On the Role of Reanalysis in Attribution Studies

4th World Climate Research Program
International Conference on Reanalyses
11-17 May 2012

Silver Spring Maryland

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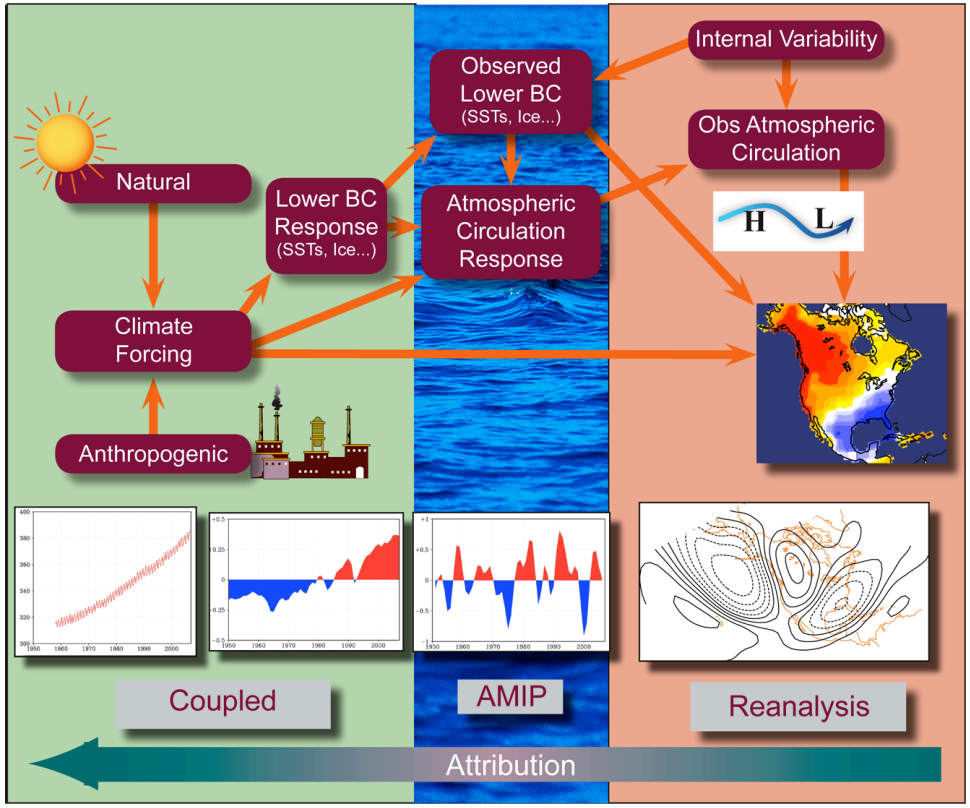
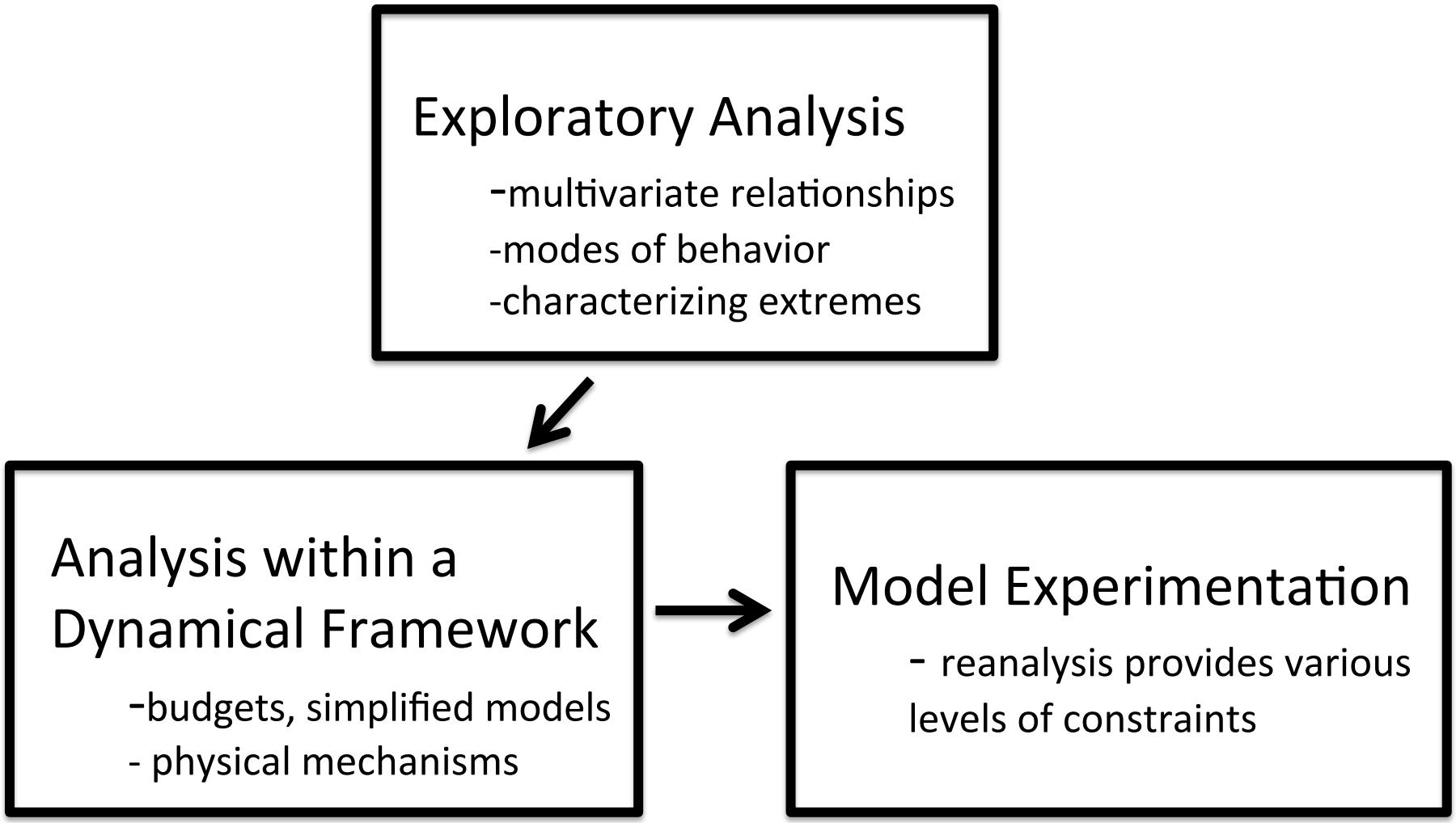
Global Modeling and Assimilation Office

"Attribution is the process of determining the most likely cause or causes for an observed variation or change in climate."



CCSP SAP1.3, 2008: Reanalysis of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change. Randall Dole, Martin Hoerling, and Siegfried Schubert (eds.)

Steps to Attribution

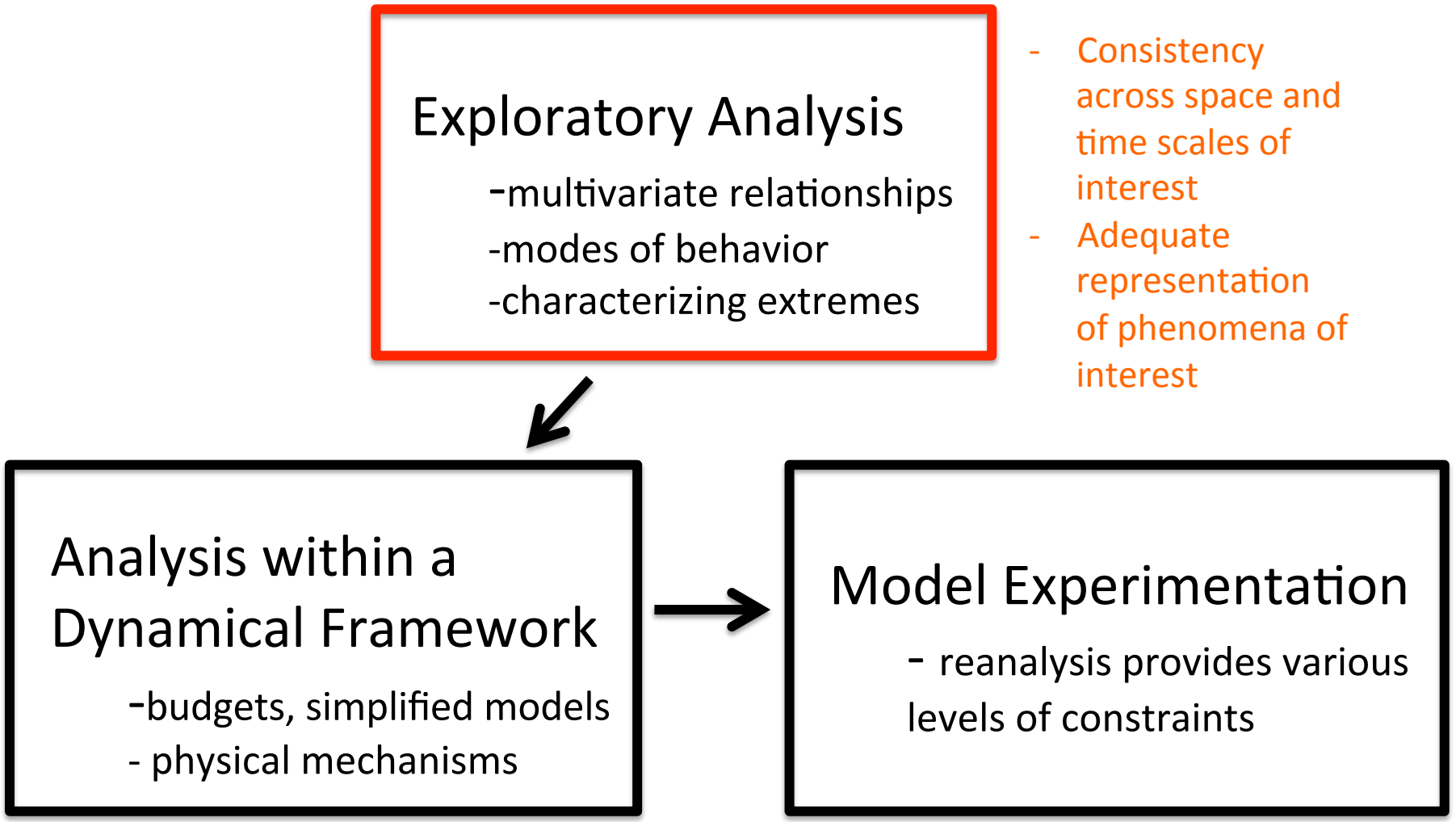


Attribution Example

What are the Causes of Heat Waves in Eurasia?
(with H. Wang, R. Koster and M. Suarez)

Recent examples are the 2010, 2011 Russian Heat Waves and the 2003 European Heat Wave

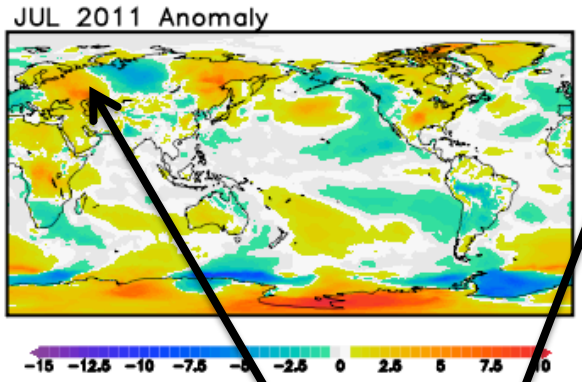
Steps to Attribution



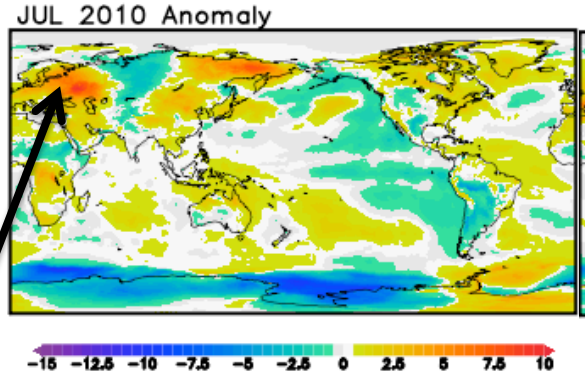
MERRA
Atlas

Temperature at 2 meters (T2m)

