OUTCOMES OF S-RIP: AN ASIAN MONSOON PERSPECTIVE

SPARC Reanalysis Intercomparison Project

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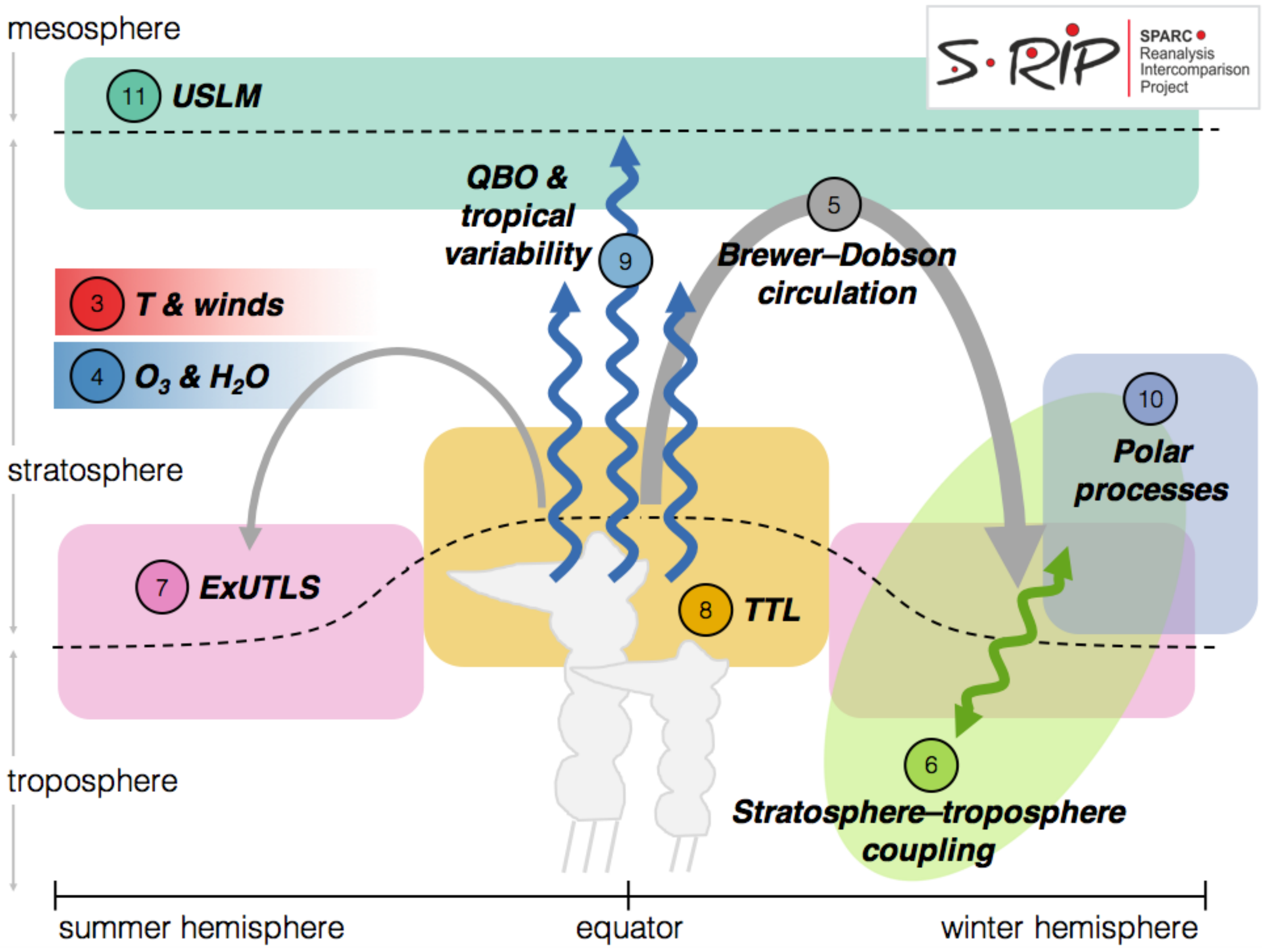
THE SPARC REANALYSIS INTERCOMPARISON PROJECT (S-RIP): INTRODUCTION

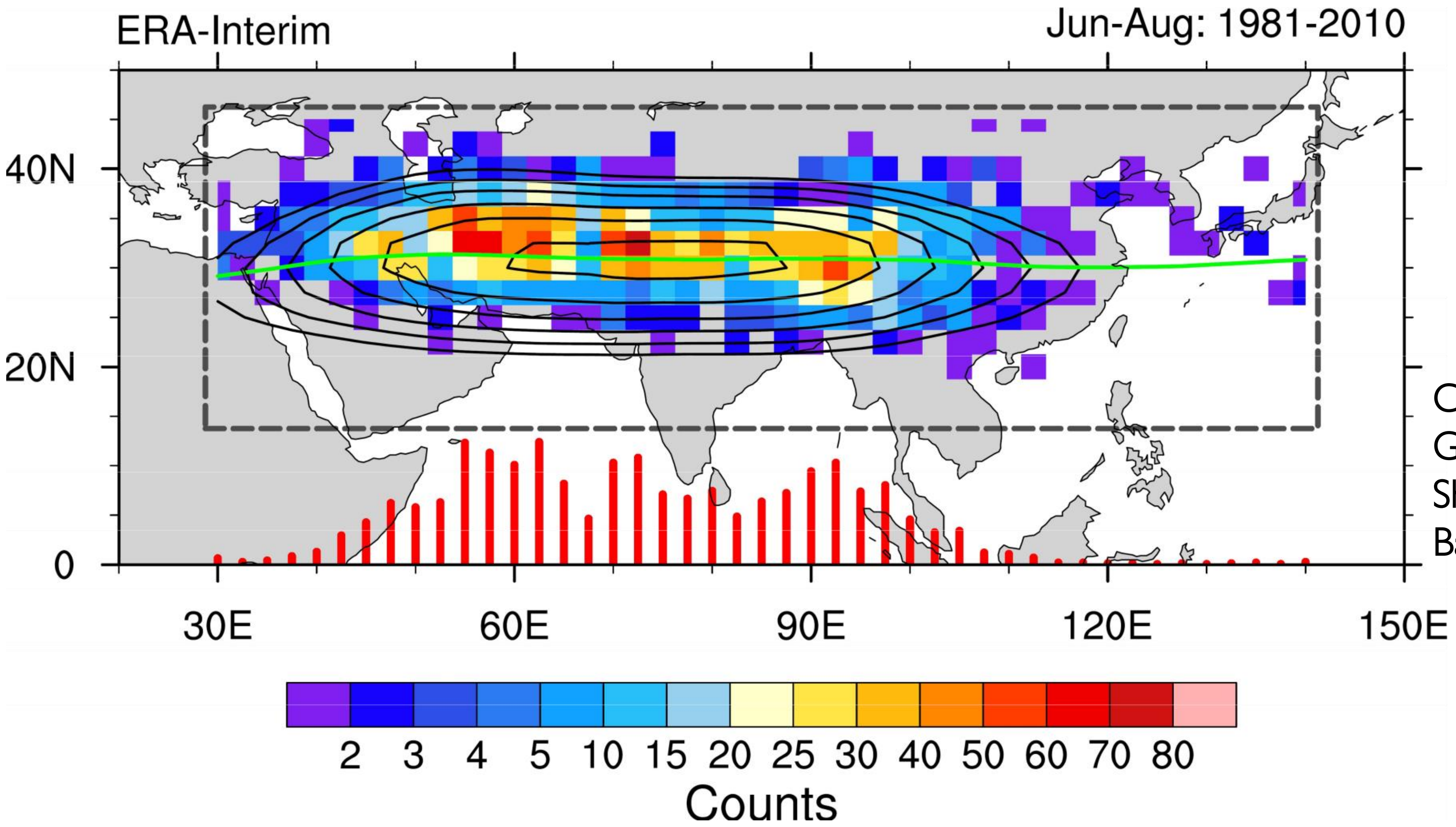


A coordinated SPARC-supported activity to:

- **compare** all (or some of the newer) reanalysis data sets for key diagnostics
- **identify and understand** the causes of differences amongst reanalyses
- **provide guidance** on the appropriate usage of reanalysis products in scientific studies
- **establish collaborative links** between reanalysis centres and the SPARC community
- **contribute to future improvements** in reanalysis products

S-RIP focuses on reanalysis outputs in the upper troposphere, stratosphere and lower mesosphere, and has been closely connected with the SPARC Data Assimilation (SPARC-DA) activity

UPPER-LEVEL ANTICYCLONE: POSITION AND VARIABILITY

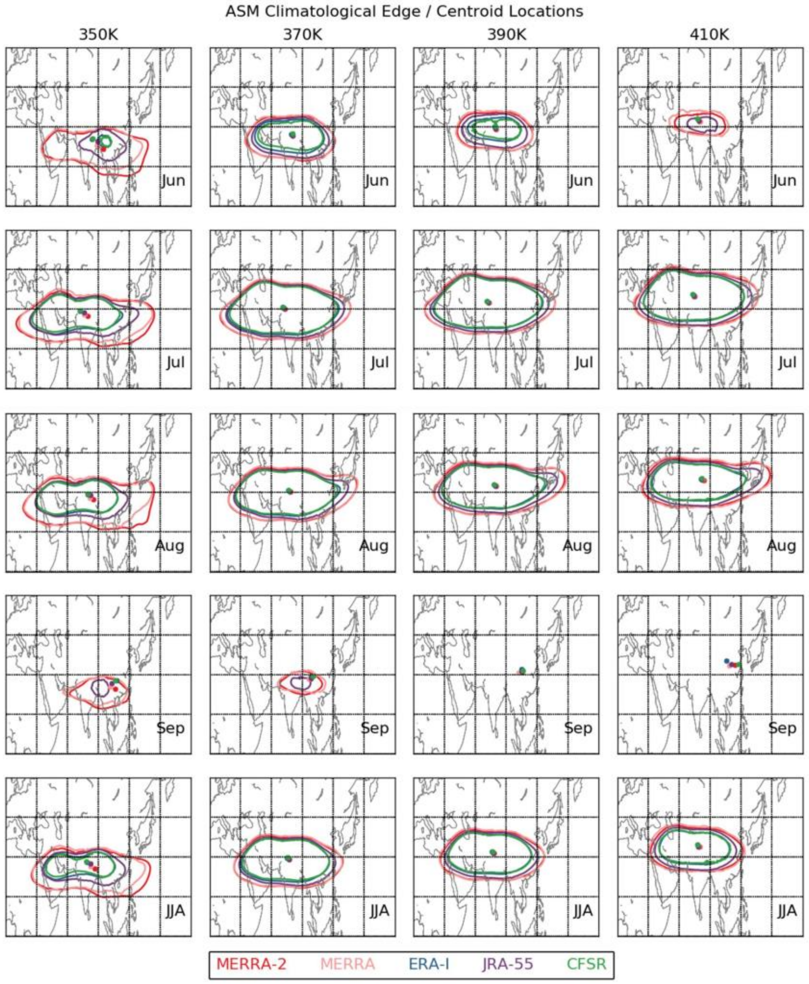


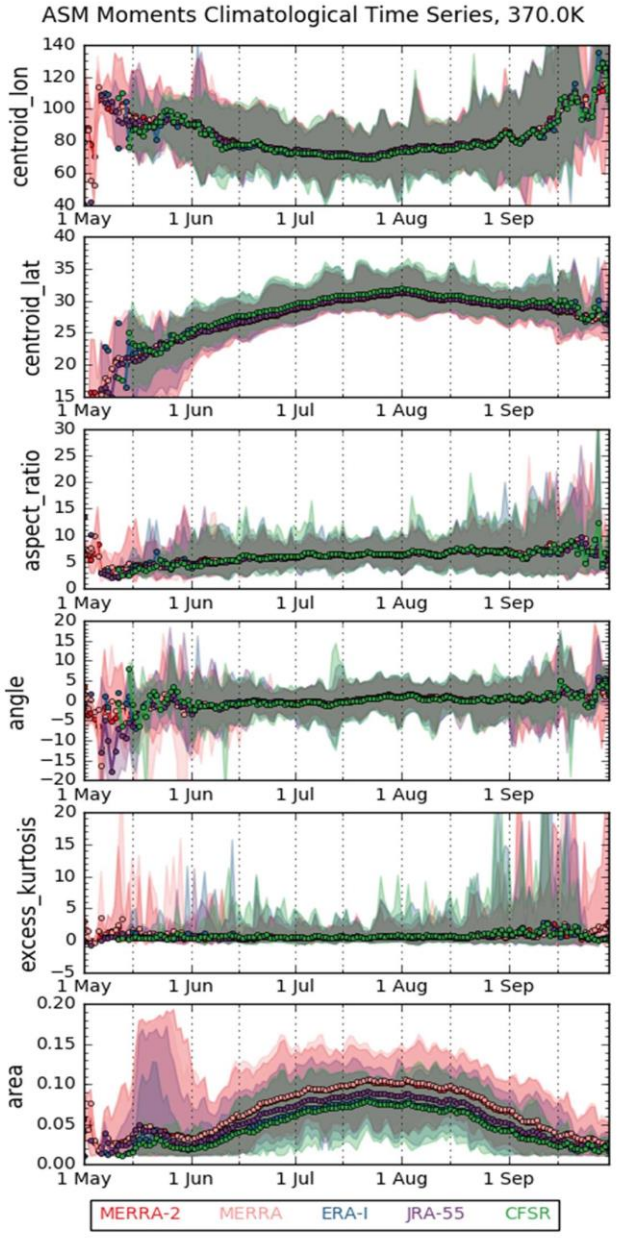
Every year a distinct UT/LS anticyclone emerges over monsoon Asia, with great impacts on composition and cross-tropopause transport

Contours: time-mean GPH
Green line: time-mean ridgeline
Shading: 2D PDF of AC center
Bars: 1D PDF of AC center

