ATMOSPHERIC CORRECTION IN THE PROBLEM OF FIRE DETECTION FROM SPACE

Sergey V. Afonin, Vladimir V. Belov

**Institute of Atmospheric Optics SB RAS,
1 Akademichesky Ave., Tomsk 634055,
Russia**

e-mail: afonin@iao.ru; belov@iao.ru

FORMULATION OF THE PROBLEM OF FIRE DETECTION FROM SPACE

Let a high-temperature object (HTO) characterized by area S_H and temperature T_H (T_H > 600 K) be in the region of the underlying surface with area S_{FOV} ($S_H \ll S_{FOV}$)

corresponding to the Field Of View (FOV) of the remote sensor and with the background underlying surface temperature T_S.

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GENERAL DECISION RULE:

$$P\{x\} > dP$$

where

dP is the threshold value of the function P{x},

{x} are satellite measurements of albedos and brightness temperatures (or their functions).

Fire detection algorithms, in fact, ignore the optical- geometric conditions of satellite measurements in the explicit form

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FIRE DETECTION ALGORITHMS

1. FIXED-THRESHOLDS TECHNIQUES

$T_4 > T_{4,\, min}$; $dT > dT_{min}$

$T_{11} > T_{11,\, min}$

$R_\lambda < R_{\lambda,\, max}$

$abs\,(R_{red} - R_{NIR}) > 0.01$

Symbols:

R_λ – channel's reflectances (albedos)

T_4, T_{11} – brightness temperatures (4 mm & 11 mm)

$dT = T_4 - T_{11}$

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FIRE DETECTION ALGORITHMS

2. SPATIAL ANALYSIS (OR CONTEXTUAL) TECHNIQUES

$$T_4 > T_{4,\,min};\; dT > dT_{min}$$

$$T_4 > mean(T_4) + C \times stddev(T_4)$$

$$dT > mean(dT) + C \times stddev(dT)$$

$$T_{11} > mean(T_{11}) + stddev(T_{11})$$

Symbols:

mean(x) – mean value of x

stddev(x) – standard deviation of x

C – fixed coefficient, $C = 2.0 \div 4.0$

mean and stddev are computed for pixels within the window $N \times N$ centered on the potential fire pixel, $N = 3 \div 21$

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THE OBSERVED THERMAL RADIANCE (I_λ)

$$I_\lambda = B_\lambda\,(T_\lambda) = I_{HOT} + I_{BG}$$

where

B_λ (T) = Planck's function
T_λ = observed brightness temperature
I_{HOT} and I_{BG} = HTO's and background radiance

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THE RADIANCE OF HTO (I_{HOT})

$$I_{HOT} = B_{HOT}\, P_\lambda, \quad B_{HOT} = p(\theta)\, \varepsilon_\lambda^{H}\, B_\lambda\, (T_H),$$

$$P_\lambda = \exp\{-\tau_\lambda(\theta)\},\; p(\theta) = S_H / S_{FOV}\, (\theta)$$

where

P_λ = atmospheric transmittance

ε_λ^{H} = HTO's emissivity (≈ 0,95)

τ_λ = optical thickness of the atmosphere

θ = view angle

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BACKGROUND RADIANCE (I_{BG})

