GOES Early Fire Detection System

development and first validation results

Alexander Koltunov, Susan Ustin,

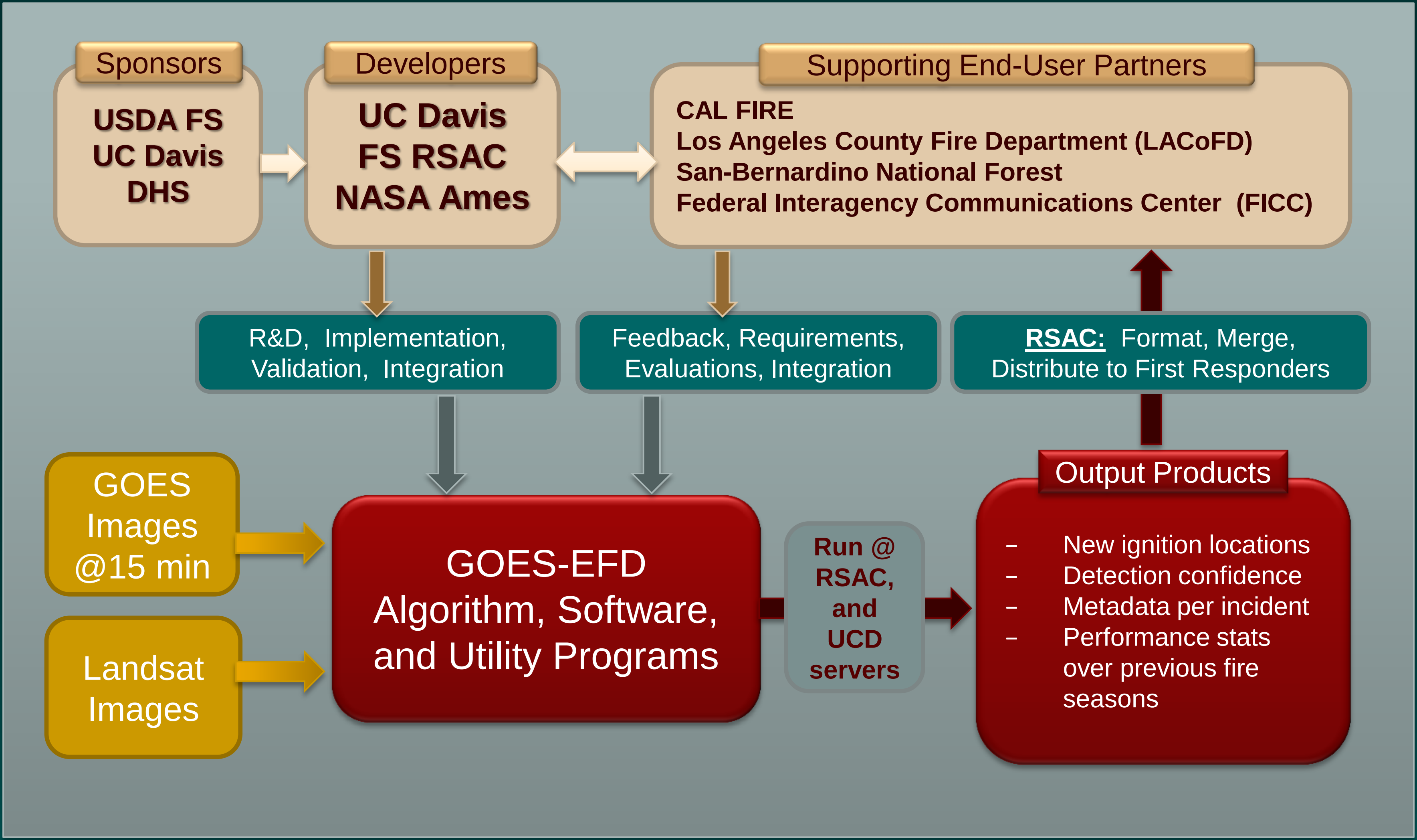
akoltunov@ucdavis.edu

Center for Spatial Technologies and Remote Sensing (CSTARS),
University of California, Davis

Brad Quayle, Brian Schwind

***USDA Forest Service* Remote Sensing Applications Center (RSAC)**

GOES-EFD effort: Data/Work Flow and Participants



Sponsors

USDA FS
UC Davis
DHS

Developers

UC Davis
FS RSAC
NASA Ames

Supporting End-User Partners

CAL FIRE
Los Angeles County Fire Department (LACoFD)
San-Bernardino National Forest
Federal Interagency Communications Center (FICC)

R&D, Implementation, Validation, Integration

Feedback, Requirements, Evaluations, Integration

RSAC: Format, Merge, Distribute to First Responders

GOES Images @15 min

Landsat Images

GOES-EFD Algorithm, Software, and Utility Programs

Run @ RSAC, and UCD servers

Output Products

- New ignition locations
- Detection confidence
- Metadata per incident
- Performance stats over previous fire seasons

