REMOTE DATA ACCESS TO POLAR-ORBITING AND GEOSTATIONARY SATELLITE OBSERVATIONS

TOWARDS NEAR REAL-TIME MONITORING OF FIRE OCCURANCES AND OTHER NATURAL HAZARDS

ITC

INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

PRESENTATION OUTLINE

1. INTRODUCTION
2. RESEARCH OBJECTIVES AND RESEARCH QUESTIONS
3. MATERIALS AND METHODS
4. RESULTS AND ANALYSIS
5. CONCLUSIONS
6. RECOMMENDATIONS

INTRODUCTION

RESEARCH ISSUES

A) DIFFERENT SENSORS HAVE DIFFERENT SPECTRAL, SPATIAL, TEMPORAL AND RADIOMETRIC PROPERTIES VITAL FOR FIRE DETECTION

B) HOW CAN THESE PROPERTIES BE EXPLOITED FOR FIRE DETECTION

C) WHICH SENSOR IS BEST FOR FIRE DETECTION, IS THERE 1 BEST SENSOR

D) DEVELOP A FIRE DETECTION METHOD

E) COMPARE DIFFERENT SENSORS FOR DETECTING FOREST FIRES

F) TO DEVELOP AN OPTIMUM NEAR REAL-TIME DETECTION CAPABILITY OF FIRES

RESEARCH OBJECTIVES	RESEARCH QUESTIONS
1. Best bands for fire detection	1.1) Which are the **most suitable bands** for detecting forest fires (MSG, MODIS and AVHRR)?
2. Develop an Algorithm	2.1) Is it suitable to detect forest fires on the basis of **TOA brightness temperature anomalies**? 2.2) What **methods** can be applied for detecting and extracting the fire pixels? 2.3) How **precisely** can forest fires be detected and monitored **spatially and temporally** with the help of MODIS, AVHRR and MSG.
3. Compare the 3 Sensors	3.1) What are the **relative advantages and limitations** of the 3 sensors terms of their fire detection capabilities? 3.2) Which is the **best sensor** for fire detection?

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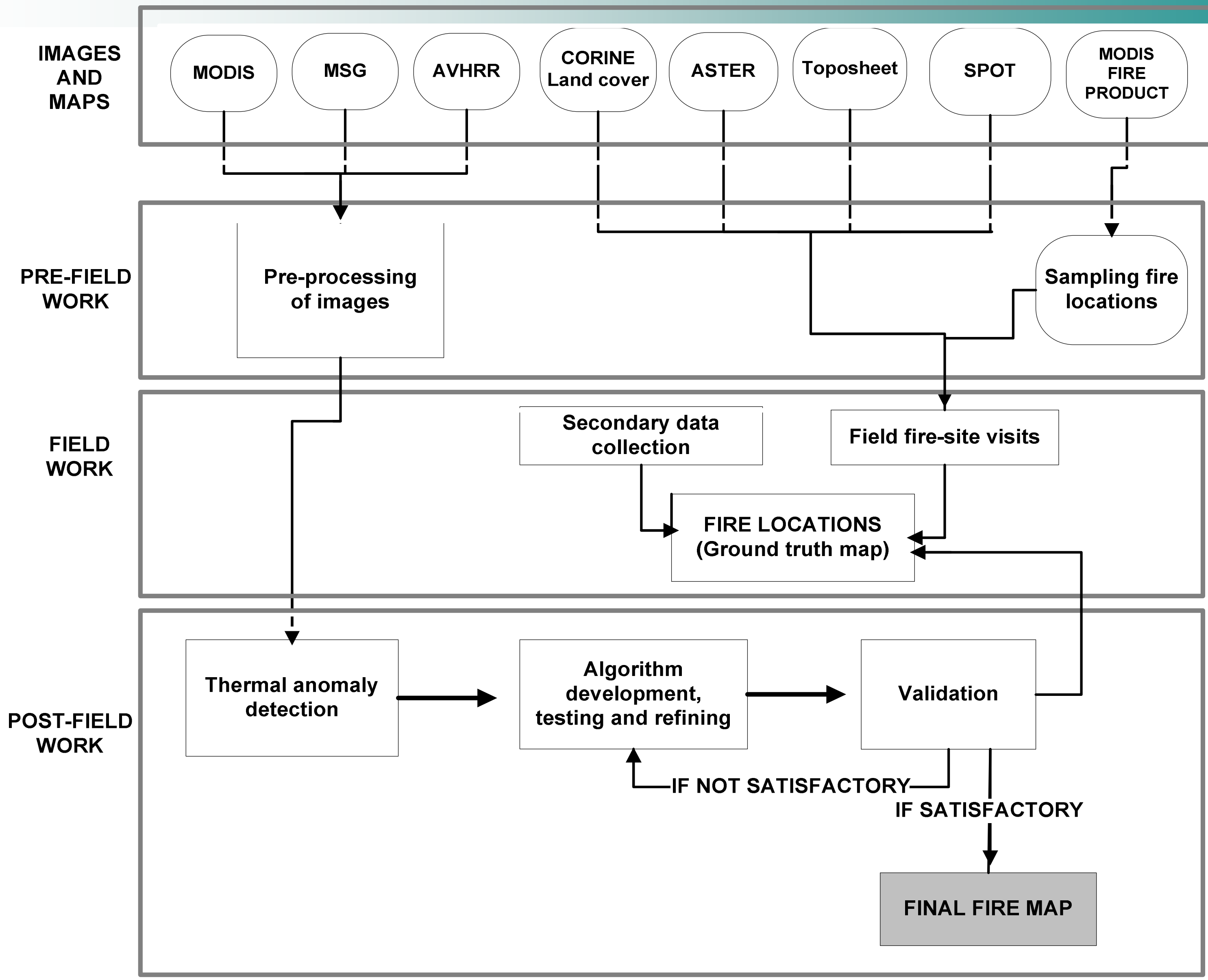
MATERIALS AND METHODS

A SCHEMATIC APPROACH TO RESEARCH METHOD



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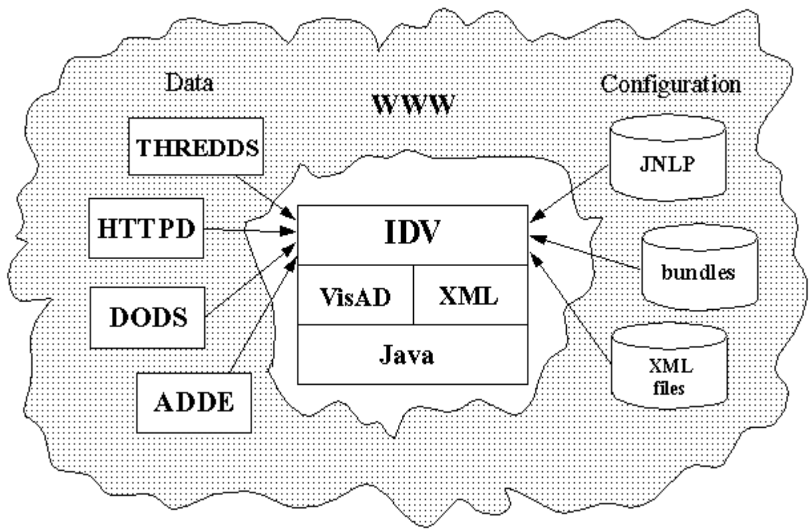
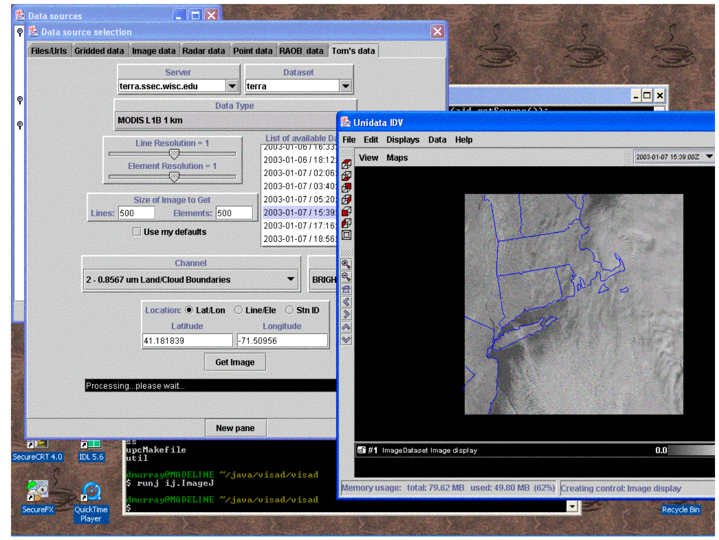
Web enabled features

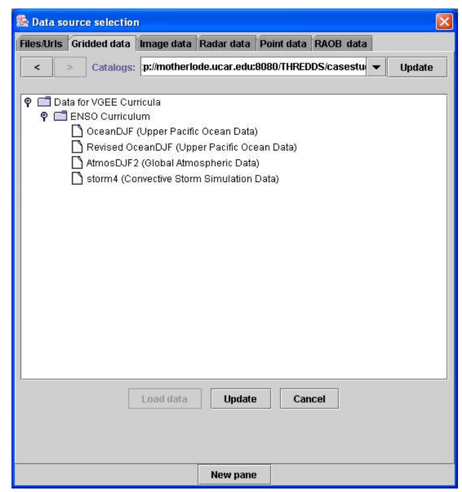
- Client/Server data access
- XML Configuration
- XML Persistence
- Integrated HTML Viewer
- Use of Java Web Start
- Real-time collaboration



Client/Server Data Access

- Access data from DODS/OPeNDAP, ADDE or WMS servers, as well as local files, HTTP and FTP
- Allows subsetting of large datasets
- Can use THREDDS catalogs of data holdings indexed in digital libraries (e.g. DLESE) for discovery and usage metadata

