Atmospheric Rivers

Introduction

Key Moisture-Related Variables

Learning Objectives

- After this class you should:

  - Be able to identify atmospheric rivers and their potential impacts using atmospheric analyses and numerical forecasts

  - Understand the processes that contribute to AR decay or maintenance during penetration into the interior western U.S.

  - Be able to forecast potentially high-impact AR events including comparisons with past events

Key Moisture-Related Variables

- Integrated water vapor (IWV) – the amount of water vapor in an atmospheric column expressed as the depth of water if that vapor were condensed

  - a.k.a. precipitable water or total precipitable water

  \[ IWV = \frac{1}{g} \int_{0}^{100\,\text{hPa}} q \, dp, \]

- Integrated water vapor transport (IVT) – the total amount of water vapor transport in an atmospheric column

  \[ IVT = \frac{1}{g} \int_{0}^{100\,\text{hPa}} q \mathbf{V} \, dp, \]

IWV & IVT are not equivalent

High IWV, Low IVT
Key Moisture-Related Variables

- IVT decreases poleward, IVT increases

Atmospheric Rivers (ARs)

- Narrow corridors (i.e., filaments) of strong vertically integrated water vapor transport (Newell et al. 1992; Newell and Zhu 1994; Zhu and Newell 1998)
- Often found along the pre-cold-frontal LLJ and may contribute to the moisture-rich portion of the broader, ascending warm conveyor belt (Ralph et al. 2004; Sodemann and Stohl 2013)
- Achieve their high water vapor content through transport from the tropics (i.e., tropical moisture exports (TMEs)) and/or moisture convergence (Knippertz et al. 2013; Cordeira et al. 2013)
- Associated with midlatitude hydrologic extremes

Examples

- November 07, 2006 00-12 UTC
  - SSMI Water Vapor (Thompson algorithm)

- October 13, 2009 12-24 UTC
  - SSMI Water Vapor (Thompson algorithm)

Importance of Pre-Frontal LLJ

Identification

- Satellite based (Ralph et al. 2004)
  - IVT readily available; IVT not readily available
  - Use IVT as an IVT proxy (OK, but not great)
  - ARs identified as contiguous regions of IVT ≥ 20 mm that are ≥ 2000 km in length and ≤ 1000 km in width
- Analysis or NWP based
  - IVT magnitude
    - e.g., contiguous regions of IVT ≥ 250 kg m⁻¹ s⁻¹ ≥ 2000 km long (Rutz and Steenburgh 2012; Rutz et al. 2014)
  - Percentile IVT approaches
    - e.g., seasonally varying 85th percentile IVT (Guan and Waliser 2015)
Global Frequency/Mean AR IVT

(a) AR Frequency and IVT

Global Landfall Distribution

Importance of IVT

Western US Events

Example AR Events

Characteristics of ARs over Western U.S.
Discussion

• Where and why do you think atmospheric rivers are most common
  • Along the US west coast?
  • In the western US interior?

• What processes favor AR decay during penetration into the western US?

• What processes might contribute to AR maintenance or intensification?

AR Characteristics: Western U.S.

• Reanalysis data:
  • ERA-Interim
  • Cool-season (Nov-Apr)
  • Nov 1988–Apr 2011

• AR definition:
  • ≥ 2000-km in length
  • IVT ≥ 250 kg m⁻¹ s⁻¹

• Precip:
  • NOAA/CPC unified daily precip analysis (0.25º)
  • SNOTEL gauge

AR Frequency

AR Duration

Fraction of Cool-Season Precip

Significance of Infrequent ARs
Top Decile 24-h Events

AR Pathways/Sierra Influences

Composite 500-mb height and conditional AR frequencies

AR Pathways/Sierra Influences

Aspect, Exposure, WV Depletion

Lagrangian Perspective

- Launch 950-hPa trajectory from T₁ when AR is present
- Coastally Decaying: Reaches T₂, but not in an AR
- Inland Penetrating: Reaches T₂ in an AR
- Interior Penetrating: Reaches T₃ in an AR

Overview
Overview

Characteristics @ Initiation

The best way to get an interior penetrating AR is to start with a “big” AR at the coast.

Drying Ratio

Integrated Momentum Change

Summary

AR Prediction
Useful Web Sites

- Atmospheric River Portal, Center for Western Weather and Water Extremes
  - http://mead.ucsd.edu/  
  - Many many products - good for IVT identification, intensity, structure, probability, etc.

- NWS/WR Ensemble graphics
  - http://ssd.wrh.noaa.gov/satable/
  - GEFS IVT

- NWS Situational Awareness Table
  - http://ssd.wrh.noaa.gov/naefs/
  - IVT standardized anomalies and return periods

Real-Time Examples & Exploration

Group Activity

- Evaluate the characteristics of a future AR event along the west coast of North America over the next 10 days
  - What is the range of potential intensities and landfall locations?
  - How unusual are the lowest and highest intensities relative to past events?
  - How long might the event persist at a specific location?
  - What sort of forecast, watch, or warning action does the event warrant at the present time?

References