GOES Early Fire Detection (GOES-EFD) System

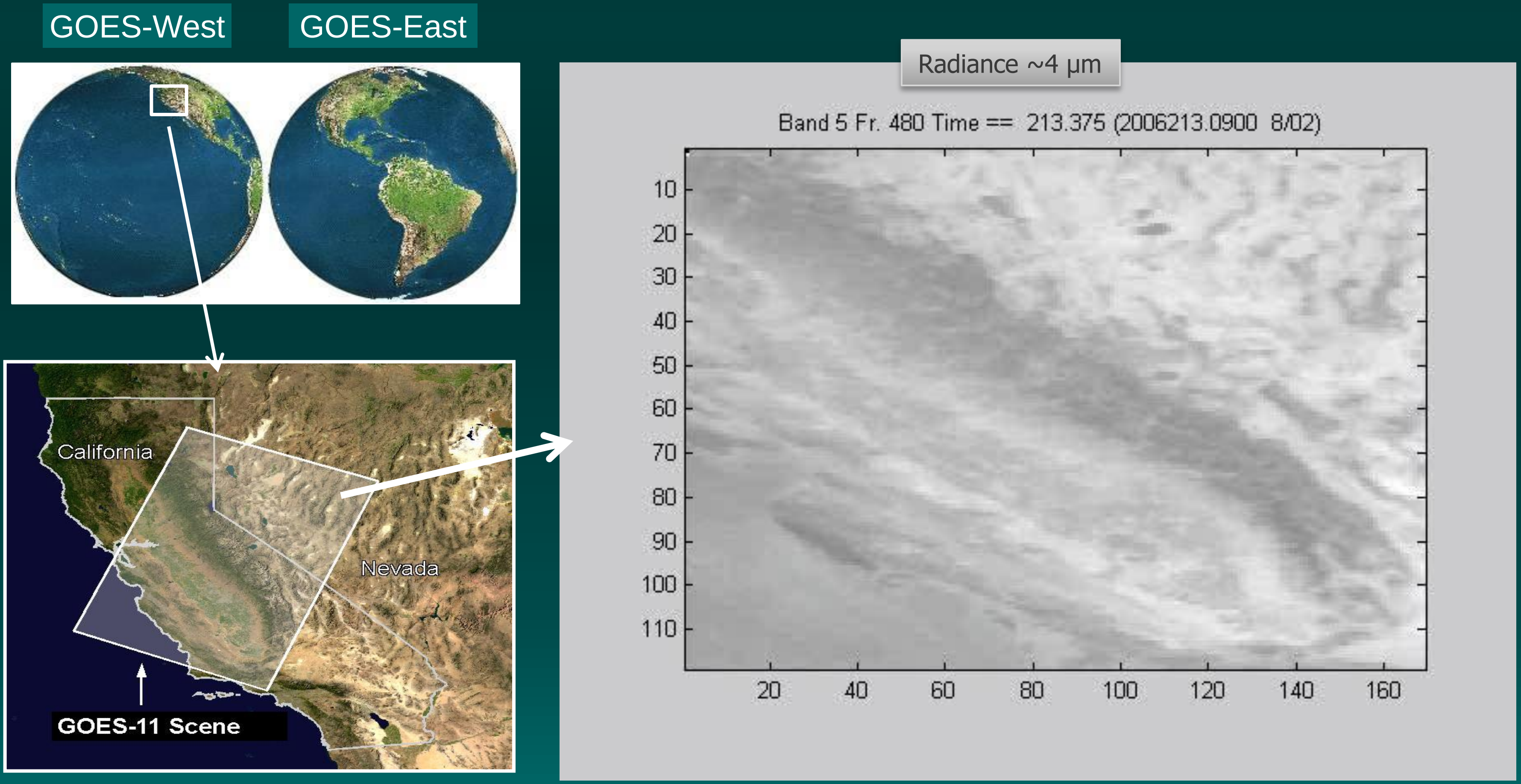
Objective: A low-cost and reliable capacity for systematic *rapid* detection and initial confirmation of new ignitions at regional level (TBD)

Detect new wildfire incidents consistently within first 1-2 hours after start, preferably before they are reported by conventional sources

Geostationary Satellites: GOES

GOES Imager :

- Viewing geometry – fixed
- VIS and TIR images every 15-30 min
- TIR pixel size ~ **6** x **4 km** over CA



WF-ABBA* operational algorithm for active fire monitoring

Designed for applications interested in, for example:

- % eventually detected fires
- burned area accuracy
- number of false positive pixels

Optimized well for global scale performance

***Wildfire Automated Biomass Burning Algorithm** (Prins & Menzel, 1994)

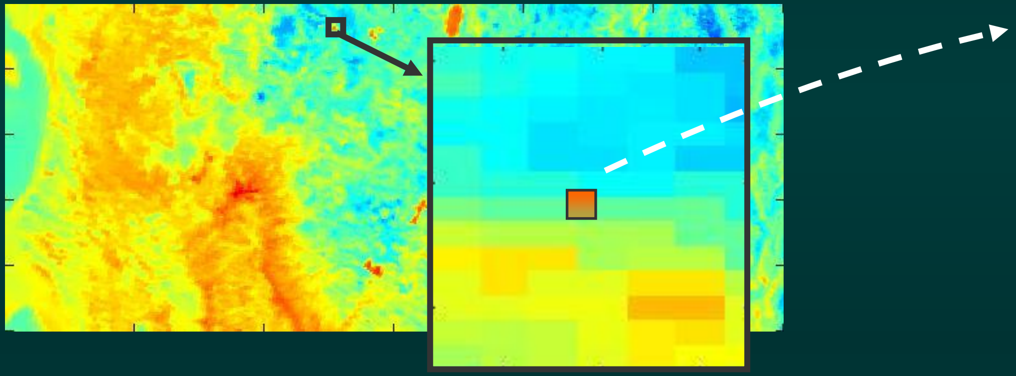
In contrast,

Early Detection has different priorities:

- Minimize the time to initial detection of an incident
- Minimize the number of false incidents (alarms)

WF-ABBA Principle: Contextual Detection

(find pixels that are much hotter than neighbors)



