(Street) Lights Will Guide You:
Georeferencing Nighttime Astronaut Photography of Earth

Supplementary Material

8. AIMS-Night Details

AIMS-Night contains 363 images that are representative of nighttime astronaut photography as a whole (Fig. 7). The photo center points are globally distributed, though there is a geographic bias toward densely populated areas. This trend in AIMS-Night mirrors the trend of nighttime astronaut photography as a whole, and can primarily be attributed to a few factors: (1) most research requests for nighttime imagery are for cities, and (2) at night, artificially lit cities stand out against the rest of the view, drawing astronaut attention and making them easier to photograph than unlit areas.

In Fig. 8, we show that AIMS-Night contains images that span from 2008-2022, with more images from earlier years as this was a period of concerted manual geolocation effort, so most labeled imagery is from this time. The obliquity distribution highlights the challenge associated with astronaut photography - less than 3% of photos are taken nadir or near nadir (0°, facing directly down), and most have 20° or more obliquity, which induces a perspective change with respect to nadir generated reference imagery that poses difficulty for matching. Astronauts have a variety of focal length lenses to choose from when taking photos. Focal length is inversely related to field of view - the higher the focal length, the smaller the area covered by the image. For astronaut photos taken from the ISS, 180mm focal length imagery can usually encompass an entire city and some of its surrounding rural area, while a 400mm focal length image more tightly captures the city itself. Higher focal lengths can highlight individual sectors or neighborhoods within a city, and are especially difficult to localize. AIMS-Night contains primarily 180-400mm focal length imagery to emphasize the goal of localizing city scale imagery.

9. Examples from AIMS

9.1. Success Cases

Examples of successful matching cases are in Fig. 9. ISS026-E-14962 and ISS037-E-15303 show the value of the satellite image background, as the matching regions have very sparse street data. Our method is also robust to moderate scale and perspective shift (ISS026-E-8497, ISS038-E-9625, ISS026-E-5515). By combining the rasterized street data with the daytime satellite image background, we can match images where even if one of the two data sources does not produce prominant features. For example, there are few roads in ISS037-E-15303, but they daytime satellite image contains matching features, while in ISS026-E-28896, there are few daytime features present, and the road network produces matchable keypoints.

9.2. Failure Cases

Fig. 10 contains examples of failure cases, where the astronaut photo and reference image were not able to confidently match in the "best case" matching scenario, where both images share the same extent. In these cases, we see that many failures are due to large perspective changes between the photos (ISS026-E-6221, ISS026-E-8209). Other failures are due to large changes in scale (ISS026-E-5392) due to poor modeling of the field of view, or sparse road network data (ISS022-E-70679).

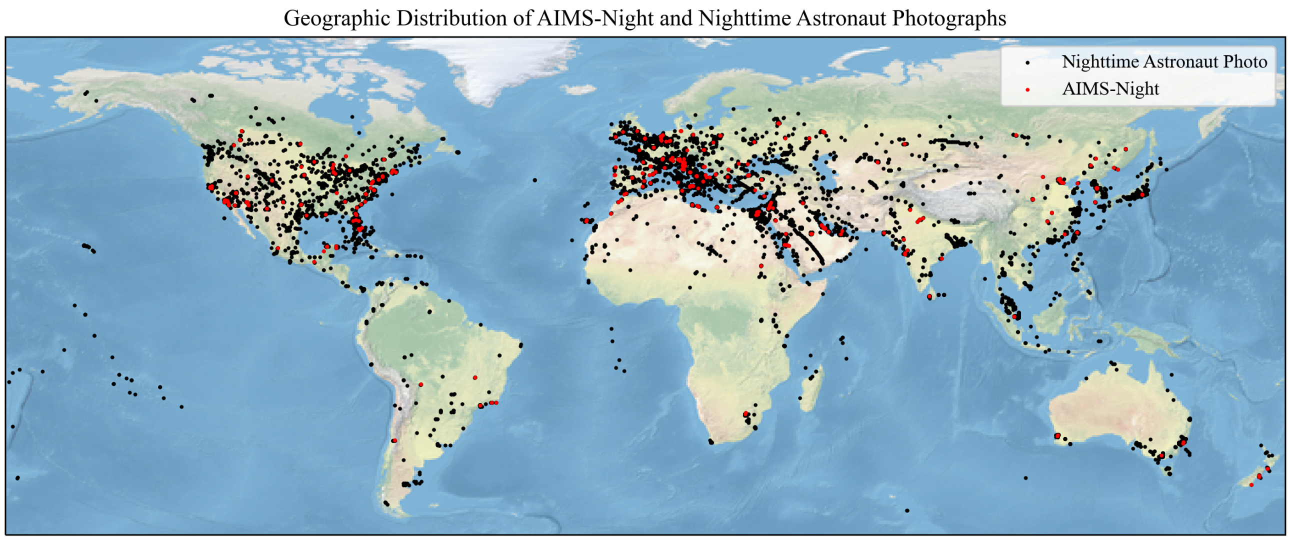

Figure 7. **AIMS-Night Geographic Distribution.** AIMS-Night photos (red) and all georeferenced nighttime astronaut photographs (black, manually located).

