NOAA-20 VIIRS
Surface Type
Beta Maturity
March 19, 2018

VIIRS Surface Type Team
Xiwu Zhan (STAR); Chengquan Huang (UMD); Ivan (STAR)
Outline

- Surface Type Team Members
- Product Requirements
- Findings/Issues for Beta maturity
- Documentation (Science Maturity Check List)
- Conclusions and Path Forward
## VIIRS Surface Type Team

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Major Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xiwu Zhan</td>
<td>NESDIS/STAR</td>
<td>Surface Type lead</td>
</tr>
<tr>
<td>Chengquan Huang</td>
<td>UMD</td>
<td>Surface type algorithm/product lead</td>
</tr>
<tr>
<td>Ben DeVries</td>
<td>UMD</td>
<td>Algorithm development and testing</td>
</tr>
<tr>
<td>Zhenhua Zou</td>
<td>UMD</td>
<td>Code refinement and optimization</td>
</tr>
<tr>
<td>Jiaming Lu</td>
<td>UMD</td>
<td>Training data collection, validation</td>
</tr>
<tr>
<td>Ivan Csiszar</td>
<td>NESDIS-STAR</td>
<td>VIIRS Land Team Lead</td>
</tr>
</tbody>
</table>
## AST Requirements from JPSS L1RD

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic coverage</td>
<td>Global</td>
</tr>
<tr>
<td>Vertical Coverage</td>
<td></td>
</tr>
<tr>
<td>Vertical Cell Size</td>
<td>N/A</td>
</tr>
<tr>
<td>Horizontal Cell Size</td>
<td>1 km at nadir</td>
</tr>
<tr>
<td>Mapping Uncertainty</td>
<td>1 km</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>17 IGBP classes</td>
</tr>
<tr>
<td>Measurement Accuracy</td>
<td>70% correct</td>
</tr>
</tbody>
</table>

- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forest
- Mixed Forests
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Permanent Wetlands
- Croplands
- Urban and Built-up Lands
- Cropland/Natural Vegetation Mosaics
- Snow and Ice
- Barren
- Water Bodies
### JPSS/GOES-R Data Product Validation Maturity Stages – COMMON DEFINITIONS (Nominal Mission)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Beta</strong></td>
<td>Product is minimally validated, and may still contain significant identified and unidentified errors. Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose. Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.</td>
</tr>
<tr>
<td><strong>2. Provisional</strong></td>
<td>Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts. Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose. Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists. Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.</td>
</tr>
<tr>
<td><strong>3. Validated</strong></td>
<td>Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal). Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level. Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose. Product is ready for operational use based on documented validation findings and user feedback. Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.</td>
</tr>
</tbody>
</table>
Beta Evaluation Methodology

- Use Suomi NPP as reference, compare NOAA-20 data to SNPP data for key steps of the AST algorithm
  - Surface reflectance data
    - Gridded daily data (Level 1)
    - Monthly composites (Level 2)
    - Annual metrics (Level 3)
  - Annual surface type classification (Level 4)
Beta Evaluation Methodology

- Comparison methods
  - Image/map level
    - Visual comparison
  - Pixel level
    - Scatter plots

Level 1

Level 2

Level 3

Level 4

Pre-processing

(Huge data processing job, handled by a dedicated team for MODIS)

- VIIRS surface reflectance data (swath)
- Gridded surface reflectance data
- Global composite surface reflectance (daily)
- Global composite surface reflectance (monthly)

Classification and Final Product Generation

- Global annual metrics
- Machine Learning:
  - Decision trees
  - SVM
- Initial classification map
- Post-processing
- Final global surface type map
- Accuracy assessment
• Focus on bands used in surface type mapping
  – M1-M5, M7, M8, M10, M11
• Conducted a comprehensive assessment, but only a sample of representative results presented
  – Important, commonly used bands/indices
  – Selected sites
  – Selected day/month
Level 1 Comparison: Daily Surface Reflectance

- VIIRS on NOAA-20 and S-NPP near identical
  - Same spectral bands
  - Same spatial resolutions
  - Follow each other on the same orbit
  - Near identical equator crossing time
- However, NOAA-20 and S-NPP data from same day over same ground targets not identical
  - NOAA-20 and SNPP are about half an orbit apart: ~50 minutes
  - When a ground location is observed by the two satellites in any given day, it
    - has different local solar time
      - 50 minutes difference
    - is viewed at very different sensor zenith angles
Same Day NOAA-20 and SNPP Data Not Identical