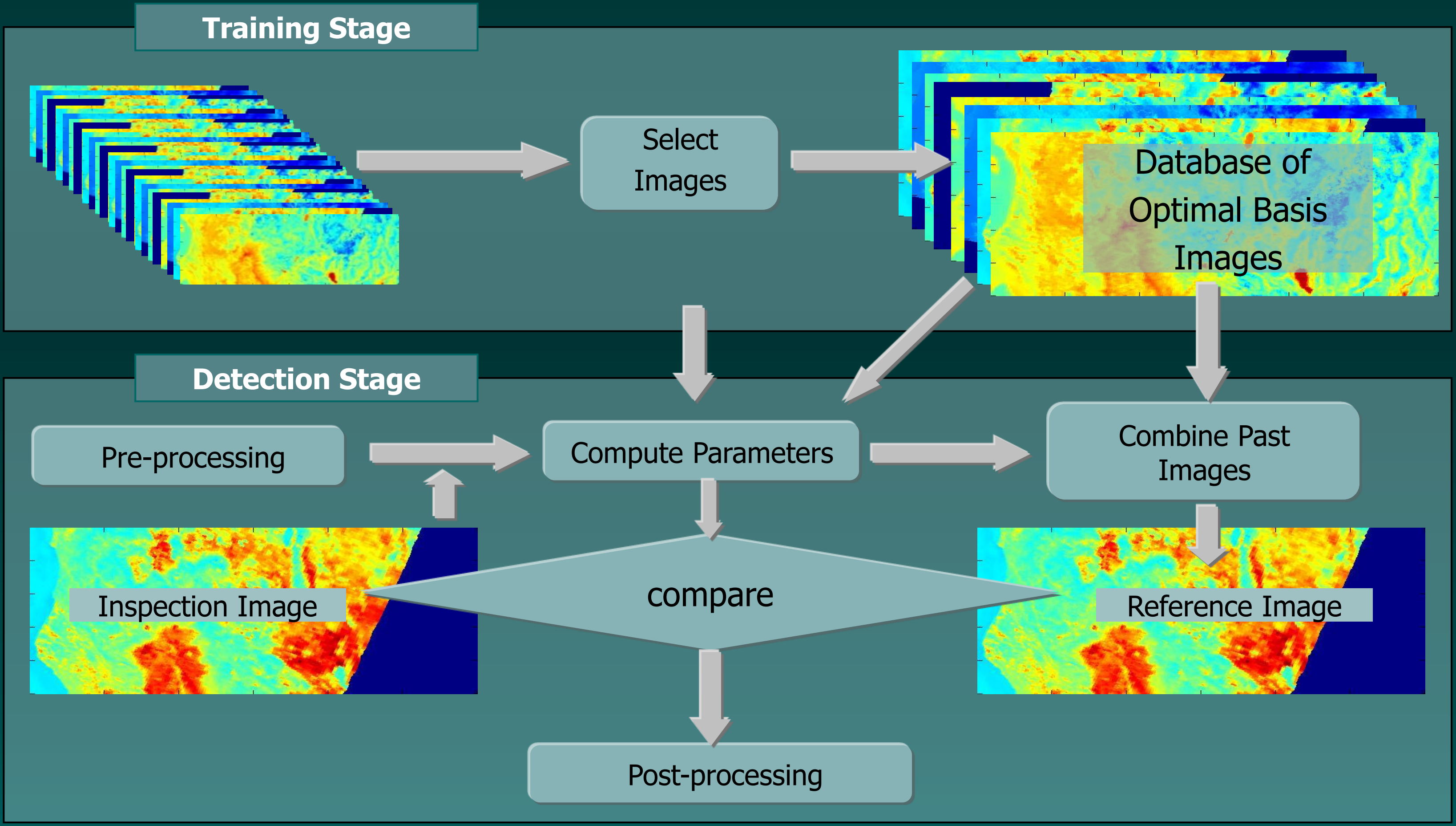
Fire Candidate

$$\boxed{T > \mu + 3\sigma}$$

- Good for detecting large/hot fires (sooner or later)
- OK for thermally homogeneous areas (**σ is small**)
- Less effective on ecosystem boundaries

GOES-EFD principle: Temporal + Contextual
(detect anomalous changes in surface properties)

Multitemporal background prediction by Dynamic Detection Model:



Training Stage

Select Images

Database of Optimal Basis Images

Detection Stage

Pre-processing

Compute Parameters

Combine Past Images

Inspection Image

compare

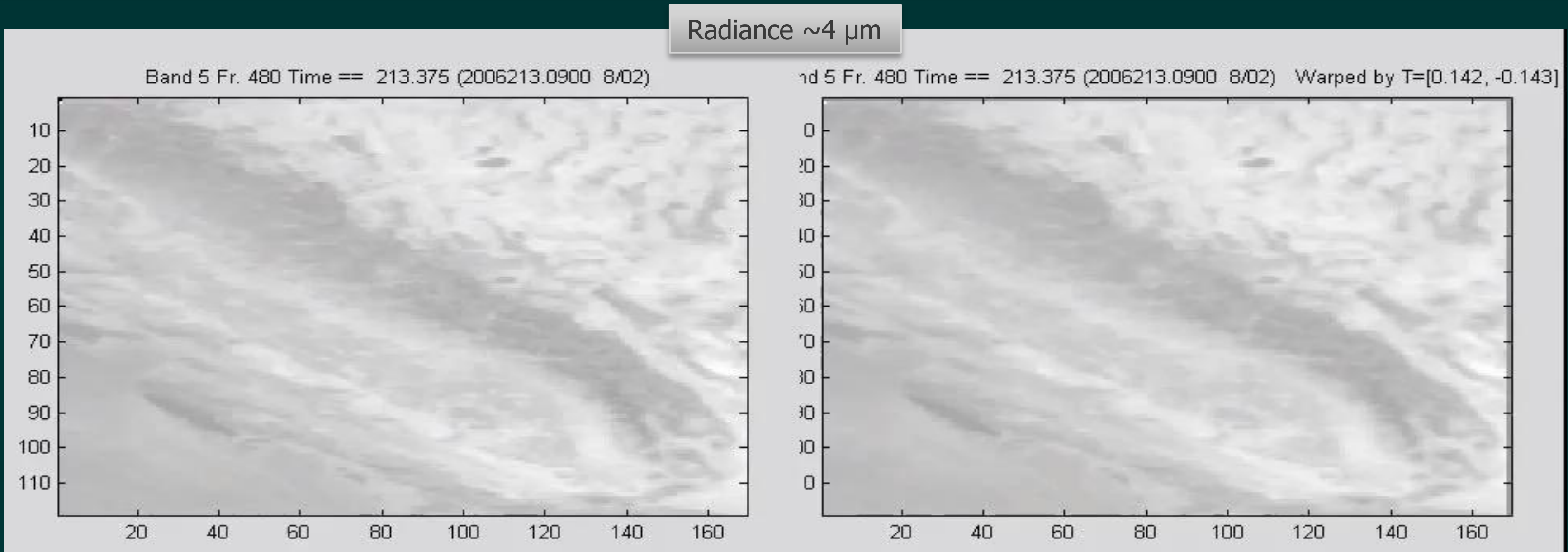
Reference Image

Post-processing

Koltunov & Ustin S.L. (2007) *Rem Sens Environ*

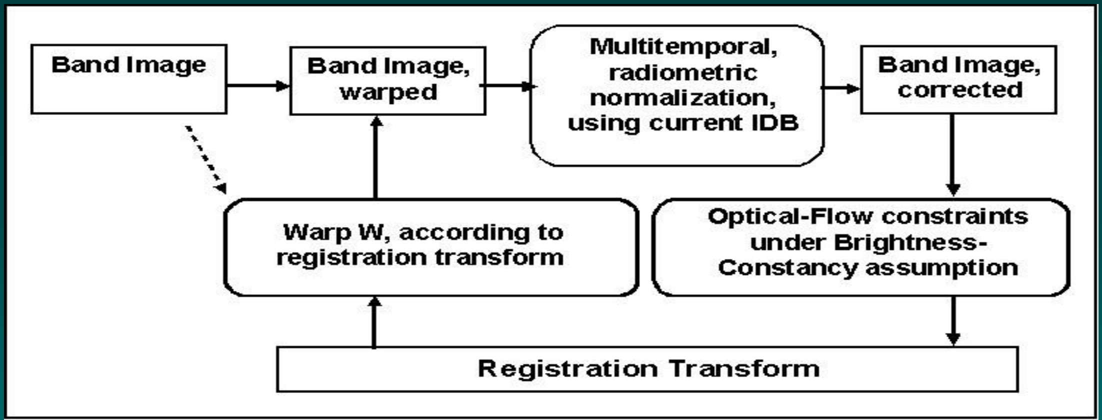
Koltunov, Ben-Dor, & Ustin (2009) *Int J of Rem Sens*

