


## Satellite observed nighttime lights as an indicator of human induced stress on coral reefs

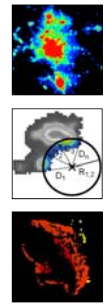
C. Aubrecht, C.D. Elvidge  
August 22, 2008  
Darksky 2008  
Kuffner Observatory – Vienna, Austria




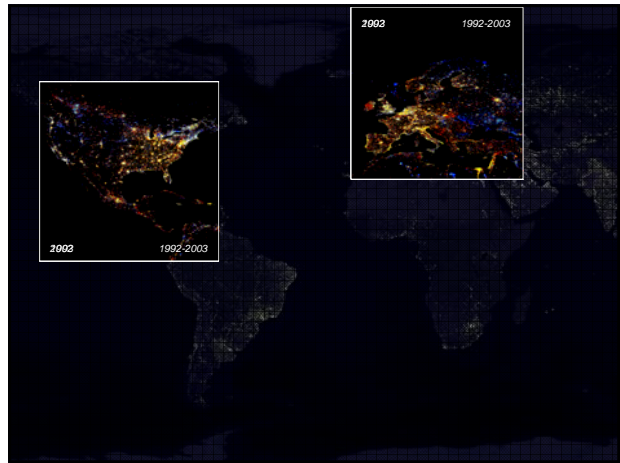
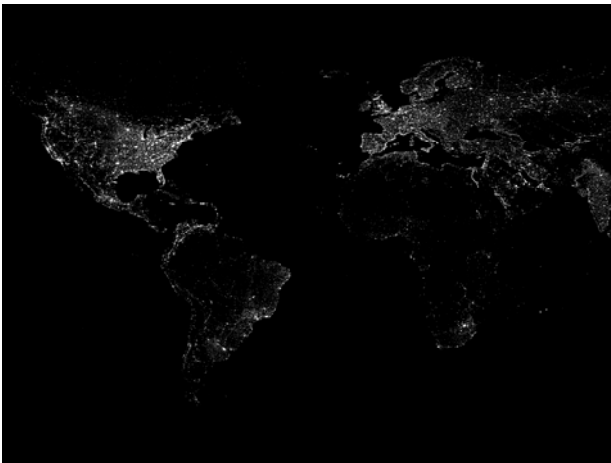
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## Outline

- Artificial night lighting as seen from space
  - NGDC - Defense Meteorological Satellite Program
- Applications based on DMSP data
  - Gas flaring
  - Population estimation
  - Light pollution ...
- Impact of ANL on ecosystems
  - Coral reefs, sea turtles
- Lights Proximity Index
  - Methodology
  - Results for 2003
  - Temporal trends 1992-2003
- Conclusion and outlook

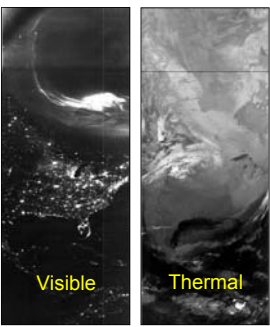


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## Artificial night lighting as seen from space



- The U.S. Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) has a unique capability to collect low-light imagery
  - Polar orbiting
  - 3000 km swath
  - Two spectral bands
    - Visible and thermal
  - Nightly global coverage
  - Flown since 1972
  - Will continue till ~2012

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## Applications based on DMSP nighttime lights

- Monitoring of gas flaring ▶
- Population estimation
  - Gridded population of the world
- Power outage detection following natural disasters ▶
- Light pollution
  - First Atlas of light pollution
- Impact of artificial night lighting on ecosystems
  - Potential risk of coral reefs

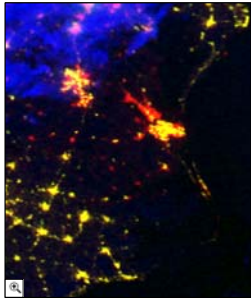
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## Power outage detection from hurricane Wilma

- Annual composite
  - Lights (visible band)
  - Cloud free
- Daily imagery
  - Lights (visible band)
  - Clouds (thermal band)
- RGB composite
  - Change detection
    - R
    - G
    - B



Elvidge, Aubrecht, Baugh, Tuttle, Howard (2007) Satellite detection of power outages following earthquakes and other events. International Geohazards Week. ESA/ESRIN, Frascati, Rome, Italy.