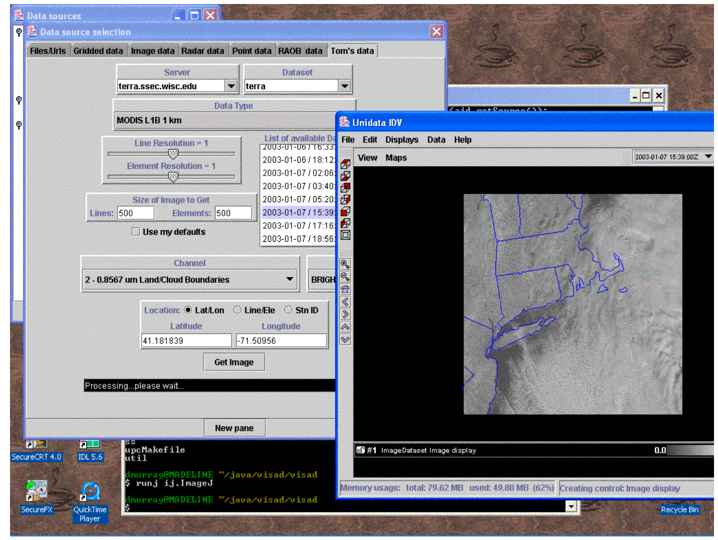


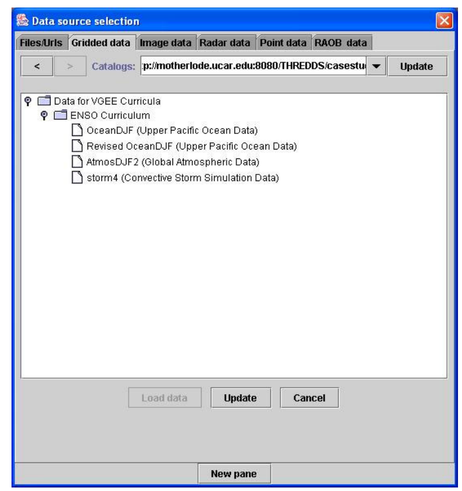


ITC's contribution to Web Enabled Features

Client/Server Data Access

- Compress data at server side to limit storage requirements
- Allows serving of wavelet compressed Geostationary Satellite Data
- Allow png-compressed McIDAS AREA through ADDE

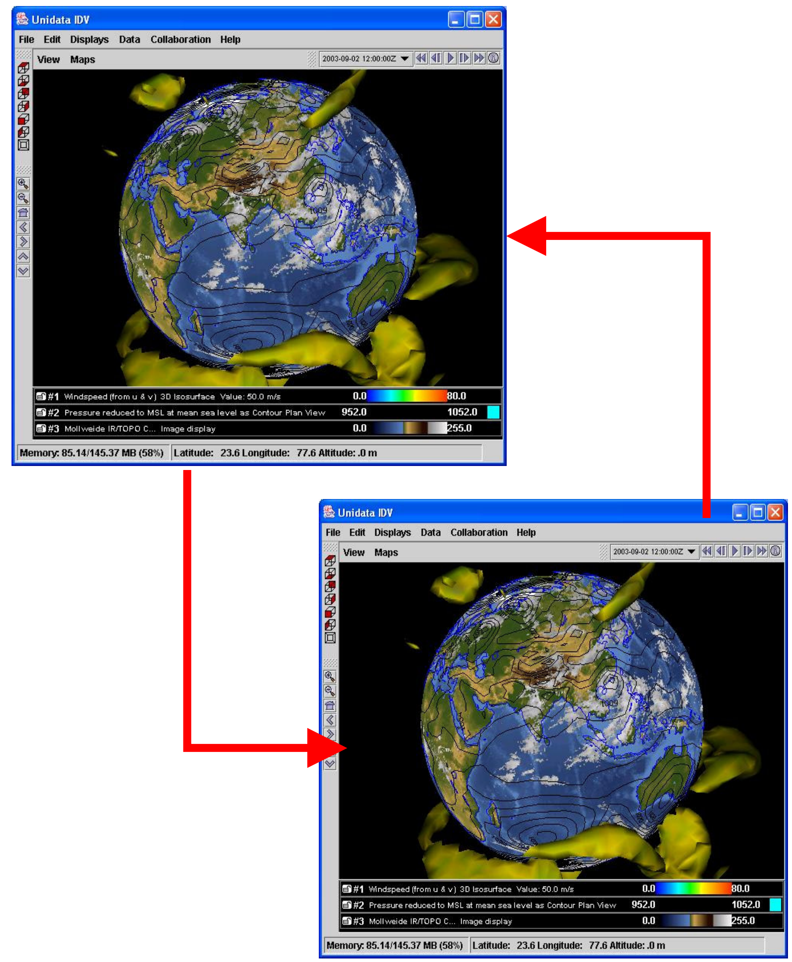




Web Enabled Features

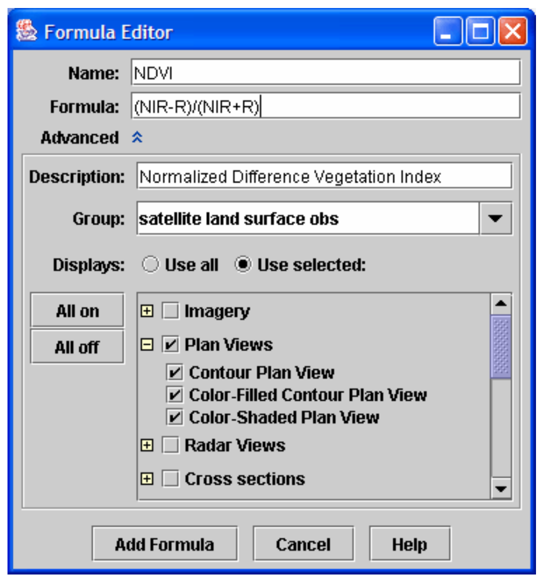
Collaboration Features

- Users can share IDV sessions
- Works locally in a classroom or remotely through the Internet
- Configurable as peer-to-peer, or client-server mode
- Incorporated chat facility and drawing tool for communication



Modeling

- The simplest technique is using ITC IDV "formulas" which are named one-line mathematical expressions. The steps for computing and displaying an ITC IDV formula are:
  - Defining an ITC IDV formula by name, description, and mathematical formula.
  - Saving the formula.
  - Selecting what kind of display to use.
  - Selecting exactly which particular data you want to use in the formula-based computation.



Jython scripting language

More powerful by writing methods (subroutines) in the Jython computer language:

- Java equivalent of Python
- Various on Jython:
  http://www.factbites.com/topics/Jython
  http://www.jython.org/j-jython1-ltr.pdf

- Using Python with VisAD
  http://www.ssec.wisc.edu/~tomw/visadtutor/

- Python:math module
  http://www.aims.ac.za/wiki/index.php/Python:math_module

  There are built-in mathematical functions, too, but preparation for them requires _importing_ the "math module": do

- ITC N52 Framework function

Jython scripting language

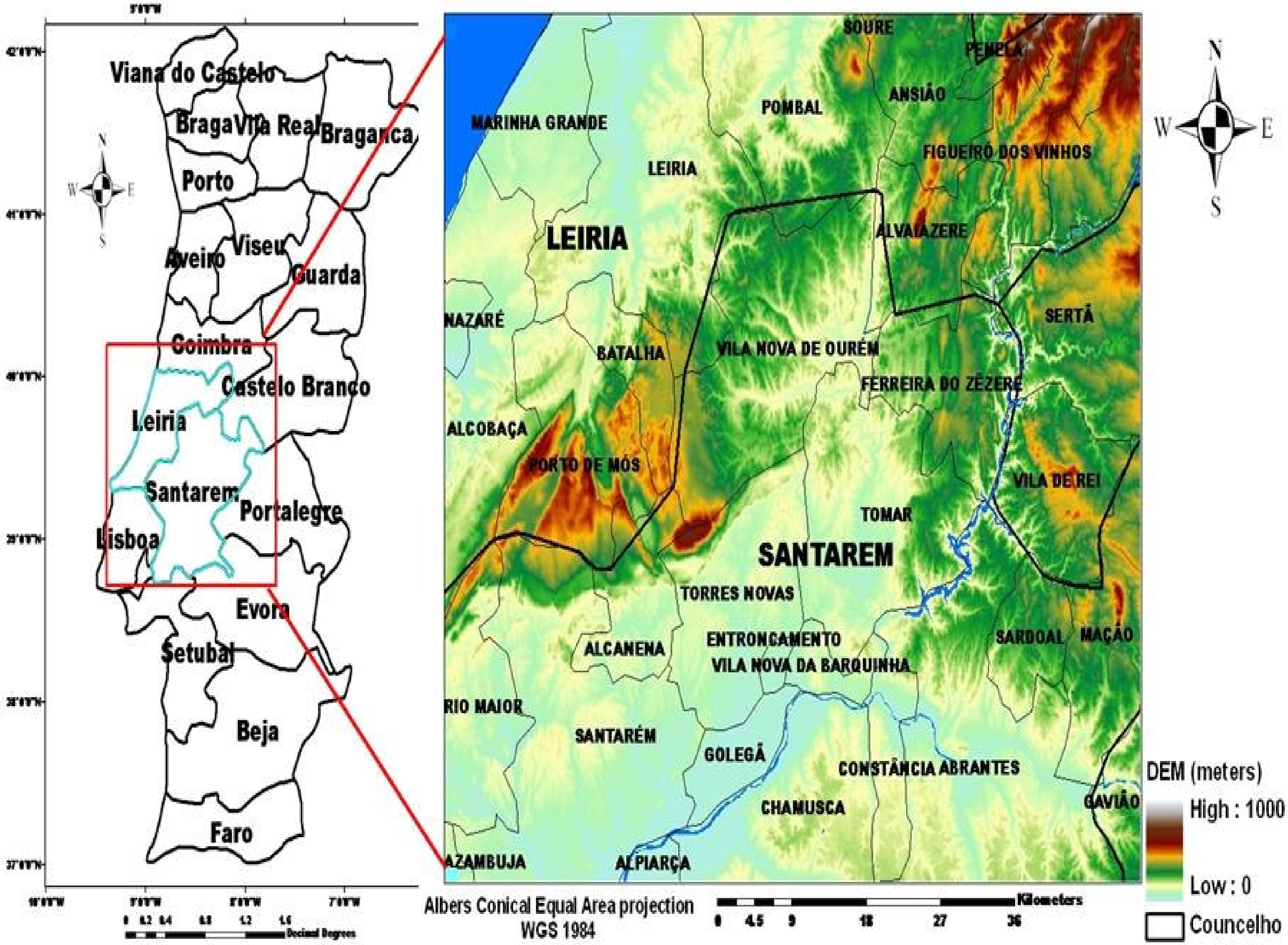
- ITC N52 Framework function

(http://www.52north.org/index.php?hot_tools)

Custom JAVA functions at:

http://adde.itc.nl/IDV/operation/doc/index.html

STUDY AREA



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THERMAL ANOMALY DETECTION AND SELECTION OF BANDS

FIELD VISITED SITES
(Date, Time, coordinates)

