Global Precipitation Characteristics

VU2: Course Number 707813

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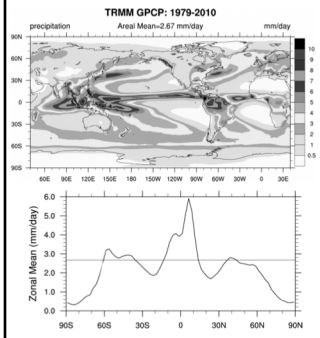
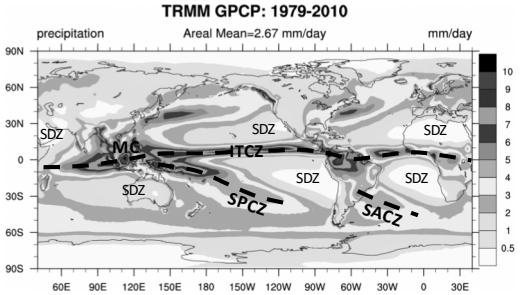
Annual Mean Precipitation



- Discussion
  - What are the primary features of the annual mean global precipitation distribution?
  - Why do these features exist?

UCAR (2018)

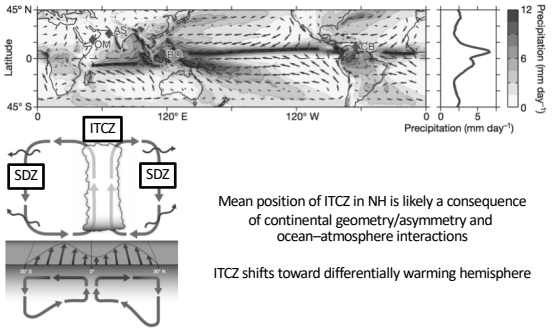
Key Features: Tropics and Subtropics



ITCZ = Intertropical Convergence Zone
MC = Maritime Continent
SDZ = Subtropical Dry Zone
SPCZ = South Pacific Convergence Zone
SACZ = South Atlantic Convergence Zone

UCAR (2018), See also Adler et al. (2017)

ITCZ/SDZ Mechanisms

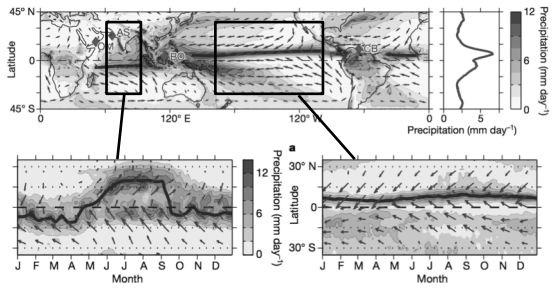


Mean position of ITCZ in NH is likely a consequence of continental geometry/asymmetry and ocean–atmosphere interactions

ITCZ shifts toward differentially warming hemisphere

Schneider et al. (2014)

ITCZ Seasonal Cycle

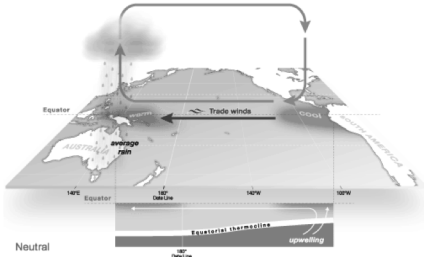


Strong influence of Asian Monsoon

More subtle migration

Schneider et al. (2014)

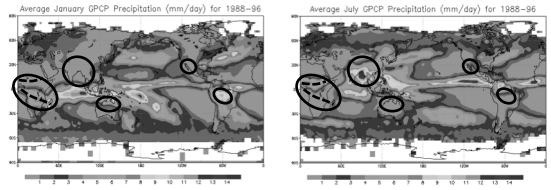
Walker Circulation



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.

Australian Government Bureau of Meteorology (2018)

Monsoons

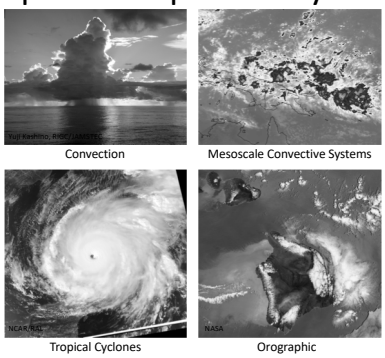


Large-scale circulation change produced by asymmetric heating of land & water areas, leading to a seasonal wind reversal and modulation of precipitation, typically resulting in pronounced dry and wet seasons

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

Geerts and Linacre (2002)

