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Global Monitoring with LoRes EO-Imagery Time Series Analysis with SPIRITS software

Vlaamse Instelling voor Technologisch Onderzoek

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1. VITO's Remote Sensing Centre (TAP)
2. EU-MARS: Global Agricultural Monitoring
3. FAO-ASIS: Global Drought Monitoring
4. **SPIRITS: Introduction & Overview**
5. SPIRITS: Some practical exercises

SPIRITS: Introduction & Overview

Contents:

- Backgrounds
- Image Format & Conventions
- Functionalities

SPIRITS: Backgrounds

- GLIMPSE = Global Image Processing Software
  - Set of programs for image processing, mainly for:
    - *Time series analysis (LoRes)*
    - *Classification (HiRes/Hard, LoRes/Soft)*
  - ± Extension to commercial packages IDRISI and ENVI

History	Language	Image Format	
• 1986→1996:	DOS/QuickBasic	IDRISI	
• 1997→present:	DOS/ANSI-C	IDRISI & ENVI	
• 2010→present	Windows/JAVA	ENVI	⇒ SPIRITS

- SPIRITS = Software for the Processing and Interpretation of Remotely sensed Image Time Series:
  - Windows GUI with C-modules of Glimpse (no BASIC)
  - New features: User tools, RUM-database/viewer, import/export, …
- Why not simply using existing software?
  - Nineties: no software (IDRISI around 1992?) or too expensive
  - Not always exactly what is needed → Adaptations always needed

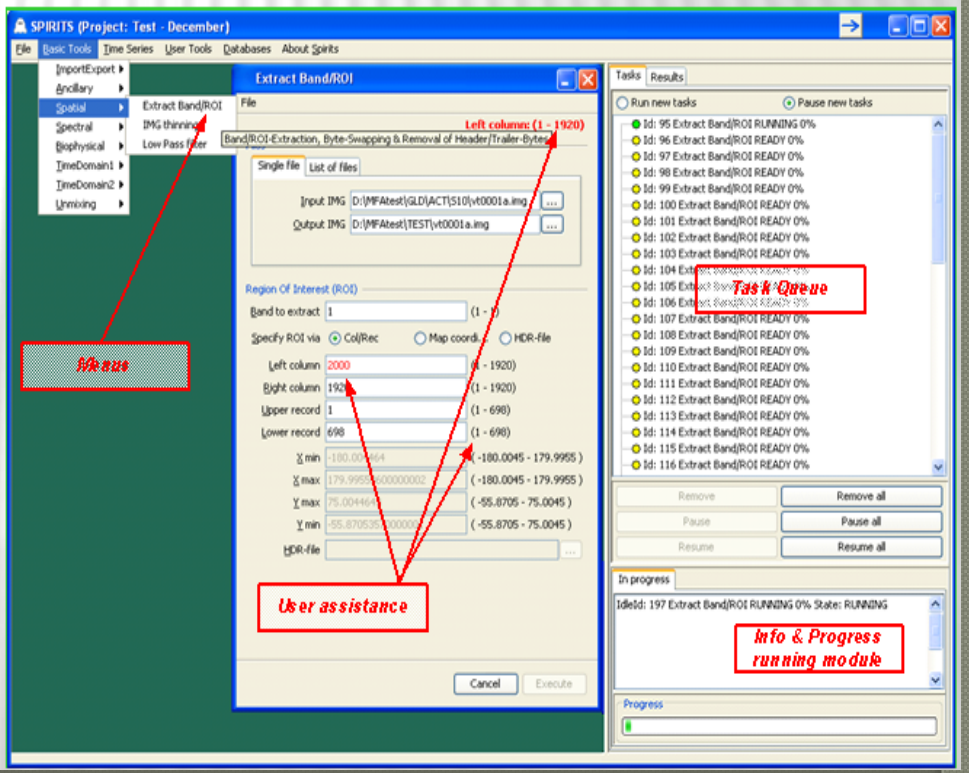
SPIRITS: Backgrounds

Glimpse (Herman Eerens)

```
VGTflag: ADD FLAGS from SM/MASK to SPOT-VGT NDVI IMG

    VGT-IMGs from CTIV, E-STATION or DEVCOCAST, CONVERTED from HDF/TIF to IMG:
p1. NDVI-IMG (BYTE - no extension)
    - Scale: NDVI [-0.10 -> +0.92] = -0.10 + 0.004 * V [0 -> 255]
    - Flags: none (they are stored in the Status Mask SM)
p2. Corresponding Status Mask IMG (BYTE - no extension)
    - Meaning of SM-bits when switched to 1 (MSB=bit7):
        bit 7-4: NO error in Blue, Red, NIR, SWIR
        bit  3 : Land (following SM Land Mask)
        bit  2 : Snow/Ice over land
        bit  1 : Cloud over land
        bit  0 : Cloud shadow
    - NB: . SM Land mask includes wide rim of sea pixels along the coasts.
          . No data (NDVI=SM=0) for sea pixels
            but also for boreal pixels in winter (no light).

    OPTIONAL LAND MASK (BYTE):
p3. Name of Land Mask IMG (no extension - enter blank/dummy if none)
    - BYTE-range: values > 0 are 'land', 0 = 'sea'
    - Useful for two differentiations, not made in original SPOT-VGT data:
      . Real sea  pixels vs. boreal pixels in winter (no light).
      . Real land pixels vs. sea pixels around coasts (in VGT land mask).

    OUT-IMG to CREATE (COPY OF NDVI-IMG p1 but RESCALED and FLAGGED):
p4. Name of NDVI OUT-IMG (BYTE - no extension)
    - Scale: NDVI [-0.08 -> +0.92] = -0.08 + 0.004 * V [0 -> 250]
      The original NDVI V-values are shifted downward with 5 units.
      Lowest values (V=0-5, NDVI<-0.08) are lost but these are water/clouds.
      The range 251-255 becomes free to store the flags.
    - Flags: 251=missing (error+boreal), 252=cloud/shadow, 253=snow/ice,
             254=sea, 255=background

NB: - All info is now combined in one IMG: real data + special cases (flags).
      This simplifies the further processing.
      Otherwise one always has to include/consider the ancillary masks.
    - Land Mask (p3) used:
      YES: Fraction of background flags (255) will be minimum to zero.
      NO : All sea and boreal winter pixels mixed in flag 255 (no 254-pixels).
```

- ANSI C-programs
- DOS Command line
- Automated “chains” via scripts (BAT, Python, TCL,…)

Spirits (Dominique Haesen)



- Windows/JAVA based GUI
- Glimpse programs + Many others
- Database & graphical tools
- Main objective: Interactive use!

SPIRITS: Backgrounds

USAGE OF GLIMPSE PROGRAMS

1. Interactive mode → Enter PROG name & simply answer questions
2. Command Line mode → PROG name followed by all parameters
3. Batch mode → Include CL-lines in SCRIPT (BAT, TCL, Python,…)

Example of a Script to extract data over Brazil from Global METOP IMGs for all 36 dekads in 2015. NB: "otYYTTk"=smoothed NDVI. IMGcvt.exe is GLIMPSE program to extract a ROI from a bigger IMG.

```
SET IN=c:\METOP\GLO                    'Here are the GLOBAL IMGs
SET OUT=d:\METOP\BRA                   'Here the extracts over BRAZIL
SET YY=2015                            'We only treat year 2015

FOR TT=01 to 36                        'Scan all dekads in year 2015

   IMGcvt %IN%\ot%YY%%TT%k  [other parameters] %OUT%\ot%YY%%TT%k

NEXT TT
```

SPIRITS allows to treat such Time Series (TS) at once.

SPIRITS: Backgrounds

- **Intellectual Property Rights (IPR):**
  - Fully developed by VITO
  - But mainly on funds of MARSOP contracts → IPR for EU-JRC
  - Contributions from VITO and FAO (ASIS)
  - EU-JRC maintains website (forum)
- **Versions**
  - First official release in November 2013 (Africa-GIS, Ethiopia)
  - Today: Version of March 2016
  - More improvements on-going and envisaged (JRC, FAO, VITO)
  - Eerens H, Haesen D, Rembold F, Urbano F, Tote C, Bydekerke L, 2013, *SPIRITS: An image processing software for crop and vegetation monitoring*
    Environmental Modelling and Software 53C (2014), pp. 154-162.
  - *NB: SPIRITS not always contains latest version of GLIMPSE modules.*

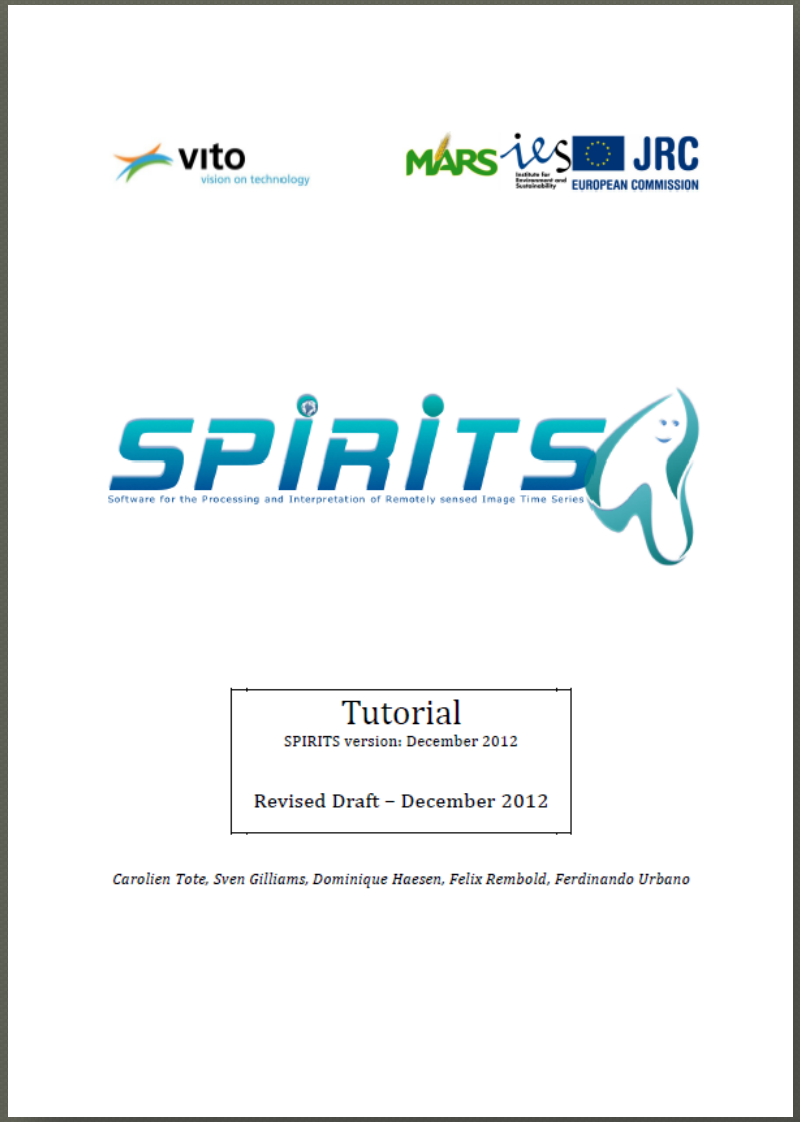
SPIRITS: Backgrounds

SPIRITS website

- Maintained by JRC-FoodSec (Felix Rembold & Ferdinando Urbano)
- All aspects: Intro, downloads, support, tutorial & test data.

http://spirits.jrc.ec.europa.eu/

SPIRITS Documentation



SPIRITS: Backgrounds

WHO ARE THE USERS ?

- Internally at VITO & JRC.
- Agricultural monitoring experts (e.g. Ministries of Agriculture and Forestry, Rural Development projects, FAO, WFP, etc…)
  → AgroMet Bulletins
- Remote sensing or GIS experts/students in research organizations
- Others…

Many training sessions…

NB: SPIRITS replaced WINdisp

SPIRITS: Backgrounds

Software Installation:

- Standard Microsoft Windows with enough Disk Space for DATA
- JAVA Runtime Environment (JRE 1.6 or higher)
- Download file **SPIRITSextract.exe** from JRC website
- Run it – Only question is in which folder? Mostly "*x*:\SPIRITS"
- Situation afterwards in "*x*:\SPIRITS" (± 600 MB for the software):

FOLDER\FILE	CONTENTS
Spirits.jar	**Main JAVA-executable**
Spirits*.ico	Icons to call SPIRITS from desktop
SpiritsManual.pdf	Manual (also accessible via HELP)
LIBS*.*	Libraries (open source) for DB, QLK,…
LIBS\GLIMPSE	GLIMPSE executables
SpiritsDefaultProject*.*	Default/initial place for all user data (modifiable via Projects in FILE menu)

SPIRITS: Introduction & Overview

Contents:

- Backgrounds
- Image Format & Conventions
- Functionalities

SPIRITS: "Modified ENVI" Image format

IMAGE DATA

- Binary files with fixed extension *.IMG (X.IMG)
- Only 2D (one IMG-file=one image layer) → 3D via "Metafiles"
- No leader/trailer bytes
- Only 4 datatypes allowed (BPP=bytes-per-pixel):

DOMAIN	DATATYPE		BPP	MIN_VAL	MAX_VAL
Integers	BYTE	(8 bit unsigned)	1	0	255
	INTEGER	(16 bit signed)	2	-32 768	+32 767
	LONG	(32 bit signed)	4	-2 147 483 648	+2 147 483 647
Reals	FLOAT	(32 bit signed)	4	-3.4 E+38	+3.4 E+38

- Image size in bytes = Ncol x Nrec x BPP

ANNOTATION or "METADATA"

- Via ASCII-formatted ENVI HDR-files (X.HDR)
- Also support for IDRISI DOC-files (X.DOC) → **Obsolete**

ENVI HDR-files (white=added by SPIRITS)

