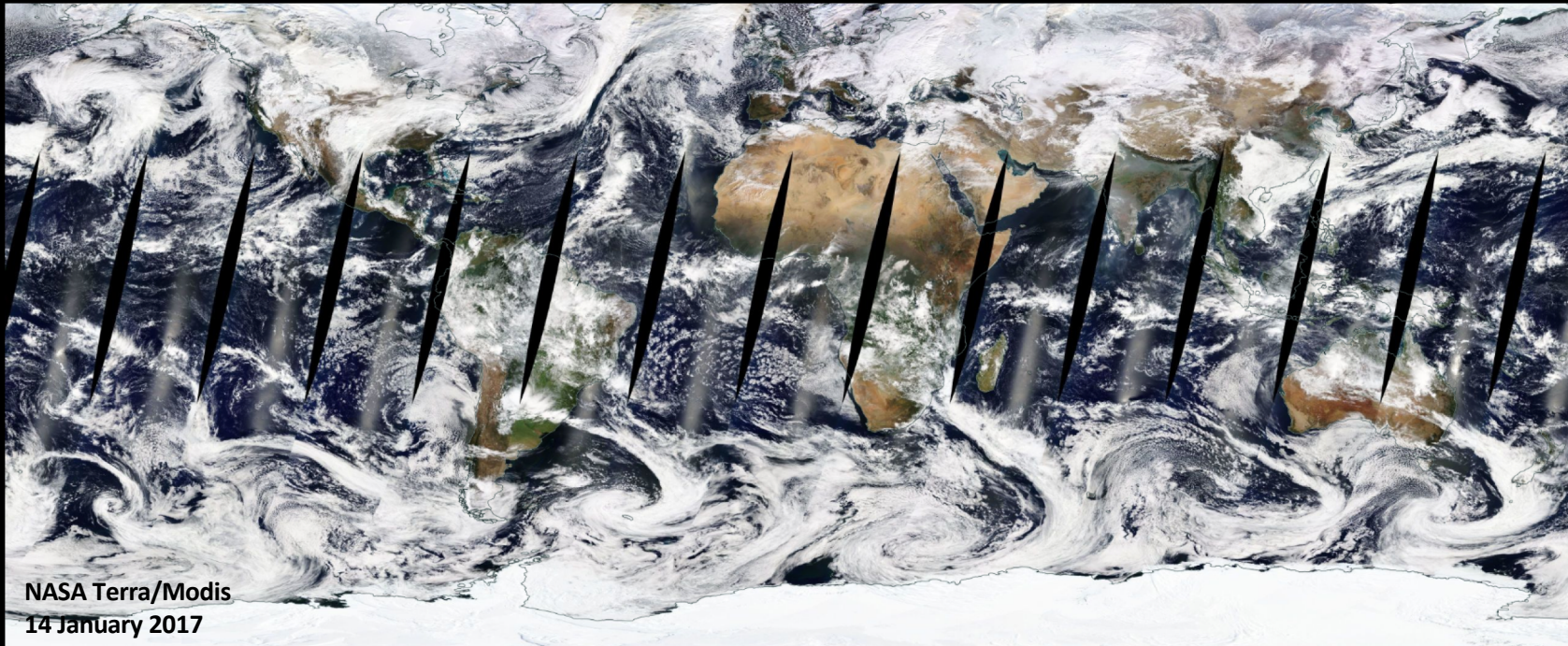


Global Precipitation Characteristics

Atmos 5210: Synoptic Meteorology II



NASA Terra/Modis
14 January 2017

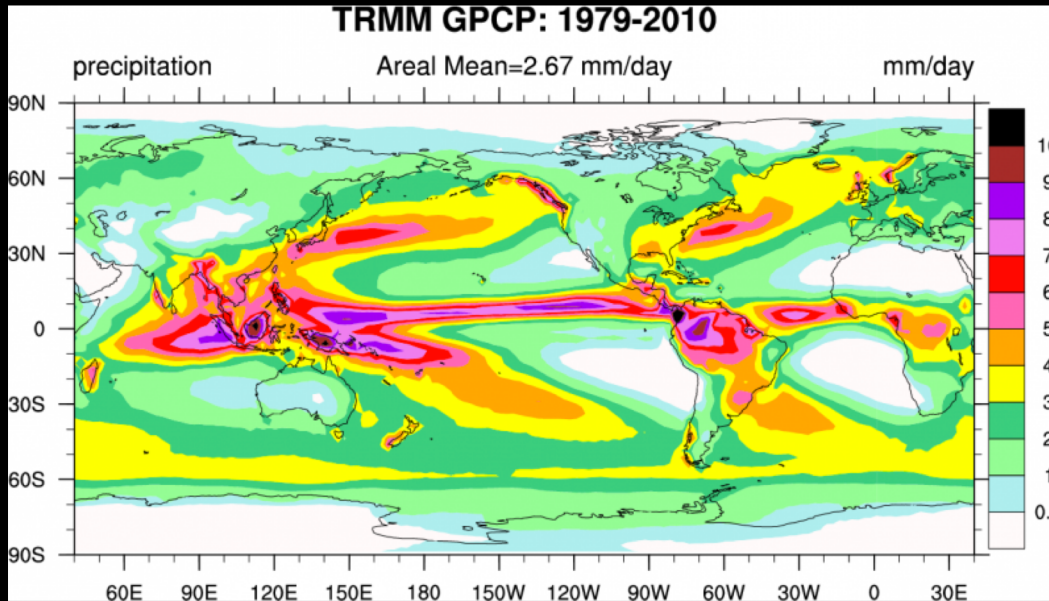
Jim Steenburgh

Department of Atmospheric Sciences

University of Utah

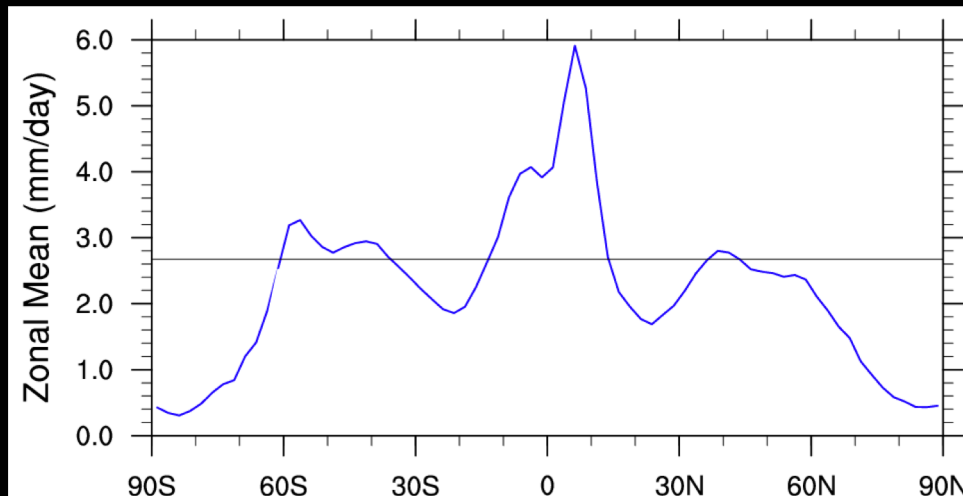
jim.steenburgh@utah.edu

Annual Mean Precipitation



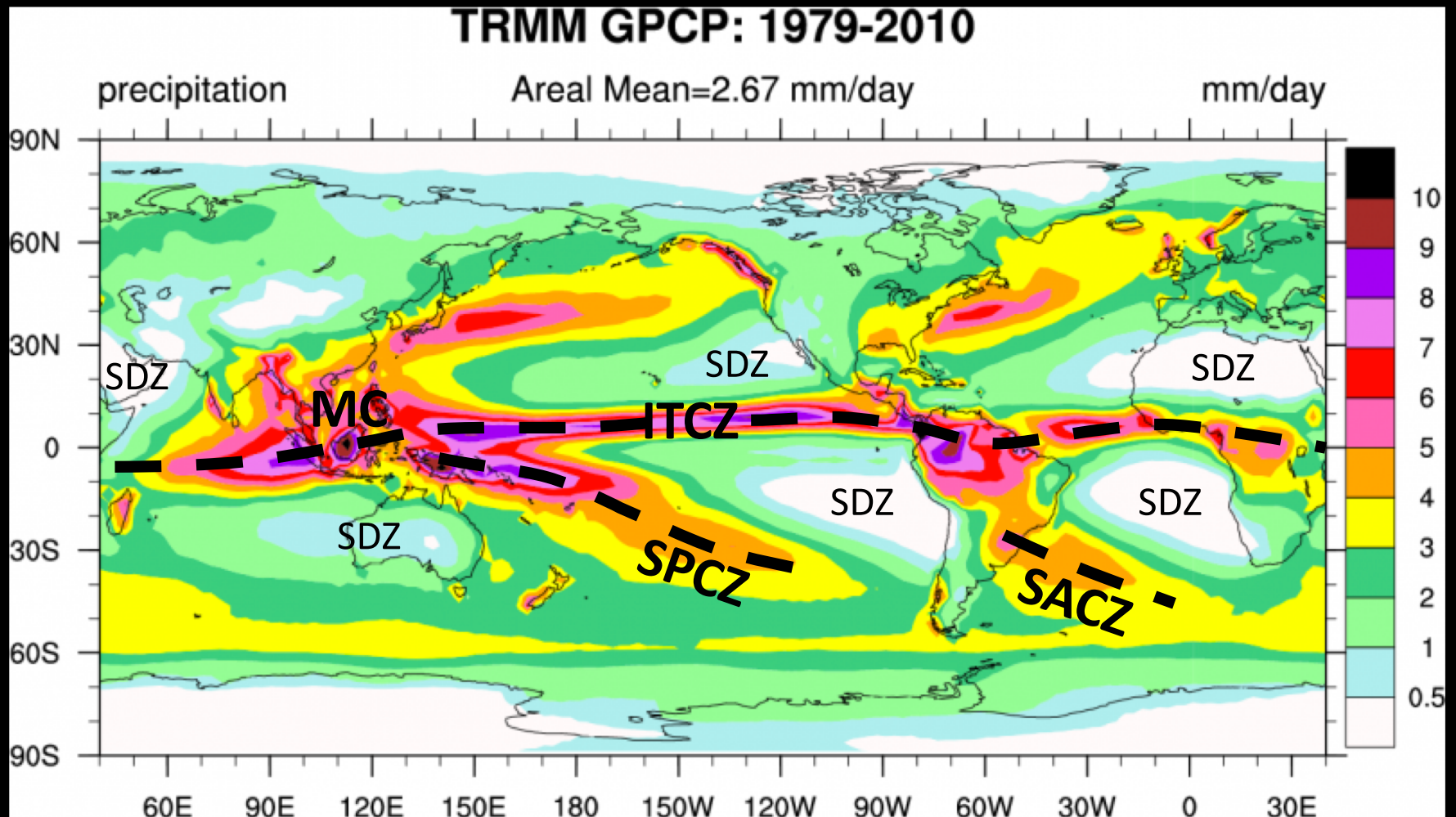
- Discussion

- What are the primary features of the annual mean global precipitation distribution?



- Why do these features exist?

