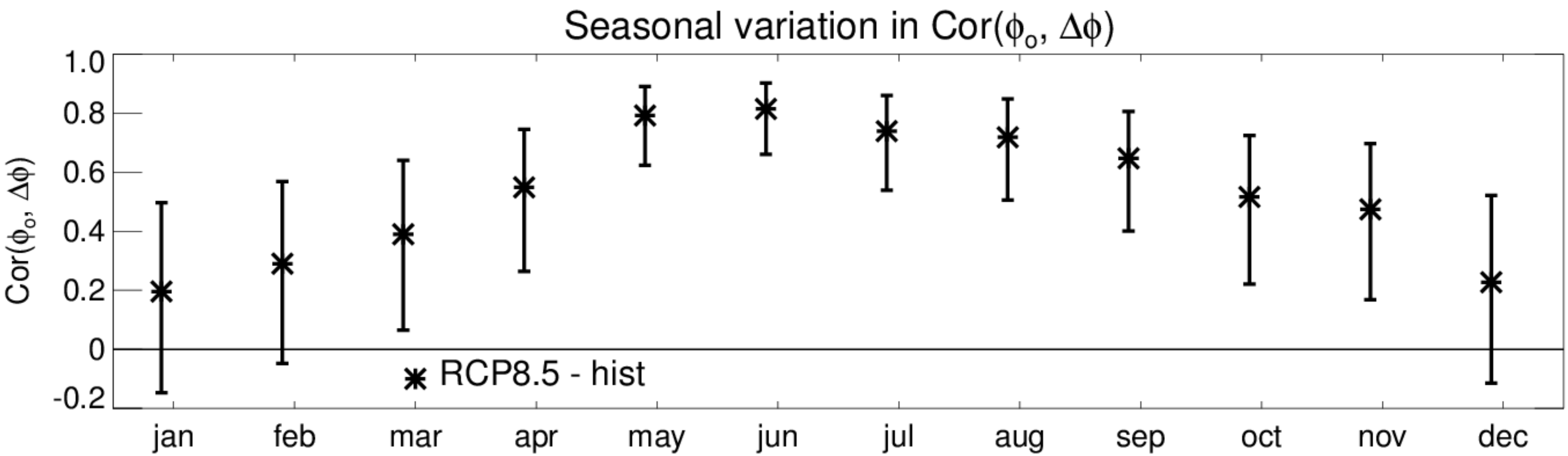


JJA



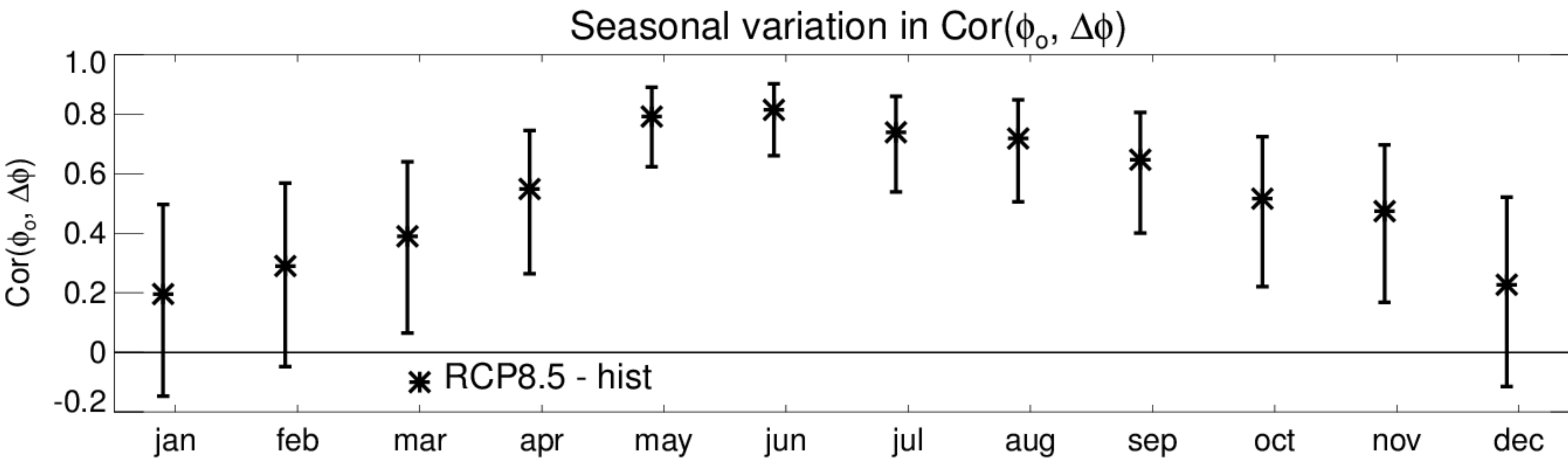
Simpson and Polvani 2016

Seasonal variation of the correlation between ϕ_o and $\Delta\phi$



Simpson and Polvani 2016

Seasonal variation of the correlation between ϕ_o and $\Delta\phi$

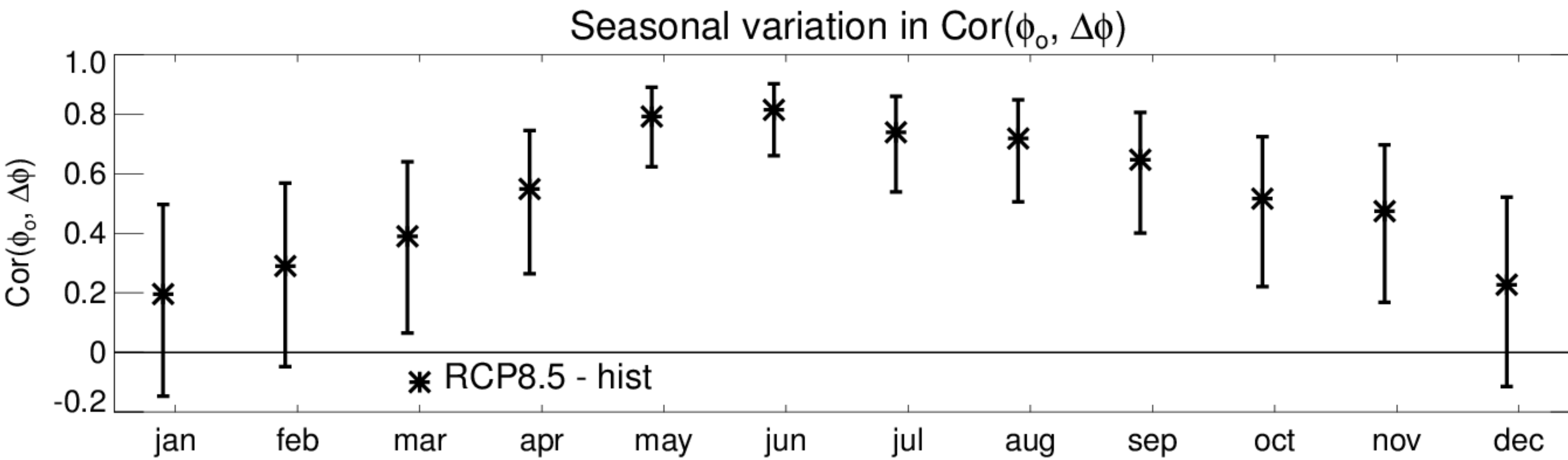


	SON	DJF	MAM	JJA	Annual[a]
corr(Φ^{20C}, $\Delta\Phi$)	−0.61	−0.08	−0.76	−0.81	−0.77

Kidston and Gerber (2010)

Simpson and Polvani 2016

Seasonal variation of the correlation between ϕ_o and $\Delta\phi$

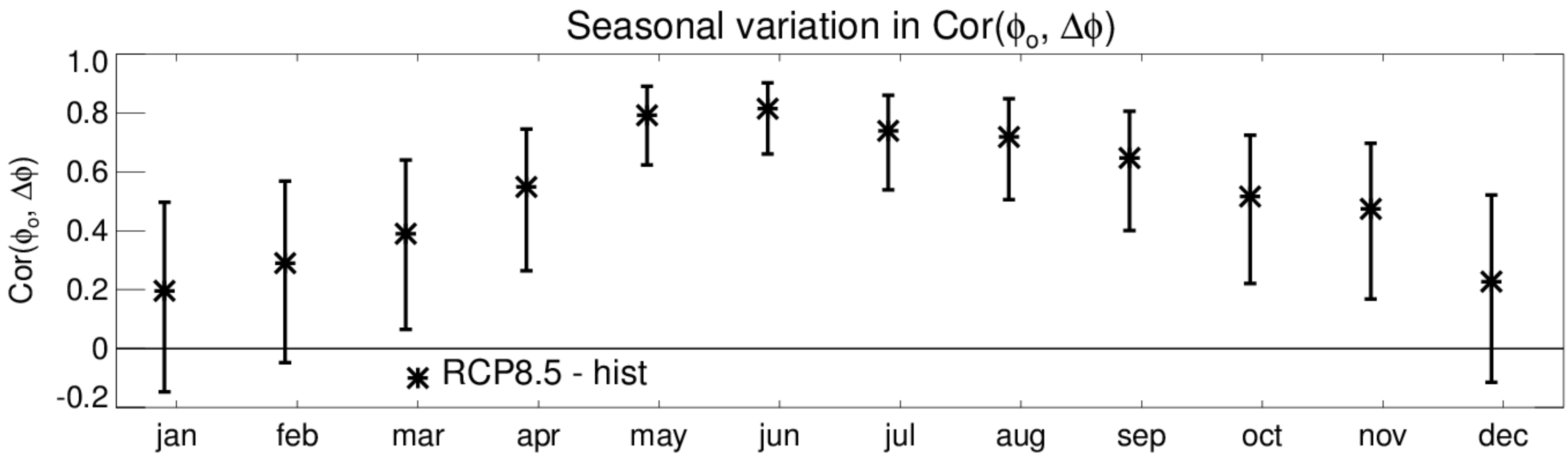


	SON	DJF	MAM	JJA	Annual[a]
corr(Φ^{20C}, $\Delta\Phi$)	−0.61	−0.08	−0.76	−0.81	−0.77

Kidston and Gerber (2010)

Simpson and Polvani 2016

Seasonal variation of the correlation between ϕ_o and $\Delta\phi$



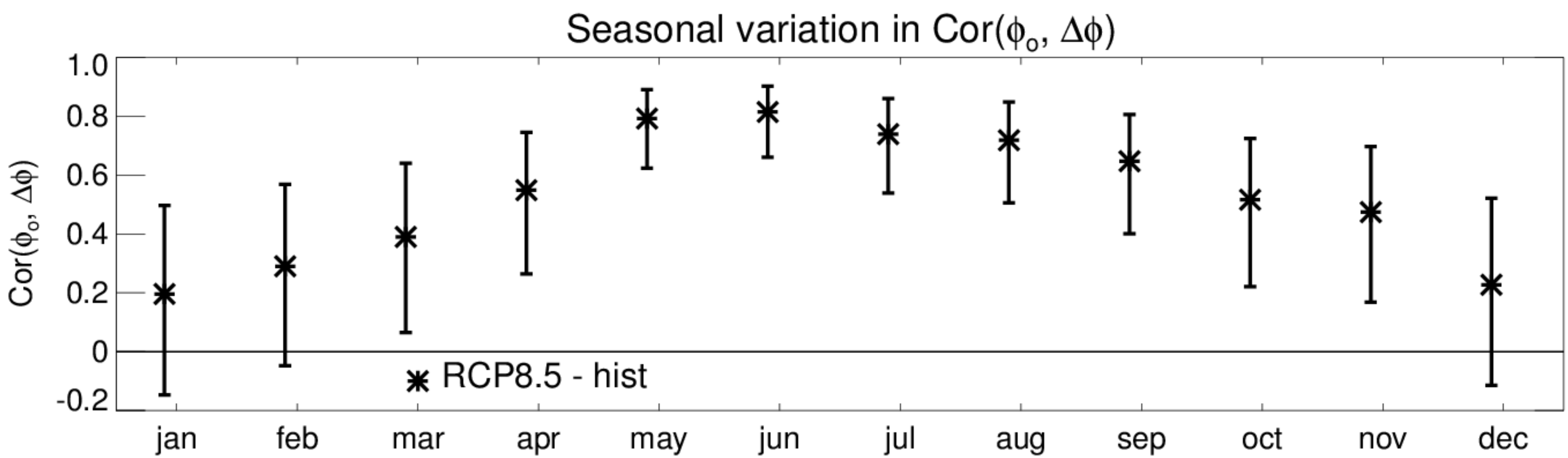
	SON	DJF	MAM	JJA	Annual[a]
corr(Φ^{20C}, $\Delta\Phi$)	−0.61	−0.08	−0.76	−0.81	−0.77

Kidston and Gerber (2010)

Suggested that the relationship in summer breaks down because of the varying representation of ozone depletion/recovery among the models.

Simpson and Polvani 2016

Seasonal variation of the correlation between ϕ_o and $\Delta\phi$

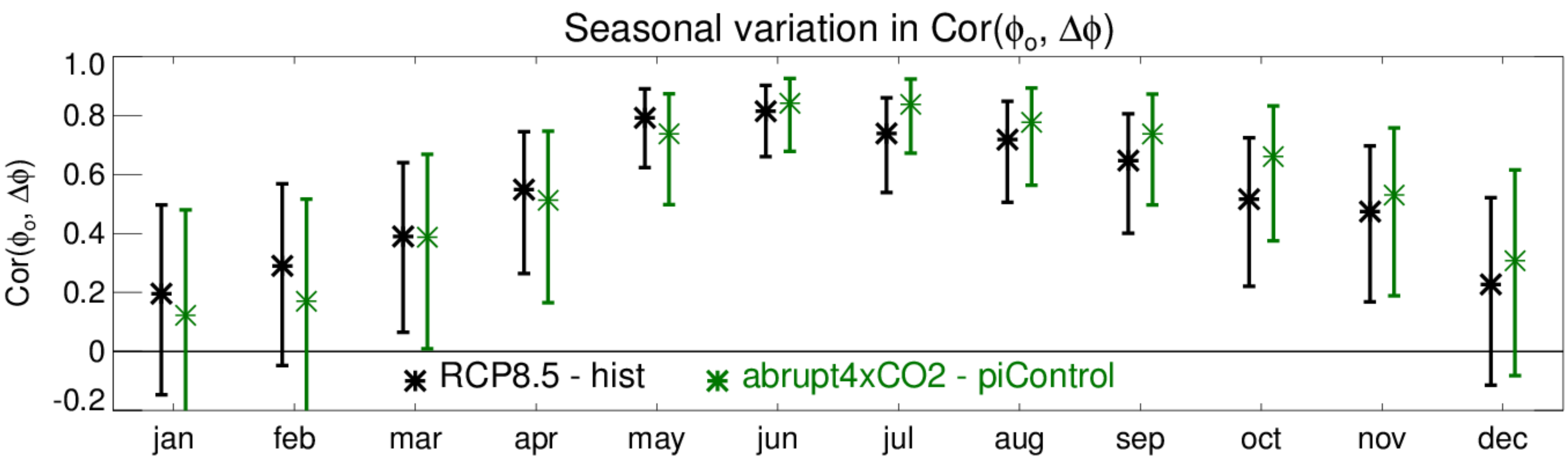


How does it look in the abrupt4xCO2 simulations?

- piControl (200y), o
- abrupt4xCO2 (years 50-100) – piControl (200y),

Simpson and Polvani 2016

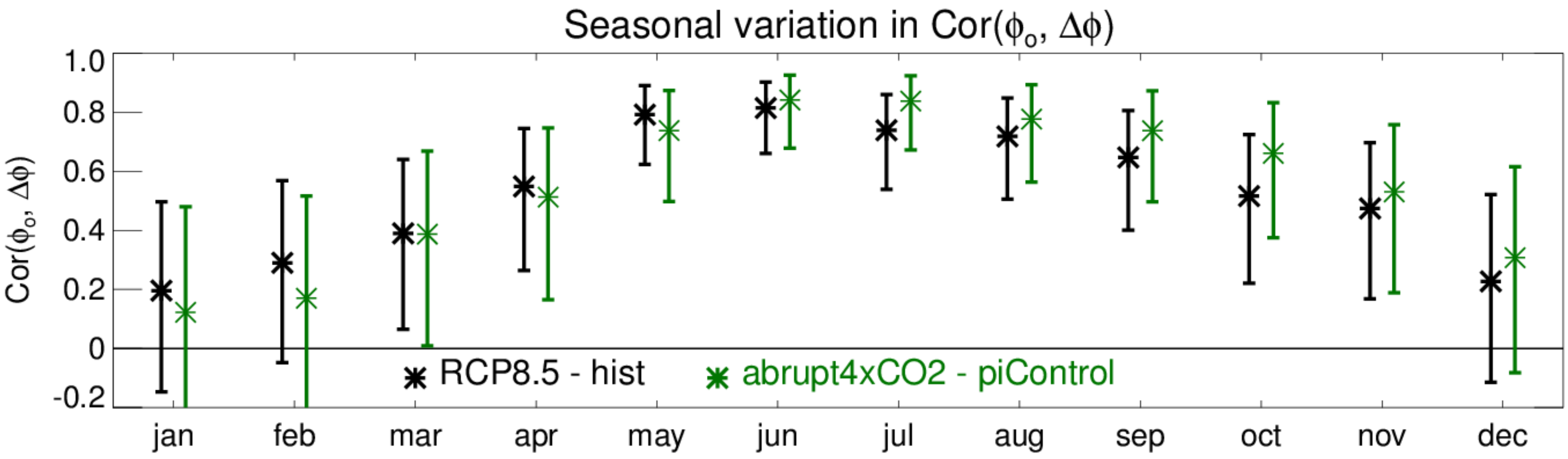
Seasonal variation of the correlation between □$_o$and Δ□



How does it look in the abrupt4xCO2 simulations?

- piControl (200y), o
- abrupt4xCO2 (years 50-100) – piControl (200y),

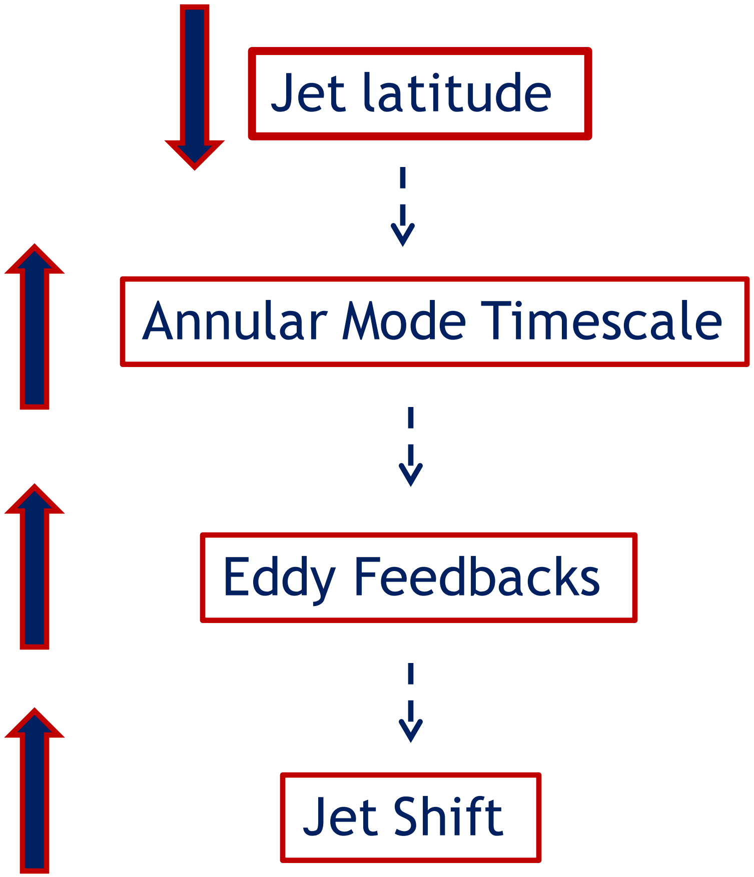
Seasonal variation of the correlation between ϕ_o and $\Delta\phi$



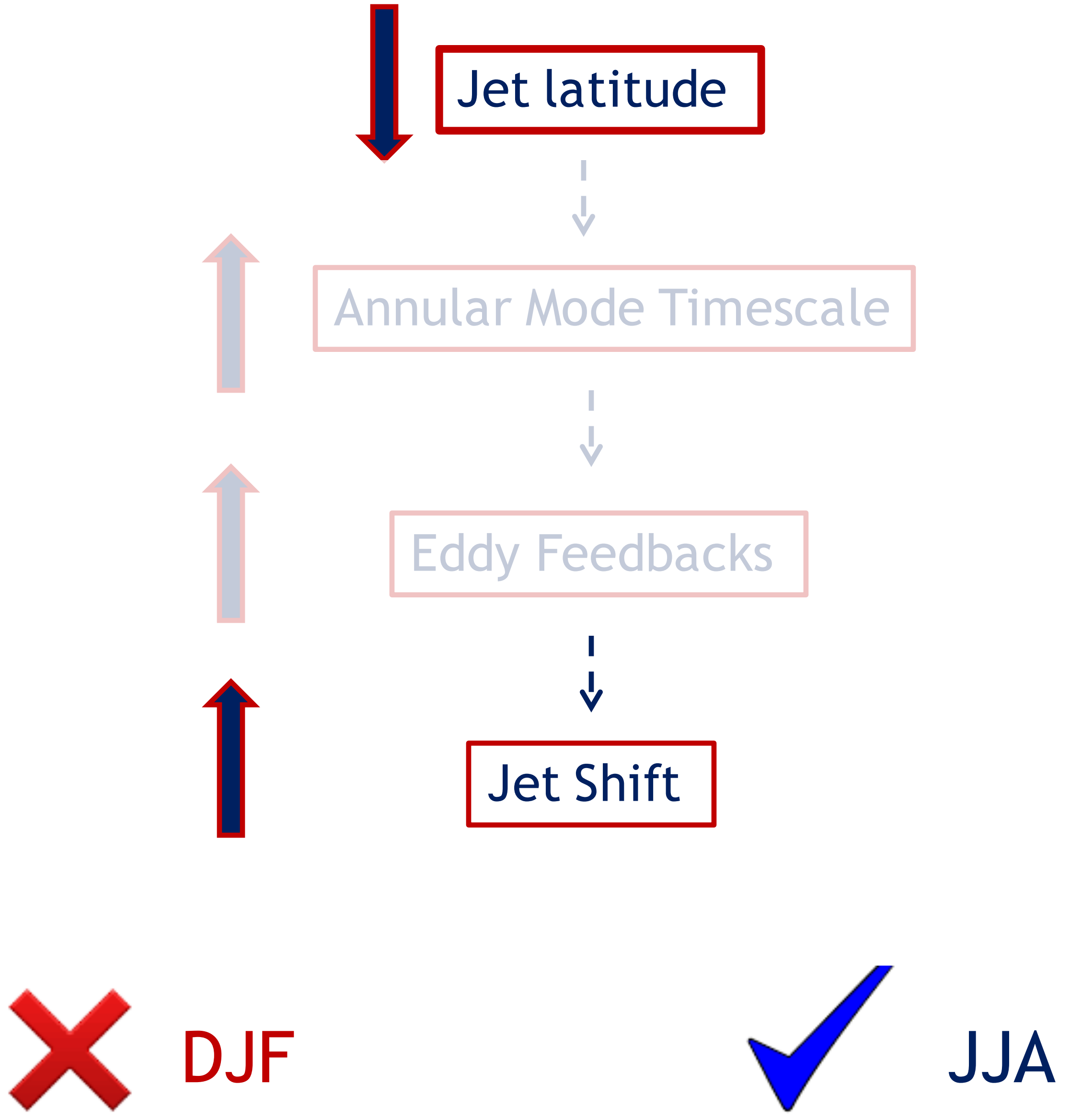
The relationship breaks down in summer, regardless of the representation of ozone depletion/recovery

Simpson and Polvani 2016

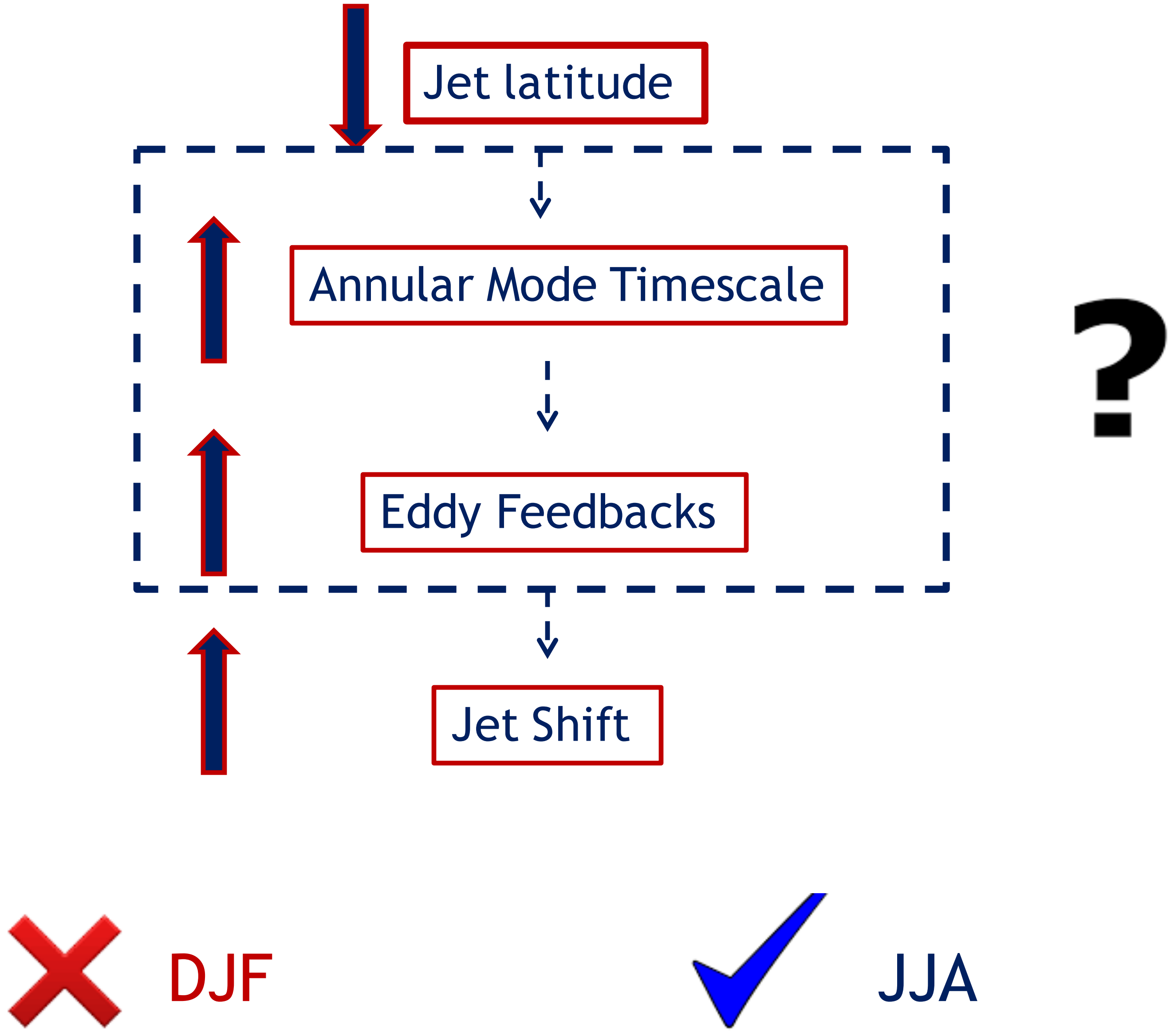
Line of reasoning:

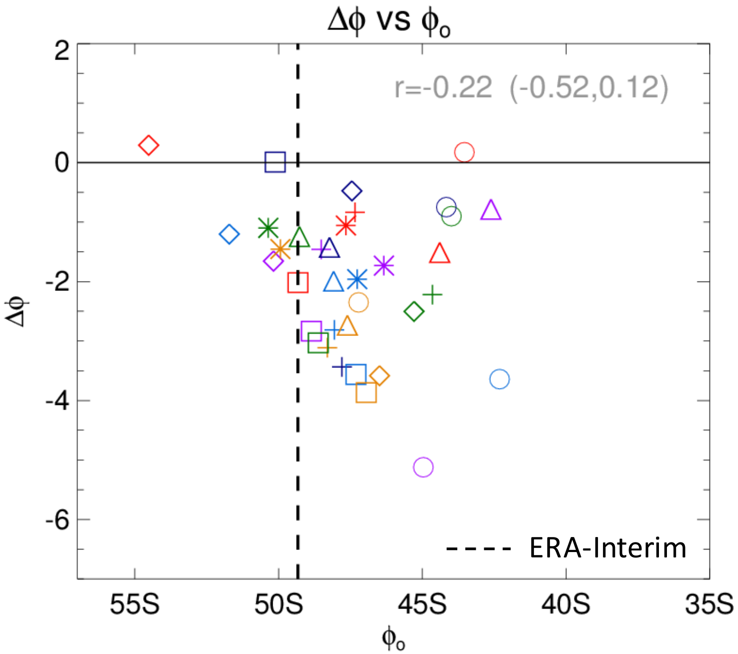


Line of reasoning:



Line of reasoning:



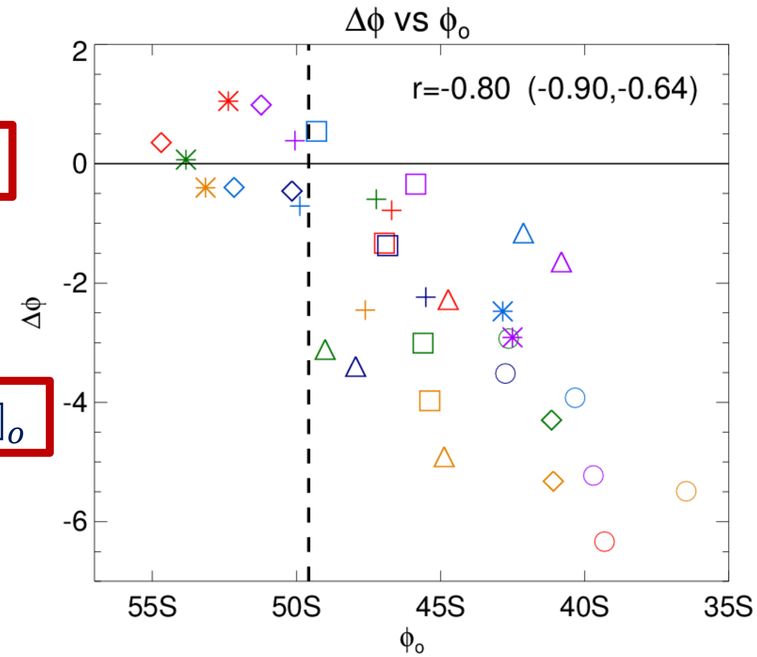


DJF

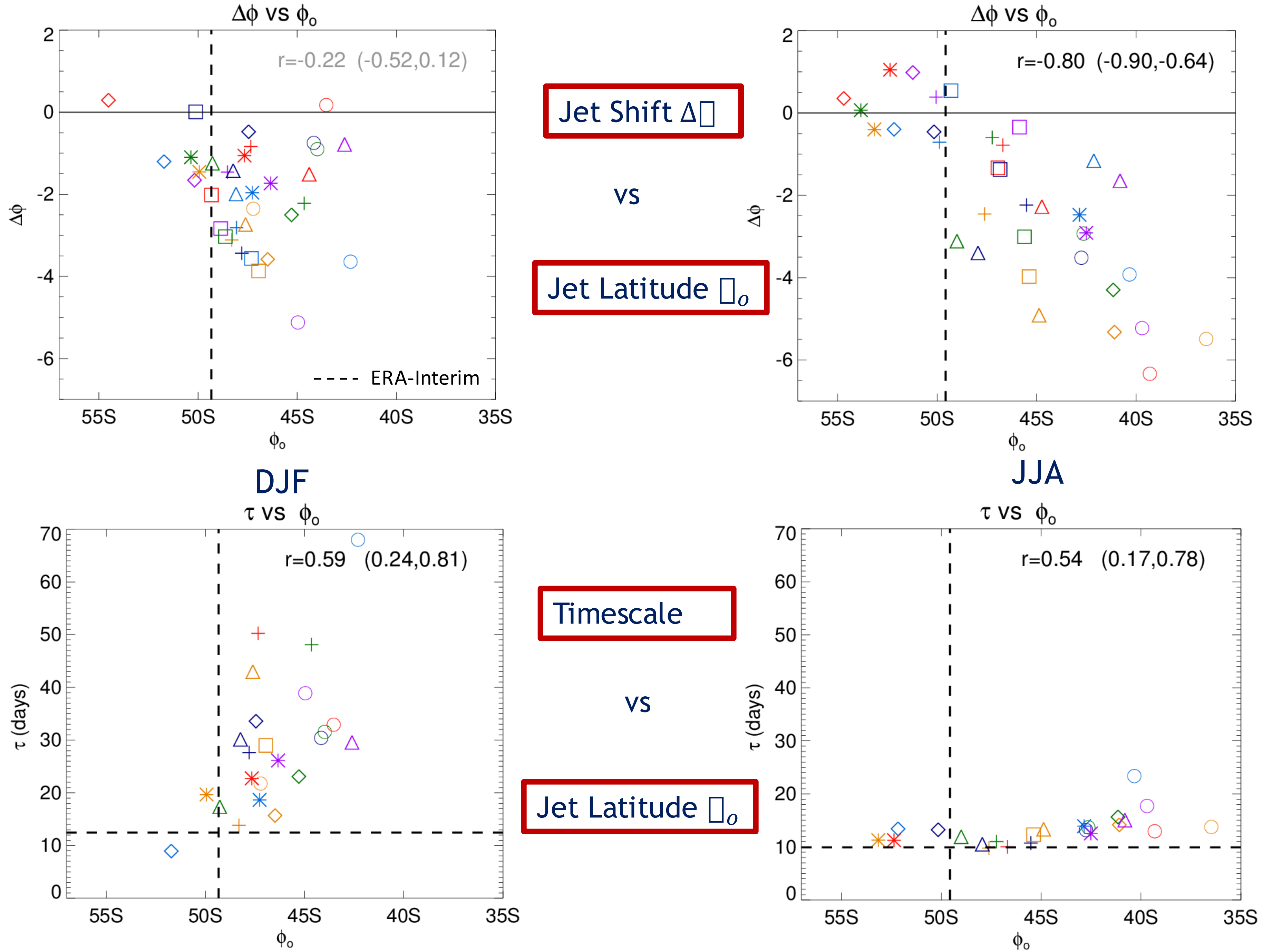
Jet Shift Δ□

vs

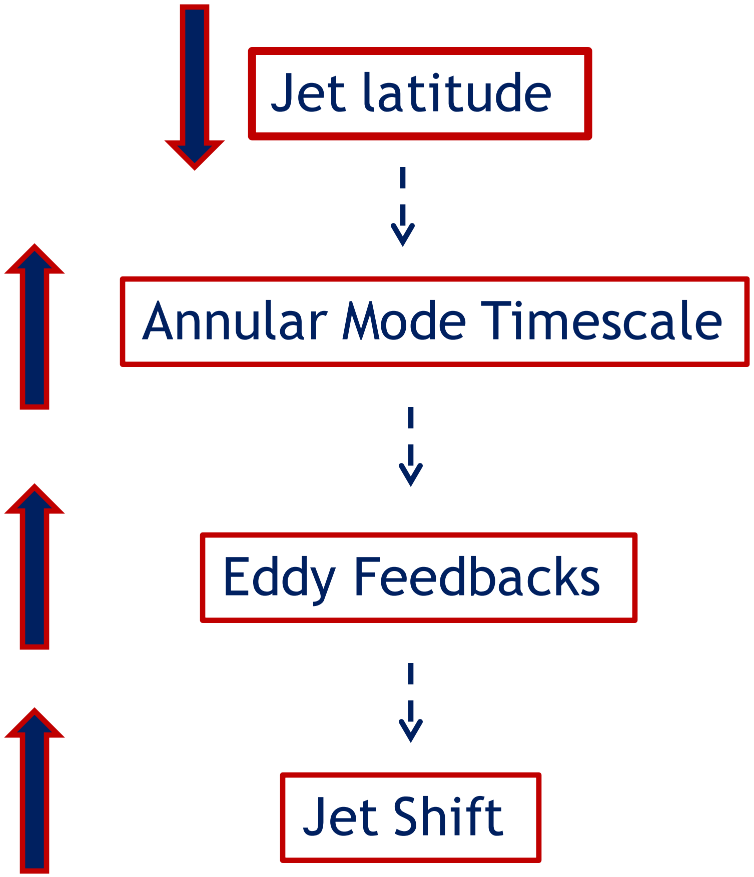
Jet Latitude $\square_o$



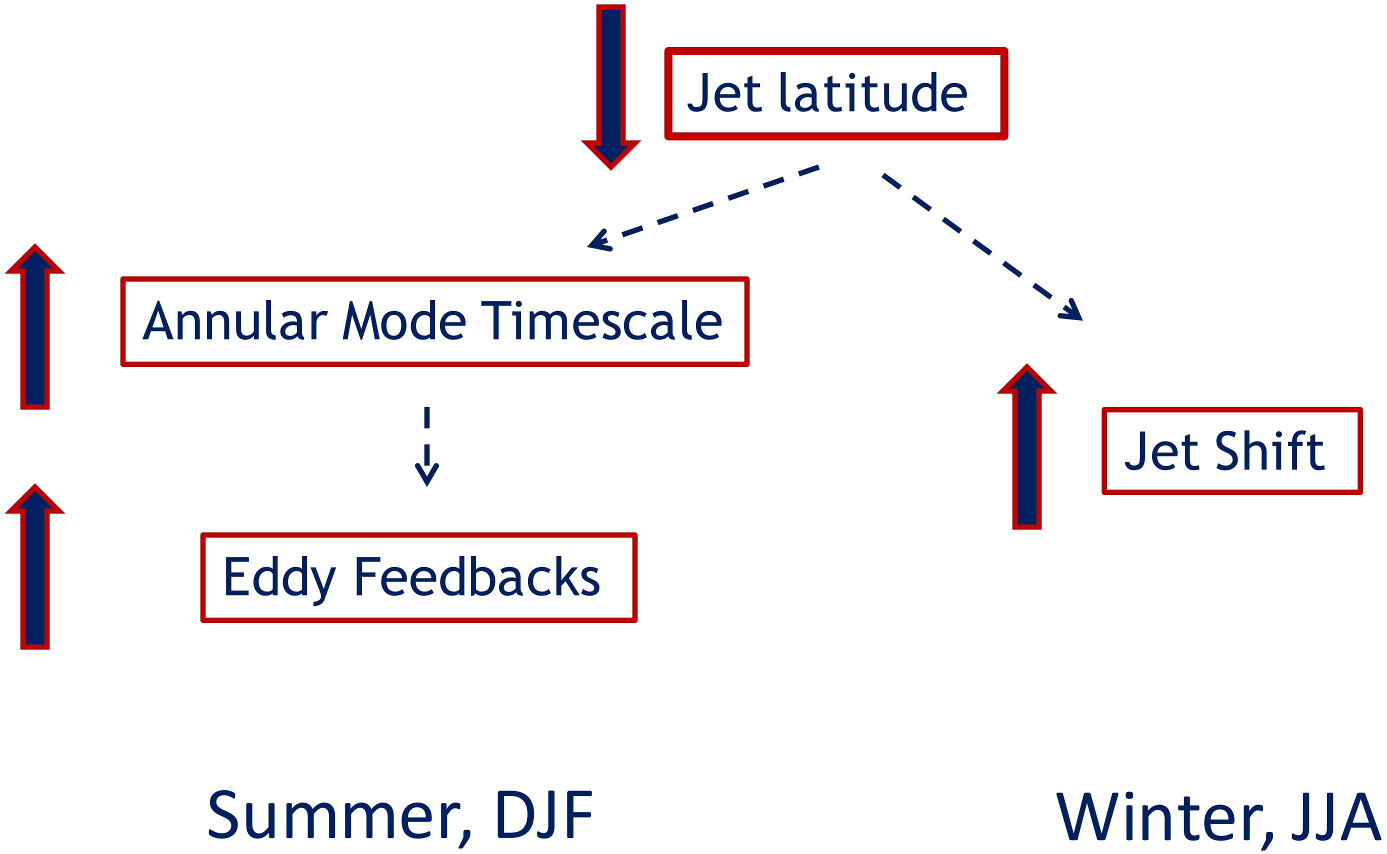
JJA


Δφ vs φo
r=-0.22 (-0.52,0.12)
ERA-Interim
Δφ
φo
Δφ vs φo
r=-0.80 (-0.90,-0.64)
Δφ
φo
Jet Shift Δ□
vs
Jet Latitude □o
DJF
τ vs φo
r=0.59 (0.24,0.81)
τ (days)
φo
JJA
τ vs φo
r=0.54 (0.17,0.78)
τ (days)
φo
Timescale
vs
Jet Latitude □o
55S
50S
45S
40S
35S

Line of reasoning:

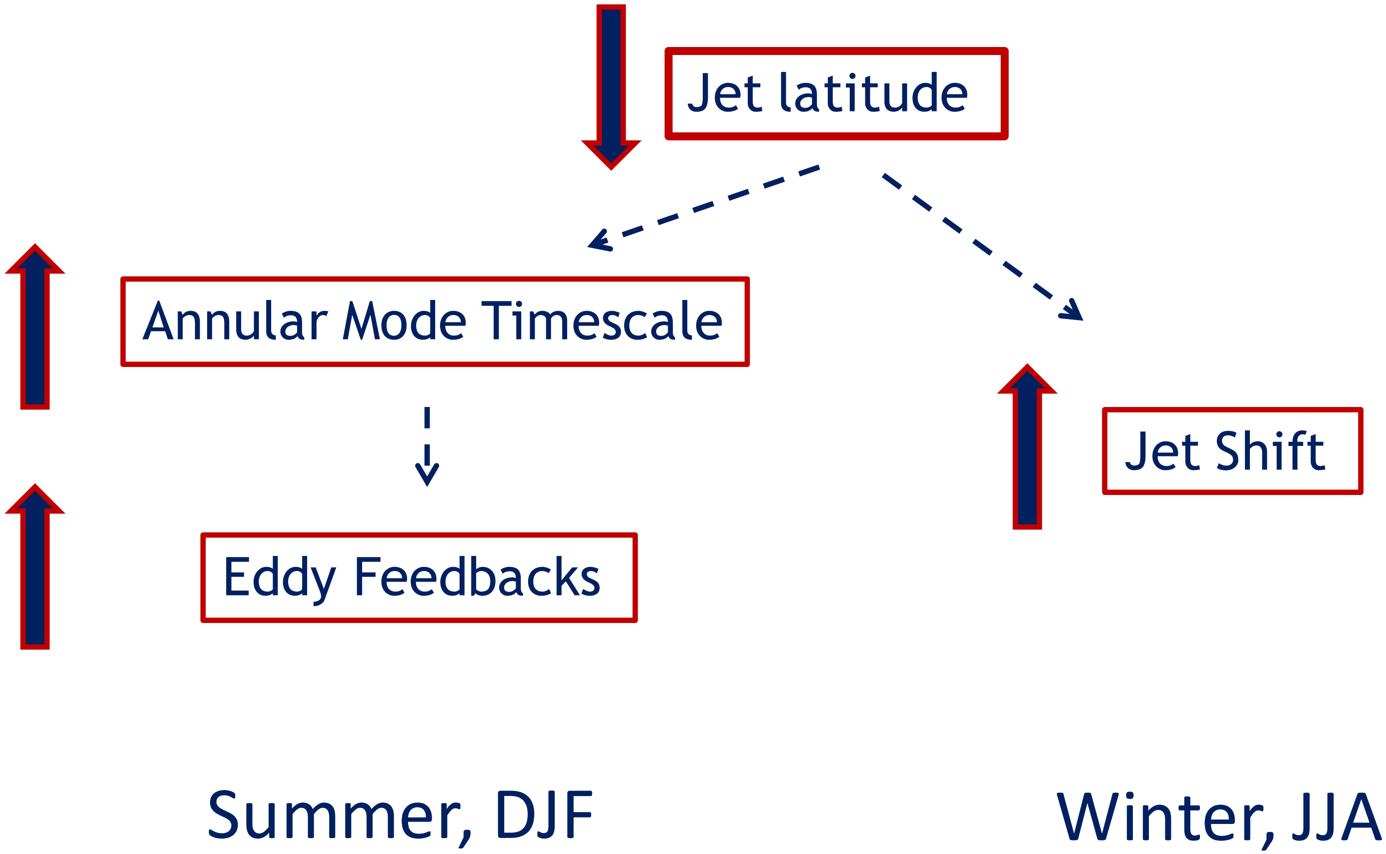


Line of reasoning:



See also Simpson et al 2013 for DJF
model spread in eddy feedback strength

Line of reasoning:



See also Simpson et al 2013 for DJF
model spread in eddy feedback strength

The Southern Annular Mode - Summary

The Southern Annular Mode - Summary

We do have an emergent constraint…

The Southern Annular Mode - Summary

We do have an emergent constraint…

Models with lower latitude climatological jets, shift further poleward under climate change

The Southern Annular Mode - Summary

We do have an emergent constraint...

Models with lower latitude climatological jets, shift further poleward under climate change

BUT this is only really true in the winter months

The Southern Annular Mode - Summary

We do have an emergent constraint…

Models with lower latitude climatological jets, shift further poleward under climate change

BUT this is only really true in the winter months

This seasonality doesn’t fit with our theoretical understanding

The Southern Annular Mode - Summary

We do have an emergent constraint…

Models with lower latitude climatological jets, shift further poleward under climate change

BUT this is only really true in the winter months

This seasonality doesn’t fit with our theoretical understanding

Is it reasonable to use emergent constraints like this, when we don’t fully understand them?

Topics

- SAM (Southern Annular Mode)

  A case where we have a clear emergent constraint

  Although it may not be fully understood

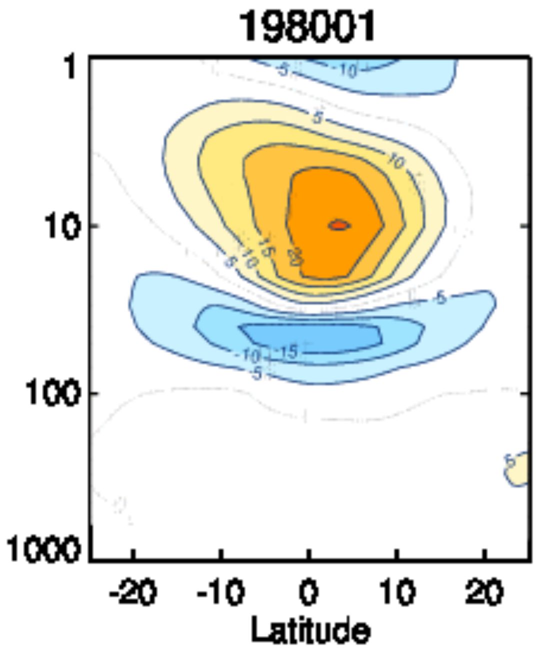
- QBO (Quasi-Biennial Oscillation)

  New results from QBOi – models are all over the place

- North Atlantic Jet

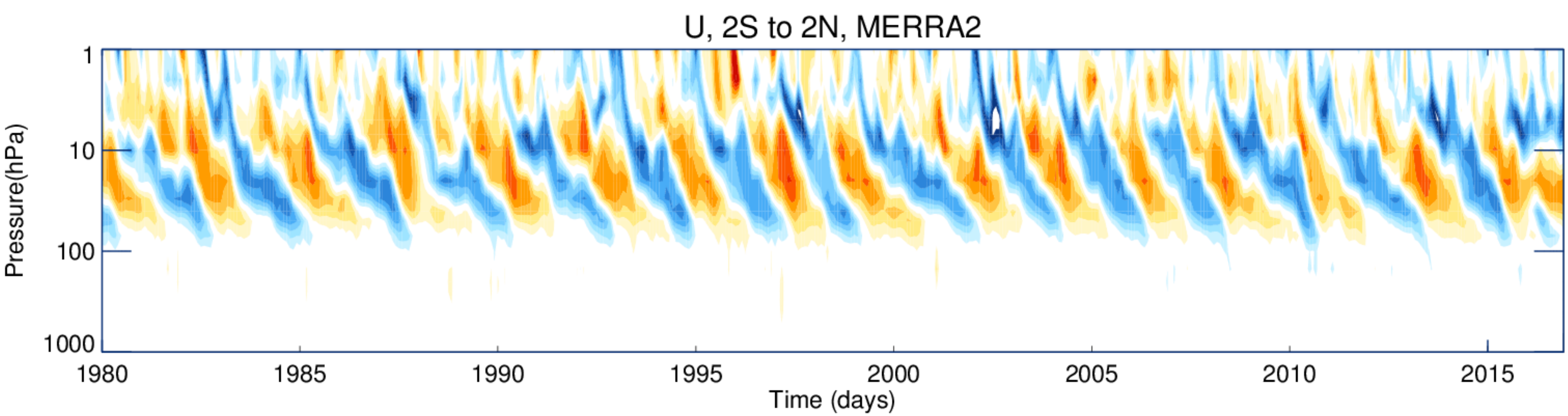
  A case where we need to be careful with our observational uncertainty

QBO = Quasi-periodic oscillation between easterly and westerly winds in the equatorial stratosphere. Period or roughly 2 years.



Monthly mean zonal mean zonal winds in the tropical stratosphere.

Historical evolution of 2S-2N, zonal mean zonal wind from MERRA2.



Why care about the QBO?

Why care about the QBO?

- Important component of variability in the stratospheric circulation/ozone

Why care about the QBO?

- Important component of variability in the stratospheric circulation/ozone
- Connections to NH polar vortex variability, with subsequent tropospheric impacts (Holton-Tan effect, Holton and Tan 1980)

BBC suggesting the westerly phase of the QBO might have played a role in the extremely wet winter of 2013/2014.

BBC | Sign in | News | Sport | Weather | Shop | Earth | Travel | M

NEWS

Home | Video | World | US & Canada | UK | Business | Tech | Science | Magazine | Ent

UK | England | N. Ireland | Scotland | Wales | Politics

UK weather: Why has it been so wet?

By Nick Miller
Meteorologist, BBC Weather Centre

30 January 2014 | UK

Share

Nick Miller: "It's a weather pattern which has been relentless so far this winter and is set to stay with us into February"

All of this might just be down to the UK weather's natural variability. It seems to like going from one extreme to another. This time last year there was plenty of snow around and more was to come in March.

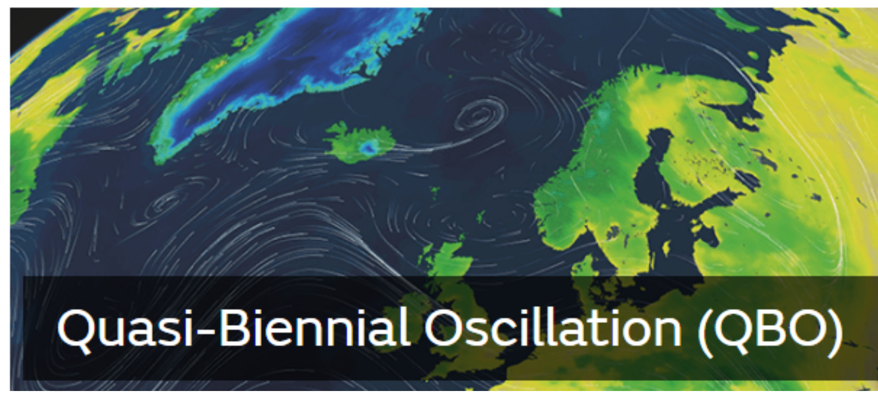
But there might be another reason the jet stream is behaving as it is - the quasi-biennial oscillation or QBO for short.

This is a cycle involving a band of winds high above the equator. Every 14 months or so these winds switch from easterly to westerly.

The Met Office believes a westerly phase is more likely to produce stormy winter weather in the UK. There has been a westerly phase since early last year.

http://www.bbc.com/news/uk-25962332

Met Office



- When the QBO is easterly, the chance of a weak jet stream, sudden stratospheric warming events and colder winters in Northern Europe is increased.
- When the QBO is westerly, the chance of a strong jet, a mild winter, winter storms and heavy rainfall increases.

http://www.metoffice.gov.uk/learning/quasi-biennial-oscillation

Why care about the QBO?

- Important component of variability in the stratospheric circulation/ozone
- Connections to NH polar vortex variability, with subsequent tropospheric impacts (Holton-Tan effect, Holton and Tan 1980)

Why care about the QBO?

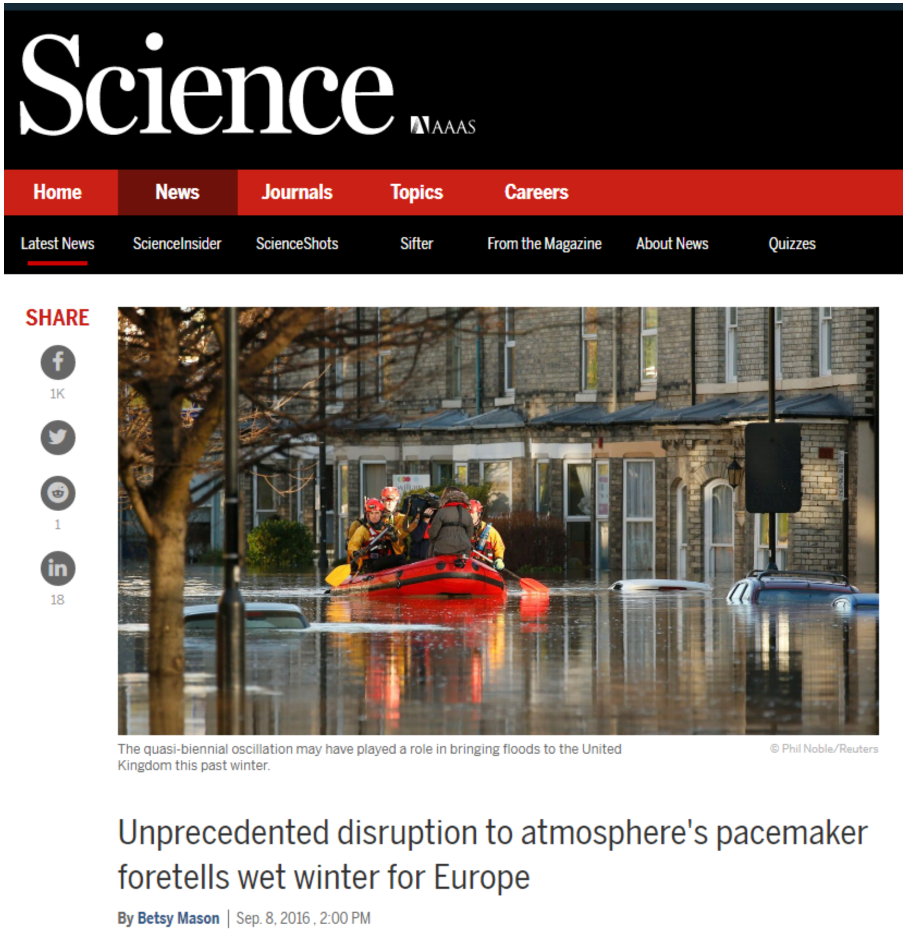
- Important component of variability in the stratospheric circulation/ozone
- Connections to NH polar vortex variability, with subsequent tropospheric impacts (Holton-Tan effect, Holton and Tan 1980)
- Impacts on tropical deep convection (Nie and Sobel 2015)

Why care about the QBO?

- Important component of variability in the stratospheric circulation/ozone
- Connections to NH polar vortex variability, with subsequent tropospheric impacts (Holton-Tan effect, Holton and Tan 1980)
- Impacts on tropical deep convection (Nie and Sobel 2015)
- Modulation of the Madden Julian Oscillation (MJO) (Marshall et al 2016, Son et al 2017)

Why care about the QBO?

- Important component of variability in the stratospheric circulation/ozone
- Connections to NH polar vortex variability, with subsequent tropospheric impacts (Holton-Tan effect, Holton and Tan 1980)
- Impacts on tropical deep convection (Nie and Sobel 2015)
- Modulation of the Madden Julian Oscillation (MJO) (Marshall et al 2016, Son et al 2017)
- In general, a possible source of predictability given its regularity (?)



Science AAAS

Home News Journals Topics Careers

Latest News ScienceInsider ScienceShots Sifter From the Magazine About News Quizzes

SHARE

1K

1

18

The quasi-biennial oscillation may have played a role in bringing floods to the United Kingdom this past winter.

