FOREST TEST SITE AT JÄRVSELJA, ESTONIA

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ABSTRACT

The forest test site at Järvselja, Estonia is addressed in the new proposal for CHRIS multispectral multiangular acquisition. Short introduction of the test site, the previous work done, and the plans of using CHRIS data are described.

1. INTRODUCTION

The forest test site at Järvselja, Estonia is addressed in the CHRIS proposal "Validation of the directional multispectral forest reflectance model and estimation of forest parameters by model inversion". Several canopy reflectance models have been developed at Tartu Observatory for the interpretation of remote sensing data. There is a forest study area at Järvselja which serves as a field base for forestry students of the Estonian Agricultural University. A 10x10 km test site for the POLDER mission was there. Several satellite images (Landsat TM, Spot) of the area have been collected since 1985. Thorough ground measurements on the test site (forest inventory data, LAI, fish-eye images, ground vegetation reflectance spectra) have been performed several times in the frame of VALERI (2005) project. A short overview of the work on radiative transfer in vegetation canopies, and a description of the Järvselja test site are given.

2. STUDY OF RADIATIVE TRANSFER IN VEGETATION CANOPIES IN TARTU OBSERVATORY

Radiative transfer in vegetation canopies has been studied at Tartu Observatory for several decades. Theoretical studies by J. Ross, T. Nilson, Y. Knjazikhin, A. Marshak, A. Kuusk and M. Mõttus, and field studies by J. Ross, T. Nilson, A. Kuusk, M. Lang, U. Peterson, M. Sulev, M. Mõttus have been mainly published in remote sensing journals (Myneni and Ross, 1991; Nilson, 1992; Peterson and Nilson, 1993; Kuusk, 1994; Ross and Sulev, 1997; Nilson and Ross, 1997; Kuusk and Nilson, 2000; Nilson et al., 2003; Nilson and Kuusk, 2004; Mõttus, 2004).

During last few years much attention has been paid to the off-nadir reflectance characteristics of ground surface and, in particular, to the bidirectional reflectance distribution functions (BRDF). Non-Lambertian reflectance character is now treated not only as a source of noise for remote sensing systems that causes problems in the interpretation of satellite images, but rather as a source of additional information e.g. (Asner et al., 1998).

In a majority of practical applications, simple models with a minimum amount of parameters to determine, such as kernel driven BRDF models (Wanner et al., 1995) are preferred. However, more sophisticated models are also needed to understand how the reflected signal is formed and which are its most important driving factors.

Several theoretical models of the radiative transfer in vegetation canopies have been developed in Tartu Observatory (Nilson and Kuusk, 1985, 1989; Nilson and Peterson, 1991; Kuusk, 1994, 1995; Nilson and Ross, 1997; Kuusk and Nilson, 2000; Kuusk, 2001). These models are used both for the study of the energetics of vegetation canopies, and for the interpretation of remote sensing data and estimation of canopy parameters using the information provided by remote sensing satellites (Kuusk, 1991; Kuusk et al., 1997; Kuusk, 1998; Nilson et al., 1999; Eklundh, 2001; Gemmell et al., 2002; Fang et al., 2003; Rautiainen et al., 2003). The canopy reflectance models developed at Tartu Observatory have been validated using field data (Kuusk et al., 1997), data of the BOREAS experiment (Nilson et al., 1999; Kuusk and Nilson, 2001), and by comparing to other canopy reflectance models at the Radiation Transfer Model Intercomparison (RAMI) (Pinty et al., 2004).

3. VALIDATION OF THE FOREST RADIATIVE TRANSFER MODEL FRT

Directional multispectral forest radiative transfer model FRT by Kuusk and Nilson (2000) describes directional

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spectral radiance of a forest canopy both in downward and upward directions. The model works in the optical spectral domain, from 400 to 2500 nm and is a mixed radiative-transfer/geometric-optical type of model. The use of analytical solutions of the radiative transfer problem makes it computationally undemanding, the model can be run on common PC-s. In the input to run the model, structural data on the main tree storey (stand density, tree height, crown height and diameter, trunk breast-height-diameter, one-sided leaf-area index, branch area index, shoot-level leaf (needle) clumping index, and parameters describing the tree distribution pattern and typical foliage element size) are needed.