Key Features: Tropics and Subtropics



ITCZ = Intertropical Convergence Zone

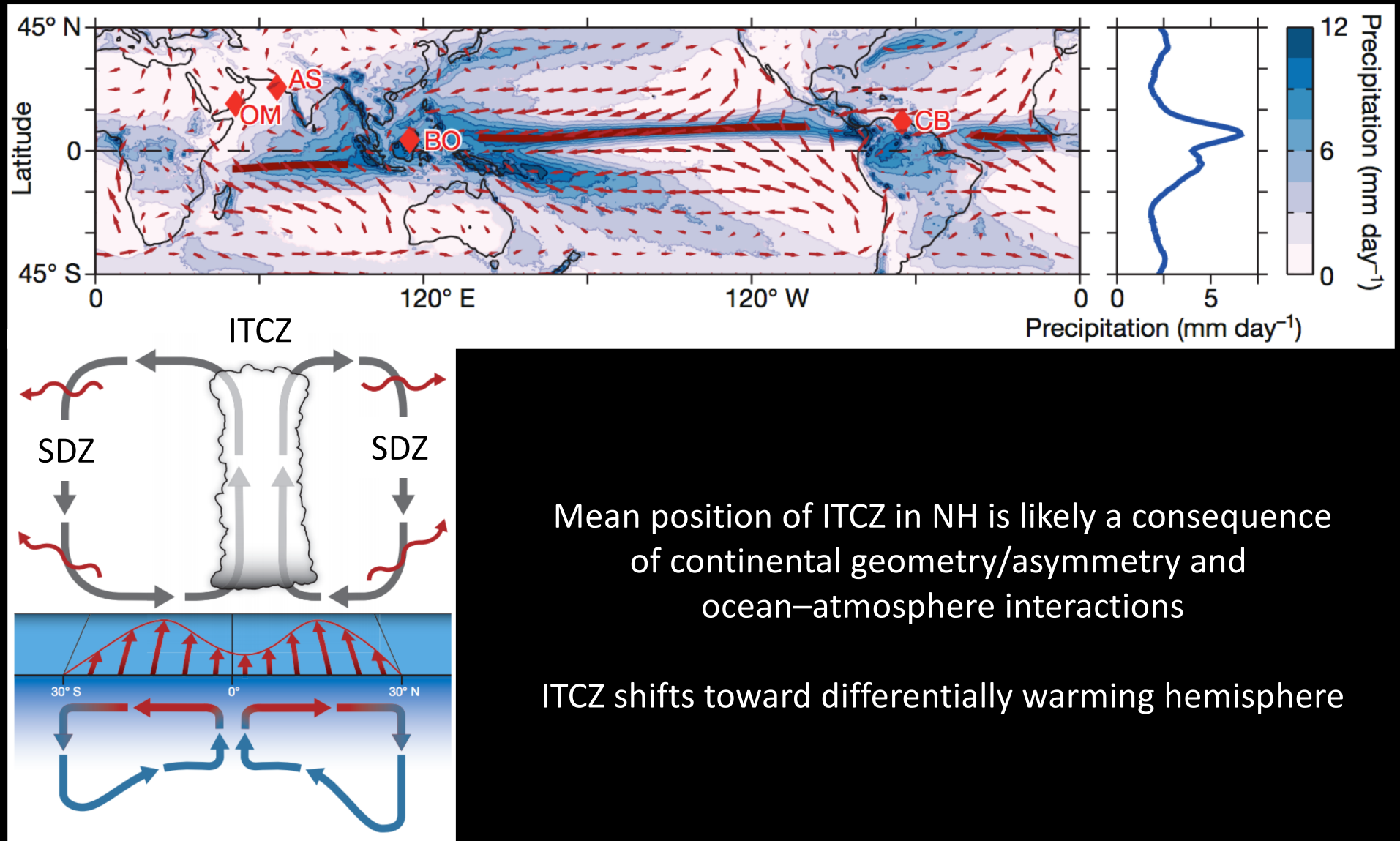
MC = Maritime Continent

SDZ = Subtropical Dry Zone

SPCZ = South Pacific Convergence Zone

SACZ = South Atlantic Convergence Zone

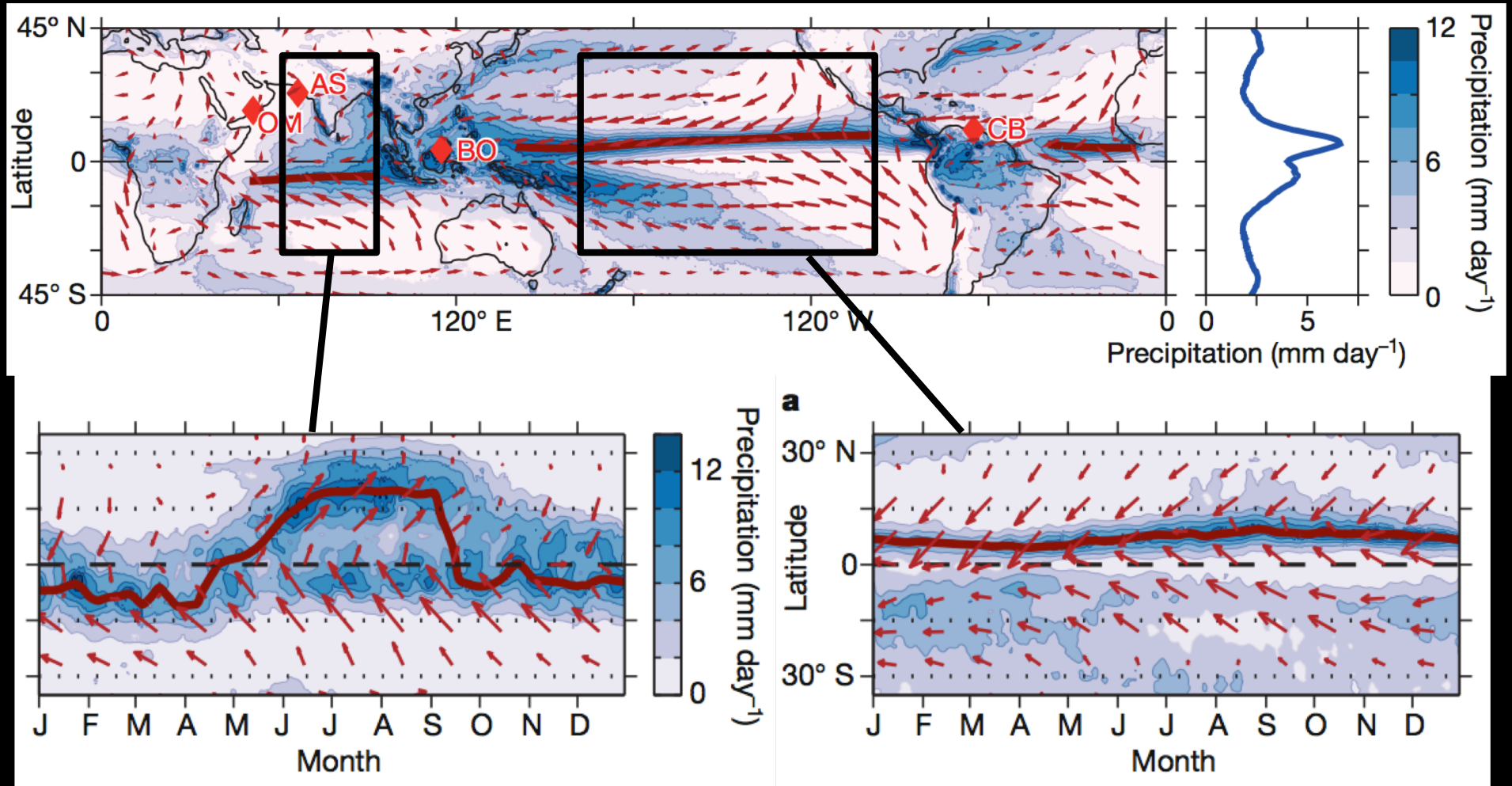
ITCZ/SDZ Mechanisms



Mean position of ITCZ in NH is likely a consequence of continental geometry/asymmetry and ocean–atmosphere interactions