UPPER-LEVEL ANTICYCLONE: POSITION AND VARIABILITY

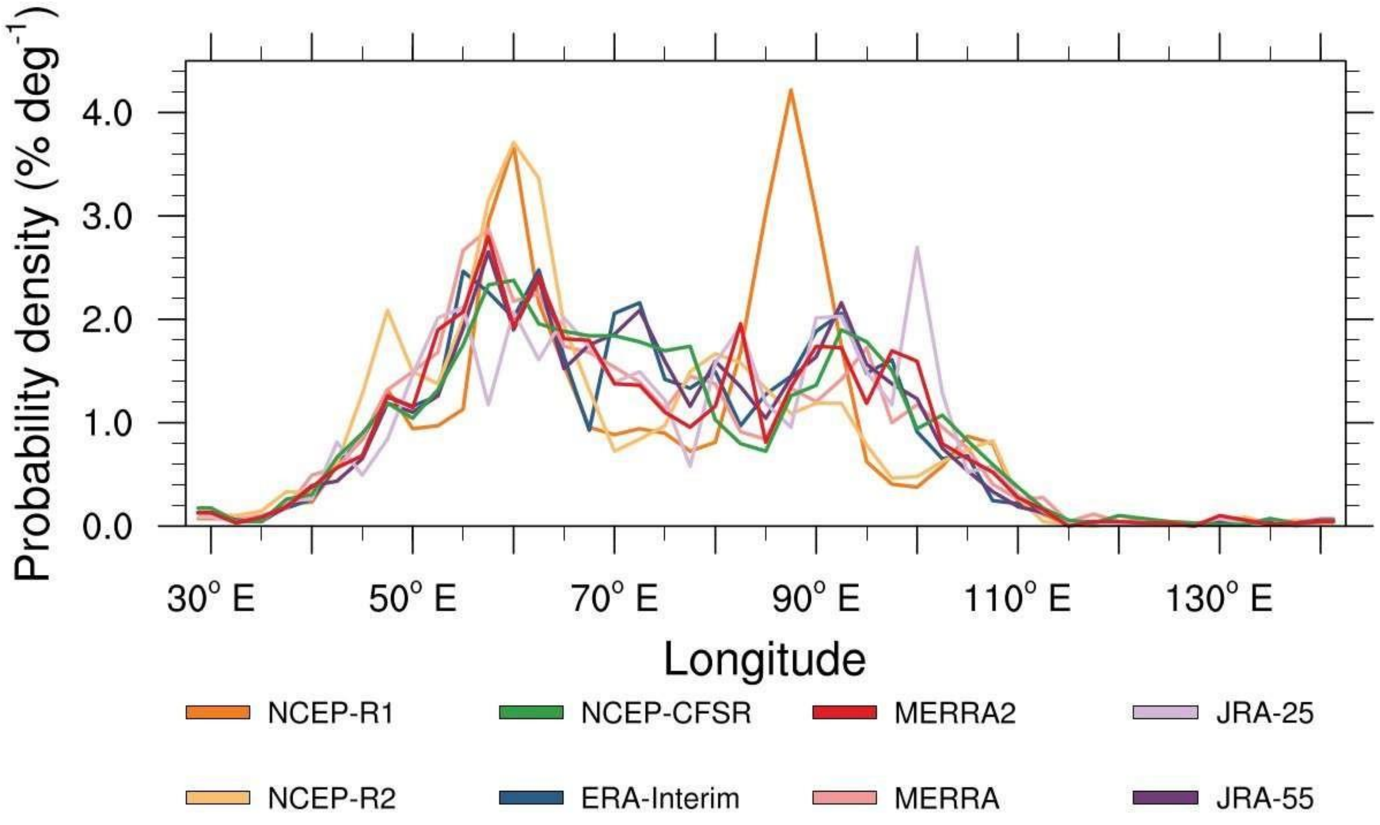
- Recent reanalyses agree well on the climatological position and seasonal cycle of the anticyclone center
- Other modes, such as the aspect ratio and orientation of the anticyclone, are also very consistent
- The main differences are in the area of the anticyclone, with MERRA and MERRA-2 producing larger anticyclone areas than other reanalyses
- Differences are larger in the upper troposphere (350K) than in the lower stratosphere (410K)



