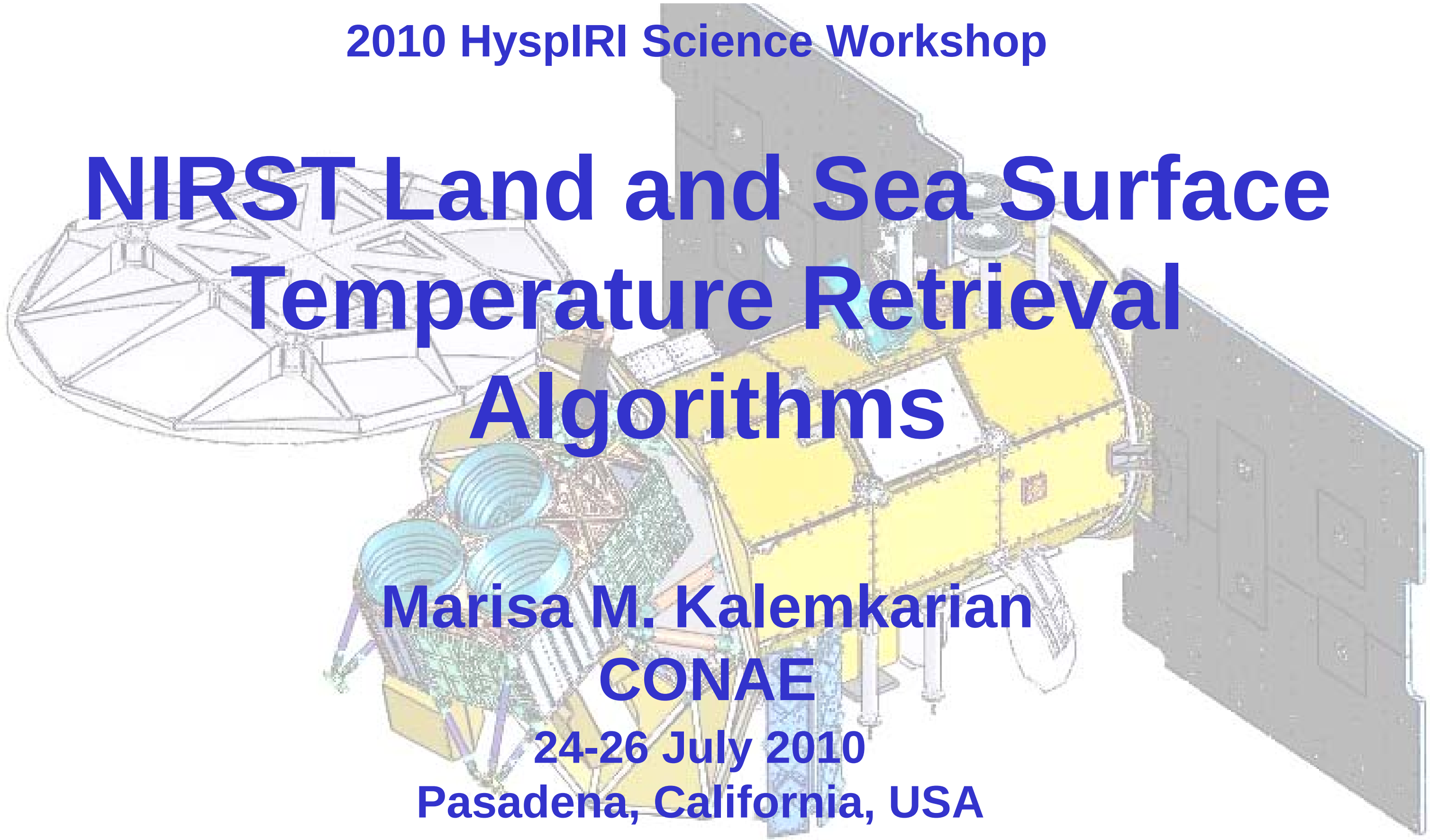
AQUARIUS/SAC-D

2010 HyspIRI Science Workshop

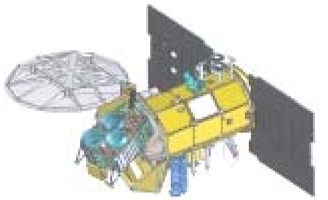


NIRST Land and Sea Surface Temperature Retrieval Algorithms

Marisa M. Kalemkarian
CONAE

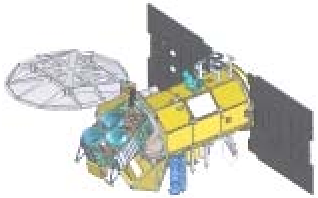
24-26 July 2010
Pasadena, California, USA

CONAE
COMISION NACIONAL DE ACTIVIDADES ESPACIALES



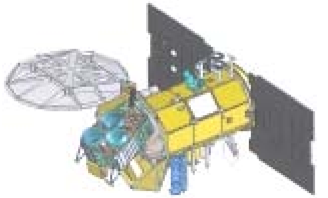
NIRST DERIVED PRODUCTS (Level 2)

- FIRE MAPPING AND FIRE RADIATIVE POWER
- VOLCANIC ACTIVITY MONITORING
- SEA SURFACE TEMPERATURE (SST)
- LAND SURFACE TEMPERATURE (LST)



Summary of Processing Levels:

- L0A: No calibration or correction applied
- L1A: Relative Radiometric Calibration + Inter Band Co-registration
- L1B1: Relative Radiometric Calibration + Absolute Radiometric Calibration + Co-registration
- L1B2: Relative Radiometric Calibration + Absolute Radiometric Calibration + Geometric Correction (Map Projection – includes inter band co-registration).
- **L2: Geophysical Parameter**



Product generation sequence:

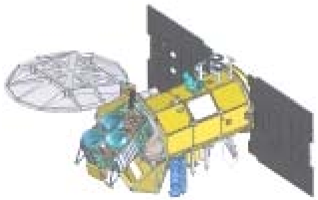
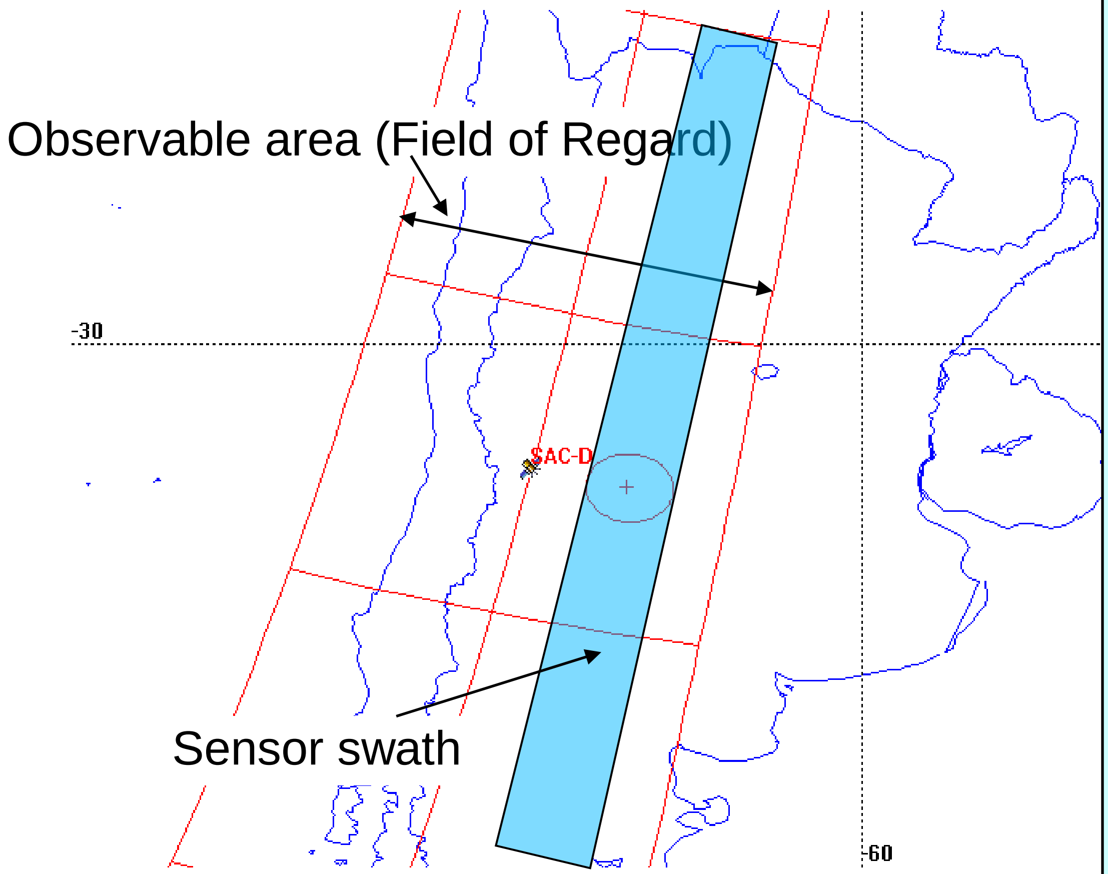
- L1A is generated from L0 (+ Relat. Radiom. Calib. + Co-regist.)

- L1B1 is generated from L1A (+ Absol. Radiom. Calib.)

- L1B2 is generated from L0 (+ Relat. Radiom. Calib. + Absol. Radiom. Calib. + Geom. Calib. (Map Projection).

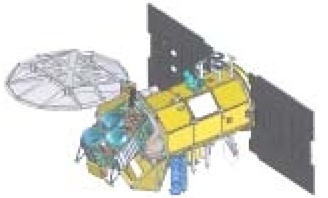
- **L2 is generated from L1B1 (+ Retrieval Algorithms)**

NIRST Land and Sea Surface Temperature Algorithms

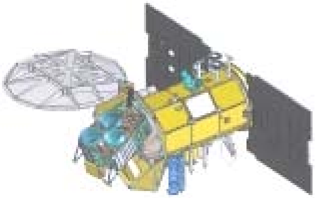
NIRST Bands and Geometry

- 3 Bands:
  - ✓ B1: 3.4 – 4.2 μm
  - ✓ B2: 10.4 – 11.3 μm
  - ✓ B3: 11.4 – 12.3 μm
- Swath: 180 Km at nadir
- Spatial resolution:
  - ✓ 350 m across track
  - ✓ 410 m along track
- Boresight pointing: +/-30° from nadir
- About 1000 km observable area across track

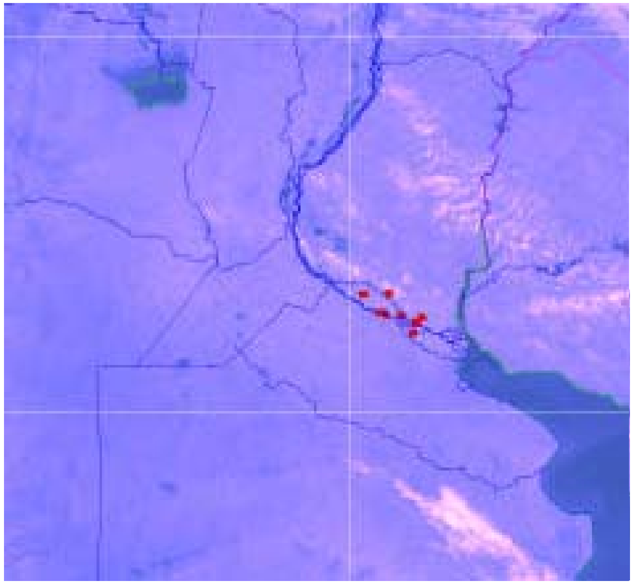


Fire Mapping
and
Fire Radiative Power

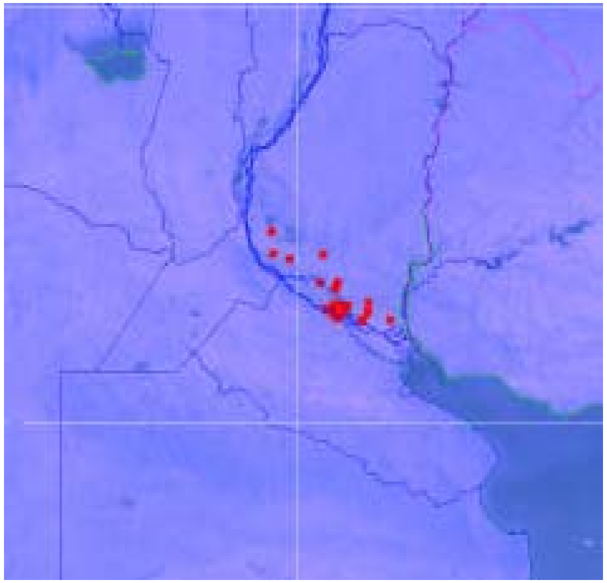
Fire Mapping and Fire Radiative Power



Examples of fires detected by MODIS algorithm in the Delta of Parana River - 2008