The model has been tested using various available forest reflectance data. Figure 1 shows the reflectance spectrum of a 65-year-old pure Norway spruce (*P*icea abies) stand near Stockholm measured on board a helicopter by G. Alm and P. Syren using a GER-2600 spectrometer, compared to our model simulations (Nilson and Kuusk, 2002). In the model simulations different sets of leaf biochemistry data (contents of chlorophyll, protein, lignin+cellulose, water) have been used: expert estimates of biochemical data and the results of the inversion of leaf optics model using the published data of needle reflectance.

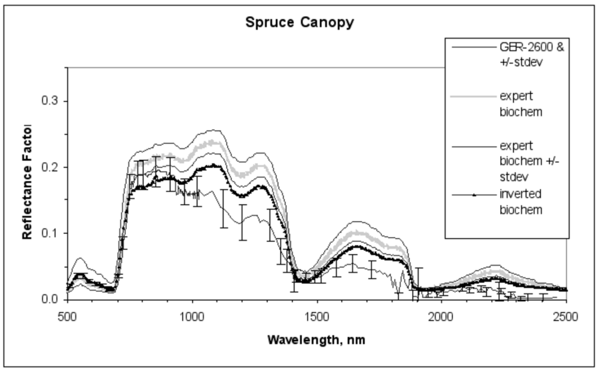

Figure 1. Measured on board a helicopter by GER-2600 reflectance spectrum and simulated spectra for a 65-year-old pure Norway spruce (Picea abies) stand near Stockholm.

Figure 2 shows the age dependence of the red reflectance of spruce-dominated stands at Järvselja, Estonia. The stand reflectances are measured from an atmospherically corrected Spot-4 image (triangles) and simulated by the FRT model (curve). For simulation, the time course of stand parameters is determined by means of spruce forest growth functions.

The FRT model enables us to calculate forest stand reflectance for any view direction and for the whole optical range of 400-2500 nm. Either bidirectional (BRF) or hemispheric-directional (HRF) reflectance factors of a forest stand can be calculated. The directional reflectance dependence of the old black spruce stand at the BOREAS-South study site measured with PARABOLA instrument (Deering et al., 1999) and airborne POLDER

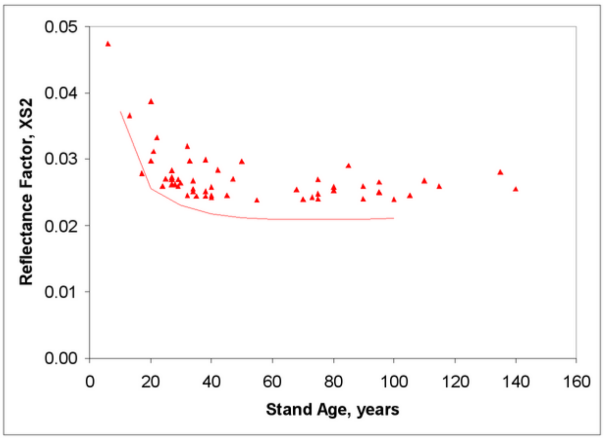

Figure 2. Age dependence of the red reflectance of spruce-dominated stands at Järvselja.

scanner (Bicheron et al., 1997) are compared to the simulated one in Figs. 3 and 4. The PARABOLA measurements were done on 7th June and 4th August 1994 (Deering et al., 1999), and the POLDER measurements on 31th May, 1th June, and 21th July 1994 (Bicheron et al., 1997). The agreement between the simulated and measured BRF distributions is rather good in the red region of the spectrum, while in the NIR region the simulated reflectances are systematically overestimated. However, the general shape of the BRF curve is adequately reproduced by the model in the NIR region, too. The used values of needle reflectance ρ_L and transmittance τ_L from the PROSPECT2 model are noted in the figure legends.