- Correlated but not identical due to BRDF effect
  - Sun angle changes substantially in 50 minutes
  - Large differences in view geometry
- Not comparable when clouds/shadow present
  - Clouds can move a lot in 50 minutes
  - Shadow will follow
Clear View NOAA-20 and SNPP Data Correlated

Southwest Africa
June 28, 2019
RGB: M10/7/5
Global Daily Mosaics Are Very Similar

NOAA-20 Mosaic, July 25, 2019, RGB: M10, M7, M5
Global Daily Mosaics Are Very Similar

S-NPP Mosaic, July 25, 2019, RGB: M10, M7, M5
Level 2: Monthly Composites

- **Purpose:** create global data with minimum or no cloud cover
- **General idea:**
  - Define compositing period: one month
  - At each pixel location, select the best observation within each month as the composited observation for that month
- **Input:**
  - Gridded daily surface reflectance for all days within a month
- **Output**
  - One composite per month, near cloud free
SA-Comp Better Than Existing Methods

- Less shadow
- Non-snow selected when exist
- Better Than MODIS
- Less cloud

Heritage Methods
Smother results over vegetated and non-vegetated areas
Monthly Composites Assessment: Scope and Expectations

- Monthly composites generated
  - Month: May, June, July, 2019
    - Full month NOAA-20 not available until May 2019
- How comparable can NOAA-20 and S-NPP monthly composites be?
  - Not always identical at individual pixel level
    - Not identical in each individual day
    - NOAA-20 and S-NPP composites may be selected from different dates
  - Statistically comparable, visually very similar
Monthly Composites Comparison Examples

May 2019, US Midwest
RGB: M10, M7, M5

S-NPP
NOAA-20
Monthly Composites Comparison Examples

May 2019
US Midwest
Monthly Composites Comparison Examples

May 2019, Central Asia
RGB: M10, M7, M5

S-NPP

NOAA-20
Monthly Composites Comparison Examples

May 2019
Central Asia
Monthly Composites Comparison Examples

July 2019, Central South America
RGB: M10, M7, M5

S-NPP

NOAA-20
Monthly Composites Comparison Examples

July 2019
South America
Level 3: Annual Metrics

- **Purpose:**
  - minimize spectral differences between northern and southern hemispheres and/or along other geographical gradients
- **Input:** Monthly composites in "one year"
  - May, June, July
    - 2019 NOAA-20 used to create NOAA-20 metrics
    - 2019 S-NPP data used to create S-NPP metrics
  - Other months
    - 2018 SNPP data used to create both sets: No NOAA-20 composites before May 2019
- **Output**
  - A set of 69 metrics (Zhang et al. 2016, 2017)

Table 2. Details of annual metrics used in classification.

<table>
<thead>
<tr>
<th>Metrics number(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maximum NDVI value</td>
</tr>
<tr>
<td>2</td>
<td>Minimum NDVI value of eight greenest months</td>
</tr>
<tr>
<td>3</td>
<td>Mean NDVI value of eight greenest months</td>
</tr>
<tr>
<td>4</td>
<td>Amplitude of NDVI over eight greenest months</td>
</tr>
<tr>
<td>5</td>
<td>Mean NDVI value of four warmest months</td>
</tr>
<tr>
<td>6</td>
<td>NDVI value of warmest month</td>
</tr>
<tr>
<td>7,14,21,28,35,42,49,56,63</td>
<td>Maximum band x value of eight greenest months</td>
</tr>
<tr>
<td>8,15,22,29,36,43,50,57,64</td>
<td>Minimum band x value of eight greenest months</td>
</tr>
<tr>
<td>9,16,23,30,37,44,51,58,65</td>
<td>Mean band x value of eight greenest months</td>
</tr>
<tr>
<td>10,17,24,31,38,45,52,59,66</td>
<td>Amplitude of band x value over eight greenest months</td>
</tr>
<tr>
<td>11,18,25,32,39,46,53,60,67</td>
<td>Band x value from month of maximum NDVI</td>
</tr>
<tr>
<td>12,19,26,33,40,47,54,61,68</td>
<td>Mean band x value of four warmest months</td>
</tr>
<tr>
<td>13,20,27,34,41,48,55,62,69</td>
<td>Band x value of warmest month</td>
</tr>
</tbody>
</table>

Note: x is the band used in annual metrics, which includes M1, M2, M3, M4, M5, M7, M8, M10 and M11.
Annual Metrics Comparison Examples