ITCZ shifts toward differentially warming hemisphere

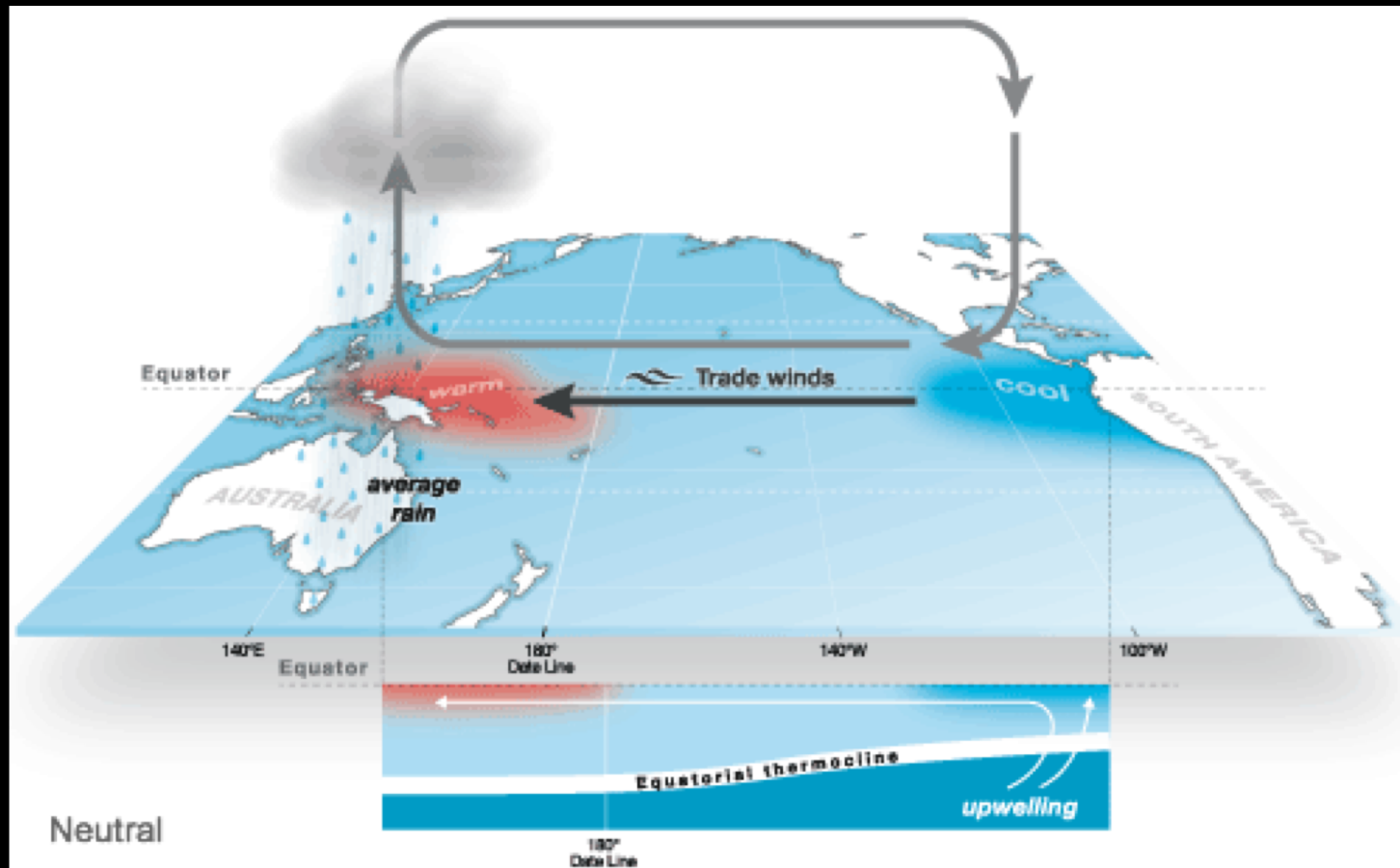
ITCZ Seasonal Cycle



Strong influence of Asian Monsoon

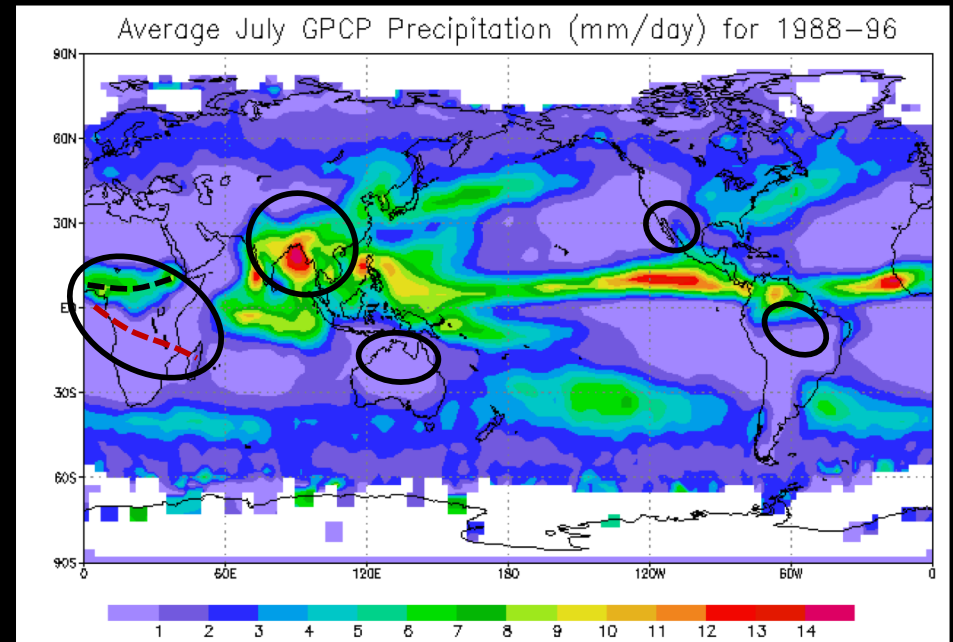
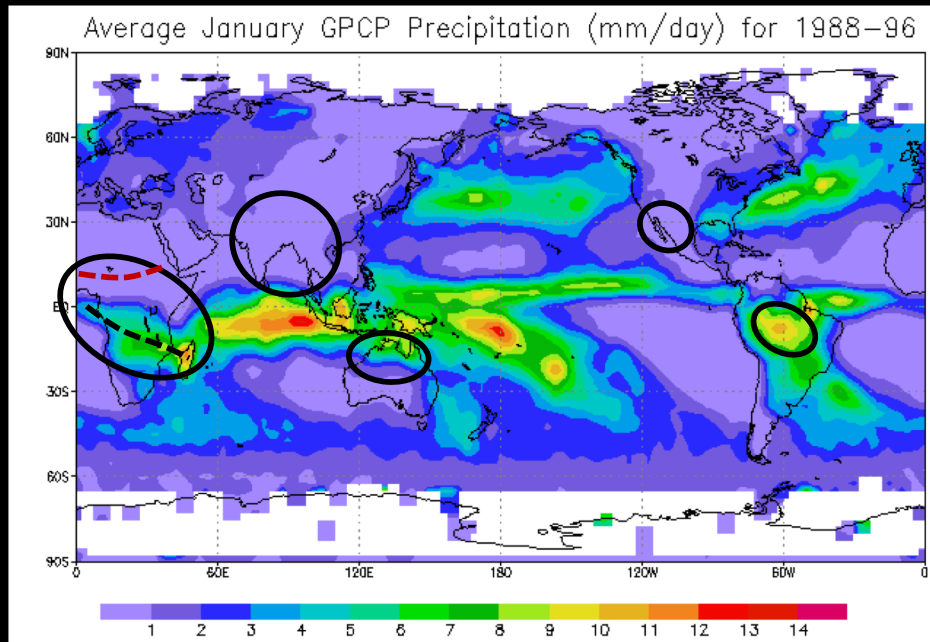
More subtle migration

Walker Circulation



Large-scale circulation over the tropical Pacific Ocean featuring easterly surface winds, rising motion and convective storms over the western Pacific and maritime continent, westerly flow aloft, and subsidence over eastern Pacific.

Monsoons



Large-scale circulation change produced by asymmetric heating of land & water areas, leading to a seasonal wind reversal and modulation of precipitation, typically resulting in pronounced dry and wet seasons

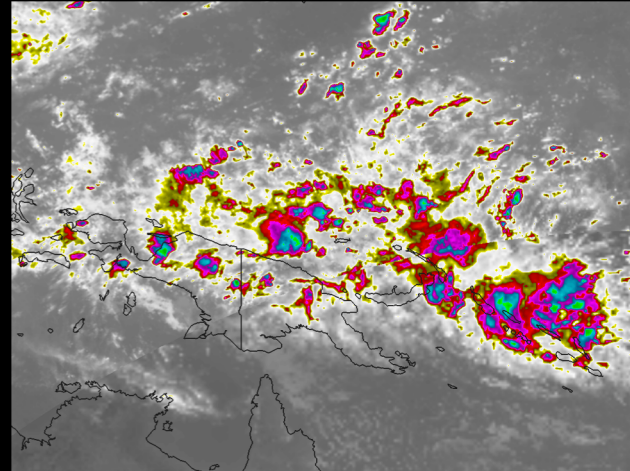
Where: Central Africa, SE Asia, N Australia, SW North America, Amazon

Tropical Precipitation Systems

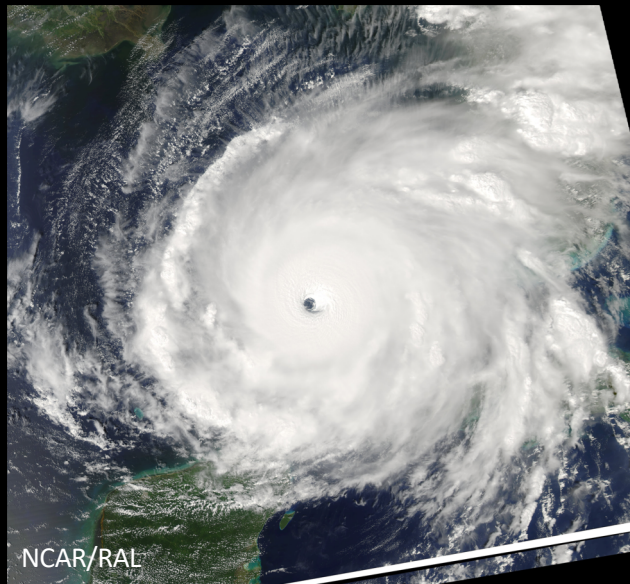


Yuji Kashino, RIGC/JAMSTEC

Convection

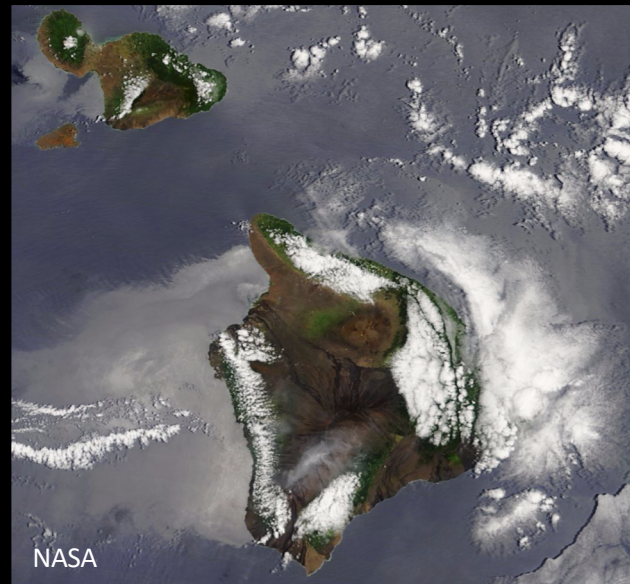


Mesoscale Convective Systems



NCAR/RAL

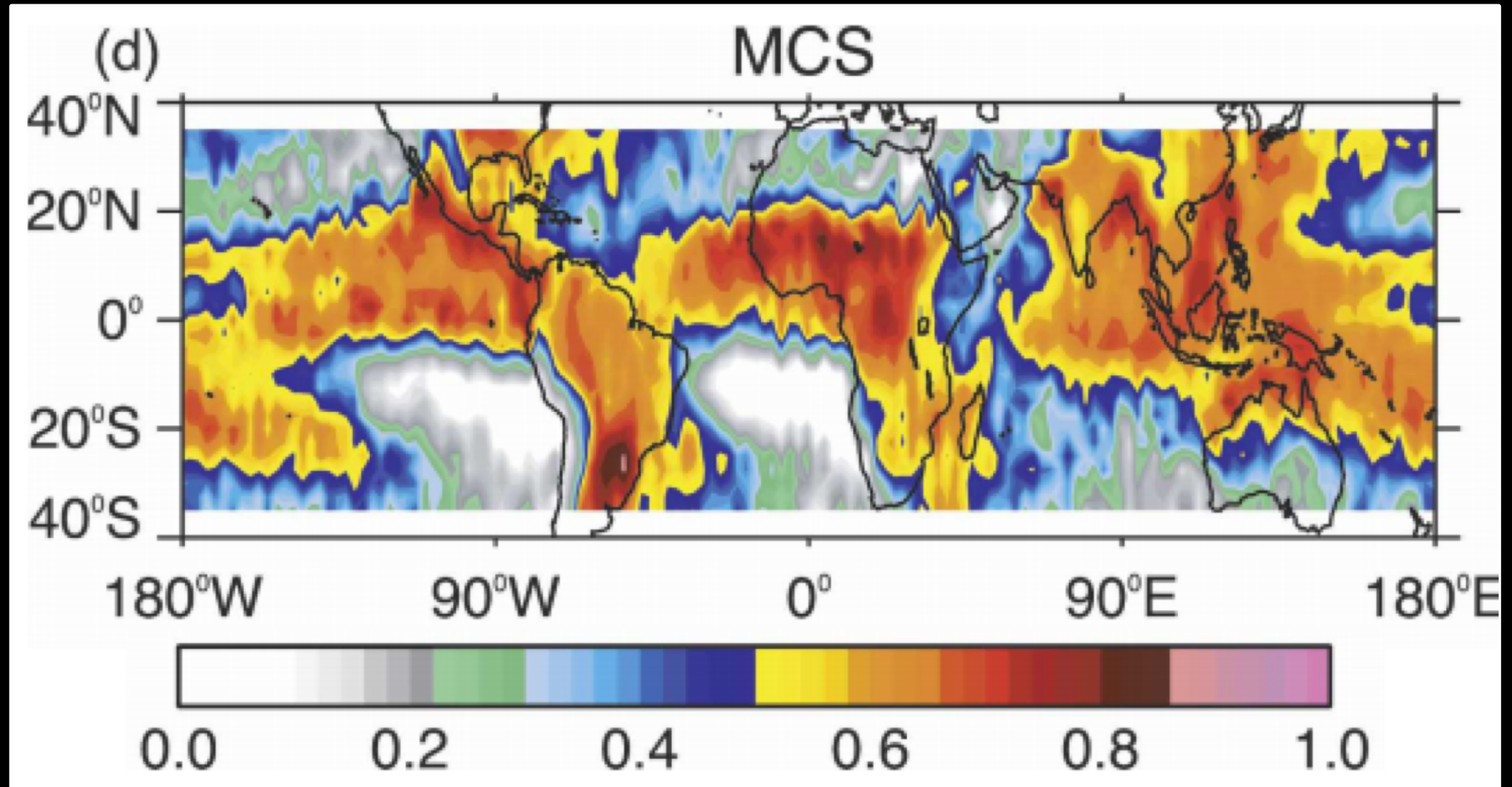
Tropical Cyclones



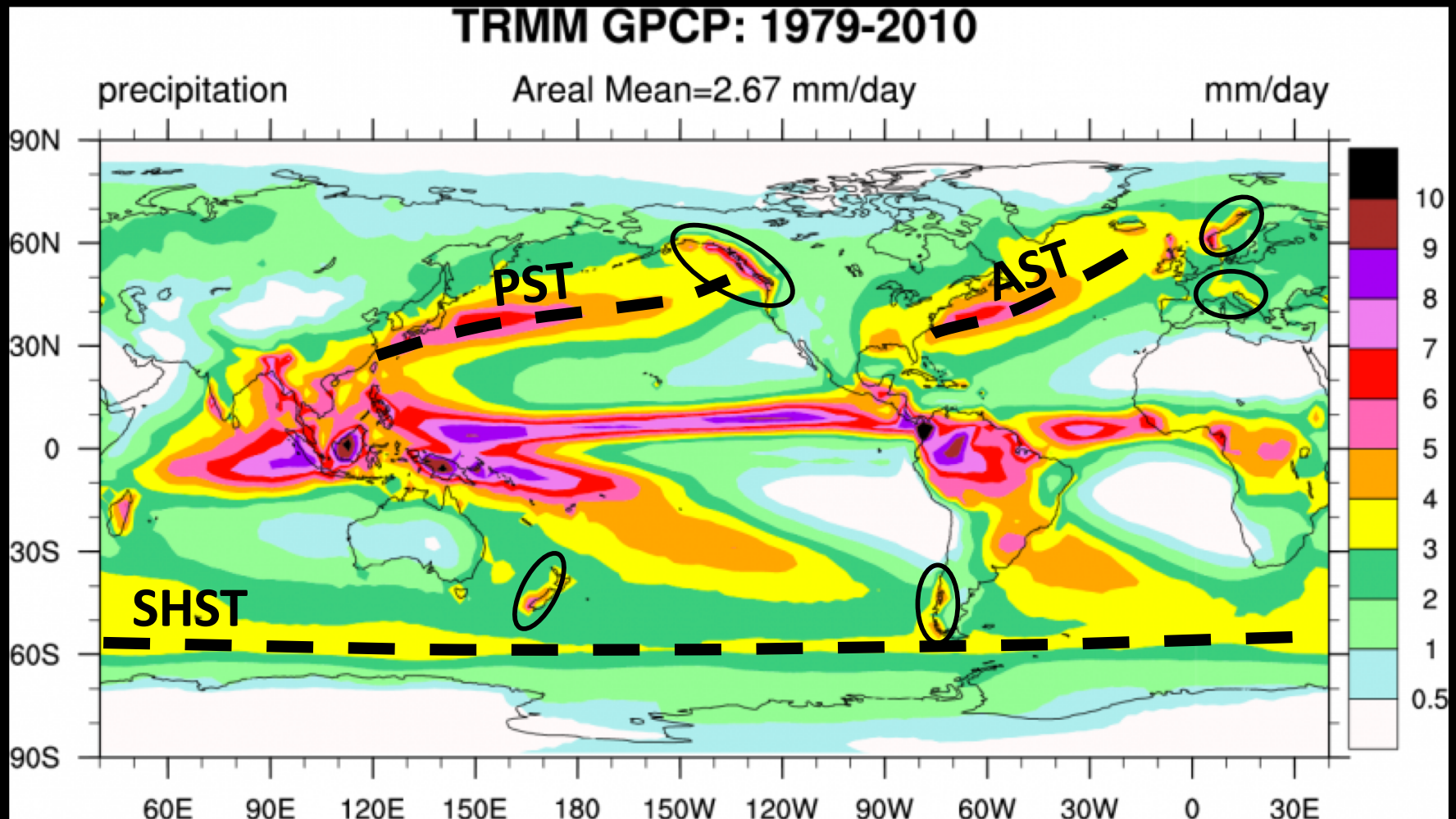
NASA

Orographic

Importance of MCS



Key Features: Midlatitudes



PST = North Pacific Storm Track
AST = North Atlantic Storm Track
SHST = Southern Hemisphere Storm Track