❖MODIS (Terra) sensor – April 15, 2008
Nighttime acquisition

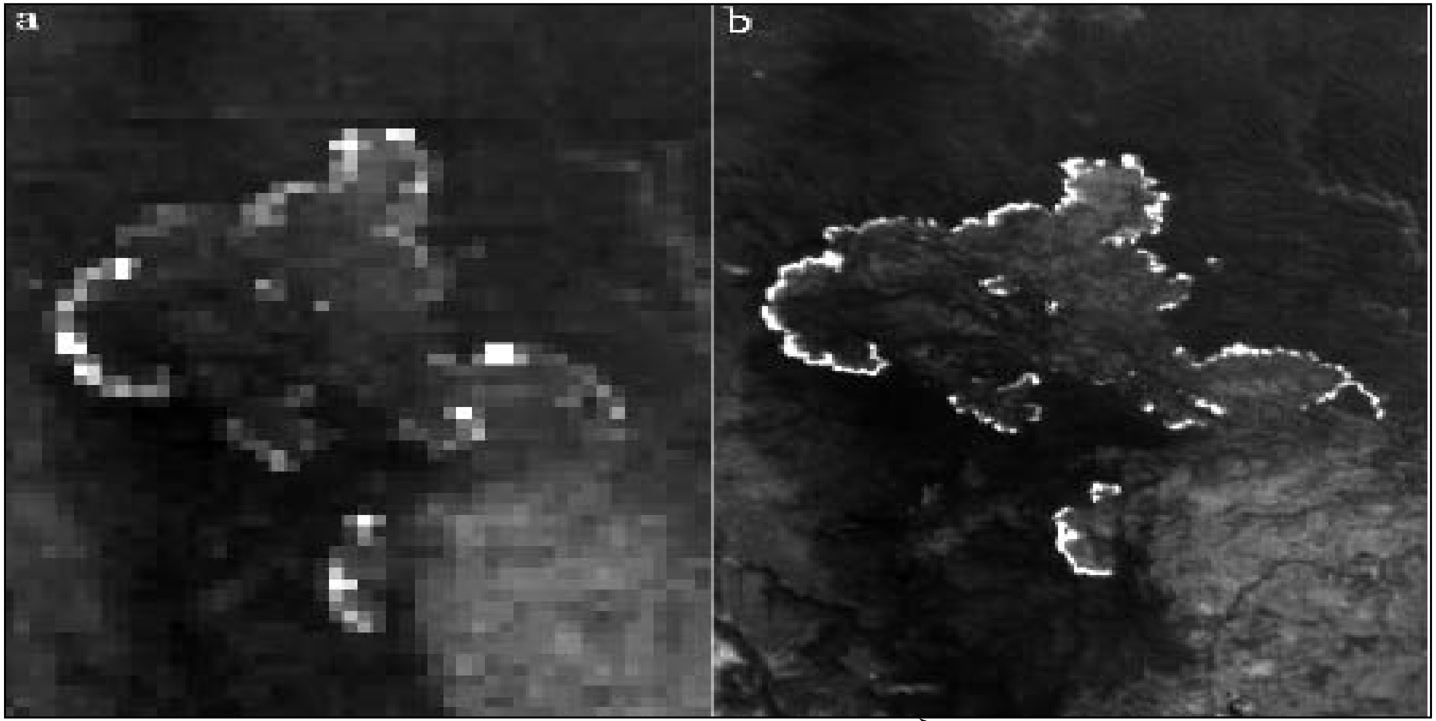


❖MODIS (Aqua) sensor – April 17, 2008
Nighttime acquisition

Fire Mapping and Fire Radiative Power

Example of MODIS resolution compared to BIRD resolution, which is similar to NIRST

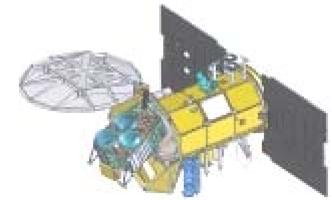
MODIS data – 4µm band | BIRD data – 4µm band

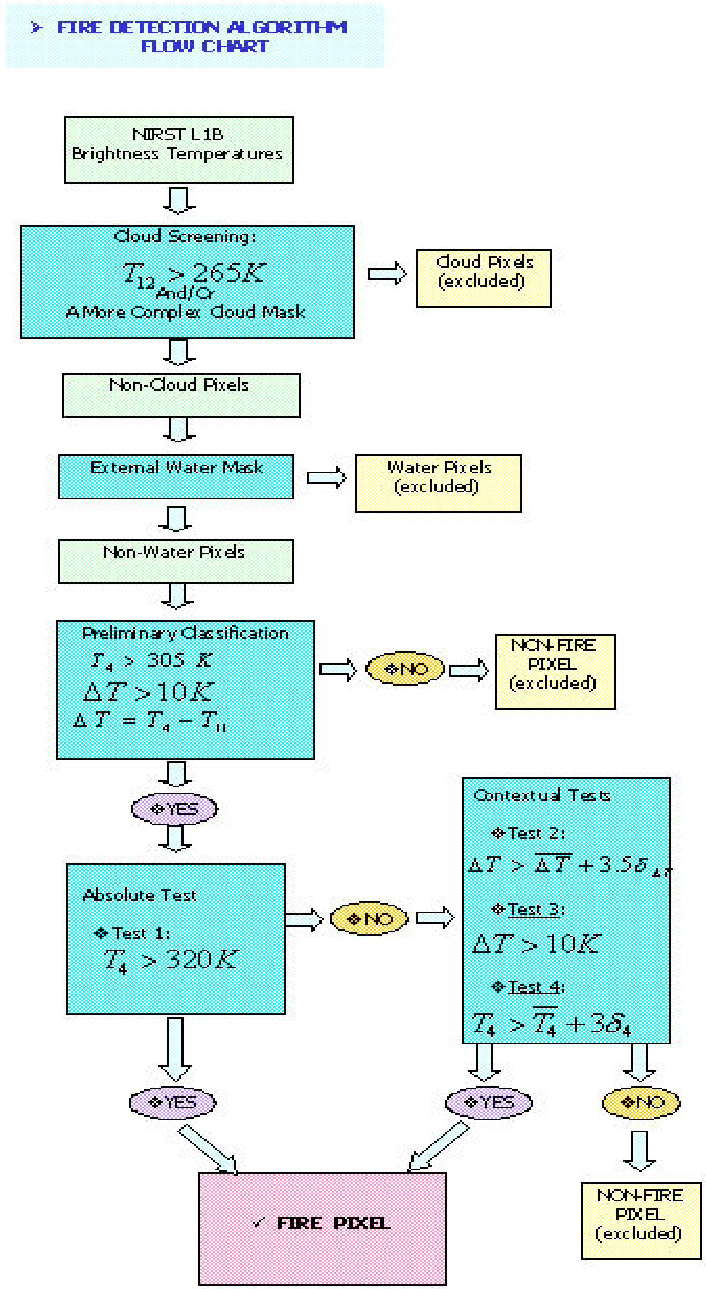


(From Wooster et al., 2003)

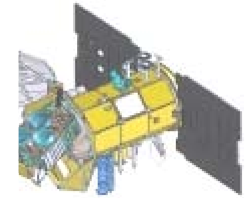
NIRST pixel size is similar to BIRD pixel size

FIRE Detection Algorithm (based on MODIS algorithm, Giglio 2003)