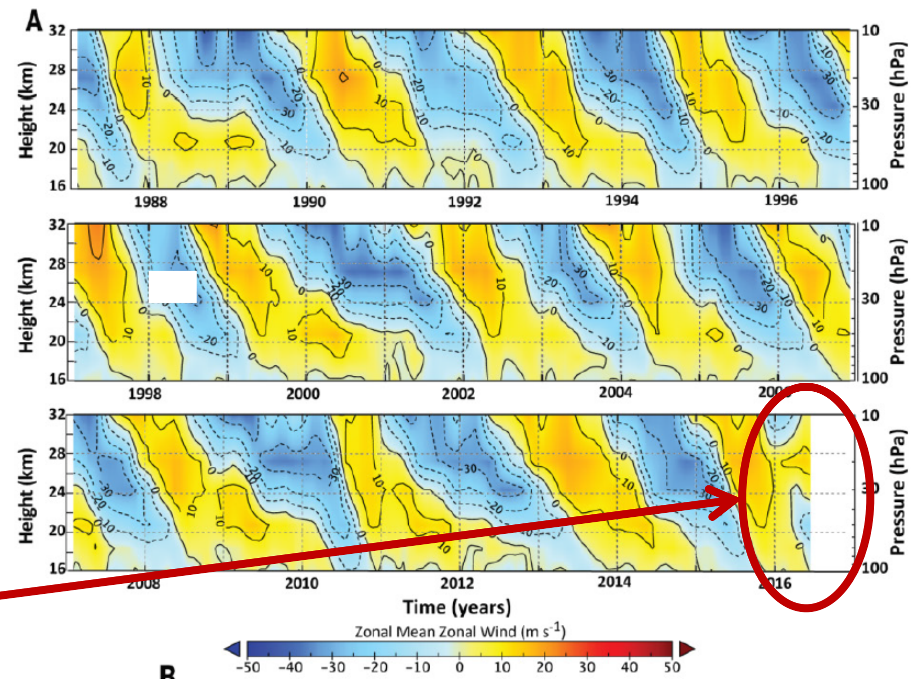
© Phil Noble/Reuters

Unprecedented disruption to atmosphere's pacemaker foretells wet winter for Europe

By Betsy Mason | Sep. 8, 2016 , 2:00 PM

Unprecedented disruption of the QBO in early 2016

Not predicted by seasonal forecasts



Disruption of the decending westerly phase

Osprey et al (2016), Newman et al (2016)

The QBO in models

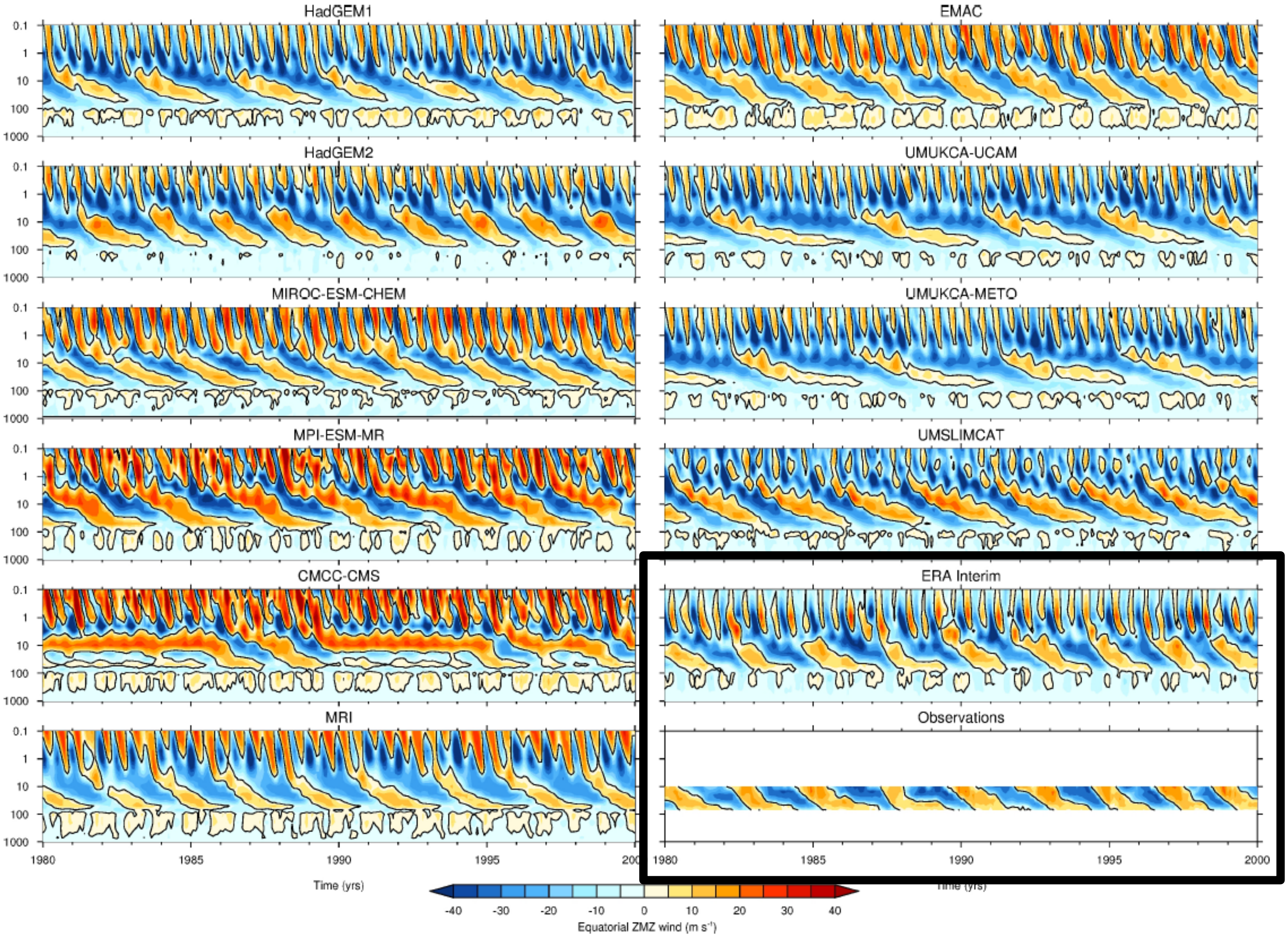
Models with an internally generated QBO

CMIP3 1 model (HadGEM1)

CCMVal2 5 models (EMAC, MRI, UMSLIMCAT, UMUKCA-METO, UMUKCA-UCAM)

CMIP5 4 models (MIROC-ESM-CHEM, MPI-ESM-MR, HadGEM2-CC, CMCC-CMS)

The QBO in models



Schenzinger et al 2017

QBOi

SPARC activity to improve our understanding of the QBO, its impacts and its representation in models

Lead by Scott Osprey, Neal Butchart and James Anstey

QBOi

SPARC activity to improve our understanding of the QBO, its impacts and its representation in models

Lead by Scott Osprey, Neal Butchart and James Anstey

- 17 models participating
- 5 main experiments

AMIP
Historical climatological SSTs
2xCO2 (Historical climatological SSTs + 2K + 2xCO2)
4xCO2 (Historical climatological SSTs + 4K + 4xCO2)
Hindcasts

Present day QBO
In the QBOi models

ERA-Interim

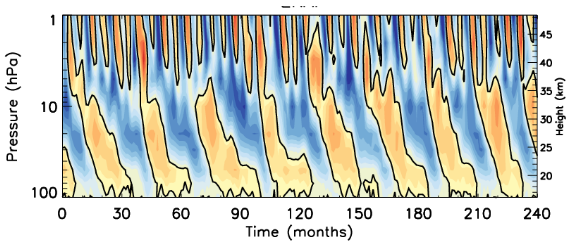
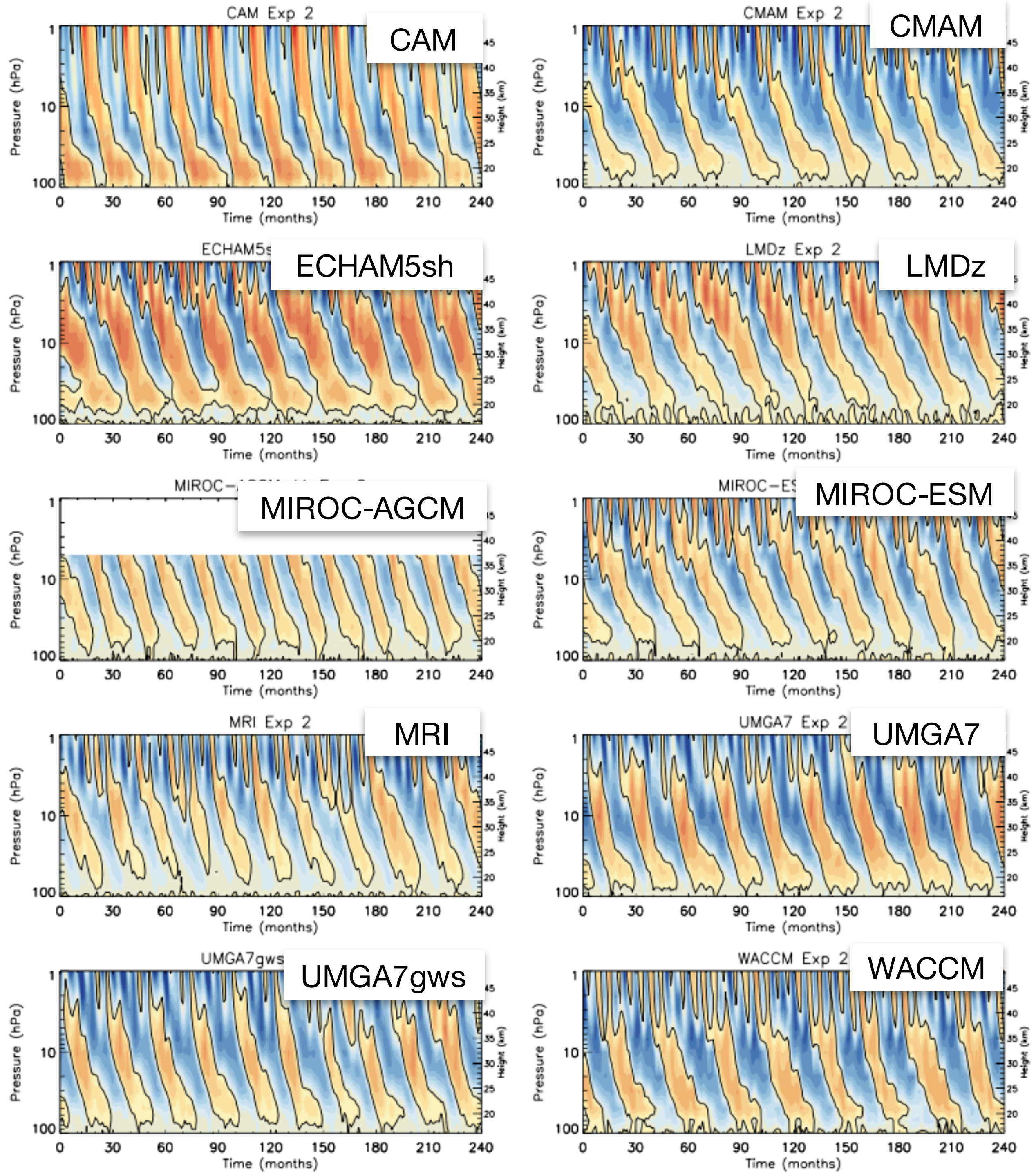


Figure: Yaga Richter (NCAR)



4xCO2 QBO
In the QBOi models

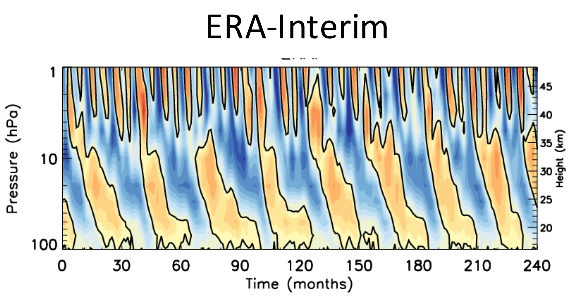
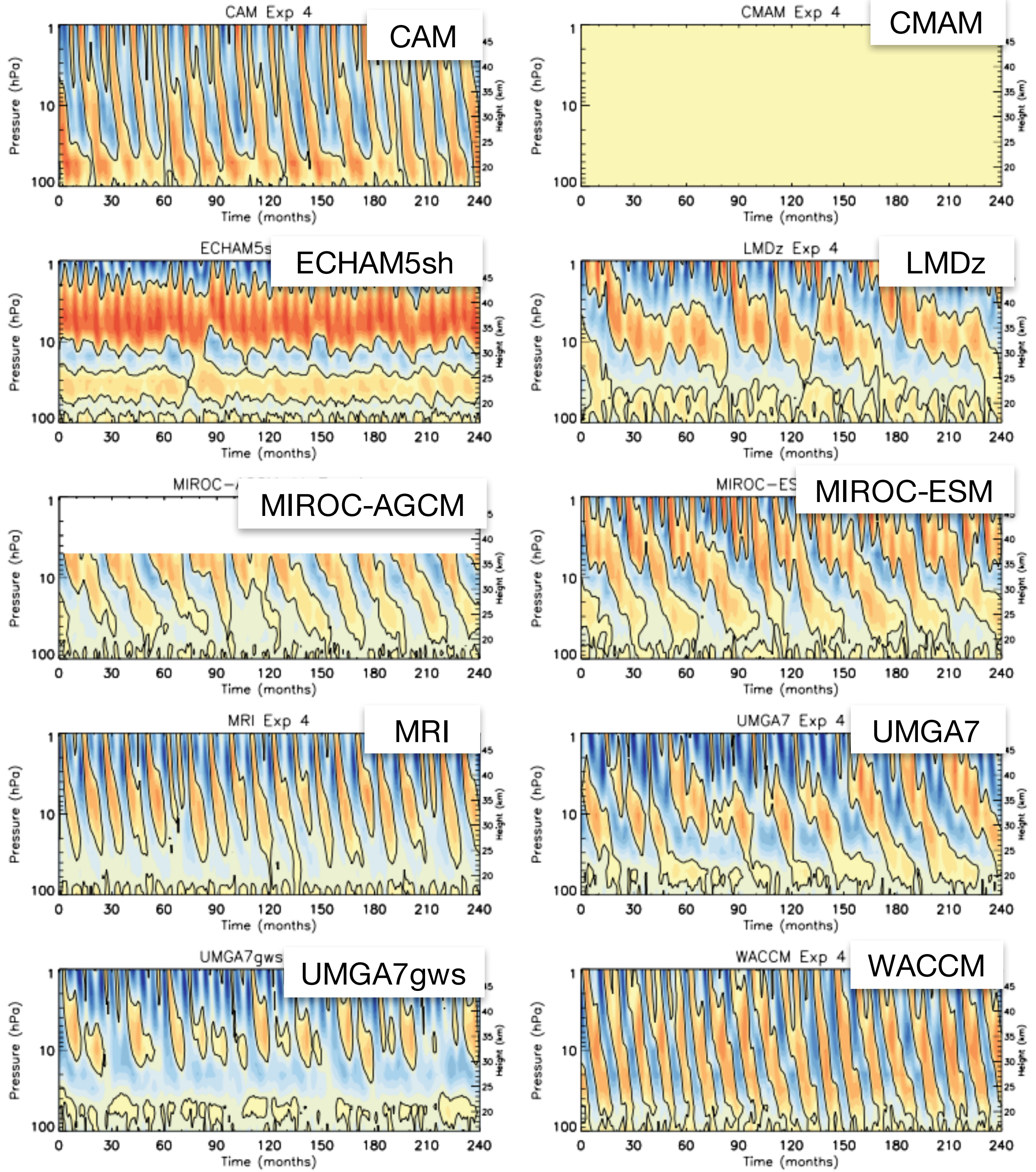
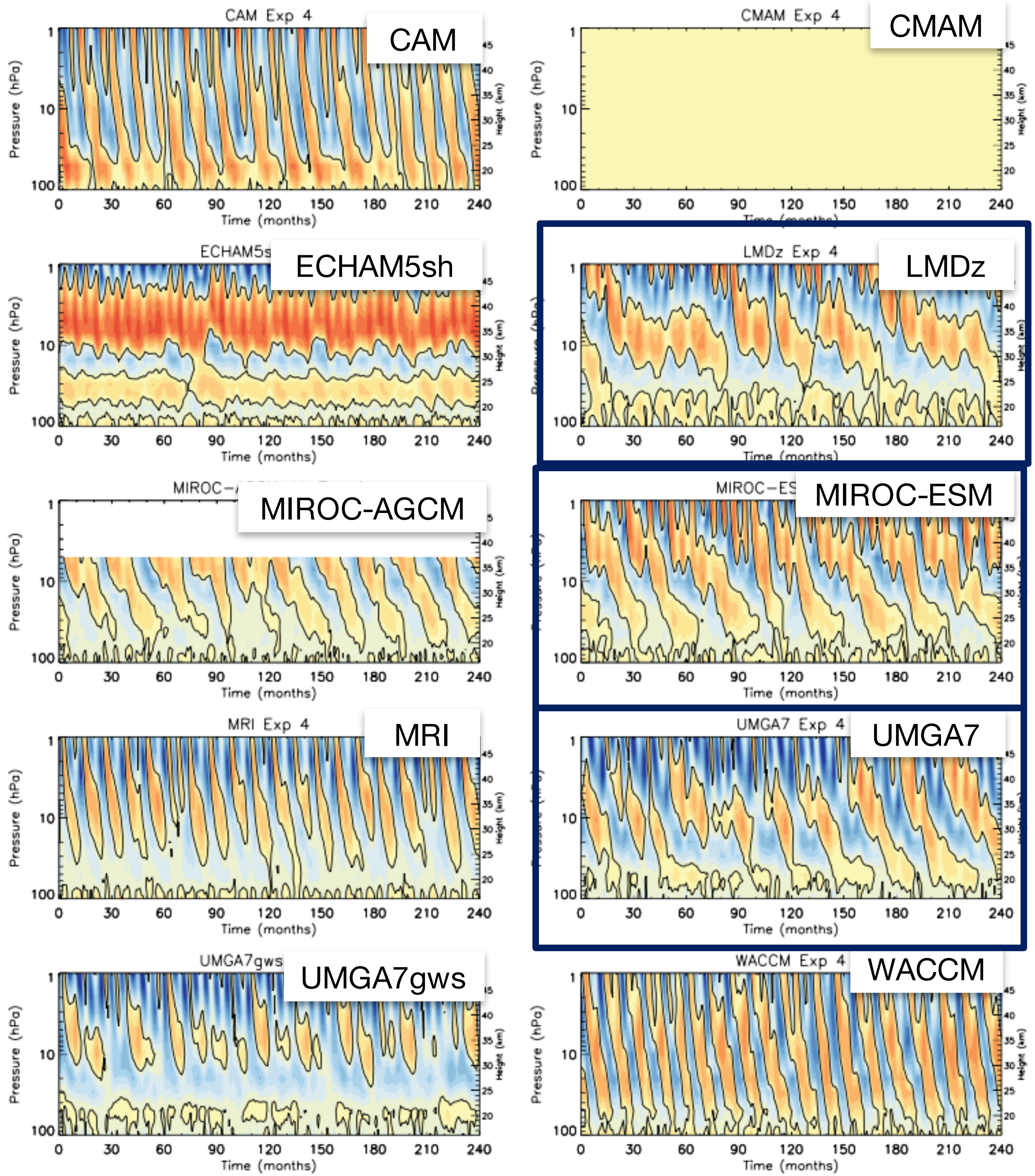


Figure: Yaga Richter (NCAR)



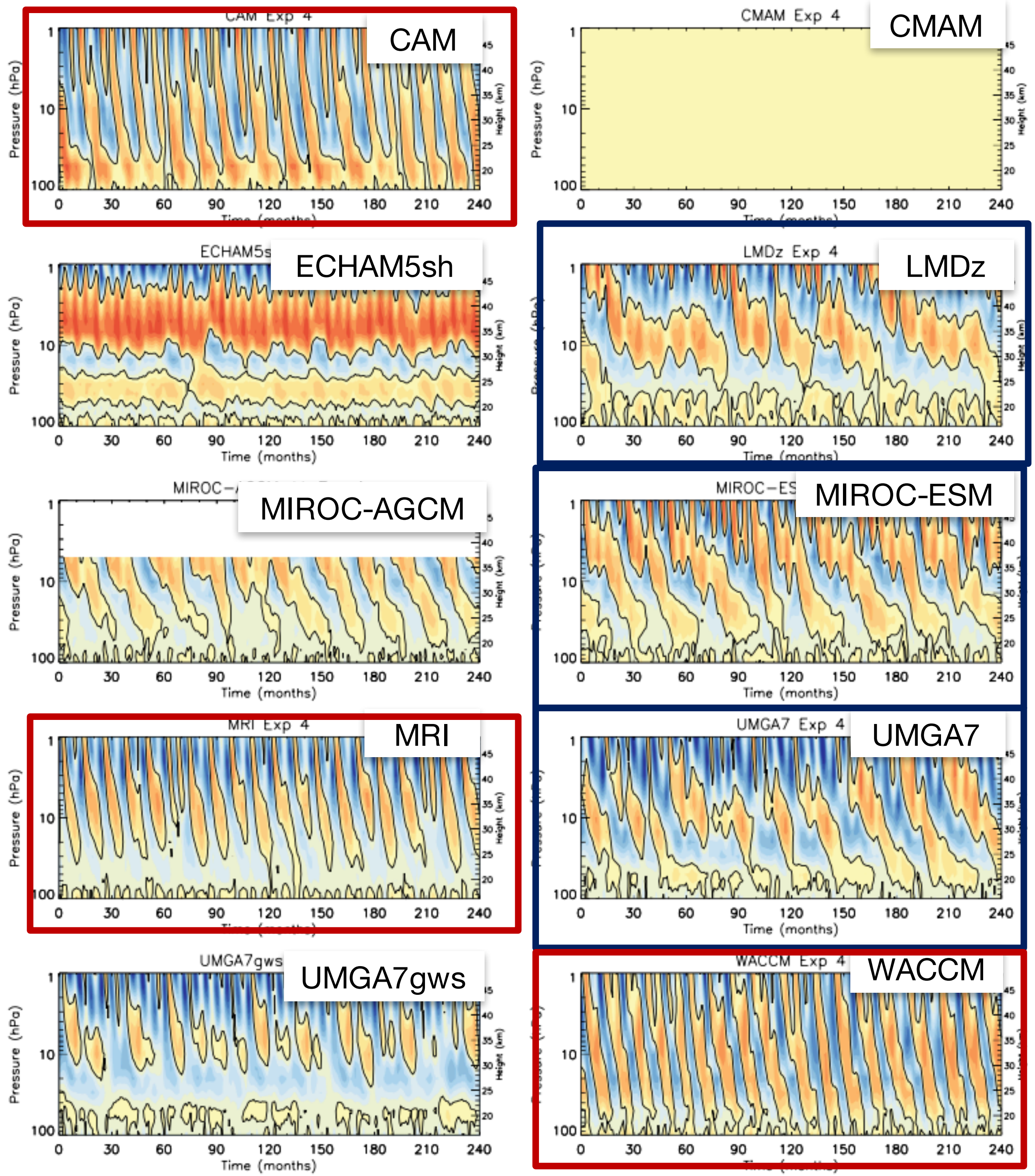
4xCO2 QBO
In the QBOi models

Figure: Yaga Richter (NCAR)

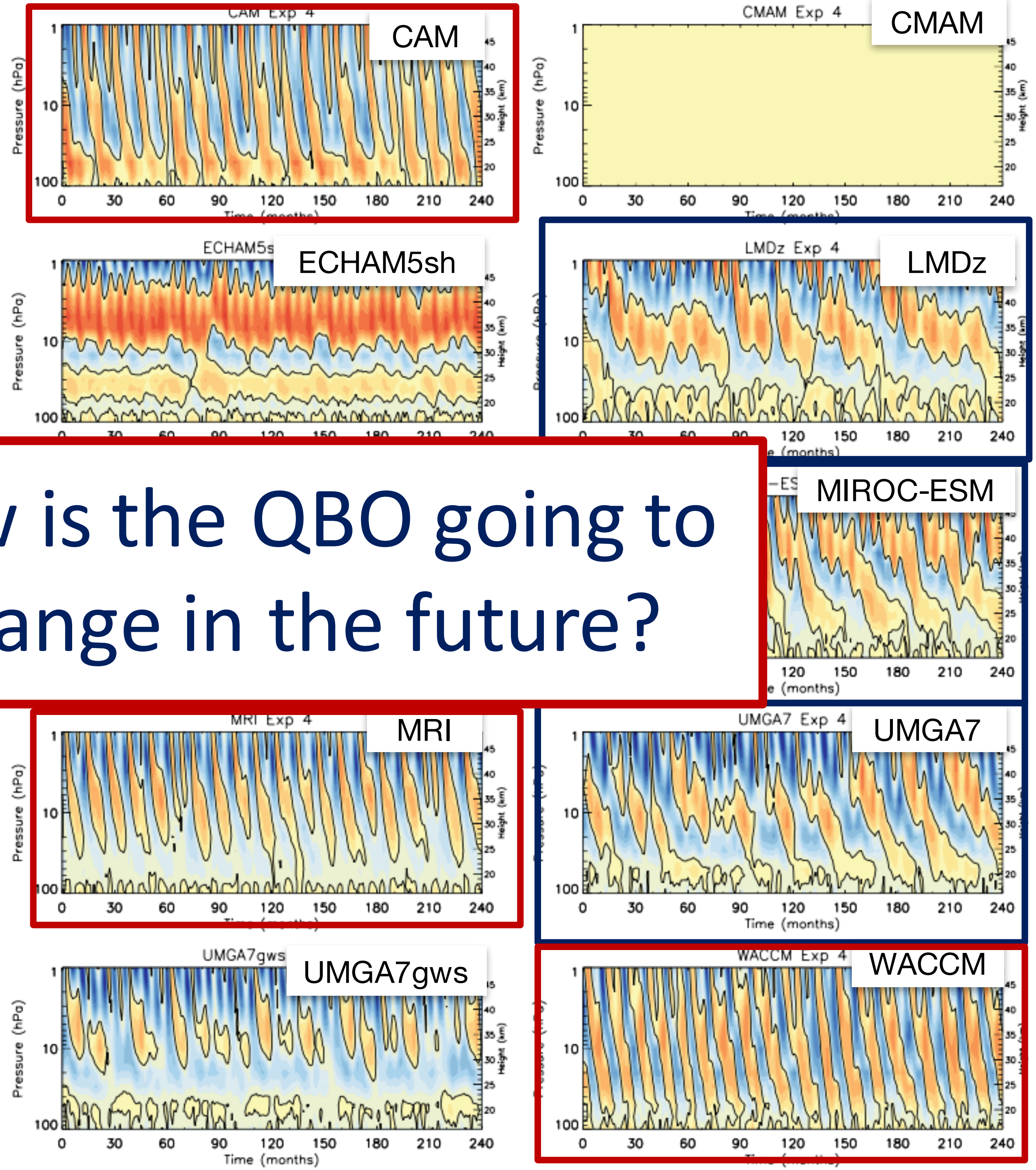


4xCO2 QBO
In the QBOi models

Figure: Yaga Richter (NCAR)



4xCO_2 QBO
In the QBOi models



How is the QBO going to change in the future?

