Developing Enterprise Algorithm for Land Surface Albedo Product

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Team Members/Users

	Name	Institute	Function
JPSS-STAR	Land Lead: Ivan Csiszar	NOAA/NESDIS/SATR	Project Management
	EDR Lead: Yunyue Yu	NOAA/NESDIS/SATR	Team management, algorithm development, validation
	Marina Tsidulko	IMSG	STAR AIT support: product verification, testing
UMD/CICS			
	Shunlin Liang	UMD/CICS –project PI	algorithm development, validation
	Dongdong Wang	UMD/CICS	algorithm development, validation, monitoring
	Tao He	UMD/CICS	algorithm development, validation, monitoring
	Yuan Zhou	UMD/CICS	algorithm development, validation, monitoring
	Yi Zhang	UMD/CICS	algorithm development, validation, monitoring
NCEP-EMC			
	Michael EK	NOAA/EMC/NCEP	user readiness
	Jesse Meng	NOAA Affiliate	user readiness
	Weizhong Zheng	NOAA Affiliate	user readiness
	Yihua Wu	NOAA Affiliate	user readiness

External Users of LSA product (Point of Contact)

- **U. S. Users:**
  - USDA Agricultural Research Services(Martha Anderson)
  - USDA Forest Service (Brad Quayle)
  - NOAA/NESDIS National Climate Data Center (Peter Thorne)
  - Academy -- University of Maryland (Konstantin Vinnikov, Cezar Kongoli)
  - Army Research Lab (Kurt Preston)
- **Potential foreign Users**
  - EUMETSAT (Yves Govaerts)
  - Météo France (Jean-Louis Roujean)
  - Academy: Italy IASMA Research and Innovation Centre (Barbara Marcolla), Beijing Normal University (Qiang Liu)

Requirement Summary

Albedo EDR		
Attribute	Threshold	Objective
Albedo Applicable Conditions: Day time, Clear only		
a. Horizontal Cell Size		
Nadir	4 *km*	0.5 *km*
b. Mapping Uncertainty, 3 Sigma	*4 km*	*1 km*
c. Measurement Range	0 to 1.0	0 to 1.0
d. Measurement Precision (1 sigma)	0.05 (albedo unit)	0.02
e. Measurement Accuracy (bias)	0.08 (albedo unit)	0.0125
f. Refresh	At least 90% coverage of the globe, every 24 hours (monthly average)	4 *hrs*

Background

- Surface albedo is the ratio between outgoing and incoming shortwave radiation at the Earth surface. It is an essential component of the Earth's surface radiation budget.
- A direct estimation method (Bright Pixel Sub-Algorithm, BPSA) is currently used to generate LSA from VIIRS data.
- The direct estimation method can be modified and optimized for GOES-R ABI albedo production as well.
- End users need a *continuous gridded product of daily albedo without data gaps*, which is the out put of this enterprise albedo algorithm.

Current Operational Product

- Surface albedo produced from **S-NPP VIIRS** is a granule Environmental Data Record (EDR), with global coverage. It is a combination of land surface albedo (LSA), ocean surface albedo (OSA) and sea-ice surface albedo (SSA); only LSA is maintained.

- The BPSA approach is used to generate LSA and SSA. Several improvements have been made on the LSA algorithm since the S-NPP launch.

- BPSA is a direct estimation, retrieving albedo from TOA reflectance with pre-determined regression coefficients.

$$a = c_0(\theta_s, \theta_v, \varphi) + \sum_i c_i(\theta_s, \theta_v, \varphi) r_i$$

- Inputs of the VIIRS LSA algorithm include TOA reflectance, cloud mask, snow cover and surface type (for selection of LUT).

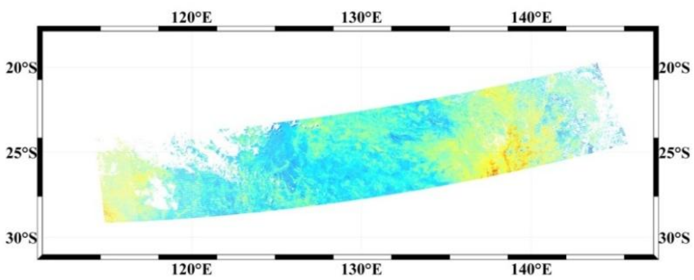
- An physics model, optimization-based algorithm is currently under implementation to generate the GOES-R ABI albedo product suite (includes LSA, surface reflectance, BRDF).