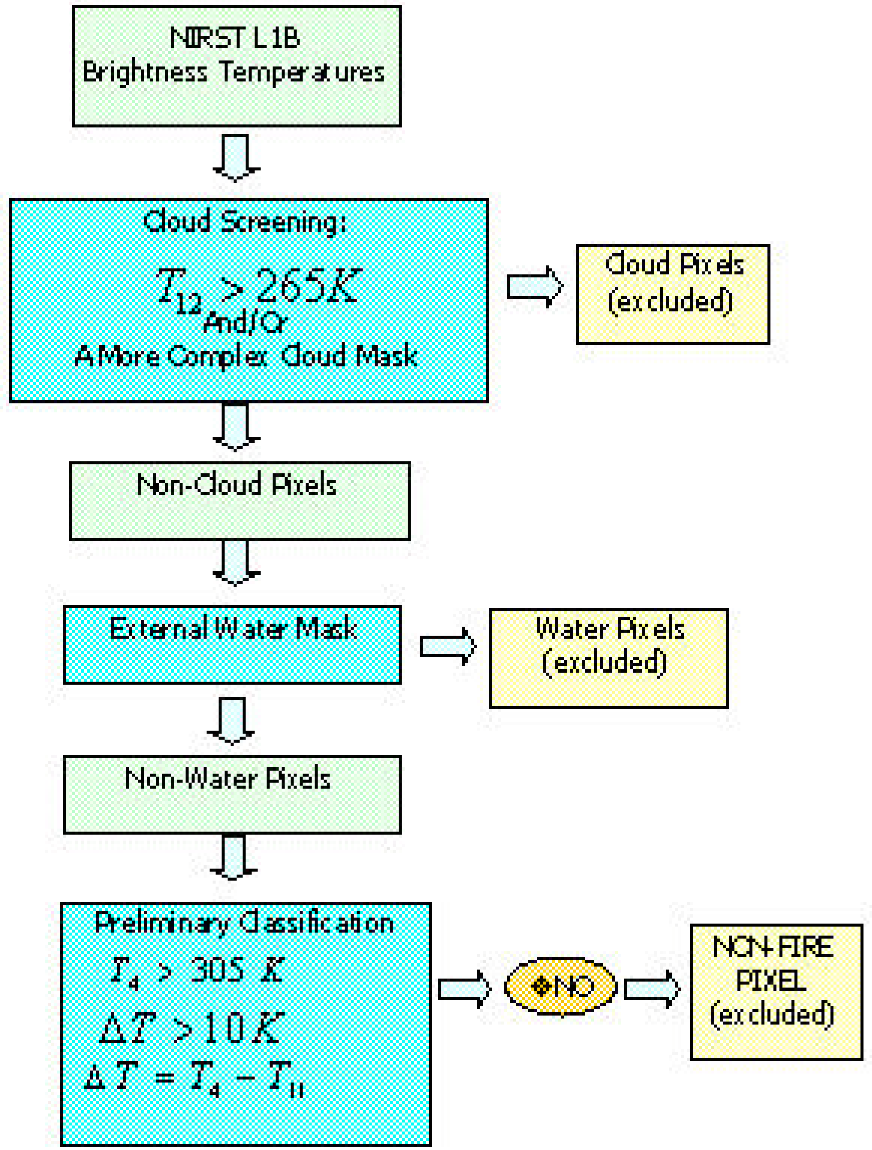




➢ FIRE DETECTION ALGORITHM FLOW CHART



Flow chart of the
Fire Detection Algorithm:

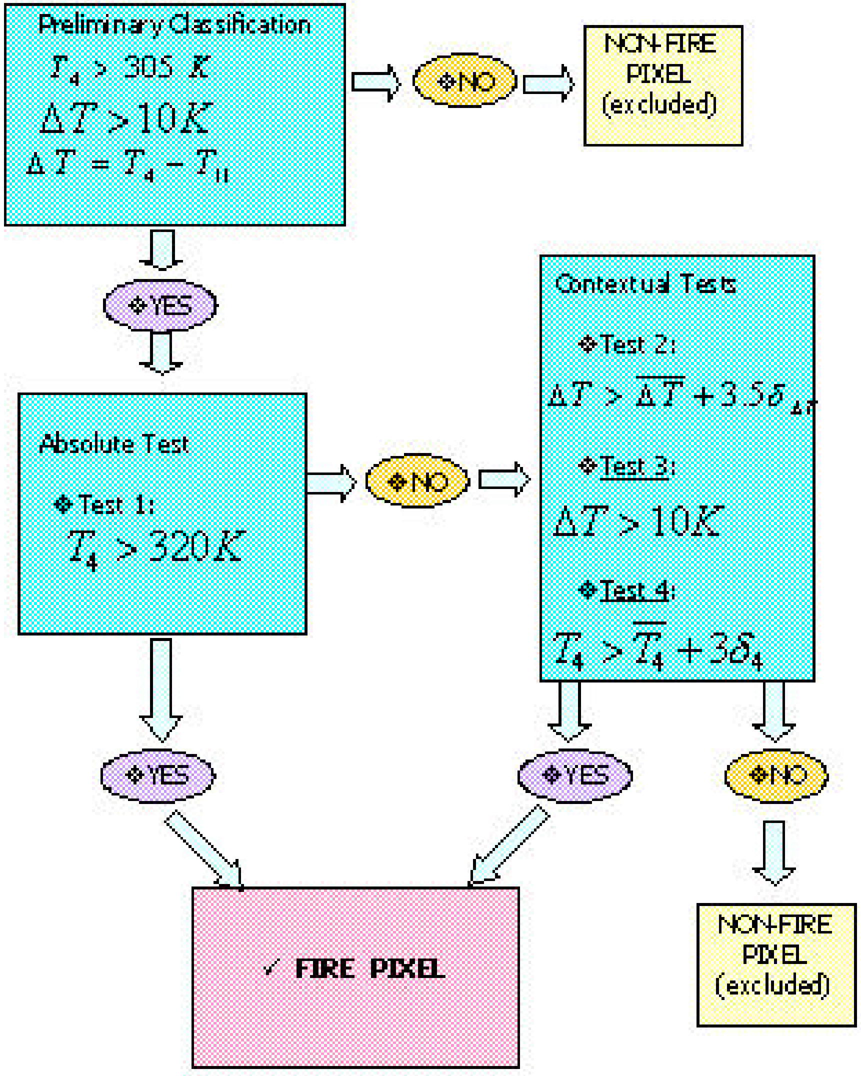


Continued…

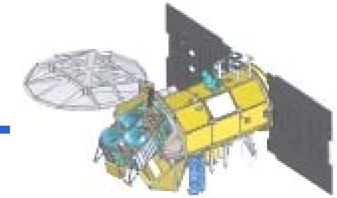
Fire Mapping and Fire Radiative Power

Flow chart of the Fire Detection Algorithm:

Continued…



Fire Mapping and Fire Radiative Power



❖Fire Radiative Power (FRP)

Fires burn extensive areas in different vegetated landscapes across the globe, and constitute a major disturbance to land-based ecosystems.

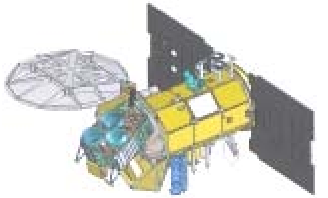
By voraciously consuming biomass, releasing intense heat energy, and emitting thick plumes of smoke into the atmosphere, such large-scale fires exert several adverse effects on life, property, the environment, weather, and climate both directly and indirectly**.**

- **FRP is the amount of radiant heat energy liberated per unit time**
- **FRP** is related to the rate at which fuel is being consumed.