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## Applications based on DMSP nighttime lights

- Monitoring of gas flaring
- Population estimation
  - Gridded population of the world
- Power outage detection following natural disasters
- Light pollution
  - First Atlas of light pollution
- Impact of artificial night lighting on ecosystems
  - Potential risk of coral reefs

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## Ecological impact of artificial night lighting

- Nocturnal lighting can have direct effects on ecosystems
  - Rich, C., T. Longcore (2006) *Ecological Consequences of Artificial Night Lighting*. Island Press, Washington DC.

Examples:

- Effects of artificial night lighting on migrating birds
  - Gauthreaux Jr. and Belsler in Rich and Longcore (2006)
- Threatened sea turtle nesting sites
  - Salmon in Rich and Longcore (2006)
- Fish response to artificial night lighting
  - Nightingale, Longcore and Simenstad in Rich and Longcore (2006)
- ...


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## Coral reef related research

- Coral reefs are fragile and being damaged worldwide due to both physical and anthropogenic stressors
  - Physical stressors
    - Heat stress
  - Anthropogenic stressors
    - Development and agriculture resulting in water pollution
    - Overuse (recreation, fishing...)



- Not much is known about interactions of the stressors


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## Coral reef related research

- NOAA has a global program to monitor SST (sea surface temperature) anomalies
- To date there has only been one single global survey of anthropogenic stress on coral reefs → 'Reefs at risk'
- The new research objective was to create a globally consistent assessment of the proximity of specific anthropogenic stressors to coral reefs using DMSP nighttime lights
  - Development
  - Gas flaring
  - Heavily lit fishing boats



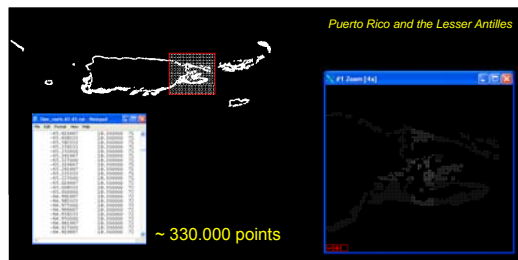
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## Coral reef related research – Data

- Global spatial compilation of coral reefs
  - Obtained from WRI (1998) – originates from UNEP, WCMC