Examples of orographic effects
(poorly resolved)

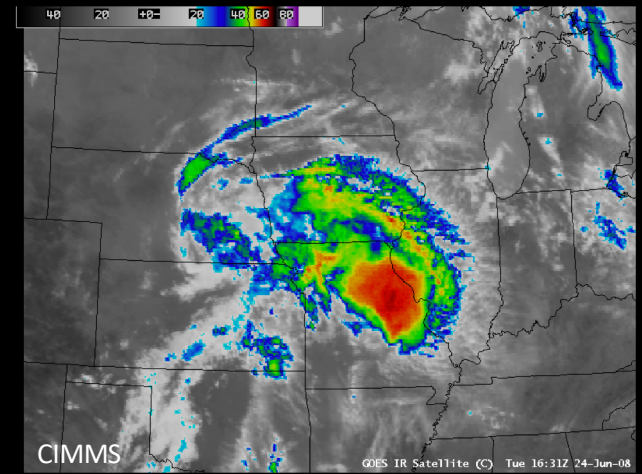
Midlatitude Precipitation Systems



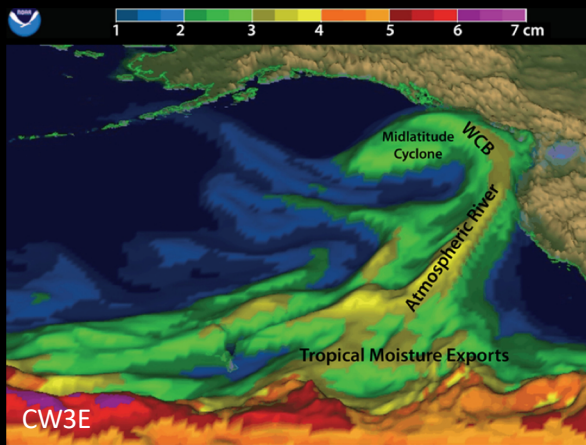
Extratropical Cyclones/Fronts



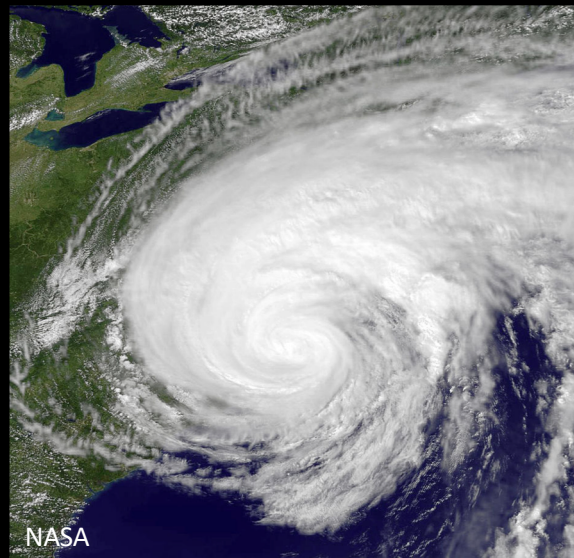
Convection



Mesoscale Convective Systems



Atmospheric Rivers*



Tropical Cyclones

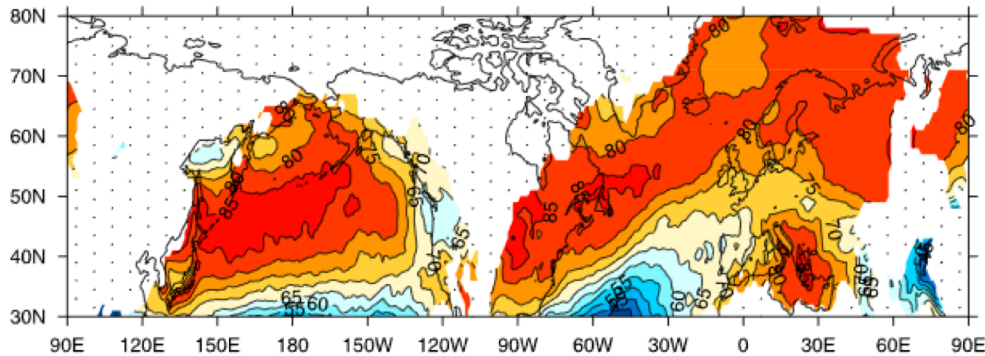


Orographic Forcing

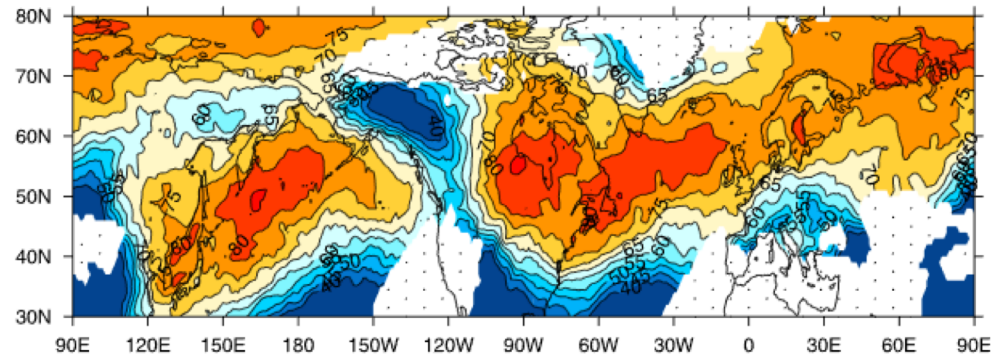
*Moisture transport feature

Cyclone Contribution

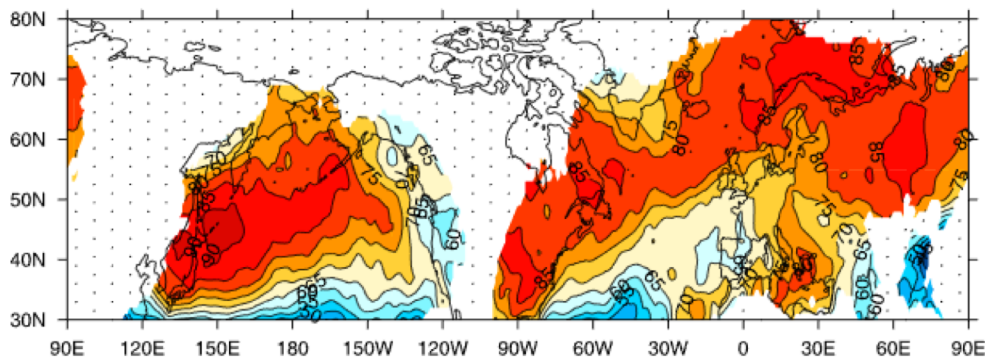
ERA-Interim DJF



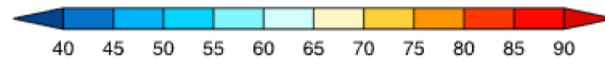
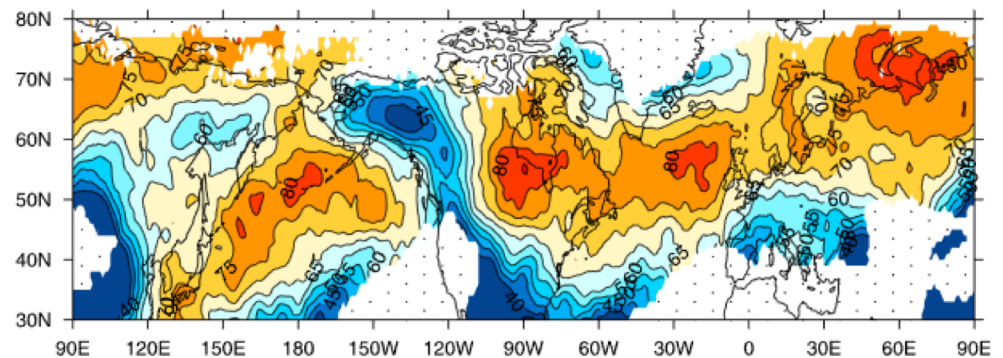
ERA-Interim JJA



GPCP DJF



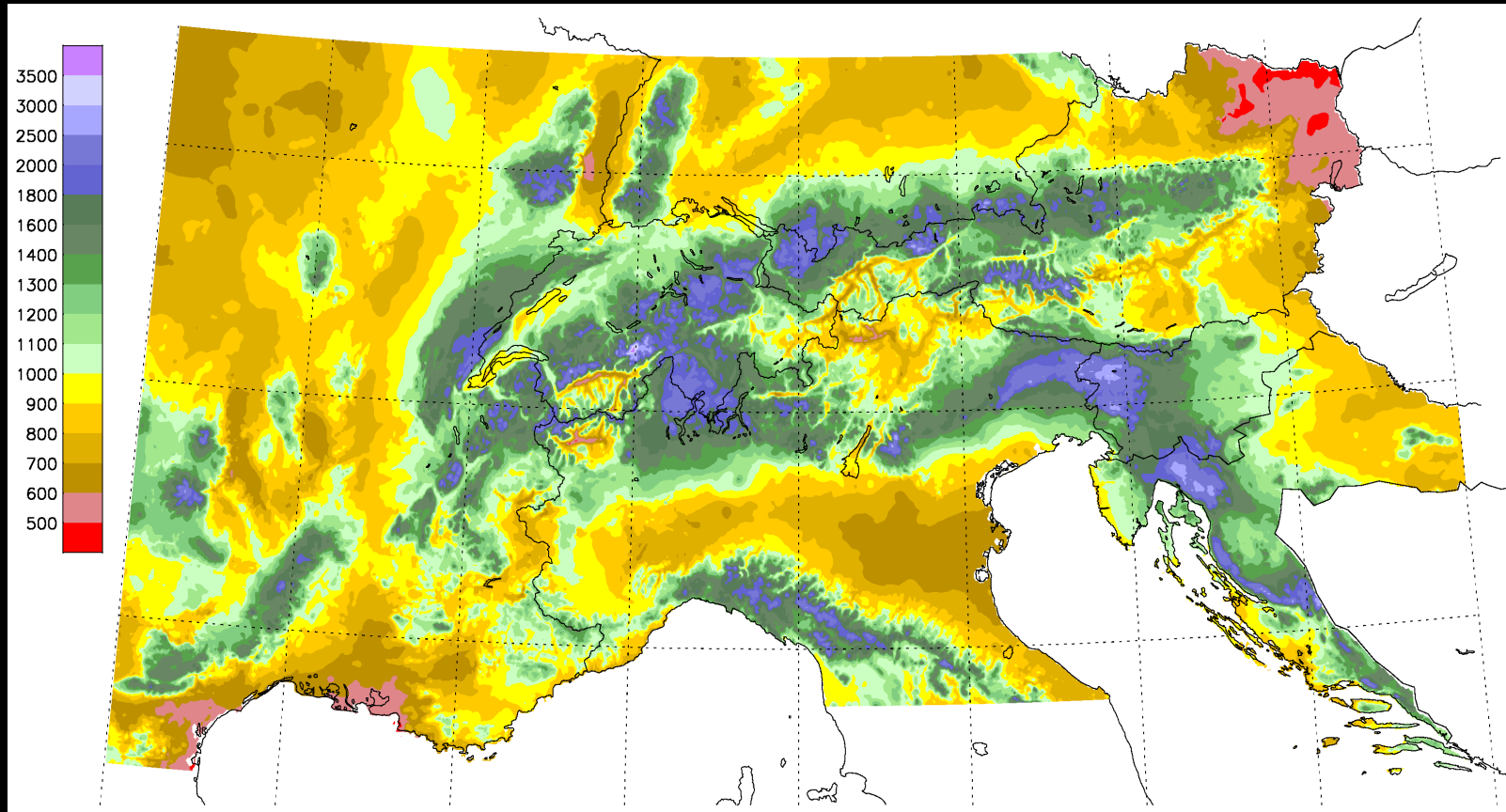
GPCP JJA



Winter (DJF)