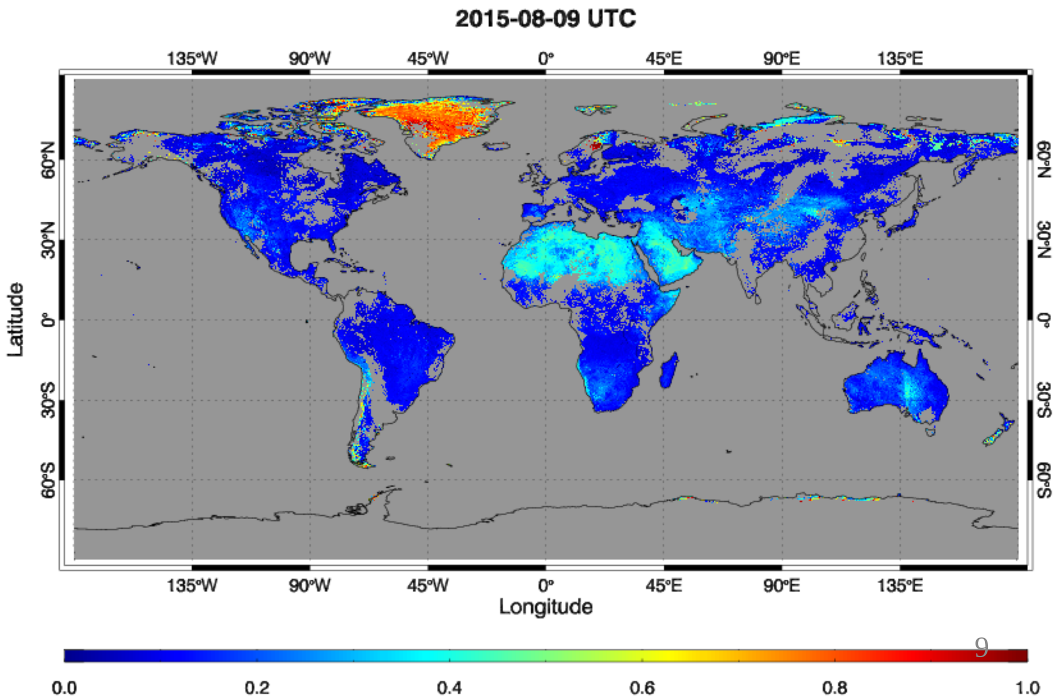
S-NPP VIIRS and GOES-R ABI LSA algorithms: comparison

	S-NPP VIIRS albedo	GOES-R ABI albedo
Temporal resolution	Instantaneous	Daily
Spatial resolution	750m	1km
Map projection	Granule	Full disk
Spatial coverage	Global	Regional
Retrieval algorithm	Direct estimation	Physics Model based Inversion
Major input data	Instantaneous Observation	Daily Observations
Major output results	Albedo	Albedo, reflectance and BRDF

Current VIIRS LSA product

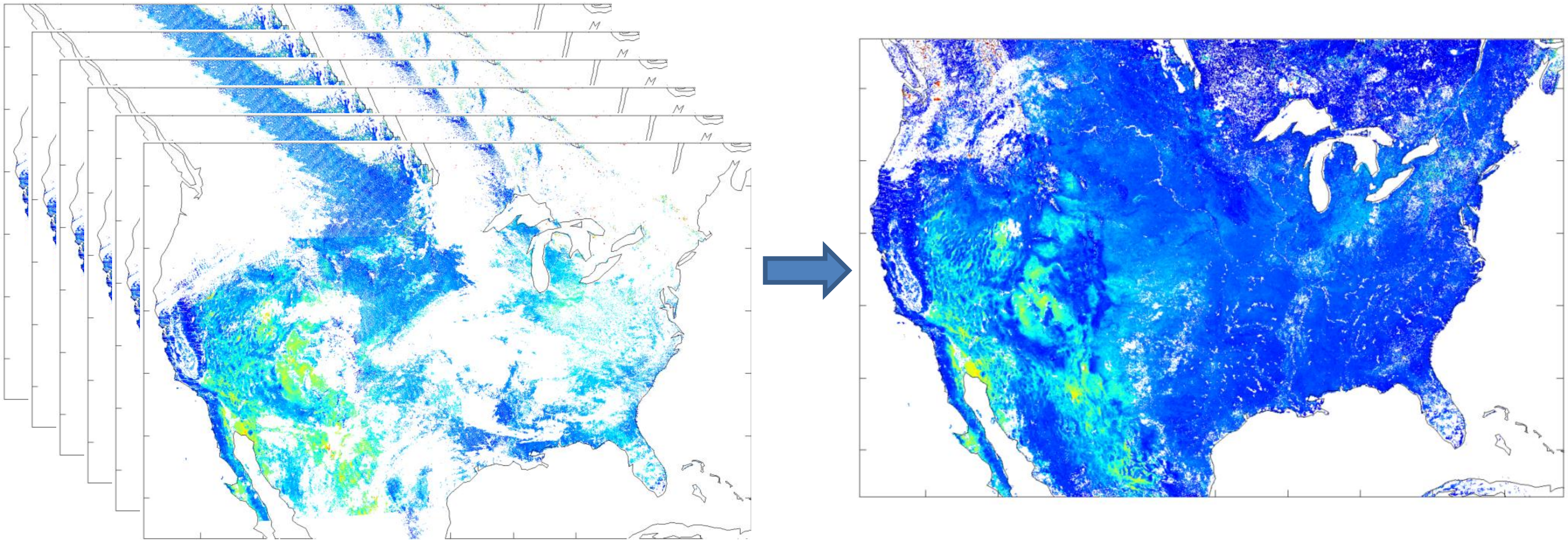
- VIIRS LSA is a granule product of instantaneous, available only for **clear-sky pixels**.
- The VIIRS BPSA algorithm requires simple inputs and is rather easy to implement. It captures rapid change of surfaces (including noises).
- Pitfalls: the current product contains lots of missing values, very noisy, hard to use.