- Measuring **FRP** and integrating it over the lifetime of the fire provides an estimate of the **total Fire Radiative Energy (FRE),**

- **FRE,** for wildfires should be **proportional to the total mass of fuel biomass combusted.**

Fire Mapping and Fire Radiative Power



For each fire pixel detected, FRP is estimated using the empirical relationship of Kaufman et al. (1998),

$$FRP = (\kappa_{sensor} 4.34 \times 10^{-19} MWK^{-8} km^{-2})(T_4^8 - \overline{T}_4^8) A_{pix}$$

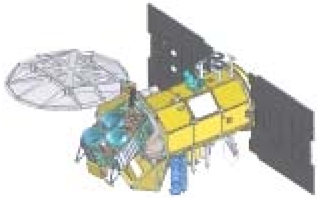
where,

T_4 → 4-µm brightness temperature of the fire pixel

$\overline{T}_4$ → mean 4-µm brightness temperature of the non-fire background

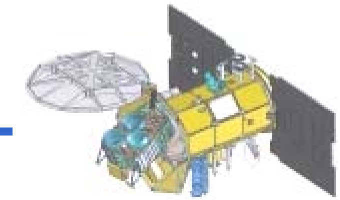
A_{pix} → total area (in km2) of the pixel in which the fire was detected, taking into account its deformation due to projections and scan angles.

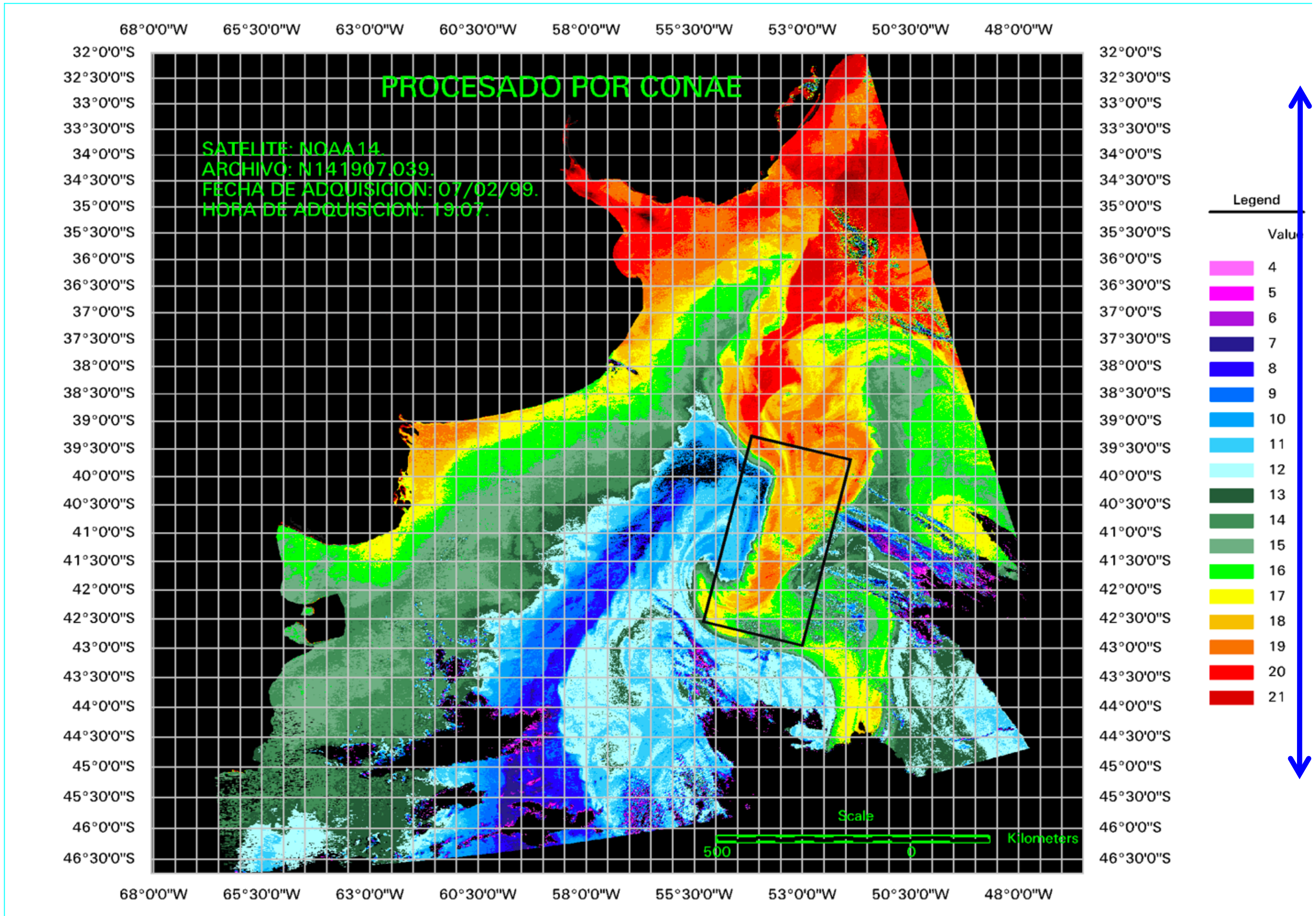
✓ The resulting value of the FRP is expressed in MW.

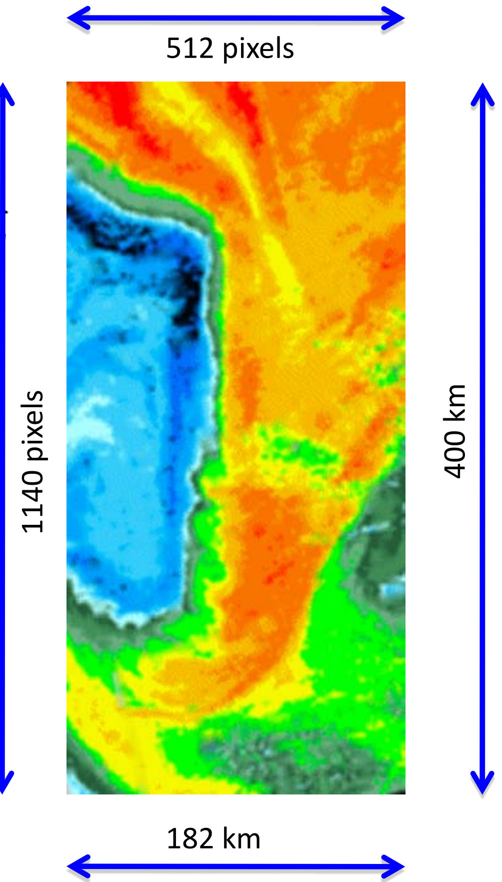


Sea Surface Temperature

Sea Surface Temperature

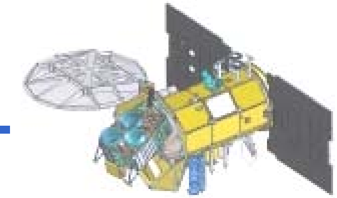






What a NIRST (almost 1 minute long) nadiral scan over the Malvinas-Brazil eddies would be