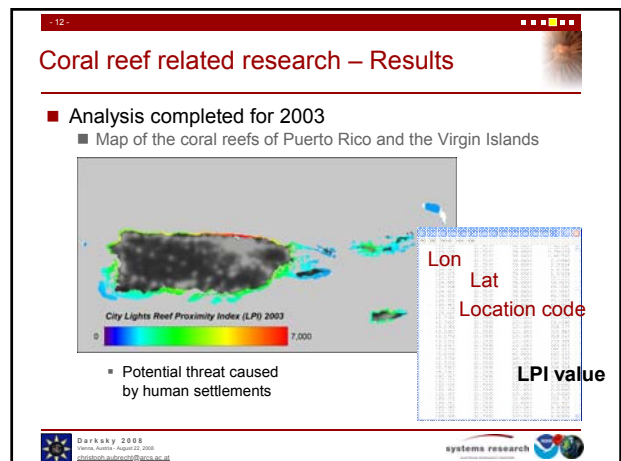
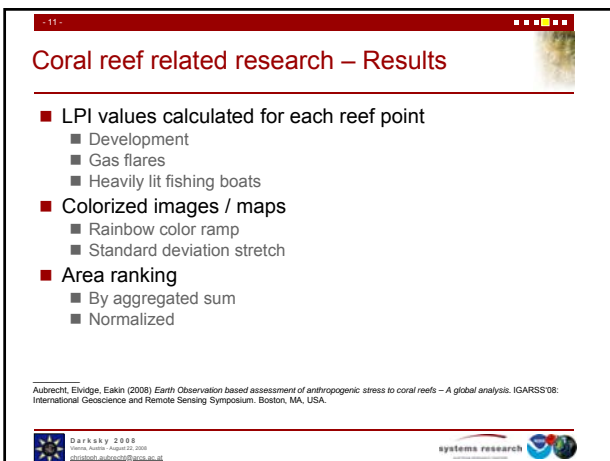
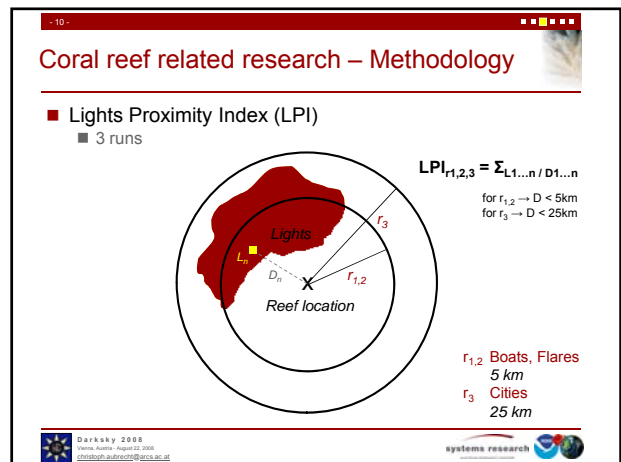
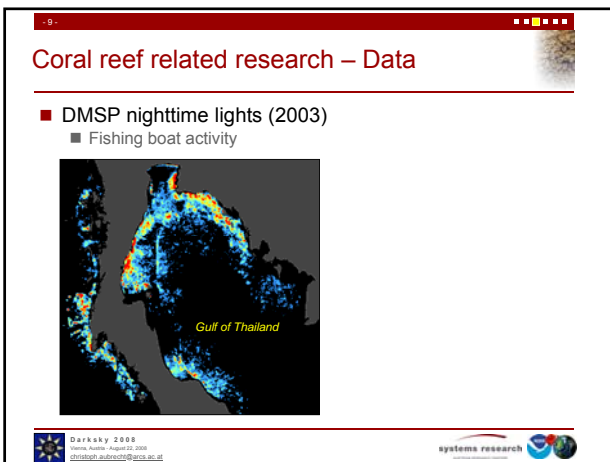
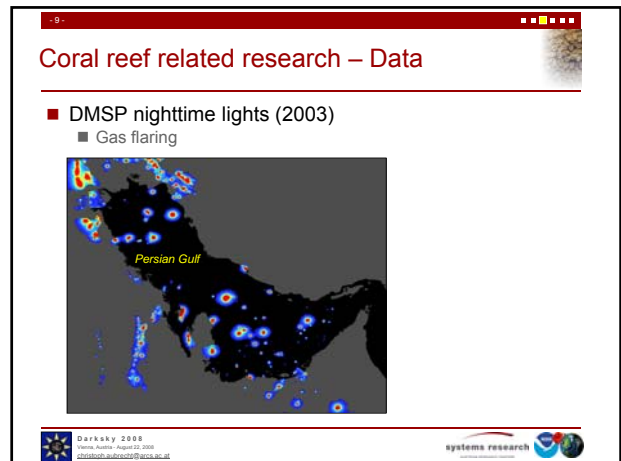
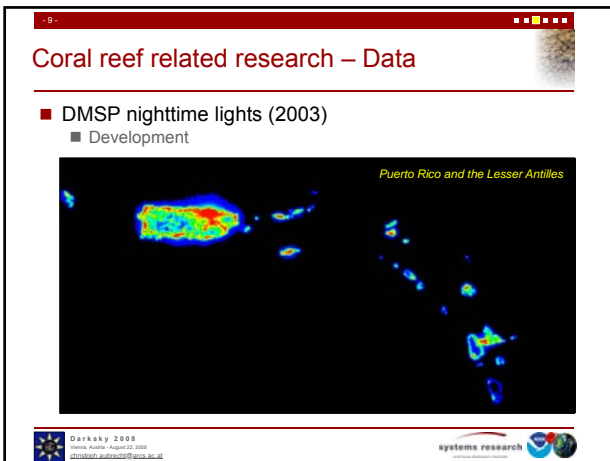


Puerto Rico and the Lesser Antilles

~ 330.000 points

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### Coral reef related research – Results

