HOMOGENIZING THE RUSSIAN FEDERATION CLIMATE RECORD BY ADJUSTING RADIOSONDE TEMPERATURES AND DEW POINTS FOR INSTRUMENT CHANGES

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Motivation and goals

- Climate trends using archived upper air data are not correct
  - •• All long-period stations have changed radiosonde types
  - •• Newer instruments generally are more sensitive and better protected from radiation errors
  - •• Global average effect is false cooling and drying trend
- Data adjustments are needed to correct instrument biases
  - •• First need is complete metadata listing station locations, elevations, instruments, and dates of changes
  - •• Second need is adjustments to correct instrument biases
  - •• Proposed “histogram matching” homogenization

Summary

- 1. Status of current and historical data and metadata for the global upper air network
- 2. Development of complete station and instrument metadata using time series of sensitive variables
- 3. The Russian Federation upper air network
- 4. Radiosonde models used in the Russian Federation since 1973
- 5. Summarized characteristics of radiosonde types
- 6. Proposed “histogram matching” homogenization method

1. Status of global upper air data and metadata

- Current and recent data through 4 January 2009
  - •• Operational upper air data from Unidata
  - •• NCAR Data Set 351.0 from NCEP has about 2-week lag
  - •• Some stations are in one data set and not in the other
  - •• Total 1147 “valid” stations in 2007 and 2008 including land stations, ships, dropsondes, field sites
- Partial list of historical data sets
  - •• NCAR Data Set 353.4 from NCEP, 1973 to Feb 2007
  - •• Integrated Global Radiosonde Archive (IGRA)
  - •• Data rescue, field programs, ozonesondes, etc.
  - •• Could include atmospheric profilers, rocketsondes, etc.

1. Status of global upper air data and metadata

- Current and recent metadata
  - •• Upper air and surface station catalogs from WMO, countries, agencies, forecast centers
  - •• Instrument codes in 31313 group now reported in almost all soundings except from China
  - •• Manufacturer and agency information about instruments
- Partial list of historical metadata
  - •• IGRA metadata based on Gaffen (1996): Only a few new stations or other updates more recent than 1993
  - •• Journals, field program reports, actual radiosondes
- Problems: Delayed reporting or updating of changes, little emphasis on accurate station locations and elevations

2. Developing complete station and instrument metadata

- First, TAMU metadata file combines many sources
  - •• Start with IGRA metadata file and Gaffen (1996, 1993)
  - •• References lead to many additional sources
  - •• Over 5000 upper air stations now partially documented
  - •• Over 1100 radiosonde types, 1400 other instruments
- Second, develop complete metadata from archived data
  - •• Examine station time series
  - •• Consistent characteristics of distinct instrument types
  - •• Discontinuities coincide with instrument changes
  - •• Problem: In variables of climate interest, natural variations are often larger than instrument discontinuities

2. Developing complete station and instrument metadata

- Focus on variables that amplify instrument differences
  - Sensitive variables have little or no climate interest
    - Mostly moisture-related
    - Reported dew point depressions at various levels
    - Coldest temperature with reported dew point
    - Also number of reported temperature or wind levels
  - Develop characteristics from well-documented stations
  - Same characteristics without documentation allow inference of specific instrument types and changes
- Many stations have very complex histories
  - Two or more instrument types used in same period
  - Frequent alternations may be exactly identifiable

2. Developing complete station and instrument metadata

- Validation of station locations
  - •• Limited validation: Consistency of sources, data values appropriate for location
  - •• Online satellite photos locate many stations exactly
  - •• Many small discrepancies, few large errors in catalogs
  - •• Many catalog changes are corrections, not actual moves
- Validation of station elevations
  - •• Hydrostatic calculations give very accurate averages
    - ◆ Change of 5 meters probably exactly detectable
    - ◆ Change of 1 m usually detectable in a few weeks
  - •• Catalog elevations often disagree with computed values
- Difficult to confirm locations associated with elevations

3. The Russian Federation upper air network

- Historical stations since 1973
  - •• 204 former USSR, 6 Antarctic, 33 ships, 6 ice islands
  - •• Stations using Russian instruments in other areas of world not specifically considered here
  - •• Many stations closed for short or long periods in last 15 years, almost all have short gap around 1999
- Recent stations in 2007 to early 2009
  - •• 127 former USSR, 2 Antarctic
  - •• 7 stations resumed soundings after > 4 year gap in 2007 or 2008, 1 new station in late 2006
  - •• 1 new ship in 2008