Automatic Thermal Image Registration



original

registered



Band Image

Band Image, warped

Multitemporal, radiometric normalization, using current IDB

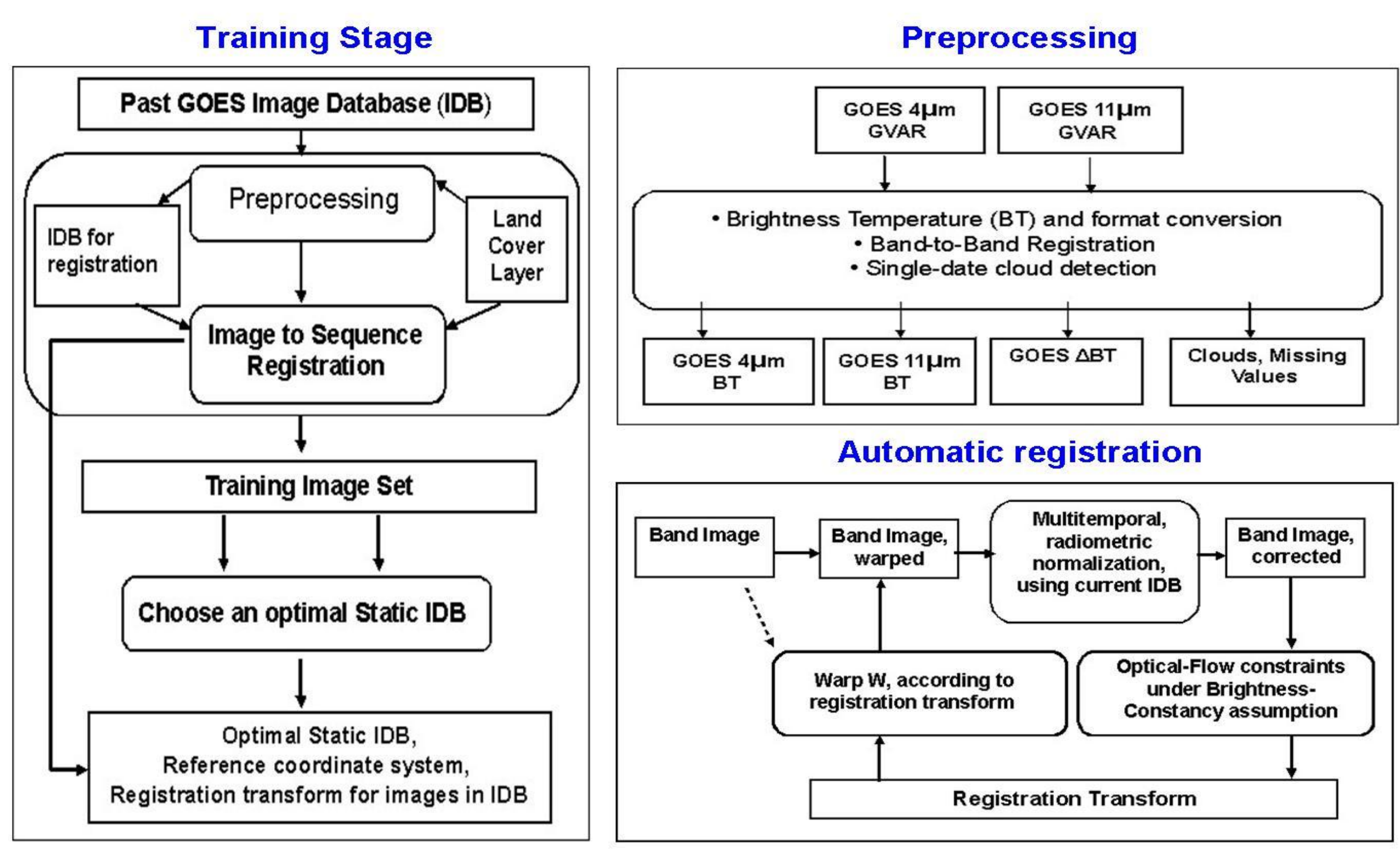
Band Image, corrected

Warp W, according to registration transform

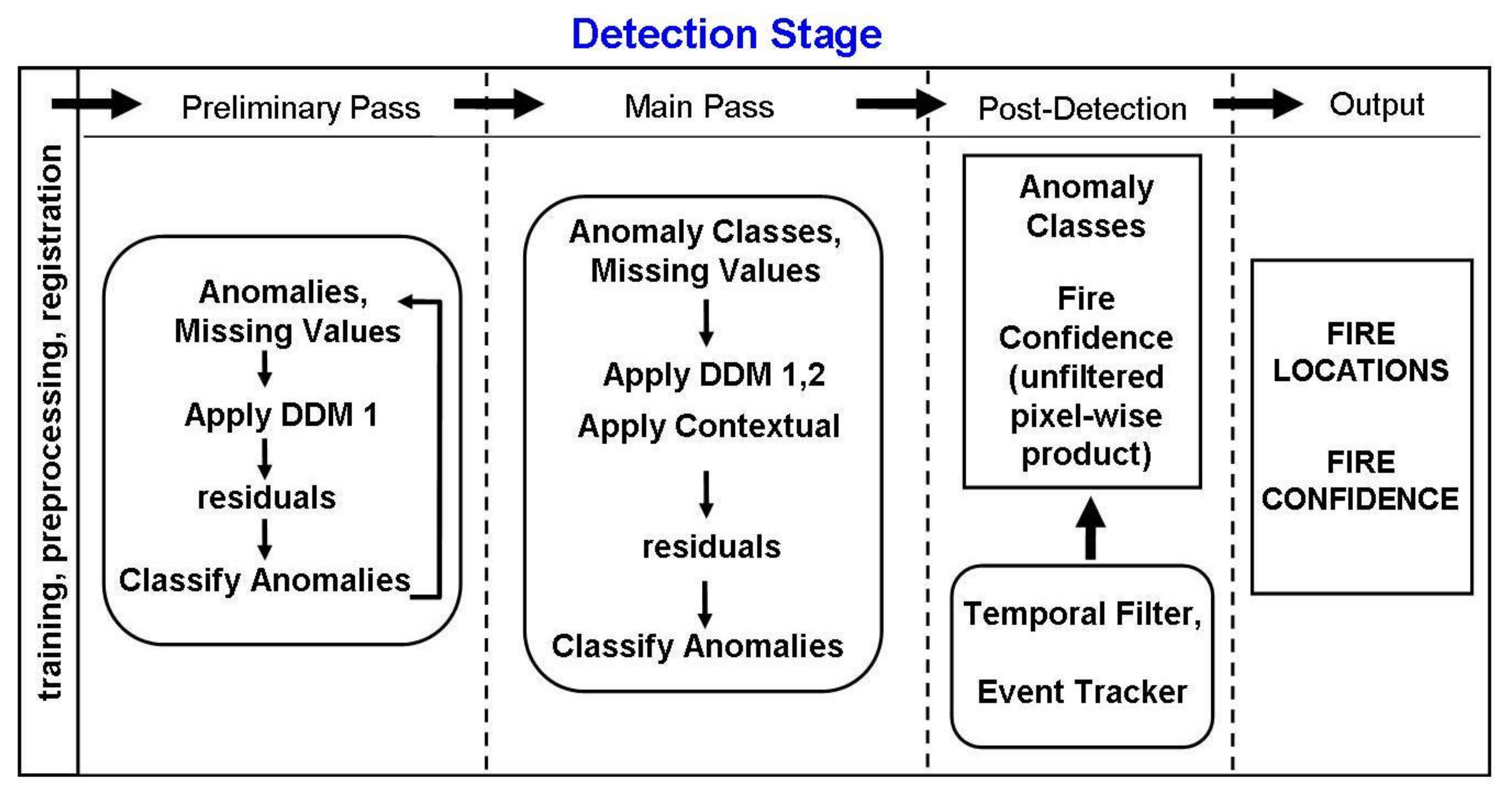
Optical-Flow constraints under Brightness-Constancy assumption