A) TOA TEMPERATURES OBSERVED
1. FIRE AND NON-FIRE PIXELS
2. DIFFERENT BANDS

B) SELECTION OF MOST RESPONSIVE BAND TO FOREST FIRES

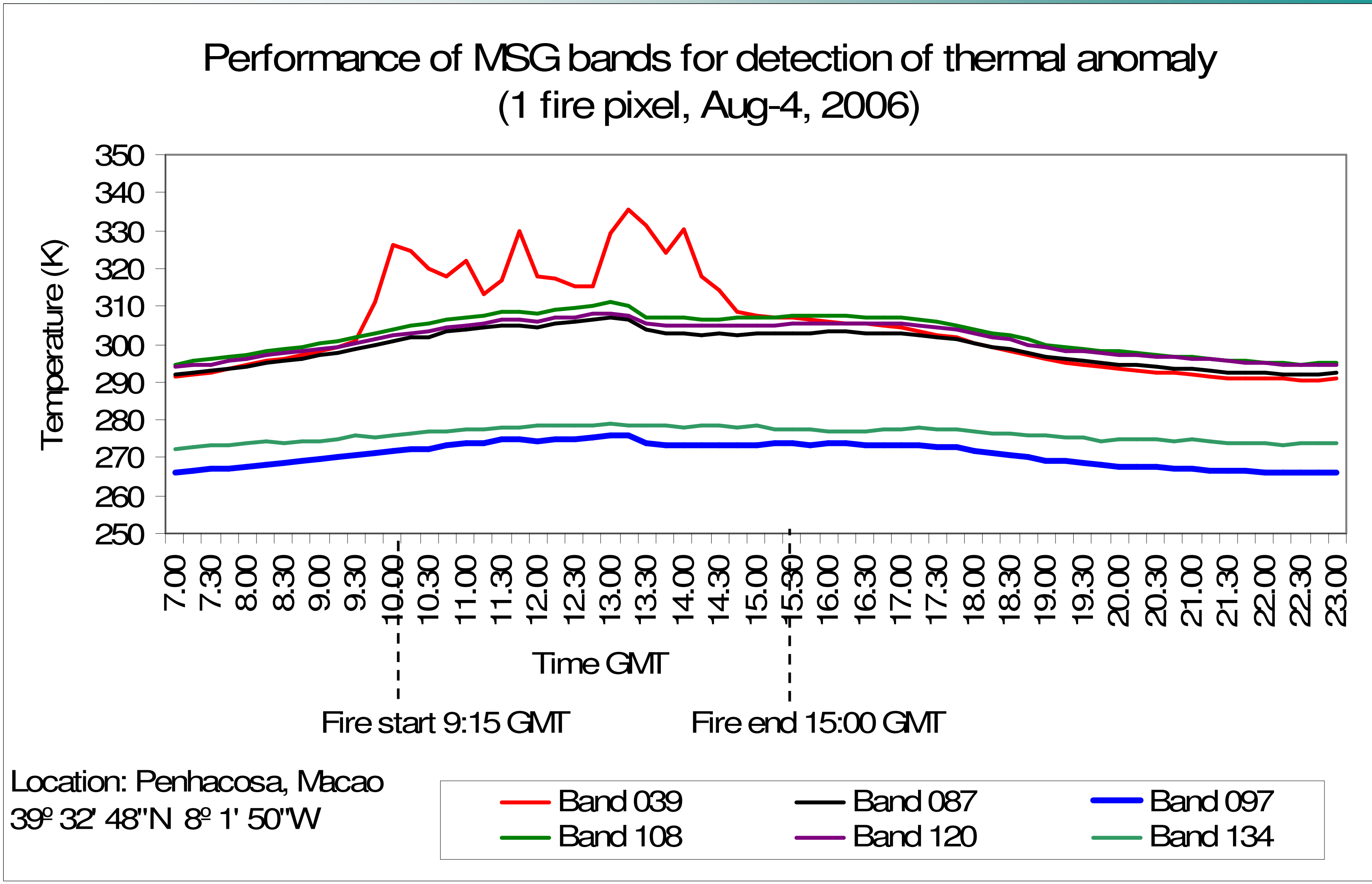
C) DIFFERENCE OBSERVED BETWEEN MOST RESPONSIVE BAND AND OTHER BANDS

D) SELECTION OF LEAST RESPONSIVE BAND TO FIRE

E) DIFFERENCE OBSERVED BETWEEN THE MOST RESPONSIVE AND LEAST RESPONSIVE BAND

These observations were vital for development of the fire detection algorithm

THERMAL ANOMALY DETECTION AND SELECTION OF BANDS (MSG)

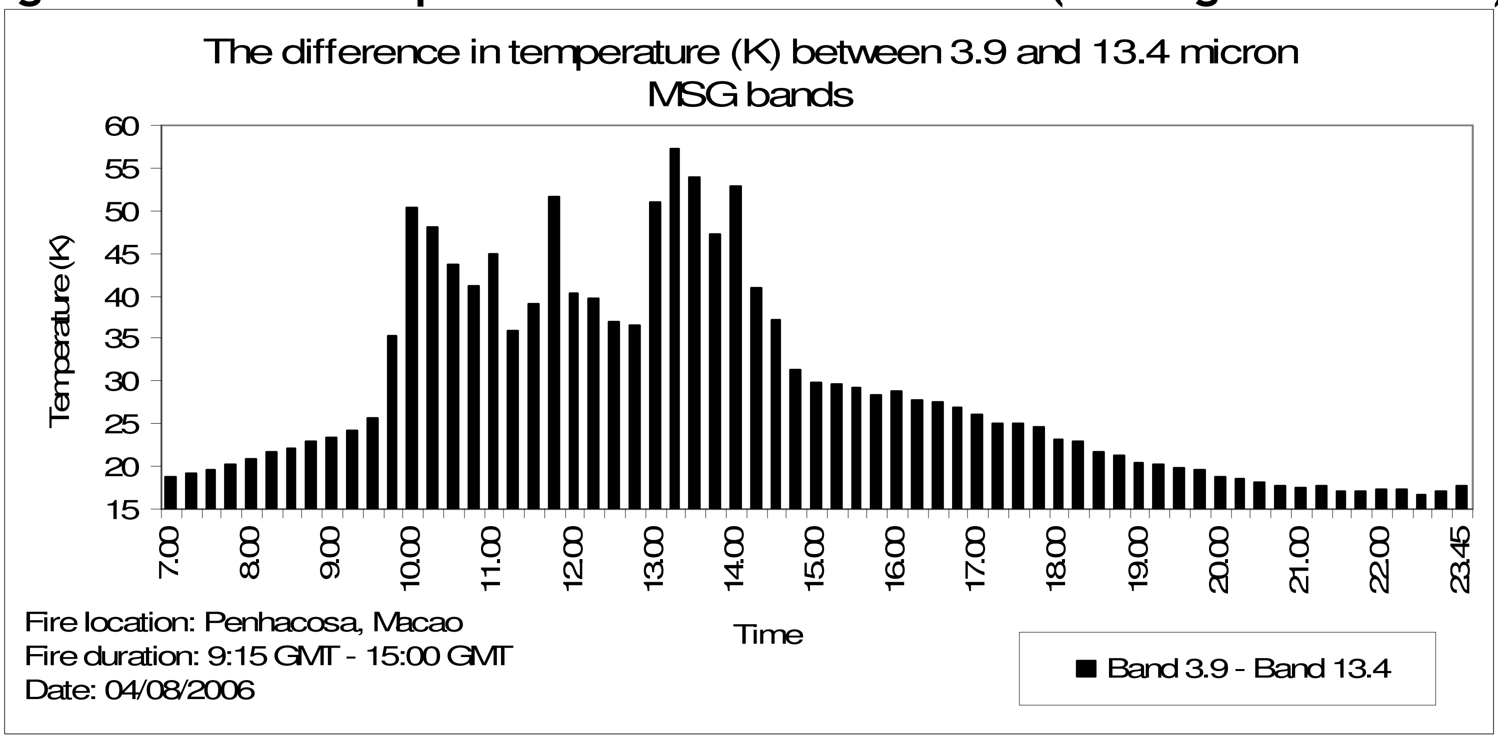


Example: Thermal anomaly for 1 fire pixel (Penhacosa fire 04-August, 2006)

THERMAL ANOMALY DETECTION AND SELECTION OF BANDS (MSG)

CATEGORIES	$T_{3.9}$ -$T_{8.7}$	$T_{3.9}$ -$T_{9.7}$	$T_{3.9}$ -$T_{10.8}$	$T_{3.9}$ -$T_{12.0}$	$T_{3.9}$ -$T_{13.4}$
Day fire pixels (A)	14.08	43.86	10.27	11.90	36.02
Day non-fire pixels (b)	1.79	31.85	1.87	0.43	23.34
DIFFERENCE (A-B) (K)	**12.29**	**12.01**	**12.14**	**12.32**	**12.68**
Night fire pixels (C)	9.82	35.54	5.71	7.91	29.66
Night non-fire pixels (D)	-0.95	25.89	3.80	3.42	15.18
DIFFERENCE (C-D) (K)	**10.76**	**9.65**	**9.50**	**11.32**	**14.47**

Testing for the least responsive band to forest fires (Average of 20 fires)



Example of 1 fire (3.9-13.4 micron)

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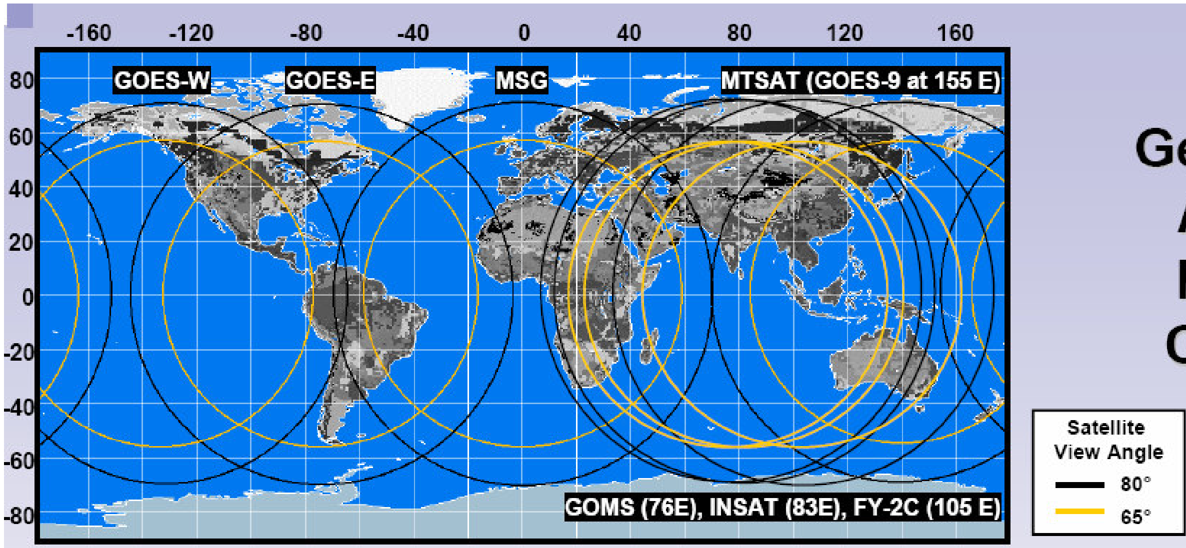
Global Geostationary Fire Detection