- Analysis completed for 2003
  - Area ranking (development)
    - By aggregated sum

A	B	C	D	E	F
Area Code	Area Name	Sum Values	Hum. Points	Avg	Lights
1	71 Puerto Rico	413137.0	2626	1573.24	cbtes
2	17 Red Sea - Saudi Arabia & Yemen	305749.3	7712	400.37	cbtes
3	20 Japan	252494.3	3303	769.99	cbtes
4	161 Indonesia	214356.7	54861	38.55	cbtes
5	10 Red Sea - Egypt	190468.0	6018	316.50	cbtes
6	56 Philippines	162797.2	31029	52.46	cbtes
7	70 Jamaica	1071520.0	1459	734.42	cbtes
8	27 Bahrain	902004.3	653	1506.06	cbtes
9	107 Martinique	952006.8	733	1298.89	cbtes
10	33 United Arab Emirates	926004.1	1367	677.76	cbtes
11	72 Virgin Islands	774166.3	1074	720.83	cbtes
12	42 India	725356.6	1906	380.56	cbtes
13	37 Taiwan	723606.1	1024	705.67	cbtes
14	36 Florida Keys	715195.9	1431	499.78	cbtes
15	15 Hawaii	690004.1	1302	505.38	cbtes

### Coral reef related research – Results

- Analysis completed for 2003
  - Area ranking (development)
    - Normalized

A	B	C	D	E	F	G
Area Code	Area Name	Sum Values	Hum. Points	Avg	Lights	Index
1	71 Puerto Rico	28613.0	61	4856.30	cbtes	100.0
2	175 Singapore	49665.9	16	3104.12	cbtes	63.4
3	11 Red Sea - Israel & Jordan	216102.8	124	1742.78	cbtes	35.6
4	115 Barbados	413137.0	2626	1573.24	cbtes	32.1
5	27 Bahrain	962004.3	653	1505.06	cbtes	30.7
6	75 St. Martin	192004.5	100	1920.05	cbtes	30.7
7	13 Kuwait	192045.8	126	1520.20	cbtes	29.6
8	124 Aruba	92273.4	57	1643.39	cbtes	28.9
9	113 Guam	340553.4	241	1413.13	cbtes	27.3
10	95 Guadeloupe	56831.4	425	1337.20	cbtes	26.5
11	107 Martinique	962006.8	733	1298.89	cbtes	25.8
12	237 Reunion	64480.9	51	1264.33	cbtes	24.3
13	108 Senegal	53538.4	45	1189.74	cbtes	22.3
14	90 Northern Mariana Islands	40416.8	37	1092.36	cbtes	18.1
15	16 Persian Gulf - Saudi Arabia	420661.2	474	887.47	cbtes	

Normalization in order to account for the varying number of reef points per area

### Coral reef related research – Results

- Analysis completed for 2003
  - Area ranking (fishing boat activities)
    - Normalized

A	B	C	D	E	F	G
Area Code	Area Name	Sum Values	Hum. Points	Avg	Lights	Index
1	137 Thailand - Gulf of Thailand	30269.7	1890	76.05	boats	100.0
2	117 Thailand West	24993.9	1126	22.20	boats	28.4
3	18 China	17759.8	1726	10.31	boats	13.2
4	52 Vietnam	3043.0	1098	2.95	boats	3.8
5	37 Taiwan	2580.9	1024	2.52	boats	3.2
6	120 Myanmar - Mergui Archipelago	1698.6	795	2.13	boats	2.7
7	56 Philippines	27923.9	31029	0.90	boats	1.2
8	162 Malaysia	1286.9	4061	0.32	boats	0.4
9	161 Indonesia	4489.2	47064	0.10	boats	0.1

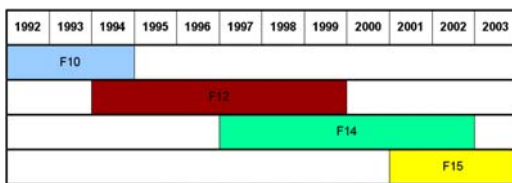
### Coral reef related research – Results