Figure: Yaga Richter (NCAR)

Topics

- SAM (Southern Annular Mode)

  A case where we have a clear emergent constraint

  Although it may not be fully understood

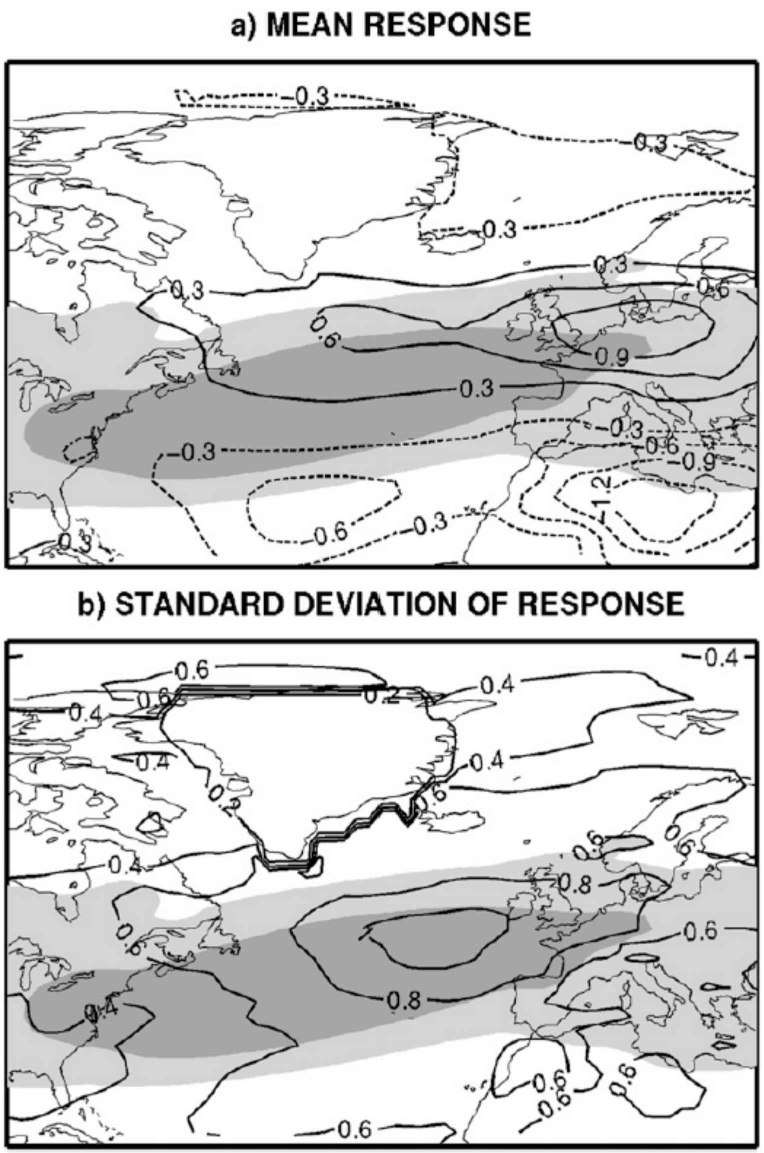
- QBO (Quasi-Biennial Oscillation)

  New results from QBOi – models are all over the place

- North Atlantic Jet

  A case where we need to be careful with our observational uncertainty

North Atlantic jet stream response to climate change



Woolings and Blackburn 2012

CMIP3

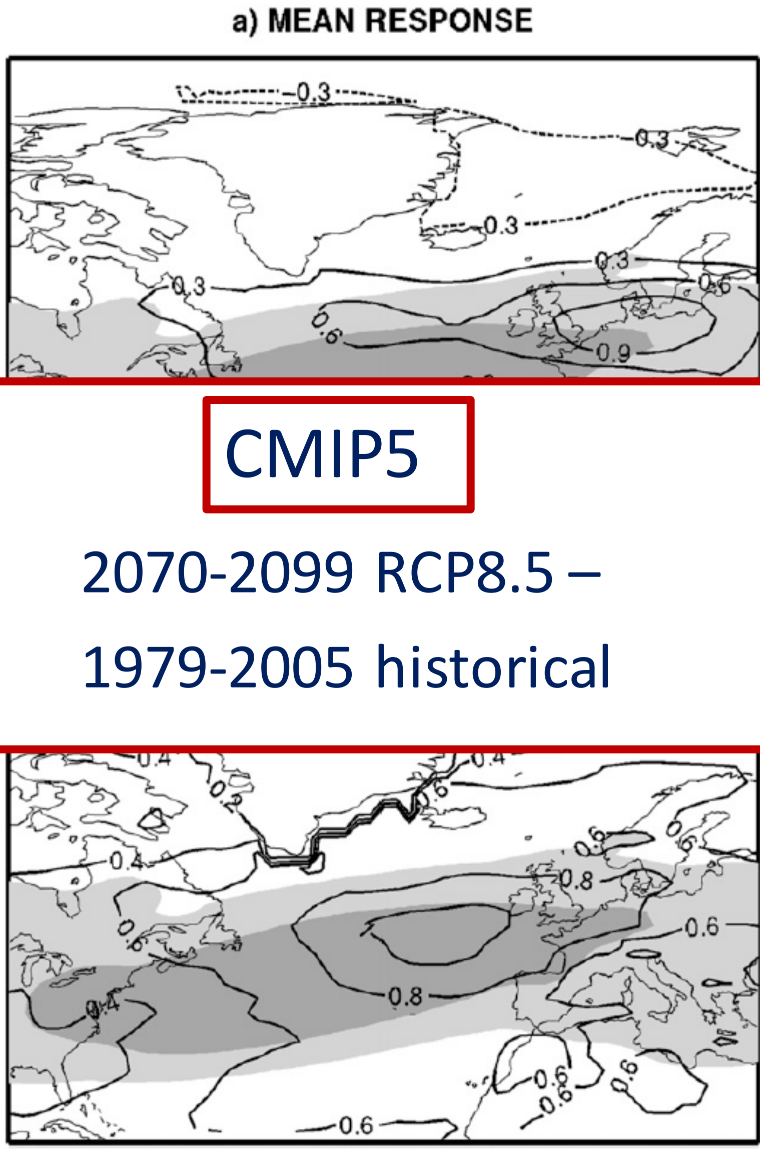
Winter (DJF)

850hPa zonal wind

Shading = 1960-1999 climatology

Contours = 2060-2099 A1B – 1960-1999 20C3M

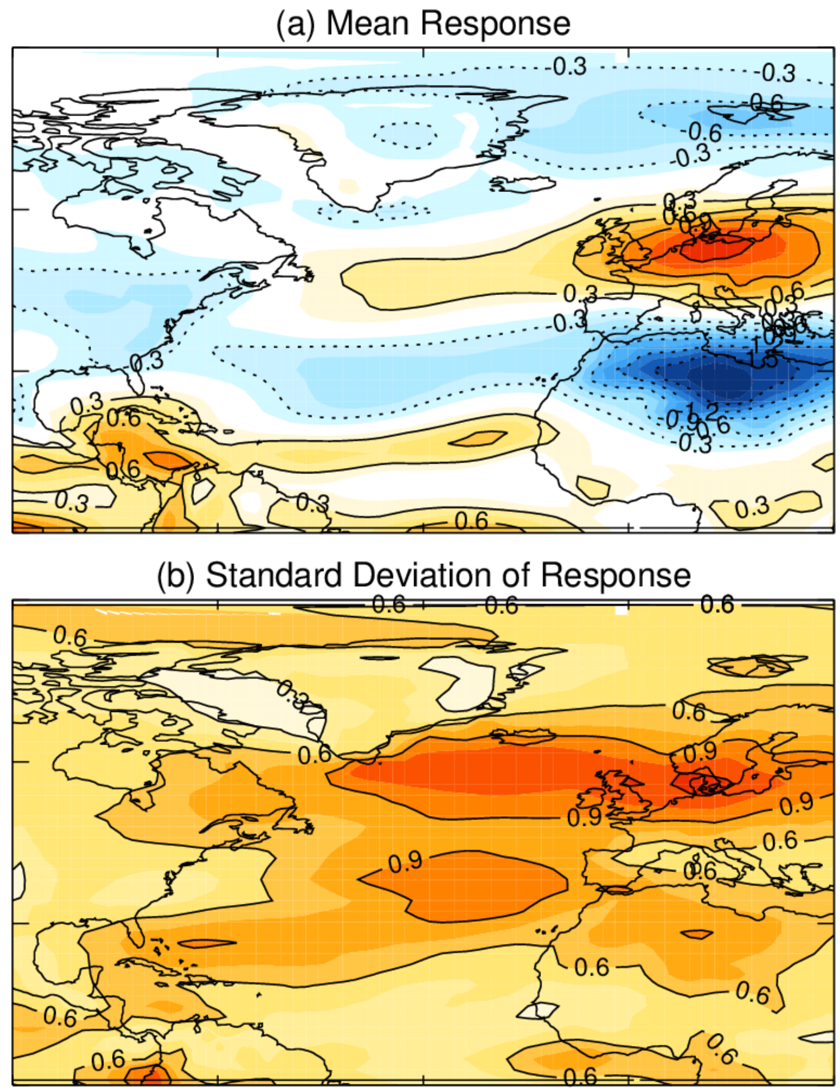
North Atlantic jet stream response to climate change



CMIP5

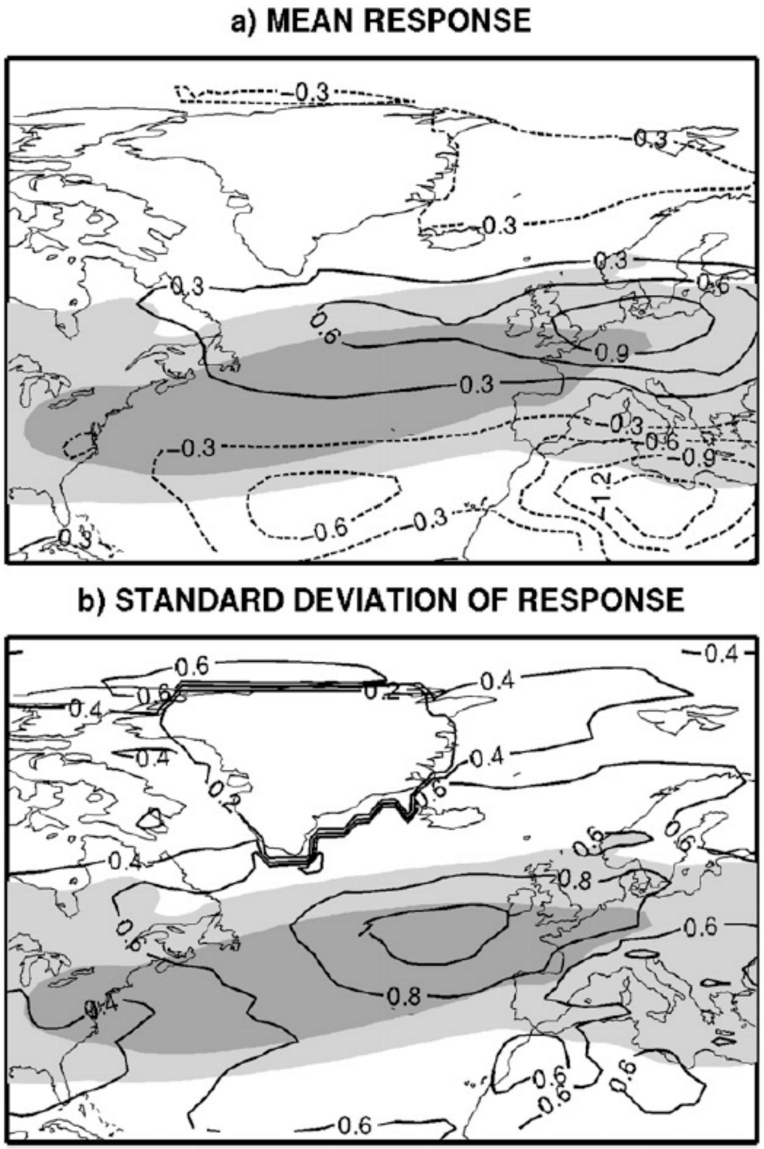
2070-2099 RCP8.5 –

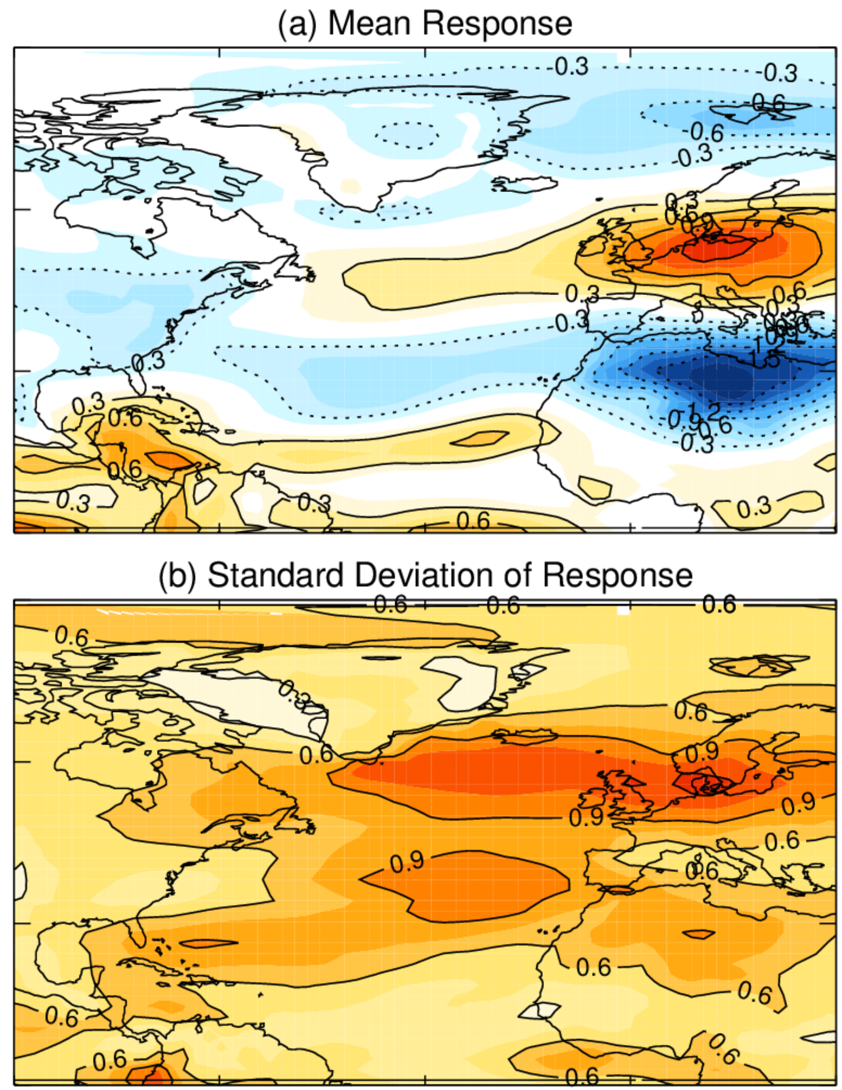
1979-2005 historical



Woolings and Blackburn 2012

North Atlantic jet stream response to climate change

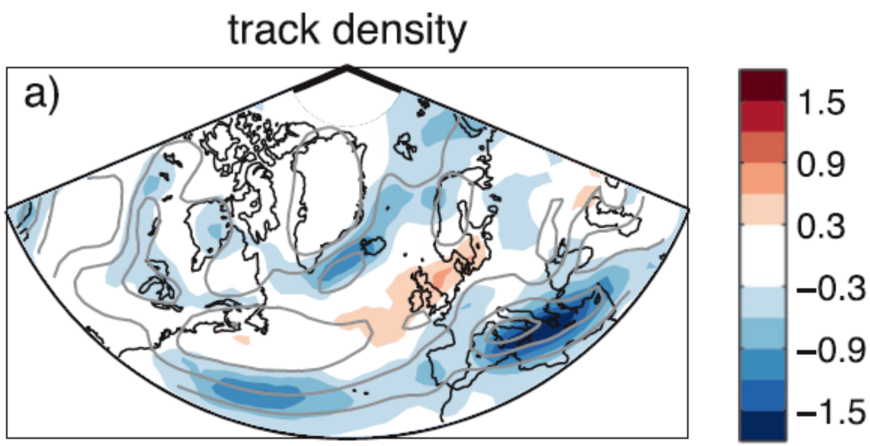




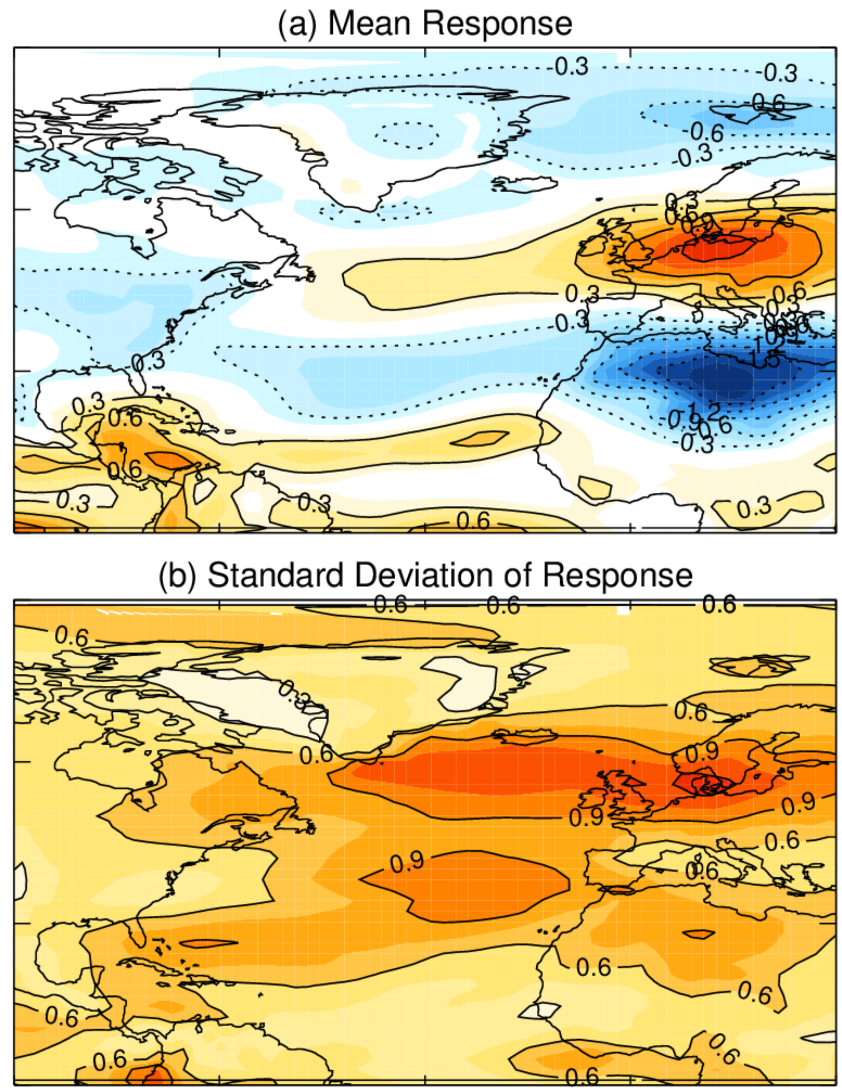
Woolings and Blackburn 2012

North Atlantic jet stream response to climate change

Multi-model mean change in storm track density in cyclones/month

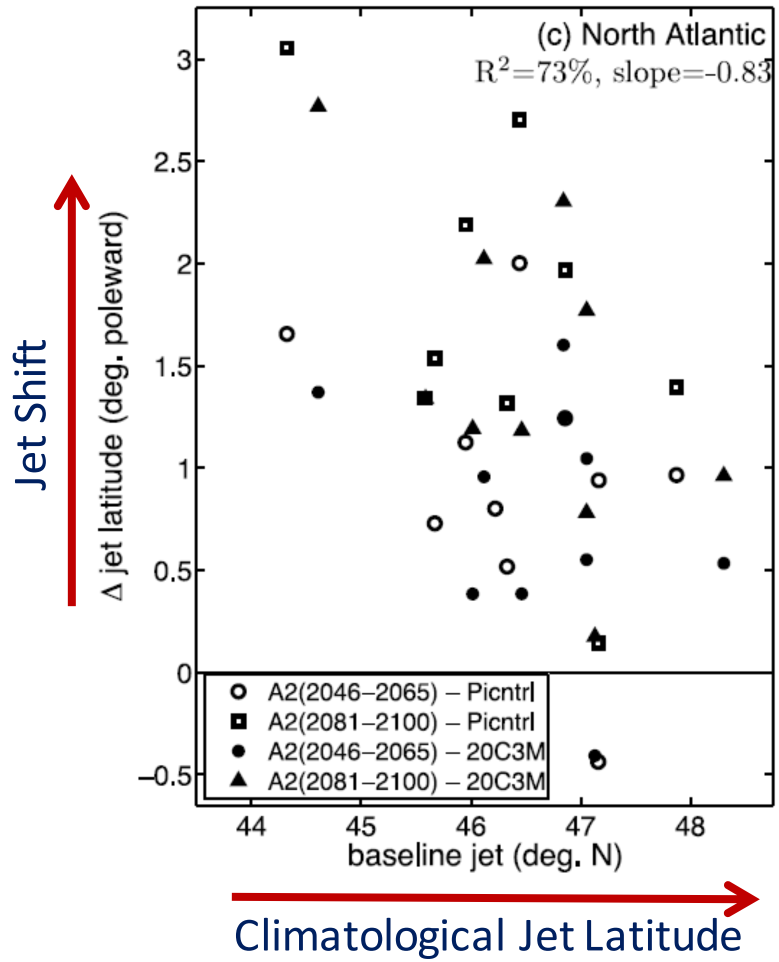


Zappa et al 2013



Emergent constraint on the North Atlantic jet stream response?

Jet Shift vs Jet Latitude
CMIP3, Annual Mean

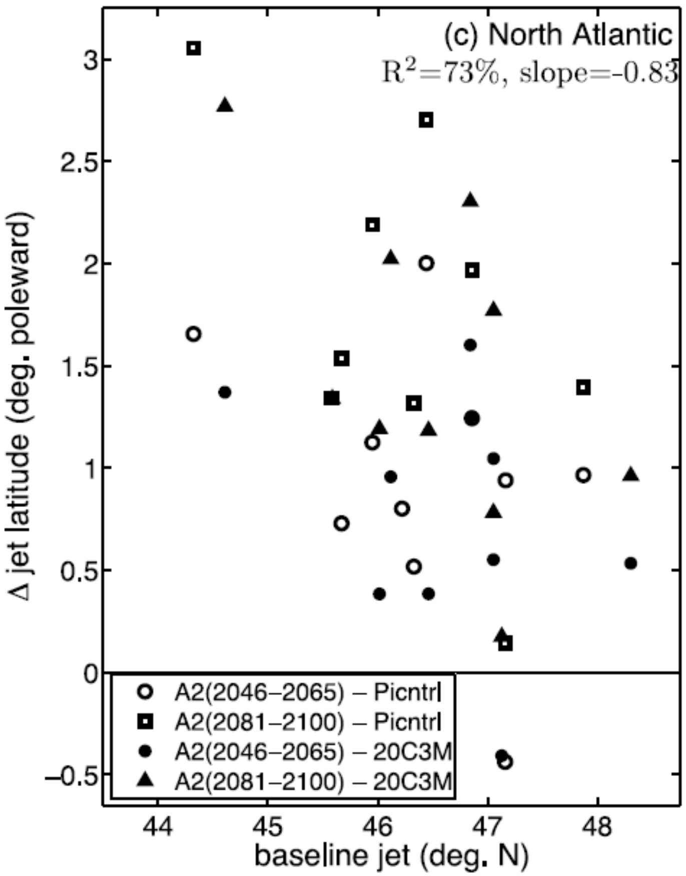


Barnes and Hartmann 2010

Emergent constraint on the North Atlantic jet stream response?

Jet Shift vs Jet Latitude
CMIP3, Annual Mean

Jet Shift

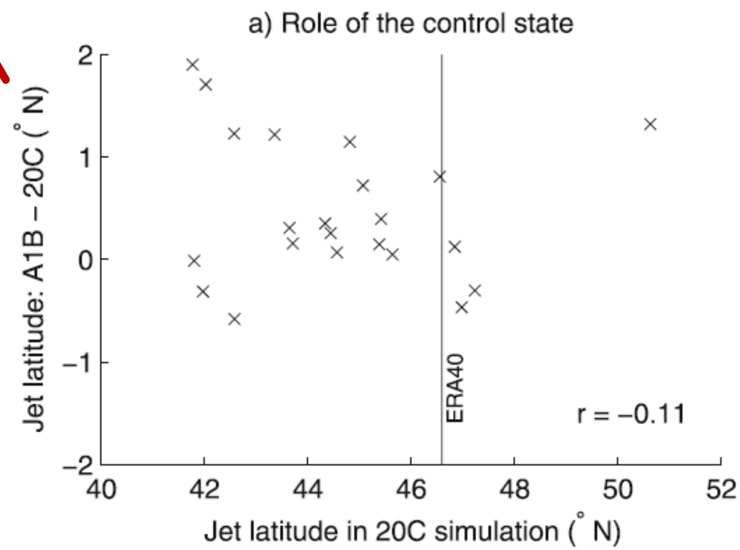


Climatological Jet Latitude

Barnes and Hartmann 2010

Jet Shift vs Jet Latitude
CMIP3, DJF

Jet Shift



Climatological Jet Latitude

Woolings and Blackburn 2012

A concerning bias?

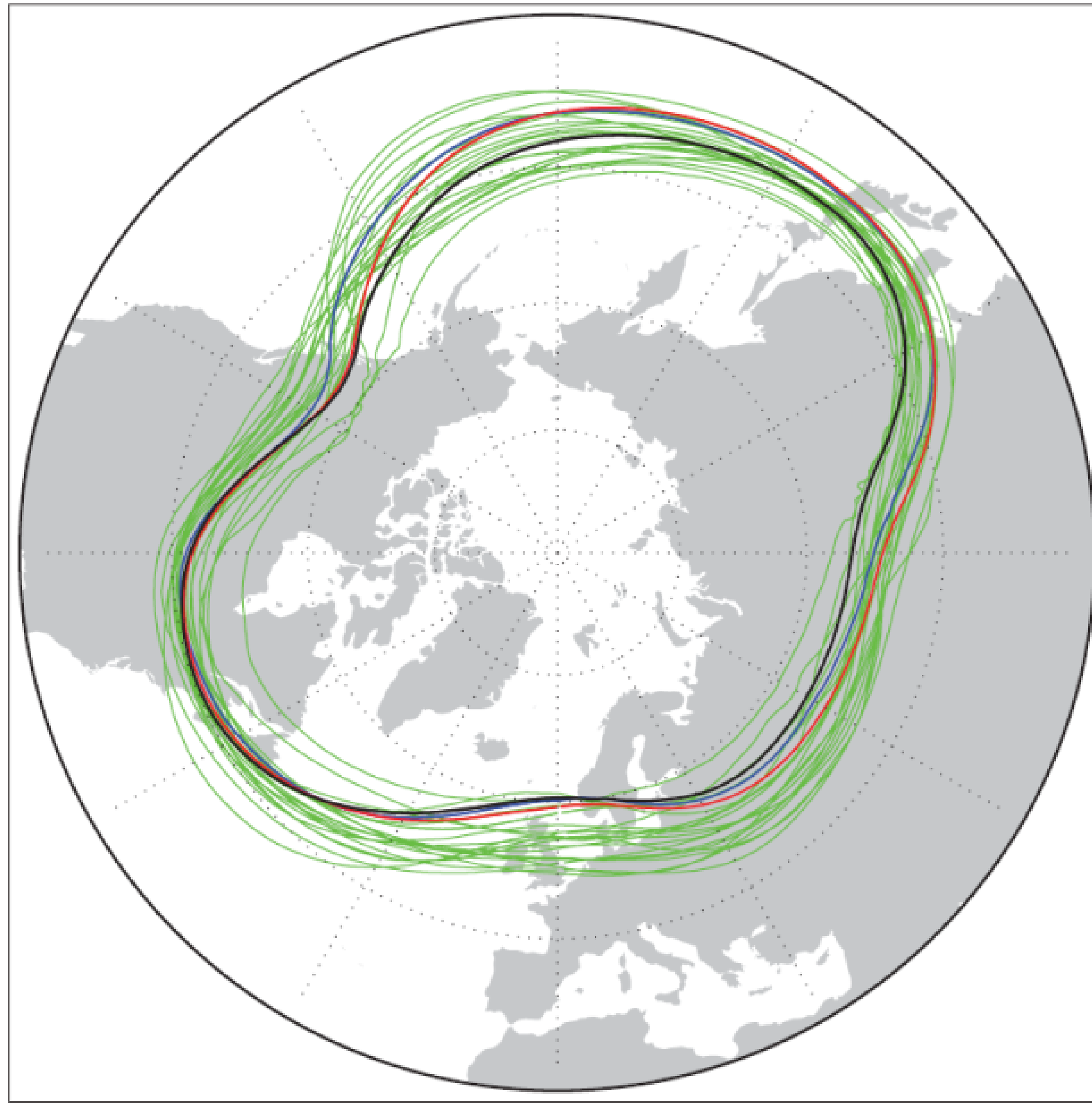
One particular contour of 500hPa geopotential height during DJF →

(Indicates the location of the jet stream)

ERA-40 1957-2001

CMIP3

High resolution models

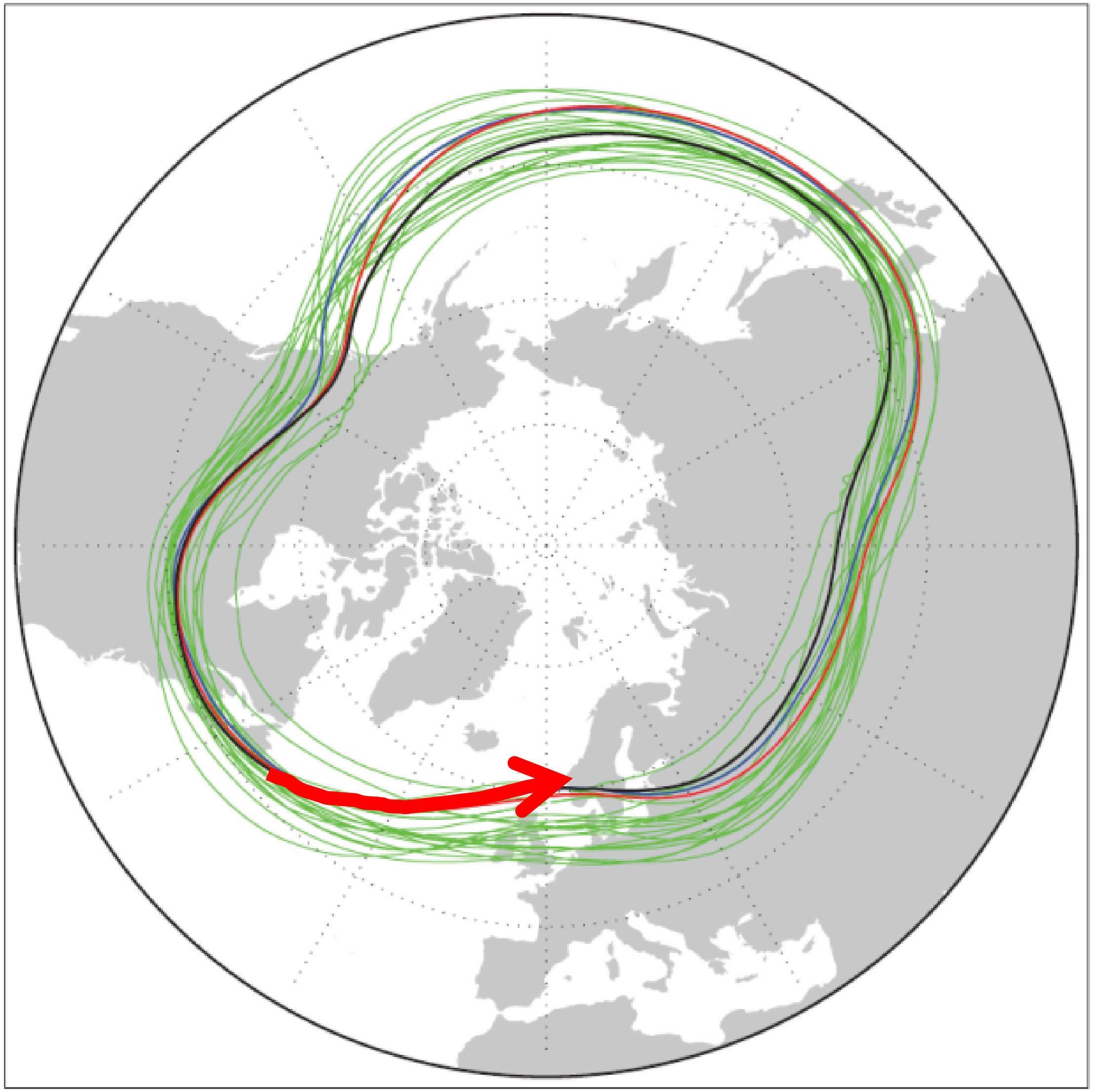


Woolings 2010

A concerning bias?

