Hirschboeck, K. K., 1991, Hydrology of floods and droughts, climate and floods: U.S. Geological Survey Water Supply Paper 2375, p. 67-88.

I. Introduction

A. U.S. Climatic Regimes
1. humid coastal plains
2. arid desert basins
3. temperate woodlands
4. semiarid grasslands
5. tropical islands
6. subarctic interiors
7. complex microenvironments in mountainscapes

B. Flooding in U.S.
1. climate driven: more rain than drainage basin can store... flooding
2. Types of weather conditions that cause flooding
   a. convective thunderstorms
   b. tropical storms/hurricanes
   c. extratropical cyclones
   d. frontal systems
   e. rapid snowmelt
3. Large-scale climate framework
   a. seasonal availability and large-scale delivery pathways of atm. moisture
   b. seasonal frequency, localtions, and degree of persistence of weather/ppt events
   c. seasonal variation of climate, land surface conditions that effect runoff (antecedent soil moisture, snow cover)

II. Moisture in Atmosphere

A. General
1. Primary source = oceans
   a. evaporation
   b. moisture transport
   c. general atmospheric circulation/diff. heating
2. Ppt process
   a. warm air > moisture capacity
      (1) moist air masses = warm, tropical ocean locals
      (2) cold dry air masses = polar continental

   b. Most precipitable moisture held in lower, warmer parts of the troposphere
      (1) max moisture content in warm oceanic areas
      (2) min moisture content in mountainous regions of western

U.S.

3. Seasonal Flux in U.S.
   a. Summer/July = max. ppt/water vapor on avg.
      (1) concentrated in Gulf states

B. Large-scale, moisture delivery pathways
   1. General
      a. Moisture pathways in air determined seasonally by direction of surface winds

         (1) January
            (a) Nw terly jetstream dips down into south central states
            (b) moisture delivery from Gulf and southern Atlantic in southern states; delivery to ne along appalachians (winter storms in ne)

         (2) April

            (a) Moisture from Gulf/Atlantic pushes northward in east, se
            (b) moisture from Pacific in West

         (3) July: heavy rainfall month
            (a) Pacific to west coast
            (b) Atlantic to Gulf on east U.S./central U.S.

         (4) October

            (a) Gulf air shifts back to south as jet stream from NW begins to shift southward

      b. Air Pathways shift seasonally
         (1) determine montly ppt patterns
         (2) control tendency for regional flooding
            (a) via intense/prolonged storms

      c. Air mass source of moisture (regionally)
         (1) Pacific Ocean

            (a) seasonally shifts with seasons, from 60 to 35 N lat.
            (b) westerly winds, moisture to west coast
            (c) stabilizing effect to prevent extensive moisture from Pacific...
               i) North Pacific anticyclone (high press)

ii) cold California current
a) especially in summer, with dry area along west coast

(d) Orographic effect with Cascades/Sierras

(e) Winter chinooks: modified dry Pacific air passes into western interior, with warm dry air, causing snow melt

(2) Atlantic Ocean-Gulf of Mexico

(a) dominant process of ppt delivery in east and central states

(b) Summer months
i) subtropical high pressure of N. Atlantic shifts north and west allowing maritime tropical air masses to move onto continent
ii) spring and summer rain in central/east U.S.

(c) Gulf air to southwest occasionally

(3) Arctic Region

(a) cold, relatively dry arctic air pushes south into U.S.
i) frontal system dynamics
a) cold air on bottom
b) collision with warm moisture laiden air on top
c) unstable, cyclonic frontal systems

III. Atmospheric Processes that Release Moisture

A. General

1. Process of moisture release from atmosphere

a. controlled by uplift mechanisms that cool and condense layers of moist air leading to
(1) clouds development
(2) ppt
(3) possible flooding

b. Air Uplift Mechanisms
(1) Thermal convection of moist, unstable air
(a) limited spatial distribution
(b) high intensity storms
(2) large-scale frontal convergence
(a) extensive spatial distribution
(b) low to mod. intensity
(3) forced vertical motions via perterbations in upper

atmosphere
(a) local or widespread effects
(4) orographic lifting
(a) local or widespread effects depending on topographic extent and configuration