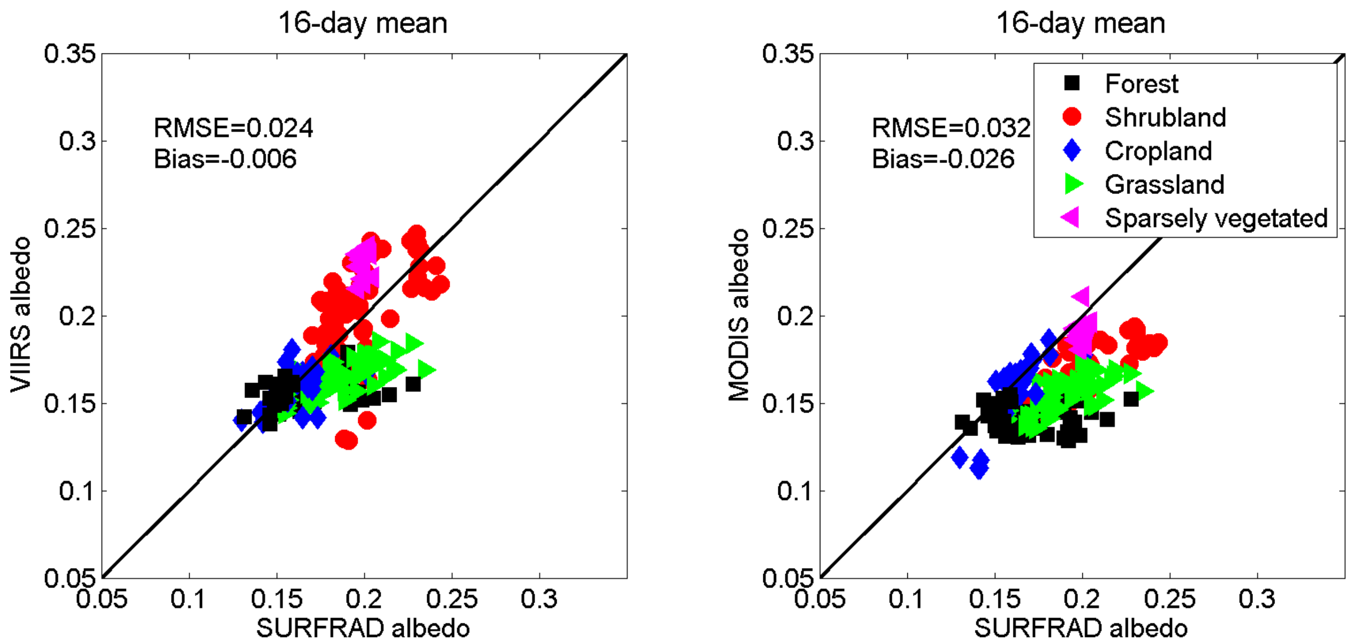
Granule vs Gridded Product

- VIIRS albedo: not "ready-to-eat" for users, with current granule files.
  - Not converted to map-projection
  - Not stable due to high temporal variation composite" before they can actually use the granule data in their modeling or analysis.
- LSA is required as input for weather forecasting model; the pitfalls discourage use of current VIIRS LSA product.



Quality of current VIIRS LSA data

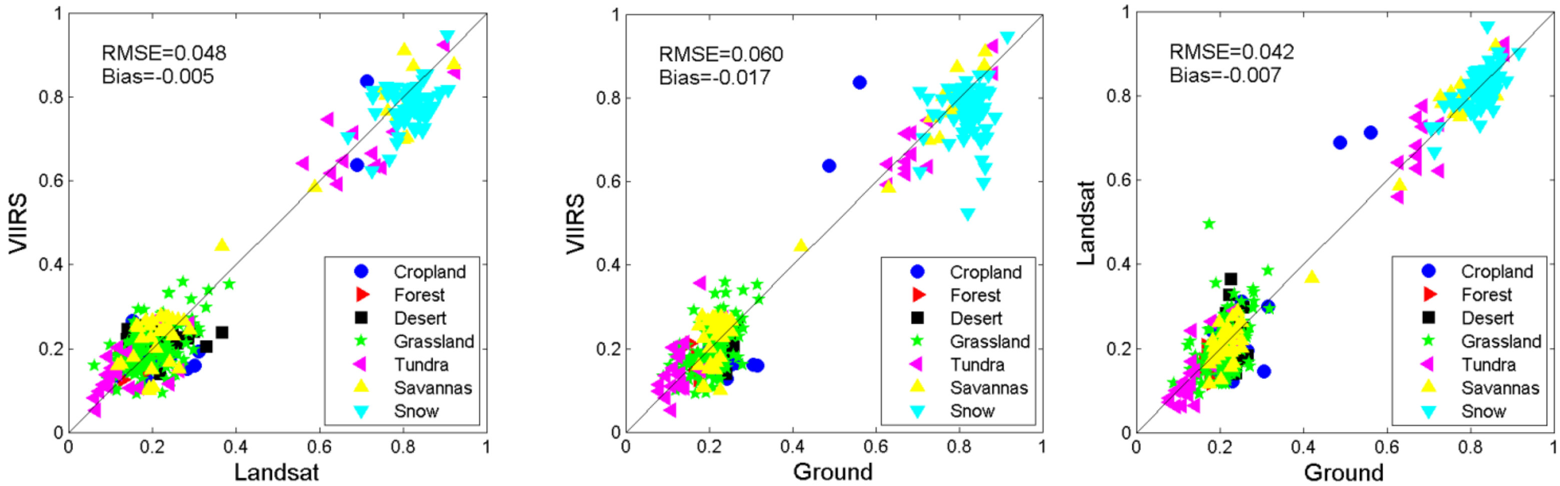
- Several algorithm improvements have been made since S-NPP was launched.
- A set of surface-specific LUTs with consideration of surface reflectance anisotropy are used.
- Validation results suggest the VIIRS direct estimation approach can generate albedo retrievals with accuracy similar (or superior) to existing products.