One particular contour of 500hPa geopotential height during DJF →

(Indicates the location of the jet stream)



ERA-40 1957-2001

CMIP3

High resolution models

Woolings 2010

A concerning bias?

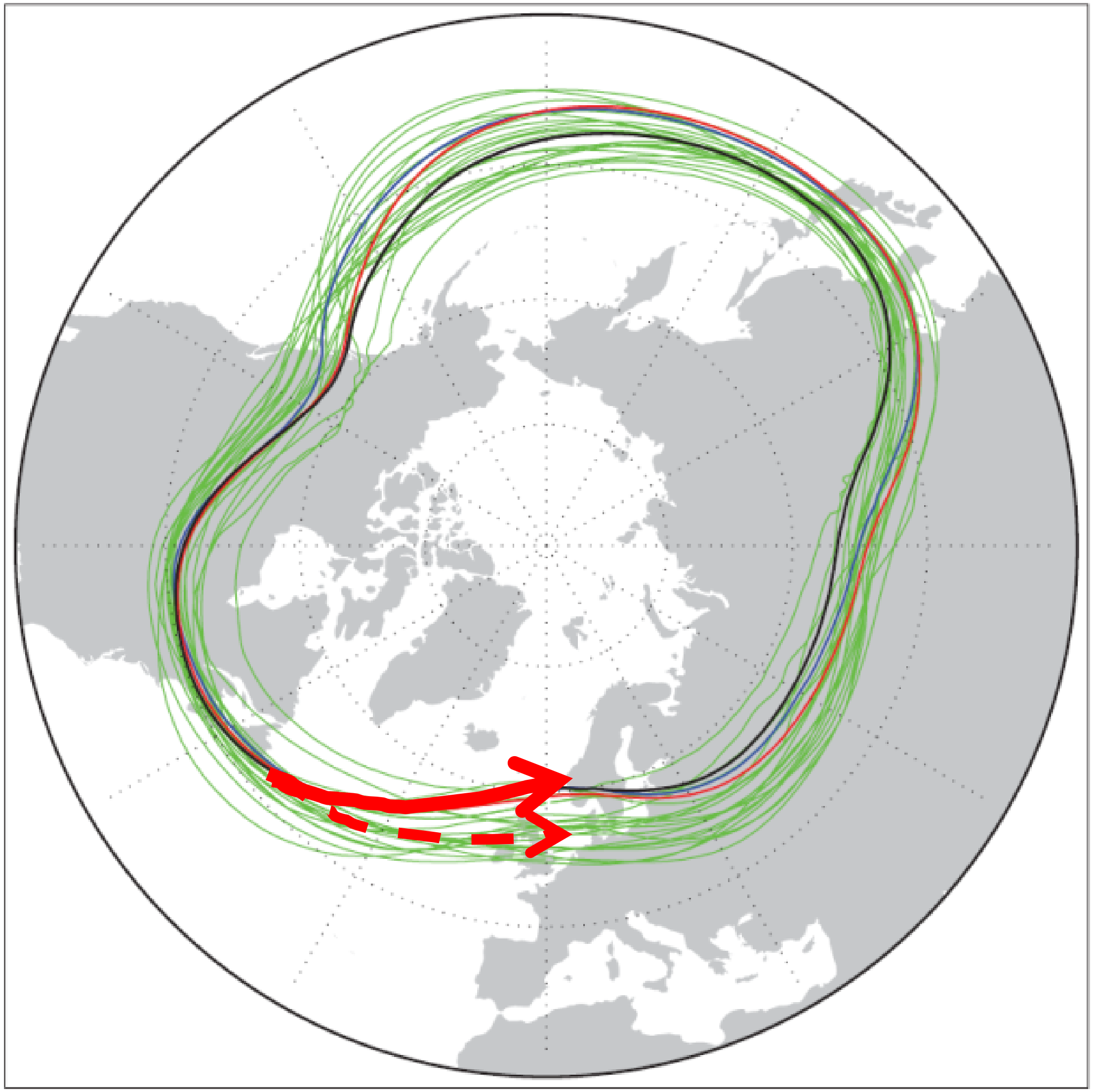
One particular contour of 500hPa geopotential height during DJF →

(Indicates the location of the jet stream)

ERA-40 1957-2001

CMIP3

High resolution models

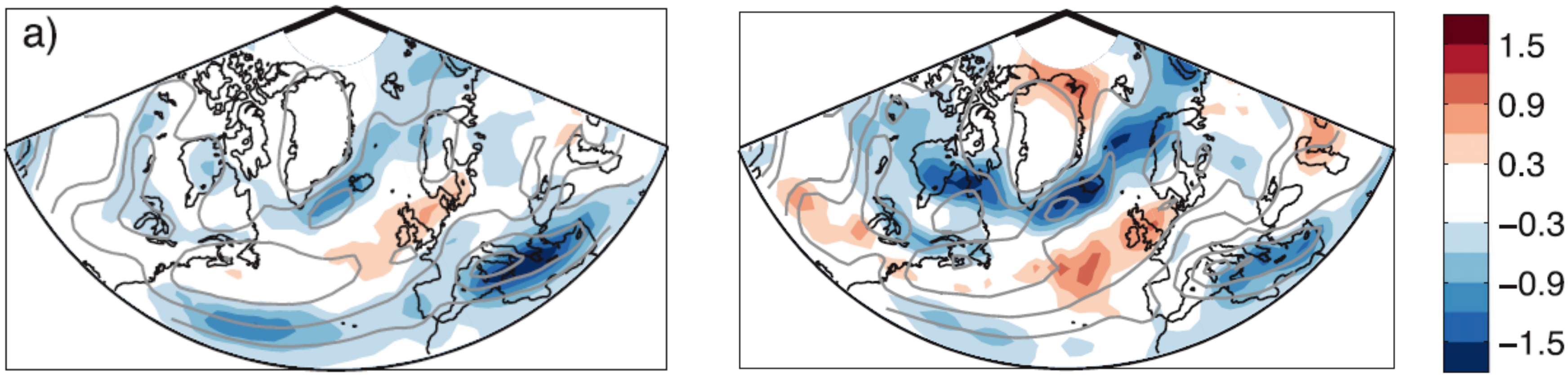


Woolings 2010

Change in storm track density under climate change in cyclones/month

CMIP5 multi-model mean

The 4 best models in terms of jet location and tilt



"The broad features of the North Atlantic and European response appear to be weakly sensitive to the historical biases"

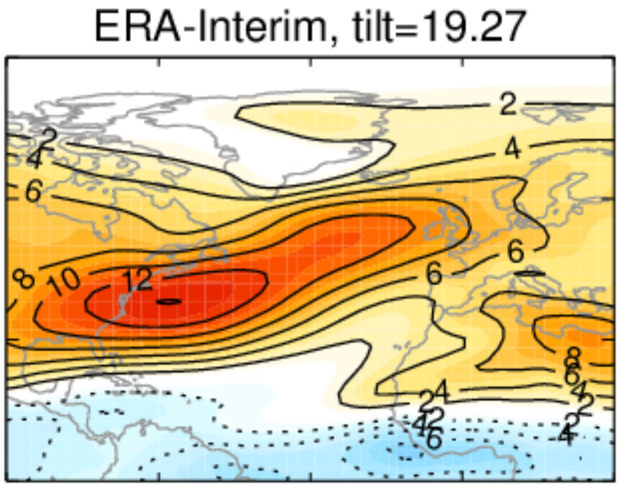
Zappa et al 2013

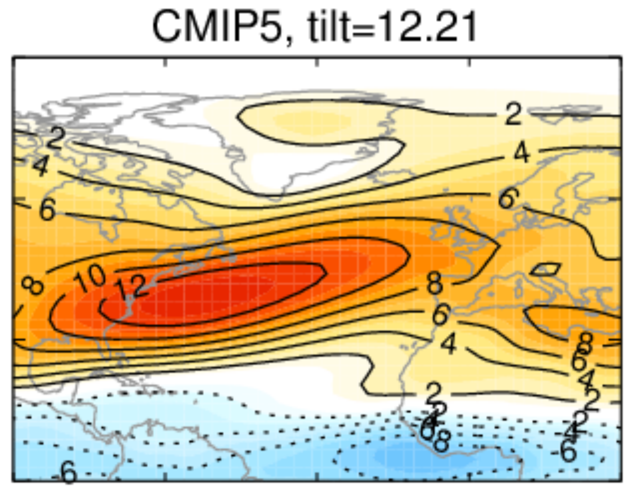
But how well do we really know the climatology of the real world?

Is the climatology over the satellite record truly representative?

Is this really the climatology that we should be aiming for with our models?

A motivational example…jet tilt in March

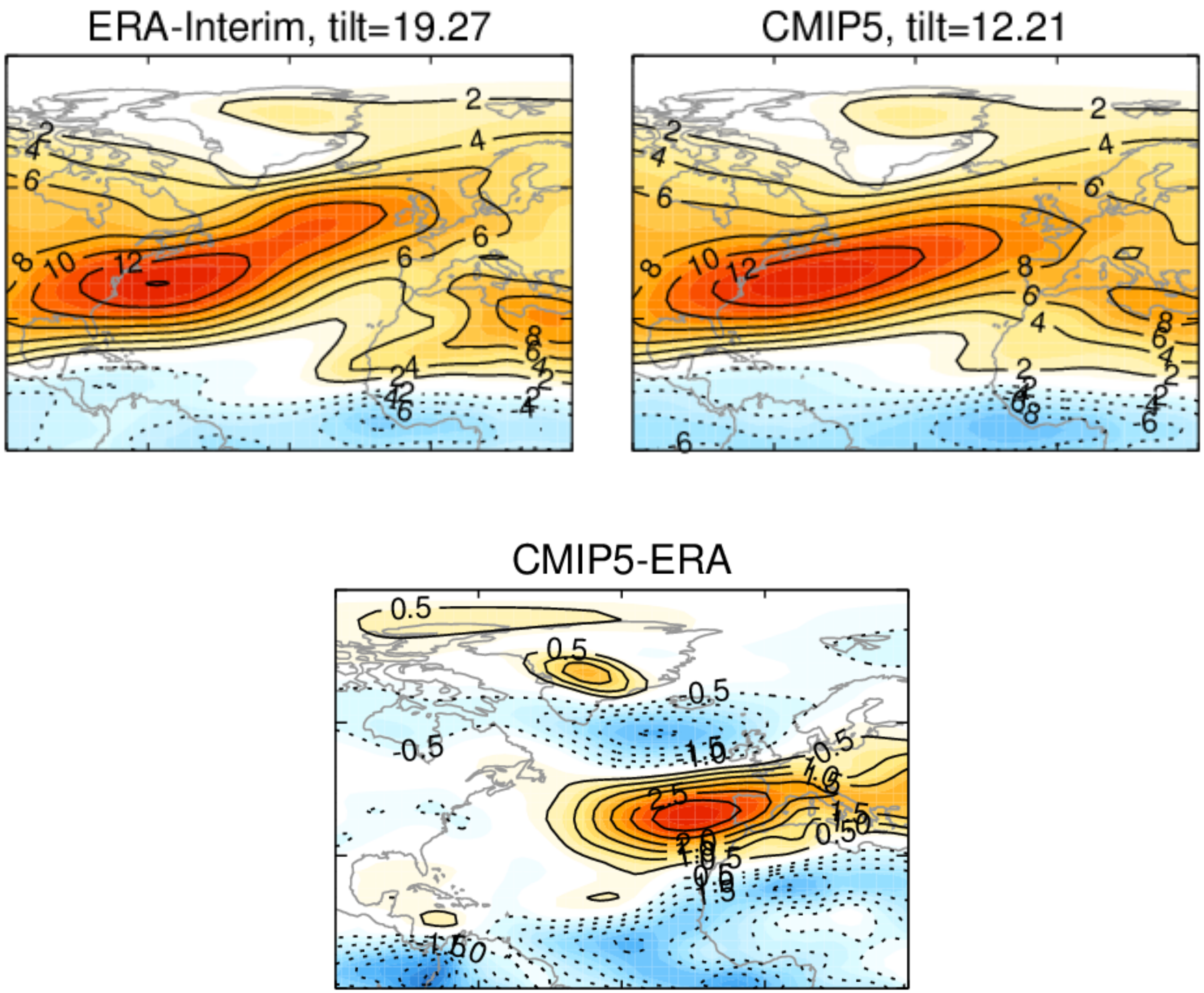




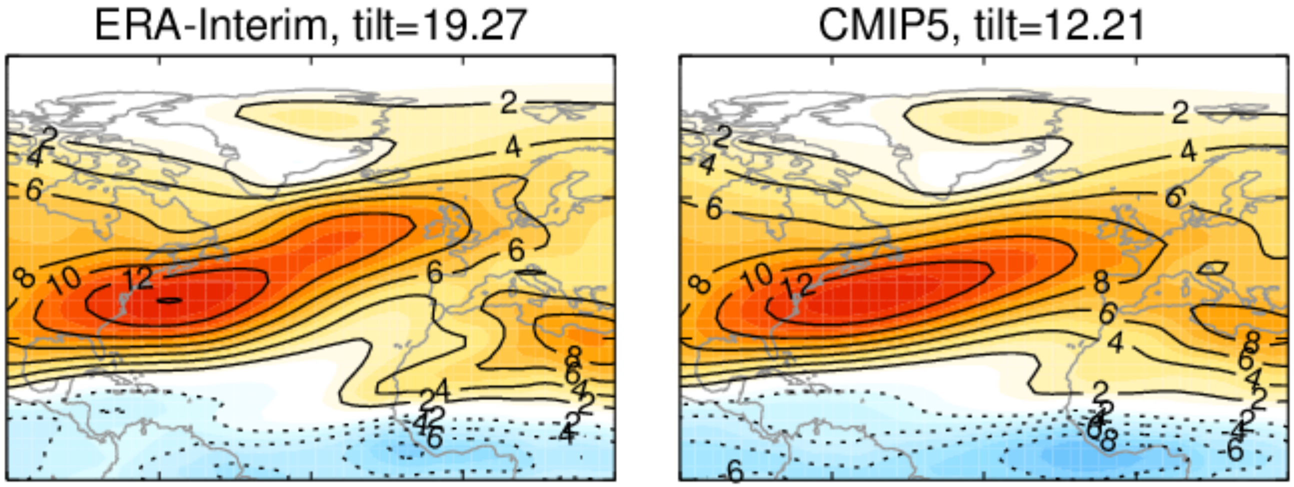
ERA-Interim climatology (1979-2005)

CMIP5 multi-model mean climatology (35 models, 1979-2005)

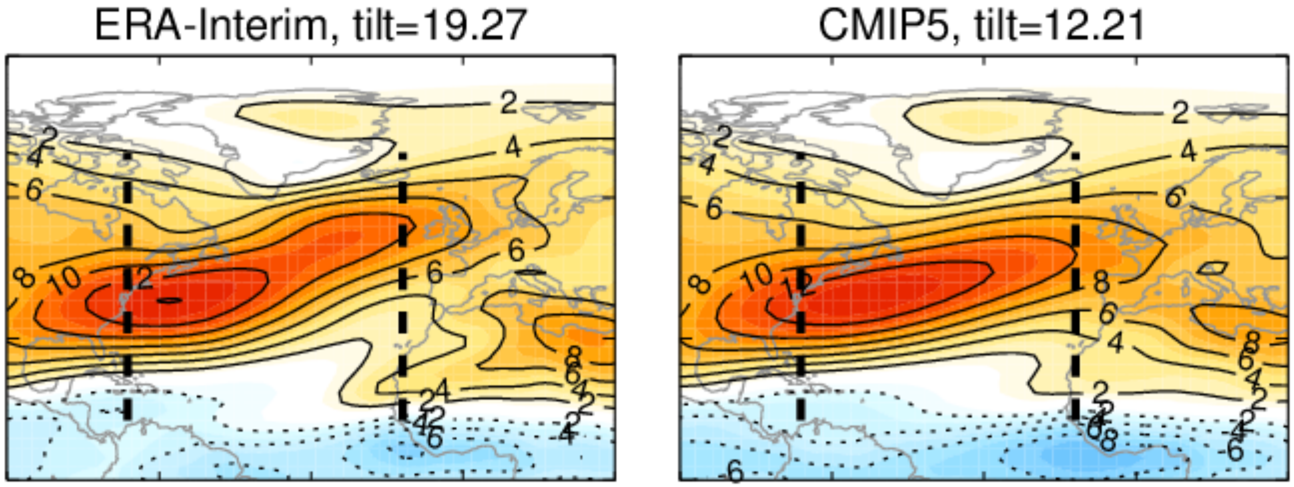
A motivational example…jet tilt in March



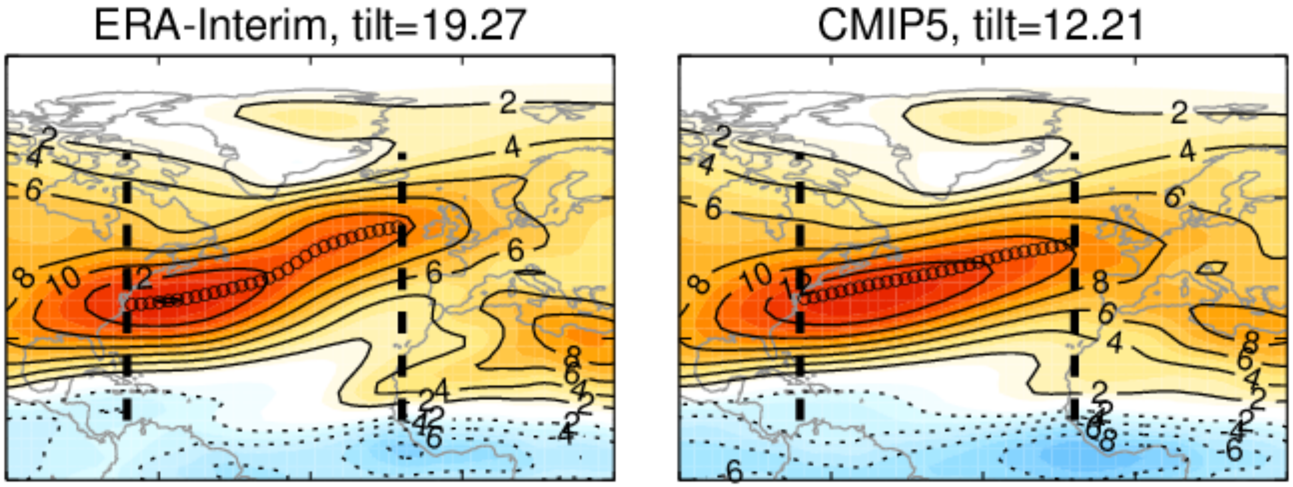
A motivational example…jet tilt in March



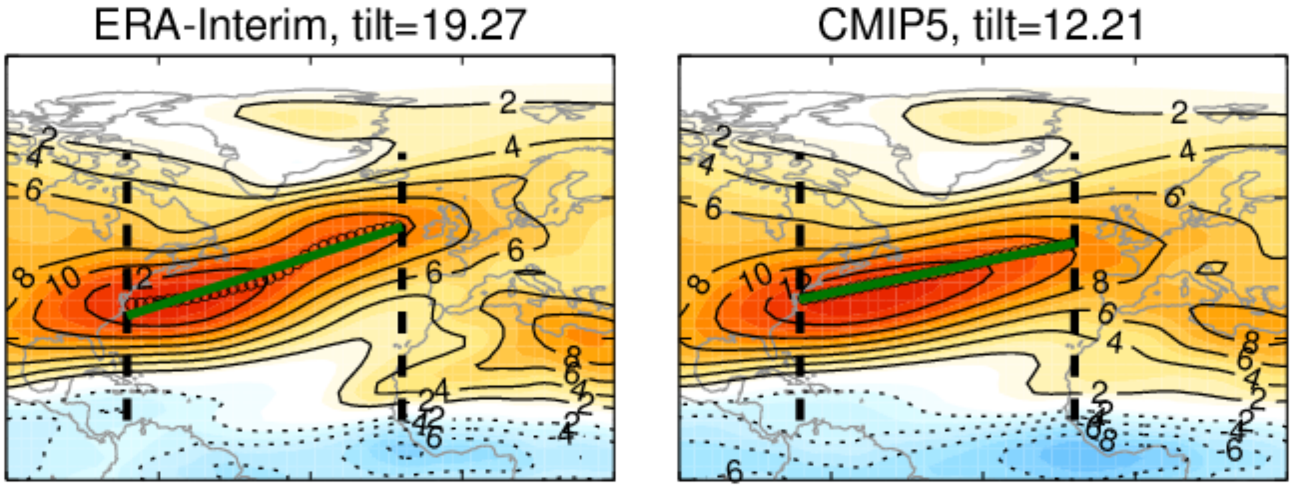
A motivational example…jet tilt in March



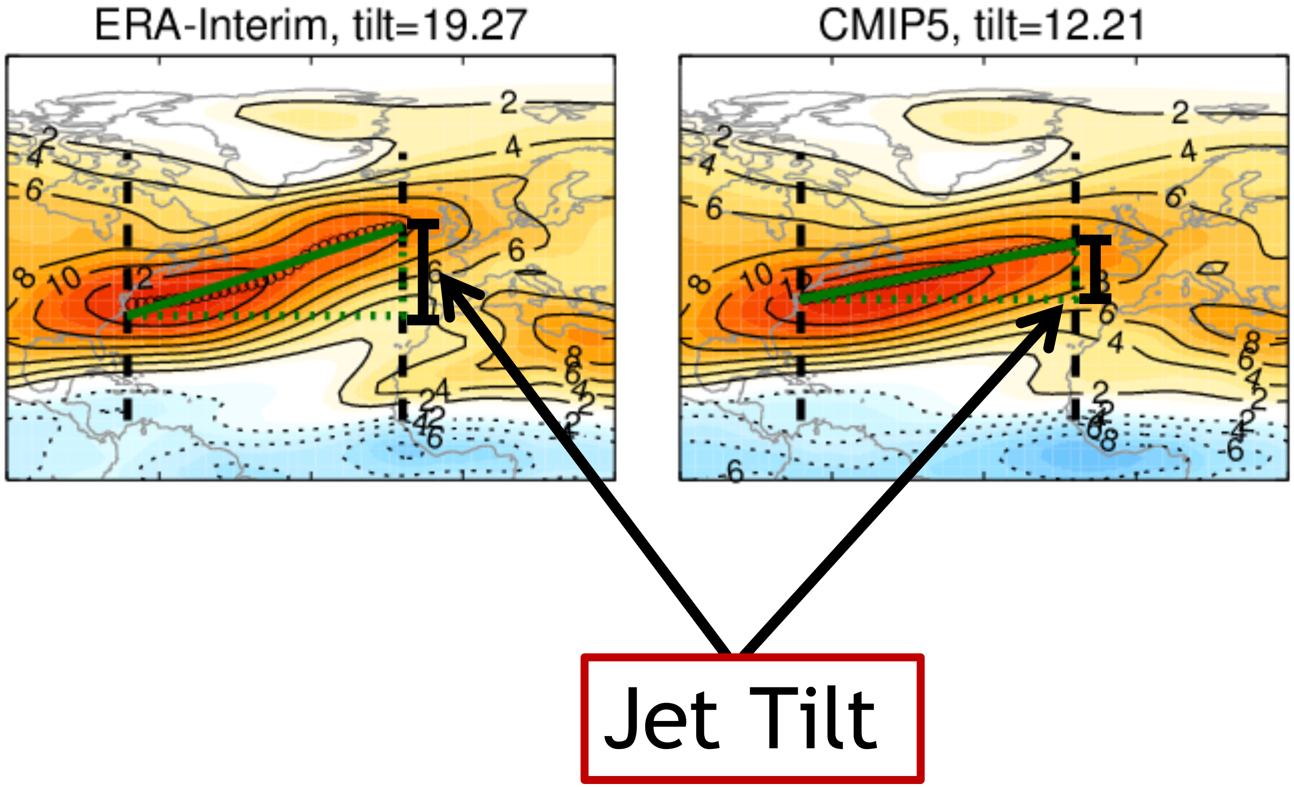
A motivational example…jet tilt in March



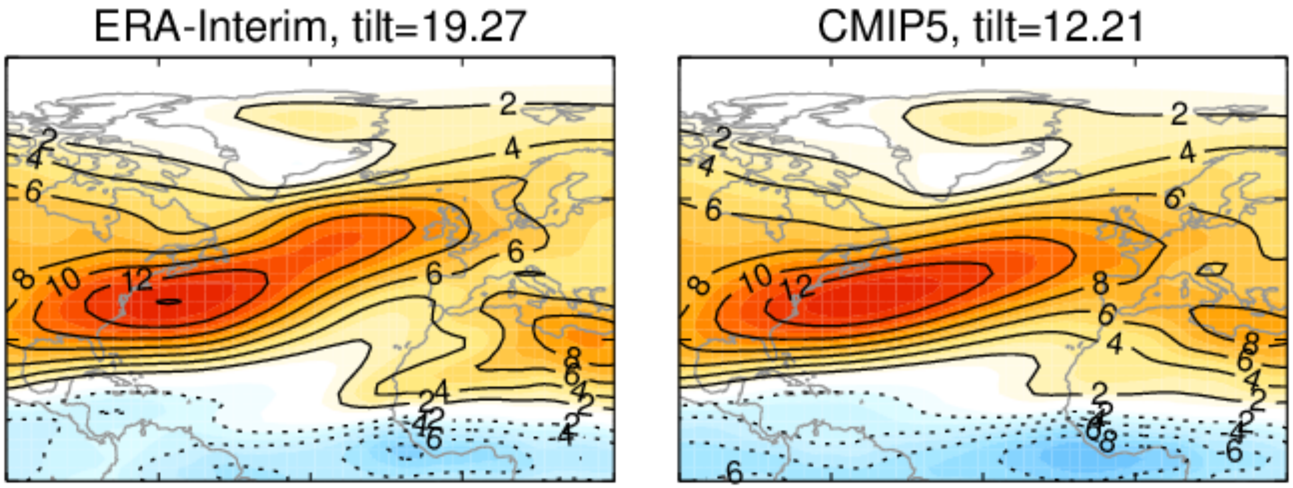
A motivational example…jet tilt in March



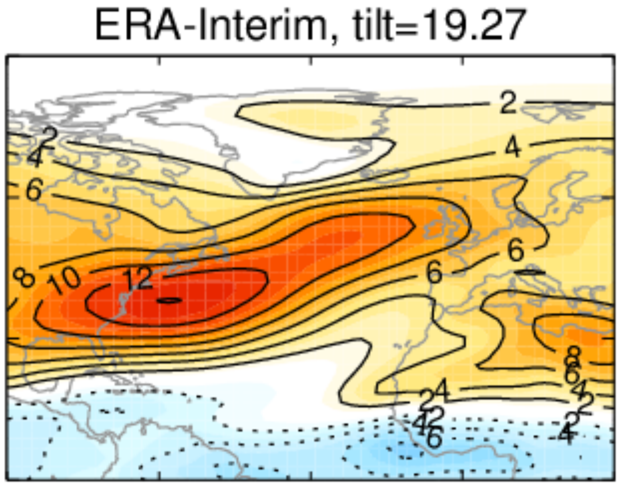
A motivational example…jet tilt in March

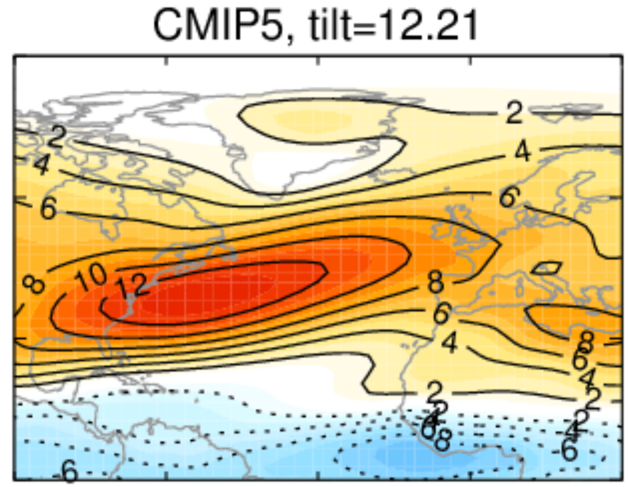


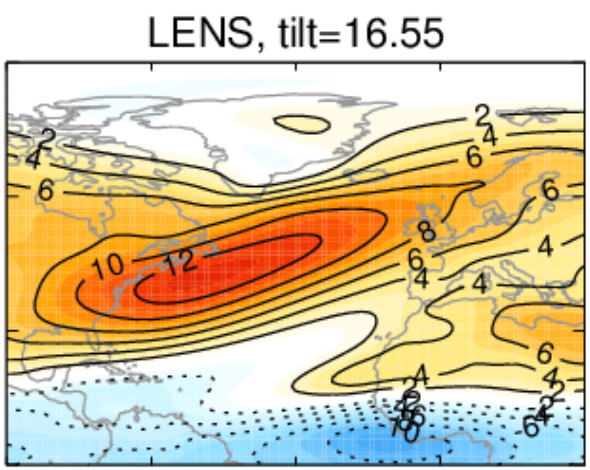
A motivational example…jet tilt in March