$$I_{BG} = I_{SRF} + I_{ATM} + I_{RFL} + I_{SCT}$$

$$I_{SRF} = (1-p)\, \varepsilon_\lambda^S\, B_\lambda(T_S)\, P_\lambda$$

where

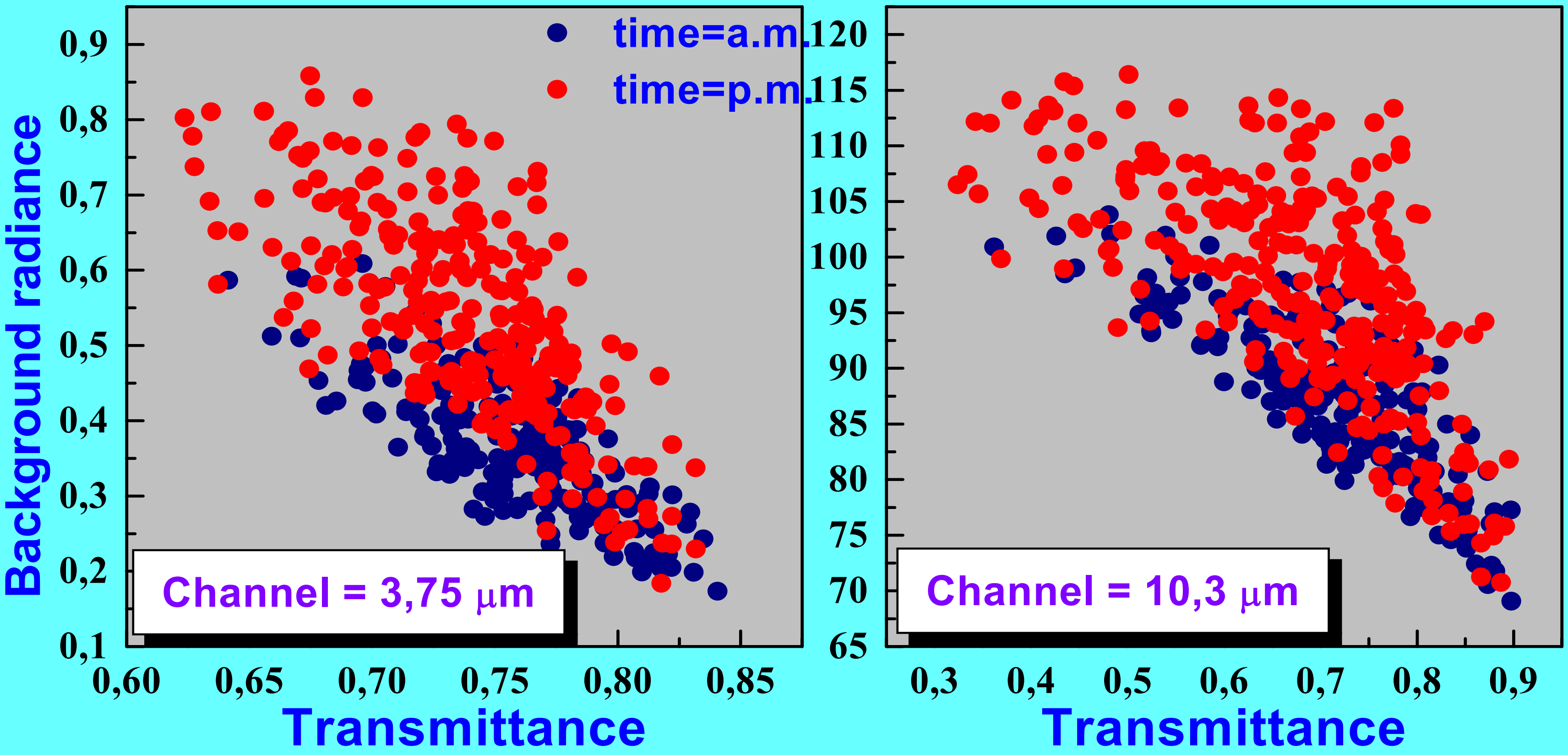
I_{SRF} = **transmitted surface radiance**

I_{ATM} = **atmospheric radiance**

I_{RFL} = **ground reflected (thermal and solar) radiance**

I_{SCT} = **path scattered (thermal and solar) radiance**

ε_λ^S = **background emissivity (≈ 0,96-0,98)**



Mean value and standard deviation:

I_{BG} = 0.4644, 0.1468 (31.6%)

P_{λ} = 0.7465, 0.0413 (5.5%)

T_{λ} = 289.96, 7.22

Mean value and standard deviation:

I_{BG} = 93.064, 10.108 (10.9%)

P_{λ} = 0.6924, 0.1163 (16.8%)

T_{λ} = 287.36, 6.74

Radiance = $mW/(m^2 \cdot sr \cdot cm^{-1})$

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RESULTS OF MODELLING

Visibility	exp(-τ)	I_{BG}	Fraction of I_{BG} (%)		
			$I_{SRF}+I_{ATM}$	I_{RFL}	I_{SCT}
mol	0.74648	0.46435	89.77	10.22	0.02
40 км	0.73267	0.46510	88.58	9.95	1.47
40 км	0.72971	0.46356	88.96	9.83	1.21
20 км	0.71791	0.46592	87.35	9.68	2.97
10 км	0.68934	0.46691	85.07	9.19	5.74
5 км	0.64510	0.46854	81.33	8.45	10.21
2 км	0.53298	0.47356	71.06	6.67	22.27
2 км	0.49339	0.45236	77.14	5.25	17.60
2 км vs mol	- 28.60%	+1.98 %			
2 км vs mol	- 33.90%	- 2.58 %			