Registration Transform

GOES-EFD ver. 0.2: Training and Preprocessing



GOES-EFD ver. 0.2: Detection Stage



Detection Stage

training, preprocessing, registration

Preliminary Pass

Anomalies, Missing Values

Apply DDM 1

residuals

Classify Anomalies

Main Pass

Anomaly Classes, Missing Values

Apply DDM 1,2

Apply Contextual

residuals

Classify Anomalies

Post-Detection

Anomaly Classes

Fire Confidence (unfiltered pixel-wise product)

Temporal Filter,

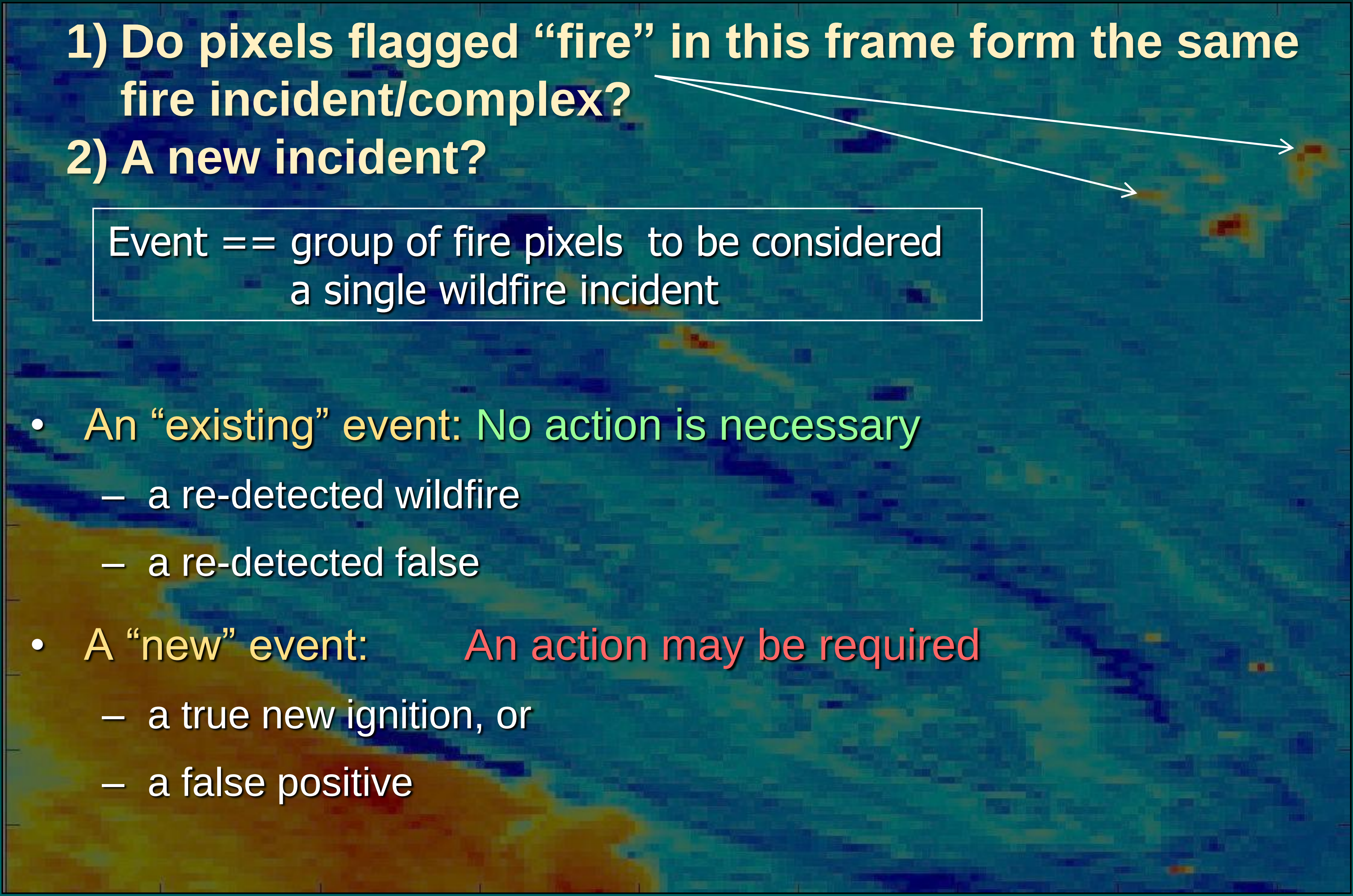
Event Tracker

Output

FIRE LOCATIONS

FIRE CONFIDENCE

Event Tracking: from pixels to events



1) Do pixels flagged "fire" in this frame form the same fire incident/complex?

2) A new incident?

Event == group of fire pixels to be considered a single wildfire incident

- An "existing" event: No action is necessary
  - a re-detected wildfire
  - a re-detected false
- A "new" event: An action may be required
  - a true new ignition, or
  - a false positive

Initial Experiment with fire season 2006 Central California

Detection Period: **40** days; **2852** images: **Aug 3 – Oct 1** at ~**20**-min time step on average.

-- Substantial Cloud Cover

Wildfire Incidents* Used: Large (>2 ha final size) wildfires; CA only

Sample #1: **13** fires with known initial report HOUR

Sample #2: **25** fires with known initial report DATE

* Used wildfire incident databases from:

- California Department of Forestry and Fire Protection (CAL FIRE)
- Geospatial Multi-Agency Coordination (GeoMAC) group

Include wildfire incident reports from: USFS, BLM, NPS, CAL FIRE, et al.