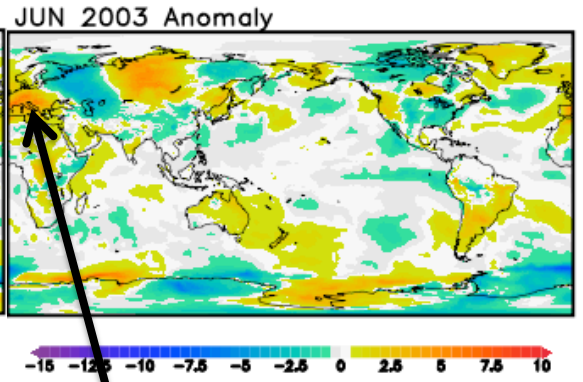
July 2011



July 2010



June 2003

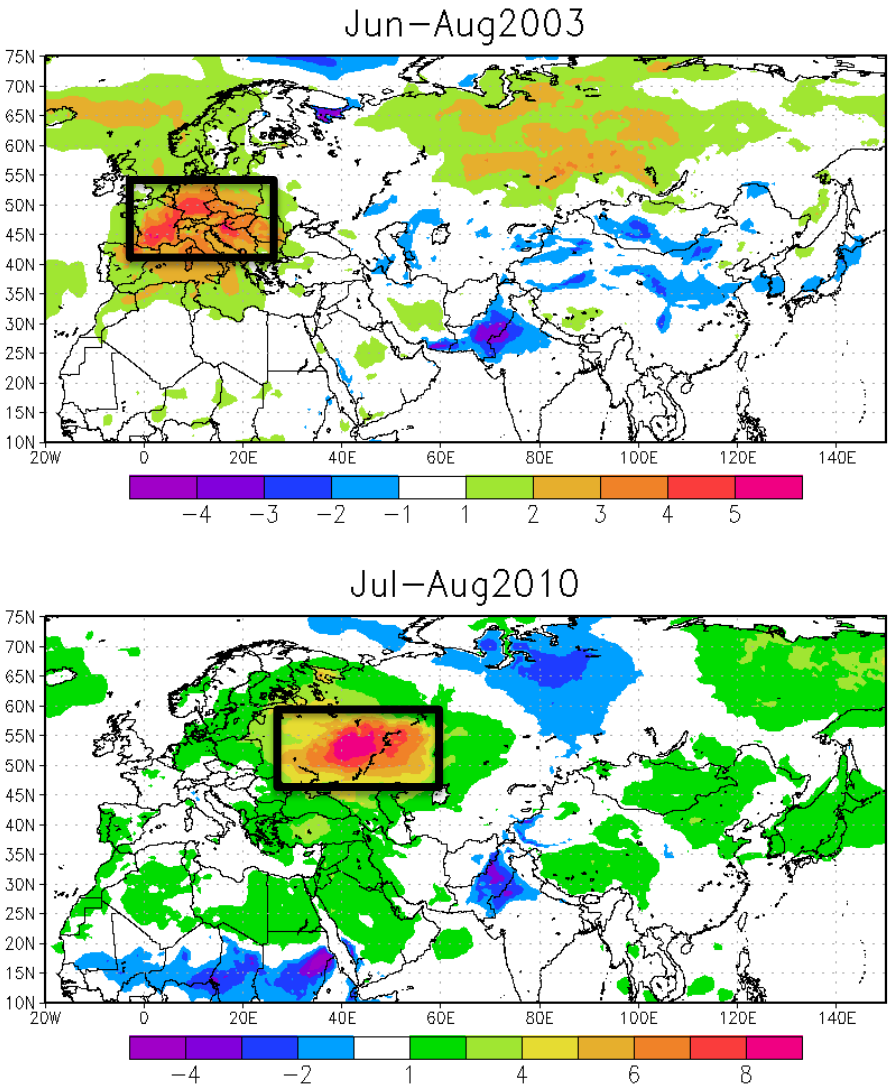


°C

Russian Heat Waves

European Heat Wave

MERRA: T2m Anomaly (°C)

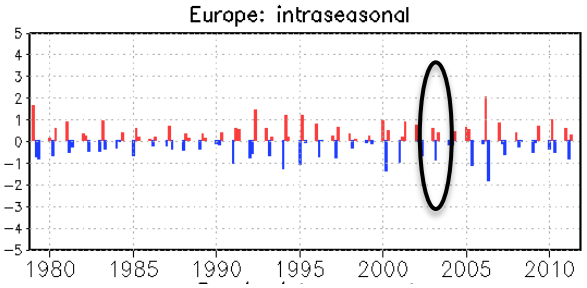


Area Averages: European region: 0-25E; 40N-55N;
western Russia region: 25E-60E;46N-62N

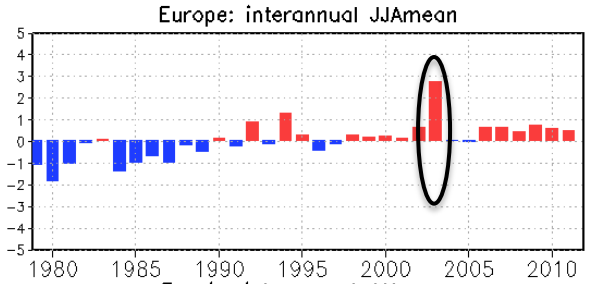
1979-2011 JJA T2m Anomalies (°C) based on MERRA

Europe

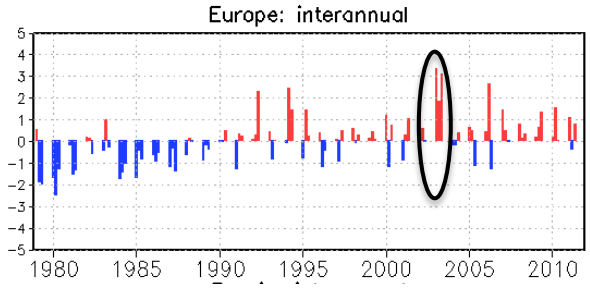
JJA intraseasonal



JJA Seasonal Mean

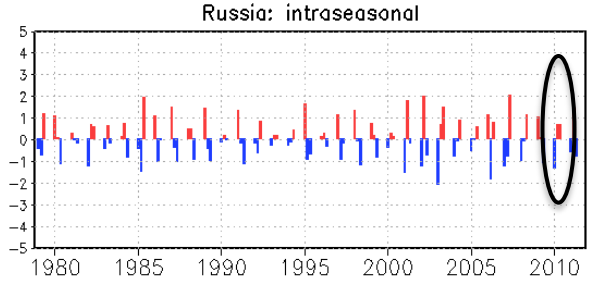


JJA Total Interannual

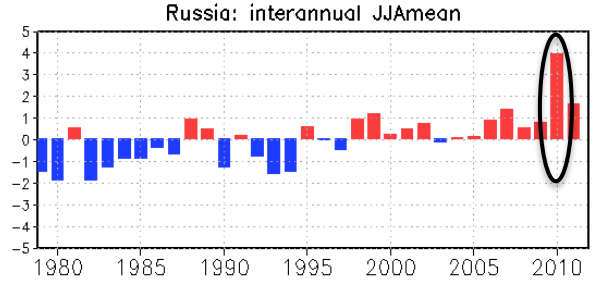


Western Russia

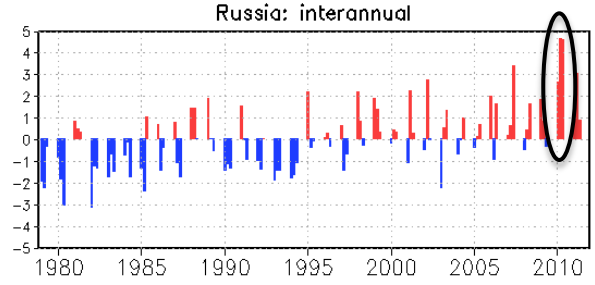
JJA intraseasonal



JJA Seasonal Mean

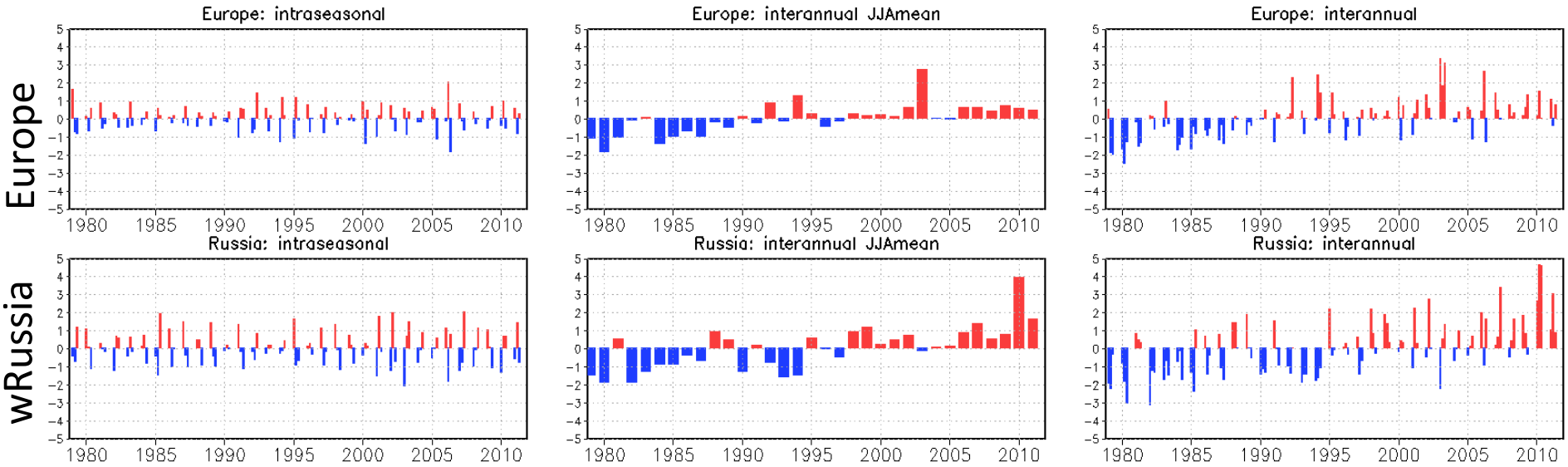


JJA Total Interannual

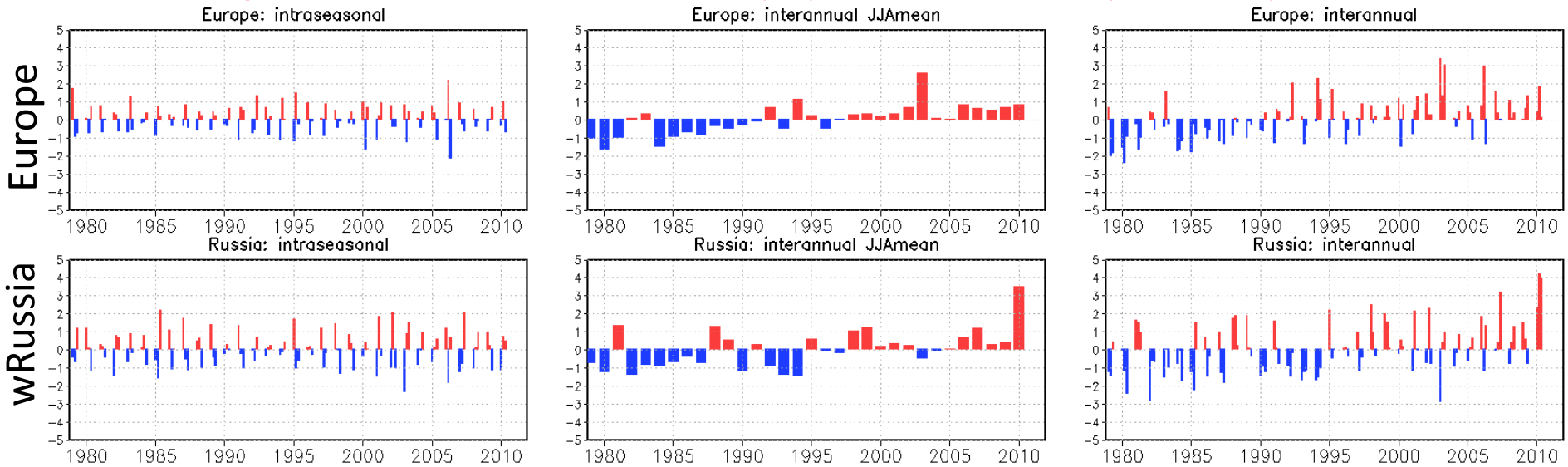


Near surface: intraseasonal and seasonal components are comparable, extreme heat waves reflected in seasonal components, with some intraseasonal modulation, apparent trend in seasonal means. **2003 over Europe,and 2010 over Russia state out**

JJA Tsfc based on MERRA (1979-2011



JJA Tsfc based on CRUTEM4 (1979-2010)



Why the alternating east/west oriented anomalies in Tfcs?

Nature of subseasonal (monthly) Tsfc variability?

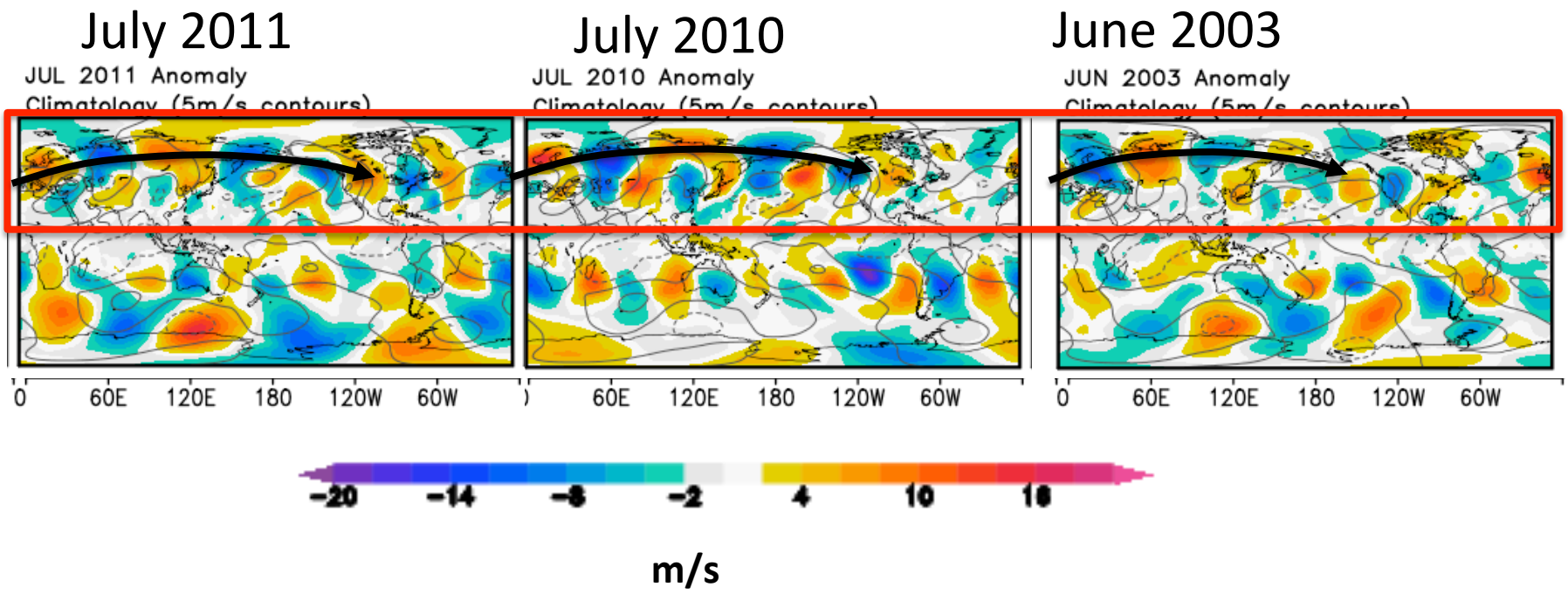
Nature of seasonal mean Tsfc variability?