Global Geostationary Active Fire Monitoring Capabilities

Satellite	Active Fire Spectral Bands	Resolution IGFOV (km)	SSR (km)	Full Disk Coverage	3.9 μm Saturation Temperature (K)	Minimum Fire Size at Equator (at 750 K) (hectares)
GOES-12 Imager	1 visible 3.9 and 10.7 μm	1.0 4.0 (8.0)	0.57 2.3	3 hours	~335 K	0.15
GOES-9 & GOES-10 Imager	1 visible 3.9 and 10.7 μm	1.0 4.0 (8.0)	0.57 2.3	1 hour (G-9) 3 hours (G-10)	~324 K (G-9) ~322 K (G-10)	0.15
MSG SEVIRI	1 HRV 2 visible 1.6, 3.9 and 10.8 μm	1.6 4.8 4.8	1.0 3.0 3.0	15 minutes	~335 K	0.22
FY-2C SVISSR (Fall 2004)	1 visible, 3.75 and 10.8 μm	1.25 5.0		30 minutes	~330 K (?)	
MTSAT-1R JAMI (2005)	1 visible 3.7 and 10.8 μm	0.5 2.0		1 hour	~320 K	0.03
INSAT- 3D (2006)	1 vis, 1.6 μm 3.9 and 10.7 μm	1.0 4.0	0.57 ? 2.3 ?	30 minutes		
GOMS Electro N2 MSU-G (2006)	3 visible 1.6, 3.75 and 10.7 μm	1.0 km 4.0 km		30 minutes		

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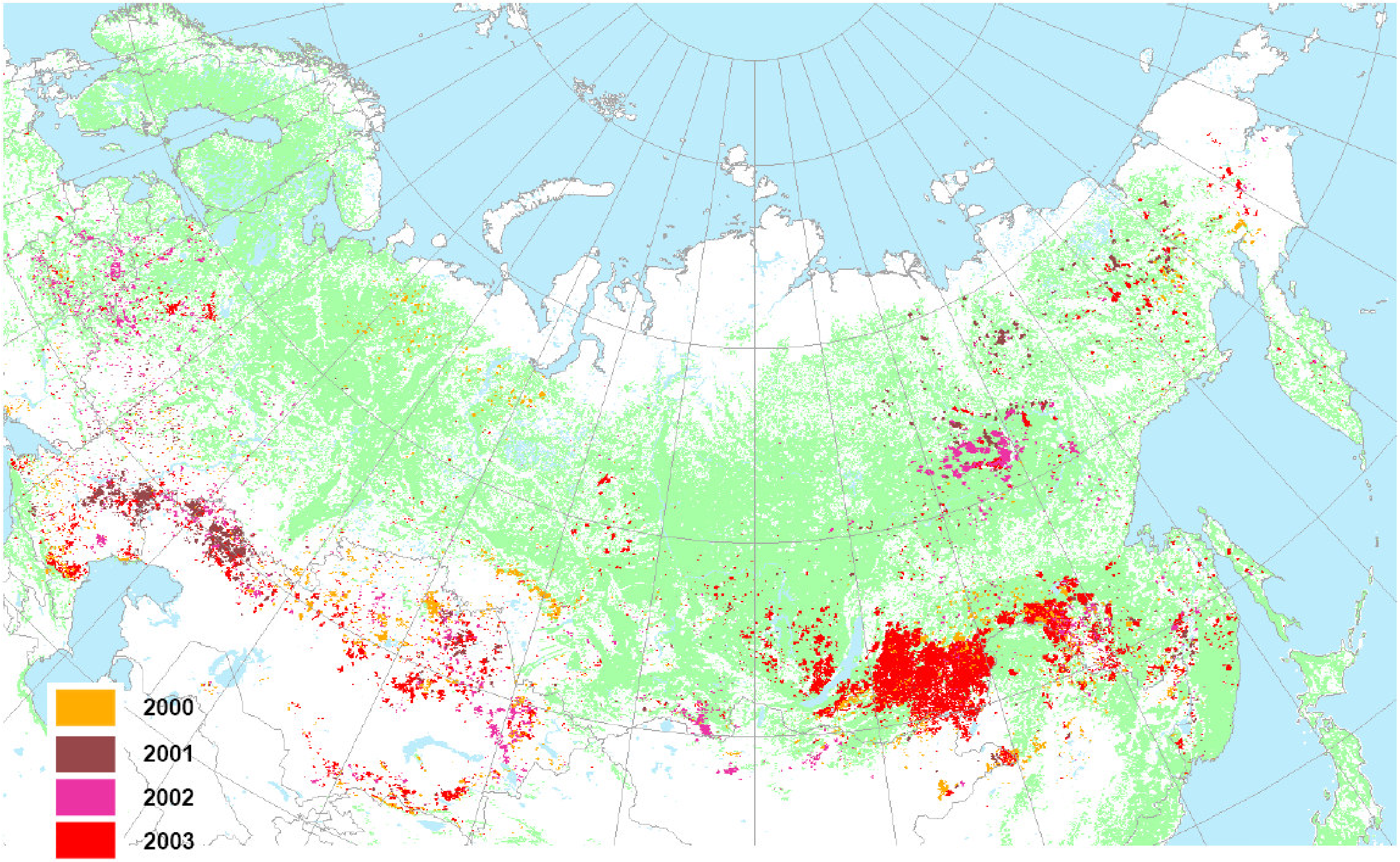
Burnt Area in Northern Eurasia



Bartalev et al. RAS/SRI

ALGORITHM DEVELOPMENT FOR DETECTING FIRE
(MSG SEVIRI)

ABSOLUTE THRESHOLDING (Day fire)	CONTEXTUAL THRESHOLDING (Day fire)
$pf = (df - dp) > 5K$ and $df > 35K$ and $VIS_{0.6} \leq 0.15$ *pf* : Possible fire pixel *df* : 3.9µm minus 13.4 µm (for the fire pixel) *dp* : [Average (3.9 µm minus 13.4 µm)] for the fire pixel, during the previous 10 non-cloudy days) *VIS0.6* : visible band at 0.6 µm.	$pf = t_{3.9} - t_{3.9nb\min} > 15K$ and $t_{3.9} > 315K$ and $t_{3.9} - t_{13.4} > 40K$ and $VIS_{0.6} \leq 0.15$ *Pf* : Possible fire pixel *t* : Temperature (K); *VIS*: Visible band *nbmin* : minimum value of the neighbour pixel Subscripts: Bands wavelenghts

Night fire algorithms are same BUT do not include reflection threshold

ALGORITHM DEVELOPMENT FOR DETECTING FIRE MODIS

- Small fire test $t_{21,22,23(\geq 80\% p)} \leq 310K$
- Large fire test $t_{21,22,23(\geq 50\% p)} \geq 310K$

LARGE FIRE ALGORITHM (DAY FIRES)

$$pf = (T_{21} - T_{21nb\min} > 40K)\text{or}(T_{22} - T_{22nb\min} > 40K)\text{or}(T_{23} - T_{23nb\min} > 40K)$$

$$pf = (T_{21} > 350K)\text{or}(T_{22} > 350K)\text{or}(T_{23} > 350K)$$

$$p_f = (T_{21} - T_{36} > 100K)\text{or}(T_{22} - T_{36} > 100K)\text{or}(T_{23} - T_{36} > 100K)$$

$$p_f = R_1 \leq 0.2$$

SMALL FIRE ALGORITHM (DAY FIRES)

$$pf = (T_{21} - T_{21nb\min} > 15K)\text{or}(T_{22} - T_{22nb\min} > 15K)\text{or}(T_{23} - T_{23nb\min} > 15K)$$

$$pf = (T_{21} > 320K)\text{or}(T_{22} > 320K)\text{or}(T_{23} > 320K)$$

$$p_f = (T_{21} - T_{36} > 95K)\text{or}(T_{22} - T_{36} > 95K)\text{or}(T_{23} - T_{36} > 95K)$$

$$p_f = R_1 \leq 0.2$$

p: pixel; Pf : is the Possible fire pixel; T: Brightness temperature; Subscript: Band number ; R : Reflectance *nbmin* : minimum value of the neighbour pixel

Night fire algorithms are same BUT do not include reflection threshold

ALGORITHM DEVELOPMENT FOR DETECTING FIRE NOAA AVHRR

- **Small fires test (day fires)**

$$pf = (T_3 - T_{3nb\min} > 3K)\text{and}(\mathrm{T}_3 - T_4 > 10K)\text{and}(\mathrm{T}_3 > 315)\text{and}(\mathrm{T}_4 > 300)\text{and}$$
$$(\mathrm{R}_1 \leq 0.1) \text{ and } (\mathrm{R}_1 - R_2 \leq 0.1)$$

- **Small fires test (night fires)**

$$pf = (T_3 - T_{3nb\min} > 3K)\text{and}(T_3 - T_4 > 5K)\text{and}(T_3 > 300)\text{and}(T_4 > 290)$$

- **Large fires test (day fires)**

$$pf = (T_3 > 325)\text{and}(\mathrm{T}_4 > 320)\text{and}(R_1 \leq 0.1) \text{ and } (\mathrm{R}_1 - R_2 \leq 0.1)$$

- **Large fires test (night fires)**

$$pf = (T_3 > 320)\text{and}(T_4 > 310)$$

pf : Possible fire pixel; *T*: Temperature (K); Subscript: Channel number of AVHRR, *nbmin* : minimum value of the neighbour pixel

