Artificial Intelligence for Earth Observation Data Processing : ISRO Use cases

Ashutosh Gupta, ISRO

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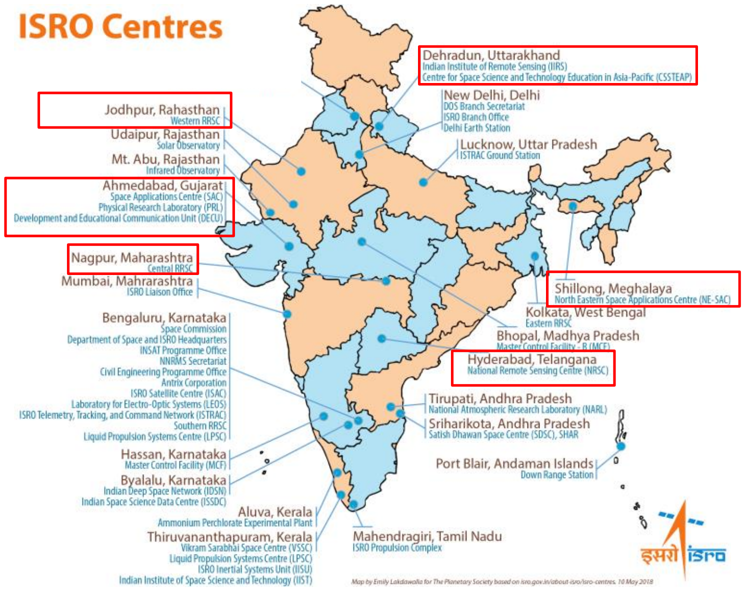
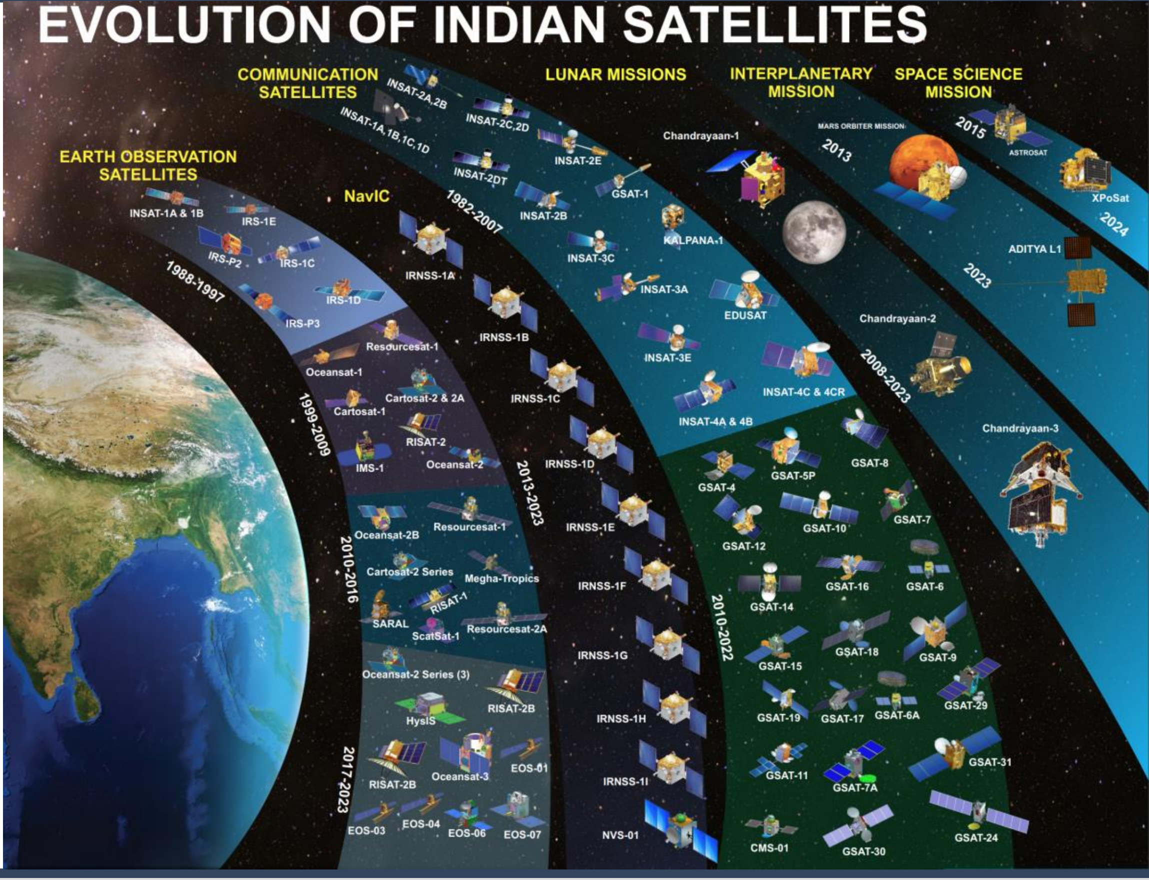
CEOS
Committee on
Earth Observation Satellites

Outline

- AI/ML at ISRO
- Different use cases of AI/ML
  - Data acquisition related
  - Data processing/augmentation related
  - Information extraction related
- Conclusions and Outlook

Indian Space Research Organisation (ISRO)





☐ Centres with projects on AI-EO.