A motivational example…jet tilt in March

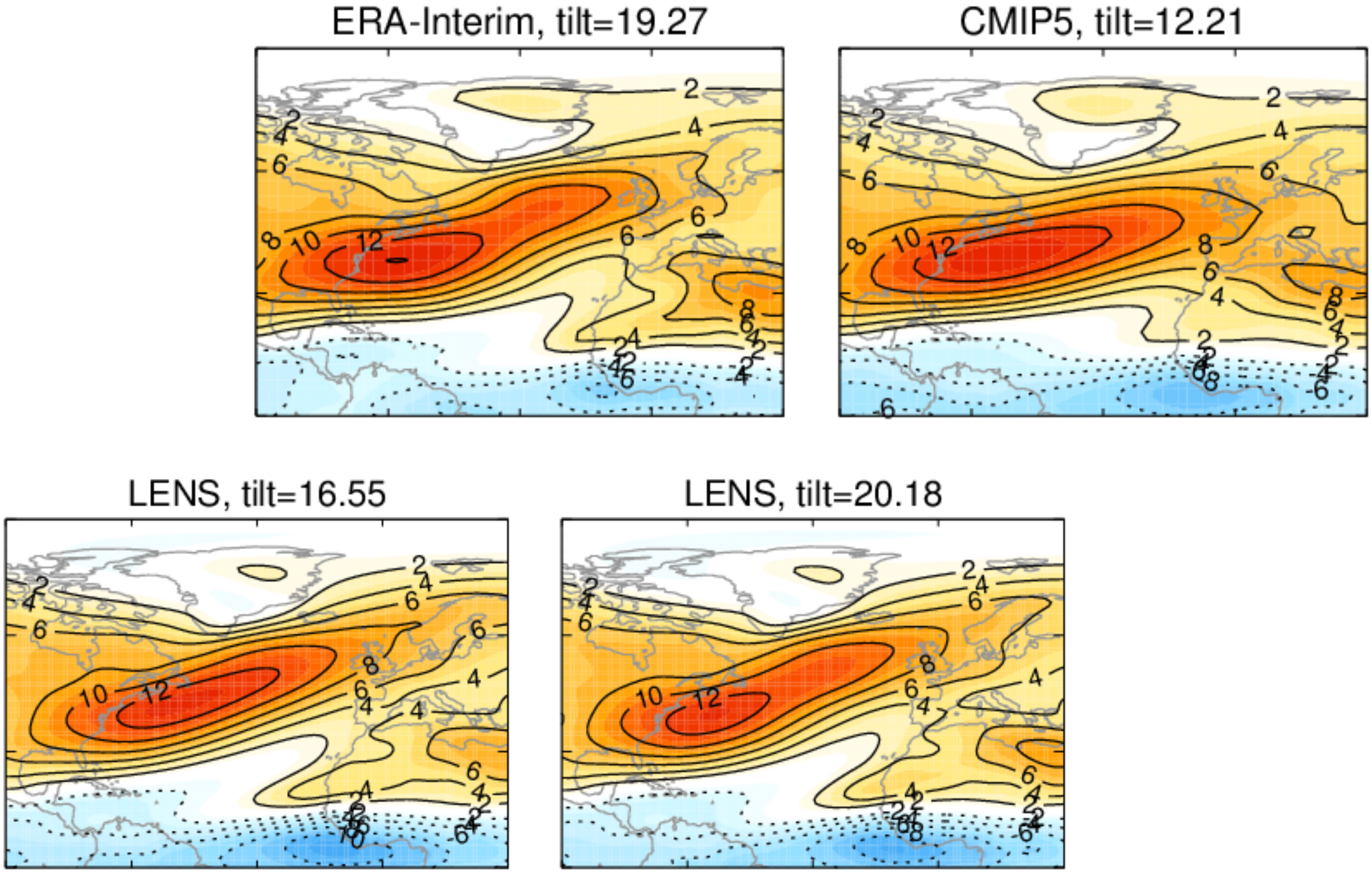




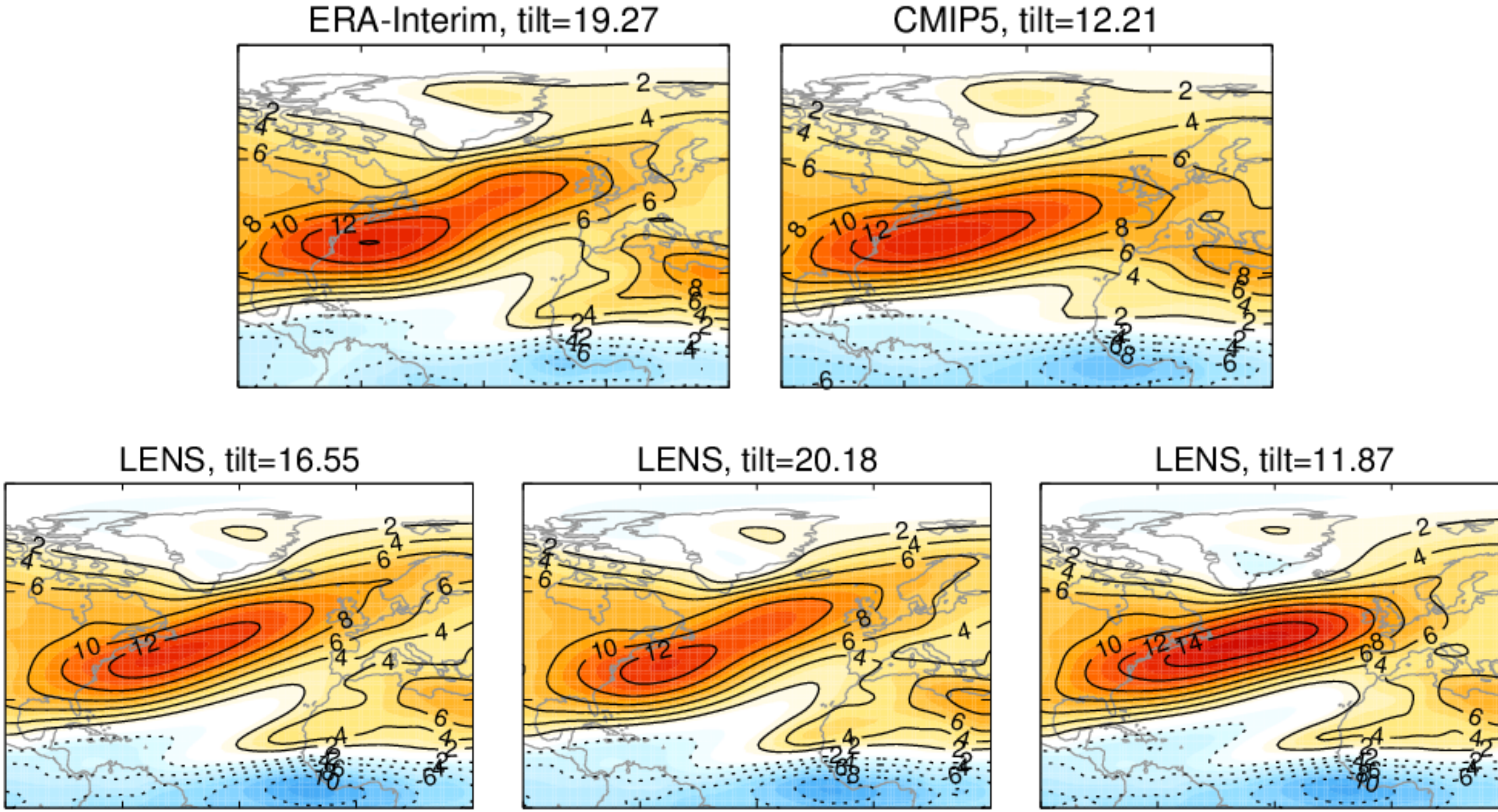


CESM large ensemble
Ensemble mean of 42 members
1979-2005

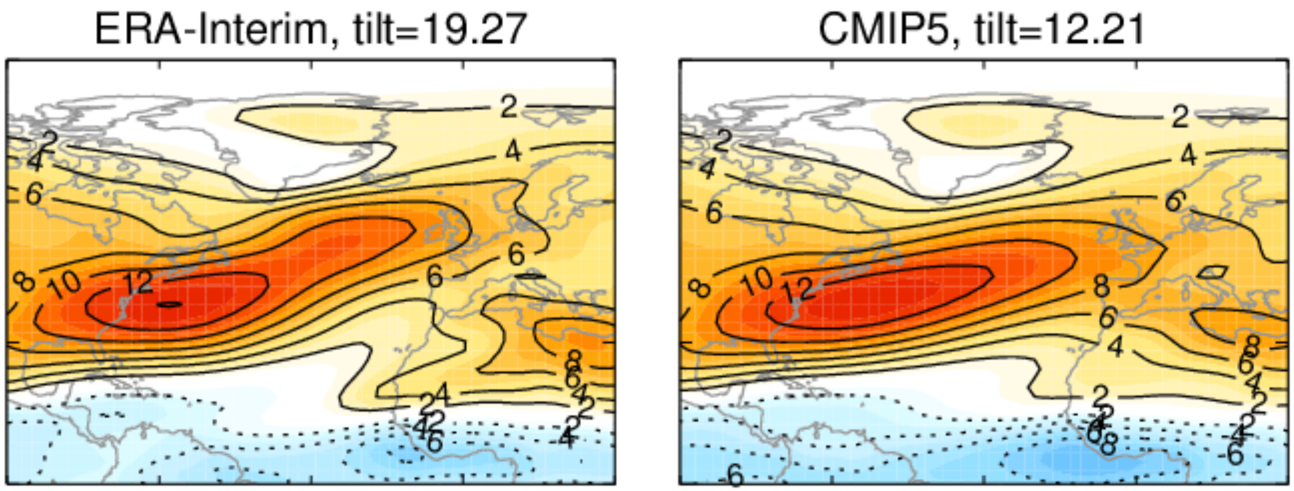
A motivational example…jet tilt in March

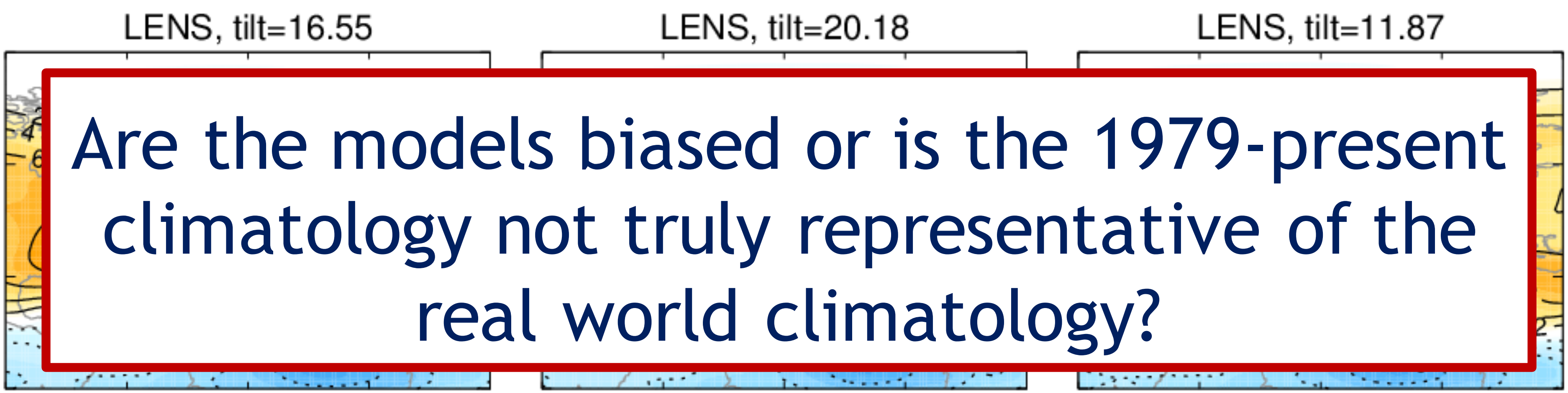


A motivational example…jet tilt in March



A motivational example…jet tilt in March





Are the models biased or is the 1979-present climatology not truly representative of the real world climatology?

Can we look at jet metrics further back in time?

Can we look at jet metrics further back in time?

Over the satellite ERA we have ~37 years of data (1979 – now)

ERA-Interim (1979-now), MERRA2 (1980-now), JRA-55 (using 1979-now)

Can we look at jet metrics further back in time?

Over the satellite ERA we have ~37 years of data (1979 – now)

ERA-Interim (1979-now), MERRA2 (1980-now), JRA-55 (using 1979-now)

We now have two 20th Century reanalyses

- 20th Century reanalysis, Compo et al 2011 (20thC)

  From 1850 to 2014, assimilates only surface pressure

- ERA-20C, Poli et al 2016

  From 1900 to 2010, assimilates surface pressure and marine winds

Can we look at jet metrics further back in time?

Over the satellite ERA we have ~37 years of data (1979 – now)

ERA-Interim (1979-now), MERRA2 (1980-now), JRA-55 (using 1979-now)

We now have two 20th Century reanalyses

- 20th Century reanalysis, Compo et al 2011 (20thC)

  From 1850 to 2014, assimilates only surface pressure

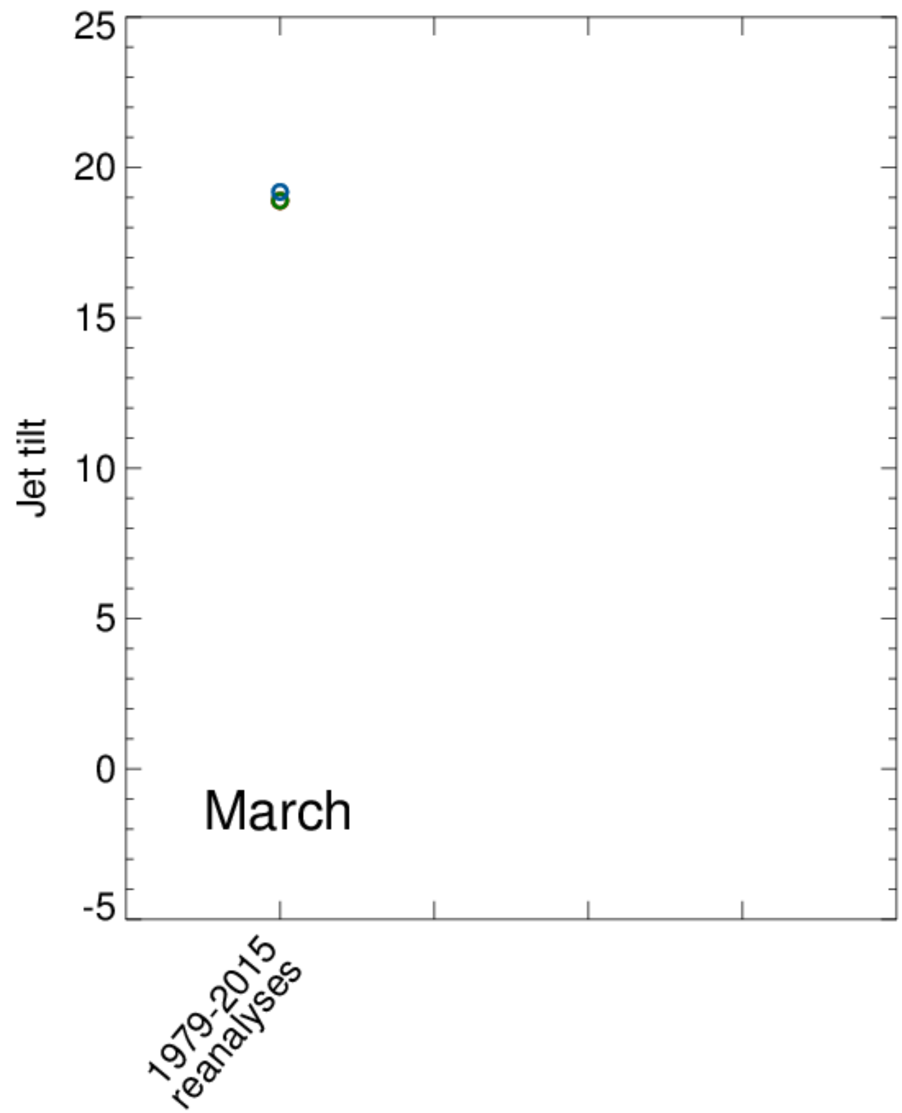
- ERA-20C, Poli et al 2016

  From 1900 to 2010, assimilates surface pressure and marine winds

If these two reanalyses agree on North Atlantic jet metrics further back in time then we can have some confidence that they are being adequately constrained by observations

Comparing model climatologies with reanalysis, placing the climatology of the satellite era within the context of the full 20^{th} Century

An example: Jet tilt in March

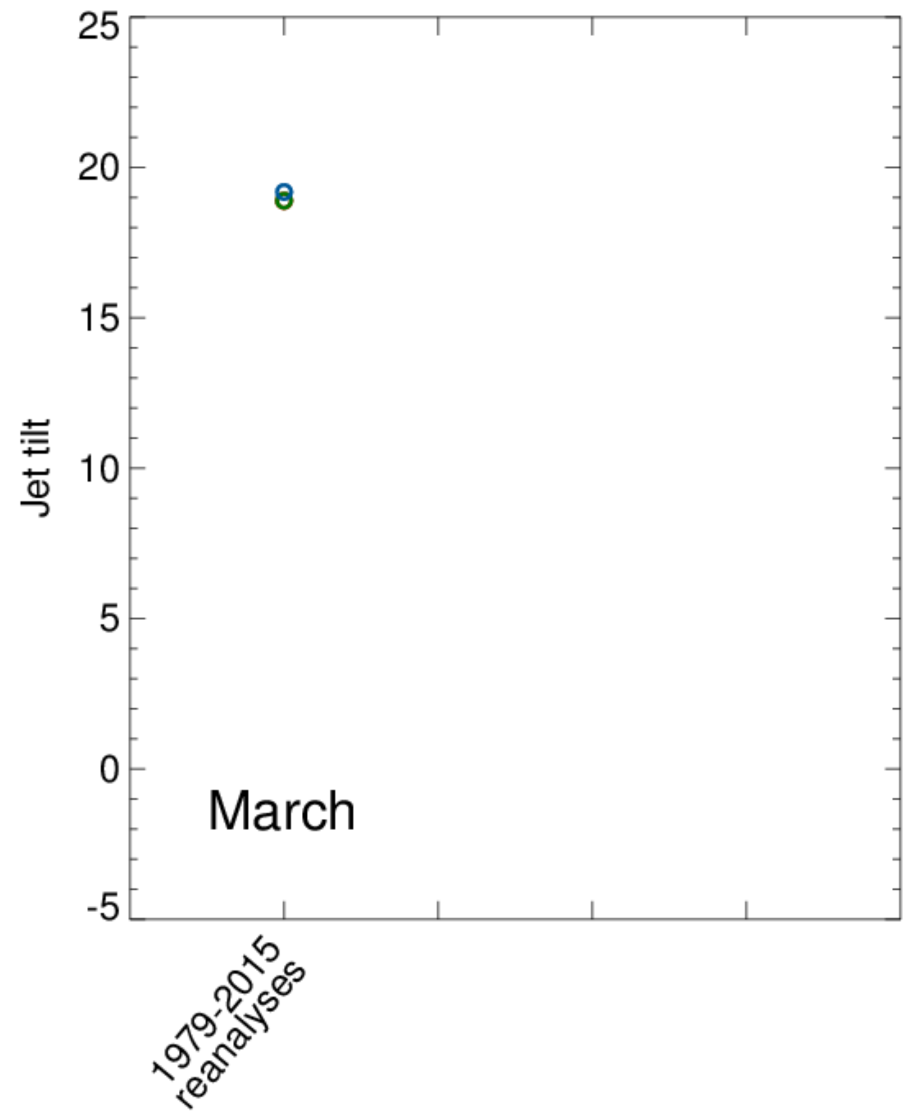


○ ERA-Interim ○ MERRA2 ○ JRA-55

Comparing model climatologies with reanalysis, placing the climatology of the satellite era within the context of the full 20th Century

An example: Jet tilt in March

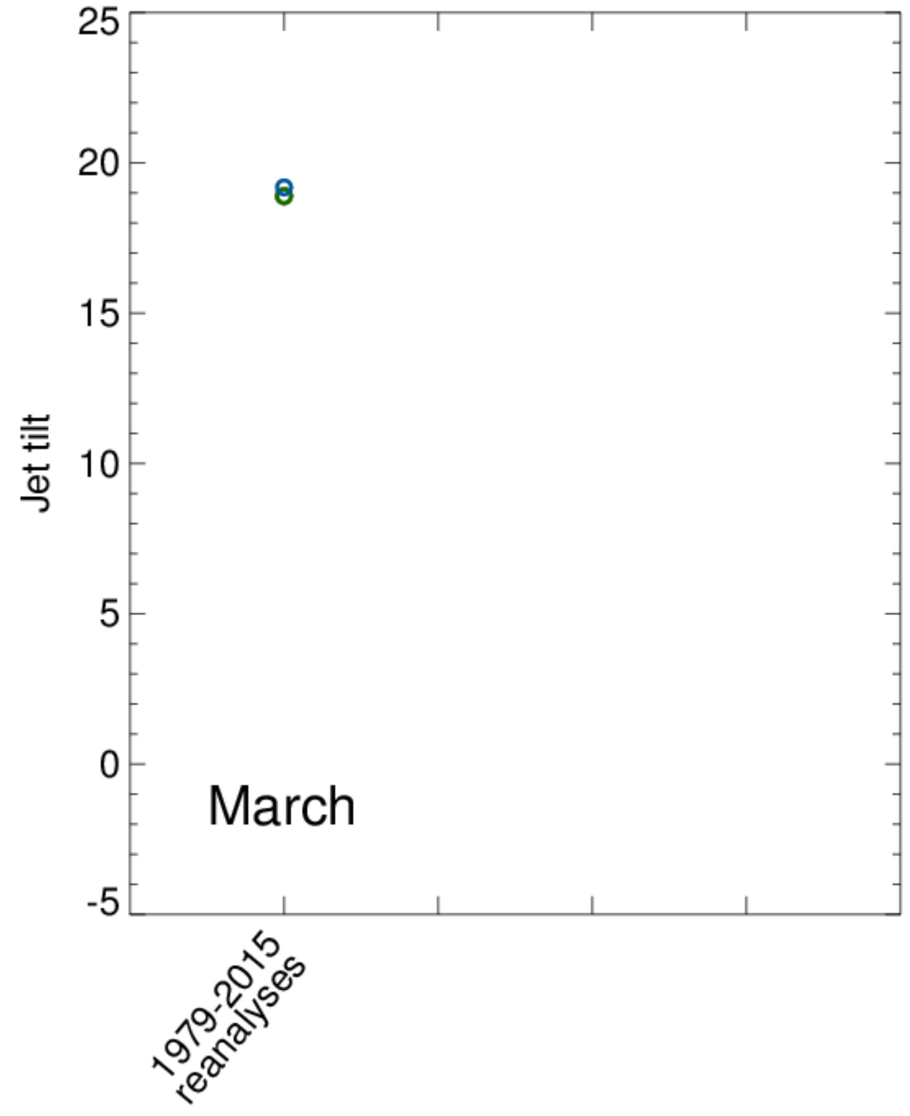
!!Note, March is an extreme example!!



ERA-Interim MERRA2 JRA-55

Comparing model climatologies with reanalysis, placing the climatology of the satellite era within the context of the full 20th Century

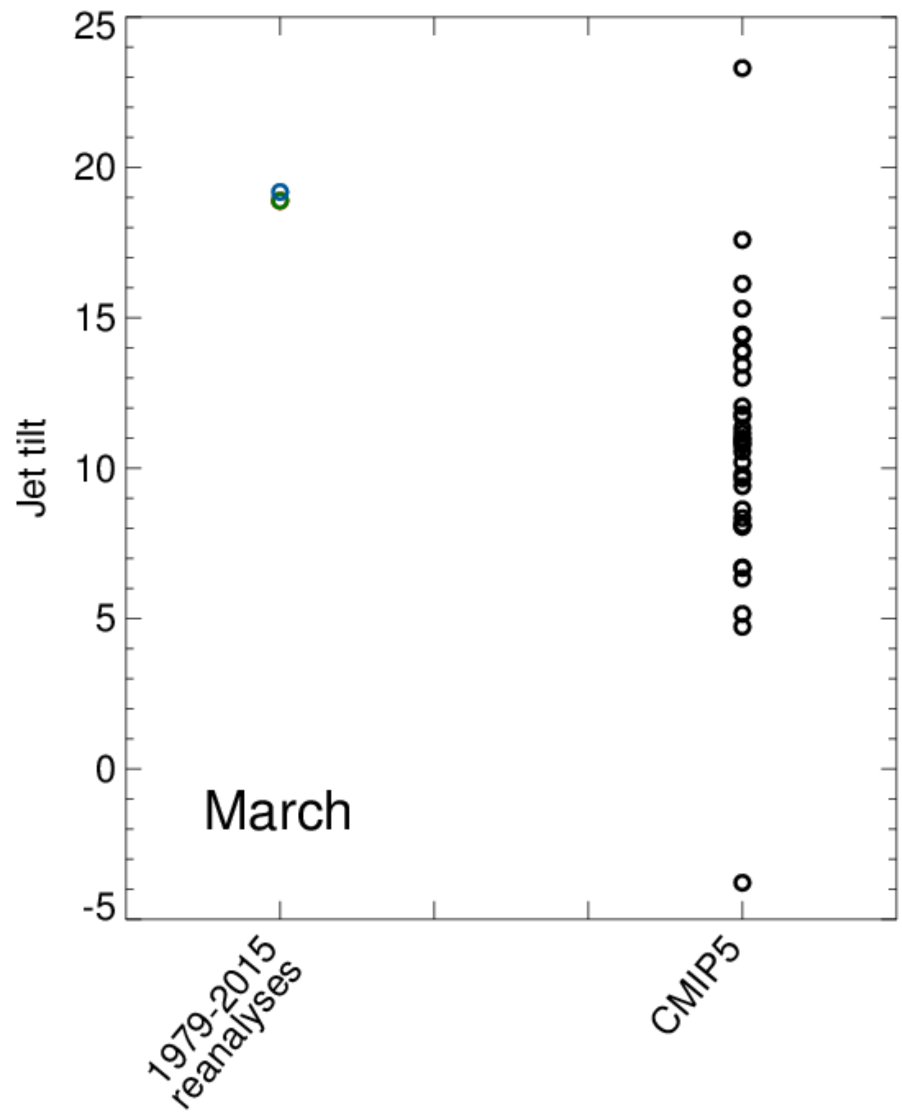
An example: Jet tilt in March



ERA-Interim MERRA2 JRA-55

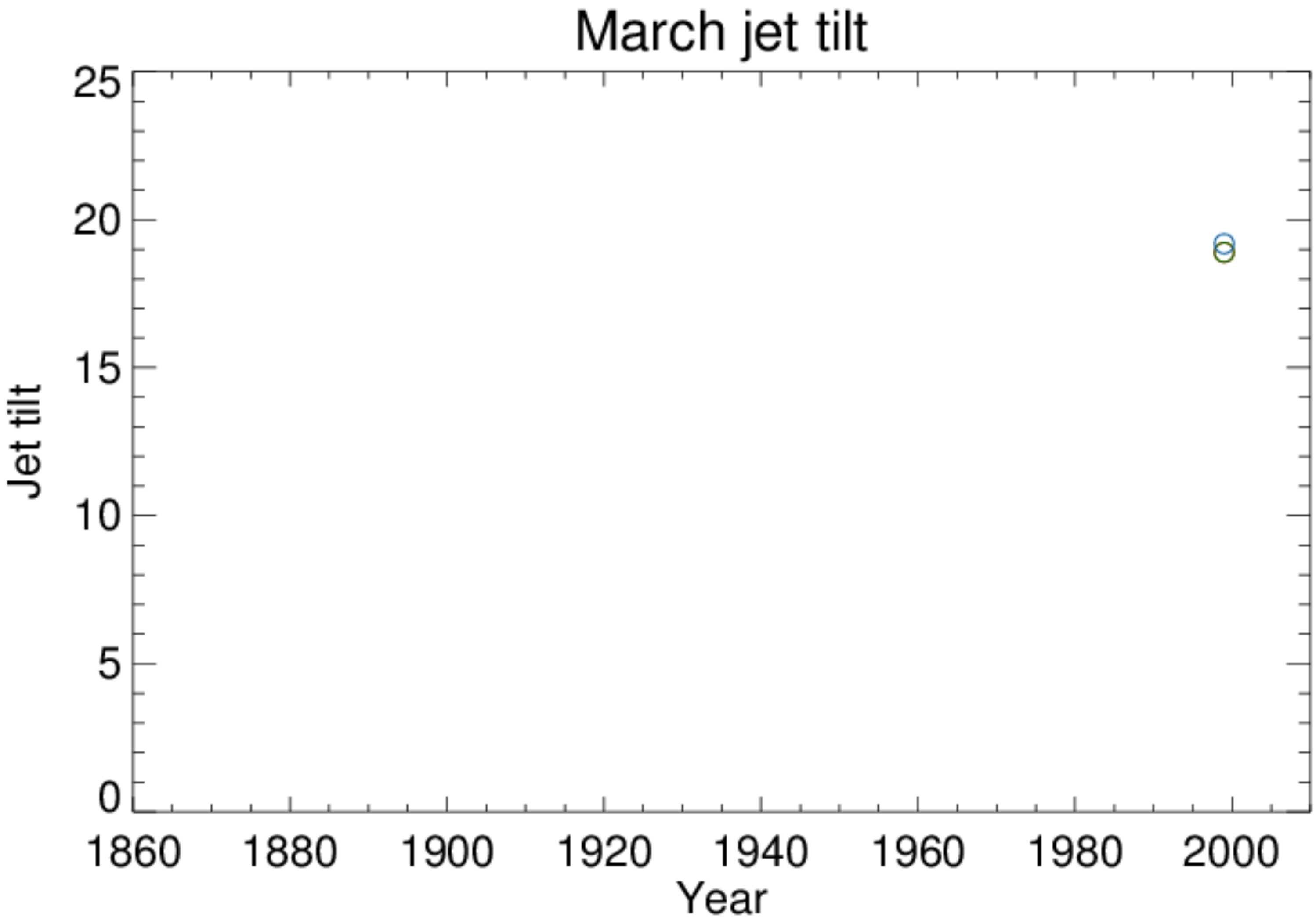
Comparing model climatologies with reanalysis, placing the climatology of the satellite era within the context of the full 20th Century