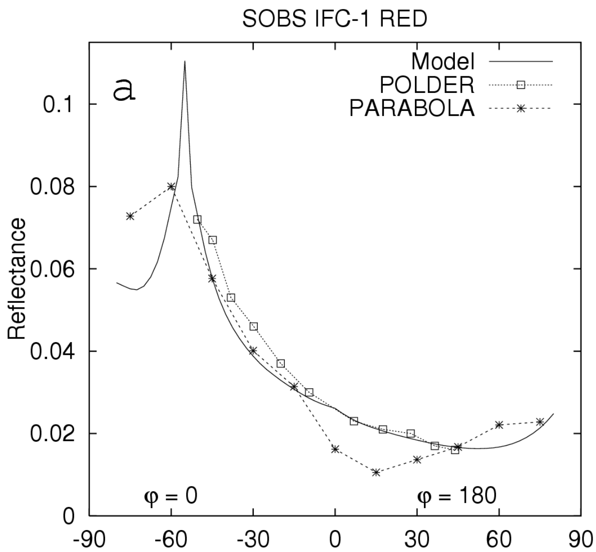

Figure 3. Red reflectance distribution of the SOBS stand in the principal plane (φ = 0, 180°), model calculations, and POLDER and PARABOLA data, IFC-1, Sun zenith 55°; ρ_L = 0.076, τ_L = 0.014.

The forest model FRT was compared to other canopy ra-

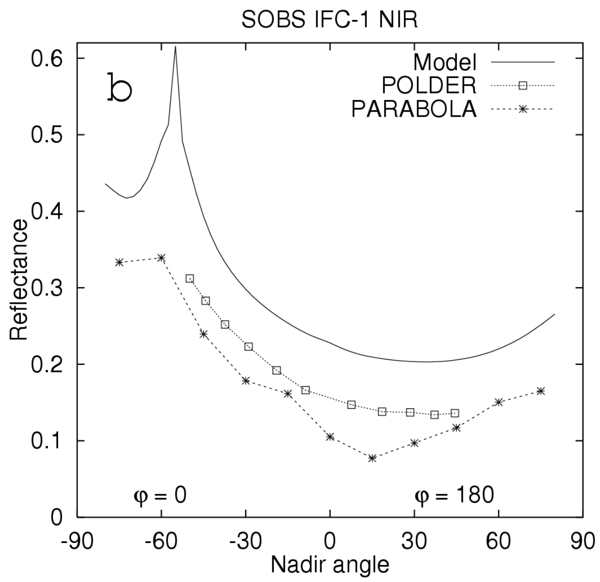

Figure 4. As Fig. 3, NIR; ρ_L = 0.475, τ_L = 0.301.

diative transfer models in the Radiation Transfer Model Intercomparison (RAMI) Phase 2 (Pinty et al., 2004). Some results of comparison are shown in Figs 5, 6, 7 and 8.

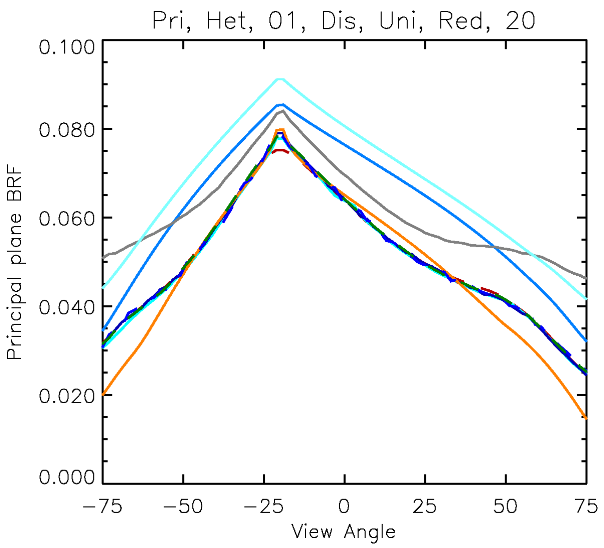

Figure 5. Comparison of canopy reflectance models, red spectral region, Sun zenith angle 20° (Pinty et al., 2004).

The RAMI excercise demonstrated that the forest model FRT performs well if compared to other more complex models which could be run only on mainframe computers. Some problems appeared in the NIR region, evidently due to the approximate solution of multiple scattering problem in the FRT model.

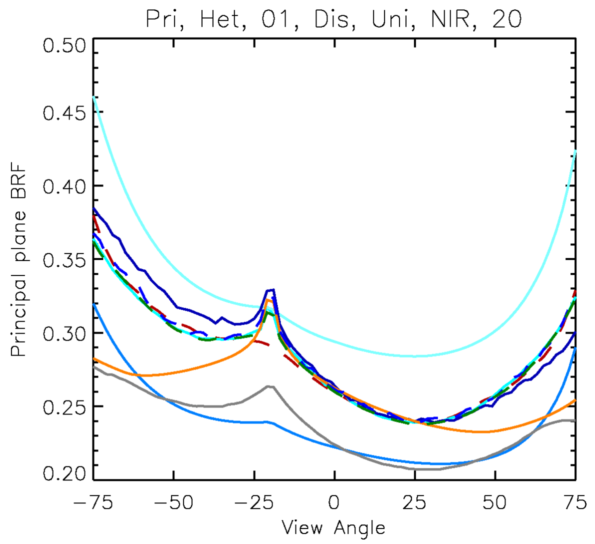

Figure 6. As Fig. 5, the NIR channel.