ISRO – AI/ML Technology

AI/ML ISRO

1 Process definitions

Adhoc/team level →	defined →	Matured

2 Delivery

Background Models →	Open Models / Portals and platforms →	AI aaS Edge

3 Data and Development platforms

Silos Individual Platforms and Systems →	Data lakes, Repositories Notebooks, distributed dev. On Cloud →	AI/ML Ready data, MLOps CI/CD

4 Technology

ML/NN Models New app. domains →	New models, Theory for geospatial AI New applications →	Explainable AI Generalized models Onboard models

ISRO - Areas of AI use

Thrust areas of AI for EO data processing at ISRO

Data acquisition related

- Intelligent image acquisition (onboard AI)
- Data loss handling
- Image Restoration
- Thermal resolution improvement
- AI enabled compression

Data processing and augmentation

- Super-resolution
- Multi-modal Fusion
- Image-to-Map translation
- Analysis Ready Datasets
- AI-Ready datasets

Information extraction

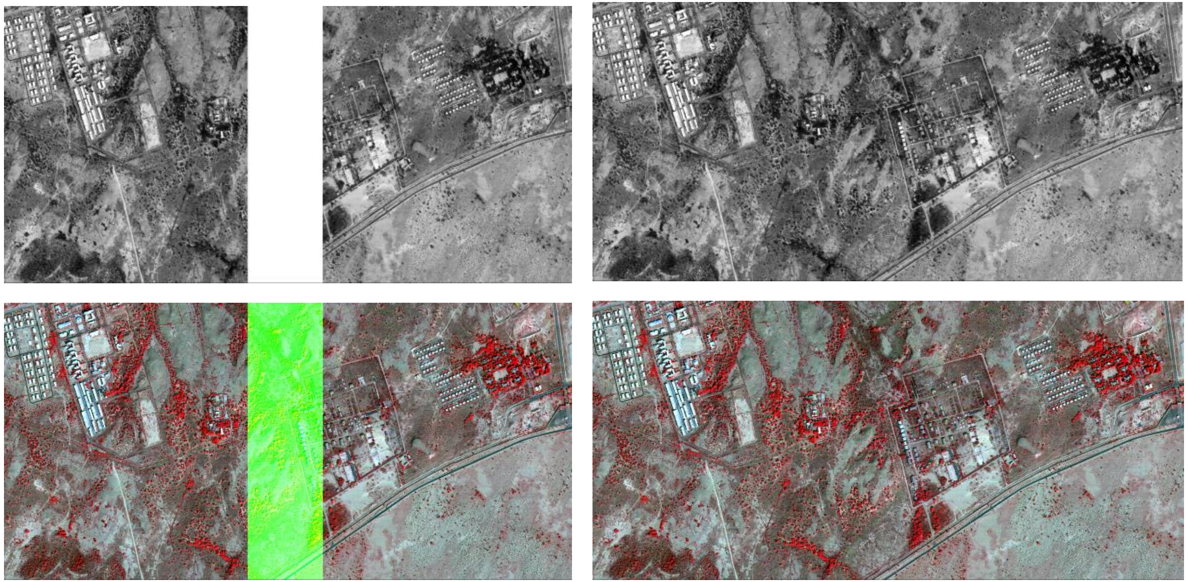
- Object detection and classification pipelines
- Semantic segmentation models
- Time-series and higher level products
- Onboard intelligence (Information to user)
- Information portals

AI-Research | **Foundation Models** | **AI Platforms and Infrastructure** | **AI-Applications** | **Explainable-AI**

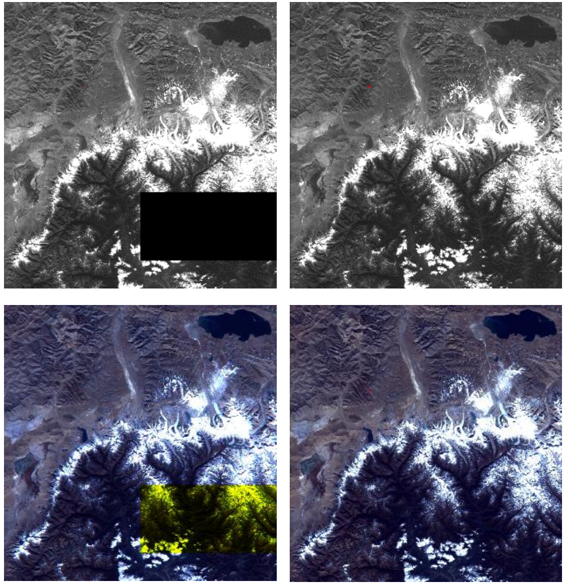
Use cases for AI/ML at ISRO

Missing data reconstruction

Loss in band data due to detector failure/Read-out error or transmission



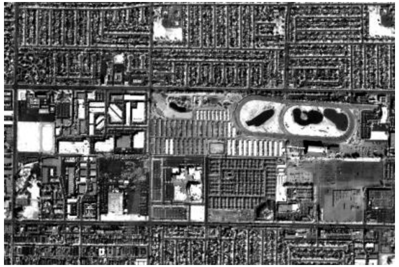
Cartosat device data loss reconstruction



INS-2B Nano MX – Frame data loss reconstruction (B2)

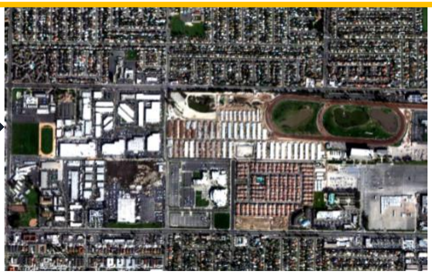
Alert: Adversarial learning with expert regularization using tikhonov operator for missing band reconstruction," IEEE TGRS, pp. 4395–4405, 2020, L.Rout et. al.