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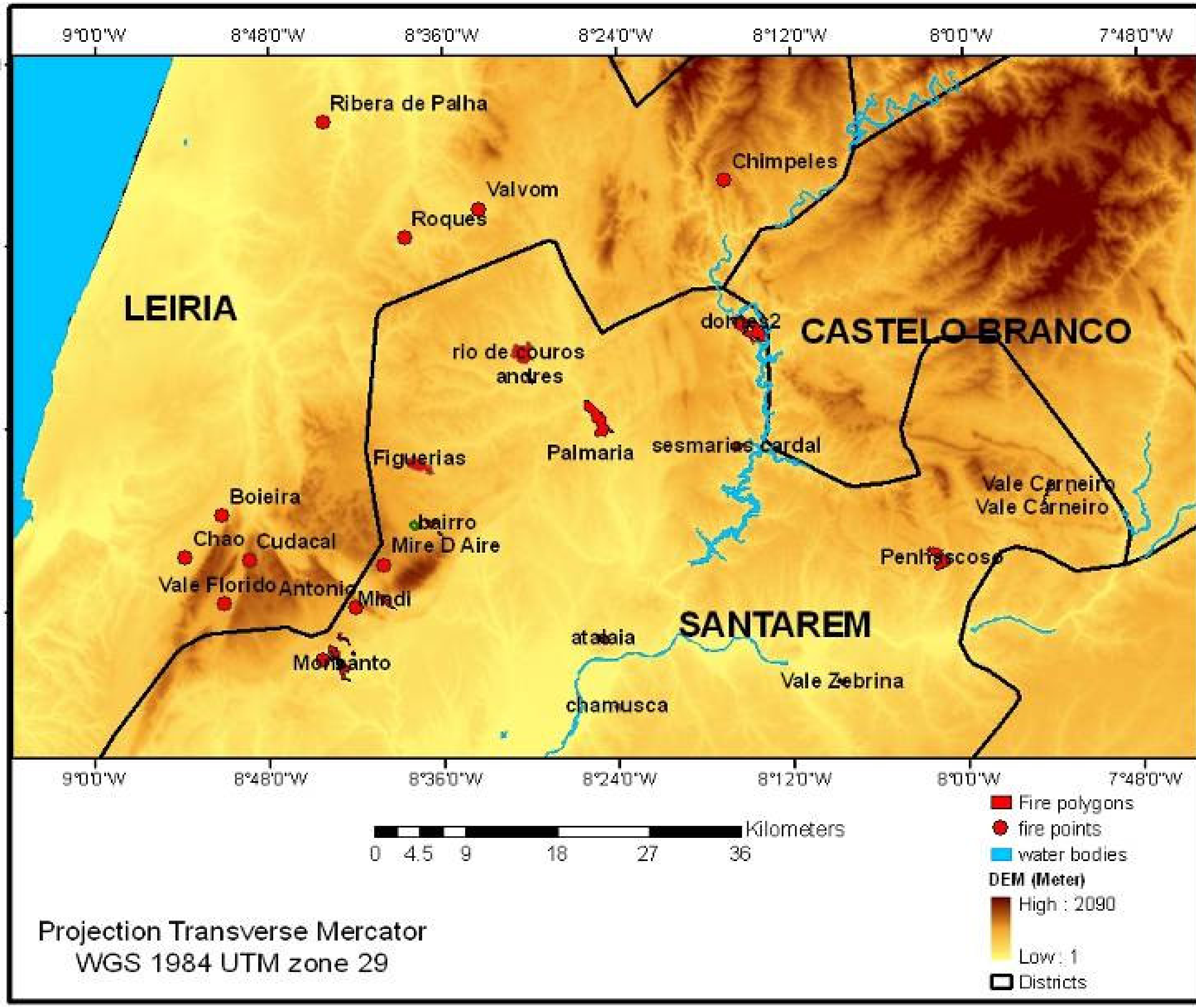
RESULTS

FIELD WORK RESULTS



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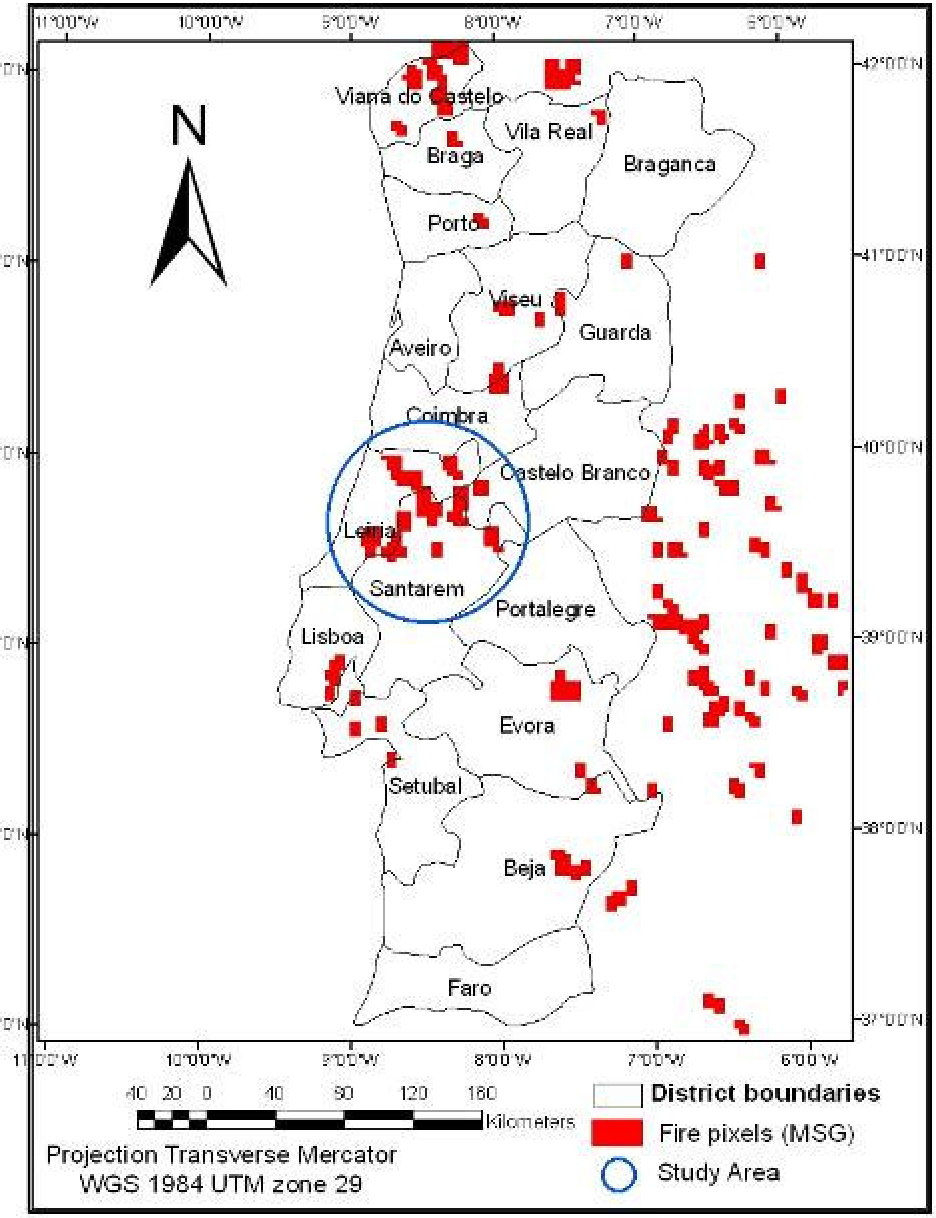
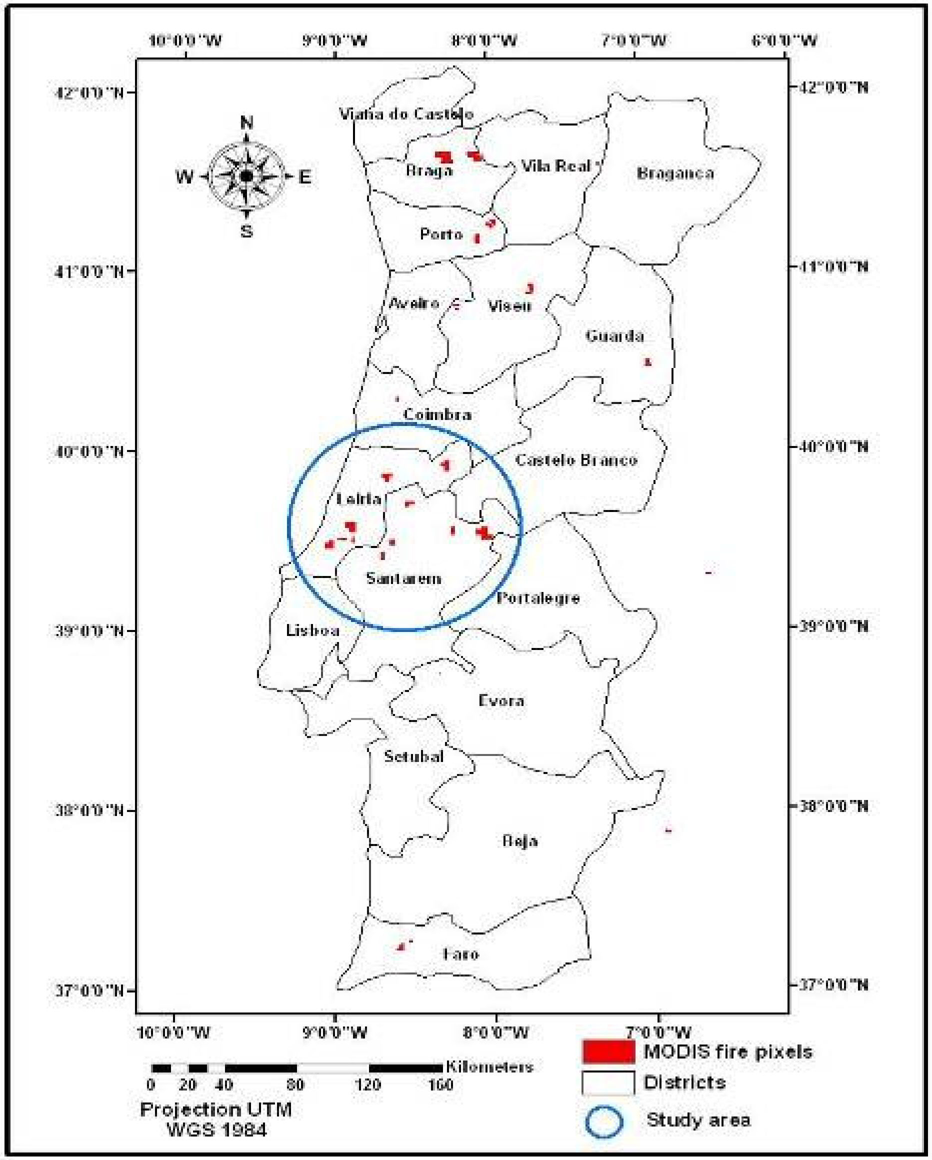
MAP SHOWING MSG FIRE PIXELS FOR SELECTED DAYS