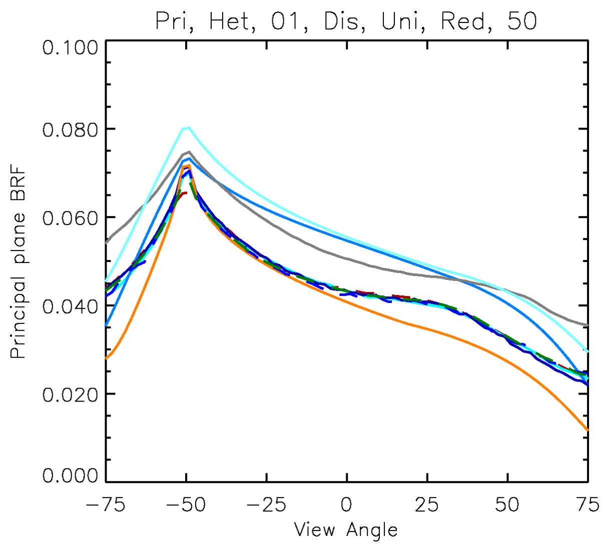

Figure 7. As Fig. 5, Sun zenith 50°.

4. FOREST TEST SITE AT JÄRVSELJA

The forest test site at Järvselja is a training base for the forestry students of the Estonian Agricultural University. The test site is located in South-East Estonia, 27.2624E 58.2986N, Fig. 10.

The Landsat7 ETM+ scene of May 31, 2002 in Fig. 11 shows the boundaries of the training base. The boundaries of the VALERI test sites of 3 × 3 and 10 × 10 km are drawn with yellow lines.

Area division at Järvselja study base is shown in Fig. 12, the species composition in Table 1, and the land use in Fig. 13.

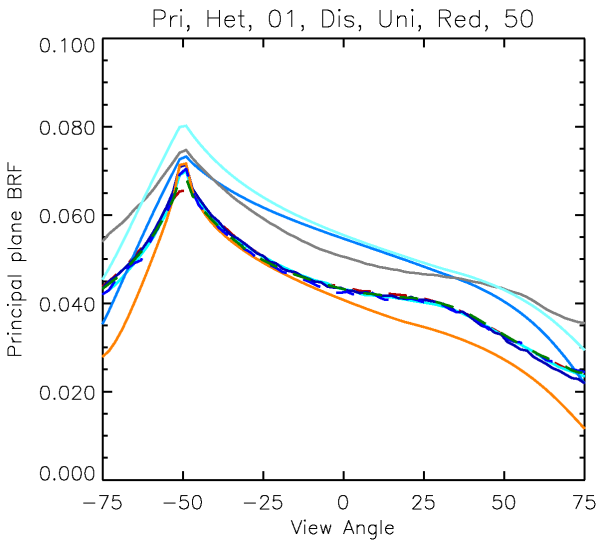

Figure 8. As Fig. 7, the NIR channel.

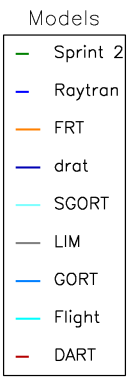

Figure 9. Key for the plots of RAMI results. Other models are introduced in (Pinty et al., 2004).

Table 1. Species composition at Järvselja test site.