Multi-band reconstruction



Good NIR or PAN image

RGB image with missing data



Recover RGB info using Deep Learning

Cartosat-MX before reconstruction

Cartosat-MX after reconstruction

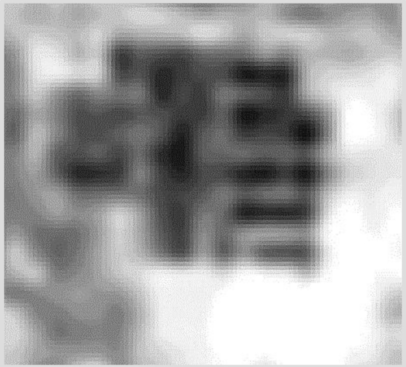
Typical model architecture
Conditional GANs, **Spatial attention with Cyclic loss**

Criterion: MSE-Loss with regularization on network weights

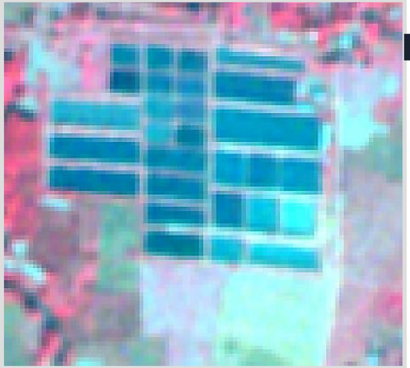
“Reconstruction of Missing Multiband Images for high resolution multispectral sensors using Wassersteing GAN”, In proceedings of InGARSS, 2023, M. A. Hossain, A. Gupta, S. Paul, S. K. Singh, S. D. Naidu, D. Dhar,

Improved thermal band

Sensed from Space



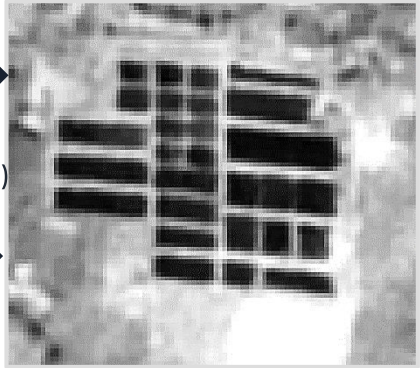
LISS-3 SWIR (at 24.0 m resampled at 5.0 m)



LISS-4 FCC (at 5.0 m)

DL Model Design for high resolution SWIR

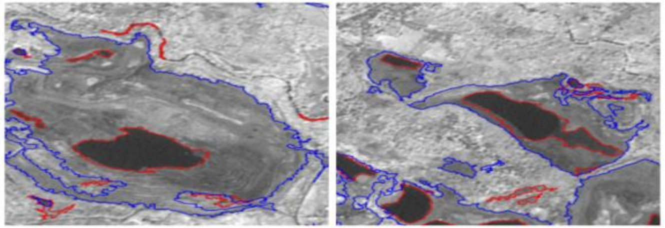
Training and Inference using
4.7 Million parameters



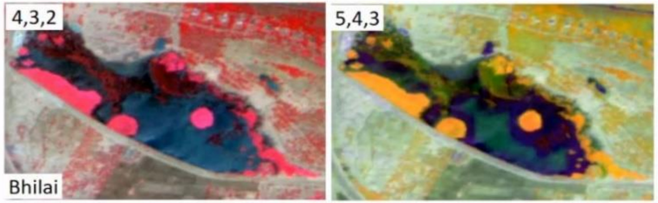
Deep SWIR (at 5.0 m)
Spatial information from high resolution L4 bands: NIR, R, G at 5m and Spectral information from low resolution L3 band: SWIR at 24m

L. Rout, et al. "Deepswir: A deep learning based approach for the synthesis of short-wave infrared band using multi-sensor concurrent datasets." TGRS, 2019

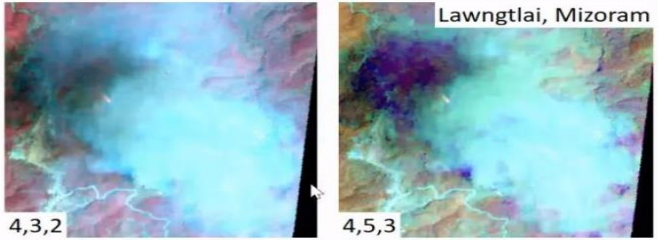
Potential Applications



Wetland Inventory and Mapping



Lake Segmentation Studies



Forest Fire

Image Restoration

- **Use of some new models** such as Generative Adversarial Networks (GANs), diffusion models, and vision transformers for recovering image information.

<u>Challenges:</u>

- **Training dataset generation** for supervised deep learning.