- Analysis completed for 2003
  - Area ranking (gas flaring)
    - Normalized

A	B	C	D	E	F	G
Area Code	Area Name	Sum Values	Hum. Points	Avg	Lights	Index
1	27 Bahrain	22955.4	653	361.95	flares	100.0
2	8 Iran - Persian Gulf	183261.0	599	306.94	flares	67.0
3	26 Oman	3699.3	12	309.95	flares	66.1
4	31 Qatar	61449.4	808	76.05	flares	21.6
5	10 Red Sea - Egypt	25219.5	3229	72.85	flares	20.7
6	168 Borneo	9515.4	223	42.87	flares	12.1
7	33 United Arab Emirates	57036.4	1352	42.19	flares	12.0
8	16 Persian Gulf - Saudi Arabia	4225.6	474	8.91	flares	2.5
9	199 Australia	7225.6	860	7.53	flares	2.1
10	162 Malaysia	6709.0	2083	3.22	flares	0.9
11	39 Mexico Gulf	81.6	27	3.02	flares	0.9
12	56 Philippines	20733.0	8132	2.56	flares	0.7
13	161 Indonesia	8682.3	3846	2.20	flares	0.6
14	19 Flower Garden Banks	5.4	10	0.54	flares	0.2
15	13 Kuwait	2.4	126	0.02	flares	0.0