CAT	KEYWORD	DESCRIPTION
GENERAL	Description = {…}	Textual info, general title
	Comment = {…}	More textual info
	Program = {…}	Name of program, which generated this IMG (+ version between brackets)
	Sensor type	E.g. SPOT-VGT, NOAA-AVHRR,… (only textual information)
	Bands	Nr. of image layers (for GLIMPSE/SPIRITS: normally Bands=1)
	Interleave	BSQ, BIL or BIP – Only for 3D-IMGs with Bands > 1
SPECTRAL	File type	"ENVI Standard" for ordinal IMGs, "ENVI classification" for categorical IMGs
	Header offset	Number of leader bytes before the real image data
	Data type	1=BYTE, 2=INTEGER, 3=LONG, 4=FLOAT
	Byte order	0=High-Endian, 1=Low-Endian (only if datatype > 1)
	Values = { V_{name}, V_{unit}, V_{lo}, V_{hi}, V_{min}, V_{max}, V_{int}, V_{slo} }	Name of physical variable Y (e.g. reflectance, temperature, class,…) Dimension of physical variable Y (e.g. %, ° C, -, …) Lowest digital value of significant range (values beyond V_{lo}/V_{hi} are flags) Highest … Lowest significant value which really occurs in this IMG Highest … NB: $V_{lo} \leq V_{min} \leq V_{max} \leq V_{hi}$ Intercept of linear scaling: physical Y = V_{int} + V_{slo} x V Slope … NB: The scaling only applies to significant range
	Classes	Nr. of classes, incl. unavoidable class 0. More correct: highest class_ID + 1
	Class names = {…}	For each class, starting with 0: class name (avoid commas!)
	Class lookup = {…}	For each class, starting with 0: R, G, B-values in range 0-255
	Flags = {…}	For each flag: "V=meaning" with V=digital value (only textual info)
SPATIAL	Samples	Number of IMG columns
	Lines	Number of IMG records
	Map info = { Name, Col_m, Rec_m, X_m, Y_m, ΔX, ΔY }	Projection_Name (= entry in file Map_proj.txt) IMG Col/Rec co-ordinates of "Magic Point" (see figure 3.3) Map X/Y co-ordinates of same "Magic Point" X/Y pixel size in MAP-units
TMP	Date	YYYYMMDD: IMG registration date, or startdate for composite IMGs
	Days	Periodicity in days: 1, 10, 30,…; 0=unknown/irrelevant; -1=actual registration

VALUES = {Vname, Vunit, V_{lo}, V_{hi}, V_{min}, V_{max}, V_{int}, V_{slo}}

Meaning of the image values V & Scaling to Physical values Y

- ***Ordinal images, with linear relation: Physical value Y = V_{int} + V_{slo}.V***

E.g. VGT-S10: NDVI [-] [-0.1 … +1.0] = -0.1 + 0.0040.V
Reflectance [-] [0.0 … +1.0] = 0.0 + 0.0005.V

- ***Categorical images (classifications): V = ID-nr of class (V_{int}=0, V_{slo}=1)***

E.g. "legend" or "key" 1=forest, 2=cropland, 3=water, …

Range of Digital Values V

-***Potential range***: Defined by Datatype (see before)

DOMAIN	DATATYPE		BPP	MIN_VAL	MAX_VAL
Integers	BYTE	(8 bit unsigned)	1	0	255
	INTEGER	(16 bit signed)	2	-32 768	+32 767
	LONG	(32 bit signed)	4	-2 147 483 648	+2 147 483 647
Reals	FLOAT	(32 bit signed)	4	-3.4 E+38	+3.4 E+38

NB: 99% of images are (or should be) Byte (most compact)

- ***Significant range***: Only these V are meaningful, others are excluded ⇒ "**flags**"
(V_{lo}, V_{hi}) The scaling only holds for this Significant range, not for flags!

- ***Observed range***: Truly occurring ($V_{lo} \leq V_{min} \leq V_{max} \leq V_{hi}$)
(V_{min}, V_{max}) No essential information, only used for visualisation.

FLAGS = {*V1*=meaning1, *V2*=meaning2, …}

- Special values/codes, selected beyond Significant range V_{lo} - V_{hi}.
- Used to indicate special cases: no data, clouds, water, …

SPIRITS: "Modified ENVI" Image format

The 16 image layers comprised in each dekadal composite of METOP-AVHRR.
The lower table gives the SM interpretation.
DT=1 for BYTE, 2 for SHORT INTEGER.

IMAGE		Physical Values Y			Scaling	Digital Values V	
vvv	DT	CONTENT	UNIT	$Y_{lo} \rightarrow Y_{hi}$	$Y = V_{int} + V_{slo}*V$	$V_{lo} \rightarrow V_{hi}$	V_{flag}
B1_REF	1	$R_{s,RED}$	%	0 → 62.50	Y=0.250*V	0 → 250	255
B2_REF	1	$R_{s,NIR}$	%	0 → 83.33	Y=0.333*V	0 → 250	255
B3A_REF	1	$R_{s,SWIR}$	%	0 → 62.50	Y=0.250*V	0 → 250	255
B4_BT	2	BT-Band 4	K	0 → 3276.7	Y=0.100*V	0 → 32767	-1
B5_BT	2	BT-Band 5	K	0 → 3276.7	Y=0.100*V	0 → 32767	-1
NDVI	**1**	**NDVI**	**-**	**-0.08 → 0.92**	**Y=-0.08 + 0.004*V**	**0 → 250**	**255**
LST	**1**	**Land surface temp.**	**°C**	**-50 → 75**	**Y=-50 + 0.5*V**	**0 → 250**	**255**
SZA	1	Sun Zenith Angle	degrees	0 → 125	Y=0.500*V	0 → 250	255
VZA	1	View Zenith Angle	degrees	0 → 125	Y=0.500*V	0 → 250	255
SAA	1	Sun Azimuth Angle	degrees	0 → 360	Y=1.500*V	0 → 240	255
VAA	1	View Azimuth Angle	degrees	0 → 360	Y=1.500*V	0 → 240	255
TVO	1	Nr. of Valid obs.	-	1 → 255	Y=V	1 → 255	0
TCO	1	Nr. of Clear obs.	-	1 → 255	Y=V	1 → 255	0
DAY	1	Day in Dekad	-	1 → 11	Y=V	1 → 11	0
ID	2	Segment_ID	-	1 → 32767	Y=V	1 → 32767	0
SM	1	Status Map	-	*bit-interpretation (see table below)*		1 → 255	0

Decimal	128	64	32	16	8	4	2	1
Bit-Value	**Bit7**	**Bit6**	**Bit5**	**Bit4**	**Bit3**	**Bit2**	**Bit1**	**Bit0**
1	Land	ValidObs	never	never	Good	Cloud or shadow	Cloud	Snow
0	Sea	NoValidObs	always	always	Acceptable	none of these	Cloudfree	NoSnow

SPIRITS: "Modified ENVI" Image format

- **Importance of added keywords VALUES and FLAGS:**
  - Standard software (ENVI, etc.): all operations on raw V-values
    $\Rightarrow$ Often wrong, Flags treated as normal data
  - GLIMPSE always accounts for …
    - Flags = all values beyond potential range (V_{lo} … V_{hi})
    - Scaling ($Y = V_{int} + V_{slo} \times V$)

Example for Ratio Vegetation Index RVI (R=RED, N=NIR):

- ENVI: $RVI' = V_N / V_R$
- GLIMPSE: $RVI = Y_N / Y_R = [a_N + b_N \times V_N] \,/\, [a_R + b_R \times V_R]$

- **HDR-files of the "Modified ENVI" Image Format:**
  - Only subset of ENVI-keywords $\Rightarrow$ Others are lost by SPIRITS
  - Added keywords $\Rightarrow$ Kept by ENVI !

ENVI HDR-files (white=added by SPIRITS)

CAT	KEYWORD	DESCRIPTION
GENERAL	Description = {…}	Textual info, general title
	Comment = {…}	More textual info
	Program = {…}	Name of program, which generated this IMG (+ version between brackets)
	Sensor type	E.g. SPOT-VGT, NOAA-AVHRR,… (only textual information)
	Bands	Nr. of image layers (for GLIMPSE/SPIRITS: normally Bands=1)
	Interleave	BSQ, BIL or BIP – Only for 3D-IMGs with Bands > 1
SPECTRAL	File type	"ENVI Standard" for ordinal IMGs, "ENVI classification" for categorical IMGs
	Header offset	Number of leader bytes before the real image data
	Data type	1=BYTE, 2=INTEGER, 3=LONG, 4=FLOAT
	Byte order	0=High-Endian, 1=Low-Endian (only if datatype > 1)
	Values = { V_{name}, V_{unit}, V_{lo}, V_{hi}, V_{min}, V_{max}, V_{int}, V_{slo} }	Name of physical variable Y (e.g. reflectance, temperature, class,…) Dimension of physical variable Y (e.g. %, ° C, -, …) Lowest digital value of significant range (values beyond V_{lo}/V_{hi} are flags) Highest … Lowest significant value which really occurs in this IMG Highest … NB: $V_{lo} \leq V_{min} \leq V_{max} \leq V_{hi}$ Intercept of linear scaling: physical Y = V_{int} + V_{slo} x V Slope … NB: The scaling only applies to significant range
	Classes	Nr. of classes, incl. unavoidable class 0. More correct: highest class_ID + 1
	Class names = {…}	For each class, starting with 0: class name (avoid commas!)
	Class lookup = {…}	For each class, starting with 0: R, G, B-values in range 0-255
	Flags = {…}	For each flag: "V=meaning" with V=digital value (only textual info)
SPATIAL	Samples	Number of IMG columns
	Lines	Number of IMG records
	Map info = { Name, Col_m, Rec_m, X_m, Y_m, ΔX, ΔY }	Projection_Name (= entry in file Map_proj.txt) IMG Col/Rec co-ordinates of "Magic Point" (see figure 3.3) Map X/Y co-ordinates of same "Magic Point" X/Y pixel size in MAP-units
TMP	Date	YYYYMMDD: IMG registration date, or startdate for composite IMGs
	Days	Periodicity in days: 1, 10, 30,…; 0=unknown/irrelevant; -1=actual registration

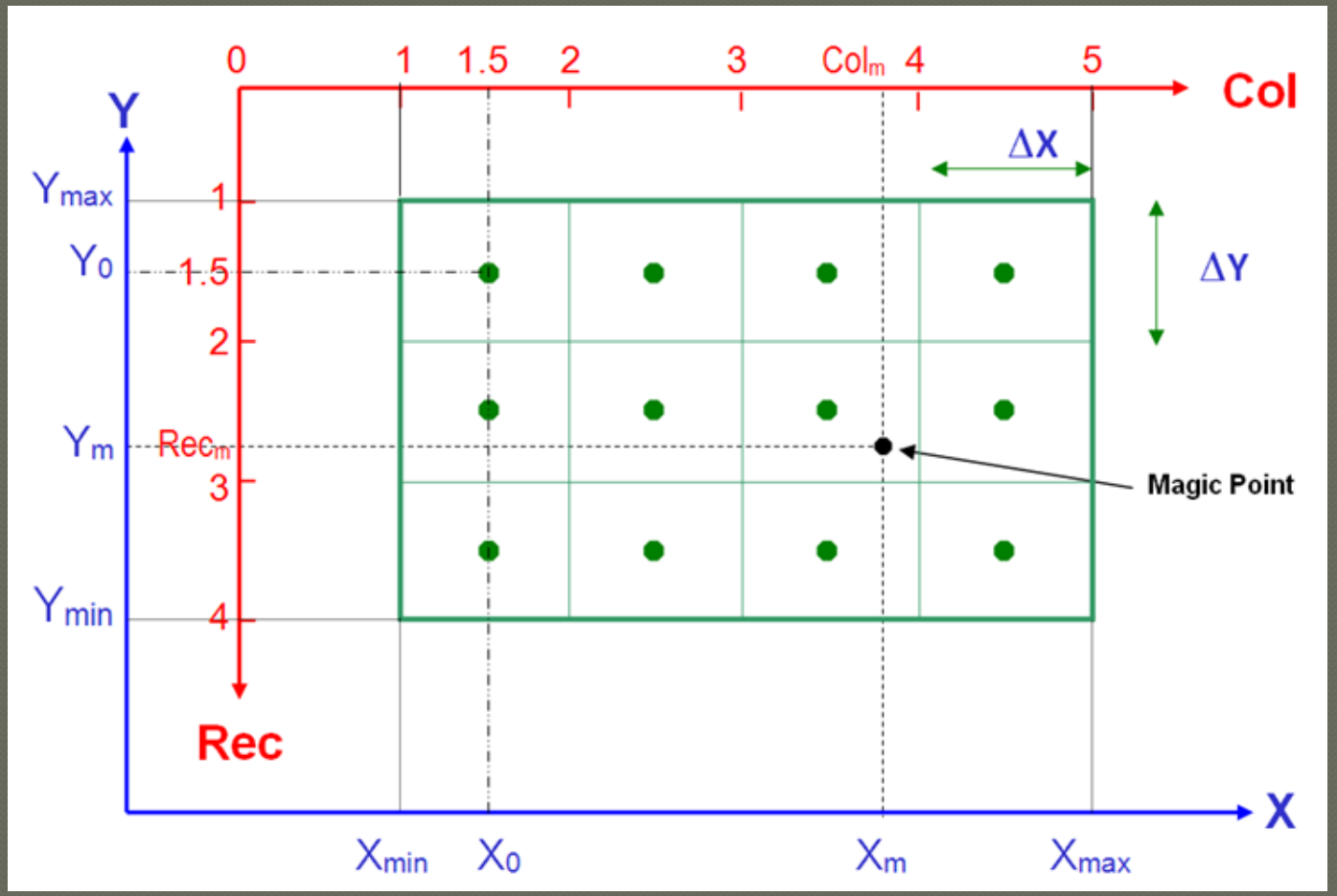
Formats: Spatial/geographical annotation

Needed to combine the image with other geo-information

in different datums/projections/framings. Four elements:

1. **Map projection**: three possibilities
   - ⇒ *Arbitrary:* *Raw registrations, simple "pictures"*
   - ⇒ Unprojected: X=Lon, Y=Lat, both in decimal degrees ("Geographic Lat/Lon")
   - ⇒ Projected: X/Y-units in meters (e.g. "Albers Equal Area", "UTM",…)
2. **Geodetical Datum** (e.g. WGS84, ED50, NAD63, …)
   - ⇒ Ellipsoid of datum (a, b)
   - ⇒ Shift parameters (Δx, Δy, Δz) w.r.t. the reference (WGS84)
3. **Parameters of the Projection**: Number and nature ≈ projection, for instance:
   - Geographic Lon/Lat: no parameters
   - Albers Equal Area: Ellipsoid of projection (a, b)
     Lat of 2 standard parallels
     Lon/Lat of origin
     False easting/northing
4. **<u>Framing</u> of the image raster within the X/Y (or Lon/Lat) system**:
   - Needed for conversions: Image ⇔ Map-coordinates
     Col = $f_1(X)$ inverse: $X = f_1^{-1}(Col)$
     Rec = $f_2(Y)$ $Y = f_2^{-1}(Rec)$
   - 6 parameters needed (different methods)

Formats: Spatial annotation → Framing



IDRISI (6)

N_{col}, N_{rec}
X_{min}, X_{max}
Y_{min}, Y_{max}

ArcView (6)

N_{col}, N_{rec}
ΔX, ΔY
X_0, Y_0

ENVI (8!)