- Design of network which specifically **handle non-standard assumptions**

    - Non-uniform blurs
    - non- AWGN noise
    - Correlated noise

Denoising

Deblurring

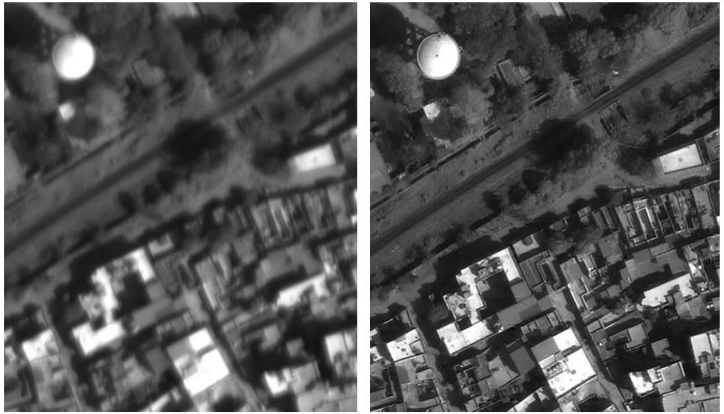
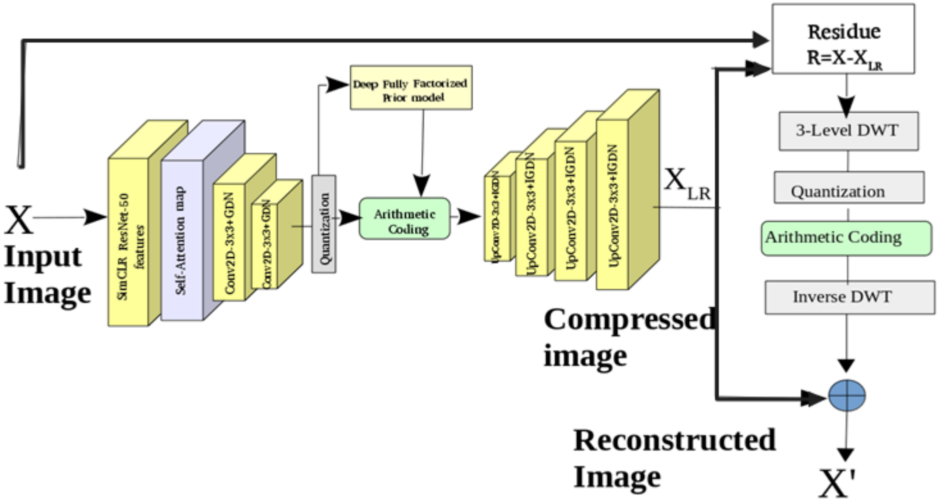
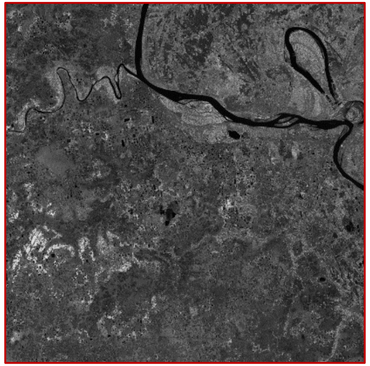
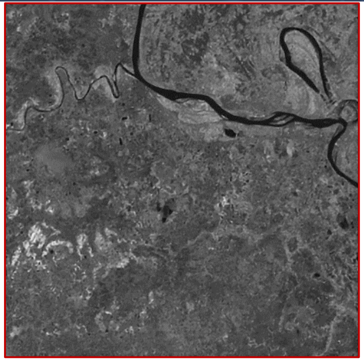


Image Compression

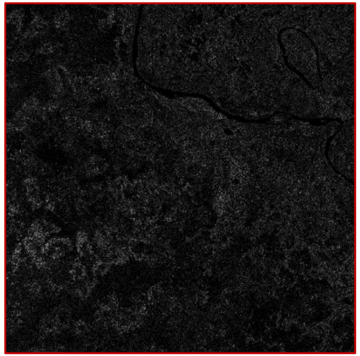




High resolution optical image



Low-frequency components (CR-37.7)



High-frequency components (CR-4.4)

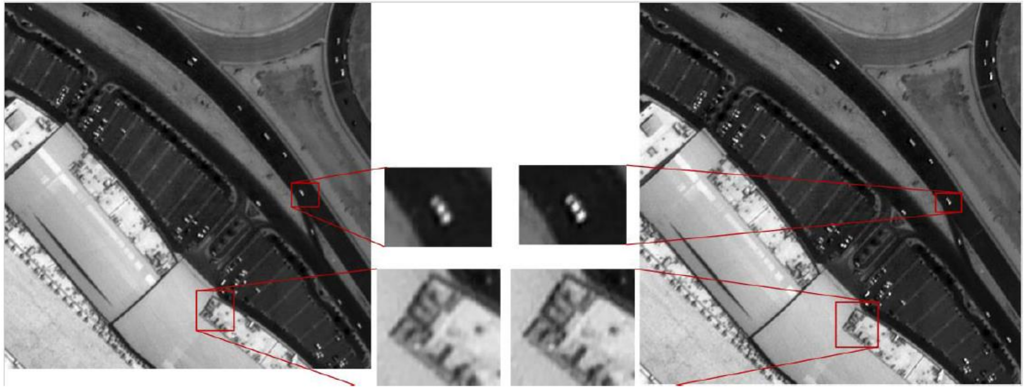
Neural net fused with traditional image compression pipeline outperforms the state-of-the art lossless compressors on optical remote sensing data.

A. Sinha, S. Manthira Moorthi, and D. Dhar. "Self-Supervised Variable Rate Image Compression Using Visual Attention." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2022.