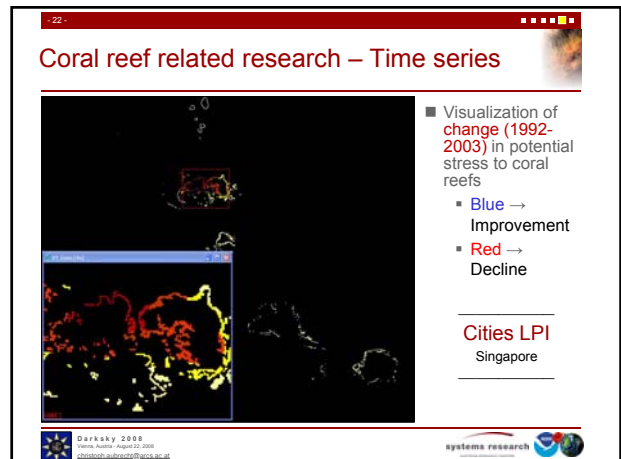
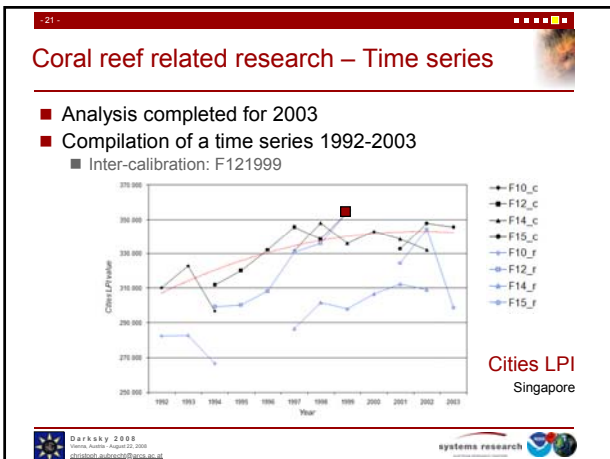
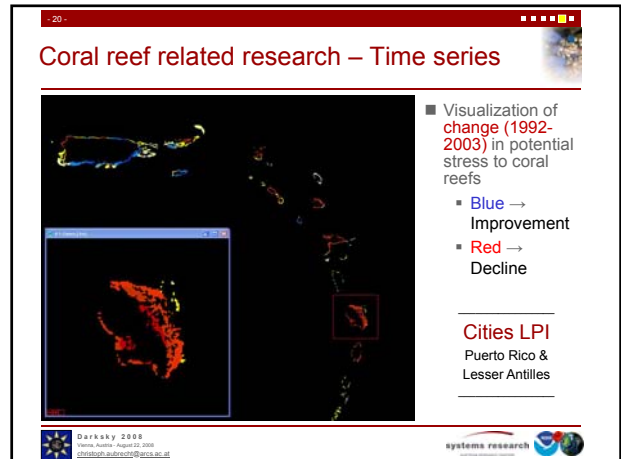
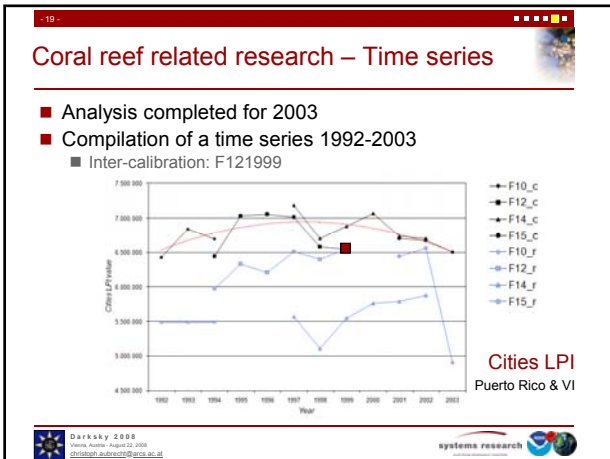
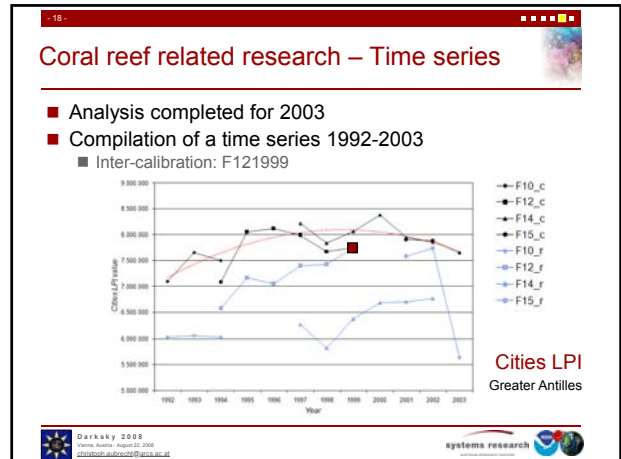
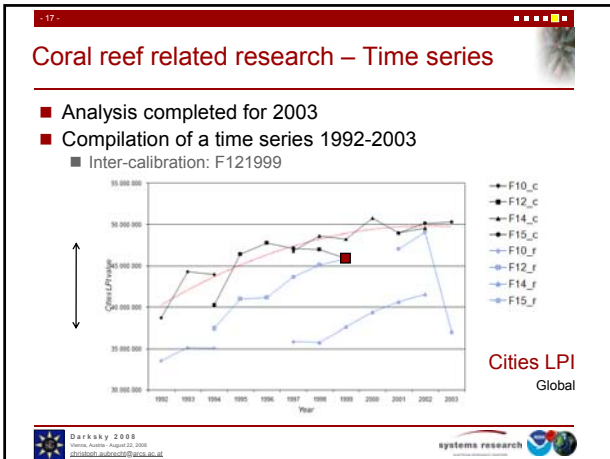
### Coral reef related research – Time series