N_{col}, N_{rec}
ΔX, ΔY
X_m, Y_m
Col_m, Rec_m (!)

NB: Xm/Ym = "Magic Point"

ENVI Georeferencing Files

Three system files of ENVI

ELLIPSE.TXT

Clarke 1880, 6378249.1, 6356514.9
…
International, 6378388.0, 6356911.9
…
WGS 72, 6378135.0, 6356750.5
WGS 84, 6378137.0, 6356752.3

DATUM.TXT

Adindan, Clarke 1880, -166, -15, 204
…
European 1950, International, -87, -96, -120
…
WGS-72, **WGS 72**, 0, 0, 5
WGS-84, WGS 84, 0, 0, 0

MAP_PROJ.TXT

; ENVI CUSTOMIZED PROJECTION FILE
; 9 - Albers Conical Equal Area: a, b, lat0, lon0, x0, y0, sp1, sp2, [datum], name
; 11- Lambert Azimuthal Equal Area: a, b, lat0, lon0, x0, y0, [datum], name

9, 6378135.0, 6356750.5, 51.4, 22.65, 0.0, 0.0, 32.500000, 54.50, **WGS-72**, **Space2**
11, 6378137.0, 6356752.3, 52.0, 10.00, 4321000, 3210000, ETRS89, INSPIRE-LAEA

HDR: MAP INFO={Name, COL_m, REC_m, X_m, Y_m, ΔX, ΔY}

- Name must be entry in MAP_PROJECTION.TXT.
  Exceptions: "Arbitrary" and "Geographic Lat/Lon"
- NB: Topleft corner of topleft pixel has $COL_m=1.0$, $REC_m=1.0$
  Centre of topleft pixel has $COL_m=1.5$, $REC_m=1.5$

SPIRITS: "Modified ENVI" Image format

Example 1: European MSG-S10 with fAPAR (Ordinal!)

```
ENVI
description = {MSG-S10: Mean fAPAR}
sensor type = MSG-SEVIRI
comment = {SPC=M:\DINO\ROIS\EU5\REF\SPC\S10a.SPC}
program = {COMPOSIT.exe (V710)}
header offset = 0
bands = 1

samples = 1081
lines = 930
map info = {INSPIRE-LAEA, 1, 1, 2275000, 5415000, 5000, 5000}

file type = ENVI Standard
data type = 1
values = {fAPAR, %, 0, 200, 0, 189, 0, 0.5}
flags = {251=missing, 254=water}

date = 20080521
days = 10
```

SPIRITS: "Modified ENVI" Image format

Example 2: Global classification with 5 classes (categorical!)

```
ENVI
description = { Reclassification of GLC2000 to 5 classes }
comment = {glc2000.img scaled with glc5.SPS}
program = {IMGscale.exe (V410)}

samples = 1920
lines = 698
map info = {Geographic Lat/Lon, 1.5, 1.5, -180.0, 75.0, 0.1875, 0.1875}

file type = ENVI classification
data type = 1
values = {classes, -, 1, 5, 1, 5, 0, 1}
flags = {0=Water/Background}

classes = 6
class names = { Background, Cropland, Grassland,
                Shrubland , Forests , Other land }

class lookup = { 255,255,255,    255,0,0,     255,255,0,
                   0,255,255,     0,255,0,     0,0,255    }
```

SPIRITS: Date formats in Time Series

General Image Names (without extensions): P[date]S

P = Prefix (may be blank, may include drive/path)

[date] = Date, according to one of twelve date formats

S = Suffix (may be blank)

E.g. for dekad 3 of 2015, with Date Format=6: d:\DATA\vt1503ndvi

N	DATE FORMAT	MINIMAL PERIOD
1	YYYYMMDD	Day
2	YYMMDD	
3	YYYY*m*DD	
4	YYmDD	
5	YYYYTT	Dekad
6	YYTT	
7	YYYYMM	Month
8	YYMM	
9	YYYY*m*	
10	YY*m*	
11	YYYY	Year
12	YY	

EXPLANATION of TERMS

YYYY	= Year	[1950 → 2049]
YY	= Year	[50=1950 → 49=2049]
MM	= Month in year	[01=Jan. → 12=Dec.]
m	= Month in year	[A=Jan. → L=Dec.]
TT	= Dekad in year	[01 → 36]
DD	= Day in month	[01 → 31]

GLIMPSE/SPIRITS can only treat Time Series with Frequency of Day, Dekad, Month, Year!

SPIRITS: Metafiles

"Metafiles" for Treatment of 3D images/series

- ASCII-files with names of IMGs belonging together for particular analysis
- Alternative for 3D-images
- Two versions:
  - ENVI: *.MTA
  - GLIMPSE *.VAR
- Two programs to generate them:
  - VARmakeP: for time series
  - VARmakeI: for non-periodic IMGs
- Automatically generated by many modules

```
ENVI META FILE
File :
D:\TESTS\clas\f1r.img
Bands: 1
Dims : 1-500,1-500

File :
D:\TESTS\clas\f1n.img
Bands: 1
Dims : 1-500,1-500

File :
D:\TESTS\clas\f1s.img
Bands: 1
Dims : 1-500,1-500
```

```
---- ---- ----------------
  Vu CODE COMPLETE FILENAME
---- ---- ----------------
11   R1   d:\tests\clas\f1R
12   N1   d:\tests\clas\f1N
13   S1   d:\tests\clas\f1S
```

SPIRITS: Last remarks

UNIFLAGS: General flagging system followed whenever possible

BYTE	INTEGER	MEANING / INTERPRETATION
0 – 250	0 – 32767	Significant range - scaling: $Y = V_{int} + V_{slo}.V$
251	-5	Missing value over land (data error, missing inputs)
252	-4	Cloud over land
253	-3	Snow/Ice over land
254	-2	Sea/Water
255	-1	Background (no information at all, mostly: no data)

SPx-FILES (ASCII)

Additional (and rather fixed) inputs for some programs, e.g.:

- IMGscale → SPs
- PHENOdat → SPp
- IMG2RUM → SPu

⇒ Generated manually (from example files) or via SPIRITS

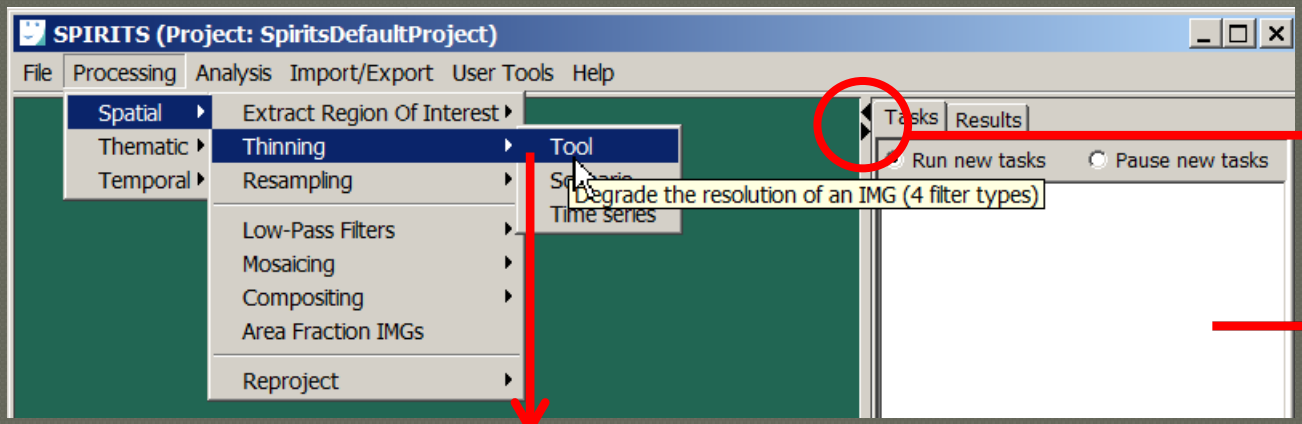
25

SPIRITS: Introduction & Overview

Contents:

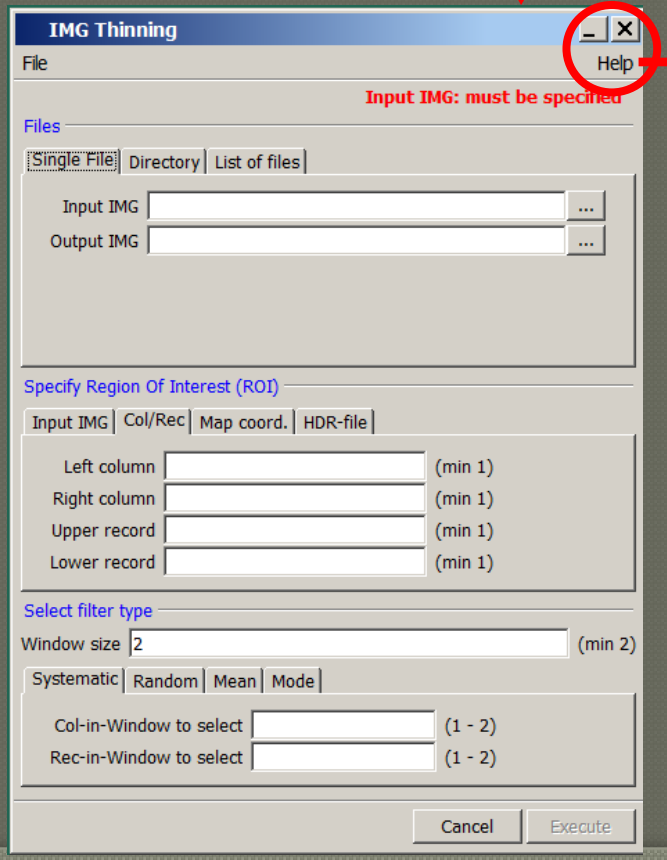
- Backgrounds
- Image Format & Conventions
- Functionalities

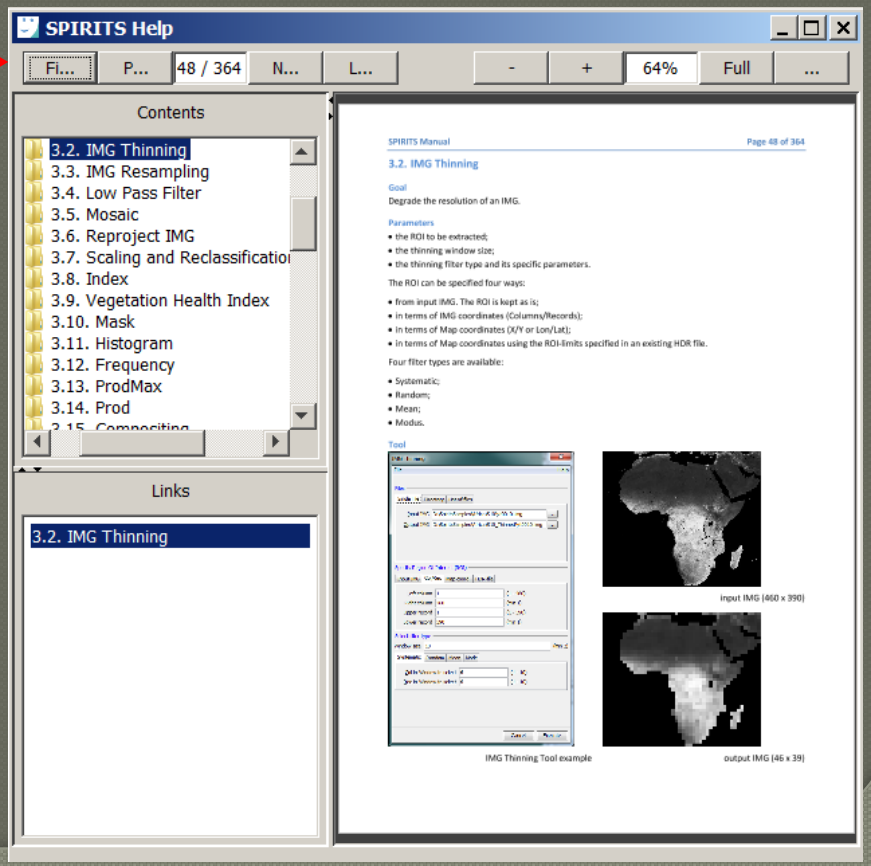
SPIRITS: General Menu



Hide/Show this Panel

Panel with Tasks & Results



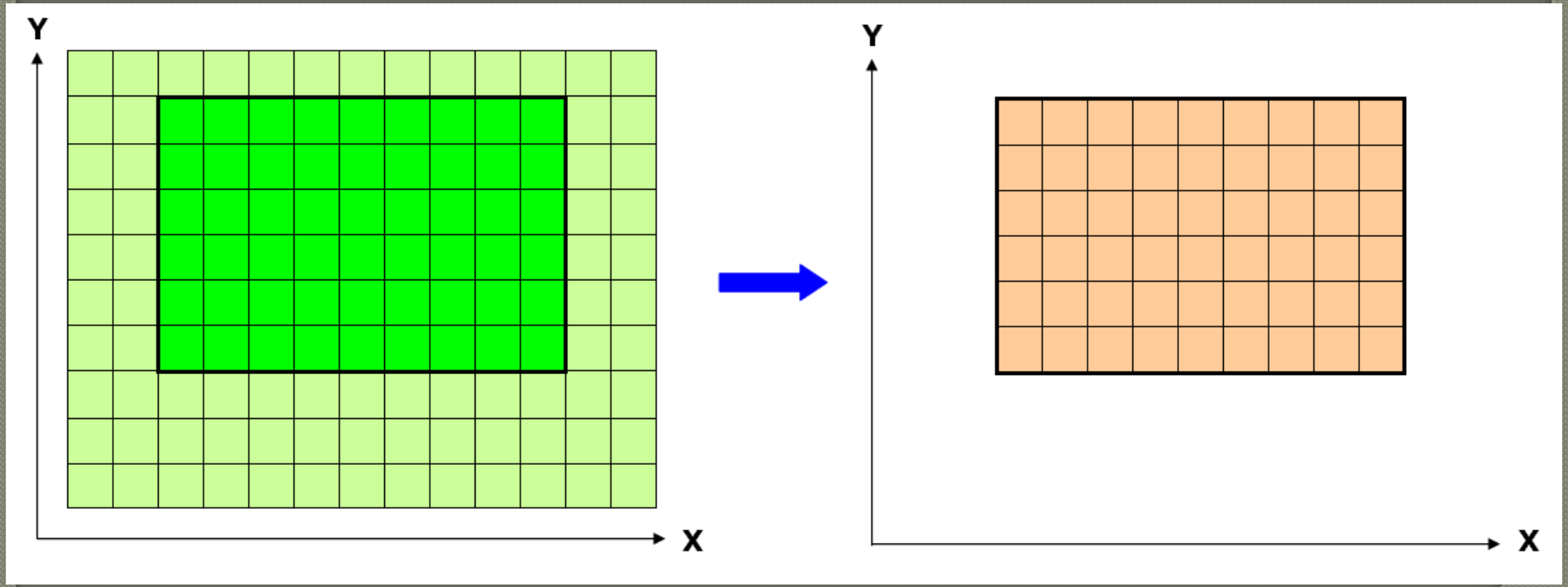


SPIRITS: Functionalities

- Processing: (=*GLIMPSE*)
  - **Spatial domain**
  - **Thematic domain**
  - **Temporal domain**
- Analysis:
  - Maps
  - Database (setup)
  - Charts
- Import/Export
- File
  - Some auxiliary tools
- User tools
  - Advanced