Sea Surface Temperature

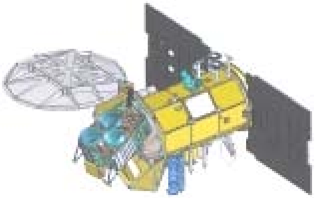


NIRST SST Algorithm will be based on the current algorithm that is used to calculate the AVHRR SST product, a non-linear split window equation:

$$\mathbf{SST = \alpha + \beta BT_{11} + \gamma(BT_{11} - BT_{12})T_{ref} + \delta[\sec(\Theta) - 1](BT_{11} - BT_{12})}$$

Where,

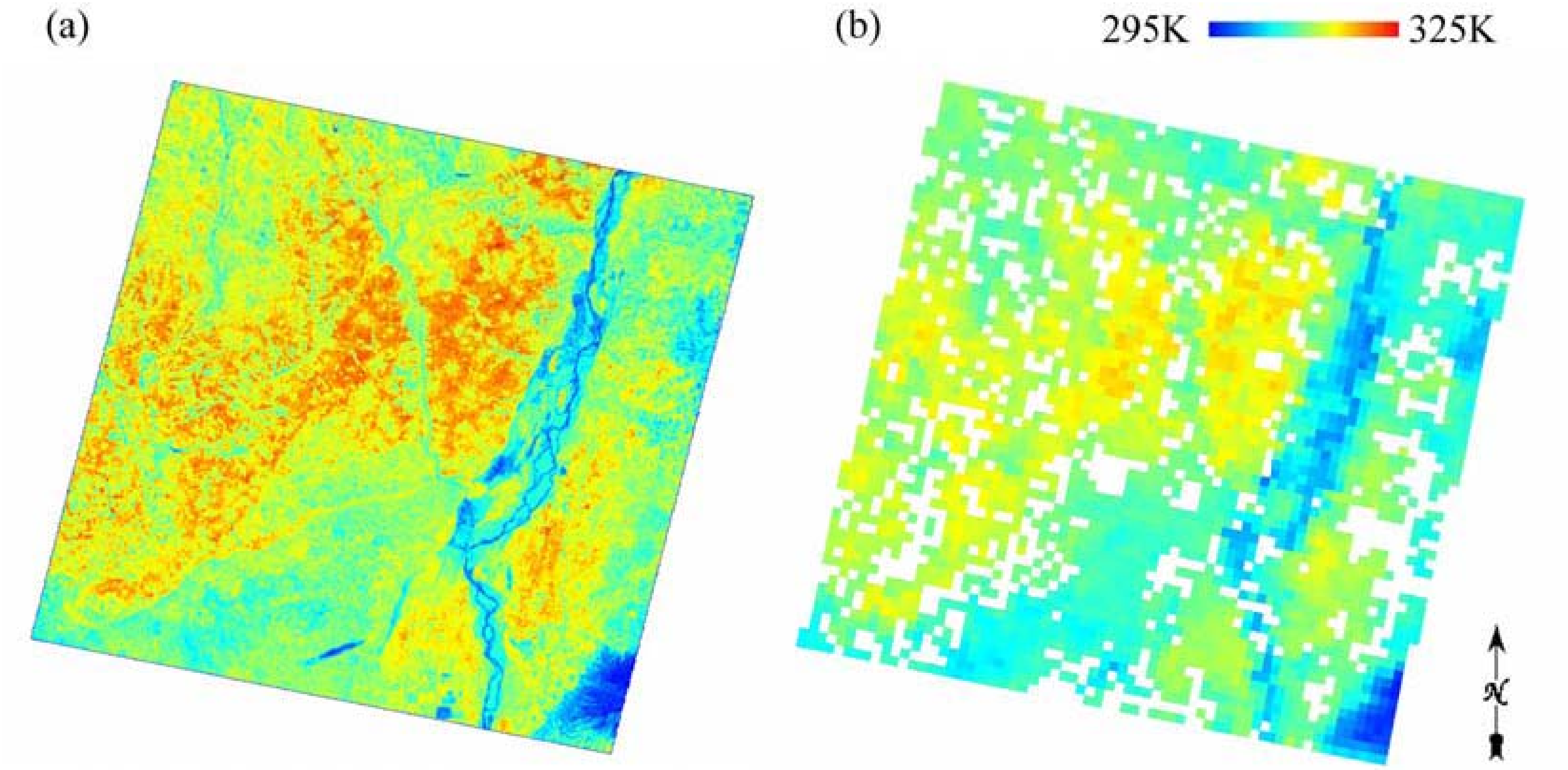
- T_{ref} is an estimated SST
- $\mathbf{BT_{11}}$ and $\mathbf{BT_{12}}$ are the brightness temperatures in bands 11 and 12 µm
- **α , β, γ and δ** *are* coefficients that should be **computed locally**
  (By regressing equations with in-situ data, plus either MODTRAN simulated BT_{11} and BT_{12}, or NIRST data once in orbit) and updated periodically.
- **Θ** is the **viewing angle**



Land Surface Temperature

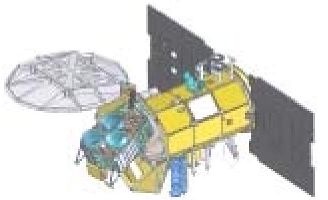
Land Surface Temperature

Example of ASTER LST compared to MODIS LST for the same area of study



(From Liu et al., 2009)

Land Surface Temperature



LST Algorithm

$$T_S = (A_1 + A_2 \frac{1-\varepsilon}{\varepsilon} + A_3 \frac{\Delta\varepsilon}{\varepsilon^2}) \frac{T_{11}+T_{12}}{2} + (B_1 + B_2 \frac{1-\varepsilon}{\varepsilon} + B_3 \frac{\Delta\varepsilon}{\varepsilon^2}) \frac{T_{11}-T_{12}}{2} + C$$

Where:

$$\Delta\varepsilon = (\varepsilon_{11} - \varepsilon_{12}) \qquad \varepsilon = \frac{(\varepsilon_{11} + \varepsilon_{12})}{2}$$

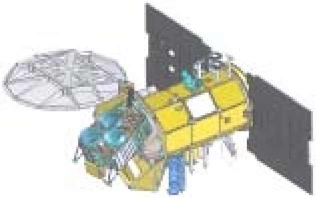
are the difference and mean of surface emissivities in bands 11 and 12 μm, which will be obtained with the MODIS 250m NDVI product,

T_{11} and T_{12} are the brightness temperatures in bands 11 and 12 μm,

A_1, A_2, A_3, B_1, B_2 and B_3 are coefficients that will be obtained by regressing equations with in situ data and MODTRAN simulated brightness temperatures.