Wang, D., Liang, S., He, T., & Yu, Y. (2013). Direct Estimation of Land Surface Albedo from VIIRS Data: Algorithm Improvement and Preliminary Validation. *Journal of Geophysical Research, 118*, 12577-12586

Comprehensive assessment of VIIRS albedo

- Two years data over 23 sites
- Field measurements together with Landsat 7 ETM+ and Landsat 8 OLI maps (~3Tb)
- Intercomparison with MODIS product



Zhou, Y., Wang, D., Liang, S., & He, T. (2016). Assessment of the Suomi NPP VIIRS land surface albedo data using station measurements and high-resolution albedo maps. *Remote Sensing*, 8, 137, doi: 10.3390/rs8020137.

Strategy of Enterprise Algorithm Development

- It is urgent to provide user community a *gridded and gap-filled albedo product*, to replace the granule albedo product

- A consistent and reliable algorithm for the gridded LSA is needed for S-NPP mission and later to future JPSS missions.

- The algorithm shall be applicable to the GOES-R mission (albedo only).

- The proposed enterprise algorithm is similar to the current VIIRS albedo algorithm (BPSA), but with more complicated gridding and post-processing procedures. It has the following features:
  - Gridded
  - Diurnal variations being considered
  - Gap-filled
  - Noise-reduced

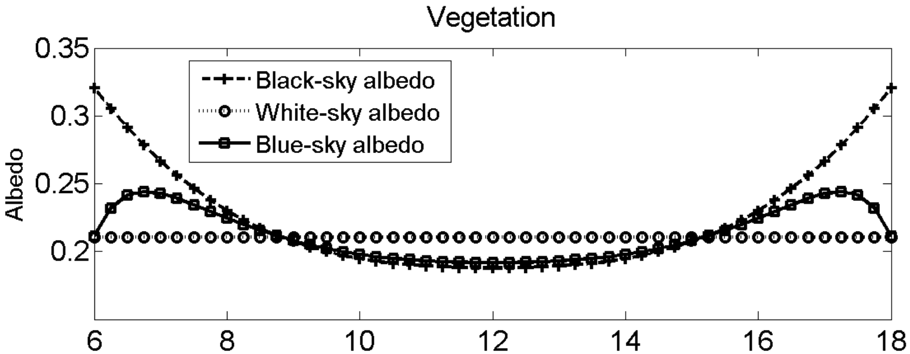
  Ready-to-eat!!

Technical approaches

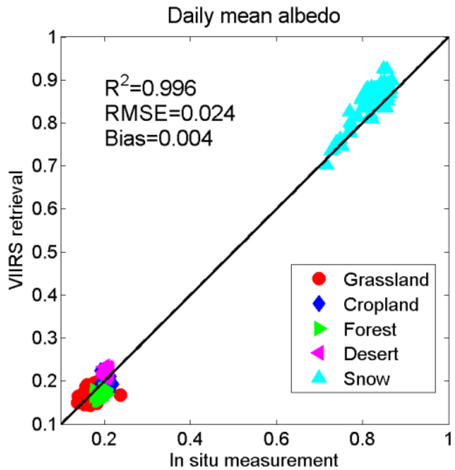
- Map projection (tiling)
  - Convert granule data to sinusoidal projection
  - Use a common VIIRS tile system
- Consideration of LSA diurnal change
  - Change output from instantaneous albedo at the overpass time to daily mean albedo
  - Surface BRDF database and atmospheric radiative transfer modeling used (for a comprehensive LUT).
- Temporal filter
  - Apply temporal filter to gridded data on a daily basis
  - Reduce residual variations
  - Fill data gaps
- The enterprise algorithm will be firstly applied to VIIRS data and later for other satellite missions.

Daily mean albedo

- Use of instantaneous albedo to calculate daily surface radiation budget results in ~10% bias for snow-free conditions.
- We developed a new method to estimate daily mean albedo directly from VIIRS data.
- The new method uses similar LUTs of regression coefficients, but with two additional dimension of Earth declination angle and latitude.