Image/DEM Super-resolution

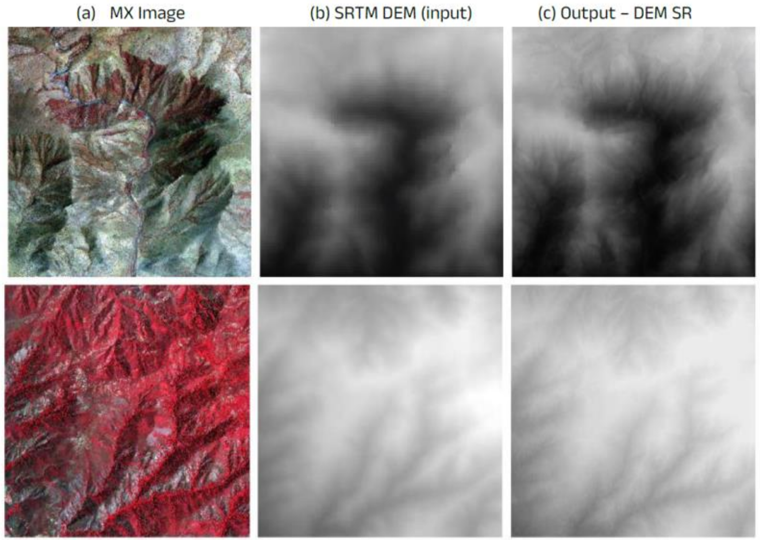
Deep learning for Single/Multi-frame super-resolution.

Image guided super-resolution for DEM



Cartosat-PAN super-resolution (Self super resolution)

Image guided DEM Super-resolution



❖ Useful in improved surface visualisation in absence of high resolution images/DEM

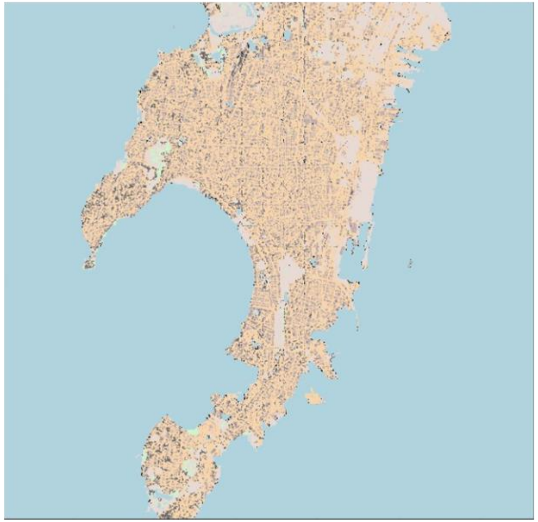
S. Paul, and A. Gupta. "SIRAN: Sinkhorn Distance Regularized Adversarial Network for DEM Super-resolution using Discriminative Spatial Self-attention." arXiv preprint arXiv:2311.16490 (2023).

Image-to-Image translation

- Map generation is key objective of Cartographic satellites.
- **Image to Map translation** using Generative deep learning models.
- Trained with Openstreetmap, but **dataset generation is a challenge**!

Model Output for Cartosat-2S Scene: Mumbai

Full Cartosat-2S Scene



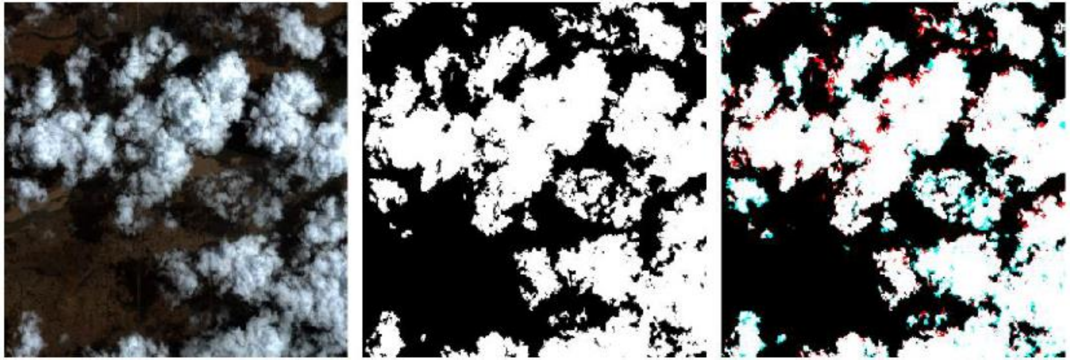
Predicted Map

Full-resolution MX Image

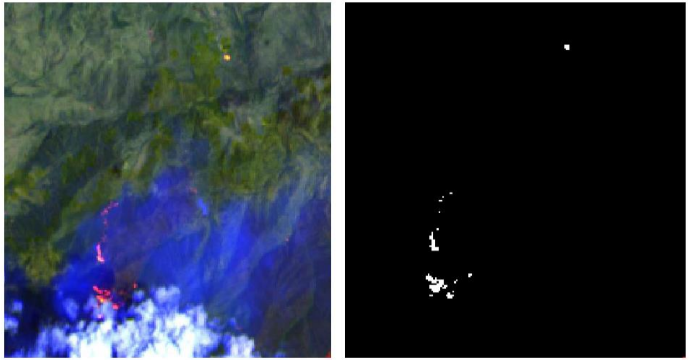
Predicted Map

Segmentation/Classification

Cloud segmentation in Cartosat images



Forest fire segmentation (L8 dataset)