Extract Region of Interest (ROI) + Band-selection

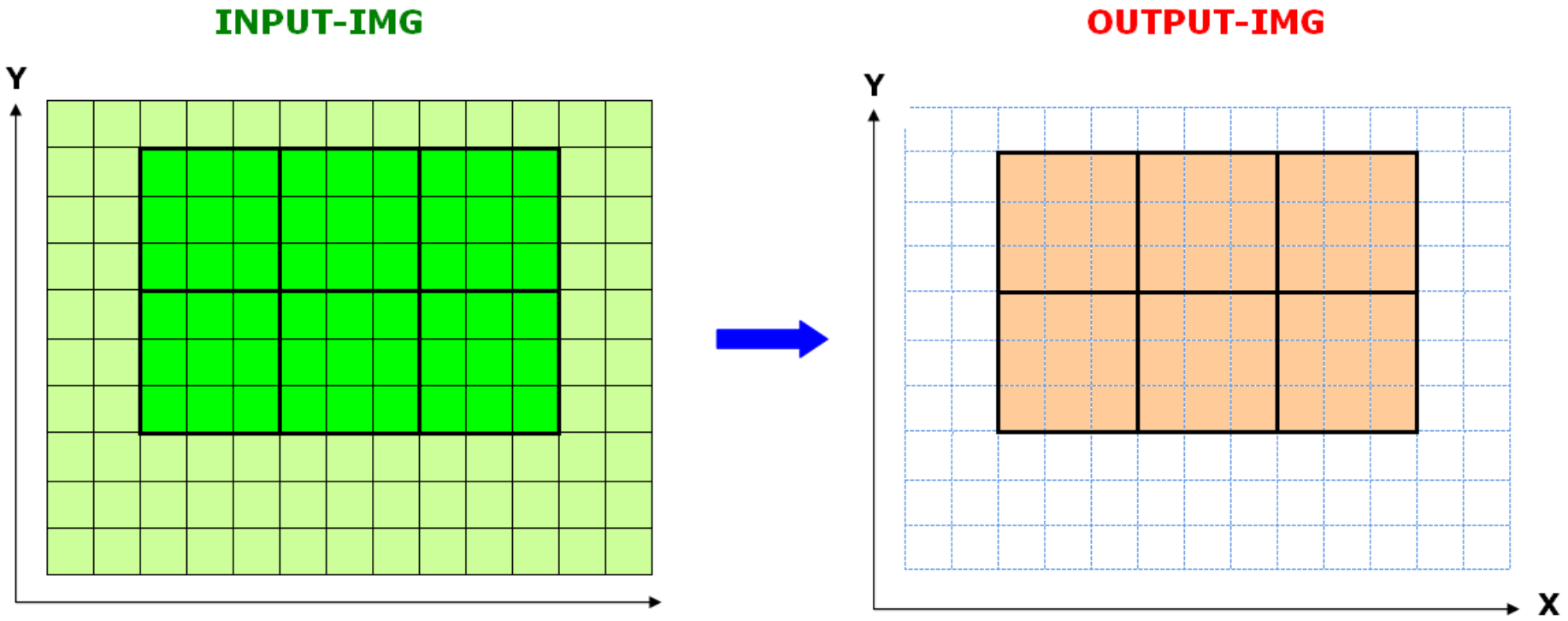
INPUT: ANY IMAGE	OUTPUT: GLIMPSE IMG + HDR
Mono-layer (2D) or multi-layer (3D)	2D, only selected band
3D-Layout: BSQ/BIL/BIP	No more needed
Leader/trailer bytes allowed	Leader/trailer bytes removed
Any datatype (Byte/Integer/Long/Float)	Same as INPUT
High-Endian (PC) or Low-Endian (UNIX)	High-Endian (Byte swap performed)
Specific coverage (Eg. global)	**Selected Region of Interest (ROI)**



Processing - SPATIAL

Thinning: Spatial Degradation (Reduction of Resolution)

USER-SPECs:
- Optional ROI-selection
- Size of degradation window (= output resolution)
- Filter type: Systematic, Random, Mean, Mode



Processing - SPATIAL

IMG2AFI: Derive Area Fraction Images (AFI)

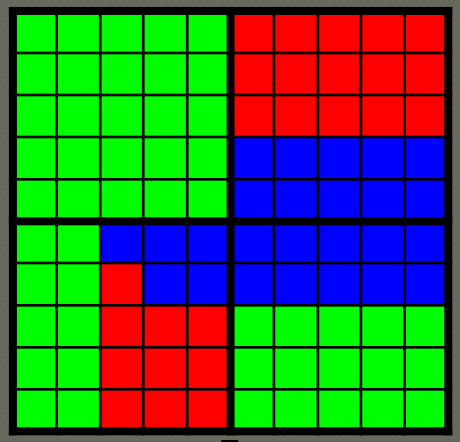
HiRes CLASSIFICATION

- 1 Image/Raster

- N Classes (N = 3)

- HARD:

1class per HR-pixel



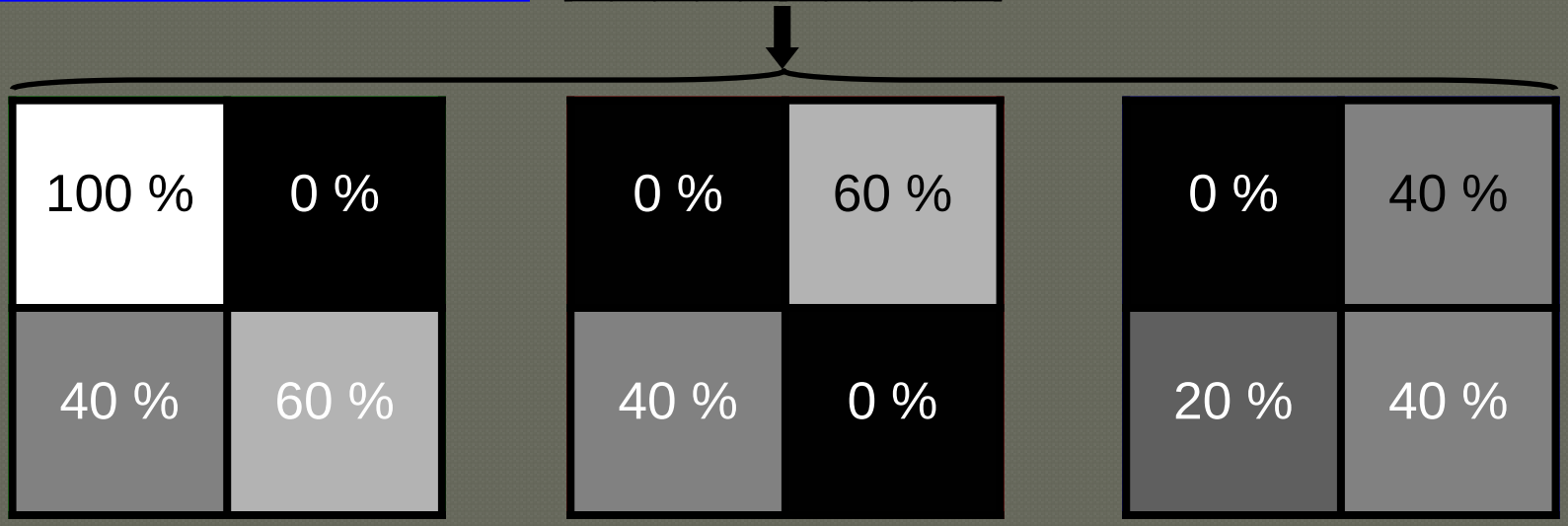
LoRes AFI's

- N Images/Rasters

- N Classes (N = 3)

- SOFT or FUZZY:

≠ classes per LR-pixel



LoRes <u>AREA FRACTION IMAGES</u> (AFI), one for each Class (Σ = 100%):

- Con: Location of fields/boundaries is lost

- Pro: Compatible with LR Imagery, Area information still sufficient

Resampling: Extraction of ROI & Change of Framing

IN=ORDINAL (NDVI, rainfall,…) → Four datatypes allowed

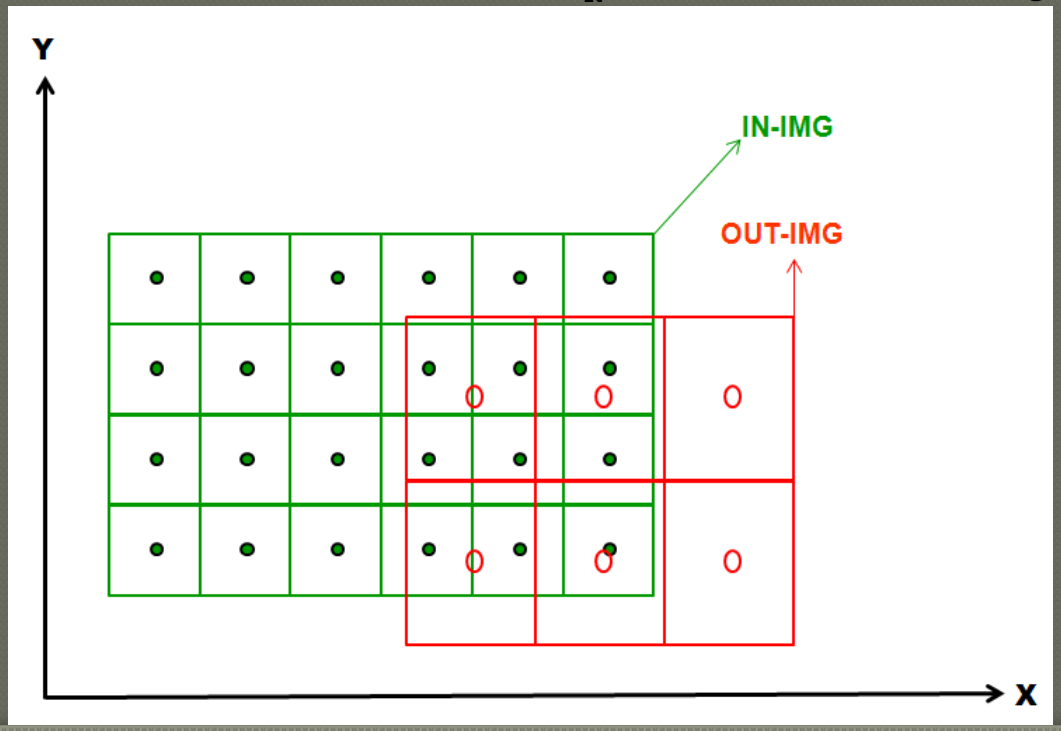
Case 1: OUT = Same but resampled with Area-weighted mean

Case 2: OUT = Same but resampled with Distance-weighted mean

IN=CLASSIFICATION → Only BYTE allowed

Case 3: OUT = 1 IMG with area-weighted Modal class

Case 4: OUT = N_k AFIs with area-weighted Area Fractions for N_k classes



NOTES

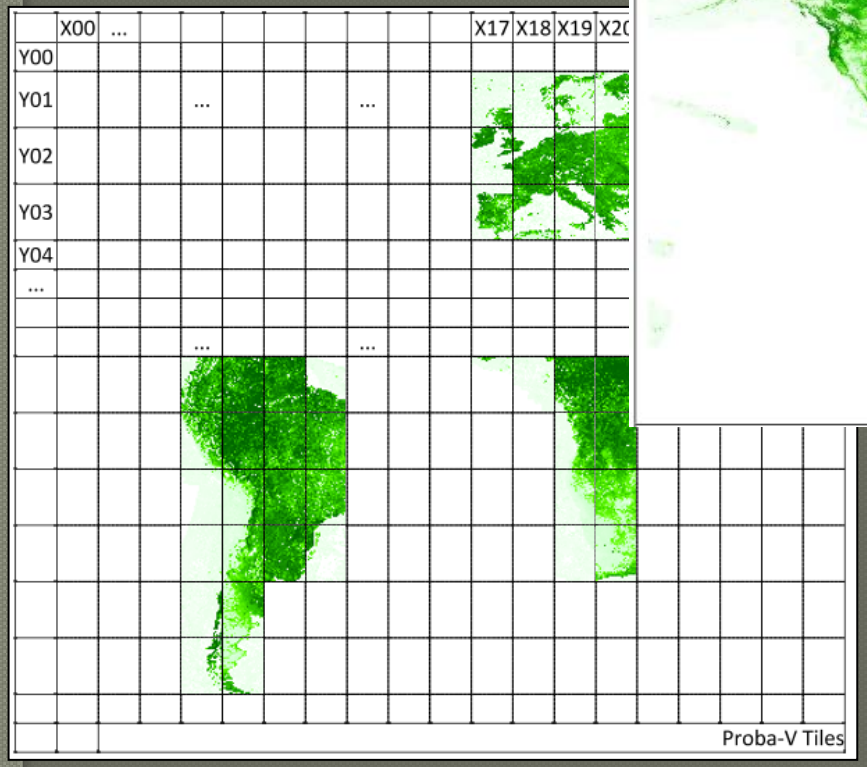
- **MapSys still must be the same!**
- Here OUT>IN as to resolution. Same approach for OUT < IN
- Additional parms MINgood% and BADflag: OUT-pixels will be flagged if less than this area is covered by the areas of "good" IN-pixels.