Red color = rural aerosol

Blue color = urban aerosol

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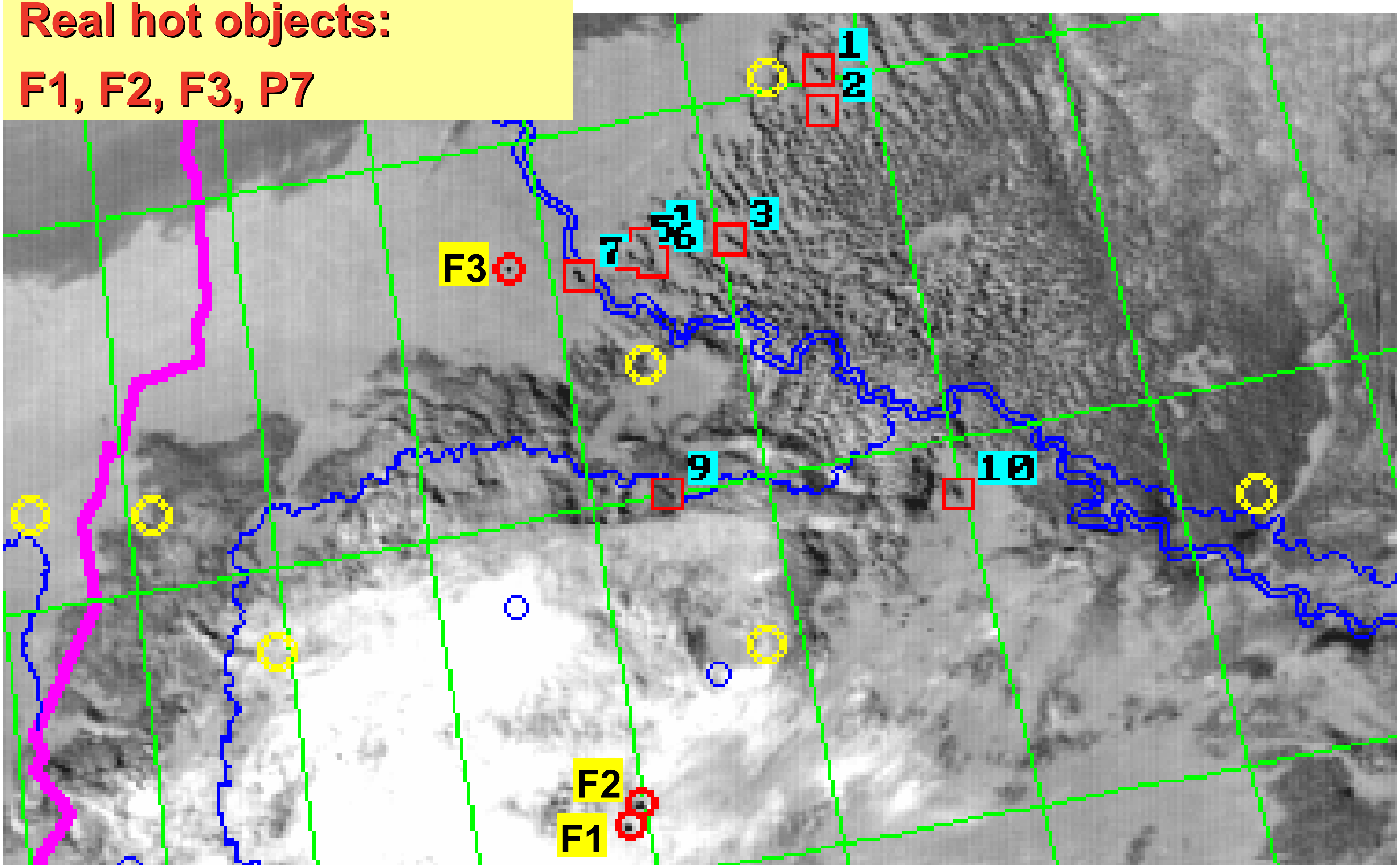
Channel 3 (λ = 3.75 μm)

Real hot objects:

F1, F2, F3, P7



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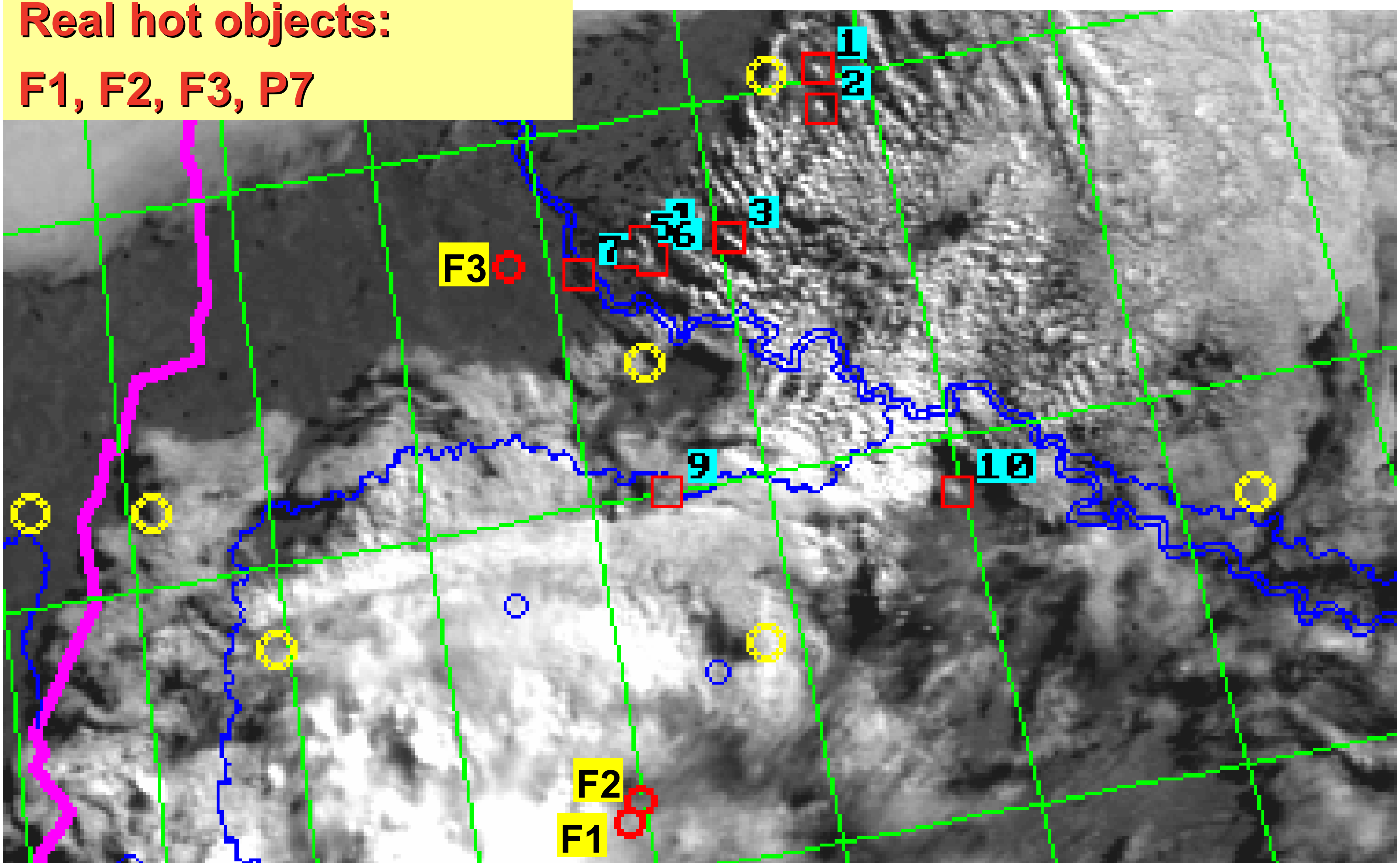
Channel 2 (λ = 0.84 μm)

Real hot objects:

F1, F2, F3, P7



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$$B_{HOT} = (I_\lambda - I_{BG}) / P_\lambda$$

where

I_λ is the observed thermal radiance and the values;

I_{BG} and P_λ are calculated from *a priori* optical-meteorological data.