Volcanic Activity Monitoring

Volcanic Activity Monitoring



✓**Volcanic ash detection**

In standard visible and infrared satellite imagery volcanic ash clouds can resemble water-bearing clouds.

However, the radiative absorption properties of the silicate in the volcanic ash are different to those of water in the infrared wavelength range 11-12 microns.

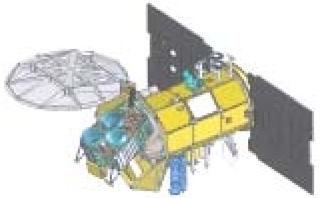
An image showing the brightness temperature difference between channels at 11 and 12 microns (BT11 - BT12) can be used to **distinguish volcanic ash** from water-bearing clouds.

In general:

- BT11 - BT12 > 0 for water-bearing clouds
- BT11 - BT12 < 0 for volcanic ash clouds

AQUARIUS/SAC-D

Volcanic Activity Monitoring



✓ **Hot Spot Detection -** Normalized Thermal Index Product (Wright et al., 2003)

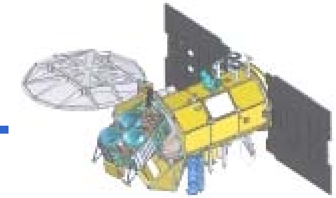
$$NTI = \frac{B\ 4\ \mu m - B\ 12\ \mu m}{B\ 4\ \mu m + B\ 12\ \mu m} \quad (\ Watt\ /\ m^2\ \ str\ \mu m\ )$$

NTI > Threshold

✓ **Hot Spot Detection Product -** Average Zones. (Vicari et al., 2007)

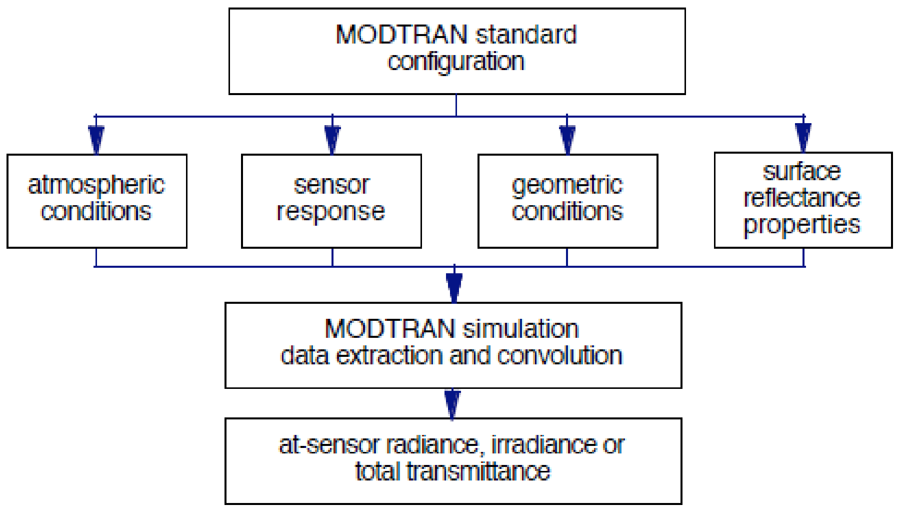
Works with a difference image: **BTD (3.9 – 11) µm,**

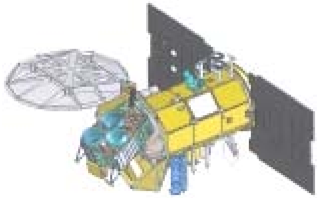
and compares values between the zones containing the presumable hot spot and its neighbouring areas.



NIRST simulated data

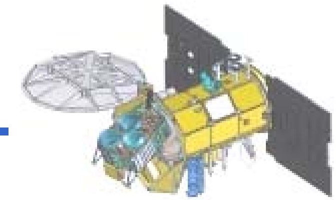
Simulations shall be made by using the atmospheric **radiative transfer model MODTRAN** to simulate the TOA radiance with the appropriate thermal infrared channel **response function** of the NIRST sensor on board Aquarius/SAC-D.