Processing - SPATIAL

MOSAIC: Merge several IN-IMGs → Single OUT-IMG

IN-IMGs:

- **Spectral:** all same **VALUES** (e.g. NDVI)
- **Spatial:** all same **MAP SYSTEM**, different locations allowed
  overlapping zones → Select via Min/Max/Mean rule



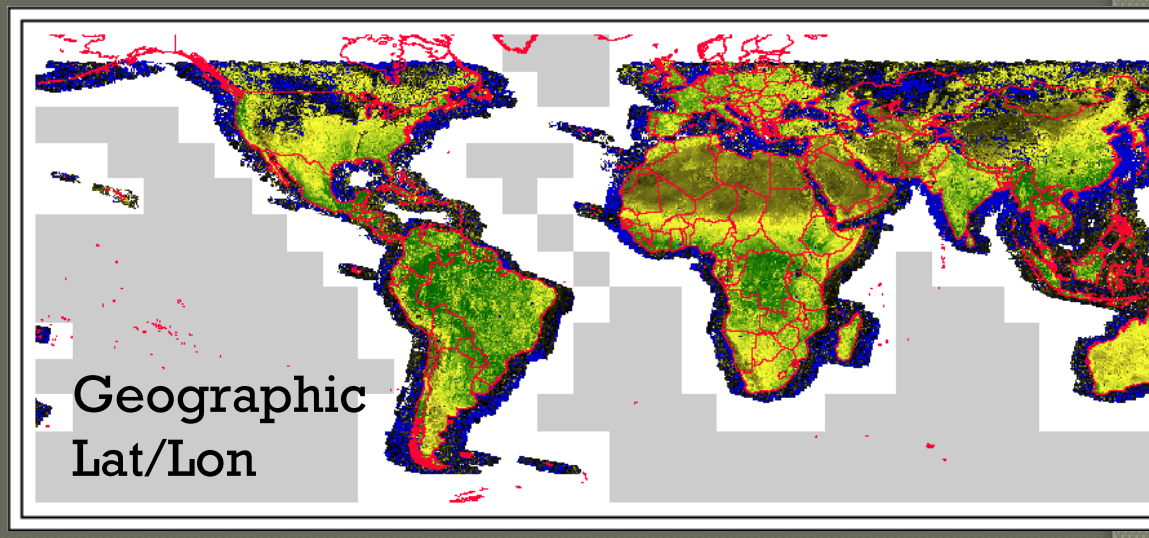
Data of MODIS, PROBA,… distributed via "Tiles" of 10° x 10°.

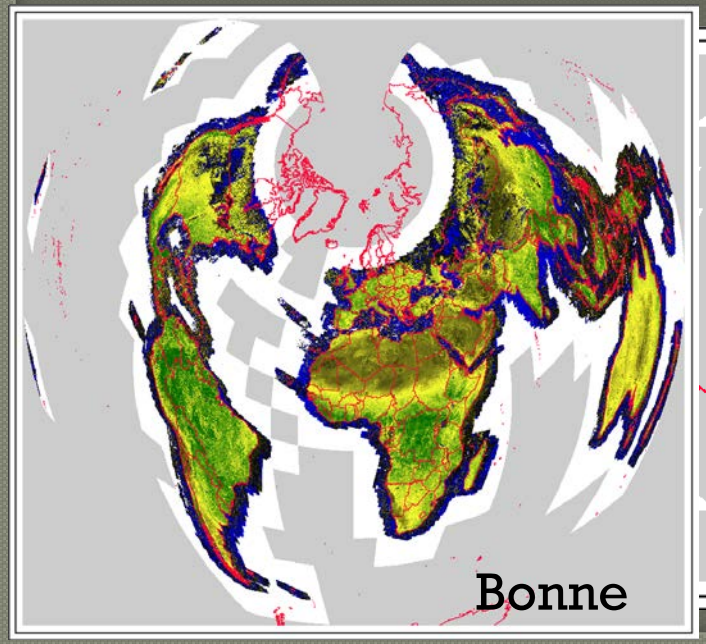
→ MOSAIC used to make global IMG

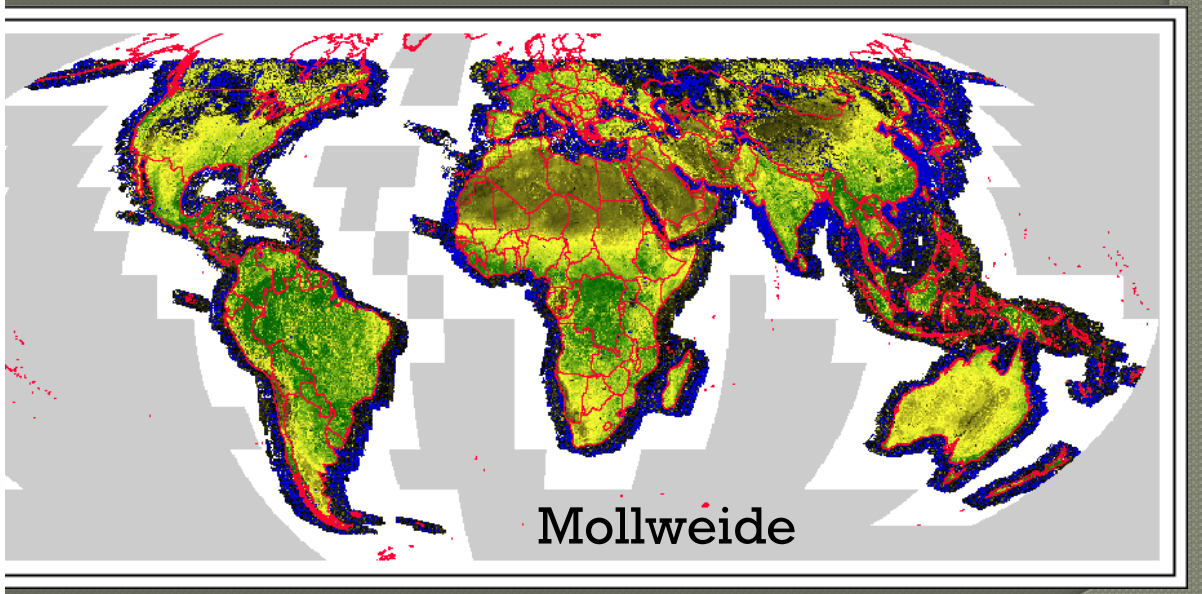
Reproject (Images & Vectors)

Full conversion of:

- **Map projection**
- **Geodetic datum**
- **Image framing**

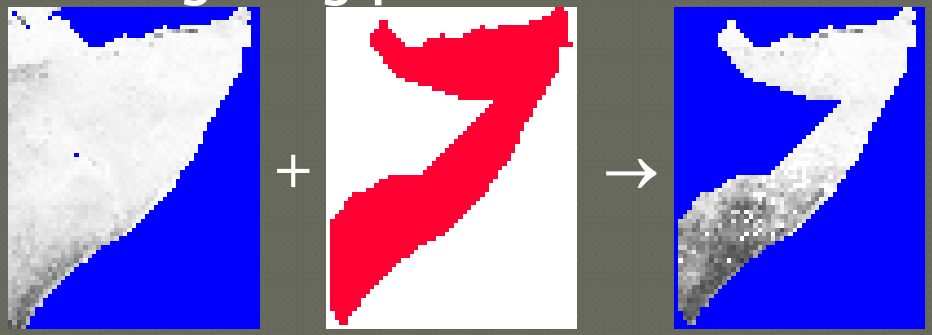




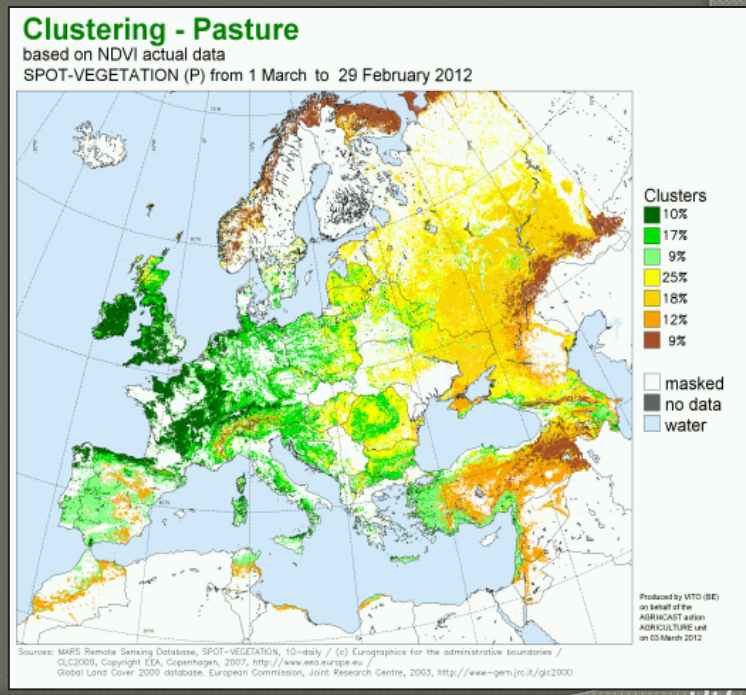


Processing - THEMATIC

- Rescale: Modify IMG-values ≈ User-defined scheme
  - Change of data type
  - Stretching, histogram equalisation
  - Reclassification
- Band combinations (2/3 IN-IMGs → 1 OUT-IMG) → NDVI, RVI, …
- Vegetation Health Index
- Masking: Flag pixels ≈ Values in Mask IMG



- fAPAR
- Dry Matter Productivity (DMP)
- IsoClustering



Processing - TEMPORAL

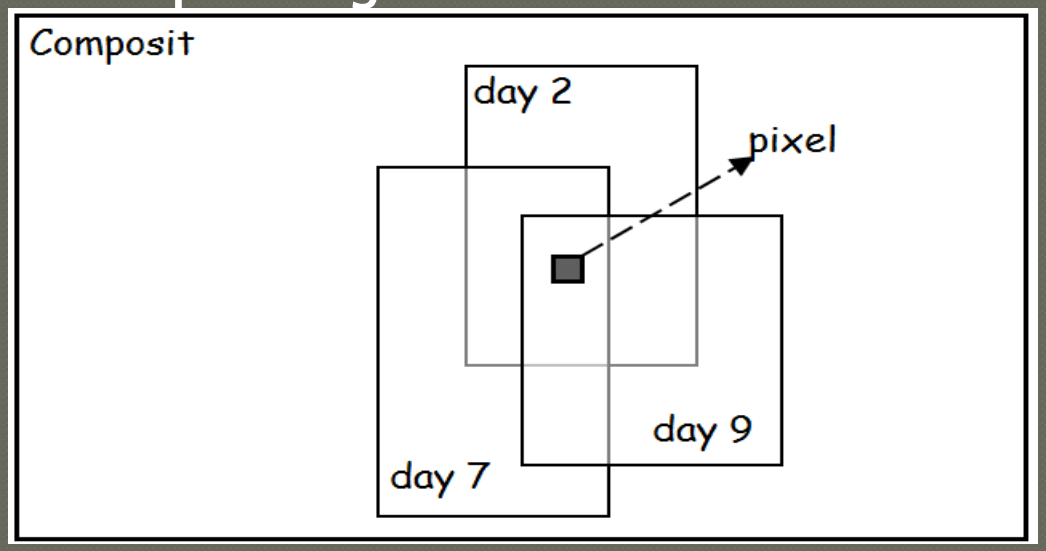
- Smoothing & Gap filling
- Phenology: Define SOS/EOS for 1/2 seasons per year
- Compute Sum or Mean of Images in a Time Series
    - Between two fixed dates
    - Between pixel-specific SOS and EOS (or in-between)

- Long-Term Statistics (LTS)
- Anomalies (ACT ↔ LTS), e.g. VCI, TCI

- Standardized Precipitation Index (SPI)
- Similarity analysis
- Similarity-based Yield Forecasting

Processing – SPATIO-TEMPORAL

Compositing



Value \ Day		2	7	9
RED	[%]	45	***5***	10
NIR	[%]	55	***35***	30
MIR	[%]	-7	***8***	10
TIR1	[°C]	-30	***15***	13
TIR2	[°C]	-33	***14***	12
NDVI	**[-]**	0.10	***0.75***	0.50
θ_v	[°]	30	***35***	21
θ_s	[°]	40	***42***	43
$\Delta\varphi$	[°]	110	***107***	71

IN-IMGs:

- *Spatial:* *Same map system, different framings, all within OUT-ROI*
- *Temporal:* *All within specified Time Window (mostly one dekad)*
- *Spectral:* *Different registrations, each with same set of image layers*

OUT-IMGs = "Composite" or "Synthesis", covering the OUT-ROI and comprising the same set of image layers as in each IN-registration.

For each pixel, the "best-available" observation is searched amongst the IN-registrations, following a "compositing rule" (often Max-NDVI).