Conifers	
Pine	63.19
Spruce	36.02
Larch	0.36
Douglase spruce	0.06
Swiss pine	0.04
Fir	0.03
Deciduous trees	
Birch	84.97
Alder	11.29
Aspen	2.20
Lime	0.59
Gray alder	0.59
Ash	0.30
Oak	0.04
Mountain ash	0.01

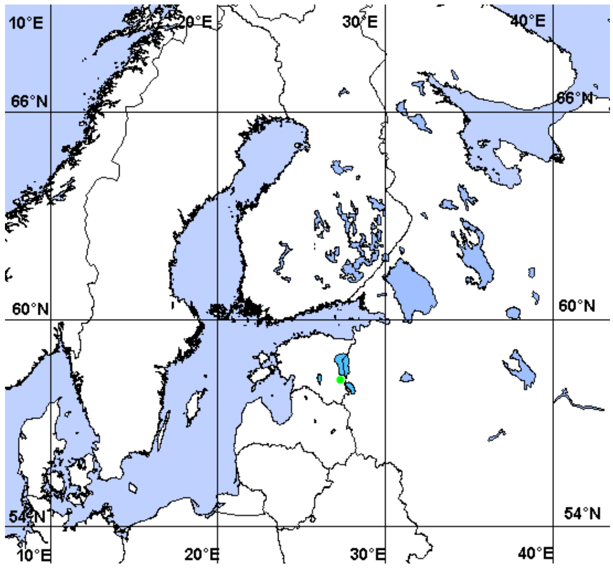

Figure 10. Location of the Järvselja test site.

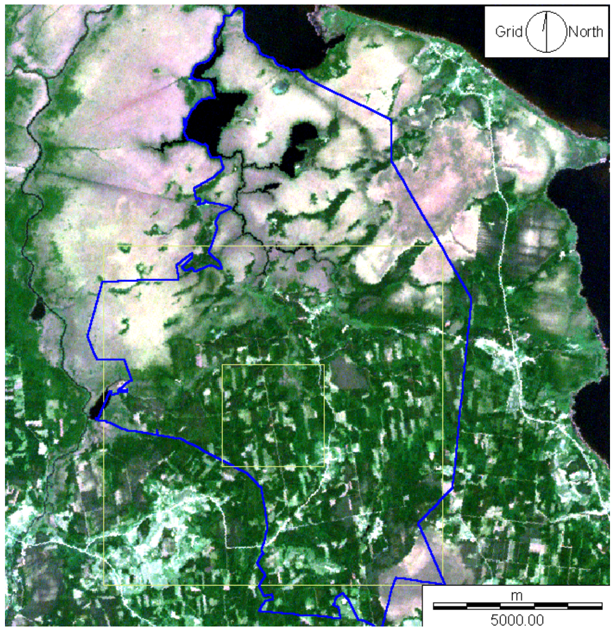

Figure 11. The Landsat ETM+ scene of the study area, 31 May 2002.

5. PRESENT INFORMATION

5.1. Mensuration data

Regular forest mensuration in Järvselja is performed with the time interval of 10 years, the last complete set of measurements and the respective database are from year 2001. Several forest inventory parameters like species composition, age, breast-height diameter, tree height, site type have been measured/recorded for every stand. There are 3561 homogeneous stands in the 10 × 10 km VALERI site, and 515 stands in the 3 × 3 km square, while

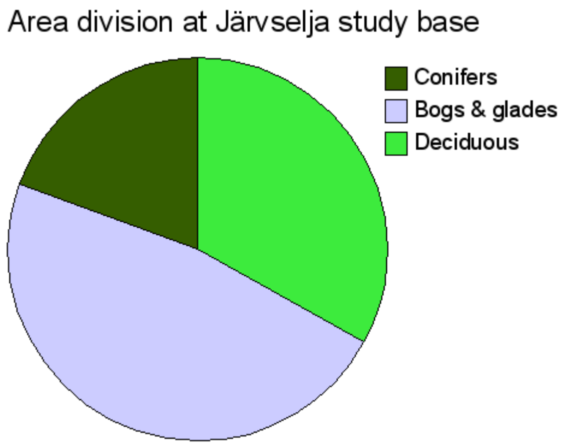

Figure 12. Area division at Järvselja study base.

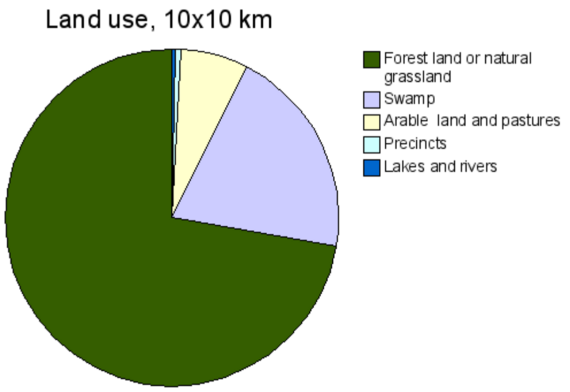

Figure 13. Land use in the test site.

the latter is more thoroughly studied.