Typical vegetation albedo along the hour

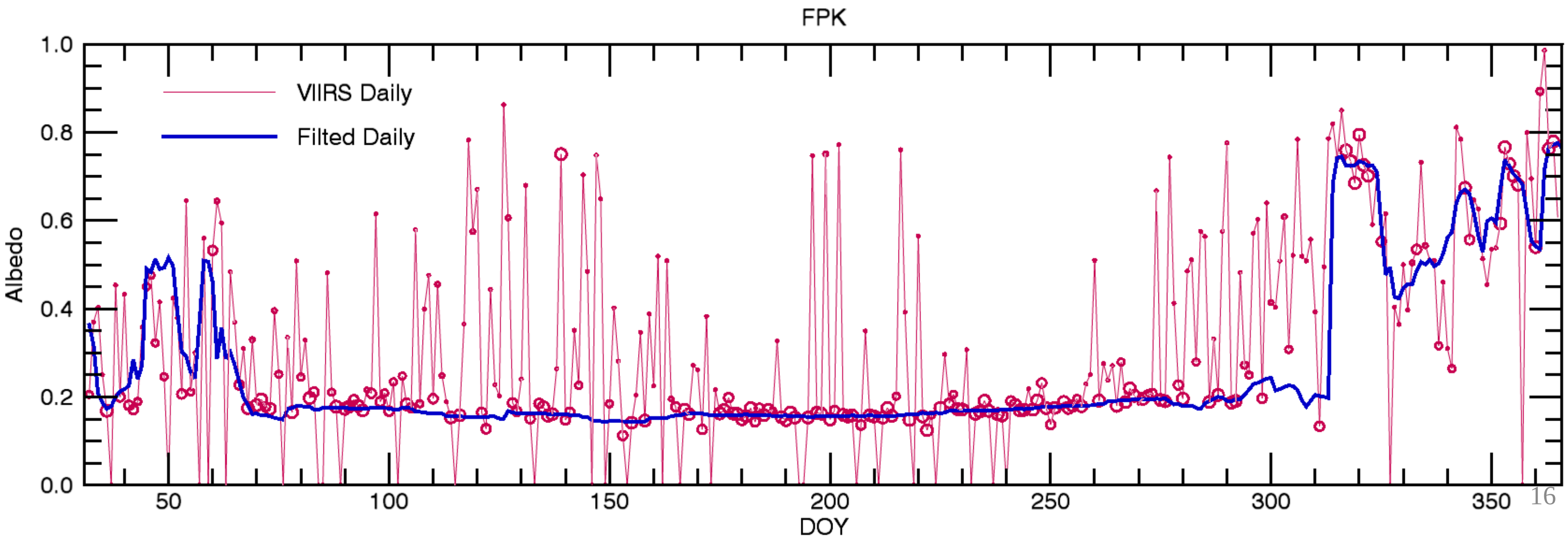


WANG, D.D., Liang, S.L., He, T., Yu, Y.Y., Schaaf, C., & Wang, Z.S. (2015). Estimating daily mean land surface albedo from MODIS data. *Journal of Geophysical Research-Atmospheres, 120*, 4825-4841

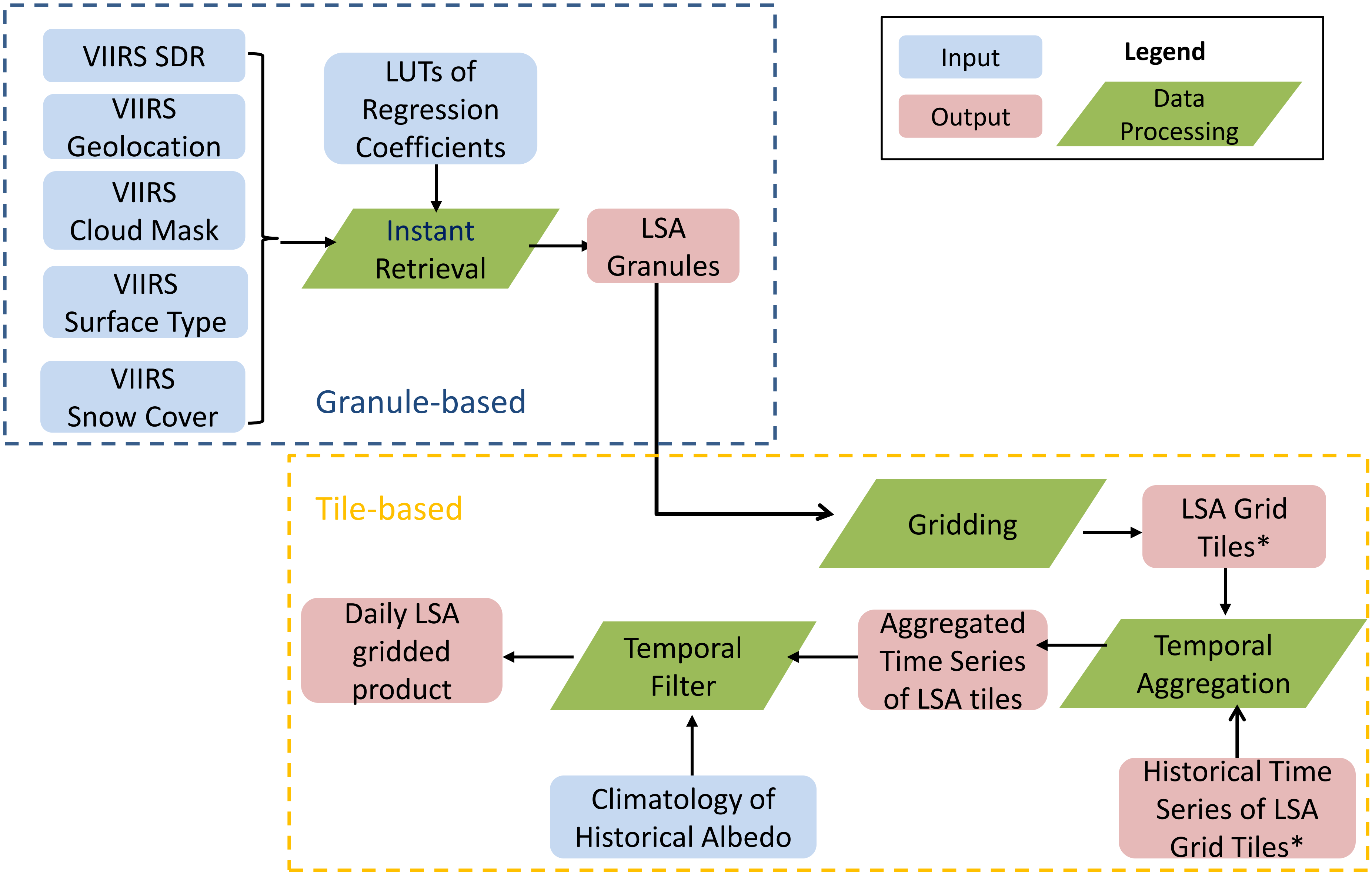
WANG, D., Liang, S., Zhou, Y., & Yu, Y. (2015). A new method to retrieve daily albedo from VIIRS data. *Remote Sensing of Environment*, submitted