SPIRITS: Functionalities

- Processing:
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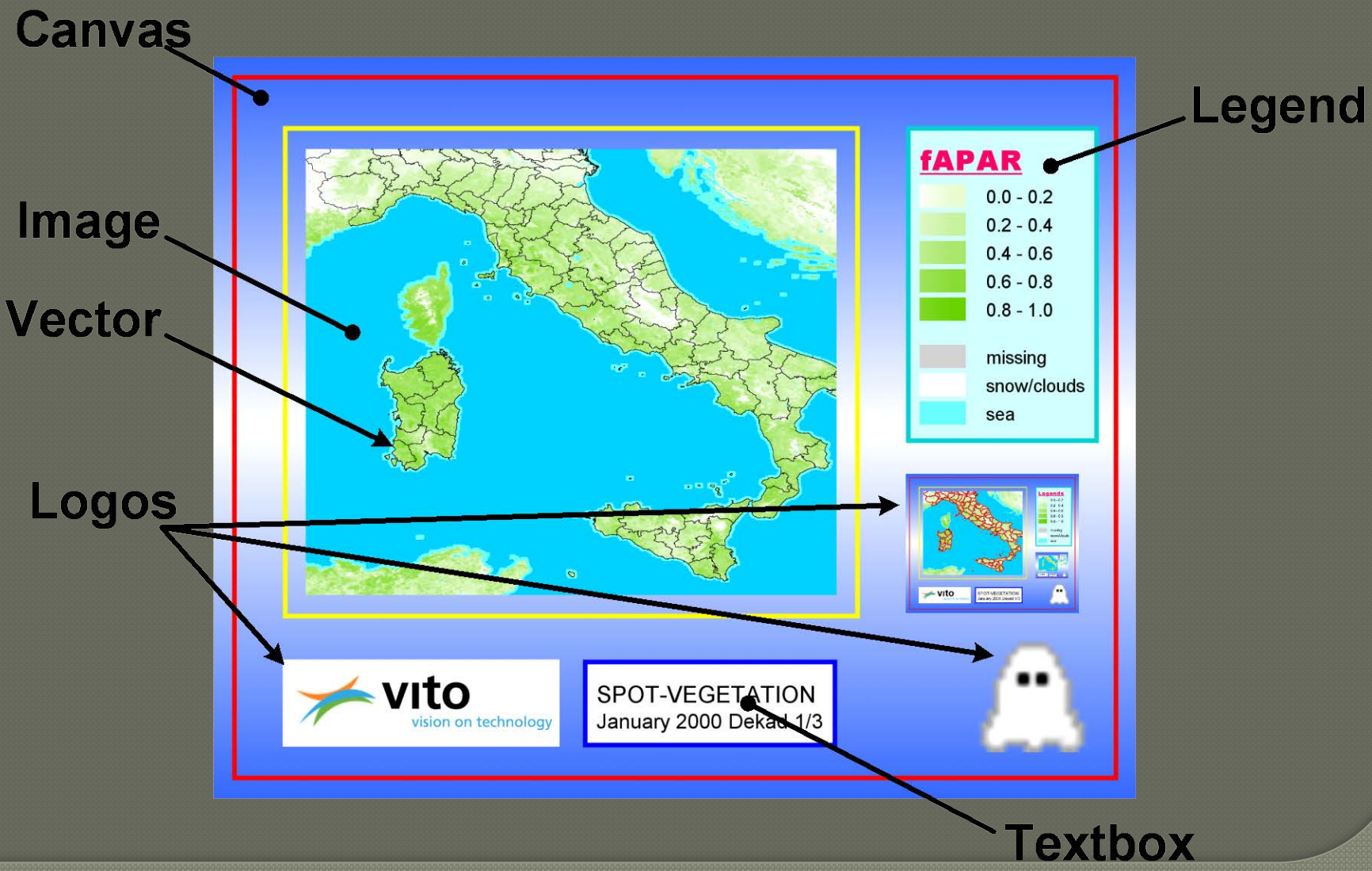
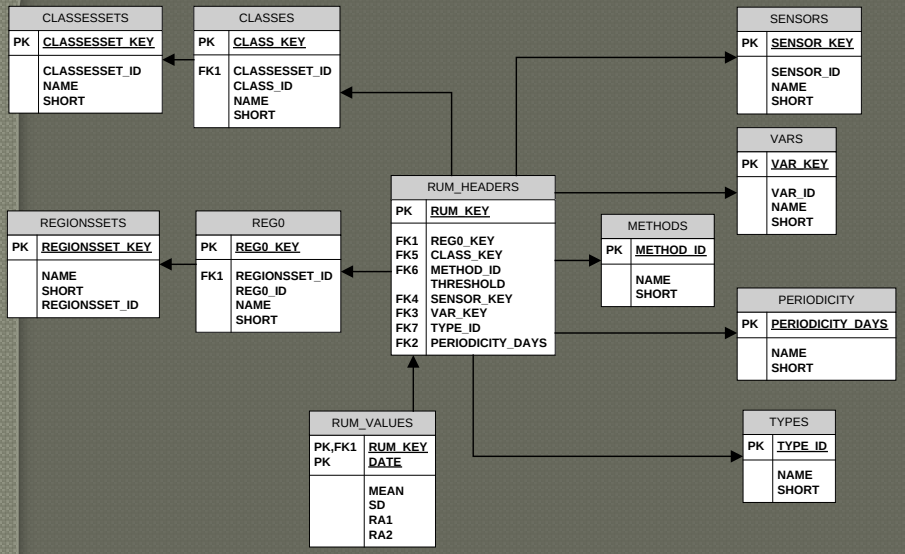
  - Thematic domain
  - Temporal domain
- Analysis:
  - Maps
  - Database (setup)
  - Charts (or Database Viewer)
- Import/Export
- File
  - Some auxiliary tools
- User tools
  - Advanced

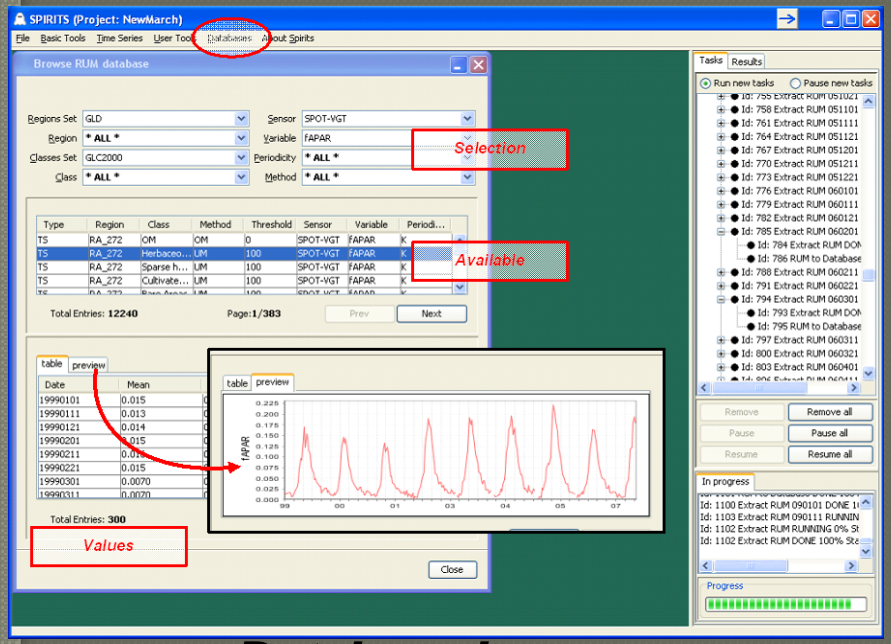
QuickLook Generator



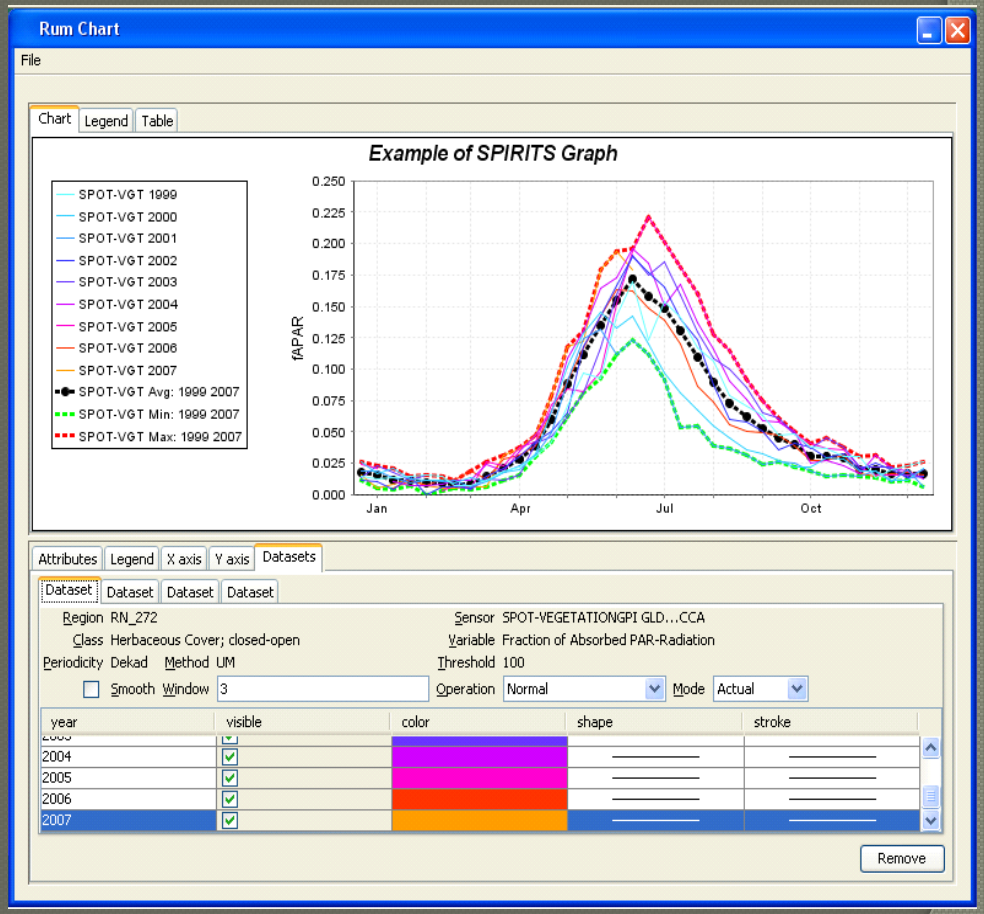
Analysis – RUM DATABASE & CHARTS



RUM=
Regional Unmixed Means



Database browser



Database viewer

SPIRITS: Functionalities

- Processing:
  - Spatial domain
  - Thematic domain
  - Temporal domain
- Analysis:
  - Maps
  - Database (setup)
  - Charts (or Database Viewer)
- Import/Export
- File:
  - Some auxiliary tools
- User tools:
  - Advanced

IMPORT/EXPORT

IMPORT: External Images → "Modified ENVI" IMG

- Generic importer (ca. 100 formats), via GDAL-library
- HDF5 (Proba, MSG, …)
- ASCII-TXT (mostly meteorological data)
- ENVI-generic: 3D, Byte order,…
- Change periodicity. E.g. from S16 to S10, from S8 to S30

EXPORT: "Modified ENVI" IMG → External Image Formats

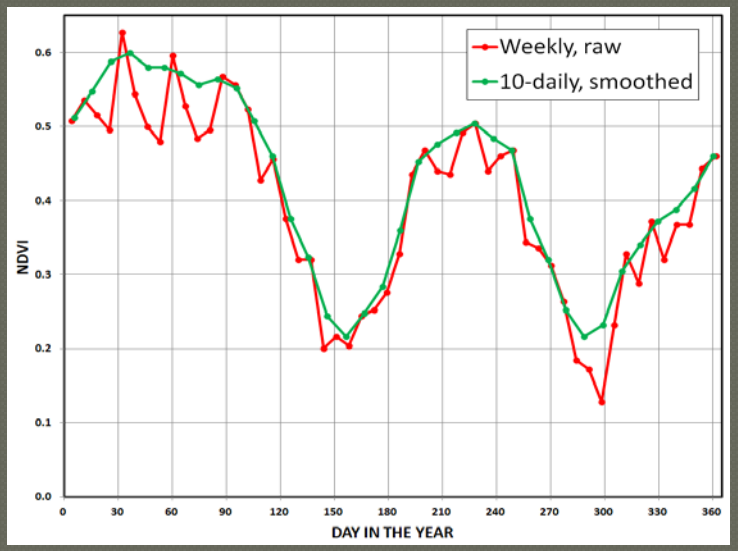
- IDRISI, ArcGIS (BSQ/BIL/BIP)
- ENVI-3D ("Layer Stack")
- Descale: Convert IMG to "float" (DT=4), remove scaling (V=Y)

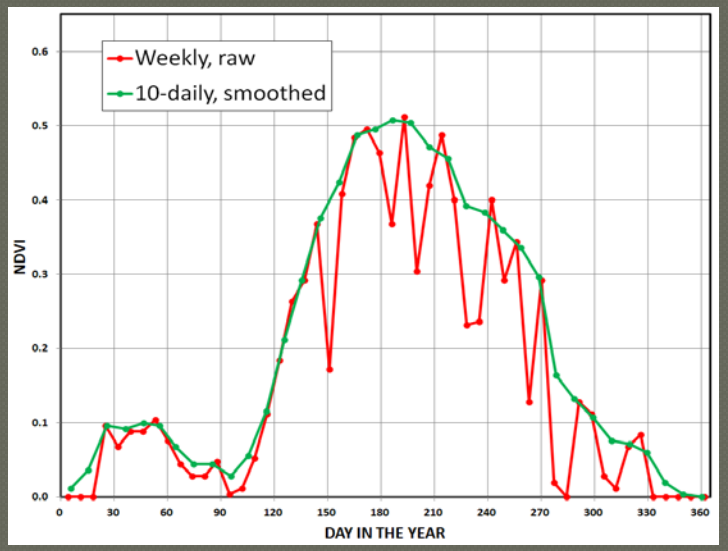
SHP VECTOR-FILES

- Rasterize SHP-file
- Reproject SHP-file

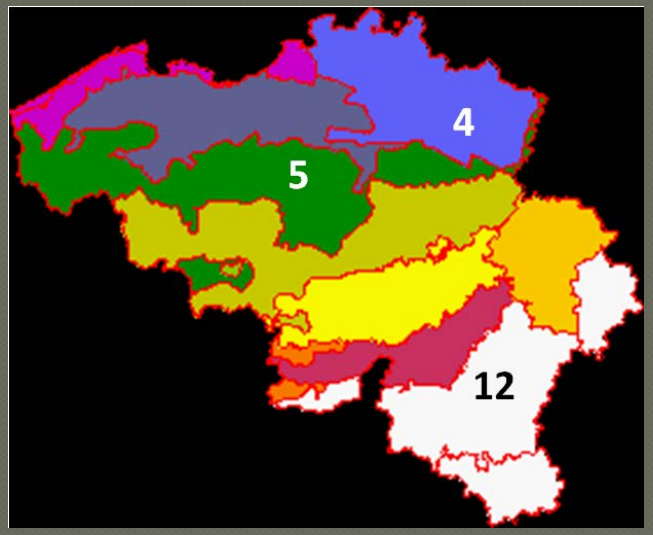
IMPORT/EXPORT

Change periodicity: NOAA-AVHRR from STAR, from S7 to S10





Rasterize SHP-file



SHP: 13 agro-regions of Belgium

Associated Database (DBF) contains different attributes: Reg_ID, soil type, area,…