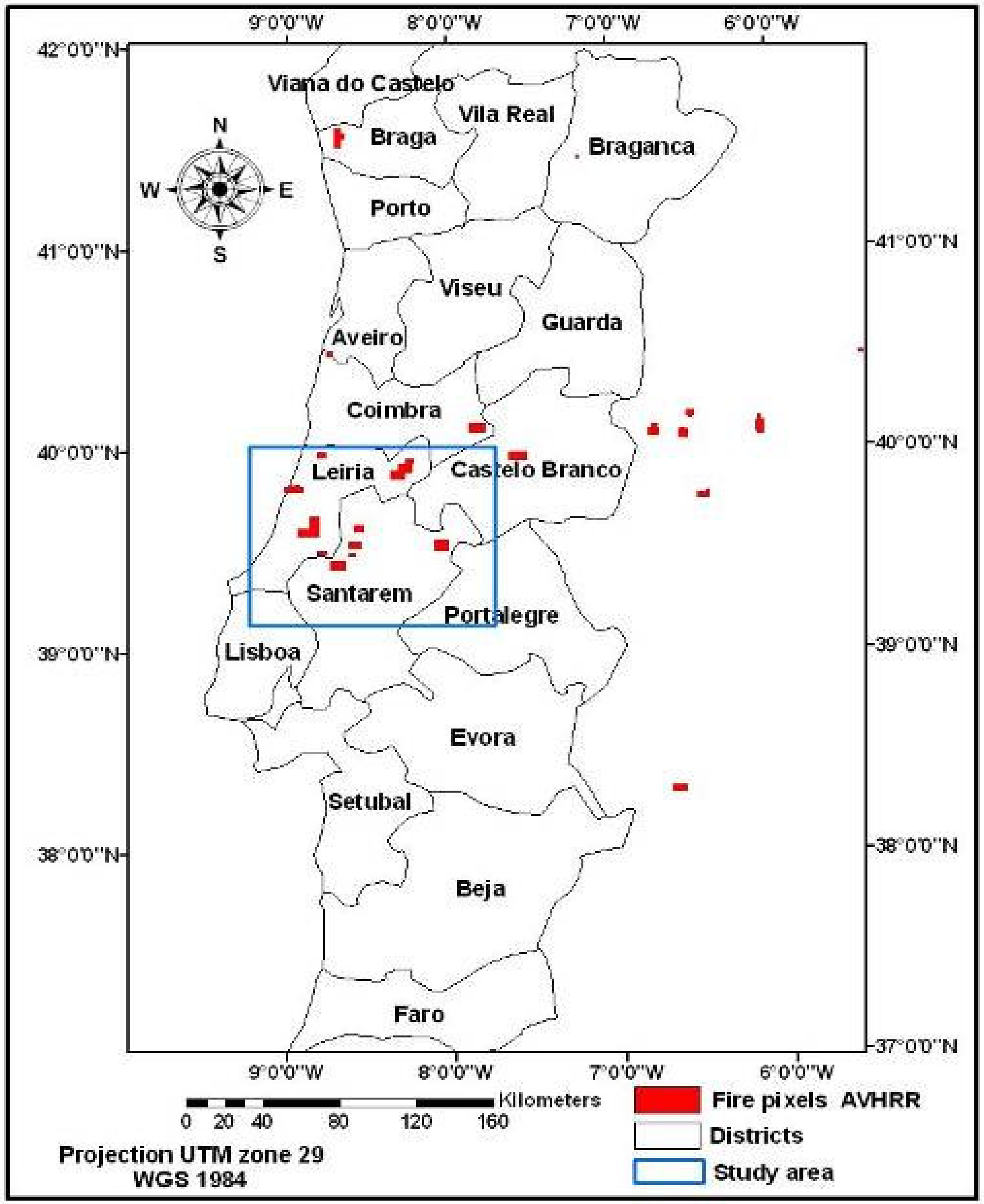
Dates: July (14,15,17 and 26) August (4-11,14 and 27) September (4 and 6)

MAP SHOWING MODIS FIRE PIXELS FOR SELECTED DAYS



Dates: July (15th) August (4-7th, 10 and 11) September (4th)

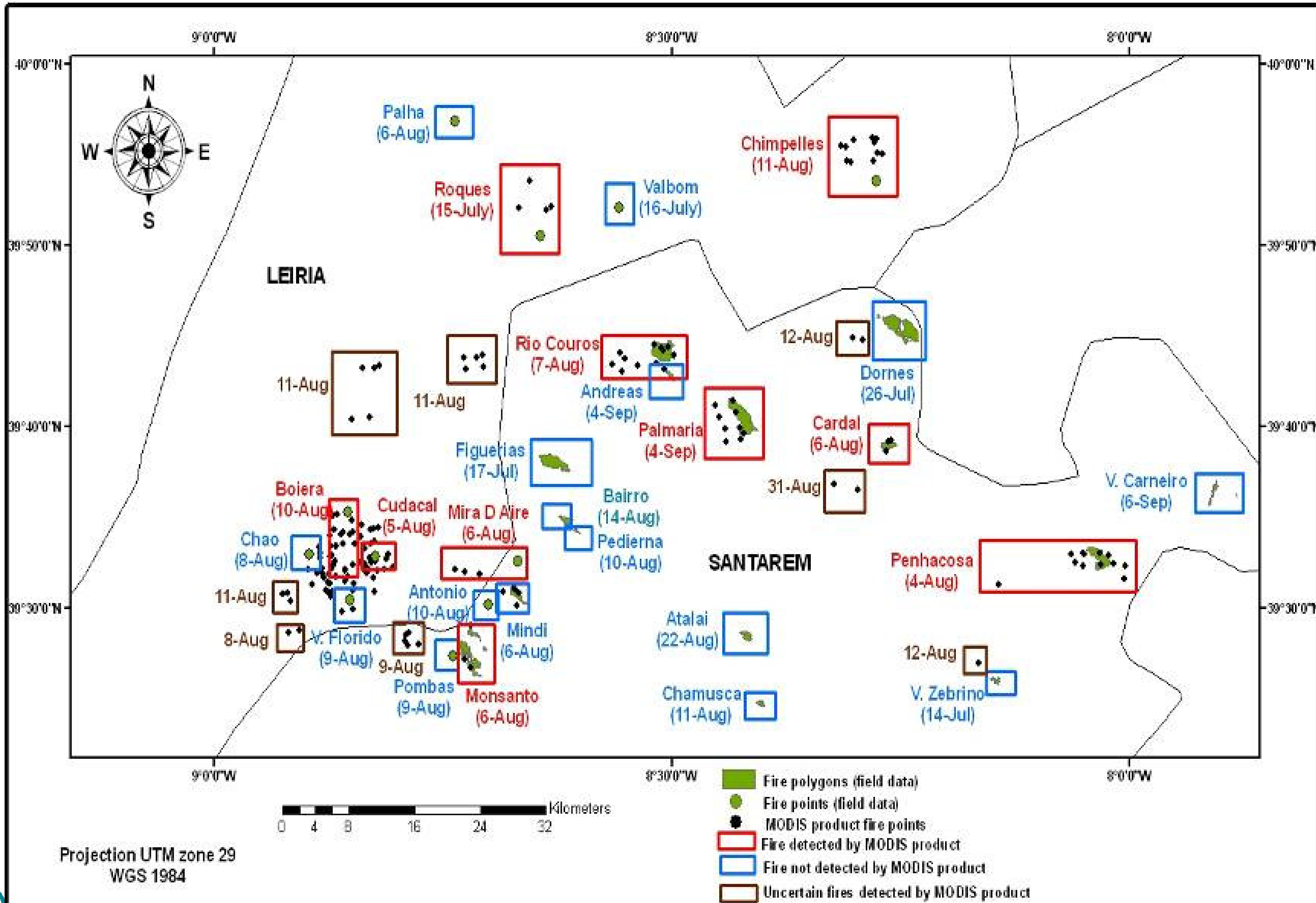
MAP SHOWING AVHRR FIRE PIXELS FOR SELECTED DAYS



Dates: July (17) August (4, 6, 10, 11)