5.2. Special studies

Various specific measurements have been carried out in several stands of the 3 × 3 km VALERI test site, Fig. 14:

- LAI-2000 measurements for the angular distribution of gap fraction and leaf area index
- digital upward and downward hemispherical images for the same purpose
- canopy spectral transmittance with 4-channel hemispherically integrating radiometer and 2-channel imaging CCD-radiometer of 180° FOV
- reflectance of ground vegetation with 4-channel radiometer of 13° FOV and GER-2600 visible-NIR spectrometer

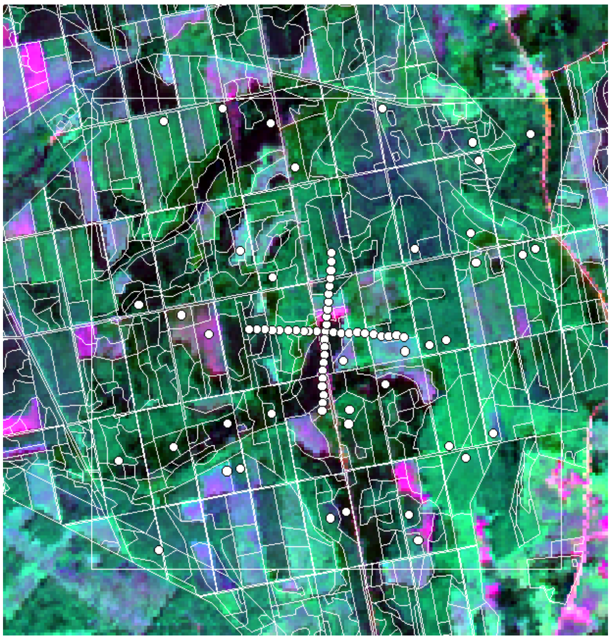

Figure 14. A false-color SPOT4 image (26 June 2003) of the VALERI test site overlayed with the grid of stand boundaries. The white points correspond to locations of ground-based measurements.

5.3. Satellite images

Satellite images of the study area have been collected since 1986, Table 2.

6. CHRIS DATA

The CHRIS mode 3 images at five directions will be used for the validation of the forest reflectance model FRT, and for the developing of the methods of model inversion. The CHRIS images will also be used within the ongoing VALERI project (principal investigator F. Baret, INRA, France (VALERI, 2005)) to test methods of determination of vegetation parameters like LAI and APAR by large-swath satellite sensors. Järvselja site is one of the ground test areas of the VALERI project.

The forest reflectance model FRT developed at Tartu Observatory can be used for the interpretation of multispectral and/or multiangular remote sensing data in the wide range of Sun and view angles in the whole optical domain 400-2500 nm. As several stands at the Järvselja test site are rather small (the average size of stands does not exceed 3 ha) the CHRIS spectrometer in mode 3 (full spatial resolution, full swath, 18 bands) will provide data which meet the needs of model validation in the best way.

Table 2. Satellite images of the test site.

	Sensor	Frame	Year/M/D
1	HRV		1986/6/15
2	TM	185-19	1987/5/23
3	TM	186-19	1988/5/16
4	TM	186-19	1988/6/9
5	TM	186-19	1992/5/27
6	TM	186-19	1992/6/28
7	HRV		1992/7/24
8	TM	186-19	1993/3/11
9	HRV		1994/5/9
10	TM	186-19	1994/5/10
11	TM	186-19	1995/8/24
12	TM	186-19	1996/3/19
13	TM	186-19	1996/5/22
14	HRV		1997/8/12
15	TM	186-19	1997/8/29
16	TM	186-19	1998/5/12
17	ETM+	186-19	1999/7/10
18	ETM+	186-19	2000/4/23
19	ETM+	186-19	2000/5/9
20	ETM+	186-19	2000/6/10
21	HRV-IR		2000/8/26
22	ETM+	186-19	2000/9/30
23	ETM+	185-19	2001/5/5
24	HRV		2001/6/25
25	HRV-IR		2001/7/4
26	ETM+	186-19	2002/5/31
27	HRV-IR		2002/7/13
28	ETM+	186-19	2002/7/18
29	ASTER-VNIR	186-19	2002/8/10
30	ETM+	186-19	2002/8/19
31	HRV		2003/6/26

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