Input data:

- geometrical conditions of observations: the view angle θ, solar zenith angle Z, and relative azimuth j;

- meteorological parameters of the atmosphere;

- optical characteristics of the atmospheric aerosol (clouds);

- surface parameters (reflectance, emessivity, temperature).

decision rule $B_{HOT} > dB$ will be independent of the optical-geometrical conditions of observations

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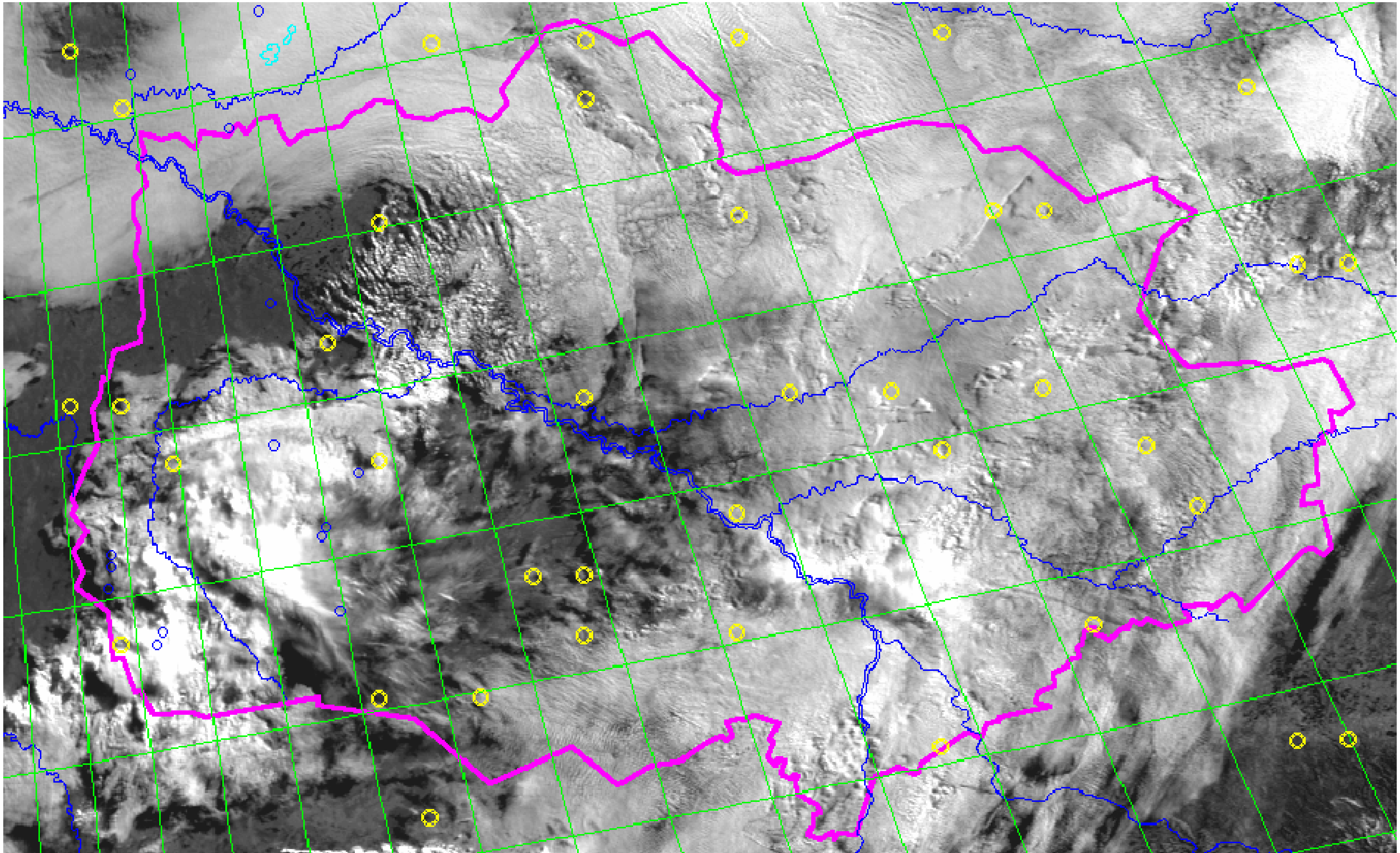

NOAA/AVHRR image, channel 2 (λ = 0.84 μm)
Tomsk region, date=21.05.2001, time=23:56 GMT
TOVS-meteo = yellow circles