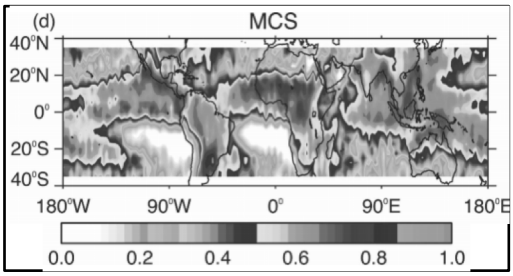
Tropical Precipitation Systems



Convection | Mesoscale Convective Systems

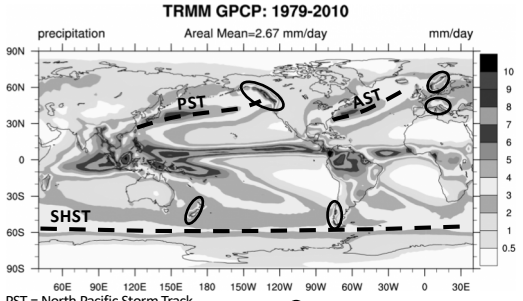
Tropical Cyclones | Orographic

Importance of MCS



Nesbitt et al. (2006)

Key Features: Midlatitudes

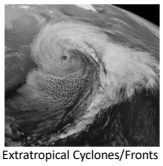


PST = North Pacific Storm Track
AST = North Atlantic Storm Track
SHST = Southern Hemisphere Storm Track

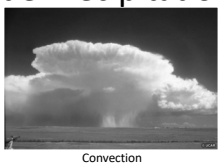
Examples of orographic effects (poorly resolved)

UCAR (2018)

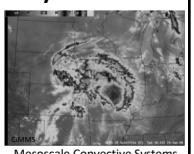
Midlatitude Precipitation Systems



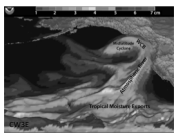
Extratropical Cyclones/Fronts



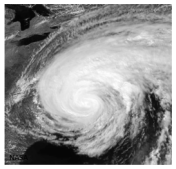
Convection



Mesoscale Convective Systems



Atmospheric Rivers*

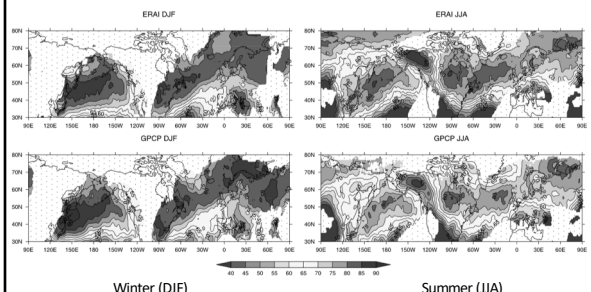


Tropical Cyclones

Orographic Forcing

*Moisture transport feature

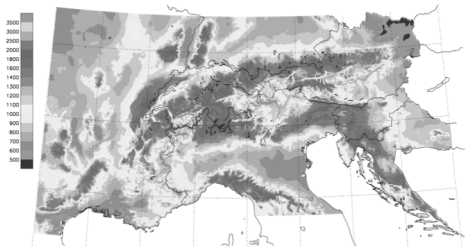
Cyclone Contribution



Winter (DJF) | Summer (JJA)

Hawcroft et al. (2012)

Orographic Effects

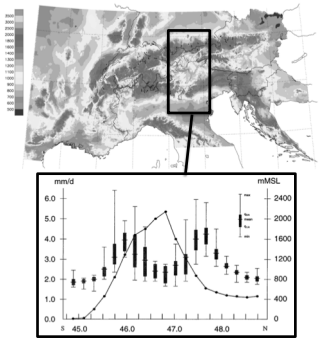


Annual Mean Precipitation (mm)

- 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?

Frei and Schär (1998)

Orographic Effects

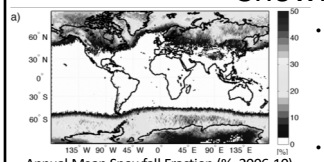


- Strong precipitation—altitude relationship, but also important:
  - Regional moisture availability and transport
  - Storm track and frequency
  - 3-D terrain effects
    - Effects of western hook
    - Concavity near Lago Maggiore
  - Barrier width and upstream water-vapor depletion
    - Tirol vs.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

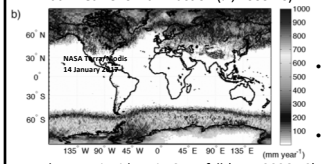
Frei and Schär (1998)

Snow

Snowfall



Annual Mean Snowfall Fraction (%, 2006-10)

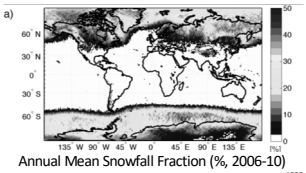


Annual Mean Liquid Equiv. Snowfall (mm, 2006-10)

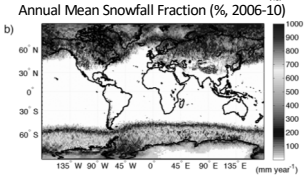
- NH Fraction greatest over Labrador Sea, South Greenland, Greenland Sea, Barents Sea, Sea of Okhotsk, Bearing Sea, Central Asia, Coastal Alaska/British Columbia
- Poleward shift over eastern Pacific and Atlantic, the latter producing lower fractions over western Europe
- NH Snowfall similar, except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

Kulie et al. (2016), se also Adhikari et al. (2018)

Snowfall



Annual Mean Snowfall Fraction (%, 2006-10)