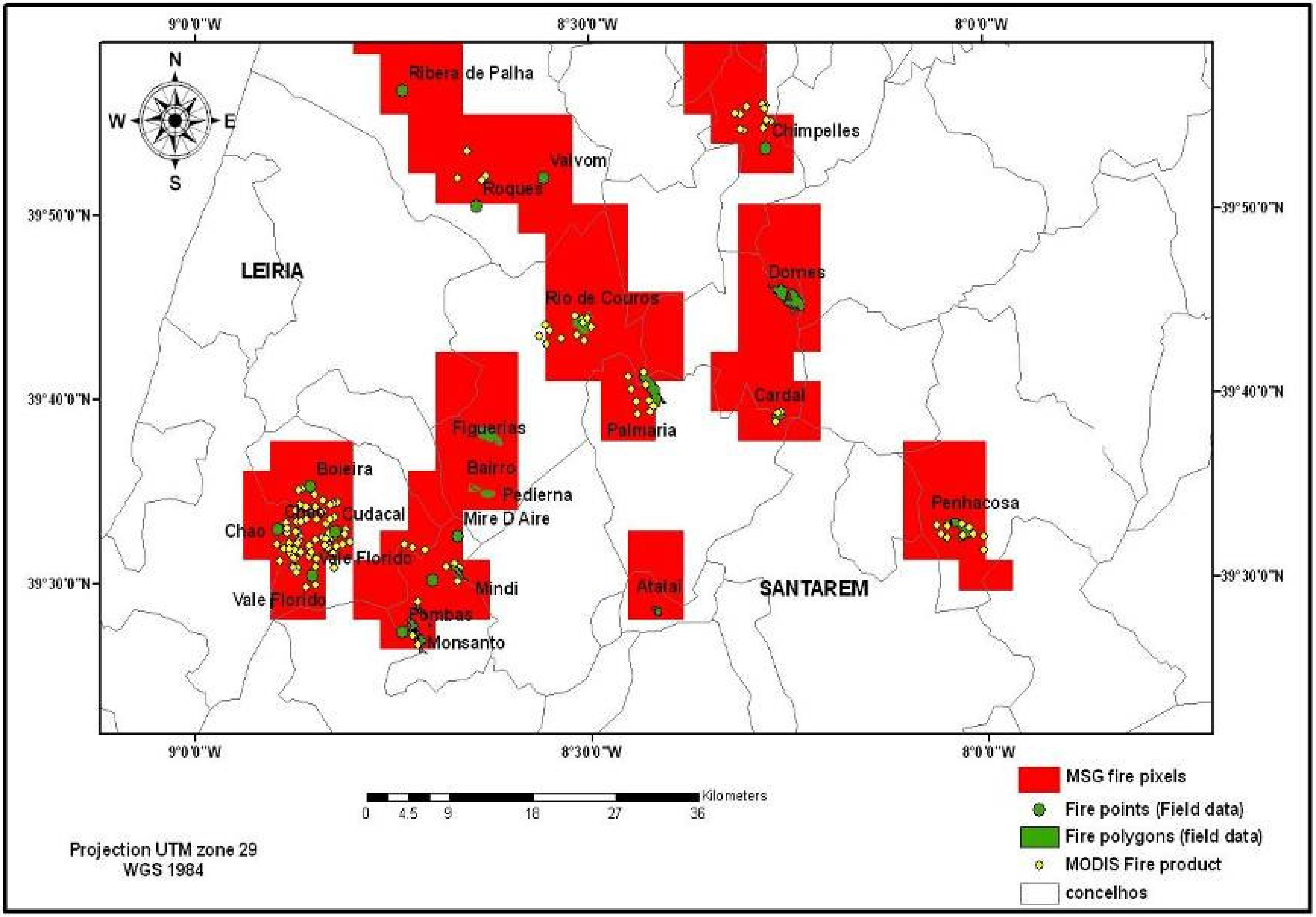
VALIDATION OF THE MODIS PRODUCT

(MODIS rapid response system)



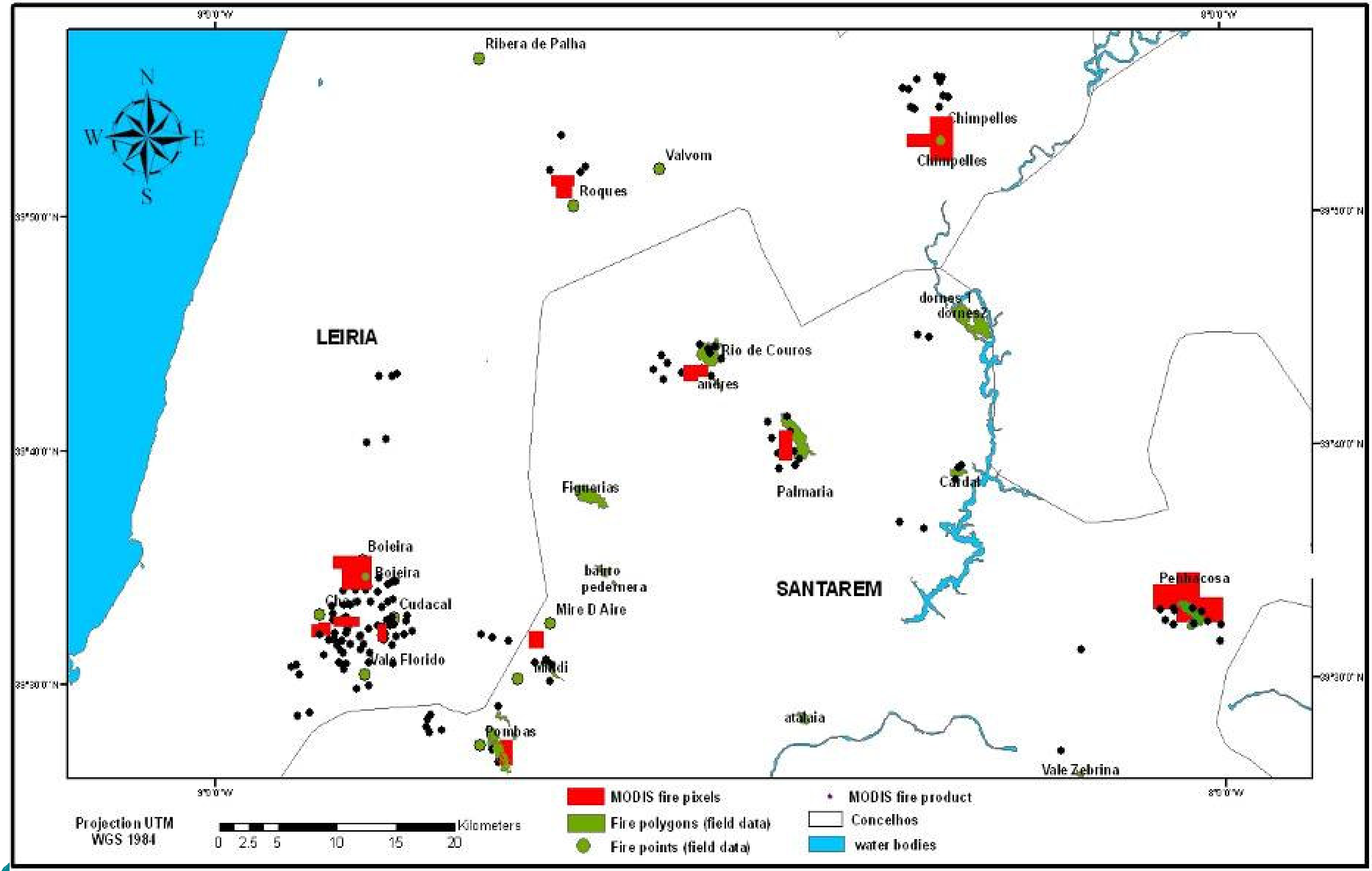
Fires detected 10/27; Fires not detected 17/27

VALIDATION (MSG FIRE PIXELS)



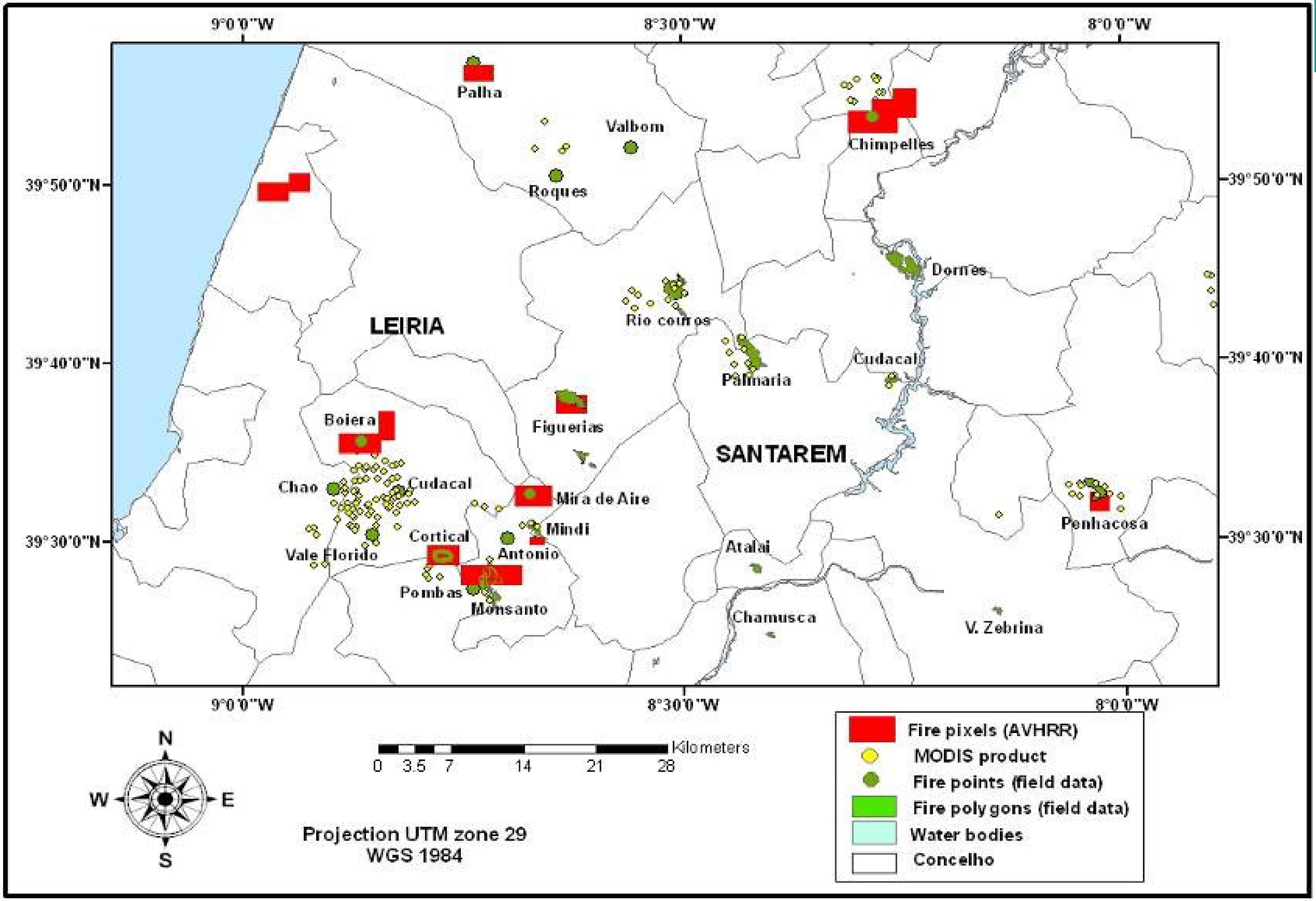
Fires detected 22/25. Not detected 3/25

VALIDATION (MODIS FIRE PIXELS)