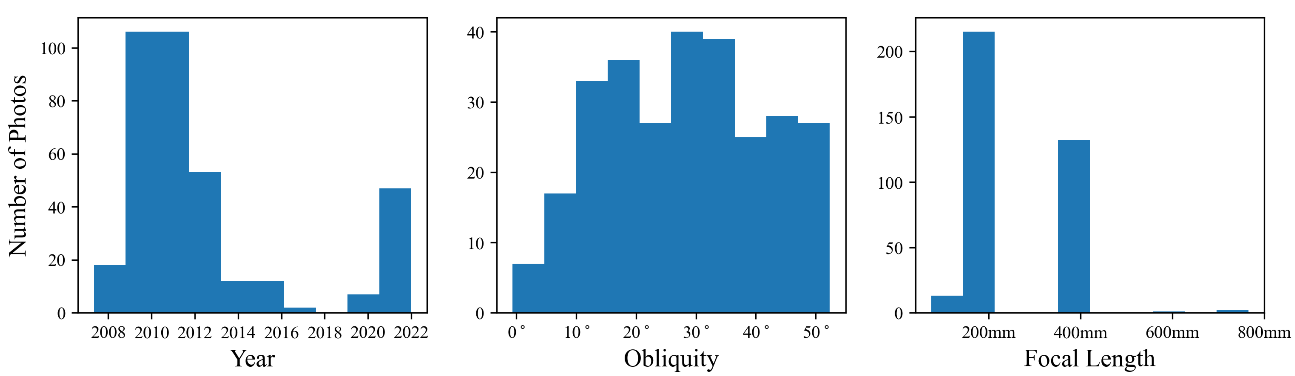

Figure 8. **AIMS Night Metadata.** AIMS-Night contains imagery from 2008-2022 that varies in terms of obliquity and focal length. Most city scale images have focal lengths between 180 and 400mm.

