# *Physical* Cloud Detection for Proba V

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# Algorithm Theoretical Basis 1

Calculation of cloud optical thickness.

- If smaller than threshold → No cloud
- If larger than threshold → Cloud
- (If within *threshold range* → semitransparent cloud, currently not implemented (but easy))

# Algorithm Theoretical Basis 2

**Calculation of cloud optical thickness**.

- Based on radiative calculations (MoMo). Variations:
  - Cloud optical thickness
  - Cloud height
  - Surface brightness
    - Lambert for land
    - Cox and Munk for sea surface (wind speed)
  - Geometry
  - Water vapor constant, Ozone constant

**Inverse Modelling using of ANN (fast and simple)**

# Algorithm Theoretical Basis 3

Cloud optical thickness → Cloud Mask

- Over Sea NIR COT Threshold
- Over Land RED COT Threshold (vegetation!)
- BLUE not used (height / Rayleigh ambiguity)
- SWIR not used (yet) for COT ( Ice Clouds/ snow ambiguity) , but for NDSI (snow restoral)

# Auxillary Data

- DEM (GTOPO 30), land sea mask
- Sea: wind speed (currently ERA Interim)
- Land: NIR, RED albedo climatology
  - Utilization of AlbedoMap climatology (based on few years MERIS)
- T2M (ERA Interim) for snow restoral

# Program Flow:

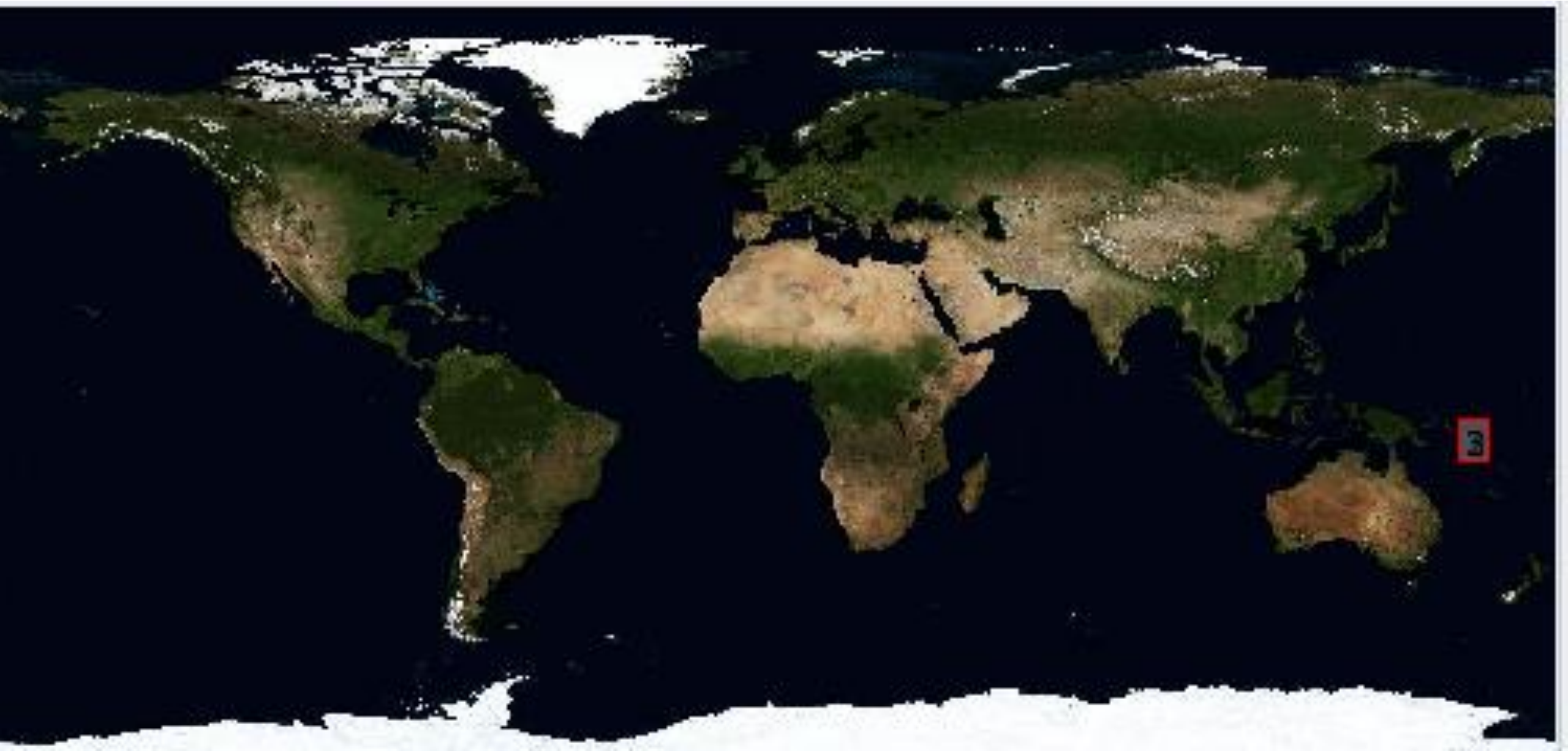
- Interpolate AUX data to Proba-V swath location and time
- Calculated NIR and RED COT
- If threshold (sea: NIR COT, land: RED COT) reached: set cloud flag
- Compare NIR/RED COT. If deviation > 10%: set inconsistency warning flag (mostly semitransparent clouds + cloud borders, or saturation)
- If T2M < 10°C and cloud flag: calculate NDSI>0.45 and set snow warning flag if threshold.