Temporal filter

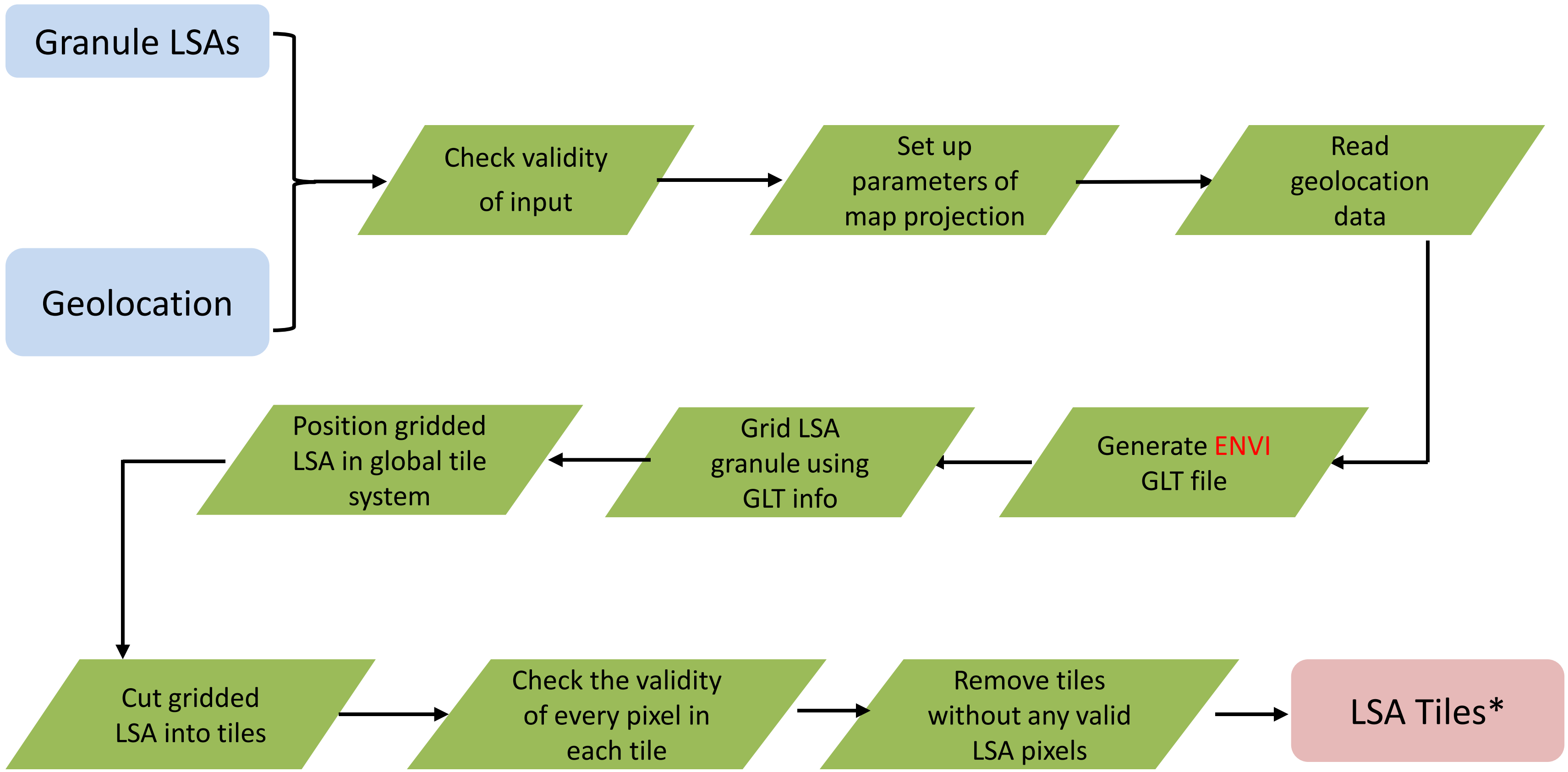
- An algorithm based on temporal autocorrelation and climatology is developed.
- Objectives
  - Improve accuracy
    - Reduce temporal variations
    - Exclude undetected cloud and shadow
  - Fill data gaps
- Integrate multisource of information
  - VIIRS retrieval and its QF
  - Climatology (mean and variance)
  - Temporal correlation (historical observation)