Causes of apparent trend in seasonal means of Tsfc during the period 1980-2011?

Why are 2003 and 2010 so extreme?

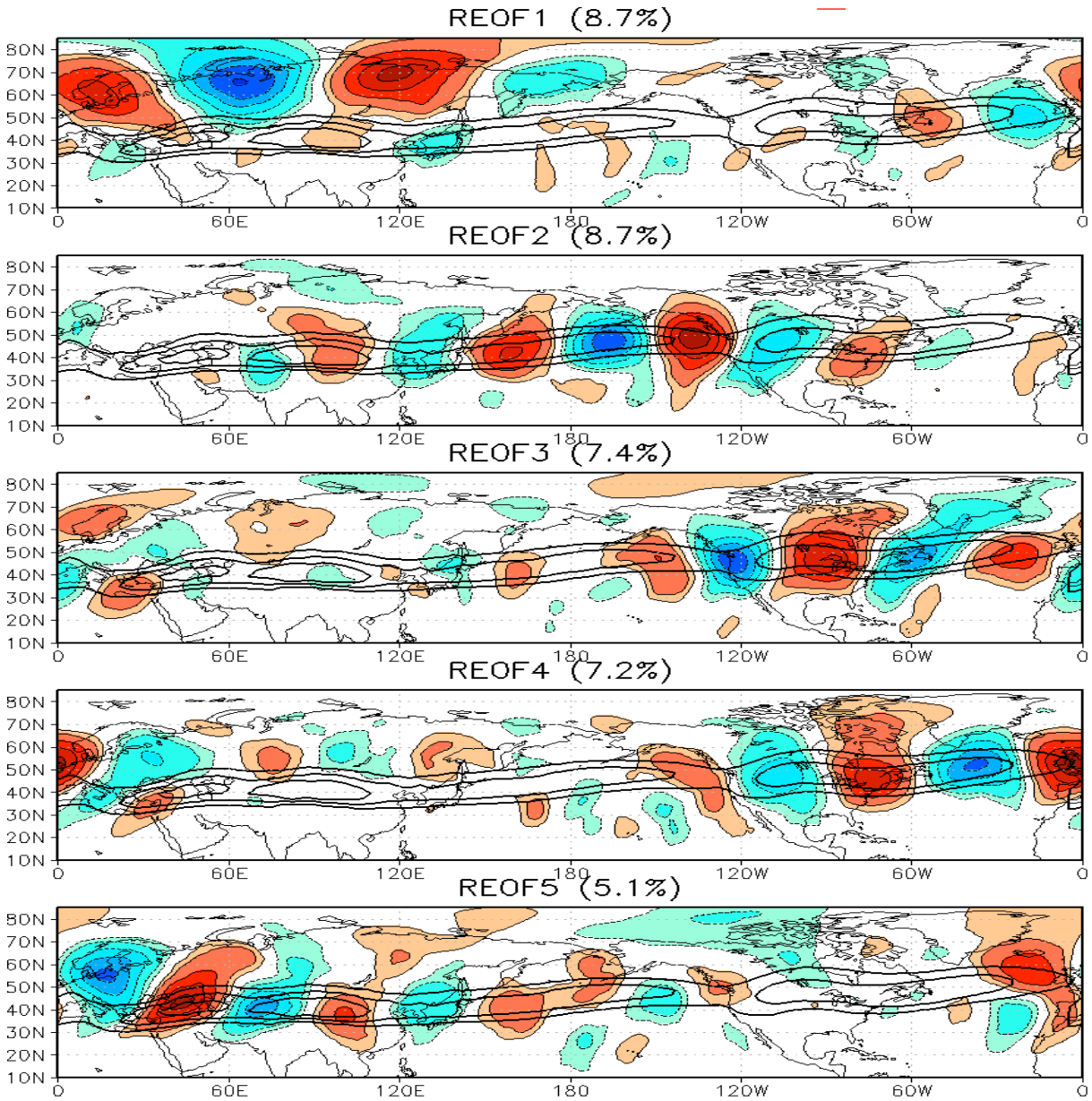
MERRA
Atlas

V250mb Anomalies (m/s)



All three years show prominent upper tropospheric stationary Rossby waves extending across northern Eurasia

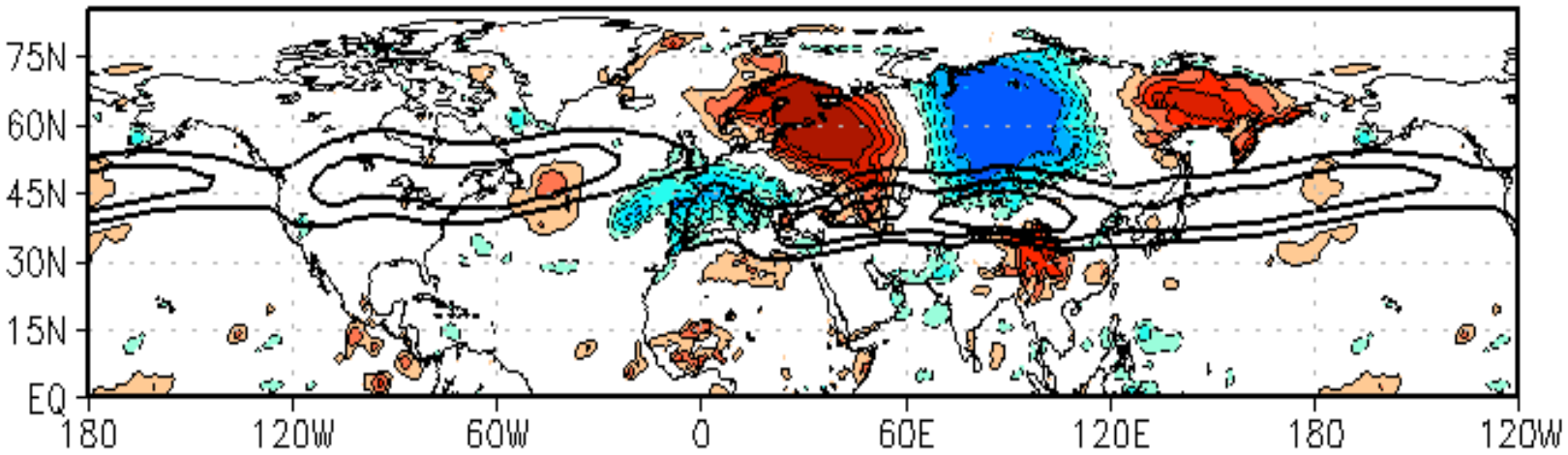
Leading Rotated EOFs of Intraseasonal (Monthly JJA) V250mb



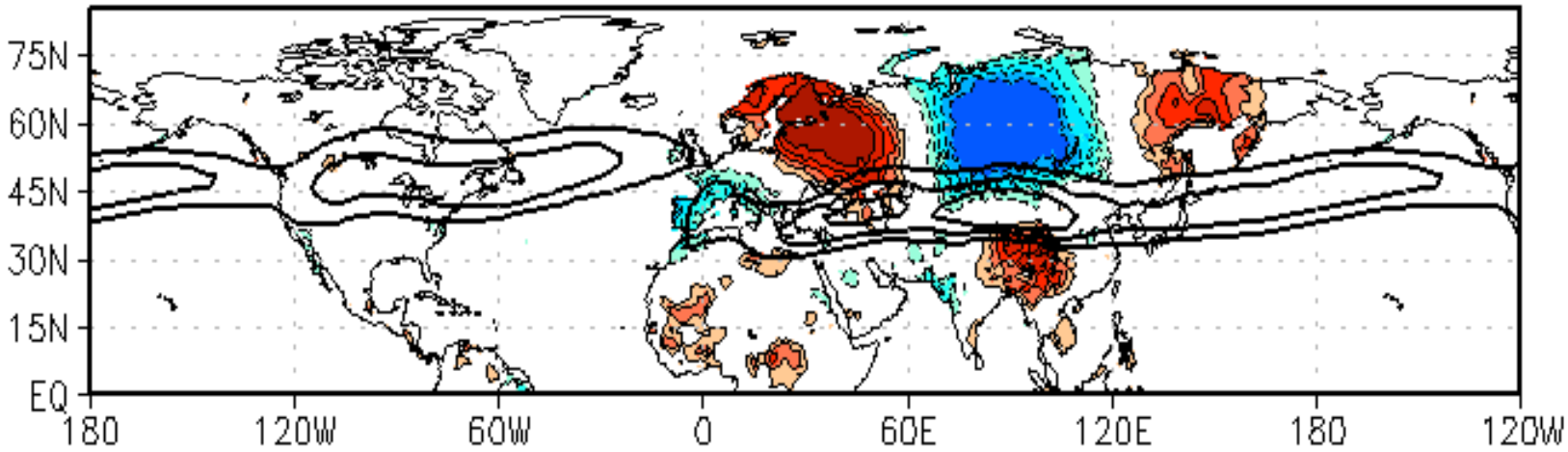
Based on MERRA: 1979- 2010

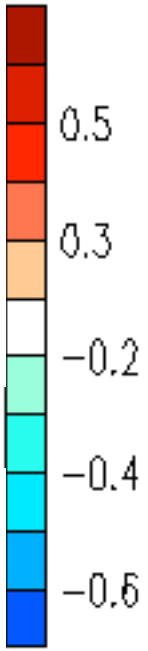
Correlation Between V250 REOF 1 and T2m

MERRA T2m



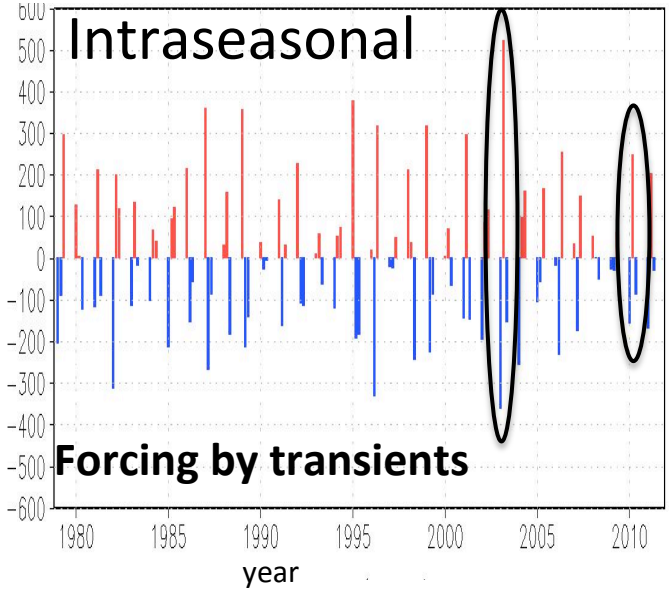
HADCRU Gridded Station Data T2m

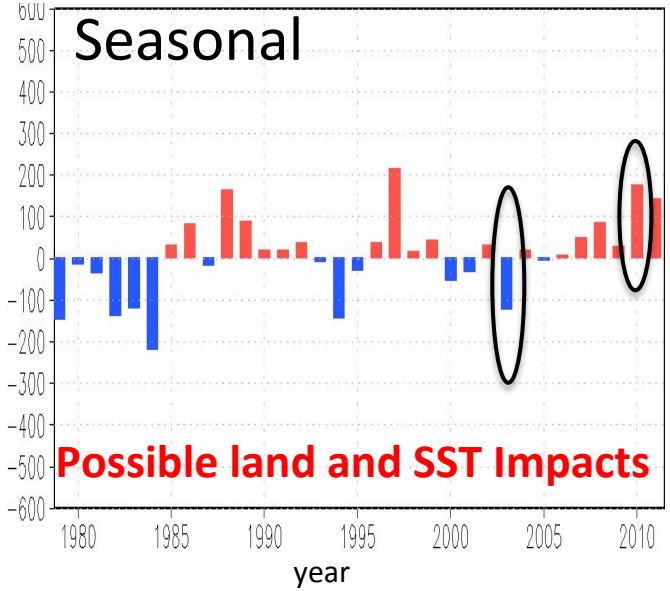




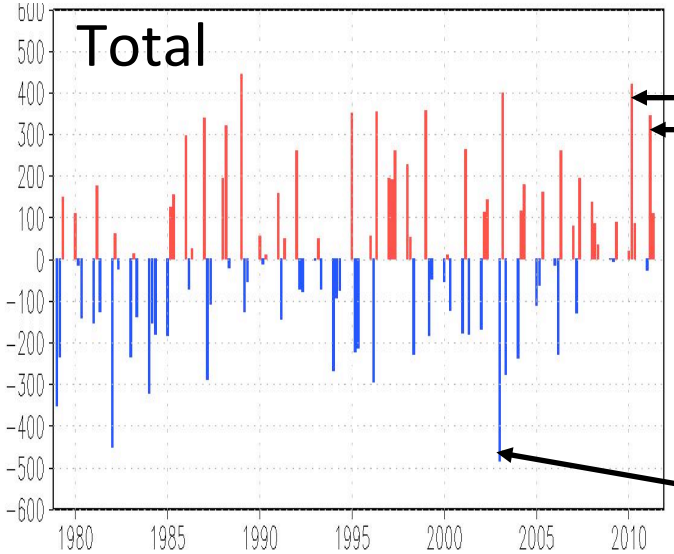
Based on Monthly (subseasonal) data JJA (1979-2008)

v250mb REOF 1 (PC, JJA 1979-2011)