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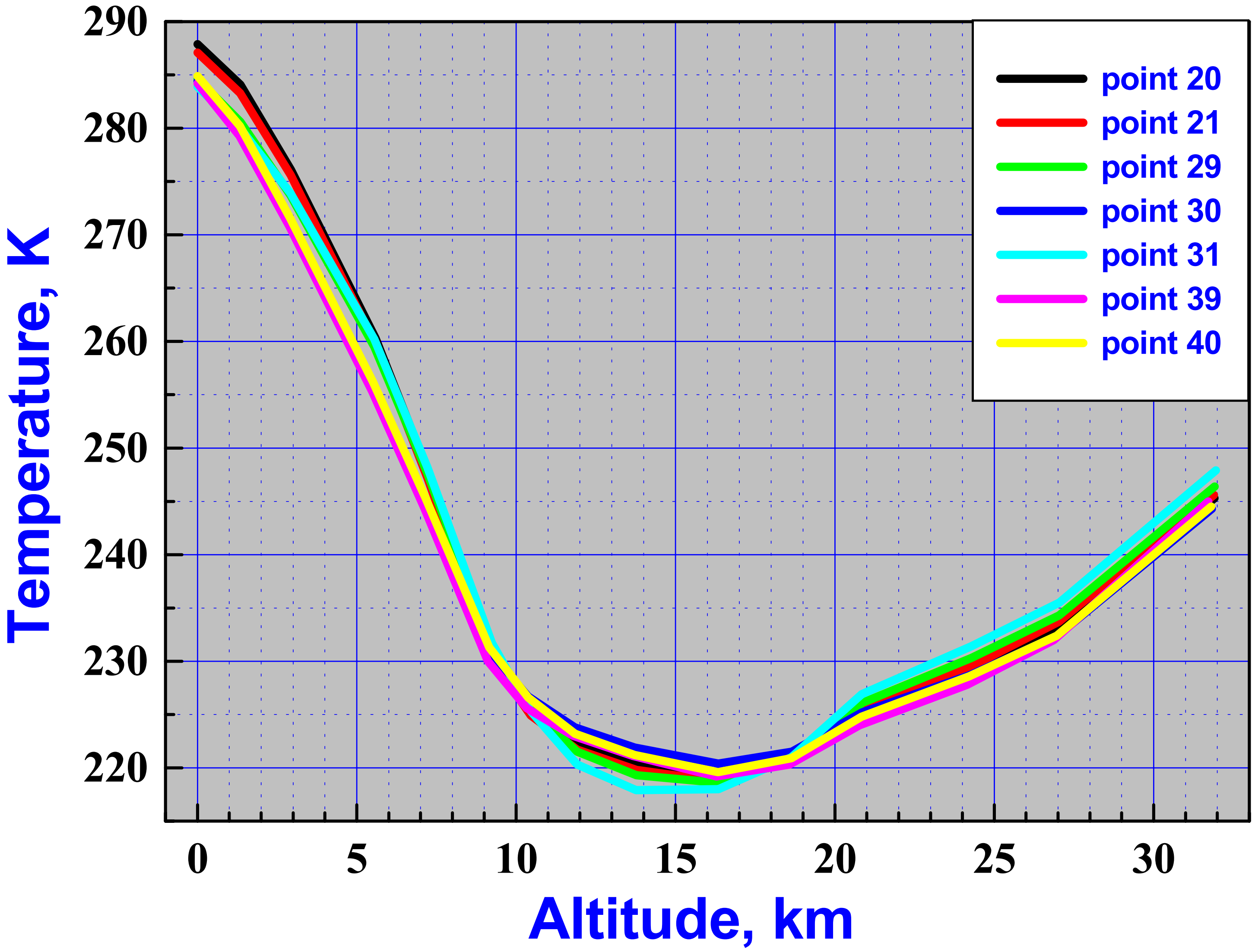
TOVS – meteo:
date = 21.05.2001; time = 23:56 GMT