High Level Process Flow for VIIRS data

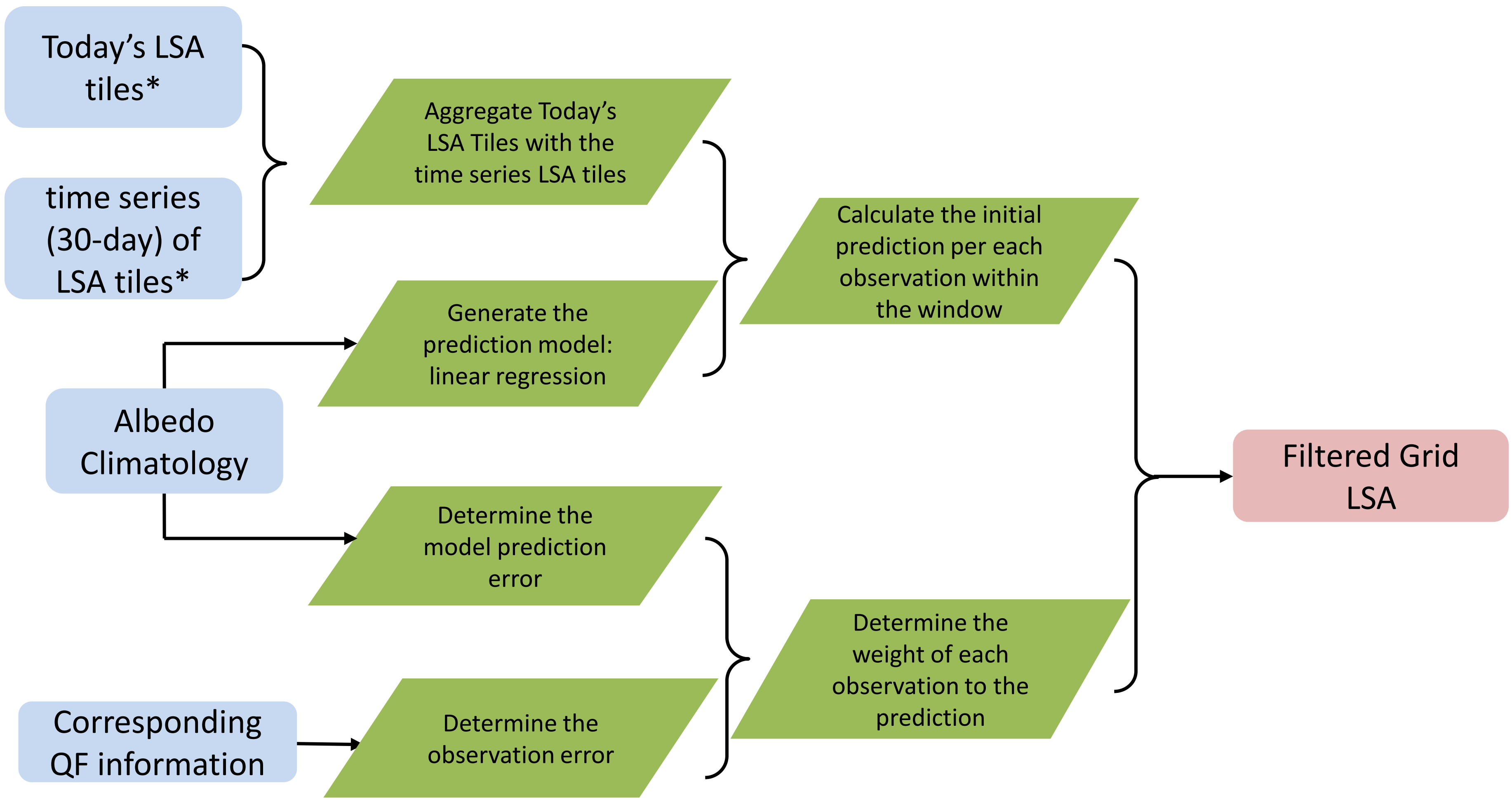


Flowchart of gridding (map projection)



This tile process has to be replace with STAR tool

Flowchart of temporal filter



Design of Quality Flag

Byte	Bit	Flag	Source	Description
0	0-1	Overall quality	LSA	00: no retrieval, 10: retrieval, 11: high-quality retrieval
	2-3	Cloud condition	Cloud mask	00=confidently clear, 01=probably clear,10=probably cloudy,11=confidently cloudy
	4-5	Retrieval path	LSA	00: generic, 01: desert, 10: snow
	6	Solar zenith angle flag	SDR	0: favorable SZA, 1: very large SZA
	7	View zenith angle flag	SDR	0: favorable VZA, 1: very large VZA
1	0	Temporal filter flag	LSA	0: high-quality retrieval, 1: degraded retrieval
	1	SDR quality	SDR	0=normal, 1=bad data VIIRS: (bad , missing , not calibrated) GOES-R: (bad , missing , not calibrated, out of space)
	2-3	Land surface cover	Land/sea mask, snow/ice mask	00=land;01=snow/ice;10=in land water;11=coastal
	4-7	Reserved		Reserved for future use

Input data

Name	Type	Description	Dimension	Unit
Primary Sensor Data(SDR)				
Spectral reflectance	input	TOA spectral reflectance at M1,2,3,4,5,7,8,10,11	grid (xsize, ysize)	unitless
Latitude	input	Pixel latitude	grid (xsize, ysize)	Degree
Longitude	input	Pixel longitude	grid (xsize, ysize)	Degree
Solar zenith	input	solar zenith angles	grid (xsize, ysize)	Degree
View Zenith	input	Satellite view zenith angle	grid (xsize, ysize)	Degree
SDR QC flags	Input	Level 1b data quality	grid (xsize, ysize)	unitless
Derived Sensor Data				
Cloud mask	Input	Cloud mask data	grid (xsize, ysize)	unitless
Snow/ice mask	Input	Level 2 snow/ice mask data	grid (xsize, ysize)	unitless
Surface type	Input		grid (xsize, ysize)	unitless
Climatology data for temporal filter				
Climatology	input	correlation and variance of historical climatology	grid (xsize, ysize)	unitless
LUT and Configuration File				
Coefficients LUT	Input	Regression coefficients for BPSA	2(two surface types)*18(sza) *18(vza)*23(raa)*8(coef items)	Unitless