Summer (JJA)

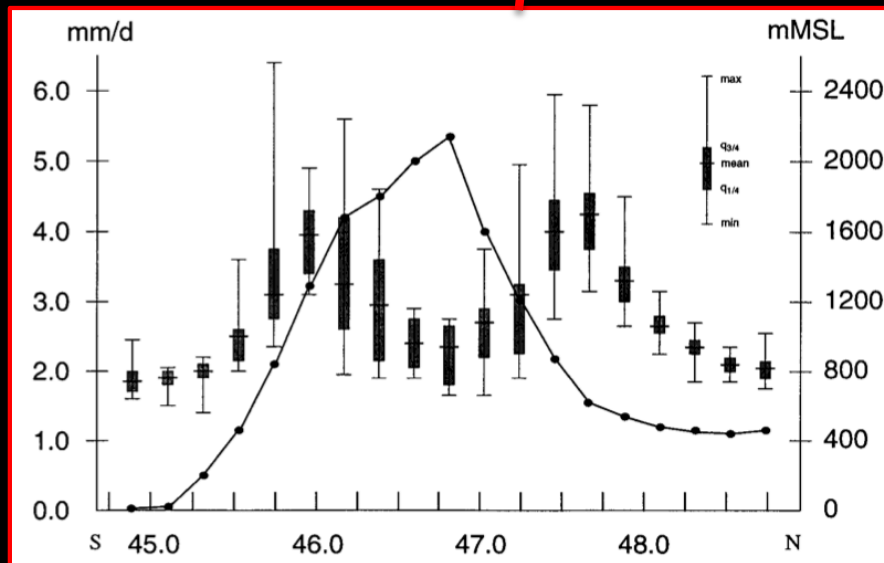
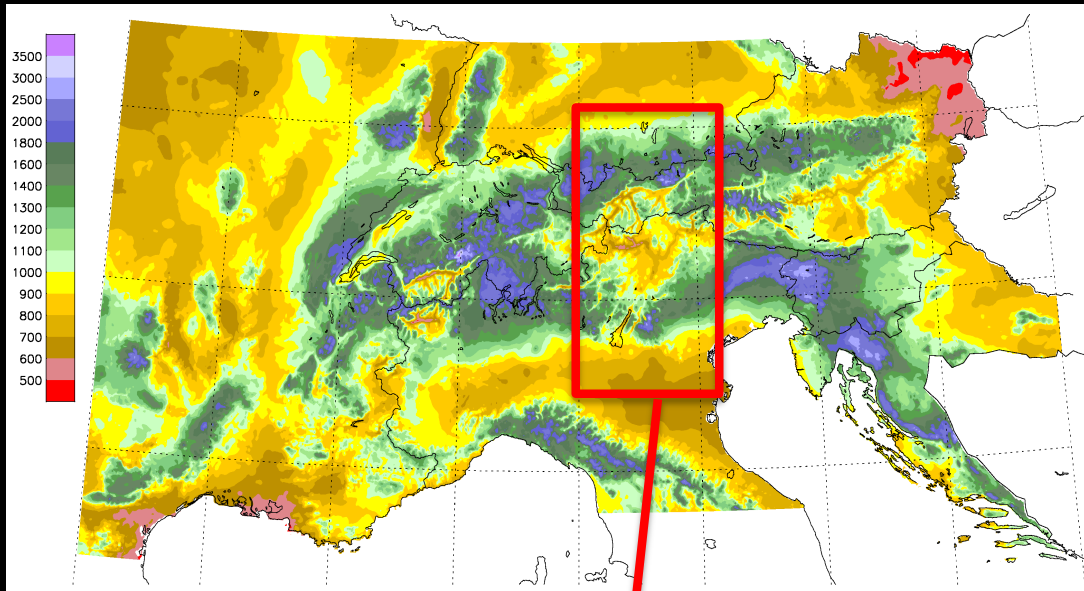
Orographic Effects



Annual Mean Precipitation (mm)

- Discussion
 - What are the primary features of the annual mean precipitation in the Alpine region?
 - Why do these features exist?
 - How do you explain local and regional maxima and minima in precipitation?

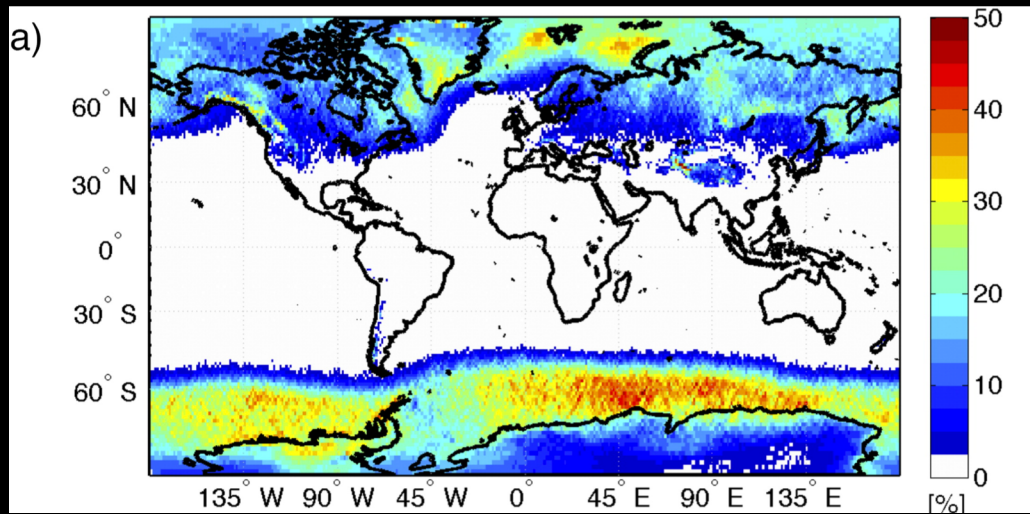
Orographic Effects



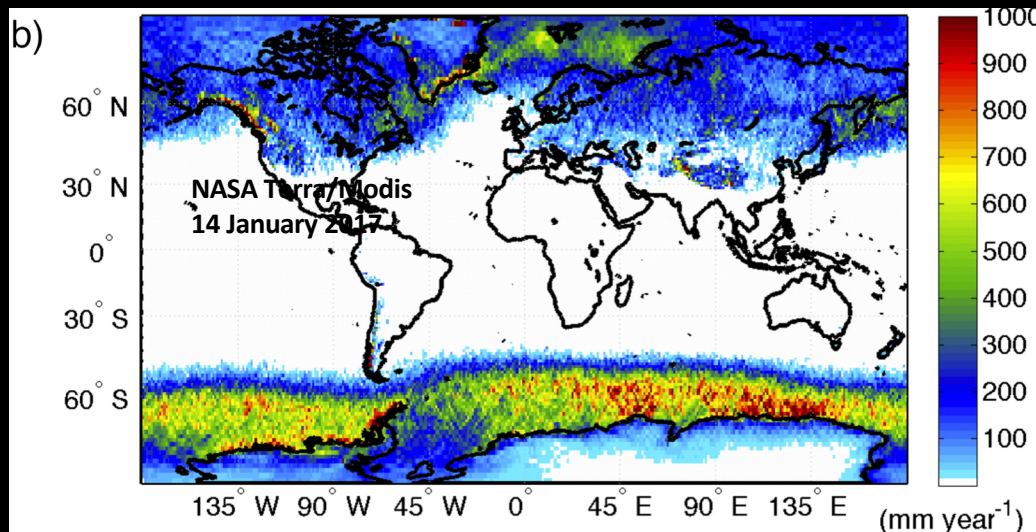
- Strong precipitation—altitude relationship, but also important:
 - Regional moisture availability and transport
 - Storm track and frequency
 - 3-D terrain effects
 - Effects of western hook
 - Concavity near Lago Maggiore
 - Barrier width and upstream water-vapor depletion
 - Tirol vs. Gotthard Pass

Snow

Snowfall



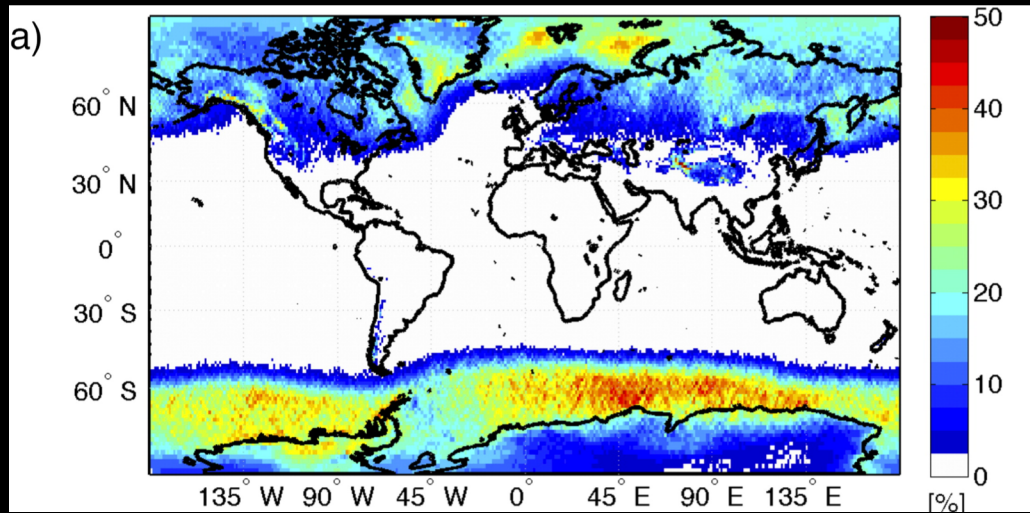
Annual Mean Snowfall Fraction (% , 2006-10)



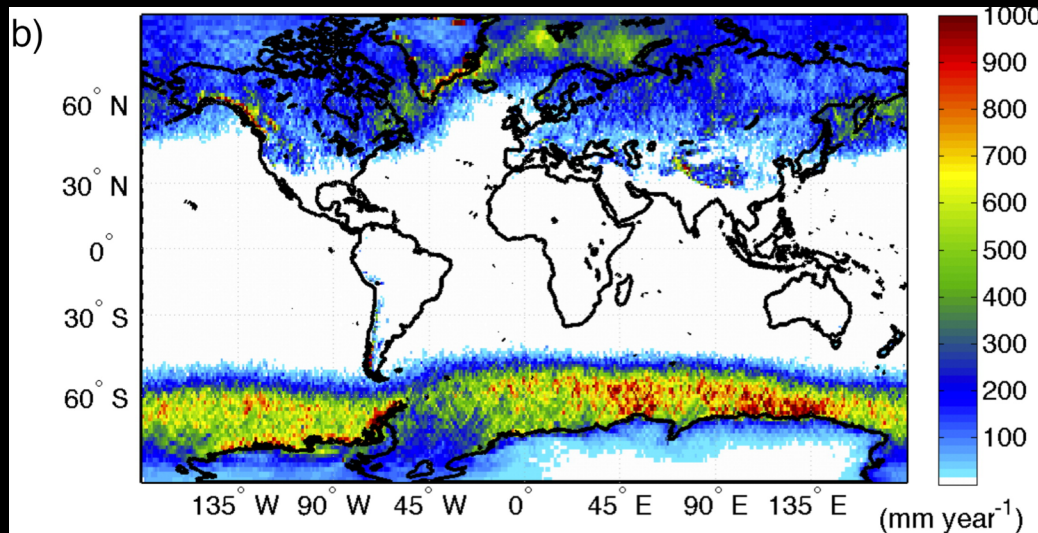
Annual Mean Liquid Equiv. Snowfall (mm, 2006-10)