Building footprints extraction from Cartosat dataset

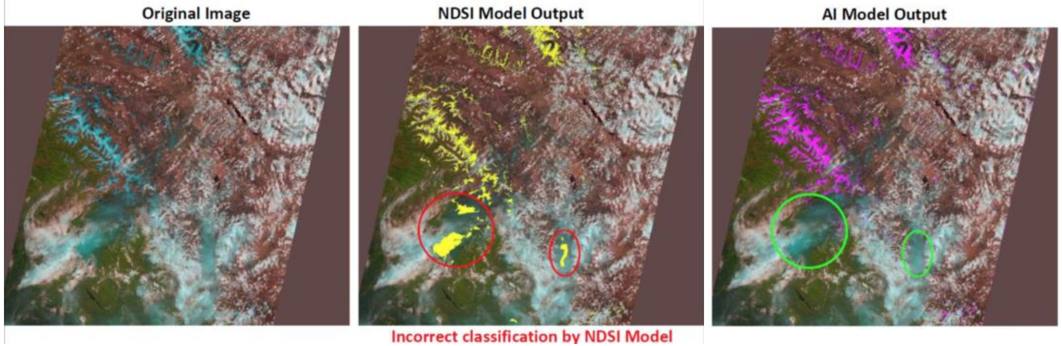
Gandhinagar City

Ahmedabad City

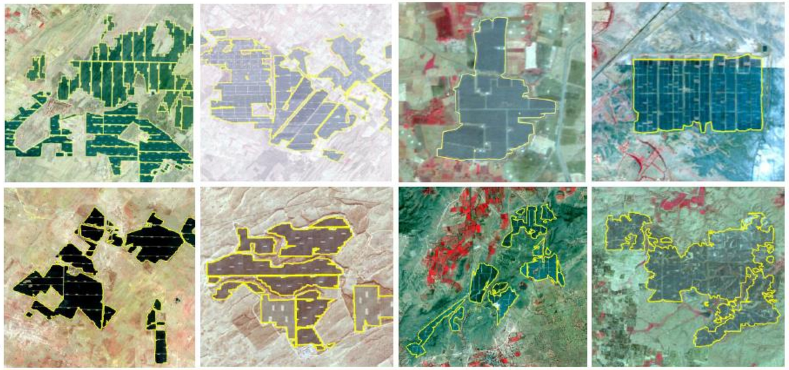
- S. Paul, and A. Gupta. "CLiSA: A Hierarchical Hybrid Transformer Model using Orthogonal Cross Attention for Satellite Image Cloud Segmentation." arXiv preprint arXiv:2311.17475 (2023).
- Kriti Rastogi, Pankaj Bodani & Shashikant A. Sharma (2022) Automatic building footprint extraction from very high-resolution imagery using deep learning techniques, Geocarto International, 37:5, 1501-1513, DOI: 10.1080/10106049.2020.1778100

Segmentation/Classification

Snow segmentation in AWiFS images

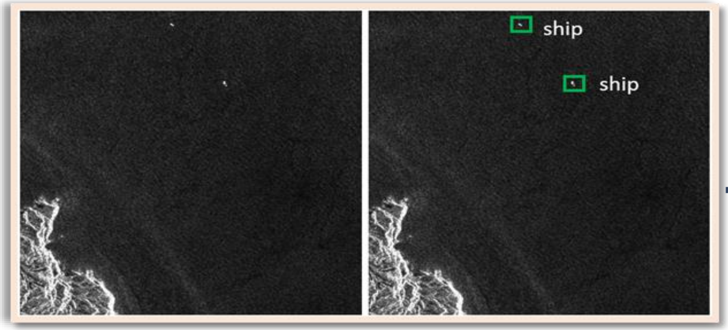


Solar power plants (R2A-LISS IV images)

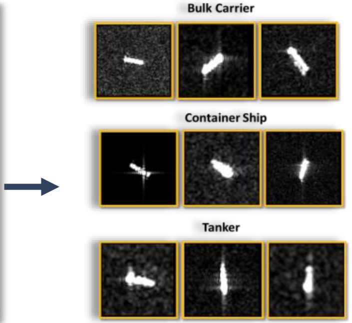


Solar power plants extracted across Rajasthan from R2A LISS IV data using Artificial Intelligence model .

Ship detection in images



Classification



Some of these models are being devised for **onboard** implementation.

Object detection and CBIR

- **Object detection pipelines** for different objects in Satellite imagery.
- **Content Based Image Retrieval (CBIR)** with natural language query and object indexing.