# Timing:

20 sec for 10^6 pixel  on my notebook (python + numpy)

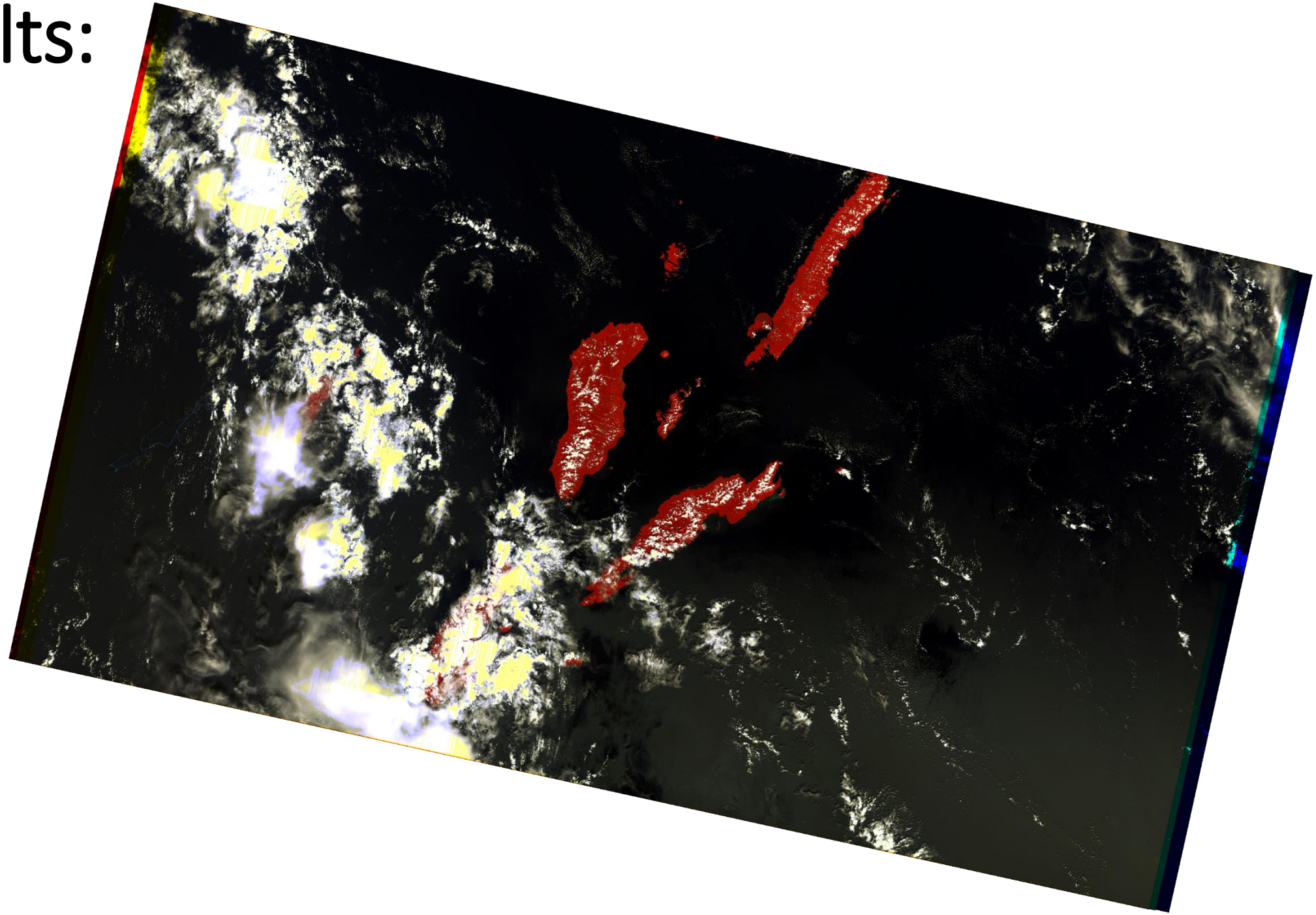
- Interpolate ERA T2M and WSP:  11 sec
- Interpolate DEM, Abedos: 2 sec
- COT:  2*3sec = 6 sec
- IO: 2 sec