US Midwest, Annual Mean NDVI

S-NPP  NOAA-20
Annual Metrics Comparison Examples

Max NDVI      Min NDVI      Mean NDVI

SNPP

NOAA-20
Annual Metrics Comparison Examples

South America, Annual Mean NDVI

S-NPP

NOAA-20
Annual Metrics Comparison Examples

Max NDVI

Min NDVI

Mean NDVI
Level 4: Initial SVM Classification

Derivation of "NOAA-20" and S-NPP based classifications

<table>
<thead>
<tr>
<th></th>
<th>NOAA-20</th>
<th>S-NPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual metrics</td>
<td>&quot;NOAA-20&quot; metrics</td>
<td>S-NPP metrics</td>
</tr>
<tr>
<td>Training sample</td>
<td>same set</td>
<td>same set</td>
</tr>
<tr>
<td>Classification algorithm</td>
<td>same: SVM</td>
<td></td>
</tr>
<tr>
<td>Classification model</td>
<td>&quot;NOAA-20&quot; based</td>
<td>S-NPP based</td>
</tr>
<tr>
<td>Classification results</td>
<td>&quot;NOAA-20&quot; based</td>
<td>S-NPP based</td>
</tr>
</tbody>
</table>

Classifications should be similar but not identical
Classification Comparison Examples

South Central US

Legend
- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forest
- Mixed Forests
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Permanent Wetlands
- Croplands
- Urban and Built-up Lands
- Cropland/Natural Vegetation Mosaics
- Snow and Ice
- Barren
- Water Bodies

S-NPP

NOAA-20
Classification Comparison Examples

US Upper Midwest

Legend
- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forest
- Mixed Forests
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Permanent Wetlands
- Croplands
- Urban and Built-up Lands
- Cropland/Natural Vegetation Mosaics
- Snow and Ice
- Barren
- Water Bodies

S-NPP

NOAA-20
Classification Comparison Examples

South America

Legend
- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forest
- Mixed Forests
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Permanent Wetlands
- Croplands
- Urban and Built-up Lands
- Cropland/Natural Vegetation Mosaics
- Snow and Ice
- Barren
- Water Bodies

S-NPP

NOAA-20
Classification Comparison Examples

Legend
- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forest
- Mixed Forests
- Closed Shrublands
- Open Shrublands
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- Savannas
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- Cropland/Natural Vegetation Mosaics
- Snow and Ice
- Barren
- Water Bodies

Central Europe

S-NPP

NOAA-20

JPSS Data Products Calibration/Validation Maturity
Classification Comparison Examples

South Central Africa

Legend
- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forest
- Mixed Forests
- Closed Shrublands
- Open Shrublands
- Woody Savannas
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- Urban and Built-up Lands
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- Snow and Ice
- Barren
- Water Bodies

S-NPP

NOAA-20
Classification Comparison Examples

Eastern Australia

Legend
- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forest
- Mixed Forests
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Permanent Wetlands
- Croplands
- Urban and Built-up Lands
- Cropland/Natural Vegetation Mosaics
- Snow and Ice
- Barren
- Water Bodies

S-NPP

NOAA-20
Classification Comparison Examples

South Central Asia

Legend
- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forest
- Mixed Forests
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Permanent Wetlands
- Croplands
- Urban and Built-up Lands
- Cropland/Natural Vegetation Mosaics
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- Barren
- Water Bodies

S-NPP

NOAA-20
Classification Comparison Examples

Legend
- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forest
- Mixed Forests
- Closed Shrublands
- Open Shrublands
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- Savannas
- Grasslands
- Permanent Wetlands
- Croplands
- Urban and Built-up Lands
- Cropland/Natural Vegetation Mosaics
- Snow and Ice
- Barren
- Water Bodies

East Asia

S-NPP

NOAA-20
Summary and Path Forward

• NOAA-20 data are comparable to S-NPP data during 4 key stages of AST development
  – Surface reflectance data
    • Gridded daily data (Level 1): correlated under clear view conditions
    • Monthly composites (Level 2): distributed along 1:1 line
    • Annual metrics (Level 3): highly clustered along 1:1 line
    • Images very similar at each level
  – Annual surface type classification (Level 4):
    • Classification maps have very similar spatial patterns

• Next step: More comprehensive assessment when one full year of NOAA-20 data become available by May 2020

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Pre-processing
(Huge data processing job, handled by a dedicated team for MODIS)

Classification and Final Product Generation

Cannot compare at swath level:
Swath data from two satellites have different geographic boundaries

Level 1
Global composite surface reflectance (daily)

Level 2
Global composite surface reflectance (monthly)

Level 3
Gridding

Level 4
Mosaicking

Metrics generation

Global annual metrics

Post-processing

Final global surface type map

Accuray assessment

Machine Learning:
• Decision trees
• SVM

Initial classification map