Prompt:

```
"High resolution images with airplanes, taken last week"
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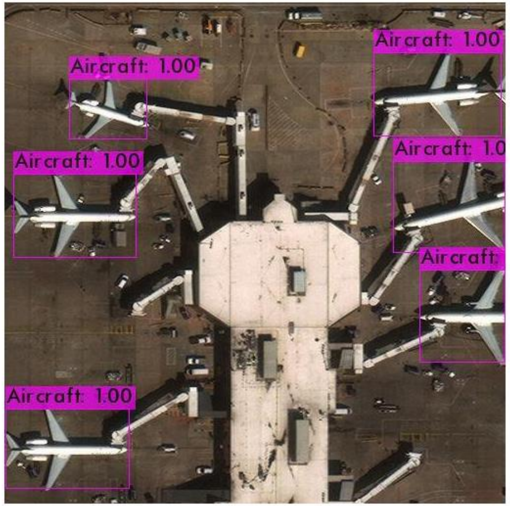
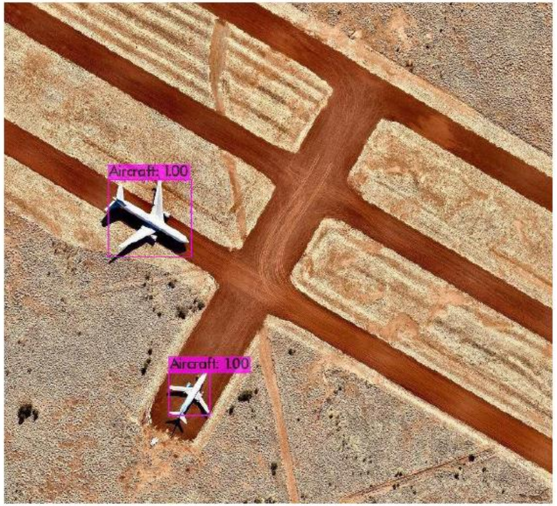
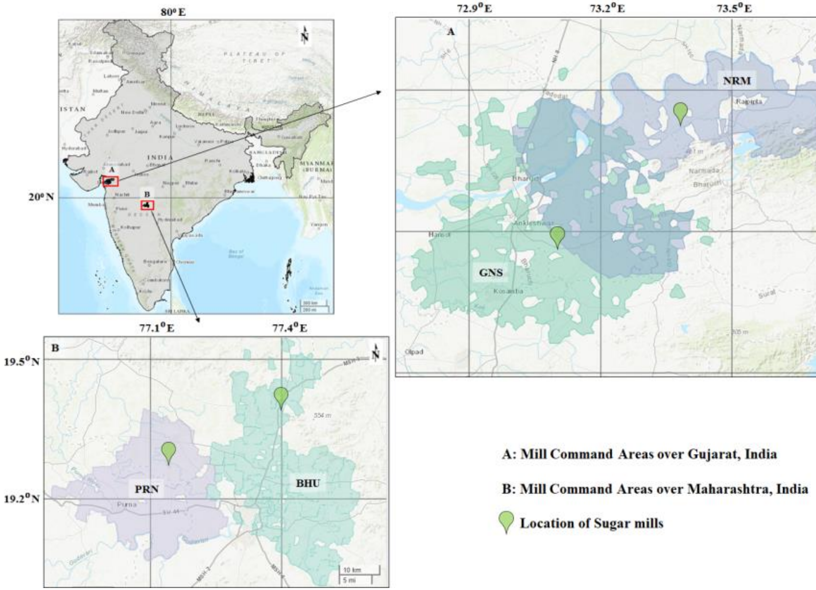
→

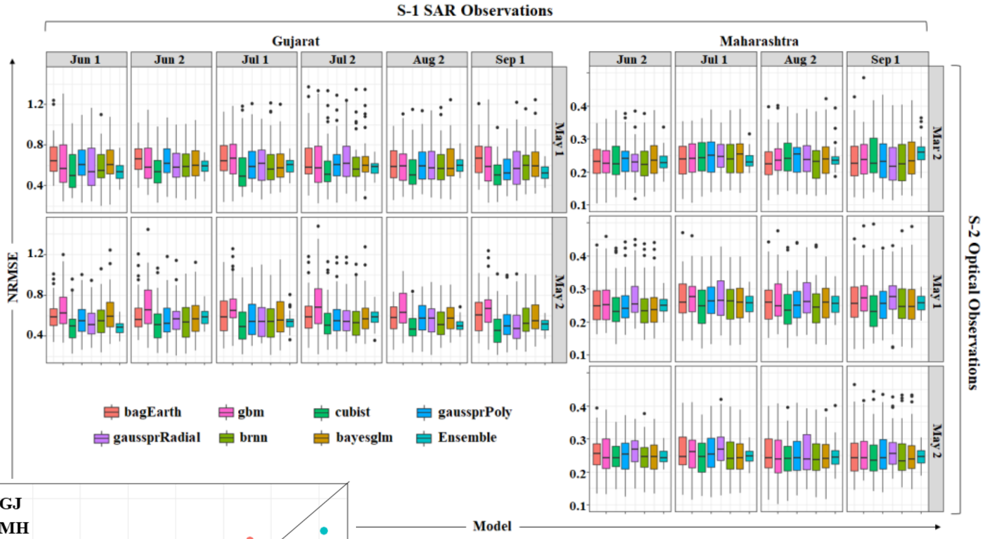


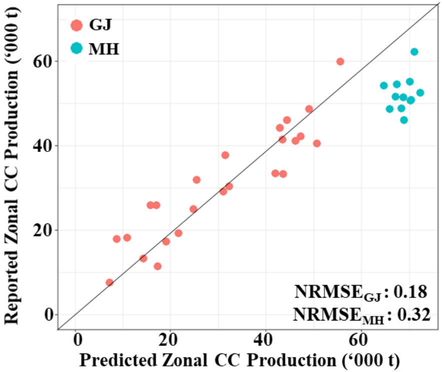


- **More intuitive** than traditional "form based" image retrieval mechanisms.

Sugarcane yield predictions using optical-SAR combination







Combination of parameters sensitive to crop water relations (SWIR-LSWI, VH) and greenness (EVI) showed better prediction accuracy

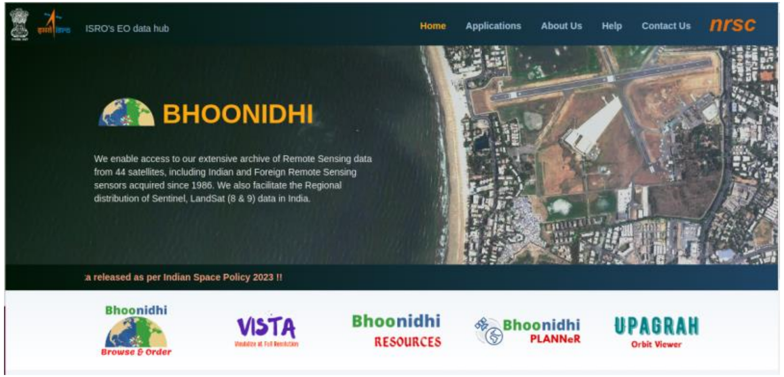
Government of India
Department of Food & Public Distribution
Ministry of Consumer Affairs, Food & Public Distribution

Das et al., 2023 (Remote Sensing Applications: Societies and Environment)

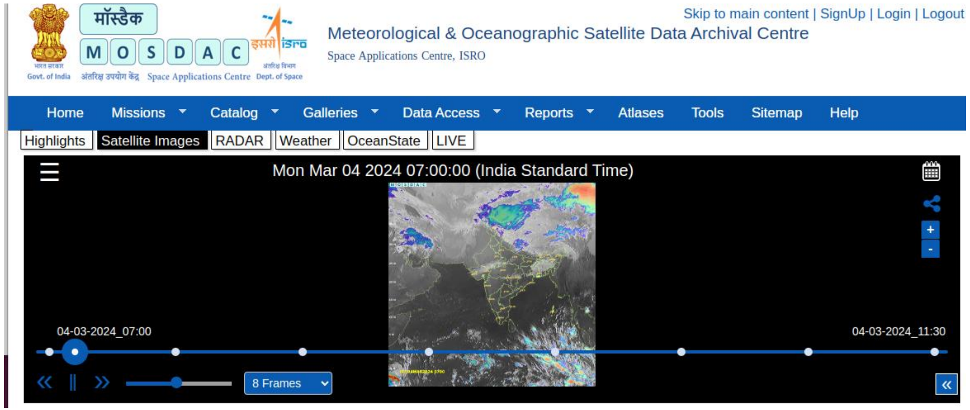
ISRO Portals

bhuvan
Indian Geo-Platform of ISRO

https://bhuvan.nrsc.gov.in



https://bhoonidhi.nrsc.gov.in



https://mosdac.gov.in

https://vedas.sac.gov.in

Conclusions and Future outlook

- ❖ Large number of AI models for different applications and domains
- ❖ Standardized AI/ML data and development is a work in progress
- ❖ Future :
  - ✓ ISRO AI/ML ready datasets for community
  - ✓ Deployment
  - ✓ EO-Workbench

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- SIPA and EPSA, SAC colleagues for their inputs.
- Colleagues at ISRO.
- CEOS/WGISS members.

References

1. I. Goodfellow, J. P. Abadie, M. Mirza, B. Xu, D. W. Farley, S. Ozair,A. Courville, and Y. Bengio, “Generative adversarial networks,” Communications of the ACM, vol. 63, no. 11, pp. 139–144, 2020.
2. L. Rout, “Alert: Adversarial learning with expert regularization using tikhonov operator for missing band reconstruction,” IEEE TGRS, pp. 4395–4405, 2020.