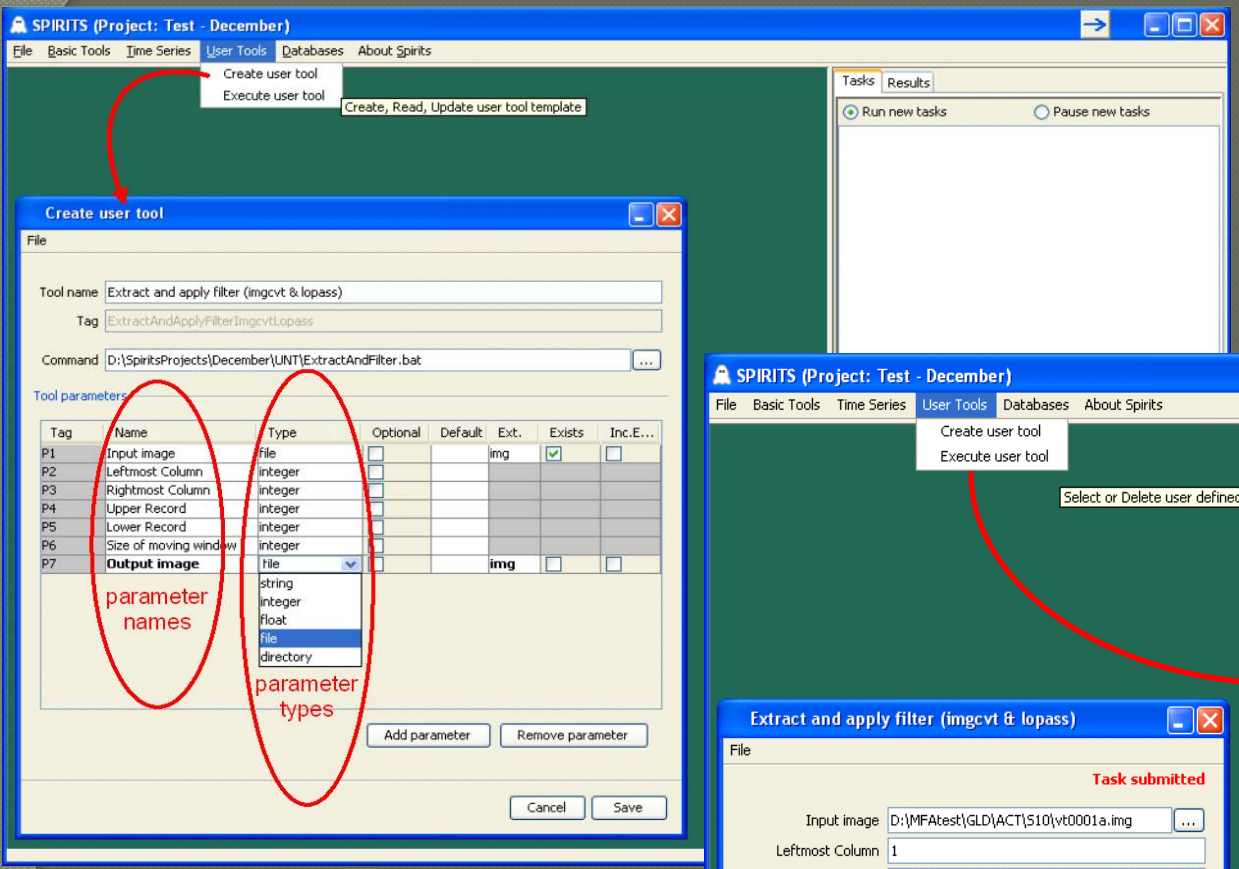
Rastered to IMG-format using REG_ID as attribute.

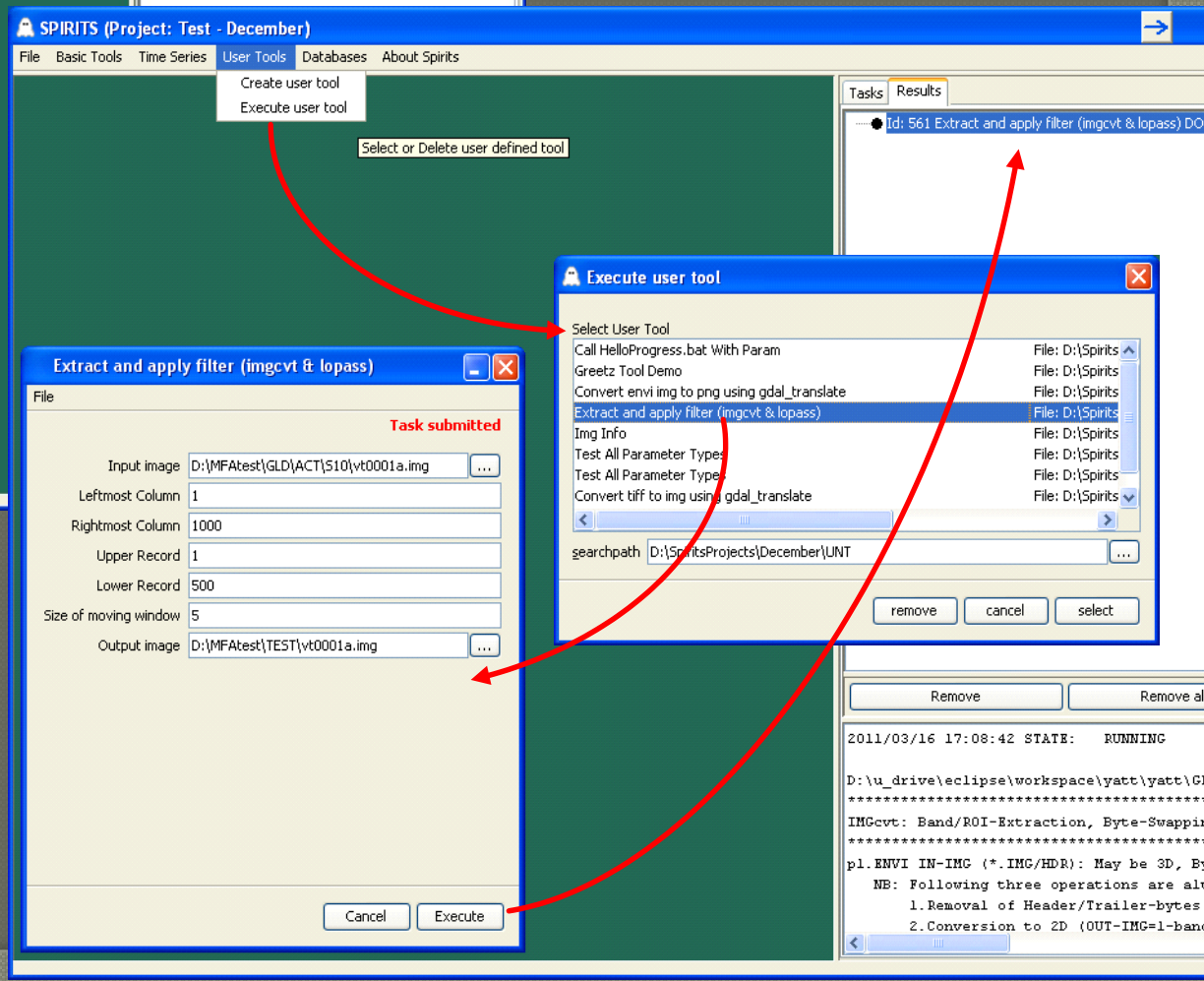
FILE Menu

- **HDR-files: View / Adapt**
- **Create Metafiles (Lists of IMG-names)**
- **GLIMPSE SPx-files & SPIRITS Scenario's:**
  - Create / Adapt
  - Can also (better) be done in each tool
- **Generic File Renamer:**
  NB: IMG names must follow pattern *P[date]S*
- **Projects: Create/Define/Select (see further)**

