Retrospective and Realtime Snow Analysis of the National Water Model Using In-Situ and Remotely Sensed Observations

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National Water Model Description: WRF-Hydro Modeling System

Meteorological Forcing Engine

Geospatial Pre-Processing

NoahMP LSM

Terrain Routing Module

NHDPlus Catchment Aggregation

Channel & Reservoir Routing Modules

Model Evaluation & Calibration

HydroInspector Web-Mapping Service

MODEL PHYSICS

Geospatial Pre-Processing

MODEL PHYSICS

HydroInspector Web-Mapping Service
National Water Model (NWM)

- NWM implemented in August 2016 and upgraded in May 2017 by OWP, NCEP and NCAR
- Hydrologic core is WRF-Hydro, a community-based hydrologic modeling framework supported by NCAR
- Chief Goal: Provide foundation for sustained growth in nationally consistent operational hydro forecasting
- Full spectrum hydrologic model, providing guidance for underserved locations
- Hourly analyses and short-range forecasts along with 4 x day medium-range and daily long-range forecasts

**Hydrologic Output**
- River channel discharge and velocity at 2.7 million river reaches
- Reservoir inflow, outflow, elevation
- Ponded water depth and depth to soil saturation on 250 m CONUS+ grid

**Land Surface Output**
- 1km CONUS+ grid
- Soil and snow pack states
- Energy and water fluxes
<table>
<thead>
<tr>
<th>Component</th>
<th>WRF-Hydro Options</th>
<th>Current NWM Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column Land Surface Model</td>
<td>3 up-to-date column land models: Noah, NoahMP (w/built-in multi-physics options), Sac-HTET</td>
<td>NoahMP: 4-layer soils 3-layer snowpack</td>
</tr>
<tr>
<td>Overland Flow Module</td>
<td>3 surface routing schemes: diffusive wave, kinematic wave, direct basin aggregation</td>
<td>Diffusive wave</td>
</tr>
<tr>
<td>Lateral Subsurface Flow Module</td>
<td>2 subsurface routing schemes: Boussinesq shallow saturated flow, 2d aquifer model</td>
<td>Boussinesq shallow saturated flow</td>
</tr>
<tr>
<td>Conceptual Baseflow Parameterizers</td>
<td>2 conceptual baseflow schemes: direct aggregation storage-release with pass-through or exponential model</td>
<td>Exponential model</td>
</tr>
<tr>
<td>Channel Routing/Hydraulics</td>
<td>5 channel flow schemes: diffusive wave, kinematic wave, RAPID, custom-network Muskingum or Muskingum-Cunge</td>
<td>Custom-network (NHDPlus) Muskingum-Cunge model</td>
</tr>
<tr>
<td>Lake/Reservoir Management</td>
<td>1 lake routing scheme: level-pool management</td>
<td>Level-pool management</td>
</tr>
</tbody>
</table>
• For snow depth < 45 mm, snow is combined with top soil layer.

• Once snow depth is equal to or above 45 mm, snow layers are created depending on thresholds.

• Snow depth derived from SWE and density.

• Snow cover fraction impacted by MFSNO parameter in NoahMP

\[ f_{sno} = \tanh \left( \frac{h_{sno}}{2.5 z_0 g (\rho_{sno} / \rho_{new})^m} \right) \]
NoahMP Snow Physics in the National Water Model

- NWM Versions 1.0-1.2 use the CLASS snow albedo scheme within the NoahMP model.
  - Simple decay of snow albedo based on age from fresh snowfall.
  - Albedo resets after fresh snowfall.
    - 0.84 for fresh snow
    - Exponential decay based on age.

  \[
  \alpha_{s,\text{VIS}} = 0.79[\alpha_{s,T} - 0.70] + 0.84 \\
  \alpha_{s,NIR} = 1.21[\alpha_{s,T} - 0.70] + 0.56 \\
  \alpha_{s,\text{VIS}} = 0.97[\alpha_{s,T} - 0.50] + 0.62 \\
  \alpha_{s,NIR} = 1.03[\alpha_{s,T} - 0.50] + 0.38
  \]