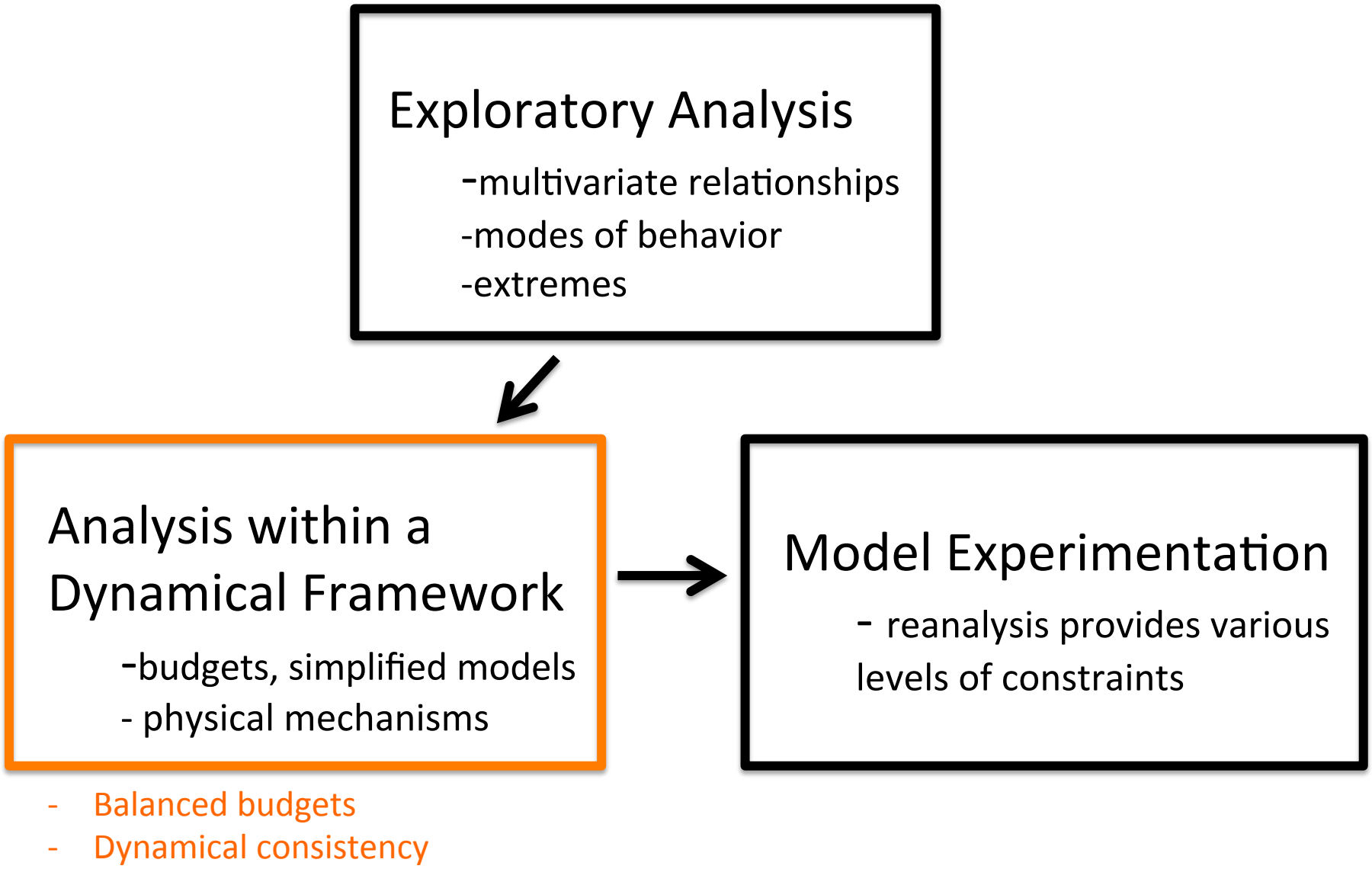
At upper levels: intraseasonal component is large, trends less apparent, peaks in heat waves linked to intraseasonal variability



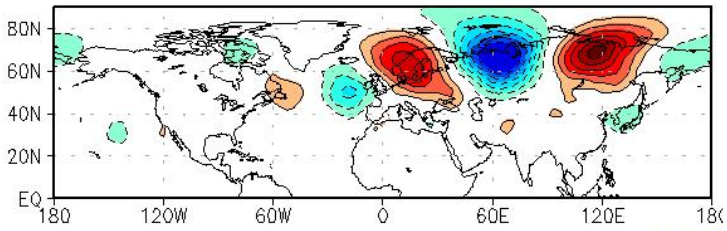
2010, 2011
July, Russian Heat Waves

2003 June European Heat Wave

Steps to Attribution



REOF 1



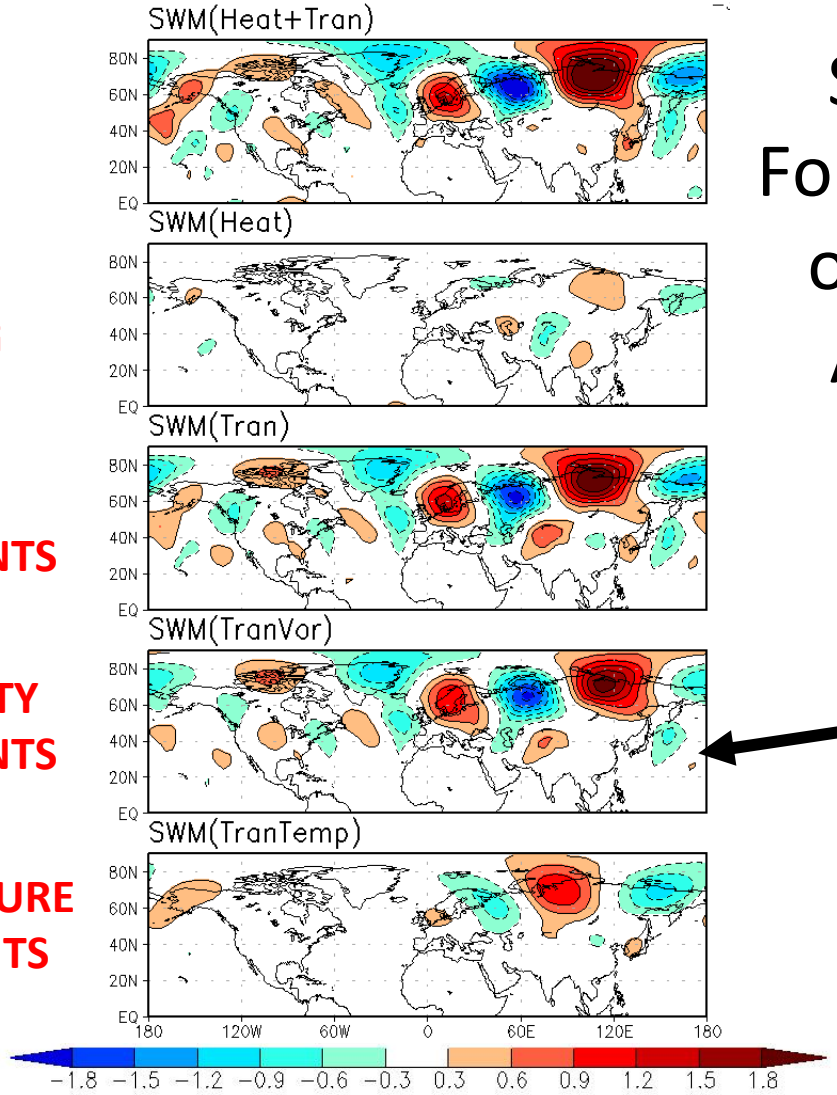
TOTAL FORCING

HEATING

Total TRANSIENTS

VORTICITY TRANSIENTS

TEMPERATURE TRANSIENTS

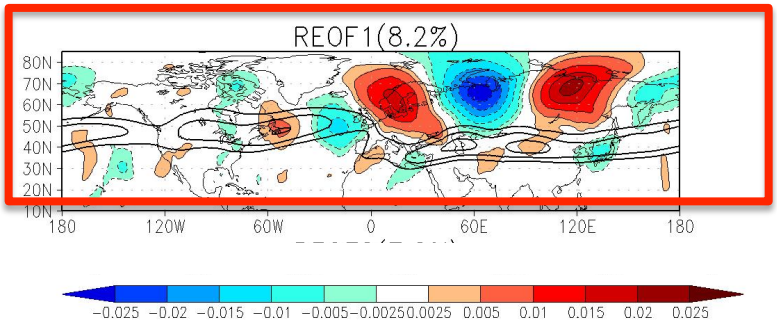


Stationary Wave Model Forced By MERRA Estimates of Various Forcing Terms Associated with REOF 1

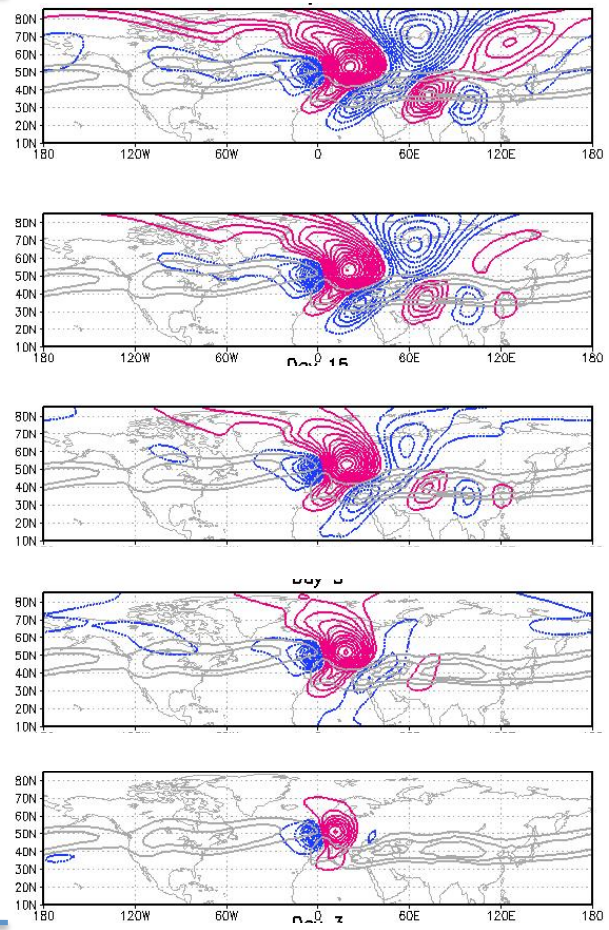
At subseasonal time scales vorticity transients are the main forcing

Leading Rotated EOFs
Monthly JJA V250mb

REOF 1



SWM response of the eddy v-wind at σ=0.257 to an idealized vorticity source at 0E, 50N