USER TOOLS

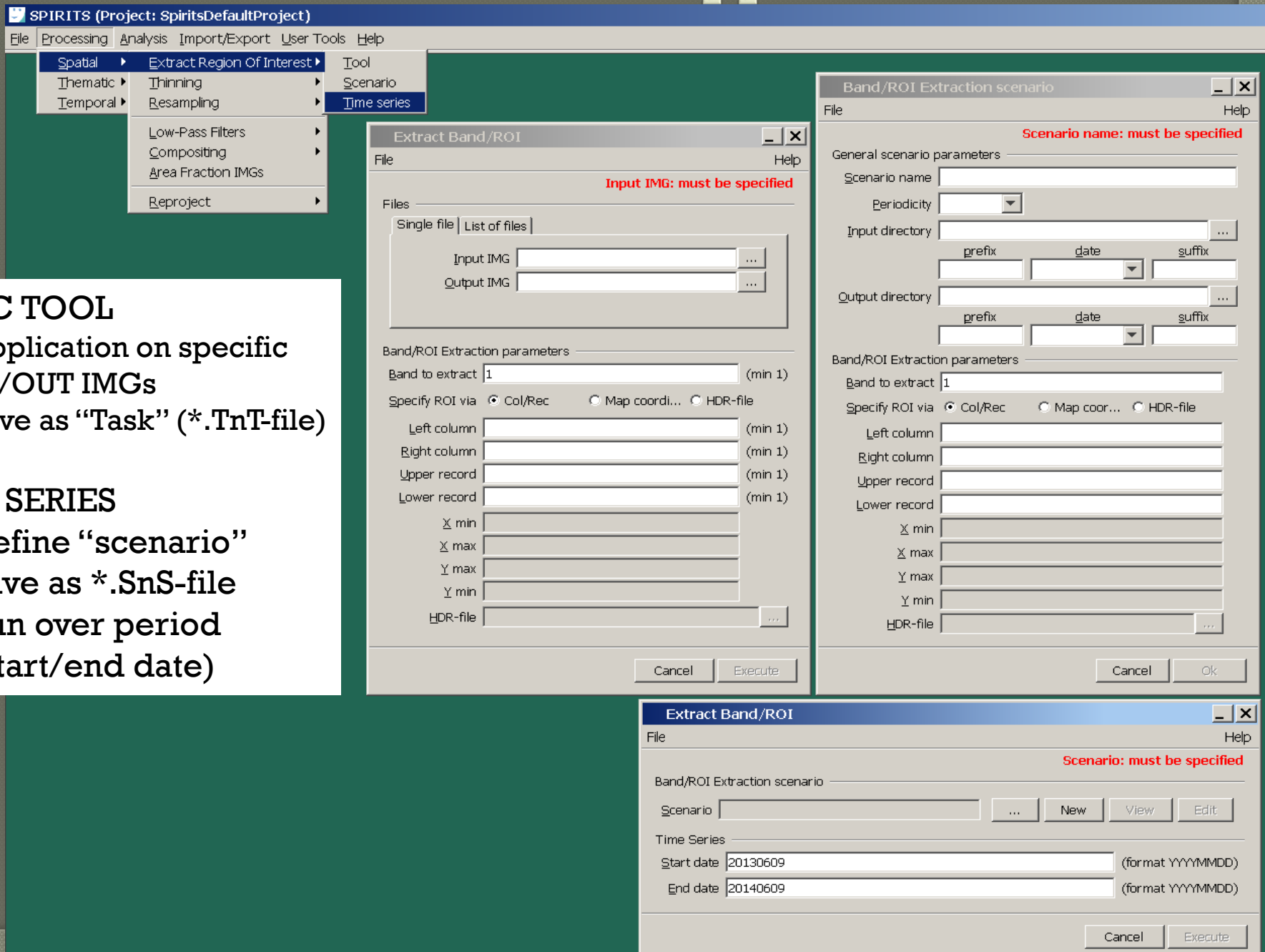
Create Tool





Execute Tool

SPIRITS Application Modes



BASIC TOOL

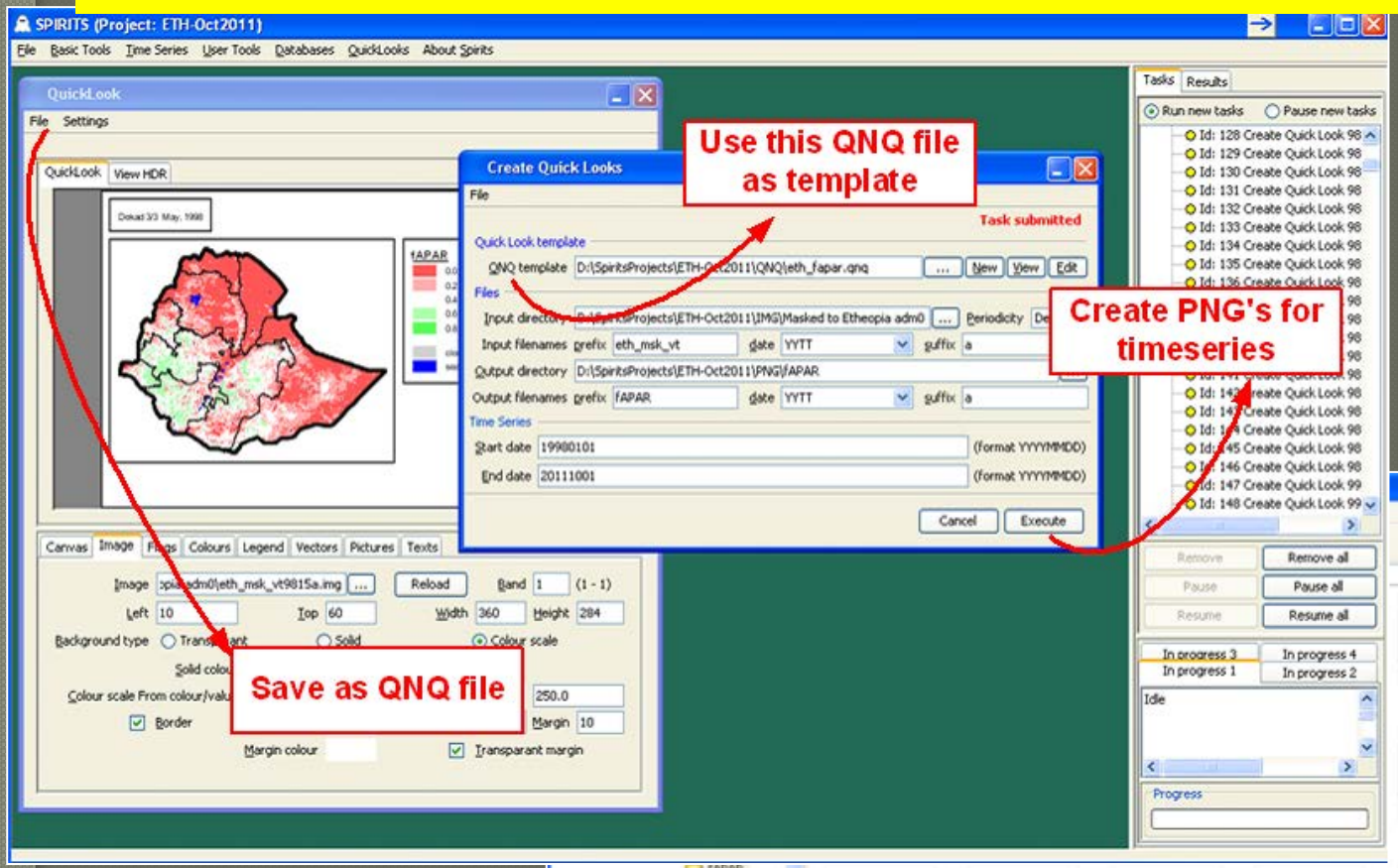
- Application on specific IN/OUT IMGs
- Save as "Task" (*.TnT-file)

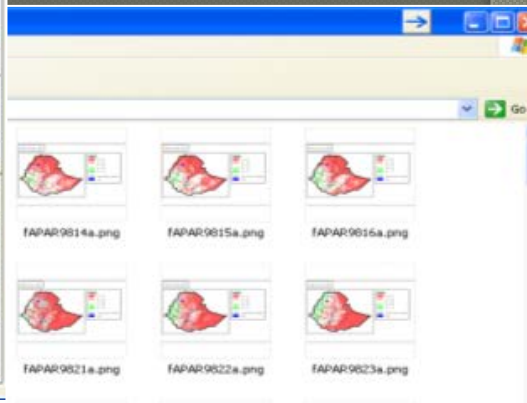
TIME SERIES

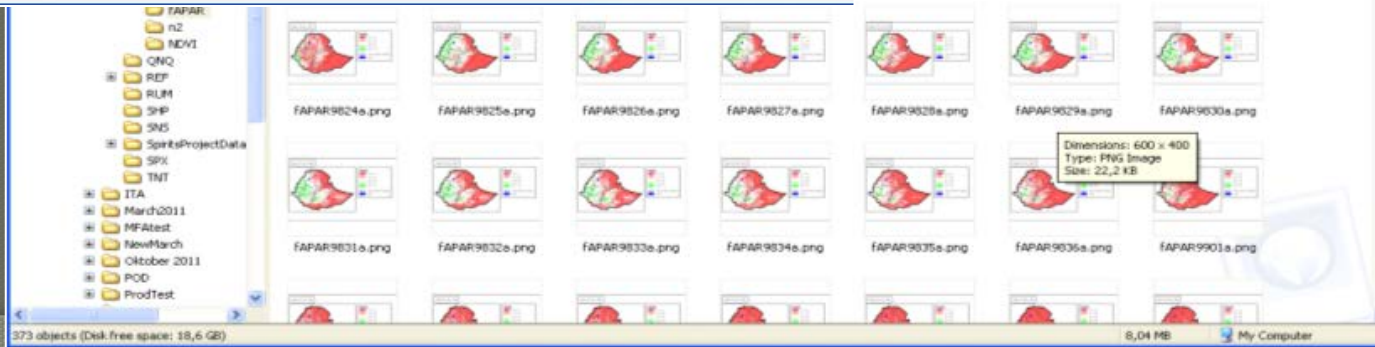
- Define "scenario" Save as *.SnS-file
- Run over period (start/end date)

SPIRITS Application Modes

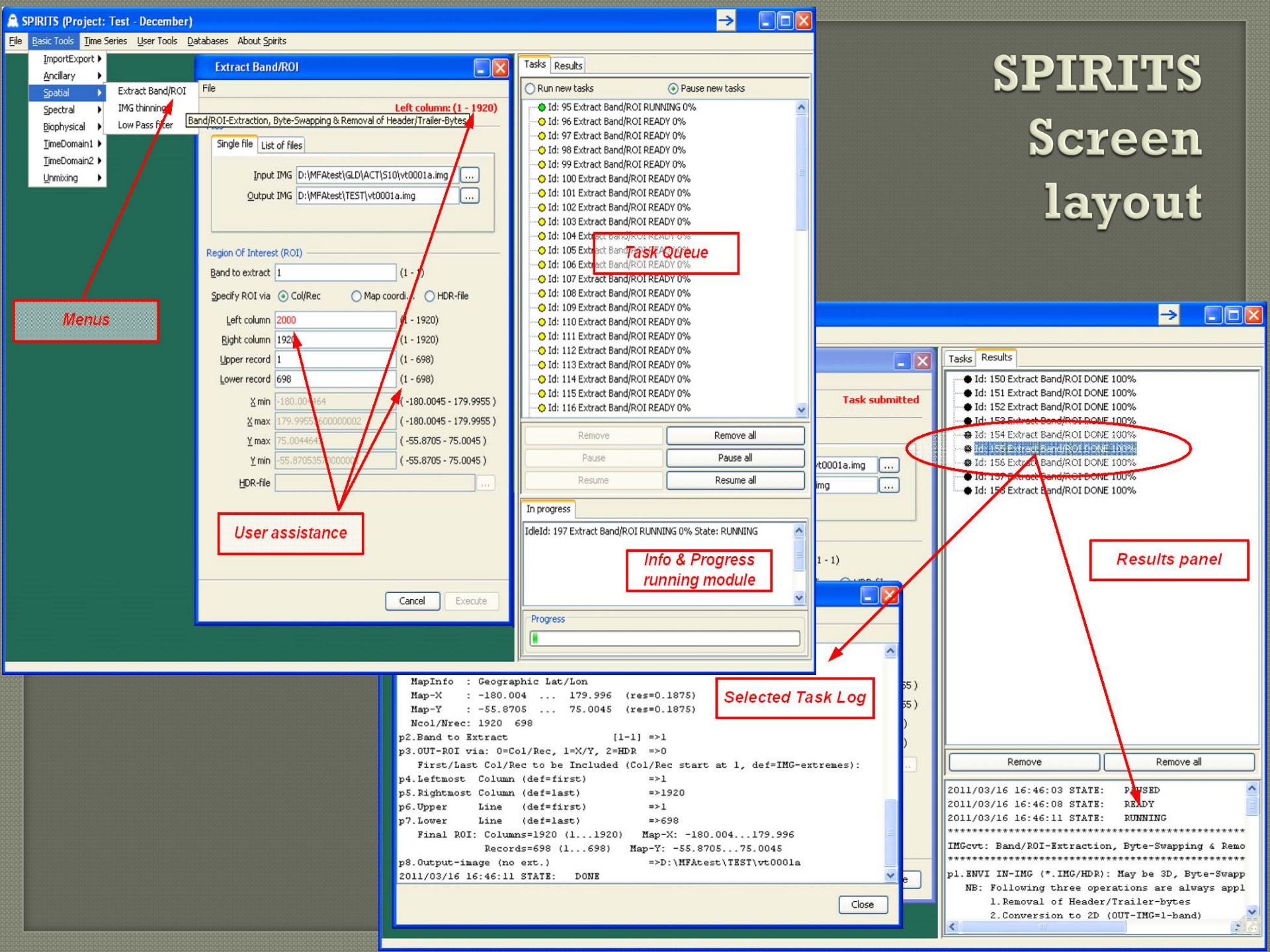
QuickLook Generator for Time Series





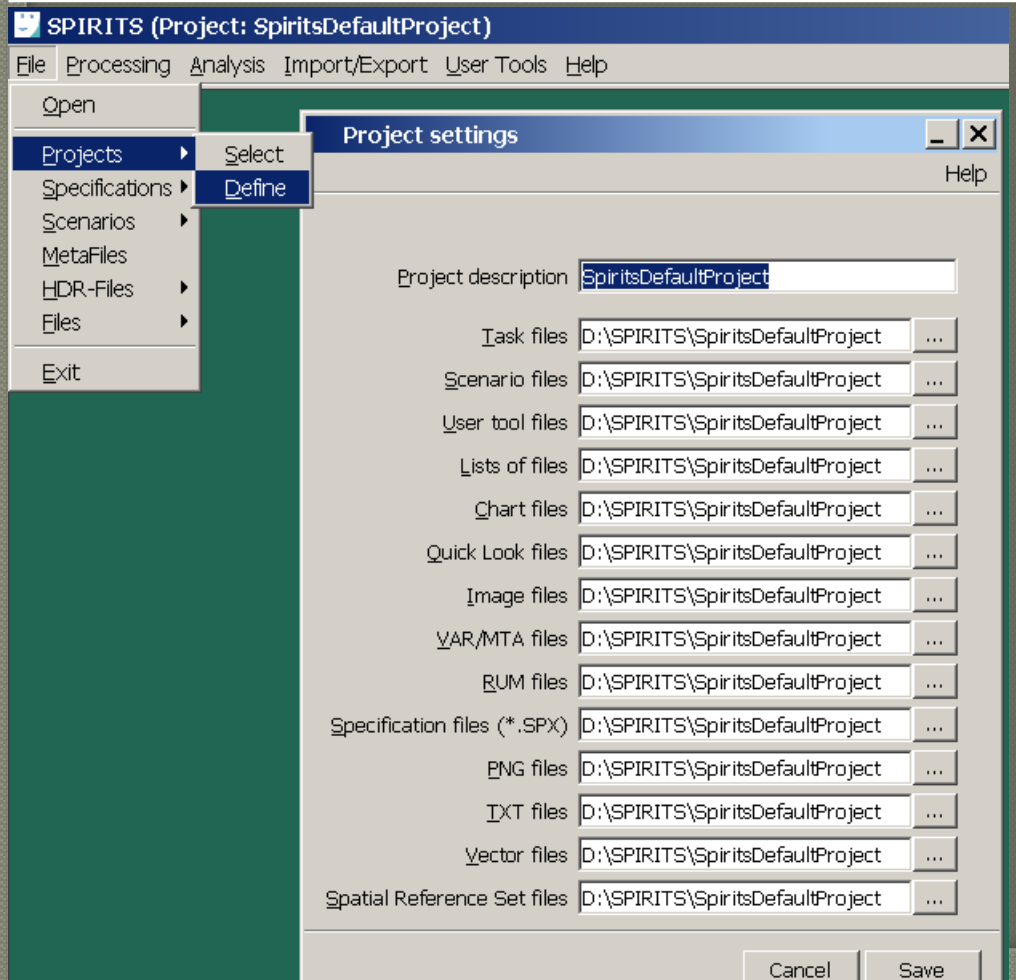


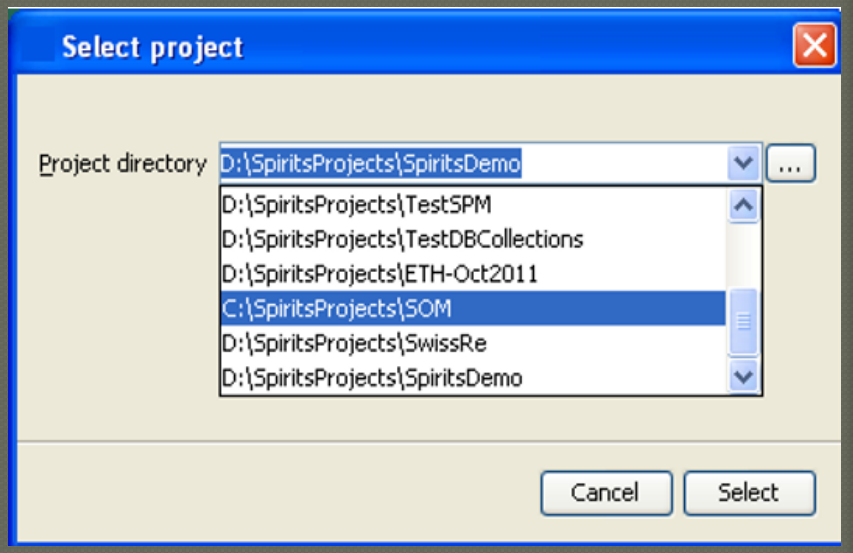
SPIRITS Screen layout



SPIRITS Projects

FOLDER\FILE	CONTENTS
Spirits.jar	**Main JAVA-executable**
Spirits*.ico	Icons to call SPIRITS from desktop
SpiritsManual.pdf	Manual (also accessible via HELP)
LIBS*.*	Libraries (open source) for DB, QLK,…
LIBS\GLIMPSE	GLIMPSE executables
SpiritsDefaultProject*.*	**Default/initial place for all user data**





UNESCO-Brazil, Foz de Iguacu, 19 July 2016

Global Monitoring with LoRes EO-Imagery Time Series Analysis with SPIRITS software

Vlaamse Instelling voor Technologisch Onderzoek
Flemish Institute for Technological Research
Herman Eerens

1. VITO's Remote Sensing Centre (TAP)
2. EU-MARS: Global Agricultural Monitoring
3. FAO-ASIS: Global Drought Monitoring
4. SPIRITS: Introduction & Overview
5. **SPIRITS: Some practical exercises**