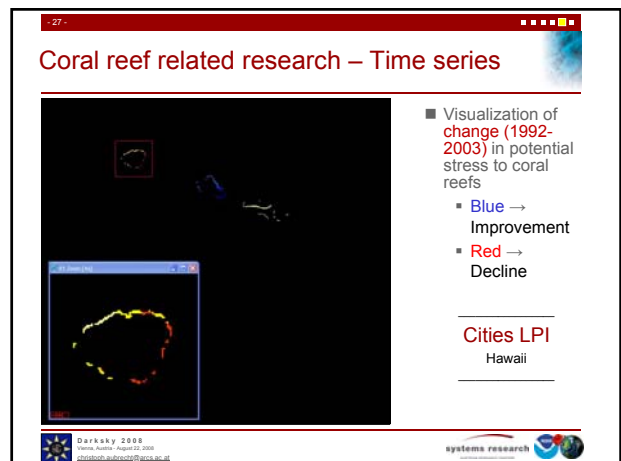
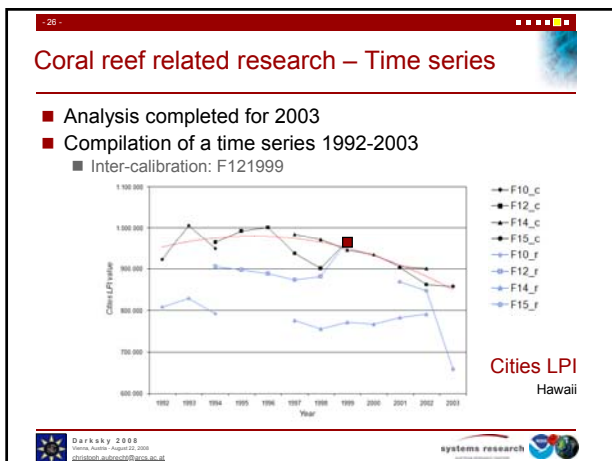
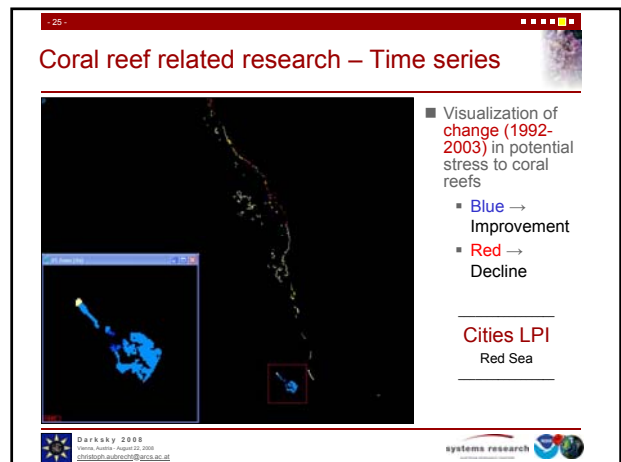
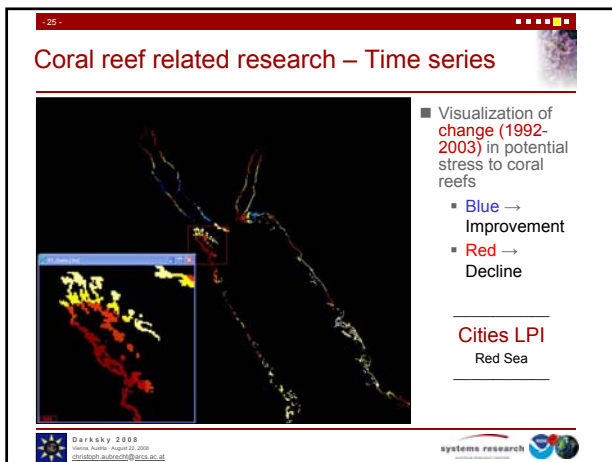
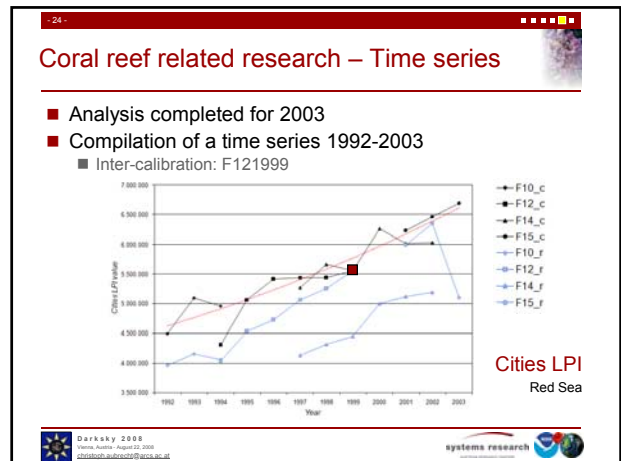
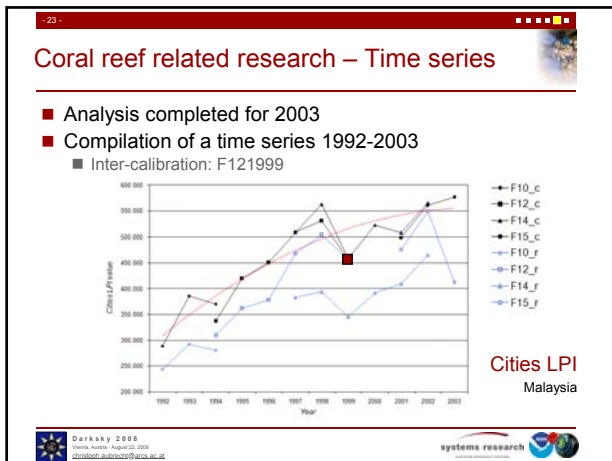
- Analysis completed for 2003
- Next step
  - Compilation of a time series 1992-2003
  - Change detection
- DMSP archive