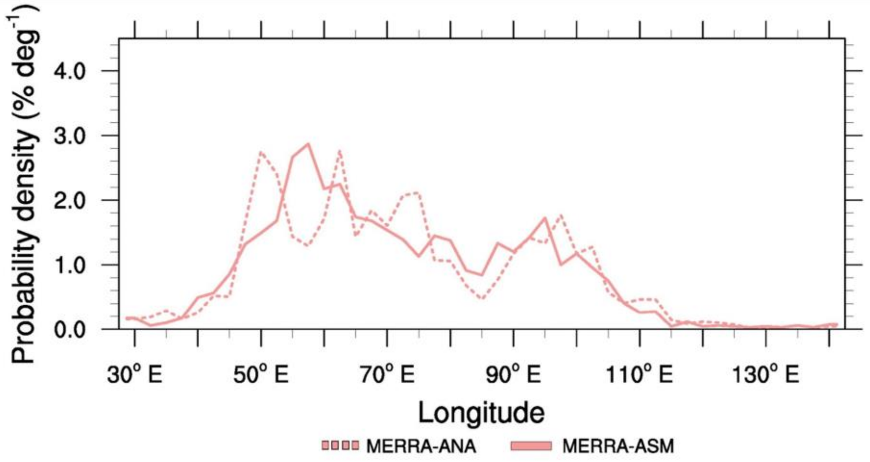


updated from Nützel et al., 2016

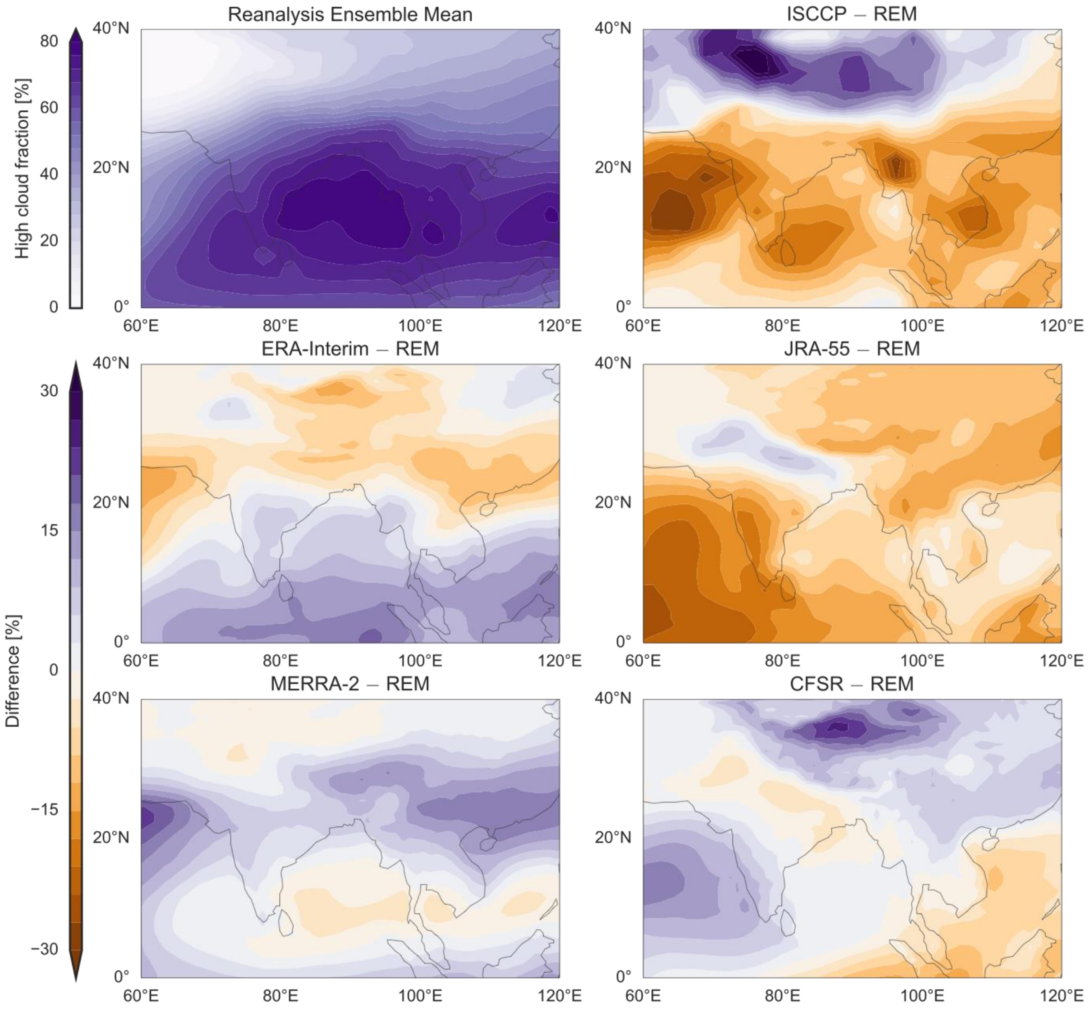
UPPER-LEVEL ANTICYCLONE: BIMODALITY



- Bimodality refers to the anticyclone center tending to locate over the TP or IP
- Significant bimodality is only present in R1
- Differences between MERRA-ASM and ANA indicate assimilation scheme matters
- MERRA-2-ANA pressure level data have an interpolation error and may be unsuitable for studies in this region



CLOUDS AND RADIATION: CLOUD COVER



Comparison with ISCCP provided for context — but not “apples to apples”

ERA-Interim has fewer high clouds over East Asia, the Plateau and its South Slope

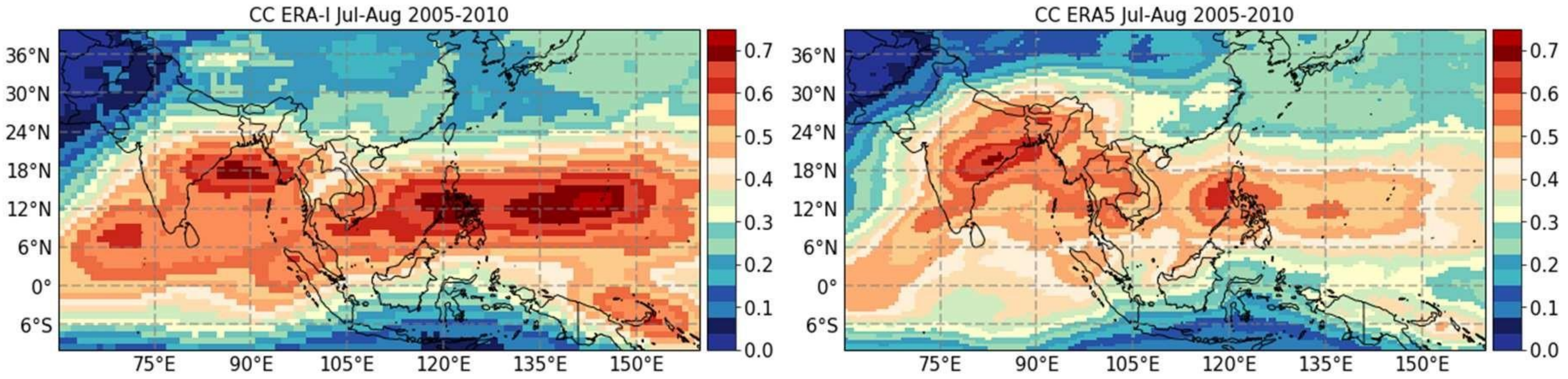
Strong convection along the South Slope in JRA-55, but fewer clouds elsewhere

MERRA-2 has more high clouds over East Asia and the SE Tibetan Plateau

CFSR has more high clouds over the Plateau and East Asia, but fewer over India

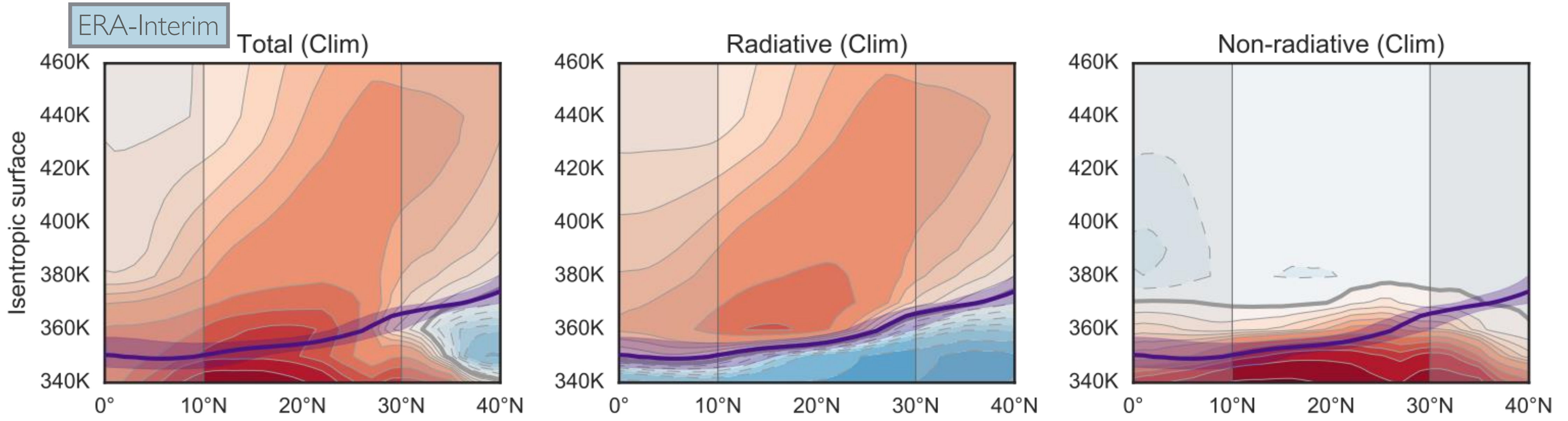
Legras et al., in prep

CLOUDS AND RADIATION:
CLOUD COVER



- The recent ERA5 shows some important differences in cloud distributions relative to ERA-Interim
- Finer horizontal resolution, more than twice as many vertical levels in the model, and more frequent analyses
- Fewer clouds over the Philippines and western Pacific warm pool
- A shift from the central Bay of Bengal to the northwestern coast and a redistribution within southeast Asia
- Much more cloud cover over the south slope of the Himalayas and the southeastern Tibetan Plateau