- NH Fraction greatest over Labrador Sea, South Greenland, Greenland Sea, Barents Sea, Sea of Okhotsk, Bearing Sea, Central Asia, Coastal Alaska/British Columbia
- Poleward shift over eastern Pacific and Atlantic, the latter producing lower fractions over western Europe
- NH Snowfall similar, except high altitude South Greenland sees relatively low amounts
- Many topographic effects poorly resolved

Snowfall



Annual Mean Snowfall Fraction (% , 2006-10)

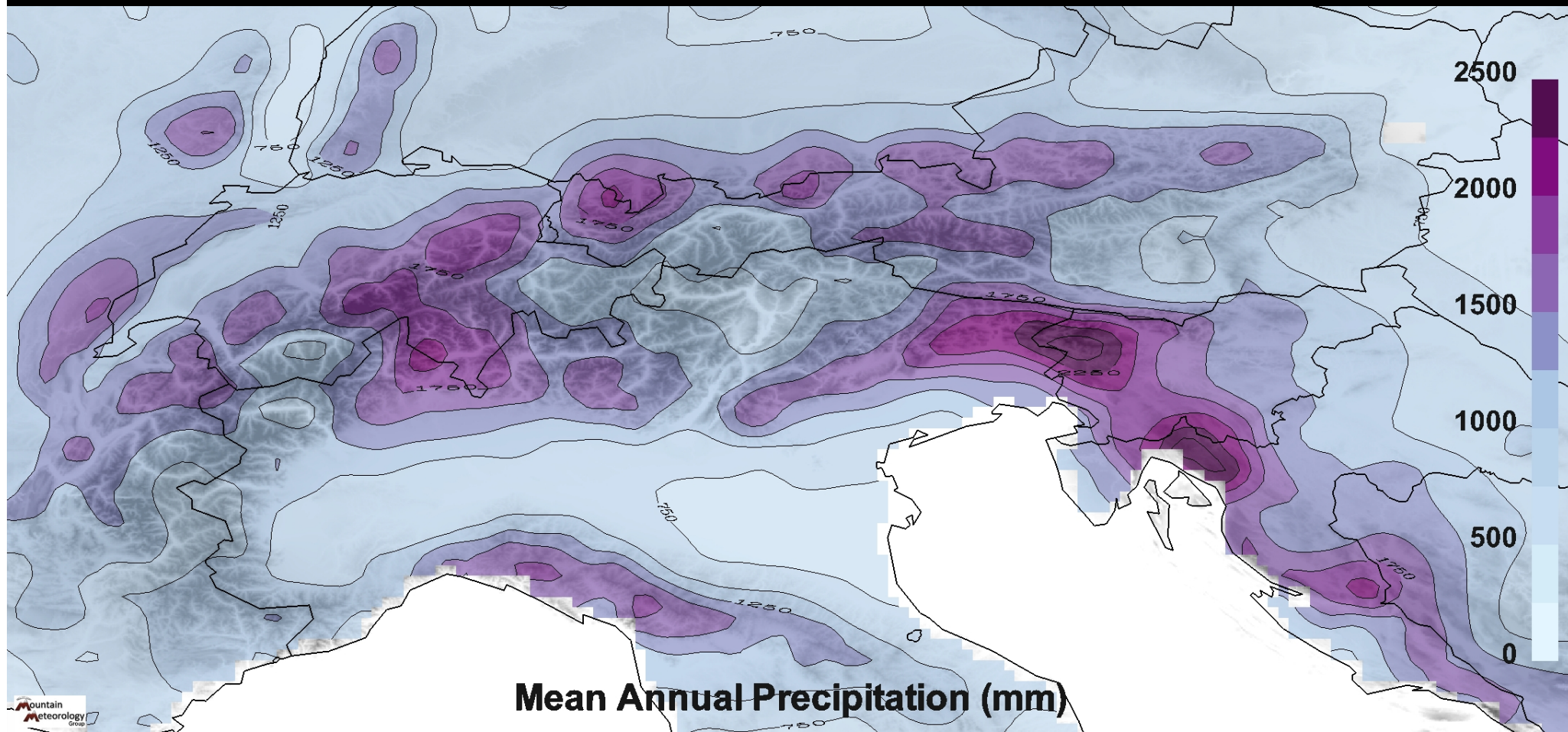


Annual Mean Liquid Equiv. Snowfall (mm, 2006-10)

- SH Fraction and amount greatest along storm track
- Note lower values east of Antarctic Peninsula

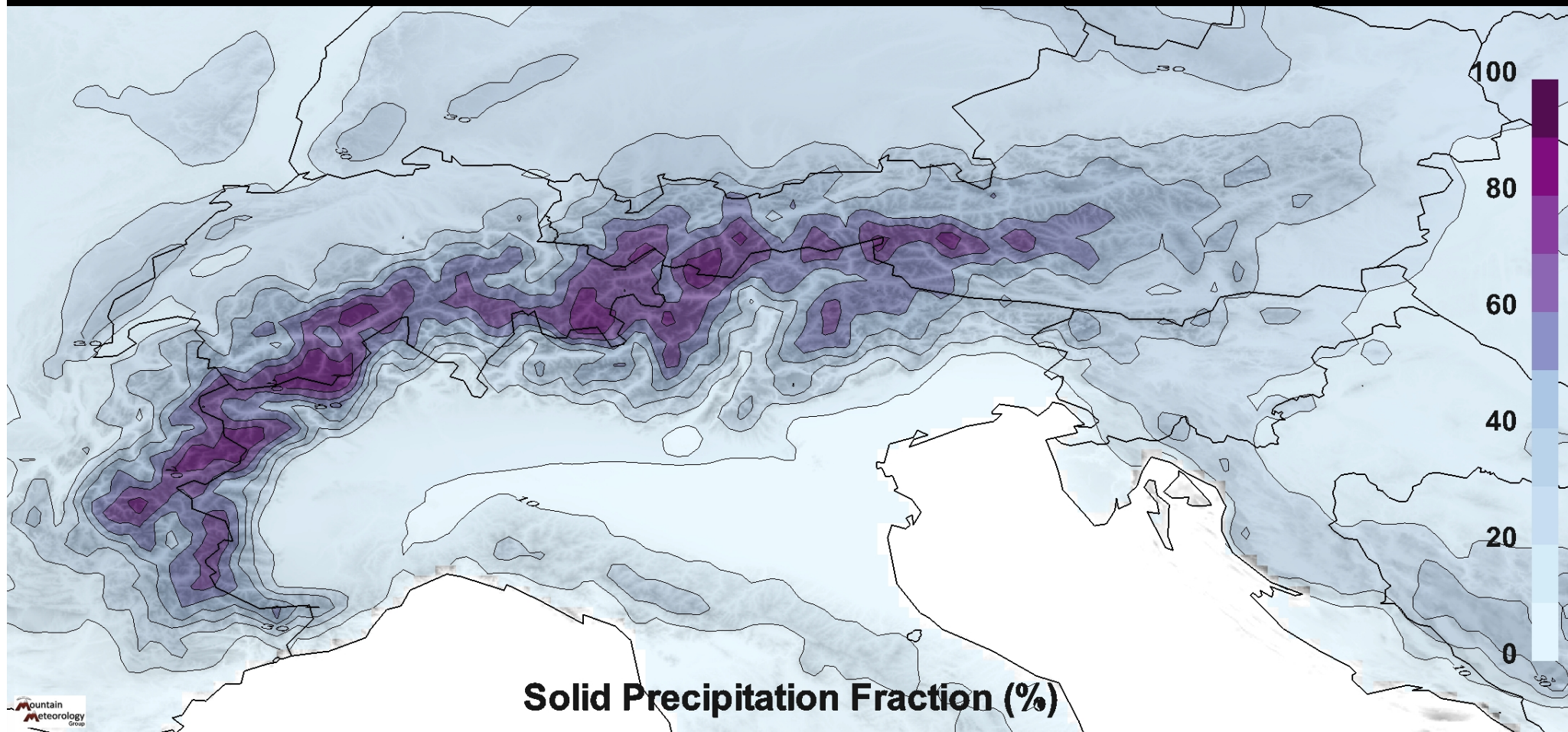
Mountain Solid Precipitation Water Equivalent

Function of precipitation amount and snowfall fraction



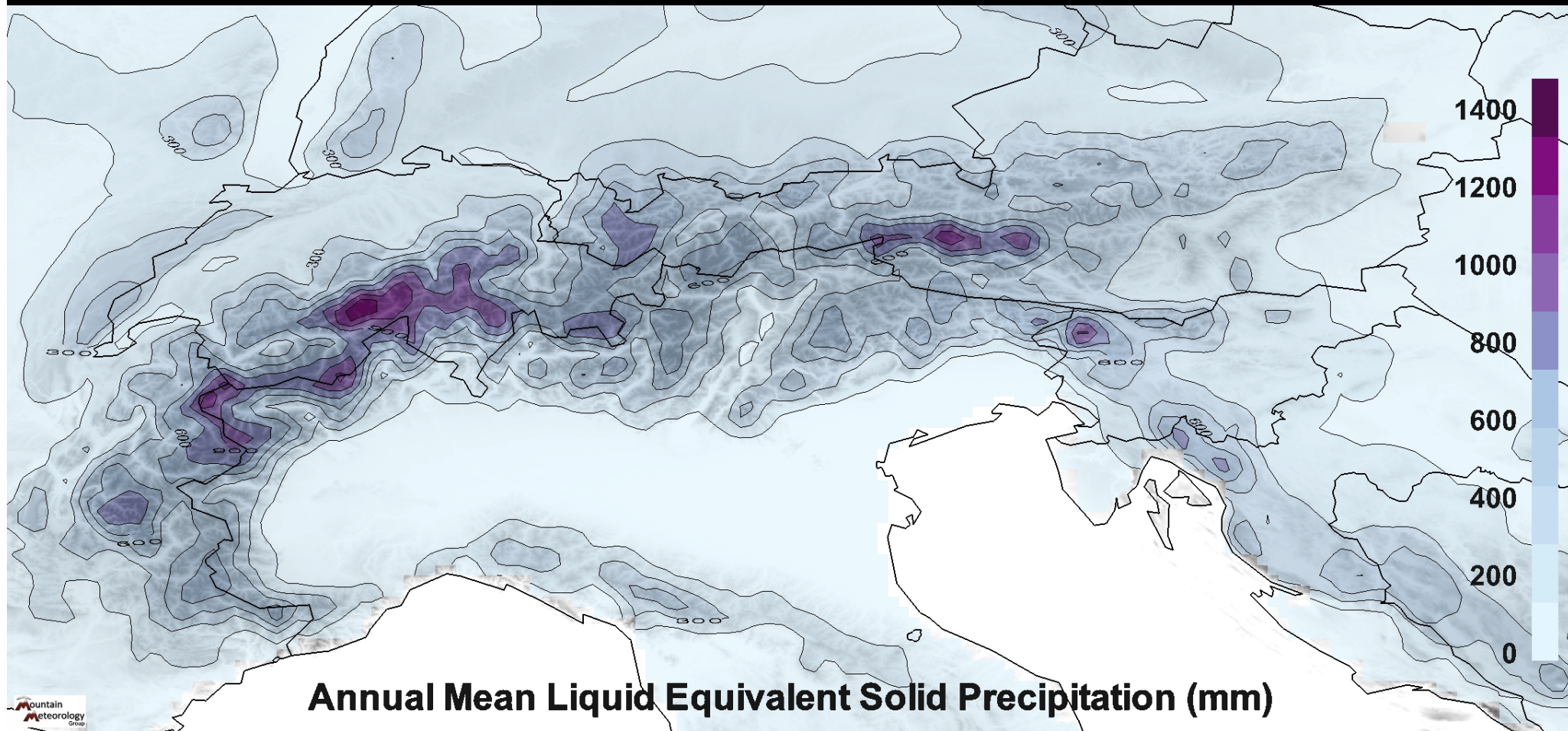
Mountain Solid Precipitation Water Equivalent