B. Convectional Processes

1. General
a. several mechanisms stimulated by convection

(1) air mass homogeneous throughout
(a) warm, wet
b. may act simultaneous with frontal or orographic conditions
c. process: thunderheads, cumulonimbus storm clouds
(1) high intensity, short duration storms
(2) flash flooding
(3) localized occurrence

2. Thunderstorm Activity
a. Character
(1) flashy, intense pppt
(2) regional variation in occurrence in U.S.
(a) Fla/ Gulf, highest occurrence in US
(3) warm, moist unstable air
(4) may form locally, or in concert with frontal systems

b. Flood generation
(1) usually storms don't produce enough ppt for flooding
(2) multicell clusters of prolongued duration can delivery hugh amts of ppt/flooding though

3. Mesoscale Convective Complexes and Systems

a. "MCC's" and MCS's

(1) huge, multiple celled, highly organized thunderstorm complexes
(2) can last for prolongued periods of time: 6-36 hours
(3) multiple, supercelled T storms
(a) tornadoes, lightening, locally intense ppt
(4) Common in spring and summer in Great Plains and Midwest
(5) e.g. Big Thompson Canyon flood in CO in 1972

4. Tropical Cyclones

a. largest atmospheric features produced by convective processes
(1) tropical low press. systems
(2) diamters = 60-600 miles
(3) sources: wester N.Atlantic, Gulf, Caribbean
(4) critical temps of sea-surface: >79 F
(5) late summer, early fall

b. Flood history
(1) commonly affect Eastern US
(2) have resulted in largest floods of record
(a) common to generate > 100 yr floods

(3) Tropical cyclones and flood processes
(a) coastal area storm surges
(b) hits land delivering much moisture

C. Large-Scale Atmospheric Convergence

1. General
a. collision of heterogeneous air masses
(1) ppt of > geographic extent
(2) long duration
(3) < intensity

(4) localized instability
(a) secondary convective storms
i) T storms near front line

b. Regional/U.S.
(1) cold polar air masses collide with warm tropical air masses
(a) shifts seasonally

2. Extratropical Cyclones and Their Associated Fronts

a. Cyclone tracks as westerlies across U.S./Midwest
(1) winter: shift with southerly dip
(2) summer: maintained in northern lat.

b. Variations
(1) Great Lakes: local lake effect, snow squalls
(2) most active in spring

3. Precipitation-Enhancing, Upper Atmospheric Air Patterns

a. Modification to cyclonic systems

(1) jetstreams in upper atmosphere
(a) U.S. jetstream: west to east
(b) sinuous air flow patterns
(c) variability can control lower atmosphere cyclones, moving or stalling systems

D. Orographic Lifting

1. Process and Products
a. lifting of air masses over topography, mountains
(1) cooling air, moisture release
(2) wet cloudy windward slopes
(3) dry lee slopes

2. Regional / US

a. moderate orographic effect with Gulf/Atlantic air over Appalachians
b. west: Oregon, WA, Calif.
c. local flash flooding
(1) > flood prone areas, as soil moisture maintained at or near saturation
(2) additional processes can easily max. out system

IV. Antecedent Land-Surface Conditions

A. General
1. Ppt may not cause flooding, also controlled by ground conditions
a. urban areas, impervious mateiral
b. vegetative cover/ evapotransp.
c. soil moisture
d. geology, soils, permeability
e. snow cover, frozen ground

B. Soil Moisture

1. soil mosture content
a. pre-existing soil moisture
b. seasonal: evapotranspiration factor
(1) summer > ET, < flood potential, < soil moisture
(2) soil moisture in general > late winter, spring

c. soil moisture determines storage ability of hillslopes

C. Snow Cover, Frozen Ground and Snowmelt

1. Frozen ground = impervious surface; > flood potential
   a. < temps, > frozen ground
   b. snow pack conditions, thickness
   c. largest snowfall recorded, Mt. Rainier 1971-72: 1120 inches (wow!!!)
   d. nice maps of average duration of frozen ground in US
2. spring rain on snow, + snow melt = flood

V. Mixed Populations of Floods

A. Magnitude-frequency analysis

VI. National Overview of Flooding

A. seasonal / regional controls
B. meteorological conditions important
C. tabulated summary of known flood tendencies in US and their cause
   1. a nice table/summary of floods of record!!

VII. Conclusions
A. summary of material above
B. emphasizes the importance of understanding climate/meteorological conditions in analyzing flood tendencies in US