VERTICAL MOTION: DIABATIC HEATING



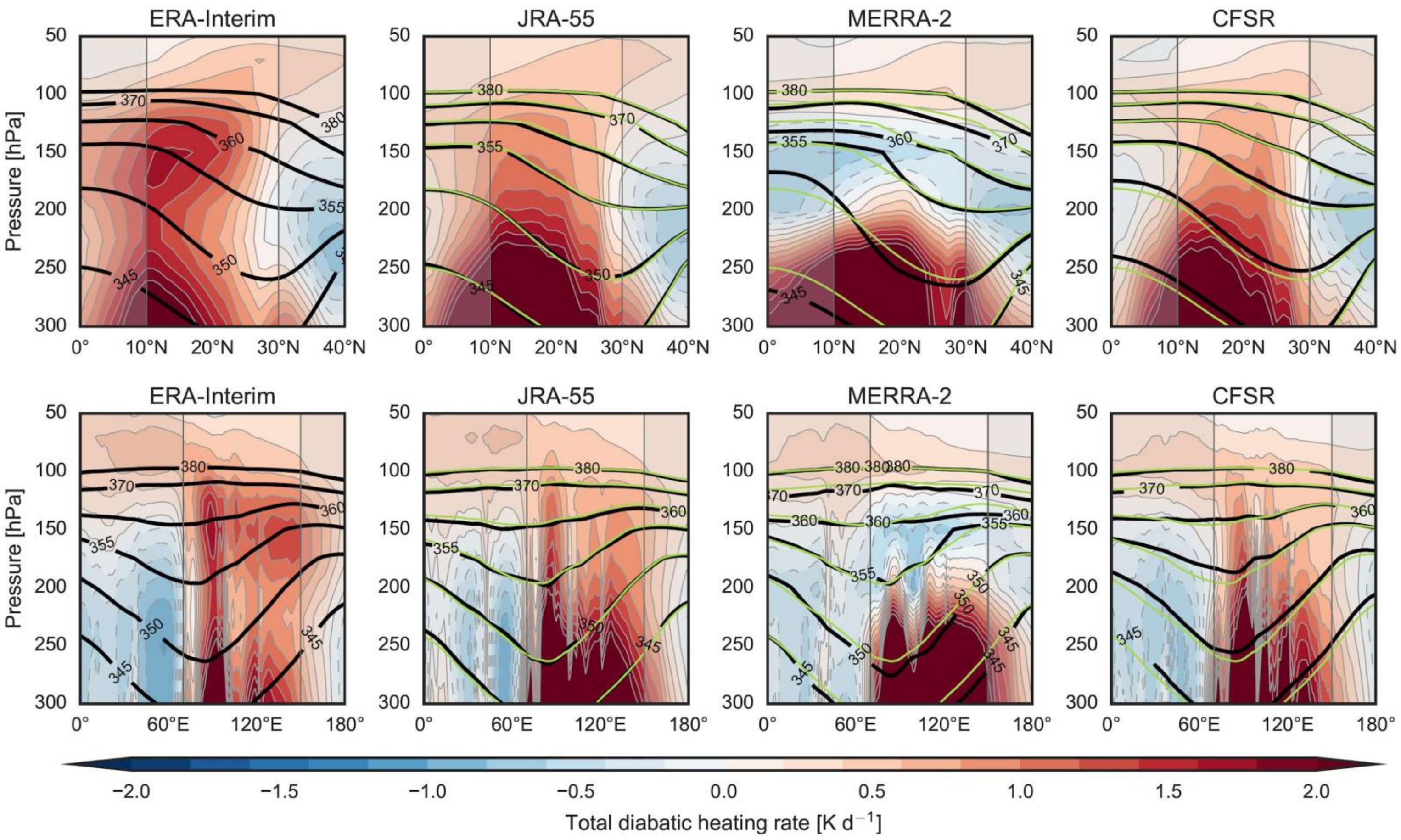
Positive heating rates correspond to diabatic ascent and negative heating rates to diabatic descent.

Radiative component varies little in time and is essential for slow ascent across the tropopause. Parcels must reach the level of zero radiative heating (LZRH) to enter the layer of slow ascent.

Non-radiative component mainly latent heating in deep convection; highly variable in time. Can be thought of as stochastically delivering parcels to the TTL, sometimes above the LZRH.