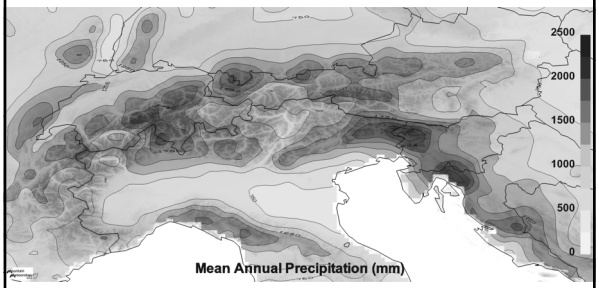
Annual Mean Liquid Equiv. Snowfall (mm, 2006-10)

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

Kulie et al. (2016), se also Adhikari et al. (2018)

Mountain Solid Precipitation Water Equivalent

Function of precipitation amount and snowfall fraction



Data Source: ZAMG, http://www.zamg.ac.at/histalp/dataset/grid/five_min.php

Mountain Solid Precipitation Water Equivalent

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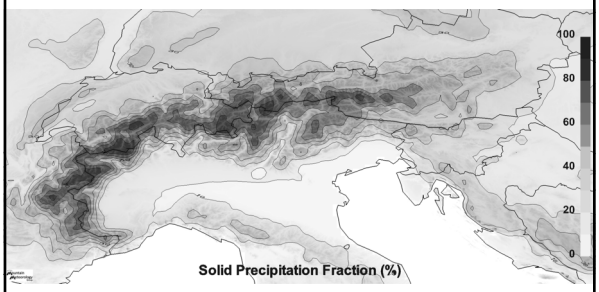

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Mountain Solid Precipitation Water Equivalent

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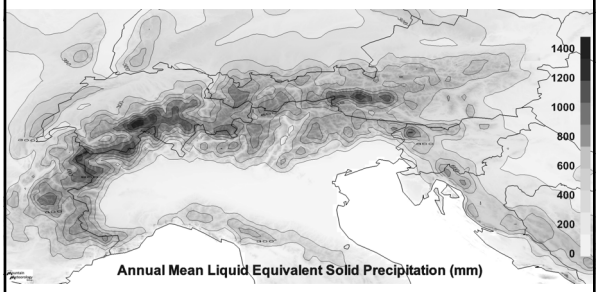


Data Source: ZAMG, http://www.zamg.ac.at/histalp/dataset/grid/five_min.php

Snowfall Amount

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

SLR = 20:1

SLR = 8:1

Steenburgh (2014)

Questions for Discussion

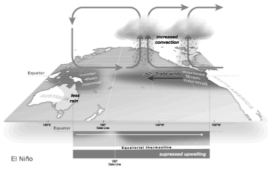
- What is the snowiest regular observing site in the world (snowfall amount)?
- What is the snowiest regular observing site in the Alps?
- What is the snowiest ski area in the world?
- What is the snowiest ski area in the Alps?
- Where are the deepest seasonal snowpacks in the world?

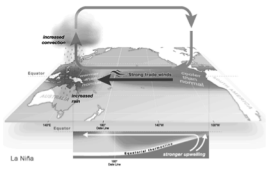
Note: The WMO does not recognize world snowfall measurements due to measurement issues

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



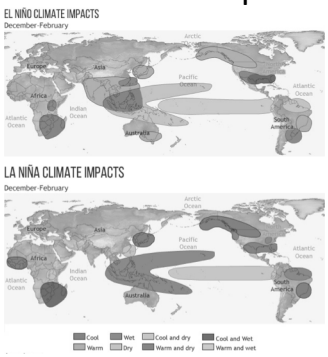


El Niño
Weaker easterly trades
Weaker upwelling
Higher SSTs central/eastern tropical Pacific
Reduced precip west Pac and MC
Greater precip central and/or eastern Pac

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

Australian Government Bureau of Meteorology (2018)

ENSO Global Impacts



Lindsey (2016)

AO

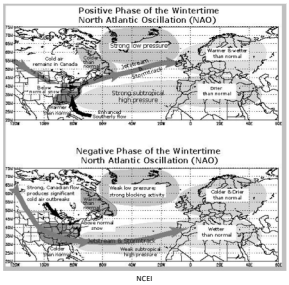
Arctic Oscillation (AO) – Large-scale mode of climate variability involving variations in the strength of the circumpolar flow

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

Negative Phase
Weak polar vortex
Warm arctric
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

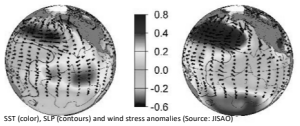
Positive Phase
Strong North Atlantic subpolar low
Strong North Atlantic subtropical high
North Europe Warm and Wet
South Europe Dry

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

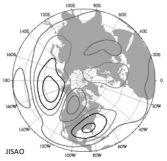
Warm Phase



Cool Phase

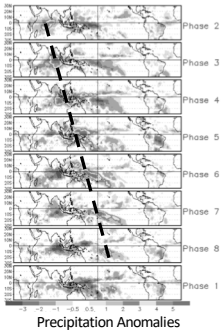
SST (color), SLP (contours) and wind stress anomalies (Source: JISAO)

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



JISAO

MJO



Precipitation Anomalies

Gottschalck (2014)

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

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