### Coral reef related research – Time series

- Analysis completed for 2003
- Next step
  - Compilation of a time series 1992-2003
  - Change detection
- Inter-calibration essential for comparability
  - F121999 → 'brightest' year
- Stable lights used for development and gas flares
  - Noise had been removed
- Raw data used for boats
  - Noise was removed individually for each year and satellite in order to not lose any lights of fishing boat activity







**Coral reef related research – Time series**

- Analysis completed for 2003
- Compilation of a time series 1992-2003
  - Inter-calibration: F121999

**Cities LPI**  
Examples

Greater Antilles, Singapore, Red Sea, Puerto Rico & VI, Malaysia, Hawaii

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**Coral reef related research – Time series**

- Analysis completed for 2003
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  - Inter-calibration: F121999

Flares LPI  
Global

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**Coral reef related research – Time series**

- Analysis completed for 2003
- Compilation of a time series 1992-2003
  - Inter-calibration: F121999

Boats LPI  
Global

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**Coral reef related research – Time series**

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Boats LPI  
Gulf of Thailand

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**Coral reef related research – Time series**

- Visualization of change (1992-2003) in potential stress to coral reefs
  - Blue → Improvement
  - Red → Decline

Boats LPI  
Gulf of Thailand

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- Analysis completed for 2003
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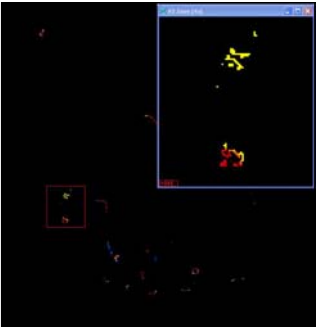
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## Coral reef related research – Time series



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  - Blue → Improvement
  - Red → Decline

Flares LPI  
Persian Gulf

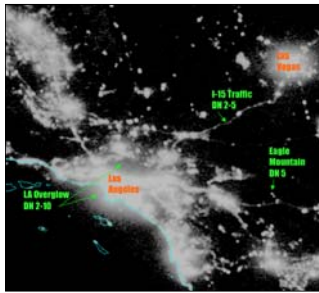
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## Conclusion and outlook

### Shortcomings of DMSP lights



- Coarse spatial resolution
  - 2.5 km GSD
- OLS lights are larger than sources on the ground → 'Overglow' surrounds bright sources
- No visible band calibration
- 6 bit quantification

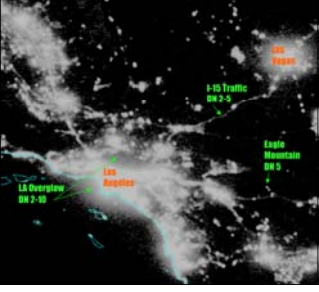
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## Conclusion and outlook

### Shortcomings of DMSP lights



- Urban centers saturate in operational data
- No spectral information on the type of the lighting or changes in lighting type

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## Conclusion and outlook

### Future possibilities

- The NPOESS Visible Infrared Imaging Radiometer Suite (VIIRS) will provide improved nighttime lights over the OLS → First launch in 2009-10.
- NPOESS will fly VIIRS in 6 a.m. / 6 p.m. plus 1 p.m. / 1 a.m. orbits. Metop is considering adding a low light imaging sensors for flights planned a decade+ from now.
- NOAA had planned a low light imager for GOES-R but this was dropped due to cost considerations.

### Higher spatial resolution / multispectral nighttime lights?

- The **Nightsat** Mission concept

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Thank you for your attention!

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