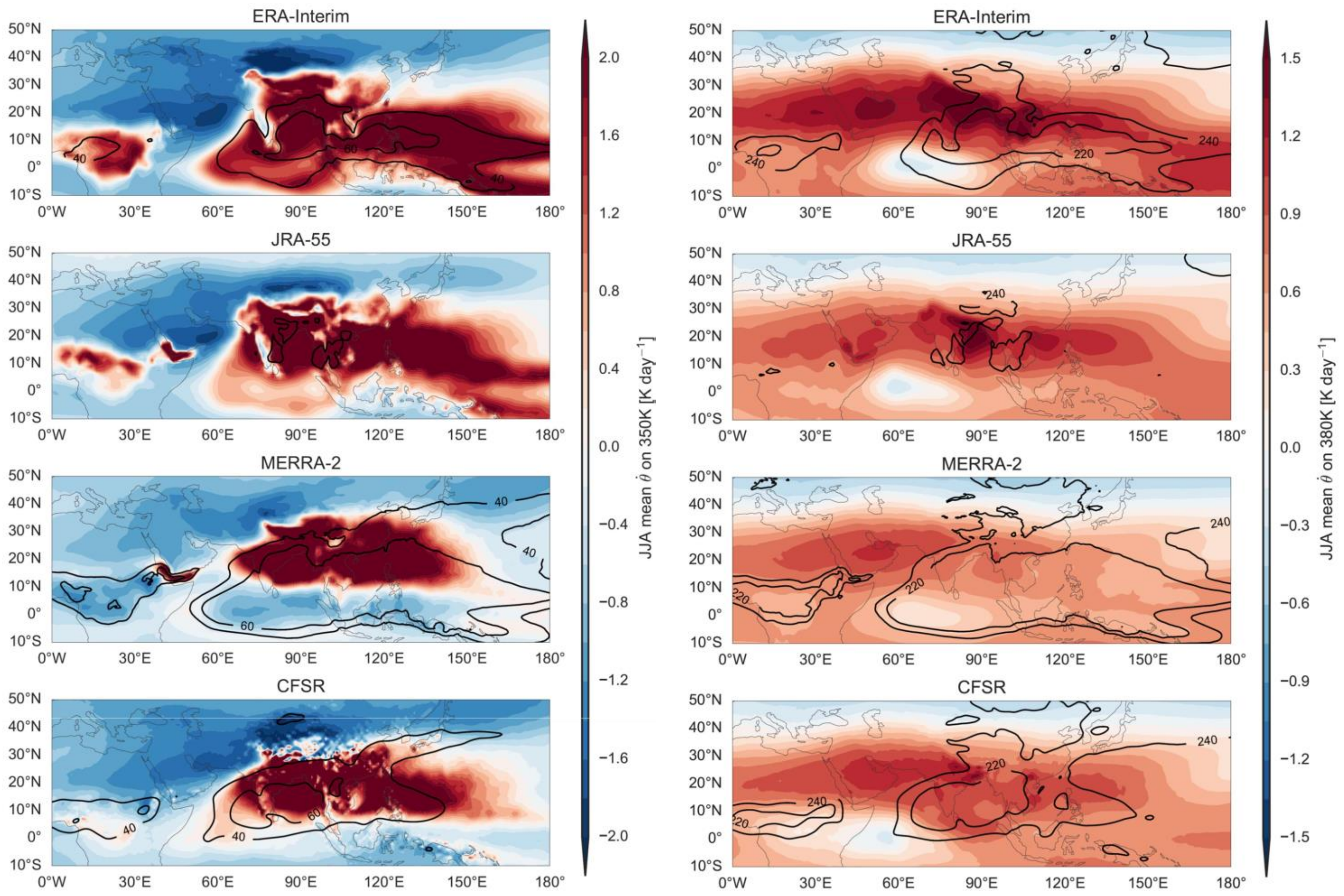
VERTICAL MOTION: DIABATIC HEATING

- Large differences in the magnitudes and distributions of diabatic heating rates within the monsoon region
- Substantial differences in the diabatic 'chimney' between the UT and LS
- Differences in diabatic heating also lead to differences in the distribution of potential temperature – may help explain the larger anticyclone areas in MERRA-2, especially in the UT
- Pressure vertical velocities (not shown) are more consistent among the reanalyses, but with much more 'noise' in time and space

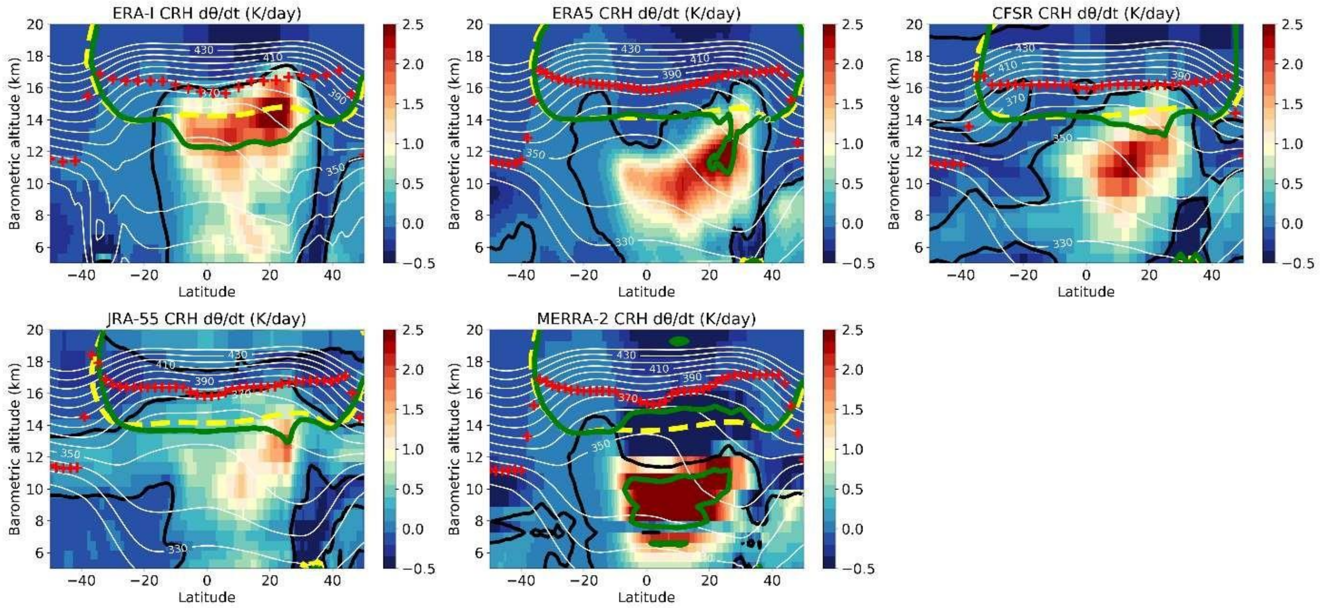


VERTICAL MOTION: DIABATIC HEATING

- Horizontal distributions of diabatic heating impact both tropospheric source regions and stratospheric transport pathways
- Different spatial patterns of very deep convection impact heating both within and above the convective column
- Largest heating rates at 380K closer to the main convective region in ERA-Interim and JRA-55 than in MERRA-2
- MERRA-2 has the smallest OLR, while JRA-55 has the largest – again this is attributable to differences in clouds