4. Radiosondes used in the Russian Federation

- Instruments from 1973 to mid-1990s
  - •• Documented by Zaitseva (1993, BAMS) with specimens at NCDC
  - •• All tracked by radiotheodolite or radar with ranging
  - •• A-22 series (introduced 1957): Bimetal thermometer, goldbeaters' skin hygrometer
  - •• RKZ (1959), MARS (1983), MRZ (1987) series: All use same thermistor, goldbeater's skin hygrometer
    - ◆ Computed pressure starting early 1960s
    - ◆ Same sensors imply few data bias changes

4. Radiosondes used in the Russian Federation

- Instruments since mid-1990s
  - •• Many stations still use MRZ, few use MARS in 2009
  - •• Most stations report 31313 codes since late 1990s
  - •• 22 different 5-digit instrument codes in 2007 to 2009
  - •• Some stations used 5 to 7 instrument types in 2007-09
- Several new instruments, little documentation found
  - •• RF95: Vaisala sensors, not widely used due to cost
  - •• MRZ-3AM: Inferred from dryness, later confirmed
  - •• BAR or MRZ*: “MRZ clone” first reported Feb 2007
  - •• RZM-2 “MRZ clone” also first reported Feb 2007
  - •• 5 stations outside Russia report Vaisala RS90 or RS92 in 2007 to early 2009

5. Examples of characteristics of radiosonde types

- Consistent characteristics seen with or without metadata
- Different models in same series usually indistinguishable
- A-22 series (A-22-III, A-22-IV)
  - •• No significant wind levels due to lack of automation
  - •• Dew point depression (DPD) reported to top of sounding
  - •• Moist, 300 hPa DPD average < 700 hPa DPD
- MARS series (MARS-2-1, MARS-2-2)
  - •• DPD reported to temperature around -40, still moist
- RKZ series (RKZ-1, RKZ-2, RKZ-5) and MRZ-3A
  - •• Some significant wind levels reported
  - •• DPD similar to A-22 due to same humidity sensor
  - •• Most stations use MARS in between RKZ and MRZ

5. Examples of characteristics of radiosonde types

- RF95: Quite dry due to Vaisala sensors
- MRZ-3A versus MRZ-3AM
  - •• Same 31313 codes
  - •• Some MRZ stations noticeably drier starting late 1990s
  - •• Initially inferred existence of 2 MRZ varieties
  - •• Recent documentation confirms MRZ-3AM with Russian capacitive humidity sensor, not as dry as Vaisala
- "MRZ clones" (BAR or MRZ* versus RZM-2)
  - •• BAR or MRZ*: Moist, similar to MRZ-3A, almost as widely used by late 2008 as MRZ-3A
  - •• RZM-2: Moderately dry, similar to MRZ-3AM, used in moderate quantities by late 2008

6. Proposed "histogram matching" homogenization

- Fundamental approach: Adjustments for distinct instrument types to a common "reference instrument"
- Step 1: Choose a "reference," probably an average of certain VIZ / Sippican and Vaisala models
- Step 2: Identify short "chain" of transitions from each distinct model to a "reference"
  - •• Transition from one type to another, in either direction
  - •• Frequent alternations between 2 types
  - •• Simultaneous use of each model at 2 nearby stations
  - •• Important: Match circumstances of use of each model
  - •• Problem: If transition is in same direction at all stations, adjustment might remove some of the natural trend

6. Proposed "histogram matching" homogenization

- Step 3: Develop and apply temperature adjustments for each distinct instrument
  - •• "Histogram" is cumulative probability distribution of temperature values
  - •• Adjustment is temperature change to transform same percentile of one instrument to be equivalent to other type
  - •• Stratify histograms by pressure layer and sun angle
- Step 4: Develop and apply dew point adjustments
  - •• Same method to develop and apply dew point adjustments after temperature adjustments are applied
  - •• Stratify histograms by pressure, sun angle, temperature
- Note: Repeat steps if discontinuity is uncorrected

Conclusions

- There is a very large amount of upper air station and instrument metadata which needs to be consolidated into a single metadata source
- Examining station time series of sensitive variables can
  - •• Validate available metadata
  - •• Correct erroneous metadata, and
  - •• Infer missing instrument and transition metadata
- While this project is experimenting with a different approach to make instrument adjustments, results of other methods should be more reliable with better metadata