Day 20

Day 10

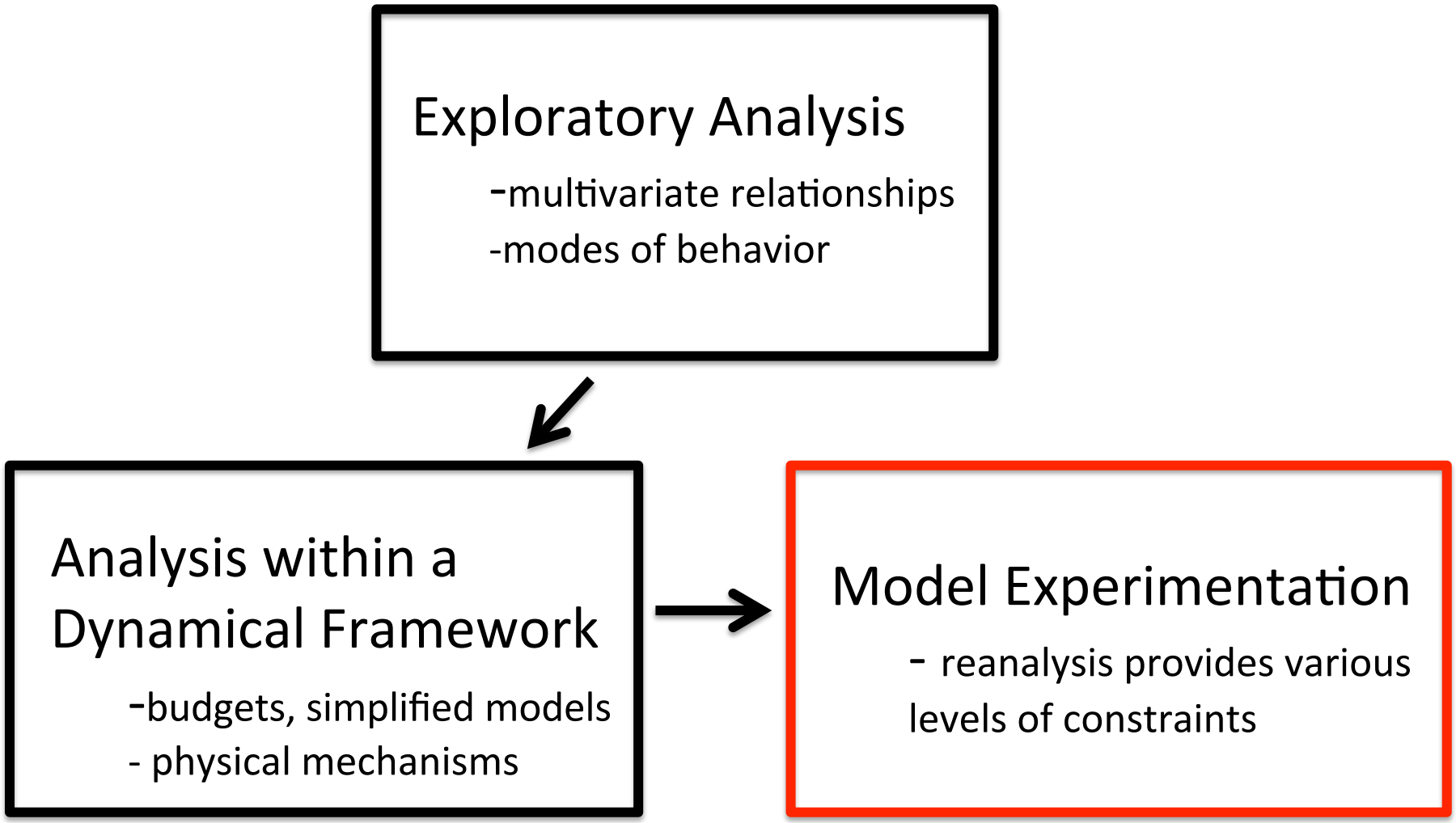
Day 5

Day 3

Day 1

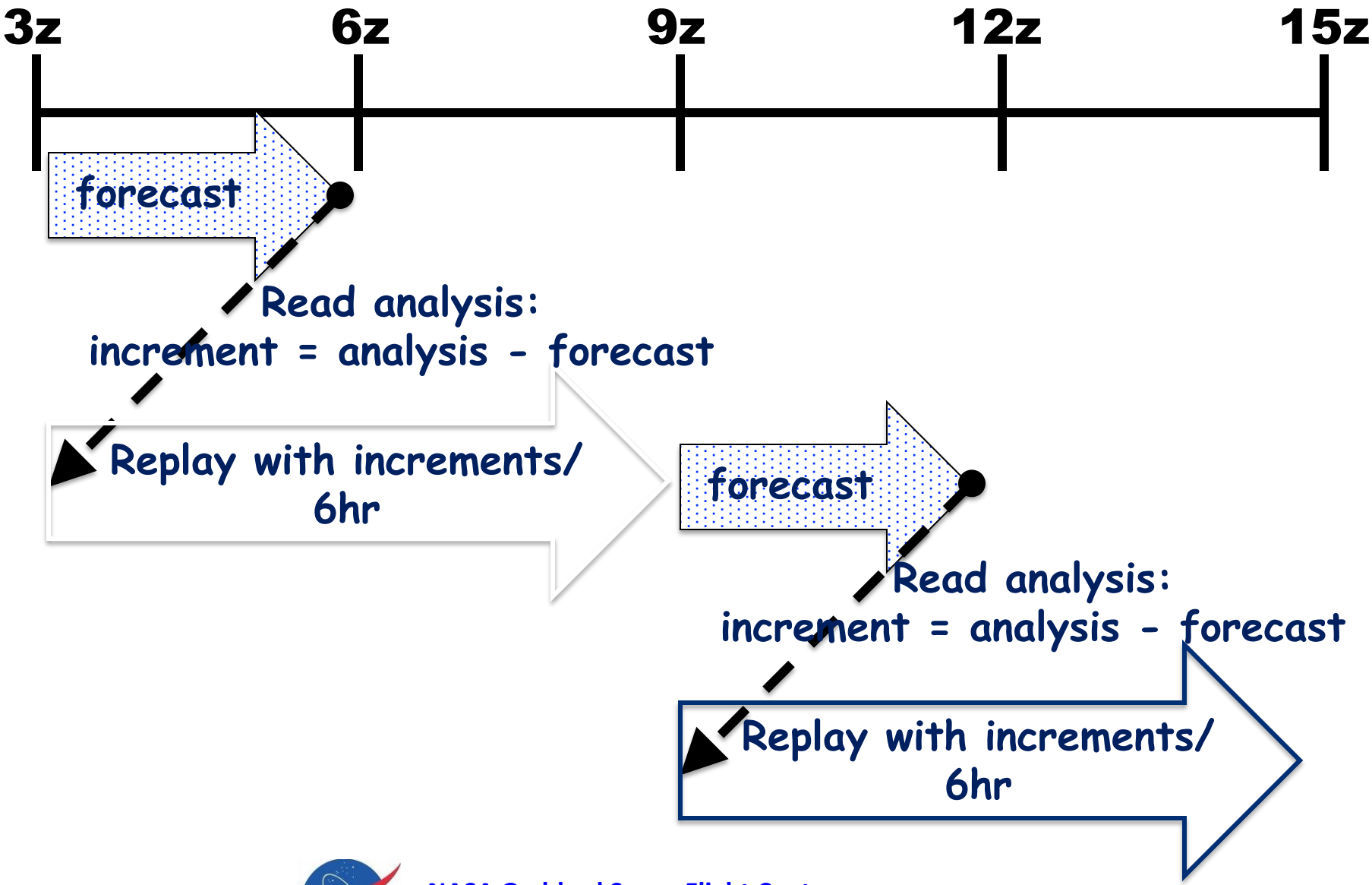
MERRA Base State: JJA 1979-2010

Steps to Attribution

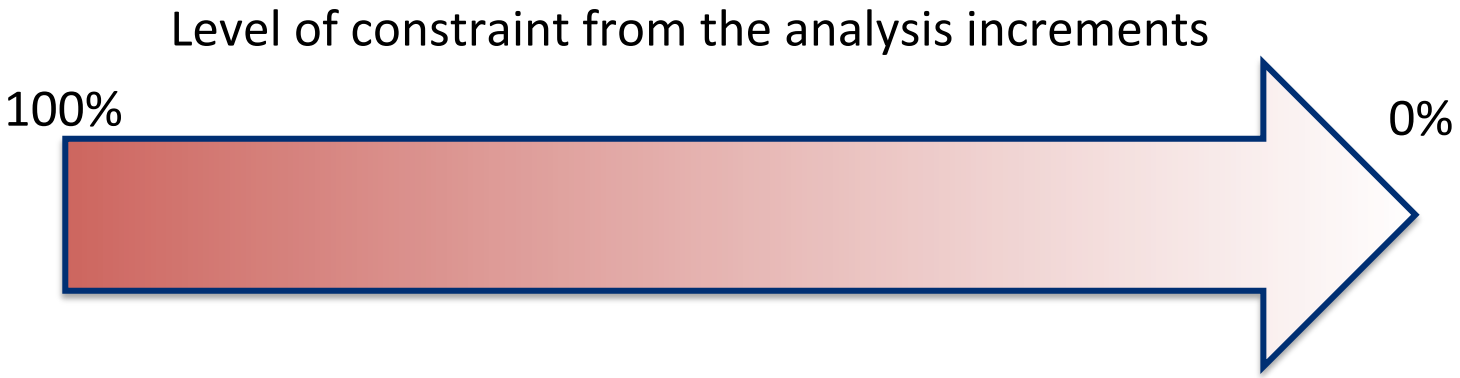


- Consistency between model and reanalysis
- (*also provides framework for model improvement*)

"Replay" at GMAO: Flow Diagram



“Replay” allows simulations with partial constraints on the model



Full replay: recovers the **original analysis**

If running coupled this is a forced ocean experiment

Partial replay: some regions, variables are unconstrained

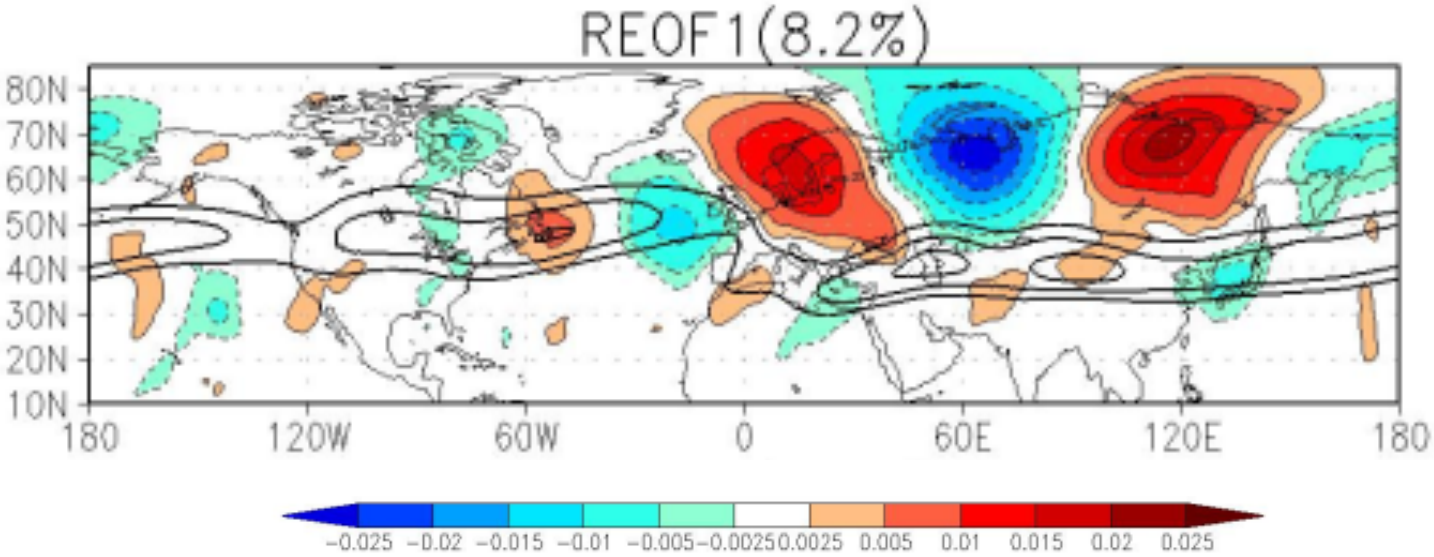
Replay in which all increments are set to zero: this is an **AMIP simulation**

GEOS-5 AMIP Simulations (1870-present)

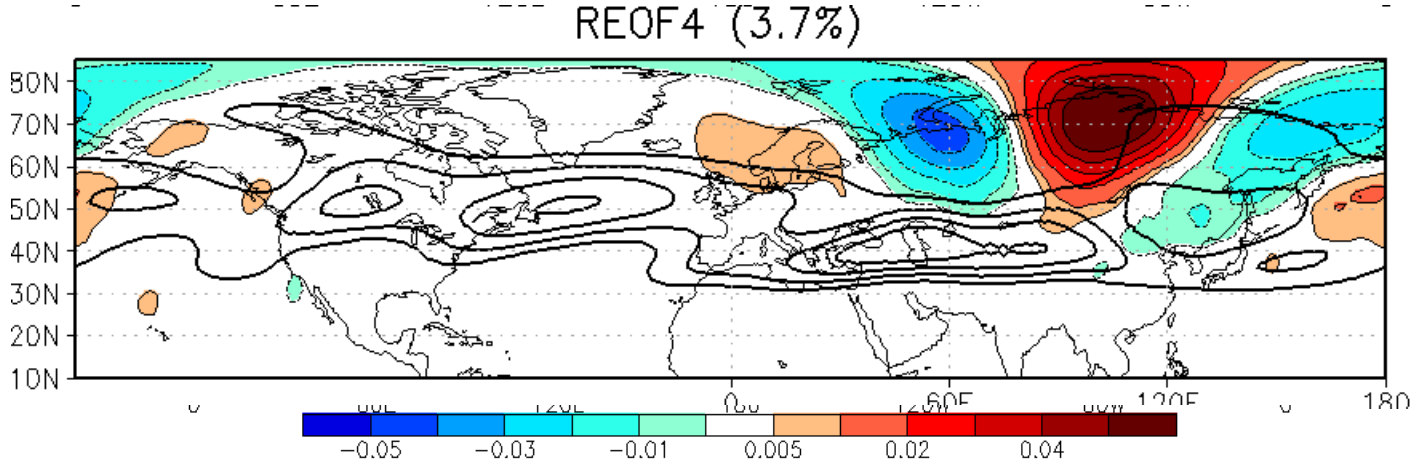
- 1 degree horizontal resolution
- 10 members with interactive aerosols
- 2 members with prescribed aerosol climatology
- IPCC CMIP-5 forcings

- Does the model reproduce REOF 1 (Eurasian Stationary Rossby Wave)?
- Does the model reproduce the subseasonal and seasonal variability, and trends in Tsfc?