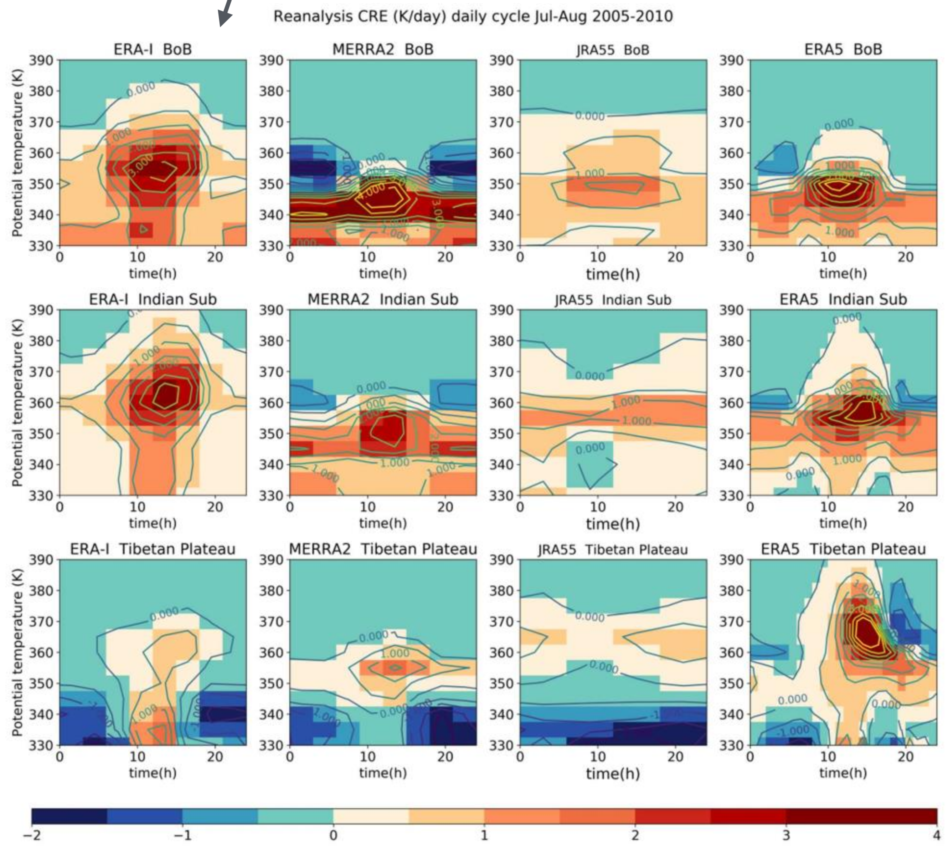


CLOUDS AND RADIATION: CLOUD RADIATIVE EFFECTS



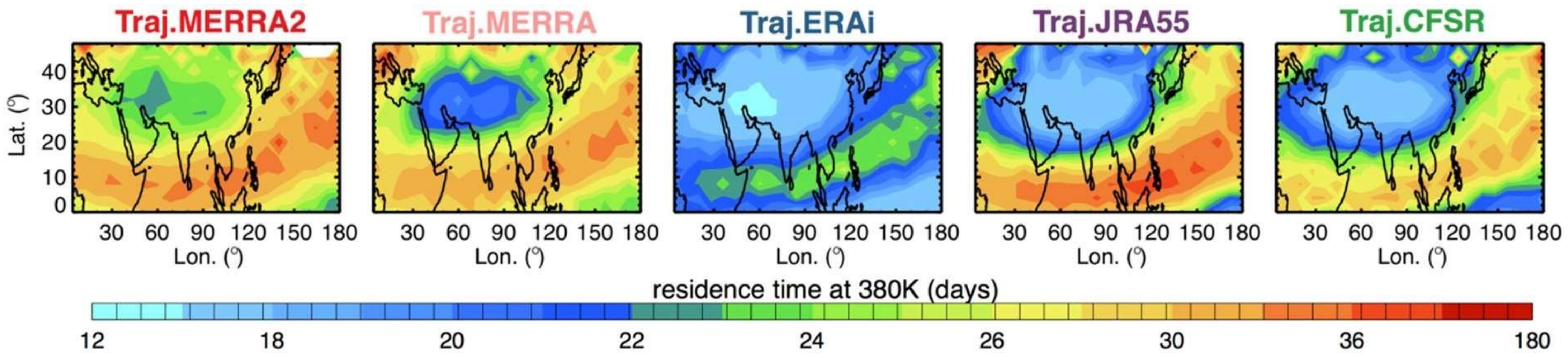
Zonal mean CREs averaged over 73°E–97°E during July-August 2005-2010, with cold point tropopause (red), clear-sky LZRH (yellow), and all-sky LZRH (green) marked for context. White contours are potential temperature

Mean diurnal cycles over various sub-domains



TRANSPORT: LAGRANGIAN TRANSIT TIMES

- The monsoon region is an important pathway to the global stratosphere
- Differences in simulated transit times to the tropical tropopause are linked to differences in vertical motion
- All reanalyses indicate that the most rapid ascent during NH summer takes place within the anticyclone region
- ERA-Interim indicates much faster transport through the TTL, consistent with larger diabatic heating rates
- MERRA-2 indicates much slower transport through the TTL, consistent with smaller diabatic heating rates
- These differences also impact the influence and characteristics of quasi-isentropic transport



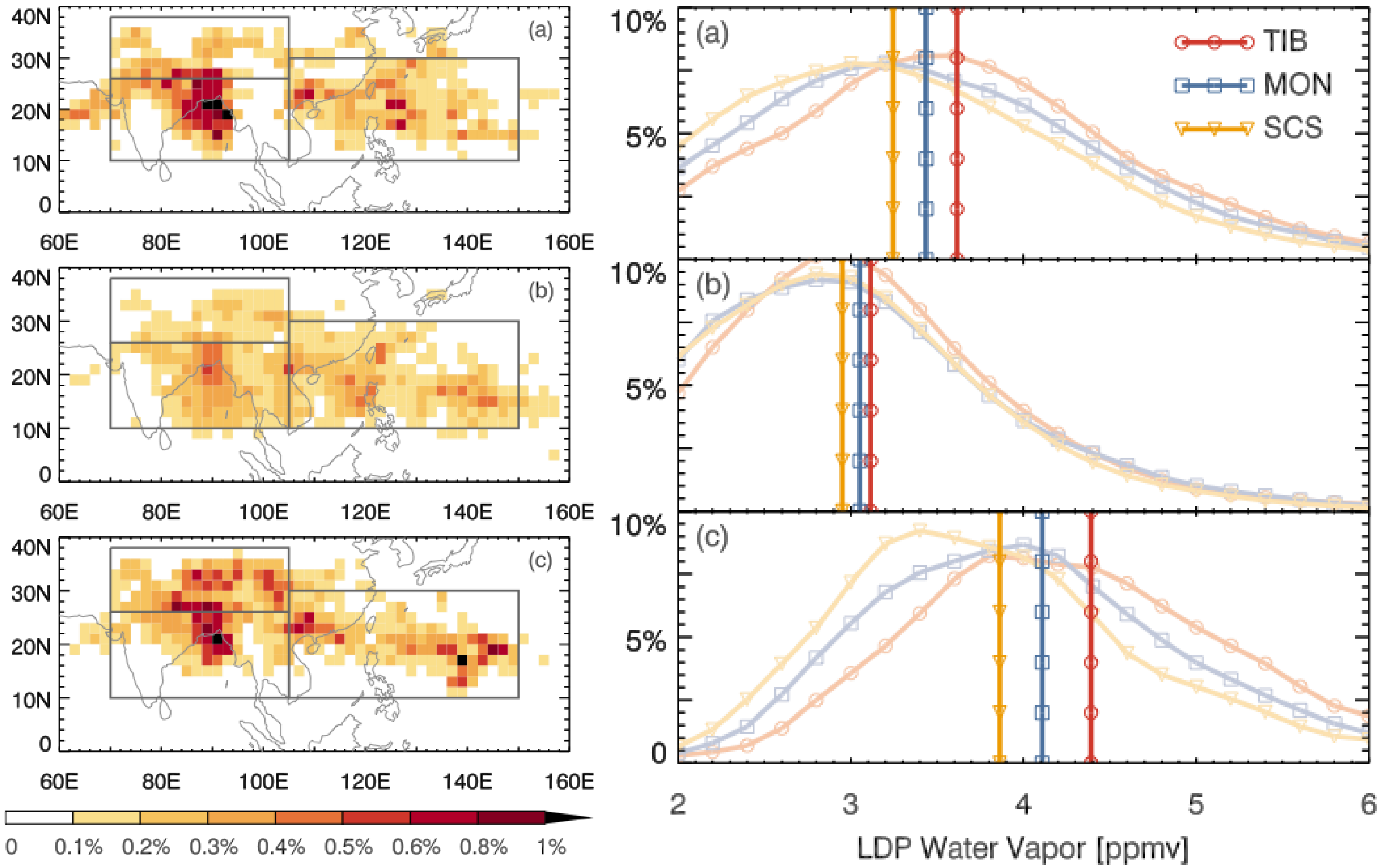
TRANSPORT:
CONVECTIVE SOURCE LOCATIONS

MERRA

Differences in transport statistics can be large even when controlling for the convective distribution