# Results: Solomon Islands



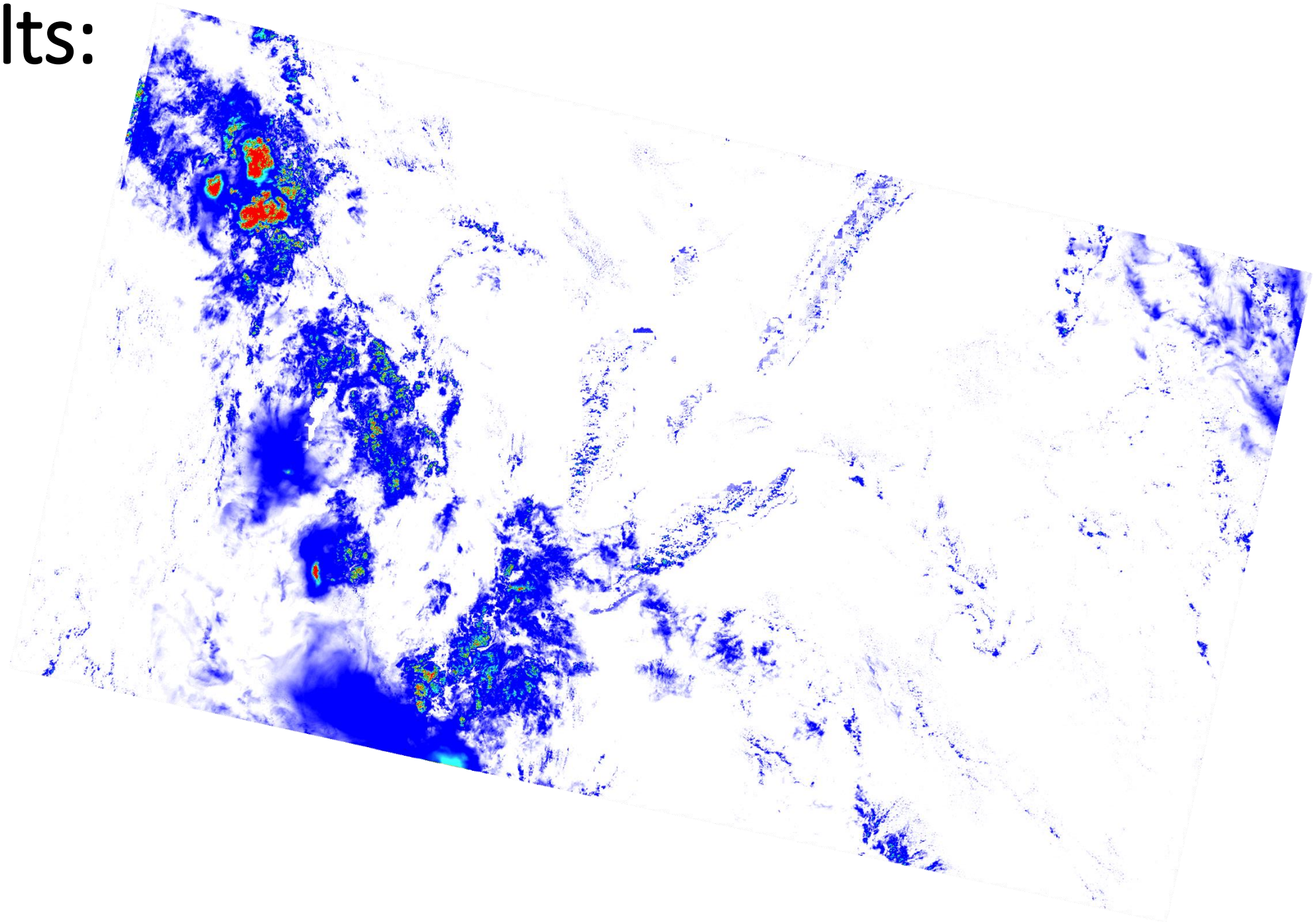
# Results:

RGB



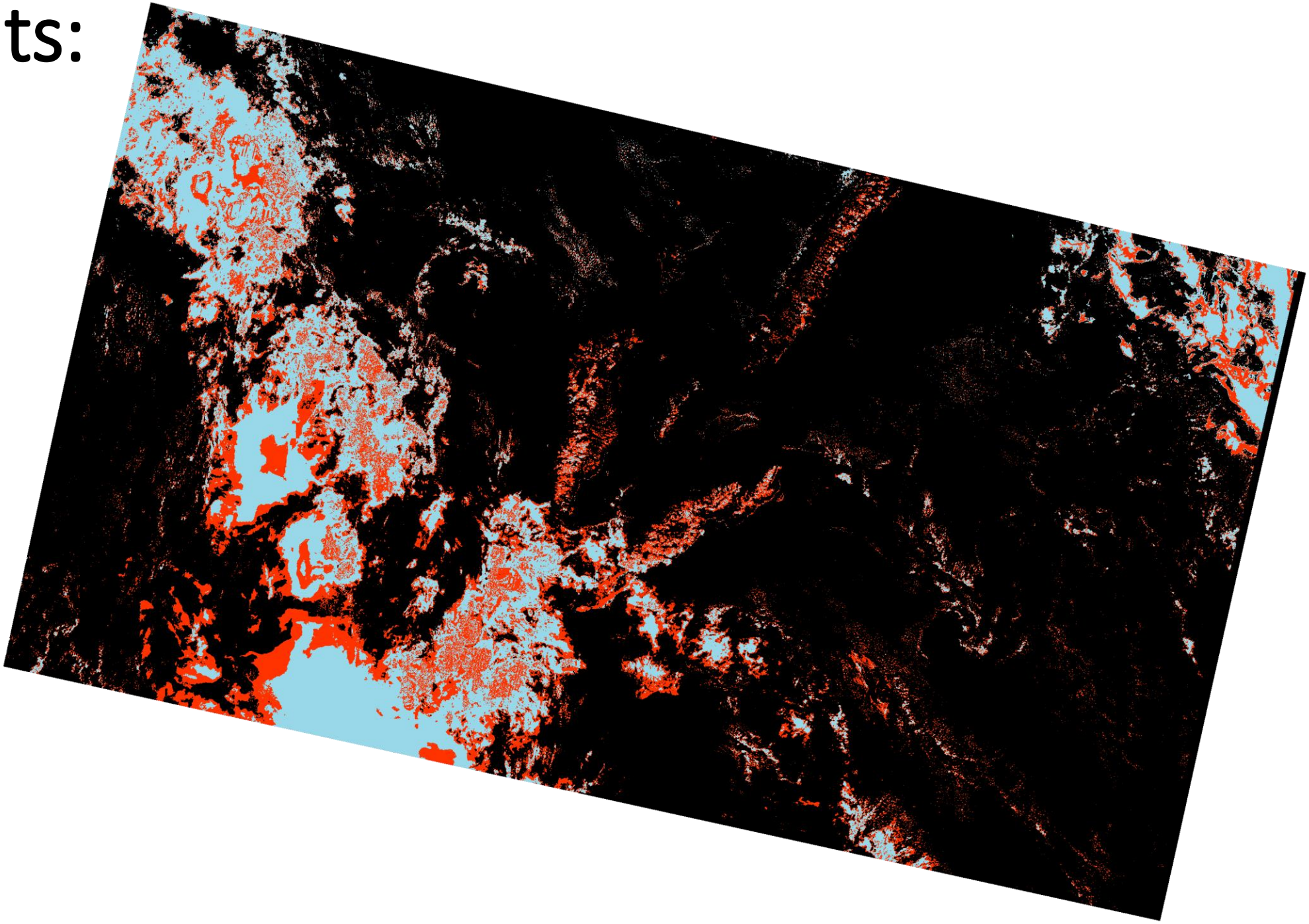
# Results:

COT



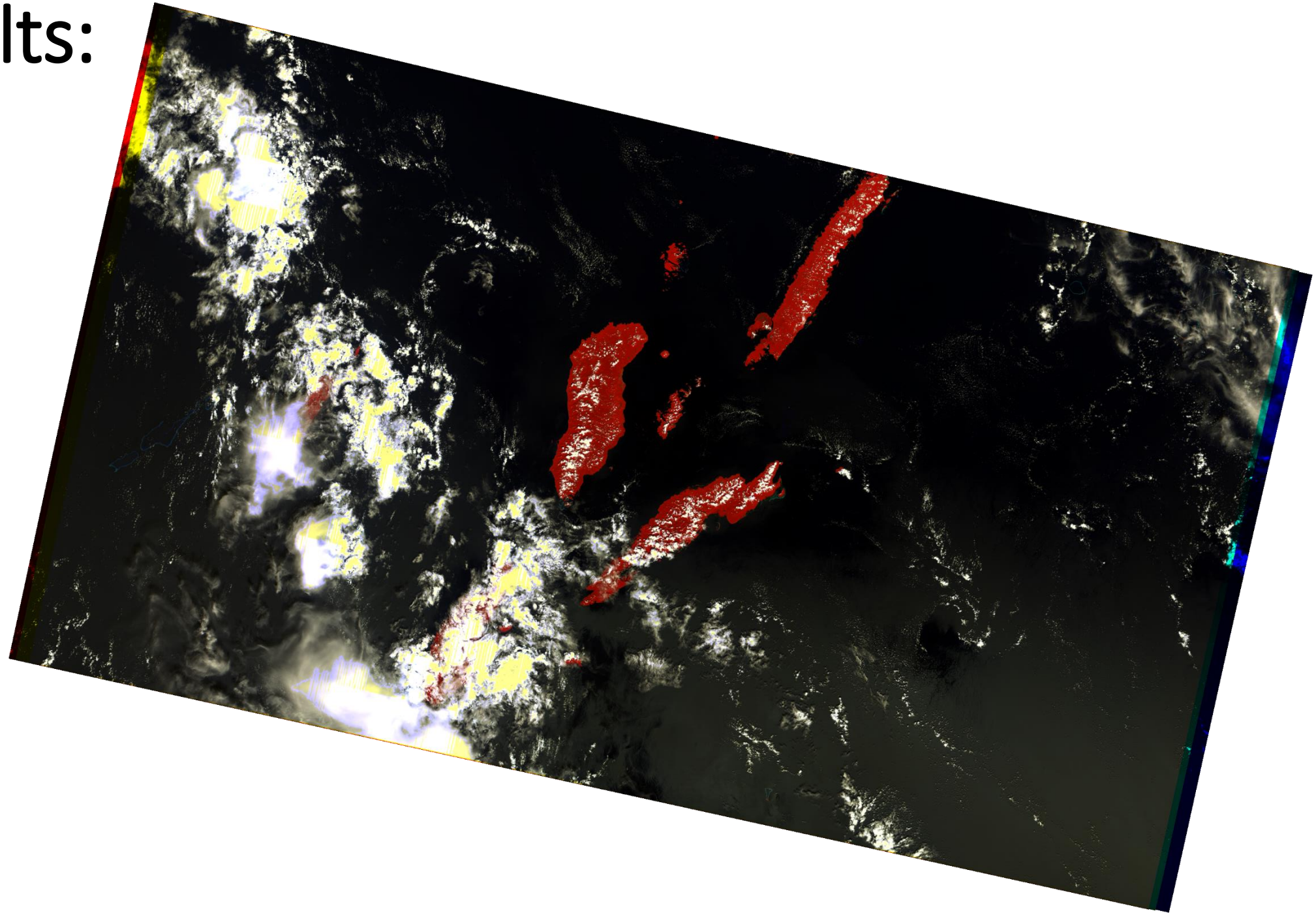
# Results:

MSK



# Results:

RGB



# Room for Improvements:

- **Better albedo maps (MODIS, 1 min ~ 1.8km)**
- Introduction of semitransparent flag
- SWIR COT for sediment loaded water, (but cloud microphysics ambiguity?)
- Introduction of cloud shadow
  - Geometrical: assuming what top height?
  - Spectral: BLUE (no good idea yet, empirically?)
- Introduction of cloud margin (trivial)
- Definition / Estimation of cloud probability. However, needs much more work:
  - Bayesian methodology
  - **Truth needed, otherwise no frequencies→ probabilities**
  - Is cloud probability anyway needed?

# Algorithm bottom-line

+ Conceptually easy: just calculate cloud optical thickness

+ Modular: each module can be exchanged / validated independently

- COT : ANN cloud be replaced by any other fast RTM (approximation) based algorithm
- Surface albedo: Can (and shall) be replaced by e.g. MODIS/VIRRS
- ERA … climatological background, DEM

+ Objective (impartial): all thresholds can be related to a cloud physical property (cloud optical thickness), which could be validated. No subjective/manual cloud detection.

→ Reasons for failures can easily be traced and mitigated

- Heavily depends on surface albedo (but this, virtually shifts the work towards MODIS/VIRRS which is **much much much …** better for cloud detection)