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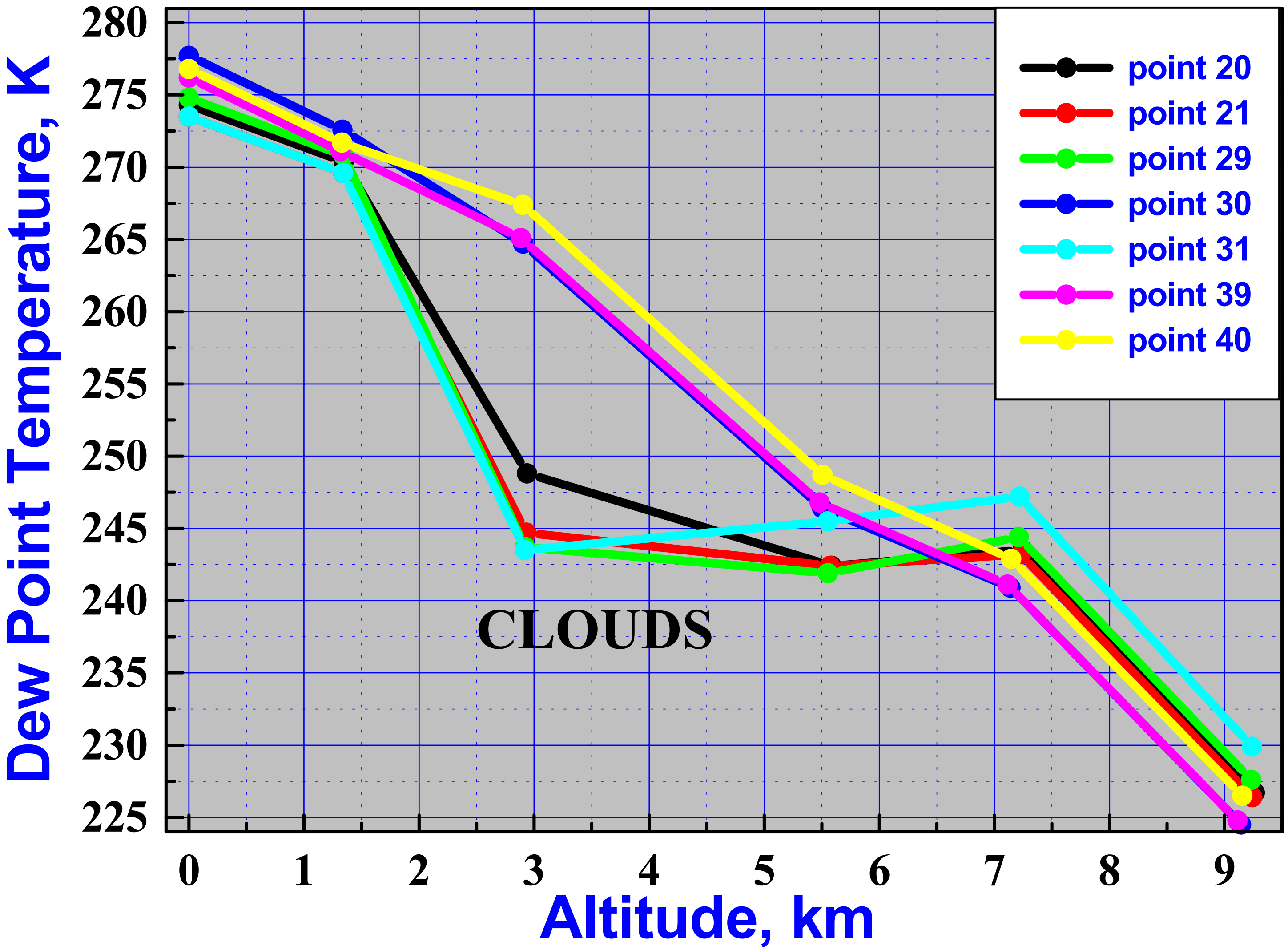
TOVS – meteo:
date = 21.05.2001; time = 23:56 GMT