ERA-Interim

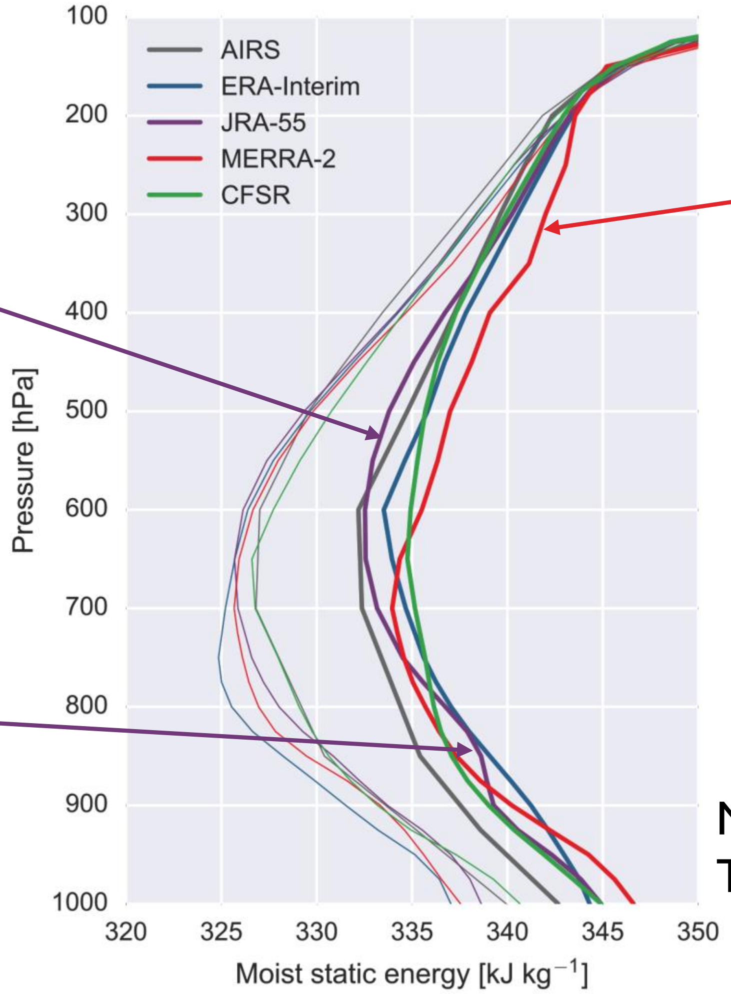
NCEP-NCAR R1



CAUTIONARY TALES: ANALYZED VARIABLES ARE AFFECTED!

JRA-55: Lower MSE in mid-troposphere due to treatment of the transition from liquid to ice in clouds (smaller q)

JRA-55: high values at 850 hPa caused by tying convective cloud base to the model level at ~900 hPa



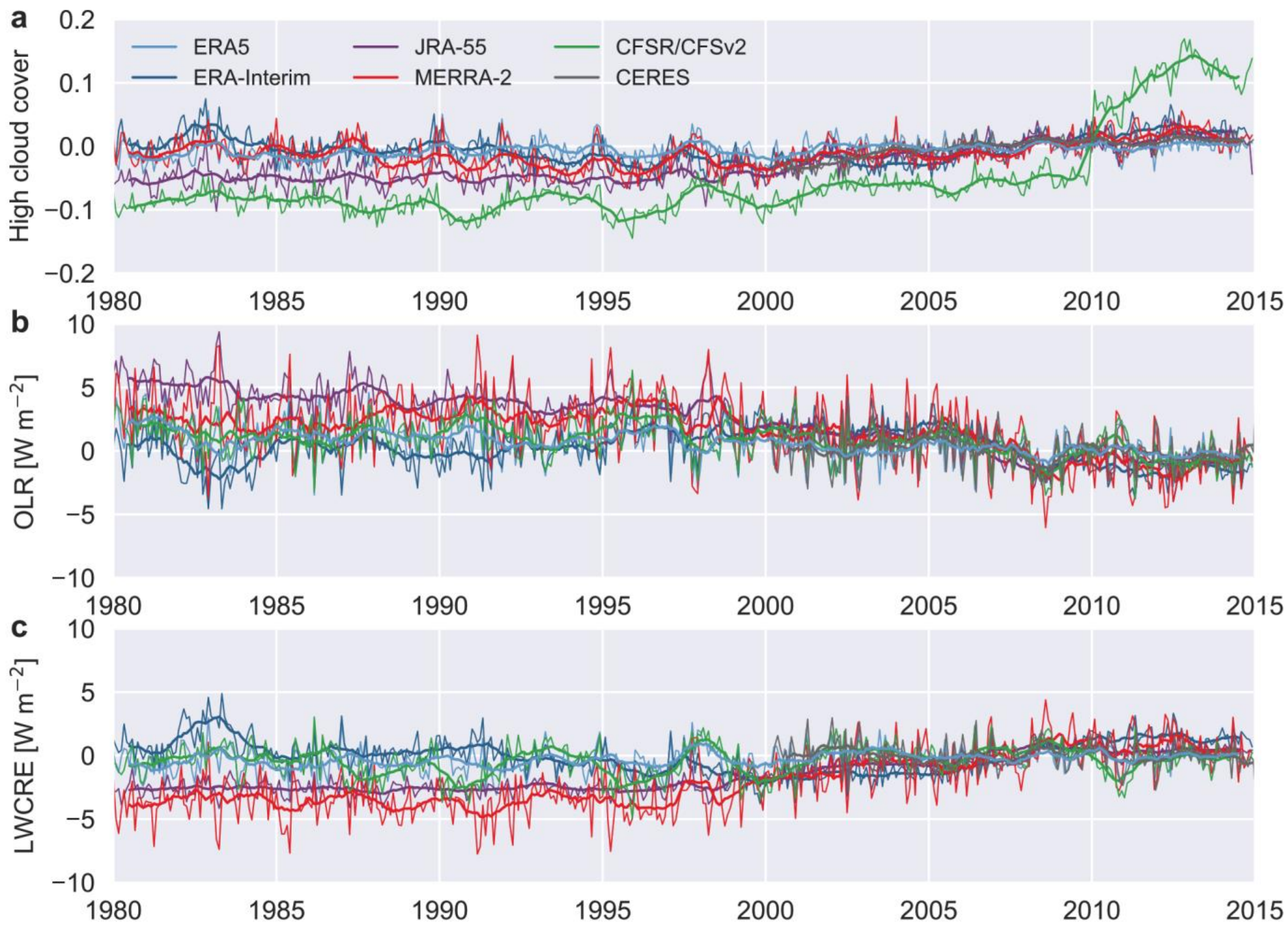
MERRA-2: large values in upper troposphere may arise from the radiative and moistening effects of thicker, more extensive convective anvil clouds – but also stabilize the upper troposphere in ways that favor the occurrence of thicker, more extensive anvil clouds.

MSE: $c_pT + L_vq + gz$

Tropical mean: 10°S–10°N

CAUTIONARY TALES: TRENDS

- Monthly anomalies relative to the mean seasonal cycle during 2001-2014 over 10°S–10°N
- Hints of consistent variations around 'super El Niño' events
- Most differences appear more likely to be structural than physical (e.g., stream transitions in CFSR; step changes in OLR around 1998)
- These same types of features are found in long-term time series for the monsoon region
- Some reanalyses suggest trends in these variables, but lack of consistency suggests that these are spurious
- Anomalies based on ERA5 are much more stable in time than those based on the other reanalyses



THE SPARC REANALYSIS INTERCOMPARISON PROJECT: RESOURCES

The S-RIP report is not yet complete, but several resources are already available for reanalysis data users:

- The S-RIP website: https://s-rip.ees.hokudai.ac.jp/
- The S-RIP special issue in ACP and ESSD: https://www.atmos-chem-phys.net/special_issue829.html
- Chapter 2: Description of the Reanalysis Systems: https://jonathonwright.github.io/

Questions, suggestions, or corrections…

Contact: jswright@tsinghua.edu.cn

Chapter 2: Description of the Reanalysis Systems

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