- NWM Version 2.0 will use the BATS snow albedo option within the NoahMP model
  - Changes in snow albedo decay
  - Impacts from impurities and dust

  \[
  \alpha_{V} = \alpha_{VD} + 0.4f(ZEN)[1 - \alpha_{VD}], \\
  \alpha_{IR} = \alpha_{IRD} + 0.4f(ZEN)[1 - \alpha_{IRD}],
  \]

  \[
  \alpha_{VD} = [1 - C_S F_{AGE}] \alpha_{VO}, \\
  \alpha_{IRD} = [1 - C_N F_{AGE}] \alpha_{IRO},
  \]

  \[C_S = 0.2, \quad C_N = 0.5,\]


Snow Albedo....
National Water Model Snow Analysis

Modeled Snow Water Equivalent for 2016 March 2, 18:00 UTC

April 20th, 2014 50-meter ASO SWE
5-Year Retrospective Study
5-Year Retrospective Study
5-Year Retrospective Study
5-Year Retrospective Study

NWM_v1_0 In-Situ SWE Observations for: 2013-10-01 to: 2014-10-01

Slope: 0.54
Intercept: 6.46
Correlation: 0.829

NWM_v1_1 In-Situ SWE Observations for: 2013-10-01 to: 2014-10-01

Slope: 0.59
Intercept: 7.80
Correlation: 0.857

NWM_v1_2_5YR_CALIB2 In-Situ SWE Observations for: 2013-10-01 to: 2014-10-01

Slope: 0.56
Intercept: 7.32
Correlation: 0.845

NWM_v1_1 In-Situ SWE Observations for: 2013-10-01 to: 2014-10-01

Slope: 0.91
Intercept: 0.20
Correlation: 0.946
5-Year Retrospective Study

- NWM_v1_0 In-Situ SWE Observations: Slope: 0.68, Intercept: -8.42, Correlation: 0.562
- NWM_v1_1 In-Situ SWE Observations: Slope: 0.71, Intercept: -5.39, Correlation: 0.573
- NWM_v1_2_5YR_CALIB2 In-Situ SWE Observations: Slope: 0.70, Intercept: -5.59, Correlation: 0.592
- SNODAS SWE: Slope: 1.07, Intercept: -5.13, Correlation: 0.61
5-Year Retrospective Study

April 20th, 2014 50-meter ASO SWE
5-Year Retrospective Study

2014-2015 Water Year Mean ASO SWE

2014-2015 Water Year Mean SNODAS SWE

2014-2015 Water Year Mean v1.0 NWM SWE

2014-2015 Water Year Mean v1.1 NWM SWE
Difference MAE From V1.1 to V1.2
(Blue Indicates Improvement):
2017-10-20

October 20th, 2017, 06Z NWM Analysis Cycle
SNODAS for observations
NWM V1.2 National Snowpack Improvement

Correlation: 0.515

Correlation: 0.561

Correlation: 0.646
Expansion of Remotely Sensed Snow Observations
Expansion of Remotely Sensed Snow Observations

VIIRS Fractional Snow Cover

2015-01-02 Analysis

Legend:
- States
- VIIRS Snow Cover:
  - 1.000000
  - 10.000000
  - 19.000000
  - 28.000000
  - 37.000000
  - 46.000000
  - 55.000000
  - 64.000000
  - 73.000000
  - 82.000000
  - 91.000000
  - 100.000000
  - Missing
Expansion of Remotely Sensed Snow Observations

November 28th, 2017 AMSR2 Snow Water Equivalent

November 28th, 2017 SNODAS Snow Water Equivalent
Next Steps

• Release of public WRF-Hydro calibration workflow
  • See public announcements for code and documentation

• Incorporation of snow observations and error metrics into calibration workflow
  • Calibration of snow-related parameters

• Exposure of additional snow-related parameters
  • Snow albedo
  • Rain/Snow partitioning

• Open to collaboration!
Questions?

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