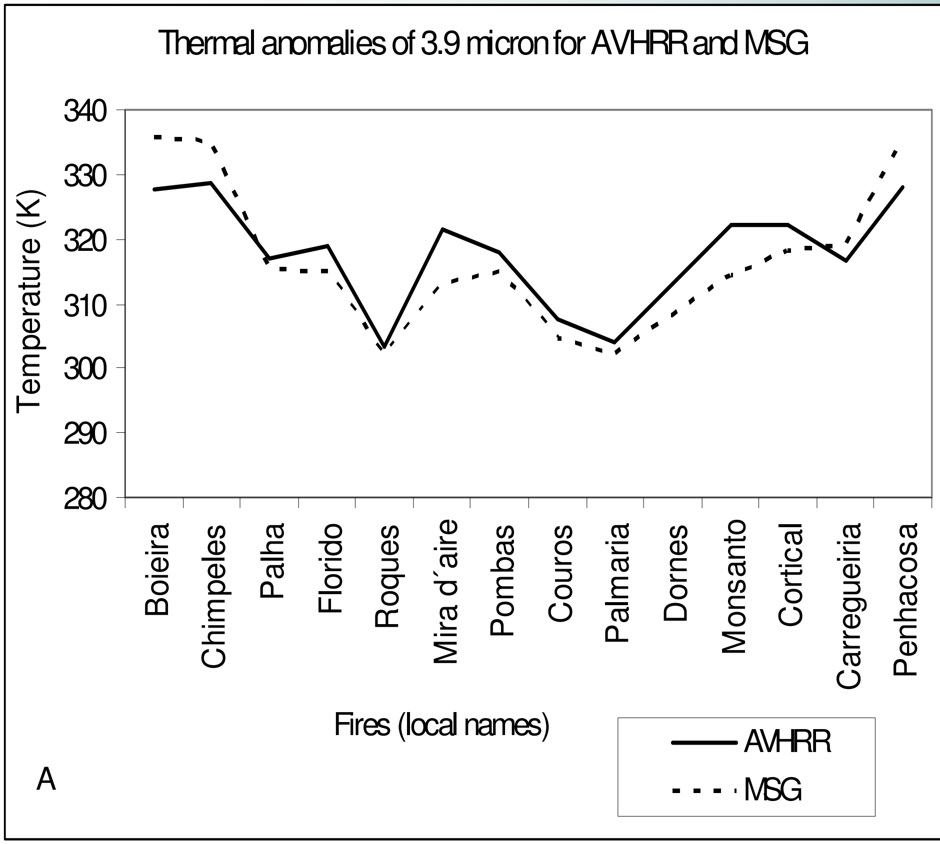
Fires detected 9/14. Not detected 5/14

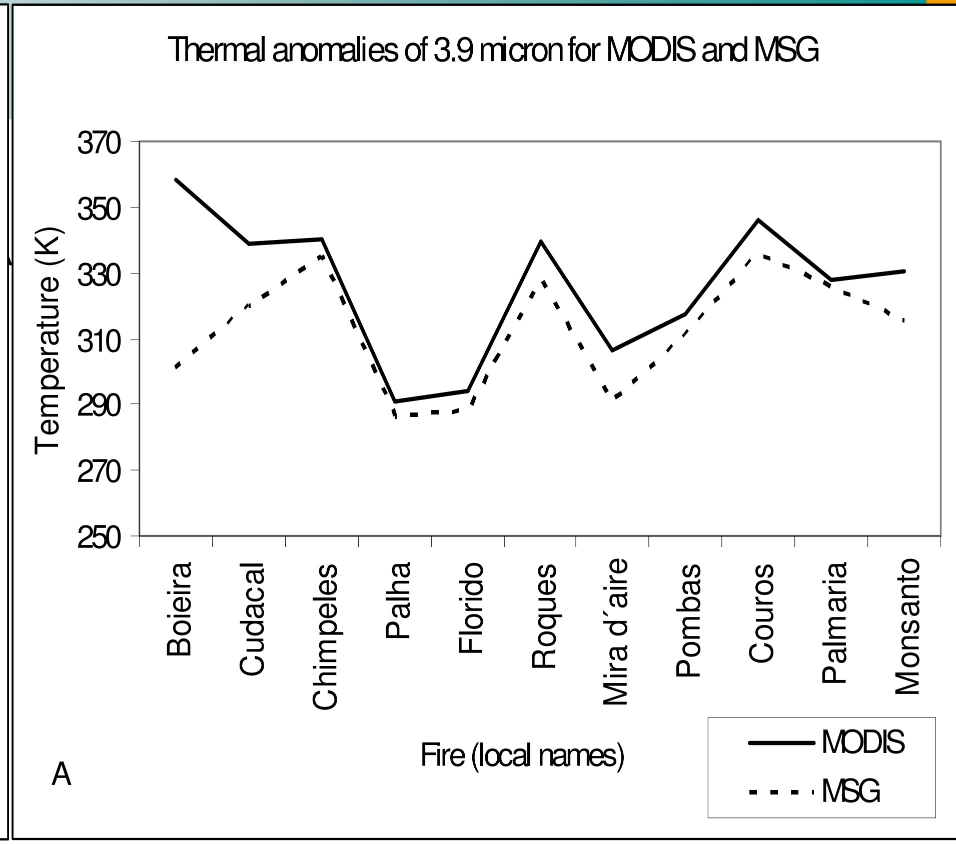
VALIDATION (AVHRR FIRE PIXELS)



Fires detected 9/24. Not detected 15/24

COMPARING THE PERFORMANCE OF 3 SENSORS

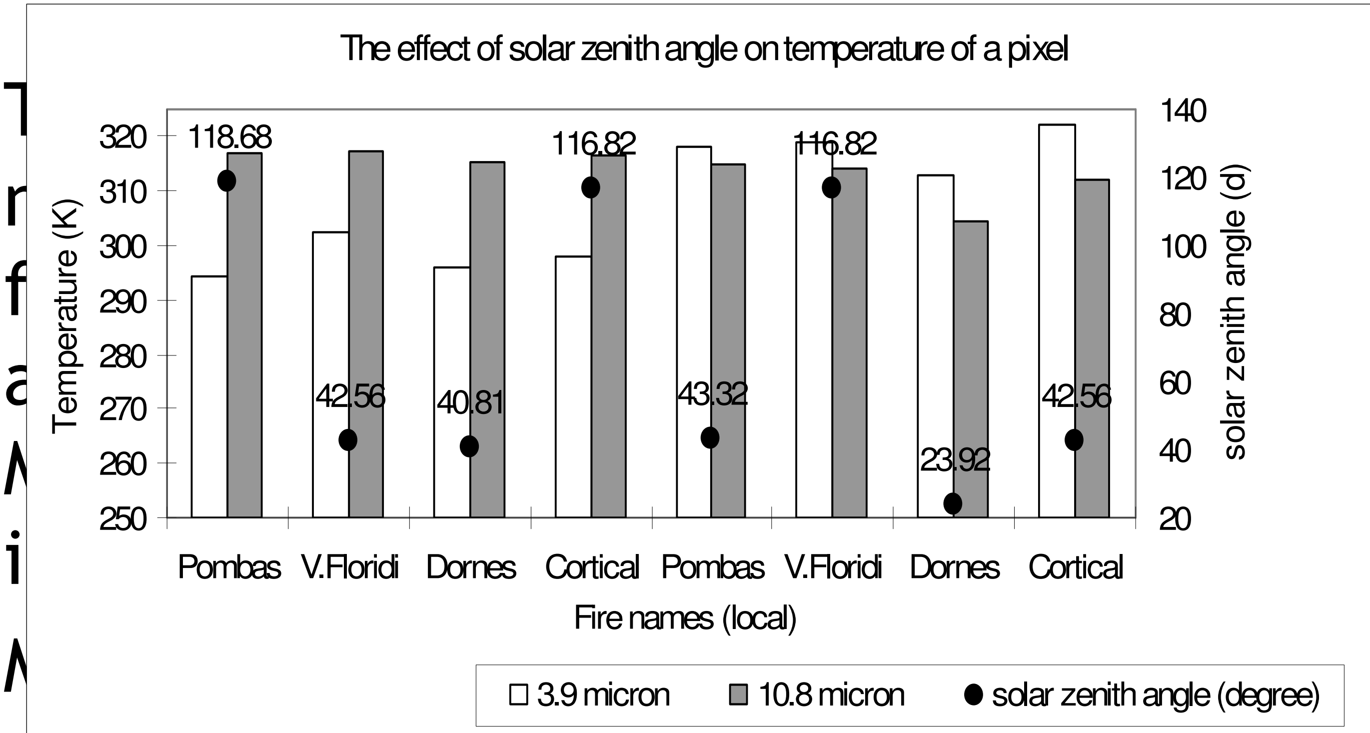




- **FIRE DETECTION: MSG DETECTED LARGEST**

	MSG	MODIS	AVHRR
Errors of omission (%)	12	36	62
Errors of commission (%)	0	0	20
Fires detected (%)	88	64	37

COMPARING THE PERFORMANCE OF 3 SENSORS



- T … le for r … -time f … MODIS a … s had M … VHRR i
- M … angle also affected greatly by solar zenith angle effects. The 3.9 μm was affected most.
- Large false alarms in AVHRR: Band 3b at 3.7 μm and low saturation temperature.

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CONCLUSIONS

SUITABLE BANDS

- The most suitable bands: 3.9-4 micron.

ALGORITHM DEVELOPMENT

- It is suitable to use **TOA brightness** temperature for detecting forest fires.
- This research **developed a different approach** to detect forest fires, by exploiting the difference in sensitivities of the most sensitive and least sensitive bands. Incase of the MSG the results were good and 88% of the fires were detected. MODIS and AVHRR did not give very good results, and this is because of their sensor characteristics.

CONCLUSIONS

HOW PRECISELY CAN FOREST FIRES BE DETECTED AND MONITORED SPATIALLY AND TEMPORALLY

- Spatially: The pixel size is large. The ground truths were within the flagged fire pixels. Relatively MODIS and AVHRR better than MSG.
- Temporally: MSG every 15 min, MODIS 2 times/day, AVHRR 2-6/day. Relatively MSG more suitable than MODIS and AVHRR

COMPARING THE PERFORMANCE

- Most suitable sensor for fire detection: MSG SEVIRI

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RECOMMENDATIONS

- Masking the vegetated pixels, cloud and water pixels.
- The threshold values would have to be manipulated according the local temperature conditions and cannot be used globally.
- The remote data access technologies facilitate decentralized application and development

THANKYOU

All photos are of Penhacosa fire. ***Source: Forest department, Macao and self taken***