3. M. A. Hossain, A. Gupta, S. Paul, S. K. Singh, S. D. Naidu, D. Dhar, “Reconstruction of Missing Multiband Images for high resolution multispectral sensors using Wassersteing GAN”, In proceedings of InGARSS, 2023.
4. L. Rout, et al. "Deepswir: A deep learning based approach for the synthesis of short-wave infrared band using multi-sensor concurrent datasets." arXiv preprint arXiv:1905.02749 (2019).
5. A. Sinha, S. Manthira Moorthi, and D. Dhar. "Self-Supervised Variable Rate Image Compression Using Visual Attention." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2022.
6. Nguyen, Ngoc Long, et al. "Self-supervised multi-image super-resolution for push-frame satellite images." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2021.
7. S. Paul, and A. Gupta. "SIRAN: Sinkhorn Distance Regularized Adversarial Network for DEM Super-resolution using Discriminative Spatial Self-attention." arXiv preprint arXiv:2311.16490 (2023).
8. S. Paul, and A. Gupta. "CLiSA: A Hierarchical Hybrid Transformer Model using Orthogonal Cross Attention for Satellite Image Cloud Segmentation." arXiv preprint arXiv:2311.17475 (2023).
9. H. Mordechai, and Patrick Weber. "Openstreetmap: User-generated street maps." IEEE Pervasive computing 7.4 (2008): 12-18.
10. O. Ronneberger, P. Fischer, and T. Brox, “U-net: Convolutional networks for biomedical image segmentation,” CoRR, vol. abs/1505.04597, 2015
11. P. Isola, J. Y. Zhu, T. Zhou, and A. A. Efros, “Image-to-image translation with conditional adversarial networks,” in Proceedings of CVPR, 2017, pp. 1125–1134.
12. Kriti Rastogi, Pankaj Bodani & Shashikant A. Sharma (2022) Automatic building footprint extraction from very high-resolution imagery using deep learning techniques, Geocarto International, 37:5, 1501-1513, DOI: 10.1080/10106049.2020.1778100

Thanks.