Function of precipitation amount and snowfall fraction



Mountain Solid Precipitation Water Equivalent

Function of precipitation amount and snowfall fraction



Snowfall Amount

Function of water equivalent and snow-to-liquid ratio (SLR)



SLR = 20:1



SLR = 8:1

Questions for Discussion

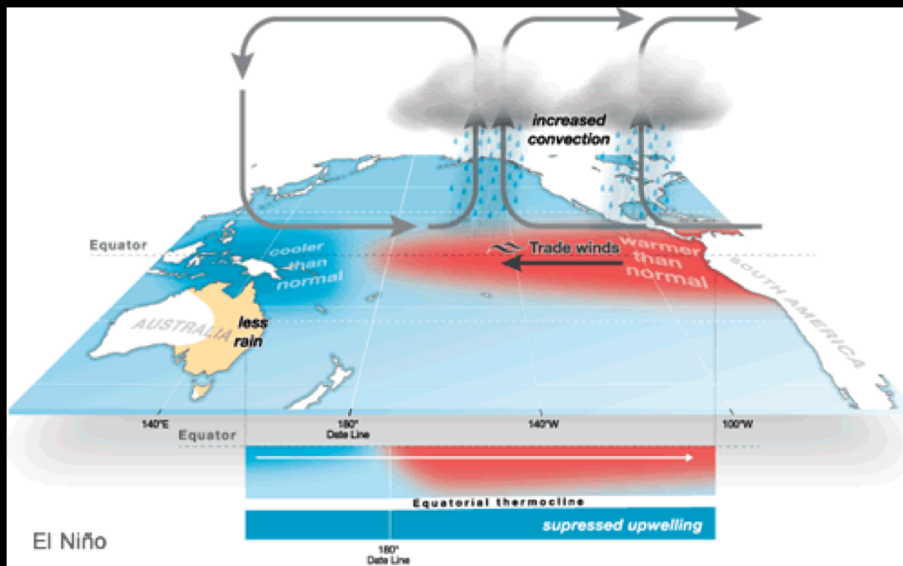
- What is the snowiest regular observing site in the world (snowfall amount)?
- What is the snowiest regular observing site in the US?
- What is the snowiest ski area in the world?
- What is the snowiest ski area in the US?
- Where are the deepest seasonal snowpacks in the world?

Note: The WMO does not recognize world snowfall measurements
due to measurement issues

Variability

ENSO

El Niño/Southern Oscillation (ENSO) – Coupled ocean-atmosphere phenomenon involving variations in wind, SST, clouds, and precipitation in the tropical and subtropical Pacific Ocean with global impacts



El Niño

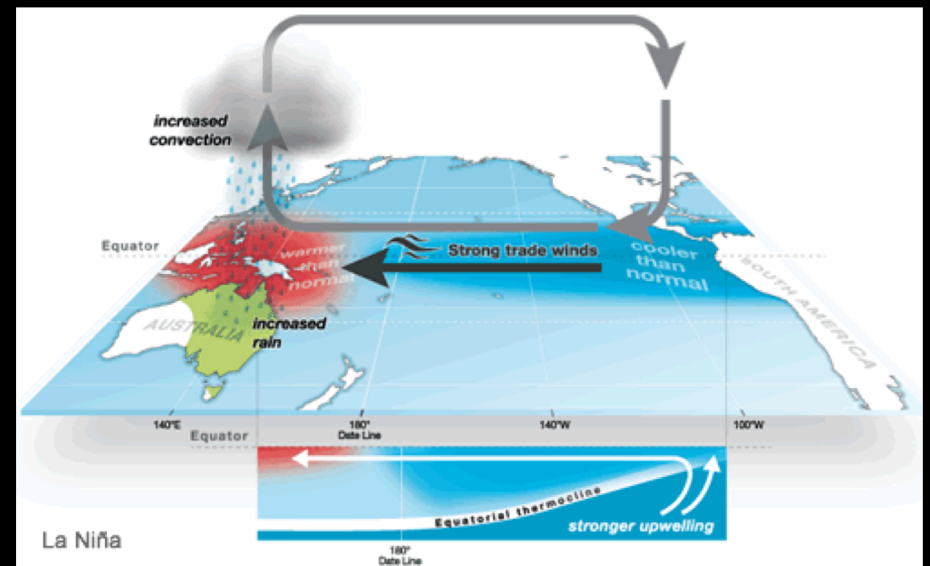
Weaker easterly trades

Weaker upwelling

Higher SSTs central/eastern tropical Pacific

Reduced precip west Pac and MC

Greater precip central and/or eastern Pac



La Niña

Stronger easterly trades

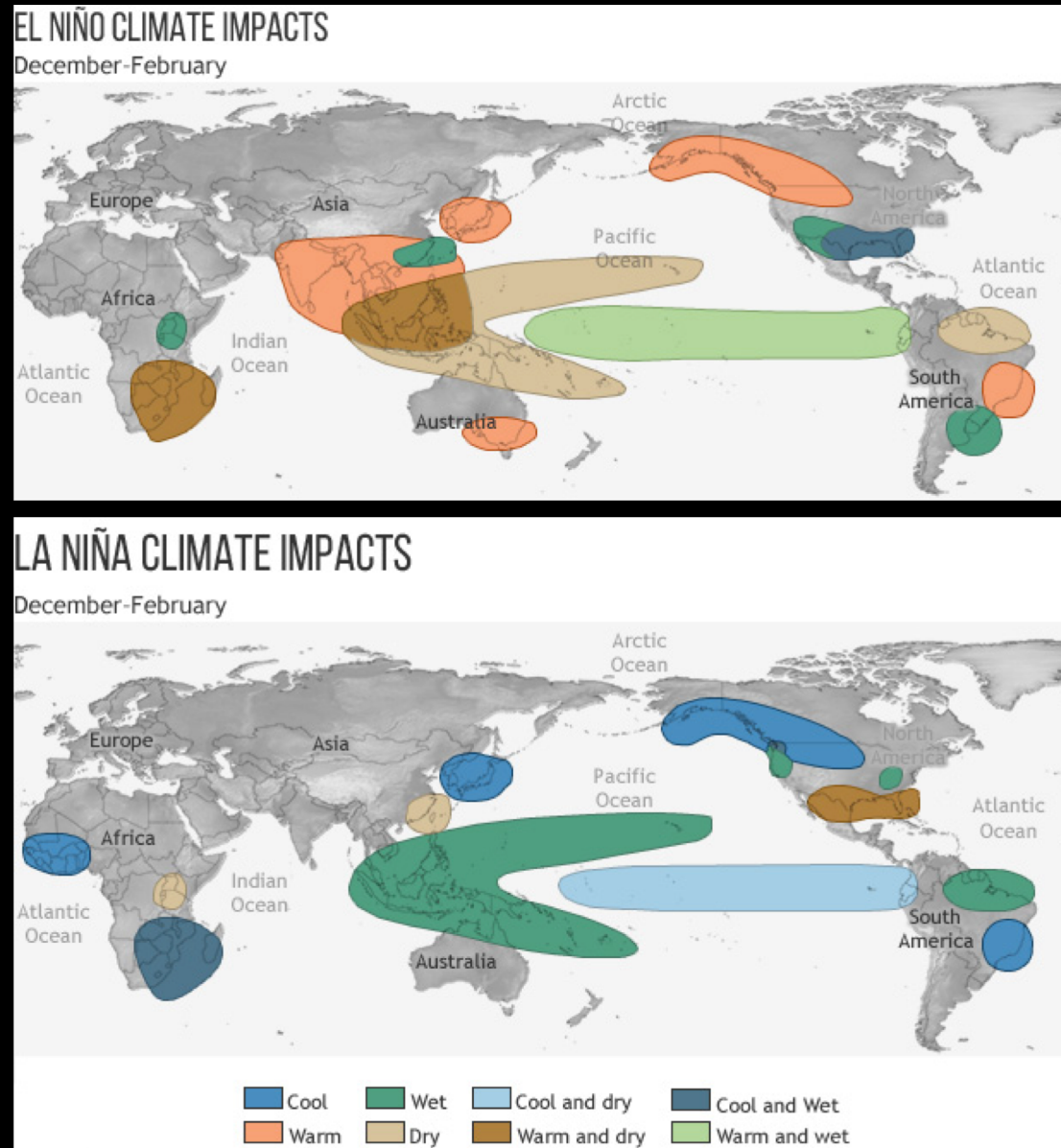
Stronger upwelling

Lower SSTs central/eastern tropical Pacific

Enhanced precip west Pac and MC

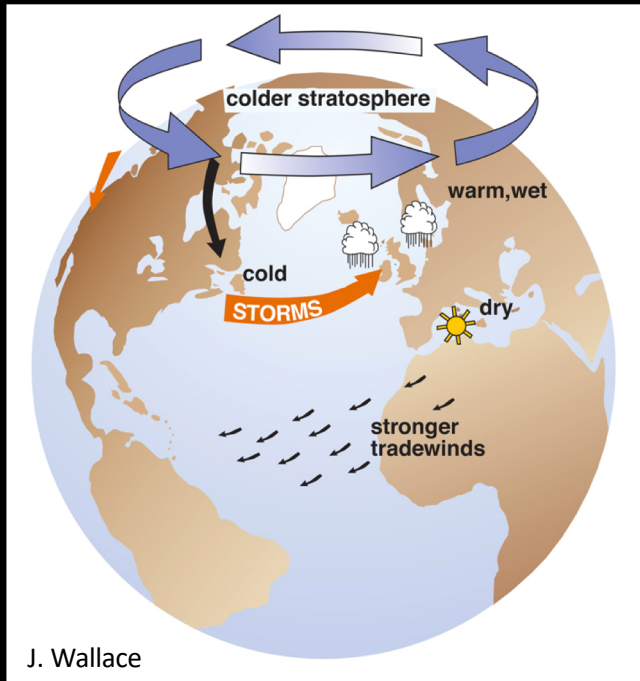
Reduced precip central and/or eastern Pac

ENSO Global Impacts

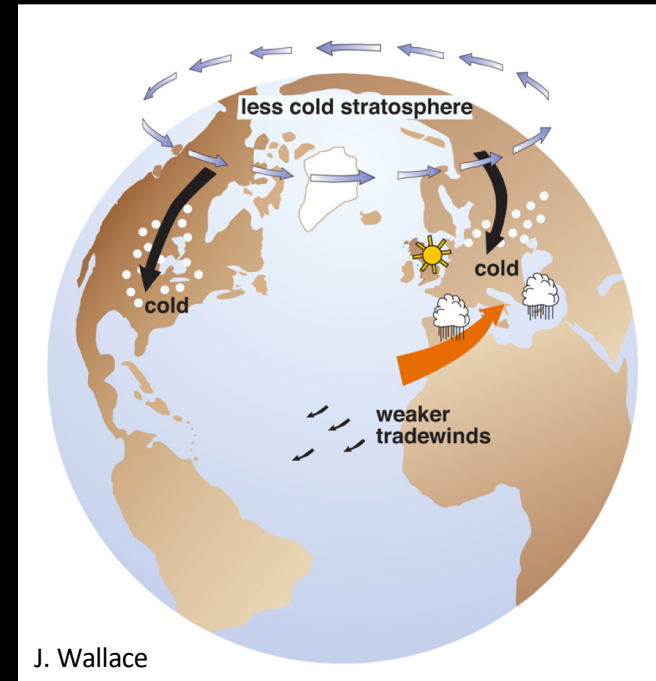


AO

Arctic Oscillation (AO) – Large-scale mode of climate variability involving variations in the strength of the circumpolar flow