Validation methodology: incidents

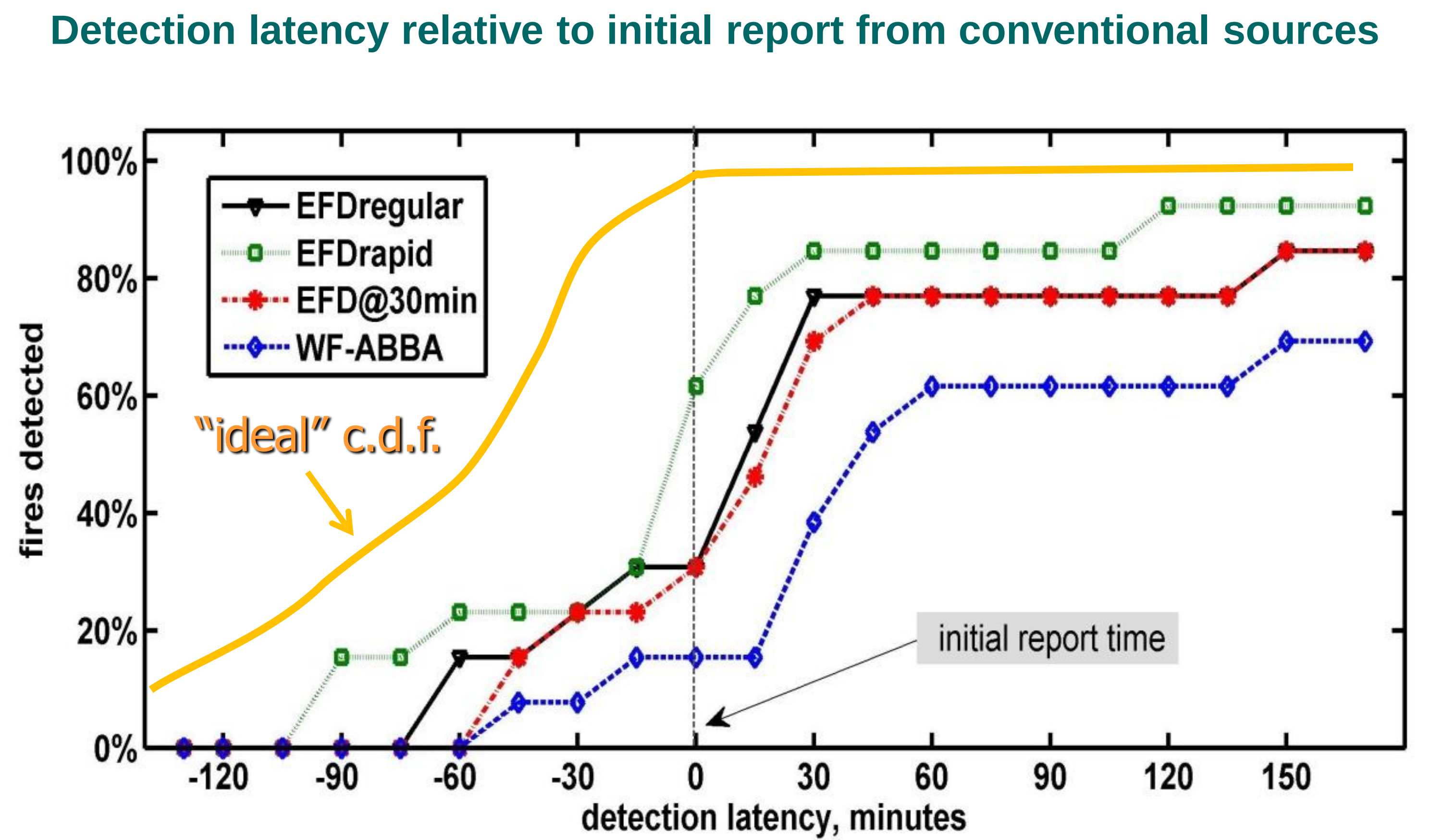
Koltunov, Ustin, & Prins (2012)

1. Match detections in space and time to official wildfire incident records (including fire initial report/start time and estimated end time)
2. Matched incidents == true positives
3. Unmatched incidents == a false positive OR un-reported fire

What about unreported/unrecorded incidents?
– check falses against new burns in Landsat

Koltunov A., Ustin, S. L., Prins, E (2012) "On timeliness and accuracy of wildfire detection by the GOES WF-ABBA algorithm over California during the 2006 fire season", *Remote Sensing of Environment*, in Revision

Detection timeliness: cumulative distribution function (c.d.f.)



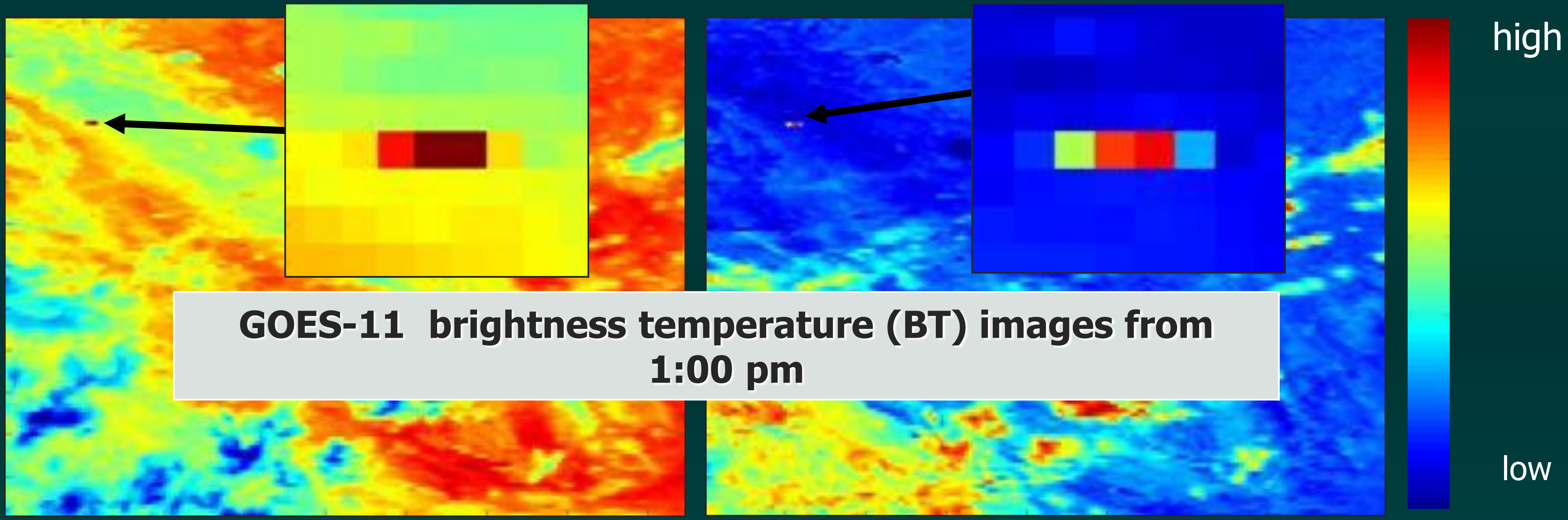
Performance statistics

Detected incidents	GOES-EFD rapid	GOES-EFD regular	GOES-EFD @30min	WFABBA @30min
for 13 fires with recorded report hour				
Detected in < 1 hour	11/13	10/13	10/13	7/13
Detected before reported	4/13	4/13	3/13	2/13
Total latency reduction	216 Min	142 min	105 min	45 min
for 25 fires with recorded report date				
Detected in < 12 hours	16/25	15/25	15/25	11/25
False/non-wildfire incidents	up to 784	up to 79	38 to 53	39 to 55

GOES-EFD detects fires earlier than WF-ABBA

Example

Marysville-Dobbins Fire: near Marysville, CA
reported @1:05 pm Aug 16, 2006



GOES-11 brightness temperature (BT) images from 1:00 pm

GOES-EFD first detection – in 12:10 pm image

Summary

- Initial, proof-of-concept version ready (optimizations under way)
- GOES-EFD will complement WF-ABBA global monitoring capabilities at regional level:

GOES Early Fire Detection algorithm	WF-ABBA algorithm
Optimized for Regional Scale Surveillance	Optimized for Global Scale Surveillance
Best for Detecting New Ignitions ASAP	Best for Consistently Monitoring Active Fires

Next steps:

- Development-test iterations
- Work with end-users partners to ensure sustained and informed use
- Validate extensively
- Deploy

Future Development Activities
(not currently funded)

- UC-Davis/RSAC team proposed to 2011 ROSES Applied Science (1-year Stage 1 "Feasibility") toward potential 3 more years of combined funding (NASA + USFS)
- Involve First Responders in the application design and tests ASAP:
  - How to best use ignition-candidates from GOES-EFD?
  - How to best combine GOES-EFD product with conventional wildfire identification means?
- Application Development:
  - Massive-scale algorithm optimizations and routine annual retrospective validations
  - Developing a stable real-time GOES GVAR data acquisition block (can NEX/RSAC facilitate real-time GOES GVAR image availability and initial standard preprocessing?)
  - Retrospective Validation: fully automate data processing flow
  - Incorporate auxiliary products MODIS daily Fuel Moisture (UC Davis), Lightning Strikes (Ames, NEX)

We gratefully acknowledge

Support by

- **USDA Forest Service**
- **University of California, Davis**
- **US Department of Homeland Security**

UC Davis GOES Receiver infrastructure and data are provided by

CIMIS (California Irrigation Management Information System) program

http://wwwcimis.water.ca.gov/cimis

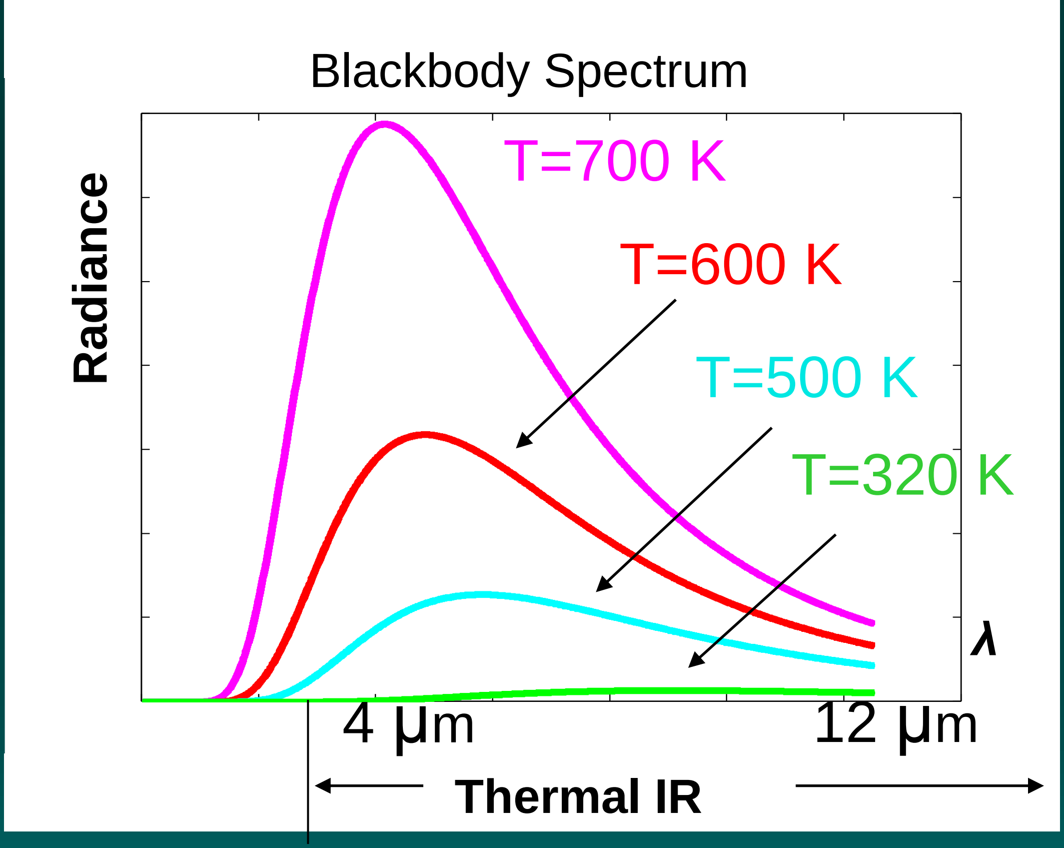
and personally thank

Vince Ambrosia	*NASA Ames*
Bruce Davis	*DHS*
Kevin Guerrero, Mark Rosenberg	*CAL FIRE*
Elaine Prins,	*UW-Madison/Consultant*
Quinn Hart,	*UC Davis*
Mui Lay, George Sheer	*UC Davis*