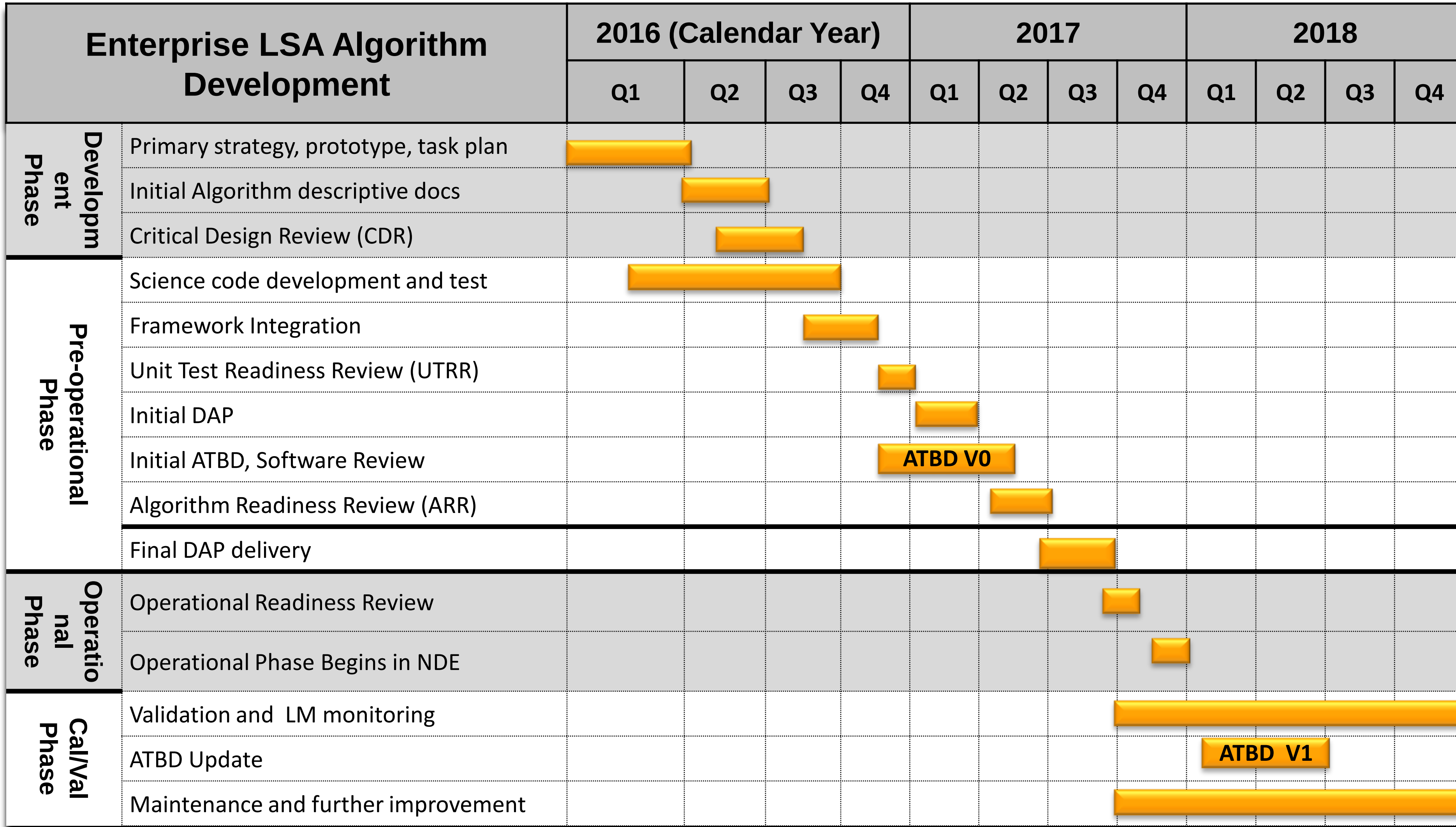
Testing and Validation

- We have conducted some assessments of the retrieval part of the enterprise algorithm. The results have been reported in a recently submitted manuscript.
- The research codes (IDL) of all the three parts are ready.
- We are currently undertaking some test of the research codes with one month data. The results will be compared with in situ data and existing products.
- We plan to carry out long-term tests with one year data over selected locations and make further evaluation of the enterprise algorithm before we deliver the codes to AIT.

Adaption of the Algorithm to GOES-R

- The albedo algorithm is initially developed and tuned for S-NPP VIIRS gridded product.
- Our research showed it can also be adapted to GOES-R ABI data and generate gridded and gap-filled daily albedo product.
- The procedure to generate enterprise GOES-R ABI albedo will be slightly different.
- The disk-based ABI data makes the gridding step easier.
- The retrieval step will be revised and tuned to take advantage of high temporal resolution of ABI data.

Schedules and Milestones



Risks and Review Items

- Gridding tool
  - Developing fast, accurate and robust gridding tool requires considerable efforts.
  - A centralized gridding tool, i.e. MODIS MRT-Swath will benefit all land teams and make product consistent.
- Software efficiency
  - Gridding and filtering is time consuming
  - Temporal filtering also has requirements for storage of historical albedo tiles.

Summary

- Current VIIRS granule LSA product of instantaneous albedo are very hard to be used by user community.
- We are developing a new enterprise algorithm to generate VIIRS daily gridded LSA product with gaps filled and residual variations reduced.
- The research codes in IDL are ready. We are developing an operational software package in C language, with STAR coding standard
- The new algorithm will be firstly applied to S-NPP VIIRS data and later to GOES-R ABI data.
- A centralized gridding tool is needed for implementation efficiency and product consistency.