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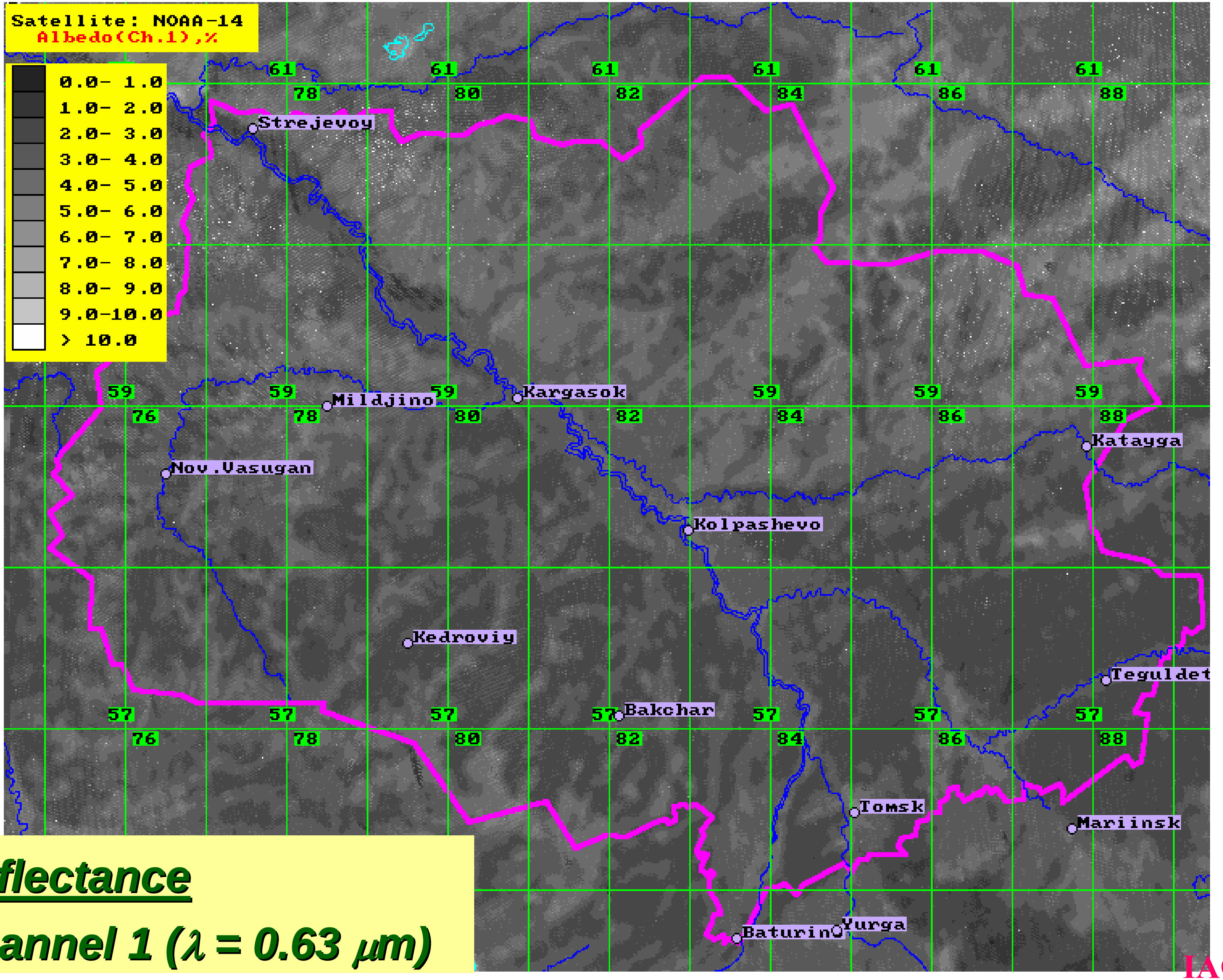

Reflectance

Channel 1 ($\lambda = 0.63\ \mu m$)

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Results of reconstruction of the HTO thermal radiance

Statistical characteristics of satellite measurements at points F1, F2

Points	A_1, %	A_2, %	T_3, K	T_4, K	T_5, K
F1	**8.38**	**8.80**	**293.0**	**259.3**	**256.9**
	8.74 1.25	8.94 1.09	272.8 3.98	259.3 2.75	257.3 2.59
F2	**5.77**	**6.40**	**322.6**	**268.4**	**266.2**
	6.16 1.276	6.49 1.28	276.0 6.45	266.0 3.24	264.0 3.11

Results of reconstruction of the HTO thermal radiance

Points	I_λ	P_λ	I_{BG}	B_{HOT}
F1	0.503	0.055	0.260	4.459 (355.5K)
F2	1.650	0.251	0.297	5.390 (358.5K)

I_λ, I_{BG}, and B_{HOT} = mW/(m^2·sr·cm^{-1})

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MAIN CONCLUSION

USING:

- geometrical conditions of observations;
- meteorological parameters of the atmosphere;
- optical characteristics of the atmospheric aerosol;
- surface parameters

WE HAVE REALIZED

decision rule $B_{HOT} > dB$ which is independent of the optical-geometrical conditions of observations


Thank you for attention !