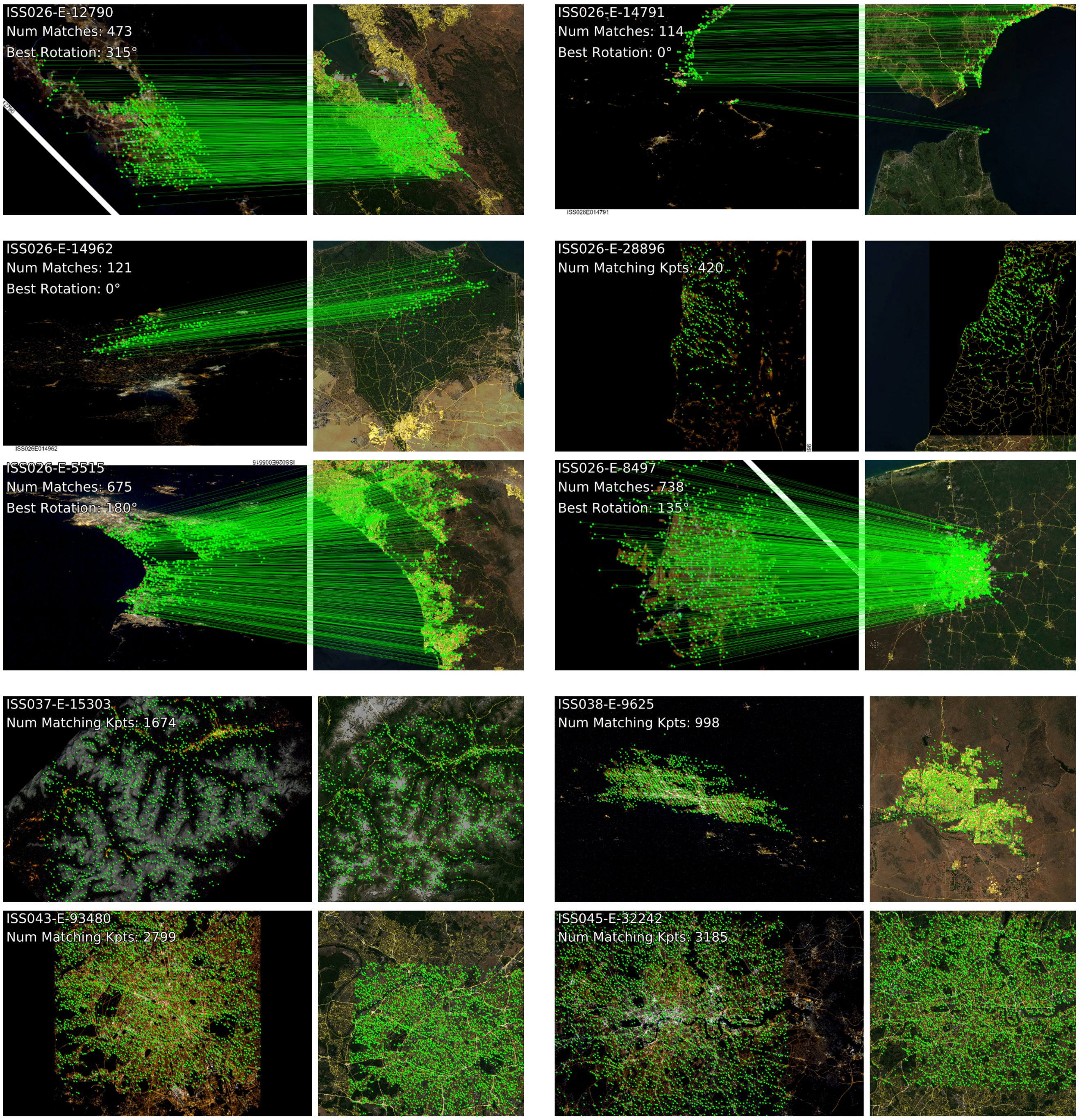

Figure 9. **Success Examples for "Best Case" Pairs**. Matching keypoints or correspondence lines for successfully matched pairs. With thousands of correspondences, the correspondence lines can obscure the image pairs - in these cases, the matching keypoints are drawn without the correspondence lines. Our method successfully matches in challenging scenarios, including regions without dense street networks and under perspective and scale change.

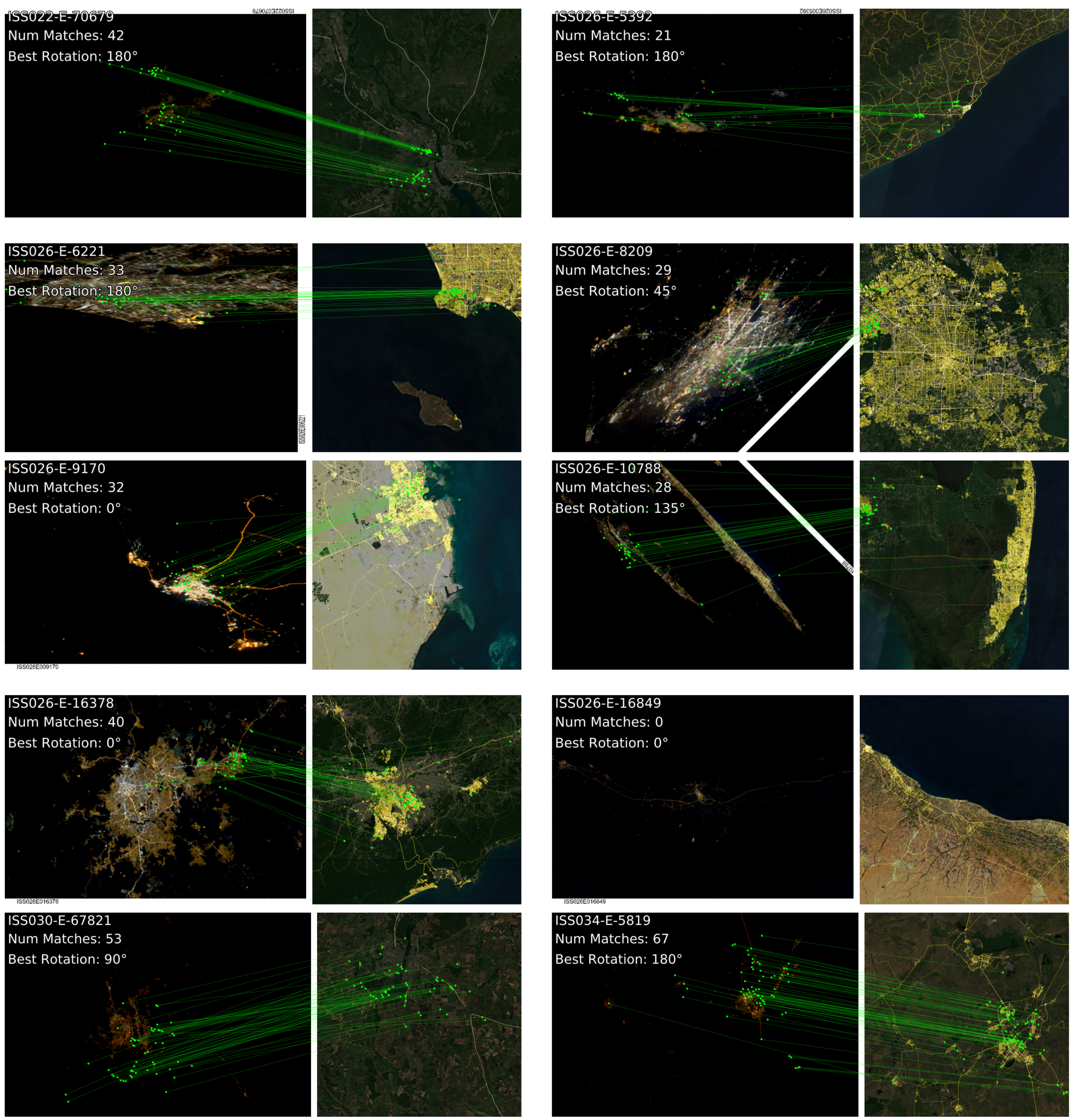

Figure 10. **Failure Cases for "Best Case" Pairs**. Most failures are due to large perspective changes, sparse roads in either the astronaut photo or the reference map, or poor field of view/scale match between the pairs.