Physical Basis for Infrared Fire Detection

Planck's Law: **Radiance (λ) = $B(\lambda, T)$**

wavelength temperature


Blackbody Spectrum

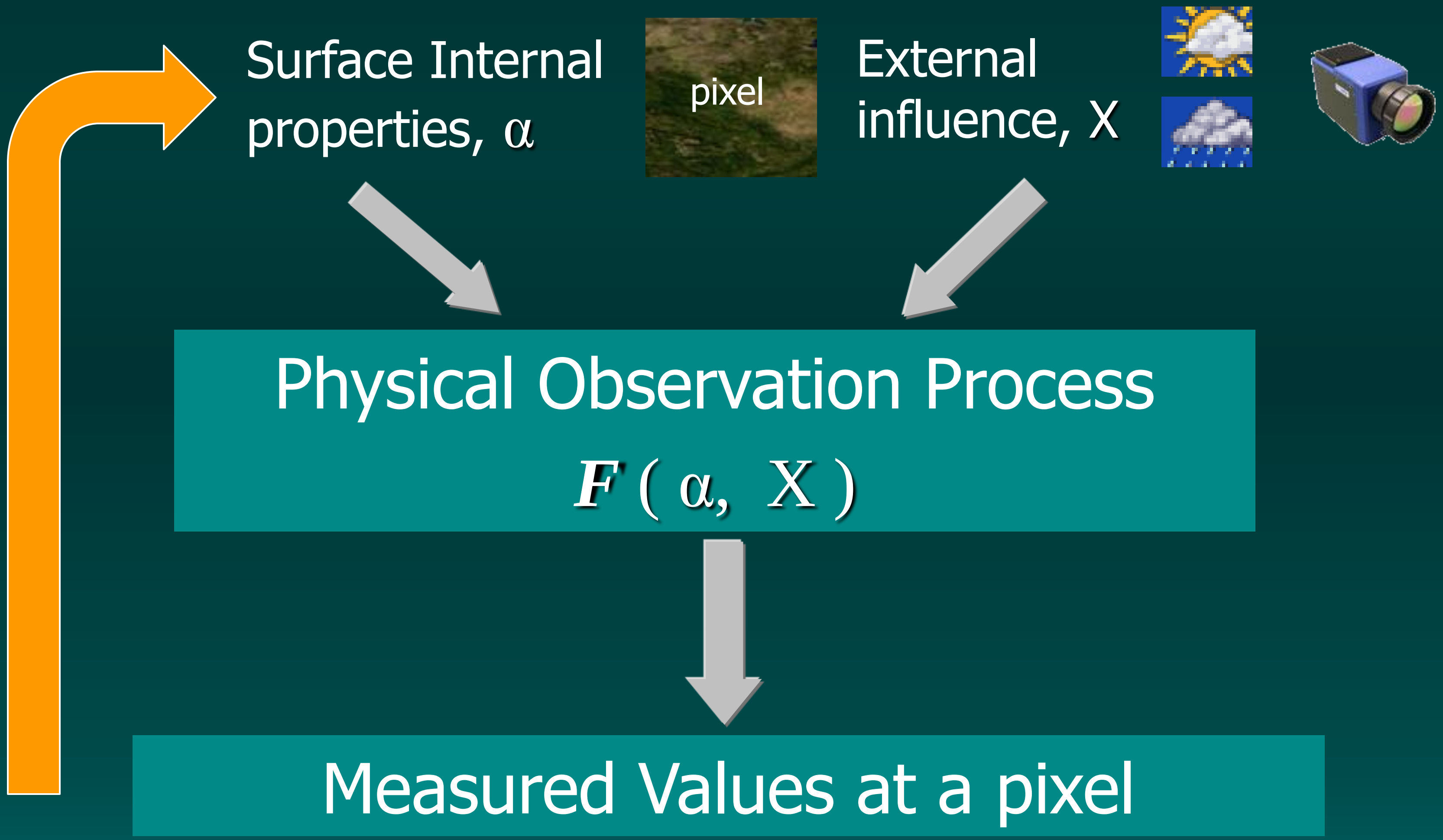
$$T_\lambda = B^{-1}(\lambda, R_\lambda)$$

$$T_{4\mu m} > T_{12\mu m}$$

Primary regions used for detection:

Short-wave TIR
(3 - 5 µm)
Long-wave TIR
(10 - 12 µm)

What’s actually happening at a pixel



Surface Internal properties, α

External influence, X

Physical Observation Process

$F(\alpha, X)$

Measured Values at a pixel

Next: What’s needed

Space-Invariant Prediction

$$W(t) \quad - \quad W_r(t) \quad = \quad \text{Residual}(t)$$

inspection image

reference image (no fires)

$$W_r(t) \approx \boldsymbol{H}[\,\gamma(t); W(t_1), \ldots , W(t_P)]$$

predictor function

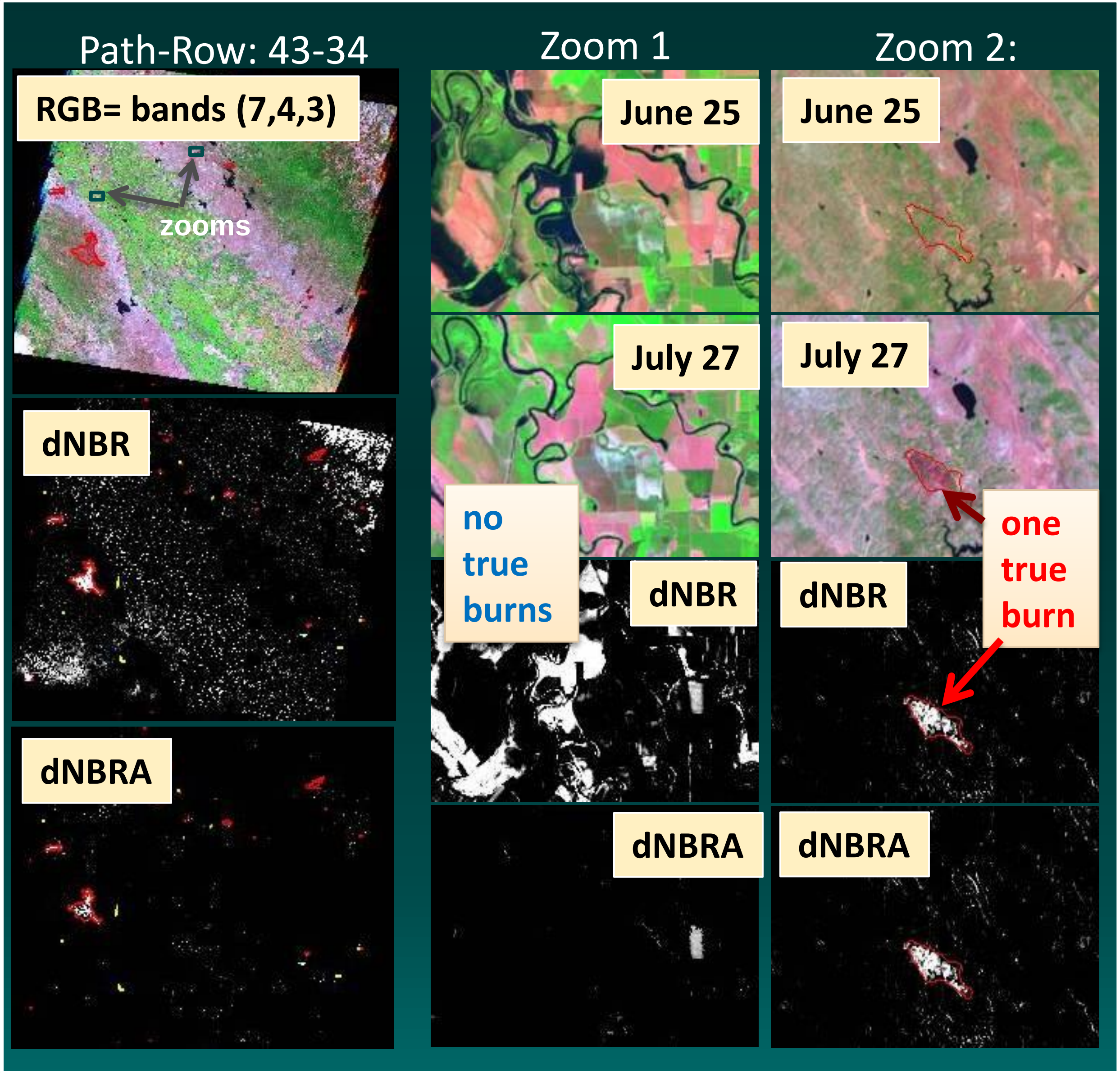
unknown parameters

past (basis) images

Koltunov & Ustin (2007) *Remote Sensing of Environment*, 110(1), 18-28

Koltunov *et al.* (2009) *International Journal of Remote Sensing*, 30(1), 57-83.

New burn detection in Landsat pairs



Is there a new burn near suspected false positive?