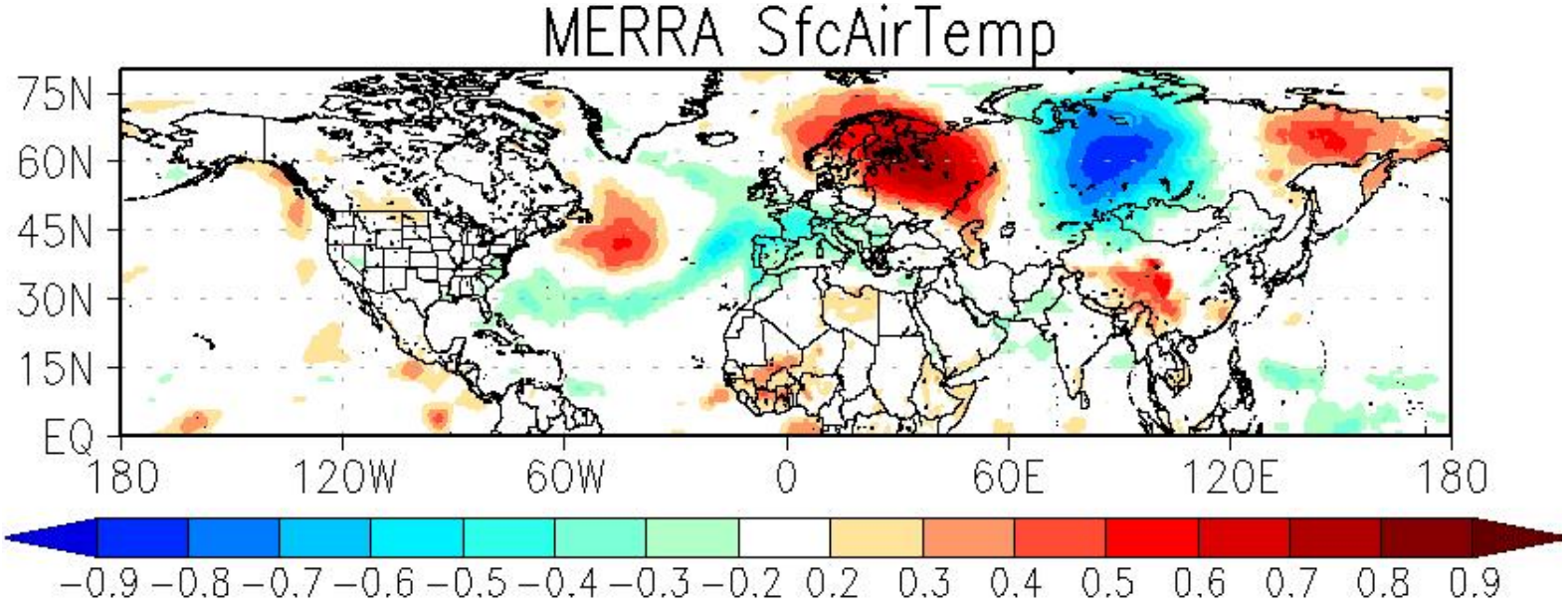
MERRA(1979-2010): REOF1_intraseasonal_v250mb



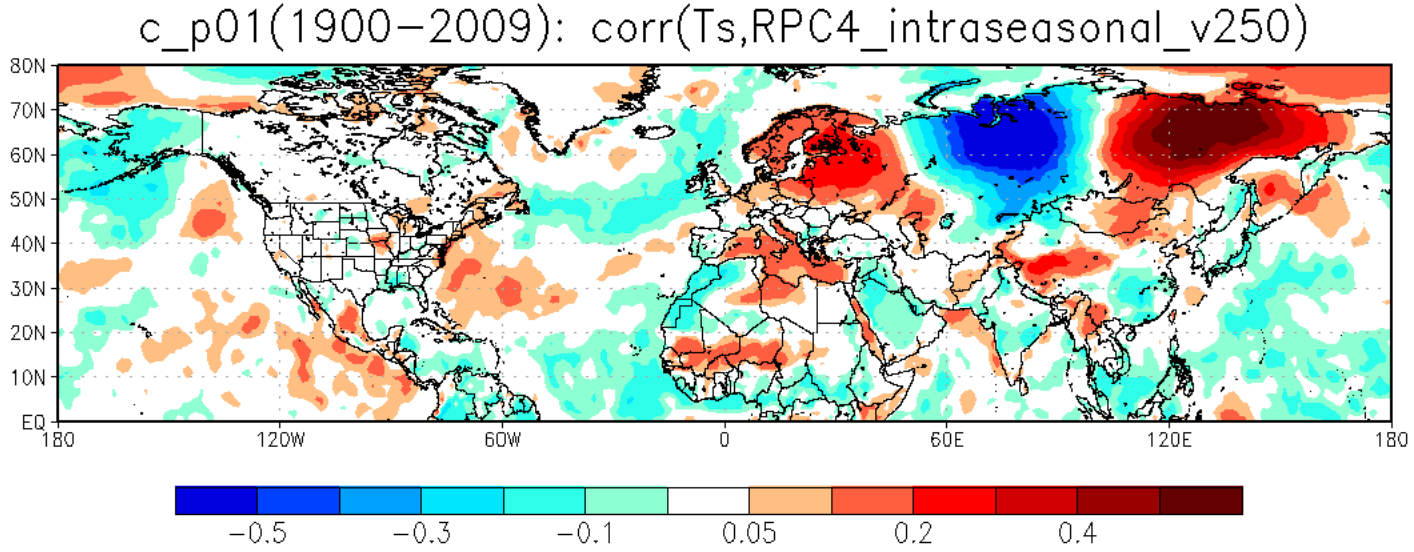
C_p01(1900-2009): REOF4_intraseasonal_v250mb



MERRA(J-J-A1979-2010): Corr(intraseasonal_Ts; RPC1_intraseasonal_v250)



C_p01(J-J-A1900-2009): Corr(intraseasonal_Ts; RPC4_intraseasonal_v250)

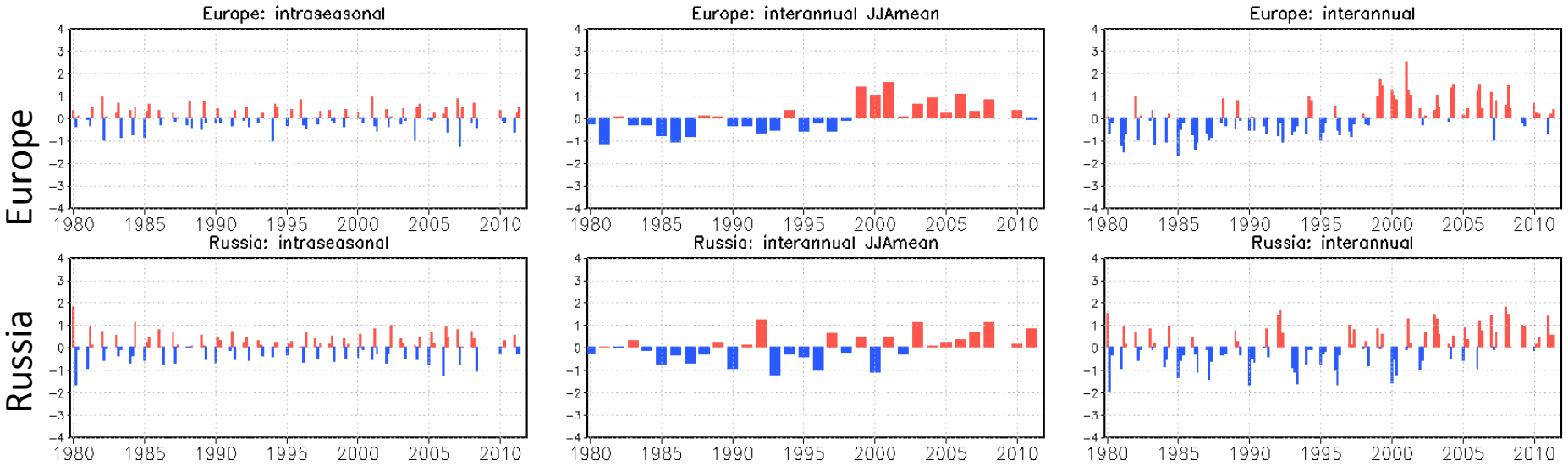


Let's look at the T2m anomalies from some of the AMIP ensemble members:

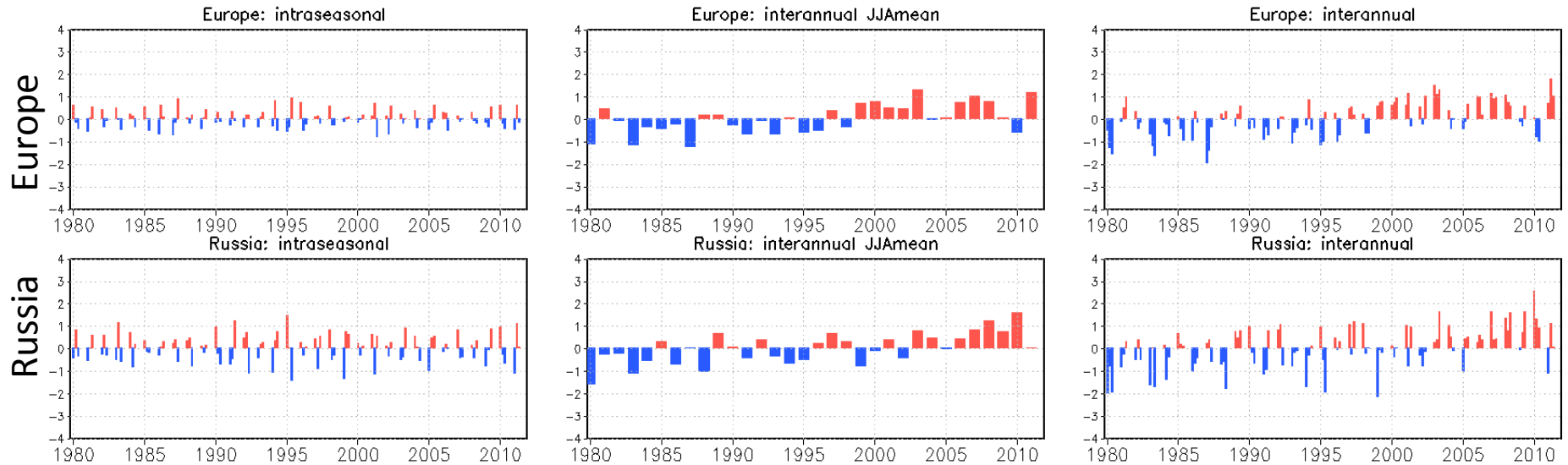
- note scale goes from -4 to + 4 °C
  (versus -5 to + 5 for MERRA)
- we have also slightly redefined the western Russia region (based on correlations with REOF 1), though not much sensitivity

T2m (°C)

AMIP Ensemble member C1

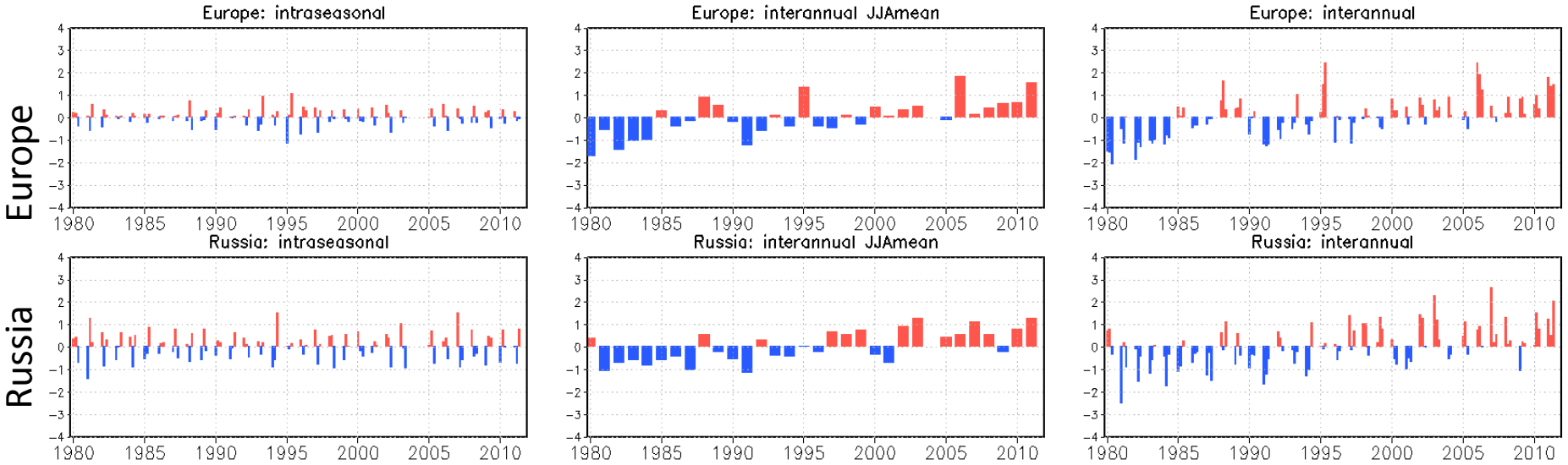


AMIP Ensemble member P1



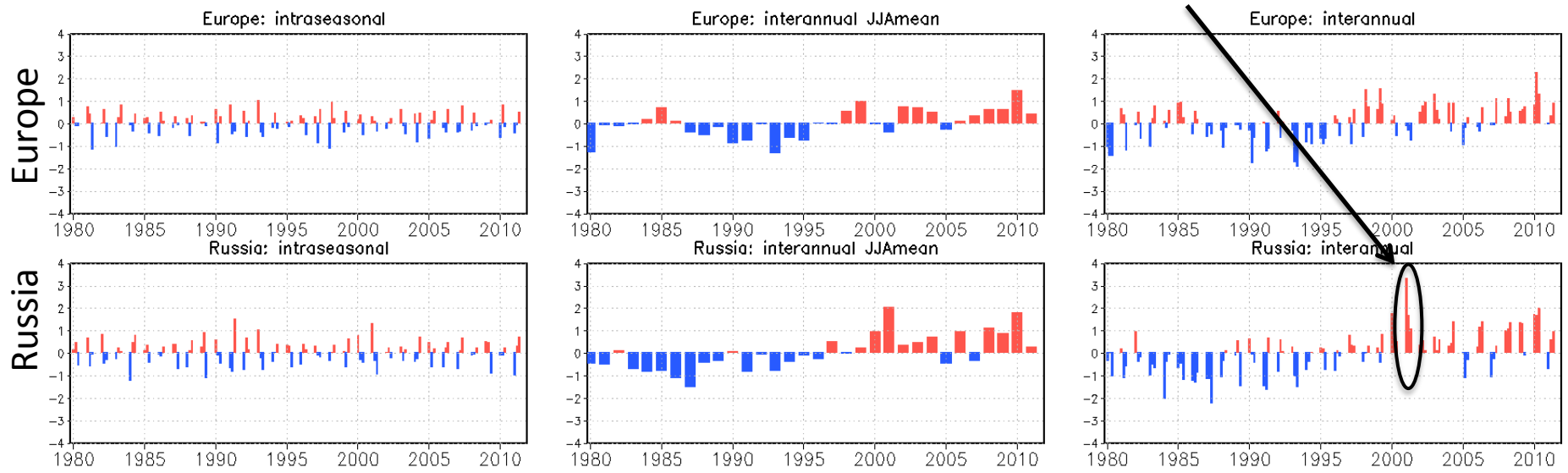
T2m (°C)