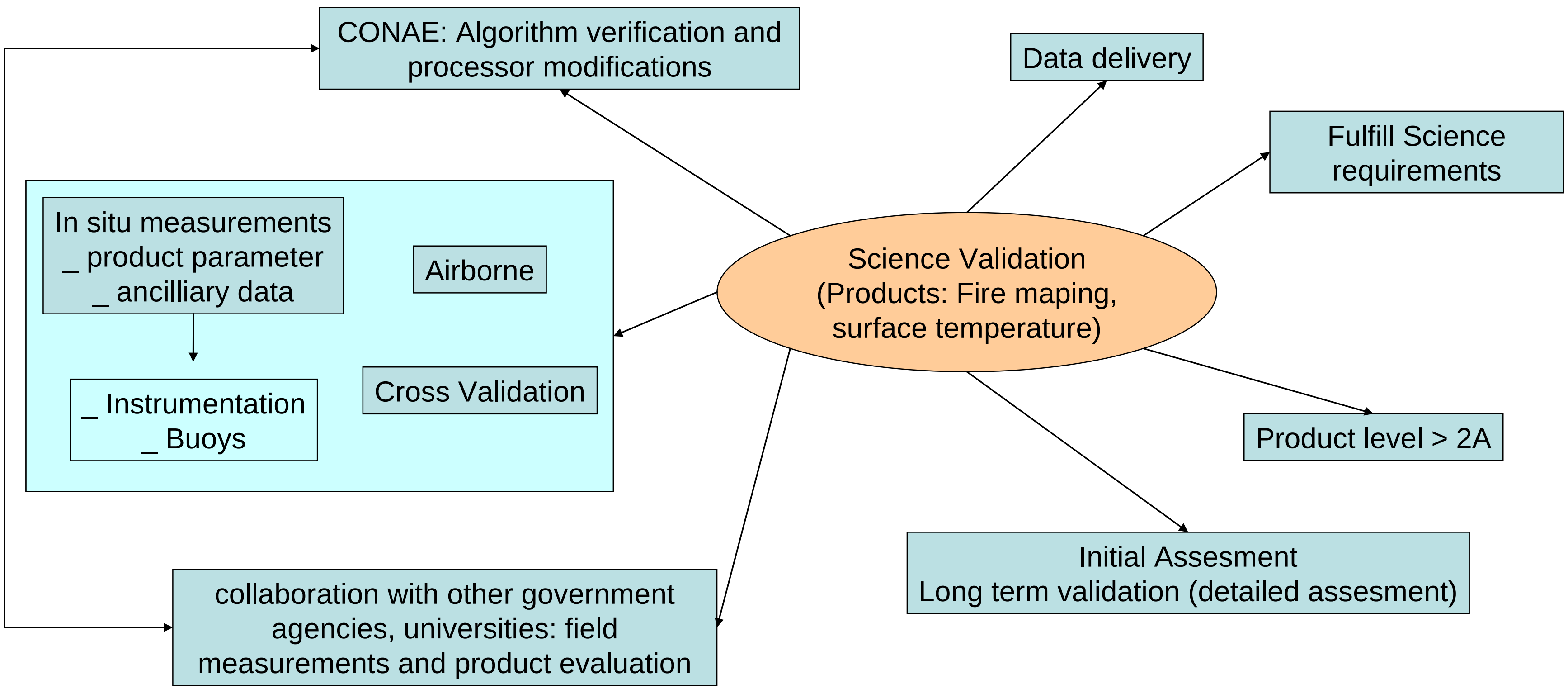


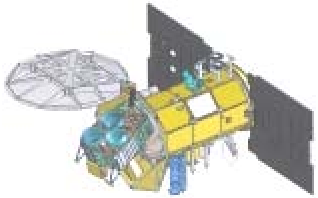
VALIDATION

- **Validation is a critical step in the quality control of products derived from Earth observation.**
- The main aim of a validation program is to assess whether the measurement processes are being achieved within the science requirements through validation of the final product.
- **Science** Validation **of NIRST derived products consists of** independent determination **of this products and** comparison **with the ones derived from NIRST processor.**
- **It may involve comparison of products with similar products derived by conventional means (in situ direct measurements of parameters such as wind, temperature, humidity, etc.). It is important that those products have themselves been validated and their accuracy and uncertainty established.**



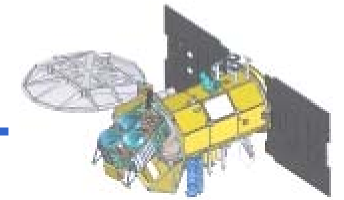
Validation outline





Thank you!

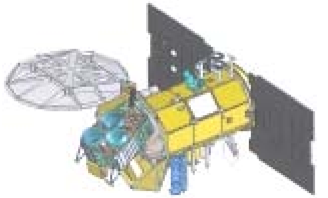
AQUARIUS/SAC-D



		MWIR2 (Band 1)	LWIR2 (Band 2)	LWIR3 (Band 3)
Central wavelength		3.8 µm	10.85 µm	11.85 µm
Band Limits		3.4 – 4.2 µm	10.4 – 11.3 µm	11.4 – 12.3 µm
Temperature	Min.	400K	250K	
	Max.	1000K	500K	
NEΔT		<1.5K @ 400K	<0.8K @ 300K	<0.4K @ 300K
Temp. accuracy		2.5K @ 400K	1.5K @ 300K	<2K @ 300K
Detectable size of fire event		$200 m^2$ @ 1000K		

VALIDATION

- **Validation is a critical step in the quality control of products derived from Earth observation.**
- The main aim of a validation program is to assess whether the measurement processes are being achieved within the science requirements through validation of the final product.
- **Science** Validation **of NIRST derived products consists of** independent determination **of this products and** comparison **with the ones derived from NIRST processor.**
- **It may involve comparison of products with similar products derived by conventional means (in situ direct measurements of parameters such as wind, temperature, humidity, etc.). It is important that those products have themselves been validated and their accuracy and uncertainty established.**

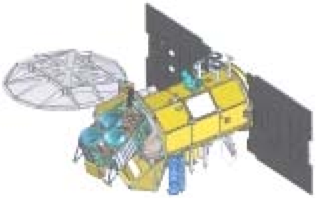


During the initial validation phase, the main objective is to make a first assessment of the quality of the NIRST derived data products, in a limited number of sites and seasons.

During the mission as a whole, the aims of the on-going validation program are:

- To make a detailed assessment of the quality of the NIRST data products in an increasing number of sites and seasons.
- To monitor the quality of the NIRST data products over the duration of the mission.

It shall be performed periodically to monitor the quality of the NIRST data products over the duration of the mission.



However data is acquired, an implementation for vicarious validation follows:

1- Site determination. The available ancillary data for the site should be taken into account. The extension of the area shall cover several NIRST pixels

2- Determination of necessary data as input to the process. This includes atmospheric and in-situ data from instrumentation or dependable sources.

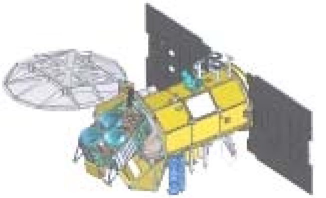
3- Temperature retrieval from satellite. This will involve the algorithm, radiative transfer calculations (MODTRAN) with emissivity and atmospheric data as input**.**

4- Surface temperature determination:

4a- Through in-situ temperature measurements. Difference between bulk and skin temperature should be made.

4b- Through simulation with radiative transfer calculations (MODTRAN) with several temperatures and measured or simulated atmospheric conditions for the site of interest.

5- Derived product and measured/simulated product comparison

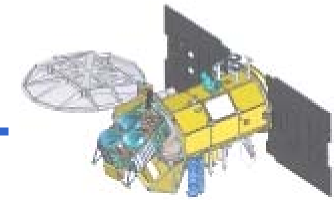


6- Evaluation of differences. This could involve a study of temperature as a function of meteorological conditions to determine whether differences can be attributed to a bad simulation or there is no possible match between both products after varying parameters among reasonable values for the site and season. This would require validation sites with equipment or buoys for time series evaluation, a global communication system could be used for this purpose to access the data. Wind speed, humidity and air temperature are some of the parameters needed to determine the boundary layer properties.

7- **Determination of causes of temperature retrieval error**. Must differentiate between:

- temperature retrieval
- model assumptions
- meteorological data

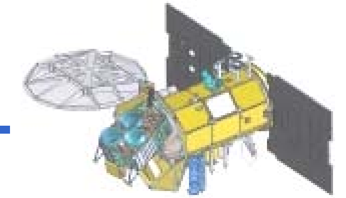
8- **Process (or algorithm) correction**.



Validation of active fire products has been recognized to be a difficult task which lacks well-established procedures.

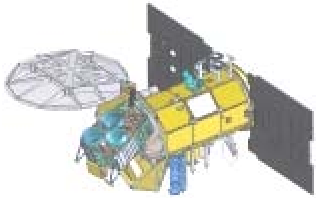
Flagging pixels that contain burning as “fire”, which yields “yes/no” binary fire maps, is commonly referred to as **“active fire detection.”**

Independent information on fires can be obtained either by the **direct observation of fires** by alternative means or by **observing fire effects such as atmospheric emissions or land cover change**. For example, smoke plumes were used for the accuracy assessment of fire detections from the Advanced Very High Resolution Radiometer (AVHRR).



Geophysical parameters validation:

- Field work is needed to measure the geophysical parameters of interest, in specified locations, simultaneously with NIRST measurements
- The campaigns must be designed to collect a statistically significant number of samples
- Data for parameters validation could be obtained from DCPs, using the DCS instrument on board SAC-D
- The selected algorithms must be used for the retrieval of the specific parameters under evaluation from NIRST measurements
- A statistical analysis relating the field measurements and the parameter retrieved values must be carried out to obtain representative figures of the algorithms performance



NIRST data Simulation:

At-sensor radiance simulation workflow with 4 input sections based on standard MODTRAN configurations.