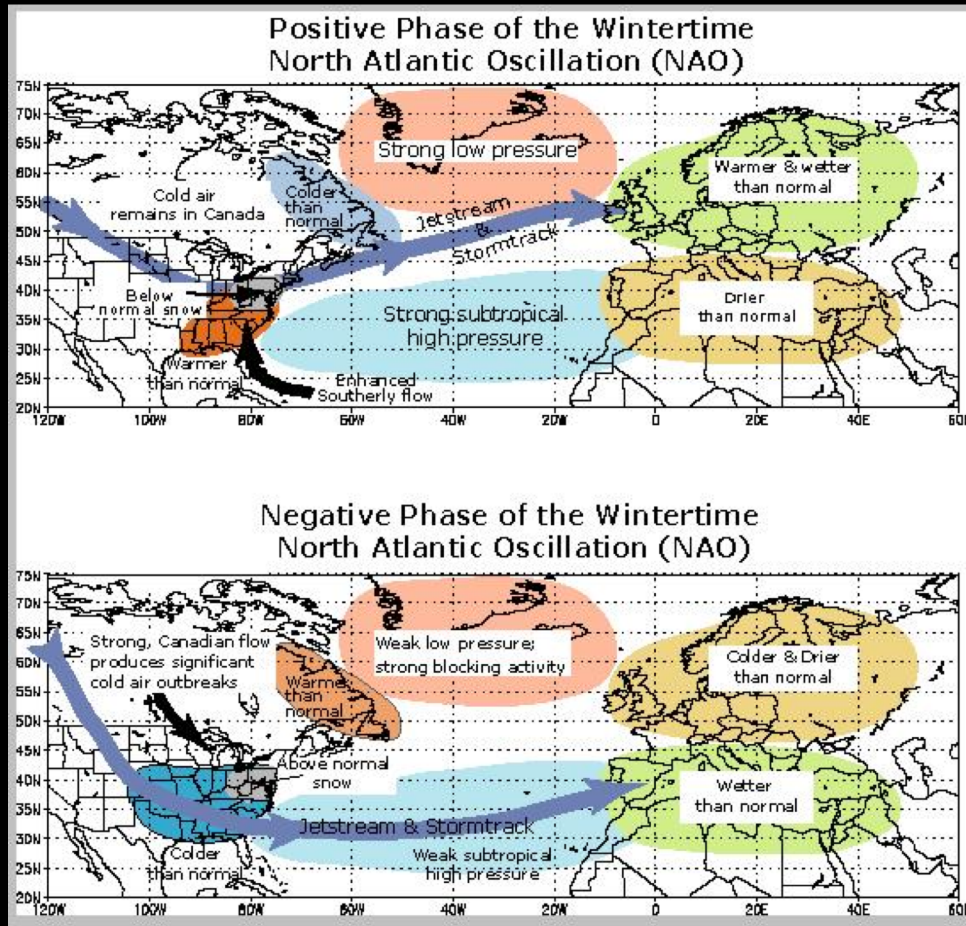
Positive Phase
Strong polar vortex
Cold arctic
More zonal mid-latitude flow
Weaker midlatitude variability



Negative Phase
Weak polar vortex
Warm arctic
Higher amplitude mid-latitude flow
Mid-latitude cold surges

NAO

North Atlantic Oscillation (NAO) – Large-scale mode of climate variability involving variations in the strength of the North Atlantic subtropical high and subpolar low



NCEI

Positive Phase

Strong North Atlantic subpolar low
Strong North Atlantic subtropical high
North Europe Warm and Wet
South Europe Dry

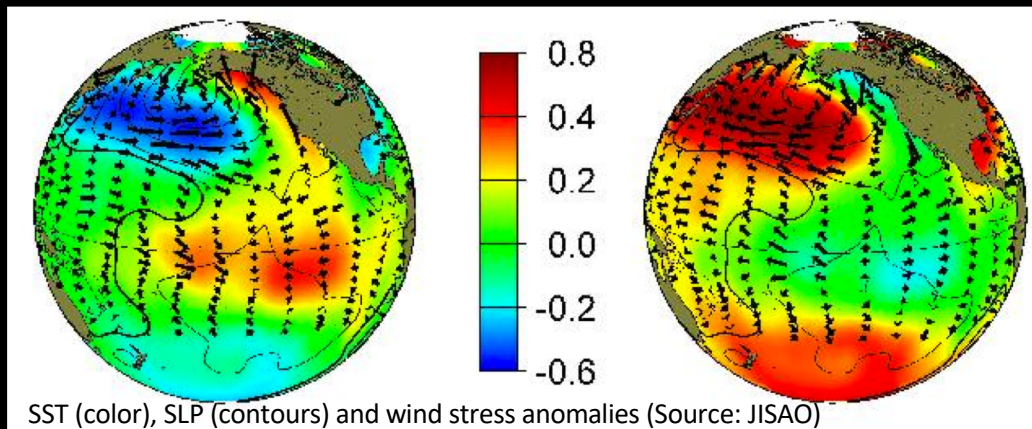
Negative phase

Weak North Atlantic subpolar low
Weak North Atlantic subtropical high
North Europe Cold and Dry
South Europe Wet

PDO and PNA

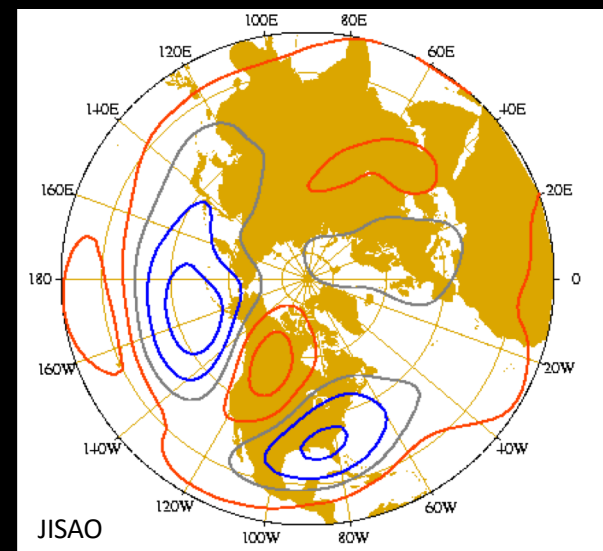
Pacific Decadal Oscillation (PDO) – “ENSO-like”, long-lived mode of North Pacific sea surface temperature variability with impacts on midlatitude circulations and weather that reflects several phenomena, including ENSO

Warm Phase

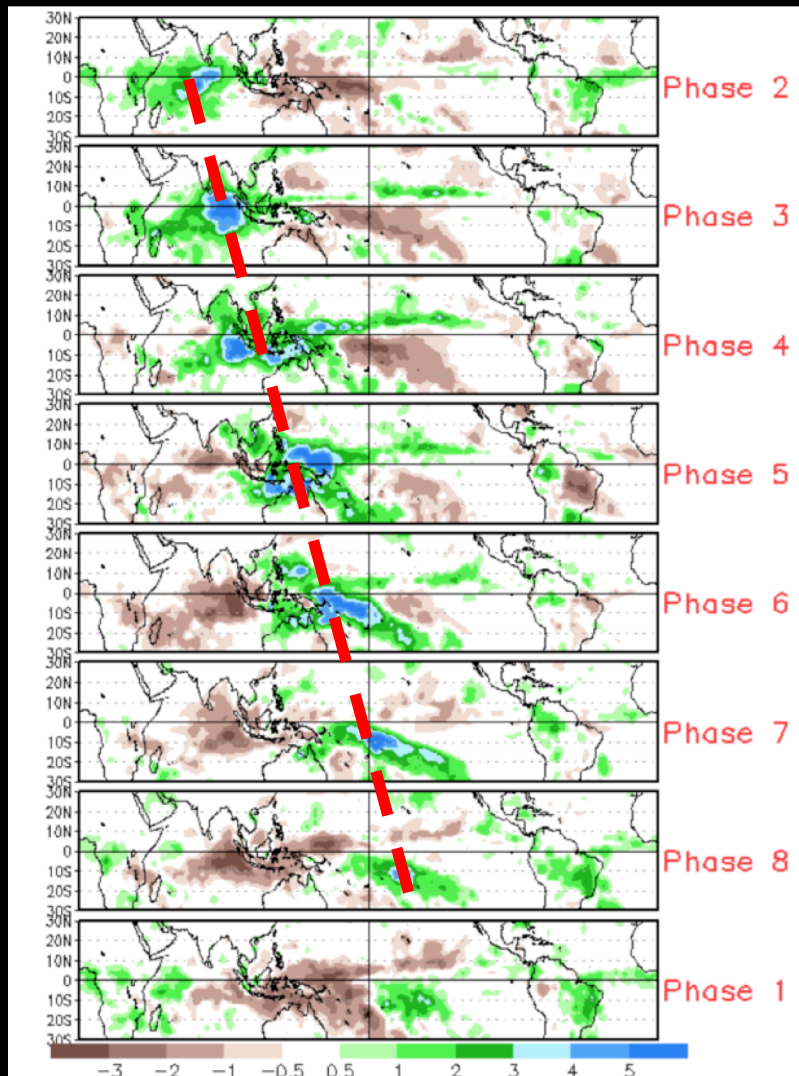


Cool Phase

Pacific-North America Index (PNA) – Large-scale mode of climate variability across the North Pacific and North America involving a “quadrupole” of 500-mb height anomalies



MJO



Precipitation Anomalies

MJO = Madden and Julian Oscillation

Named for Drs. Roland Madden and Paul Julian who identified the phenomenon (Madden and Julian 1971)

Eastward-moving disturbance that modulates tropical clouds and precipitation on seasonal to sub-seasonal time scales

Impacts on extratropics too

Words of Caution

- Multiple physical processes, sometimes involving coupling between Earth system components (e.g., ocean and atmosphere) influence ENSO, AO, NAO, PDO, PNA, etc.
- ENSO, AO, NAO, PDO, PNA, MJO are not independent “actors”
- Indices used to define these phenomena vary
- Lots of use and misuse in research and forecasting

References

- Adhikari, A., C. Liu, and M. S. Kulie, 2018: Global distribution of snow precipitation features and their properties from 3 years of GPM observations. *J. Clim.*, **31**, 3731-3754.
- Adler, R. F., G. Gu, M. Sapiiano, J.-J. Wang, and G. J. Huffman, 2017: Global precipitation: Means, Variations and Trends. *Surv. Geophys.*, **38**, 679-699.
- Australian Government Bureau of Meteorology, 2018: The three phases of the El Niño-Southern Oscillation (ENSO). <http://www.bom.gov.au/climate/enso/history/ln-2010-12/three-phases-of-ENSO.shtml> (Accessed July 27, 2018).
- Frei, C., and C. Schär, 1998: A precipitation climatology of the Alps from high-resolution rain-gauge observations. *Int. J. Climatol.*, **18**, 873-900.
- Geerts, B., and E. Linacre, 2002: Global Precipitation. http://www-das.uwyo.edu/~geerts/cwx/notes/chap10/global_precip.html (Accessed 27 July 2018).
- Gottschalck, J., 2014: What is the MJO, and Why Do We Care? <https://www.climate.gov/news-features/blogs/enso/what-mjo-and-why-do-we-care> (Accessed 27 July 2018).
- Hawcroft, M. K., L. C. Shaffrey, K. I. Hodges, and H. F. Dacre, 2012: How much Northern Hemisphere precipitation is associated with extratropical cyclones? *Geophys. Res. Lett.*, **39**, L24809, doi: 10.1029/2012GL053866.
- Kulie, M. S., L. Milani, N. B. Wood, S. A. Tushaus, R. Bennartz, and T. S. L'Ecuyer, 2016: A shallow cumuliform snowfall census using spaceborne radar. *J. Hydrometeorol.*, **17**, 1261-1279.

References

- Lindsey, R., 2016: Global impacts of El Niño and La Niña. <https://www.climate.gov/news-features/featured-images/global-impacts-el-ni%C3%B1o-and-la-ni%C3%B1a> (Accessed 28 July 2018).
- NCEI, 2018: Teleconnections. <https://www.ncdc.noaa.gov/teleconnections/> (Accessed 28 July 2018).
- Nesbitt, S. W., R. Cifelli, and S. A. Rutledge, 2006: Storm morphology and rainfall characteristics of TRMM precipitation features. *Mon. Wea. Rev.*, **134**, 2702-2721.
- Newman, M., and Coauthors, 2016: The Pacific Decadal Oscillation, Revisited. *J. Clim.*, **29**, 4399-4427.
- Schneider, T., T. Bischoff, and G. H. Haug, 2014: Migrations and dynamics of the intertropical convergence zone. *Nature*, **513**, 45-53. doi: <https://doi.org/10.1038/nature13636>.
- Steenburgh, J., 2014: *Secrets of the Greatest Snow on Earth*. Utah State University Press, 186 pp.
- UCAR 2018: GPCP (Monthly): Global Precipitation Climatology Project. <https://climatedataguide.ucar.edu/climate-data/gpcp-monthly-global-precipitation-climatology-project> (Accessed July 27, 2018).