AMIP Ensemble member C5



AMIP Ensemble member C6

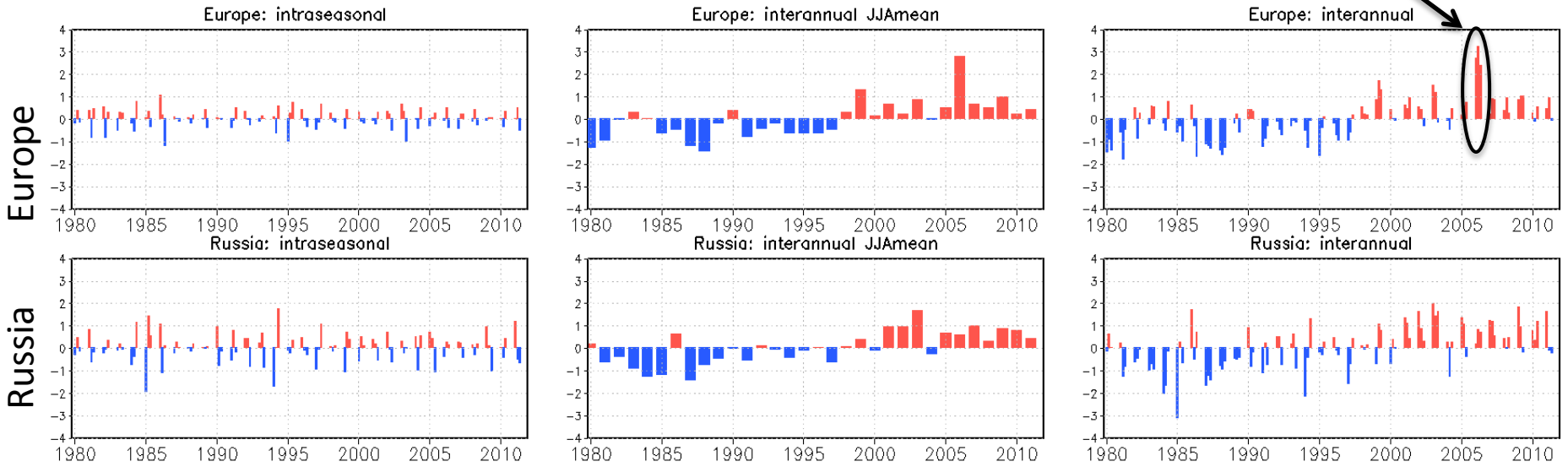
Major simulated 2002 Russian Heat Wave



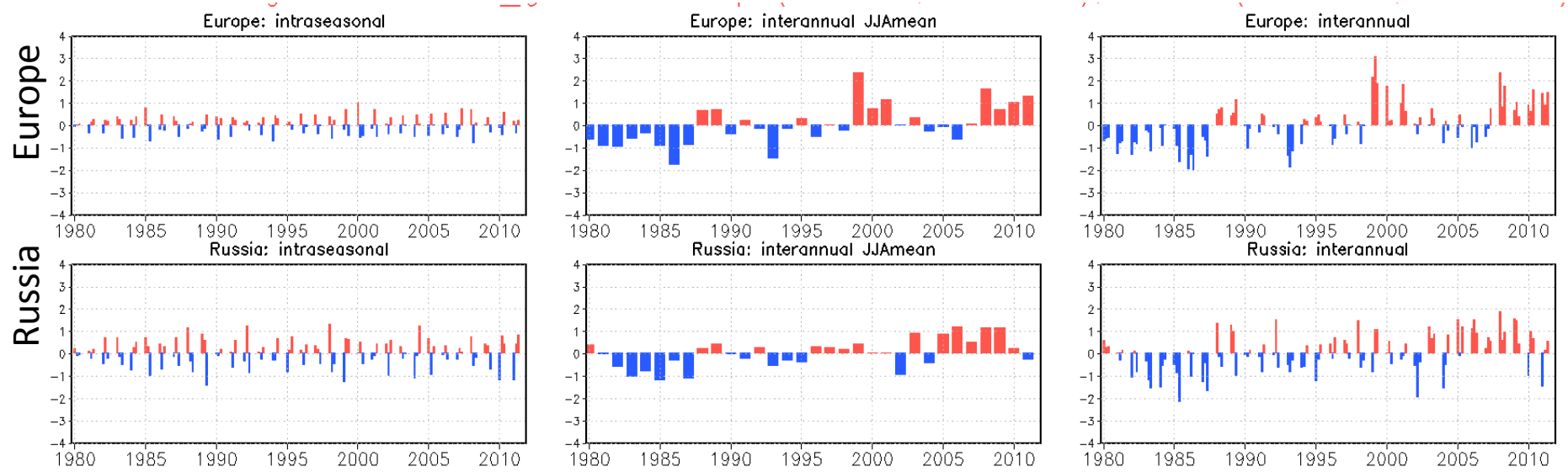
T2m (°C)

AMIP Ensemble member C8

Major simulated 2006 European Heat Wave



AMIP Ensemble member C9

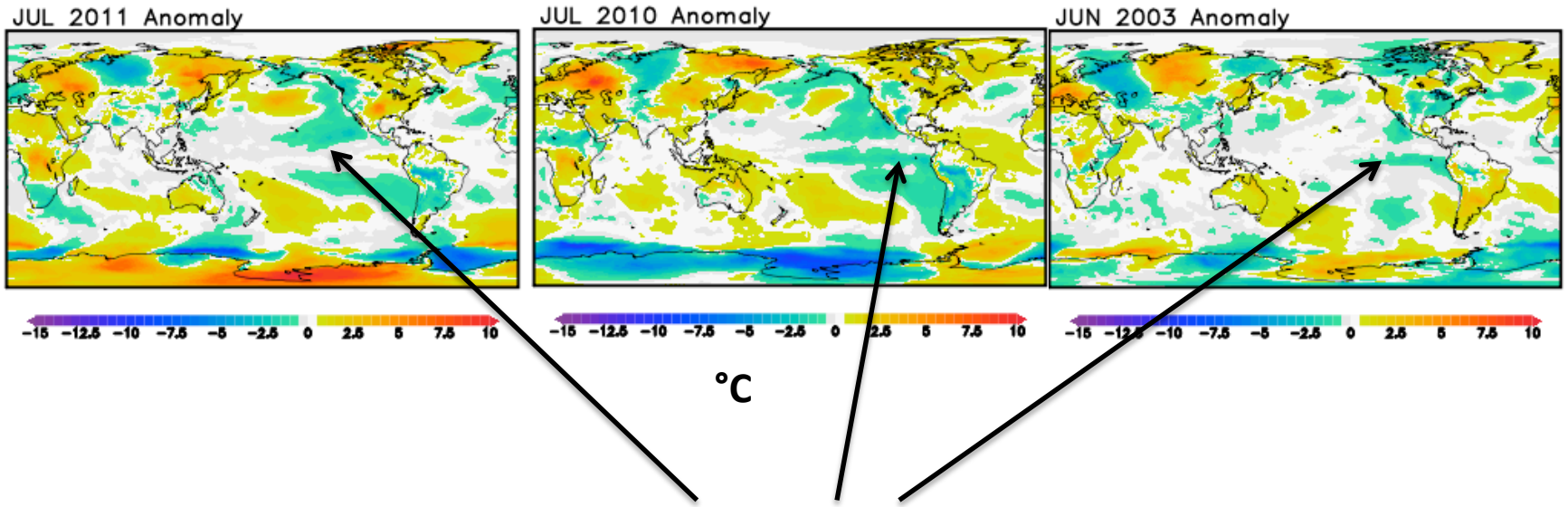


What is forcing the T2m warming trends over parts of Eurasia?

MERRA Atlas

T2m Anomalies wrt (1979-2008)

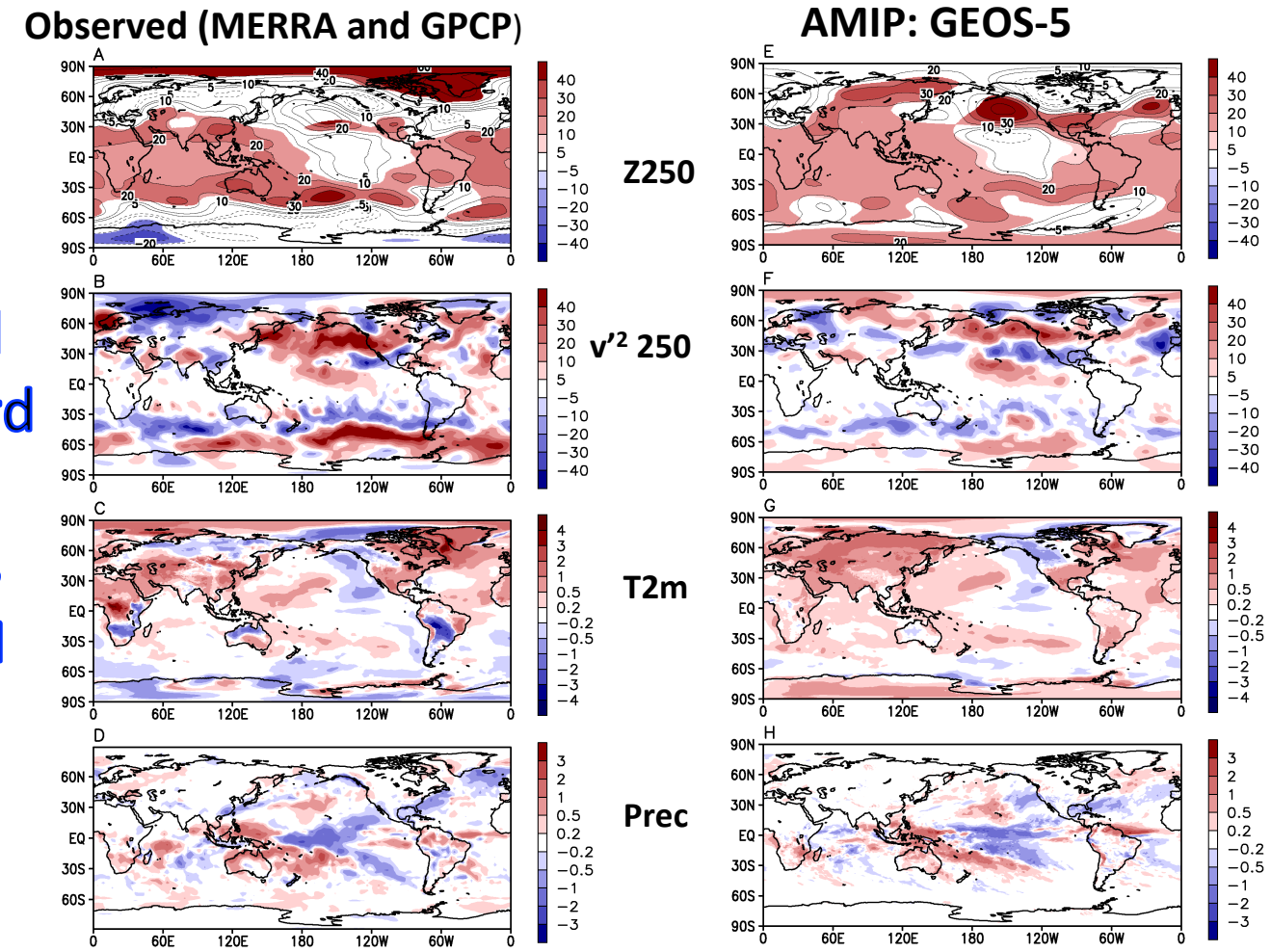
July 2011 | July 2010 | June 2003



Is there a trend toward a colder Pacific (La Nina conditions)?

(1995-2009) minus (1981-1994) for JFM

Warming with embedded trend toward La Nina Conditions during JFM



"Climate Variability and Weather Extremes: Model-Simulated and Historical Data", Schubert, S.D. and Y.-K. Lim. Accepted in ***Hydrologic Extremes in a Changing Climate - Detection, Analysis & Uncertainty.*** Sorooshian, Soroosh, Easterling, David, AghaKouchak, Amir, Schubert, Siegfried, Hsu, Kuolin, Editors, 2012.