An example: Jet tilt in March



ERA-Interim MERRA2 JRA-55

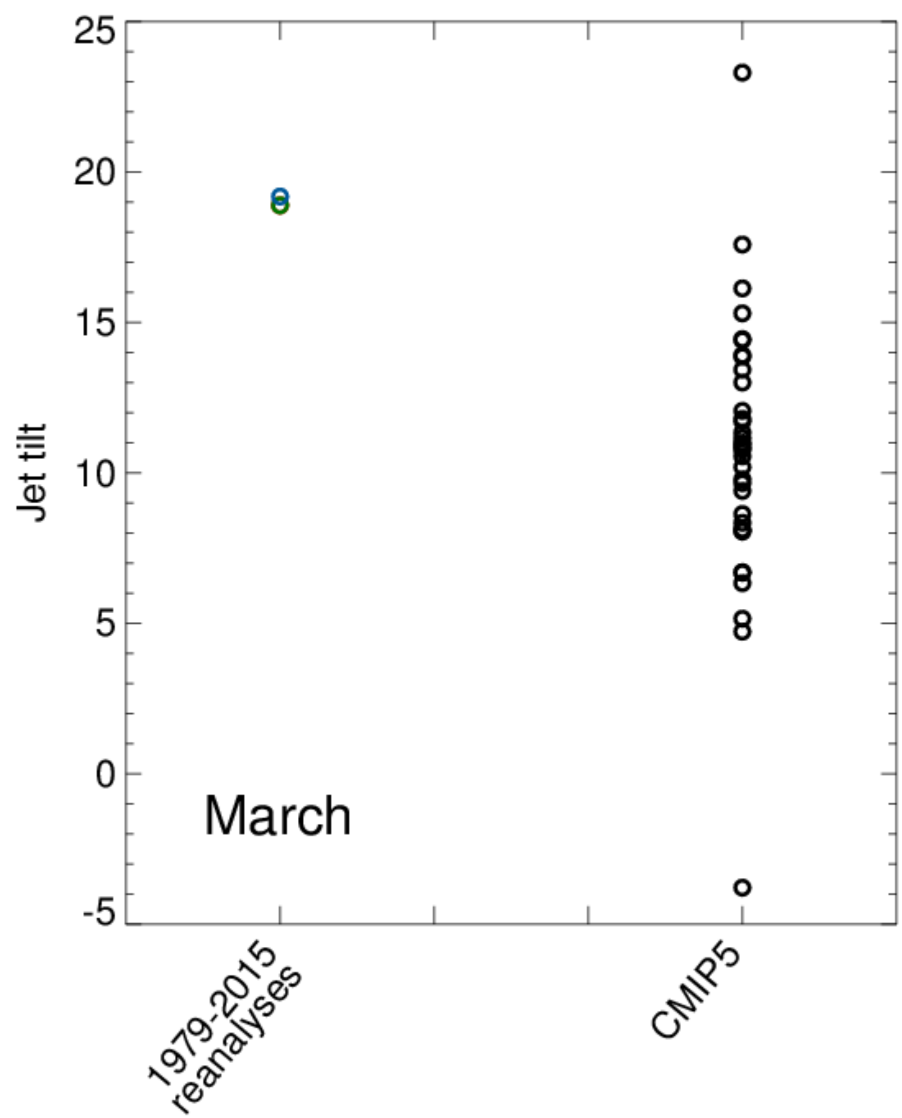
37 year running means of March jet tilt



ERA-Interim MERRA2 JRA-55

Comparing model climatologies with reanalysis, placing the climatology of the satellite era within the context of the full 20th Century

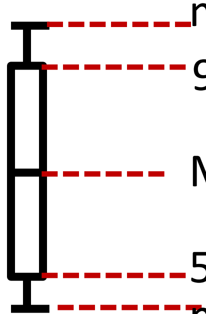
An example: Jet tilt in March

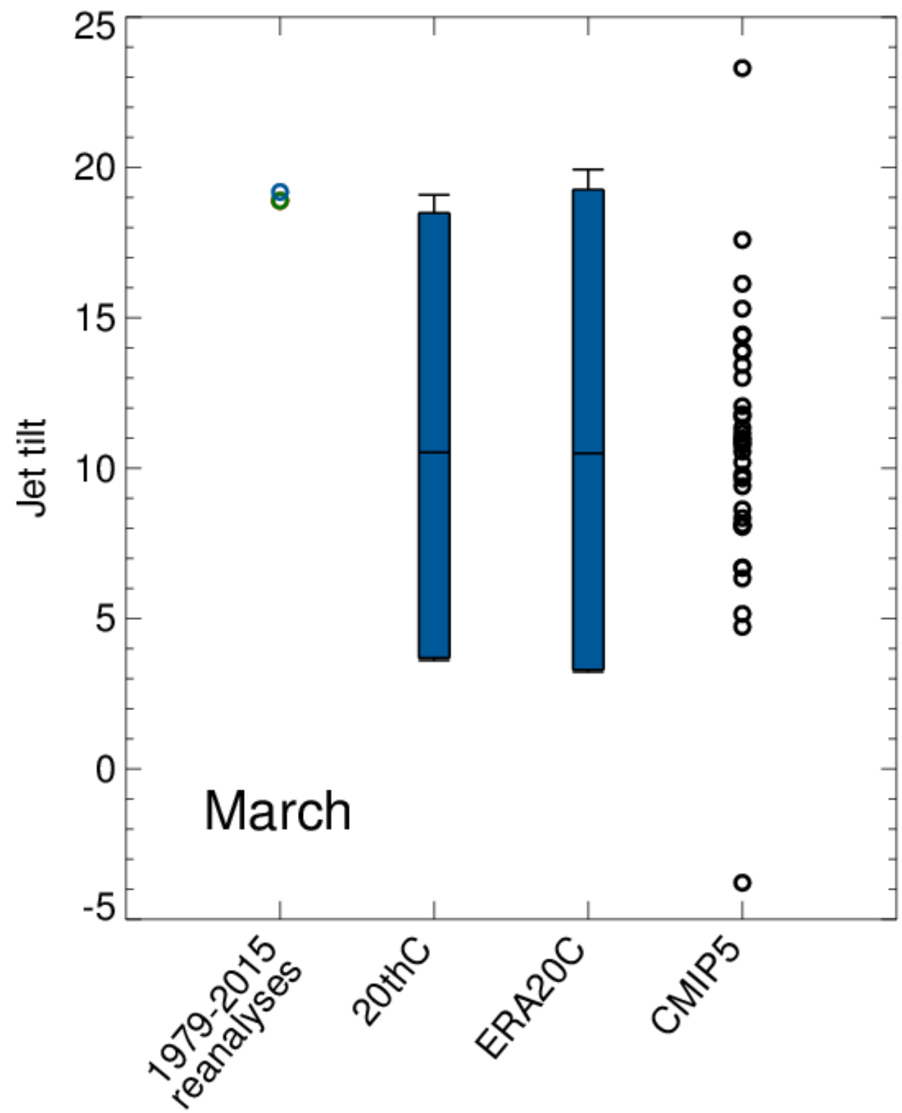


ERA-Interim MERRA2 JRA-55

Comparing model climatologies with reanalysis, placing the climatology of the satellite era within the context of the full 20th Century

An example: Jet tilt in March

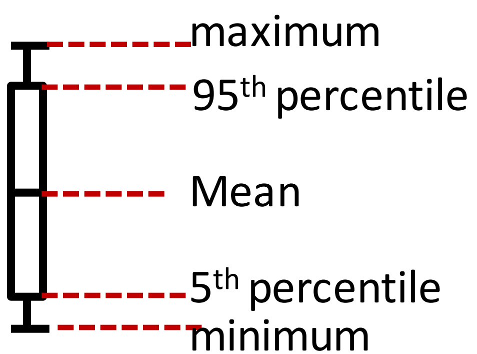


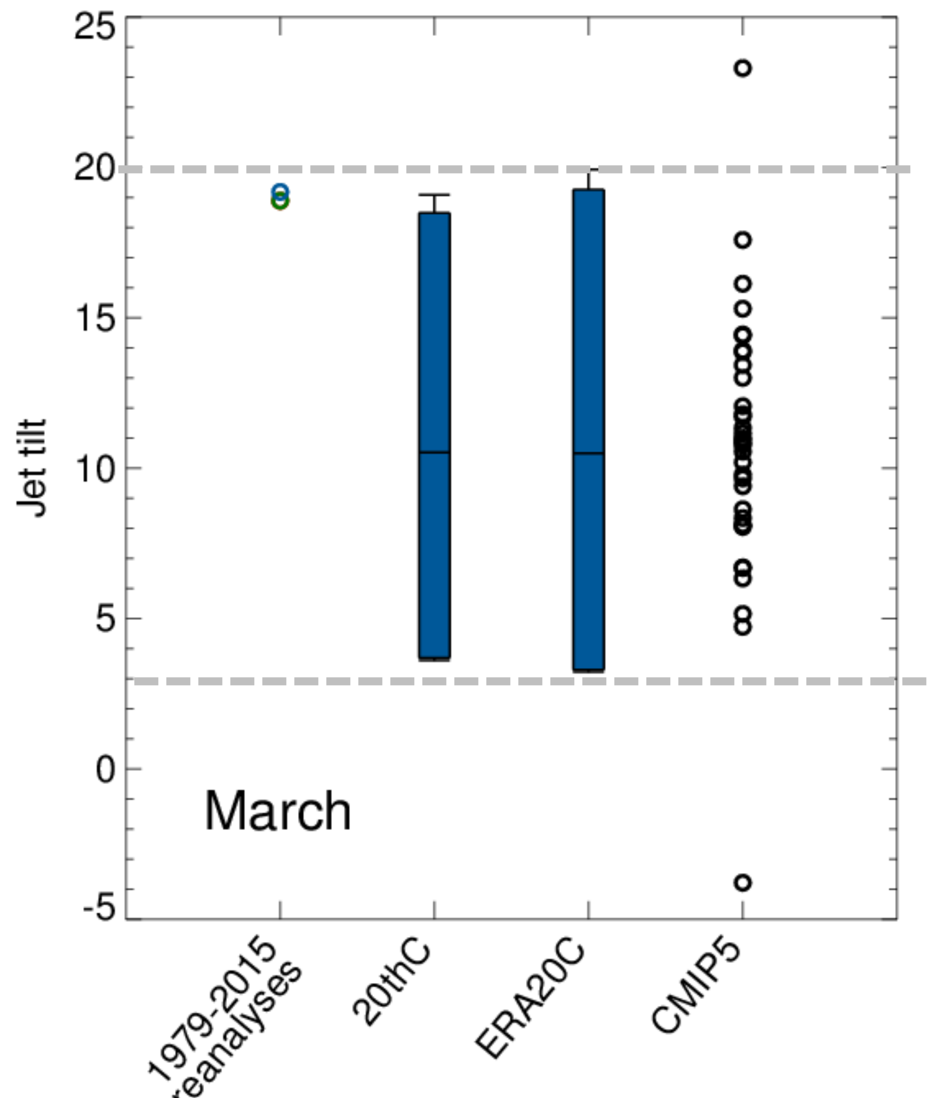


ERA-Interim MERRA2 JRA-55

Comparing model climatologies with reanalysis, placing the climatology of the satellite era within the context of the full 20th Century

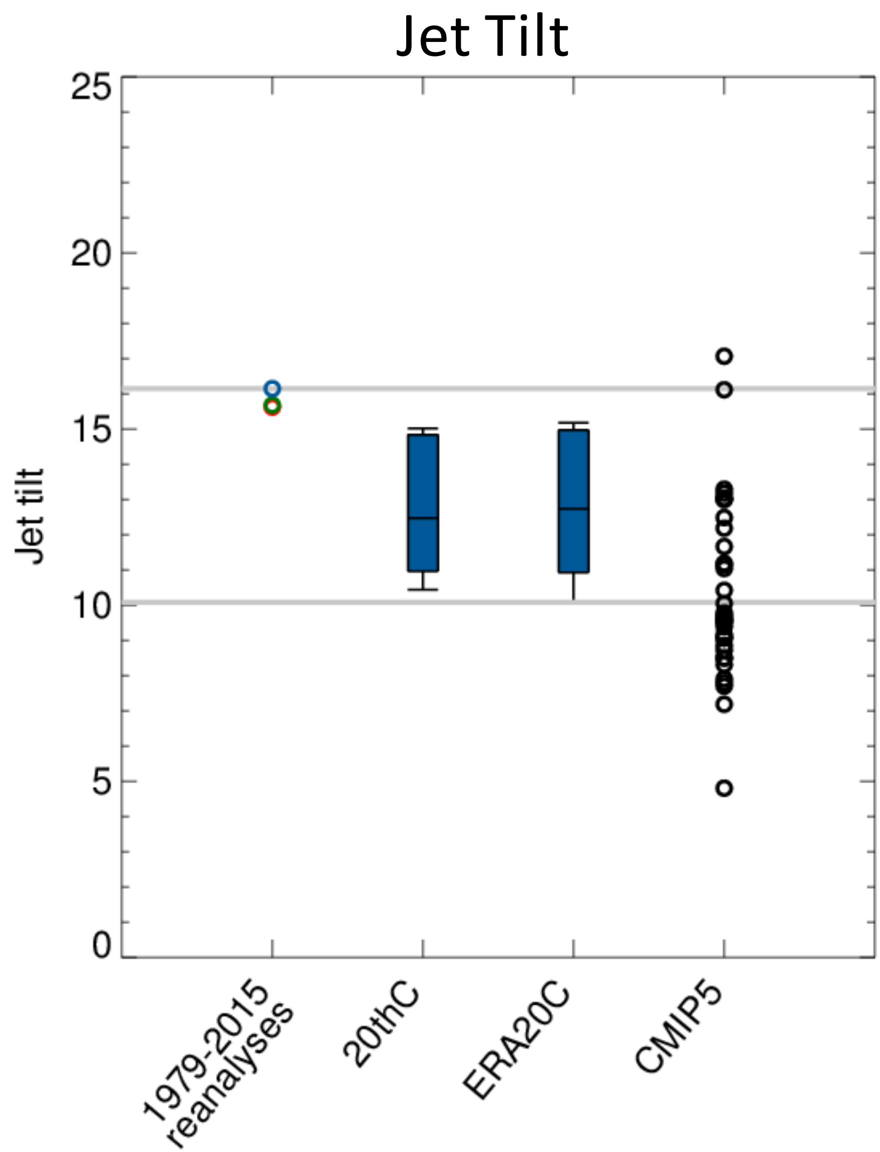
An example: Jet tilt in March





ERA-Interim MERRA2 JRA-55

The same but for JFM



ERA-Interim MERRA2 JRA-55

Does this spread in climatologies just reflect internal variability?

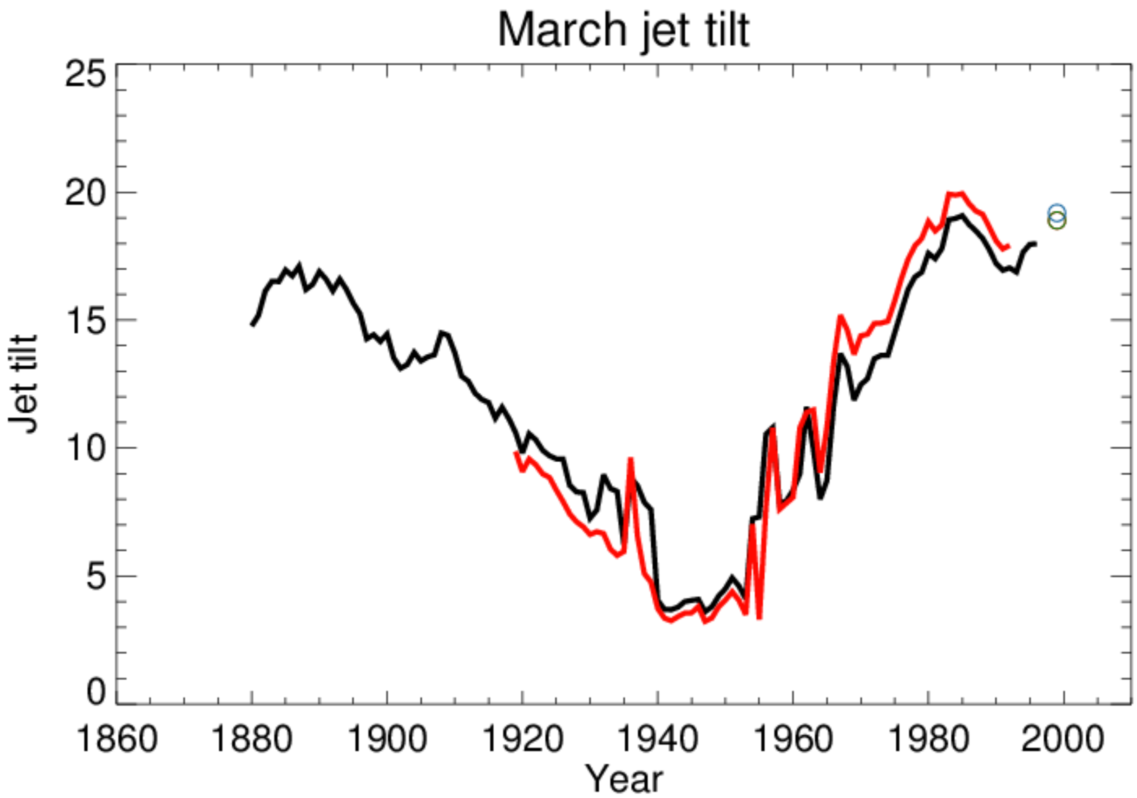
Does this spread in climatologies just reflect internal variability?

I think yes, because…

Does this spread in climatologies just reflect internal variability?

I think yes, because…

(1)Variability doesn't resemble a long term GHG forced trend

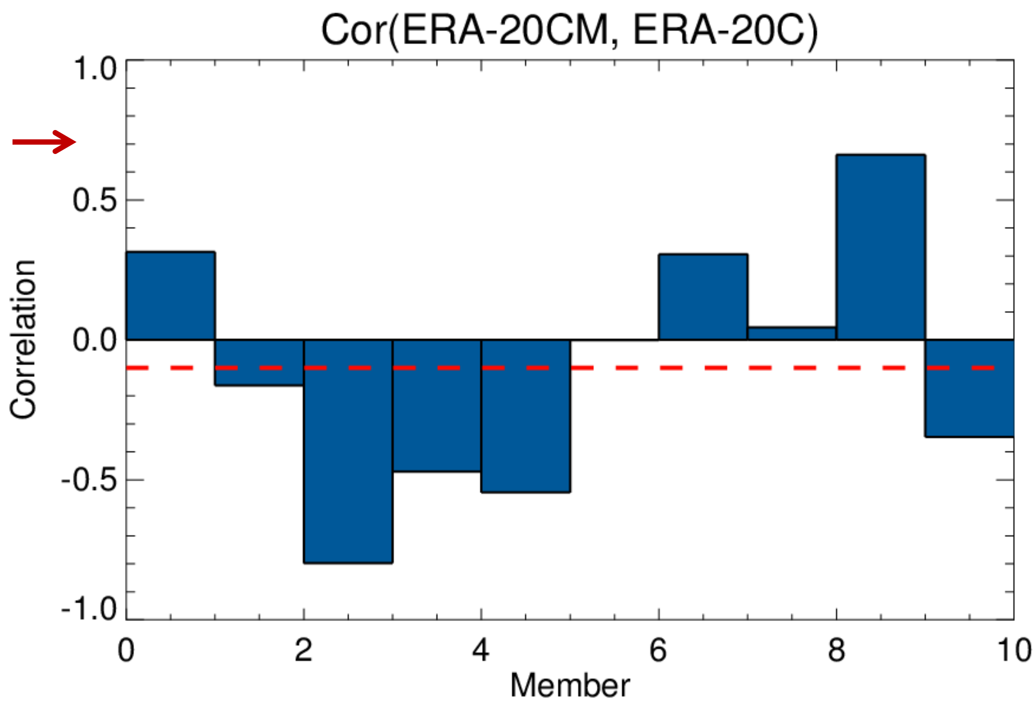


Does this spread in climatologies just reflect internal variability?

I think yes, because…

(2) Model simulations with historical SSTs and forcings don't reproduce the same variations in jet tilt…

Correlation of time evolution of 37y jet tilts between 10 ERA-20CM members and ERA-20C

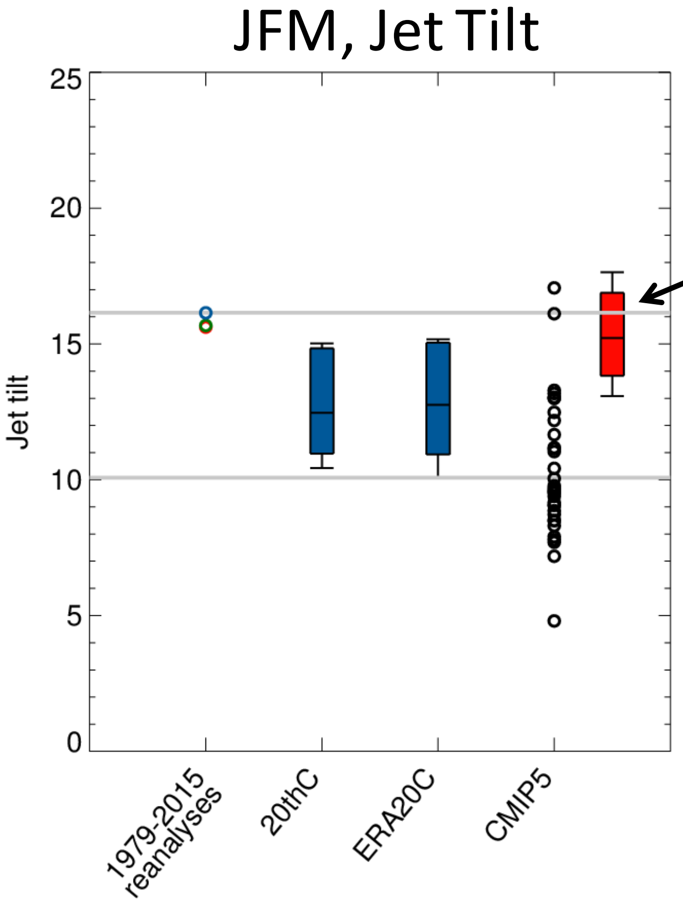


ERA-20CM = free running simulations with prescribed historical SSTs and forcings

Does this spread in climatologies just reflect internal variability?

I think yes, because…

(3) A similar degree of variability is present in long coupled control simulations (with the exception of March)



Jet tilt range for 37y climatologies of a long (1600y) 1850 control run with CESM

North Atlantic Jet Summary

- Over the North Atlantic, there is a wide spread among GCMs in their predicted climate change response.
- More robust changes occur over Europe and the Mediterranean
- Internal variability is likely an important contributor to this model spread
- When assessing the fidelity of our models in the North Atlantic, we need to consider the uncertainty that’s present in the observed climatology
- The 1979-present climatology may not necessarily be the true real world climatology that we should be aiming for

Summary

Summary

- Modes of variability allow us to assess the representation of processes within models

  e.g., SAM timescales are too long in summer in general → biased eddy feedbacks

Summary

- Modes of variability allow us to assess the representation of processes within models

  e.g., SAM timescales are too long in summer in general → biased eddy feedbacks

- Also can result in signal/noise ratio's being small and present day climatologies being uncertain.

  e.g., Lots of variability in the North Atlantic → do we really know the climatology we need to aim for?

Summary

- Modes of variability allow us to assess the representation of processes within models

  e.g., SAM timescales are too long in summer in general → biased eddy feedbacks

- Also can result in signal/noise ratio's being small and present day climatologies being uncertain.

  e.g., Lots of variability in the North Atlantic → do we really know the climatology we need to aim for?

- Modes of variability may change in the future.

  e.g., QBO. According to some models it may change a lot, others not so much.

Summary

- Modes of variability allow us to assess the representation of processes within models

  e.g., SAM timescales are too long in summer in general → biased eddy feedbacks

- Also can result in signal/noise ratio's being small and present day climatologies being uncertain.

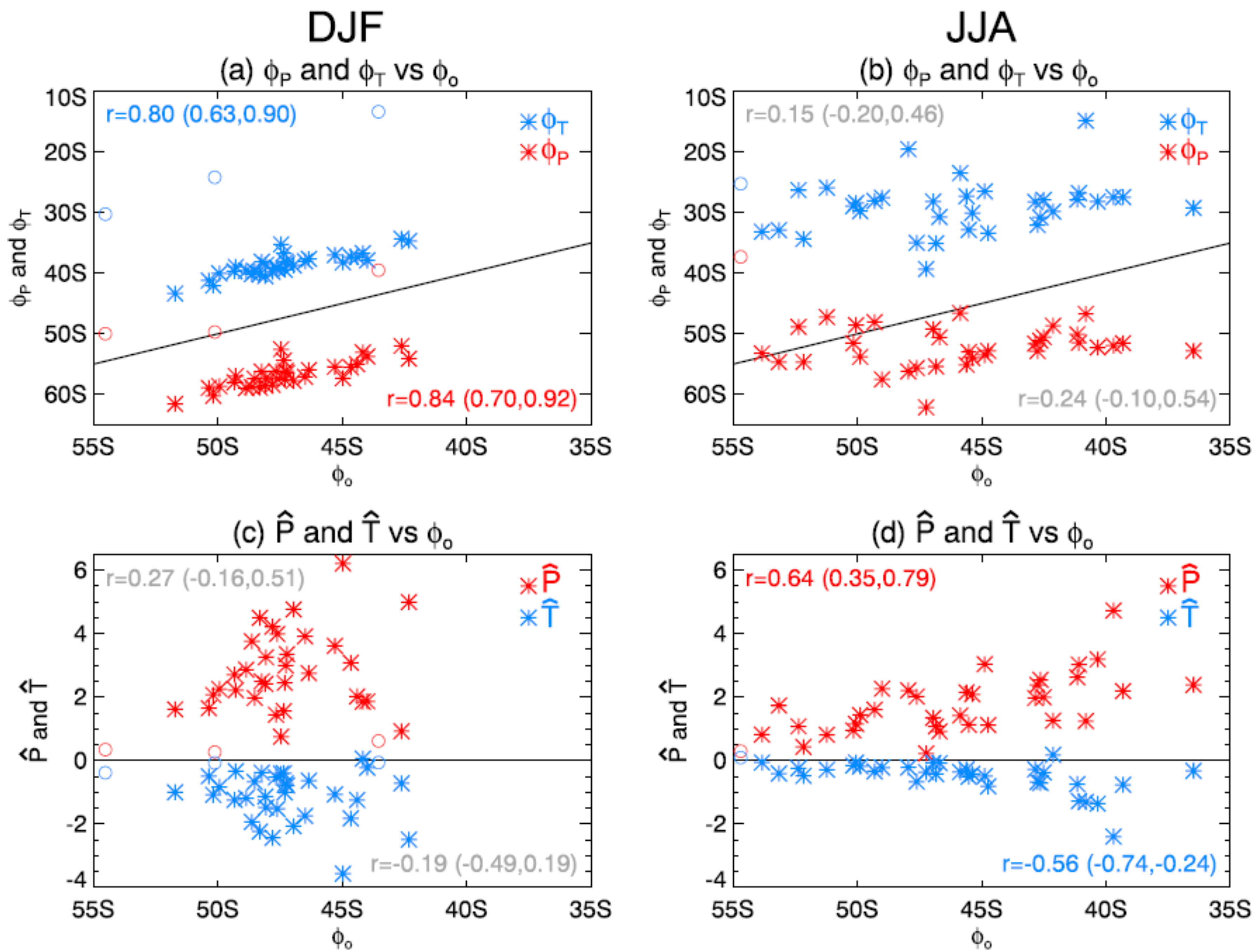
  e.g., Lots of variability in the North Atlantic → do we really know the climatology we need to aim for?

- Modes of variability may change in the future.

  e.g., QBO. According to some models it may change a lot, others not so much.

- Need to understand the reason for these changes and model spread and understand the mechanisms behind emergent constraints that exist.

