Estimating the water and energy budgets across northern Eurasia

Tara J. Troy, Eric F. Wood, and Justin Sheffield
Princeton University

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Increasing Eurasian Discharge

Peterson et al. (2002)

slope = 2.0 ± 0.7 km³/y per year
p = 0.005
Evidence of change in cryosphere

March - April NH snow-covered area

Active Layer Depth

Seasonal Frozen Depth

IPCC WG1, Chapter 4
Data & Model
Data Products

- Precipitation (P)
  - Gauge observations
  - ERA40 & ERA interim
  - PGF (Sheffield et al, 2006)
- Terrestrial Storage Changes
  - GRACE (RS)
  - VIC model
  - ERA 40 & interim

- Evaporation (E)
  - P-Q (gauges)
  - VIC model
  - ISCCP/PM (RS)
  - SEBS model (RS)
  - ERA40 & interim
    (direct & inferred)

- Discharge (Q)
  - Gauge observations
  - VIC model
  - ERA40 & ERA interim

RS=Remote Sensing
Data Products (Cont’d)

- Moisture Convergence
  - ERA40 & interim

- Atmospheric Storage Changes
  - ERA40 & interim

- Radiative Fluxes
  - PGF (Sheffield et al, 2006)
  - ERA40 & interim
  - VIC model
  - ISCCP (RS)
  - SRB (RS)

RS=Remote Sensing
Princeton Global Meteorological Forcing Dataset (PGF)

Observations
Generally low temporal/high spatial resolution

SRB 1985-2000, 3hr, 1.0deg
GPCP 1997-, Daily, 1.0deg

SRB 1985-2000, 3hr, 1.0deg
Lw, Sw

W
P

Precipitation
SW Radiation

P

Temperature

W

Reanalysis
High temporal/low spatial resolution

Bias Correct and Downscale
- corrected rain day statistics, gauge undercatch
- removal of biases in monthly P, T, DTR, SW, LW
- removal of spurious trends in SW
- adjustment for elevation effects
- downscale in time and space

Global Forcing Dataset
High temporal/high spatial resolution, bias corrected, trend corrected, etc...

CRU 1901-2006, Monthly, 0.5deg P, T, Tmin, Tmax, Cld

Sheffield et al., 2006
VIC Hydrologic model

- Large, “flat” grid cells (e.g. 100x100 km)
- Land cover “tiles” (vegetation types)
- On hourly to 3-hrly time step, simulate:
  - Soil moisture/water table
  - Snow pack
  - Runoff
  - Lake/surface water
  - Evapotranspiration/Latent heat flux
  - Soil temperature
  - Sensible heat flux
  - Ground heat flux
Model Validation
Snow: Monthly SWE Climatology

160
180
200

Yenisei Mean SWE [mm]
Obs
VIC

60
70
80

Lena Mean SWE [mm]
Obs
VIC

Ob  Yenisei Lena

Severnaya Dvina

Ural

Amur

Northern Dvina Mean SWE [mm]
Obs
VIC

Ural Mean SWE [mm]
Obs
VIC

Amur Mean SWE [mm]
Obs
VIC

Ob  Yenisei Lena

Severnaya Dvina

Ural

Amur
Seasonal Cycle of Discharge

Amur

Yenisei

Lena

Normalized Anomalies of Annual Discharge
Water Budgets
Conservation of Mass

• Atmospheric Water Budget:

\[
\frac{\partial w}{\partial t} = -\nabla \cdot qv - P + E
\]

Inferred ET calculated by rearranging this equation.

• Terrestrial Water Budget:

\[
\frac{\partial s}{\partial t} = P - E - Q
\]

Storage term includes storage in soil, lakes, and snowpack.
Annual WB Estimates

Lena River

Amur River

Atmospheric Divergence

Change in Atm. Moisture Storage

Change in Terrestrial Storage

Legend:
- Obs
- VIC
- ERA40
- ERA40 Inferred
- ERAint
- ISCCP-PM
- SEBS
- GRACE
Monthly Estimates of ET

- **Amur**
- **Aral**
- **Ob**
- **Lena**
- **Volga**
- **Yeni**

| VIC | ERA40 | ERA40 Inferred | ERAint | ISCCP-PM | SEBS |
Inferred Estimates of Annual Q

\[ R = -\nabla \cdot qv = P - E \]

- Black dots: Gauge measurements of discharge
- Circles: Runoff fields
- X’s: P-E
- +’s: Atmospheric Convergence
Inferred Estimates of Annual Q

\[ R = -\nabla \cdot qv = P - E \]

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Map showing the locations of Amur, Ob, Yenisei, Lena, and Volga.
Estimates of Radiation
Downward Shortwave Radiation

- RMSE averaged across stations for data whenever available
- NCEP has large overestimation of DSW
Radiation Evaluation
Conclusions

• Reanalysis, modeling, and remote sensing datasets provide multiple estimates of the water & energy budget components, but they also highlight the uncertainty that still exists in these estimates.

• Inferring discharge from other components of the water budgets provides a measure of the errors in estimates of the components. Storage changes from snow seem to cause the largest errors.

• Significant uncertainty exists in estimates of radiative fluxes across the region.
Trends in Cold Season Low Flows

- Cold-season low flows are increasing across Northern Eurasia at large time scales (60 years) with conflicting results over smaller trend periods.
- Consistent trends between natural and managed basins
- Ob River shows pronounced increases in low flows

Rennermalm, Wood, and Troy (in review)
Anomalies in Maximum Monthly SWE

Ob

Severnaya Dvina

Yenisei

Ural

Lena

Amur
Soil Temperature

Bias in Annual Temperature

Annual Temperature Comparison