Why the alternating east/west oriented anomalies in Tfcs? – associated with the development of a particular Eurasian stationary Rossby wave (Schubert et al. 2011 – MERRA special issue)

Nature of subseasonal Tsfc variability (monthly)?
- stationary Rossby wave forced by vorticity transients (Schubert et al. 2011 – MERRA special issue)

Nature of seasonal mean Tsfc variability? – *seasonal means in Tsfc may in part reflect a rectification of Rossby wave impacts by the land sfc …???*

Causes of apparent trend in seasonal means of Tsfc during the period 1980-2011? – *impact of greenhouse gases, trend toward La Nina conditions, possibly preconditioning the land, impact on jets, etc. ???*

Why are 2003 and 2010 so extreme? – *trend plus random subseasonal Rossby wave fluctuation, land feedbacks???*

On-going: Focus on 2010 Russian Heat Wave

- To what extent can we predict the development?

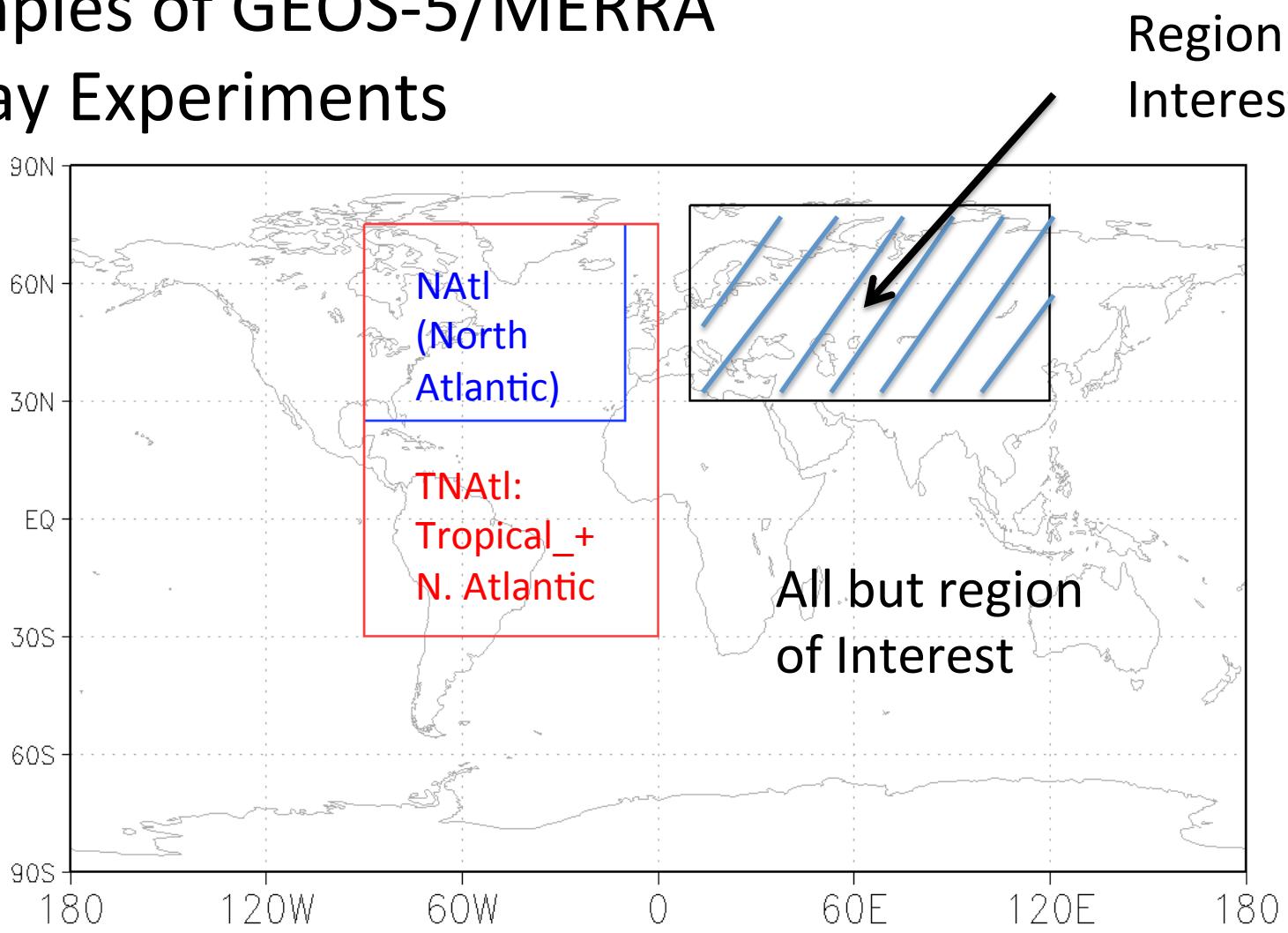
  (the Rossby waves develop often – can we predict major events, and at what time lead?)

  – internal development
    - unusual jet stream
    - unusually strong vorticity transients
    - land feedbacks

  – role of "external" forcing
    - SST, land preconditioning, aerosols, etc.

- Take advantage of replay with MERRA

Examples of GEOS-5/MERRA Replay Experiments

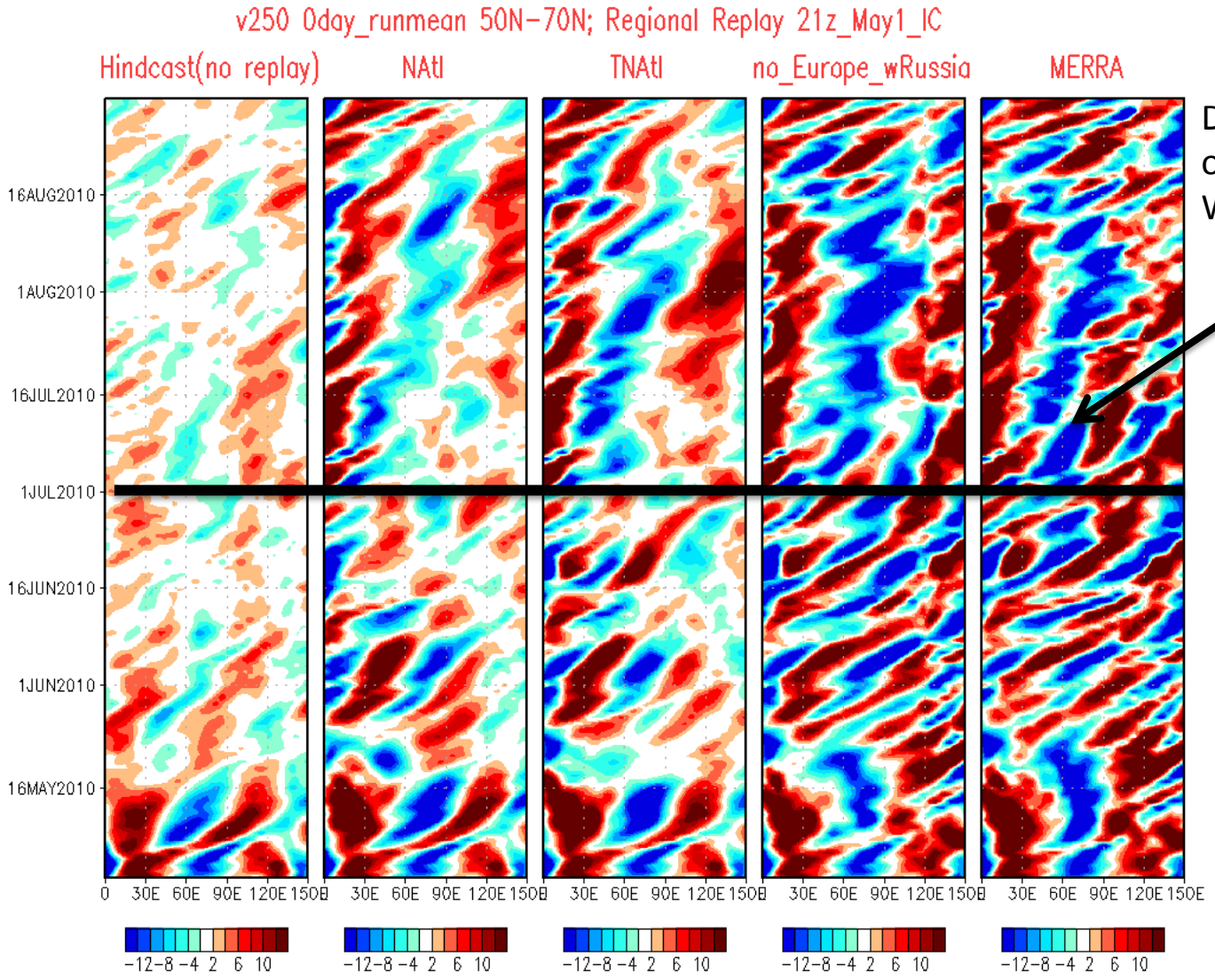


NAtl (North Atlantic): replay [90W-10W; 25N-75N]

TNAtl (Tropical +_North_Atlantic): replay [90W-0E; 30S-75N]

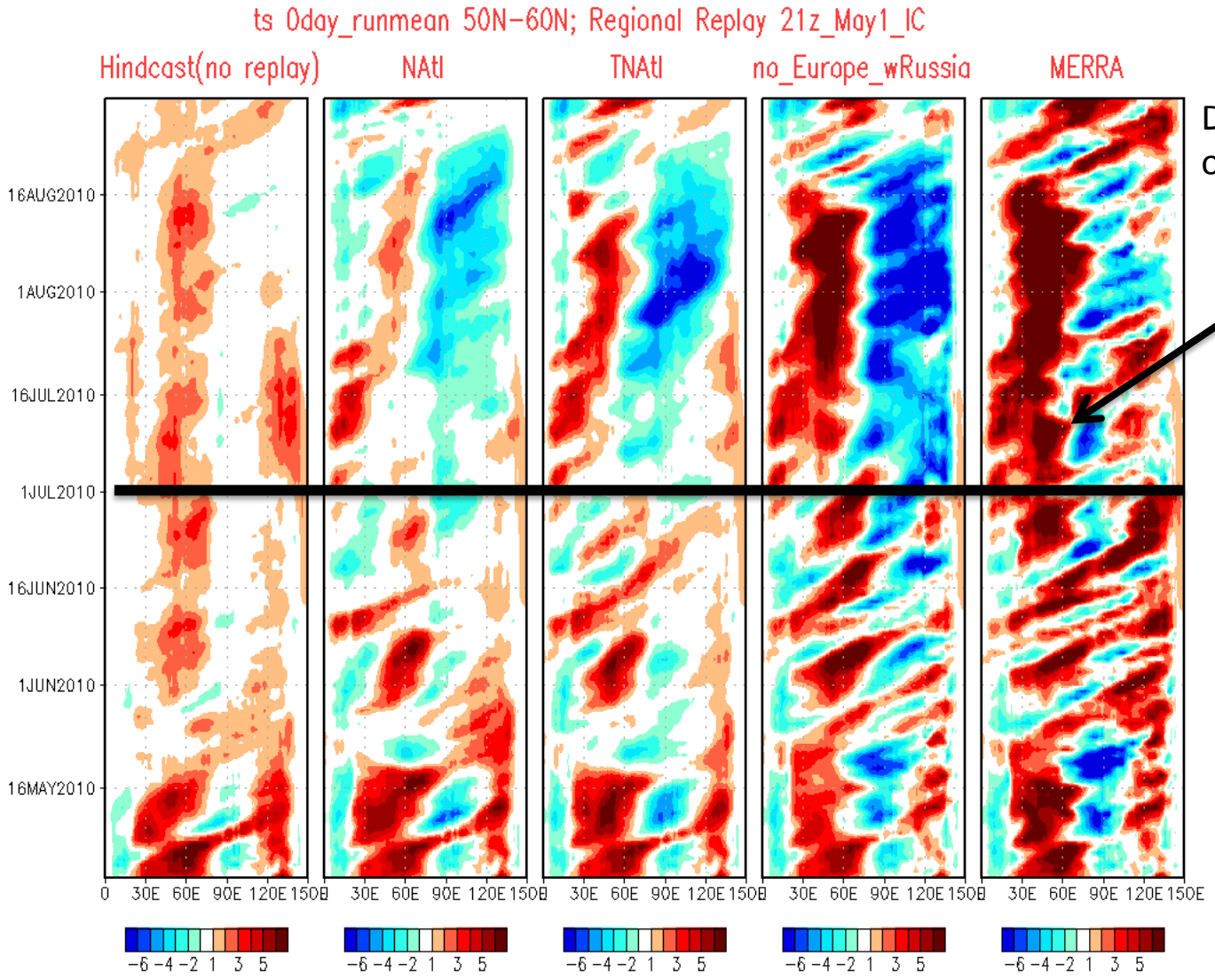
No_Europe_wRussia: replay everywhere except [10E-120E; 30N-80N]

Evolution of **V250mb** (50-70N)
(GEOS-5 AGCM runs forced with obs SST, IC May 1, 20 ensemble members)



V250mb Anomalies m/s

Evolution of **T2m** (50-70N)
(GEOS-5 AGCM runs forced with obs SST, IC May 1, 20 ensemble members)



Summary Regarding Reanalysis and Attribution:

- Exploratory phase: requires consistency across space and time scales of interest, requires adequate representation of phenomena of interest, can tolerate some bias, but not jumps or other shifts

- Analysis within a dynamical framework phase: requires dynamical consistency for the diagnosis of processes of interest, balanced budgets (contributions of analysis increments should be minimal)

- Model experimentation (prognostic analysis) phase: overall consistency between model and reanalysis (initial conditions, boundary and other forcing). Model simulated and observed fields should be in some sense dynamically indistinguishable