Extra Slides



DJF
JJA
(a) ϕ_P and ϕ_T vs ϕ_o
r=0.80 (0.63,0.90)
r=0.84 (0.70,0.92)
(b) ϕ_P and ϕ_T vs ϕ_o
r=0.15 (-0.20,0.46)
r=0.24 (-0.10,0.54)
ϕ_T
ϕ_P
ϕ_P and ϕ_T
10S
20S
30S
40S
50S
60S
55S
50S
45S
40S
35S
ϕ_o
(c) $\hat{P}$ and $\hat{T}$ vs ϕ_o
r=0.27 (-0.16,0.51)
r=-0.19 (-0.49,0.19)
(d) $\hat{P}$ and $\hat{T}$ vs ϕ_o
r=0.64 (0.35,0.79)
r=-0.56 (-0.74,-0.24)
$\hat{P}$
$\hat{T}$
$\hat{P}$ and $\hat{T}$
6
4
2
0
-2
-4

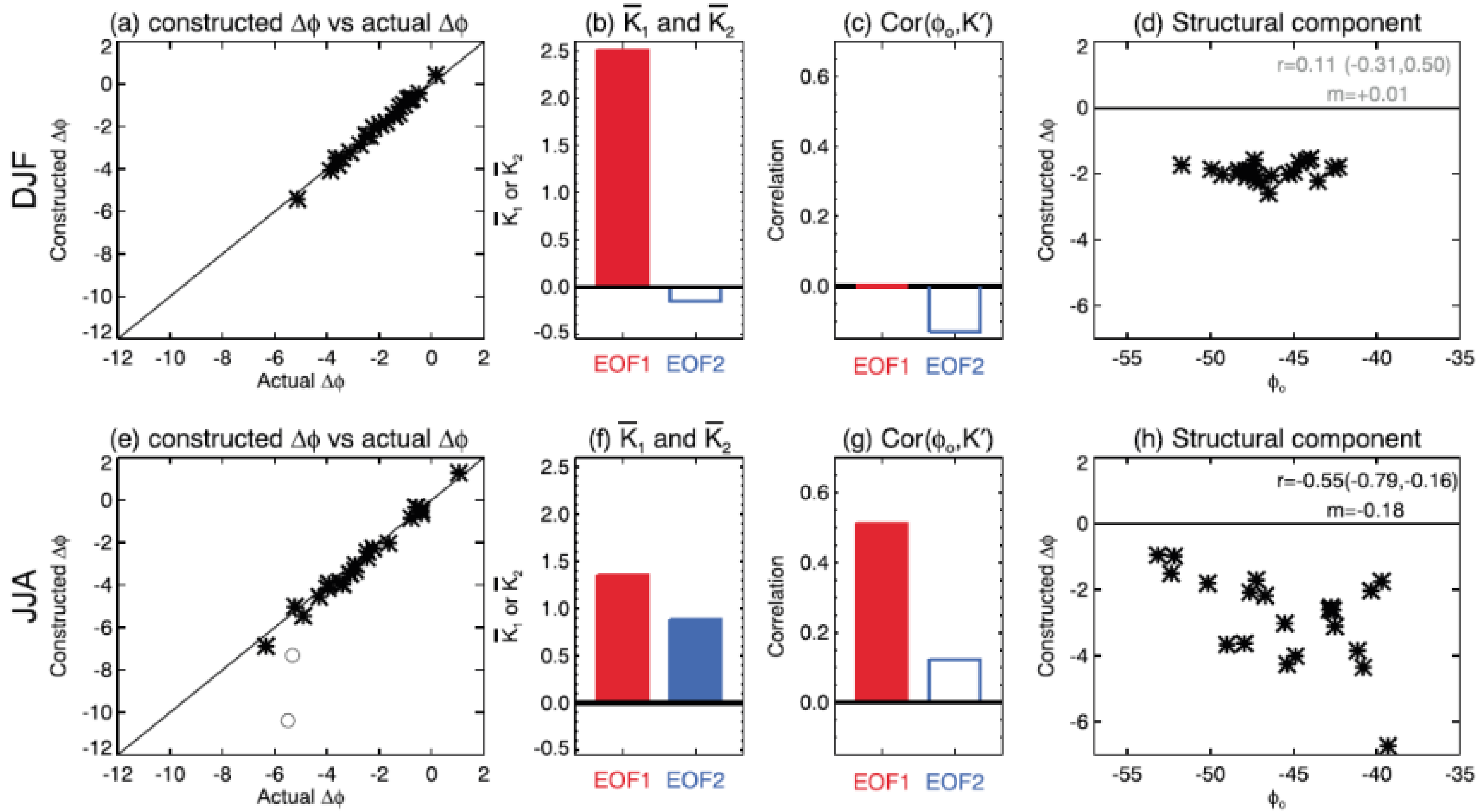


Figure 5. Relating the jet shift to the first two EOFs of natural variability in (top row) DJF and (bottom row) JJA. (a and e) constructed jet shift based on (1) versus actual jet shift. This does not work well for the two circled models in Figure 5e, so these are omitted from the remaining panels. (b and f) multimodel mean projection of the Future-Past difference onto EOFs 1 and 2 and (c and d) the correlation between the projection onto EOFs 1 and 2 and ϕ_o. Shaded bars are statistically significant at the 95% level by a students *t* test in Figures 5b and 5f and by the Fisher transform in Figures 5c and 5g. (d and h) The relationship between $\Delta\phi$ and ϕ_o obtained from the structural effect alone, i.e., omitting the last two terms in (2).

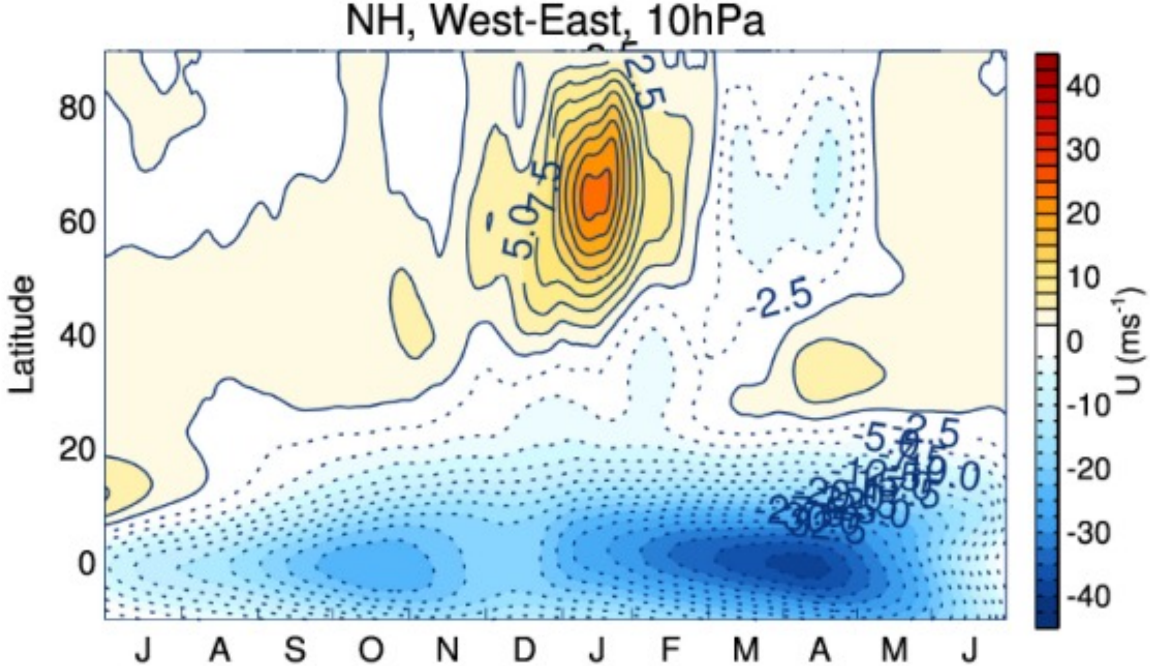
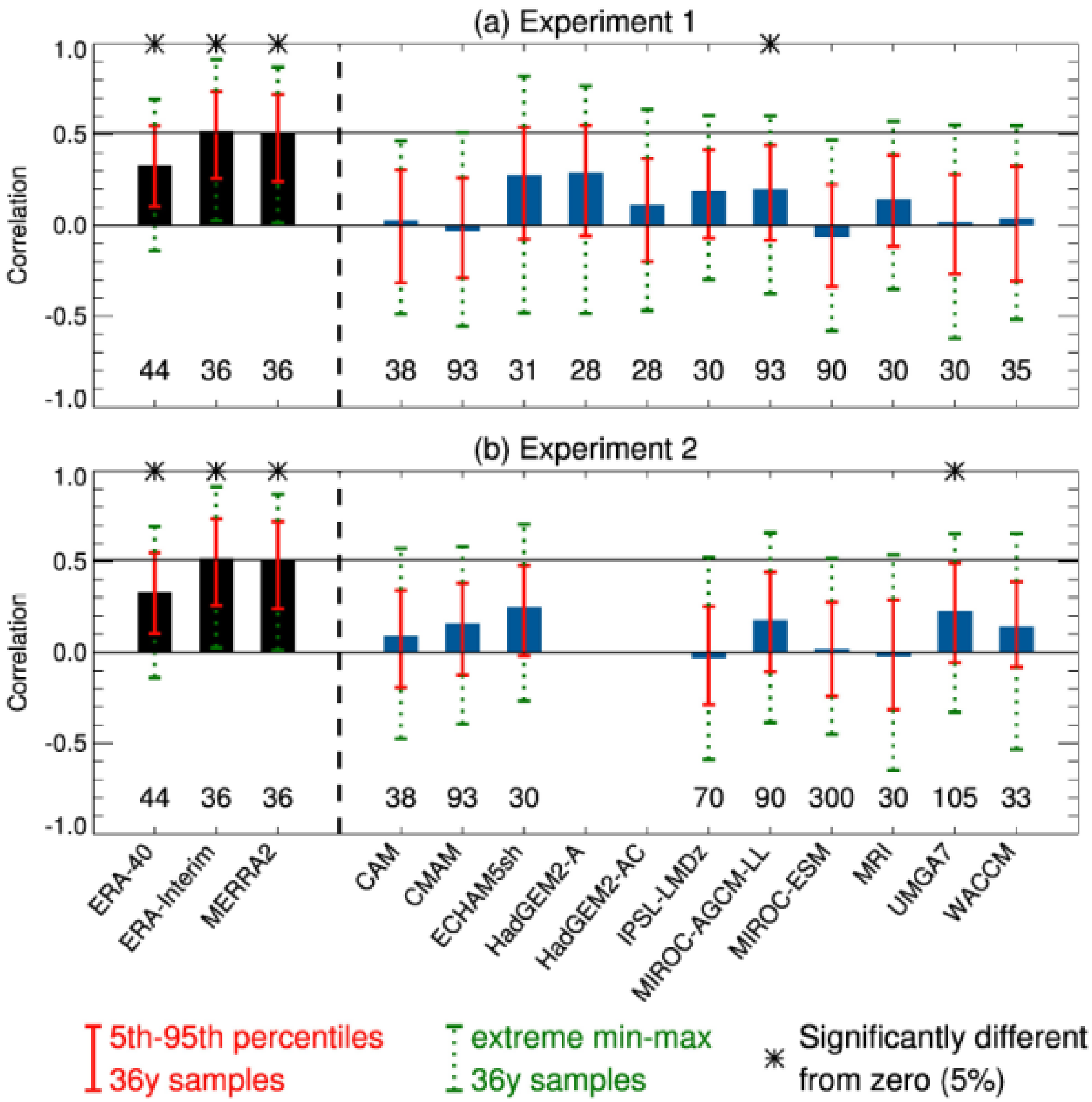
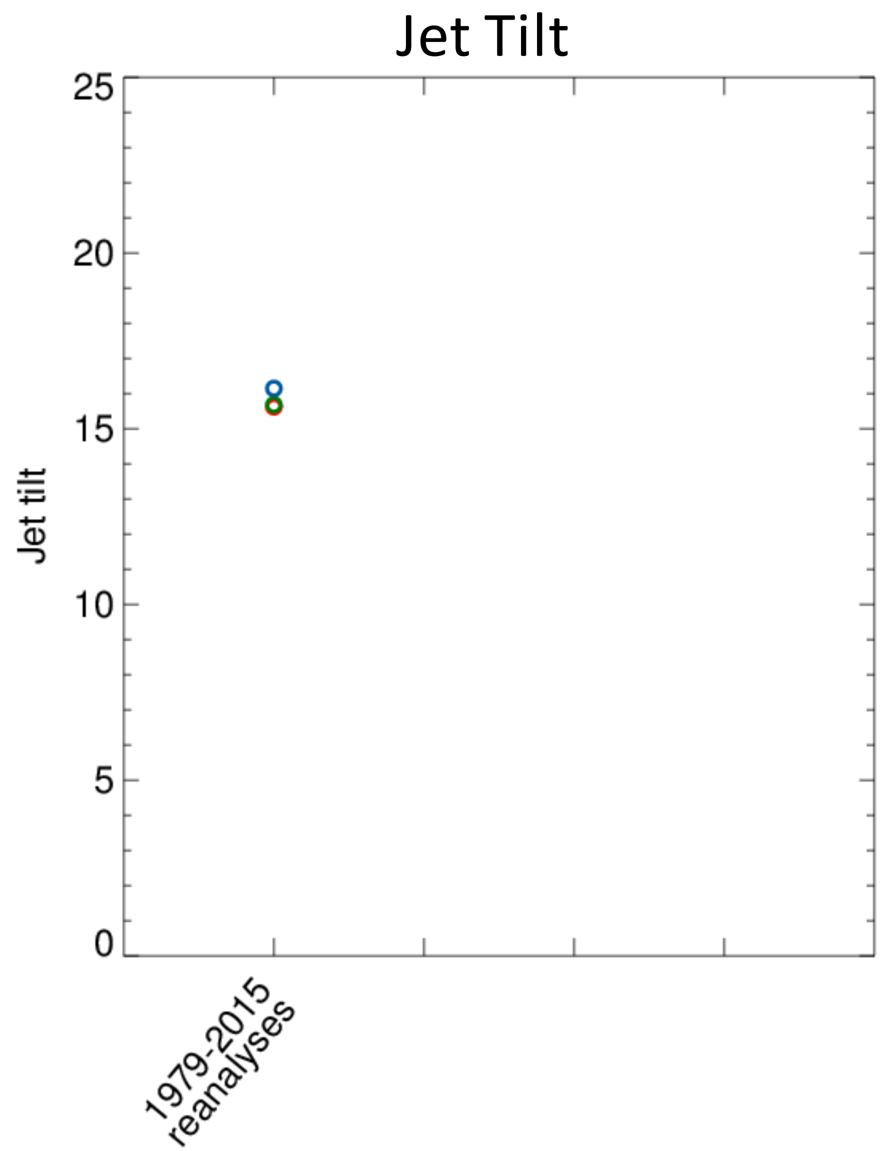


Figure 1: The composite difference (Westerly - Easterly) in zonal mean zonal wind at 10hPa. The QBO phase has been defined based on the sign of the equatorial zonal winds at 50hPa in January. This is a reproduction of Figure 3 of Anstey and Shepherd (2014) but using 36 years of MERRA2 data.



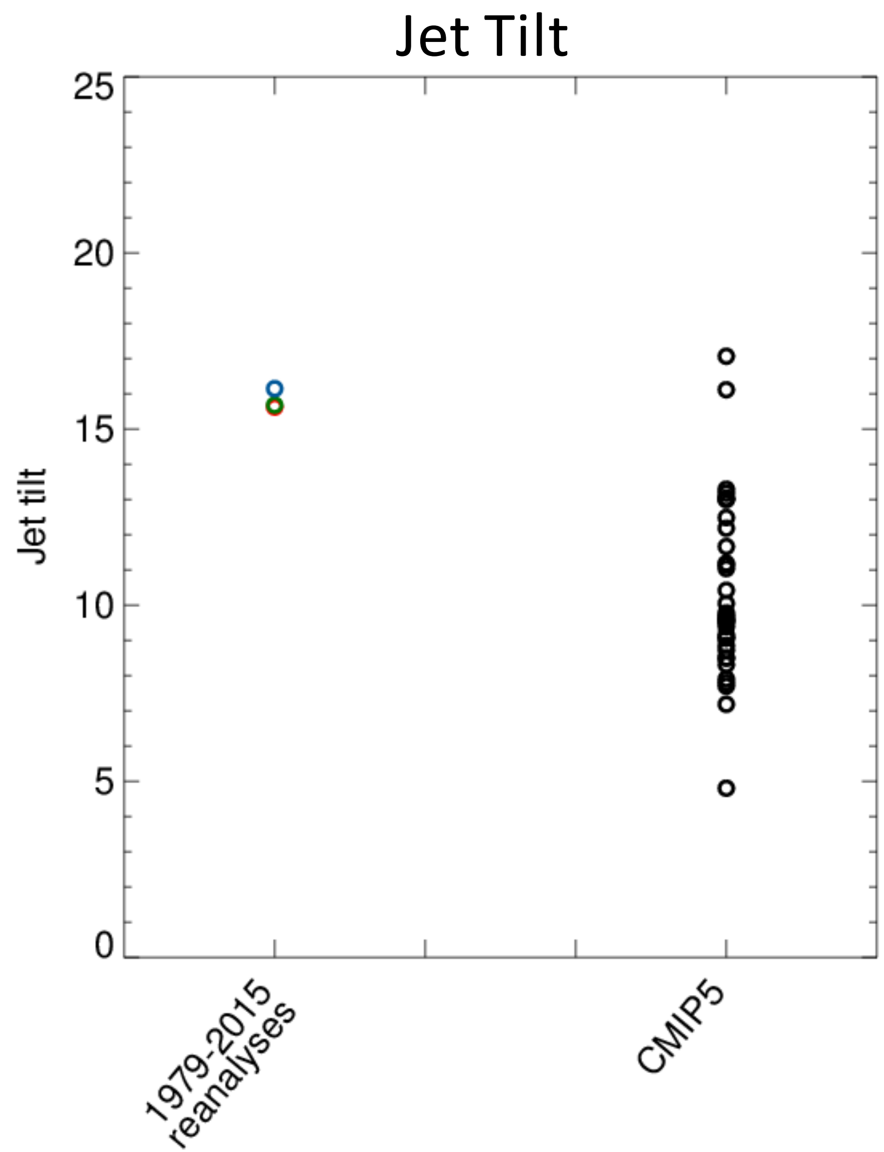
(a) Experiment 1
(b) Experiment 2
Correlation
1.0
0.5
0.0
-0.5
-1.0
44 36 36 38 93 31 28 28 30 93 90 30 30 35
44 36 36 38 93 30 70 90 300 30 105 33
ERA-40
ERA-Interim
MERRA2
CAM
CMAM
ECHAM5sh
HadGEM2-A
HadGEM2-AC
IPSL-LMDz
MIROC-AGCM-LL
MIROC-ESM
MRI
UMGA7
WACCM
5th-95th percentiles
36y samples
extreme min-max
36y samples
Significantly different
from zero (5%)

The same but for JFM



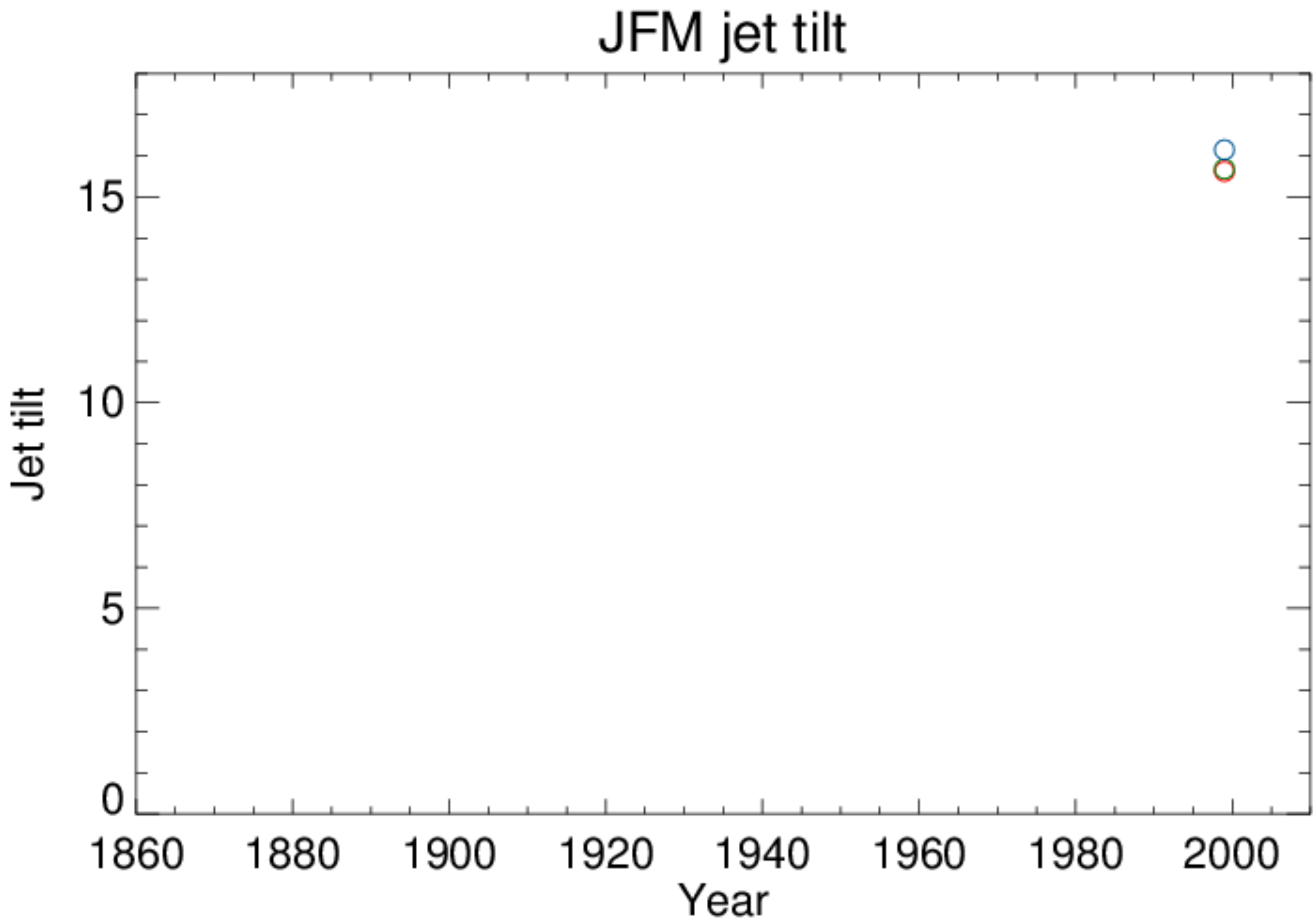
ERA-Interim MERRA2 JRA-55

The same but for JFM



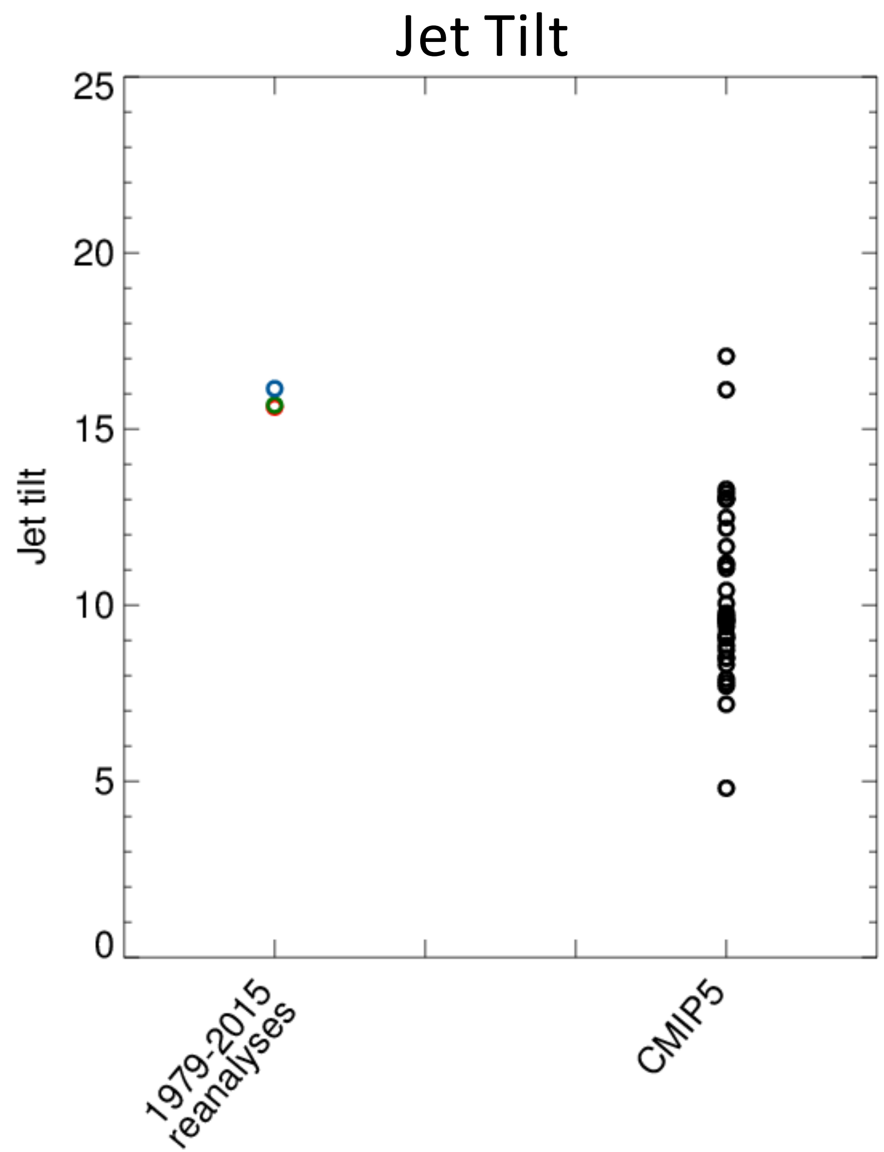
ERA-Interim   MERRA2   JRA-55

JFM, 37 year running means jet tilt



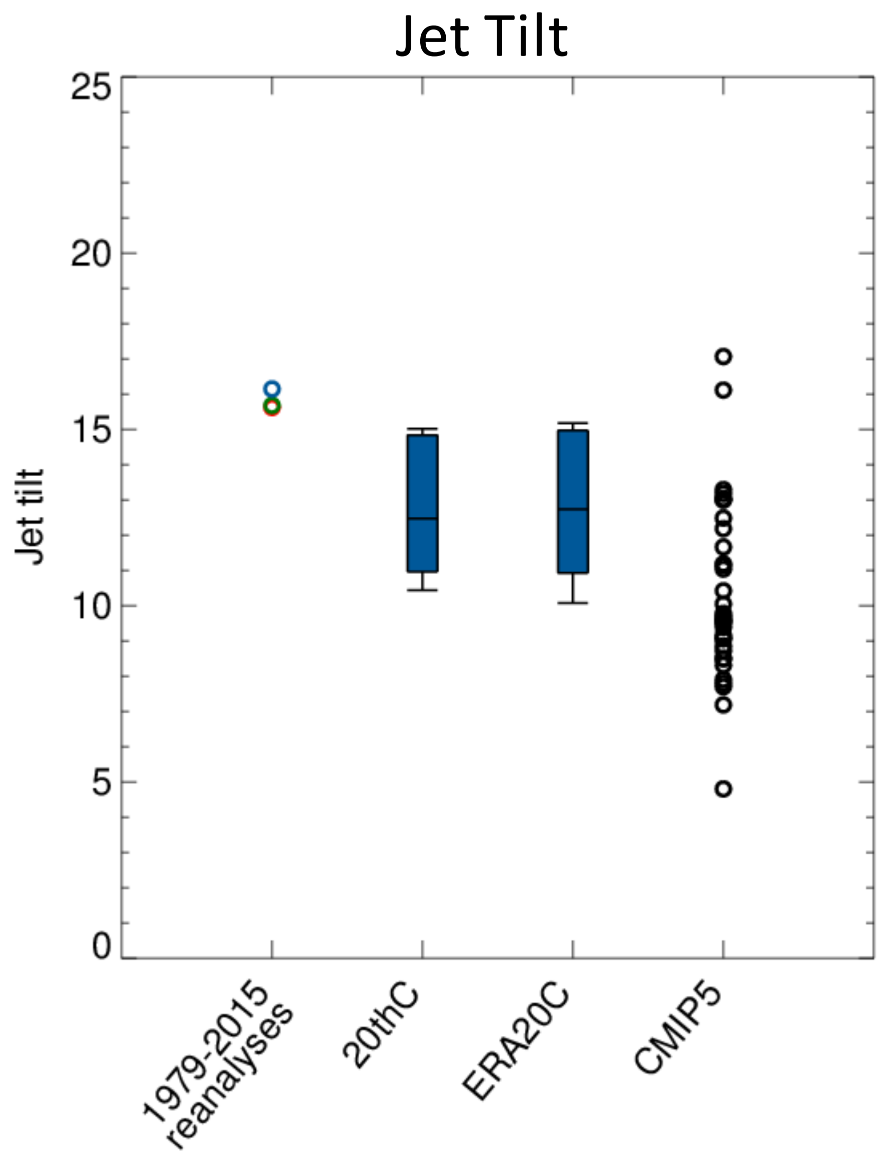
ERA-Interim MERRA2 JRA-55

The same but for JFM



ERA-Interim MERRA2 JRA-55

The same but for JFM



ERA-Interim MERRA2 JRA-55